Evaluating Fire Sprinklers

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Automatic fire sprinklers not only detect a fire but also hold it in check till appropriate action can be taken to extinguish it. The authors discuss here the various tests for evaluating the performance of an automatic fire sprinkler based on the procedures laid down in standards developed in other countries. An Indian standard on the subject has been recently finalized on the basis of data collected by the Fire Research Laboratory of Central Building Research Institute, Roorkee, and other research institutions — Ed.

■ A fire has a critical period of growth and spread and, unless detected and controlled in time, it may go out of control, assume serious proportions and result in heavy loss of life and property. Thus, detection of fire followed by a call to the fire brigade, the latter's arrival on the scene and commencement of fire fighting operations after location of hydrants, laying out of hoses, etc, entails a lapse of time which is unacceptable from the viewpoint of the necessity to attack the fire within its critical period of growth and spread. This is in addition to possible failure of the human element and lack of reliability of fire fighting equipment.

The automatic sprinkler system has obvious advantages over dependence on watch and ward personnel. It not only operates as a fire detector but also starts taking fire control action within the critical period referred to and helps control the fire or hold it in check till the fire brigade arrives on the scene and initiates appropriate and adequate fire fighting operations. Through the flow of water in the system actuated by opening of the sprinkler, the latter also serves to sound an alarm. While an automatic sprinkler installation is absolutely essential in situations, such as basements and different storeys of high-rise buildings beyond the reach of the fire-brigade fire-fighting equipment, sprinklerization of all buildings is desirable. Though adoption of this 'active' form of fire protection is a costly proposition it attracts substantial rebate from insurers besides permitting relaxation of building regulation requirements in respect of materials, life safety, etc, and pays for itself over a period of years. The only reservation sometimes voiced against installation of sprinklers is the possible water damage that might occur to material susceptible to such damage. The loss on account of water damage is, however, very small in comparison to the fire damage that might otherwise result in other sprinkler installations in which only a minimum number of sprinklers open in close proximity to fire.

The automatic sprinkler and a sprinkler system are only as efficient and reliable as methods of evaluation and quality control in their manufacture and installation can make them. In the context of the trend towards urbanization and inescapable vertical growth of buildings in the cities, wider use of sprinklers is foreseen. The Fire Research Laboratory at the Central Building Research Institute (CBRI), Roorkee, is assisting the Indian Standards Institution in bringing out an Indian standard for automatic sprinklers based on the requirements laid down in other national and international standards, providing the required equipment for evaluation of sprinklers and making available testing or evaluation service manned by technically competent and qualified personnel. This paper gives an idea of the evaluation procedures considered desirable and the equipment provided by the Fire Research Laboratory at CBRI.

EVALUATING PROCEDURES

Evaluating procedures are enforced in the form of standards. These standards are formulated on the basis of experience and test results. In the United States, agencies like Factory Mutual Research Corporation (FMRC), Underwriters' Laboratories (UL), Factory Insurance Association (FIA), National Board of Fire Underwriters (NBFU) and manufacturers under the auspices of National Fire Protection Association (NFPA) have produced a standard NFPA 13 for installation of sprinklers. FMRC and UL have also published their own standards. In the United Kingdom, the *Fire Offices' Committee (FOC) Rules* are followed. The latest edition of *FOC Rules* was published in 1968. These rules are very much similar to those of *Comité European des Assurances* (CEA) which are intended to form the basis of the rules for 18 member-countries. The other member-countries, such as Germany, France and Sweden have also prepared their own rules in the light of CEA proposals.

In order to have a common universal standard, the International Organization for Standardization (ISO) has recently brought out a draft which incorporates almost all the important tests. The Indian standard finalized on the subject is also similar to the ISO draft. A critical analysis of the various tests mentioned in different standards is given here along with the testing facilities available at CBRI, Roorkee.

Nominal Release Temperature Test

The test is performed to determine the release temperature of the thermal element, that is, glass bulb or fusible element. For fusible element sprinklers, the release temperature is permitted to vary by ±4°C while for glass bulbs the variation may be −3°C to +8°C. The range for glass bulb is wider because the release temperature which depends upon the air bubble diameter is difficult to control and hence there is a danger that the operating time is also slightly higher.

