Automatic Sprinkler System (Design Consideration)

A.K. Gupta & S.B. Gupta

Shri A.K. Gupta, is a Chemical Engineer. He obtained his Bachelor's and Master's Degree in Chemical Engineering from the University of Roorkee. He is presently working as a Scientist at the Fire Research Laboratory, CBRI, Rookee and engaged in the design, development and installation of fixed fire protection devices.

Shri S.B. Gupta, a Mechanical Engineer, is also engaged in the development of fire protection devices at CBRI, Roorkee. He has obtained Sub-Officer's certificate from NFSC Nagpur. —*Ed*

Although the automatic sprinkler system is supposed to be a fool proof and full time fire protection measure, there are cases where this system has not shown its efficacy. The reason found behind its failure was either inadequate supply and pressure of water, improper maintenance, less number of sprinklers per square metre of floor area, lower size of sprinkler nozzle, under-estimation of the hazard or higher rating of sprinkler heads etc. Unskilled compromise with these parameters has led to a disastrous situation. Therefore it is in the interest of users, designers, manufacturers and insurers to ensure that the design has been made optimum keeping in view the best guidelines available. These guidelines have been formulated mainly by the National Fire Protection Association[1] of U.S.A. and Fire Offices Committee[2] U.K. based upon the reasearch work carried by the National Board of Fire Underwriters (NBFU), Factory Insurance Association (FIA), Undetwriters' Laboratory Inc. (UL) and Factory Mutual Research Corporation (FMRC) all of U.S.A. and the Joint Fire Research Organisation (JFRO) of U.K. IS : 1648-1961[3] also provides a few guidelines which are based largely on FOC Rules of U.K. A few organisations in the private sector are also contributing a lot in the fabrication of these guidelines. These guidelines and the research work carried out in the relevant field have been analysed critically and is covered under the scope of this article. The various parameters and the science behind them have been discussed one by one in the following paragraphs.

Hazard Classification

The first step must be taken while designing an automatic sprinkler system, is to access the quantity and combustibility of the materials to be protected so that the low risks are not over protected and that the high risks are not under protected. For this reason the occupancies have been divided in three groups namely extra light hazard, ordinary hazard and extra high hazard occupancy, depending upon the nature and the combustible contents of the material contained inside the occupancy. The classification as defined in the NFPA Codes of U.S.A. and the FOC Rules of U.K. is similar. Following are the important risks covered under various categories :

1. Extra light hazard

This includes occupancies such as hospitals, hotels, theatres, libraries, educational buildings, museums etc. where a fire of low intensity is expected because of low combustible contents present in these occupancies.

2. Ordinary Hazard

Occupancies in which the combustible materials are of such nature that its calorific value is low but the quantity is fairly high are categorised as ordinary hazard occupancies. Majority of the industrial and commercial occupancies are covered under this hazard group and is therefore further classified into three groups in U.S.A. and in four groups in U.K. in order of the increasing risk viz. ordinary group-1, ordinary group-2, ordinary group-3 and ordinary group-3 (S). The important premises come under this hazard class, in order of increasing risk are beverage manufacturers, dairies, laundries, automobiles, chemical plants, cold storages, confectioneries, textiles, wood products, carpet, corn mills, glass factories, paper mills, small warehouses, match factories and distilleries etc.

3. Extra High Hazard

Occupancies such as aircraft hangars, plastic manufacturers and industries involving flammable liquids, where large quantity of highly combustible materials are stored or processed and are likely to develop rapid and intensely burning fires are classified as extra hazardous premises. These are further classified into two groups viz. process and storage groups. Process groups include explosives, chemical works, tar, distilleries etc. and storage group includes high racked storages of clothing, paper bales, wooden furniture etc. etc.

There are a few occupancies, which are just at the border between the two classifications and are likely to pose problem before the designer as to which class should be considered. IS:1641-1960[4] classifies occupancies based on the fire load as follows :

Low fire load-below 275,000 $\frac{\text{K Cals}}{\text{m}^2}$

Moderate fire load-275000-550000 $\frac{\text{K Cals}}{\text{m}^2}$

High Fire Load-550000-1100000 $\frac{\text{K Cals}}{\text{m}^2}$

Thus if we make the fire load as a basis in addition to the classification given by either FOC Rules or NFPA Codes, it is possible to identify the right group of the hazard. Gustav[5] has also proposed a method of evaluating fire risks as a basis for planning automatic fire protection system which can also be used successfully.

Sizes of Sprinklers

Normally three sizes of sprinklers are used depending upon the nature of risk involved. In United Kingdom the commonly used sizes are 10 mm, 15mm. and 20mm. orifice diameter sprinklers whereas in America these are 9.5 mm. (3/8"), 12.5 mm. (½") and 13.5mm. (17/32") orifice diameter sprinklers.

Three sizes are according to their suitability in various occupancies in order of increasing risk. Although the ½" U.S.A. or 15mm. U.K. sprinkler are used most commonly but 10mm. sprinkler is considered suitable for light hazard occupancies and 20 mm sprinkler is used to protect high hazard occupancies. For intermediate risks that is ordinary hazard occupancies or light hazard occupancies where large water application rate is required or high hazard occupancies where low water application rate (described in the following paragraph) is required. 15mm. orifice sprinkler should be used. For one value of water application rate, larger orifice sprinklers will be required in small numbers at the cost of poor distribution of water. Table-1 shows the discharge rates of British & American sprinklers at various pressures. Thus having known the litres/min of water required the number and size of sprinklers can be found out.

