IMAGE EVALUATION
TEST TARGET (MT-3)

Ca

Technical Notes / Notes techniques

The Institute has attempted to obtain the best original copy available for filming. Physical features of this copy which may alter any of the images in the reproduction are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Certains défauts susceptibles de nuire à la qualité de la reproduction sont notés ci-dessous.

- [x] Coloured covers/ Couvertures de couleur
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Tight binding (may cause shadows or distortion along interior margin)/ Reliure serré (peut causer de l'ombre ou de la distortion le long de la marge intérieure)
- [ ] Additional comments/ Commentaires supplémentaires
- [ ] Coloured pages/ Pages de couleur
- [ ] Coloured plates/ Planches en couleur
- [ ] Show through/ Transparence
- [ ] Pages damaged/ Pages endommagées

Bibliographic Notes / Notes bibliographiques

- [ ] Only edition available/ Seule édition disponible
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Plates missing/ Des planches manquent
- [ ] Additional comments/ Commentaires supplémentaires
- [ ] Pagination incorrect/ Erreurs de pagination
- [ ] Pages missing/ Des pages manquent
- [ ] Maps missing/ Des cartes géographiques manquent

The pos of t film

The con or t app

The film inst

Map in o upp bot foll

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

The last recorded frame on each microfiche shall contain the symbol ⟶ (meaning CONTINUED"), or the symbol ∇ (meaning "END"), whichever applies.

The original copy was borrowed from, and filmed with, the kind consent of the following institution:

Library of the Public
Archives of Canada

Maps or plates too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:

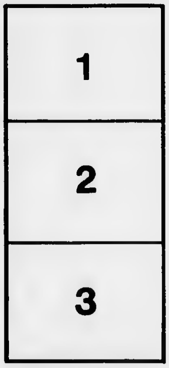
Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

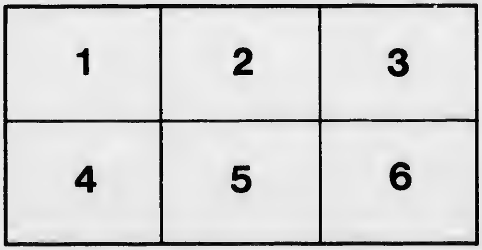
Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole ⟶ signifie "A SUIVRE", le symbole ∇ signifie "FIN".

L'exemplaire filmé fut reproduit grâce à la générosité de l'établissement prêteur suivant :

La bibliothèque des Archives
publiques du Canada

Les cartes ou les planches trop grandes pour être reproduites en un seul cliché sont filmées à partir de l'angle supérieure gauche, de gauche à droite et de haut en bas, en prenant le nombre d'images nécessaire. Le diagramme suivant illustre la méthode :





Sandford Fleming Esq.
C. M. G.
With the Compts of the
Author —

CUNINGHAM

ON

THE ENERGY OF FUEL

IN

LOCOMOTIVE ENGINES.

T

G.

Excer

4989

ON

THE ENERGY OF FUEL

IN

LOCOMOTIVE ENGINES.

BY

GRANVILLE CARLYLE CUNINGHAM, M. Inst. C.E.

By permission of the Council.
Excerpt Minutes of Proceedings of The Institution of Civil Engineers.
Vol. lxxxiii. Session 1885-86. Part i.
Edited by James Forrest, Secretary.

LONDON:
Published by the Institution,
25, GREAT GEORGE STREET, WESTMINSTER. S.W.
[Telegrams, "Institution, London." Telephone, "3051."]
1886.

ADVERTISEMENT.

The Institution as a body is not responsible for the facts and opinions advanced in the following pages.

LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

THE INSTITUTION OF CIVIL ENGINEERS.

Sect. II.—OTHER SELECTED PAPERS.

(Paper No. 1995.)

"On the Energy of Fuel in Locomotive Engines."

By Granville Carlyle Cuningham, M. Inst. C.E.

