SERVICE TESTS ON COLUMBUS CITY CARS OPERATED SINGLY AND IN TWO-CAR TRAINS WITH MULTIPLE UNIT CONTROL

A little over a year ago the Columbus (Ohio) Railway & Light Company started a two-car train service to reduce the congestion on its High Street line. Instead of attaching a trailer to a motor car, or coupling two straight motor cars, the company resorted to the then novel expedient of placing two motors on each car, but using type M multiple-unit control on the leading car, and a K-10 controller on the rear car. This was done to save the cost of an additional multiple-unit equipment, as it was found that regular train control could be obtained by tapping the usual leads for motors Nos. 3 and 4 into a common bus line, connected to the second equipment and making a few other changes. A full description of the company's practice with the corresponding wiring diagram was published in the STREET RAILWAY JOURNAL of June 30, 1906, and brief reference made to it also in the Oct. 13, 1906, issue.

This practice of the Columbus company led to the interesting comparative service tests of train and single-car operation by the Ohio State University's Department of Electrical Engineering, of which a summary is presented in this article. The tests were made for thesis purposes under the direction of Prof. F. C. Caldwell, by F. F. Sheldrick, H. D. Cranston, E. S. Zuck and C. P. Galleher.

The experiments were carried out on the High Street line, which is about 6.6 miles long. The leading car used both in the single car and train tests is specified by the following: weight of body, 20,185 lbs.; trucks, 6175 lbs.; motors and gearing, 4920 lbs.; air and electric equipment, 3176 lbs.; total weight, 34,366 lbs.; seating capacity, 40; length over the vestibules, 40 ft. 8 5/16 ins.; length over the body, 28 ft. 8 5/16 ins.; width over the posts, 7 ft. 11¼ ins.; height, 9 ft.; wheel diameter, 33 ins.; Brill maximum traction trucks; two GE-67 motors, 40 hp each and geared 67:17. The trail car was similar to the leading car except that its platforms were each 1 ft. shorter. Both cars were in ordinary operating condition and picked at random.

On the type M car, power is consumed in the motor, control and air compressor circuits; on the K-10 car, power is consumed only in the motor and air circuits. The general scheme of the test was to place the proper power-recording instruments in these circuits in addition to several special instruments for recording speed, etc.

After preliminary runs on April 4, 1907, the two-car train was tested on April 5, and the single car on April 6. The test car left the North High Street car house at 6:10 a. m. and made its regular schedule on the High Street line until about 11 a. m., when three round trips were completed. Some extra trips were made, however, to secure additional data.

The following tables Nos. 1, 2, 3, 4, 5 and 6, summarize the calculated results of all tests.

The data for the individual runs differ somewhat, but the discrepancies are very small when the varying conditions of load, track, etc., are considered. The fact, however, that both the train and single car were operated over the same route and on the same general schedule facilitates comparison.

In comparing the results, several interesting conclusions are obtained.

1. The kw-hours per car-mile (motor circuit only) were 2.20 on Friday, April 5, and 2.01 on Saturday, April 6 (Tables 4 and 5); the respective watt-hours per ton-mile (motor circuit) were 122.6 and 103.4. The results show that 52 watt-hours per car-mile were consumed on Friday, and 50.6 on Saturday. In this connection it should be noted

TABLE No. 1.—CALCULATED RESULTS OF TESTS.
TWO-CAR TRAIN, FRIDAY, APRIL 5, 1907.

NUMBER OF RUN	(1)	(2)	(3)	(4)	(5)	(6)
1. Average amperes	147	158	136	158	151	143
2. Average volts	509	508	513	521	524	528
3. Average watts	75000	80300	69800	82200	79400	75400
4. Length of time power is on (seconds)	1366	1402	1351	1317	1343	1313
5. Total watt hours	28450	31300	26250	30050	29670	27500
6. Length of run (miles)	6.63	6.63	6.25	6.63	6.63	6.63
7. Kw-hours per car mile	2.14	2.36	2.10	2.27	2.24	2.07
8. Total number passengers	102	101	63	90	85	84
9. Average number on car	35.2	40.8	25.2	29.3	29.1	23.8
10. Weight of car and live load (tons)	36.15	36.50	35.50	35.75	35.72	35.41
11. Watt hours per ton mile	118.6	129.5	118.4	126.8	125.2	117.2
12. Total number of stops	55	56	48	54	57	54
13. Stops per mile	8.3	8.4	7.2	8.2	8.6	8.2
14. Total time of stops (seconds)	248	215	185	230	252	220
15. Average time of stop	4.5	3.8	3.8	4.3	4.4	4.1
16. Average speed (m. p. h.)	11.10	10.90	11.04	10.70	11.11	10.36
17. Schedule speed (m. p. h.)	9.95	9.94	10.03	9.71	9.95	9.60
18. Kw-hours per car mile	2 21	2.43	2.16	2.33	2 30	2.14
19. Watt hours per ton mile	122.2	133.1	121.9	130.4	129.0	120.8
20. Watt hours per passenger (total)	287	319	429	343	359	338

