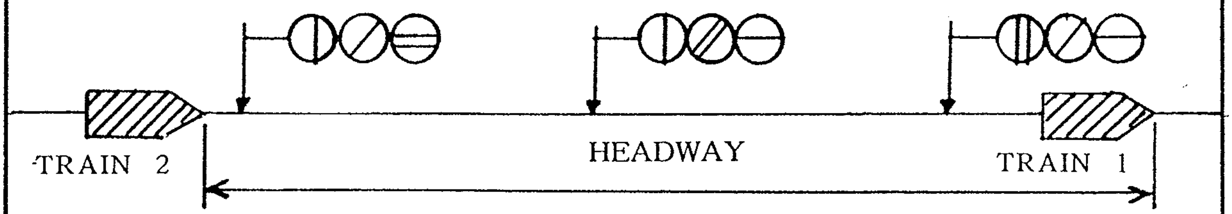
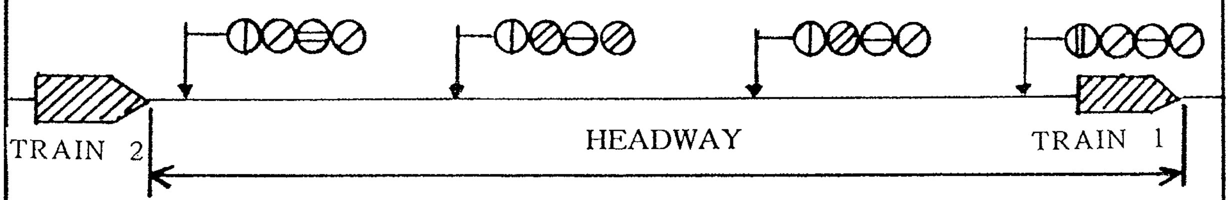
DIRECTOR OF S & T ENGINEERING.
WEST MIDLANDS PROJECTS GROUP.

