

shew the influence of some of these factors the accompanying diagrammatic sketches (No. 14) of four modern rapid transit cars have been prepared.

The first car is the Tait car of the Victorian Government Railways. This car has great seating capacity per unit of length, all seats are crosswise, which, with high rates of change of speed, provide maximum comfort to passengers, longitudinal seats being uncomfortable during starting or stopping. A sliding door is provided to each ten seats (except at the

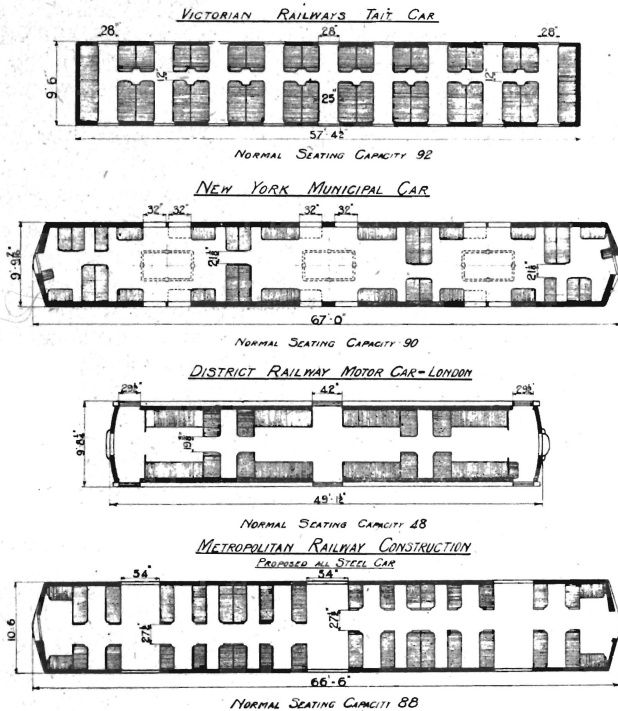


Diagram No. 14.

ends), and during crush loading this may mean one door to fourteen or fifteen passengers.

It must be recognised that it is the worst door on a train that keeps the train waiting at the station, and that in a long train it is reasonably probable that at least one door there will be circumstances impeding the free movement of passengers, e.g. aged or infirm people alighting, or passengers with more than a reasonable amount of hand baggage. Considering the Tait car, passengers to alight have probably to pass between

passengers sitting on the seats adjacent to the doors; knee room taken up by these seated passengers reduces the 25in space between seats to about 17in with probably less width on the floor. These conditions are unfavourable to alighting passengers getting near the door before the train has come to rest. If they do, they must lean over a sitting passenger for support or risk being jolted at the moment of stopping.

The new car of the New York Municipal Railways, shown second on the diagram, was the result of the most thorough investigation yet made into car design. The crowding on the New York Rapid Transit Subways exceeds that in any other city. The new car was designed to seat 78 people during rush hours, and to carry 270 passengers seated and standing. The twelve seats shown dotted are hinged, and are lowered during normal traffic, providing a total of 90 seats. With these twelve seats raised the door capacity is doubled. It will be seen that six sliding doors, each 32in wide, are located on each side of the car in pairs, approximately at the quarter points. The dotted lines in the spaces between doors are enamelled $1\frac{1}{4}$ in pipe standards intended to take the place of straps for "strap hangers," and to provide support for passengers alighting. The utility of the folding seats is questionable as during normal times there are ample seats, and the change from normal conditions to conditions where only the fortunate few can sit is so rapid in New York that the folding seats are seldom in use, though they are always available during the non-rush periods.

The access to the doors is good, and generally before a train comes to a standstill alighting passengers are bunched around the doors.

In the New York subways all doors are operated by compressed air controlled by electro-magnet valves, and trains cannot start until all doors are closed. The door control switch and push buttons are located on panels between each pair of centre doors. Since the U.S.A. joined in the war female conductors have replaced the men as door attendants. The use of air operated doors with the compulsory door shut feature introduces a time element lengthening the station stop, in addition the necessary studs dividing the end doors and panels dividing the centre doors decrease the efficiency of the door widths, for only one person at a time can pass through a 32in door, whereas three abreast could leave the car if the opening were equal to the combined width of two doors.

In Philadelphia and other cities where cars with end and centre doors are operated, attempts have been made to reduce the station stop by compelling alighting passengers to use the

end doors and embarking passengers to use the centre doors. The practice is not to be commended as the station stop is only of great importance during rush periods, and then the bulk of traffic is in one direction, resulting in greater efficiency being obtained if all door space is available to the crowd.