The apparatus for carrying out this test is essentially a well-stirred water bath (*see* Fig. 1) for elements of operating temperature less than 100°C and refined groundnut oil bath for higher grades. The release element is suspended in the bath which is heated to a temperature 20°C below the operating temperature at the rate of 20°C/min and held at this temperature for 10 minutes to ensure uniformity in the temperature. After this, the bath is heated at the rate of 0·4 -0·7°C/min until the sprinkler starts operating. The sprinkler should operate well within the specified range.

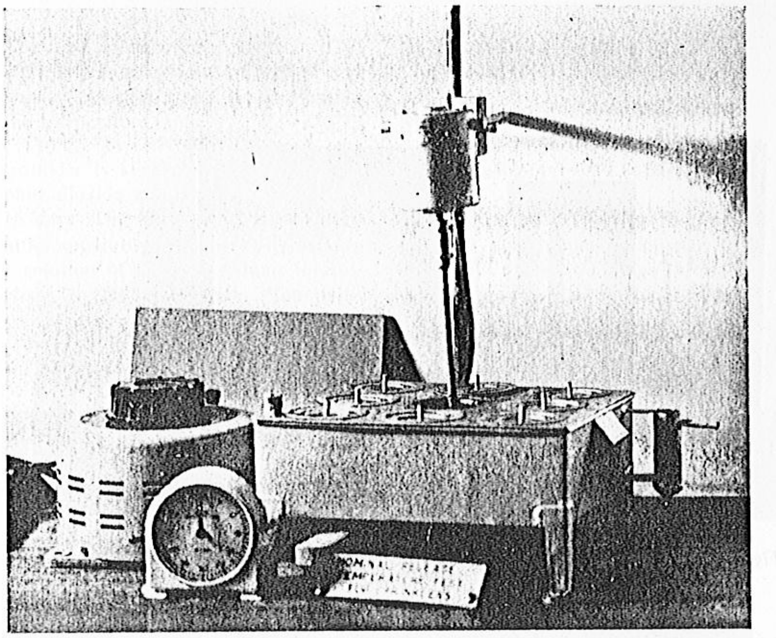

Fig. 1 Nominal release temperature test set-up

Leak Resistance Test

This test is performed to ensure that the sprinkler does not leak throughout its life under the service pressure of 10 bars. In European countries the sprinkler is subjected to a water pressure of 25 bars (2·5 times the service pressure) for three minutes while in America the pressure is of the order of 35 bars for one minute. In addition to this, Underwriters' Laboratories also recommend that the sprinkler should be subjected to a water pressure of 20 bars for 30 days without any failure.

The Fire Research Laboratory at CBRI has designed an apparatus (*see* Fig. 2) for this test. The sprinkler to be tested is mounted below the cylinder which is then filled with water and finally air pressure is applied to it for a specified period.

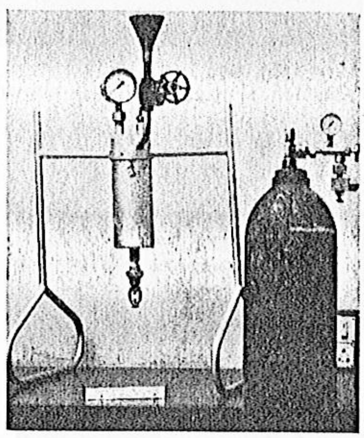

Fig. 2 Leak resistance test apparatus

Functional Test

The test is intended to see whether the sprinkler operates successfully under the rising temperature of ambient atmosphere and whether the release element, after being operated, disturbs the distribution pattern of the sprinkler by lodging on the distribution plate. The size of glass fragments may be less than 2/3 of the distance between the mounting points. The test is carried out at a water pressure of 0·35, 3·5 and 7·0 bars, subjecting eight sprinklers to each pressure condition.

The test is carried out in a specially designed oven (*see* Fig. 3) in which a temperature of 250 ±20°C is achieved in two minutes. The sprinkler is mounted under the ceiling of the oven and water pressure of desired value is applied to it. Then the burner is lighted and the time of its operation is recorded. After this the water supply and burner are turned off and the sprinkler is inspected for any lodgement.