The object of this Paper and of the accompanying Table, is to show, by data obtained from different railway companies, what is the amount of fuel consumed per unit of work done by locomotive engines; how this consumption varies on different lines of railways; and how the energy of the fuel utilized compares with the full energy, in other words, how much of the energy is used, and how much lost.

The consumption of fuel per unit of work, that is, per ton weight moved 1 mile, is perhaps the most certain and reliable scale by which the capacity of a railway for doing work can be measured, and compared on the same scale with another railway. Any estimate based upon cost is misleading, since the price of labour, fuel, and everything that enters into the working of a railway, varies at different times and in different places. It might thus happen that a line showing a large cost per train-mile, or per car-mile, was more economically and carefully worked, and better able to do the work for which it was constructed, than another showing a smaller cost per car-mile. The comparison plainly depends upon the cost of labour and material in the two localities, and is vitiated by the rise and fall of markets. No true comparison of the respective railways, or even of different periods of the same railway, can be made until such vitiating elements have been eliminated, and a basis arrived at which shall be common to each, and unaffected by any adventitious circumstances. In the consumption of fuel per unit of work there exists such a common basis of comparison, and one which demonstrates the capacity for doing work which the railway possesses. For the consumption of fuel is almost an absolute standard, varying only with the quality of the fuel used, and is not affected by any other uncontrollable circumstance. Thus, if on one line of railway the consumption per ton moved 1 mile is very much greater than on another, it is evident that on the former the gradients and curves, and such elements of resistance, must be more severe than on the latter; and that therefore the latter line is the better able to do its work, and can, other things being equal, do it more cheaply. Of course other circumstances may cause an unusual consumption of fuel, such as severity of climate, inducing large evaporation and loss of heat; or badly-designed engines, resulting in waste of fuel. But even these are matters that can be controlled, because the first may be obviated by having the engine more thoroughly protected from the weather, and the second by improvements in the type of engine. With similar engines acting under not very dissimilar climatic influences, it remains that the consumption of fuel per unit of work may be taken as a certain index to the character of the railway.

In preparing the Table which accompanies this Paper, considerable difficulty has been experienced in arriving at the requisite data. The published annual reports seldom give the information in the direct manner in which it is required; but all the figures made use of have been drawn either from the published reports, or from information obtained directly from the railway officials.

On the Canada Southern Railway, where the consumption of fuel is lower than on any of the other lines, the gradients and curvature are very light. The main line of this railway extends through the southern part of the province of Ontario in Canada, from Fort Erie on the Niagara River, where the International Bridge gives access to the State of New York, and opposite to the city of Buffalo, to Amherstburg on the Detroit river, separating Ontario from the State of Michigan. The Detroit river is crossed by ferry-boats, on which the carriages are taken over to Grosse Isle; from whence they run into Toledo (where connection is made with the Wabash railway system), or into Detroit (where connection is made with the Michigan Central system), over the Toledo, Canada Southern and Detroit Railway. The distance from Fort Erie to Amherstburg is 229 miles, and throughout there is no gradient steeper than 15 feet to the mile (1 in 352), and the alignment is remarkably free from curves. On the western portion of the line, the distance from St. Clair junction to Amherstburg, 107 miles, is made up of two straight lengths of 53 and 54 miles, joined by a light curve. The same gradient is maintained on the Toledo, Canada Southern and Detroit Railway, and on the St. Clair branch of the main line. The only parts of the system on which steep gradients exist are the Erie and Niagara, and Michigan Midland lines; but on these the traffic is extremely small, and they aggregate only 45·28 miles in extent, as compared with 403·64 miles of the entire system. The locomotives used are of the Baldwin type, with two pairs of driving-wheels coupled, and weighing about 60,000 lbs. on the drivers.

The main line of the Michigan Central Railroad, which extends through the southern part of the State of Michigan from Detroit to Chicago, is 284·07 miles in length, but with branches and leased lines, it comprised 949·59 miles in 1881. The gradients on the main line and branches are considerably steeper than those on the Canada Southern, and in places reach 52 feet to the mile (1 in 100). The locomotives used are similar to those on the Canada Southern, and the fuel is also similar, being bituminous coal from Ohio.

