Hydraulic Calculations for Small Rooms

By Kenneth E. Isman, P.E.

We've all used the Small Room Rule in NFPA 13 to gain some flexibility in spacing sprinklers. But how are the hydraulics in small rooms different from the hydraulics in large open spaces? The answer is that there are pitfalls to the hydraulic calculation procedures in small rooms. People that just plug numbers into computer programs and don't understand what to look for in the output can get caught with insufficient flow or pressure for their sprinkler systems. Likewise, plan reviewers need to understand what to look for in the calculation of small rooms so that they only approve hydraulic calculations that have been performed correctly. This article will address some of the potential pitfalls and show how to find them on computer program outputs.

This article will reference sections from the 2010 edition of NFPA 13. But the concepts and requirements are the same in all recent previous editions (going back before the 1990's). The section numbers in previous editions may be different depending on the edition.

What is the Small Room Rule?

The Small Room Rule is actually a combination of three different sections of NFPA 13. When used together, these sections allow the user to select one wall in a room and place sprinklers up to 9 ft from that single wall. In addition, the Small Room Rule allows the user to average the area of the room using the number of sprinklers in the room to determine the area of coverage per sprinkler rather than using the S x L rules of section 8.5.2.

The first section in the Small Room Rule is section 3.3.17, which defines a Small Room as one not greater than 800 sq ft with unobstructed ceiling construction in a light hazard occupancy. This last limitation is important in that the Small Room Rule cannot be used in ordinary hazard, extra hazard, or high piled storage. Limited openings are allowed in the walls leading to other rooms.

The second section in the Small Room Rule is section 8.6.3.2.4, which permits upright and pendent standard spray sprinklers to be installed up to 9 ft from a single wall. Note that this only allows the sprinklers to be 9 ft from one wall in the room, not from two or more walls. Also note that this only applies to upright and pendent standard spray sprinklers. This rule does not apply to residential sprinklers, extended coverage sprinklers, or any kind of sidewall sprinkler.

The third section in the Small Room Rule is section 8.6.2.1.2, which permits to user to ignore the S x L Rule of 8.5.2 and average out the size of the room by the number of sprinklers to determine the area of coverage per sprinkler. In order to use this portion of the rule, it is not necessary to have any sprinklers up to 9 ft from a wall. This section of NFPA 13 is independent of the portion of the rule that allows sprinklers to be more than 7.5 ft from a wall.

Note that the averaging is only in the section for upright and pendent standard spray sprinklers, so it does not apply to extended coverage sprinklers or sidewall spray sprinklers. However, section 11.3.1.3, which covers the minimum density of 0.1 gpm per sq ft being applied to residential sprinklers when such sprinklers are used in an NFPA 13 system references this section for calculating the area of coverage for residential sprinklers in small rooms. Therefore, in this one limited circumstance, residential sprinklers can use the Small Room Rule to determine the minimum required discharge from the sprinkler.

See the article, "The Small Room Rule" in the Spring 2000 issue of Sprinkler Quarterly for more information on how to use the Small Room Rule for spacing of standard spray sprinklers.

Design Area

The first step in hydraulics is to determine the design area (the reasonable worse-case sprinklers that would be open if there was a fire in the building). As with all sprinkler systems, this is determined using the Room Design Method or the Density/Area Method.

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In a building with many small compartments, it might be tempting to use the Room Design Method. But the most demanding room can be difficult to find, and if there is one larger room in the building, this may not be practical. This article will focus on the use of the Density/Area Method.

When using the Density/Area Method, the location of walls is ignored when making the initial decision about which sprinklers are the hydraulically most demanding. However, before finishing with the determination of which sprinklers are in the design area, you do need to make sure that the actual area protected by the sprinklers meets the minimum design area. In other words, you can't count on sprinklers spraying past a wall to cover area on the other side of a wall, even if the area on the other side of the wall is mathematically less than one-half of the allowable distance between sprinklers.