NOTE.—"Kw-hours per car mile" and "Watt-hours per ton mile" (items No. 5, No. 7 and No. 11) do not include the energy used in the air nor control circuit. Items No. 18, No. 19 and No. 20 take these quantities into consideration.

TABLE No. 2.—RESULTS FROM RECORDING WATTMETERS

NUMBER OF RUN	(1)	(2)	(3)	(4)	(5)	(6)
1. Total watt hours	29900	31900	24900	25900	28900	29900
2. Watt hours (air circuit)	550	560	440	520	600	490
3. Watt hours (control circuit)	340	380	340	330	300	360
4. Watt hours (motor circuit)	29000	30960	24100	25050	28000	29050
5. Kw-hours per car mile	2.19	2.33	1.82	1.89	2.11	2.19
6. Watt hours per ton mile	121.0	128.0	108.6	105.8	118.2	123.8

TABLE No. 3.—CALCULATED RESULTS OF TESTS.
SINGLE CAR, SATURDAY, APRIL 6, 1907.

NUMBER OF RUN	(1)	(2)	(3)	(4)	(5)	(6)
1. Average amperes	67	70	81	69	67	71
2. Average volts	507	504	519	527	538	531
3. Average watts	34000	35300	41800	36400	36100	37700
4. Length of time power is on (seconds)	1343	1353	1386	1265	1271	1176
5. Total watt hours	12690	13300	16090	12800	12740	12300
6. Length of run (miles)	6.63	6.63	6.63	6.63	6.63	6.63
7. Kw-hours per car mile	1.91	2.00	2.43	1.93	1.92	1.86
8. Total number passengers	76	88	98	82	74	55
9. Average number on car	33.2	35.6	36.8	27.7	34.0	24.0
10. Weight of car and live load (tons)	19.52	19.67	19.73	19.15	19.56	18.91
11. Watt hours per ton mile	98.0	101.8	123.0	100.8	98.3	98.4
12. Total number of stops	47	51	58	45	46	40
13. Stops per mile	7 1	7.7	8.8	6.8	6.9	6.0
14. Total time of stops (seconds)	173	222	247	299	200	193
15. Average time of stop	3.7	4.4	3.3	6.6	4.4	4.8
16. Average speed (m. p. h.)	10.91	10.48	10.18	11.35	10.84	11.44
17. Schedule speed (m. p. h.)	10.11	9.60	9.32	9.95	9.95	10.48
18. Kw-hours per car mile	2.03	2.10	2.54	2.03	2.01	1.94
19. Watt hours per ton mile	104 0	106.9	128.6	105.9	103.0	102.8
20. Watt hours per passenger (total)	177	158	172	164	180	234

NOTE.—"Kw-hours per car mile" and "Watt hours per ton mile" (items No. 5, No. 7 and No. 11) do not include the energy used in the air and control circuits. Items No. 18, No. 19 and No. 20 take these quantities into consideration.

TABLE No. 4.—RESULTS FROM RECORDING WATTMETERS.

NUMBER OF RUN	(1)	(2)	(3)	(4)	(5)	(6)
1. Total watt hours	20900	18900	19900	15900	11900	12900
2. Watt hours (air circuit)	330	310	400	290	300	290
3. Watt hours (control circuit)	420	310	340	340	310	290
4. Watt hours (motor circuit)	20150	18280	19160	15290	11330	12360
5. Kw-hours per car mile	3.05	2.76	2.89	2.31	1.71	1.86
6. Watt hours per ton mile	156.5	140.3	146.5	120.4	87.3	98.6

TABLE No. 5.—AVERAGE LOG SHEET FOR FRIDAY, APRIL 5, 1907.
TWO-CAR TRAIN.

