

## Category 1 Standard

# S1197 Signalling and Signalling Control - Design and Implementation



Please read the Written Notices  
attached to this standard

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## 1 Purpose

- 1.1 The purpose of this Standard is to define the Signalling and Signalling Control Design and Implementation requirements which are mandatory to the design and modification of all Signalling Systems used anywhere on the London Underground railway.

## 2 Scope

- 2.1 This Standard applies to all running lines and depot areas of the London Underground railway that are signalled using conventional or transmission based technology. Unless specifically stated to the contrary, a requirement applies to signalling and signalling control systems for both running lines and depot areas.
- 2.2 This Standard focuses on requirements for second stage of the lifecycle, Design and Implementation. The totality of requirements contained within the complete suite of signalling and signalling control standards (see 5.1.2) must be complied with for these systems.
- 2.3 The issue of this standard replaces 1-197 A3

## 3 Requirements

### 3.1 System requirements

- 3.1.1 Design shall address the applicable functional requirements defined in Standards: S1194, Signalling Control - Functional Requirements; and S1195, Signalling - Functional Requirements.
- 3.1.2 Design shall progress from the System Requirements Specification(s) produced in accordance with Standard S1196, Signalling and Signalling Control - Concept and Requirements.

### 3.2 Signalling design

**Note:** These requirements are written for conventional LU fixed block signalling. Other systems, such as Moving Block, should meet or exceed the underlying safety and design requirements presented here for a fixed block system. These principles are to be adapted for use in design of other types of signalling system.

#### 3.2.1 Signal overlap design process management

- 3.2.1.1 The Designer shall be responsible for the completion and documentation of signal overlap calculations.
- 3.2.1.2 The design records shall include the data for gradients, design VMAX, Permanent Speed Restrictions (PSRs), train speed and the overlap calculations.
- 3.2.1.3 The design records shall be retained in accordance with Standards 1-538, Assurance, and 1-551, Procuring and Managing Suppliers and Contractors - Health and Safety Files.

#### 3.2.2 Signal overlap calculations

- 3.2.2.1 Overlaps shall be calculated from the signal's trainstop, or equivalent, and the speed shall be taken from the signal overlap curve.

### 3.2.2.2 Overlaps shall be defined as follows:

- a) Calculated overlaps: the Designer shall use the formula given in 3.2.2.3.1 for the calculation of overlaps. If this is impracticable, it may be acceptable to use the more basic 1955 formula for overlap calculations. The conditions for the use of this formula and the formula itself are detailed in section 3.2.2.6.
- b) Re-start overlap: The risks associated with the acceleration of a train against a signal at danger shall be managed to be As Low As Reasonably Practical (ALARP). The associated overlap shall be calculated as per (a).

### 3.2.2.3 Current overlap calculation formula

#### 3.2.2.3.1 The length of the overlap shall be calculated using the following formula:

$$D = Ca + 1.05 \left\{ 0.278 V \cdot t + \frac{0.077 V^2}{2(F + 0.1 G)} + 7.82 V^4 \cdot 10^{-7} \right\}$$

where:

- D* Is the calculated overlap length (in metres).
- Ca* Is the cab allowance (in metres) as defined in section 3.2.2.4 .
- V* Speed of the train in Kilometres per hour, taken from the signal overlap curve, at the point at which the signalling system initiates emergency braking. This speed shall be determined in accordance with section 3.2.3.4.
- t* Is the time delay between the initiation of braking by the train and achievement of full braking effort (in seconds). This shall be taken as 1.5 seconds.
- F* Is the nominal emergency braking rate of the train (m/s/s) on level gradient. This shall be taken as:
- In tunnel: 1.3 m/s/s  
In open or sub-surface: 1.1 m/s/s
- Signals from a tunnel portal up to and including the starting signal of the first station in a tunnel section shall be considered to be in open or sub-surface for the purpose of overlap calculations.
- G* Is the percentage gradient calculated in accordance with section 3.2.2.5.

#### 3.2.2.3.2 The value calculated using the formula in 3.2.2.3.1 shall be rounded up to an integer value which shall be the design overlap.

