AASHO Road Test Vehicle Operating Costs Related to Gross Weight*

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In the variations of gasoline consumption due to increases in gross vehicle weight, the AASHO trend line was parallel to but slightly lower than the trend line recently reported for the operation of commercial vehicles. Diesel fuel consumption on the Road Test for 70,000-lb vehicles closely approximated the commercial consumption rate previously reported for this gross weight. Diesel fuel consumption rates for gross weights higher than the prescribed maximum for the Interstate Highway System were 0.245 gal per mi (4.1 mpg) at 90,000 lb and 0.290 gal per mi (3.4 mpg) at 110,000-lb loaded gross weights.

Oil added to Road Test vehicles exclusive of regular oil changes tended to increase as the gross weights of vehicles increased.

Tire costs on the Road Test for 22,400-lb axles were found to be 40 percent higher than for tire costs of 18,000-lb axles. Tire costs for 30,000-lb single and 48,000-lb tandem axles were found to be more than twice the tire costs for 18,000-lb axles.

A special study of tire air-pressure buildup indicated that AASHO vehicle tire pressures increased from 8 to 11 psi within 1½ hours from first start of operation. This buildup decreased the area of the tire contacting the pavement thereby increasing the unit pressures to the pavement.

• The AASHO Road Test was a controlled experiment with respect to load applications to the road, the collection of vehicle performance and operating cost data being incidental to the main purpose of the Test. There is no implication that the performance data collected during this Test represent data which might be expected from commercial over-the-road operations. The fuel, maintenance, tire, and component-replacement data, by weight of vehicle, resulting from the operation of motor freight vehicles on the AASHO Road Test are of interest because ratios may be derived which can be used for comparison with similar data obtained from operation of commercial vehicles on public highways. Some of the test vehicles were loaded to heavier gross weights than are now permitted in most States. Vehicular operating data from operation of these heavier vehicles will give an insight into relative costs of operating heavier vehicles than are now being run over public highways.

Relationships developed from four categories of motor-vehicle operating costs may prove to be of greater value than actual vehicular operating results obtained at the Road Test. The vehicles used in this Road Test were similar, except for gear ratios, to those that are used in normal highway operation. However, certain operational differences between these two types of travel existed as follows:

1. Test vehicles were run at 35 mph on tangents and 25 mph on turnarounds, whereas freight vehicles on the open highway are usually operated at variable speeds and, when permitted, at higher rates of speed than the constant speed prescribed for the Road Test.
2. The test terrain average rate of rise and fall was 0.22 ft per 100 ft, which is very low as compared to the mixture of level, rolling and mountainous terrain on public highways. (All major loops had a 0.20-ft rate of rise and fall per 100 ft on tangents except for Loop 3 where it was 0.30.)
3. Test vehicles were fully loaded at all times, whereas highway freight vehicles carry loads on public highways, on the average, about 67 percent of the time (*1*).
4. The scrubbing action to tires at the test loop turnarounds is considered of greater frequency and intensity than experienced on curves in public highways.
5. Stops and starts in test operation were fewer than those encountered in normal city operation and combined city and rural highway operation.
6. Differential ratios were selected and gears installed in test vehicles to give optimum fuel economy for the speeds prescribed for the Road Test.

* Approved by the Advisory Panel for Economic Data, AASHO Road Test, G. P. St. Clair, Chairman.

7. All diesel engine vehicles and some of the gasoline engine vehicles were left running in cold weather during the short rest periods.

8. Test drivers were Army Transportation Corps personnel who were first trained on Army vehicles at Ft. Eustis, Va., and re-trained on the test to drive the various-sized commercial vehicles.

9. The test vehicles often were operated over pavements that were rougher than those ordinarily encountered in line-haul commercial service. This was to be expected as test traffic was continued over all sections until some of the sections of pavement failed.

In addition to operational differences between the two types of travel, two other factors may have contributed to the vehicle operation test results.

1. It was the view of the AASHO Road Test staff that tractors operated in several lanes were not of sufficient horsepower to provide adequate performance.

2. In Loop 6 the largest vehicle components (springs, frames, etc.) in commercial use were employed. In the view of the staff, these proved to be of inadequate design to support the loads placed upon them.

DEFINITION OF TERMS

Certain terms used in this paper must be thoroughly understood in order to have a clear conception of the results.