The London Metropolitan District Railway car is much shorter than the New York car, but has many points in common. The maximum distance to a door is about the same, whilst the seating arrangements enable alighting passengers to congregate near the doors and stand in comfort while a train is stopping. The 42in centre doors provide ample width for two people abreast, and frequently three go through together. The provision of over 19in clear in the aisle allows easy passage with hand baggage, and the longitudinal seats, together with the end compartments, allow plenty of room for a reasonable proportion of standing passengers.

The last car on the diagram is one that has been proposed by Mr. Bradfield for use on the Sydney Suburban and Underground Railways. The design is based on the new New York car, but all seats are arranged transversely, giving more comfortable conditions for passengers and restricting the area available for standing passengers. The studs separating the pairs of side doors have been omitted, providing a clear width of 54in, sufficient for three passengers abreast. Access to the doors under any condition of loading is direct and easy while the car is stopping, whilst the width of aisle is greater than in any of the other cars shewn, and will provide comfortable conditions even though a fair proportion of passengers are standing.

Two general factors not previously mentioned in discussing the effect of the cars on station stop are the car lighting and the arrangement of step to the platform edge. The car lighting should be of as uniform intensity as possible, lights being arranged so that shadows thrown by standing passengers will not prevent seated passengers from reading, nor should the arrangements of lights be such as would render certain portions of the standing area more desirable than others, else the natural tendency to stand where reading is most comfortable will hamper the egress of alighting passengers. Most modern cars have a lighting intensity of about 3 foot-candles at 3 feet above car floor.

In the New York subways and on the London underground railways the steps at car entrances are flush with the car floor, and in London are arranged to over-sail the platform edge by about two inches, with a maximum of six inches drop from step to platform. This arrangement gives unimpeded move-

ment, as there is complete absence of gap on tangent or even curves of medium radius.

Most of the factors mentioned as affecting the egress of passengers will also affect ingress. One general consideration, however, worthy of attention, is the provision of a continuous aisle through the train available for passengers. The value of this aisle is well shewn on the Interborough Rapid Transit Subway in New York. At certain stations crowds collect on a short portion of the platform near stairs. These people board a few carriages, possibly already comfortably filled, but after the train has left the station they, by walking along the aisle, find seats or more comfortable standing conditions in other carriages.

On the platforms ample widths and good lighting conditions must be provided to enable the free movement of passengers between the trains and stairways, escalators, or passages leading to the streets. The careful routing and segrega-

SUBURBAN LINE		PINNER NORTHWOOD CHESHAM AND AYLESBURY LINE	
FIRST TRAIN OUT PLATFORM CALLING AT	SECOND TRAIN OUT PLATFORM CALLING AT	NEXT TRAIN DEPARTS PLATFORM CALLING AT	
WYLLIE WOOD ROAD			BRICKMANNSWOOD
REMBOLDIAN ROAD			ROBERT WOOD
SWAYNE COITAGE			CHALFONT ROAD
FIRCHLEY ROAD			CHESHAM
WENTHAMPTON			WAMERSHAM
KILBURN BRIDGE			
WILKESDEN GREEN		WILKESDEN GREEN	GREAT WISSENDEN
QUEEN'S HILL			WENDOVER
NEASDEN			STOKE MENDENHILL
			WYLESBURY
			WADDESDON MARSH
		BARROW GREEN HILL	QUINTON ROAD
		PINNER	
		NORTHWOOD	

TRAINS LEAVE N°5 PLATFORM EVERY FEW MINUTES FOR EUSTON SQUARE, KINGS CROSS, LIVERPOOL STREET, CANNON STREET AND EAST END STATIONS

TRAINS LEAVE N°6 PLATFORM EVERY FEW MINUTES FOR RADDINGTON, BAYWATER, NOTTING HILL, KENSINGTON, HAMMERSMITH, VICTORIA & WEST END STATIONS

TRAIN INDICATOR BOARD

Diagram No. 15.

tion of inward and outward passengers and the provision of well located areas for waiting passengers - all aid in producing a short station stop. Besides satisfactorily routing passengers, it is necessary to give them full information regarding incoming trains, and, in cases where trains may start from more than one platform, to direct passengers to the correct platform. In London the art of giving information concerning incoming trains is developed more completely than in any other city operating rapid transit railways. As an example, the Diagram No. 15 shews an illuminated train indicator installed at Baker