In a situation like this, it is often advantageous to consider an example. For this article, we will use the sprinkler system shown in Figure 1 as an example of some of the pitfalls we might encounter in conducting hydraulic calculations in buildings with small rooms. The building in this case has three rooms. Room A is 245 sq ft in the northwest corner. Room B is 637 sq ft next to Room A. The third room is the large space that is the rest of the building. The ceiling is 15 ft high (unobstructed construction) in this building and the occupancy is considered light hazard. The sprinklers are all standard spray quick response sprinklers (k-5.6), none of which is covering more than 225 sq ft (but many of which cover much less). *(see figure 1)*

For a light hazard occupancy with a 15 ft ceiling and quick response sprinklers, the design point of 0.1 gpm per sq ft over 1500 sq ft can be selected from the density/area curves. From there, the density can be adjusted by 32.5% (see 11.2.3.2.3) so that the final density/area requirements are 0.1 gpm per sq ft over 1013 sq ft.

Section 22.4.4.1.1.1 of NFPA 13 requires that the design area have a dimension of at least 1.2 times the square root of the design area. In this case, 1.2 times the square root of 1013 is 38.2 ft. If you start at the northwest corner and count 38.2 ft parallel to the branch lines, you get to a point 2.2 ft to the east of the wall between sprinklers 3 and 4. This means that sprinkler 4 needs to be included in the design area, as well as sprinklers 1, 2 and 3.

Next, sprinklers 5, 6, 7, and 8 need to be considered to be added to the design area. With these 8 sprinklers, the design area would be 1250 sq ft, which exceeds the 1013 sq ft required. If sprinkler 5, covering 122.5 sq ft at the end of the second branch line is dropped, the design area becomes 1127.5 sq ft, which still exceeds the required 1013 sq ft. If sprinkler 6 is dropped, the design area falls below the required 1013 sq ft, so the design area must be sprinklers 1, 2, 3, 4, 6, 7, and 8 as shown in Figure 2. *(see figure 2)*

Discharge from First Sprinkler

The next step is to determine the discharge from the most remote sprinkler, which in this case is sprinkler 1. According to the Small Room Rule, Room A is 245 sq ft and is protected by 2 sprinklers. This means that each sprinkler in Room A cov-

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Figure 1 – Sprinkler System Example