Vehicle type code.—The three types of vehicles used on the Road Test are coded "2", "2-S1," and "3-S2" and shown in silhouette in Figure 1. Each digit indicates the number of axles of a power unit or trailer. A single digit indicates the number of axles of a single-unit truck. The S designation represents a semitrailer.

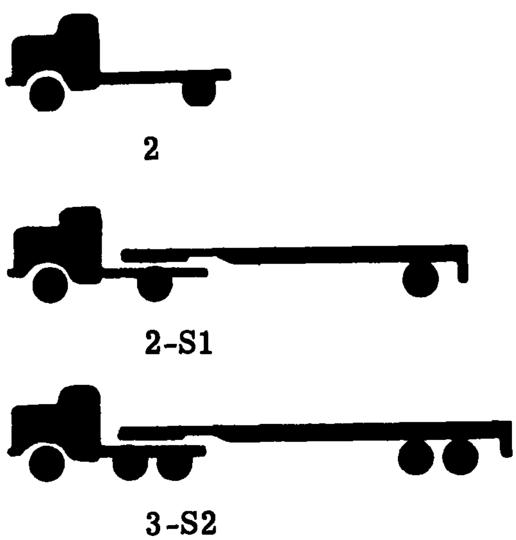


Figure 1. AASHO Road Test vehicles.

Engine cubic-inch displacement.—The cross-sectional area of a cylinder multiplied by the length of piston stroke (which gives the piston displacement) multiplied by the number of cylinders.

Net brake horsepower.—The brake horsepower of the engine, operating with all its normal accessories, that is available at the clutch or its equivalent. It is the maximum brake horsepower minus the horsepower absorbed by fan, compressor, generator, etc. For practical purposes net brake horsepower is assumed to be 90 percent of the maximum brake horsepower.

Rate of rise and fall.—The total rise and fall for any section of highway in feet divided by the length of section in hundreds of feet. (It is not to be confused with the percent of grade. It is equivalent to the average percent of grade only when an entire section of road has a continuous rise or a continuous fall.)

Ambient air temperature.—Fahrenheit temperature of the air at vehicle site at a distance above the pavement approximately equivalent to the diameter of the tire.

Cold-tire air pressure.—Tire pressure at AASHO Road Test when tire had been stationary for at least 5 hours.

Hot-tire air pressure.—Tire pressure at AASHO Road Test after tire had been in operation at least 1½ hours.

SUMMARY FINDINGS

1. Gasoline consumption rates for 4-tire and 6-tire single-unit trucks were 0.070 (14.3 mpg) and 0.083 (12.0 mpg) gal per mi, respectively.

2. Gasoline consumption rates for semitrailer combinations were less for equivalent loaded gross weights than consumption rates reported in a previous study of commercial operation (*2*) but followed the same general slope of curve as reported for commercial operation.

3. Gasoline consumption per gross and payload ton-mile decreased quite rapidly as the loaded gross weight of vehicles increased from 4,200 to 54,800 lb.

4. Diesel fuel consumption rates for higher loaded gross weights than the prescribed maximum for the Interstate Highway System were approximately 0.245 gal per mi (4.1 mpg) at 90,000 lb and 0.29 gal per mi (3.4 mpg) at 110,000 lb loaded gross weights.

5. Diesel fuel consumption per gross and payload ton-mile decreased only slightly as the loaded gross weight of vehicles increased from 70,100 to 108,600 lb.

6. Oil-added rates per vehicle-mile tended to increase as loaded gross weights increased for both gasoline- and diesel-powered vehicles. The oil-added rates per gross ton-mile, however, decreased as loaded gross weights increased

throughout the range of the different sizes of single-unit trucks and tractor semitrailer combinations.

7. Miles per engine replacement decreased, with one exception, as loaded gross weights increased.

8. Tire costs for 22,400-lb single and 40,000-lb tandem axles were found to be approximately 40 percent higher than for 18,000-lb single and 32,000-lb tandem axles. Also, tire costs for 30,000-lb single and 48,000-lb tandem axles were found to be more than double the tire costs for 18,000-lb single and 32,000-lb tandem axles.

9. Although the tire cost per casing-mile increased generally as the load per tire increased, the cost per casing-ton-mile remained rather constant at about 0.1 cent a ton-mile for each of the various sized tires used.

10. Average hot-tire air inflation pressures were about 11 psi above the recommended cold-tire air inflation pressures as compared with 8 psi reported in a survey made in 37 States in the summer of 1954 (*3*).