Street station, where there are four platforms serving a branch line to the north-west, and two platforms serving the inner circle. Incoming passengers at the station must pass the diagram illustrated, which it will be seen gives complete information concerning the next two suburban trains and the next long distance train. The whole is under the control of the signal-man in the nearest signal box, and the setting up of any combination of indications necessitates only the movement of a pointer on a dial, each number on the dial representing one combination of stations on the illuminated board. On the London platforms information concerning the next three trains is given by an illuminated indicator. These operate automatically, the train leaving the station causing the indication to change, 2 becoming 1, 3 becoming 2, and a new 3 appearing against the correct destination. Indicators of this form are of great value, as passengers knowing their train is the next in the platform wait near the platform edge, while those who have to wait for the second train will keep away from the edge in order to be clear of the people moving towards and away from the train. The location of the stairs or passages giving access to the platform from the street may seriously affect the duration of stop. If, for instance, at a number of stations of heavy traffic the stairways or passages all lead to the centres of the platforms overcrowding of the centre carriages will follow, while end carriages may be running with vacant seating accommodation.

Next in order among the important factors affecting capacity is the rate of deceleration. Its influence on capacity has been shewn to be great at all times, but its greatest effect is manifested when the ordinary automatic system of signalling and automatic train stops are used. Neither the problems of high duty braking, nor the great advances and elaborate detail of the modern rapid transit air brake to overcome these problems, are generally realised.

The brake shoes must be brought against the wheels with a certain pressure for a given retardation, but unfortunately that pressure does not vary with the retardation desired alone. While wheels are not skidding the co-efficient of friction between wheel and rail remains constant at all speeds, but the co-efficient of friction of shoe on wheel is a very variable function. The curves on the diagram (No. 16) have been plotted from results of the Galton Westinghouse tests, and are reproduced only to shew the form of variation of the co-efficient of friction. They are not given as accurate values, having been plotted from miscellaneous tests recorded in the report. It will be seen that the co-efficient of friction decreases rapidly

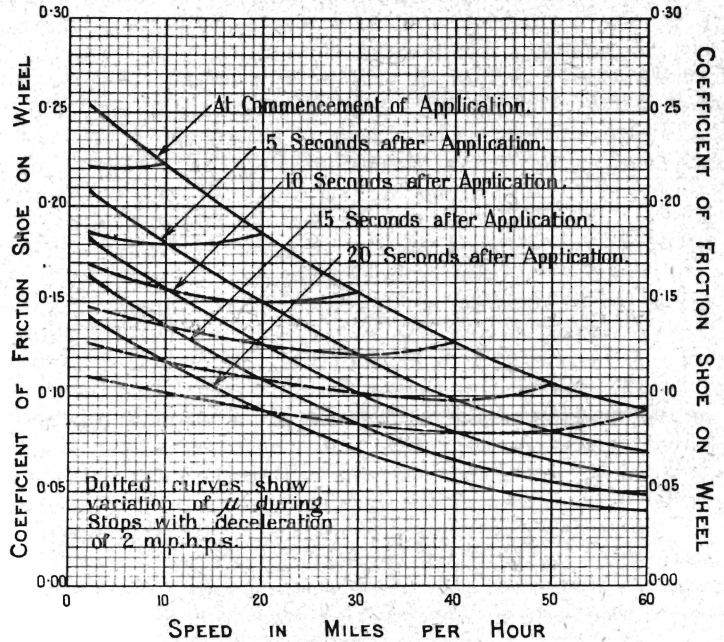


Diagram No. 16.

with increase of speed, and also with time of application. Throughout a stop with a deceleration of about 2 m.p.h.p.s., as shown by the dotted lines μ remains nearly constant, but at the higher speeds μ becomes very small, resulting in the necessity of very high total cylinder pressure for high rates of deceleration. The order of these pressures may be gathered by taking the case of $v=50$ m.p.h.; it then equals about 0.1, and to make use at the rail of only half the weight on axles, requires a pressure on the brake shoes of 125 per cent. of the axle load. The problem of designing the brake beams and rigging for satisfactorily withstanding the stresses necessary for high rates of deceleration is self evident.

The pneumatic portion of the brake equipment also necessarily assumes big proportions. With an ordinary equipment the brake action is serial, owing to the fact that the operation of the brakes on each car is dependent on the reduction of pressure in the train pipe, and that reduction takes place in service applications wholly through the driver's brake valve. The time element introduced is serious with high-braking powers, giving rise to uncomfortable bumps between carriages, and frequently resulting in skidding wheels with lessened brake

power because of the reduction of the co-efficient of friction between the wheel and rail. Most important of all, however, as affecting capacity is the increased length of stop as a result of serial action.