Condition of track	Dry and clean.
Route	Entire length of High Street.
Length of single run	6.63 miles.
Number of runs	6.
Time of runs	From 6:10 a. m. to 10:39 a. m.
Passengers carried	Total per trip, 88; average number on the train, 30.6.
Stops per mile	Average per trip, 8.1.
Voltage measurements	Average per trip, 517 volts.
Current measurements	Average per trip, 149 amperes.
Power measurements	Average per trip, 77000 watts.
Time measurements	Time power is on; average per trip, 1349 seconds.
Energy measurements	Average per trip, 28900 watt hours; kw-hours per car mile, 2.20; watt hours per ton mile, 122.6.
Control circuit	Watt hours per car mile; average per trip, 52.0.
Air circuit	Watt hours per mile; average per trip, 80.5. Watt hours per car mile; average per trip, 40.3.
Total energy per trip	Including motor, air and control circuits, 2.29 kw-hours per car mile.
Total energy per trip	Including motor, air and control circuits, 345 watt hours per passenger.
Total energy per trip	Including motor, air, control and heater circuits, 3.04 kw-hours per car mile.

that the average stops per mile were 8.1 on Friday, and 7.4 on Saturday.

2. The energy charged against the heater is based on the measured resistance of the heater circuits and on the assumption that if continuously operated they would have used .75 and .73 kw-hours per car-mile respectively, for Friday and Saturday.

3. The total energy per trip, including the motor, air control and heater circuits, was 3.04 kw-hours on Friday, and 2.84 kw-hours on Saturday. The watt-hours per ton-mile on Friday were 146, and on Saturday 169.8; watt-hours per passenger were 345 on Friday, and 177 on Saturday.

TABLE No. 6.—AVERAGE LOG SHEET FOR SATURDAY, APRIL 6, 1907.
SINGLE CAR.

Condition of track	Dry and clean.
Route	Entire length of High Street.
Length of single run	6.63 miles.
Number of runs	6.
Time of runs	From 6:10 a.m. to 10:36 a.m.
Passengers carried	Total per trip, 79; average number on the car, 31.9.
Stops per mile	Average per trip, 7.4.
Voltage measurements	Average per trip, 521 volts.
Current measurements	Average per trip, 70.8 amperes.
Power measurements	Average per trip, 36900 watts.
Time measurements	Time power is on; average per trip, 1299 seconds.
Energy measurements	Average per trip, 13300 watt hours; kw-hours per car mile, 2.01; watt hours per ton mile, 103.4.
Control circuit	Watt hours per car mile; average per trip, 50.6.
Air circuit	Watt hours per car mile; average per trip, 48.2.
Total energy per trip	Including motor, air and control circuits, 2.11 kw-hours per car mile.
Total energy per trip	Including motor, air and control circuits, 177 watt hours per passenger.
Total energy per trip	Including motor, air, control and heater circuits, 2.84 kw-hours per car mile.

It is seen from the foregoing that the two-car train is the more economical on the ton basis, but from the standpoint of energy per car-mile and passenger, the single car shows a decided advantage, and especially in regard to the watt-hours per passenger. The traffic conditions, however, were such that the two-car train was not worked at the same relative load, the number of passengers being about the same for both days. If there had been the same number of passengers on each car in the two-car train as there were in the single car on Saturday, the results would have been quite different; instead of the watt-hours being 345, they would have been nearly halved. The watt-hours per ton-mile would also have been still lower on Friday than on Saturday, and the two-car train would then show up better than it does. This leads to the conclusion that the trains should be operated only when traffic is dense enough to fill both cars. Only the power consumption has been considered in this connection and no account is taken of any differences in other operating expenses such as labor and maintenance.

It will be noticed from tables Nos. 2 and 3 that the data from the recording wattmeters do not check with those from the voltmeter and ammeter measurements; neither are they consistent. For these reasons their indications were not regarded as reliable. As the wattmeters were carefully calibrated before and after the test, the discrepancies are attributed to the conditions of the test, since recording wattmeters are constructed with jewel bearings and should be mounted free from vibration. Evidently the frame of a moving car does not fulfil this requirement.

TEST OF THE CONTROL SYSTEM

The control system was tested to determine definitely how much power it required. A wattmeter was placed in the control circuit, the resistance of the contactors measured and the current consumption determined for each step. This test was comparatively short and simple, but proved the statement of the control manufacturer that the current taken by the master controller is about 2.5 amps. for an equipment of 400 hp or less. The power measurements are found in tables Nos. 2 and 4 and show that the power taken by the control apparatus is very small.