11. Tire air-pressure buildup from cold-tire air inflation pressure did not significantly increase after the first 1½ hours of operation.

12. The tire air-inflation buildup in front-axle tires carrying approximately 60 percent of the recommended load was about one-half the pressure buildup of that found in tires carrying the recommended load.

TEST LOOPS

The AASHO Road Test near Ottawa, Ill., was conducted on six separated loops of 4-lane divided highway. Turnarounds connected the roadways to form elongated loops, each having two continuous traffic lanes. The tangent sections of the loops contained 836 separate test sections representing 169 different combinations of various thicknesses of surfacing, base, and subbase material. One-half of each test loop was surfaced with portland cement concrete (rigid) and half with asphaltic concrete (flexible). No traffic was operated on Loop 1, which was used only for the purpose of evaluating the effect of weather on test pavements and for other special studies. Loops 2 to 6 inclusive were operated with different test axle loads and loaded gross weights on each lane. All traffic movement was counterclockwise on the loops.

TEST VEHICLES

Two-axle single-unit trucks, using several makes of engines of different horsepower ratings, were operated on Loop 2. One lane of this loop carried 4-tire vehicles and the other lane 6-tire vehicles. Tractor semitrailer combinations operated on Loops 3, 4, 5, and 6 were of several makes and equipped with engines of different horsepower ratings.

Axle loads applied to the test pavements varied widely. Single-axle loads were 2,000, 6,000, 12,000, 18,000 22,400 and 30,000 lb. Tandem-axle loads were 24,000, 32,000, 40,000 and 48,000 lb. In both single- and tandem-axle ranges, the upper limits were above those allowed by vehicle weight laws throughout the States. An attempt was made to control the axle load within ±5 percent. There were, of course, minor variations in axle loads due to weight of fuel, snow and ice conditions during the winter months, and absorption of moisture by the cement blocks. In practically all cases, axle loads remained on the plus side of the weights set for the test.

TEST PROCEDURES

Test vehicles were operated on tangents at 35 mph and on turnarounds at 25 mph. Vehicles were in actual operation slightly more than two years (from November 1958 through November 1960) for 15 hours each day exclusive of rest and lunch periods. Inclusive of rest and lunch periods the vehicles were run for 19 hours and were continuously idle for 5 hours in each 24 hours.

AVERAGE FUEL CONSUMPTION RATES

A 1958 report on motor fuel consumption rates (*2*) with which AASHO Road Test data may be compared, was concerned with motor fuel usage by commercial truck operation on public highways in seven States. In that report fuel consumption was reported for motor trucks carrying different loaded gross weights and equipment with engines of various net horsepower ratings and cubic-inch displacement. Trend lines in the 1958 report were compared with trend lines of the Road Test operation, in order to provide some guidance for the prediction of diesel fuel consumption rates at higher levels of gross vehicle weights than are now permitted in most States.

A summary of the average rates of fuel consumption on the AASHO Road Test is given in Table 1 and shown in Figures 2 and 3. The gallons per mile are plotted for each group of similar vehicles and curves of the form $y = a\,x^b$ (where y = gallons per mile and x = loaded gross weight) have been computed representing the best fit of these points. Also shown are similar curves computed from data given in the 1958 study (*2*) of fuel consumption rates of commercial vehicles operated on public highways. The rate of rise and fall for the 1958 study was 1.22 ft per 100 ft and for the AASHO Road Test 0.22 ft per 100 ft.

Gasoline Consumption Rates

Gasoline-powered single-unit trucks weighing 4,200 lb had an average fuel consumption

TABLE 1

GASOLINE AND DIESEL FUEL CONSUMPTION RATES OF SINGLE-UNIT TRUCKS AND TRACTOR-SEMITRAILER COMBINATIONS OPERATED ON AASHO ROAD TEST, BY VARIOUS LOADED GROSS WEIGHTS, 1958-60[1]