To overcome serial action and apply all brakes at the same instant the electro-pneumatic brake has been developed. The driver's brake valve has mounted above it a small drum controller which controls magnets on all triple valves, causing instantaneous and uniform changes in braking conditions throughout the train.

The great capacity of modern rapid transit cars also seriously affects the braking, for if brakes be designed on full load they are likely to skid the wheels when the cars are empty, and if designed on tare weights the braking distance will be considerably lengthened on full load. An empty and load attachment has been devised by the Westinghouse Co. to adjust the brake force in accordance with the total weight of car. An extra reservoir with four compartments is provided, and combinations of these volumes with the auxiliary reservoir volume provide for the brake pressure at all times being proportional to the total weight of the car.

The great frequency of stops on a rapid transit railway followed frequently by long runs without a stop has necessitated a radical departure in the equalisation of main reservoir, auxiliary reservoir, and brake cylinder pressures, so that whatever the main reservoir pressure the brake pressure will be constant with constant load. The provision of brake equipment with the refinements mentioned is, of course, costly, but its great effect on the capacity warrants the expenditure. Motormen can run at speed to an exact spot under any conditions of loading and be sure of making the stop in the same distance every time. It may be interesting to note that the same device that actuates the empty and load brake is used to adjust the maximum current relay, limiting the motor current so that under all conditions of loading all motors on a train take current proportioned to the load on the motor, resulting in constant acceleration under all conditions.

If the time of run between stations be fixed, i.e. if schedule speed be fixed, ranges of acceleration and running speeds can be determined that will just allow coasting to a given proportion of the maximum speed, braking being assumed constant at all speeds. (See Diagram No. 17).

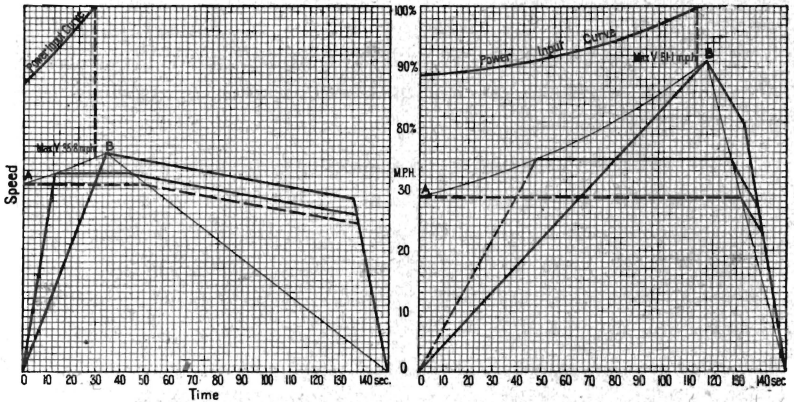


Diagram No. 17.

Example No. I.

$D = 6,000$ Ft. $fb = 2$ m.p.h.p.s., $fc = 0.07$ m.p.h.p.s.

Coasting to 0.8 of Maximum Speed.

Assuming Max. $V = 35$ m.p.h. and $fa = 1.25$ m.p.h.p.s. $T = 149.4$ secs.

Power Input corresponding to Max. $V = 35$ m.p.h. is reckoned 100%.

Run on Level Tangent.

Example No. II.

$D = 6,000$ Ft. $fb = 2.00$ m.p.h.p.s., $fc = 0.07$ m.p.h.p.s. (on Level Tangent).

Coasting to 0.8 of Maximum Speed.

Assuming Max. $V = 51$ m.p.h. and $fa = 1.25$ m.p.h.p.s. (on Level Tangent). $T = 148.6$ secs.

Power Input corresponding to Max. $V = 51$ m.p.h. is reckoned 100%.

Run on 2.5% grade.

Diagrams showing Relations between Maximum Velocity, Acceleration, Coasting and Braking for Constant Schedule Speed.

General relations between Acceleration and Deceleration Rates, Maximum and Schedule Speeds and Power Input—for a given schedule:—

Let $T =$ Running Time between stops in seconds.

$D =$ Distance between stops in feet.

$f'a, ta, da$ Acceleration rate, time and distance in foot sec. units.

$f'b, tb, db,$ Braking rate, time and distance in foot sec. units.

$f'c, t'c, d'c,$ Coasting rate, time and distance in foot sec. units.

$tv, dv,$ Constant speed time and distance in foot sec. units.

