

**FEASIBILITY OF AUTOMATIC  
SPRINKLER SYSTEMS FOR  
FIRE CONTROL ALONG  
LONGWALL FACES**

**Mark W. Ryan**  
Fire Prevention Engineer  
U.S. Bureau of Mines  
P.O. Box 18070  
Pittsburgh, Pennsylvania 15236

Alex C. Smith  
U.S. Bureau of Mines

# FEASIBILITY OF AUTOMATIC SPRINKLER SYSTEMS FOR FIRE CONTROL ALONG LONGWALL FACES

By Mark W. Ryan<sup>1</sup> and Alex C. Smith<sup>2</sup>

U.S. Department of the Interior  
Bureau of Mines, Pittsburgh Research Center  
P.O. Box 18070, Pittsburgh, Pennsylvania 15236

## ABSTRACT

The U.S. Bureau of Mines conducted a feasibility study on the use of automatic sprinkler protection for fire control along a longwall face of an underground coal mine. Experiments were conducted to evaluate the effect of ventilation on sprinkler discharge patterns and activation characteristics. The results showed delays in activation and shifts in total water coverage areas and water density distribution patterns as ventilation increased. Other test results indicated that as the airflow increased, the size of fire needed to activate an automatic sprinkler system also increased and that sprinklers located directly above the fire did not activate. The use of directional sprinklers at airflows of 300 fpm and greater were able to compensate for the effect of ventilation on the water spray pattern and the sprinkler activating downstream to extinguish the fire. An assessment of whether automatic sprinklers can withstand the high static water pressure in deep underground coal mines showed that although commercial sprinklers may be able to withstand high static pressures, they may not provide the same reliability and safety factor as when used aboveground at or below their rated pressure. Other parameters that were considered in the feasibility study were sprinkler durability, water supply, and water delivery on the longwall face. The typical water supply to a longwall face should be adequate for an automatic sprinkler system. Utilization of a 2 in diameter flexible high pressure hose should meet space, mobility, and safety constraints. After all these factors are considered, it appears feasible that automatic sprinkler systems can be effectively used for fire control along longwall faces if warranted by the incidence of fires.

## INTRODUCTION

In recent years, use of the longwall mining method has steadily increased. Currently, equipment manufacturers and suppliers report that the percentage of coal mined underground by the longwall method is 37% of the total production. In 1992 there were 93 longwalls in operation, with 27 companies operating systems in 11 states. Along with the percentage of coal produced by longwall mining, the average width of longwall panels has also increased, from 495 ft in 1980 to 715 ft in 1992. The width of several panels now exceeds 900 ft and there are two longwall panels in operation in the United States that surpass 1000 ft (1). Wider and longer panels have helped increase productivity; this correlation ensures that the width of longwall faces will continue to grow. However, this increase in panel width also increases the difficulty of evacuation of mine personnel and fire fighting efforts along a longwall face in the event of a fire. Extended longwalls may require improvements with respect to both fixed and mobile fire suppression systems (2). In recent years the Mine Safety and Health Administration has investigated several fires

---

<sup>1</sup>Fire prevention engineer.

<sup>2</sup>Research chemist, Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.

which occurred along longwall faces (3,4,5). This paper examines the feasibility of automatic sprinkler protection systems for fire control along longwall faces.

There are several fire extinguishing agents available for use in underground coal mines, such as water, dry chemical, inert gas, or high expansion foams. However, water is still considered the most effective. In fact, water sprinkler systems are the primary method of protecting lives and property from fire in aboveground facilities. Automatic sprinkler systems are more reliable and require less maintenance than most other extinguishing systems. Another type of extinguishing system that uses water is a water deluge system, which uses either water nozzles or sprinklers with the fusible element or glass bulb removed. When a fire detecting device is actuated, a valve is opened to a group of open sprinklers or nozzles and the entire protected area is deluged with water. One of the major advantages of a system with individually operated sprinklers in an automatic sprinkler system is that water is provided only where it is needed. A limited water supply can be overtaxed and the system rendered ineffective if water is discharged outside the fire area. Considering the environment found in underground coal mines and the above-mentioned characteristics, an automatic sprinkler system is a logical choice for examining its feasibility for providing automatic fire protection along a longwall face.

