

Evolution of the Fire Sprinkler

A look at the history of fire protection through the years involves piecing together the first sprinkler systems, some dating back to the 1800s, and understanding the organizational formations that helped provide the standards we use today. The evolution of different specialized sprinkler heads and systems for specific occupancies have brought a spotlight and responsibility to the field of fire protection. Taking a walk down the memory lane of fire protection brings us from the most primitive of systems to a view of the ongoing research and development in this field.

PERFORATED PIPE SPRINKLER SYSTEMS

Automatic fire sprinklers have been in use in the U.S. since 1874. In the early days of the industrial revolution, manufacturing plants began to evolve. The manufacturing plants were much larger than the small shops of sole proprietors. The property values exposed in the event of a fire were exponentially greater than small shops and factories of the day.

Sprinkler systems in the early stage of development were uncharged pipes with perforations. The pipes usually had perforations at approximately 60°, and the water would spray out in an upward direction. The holes were approximately 1/8 in and spaced at intervals between 3 and 10 in. In the event of fire, water was pumped into the pipes to spray water into the burning room. The fixed pipes would allow the fire department to apply water directly into the building and directly over the fire. Firefighting operations at that time were primarily an exterior operation, as self-contained breathing apparatus was not typically found in fire departments. The main disadvantage of these systems was that they were manually operated. The fire department would connect hoses into the standpipe and charge the pipes. By the time the fire department arrived, connected to a water supply and charged the standpipe, a fire would have gained significant headway. Holes would clog as a result of rust and foreign materials, and the water distribution pattern was usually less than optimal.

The next evolution of the perforated pipe was to coat the pipes with tar and pitch to seal the holes. In a fire, the tar would melt, opening the holes directly over the fire. The hydraulics of the piping systems improved, and water damaged was slightly reduced. Time was of the essence, and delayed water application permitted much of the tar to melt, opening more holes than desirable.

Open sprinklers, which had no fusible elements, were later employed. These sprinkler heads had metal bulbs with numerous perforations. These early open sprinkler heads provided better water distribution. Unfortunately,

these heads were only a minor improvement over the perforated pipes. Again, time was of the essence, and delayed water application permitted significant damage.

Perforated pipes were used not only in industrial buildings, but also used in the basements of buildings in cities, such as New York City. In the late 1800s, perforated pipes were required to be installed in the basements of large commercial buildings. In the early 1900s, a shift in protection was required by building codes. Automatic sprinklers were required in the basements of large commercial buildings in cities. For many decades thereafter, high-rise buildings often had automatic sprinkler systems installed on every floor below grade level because basement fires are difficult to fight. During the transition between perforated pipes and automatic sprinkler protection, some buildings had both systems installed. This was a recognized problem because water discharged from the perforated pipes would wet the sprinkler heads and could prevent the automatic sprinkler heads from opening. In New York City, perforated pipe systems were eventually ordered to be dismantled.

Sprinkler systems in the early stage of development were uncharged pipes with perforations.

DEVELOPMENT OF THE SPRINKLER HEAD IN THE U.S.

Eventually, heat-actuated sprinkler heads were developed. In 1872, the first U.S. patent for an automatic sprinkler system was issued to Phillip W. Pratt, of Abington, MA. Cords and fuses held valves closed with a spring-loaded lever. The sprinkler head had a spinning head, which would spin from the water pressure and fling water out in a circular pattern. In the event of fire, the fuses ignited, the cords burned and the valve opened. The ceiling, walls and floor would be wetted by this sprinkler system.

Henry S. Parmelee is an early pioneer in the development of sprinkler heads. In 1878, Parmelee developed a sprinkler head referred to as "Model No. 5." This was a solder-sealed sprinkler head with a brass cap over a rotating turbine deflector. In 1892, Charles E. Buell developed a sprinkler head that used a tooth deflector, which is similar to deflectors on modern sprinkler heads. During these early years, there were many various design attempts to create an effective, reliable and cost-effective sprinkler head.

Not long after, in 1894, George E. Hibbard of Chicago, IL developed a sprinkler head that utilized levers and a two-piece fusible element, which became a standard on many sprinkler heads thereafter. When the fusible link melted, the link slid apart, and the water



Photo 1: (left) Rockwood 1912 Model D. Rockwood sprinklers could be readily identified by their distinctive four-piece fusible element, which they developed in 1906 and used for decades later.

Photo 2: (right) The 1925 Rockwood Model D sprinkler had a slightly larger deflector than some other heads and had holes drilled into it to allow more water to be directed upward to wet the ceiling timbers.

Photo 3: This Grinnell Model B-29 head has a quartzoid releasing mechanism on a glass seat. While many other sprinklers had glass seats, this glass seat is quite visible.



(today it is owned by TYCO). In 1890, Grinnell developed an upright sprinkler head with a glass valve seat, which was held in place by a three-piece fusible element. This sprinkler head was one of the early heads that had a small toothed deflector, which we have become accustomed to seeing on early automatic sprinkler heads. In 1898, Grinnell went on to patent another sprinkler head, which had a flat disc and a glass seat.

Early manufacturers developed sprinkler heads with an assortment of releasing mechanisms. Almost all sprinkler heads had 1/2-in threads and used solder to activate the sprinkler head. The method of keeping the sprinkler head sealed during normal times and allowing it to open during a fire varied greatly. Some manufacturers used a simple solder link, which would slip on itself when melted, while other manufacturers used an intricate arrangement of

pressure allowed the cam-action levers to fly away, opening the sprinkler head.

