टेलैक्स : 0535-2424 RDSO-IN
फैक्स : 91-0522-458500
तार : 'रेलमानक' लखनऊ
Telegram : 'RAILMANAK', Lucknow
टेलीफोन/Tele : 451200 (PBX)
450115 (DID)

सत्यमेव जयते

भारत सरकार - रेल मंत्रालय
अनुसंधान अभिकल्प और मानक संगठन
लखनऊ - 226 011
Government of India-Ministry of Railways
Research Designs & Standards Organisation
LUCKNOW - 226 011

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TECHNICAL CIRCULAR NO. 27

No. EL/3.1.39 / 1 Dated 27/31.7.1998

CHIEF ELECTRICAL ENGINEER,

- Central Railway, Mumbai CST-400 001
- Eastern Railway, Fairlie Place, Calcutta-700 001
- Northern Railway, Baroda House, New Delhi-110 001
- Southern Railway, Park Town, Chennai-600 003
- South-Eastern Railway, Garden Reach, Calcutta-43
- South-Central Railway, Rail Nilayam, Secund-rabad-71
- Western Railway, Churchgate, Mumbai-400 020
- Chittaranjan Locomotive Works, Chittaranjan-713 331

Director, IRIEEN, Post Box No.233, Nasik Road, Nasik – 422 101

Sub: Tractive Effort requirement calculation for starting and hauling BOXN loads.

From time to time RDSO have issued letters/reports for guidance of the Railways on the above subject. References have been received from Railways asking for clarifications. Through this circular, the basic methodology of calculations with the formulae, have been described for the information of the Railways. The method for calculation of tractive effort required for starting and hauling loads at particular speed, gradient and degree of curvature and also horse power, OHE current calculation is given in the following paragraphs. The methodology and the various formula adopted are also given.

I. Formula to be used are:

1. Tractive effort (TE) required for hauling a load " T " tonnes on one in " G " grade and " S " degree curve is given by

$$\mathbf{TE\ (kg) = T1 + T2 + T3 + T4}$$

Where T1 is Train resistance in kg/t.
T2 is locomotive resistance in kg/t.
T3 is Grade Resistance for train and loco in kg/t.
T4 is curvature resistance for train and loco in kg/t.

2. Train resistance (T1) in Kg/t as applicable to loaded BOXN wagons is given by

$$\mathbf{T1 = 0.6438797 + 0.01047218\ V + 0.00007323\ V^2}$$

(For details please refer para II below).

3. Locomotive Resistance (T2) in kg/t is given by

$T2 = 0.647 + (13.17 / W) + 0.00933\ V + (0.057 / WN)\ V^2$

where N is number of Axles.
W is axle load of the locomotive in tonnes.
V is speed in Kmph.

4. Grade Resistance (T3) in kg/t is given by

T3 = (1 / G) X 1000 X (Train load in tonnes +loco wt. in tonnes).

5. Curvature Resistance (T4) in kg/t is given by

T4 = 0.4 X S Degree of curvature X (Train load tonnes+loco wt.in tonnes)

6. Starting Resistance of BOX `N' and BOX wagon is taken as 4.0 kg/t and 5.0 kg/t respectively including Acceleration Reserve.

7. Starting Resistance of the locomotive is taken as 6 Kg/t including Acceleration reserve.

8. Rail Horse Power ` H ' is given by

H = (T.E. (kg) X V (Kmph) / 270) hp

9. Current 'I ' drawn from OHE is given by

$I = \{ (Hx735.5) / (OHE\ Voltage\ X\ P.F.\ X\ \eta) \}$ Amps.

Where η is the efficiency of the locomotive
P.F. is the power factor of the locomotive.
For conventional locomotive n is taken as 0.80 and P.F. is taken as 0.84

Note- It is the practice in Railways to take into consideration "Compensated Gradient", while deciding the ruling gradient, in such a case T4 is to be excluded.

II The rolling resistance of BOXN/BOX wagons in kg/t is represented by the formulae:

i) **$R = 1.333973 + 0.021983V + 0.000242\ V^2$**
for empty BOX`N` wagons train.

ii) **$R = 0.6438797 + 0.01047218V + 0.00007323\ V^2$**
for loaded BOX `N` wagon train.

iii) **$R = 1.517 + 0.01074\ V + 0.000495\ V^2$**
for empty BOX wagons train.

iv) **$R = 0.870 + 0.0103\ V + 0.000056\ V^2$**
for loaded BOX wagons train.

