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HYDRAULIC GAIN IN SPRINKLER SYSTEM DESIGN

Fire and Security Consulting Services (FSCS) is frequently asked why the calculated sprinkler system water flow and storage requirements exceed what one would normally expect.

This always occurs in multi-storey buildings and it is a function of the system requirement that a minimum flow from each and all sprinkler heads is required to be achieved regardless of their location.

The increase in flow from the sprinkler heads nearest the water supply is termed “hydraulic gain’ is the technical term used to describe the increase in flow because the system pressure has to be such that the most “unfavourable“(remotest) sprinkler array requires the minimum pressure such that the design density is achieved, but then the most “favourable” (closest) sprinkler array to the supply point will have an operating pressure higher than necessary to achieve the minimum design density. Thus we design the pressure to suit the most remote sprinklers but have to assess the flow from the nearest. This usually results in an increase of over the base design flow dependant on the competence of the systems designer.

The % increase in flow is lowest for single storey buildings and greater the higher the building.

The following is an example of a nine (9) storey residential or office building which under the BCA and being greater than 25m effective height requires sprinkler protection. This is a typical city building however for ease of understanding; the potential inclusion of retail or car parking spaces has been ignored.

AS2118.1 (1999) requires this type of occupancy to have a “Light Hazard” sprinkler system and Part 9 of the Standard provides for the following design parameters:-

- Flow of 48 litres/minute (l/min) from each of six sprinklers in the most unfavourable array.
- 10mm fast response sprinklers to be used with a “k” factor of 5.7. The “k” factor is a constant for a particular size of sprinkler head where the flow (Q l/m) is proportional to the water pressure (p) according to the formula $Q = k \sqrt{p}$.
- The system is to be fully hydraulically calculated, i.e. the design methodology cannot utilise simple pipe size schedules.
- Grade 1 water supply.
- The water supply in a pump suction tank or reservoir must be capable of supplying the design flow for 30 minutes plus 20%. Where reliable automatic inflow is available from a municipal main, the quantity may be reduced by up to 33% provided the automatic inflow is available at all times and can restore the difference within 30 minutes.
- The maximum coverage per sprinkler is 21m^2. This equates to a design density of 2.48 mm/min. As a comparison the design density for Ordinary Hazard systems is 5mm/min.
- The maximum coverage per sprinkler is reduced to 12m^2 in associated plant rooms, kitchens, cafes etc. In areas designed for compactus units, the area per sprinkler is reduced to 9m^2 (AS2118.1 2006).

Figure 1 below shows a section through the building and the calculations for sprinkler flow and storage.