In aboveground installations, commercial automatic sprinkler systems are designed to operate in non-ventilated conditions in an environment less harsh than that found in underground coal mines. Along a longwall face, high airflow is needed to remove flammable gases and dust from the working face. The use of water sprays to suppress dust and clean equipment creates damp conditions, which can cause metal surfaces to rust and corrode. Because of the poor visibility and cramped conditions along most longwall faces, sprinklers would be more susceptible to being struck by various objects. The sprinklers may also be subjected to static water pressure as high as 1000 psig. These conditions are much harsher and different than the conditions found aboveground.

There are several factors that must be considered in determining the feasibility of automatic sprinkler protection for fire control along a longwall face. The effects of ventilation on the sprinkler activation time and the water coverage area when exposed to a fire are the most important factors. The ability of sprinklers to withstand high static water pressures, the durability of commercial sprinklers, and the availability of an adequate water supply are also factors which must be addressed. This study will help the Bureau to improve fire safety in the mining industry, thus enhancing the safety of the Nation's miners.

## EFFECT OF VENTILATION

Commercial sprinklers are designed to operate in aboveground facilities where there is little or no forced ventilation. During a fire in an aboveground facility, heat collects at the ceiling and melts the fusible link of the sprinkler. This releases the mechanism that holds the seal over the orifice and water is discharged from the sprinkler in a designated spray pattern. Standard sprinklers are usually designed to cover an area up to 13 ft by 10 ft. The size of the area of a fire for a particular occupancy or storage arrangement is predicted through research and fire loss history. The number of sprinklers that operate are controlled by the area of the fire size, spacing between sprinklers, and the temperature rating and Response Time Index (RTI) of the sprinklers. The RTI value is a measure of the sensitivity of a sprinkler.

The ventilation rate along a longwall face can reach as high as 1000 fpm. High ventilation rates may not allow heat to collect at the ceiling and will

probably increase the time and fire size needed to activate a sprinkler. The smoke and heat produced by a well developed fire would hinder both the evacuation of mine personnel and fire fighting efforts. The ventilation rate along a longwall face may also affect where the sprinklers operate in relationship to the location of the fire. In a ventilated area such as a longwall face, sprinklers downstream of the fire may operate instead of sprinklers directly above the fire. The effect of the sprinkler downstream operating is compounded by the fact that the water distribution pattern of the sprinkler will also be shifted downstream. This means that water may not be discharged on the fire located upstream of the operating sprinkler.

The Bureau of Mines conducted a study to evaluate the effect of ventilation on the water spray patterns of automatic sprinklers. Experiments were performed in a rectangular tunnel with pendent, upright, pendent sidewall, and horizontal sidewall sprinklers at air velocities of 0, 150, 300, 500, and 800 ft/min. Examples of the four types of sprinklers are shown in Fig. 1. (Sidewall sprinklers have a deflector that discharges water in a semi-circle instead of a full circle.) At 0 ft/min airflow, the pendent and upright sprinklers exhibited circular coverage patterns, extending from 10 to 14 ft upstream and downstream of the sprinkler. The horizontal sidewall heads covered areas ranging from 2 ft downstream to 24 ft upstream, while the pendent sidewall head at 0 ft/min airflow covered an area from 14 ft downstream to 24 ft upstream. As the air velocities were increased, there were significant shifts in the total coverage areas and in the density distribution patterns, as well as in the maximum coverage densities, for all types of sprinklers. The pendent and upright sprinklers exhibited upstream shifts in total coverage in the direction of the airflow ranging from 4 to 6 ft, while the downstream coverage distances were extended up to 12 ft at the 800 ft/min airflow. The shift in upstream coverage distance for the sidewall heads ranged from 6 to 12 ft, while the downstream coverage was extended up to 22 ft at 800 ft/min (6).