The Lake Shore and Michigan Southern Railway extends along the southern shore of Lake Erie from Buffalo to Chicago, with branches to Detroit and other places. The total mileage of the system in 1880, including leased lines, was 1,177·67, and of this the length of main lines is 504·49 miles. The gradients of the main line are considerably easier than those of the Michigan Central, and nearly as good as those of the Canada Southern Railway. The engines and fuel are similar to those on the lines before-mentioned.

The Hannibal and St. Joseph Railroad is in the State of Missouri. Its mileage in 1880 was 292·35. From the length of trains hauled, the gradients would seem to be steep.

In preparing the Table in the Appendix, information has not always been obtainable from the printed reports in the exact form required. In these cases the method adopted for supplying the particulars has been as follows. The total amount of coal and wood (the latter turned into its equivalent in coal) consumed is noted. When the amount to be apportioned of the freight and passenger services respectively is not stated in the printed report, the total amount is divided into two portions in the ratio of the respective engines, mileages, and also in the ratio of 26 to 34, being that in which the consumption of a passenger-engine, as determined by careful observation, stands to the consumption of a freight-engine. This, in the first instance, gives the total amount of coal consumed in each service, including switching or shunting. In order to arrive at the amount consumed in moving freight-trains on the line, the total amount of engine-mileage made in switching or shunting is noted, and this is divided into two portions, in the proportion in which the passenger-train mileage stands to the freight-train mileage, and the switching is thus allotted to the respective services. The coal consumed in the service is then calculated by allowing 70 miles per ton, and the quantity thus obtained is deducted from the total quantity apportioned to the freight service. This estimate of 70 miles switching per ton of coal consumed is taken from the observations of the Lake Shore and Michigan Southern Railway, extending over a number of years. It will be seen, therefore, that the results obtained are only close approximations to the absolutely true figures of this subject; but still they are sufficiently close to be valuable as comparisons.

The Table shows that the coal consumed in passenger traffic is less on the Lake Shore line than on any of the others, being 12·8 lbs. per passenger-carriage mile. Taking the average weight of the cars composing the passenger train at 16 tons, this would give a consumption of 0·8 lb. per ton hauled 1 mile; at the same time it is interesting to note that there is a consumption of 1·16 lb. per passenger moved 1 mile. The very large consumption of fuel per ton moved 1 mile in the passenger service, as compared with the freight-service, is undoubtedly due to the much higher rate of speed of the former, as compared with the latter. Confirmation of this is found on considering the figures applicable to the Hannibal and St. Joseph line. There the consumption per ton-mile in the passenger-service is less than that of either the Canada Southern or Michigan Central, and only very little greater than that of the Lake Shore line; whereas the consumption per ton-mile in the freight service of the Hannibal and St. Joseph line is very much greater than any of the others, being more than double that of both the Canada Southern or Lake Shore lines. This apparent anomaly is explained by the fact that the speed of the passenger trains on the Hannibal and St. Joseph line is much less than that on any of the others under consideration.

The consumption of fuel in freight-service on the Canada Southern and Lake Shore lines is nearly the same, with a small fraction in favour of the former, while on both lines it is less than on the Michigan Central, or Hannibal and St. Joseph. The amount of fuel consumed in moving 1 ton gross weight (including the fuel consumed in shunting) is barely $2\frac{3}{4}$ ozs.—a quantity which is surprisingly small. This is on the two first-mentioned lines; while on the Michigan Central and Hannibal and St. Joseph lines it amounts to 4 ozs. and 6·4 ozs. respectively.

In the latter part of the Table the amount of coal consumed in the switching or shunting work of the freight service has been deducted, and that consumed in the work of moving freight-trains on the line of railway only dealt with, with a view of arriving at the quantity consumed in moving 1 ton weight 1 mile. The result arrived at is as follows:—Canada Southern, 2·30 ozs.; Lake Shore, 2·38 ozs.; Michigan Central, 3·52 ozs.; and Hannibal and St. Joseph, 5·76 ozs.