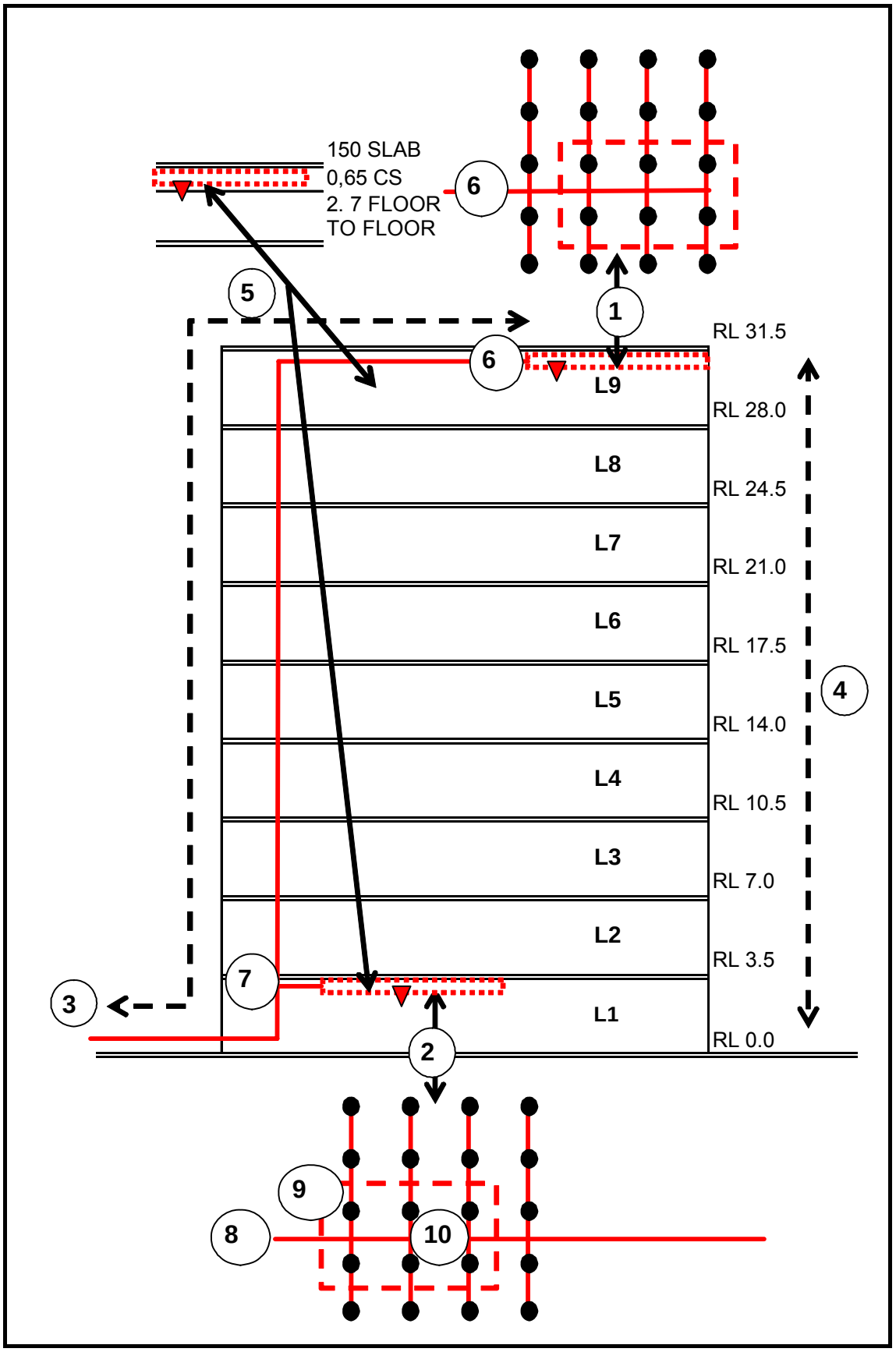

Figure 1 – Worked Example

Legend & Calculations

1 Most unfavourable sprinkler array

2 Most favourable sprinkler array

3 Water supply

4 Static head – in this instance = 30.2m of 296kPa

5 Friction loss – say 20kPa

6 Pressure required at most unfavourable array = 71kPa

7 Pressure calculated at point 7 = 71 + 296 = 20 = 387kPa

8 Pressure at most unfavourable array = 387 kPa

9 Flow at most unfavourable array single sprinkler, $Q = k \sqrt{p} = 5{,}7\sqrt{387}$ = 112l/min

10 Flow for 6 sprinklers in most unfavourable array – 672l/min

Now considering that the baseline AS2118.1 requirements are (simply) calculated as 6 x 48l/min, being 288l/min, the calculated 672 l/min represents a "hydraulic gain" of 133%.

This is an extreme incidence and most sprinkler designers can reduce this to a more acceptable level of ~50% by reducing pipe sizes in the distribution pipes on the lower levels with the proviso under AS2118.1 Part 12.13 and 12.14 that the minimum pipe size cannot be less than 25m nb.

The issue that will always give an increased water demand is building height; for buildings in excess of 50m effective height, sprinkler system design becomes more complex again and "staged" systems are used with tanks and pumps at intermediate levels.

For single or two storey buildings hydraulic gain is usually in the order of 15%.

The required 30 minute water supply is calculated as 24,192 litres against the baseline quantity of 10,368 litres.

Coincidentally, the Building Code of Australia (BCA) requires in Section 7 of Specification E1.5 (sprinkler systems) that in a required sprinkler system in a building with an effective height of >25m, that the secondary supply in a Grade 1 water supply may be a 25,000 litre water tank located on the top of the building – see Note 1 below.

Note 1 - Under BCA Part A1.4, the requirements of the BCA have precedence over the Australian Standards.

The same hydraulic gain issues occur in hydrant system design with the added complexity that a hydrant flow of 5l/second at 700kPa is required at the uppermost level and a pressure limitation of 1,200kPa at the lowest level.

I trust that this paper provides useful advice on sprinkler system water demand.

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