TEST OF THE AIR-BRAKING EQUIPMENT

The air-brake trial was also a service test and was taken principally to learn over what distance a car passed from the brake application until standstill; to compare the performance of a single car with a two-car train; and to determine the power used in braking.

The brake equipment was made by the General Electric Company. The cylinders were 8 ins. in diameter and the compressor motor took 4 amps. at 500 volts. The ratio of the brake levers was 8½ ins to 10½ ins., the 10½-in. end being connected to the rod from the brake cylinder. On the two-car train all the air was supplied from the reservoir of the leading car and the trail car reservoir was cut out to be used only in emergencies.

The results of the tests, which were made with the usual stop-watch, speed indicator, etc., were averaged and then plotted as curves in the following manner. In averaging, the results for each run were recapitulated by placing in one column all the time readings which lay between values differing by unity, as, for instance, all readings between 10 and 11 seconds; the corresponding readings of distance,

TABLE No. 7.—POWER CONSUMPTION OF BRAKES.

Number of Run.	Number of Stops.	Watt Hours.	Watt Hours per Stop.	Weight in Tons.	Watt Hours per Ton.	Watt Hours per Ton per Stop.
Car No. 524. April 6, 1907. Condition of Track, Good.						
1	47	330	7.02	19.52	16.90	.360
2	51	310	6.07	19.67	15.75	.309
3	88	400	6.90	19.73	20.25	.349
4	45	290	6.45	19.15	15.15	.337
5	46	300	6.52	19.56	15.33	.333
6	40	290	7.25	18.91	15.32	.383
Cars Nos. 524 and 452. April 5, 1907. Condition of Track, Good.						
1	55	550	10.00	36.15	15.20	.276
2	56	560	10.00	36.50	15.32	.274
3	48	440	9.17	35.50	12.39	.258
4	54	520	9.63	35.75	14.55	.270
5	57	600	10.51	35.72	16.80	.295
6	54	490	9.07	35.41	13.81	.256
					Average...	.272
Car No. 524. April 4, 1907. Condition of Track, Wet.						
4	48	300	6.25	18.08	16.60	.346
5	46	310	6.74	18.97	16.35	.356
6	48	300	6.25	17.86	16.80	.350
					Average...	.351

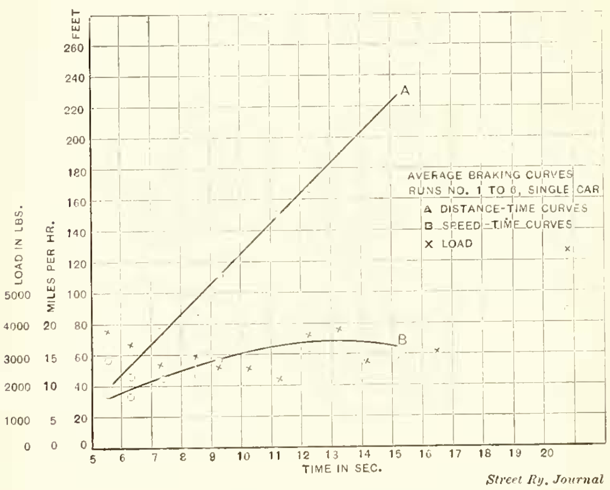
speed and load were arranged in three other columns and all were then averaged, securing an average time with the corresponding average speed, distance and load. Then curves for each run were plotted with these values between time and distance as well as time and initial speed. The average load also was indicated on the same sheet.

To enable comparison of single cars with two-car trains, average curves were plotted by averaging all the runs with the single car and with the train. These averages of averages then were plotted in the same way as the others.

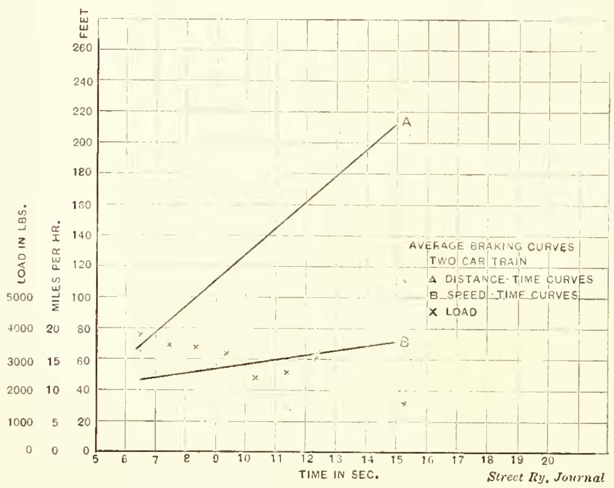
The following results were obtained from the power readings of the recording wattmeter in the air-brake circuit: Total watt-hours, watt-hours per stop, watt-hours per ton and watt-hours per ton per stop. It was also possible to compare the work of the single car on both wet and dry track. To obtain the watt-hours per stop, the total watt-hours were divided by the total number of stops in the particular run.