Frederick Grinnell, owner of Providence Steam and Gas Pipe Co., was an early name associated with fire protection and fire sprinklers. He patented his first sprinkler head in 1881 and formed the General Fire Extinguisher Company in 1883. In 1944, it became known as the Grinnell Company

levers, which moved as a result of water pressure. Others used weights, which dropped to activate the head.

In 1906, George I. Rockwood of Worcester, MA patented his Model A sprinkler head. The fusible element on the sprinkler used a triangular, four-piece fusible element, which became a mainstay of the Rockwood sprinkler into the 1950s and beyond.

Sprinklers continued to evolve in design over the years. The deflector was designed to spray 60% of its water onto the materials below, and 40% of the water continued in an upward direction to wet the timbers at the ceiling above the sprinkler heads. The heads may be identified by their small deflector size. Even as the deflectors increased in size, holes were placed in the deflector to allow more water to be directed in an upward direction.

The solder in early sprinkler heads was determined to be unreliable. In 1920, sprinklers had a change in the solder composition. When this change occurred, Grinnell changed the shape of the base of its heads. In North America, the wide base was not used again. Because of this change, many pre-1920 sprinkler heads may be readily identified from floor level.

Most early sprinklers used solder-fusible links to actuate the sprinkler heads. As early as the 1920s, Grinnell manufactured quartzoid glass bulb heads.

SPRINKLER SYSTEMS HEAT THE BUILDING

Some early sprinkler systems were installed as a combined sprinkler and heating system. The first sprinkler system installed by Parmelee used the system for heating in extreme weather by running steam or hot water into the feed main pipes. A water heater and pump were installed to pump the hot water through the feed mains in a circulating fashion. Additional steam piping was installed because the sprinkler piping was usually insufficient to provide enough heat.

In storage areas and warehouses, it was noted that additional steam piping was probably not needed to heat the building. The financial advantage of this arrangement was a cost savings estimated to be as much as 33% of separate sprinkler and heating systems. Some of the major disadvantages of this arrangement were the complicated valve arrangements, which needed more maintenance and shutdowns for repairs. Corrosion of the pipe interior, accidental operation of sprinkler heads and interference with sprinkler alarm supervision were other problems. This arrangement was a crude attempt at reducing the cost of the installation and was quickly abandoned.

In the late 1800s and early 1900s, the idea of the combined heating and sprinkler system was revived, and some factories in New England attempted to install such equipment again. Problems were encountered, and the idea was again eventually abandoned. The sprinkler heads activated at 160 °F (71 °C) while the steam-heated water could reach 212 °F (100 °C) prior to boiling. Also,

the steam pressurized the system to a higher level than normal water pressure. An arrangement to keep the temperature below the operating temperature of the sprinklers was accomplished by installing riser nipples approximately a foot long so the hot water would not come too close to the sprinkler heads. Another method to help insulate the solder element was developed by Frederick Grinnell, and manufactured by General Fire Extinguisher Company. These sprinkler heads used glass seat valves. In 1913, two instances of accidental sprinkler actuation from overheating occurred. The sprinkler leakage endorsement placed on insurance policies apparently prohibited these arrangements. The idea fell into disfavor, was eventually abandoned and was not attempted again.

INSURANCE AS A DRIVING FORCE IN THE ADVANCEMENT OF FIRE PROTECTION

One of the greatest driving influences in the development and advancement of fire protection was the economic incentive to install and develop new and better systems. Steam and waterwheel power improved, and the textile industry automated. This equipment was technologically advanced for the time and expensive. To make matters worse for underwriters, manufacturing plants became larger, and the concentration of values increased. This became a major concern to insurance underwriters. Most insurance companies were not capable of absorbing the financial loss of a large industrial manufacturing facility. Prior to the industrial revolution, most shops were small, and insurers were able to manage the loss, even if it was a total loss. This was not the case with a large manufacturing plant. Few underwriters were willing to offer significant rate reductions to large facilities that installed fire protection

features. The fixed fire protection was sometimes crude, unreliable and did not have a proven track record for mitigating losses.

In the early 1800s, most insurance companies were backed by sole underwriters or were stock companies. Property insurance was in its early stages of development. Underwriters were businessmen, and few were engineers. Few were willing to place their companies at risk based on unproven technology.

FORMATION OF THE FACTORY MUTUAL SYSTEM

In 1835, Zachariah Allen, a textile mill owner, made property conservation improvements to his property that would help minimize the fire hazard. He requested an insurance rate reduction from his insurance company, and was denied. Rather than accepting that as an answer, he enlisted other local textile owners to band together, make improvements to their properties and share in their efforts to make their factories good risks. The program became known as Highly Protected Risk (HPR). Owners placed their premium into a pool to be used in the event that any member suffered a loss. If the mutual had few losses, the money from one year would be returned or carried over into the next, rewarding the members. Over the next 20 years, more mutual insurance companies were founded, and they too joined forces to provide additional capacity to pay losses. These companies evolved into the Associated Factory Mutual Fire Insurance Companies, or as they became known, the Factory Mutuals.

