Appendix F: The Velocity- travel diagram, traction and indication

In order to see which performance the locomotive can initially supply the method is used as discussed in the Handboek der Spoorwegtechniek Part III p. 189 and further. First of all, for the locomotive, the tractive effort at the various speeds should be determined. The resistance of the locomotive and train are then calculated separately.

Tractive effort (t.e.)

The tractive effort of the engine, when stationary, is given by:

$T = p\frac{d^2 l}{D}$. Herein p was the pressure, in Europe in general, 70% of the boiler pressure. *D* is the diameter of the cylinder, *l* is the stroke of the piston, and *D* is the driving wheel diameter. The classical units were used, in kilos for forces, pressure in kilos/cm² and the diameters and stroke in cm. If the values for the locomotive are used, *p* = 15, *d* = 55 cm, *l* = 66 cm and *D* = 201.6 cm, the tractive effort would be 8200 kilos. Now a method should be used to determine the t.e. at different speeds. The method used in the Handboek starts from the steam production and what was feasible from there. The formula used in the Handboek for steam consumption per IPK (indicator horse power) is: $q = \frac{7}{100}\{100 - (p - 12)\}$kilos.

This is because at 12 kg/cm² the consumption was between 6.5 and 7 kilos. At a higher steam pressure the consumption will be adjusted by 1% per atm(~bar). In the previously used calculation, however, the graph of Postupalsky was used which showed that is valid for a steam temperature of 325 to 350 ° C. Because the locomotive uses superheated steam of 420 °C this value drops in accordance with the graph to 5.9 kilos at 12 bar, so that this value is used instead of the 7 in the formula. The maximum power $N_i^{'}$ of the locomotive at the most favorable speed can now be calculated from:

$N_i^{'} = \frac{Q}{q}$ in which *Q* is the total steam production.

This was calculated at 5744 kg /hr. So that the power would be 5744/5723 = 1003 hp

That power could also be defined as: $N_i^{'} = \frac{T_i^1 V^1}{270}$ from which follows that the most favorable speed is: $V^1 = 270\frac{N_i^{'}}{T_i^1}$ The t.e. would be: $T_i^1 = p_m \frac{d^2 l}{D}$ in which the average pressure in the cylinders should be determined from experimental data. This appears to be 3.6 kg/cm² at a pressure of 12 kg/cm² and for each atm. higher it is 3% extra: $p_m^{'} = \frac{3,6}{100}\{100 + 3(p - 12)\}$

Based on experience the t.e. at a different speeds other than the most favorable can be determined by: $\frac{T_i}{T_i^1} = 0,6\left(2 - \frac{V}{V^1}\right) + 0,4\frac{V^1}{V}$ at a lower speed then the most favorable, so $\frac{V}{V^1} < 1$. In case of a higher speed it is: $\frac{T_i}{T_i^1} = 0,5\left(3 - \frac{V}{V^1}\right)\sqrt{\frac{V^1}{V}}$ with $\frac{V}{V^1} > 1$

Since the various values are known they can be entered in a spreadsheet (like Excel). This gives the following calculated values: q = 5.723 kg / Ipk, the power $N_i^{'} = 1004$ hp, the cylinder pressure $p_m^{'} = 3{,}924$ kg / cm ^{2,} and the most favorable speed is then $V^1 = 84{,}383$ km/h with the t.e. $T_i^1 = 3212$ kg which belongs to this speed. With the aid of the tractive effort ratio in accordance with the above formulas for other speeds the following table is established:

Ratio T / T [1]	tractive effort	at speed	ideal speed
2,745	8817	20	84
2,112	6782	30	84
1,759	5651	40	84
1,520	4880	50	84
1,336	4290	60	84
1,184	3804	70	84
1,054	3384	80	84
0,936	3006	90	84
0,834	2677	100	84
0,743	2386	110	84
0,662	2125	120	84

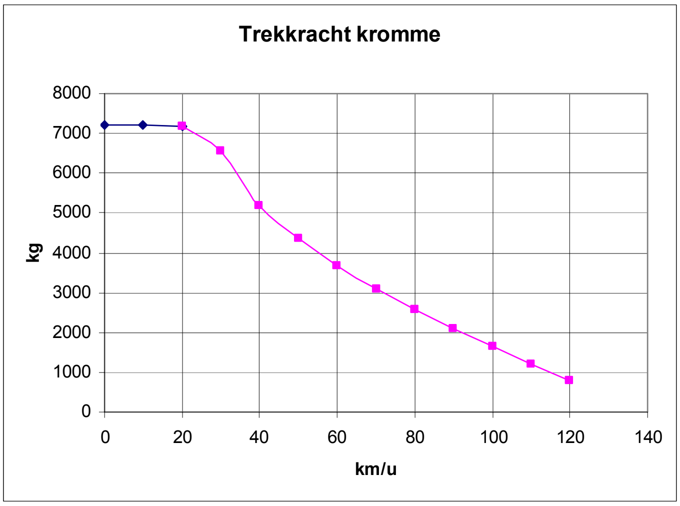
To get the t.e. at the drawbar the resistance of the locomotive itself should be deducted. The Handbook uses the following formula:

$W_1 = 2{,}5G_l + 5{,}8G_a + 0{,}6F\left(\frac{V + \Delta V}{10}\right)^2$ where G_l is the weight in tons of non-coupled axles, 44,7 ton, G_a is the adhesion weight, 35 ton and F is the surface of the cross section of the locomotive, about 10 m^2 It should be noted that this formula, according to the postwar tests, probably overstates the resistance.