Activation of the sprinkler is probably the most critical step in the effective operation of an automatic sprinkler system along a longwall face. The fire must quickly activate the sprinkler and discharge water on the fire for the system to be effective. If the sprinkler is not activated quickly enough, the fire may grow too large for the extinguishing system to extinguish and/or control the fire before the water supply is exhausted.

Initially, it must be determined if a commercial sprinkler is sensitive enough to respond to the early stages of a fire along a ventilated longwall face. The response time of a sprinkler is a function of the rated temperature and the sensitivity. Sprinklers are typically rated at temperatures no lower than 135° F. The sensitivity of a sprinkler is defined by the RTI value, which is equal to the tau factor multiplied by the square root of the air velocity where it is evaluated. The tau factor is determined by the performance of a sprinkler in a standardized air oven tunnel test. In this test a sprinkler at room temperature is plunged into a heated air stream. The tau factor is the time when the excess temperature of the sensing element of the sprinkler is approximately 63 percent of the excess gas temperature. The smaller the RTI, the faster the sprinkler will operate. Consequently, even if a sprinkler is rated at a lower temperature, the sensing element of a sprinkler with a higher temperature rating may reach its rated temperature faster and operate quicker if it has a lower RTI value. Standard sprinklers have RTI values in the range of 225 to 700 sec<sup>1/2</sup> ft<sup>1/2</sup>, while the RTI range for quick response sprinklers is about 50 to 90 sec<sup>1/2</sup> ft<sup>1/2</sup> (7).

The Bureau of Mines conducted experiments to determine the effect of ventilation on the performance of automatic sprinkler systems. Experiments were conducted at airflows of 0, 150, 300, 500, and 800 fpm. Two experiments were conducted at each airflow using 135° F fast response pendent sprinklers in one experiment and 135° F fast response horizontal sidewall sprinklers in

the other experiment. In the experiments at 0 and 150 fpm, the pendent and horizontal sidewall sprinkler located directly above a wood crib fire operated and extinguished the fire. In the experiments at 0 airflow, activation of the sprinkler occurred approximately 5 min after ignition of the wood crib, while at 150 fpm activation occurred approximately 16 min and 40 s after ignition. At airflows of 300 and 500 fpm, the sprinkler located 8 ft downstream of the fire activated 16 min and 40 s after ignition. In these experiments, the wood crib fires were extinguished by the horizontal sidewall sprinklers, while the pendent sprinklers failed to extinguish the fires. At 800 fpm, neither sprinkler activated for fire sizes less than 200 kW. The limits of the experimental tunnel prevented further testing with larger fires. Also, as the airflow was increased, larger fires were required to activate the sprinklers. At 0 fpm, a 30 kW fire was needed to activate the sprinkler, while at 500 fpm a 190 kW fire was needed to activate the sprinkler. The results showed that ventilation has an effect on the performance of automatic sprinkler systems, but the use of directional sprinklers at airflows of 300 fpm and greater compensated for the effect (8).

### PRESSURE CAPABILITIES OF AUTOMATIC SPRINKLERS

The ability of commercially available sprinklers to withstand high static and residual pressures could also affect the feasibility of using automatic sprinkler protection along a longwall face. The water pressure in an underground coal mine can be as high as 1000 psig. This high static pressure occurs when water is supplied from aboveground sources, such as ponds or reservoirs and pressure regulators are not used.

Commercially available automatic sprinklers usually have a rated working pressure of 175 psig. However, they are designed so that the mechanical pressure normally exerted on the top of the cap or valve is many times that developed by the water pressure below, so that the possibility of leakage, even from water hammer or exceptionally high water pressure, is practically eliminated (9). Standard sprinklers using various combinations of links, levers and struts, or frangible bulbs to activate the sprinkler are shown in Fig. 2. The frame arm of the standard sprinkler is used to exert pressure on the levers and struts to hold the cap over the orifice. Some fast response sprinklers do not use the frame of the sprinkler to exert pressure on the cap over the orifice. A typical design uses a plunger with balls in a retaining groove to hold the orifice sealing mechanism in place.