$v' =$ Velocity at commencement of braking.

$$T = ta + tv + tc + tb$$

$$= \frac{v}{f'a} + tv + \frac{v - v'}{f'c} + \frac{v'}{f'b} \quad (1)$$

$$D = da + dv + dc + db$$

$$= \frac{v^2}{2 f'a} + v tv + \frac{v^2 - v'^2}{2 f'c} + \frac{v'^2}{2 f'b} \quad (2)$$

Assume that speed through which train coasts is a fixed ratio of maximum speed

i.e. that $\frac{v'}{v} = \text{constant} = k$ say

$$\begin{aligned} \text{then } T &= \frac{v}{f'a} + tv + \frac{v(1-k)}{f'c} + \frac{kv}{f'b} \\ &= v \left(\frac{1}{f'a} + \frac{1-k}{f'c} + \frac{k}{f'b} \right) + tv \end{aligned} \quad (3)$$

$$\begin{aligned} D &= \frac{v^2}{2f'a} + vtv + \frac{v^2(1-k^2)}{2f'c} + \frac{k^2v^2}{2f'b} \\ &= v^2 \left\{ \frac{1}{2f'a} + \frac{1-k^2}{2f'c} + \frac{k^2}{2f'b} \right\} + vtv \end{aligned} \quad (4)$$

To find v eliminate tv

$$vT - D = v^2 \left\{ \frac{1}{2f'a} + \frac{(1-k)^2}{2f'c} + \frac{k(2-k)}{2f'b} \right\} \quad (5)$$

For any grade P

if f_a, f_b, f_c are acceleration, braking and coasting rates on level tangent, and $f'a, f'b, f'c$ are corresponding rates on grade P .

$$f'a = f_a - 30p, \quad f'b = f_b + 30p, \quad f'c = f_c + 30p.$$

Hence general equation for curve A B Diagram No. 17 becomes

$$vT - D = \frac{v^2}{2} \left\{ \frac{1}{f_a - 30p} + \frac{(1-k)^2}{f_c + 30p} + \frac{k(2-k)}{f_b + 30p} \right\} \quad \dots \quad (6)$$

If f_c, f_b, p, T, D are constant, the equation becomes a function of v and f_a only, i.e. of v and t_a and the curve is a parabola.

To find limits of velocity for given acceleration.

(a). Minimum value of velocity. Put $f'a = \infty$ in Eq. (5).

$$Tv - D = v^2 \left\{ \frac{(1-k)^2}{2f'c} + \frac{k(2-k)}{2f'b} \right\}$$

(b). Maximum value of velocity. This occurs when there is no constant speed running.

Put $tv = 0$ in equations (3) and (4).

$$\begin{aligned} T &= v \left\{ \frac{1}{f'a} + \frac{1-k}{f'c} + \frac{k}{f'b} \right\} \\ D &= v^2 \left\{ \frac{1}{2f'a} + \frac{1-k^2}{2f'c} + \frac{k^2}{2f'b} \right\} \end{aligned}$$

and eliminate $f'a$

Energy Equation.

If F_a = average train resistance during acceleration

F_v = average train resistance at constant speed v in lbs. per ton.

F_g = grade and curve resistance.

The Energy Input per ton is given by (at 100% efficiency)

$$E = \frac{2000}{2g} v^2 + da F_a + dv \cdot F_v + (da + dv) F_g$$

$$= \frac{2000}{2g} v^2 + \frac{v^2}{2 f'a} \cdot F_a + vtv F_v + \left(\frac{v^2}{2 f'a} + vtv\right) F_g \quad (7)$$

Hence E can be derived from above equations, assuming values for F_a , F_v and F_g .

The Diagram No. 17 shows the straight line loci of commencement of coasting and braking, and the curved line A B the loci of the points of change from acceleration to constant speed running.

The energy consumption for the run is shewn on a percentage basis by the curves at the top of diagrams; ordinates to these curves represent the power input for a maximum speed equal to the speed at which they cut the curve A B.

The decrease in power consumption, with increase in acceleration, though not great, is apparent and general, and is a further argument in favour of adopting high rates of acceleration.

The influence of different rates of acceleration on the necessary power of motor for constant schedule speeds is outside the scope of this paper, but generally it may be stated that the attainment of high acceleration rates is not difficult with present commercial motors, though on account of the effect of increased acceleration on capacity being less proportionately than the effect of a corresponding increase in rate of deceleration it is reasonable to expect that economical braking rates will always be greater than corresponding economical rates of acceleration.

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