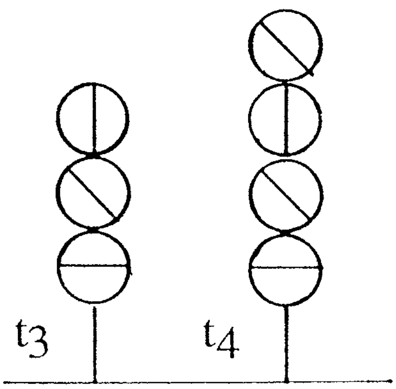
SYSTEM CAPACITY & HEADWAY

3 ASPECT SIGNALLING



4 ASPECT SIGNALLING





$$t_3 = \frac{1}{V}(S + 2D + O + L)$$

$$t_4 = \frac{1}{V}(S + 1.5D + O + L)$$

SYSTEM CAPACITY AND HEADWAY

Introduction

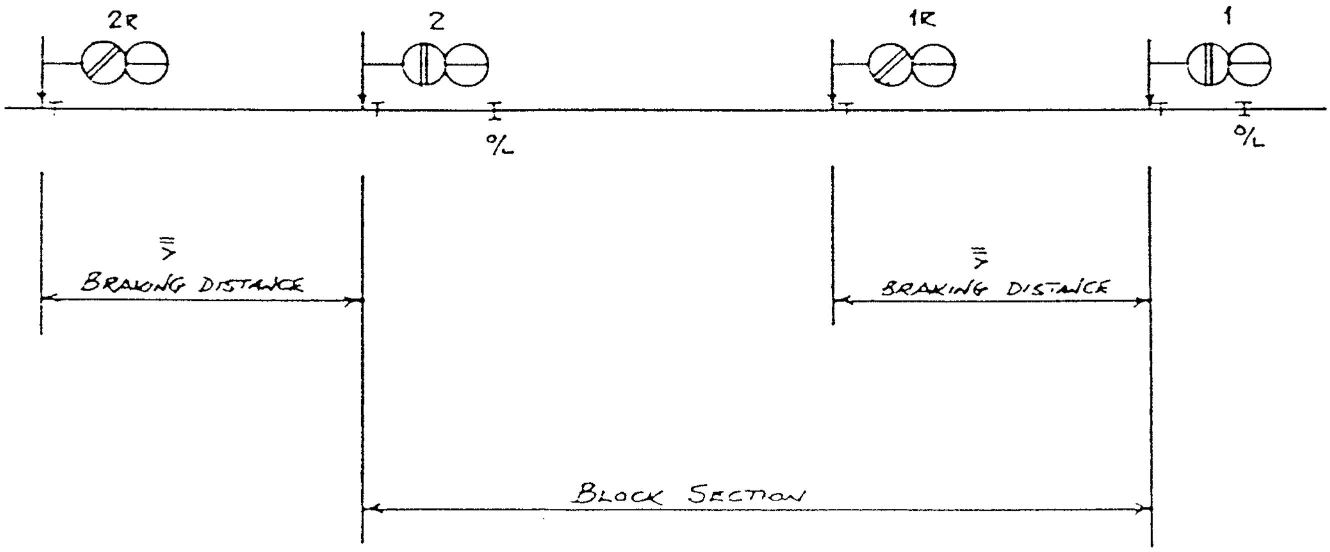
The development of track-circuit block made it possible for signals to work automatically - a signal shows Proceed when the section track circuit is clear, and Danger if otherwise. This, in turn, made it economic to have short block sections (necessary for high frequency services) as a signalbox is not needed for each section.

The first application of automatic signalling was on the line between Woking and Basingstoke, at the turn of the century. This used pneumatically operated semaphore signals. However, it was with the general adoption of colour-light signals, that automatic signals became really practical.

At night, early semaphore signals displayed red when "on", and green when "off" (clear). The driver was again expected to know from his route knowledge whether the red light was a stop or distant signal. It was clearly impractical for colour-light signals to display the same colour for both stop and caution, so in 1923 the use of yellow was agreed for caution. It was then similarly applied to semaphore distant signals.

The earliest use of colour-lights was as a direct replacement for semaphore signals, a red/green head for a stop signal and a yellow/green head for a distant signal. As such, they were widely introduced to replace signals a great distance from the signalbox, particularly distant signals on the high speed lines of the L.M.S. and L.N.E.R. These types of signal are known as "2 Aspect" signals.

2 Aspect Signalling Sequence



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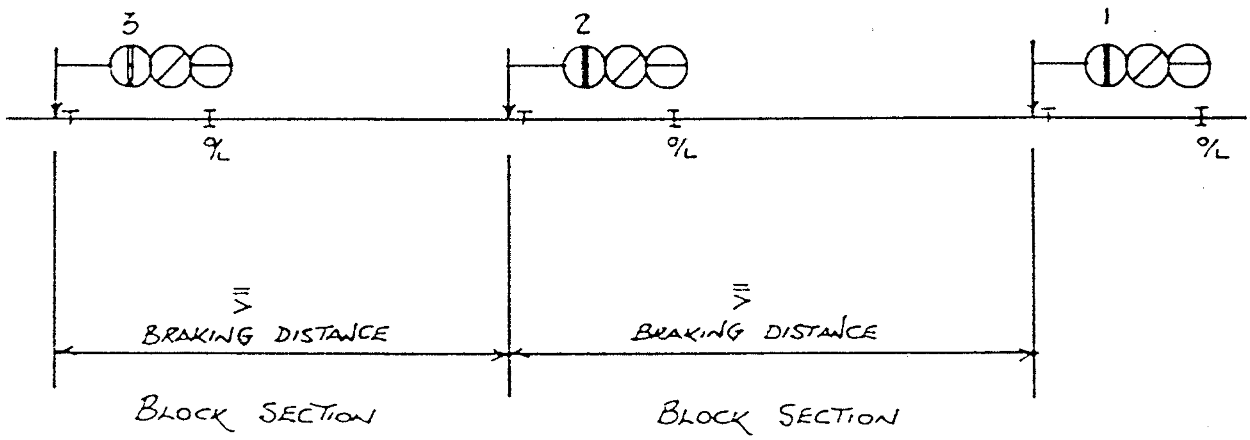
Where block sections are short, it is often necessary to have the distant signal for one signalbox at the same place as the starting signal of the box (or section) in rear. Early practice on some railways, notably the G.W.R., was to mount both 2 aspect heads on the same post - giving 2 green lights if both the stop and distant signals were clear. This is still the practice on the London Underground.