Item	Single-Unit Trucks		Tractor-Semitrailer Combinations							
	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Diesel	Diesel	Diesel
Loop—lane	2–1	2–2	3–1	4–1	5–1	3–2	6–1	4–2	5–2	6–2
Vehicle type code	2 (4 tire)	2 (6 tire)	2–S1	2–S1	2–S1	3–S2	2–S1	3–S2	3–S2	3–S2
Number of vehicles	8	15	13	13	13	13	13	13	13	13
Engine displacement range (cu in.)	235–240	223–314	261–272	331–348	331–361	302–406	426–672	401–672	672–743	743
Net brake hp range	109–115	126–165	130–149	134–194	158–195	141–186	166–192	162–166	173–192	230–239
Axle test load (lb)	2,000	6,000	12,000	18,000	22,400	24,000	30,000	32,000	40,000	48,000
Loaded gross weight (lb)	4,200	8.200	28,900	42,600	51,600	54,800	70,100	74,000	89,800	108,600
Empty weight (lb)	3,600	4,600	12,300	14,700	15,800	19,000	22,600	23,800	26,900	31,900
Payload weight (lb)	600	3,600	16,600	27,900	35,800	35,800	47,500	50,200	62,900	76,700
Mileage, vehicle group (1,000) A[2]	490	1,646	596	347	638	677	670	909	868	599
B	361	582	719	565	972	499	1,075	853	894	1,089
C	228	—	479	868	155	106	—	—	—	—
D	—	—	—	—	—	199	—	—	—	—
E	—	—	—	—	—	351	—	—	—	—
Total mi (1,000)	1,079	2,228	1,794	1,780	1,765	1,832	1,745	1,762	1,762	1,688
Gasoline, vehicle group (gal) A[2]	33,231	133,110	101,517	71,971	140,451	163,599	124,085	186,221	195,428	170,747
B	25,123	51,717	127,207	123,357	215,299	123,978	217,610	182,065	221,788	322,244
C	17,107	—	89,320	195,763	35,224	26,795	—	—	—	—
D	—	—	—	—	—	53,460	—	—	—	—
E	—	—	—	—	—	104,453	—	—	—	—
Total gal. gasoline	75,461	184,827	318,044	391,091	390,974	472,285	341,695	368,286	417,216	492,991
Gal. per mi., vehicle group A[2]	068	081	170	207	220	242	185	205	225	285
B	070	089	177	218	222	249	203	214	248	296
C	075	—	186	226	227	251	—	—	—	—
D	—	—	—	—	—	268	—	—	—	—
E	—	—	—	—	—	298	—	—	—	—
Over-all average	070	083	177	220	222	258	196	209	237	292
Gross tons	2 10	4 10	14 45	21 30	25 80	27 40	35 05	37 00	44 90	54 30
Payload tons	30	1 80	8 30	13 95	17 90	17 90	23 75	25 10	31 45	38 35
Gal. per 1,000 gross ton-mi.	33 30	20 24	12 24	10 33	8 60	9 42	5 59	5 65	5 28	5 38
Gal. per 1,000 payload ton-mi.	233 33	46 11	21 33	15 77	12 40	14 41	8 25	8 33	7 54	7 61

[1] No inference should be made that the data in Tables 1 through 5 represent data which might be expected from commercial over-the-road operations. Operating relationships between data from different size test units may prove useful in estimating relationships between different size commercial units.

[2] A, B, C, D, and E refer to different groups of similar vehicles.

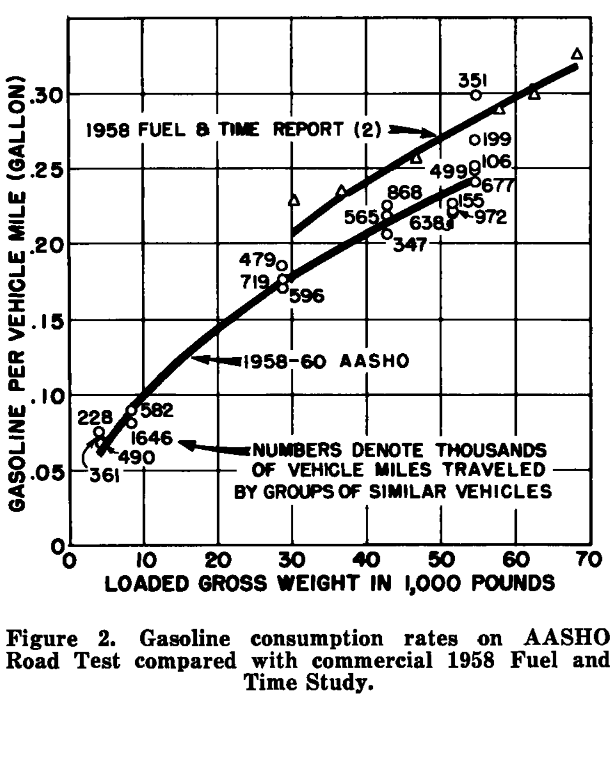


Figure 2. Gasoline consumption rates on AASHO Road Test compared with commercial 1958 Fuel and Time Study.