The load of the locomotive is formed by the resistance of the train. For that, the formula: $W = 2{,}5 + \frac{1}{40}\left(\frac{V + \Delta V}{10}\right)^2$ kilos per ton of train weight was used. From its use is refrained, it is a formula for pre-war railway stock. During the BR tests of the fifties train resistances were also determined. These values have been converted to metric, and by means of "curve fitting" the corresponding formula is provided, this gives: $W = 2{,}0606 - 0{,}0046V + 0{,}0003V^2$ kilos per ton of train weight. The formulas clearly show how small the influence of the square of the speed is. For locomotives and its train of 300 tons we get the following table:

Speed Km / h	**loc Resistance**	**tractive effort**	**train resistance**
0	118	7216	618
10	136	7198	613
20	166	7168	627
30	208	6575	658
40	465	5186	707
50	531	4349	774
60	609	3682	859
70	699	3105	963
80	801	2583	1084
90	915	2092	1223
100	1041	1636	1380
110	1179	1207	1555
120	1329	796	1749

The graph of the tractive effort looks like this:

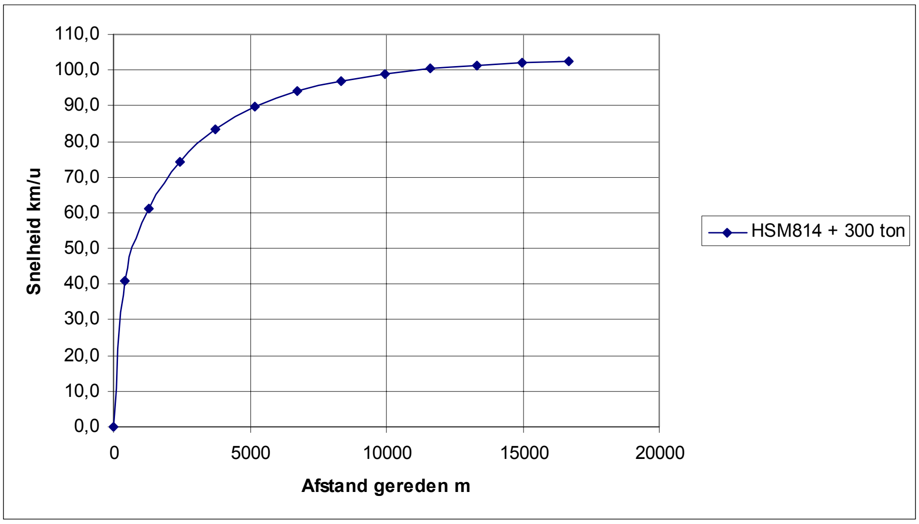


It should be noted that the tractive effort formula gives a value at standstill and at low speeds which is larger than the adhesion weight and the friction with the rail permits. Depending on the wheel tire quality,-profile and condition of the rails a factor of 4.5 is chosen, so that the maximum tractive effort of the HSM 814 does not exceed 7777 kilos. The graph is adjusted accordingly.

Because now the locomotive tractive effort, the resistance of the locomotive and that of the train can be calculated at different speeds, the remaining force can be determined with which the total train can be accelerated $F = T - W_{loc} - W_{train}$.
The Handbook uses a graphical method to determine thus the speed-travel diagram. In this computer age this is no longer necessary and in increments of say 10 seconds, the speed and distance traveled of the train could be calculated.
In this process, the Newton's law applied: $F = ma$, Force equals mass times acceleration. The acceleration is then tractive effort divided by mass: $a = F / m$
The acceleration has a dimension of m/sec^2 and when an acceleration is multiplied by the time interval *t,* say 10 (seconds), in which the acceleration occurs, the speed increase is calculated $\Delta V = a * t$ with a dimension of m/sec. The speed at the end of the time interval would be $V + \Delta V$ and the road traveled will be the average speed during the time interval times the length of the time interval:
$\Delta S = (\Delta V + V + V) / 2 * t$. The dimension is now m/sec*sec, and thus becomes a distance in meters. This process must take care of the use of correct units. The tractive effort must be expressed in N(ewton) to get to the proper combination with the mass of the locomotive and its train. The results of these calculations are:

Minute	Travel m	Speed km / h
0	0	0,0
1	434	41,1
2	1300	61,2
3	2436	74,3
4	3754	83,3
5	5198	89,6
6	6729	93,9
7	8321	96,9
8	9955	99,0
9	11618	100,4
10	13301	101,4
11	14997	102,1
12	16704	102,6

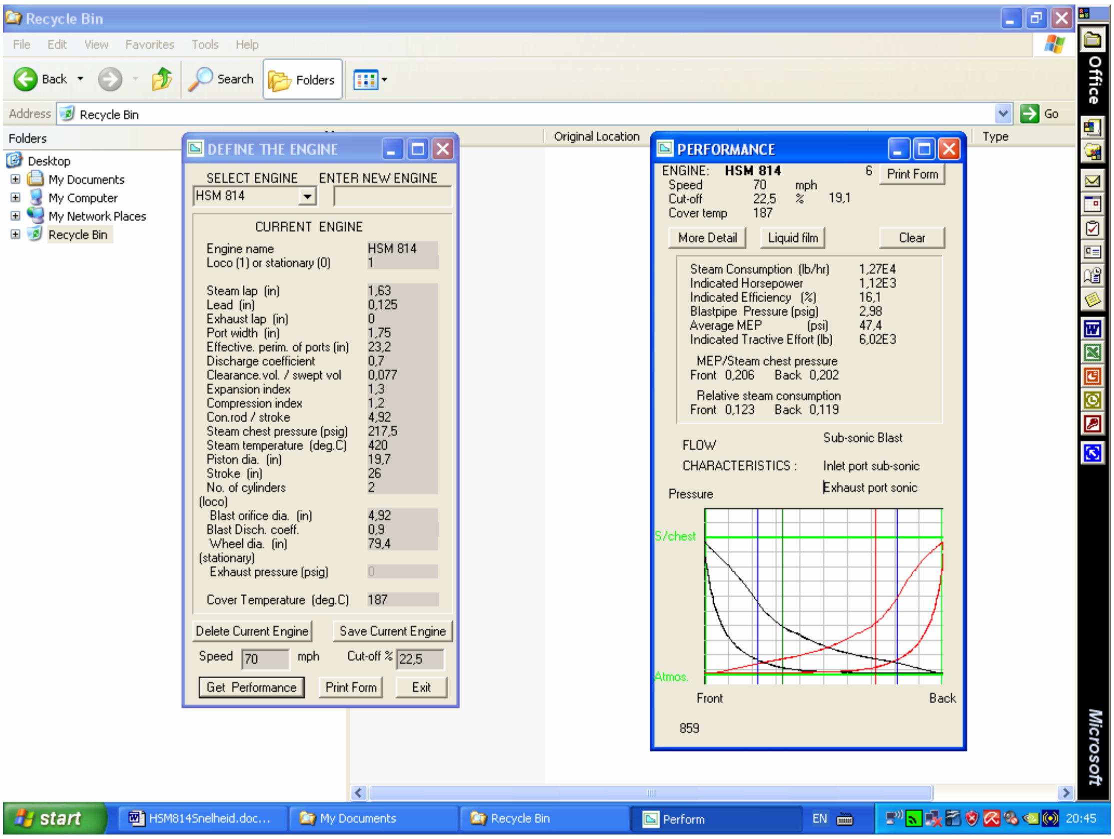
and graphically:



This shows that the HSM814, with this classic calculation, will arrive at a speeds of around 103 km/hr, after about 12 minutes.

What are the limitations to this method?
The method is fully based on classical data, 12 atm and 320 ° C superheating. Another level of superheating is not accounted for in the average cylinder pressure of 3.6 kg/cm^2. Improvements to the valves and the exhaust, the increased superheating and the higher pressure will make sure that the indicator diagram will have another shape.

Tractive effort and Indication
For an estimate of the effects of superheating, improved valves and exhaust a program is used designed by Prof. W.Hall, nuclear safety expert and like many other British subjects of reputation highly interested in steam locomotives. Using the data from the reports of the tests of British Railways, he has modeled the theoretical approach to expansion of steam in an engine cylinder so that the calculation results make it possible to study the effects of various changes. In the case of the HSM814 the Perform approach of the tests of the LNER B1 could therefore be used for the boiler pressure applied, superheating, and the area of the exhaust orifice.
The calculations show that the locomotive has a 13% higher power than the Handboek assumes, also the tractive effort is larger. The consequence is that the locomotive, with its nominal amount of steam, can obtain a speed above 110 km/h. A further increase of the speed can be obtained with extra steam by additional firing. There are nominally about 900 kilos of coal burned per hour. The by BR so called "grate limit" for a grate of 2 m^2 and 600 kilos of grateload per m^2 grate gives already 1200 kilos while during the experiments with the B1 firing continued to 924 kg/m^2.



Example Perform at 70 mph (112.5 km / h) and 22.5% cut-off.

Conclusion

The steam production and its use in the cylinders give sufficient reason to be confident on maximum speeds of around 120km/h with a train load of 300 tons.

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