### 3.2.2.4 Cab allowance

#### 3.2.2.4.1 The value for Ca shall be taken as:

- a) 6 metres, where the overlap starts at a trainstop and ends at an insulated rail joint;
- b) 3 metres, where the overlap starts at a trainstop and ends at a buffer face, fouling point or opposing overlap, or for a station starting signal full speed overlap used to support a 35 km/h overlap.

3.2.2.4.2 Where the overlap starts at a trainstop and ends at a jointless track circuit undetected area track circuit boundary, an additional nominal distance shall be included in Ca to allow for the length of the undetected area.

### 3.2.2.5 Gradients

3.2.2.5.1 A percentage gradient shall be calculated for a train length of both zero metres and 130 metres for the purpose of overlap calculation. The percentage gradient used in the overlap calculation shall be that which results in the longer overlap.

3.2.2.5.2 The percentage gradient shall be calculated using the following formula:

$$G = \frac{H_e}{D_h} \times 100$$

where:

*G* Is the percentage gradient.

*He* Is the difference between the height of the centre of gravity of the train at tripping and the height of the centre of gravity of the train at the point at which the train comes to rest (in metres). The centre of gravity shall be taken as a point half-way along the length of the train.

*Dh* Is the corresponding distance travelled by the centre of gravity of the train (in metres).

3.2.2.5.3 Rising gradients shall be positive and falling gradients shall be negative.

3.2.2.5.4 For a zero length train the height at tripping shall be taken as the height of the track at the trainstop. The height at the point at which the train comes to rest shall be taken as the height of the track at the end of the calculated overlap as set out in the overlap formula, but excluding the cab allowance Ca.

3.2.2.5.5 For a 130 metre length train the height at tripping shall be taken as the height of the centre of gravity of the train with the front of the train 3 metres beyond the trainstop.

3.2.2.5.6 For a 130 metre length train the height of the centre of gravity of the train shall be calculated by assuming that the mass of the train is uniformly distributed along the length of the train.

3.2.2.5.7 The resultant calculated percentage gradient shall be rounded to 0.1 percent. The rounding shall be up or down; whichever results in the longer overlap.

**Note:** The calculation of the height of the centre of gravity for conditions described in paragraphs 3.2.2.5.5 and 3.2.2.5.6 is an iterative process, involving an initial estimation of 'G' to find the stopping position of the centre of gravity of the train, needed to calculate 'He' which will in turn allow 'G' to be calculated.

### 3.2.2.6 Use of 1955 signal overlap formula

3.2.2.6.1 The 1955 signal overlap formula shall be used when:

- a) Use of the main overlap formula is not practicable;
- b) Use of this formula shall be limited to modification of an existing site where the calculations of overlaps for other signals at that site have been calculated using this formula;



- c) Acceptance of the use of the 1955 signal overlap formula shall be supported by a written justification approved by the Design Authority.

3.2.2.6.2 If there are major changes, such as track layout, then the protection arrangements for that new junction work shall use the overlap formula described in 3.2.2.3.1.

3.2.2.6.3 The 1955 Signal Overlap Formula shall be:

**Note:** The 1955 formula uses imperial units throughout.

$$D = \frac{4.34 V^2}{\eta + \text{gradient}}$$

Where,

$D$  Overlap distance in feet.

$V$  Speed of the train in miles per hour, taken from the signal overlap curve, at the point at which the signalling systems initiates emergency braking. This speed shall be determined in accordance with section 3.2.3.6.

$\eta$  Retardation rate is:

12% in tunnel

10% in open and sub surface.

Sections up to and including the first station in a tunnel section shall be considered to be open / sub-surface for the purpose of overlap calculations.

$\text{gradient}$  Gradient, as defined in section 3.2.2.5

The resultant calculated value of  $D$  shall be converted to metres to be consistent with other overlap distances.

### 3.2.3 Train speeds

3.2.3.1 Train speed shall be determined by prediction. The results of such a prediction shall be shown in graphical (curve) and tabular format.

3.2.3.2 The location and values of the allowable Line Speeds and PSRs shall be determined prior to the overlap calculation.