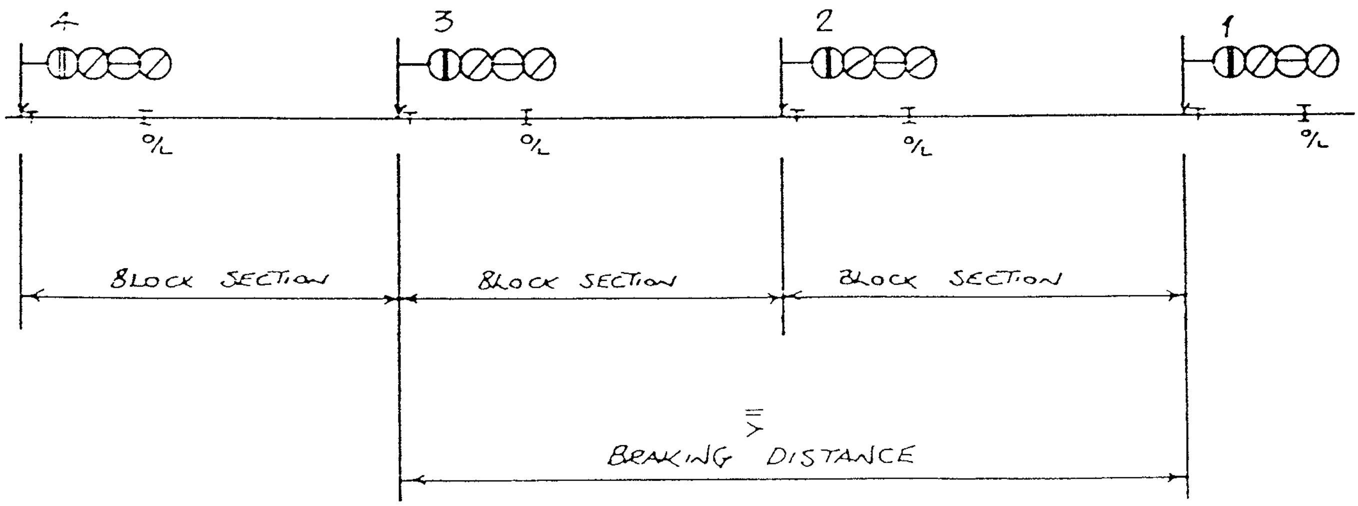
3 Aspect signalling economises on this arrangement by combining the two heads and only having one green aspect. The signal then displays red for stop, yellow for caution and green for clear.

3 Aspect Signalling Sequence



On high speed or high frequency lines, it is often necessary to have block sections shorter than braking distance. It is then necessary to give the driver an earlier caution indication, as he has insufficient distance to stop between seeing the yellow and arriving at the red signal. In such cases, the signal in rear of yellow shows two yellow lights ("double yellow"), as a Preliminary Caution. This is termed "4 aspect" signalling.

4 Aspect Signalling Sequence



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SYSTEM CAPACITY AND HEADWAY

A signalling system has to be designed around the operating requirements for a certain train service. For example, an operator may ask for a service of trains to be run at 3 min. intervals non-stop at speeds of 60 mile/h or a stopping service of trains at 5 minute intervals. The signalling system must be designed so that it provides a theoretical headway which is better than the required operating headway. A reasonable margin must be aimed for, so as to cover variations in such features as driving techniques, tractive power output and train loading.

It is therefore essential to know the capacity of a signalling system. This can be defined in terms of the headway.

Headway

The headway of a system is the minimum spacing between two trains so that the second train can safely maintain identical speeds to the first train. Headways can be expressed in terms of distance or time, but the headway time is the significant term as it can be related to a system capacity.