So far as the performance of the two-car train is concerned, the curves show that it gives more uniform braking, namely, the distances covered in different stops do not vary over as wide a range as the single car. Neither does the time of braking vary as much in the case of the train. The average curves show little difference in the performance of the two cases. On the average, it takes about the same time to stop a two-car train as a single car, and the distance also is about the same for similar speeds.

The greater uniformity of the results with the two-car train can be explained as follows: All the air used in braking the two-car train was stored and drawn from the reservoir on the leading car only, but the air was received by the brake cylinders on both cars. Hence, it is evident that the motorman has no more energy available for braking with two cars than with the single car, but he has approximately twice as much kinetic energy to destroy. In other words, the ratio of energy available for braking to the energy destroyed is much smaller for the two-car train than for the single car, and therefore the range over which the motorman can vary the braking characteristics of the two-car train is limited.



BRAKING CURVES FOR SINGLE CAR



BRAKING CURVES FOR TWO-CAR TRAIN

The value of the braking curves lies in their showing the average performance of the equipment tested when in normal service. No emergency trials were made.

It appears that the load does not affect the results noticeably nor do the low grades of the track seem to have any bearing on them.

In general, the condition of the track was good throughout the test, excepting three runs over wet track on Thursday, April 4. Readings were taken for these runs to obtain comparative data for the two conditions. Only the power reading data of these runs were worked up and they show little difference in the power consumption per ton per stop, which was .351 watt-hours, as against .345 watt-hours for dry track.

In the case of the two-car train versus the single car, the results show a marked difference in the watt-hours per ton per stop, averaging .272 for the train and .345 for the single car. In the energy required for braking, the two-car train is more economical by about 27 per cent.

THE CLEVELAND SITUATION

For the past week attorneys and accountants for Charles S. Thrasher have been going through the books and records of the Forest City Railway Company in an attempt to discover the source of the cash resources upon which it has existed. Attorney Harrison B. McGraw and a stenographer undertook the work, but later on the Audit Company of Cleveland was employed to do the work. This investigation is being made by Mr. Thrasher as a stockholder.

Attorney McGraw stated that, while Secretary Fred C. Alber of the company owned only 147 shares of stock in the beginning, he had later voted 633½ shares. He said there was evidence that Mr. Alber had in his possession $1,900,000 stock at one time, and that there still remains about $1,000,000 in his name. There is nothing to show that anything was paid for what he still holds. The $900,000, Mr. Alber is said to have stated, was sold for cash, and the proceeds used to build and equip the road. The $1,000,000 remaining, Mr. Alber stated, could be sold and the proceeds used for the same purpose.

Another block of $200,000 stock was found to stand in the name of Max J. Rudolph, who is associated with Attorney Westenhaver, an attorney for the low fare companies. Albert E. Greene, who first obtained the franchises for the Forest City Railway Company, is supposed to have received this stock for his services and to have turned it over to Mr. Rudolph. The point here is that the amount paid for such services is excessive, even if Mr. Rudolph shared attorney's services with Mr. Greene.

As the property of the Forest City Railway Company is leased to the Municipal Traction Company, Mr. Thrasher, as a stockholder in the former, made a demand to be allowed to investigate the books of the leasing company also, but Secretary W. B. Colver refused on the ground that Mr. Thrasher is not a bona fide stockholder of the Forest City, but acquired stock for the purpose of making such a demand and investigation. He said any stockholder or citizen would have the right to make an examination of the company, but that Mr. Thrasher and his attorneys are disqualified. Thereupon Charles A. Otis, owner of the "Cleveland News," and well known as a broker and business man, accepted the offer, as a citizen, and employed expert accountants to go over the books.

City Clerk Peter Witt, and Ernest Bitterlich, an accountant, have been engaged for some days in going over the books and records of the Cleveland Electric Railway Company. Mr. Witt, who owns one share of stock in the company, says he will give out nothing until he is through with the work.