#### 3.2.3.3 Datum for train speed predictions

3.2.3.3.1 The start point and end point for predictions for maximum permitted speed and maximum signed speed curves shall be the platform stop mark, where dimensioned.

3.2.3.3.2 Where the platform stop marks are not dimensioned the start point and end point shall be agreed with the Design Authority.

3.2.3.3.3 The start point for signal overlap curves shall be the Top of Platform Ramp (TOR) or existing starting signal if this is positioned between platform TOR's.

3.2.3.3.4 The end point for signal overlap curves shall be 100 metres beyond the TOR of the next "all trains to stop" station.



### 3.2.3.4 Maximum permitted speed curve

3.2.3.4.1 The maximum permitted speed curve shall be used to identify the location and value for new or revised PSRs. The location and value of PSRs shall be agreed by LU and become declared PSRs.

3.2.3.4.2 The curve shall be drawn for the train performance criteria that result in the maximum speed, using the parameters below:

- a) Tare condition
- b) Line voltage - 650 Volts
- c) New size wheels
- d) Declared traction motor characteristic
- e) No coasting
- f) Brake rate - 1 m/s/s.

3.2.3.4.3 When using the 1955 overlap formula the curve shall be drawn for the train performance criteria below:

- a) Passenger load - full seated capacity + 25% standing;
- b) Line voltage - 575V;
- c) Average size wheels;
- d) Declared traction motor characteristic;
- e) No coasting.

3.2.3.4.4 The curve shall start from rest at the start point and brake to rest at the end point; see 3.2.3.3.1.

3.2.3.4.5 The curve shall be drawn up to the design VMAX. The design VMAX shall be shown on the curve and labelled in km/h.

### 3.2.3.5 Maximum signed speed curve

3.2.3.5.1 The maximum signed speed curve shall be produced when PSRs have been declared.

3.2.3.5.2 The curve shall be drawn for the train performance criteria that result in the maximum possible speed:

- a) Tare condition;
- b) Line voltage - 650 Volts;
- c) New size wheels;
- d) Declared traction motor characteristic;
- e) No coasting;
- f) Brake rate - 1 m/s/s.

3.2.3.5.3 When using the 1955 overlap formula the curve shall be drawn for the train performance criteria below:

- a) Passenger load - full seated capacity + 25% standing;
- b) Line voltage - 575V;
- c) Average size wheels;
- d) Declared traction motor characteristic;
- e) No coasting.



3.2.3.5.4 The curve shall start from rest at the start point and brake to rest at the end point; see 3.2.3.3.1.

3.2.3.5.5 The curve shall be drawn assuming that all PSRs are obeyed at their declared values.

3.2.3.5.6 All declared PSRs shall be drawn and labelled according to their declared values.

### **3.2.3.6 Signal overlap curve**

3.2.3.6.1 The signal overlap curve shall be produced when PSRs have been declared.

3.2.3.6.2 The curve shall be drawn for the train performance criteria that result in the maximum speed:

- a) Tare condition;
- b) Line voltage - 650 Volts;
- c) New size wheels;
- d) Declared traction motor characteristic;
- e) No coasting.

3.2.3.6.3 When using the 1955 overlap formula the curve shall be drawn for the train performance criteria below:

- a) Passenger load - full seated capacity + 25% standing;
- b) Line voltage - 575V;
- c) Average size wheels;
- d) Declared traction motor characteristic;
- e) No coasting.

3.2.3.6.4 The curve shall start at a speed of 35 km/h at "all trains to stop" stations except where:

- a) A speed check before the start point enforces a lower speed at the start point in which case this lower speed shall be used, or;
- b) Starting from a terminal station or bay road, or;
- c) Starting from a signalling berth where there is no signalled approaching move.

3.2.3.6.5 When using the 1955 overlap formula the train speed shall be based upon trains starting from rest at the previous all trains to stop station;

3.2.3.6.6 For stations where trains non stop but have a speed check associated with the starting signal, the curve shall start at the maximum speed attained by a train accelerating through the speed check device at the maximum speed consistent with its correct operation.

3.2.3.6.7 For terminal stations and bay roads, or when starting from a signalling berth where there is no signalled approaching move, the curve shall start from rest.