Most commercial automatic sprinklers in use in the United States today are listed by Underwriters Laboratories, Inc. (UL) and/or some other national testing agency. Most building regulations in the United States require that all sprinklers be listed by UL or some other nationally recognized testing agency. UL has established performance criteria that automatic sprinklers must meet or exceed in UL Standard 199. In regard to static pressure, UL Standard 199 states that an automatic sprinkler shall not exhibit any leakage at 500 psig or less and shall withstand for 1 minute, without rupture, an internal pressure of 700 psig. In addition, automatic sprinklers shall not exhibit any leakage when subjected to a hydrostatic pressure of 300 psig for 30 days and shall withstand, without any leakage, 3000 applications of a pressure surge increasing rapidly from 50 to 500 psig. In regard to residual pressure, an automatic sprinkler shall withstand for 30 minutes, without evidence of cracking, deformation, or separation of any part, a waterflow at a pressure equal to (1) 110 percent of the maximum rated pressure or (2) the maximum rated pressure plus 25 psig, whichever is greater (10). Using commercially available automatic sprinklers that are listed with a working pressure rating of 175 psig in underground mines under high static pressure may result in sprinkler leakage or rupture. If the sprinkler ruptures due to a large water hammer, the waterflow alarm would activate, resulting in a false

alarm. This decreases the reliability of the sprinkler system and increases maintenance of the system.

The Bureau of Mines conducted a study to determine if commercial automatic sprinklers could withstand the high static pressures typically found in deep underground coal mines without leaking and if exposure to the mine environment affected their leak pressures. Twelve types of new automatic sprinklers from four different manufacturers were evaluated, as well as six types of automatic sprinklers that had been exposed to the mine environment for various lengths of time. Sprinklers were subjected to increasing pressures until leakage occurred. The average leak pressures of the new sprinklers ranged from 640 to 2300 psig and showed a high variability between sprinklers from different manufacturers, as well as between different types of sprinklers. Generally, standard response sprinklers were able to withstand higher pressures than fast response sprinklers. The results indicated that most commercial sprinklers would withstand the high static pressures found in deep underground coal mines. However, they may not provide the same reliability and degree of safety as when exposed to pressures at or below their rated pressure of 175 psig. A comparison of the average leak pressures of the new sprinklers to the leak pressures of the sprinklers exposed to the mine environment showed the ability of 66% of the exposed sprinklers to withstand high static pressures was diminished (11).

#### DURABILITY OF AUTOMATIC SPRINKLERS

The corrosion of a sprinkler may effect its sensitivity and activation. The corrosion of the sensing element of a sprinkler may delay the activation of the sprinkler or if the corrosion is severe the sprinkler may not activate at all. If sprinklers begin to appear corroded after being installed in an underground coal mine, they should be replaced. Wax covered sprinklers are available for use in corrosive atmospheres.

A sprinkler used along a longwall face would also have to be able to withstand impact or be protected from being struck by heavy objects. A bent deflector could affect the water distribution pattern or if a sprinkler has been struck it may start to leak. Commercial sprinklers are designed to be located near the ceiling, where they have little or no physical contact with other objects. Where contact is possible, metal cage-like guards are used or the sprinklers are recessed.

#### WATER SUPPLY

In order for an automatic sprinkler system to be feasible on a longwall face, an adequate water supply is necessary. To determine the amount of water needed for an automatic sprinkler system along a longwall face, several factors such as potential fire size and spacing must be addressed. For example, assume a fire along the longwall face that involves a 30 ft length of the face. The distance from the coal face to the support jacks of the shields typically ranges from 13 to 16 ft. As stated above, standard sprinklers are designed to cover an area up to 130 ft<sup>2</sup>, so the sprinklers would be spaced every 10 ft along the length of the face. With three sprinklers flowing along the 30 ft length of the face and a residual pressure of at least 10 psig at the last flowing sprinkler, the water supply required would be approximately 50 gpm.