Where V= Speed of the train in Kmph.
R= Rolling resistance in kg/t

From the above rolling resistance has been calculated and summarised below for ready reference.

ROLLING RESISTANCE (Kg/t) AT VARIOUS SPEED

Speed kmph	BOX N Wagon		BOX Wagon	
	Empty	Loaded	Empty	Loaded
10	1.5780	0.7559	1.674	0.978
20	1.8696	0.8826	1.930	1.098
30	2.2113	1.0239	2.285	1.229
40	2.6005	1.1799	2.738	1.372
50	3.0381	1.3505	3.292	1.525
60	3.5241	1.5360	3.947	1.690
70	4.0586	1.7360	4.700	1.865
80	4.6414	1.950	5.560	2.052

III. SAMPLE CALCULATION

Load - 4700 t (BOX`N`)
Grade - 1/200 (Uncompensated)
Curvature - 2 degree
Speed - 50 Kmph
Locomotive - WAG7 of 123 t weight

1. TE required to start the load:-

TE = T1 + T2 + T3 + T4

T1 = Train load in tonnes x starting resistance of BOX`N` wagon Including acceleration reserve.

= 4700 X 4 = 18,800 kg.

T2 = Locomotive starting resistance including acceleration reserve x locomotive wt. in tonnes.

= 6x 123=738 kg.

T3 = Grade resistance

= 1/200 X 1000 (Train in tonnes load + loco wt. in tonnes).

= (1 / 200) X 1000 X (4700 + 123)

= 24115 kg

T4 = Curvature resistance = 0.4 X Curvature X (Train load in tonnes + locomotives in tonnes)

= 0 .4 X 2 X 4823

= 3858.4 kg

TE = 18800 + 738 + 24115 + 3858.4

= 47511.4 kg = 47.51 t

Note: 1: 200 gradient on 2 deg. curve is compensated to gradient of 1 : 172.4

{ (1 / G) X 1000 + (0.4 X S) } = 1000/X

where G is grade
S is Degree of curvature
X is compensated grade

if the gradient is 1 in 200 and the curve is 2 deg then G= 200, S= 2 and then the compensated grade is

{ (1 / 200) x 1000 + (0.4 X 2) } = (1000 / X)

5 + 0.8 = (1000 / X)

5.8 = (1000 / X)

Therefore X = (1000 / 5.8) = 172.41

Therefore T.E.= T1 + T2 + T3

= 18800 + 738 + { (1 / 172.41) x 1000 x 4823

= 18800 + 738 + 27974

= 47512 kg

= 47.512 t

2. Running the load at 50 Kmph:-

(i) T.E. required:-

TE = T1 + T2 + T3 + T4

T1 = BOX `N' load in tonnes x specific resistance in kg/t of BOX `N' at 50 Kmph.

= 4700 x 1.3505 = 6347.35 kg.

T2 = Locomotive wt in tonnes x specific resistance in kg/t of loco at 50 kmph.

= 123 x 2.913 = 358.3 kg

T3 = Grade resistance.

= 24115 kg

T4 = Curvature resistance

= 3858.4 kg

TE = 6347.35 + 358.3 + 2411.5 + 3858.4 = 34679 kg = 34.679 t

ii) Rail Horse Power at 50 kmph.

H = { (34679 x 50) / 270 } = 6422 hp

iii) OHE current at 50 kmph

I = { (H x 735.5) / (OHE Voltage x P.F. x n) }

I = { (6422 x 735.5) / (22500 x 0.84 x 0.8) }

I = 312.39 Amps

The above methodology is to be adopted for all haulage calculation of electric locomotives and superseed all earlier instructions issued by RDSO on the subject.

(Ramesh Chandra)
for Director General / Elerctrical

Encl: Nil

Copy to: Secretary (Elect. Traction), Railway Board, Rail Bhawan, New Delhi- 110 001

(Ramesh Chandra)
for Director General / Elerctrical

Encl: Nil