Figs. 1 and 2 show the elements that make up the headways of a three and four aspect signalling system respectively. These figures show the headways of the two trains running at a constant speed on an isolated section of plain line. If train 2 is going to maintain its constant speed and hence its headway behind train 1 it must sight all signals at green otherwise a speed reduction will occur and the headway will not be maintained. In considering a three aspect signalling system as depicted in Fig 1 the tail of train 1 clearing the overlap point of signal C, will cause signal B to change from red to yellow and signal A to change from yellow to green. If at that point in time train 2 sights signal A, it will then be running at minimum headway behind train 1.

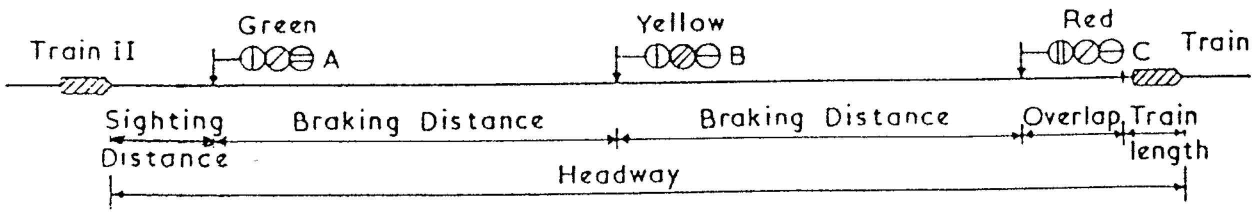

FIGURE 1. Headway of a Three Aspect Signalling System

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Similarly in the case of a four aspect signalling system, as depicted in Fig 2, if as train 2 sights signal W, it changes aspect from double yellow to green (as a result of train 1 clearing the overlap of signal Z), then it will be running at minimum headway. The minimum headway with a four aspect system is thus shown to be less than with a three aspect system.

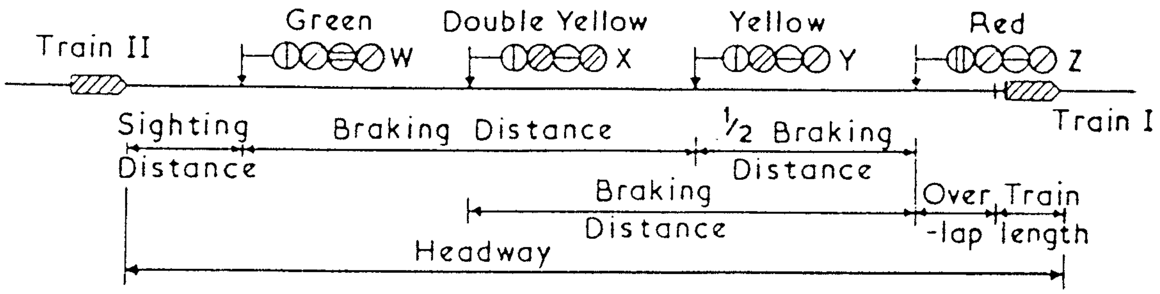


FIGURE 2. Headway of a Four Aspect Signalling System

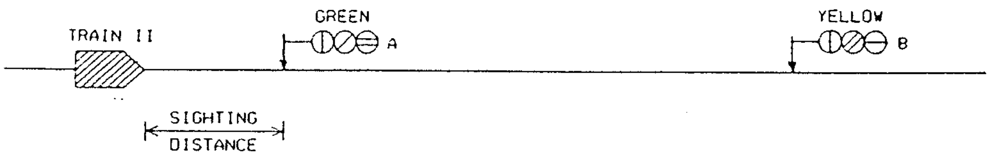
In practice signal spacing can vary from section to section and when related to train speeds it is possible to identify critical sections.

Elements of Headway

Before considering headways as a whole, the elements that make up headways should be considered. These are:-

Sighting Distance (S)

Although adequate braking distance is allowed from the first warning signal to a stop signal it is generally recognised that a driver will take some action to reduce his speed at a point before a warning signal rather than at the signal itself.



