### Calculations

**Minimum mass** = 74.7 t (2 car Class 156 as supplied by Transport Scotland)

**Maximum mass** = 335.16 t (8 car Class 380 as supplied by Transport Scotland)

**Assumptions**

Calculations are based on buffer stop type 22EB/3

Twin friction element of 3 No. Bolt clamps, Torque 150 Nm under buffer stop on running rails

Breaking = 80 kJ/m

3 pairs of twin friction element (3 clamp bolts per element), Torque 150 Nm behind buffer stop

E = 240 kJ/m

Assume track is level - no potential energy considered

**For Class 156**

<table>
<thead>
<tr>
<th>Vehicle Data</th>
<th>Train mass m</th>
<th>74.7 t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. impact speed v</td>
<td>10 km/h</td>
<td>2.78 m/s</td>
</tr>
<tr>
<td>Deceleration d</td>
<td>≤ 1.47 m/s²</td>
<td>0.15 g</td>
</tr>
</tbody>
</table>

**Kinetic energy at impact**

\[
E_{\text{kin}} = \frac{m \times v^2}{2} = \frac{74.7 \times 2.78^2}{2} = 289 \text{ kJ}
\]

**Energy absorption of buffer stop:**

Distance to second stage normally 3.5 m

Breaking capacity = 3.5 x 80 = 280 kJ

Distance required to arrest Clas 156 = 3.613 m

Therefore, contact with second stage would be minimal.

**Check deceleration**

\[
d = \frac{v^2}{2 \times s} = \frac{2.78^2}{2 \times 3.613} = 1.07 \text{ m/s}^2
\]

\[
= 0.109 \text{ g} \quad \text{Therefore, OK}
\]

Stopping distance = 3.613 m

Buffer length = 2.4 m

Additional retarders = 0 m

**Total track occupancy** = 6.013 m
For Class 380

Vehicle Data
- Train mass \( m = 335.16 \text{ t} \)
- Max. impact speed \( v = 10 \text{ km/h} = 2.78 \text{ m/s} \)
- Deceleration \( d = \frac{1.47 \text{ m/s}^2}{2} = 0.735 \text{ m/s}^2 = 0.074 \text{ g} \)

Kinetic energy at impact \( E_{\text{kin}} = \frac{1}{2} m v^2 = \frac{1}{2} \times 335.16 \times (2.78)^2 = 1295.125 \text{ kJ} \)

Energy absorption of buffer stop (normal slave spacing):
- First stage \( 3.5 \times 80 \) (1 pair) = 280 kJ
- Second stage \( 0.5 \times 160 \) (2 pairs) = 80 kJ
- Third stage \( 0.5 \times 240 \) (3 pairs) = 120 kJ
- Fourth stage \( 2.6 \times 320 \) (4 pairs) = 832 kJ

Total \( s = 7.1 \text{ m} \) = 1312 kJ

Check deceleration - \( d = \frac{v^2}{2s} = \frac{(2.78)^2}{2 \times 7.1} = 0.544 \text{ m/s}^2 \)
\( d = 0.055 \text{ g} \) Therefore, OK

Total occupancy for normal slave spacing and normal number of slaves
- Stopping distance = 7.1 m
- Buffer length = 2.4 m
- Additional retarders = 0.75 m

Total track occupancy = 10.25 m

10.25 m would give deceleration value of 0.055 g

0.15 g is allowable
Energy absorption of buffer stop (adding 1 No. pair of slaves at each location):

First stage  
3.5 x 80 (1 pair) = 280 kJ

Second stage 
0.5 x 240 (3 pairs) = 120 kJ

Third stage 
0.5 x 400 (5 pairs) = 200 kJ

Fourth stage 
1.5 x 560 (7 pairs) = 840 kJ

\[ s = 6 \text{ m} = 1440 \text{ kJ} \]

Check deceleration - 
\[ d = \frac{v^2}{2 \times s} = \frac{2.78^2}{2 \times 6} \]

\[ = 0.644 \text{ m/s}^2 \]
\[ = 0.065 \text{ g} \]
Therefore, OK

Stopping distance = 6 m
Buffer length = 2.4 m
Additional retarders = 1.5 m

Total track occupancy = 9.9 m

Energy absorption of buffer stop (adding 2 No. pair of slaves at each location):

First stage 
3.5 x 80 (1 pair) = 280 kJ

Second stage 
0.5 x 400 (5 pairs) = 200 kJ

Third stage 
0.5 x 560 (7 pairs) = 280 kJ

Fourth stage 
0.7 x 880 (11 pairs) = 616 kJ

\[ s = 5.2 \text{ m} = 1736 \text{ kJ} \]

Check deceleration - 
\[ d = \frac{v^2}{2 \times s} = \frac{2.78^2}{2 \times 7.1} \]

\[ = 0.743 \text{ m/s}^2 \]
\[ = 0.076 \text{ g} \]
Therefore, OK

Total occupancy for normal slave spacing and normal number of slaves

Stopping distance = 5.2 m
Buffer length = 2.4 m
Additional retarders = 2.75 m

Total track occupancy = 10.35 m