Water is used in underground coal mines for dust suppression and wash down of equipment along the longwall face and for fire suppression systems for conveyor belt drive areas. Most underground coal mines have aboveground ponds or reservoirs to provide water for mining operations. Some mines pump water from sumps located in the mine. Water that is gravity-fed from aboveground sources can develop high head pressure due to the change in elevation. As

mentioned earlier, water pressure in an underground coal mine may reach as high as 1000 psig. Pressure reducing valves are sometimes used to reduce this high pressure to a safer operating pressure. The main water line is typically 6 to 8 in diameter which then branches off into smaller pipes to supply each section. The longwall section is usually provided with a 2 in or larger water line which runs the length of the face. This water supply should be adequate for an automatic sprinkler system along the longwall face; however, each mine would have to be evaluated individually.

#### WATER DELIVERY SYSTEM

The amount of water needed and the available water supply determine the size of hose needed to provide adequate flow and pressure for the sprinkler system. The hose needed to supply water to sprinklers on a longwall face would have to be a flexible high pressure hose, similar to the hydraulic hose that operates the roof support shields, since the shields move individually. The hose for the sprinklers could be directed along the hydraulic hose to the shields, then branched off to the individual sprinklers located out near the tip of the shields. The sprinklers could be spaced every 10 ft to 12 ft depending on the width of the shields. Due to the cost of high pressure hose and the limited space to run the hose, the hose diameter should be as small as possible, considering the available water supply at the mine. Due to the limited space, 2-in-diameter hose is probably the largest size hose that could be used.

#### ALTERNATIVES TO FUSIBLE LINK TYPE AUTOMATIC SPRINKLER SYSTEMS

There are alternatives to a fusible link type automatic sprinkler system. One alternative that uses water is a deluge system. A deluge system uses water nozzles or sprinklers that have the lever and link mechanism or the glass bulb removed. The waterflow to a group of sprinklers is then controlled by a deluge valve. The valve is actuated by a fire detector that is activated by the heat, flame, or products of combustion of a fire, or it may be operated manually. Smoke and carbon monoxide sensors are available that can quickly detect a fire in a ventilated mine atmosphere. However, there are drawbacks to this type of extinguishing system. The advantage of properly designed automatic sprinkler systems using fusible link or glass bulb sprinklers compared to water deluge systems is that only a limited number of sprinklers activate. This concentrates water directly on the fire area. With a deluge system, the area over which water is discharged is dependent on the area covered by the detector. The discharge area should be limited so that the available water supply is concentrated on the fire. Due to the limits of the hose size, the friction loss over 1200 ft of a longwall face would be substantial. The average available water supply in an underground coal mine can probably provide adequate flow and pressure for the required water density over a small length of face at the tailgate. If detectors and deluge valves were needed for each of these lengths, the number of deluge valves and detectors required for a 1200 ft longwall face would make a conventional deluge system less reliable and more costly.

Systems using other extinguishing agents operate in the same manner and have similar drawbacks. In addition to the limitations of detectors and actuation valves being used to activate the system, systems using other agents are also limited by the amount of agent that can be stored near the face. There is very little space along the longwall face for tanks or cylinders. Additionally, long runs of hose would increase the time needed for the agent to reach the fire. The success of these systems is dependent upon complete extinguishment of the fire by the initial application of agent. This decreases the reliability of these types of systems. Further research would

be needed to make a final determination. However, at this time it is felt that a deluge system or a similar scheme using other extinguishing agents would not be as feasible for use as an automatic sprinkler system along a longwall face.

