# Jet (Nozzle) Comparisons

In this section we compare simulation results for nozzle type jets against manufacturer data and ASHRAE design formulae for centre line velocity decay.

Three jet configurations have been simulated, they are summarized in the following table.

|	Velocity m/s	Flow rate l/s	Cell dimension m	Effective Nozzle Diameter mm
Case 1	10	225	0.15	170
Case 2	4.89	110	0.15	170
Case 3	10	100	0.1	113

Because the grid used for the calculations is Cartesian and a single cell represents the nozzle, the rectangular size of the cell must be used to derive an effective circular area giving the same velocity and flow rate as the square cell face. The equivalent circular shape's diameter is shown in the last column of the table as Effective Nozzle Diameter, which is then used for the comparisons.

The simulation configuration is shown in the following wire frame perspective view.
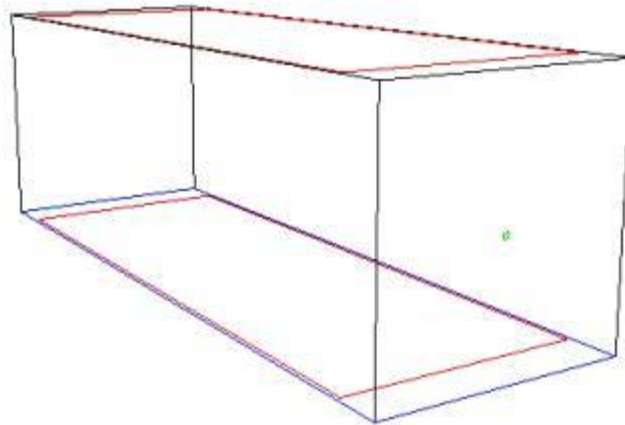
The simulation domain was 5m x 5m x 15m with the nozzle in the centre of one of the 5m x 5m faces (show here in green). Two large outlets (in red) were placed above and below the jet with a very large area to reduce the outlet velocity and consequently disturb the jet as little as possible.

The simulation result for case 1 is shown below.
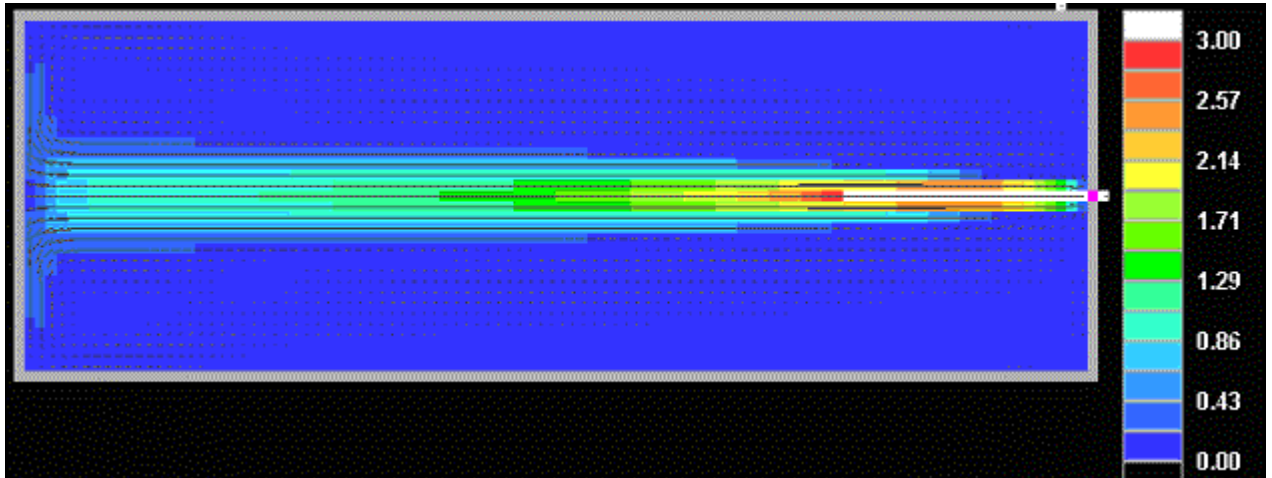
The plot shows the speed through the vertical centre line of the domain using the scale shown. The simulation results were obtained by reading the speeds at the appropriate points. For the comparisons a result was obtained for every metre up to ten metres.