By 1878, the Factory Mutuals established a dedicated unit of engineers to inspect insured facilities. Engineers would make recommendations for improvements, estimate loss potential, witness fire protection equipment testing and advise the underwriters of the standard of protection at each insured property. The Factory Mutuals developed some of the earliest fire protection standards, many through actual fire tests. Some of the fire protection standards issued by Factory Mutual Engineering pre-date NFPA. Factory Mutual had written sprinkler installation guidelines as early as 1891. Today, these services are conducted by the engineering and research groups of FM Global.

FACTORY INSURANCE ASSOCIATION

In 1890, about a dozen stock insurance companies joined forces to write insurance for factories with too much hazard and value for any one of them to handle on their own. The name of the organization was the Factory Insurance Association (FIA). Their mission was to compete with the Factory Mutual System. They followed many of the same principles and adhered to HPR levels of protection. At the end of the year, the member companies, the “owners” of FIA, would share in the profit or loss. In the mid 1970s, FIA merged with the Oil Insurance Association to form Industrial Risk Insurers (IRI). IRI’s membership subscription was eventually dissolved, and the entity was sold off.



Photo 4: Grinnell 1907 and 1915 sprinklers were patented in 1898. This head is similar to the 1890 version. These sprinkler heads have a semi-spherical glass valve covered by a metal cap to cover a circular seat. The glass helped insulate the fusible link from hot pipes when the sprinkler system was used for heating. The small toothed deflector allowed water to be directed downward, while also permitting water to spray upward to wet the ceiling. The large base was discontinued in the U.S. after 1920 when the solder formula changed. Patented by Frederick Grinnell, Providence, RI. Manufactured by General Fire Extinguisher Co., Providence, RI.

UNDERWRITERS LABORATORIES

During the late 1800s, the Factory Mutual system was the leading source of fire protection technology, testing, and approvals. However, this information was developed for the use of its insureds. Stock insurance companies did not have a similar testing and approval system. Prior to 1900, stock company underwriters would individually decide which fire protection equipment and arrangements they would accept. The step toward our current fire testing laboratory system came from the Edison light bulb and the new alternating current (AC).

At the 1893 World's Columbian Exposition in Chicago, people were amazed at the spectacular vision by 100,000 Edison light bulbs.

Today, numerous firms are qualified as a nationally recognized testing laboratory throughout the U.S.

Unfortunately, fires kept breaking out, igniting the combustible building covering. Chicago fire insurance authorities were concerned about the network of electric wires, their connections and the new AC current. In response, William Henry Merrill, an electrical inspector, set up a laboratory near the fairgrounds, above Fire Insurance Patrol Station Number

One. The lab's mission was to prevent fires by testing the new electrical devices that could cause fires and to investigate everything that affected the spread of a fire. According to *This Inventive Century*, UL's centennial publication, the one room held "a bench, table, chairs and a few electrical measuring devices purchased for the grand sum of \$350." The Chicago Board of Fire Underwriters and the Western Insurance Association provided financial backing, and the lab became the Underwriter's Electrical Bureau.

In 1900, the lab moved into larger quarters. In 1901, it was chartered as Underwriters Laboratories, Inc. (UL). Its new sponsor, the National Board of Fire Underwriters was the basis for the new name. UL maintained testing laboratories for the testing of appliances. They also entered into contracts with manufacturers of appliances to list those devices, which passed their stringent testing criteria. Those devices listed were acceptable to the subscribing insurance companies and organizations.

In 1903, the National Board funded a fireproof building located north of the Chicago River. This facility was the home of UL for the next 75 years. As an expansion to its electrical device testing, UL began fire performance testing on wire windows and fire doors, prompting UL's first standard, "'Tin Clad Fire Doors and Shutters.'" The company coined the motto "Fire is servant, not master." In 1904, UL tested and "listed" its first automatic fire sprinkler. UL began listing tested materials and equipment, which passed its standards. This was a change in terminology from the FM system, which "approved" materials and equipment.

In 1905, UL's annual budget was \$300,000, and it had published 7,500 reports. In 1905, UL moved into the fire

extinguisher arena and issued its first label for a fire extinguisher. Merrill expanded his lab's services to include field inspections to ensure that the listed fire extinguisher continued to meet safety requirements. He began sending engineers to manufacturing plants to verify adherence to the listing. By 1907, there were onsite inspectors from UL in 67 cities.

UL was the testing laboratory for the stock insurance companies. During these times, the mutual insurance companies formed their own alliances and testing laboratories. Factory Mutual (FM) began testing products in 1886. FM also had follow-up inspections at manufacturers, and, like UL, investigated failures of equipment and installations. As a young field engineer with IRI, I regularly issued nonperformance reports, which were submitted to UL, and FM engineers did likewise to FM. Today, numerous firms are qualified as a Nationally Recognized Testing Laboratory throughout the U.S.

NFPA FORMATION

In March 1895, a meeting of a small group of men with interest in fire sprinkler and fire insurance interests met at the Underwriters Bureau of New England's Boston, MA office. Within a 100-mile radius of Boston, there were 9 different sprinkler arrangements and standards for sprinkler spacing and piping schedules. They feared that the failure rate of systems would escalate, causing a detrimental effect to the entire industry. A series of additional meetings were subsequently held, culminating in a significant meeting that changed the fire sprinkler industry.

On March 18 and 19, 1896, a meeting was held to discuss the installation of sprinklers. This meeting, chaired by U.C. Crosby with E.U. Crosby as secretary and membership consisting of Anderson, Bonner, Cabot, Grinnell and Stratton, resulted in the development of a set of rules pertaining to the installation of sprinkler systems, "Report of Committee on Automatic Sprinkler Protection." On Nov. 6, 1896, a meeting of stock insurance companies was held, and an organization called the National Fire Protection Association (NFPA) was created.

