WARDALE ENGINEERING & ASSOCIATES

7D Reay Street   Inverness IV2 3AL   Great Britain

CLASS 5AT 4-6-0: FUNDAMENTAL DESIGN CALCULATIONS

1. GENERAL CALCULATIONS.

1.2. DETERMINATION OF THE TARGET LOAD – SPEED – GRADIENT CURVES.

Notes.

1. The SI system is mostly used. Unless otherwise stated "ton" refers to metric ton of 1000 kg.
2. Numbers in square brackets [ ] in column 2 refer to calculation item numbers in the Fundamental Design Calculations (FDC's): firstly the number identifying the calculations concerned, followed by the item number within those calculations, given in round brackets ( ), e.g. [1.3.(16)] refers to calculations 1.3. item no. (16). Where only a single number is given within square brackets, it refers to an item number within these calculations.
3. ***To save space, unit conversion factors for numerical consistency, where used, are <u>not</u> shown in the calculations. Any apparent small numerical discrepancies are due to giving data to limited places of decimals but to taking the full figure for any calculations involving that data.***
4. References are shown in superscript square brackets [ ] and are given in full at the end of the calculations.
5. Fundamental data is in **bold** type.

Item No.	Item									Unit	Amount
1	Calculation of the gradients and the speeds they can be climbed at by the 5AT 4-6-0 hauling various loads involves equating the locomotive's tractive effort with the train's resistance. Note that of all the resistances only rolling resistance and gradient resistance apply. Constant speed means the acceleration resistance due to inertia is zero, it is assumed that gradients are compensated for curvature so that the combined (curve + grade) resistance on curves = the grade resistance on tangent track, and still air is assumed, i.e. natural wind resistance = zero. Also, if the drawbar tractive effort is taken the rolling resistance of the locomotive does not figure in the computation.										
2	The coaching stock, rolling resistance is taken from the equation given by Koffman for BR coaches[1]: $r = 1,1 + 0,021v + 0,000175v^2$: where r is in kg/ton, v is in km/h. (Note: as given in ref. [1] the second term is 0,21v which must be an error.) Reworking this equation it is: $r = 10,8 + 0,206v + 0,00171v^2$: where r is in N/ton, v is in km/h.										
3	The locomotive's maximum drawbar tractive effort at constant speed on level tangent track is used: this is taken from **Calculations 1.1. Fig. 1.1.1** which smooths out slight irregularities in the original data [1.1.(31)]. Up to the locomotive's maximum continuous operating speed [1.3.(26)] it is:										
4	Speed	km/h	30	40	60	80	100	120	140	160	180
5	Max. d.b. t.e. at constant speed on level tangent track	kN	113,4	103,5	88,7	76,8	66,1	55,5	45,0	34,8	24,9
6	Specific rolling resistance of coaches from eq.[2]	N/ton	18,52	21,78	29,32	38,22	48,50	60,14	73,16	87,54	103,3
7	The calculation method is the same for any train load, hence the computation is made here for one trailing load only, i.e.									ton	400
8	Rolling resistance of coaches = [6] x [7]:	kN	7,4	8,7	11,7	15,3	19,4	24,1	29,3	35,0	41,3
9	T.E. available to overcome gradient resistance = [5]–[8]:	kN	106,0	94,8	77,0	61,5	46,7	31,4	15,7	-0,2	-16,4
10	The negative values of [9] at 160 & 180 km/h mean the locomotive would be unable to haul the given load at these constant speeds on level track. However the value for 160 km/h ≈ 0, suggesting this as approximately the level track balancing speed with a 400 ton load.										
11	Total train mass = [1.3.(16)] + [7]									ton	542,2
12	The available tractive effort item [9] is applied to overcome the gradient resistance of the <u>entire</u> train. The gradient at which the load can be hauled is given by [9] ÷ [11], specifically: Gradient, ‰ = tractive effort available to overcome grade resistance, kgf ÷ total train mass, tons. It is:										
13	Gradient	‰	19,9	17,8	14,5	11,6	8,8	5,9	3,0	0	-

Item No.	Item	Unit	Amount
14	The resultant speed-gradient curve for a 400 ton load, together with curves for other loads calculated by the same method (altered load in items [7] and [11]), are drawn in **Fig. 1.2.1**.		
15	Mass of a fully laden BR Mark II second class coach ≈	ton	37
16	[15] is used to give the approximate number of coaches corresponding to any given trailing load. For 400 tons the number of coaches is [7] ÷ [15]:	-	(10,8) 11

D. Wardale
Inverness
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References.

1. Quayle J. P., Editor, *Kempe's Engineers Year-Book*, 90th Edition, Morgan-Grampian Book Publishing Co. Ltd., London, 1985: page J3/4.