Though it will surprise most people who have not paid particular attention to these questions, to learn that there is sufficient energy in a piece of coal weighing only 2·3 ozs. to move 1 ton weight 1 mile; yet the investigations would not be complete if it were not ascertained what is the total energy of the fuel; what portion of it is used, and what lost.

The units of heat (Fahrenheit) developed in the combustion of 1 lb. of coal are 14133,[1] and as the mechanical equivalent is 772 foot-pounds per unit, the combustion of 1 lb. of coal is equal to 10,910,676 foot-pounds, or 5455·3 foot-tons (American).

On the Canada Southern Railway, the average of the whole line is equal to a gradient of 5 feet to the mile; this will make the resistance to haulage equal to 11 lbs. per ton, taking the resistance on the level at 9 lbs. per ton; therefore as much energy will be expended in hauling 1 ton 1 mile, as in lifting 11 lbs. 1 mile vertically. In other words, hauling 1 ton 1 mile requires an expenditure of energy equivalent to $5,280 \times 11 = 58,080$ foot-pounds, or 29·04 foot-tons.

But on the Canada Southern Railway, 1 ton is hauled 1 mile by the combustion of 0·15 lb. of coal, which quantity of coal therefore does work equivalent to raising 29·04 tons 1 foot. At the same rate 1 lb. of coal would raise 193·6 tons 1 foot vertically. But as shown above, the full energy of 1 lb. of coal is 5,455·3 foot-tons; therefore the full energy is to the work effected on the Canada Southern Railway as 100 is to 3·5, and consequently there is a loss of 96·5 per cent. of the energy of the fuel. Though the quantity, 2·3 ozs. of coal, seems extremely small to do the work of hauling 1 ton 1 mile, yet, if all the energy contained in the coal could be utilized and applied to doing work, it would haul 1 ton 28½ miles; while the quantity, 1·86 lb., consumed in moving a passenger 1 mile would, if fully utilized and applied to the transportation of freight, convey 1 ton 353 miles. Few passengers are aware of how much energy is required to make "fast time."

The speed of passenger trains on the Canada Southern Railway was from 35 to 40 miles per hour; on the Michigan Central and

[1] "A Manual of Rules, Tables, and Data, &c.," by D. K. Clark, M. Inst. C.E., p. 405.

APPENDIX.—TABLE SHOWING CONSUMPTION OF FUEL ON VARIOUS RAILWAYS.

—	Canada Southern.	Michigan Central.		Hannibal and St. Joseph.		Lake Shore and Michigan Southern.
	1881.	1879.	1880.	1879.	1880.	1880.
Total engine mileage (including shunting)	3,749,701	7,697,051	7,690,051	..	1,995,739	13,586,207
Passenger train-mileage	987,237	1,693,098	1,865,258	414,118	410,368	2,549,081
" car "	4,196,466	8,499,352	10,333,529	2,190,243	2,239,970	16,060,832
Average number of cars per passenger train	4·25	5·02	5·54	5·28	5·45	6·30
Number of passengers moved 1 mile	40,917,987	93,232,430	115,523,789	21,545,368	19,925,041	176,148,767
Average " per car	9·75	10·96	11·18	9·83	8·89	10·96
Freight train-mileage	1,775,237	3,687,305	3,658,605	938,095	975,903	7,481,489
" car- "	56,915,859	88,384,701	88,491,897	15,715,882	16,864,202	283,588,545
Average number of cars per freight train	32·06	23·97	24·16	16·75	17·28	37·90
Number of tons of freight moved 1 mile	487,965,507	721,019,413	735,611,995	111,987,174	120,665,740	1,851,166,018
Average load per freight car . . . tons	8·57	8·166	8·31	7·13	7·15	6·52
Total amount of coal consumed . . tons	127,270·5	280,160	303,971	69,990	76,898	502,320
Tons of coal apportioned to passenger service	38,072	75,250	84,078	15,190[1]	17,491[1]	102,837
Pounds of coal consumed per passenger train-mile	77·12	88·88	90·15	73·11	85·24	80·68
Pounds of coal consumed per passenger car-mile	18·14	17·70	16·27	13·84	15·63	12·80
Pounds of coal consumed per ton moved 1 mile	1·13	1·10	1·01	0·86	0·98	0·80
" " " per passenger moved 1 mile	1·86	1·61	1·45	1·31	1·75	1·16
Tons of coal apportioned to freight service	89,198	204,910	219,893	54,800[1]	59,407[1]	399,483

