There are a number of additional matters which might be touched upon in considering this side of our subject, such as the effect of the competition of coal oil, gas and Welsbach burners; the recent Governmental regulations and certain desirable extensions of the same, and so on. Not the least important of these, in view of the certain benefits to be derived, is the building up of this Association into a strong and compact organization, able on the one hand to protect the industry in which its members are engaged from the attacks of conflicting interests or of ignorant and harmful legislation, and on the other hand by a frank interchange of experience and opinion to assist in hastening the day when Progress and Profit shall be the happy watchword in all cases describing the conditions of central station operation.

It was intended, had space permitted, to discuss the subject of this paper from the other standpoint which has been mentioned—that of engineering and operation, taking up first the question of selection of apparatus which would give the ideal plant for each set of conditions, and considering in how far deviations from such an ideal installation were responsible for failure to get best results in a given case. Such a consideration of the matter, however inadequate in itself, could not fail to bring out points in discussion which, checked by the actual experience of the managers of central stations present, would become of the utmost value.

For THE CANADIAN ENGINEER.

RAILWAY ENGINEERING.*

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CHAPTER II.

TRAIN RESISTANCES AND THEIR COST.

ART. 6.—TRAIN RESISTANCES.

It is necessary in a study of routes, especially in instituting comparisons of the advantages of alternative ones, to understand the nature, amount, and cost of the resistances which are offered to the hauling of trains, inasmuch as they have a direct effect on the working expenses of a railway.

These resistances may be any or all of the following, depending on circumstances; but the first four always exist in operating over even a level straight track.

A.—(1) Journal friction in the car trucks.
(2) Rolling friction, on the rails, of the car and engine wheels.
(3) Incidental—stopping and starting resistances.
(4) Velocity (wind and oscillating resistances.)

B. Grade resistances.

C. Curve resistances.

(*A*) *Level Tangent Resistances.*—In the earlier years of railways, due to imperfect track, workmanship, etc., the journal and rolling friction was found by Clark to be about seven pounds per ton (2,000 lbs.); since then, however, the researches of Wellington and others have shown that on a good track, at ordinary speeds of over 10 miles per hour, these resistances are:—

Loaded Cars—4 lbs. per ton in summer.
" —6 " " winter.
Empty Cars—6 " " summer.
" —8 " " winter.

A change of 60° F. in temperature, showing an increase of 50 per cent. due to poor track, ice, snow, etc., and to an inherent increase in the co-efficient. Morin's law, that friction is independent of pressure or velocity, was deduced from data of a limited range, and does not hold true for extreme cases, the empty cars showing a decidedly higher co-efficient; but when we consider the co-efficient in its relation to velocity the matter becomes more important. At the point of starting a train, the co-efficient is found to be as high as 18 to 20 pounds per ton, for loaded cars, and even higher for empties, being composed of friction + stiction; the latter disappears the instant that motion begins, and the co-efficient falls suddenly, to perhaps 10 or 12 pounds per ton, at one or two miles per hour, and goes on steadily decreasing as the speed increases; but above 10 miles per hour the change is not very appreciable. Should a train get "stalled" on a grade, or be at rest at a depot, it is plain that the *maximum* load cannot be hauled on the *maximum* grade; this matter will be taken up further on.

It will thus be seen that under ordinary cases the force necessary to propel one ton along a level, straight track at ordinary speeds, and disregarding velocity resistances, varies from 4 to 8 lbs., depending on the time of year, condition of load, track and rolling stock; in future calculations in these papers it will be taken at 6 lbs. per ton for loaded train.

The resistance offered to movement through space by the air has been extensively experimented on. The weight of evidence until recently was in favor of the belief that the resistance varied as (velocity)^2. Based on this belief, the formula deduced for total level, tangent resistance on railways, by Clark, was:—

Lbs. per ton hauled $= R = 7 + .0052\, V^2$ (1)

(V being in miles per hour), in which the latter term represents the effect of the wind. Wellington also, as a result of the Burlington tests, made at moderate speeds, gave the following empyrical formulæ:—

Lbs. per ton (*a*) for loaded flat cars $= R = 4 + .0065\, V^2 + .57 \frac{V^2}{W}$ (2)
" " (*b*) " box or psgr. cars $= R = 4 + .0075\, V^2 + \cdot 64 \frac{V^2}{W}$
" " (*c*) " empty flat cars $= R = 6 + .0083\, V^2 + \cdot 57 \frac{V^2}{W}$
" " (*d*) " box or psgr. cars $= R = 6 + .0106\, V^2 + \cdot 64 \frac{V^2}{W}$

Where the 2nd term represents the head and side air resistances, and the 3rd term the effect of oscillations, which being chiefly in the engine, decrease, per ton, as the train gets longer, V = miles per hour W = gross weight of train in tons.

TABLE V.

POUNDS PER TON FOR TOTAL LEVEL TANGENT RESISTANCE.

Speed in Miles per hour.	Clark (1) $7 + .0052\, V^2$	Wellington 2(b) $4 + .0075\, V^2 + .64 \frac{V^2}{W}$ (W = 450 tons.)	Wellington (3) $2 + \frac{V}{4}$	Average
10	7·52	4 89	4.5	6
20	9 08	7·56	7.0	8
30	11.68	12.03	9 5	11
40	15·32	18.27	12.0	15
50	20 00	26.30	14.5	20
60	25·72	36.12	17.0	26
70	32·48	47·71	19.5	33
80	40.28	61.08	22.0	41
90	49·12	76.27	24.5	50
100	59.00	93·20	27.0	60

Recently, however, the very high speeds obtained on various trial runs, and even scheduled trains, have thrown doubt on the idea that at high speeds, at least, the resistances could vary as the (Velocity)^2. In 1892, Mr. Wellington, after a study of Dudley's experiments on the New York Central Railway at speeds of 51 miles per hour, Sinclair's experiments on the same road at speeds of 50 to 75

* This series of papers will be issued in book form as soon as they have appeared in THE CANADIAN ENGINEER.