Thermal Test

The test is prescribed in standards formulated in European countries and is understood to be receiving attention in America also. Since the operation of the sprinkler depends largely upon the rate of heat transfer, there is a possibility of some 'thermal lag' in its operation, which should be the minimum possible. Considering a system in which a sprinkler is suspended in an environment, whose temperature is rising by α°C/min, we have by simple heat balance:

$$C\frac{d\phi}{dt} = HA(\alpha t - \phi) \qquad \text{... (1)}$$

where

C = thermal capacity of heat sensitive element, kcal/°C;

ϕ = temperature rise of heat-sensitive element, °C;

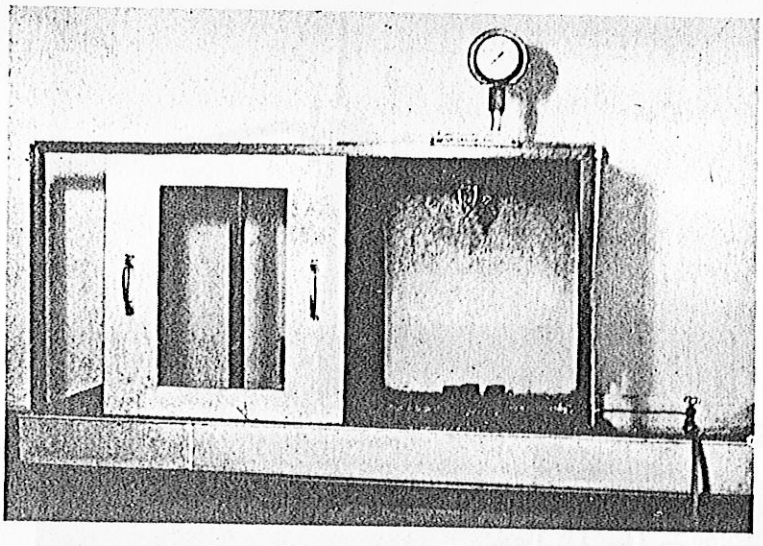

Fig. 3 Functional test apparatus

H = heat transfer coefficient, $\frac{\text{kcal}}{\text{m}^2, \text{min}, {}^\circ\text{C}}$;

A = surface of heat-sensitive element exposed to ambient atmosphere, m^2; and

t = time, min.

Equation (1) may be written as:

$$T\frac{d\phi}{dt} + \phi = \alpha t \quad \dots (2)$$

where

$$T = (C/HA) \quad \dots (3)$$

The final solution of equation (2) is

$$\phi = \alpha\,[t - T(1 - e^{-t/T})] \quad \dots (4)$$

Assuming T is very small, a condition which is a must for efficient sprinklers, we have:

$$t = \frac{\phi}{\alpha} + T \quad \dots (5)$$

In equation (5), T represents the thermal lag and is designated as 'time constant'. It may be defined as the minimum response time of the sprinkler/detector for an infinite rate of rise in temperature.

The apparatus (*see* Fig. 4) is essentially a closed circuit wind tunnel of square X-section as described in 'BS 5445: Part V: 1977 Specification for components of automatic fire detection systems: Part 5 Heat sensitive detectors — point detectors containing a static element'. The tunnel is well insulated from inside to prevent thermal loss. At one end of the tunnel a blower is provided to circulate air at a mass flow rate equivalent to 80 cm/s at 20°C and is maintained at this rate as the temperature of the air in the tunnel is raised uniformly at the rate ranging from 1°C/min to 30°C/min with the heating elements provided near the blower. The sprinkler to be tested is suspended in the test section of the tunnel and blower, and the heaters are turned on to supply air at the specified rate and temperature. The time of operation is recorded and the time constant determined from equation (5) should have a value between 1·5 and 2·5 minutes.

Fatigue Test

The test represents the conditions in which the sprinkler is likely to be subjected first to hot environment and then to cold environment. It is accepted universally for glass bulb sprinklers and is performed similar to the nominal release temperature test. The glass bulb sprinkler is suspended in a water bath whose temperature is raised until the bubble disappears. The sprinkler is then removed and cooled in air so that the bubble reappears. This is repeated four times and then examined for any defects.

Thermal Shock Test

This test is similar to the fatigue test. The fatigue test represents the conditions in which the sprinkler is heated slowly and under non-operation conditions, cools moderately in air while the thermal shock test represents the conditions in which a sprinkler may give a thermal shock when water falls on it as the neighbouring sprinkler operates. For this test the glass bulb sprinkler is immersed in a liquid bath whose temperature is kept 10°C below the normal operating temperature of the sprinkler. After immersing for 5 minutes, the sprinkler is taken out and dipped into water at 10°C. No specific apparatus is required for this test.