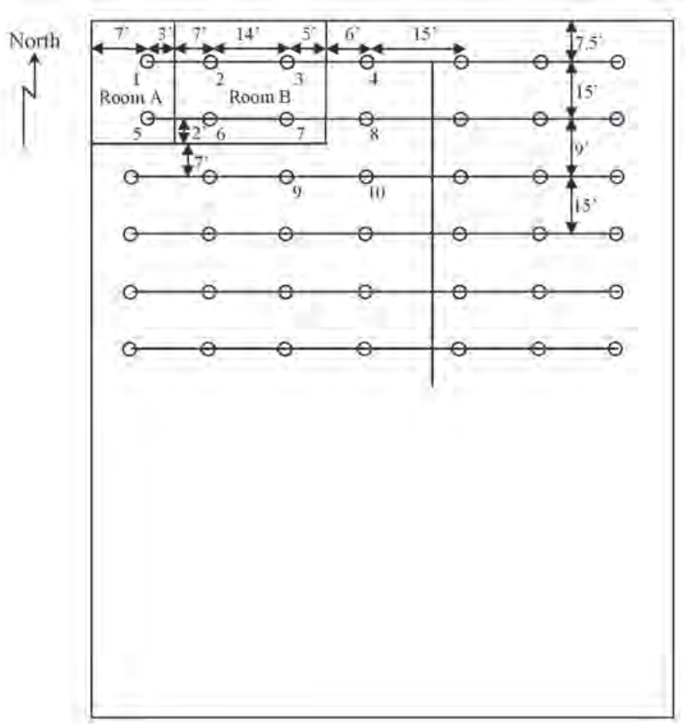

Figure 2 – Design Area for Example

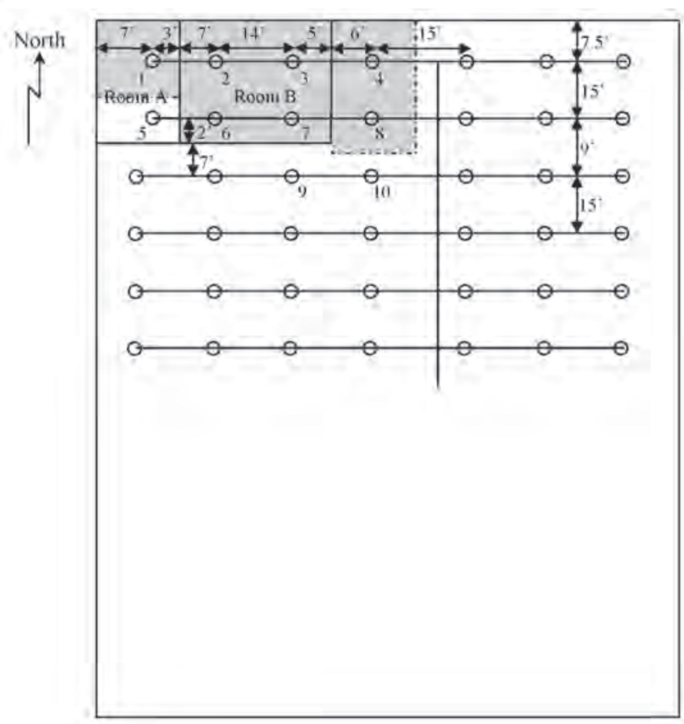

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Table 1 – Discharge from Sprinklers in Example

Sprinkler	Pressure (psi)	Flow (gpm)
1	7.0	14.8
2	7.2	15.0
3	8.2	16.0
4	9.9	17.6
6	9.9	17.6
7	10.4	18.1
8	11.7	19.1
	Total Flow: 118.2	

Table 2 –Sprinkler Discharge and Density for Example

Sprinkler	Pressure (psi)	Flow (gpm)	Area of Coverage	Density
1	7.0	14.8	122.5	0.12
2	7.2	15.0	159.25	0.09
3	8.2	16.0	159.25	0.10
4	9.9	17.6	225	0.08
6	9.9	17.6	159.25	0.11
7	10.4	18.1	159.25	0.11
8	11.7	19.1	225	0.08
	Total Flow: 118.2			

ers 122.5 sq ft (245/2 = 122.5). In order to achieve a 0.1 gpm per sq ft density out of sprinkler 1, the sprinkler would need to discharge 12.3 gpm (122.5 x 0.1 = 12.25 rounded up to 12.3).

For a sprinkler with a k-factor of 5.6 to discharge 12.3 gpm, the pressure at the sprinkler needs to be at least 4.8 psi $[(12.3/5.6)^2 = 4.8]$. Of course, a sprinkler is not allowed to discharge at so low a pressure. To meet the rules of NFPA 13, the pressure at the sprinkler needs to be increased to 7 psi.

Some people will stop there and consider the discharge from sprinkler 1 as 12.3 gpm at 7 psi. But that's not how the laws of physics work. Once the pressure at the sprinkler is increased to 7 psi, the flow coming from the sprinkler increases as well. At a pressure of 7 psi, a sprinkler with a k-factor of 5.6 will discharge 14.8 gpm (5.6 times the square root of 7 is 14.8). So, that is where the hydraulic calculations must start (14.8 gpm at 7 psi).

Discharge from the Other Sprinklers

Whether you perform the hydraulic calculations by hand or use a computer program, you'll need to figure out how much flow is going to discharge from each sprinkler. In order to do that, you'll need to know what the water pressure is at each sprinkler. Hydraulic calculations show that when you start with 14.8 gpm at 7 psi at sprinkler 1, the total demand for the sprinklers on the two branch lines is 118.2 gpm at 17.6 psi (assuming 1.38 inch branch lines and 3.068 inch main). Table 1 shows a printout that is typical to the one generated by hydraulic calculation computer programs, which lists the flow and pressure from each of the sprinklers in this example. *(see table 1)*

As Table 1 shows, sprinkler 1 appears to be the most demanding and each sprinkler after it discharges more water at a higher water pressure than sprinkler 1. A person might be tempted to stop the hydraulic calculations there. But they would be wrong.

After the hydraulic calculations have been performed (by hand or by computer), a check needs to be made of the density being provided to the floor surface being protected by each sprinkler. Table 2 shows the area of coverage for each sprinkler and the density it is putting into this coverage area (flow divided by coverage area). In this case, due to the configuration of the small rooms, there are three sprinklers that are not discharging enough water to sufficiently cover the floor beneath them (sprinklers 2, 4 and 8). This is not an unusual occurrence when the Small Room Rule gets used. *(see table 2)*

Sprinkler 2 covers 159.25 sq ft (the area of Room B divided by the four sprinklers in the room). This sprinkler would need to discharge a minimum of 15.9 gpm in order to create a density of 0.1 gpm per sq ft. Since the sprinkler is only discharging 15 gpm, it is falling short of the requirement.