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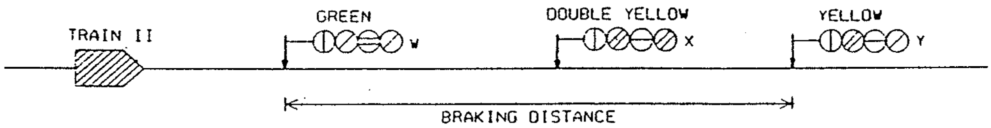
This point is known as the sighting point and it is at sighting distance from the warning signal. Where signals can be seen for a considerable distance the sighting point is not necessarily the point at which a driver first sees the signal. The point at which the driver takes first action varies from driver to driver and from railway line to railway line. On those lines where drivers are used to running trains on proceed aspects other than green, this sighting point is often close to the signal. For theoretical headway purposes a sighting distance related to time is the best figure to use. A time of 10 seconds is commonly used although a distance in the order of 300 yds, is sometimes used for trains in the speed range 60-90 mile/h particularly when it is remembered that the BR AWS is positioned at 200 yds. from the signal. The two figures are comparable.

Braking Distance (D)

Braking Distance was referred to in the module "Introduction to the Service Braking Distance". It is interesting to note that the braking distance for 70 mile/h is approximately half that required for 100 mile/h, and therefore on a four aspect signalling system, those trains running at 70 mile/h or less, with identical braking systems to 100 mile/h trains, only require braking from a single yellow aspect and could therefore, to all intents and purposes, consider the double yellow aspect as a clear aspect.



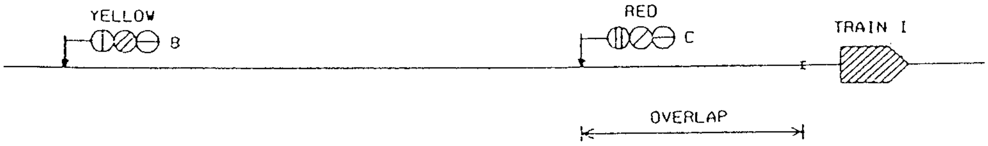
Overlaps

Overlaps are used to provide a small safety margin against the possible overrun of a signal. They are also used to guarantee a space interval between 2 trains. This means that it is not possible to clear the signal in rear until the tail of a train has cleared a point some distance beyond the next signal. The standard overlaps used on BR are:-

Extract from Standard Signalling Principle No 20.

2. The overlap length shall be 200 yards for running signals on passenger lines, reduced as necessary on account of line speed in accordance with the following table:-

Speed Not Exceeding	Overlap Distance
15 m.p.h.	50 yards
45 m.p.h.	100 yards
60 m.p.h.	150 yards



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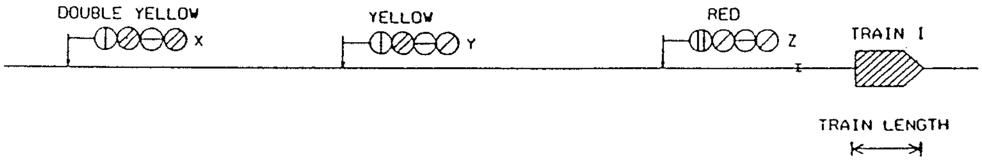
Train Length (L)

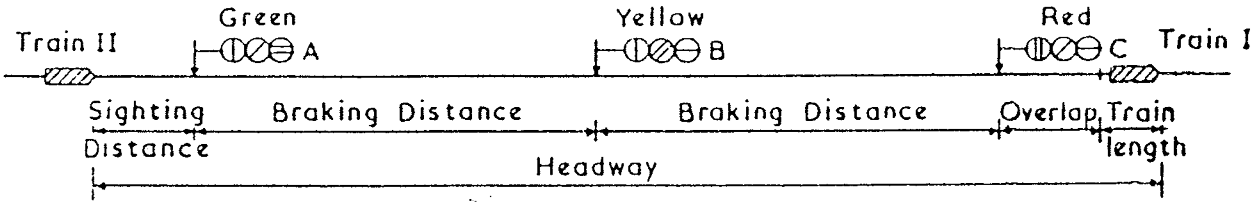
The last factor in the headway of a given line is the maximum length of trains using this line. Train lengths do not normally have a very significant effect on headways unless long trains are in use, but nevertheless it must be taken into consideration.