Strength of Heat-Sensitive Element

This test is intended to determine whether the sprinkler will fail under

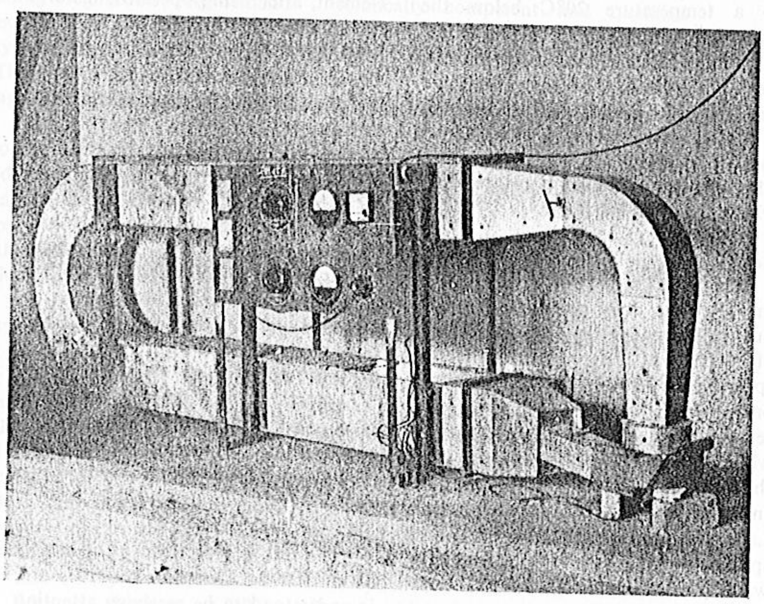

Fig. 4 Closed circuit wind tunnel for thermal test

continuous service load throughout its life of installation. This test is very important because cold flow effect in the fusible element sprinkler and vitrification process in the glass bulb sprinkler reduces the strength of the heat-sensitive element.

While standards in the European countries require only glass bulbs to be subjected to this test, UL 199 speaks in general terms applicable to any type of sprinkler. Accordingly, the European standard specifies application of a load equivalent to seven times the service load and the American standard makes it necessary to apply 15 times the service load for 100 hours. Keeping in view the two reasons mentioned above, it is better to use American specification irrespective of the type of sprinkler for better service. The apparatus used is a simple compression machine fitted with a proven ring (*see* Fig. 5).

Strength of Sprinkler Frame

Under continuous service load, it is possible that permanent elongation may set in the sprinkler frame which will allow water to leak. To avoid such an eventuality, sprinklers are stretched by a force equal to twice the service load and after releasing the load, permanent elongation is measured which should not be more than 0·02 percent of the distance between the load bearing points.

The apparatus is usually a tensometer (*see* Fig. 6).

Sulphur Dioxide Corrosion Test

This test is intended to show the capability of the sprinkler for good performance in corrosive atmosphere.

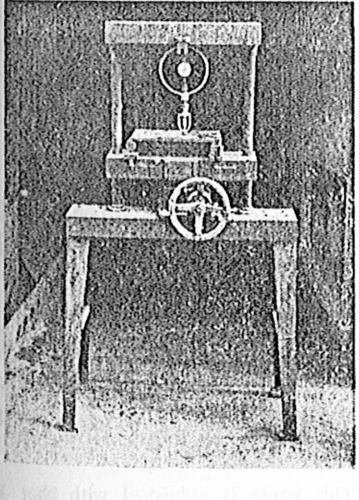

Fig. 5 Compression machine for strength of heat-sensitive element test

The test is according to 'BS 3116: 1959 Thermographics (liquid-filled and vapour pressure types) for use within the temperature range −20°F to 220°F) (30°C to 105°C) in which the sprinkler is kept under saturated sulphur dioxide atmosphere at 45°C for 16 days. The atmosphere is produced in an apparatus (*see* Fig. 7) by making a solution of 20 g of sodium thiosulphate in 500 ml of water. Ten millilitres of acid containing 156 ml normal sulphuric acid in one litre of water is added twice a day to sodium thiosulphate solutions. The solutions are replaced by fresh solutions after 8 days and the sprinkler is removed after 16 days, dried and subjected to functional test at a pressure of 0·35 bar.