## CONCLUSIONS

There are several factors that must be considered in determining the feasibility of automatic sprinkler protection for fire control along a longwall face. The effects of ventilation on the sprinkler activation time and the water coverage area when exposed to a fire are the most important factors. The results of a Bureau of Mines study showed significant delays in activation times, as well as shifts in total coverage areas and in the density distribution patterns downstream of the fire as ventilation increased. Even with the delay in activation times, once the sprinkler activates, it should be able to extinguish or at least control a fire and provide protection until personnel can evacuate. The use of directional, or horizontal sidewall sprinklers, would help negate the effect of ventilation on the spray patterns of the sprinklers. Experiments conducted by the Bureau showed that directional or horizontal sidewall sprinklers were effective in extinguishing a wood crib fire in airflows above 300 fpm, while pendent sprinklers were not effective in extinguishing the fire.

The ability of sprinklers to withstand high static water pressures, the durability of commercial sprinklers, and the availability of an adequate water supply are also factors which must be addressed. The results from a Bureau of Mines study indicated that most commercially available sprinklers would withstand the high static pressures found in deep underground coal mines. However, they may not provide the same reliability and degree of safety as when exposed to pressures at or below their rated pressure of 175 psig. The mine environment affected the ability of 66% of the sprinklers to withstand high static pressures when comparing the average leak pressures of the new sprinklers to the leak pressure of the sprinklers exposed to the mine environment.

The water supply that is typically provided on a longwall face should be adequate for an automatic sprinkler system. There is adequate space for the water hose needed and the sprinklers could easily be located near the tip of the shields. The sprinklers could be protected from damage by metal cages, if necessary.

After considering all of the factors stated above, if the incidence of fires would warrant their installation, automatic sprinkler systems can be a viable method for fire control along longwall faces.

## REFERENCES

1. Merritt, P. C. Coal. Longwalls Having Their Ups and Downs. V 97, No. 2, 1992, pp. 29-39.
2. Thimons, E. D., R. A. Jankowski, and G. L. Finfinger. Extended Longwalls: Is Bigger Better?. Paper in Proceedings of Longwall U.S.A., Pittsburgh, PA, 1992, 15 pp.
3. Pavlovich, J. W. and W. T., Dykes. Report of Investigation, Underground Coal Mine Fire, Mine No. 3, I.D. No. 01-00758, Jim Walter Resources, Inc., Adger, Jefferson County, Alabama, January 21, 1986. Mine Safety and Health Administration, 1986, 46 pp.
4. Frey, G. K. and Kretoski, S. R., Jr. Accident Investigation Report, Dutch Creek Mine, I.D. No. 05-00301, Mid-Continent Resources, Inc., Redstone, Pitkin County, Colorado, December 10, 1988. Mine Safety and Health Administration, 1988, 7 pp.

5. Pennington, R. L. Accident Investigation Report, Virginia Pocahontas No. 1 Mine, I.D. No. 44-00246, Island Creek Coal Company, Oakwood, Buchanan County, Virginia, March 9, 1990. Mine Safety and Health Administration, 1990, 7 pp.
6. Smith, A. C., M. W. Ryan, R. W. Pro, and C. P. Lazzara. The Effect of Ventilation on the Water Spray Pattern of Automatic Sprinkler Heads. BuMines RI 9459, 1993, 33 pp.
7. Cote, A. E. and R. P. Fleming. Fast Response Sprinkler Technology. Ch in Fire Protection Handbook, ed. by A. E. Cote and J. L. Linville. National Fire Protection Association, 17th ed., 1991, pp. 5-187 to 5-197.
8. Ryan, M. W., A. C. Smith, and C. P. Lazzara. The Effect of Ventilation on the Performance of Automatic Sprinkler Systems. To Be Published in Proceedings of 6th U.S. Mine Ventilation Symposium, Salt Lake City, UT, 1993, 6 pp.
9. Fleming, R. Automatic Sprinklers. Ch in Fire Protection Handbook, ed. by A. E. Cote and J. L. Linville. National Fire Protection Association, 17th ed., 1991, pp. 5-174 to 5-185.
10. Underwriters Laboratories Inc. UL 199, Standard for Automatic Sprinklers for Fire-Protection Service. Seventh Edition. Northbrook, IL, 1982, 40 pp.
11. Ryan, M. W., A. C. Smith, R. W. Pro, and C. P. Lazzara. The Effect of Pressure on the Leakage of Automatic Sprinklers. BuMines RI 9451, 1993, 38 pp.