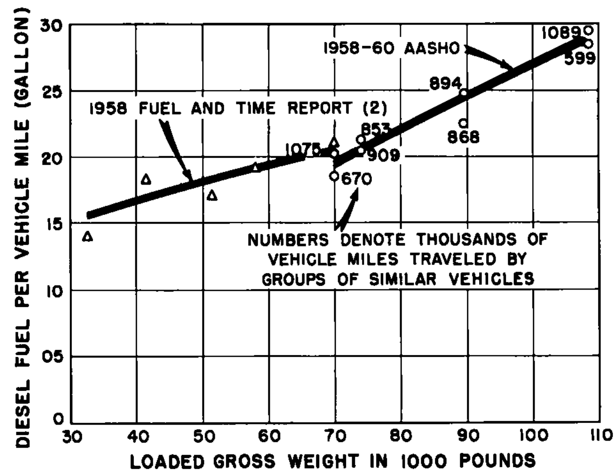


Figure 3. Diesel fuel consumption rates on AASHO Road Test compared with commercial 1958 Fuel and Time Study.

rate of 0.070 gal per mi as compared to an average consumption rate of 0.083 gal per mi for 8,200-lb single-unit trucks (Table 1). For the gasoline-powered tractor semitrailers the range was from an average consumption of 0.177 gal per mi for loaded gross weights of 28,900 lb to 0.258 gal per mi for loaded gross weights of 54,800 lb. The 1958 study observed gasoline-powered vehicles weighing up to 68,300 lb; the heaviest gasoline-powered vehicle run on the Road Test weighed 54,800 lb. The gasoline trend lines in both studies have approximately the same slope (Fig. 2), the AASHO consumption rate being lower by approximately 0.04 gal per vehicle-mile. The probable contributing factors were the constant rate of speed on the Road Test, flatter terrain and fewer stops and starts when compared to normal city-rural operation, and gear changes which were made in test vehicles to obtain optimum fuel economy.

Gasoline consumption per 1,000 gross ton-miles decreased quite rapidly from 33 gal for 4,200-lb single-unit trucks to approximately 9 gal for the 54,800-lb tractor semitrailer combinations (Fig. 4). Similarly, gasoline consumption per 1,000 payload ton-miles decreased from 233 gal for 4,200-lb single-unit trucks to approximately 14 gal for 54,800-lb tractor semitrailer combinations.

The standard errors of estimate of various loaded gross weights and coefficients of correlation for gasoline consumption per vehicle-mile and per 1,000 gross and payload ton-miles for the computed curves shown in Figures 2 and 4 are given in Appendix C.

Diesel Fuel Consumption Rates

Diesel operation on the Road Test with vehicles weighing 70,100 to 108,600 lb did not overlap the fuel and time study commercial operation report range of 32,600 to 69,900 lb. For this reason a direct comparison of the two operations cannot be made. The Road Test computed curve, however, when extrapolated down through the commercial report range, gives some indication that for equivalent gross weights the Road Test consumption rates were lower than for commercial operation (Fig. 3).

Diesel fuel consumption per 1,000 gross ton-miles decreased only slightly from 5.8 to 5.0 gal in the range of 70,100- to 108,600-lb loaded gross weights operated on the Road Test (Figure 5). Similarly, there was only a slight decrease per 1,000 payload ton-miles, from 8.7 to 6.8 gal for the same range of loaded gross weights operated.

The standard errors of estimate at various loaded gross weights and coefficients of correla-