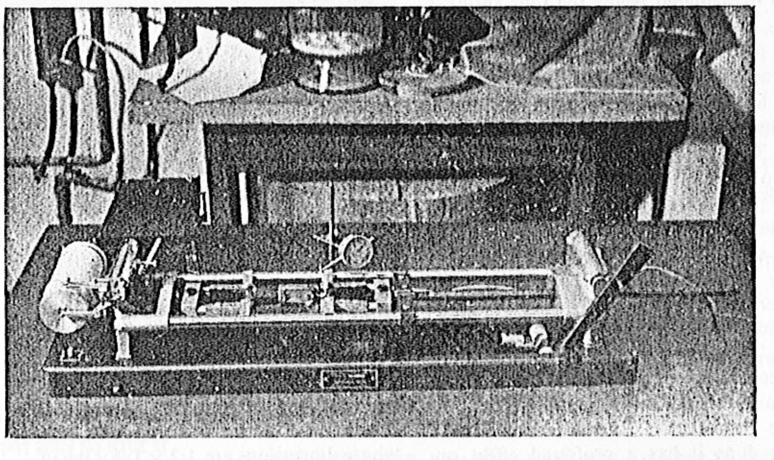

Fig. 6 Strength of sprinkler frame test apparatus

Mercurous Nitrate Stress Corrosion Test

The test is essential to find out the pressure of unrelieved stresses in the parts during casting and fabricating.

The sprinkler is immersed in a 50 percent solution of nitric acid (sp gr 1·42) in distilled water for 15 to 30 seconds. It is then taken out and washed with water and again immersed in a 1 percent (*w/w*) solution of mercurous nitrate in distilled water to which 1 ml of nitric acid has been added for each 100 ml of solution. After 30 minutes' immersion, the sprinkler is taken out and cleaned, dried and examined carefully for any sign of cracking.

Flow Test

This test is performed to determine the orifice coefficient, K, of the sprinkler nozzle using equation (6):

$$Q^2 = K^2 P \qquad ...(6)$$

where

Q = flow of water in dm^3/min, and

P = gauge pressure in bars.

The apparatus (*see* Fig. 8) consists of a 40 mm nominal diameter pipe fitted with a pressure gauge through a 3 mm dia hole. The sprinkler is fixed into a 10, 15 or 20 mm branch of a 40 mm dia tee. The flow rate of water *versus* pressure data is obtained and value of K determined from equation (6). This value should be 57, 80 and 115 with ±5 percent tolerance for 10, 15 and 20 mm dia orifice respectively.

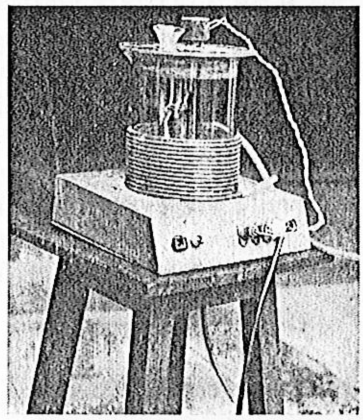

Fig. 7 Sulphur dioxide corrosion test apparatus

Distribution Test

This test is performed to find the discharge density (mm/min) of the sprinkler, which in turn gives the performance of the deflector plate. NFPA Standard No. 13 requires a minimum design discharge density of 3·78 mm/min as compared to European requirements of 2·25 mm/min.

The test is to be carried out in a room of dimensions 7 × 7 × 3·7 m (*see* Fig. 9). A square array of four sprinklers is mounted on ceiling distribution pipes. Water is collected in 100 square collecting cans, each of side 0·5 m, centered below the four sprinklers. It is required that not more than 10 percent of the area covered by the array shall have a discharge density of less than half the design discharge density.

The American set-up for distribution test is entirely different in which 16 pans are mounted on a turn table rotating at a speed of 4 rev/min. Four or six sprinklers spaced 3·05 m apart are installed above the pans and average collection by these pans recorded.

The distribution test is, however, recommended for determining the discharge density only but it is felt that the droplet size should also be measured as it has a profound effect on the extinguishing efficiency of the sprinkler. The Fire Research Laboratory at CBRI is planning work on this aspect.

Fire Test

This test is intended to show the direct performance of the sprinkler and is not covered in European standards. Specifications of this test are available in Underwriters' Laboratories Standard 199 and in the Factory Mutual Research Corporation's Standard.