Selected

Pounds of coal consumed per ton moved 1 mile	1·13	1·10	1·01	[illegible]	[illegible]	[illegible]
,, ,, ,, per passenger moved 1 mile	1·86	1·61	1·45	1·31	1·75	1·16
Tons of coal apportioned to freight service	89,198	204,910	219,893	54,800[1]	59,407[1]	399,483

Pounds of coal consumed per freight train-mile	100·49	111·17	120·20	116·83	121·77	106·78
Pounds of coal consumed per freight car-mile	3·13	4·64	4·97	6·97	7·04	2·81
Pounds of coal consumed per ton of freight moved 1 mile	0·367	0·57	0·60	0·98	0·99	0·43
Pounds of coal consumed per ton of gross weight[2]	0·168	0·25	0·27	0·40	0·41	0·17
Average miles run by engines per ton of coal	29·46	27·47	25·30	..	25·95	27·04
Total expenses (exclude renewals and taxes) $	2,550,223·11	..	..	1,223,421·97	1,304,590·08	..
Passenger ,, (exclusive ,, ,,) $	584,148·13	..	..	414,150·20	439,295·75	..
,, ,, per train-mile . $	0·59·17	..	..	1·01	1·07	0·92·29
,, ,, per car-mile . cents	13·92	..	..	18·9	19·6	14·65
Freight ,, . $	1,966,074·98	..	..	809,271·77	865,294·33	..
,, ,, per train-mile . $	1·1075	..	..	0·863	0·887	1·0767
,, ,, per car-mile . cents	3·45	..	..	5·15	5·13	2·84
Average ,, of tons of freight moved 1 mile . cents	0·40	..	..	0·72	0·72	0·43
Coal consumed in freight shunting alone, tons	9,025	22,698	20,945	..	6,122	35,282
,, ,, by freight-trains alone . tons	80,173	182,212	198,948	..	53,285	364,2[illegible]1
,, ,, per freight train-mile . lbs.	90·32	98·8	108·7	..	109·23	97·36
,, ,, per freight car-mile . lbs.	2·81	4·12	4·5	..	6·32	2·57
,, ,, per ton of freight moved 1 mile . lbs.	0·32	0·50	0·54	..	0·88	0·39
Coal consumed per gross ton moved 1 mile . lbs.	0·15	0·23	0·24	..	0·37	0·155

[1] These quantities are found from the value of fuel apportioned to the passenger and freight traffic in the Annual Report.
[2] The weight of the cars is assumed at 10 tons each.

Lake Shore lines from 33 to 36 miles per hour; and on the Hannibal and St. Joseph line about 25 miles per hour. The speed of freight trains on all the lines was between 15 and 20 miles per hour.

The position of acting Chief Engineer, which the Author until recently occupied on the Canada Southern Railway, enabled him to obtain the information in regard to gradients required to make the foregoing investigations; but the like information has not been obtainable for the other railways under consideration, and therefore it is not possible to say whether they waste more or less of the energy of the fuel consumed. A comparison on a similar basis with English railways would be interesting and valuable, but the necessary data do not seem to be available. These figures clearly indicate how much yet remains to be done in economizing the energy developed in the combustion of coal. An engine which wastes 96½ per cent. of the energy with which it is supplied cannot be called perfect.

The Table also shows the cost of the service performed, worked out in a similar manner as the consumption of fuel.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.