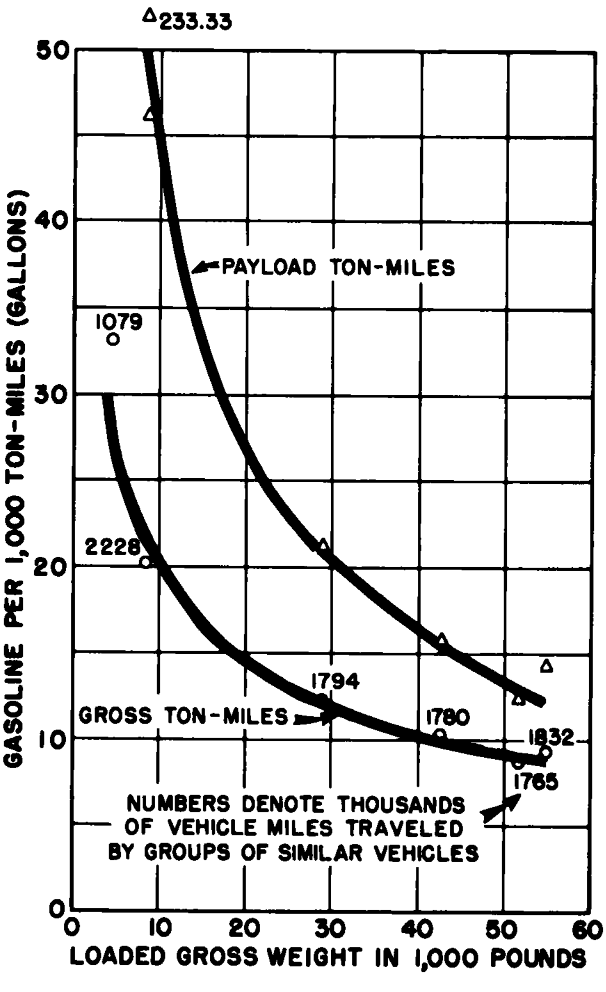


Figure 4. Gasoline consumption rates, AASHO Road Test.

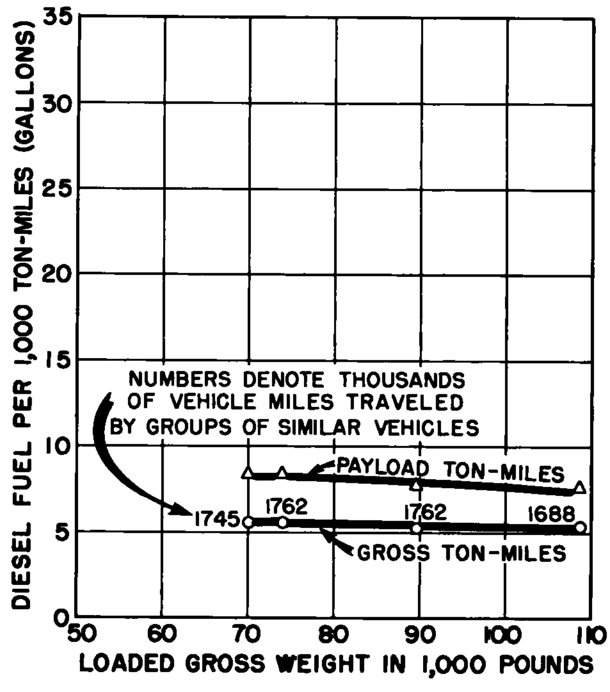


Figure 5. Diesel fuel consumption rates, AASHO Road Test.

TABLE 2

OIL-ADDED RATES OF SINGLE-UNIT TRUCKS AND TRACTOR-SEMITRAILER COMBINATIONS OPERATED ON AASHO ROAD TEST BY VARIOUS LOADED GROSS WEIGHTS AND BY FUEL-TYPE ENGINE, 1958-60[1]