Four sprinklers are mounted on a square array of 3·05 and 2·3 m above the top of wood crib placed centrally beneath the array. The wooden crib, whose dimensions are 1·2 × 1·2 × 0·6 m, may contain a moisture content between 6 and 10 percent. Heptan is sprayed from a SPRACO A5WA nozzle 104·30 cm below the crib. The rate of heptane discharge and minimum water flow per sprinkler is maintained in accordance with the requirement and observations in terms of weight loss of cribs, ceiling temperature and maximum number of sprinklers open are recorded. This test seems to be a replacement of the functional test mentioned earlier (given in CEA standard). However, to our opinion, the fire test represents better functional performance of the sprinkler.

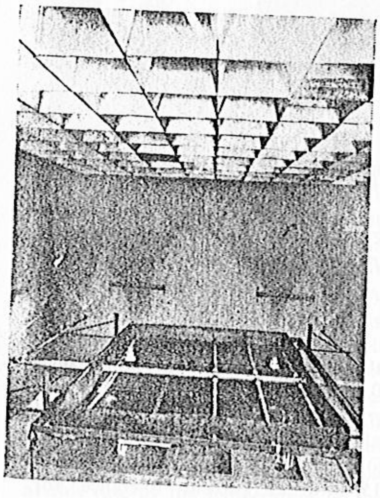

Fig. 9 Distribution test apparatus

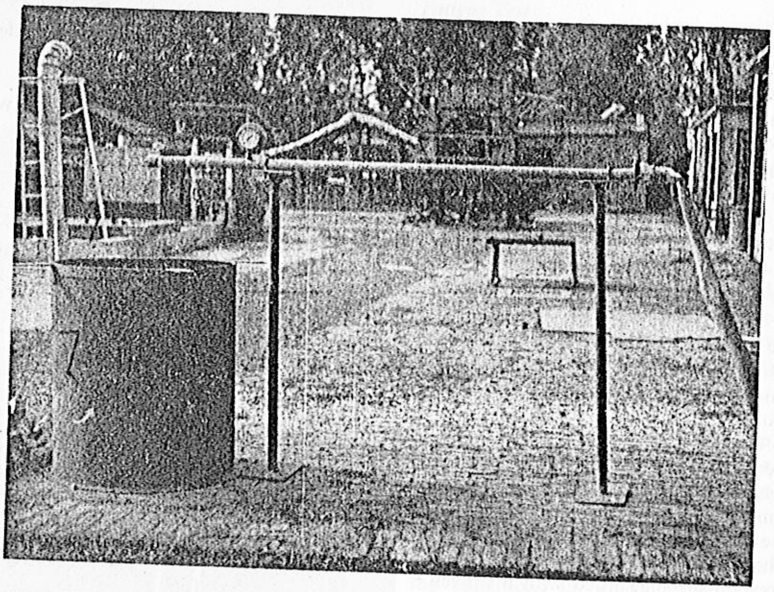

Fig. 8 Flow test apparatus

Water Hammer Test

There is a danger of water hammering on the sprinkler which may lead to leakage. To avoid the UL 199 prescribes this test in which the sprinkler is subjected to a pressure rising from 3·4 to 34 bars and back in a 1-second cycle for 3 000 times in succession. It must be noted that if the sprinkler is subjected to water hammer test, the leak resistance test would not be required.

Vibration Test

This test is performed to assess the possibility of sprinkler failure due to vibrations. The sprinklers are exposed to vertical vibrations at a rate of 35 cycles per second with an amplitude of 1 mm for a period of 120 hours. Following the exposure, the sprinkler shall not leak at a pressure of 35 bars.

High Ambient Temperature Test

This test is intended to determine the effect of sustained high ambient temperature on the performance of a sprinkler. The sprinkler is kept at a temperature 11°C below its rated operating temperature for 90 days. Following the exposure the sprinkler shall be tested for its leakage and functional requirements.

CONCLUSION

Most of the test procedures have been developed either in European countries or in the USA. A study of the various standards shows that the procedure adopted is by and large common. The testing methods given in UL 199 under different headings seem to have wider coverage. Since the sprinklers are to be installed all over the world it is necessary to have a common standard. This standard should include testing methods on the basis of merits after critically analyzing the various methods.

The Fire Research Laboratory at CBRI, Roorkee, is assisting the Indian Standards Institution in adopting the various tests on the basis of test results collected by CBRI and available from various research institutions.

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