On March 18, 1896, several national organizations, which wrote standards for electrical safety, met and created the Joint Conference of Electrical and Allied Interests to be chaired by W.J. Hammer. Five American codes, along with the German Code, the Code of the British Board of Trade and the Phoenix Rules of England, formed a committee with Professor Francis B. Crocker of Columbia University as the chair. In May and June 1897, the committee met again to produce an electrical code that was unanimously approved and called the National Code. The National Board of Fire Underwriters quickly adopted the new code in lieu of its own and issued it as the National Electrical Code of 1897. This was the beginning of the NEC that we know and use today.

The first NFPA committees appointed in 1897 included Automatic Sprinklers (now NFPA 13); Fire Doors, Shutters and Wire Glass (now NFPA 80); and Hose and Hydrants (now NFPA 14). In 1898, Thermo Electric Fire Alarms (now NFPA 72); Carbonic Acid Gas Extinguishers (now NFPA 10); and Cast-Iron Water Mains (now covered in NFPA 24) were created. Fire-Retardant Paint was introduced in 1899. In 1900, Devices and Materials; Fire Hazard of Baling Cotton; Steel Roll Shutters; Fire Pumps (now NFPA 20); and Fire-proofed Wood were created. Until 1918, not a year passed without at least one new committee being formed. The proliferation of NFPA committees continued through the years. Each from a need, some as a result of a devastating fire or event, such as NFPA 102, Standard for Grandstands, Folding and Telescopic Seating, Tents and Membrane Structures, which was established as a direct result of the July 6, 1944 circus fire in Hartford, CT, in which 168 lives were lost.

HAND-BOOK OF THE UNDERWRITERS' BUREAU OF NEW ENGLAND

In 1896, the *Hand-Book of the Underwriters' Bureau of New England* was published. At that time, 13 stock insurance companies made up the Bureau's membership. This small, 183-page handbook was one of the early attempts to standardize fire protection in the U.S. The book covered construction features, such as firewalls and fire doors; exposure protection using fire doors, shutters and open sprinklers; automatic sprinkler protection; water supply for sprinklers, including piping arrangements, hydrants and valve in; fire pumps, including steam underwriters pumps as well as rotary fire pumps; alarms, which at that time were thermostatic systems operated by heat; and rules and requirements for wiring and apparatus electric light, heat and power. This handbook was the basis of what later became the *Crosby-Fiske Handbook* (second to seventh editions) and finally the *Crosby-Fiske-Forster Handbook*, now published by NFPA as the *Fire Protection Handbook*. In 1986, NFPA produced the special 90th-anniversary facsimile edition of the first *Fire Protection Handbook*.

FIRE PROTECTION ENGINEERS: THE EARLY DAYS

Insurance company offices were typically located in major cities around the U.S. Fire protection engineers were assigned to an office, but some, even going back to the early 1900s, were located geographically around the country. They would handle the work around their towns and travel as needed to more remote areas. I recall speaking with older engineers who had retired from FIA, some of whom followed in their father's footsteps. They related that early engineers would travel mostly by train to a town and be met by a plant employee who would provide transportation to the factory. Trips in those days could be long, and in some cases, it would be weeks before the engineer returned home.

In those days, the field engineer needed to know how to test every type of valve that existed. Fire protection systems were maintained by the in-house maintenance department, and the insurance engineer witnessed all testing of wet pipe, dry pipe and deluge sprinkler systems, fire water tanks, fire pumps, testing systems and tripping dry pipe valves. Fire alarms were all individually tested for the fire protection engineer to witness.

Field engineers made recommendations that the plant owners would use to improve the protection of their plants, and underwriters would use to assess insurance rates and premiums. This model for the field engineer has evolved to meet today's environment but still continues today basically as it did a hundred years ago.

1914 FIRES

Industrial fires occurred with regularity, and lessons were learned. These loss lessons became the basis of continuing education. Several publications served the insurance and fire service. One hundred years ago, just as today, many publications were produced, which included fire loss lessons and success stories.

On July 2, 1914, *The Standard: A Weekly Insurance Newspaper* issued a special "Salem Fire Extra" edition. The issue discussed the Salem, MA fire of June 25, 1914. The property loss values were approximately \$12 million. The fire started in a shed connected to the Pump Korn Leather Co., a sprinklered property at 53-63 Boston Street at the corner of Proctor Street. In the shed were three barrels of flammable liquids. The building was primarily wood frame construction four stories in height. The roof was constructed of wood joist, and the walls and ceiling were open stud and joist. The fire spread from the leather company's plant to the Brennan Leather Company and then continued in a southwest direction due to heavy winds.

The building continued for several blocks, spreading in a fan shape. Several manufacturing facilities, as well as a large number of dwellings, were totally destroyed. The fire department connected to a fire hydrant on the 20-in. main on Boston Street. This was directly in front of the risk, which was in heavy flames by this time. The firemen were driven away from the hydrant, leaving the hydrant flowing. The firemen then tried to connect to another hydrant nearby. The spindle of this hydrant broke upon opening the hydrant, and the partially open hydrant was left flowing. The water supply in the mains was significantly reduced due to the open hydrants, the steam engines connected to several other hydrants and the flowing sprinkler systems of various sprinklered facilities. After 1.5 hours, the water pressure had fallen to

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25 PSI, and the Salem waterworks worked to open additional valves to supply more water to the fire area. Eventually, dynamiting was attempted to control the fire, with unsuccessful results.