Item	Single-Unit Trucks		Tractor-Semitrailer Combinations							
	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Diesel	Diesel	Diesel
Loop—lane	2-1	2-2	3-1	4-1	5-1	3-2	6-1	4-2	5-2	6-2
Vehicle type code	2 (4 tire)	2 (6 tire)	2-S1	2-S1	2-S1	3-S2	2-S1	3-S2	3-S2	3-S2
Number of vehicles	8	15	13	13	13	13	13	13	13	13
Engine displacement range (cu. in.)	235-240	223-314	261-272	331-348	331-361	302-406	426-672	401-672	672-743	743
Net brake hp range	109-115	126-165	130-149	134-194	158-195	141-186	166-192	162-166	173-192	230-239
Axle test load (lb)	2,000	6,000	12,000	18,000	22,400	24,000	30,000	32,000	40,000	48,000
Loaded gross weight (lb)	4,200	8,200	28,900	42,600	51,600	54,800	70,100	74,000	89,800	108,600
Mileage, vehicle group (1,000) A[2]	490	1,646	596	347	638	677	670	909	868	599
B	361	582	719	565	972	499	1,073	853	894	1,089
C	228	—	479	868	155	106	—	—	—	—
D	—	—	—	—	—	199	—	—	—	—
E	—	—	—	—	—	351	—	—	—	—
Total mi. (1,000)	1,079	2,228	1,794	1,780	1,765	1,832	1,745	1,762	1,762	1,688
Oil added (qt), vehicle group A[2]	448	1,389	1,192	583	2,479	3,285	2,479	4,877	2,993	3,610
B	305	1,334	1,852	1,165	2,290	1,721	4,139	3,389	3,069	4,897
C	398	—	740	1,924	355	208	—	—	—	—
D	—	—	—	—	—	601	—	—	—	—
E	—	—	—	—	—	1,241	—	—	—	—
Total oil added (qt)	1,151	2,723	3,784	3,672	5,124	7,056	6,618	8,266	6,062	8,507
Qt added per 1,000 mi. A[2]	0 91	0 84	2 00	1 68	3 88	4 86	3 70	5 36	3 45	6 02
B	0 85	2 29	2 58	2 06	2 36	3 45	3 85	3 97	3 43	4 50
C	1 75	—	1 54	2 22	2 29	1 95	—	—	—	—
D	—	—	—	—	—	3 01	—	—	—	—
E	—	—	—	—	—	3 54	—	—	—	—
Over-all average	1 07	1 22	2 11	2 06	2 90	3 85	3 79	4 69	3 44	5 04
Qt added per 1,000 ton-miles	0 51	0 30	0 15	0 10	0 11	0 14	0 11	0 13	0 08	0 09

[1] See footnote 1 in Table 1.
[2] A, B, C, D, and E refer to different groups of similar vehicles.

tion for diesel fuel consumption per vehicle-mile and per 1,000 gross and payload ton-miles for the computed curves shown in Figures 3 and 5 are given in Appendix C.

Some of the diesel-powered vehicles were loaded to heavier gross weights than are now permitted in most States (Fig. 3). These higher loadings have provided information on fuel consumption which might be expected of motor freight vehicles having gross loads heavier than presently permitted on public highway systems. Figure 3 indicates that average motor-fuel consumption rates for diesel-powered trailer combinations on the Road Test were in the order of 0.195 gal per mi (5.1 mpg) at 70,000 lb, 0.245 (4.1 mpg) at 90,000 lb, and 0.290 (3.4 mpg) at 110,000 lb.

AVERAGE OIL CONSUMPTION RATES

Although oil is not consumed in the same manner that motor fuel is consumed, it is lost in the lubricating process. The AASHO Road Test presented an opportunity to compare the quantities of oil used by a wide range in size and gross weight of vehicles operating under nearly identical test conditions. An examination of the oil-added records was made and it indicated that oil consumption tended to increase as the loaded gross weight of vehicles increased.

The oil added (Table 2) does not include the amount of oil which was put in the vehicles at regular preventive maintenance 3,000-mi (±500 mi—in actual practice it was mostly plus) oil changes. The mileage interval for oil changes did not vary between loops or between gasoline- and diesel-powered vehicles. It is probable that at each oil change the oil level was below the full mark and oil would have been needed to bring the oil level up to a full reading. The amount of oil which had been lost (the amount of oil needed to bring the oil level up to the full mark) was not recorded at regular oil changes and is not reflected in the oil-added figures. Although it was not possible to determine the absolute amount of oil lost, exclusive of oil supplied for oil changes, a comparison of the oil added between oil changes appears to be of interest.

Table 2 and Figure 6 give oil-added rates for 4-tire and 6-tire single-unit trucks and for gasoline and diesel tractor-trailer combinations. The trend line (Fig. 6) indicates that oil added per 1,000 mi for gasoline-powered vehicles increased from 1 qt for 4,200-lb loaded gross weights to almost 3 qt for 54,800-lb loaded gross weights. Similarly, the trend line for oil added