3.2.3.6.8 Where PSRs apply in a track section, two curves shall be drawn for use in 3.2.3.8.11:

- a) The first shall assume PSRs are ignored;
- b) The second shall be drawn allowing the speed to rise up to 15 km/h above the declared PSR value.

3.2.3.6.9 The curves shall finish 100m beyond an 'all trains to stop' station.



3.2.3.6.10 The curve before the PSR shall be drawn at the maximum speed attained by the train (with instantaneous braking to the PSR), and the curve beyond the PSR shall be drawn for maximum acceleration from the signed termination position of the PSR.

### 3.2.3.7 Starting signal overlaps

3.2.3.7.1 Starting signals shall be provided with a full speed overlap or the maximum overlap greater than 35 km/h that the site headway allows unless paragraph 3.2.3.7.2 applies.

3.2.3.7.2 Starting signals may be provided with a reduced speed overlap to achieve the required headway. The overlap provided shall be for a speed of 35 km/h provided the conditions set out in paragraph 3.2.3.7.3 are met.

3.2.3.7.3 If within the full speed overlap of the starting signal there is no potential conflict with a train berthed at a signal ahead or by a train movement on another route, then an overlap for 35 km/h may be provided.

3.2.3.7.4 If the conditions set out in paragraph 3.2.3.7.3 cannot be achieved then a speed check shall be made and a reduced speed overlap shall be provided, calculated as set out in section 3.2.3.8.

3.2.3.7.5 Where there is a signal berth beyond the starting signal that is foul of the full speed overlap or a speed checked overlap, then a conflict shall not exist if:

- a) the signal beyond the starting signal displays a "proceed" aspect or the train ahead has been proven to have passed the "proceed" aspect and there is no signalled reversing move, or;
- b) if the signal ahead is controlled or there is a signalled reversing move then the train ahead must be proven to have passed the "proceed" aspect.

### 3.2.3.8 Speed checked overlaps

3.2.3.8.1 The length of a timing section shall be calculated using the following formula:

$$D = v \cdot t$$

where:

$D$  Is the length of the timing section (in metres).

$v$  Is the average train speed through the timing section (in m/s).

$t$  Is the timer time (in seconds), with additional time for equipment response times, where necessary.

3.2.3.8.2 Where the timing section is associated with a blind trainstop and is used to check the train speed within a PSR, an average speed of 5 km/h above the PSR speed shall be used.

3.2.3.8.3 The position of the centre of a timing section shall be calculated using the formula:

$$D = l + \frac{V^2}{2a}$$

where:

$D$  Is the distance from the centre of the timing section to the speed checked signal (in metres).



- $l$  Is the distance (in metres) from the front of the train to the signal when standing at the signal displaying a “stop” aspect [5 metres nominally].
- $V$  Is the average train speed through the timing section (in m/s)
- $a$  Is the nominal braking rate, derived from the service braking rate (in m/s/s).

**Note:** Where local signage is introduced then the distance between the end of the timing section and the signal shall be sufficient to accommodate service braking from the trailing end of the timing section to the signal.

3.2.3.8.4 A value for ' $a$ ' in clause 3.2.3.8.3 shall be in the range 0.7 to 0.9 m/s/s. for LU manually driven trains.

**Note:** The value of “ $a$ ” is critical to the operation of the timing section; if the chosen value is too low, the timing section will be located too far from the signal and most trains will pass through it too fast to operate it, while if it is too high then all trains will be slowed unnecessarily. This value is subject to local conditions and gradients, for example higher values would generally apply for lower speeds and better rail adhesion conditions.

3.2.3.8.5 For trains that fail the timing section and yet manage to stop at the signal, a second timing section shall be provided, unless there is an alternative method of clearing that signal route by track circuit clearance only. Where a second timing section is required a further constraint is that the speed control provided by this second timing section shall not compromise that of the first.

**Note:** The start of this second timing section typically uses the same train detector that defines the end of the first timing section.