It was not expected that the fire sprinklers would play an important part in limiting the damage in a conflagration such as this one. Much to their amazement, the Wilkinson Counter Co. on Jefferson Avenue and the E.S. Woodberry Shoe Manufacturing Co. were practically saved by the operation of the automatic sprinkler systems, which both plants had installed. Both plants were in the direct path of the flames and all of the other buildings around them were totally destroyed. The top of the Wilkinson facility was burned off, and the remaining three stories were saved. About one third of the Woodberry plant was destroyed. The Woodberry plant building had a firewall with double fire doors. While the outer doors were burned through, the inner door held to stop the fire. Although the article does not elaborate, one could speculate that the automatic sprinklers on the unburned side of the wall helped protect the second fire door.

A third plant, Carr Brothers, had installed exposure protection sprinklers on the building exterior. The sprinklers prevented fire from entering the building until the 20,000-gallon gravity tank was exhausted.

The article notes that had additional water been available, it is likely that the conflagration would have stopped at this plant as a direct result of the outside exposure sprinklers.

This is just one account of many great successes for fire sprinklers. By 1914, many cities were passing laws requiring automatic sprinkler protection in factory and loft buildings. On July 25, 1914, *The Standard* reported that the Court of Appeals had upheld a ruling in

which the fire commissioner of New York City could order owners of factories and loft buildings to install automatic sprinklers. The building owners were bound to comply. Even 100 years ago, the value of automatic sprinkler protection was not only recognized, but was mandated by law in certain municipalities.

INTERVIEW WITH GORHAM DANA

Gorham Dana, S.B., manager of the Underwriters' Bureau of New England and a member of NFPA's Committee on Automatic Sprinklers, wrote an article in the Oct. 3, 1914 issue of *The Standard* regarding the newly published work *Automatic Sprinkler Protection*. The book was described as the best work ever published on the subject. It provided a clear description of the installation of sprinkler systems and devices, was more than 400 pages and included more than 300 illustrations. The book cost \$3 in red cloth, with a smaller edition

available containing chapters on alarm valves, dry valves, sprinkler supervisory and automatic sprinklers. It was bound in red leather for field use and sold for \$2.

In the article, Dana reports that the cost to install a sprinkler system under average conditions is \$3 to \$4 per head, exclusive of tanks, pumps and valves. At that time, the lowest insurance rates required two water supplies. However, he also notes that where a first-class public water supply exists, the additional credit given for the second supply may not provide a reasonable return on investment. He notes that this cost equates to approximately \$.04 to \$.05 per sq ft allowing 80 ft² per head. The payback for a sprinkler installation is approximately 6 years. He also noted that aside from the financial gain, the plant owners place themselves in a situation where under good care and arrangement of the fire protection system, a serious fire is "almost impossible."

By 1914, automatic sprinkler protection was growing in popularity, and the prediction at the time was that eventually every hazardous risk would be protected with automatic sprinkler protection. By 1914, automatic sprinkler supervision had been developed and in use over the past decade, although the cost to install the alarm equipment and have it monitored by a central station was costly. Also, monitoring was limited to large cities with enough business to support expensive central stations, operators and runners who needed to be on duty 24 hours a day. The success of the service demanded a high standard of maintenance and labor, which eventually led to central stations listed by agencies, such as UL, and approved by FM.

PROBLEMS & IMPAIRMENTS

In 1914, the principal causes for sprinkler system losses were freezing, deterioration of system from corrosion, poor care and maintenance, defective sprinklers and breakage from belts tearing asunder. Recall that 100 years ago, most plants had a central drive shaft system for powering machines. Tank (which were primarily wood stave) failures were often noted to be a result of corroded hoops. Even at that time, a few of the older sprinkler heads were subject to breaking open without heat, causing a loss. In 1920, the solder formula changed, and sprinkler heads manufactured prior to that date were required to be replaced.

Even as long ago as 1914, Dana offered a plea for the "poor down-trodden inspector." Some insurance agents were apt to look upon them as an unnecessary evil, however, the insurance companies must have considered their work of value or they would not have spent thousands of dollars each year to support inspection bureaus. Dana did not imagine that even 50% of the sprinkler equipment would be found in good working order after ten years of service. In the year prior, 199 valves were found shut, 30 partially closed, 49 tanks or reservoirs less than 1/3 full, 61 pumps out of order and 244 fire alarm valves

Another major revision of the pipe schedule system occurred in 1940 when the sprinkler standard created a differentiation in the hazard of occupancy.

impaired in the 2,500 systems inspected by his organization. He noted that the insurance companies, which operated at less than a 1% profit margin, could not afford to take any more chances than necessary. Education of the population was a priority, and part of the inspector's job was to educate plant owners about fire suppression systems and to urge greater care in maintaining the systems. He also noted that some of these inspectors were young because once a good man was trained, a company official would hire him for his special risk department. Some things have not changed in the past 100 years!