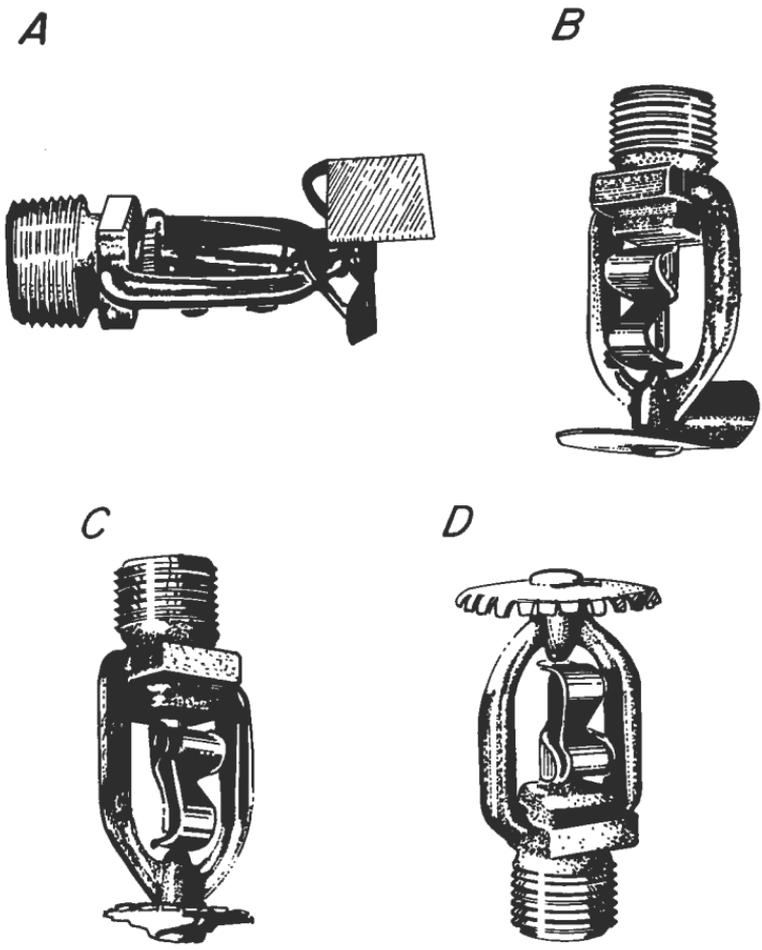
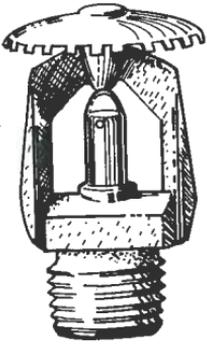
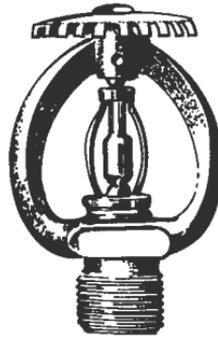


Figure 1.-- Schematic of (A) horizontal sidewall, (B) pendent sidewall, (C) pendent, and (D) upright sprinklers.

A



B



BR-92  
342

Figure 2. -- Examples of (A) glass bulb and (B) fusible type sprinklers.

LONGWALL USA 1993 CONFERENCE PAPER



INTERNATIONAL EXHIBITION & CONFERENCE

**CONFERENCE  
PAPERS**

JUNE 8-10, 1993

LAWRENCE CONVENTION CENTER  
PITTSBURGH, PENNSYLVANIA

TN  
802  
.L85  
1993

TN802  
.L85  
1993



***Maclean Hunter  
Mining and  
Construction  
Group***



***Maclean Hunter Presentations, Inc.***

12371 East Cornell Avenue

Aurora, Colorado 80014

Phone (303) 696-6100

Fax (303) 751-1880