3.2.3.8.6 After a train's speed has been checked by signalling equipment it shall be assumed that the train will re-accelerate at a rate governed by the performance used for the signal overlap curve, except where the conditions in 3.2.3.8.7 or 3.2.3.8.8 apply.

3.2.3.8.7 Where one of the following sets of conditions can be met, it may be assumed the train will not accelerate and the speed used to calculate the overlap shall be taken as the average speed of the timing section, subject to it not being below the minimum allowable speed for an overlap, see 3.2.3.8.8 below:

Either,

- a) The timing section is immediately before a speed controlled signal,  
AND The signal (or blind trainstop, or fixed trainstop associated with a fixed red light) for which the overlap is being calculated is less than 150 metres from the end of the timing section,  
AND There is continuous sighting of that signal's aspect or its repeater from the end of the timing section. Where the overlap being calculated is for a blind trainstop then it is sufficient for the “stop” aspect of the signal (or fixed red light) beyond the blind trainstop to be continuously sighted to satisfy this condition,

OR

- b) The timing section is immediately before a speed controlled signal,



AND The timing section is associated with a signed PSR which extends at least from the speed controlled signal to the signal or trainstop for which the overlap is being calculated,

AND The average speed of the timing section is equal to the PSR speed,

AND The signal (or blind trainstop, or fixed trainstop associated with a fixed red light) for which the overlap is being calculated is less than 300 metres from the end of the timing section,

AND There is continuous sighting of that signal's aspect or its repeater from the end of the timing section. Where the overlap being calculated is for a blind trainstop then it is sufficient for the "stop" aspect of the signal (or fixed red light) beyond the blind trainstop to be continuously sighted to satisfy this condition,

OR

c) The timing section is immediately before a blind trainstop,

AND It is associated with a signed PSR which extends at least from the start of the timing section to the signal or trainstop for which the overlap is being calculated,

AND The average speed of the timing section is equal to the PSR speed plus 5 km/h,

AND The signal (or blind trainstop, or fixed trainstop associated with a fixed red light) for which the overlap is being calculated is less than 300 metres from the end of the timing section,

AND There is continuous sighting of that signal's aspect, or its repeater from the end of the timing section. Where the overlap being calculated is for a blind trainstop then it is sufficient for the "stop" aspect of the signal (or fixed red light) beyond the blind trainstop to be continuously sighted to satisfy this condition.

3.2.3.8.8 Where the following conditions can be met, the speed used to calculate the overlap shall be taken as the signed PSR speed, subject to it not being below the minimum allowable speed for an overlap;

The timing section is immediately before a speed controlled signal,

AND A signed PSR extends at least from the speed controlled signal to the signal or trainstop for which the overlap is being calculated,

AND The average speed of the timing section is less than the PSR speed plus 5 km/h,

AND The signal for which the overlap is being calculated is less than 150 metres from the end of the timing section,

AND There is continuous sighting of that signal's aspect or its repeater from the end of the timing section. Where the overlap being calculated is for a blind trainstop, then it is sufficient for the "stop" aspect of the signal (or fixed red light) beyond the blind trainstop to be continuously sighted to satisfy this condition.

3.2.3.8.9 The minimum overlap speed for a signal when no acceleration is assumed shall be 35 km/h even if the average speed of the check is for a lower speed.

3.2.3.8.10 Where there is no speed check associated with a PSR, the overlap will be calculated for the speed shown on the signal overlap curve.

3.2.3.8.11 Where there is no speed check associated with a PSR and the difference in the speed of a train observing the PSR and the speed of a train ignoring the PSR is greater than 25 km/h, the risk associated with overlaps of the signals beyond that PSR shall be reviewed to ensure it is ALARP.



### 3.2.4 Signal replacing distance

- 3.2.4.1 The replacing distance for a semi-automatic signal shall be between 3 metres and 15 metres.

**Note:** The minimum distance is for availability allowing for minor overrun of a signal stopping point. The maximum distance of 15 metres relates to reducing the risk associated with release of locking where a train has stopped between the trainstop and the replacing track circuit.

- 3.2.4.2 The maximum replacing distance for an automatic signal shall be 50 metres.

**Note:** The maximum distance of 50 metres is to ensure that a signal is replaced before the end of the train passes that signal.