PIPE SCHEDULES FOR SPRINKLER SYSTEMS

In 1896, NFPA published the first fire sprinkler standard. Part of that standard prescribed the piping installation schedule. The schedule identified the maximum number of sprinklers fed by a given size pipe on a closed head system. In 1896, the first pipe schedule was the 1-2-4 system. In this system, a ¾-in. pipe could feed one sprinkler head, a 1-in. pipe could feed two sprinkler heads and a 1-¼-in. pipe could feed four sprinkler heads. This was an early attempt to ensure that sprinkler parts were designed and installed in a method that supported sound hydraulic principles of the era. When water flows through a pipe, friction loss reduces the available pressure in the system. By prescribing a maximum number of sprinklers on a given size head, pressure losses were controlled.

In 1905, NFPA revised the pipe schedule system. The 1905 system was called the 1-2-3 pipe schedule system. Beginning with 1-¼-in. pipe, the maximum number of sprinkler heads permitted was reduced. Overall, this schedule change improved the hydraulic performance of the sprinkler system.

Another major revision of the pipe schedule system occurred in 1940 when the sprinkler standard created a differentiation in the hazard of occupancy. Three occupancy hazard classifications were established, each with their own pipe schedule. Light-hazard occupancies possess a lower rate of heat release and a lower combustible fuel loading. Typical light-hazard occupancies include office buildings, schools, hospitals and public assemblies. Ordinary hazard occupancies were typical manufacturing facilities, canneries, electronic plants, repair garages and wood product assembly facilities. Extra-hazard occupancies had a higher than normal combustible loading or had the presence of minor amounts of flammable liquids in the process. Special occupancies were beyond the scope of the sprinkler standard. High-piled or high-rack storage, tire storage, facilities with significant amounts of flammable liquids storage and use and other higher-hazard occupancies were protected in accordance with other standards. Occupancy classification was classified in a subjective manner and generally focused on

Table 1
Sprinkler Pipe Sizes
Maximum Number of Sprinklers
on Closed-Head Systems

Pipe Size (Inches)	1953 Standard			1940 Standard			1905 1-2-3 System	1896 1-2-4 System
	Hazard of Occupancy			Hazard of Occupancy				
	Light	Ordinary	Extra	Light	Ordinary	Extra		
¾	0	0	0	0	0	0	1	1
1	2	2	1	2	2	1	2	2
1 ¼	3	3	2	3	3	2	3	4
1 ½	5	5	5	5	5	5	5	8
2	10	10	8	10	10	8	10	16
2 ½	30	20	15	40	20	15	20	28
3	60	40	27	No Limit	40	27	36	48
3 ½	100	65	40	-	65	40	55	78
4	No Limit	100	55	-	100	55	80	110
5	-	160	90	-	160	90	140	150
6	-	275	150	-	250	150	200	200
8	-	400	-	-	-	-	-	-

the expected heat release and amount of fuel in the occupancy. The 1940 standard created a major change in sprinkler system design and is the precursor to recognizing that some occupancies require a more robust sprinkler system, while lower-hazard occupancies are capable of controlling fires with lesser sprinkler discharge.

The 1940 standard eliminated the use of ¾-in. pipe in sprinkler systems by introducing the 1940 2-3-5 pipe schedule system. The last two pipes on a line of sprinklers were required to be at least 1 in. in diameter. Also, a light-hazard and an extra-hazard pipe schedule was introduced.

In 1953, a new pipe schedule was established. While there was no change to the extra-hazard pipe schedule, the ordinary-hazard pipe schedule introduced 8-in. pipe into the sprinkler system and allowed up to 400 heads on a single sprinkler riser, effectively allowing sprinkler systems to be not greater than 52,000 sq ft in size, a limit that continues to exist today for light and ordinary hazard sprinkler systems. Prior to this, 6-in. risers and pipe were the largest identified, and sprinkler systems had 275 or less sprinkler heads. The greatest change was to the light-hazard pipe schedule. Hydraulic characteristics were improved by limiting the number of sprinkler heads allowed on pipes up to 3½ in. diameter rather than 2½ in. in the 1940 schedule.

SPRINKLER SYSTEM PIPING LAYOUT TODAY

Over the years, a design density method was established, which identifies specific minimum end head densities and areas of operation for each occupancy classification. For many years, the pipe schedule and the density method coexisted. In the 1970s and prior, hydraulic analysis calculations were performed by hand unless the sprinkler contractor had access to an expen-

Photo 5: (left) 1971 Grinnell Model D pendant 500 °F sprinkler for use in high-temperature locations, such as inside an oven.



Photo 6: (right) 1947 Automatic Model A, 286 °F sprinkler. This head is used in areas where the ambient temperature may reach up to approximately 230 °F. It may be used near heater units to prevent accidental operation. They are also used over storage occupancies.



Photo 7: 1944 and 1955 Reliable Model C, 160°F sprinklers. The deflectors on these heads are slightly larger than some other sprinkler heads of the era and compensated by drilling holes in the top of the deflector. During World War II, brass was at a premium, and the deflector was manufactured from a different metal.



Photo 8: 1946 Hodgeman Model B chrome 165°F (left) and 1976 Model D SSU 165°F (right) heads. Hodgeman heads were readily identifiable by their distinctive frame design.

sive mainframe computer with hydraulic analysis software installed. Because of this, primarily tree piping systems were installed. Occasionally, a looped feed main might be provided on a system and a Hardy-Cross calculation performed to balance the system, but this was a time-intensive process without a computer. In the 1980s, computer programs became readily available for the personal computer. With the advent of being able to perform hydraulic analysis on a PC, gridded sprinkler systems became much more prevalent. Within the last 20 years, all new sprinkler installations are required to be hydraulically calculated prior to installation. The installation of pipe schedule systems is prohibited, except for small additions to an existing sprinkler system.