From this table, it appears that the American sprinklers are designed to discharge more water per minute. But as a matter of fact it is not fully correct since the methods and experimental set-ups used by Americans ([6]) and Britishers ([7]) are different.

Table 1 : Water discharge rates of automatic sprinklers at various pressures

Pressure (bars)	Water discharge rate lit/Min. $Q=K\sqrt{P}$, (P in bars)					
	American Sprinklers			British sprinklers		
	9.5 mm. K=41	12.7 mm K=82	13.5 mm K=115	10 mm K=57	1′ mm K=80	20 mm K=15
0.69	34	68	95	47	66	95
1.035	42	83	116	58	81	116
1.38	49	96	135	67	93.5	135
1.725	:5	100	150	75	105	150
2.415	64	129	178	88	124	178
3.45	76	151	212	105	148	212
5.175	95	187	261	129	182	261
6.90	108	216	302	149	210	302

American does not consider velocity pressure effect (8 10) at all while calculatining 'K' factor whereas Britishers does consider it. As a result of this, lower values of 'K' factor are obtained by the latter method. Although this method of determining 'K' factor is more nearer to the actual installation system. Hence it could be recommended here that the real of value 'K' factor or the discharge rate should be known for a particular design of sprinkler before its installation.

Ratings of Sprinklers

Automatic sprinklers are available in ratings of 57°C, 68°C, 79°C, 93°C, 141°C, 182°C, 204°C and 260°C. Proper selection of sprinklers rating is an important aspect in the design of sprinkler installation systems, since a lower rating sprinkler although will open quickly but at the same time the numbers of operating sprinklers may be quite high resulting in the wastage of water and wetting of mateiial that might otherwise be unaffected. On the other hand, less number of higher rating sprinkler will operate but the size of fire will become relatively larger. Rhodes [11] and Suchowel [12] have shown that sprinklers of intermediate ratings have advantage over lower ratings since under intense fire the difference in the operating times of various rating sprinklers is small and so the wastage of water will also be smaller.

Table 2 shows the ratios of number of sprinklers operating with different ratings.

Table — 2

Simpler Rating °C	Ratio of numbers of sprinklers operating
68	1
79	0.81
93	0.53
141	0.38
182	0.27

It is clear from this table that an increase in rating from 68°C to 79°C will result in 20 percent less sprinklers operating. But at the same time, the selection of higher rating sprinklers, in a likely slow fire, will result a larger size of fire at the time of its operation, although this may not be the situation in a likely to be intense fire. Dogherty [13] etc. have tried to determine the size of fire at sprinkler's operation with respect to ratings and is presented here in table - 3. It is apparent from their work that an increase in rating from 68 to 79°C will result 20 percent larger size of fire.

Table — 3

Sprinkler Rating °C	Ratio of size of fire
68	1
79	1.20
93	1.45
141	2.31
182	3.05

Hence we have to balance between the number of sprinklers operating and the size of fire. This could be done bearing two points in mind which are - maximum ambient temperature likely to be experienced in a year and the likely rate of burning of materials present in the occupancy to be protected. Bearing these points into consideration the FMRC [14] has suggested the use of various ratings in different occupancies and under different maximum ambient temperature conditions. This is given in table - 4.

Apart from considering the above parameters, it is also important to bear im mind the height of ceiling. Experiments [13] say that doubling the ceiling height results in an increase in the fire size by four times. Therefore, it could be concluded that for buildings of excessive ceiling heights, the higher rating sprinklers will operate at even larger size of fire.

Sprinkler Spacing

In order to minimise the number of sprinklers operating and to reduce the cost of sprinkler installation, sprinklers must be spaced according to the risk and requirements. The spacing between sprinkler beside other factors depends upon the size of sprinkler's orifice and the water application rate which is directly related to the class of risk. For a particular risk a sprinkler of larger size will be spaced at a larger distance than the smaller size sprinkler and hence its horizontal distance from the axis of fire will also be larger. Studies show that the size of fire increases linearly with the horizontal distance between the sprinkler and the fire axis for high ceilings. For low ceilings however the increase in fire size is limited upto about 1.5 m only from the fire axis. Therefore the ceiling height together with the size of sprinkler must be considered while fixing the spacing between the sprinklers. The maximum spacing between sprinkers and hence the coverage of one sprinkler for different risks as recommended by NFPA and FOC Rules is given in Table - 5.

Water Application Rate (WAR)

The Water application rate is defined as the litres of water required per minute to achieve satisfactory control on fire, and described in litres per second per square meter of the floor area. Some times it is also described in mm./min. The water application rate (WAR) is obviously different for different occupancies and hence the automatic sprinkler system must be designed for an optimum (WAR).

Table 4 : Selection of proper sprinkler ratings

Type of occupancy	Maximum ambient temperature under non-fire condition, °C					
	37	67	107	150	200	255
Light hazardous occupancies (Offices, Schools, hotels, hospitals etc.)	57, 71, 72	79, 100	121, 137, 141	162, 176, 182	204	260
Ordinary hazardous occupancies (dairies, laundries, automobiles, confectioneries, corn mills etc.)	79, 100	79, 100	121, 137, 141	162, 176, 182	204	260
High hazardous occupancies (flammable liquids, rubber, plastic, foam etc.)	121, 137, 141	121, 137 141	121, 137, 141	162, 176, 182	204	260