Likewise, sprinklers 4 and 8 are not in small rooms. Using the S x L rules, these two sprinklers cover 225 sq ft. This means that they need to discharge 22.5 gpm at a minimum in order to achieve a density of 0.1 gpm per sq ft. But since they are only discharging 17.6 or 19.1 gpm, this calculation is not acceptable.

In order to make sure that the calculations are acceptable, the discharge from the most remote sprinkler needs to be increased so that all of the discharges from all of the sprinklers increase to the point where all sprinklers meet their minimum discharge density requirement. Unfortunately, there is no direct way to calculate this increase. There are some computer programs that will perform this calculation for you, but not all programs do, so anyone doing hydraulic calculations should learn to try a few solutions until an acceptable one is found.

Using a "trial and correction" method of starting at sprinkler 1 and trying a higher flow (and pressure) and seeing how that effects sprinklers further down the line (then trying again because the first time through did not arrive at an acceptable answer), it can eventually be determined that a starting flow of 19 gpm at 11.5 psi yields an acceptable result. Doing this by hand took this author three tries and about 20 minutes to arrive at a solution. Use of a computer to change a few variables and try again would have saved some time.

Table 3 shows the correct minimum flow and pressure requirements for the seven sprinklers on the two branch lines.

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The total flow demand for these seven sprinklers is 150.4 gpm at 28.1 psi. Note that each sprinkler is now discharging the minimum amount of flow to achieve the density of at least 0.1 gpm per sq ft. Also note that sprinkler 4 becomes the key sprinkler in the system since it is just barely able to achieve its minimum density. Any smaller pressure delivered to this system would cause sprinkler 4 to have less than its required minimum density. *(see table 3)*

Aren't the Sprinklers in the Larger Room More Demanding?

At some point in time, someone reading this article has thought to themselves, "Wait a minute! All of this is nice, but the sprinklers in the larger room are more demanding, so we should just calculate those!"

You should always be encouraged to consider the other spaces in a building, and you should even conduct some calculations to prove that you have selected the most demanding area in the building. In this case, this area containing the small rooms and sprinklers 1, 2, 3, 4, 6, 7 and 8 is probably the most demanding. To prove it, calculations were performed for the 1035 sq ft represented by sprinklers 11, 12, 13, 14 and 15 in the northeast corner of the building as shown in Figure 3. *(see figure 3)*

Sprinklers 11, 12 and 13 each cover 225 sq ft, making the total area that these three sprinklers cover 675 sq ft. Sprinklers 14 and 15 each cover 180 sq ft (due to the shorter distance between the second and third branch lines), bringing the total area covered by these five sprinklers to 1035 sq ft. Since this exceeds the design area of 1013 sq ft and since this includes at least five sprinklers, this is an appropriate design area to consider.

Hydraulic calculations of these five sprinklers, using the same size branch lines and main as the previous calculations for this example show that the demand would be 121.1 gpm at 25 psi at the second branch line. This is significantly less than the 150.4 gpm at 28.1 psi needed at the same location for the sprinklers in the small rooms as discussed above. This means that the sprinklers calculated in the small room were a reasonable worse case for this particular situation.

Depending on the exact spacing of the sprinklers in the large room south of the small rooms and to the west of the cross main, it is possible that these sprinklers will be more demanding than the previously calculated areas. We will assume for the sake of this example that the sprinklers have been spaced in this area such that they are not more demanding than the situations calculated above.

Conclusion

When using the Small Room Rule, there are certain advantages to the hydraulic calculations. But be careful in the situations where the hydraulic calculations include sprinklers outside of the small rooms. Sprinklers closer to the riser might be more demanding, and might not be getting sufficient flow to achieve their required densities.

In any situation, always check the print-out from the hydraulic calculations to make sure that every sprinkler is discharging the minimum necessary to achieve its density. Also, check multiple design areas to make sure that you have calculated the most demanding situation.

Table 3 – Correct Minimum Flow and Pressure at Each Sprinkler in Example

Sprinkler	Pressure (psi)	Flow (gpm)	Area of Coverage	Density
1	11.5	19.0	122.5	0.15
2	11.8	19.2	159.25	0.12
3	13.4	20.5	159.25	0.13
4	16.2	22.5	225	0.10
6	16.0	22.4	159.25	0.14
7	16.9	23.0	159.25	0.14
8	18.1	23.8	225	0.11
	Total Flow: 150.4			

Figure 3 – Alternate Design Area for Example