Today, the most commonly installed wet sprinkler system uses a gridded pipe arrangement. A near main and a far main are connected with several branch lines running between them. When a sprinkler activates, water may travel through the grid in any pipe, reducing friction loss, allowing smaller pipes and less installation labor to be used. This reduces the installation cost of the sprinkler system.

Gridded piping arrangements are prohibited for use in dry sprinkler systems. When a sprinkler activates on a tree piping system, all air in the pathway between the water source and the open sprinkler expels through the open sprinkler orifice, and air in branch lines stays trapped in place due to the pitch of the pipes and the pressure of the incoming water. In a gridded piping system, the water will take the path of least resistance. Due to the nature of the grid, the water may change directions in the piping and flow through pipes that are not over the fire. A full stream of water may not be achieved for many additional minutes, and by this time, the fire may be out of control, overtaxing the sprinkler system.

SPRINKLER HEADS

In the early 1900s, fire sprinklers became more reliable as technology improved, and testing laboratories verified through actual fire testing that sprinkler heads met appropriate criteria.

Orifice sizes of sprinkler heads standardized on ½-in. nominal diameter. Also, the minimum operating pressure was set at 7 psi. The flow through a sprinkler was determined by a formula, $Flow = K \times P^{1/2}$ where the flow is in gallons per minute, K is a coefficient of discharge assigned by the manufacturer through testing and P is the discharge pressure. A ½-in. orifice sprinkler head has a K factor of 5.6. A sprinkler head operating at 25 psi would flow $5.6 \times 25^{1/2}$, or 28 GPM. As more heads open, the operating pressure of the sprinkler head is typically reduced due to friction loss and higher total system flow. The system is designed so the end sprinkler head is provided not less than 7 psi. Using our formula, the minimum head flow is 14.8 GPM. Today, this old principle has evolved, and special heads have been developed with small and larger orifices.

Sprinkler systems were designed to have a maximum head spacing of 120 or 130 sq ft per head.

Looking at the previous example, the minimum end head density at 7 psi operating pressure with 120 sq ft of floor coverage is $14.8 \text{ GPM}/120 \text{ sq ft} = 0.12 \text{ GPM per sq ft of floor area}$.

Early sprinkler heads operated at an ordinary temperature rating of approximately 165°F. As time progressed, additional temperature ratings evolved. Intermediate and high-temperature sprinklers were developed to operate at approximately 212°F and 286°F, respectively. Additional temperature ratings may be found today, with sprinklers rated at 500°F inside of ovens and other high-temperature zones.

OLD-STYLE SPRINKLERS

Sprinkler heads manufactured prior to 1953 have a smaller sprinkler deflector and are called “old-style” or “conventional” sprinklers. These heads were smaller, and approximately 40% of the water was directed upward.

SPRAY SPRINKLERS

In 1953, a new-style sprinkler head was created, and older heads were no longer manufactured, except for special applications, such as for installation below wooden piers and wharfs. The new sprinkler head had a larger deflector to create a more uniform spray pattern, hence the name “spray sprinkler.” In 1958, the new spray heads were called the “standard sprinkler” to match terminology in the 1958 edition of NFPA 13. That name has been abandoned since about the 1980s when so many different type heads were developed, and the divergence in designs made the term “standard sprinkler” irrelevant. The older term “spray sprinkler” was reintroduced to better specify the head design and to better align with international term usage. Today, they are also referred

to as control mode density area (CMDA) sprinklers.

Spray sprinklers were designed to be installed in either the upper right, pendant or sidewall position. Heads were identified with an SSU or SSP designation for standard sprinkler upright and standard sprinkler pendant. Deflectors of upright sprinkler heads could be identified by the downward projecting teeth. Pendant sprinkler heads have flat deflectors, which create an umbrella pattern and also allow water to be directed downward.

THE K-8.0 SPRINKLER HEAD

Prior to World War II, durable goods were manufactured of wood, metal or natural fibers, such as cotton or wool. Also, storage handling was often in piles on the floor. Storage rack heights were rarely greater than 20 ft. High-piled rack storage as we know it today did not exist. Pipe schedule sprinkler systems were used for sprinkler protection. After WWII, taller buildings were built and storage heights increased. Fire loads increased with the introduction of plastics, which became more common. These changes brought new and greater challenges to the fire protection engineer.

One of the first large orifice sprinkler heads was the 17/32-in., K-8.0 orifice head. This head was introduced in the 1970s, primarily for use in warehouses and storage occupancies. This is one of the first sprinkler heads requiring a hydraulic calculation as part of its installation.

The 17/32 head was not a direct replacement for the 1/2-in. head. In fact, replacing 1/2-in. heads with 17/32-in. heads could have an overall detrimental effect on the hydraulic characteristics of the system. By design, the 17/32-in. head had a 3/4-in. NPT thread. Replacement heads were also provided with a 1/2-in. NPT thread, and these were manufactured with a pintle on the top of the deflector.

FIRST HIGH CHALLENGE HEAD

In the 1970s, high challenge sprinkler heads were developed, opening the door to new, higher-flow sprinkler heads. These heads had standard response fusible



Photo 10: 1956 Rockwood sidewall 165°F, 1/2 inch K=5.6 sprinkler. This sidewall is designed to be installed in the upright position.



Photo 11: 1980 Viking High Challenge 280°F, 0.64-in orifice, K=11.2 upright sprinkler.