### 3.2.5 Signal Aspects

- 3.2.5.1 Colour light signals shall be installed on open and tunnel sections of the lines, in accordance with Standard S1195, Signalling - Functional Requirements.
- 3.2.5.2 On open sections, a hood shall be provided over each aspect and a facility to assist close-range visibility shall be provided for each aspect.
- 3.2.5.3 The red aspect shall be positioned below the green aspect.
- 3.2.5.4 All running signals shall be capable of operating in a degraded mode with a reduced level of illumination before total failure of the light source occurs. The degraded mode shall be discernable.

**Note:** Three signal head types are used on LU relating to their usage and sighting requirements, namely Long Range Colour Light (LRCL), Short Range Colour Light (SRCL) and tube tunnel types.

- 3.2.5.5 LRCL signals shall only be used in outdoor sections and shall be designed to meet visibility requirements in bright sunlight.

- 3.2.5.6 LRCL signals shall not be used for running signals in sub-surface tunnel sections.

**Note:** SRCL signals may be used in outdoor sections where there is no requirement for the signal to be seen at long range, such as on curves, as fog repeaters and as station starting signals at stations where all trains are required to stop.

- 3.2.5.7 The aspects for signals shall be as described below.

| Signal type                                                              | Aspect                                                     | Meaning                                                                                                                    |
|--------------------------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Stop signals                                                             | Red                                                        | Stop                                                                                                                       |
|                                                                          | Green                                                      | Clear to proceed                                                                                                           |
| Disc or fibre optic type or Light Emitting Diode (LED) type shunt signal | Horizontal red bar against a white background              | Stop                                                                                                                       |
|                                                                          | Horizontal red bar rotated 45° in anti-clockwise direction | Clear to proceed                                                                                                           |
| Repeating signals                                                        | Yellow                                                     | Caution – one of the next signals controlling the repeater is at danger or a train is between the signal and the repeater. |

|                             |                                                         |                                                                                                              |
|-----------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
|                             | Green                                                   | Clear to proceed - the signal controlling the repeater is at proceed.                                        |
| Fog repeating signals       | Black 'F' on yellow                                     | Caution - next signal controlling the repeater is at red, or a train is between the signal and the repeater. |
|                             | Green<br>(Lunar white in multi-aspect signalled areas). | Clear to proceed - next signal controlling the repeater is at proceed.                                       |
| Position light shunt signal | Two whites                                              | Clear to proceed<br>Note: Present practice in depots has a single white aspect.                              |
|                             | Two Reds                                                | Stop<br>Note: Present practice in some areas of running line has a single red and a single white aspect.     |
| Multi-aspect signal         | Green                                                   | Clear to proceed                                                                                             |
|                             | Two yellows                                             | Proceed at caution; next signal is currently displaying one yellow.                                          |
|                             | One yellow                                              | Proceed at caution with expectation of stopping at next signal                                               |
|                             | Red                                                     | Stop                                                                                                         |

3.2.5.8 For areas in which multiple aspect signalling is employed to facilitate the operation of other Train Operating Companies, special arrangements may be required which shall be agreed with LU.

3.2.5.9 Colours for aspects shall be in accordance with the requirements of BS 1376.

3.2.5.10 Signals shall be of a consistent type in order to assist the train operator by avoiding the continual change of signal types.

3.2.5.11 There shall be provision in the signal-mounting assembly for lateral and vertical adjustment of the signal head, for sighting and beam alignment purposes.

### 3.2.6 Sighting of signals

**Note:** This section deals with the calculation of sighting distances and approval events associated with the sighting of signals. It should be read in conjunction with section 3.9.8.2 where the installation requirements are specified.

#### 3.2.6.1 Visibility

3.2.6.1.1 A signal sighting distance shall be provided to allow the train operator to react in an appropriate and controlled manner.

3.2.6.1.2 Gantry signals and situations where multiple signals are simultaneously visible shall be given special attention with regard to the possibility of the information being misread and to the constraints of the cab design.

**Note:** The above requirement is due to the known higher Signal Passed At Danger (SPAD) rate associated with gantry mounted signals.