Two sets of manufacturer data were used. The first data was from Krantz http://www.krantz.de and the second set of design data was from Waterloo http://www.waterloo.co.uk, both sets of data can be downloaded from these web sites as PDF documents. The manufacturer data in both cases is in the form of cross-referenced charts that give the centre line velocity decay for various nozzle diameters and flow rates. The following two diagrams are from Krantz and Waterloo respectively.

Decrease in air jet velocity[1)]
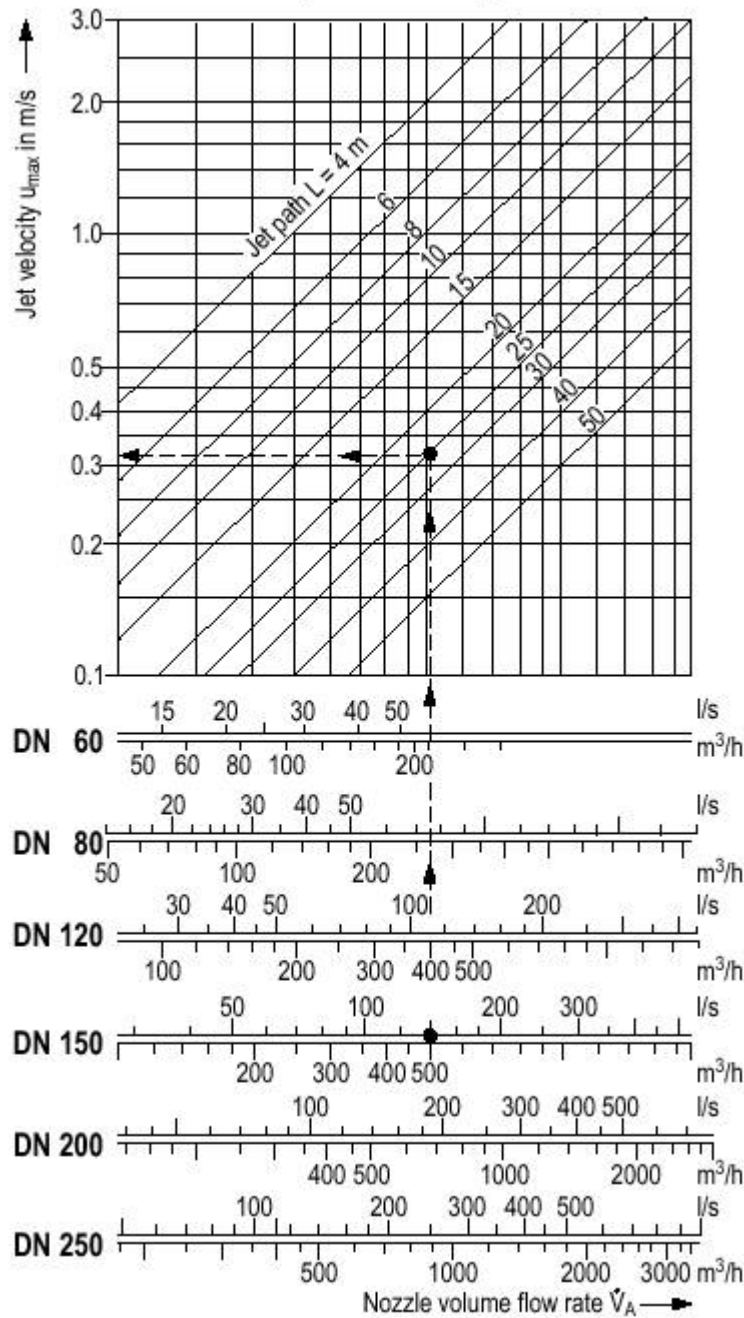
The principle behind this chart can be understood by studying the lines and arrows. In this case a 150mm diameter jet (DN 150) is running at 150l/s which gives the starting point at the bottom. Next follow the line up in the direction of the arrows until it crosses the diagonal 25m path line. At the intersection scan to the left to give the velocity at this point which is 0.33m/s. In this way any diameter, flow rate and path length can be used to find the velocity at that point.

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This chart works in a similar way. First a flow rate is chosen, in this case 200l/s. The diagonal line is followed to the diameter size, in this case 125mm. The line is followed up to the path length diagonal, then traced across to give the velocity at this point.

As can be seen from these charts that range of validity is only from 4m upward so this data is only compared from 4m up to 10m. Generally the two charts are in very good agreement with the maximum difference being approximately 17%, in this case the Krantz data was taken as it was based on slightly more recent work which should hopefully be more accurate.