Photo 9: 1985 Central, Model A, SSP, intermediate temperature 212 °F, 1/2 inch K=5.6 (left) and 1978 Central, Model A, SSP, high temperature 286 °F, 17/32 inch K=8.0 (right) sprinkler heads. Notice the color coding, white for intermediate and blue for high temperature. Also, the larger orifice sprinkler head has 3/4-inch NPT threads to allow for more waterflow through the head. The thread size is also a quick identifier that this is a k=8.0 large orifice sprinkler.



Photo 12: (left) 1997 Central K-17-231 CMSA upright 200 °F sprinkler head. This head is a special application for storage occupancies. This head has a K factor of 17. Notice the pintle on the top of the deflector, which denotes a special or nonstandard sprinkler head.

Photo 13: (right) 1997 Central ESFR Pendant K-25 160 °F sprinkler head.

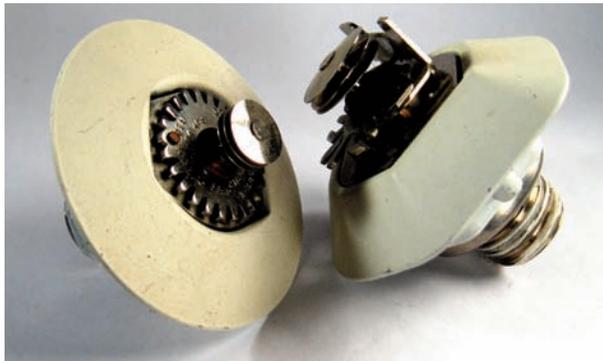


Photo 14: 1980s Central Omega residential sprinkler heads. Ceiling K=3.85 (left), and HEC-12 sidewall heads. The Omega was the subject of a 1998 recall of approximately 8.4 million heads manufactured since 1982.



Photo 15: 2003 Viking Model E-2 Sidewall Quick-Response head for residential use.

link and would produce a large droplet to penetrate deeply into the racks of storage configurations. These heads are control mode specific application (CMSA) heads. One of the first CMSA heads was the Viking High Challenge upright 280 °F standard response sprinkler head. These heads transformed the way storage sprinklers were designed and installed. This was one of the first heads requiring a specific number of heads to be designed in the design area, rather than an area of operation denoted in square feet. New standards were written specifically for the installation of systems using these heads. A new era of sprinkler fire protection was born.

EARLY SUPPRESSION FAST RESPONSE HEADS

After the success of the large drop sprinkler head, manufacturers continued research and testing of new heads with earnest. Manufacturers began testing quick-response, sprinkler-releasing mechanisms to discharge water sooner, and they focused on a pendant head. Several heads were developed, but none took off as quickly and with as much acceptance as the early suppression fast response (ESFR) sprinkler head. The design specifications for the installation of these heads are based on a minimum pressure per head with a given number of heads operating. The building height is a critical factor with the installation of these heads. Architects design buildings around the protection parameters of the ESFR sprinkler systems.

Obstructions are a critical issue in the installation of ESFR heads. If a head is too close to an obstruction, a cone without water may form in the spray pattern, allowing a fire to burn unchecked. The success of these heads is so great, they have been called suppression mode sprinklers. This is the first sprinkler head that has not needed to rely on fire department response to effect final extinguishment.

RESIDENTIAL SPRINKLER PROTECTION

Over the past 150 years, sprinkler protection has been focused on industrial, storage, commercial and public occupancies. Today, the residential sprinkler system is installed in thousands of one- and two-family homes each year throughout the U.S. Many municipalities require automatic sprinkler protection installed in all new construction, and some states, such as Pennsylvania, require the installation of sprinklers in all new residential construction statewide. In 2006, more than 3,000 lives were lost to fire, 80% of which occurred in the home. Facilities provided with working smoke detectors and sprinkler systems have very few fire fatalities. I predict that in another 20 years, buyers will look for fire sprinklers in the homes they buy.

Residential sprinklers have been produced for several decades. Today, residential sprinklers have quick response links and cover an extended area.

CHANGES FOR THE FUTURE

Automatic sprinkler protection in the U.S. continues to evolve. We are beginning to see a shift in terminology

regarding sprinkler systems. CCMDA, CMSA and suppression mode may eventually be phased out. Terms like “storage sprinkler” for heads designed for storage applications; “non-storage sprinkler” used for occupancy hazards with low to moderate challenge fire hazards; and “special protection sprinkler” for heads used to protect special hazards, such as cooling towers, ductwork, ovens and other special hazards, have come into use.

Testing and design of special sprinkler heads to be used in rack sprinkler systems are underway by several manufacturers. As new challenges emerge, engineers will develop new protection methods to control fire hazards.

I am amazed at the changes in fire protection, fire sprinkler equipment, applications and system design over the last 40 years. Future changes will most likely come at an even faster pace. This is an exciting time for those in the fire protection field, and an even more exciting time for the young practitioner who will enjoy a career during one of the most fast-paced development times in the history of fire protection. ☺

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All sprinkler heads from the author's collection. All photos ©Walter S. Beattie.



Photo 16: 2003 Viking Model VK408 concealed flush mount sprinkler with ceiling cover (left) and 2003 Viking Model VK404 concealed flush mount sprinkler without ceiling cover (right).



Photo 17: Residential sprinklers installed during construction. Much of the system may be installed using plastic pipe.