Headways of three and four aspect Signalling Systems

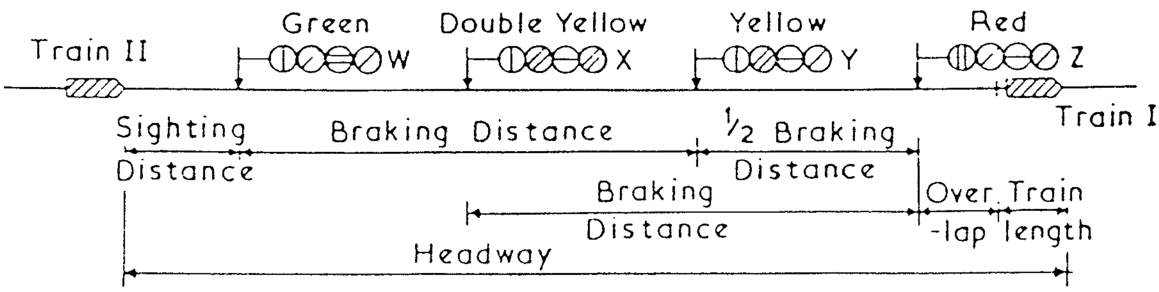
Minimum Headway Distance for a three aspect signalling system H_3

$$H_3 = S + 2D + O + L$$



and Minimum Headway Distance for a four aspect signalling system H_4 are

$$H_4 = S + 1.5D + O + L$$



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Where:

S is the Sighting Distance
D is the service Braking Distance for the maximum line speed
O is the overlap
L is the train length

A distance, as such, is of little value to an operator who wishes to know how frequently he may run trains.

Thus at a train speed of V the headway times of t_3 and t_4 for three aspect and four aspect signalling systems respectively are as follows:-

$$t_3 = \frac{1}{V}(S + 2D + O + L)$$

$$t_4 = \frac{1}{V}(S + 3/2D + O + L)$$

The headway of a two aspect signalling system is dependent upon the spacing of the stop signal aspects.

Where V is the speed of the train in feet per second.

ie. $$10 \text{ mph} = \frac{10 \times 1760 \times 3}{60 \times 60} = \frac{52800}{3600} = \underline{14.666 \text{ feet per sec}}$$

continued

MPH	SPEED IN FEET PER SECOND	MPH	SPEED IN FEET PER SECOND
10	14.666	80	117.333
20	29.333	90	132.000
30	44.000	100	146.666
40	58.666	110	161.333
50	73.333	120	176.000
60	88.000	125	183.333
70	102.666		

Quick Reference Velocity Table

continued

Let us look at a practical example of the use of these formulas.

On a 3 aspect signalling system with a maximum line speed of 40 mph the operating department require a 2-1/2 min headway. We are given the following additional information:-

Sighting Distance 300 yards
Maximum Train Length 200 yards

Using the formula for the 3 aspect Headway calculation we can determine the Signal spacing requirement.

$$t_3 = \frac{1}{V}(S + 2D + O + L)$$

$$150 \text{ secs} = \frac{900 + 2D + 300 + 600}{58.666}$$

$$150 \times 58.666 = 900 + 2D + 300 + 600$$

$$(150 \times 58.666) - 900 - 300 - 600 = 2D$$

$$8800 - 1800 = 2D$$

$$2D = 7000$$

$$\text{therefore } D = \frac{7000}{2} = 3500 \text{ feet} = 1167 \text{ yards}$$

* **Important** always work in compatible units ie. feet & seconds.

This measurement will be the maximum distance we can space the Signals along the stretch of line concerned. If we look at a level gradient and the maximum line speed of 40 mph, reading from the Composite Graph (APPENDIX 1) the Signals can be spaced at 860 yards so 1167 yards will be within the SBD + 50% rule we try to adhere to.

Of course if the average gradient between two signals was in excess of 1:160 falling we would have to look at the possibility of a 4 Aspect sequence to give the required Headway time, because steeper gradients would place the signals further apart and therefore the Headway times would be increased.

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