Our final data set comes from ASHRAE design formulae for calculating the throw of nozzle jets. According to the ASHRAE Fundamentals Handbook[1] the jet path has four distinct zones (see section 32.2). The equation for core velocity in zone 2 is given as.

$$V_x = V_0 \sqrt{\frac{1.13 K H_0}{X}}$$

V_x is the centre line velocity as a distance X from the outlet. V_0 is the average initial velocity. K is a constant depending on the jet configuration and H_0 is the width of the jet at the outlet. The value of K in zone 2 is always 5.0 for all the cases. The equation for velocities in zone 3 for the jet is as follows.

$$V_x = \frac{1.13 V_0 K \sqrt{A_0}}{X}$$

Where A_0 is the cross sectional area of the outlet. There is no way to determine where zone 2 transitions to zone 3 so in the results both curves are allowed to overlap slightly at the most appropriate point. The value of K for zone 3 depends on outlet velocity, for cases 1 and 3 K is 6.2 but for case 2 it is 5.0.

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The following graphs show the results for case 1, 2 and 3. We have also included data from Jones[2] which is an identical formula to ASHRAE zone 3 but with a K value of 7.0 and a range of application from 25 diameters to 100 diameters distance from the nozzle.
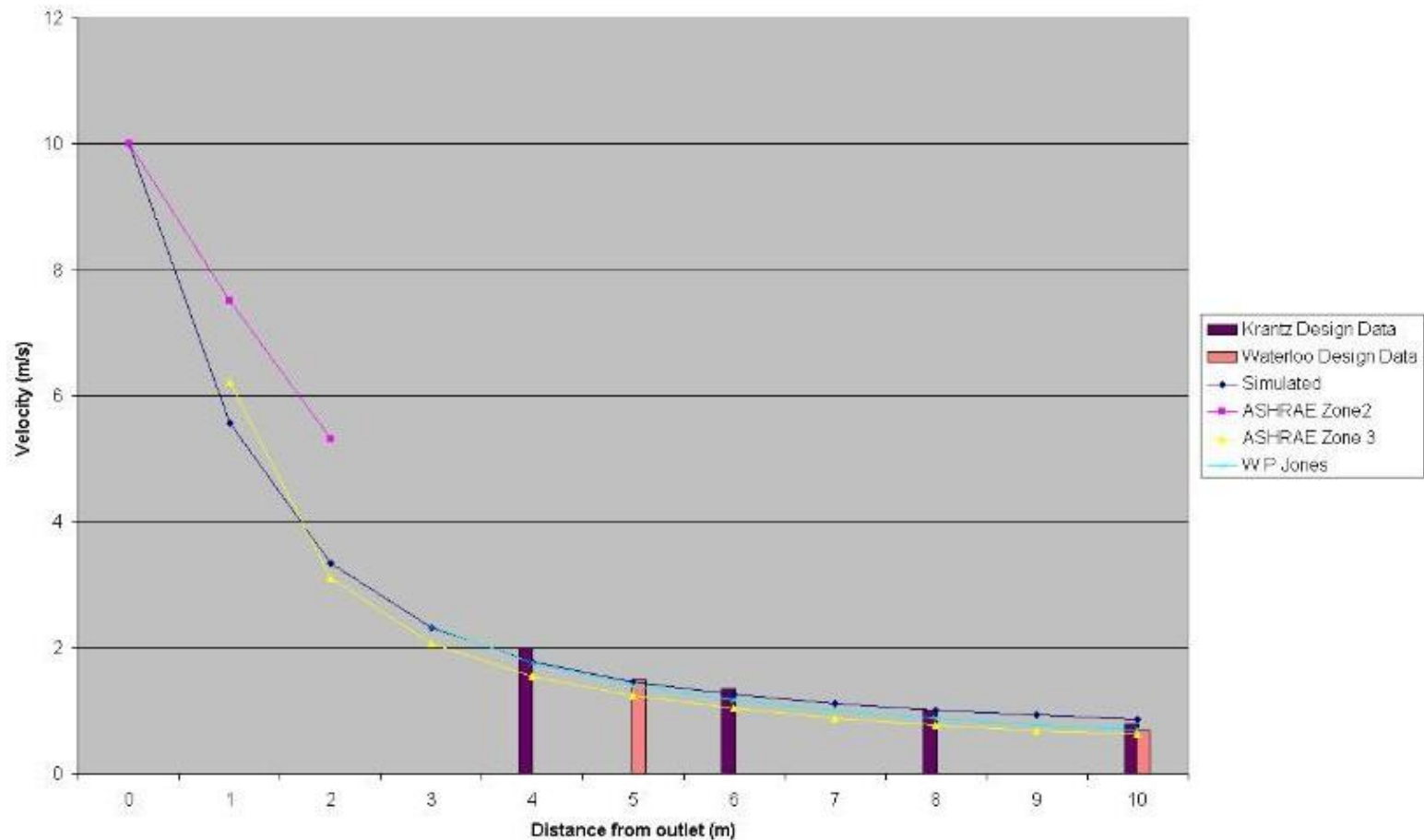
Case 1
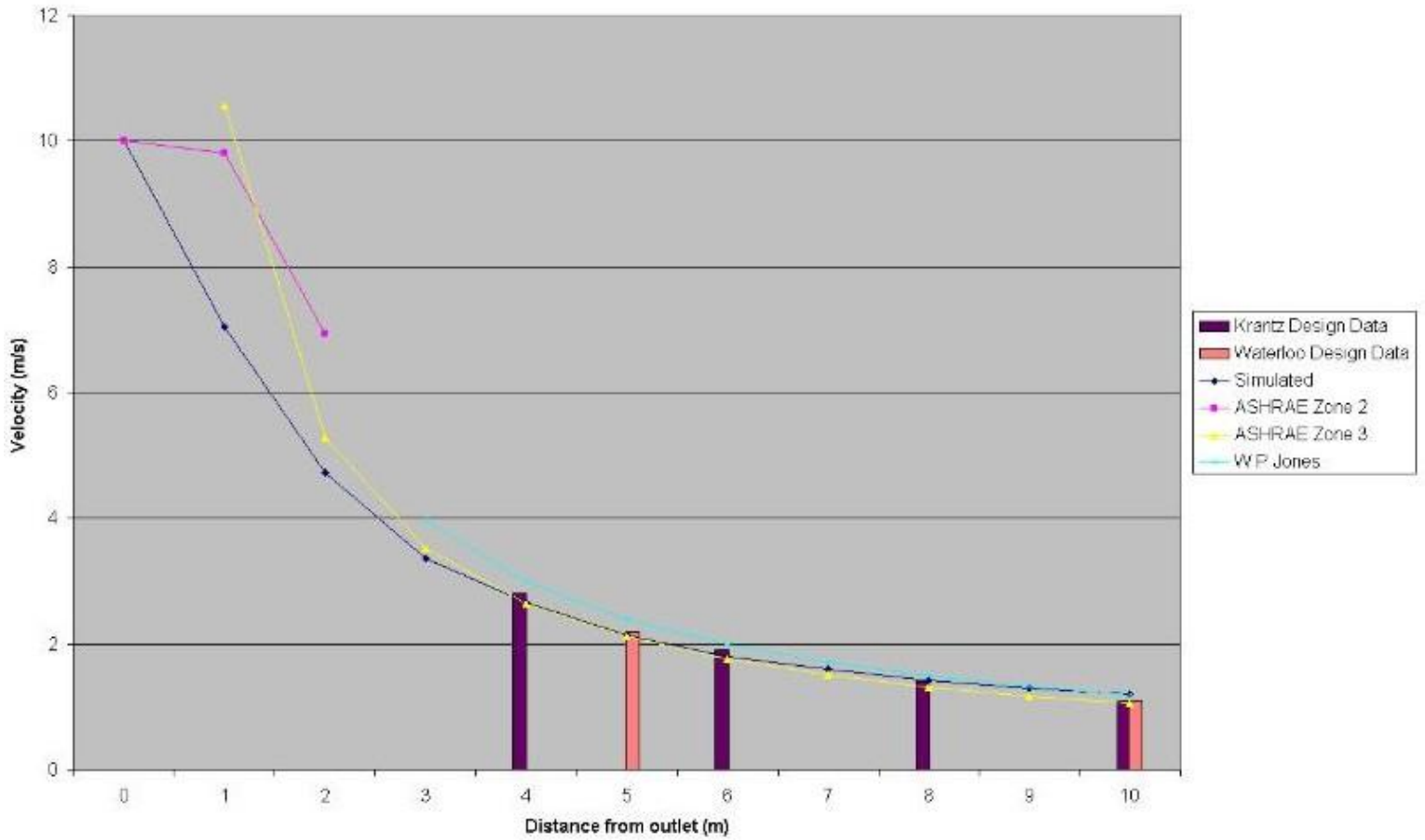
Case 2
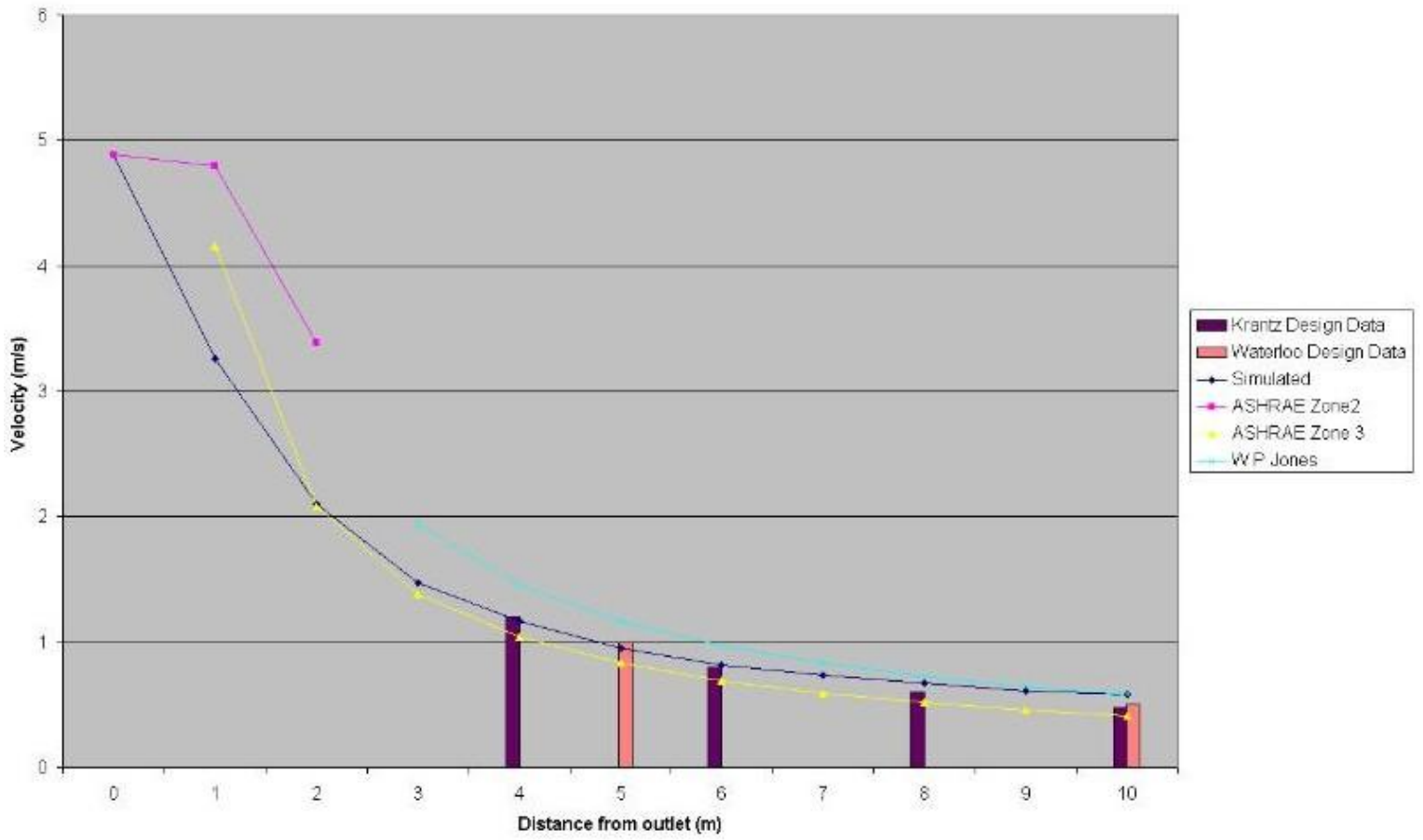
Case 3

From the graphs it is very clear that there is exceptional agreement across all the different methodologies. Closer to the outlet nozzle the situation is less clear as the ASHRAE zone 2 formula fails to overlap with the zone 3 formula in any case. This is not a significant issue as the results within zone 3 are of the greatest interest for design purposes.

Finally, we have also obtained good agreement between the Krantz jet deflection data for a cooling jet during our consultancy work on the National Gallery. The downward deflection given by the Krantz chart for a throw of 12m was just under 1m very close to the deflection seen in the simulations for the gallery.

We hope to continue these studies with a range of temperature differences, jet sizes and flow rates.

[1] ASHRAE Fundamentals Handbook, SI Edition
[2] Jones, W. P. Air Conditioning Applications and Design, Second Edition, Arnold