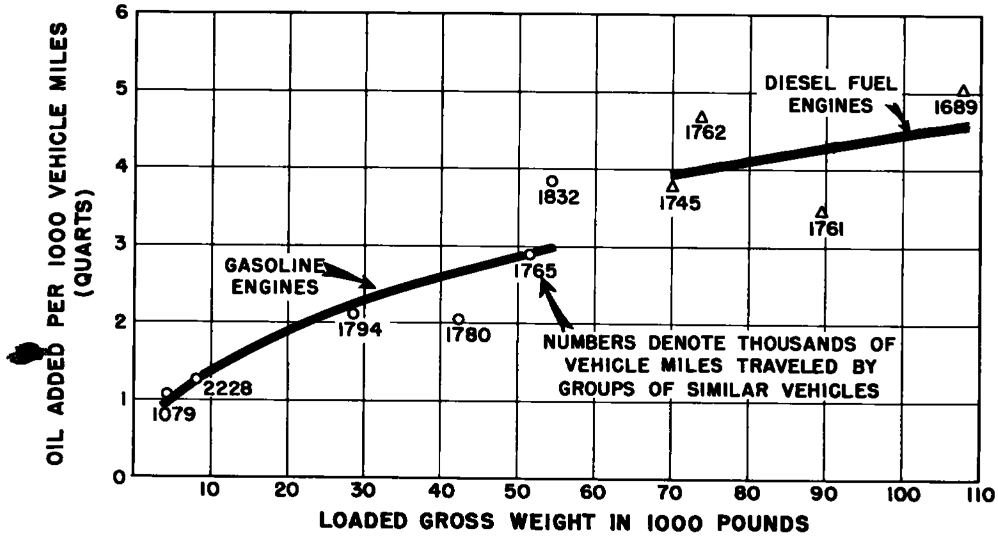


Figure 6. Oil-added rates on AASHO Road Test.

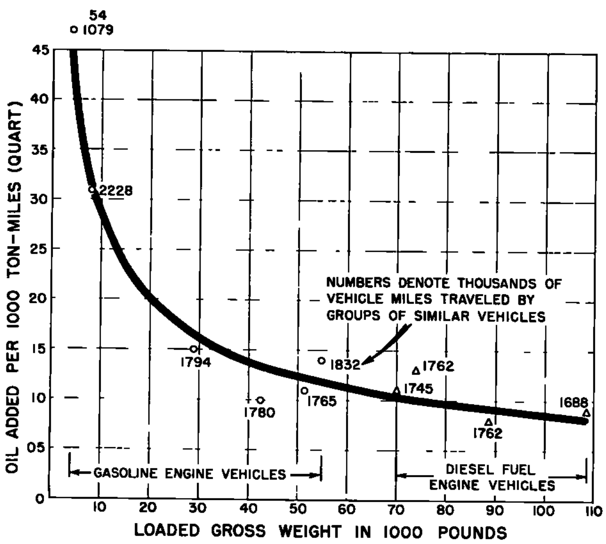


Figure 7. Oil-added rates on AASHO Road Test.

per 1,000 mi for diesel-powered vehicles increased from about 4 qt for 70,100-lb loaded gross weights to more than 4½ qt for 108,600-lb loaded gross weights.

The trend line (Fig. 7) for oil added per 1,000 ton-miles decreased rapidly from 0.43 qt at 4,200-lb loaded gross weight to 0.12 qt at 54,800 lb for gasoline-powered vehicles. The trend line for oil added then tended to level off for diesel-powered vehicles from 0.10 to 0.08 qt per 1,000 ton-miles from 70,100- to 108,600-lb loaded gross weights.

The standard errors of estimate at various loaded gross weights and coefficients of correlation for oil added per 1,000 vehicle-miles and per 1,000 ton-miles for gasoline- and diesel-powered vehicles are given in Appendix C for the computed curves shown in Figures 6 and 7.

TIRE USAGE AND TIRE COSTS

The rates of tire wear on the Road Test vehicles are probably not representative of rates of tire wear on similar vehicles used in normal operations on the public highways. However, it is believed that the relative tire wear among the various sizes used on the Test may be somewhat indicative of the relative wear that would be expected for corresponding tire sizes in normal highway operations.

A record (Fig. 8) was kept at the Test of maintenance operations for each tire. The mileage was recorded at the time each tire with original tread was withdrawn from service and at the time each recapped tire was withdrawn from service. This provided a record from which calculations were made of the average mileage by tire size to first recap and the average mileage per recap by tire size. The new tire costs and recapping costs (Table 3) are prices paid by large fleet owners during the time the Road Test was in operation.

The 10.00×20, 12-ply tire was selected as the base to which comparisons were made because this size is most frequently mounted on vehicles carrying the maximum loads presently permitted by AASHO Standards—18,000-lb single and 32,000-lb tandem axles.

Seven different tire sizes were used on test vehicles ranging in size from 6.70×15, 4-ply to 12.00×24, 14-ply. A total of 124,842,000 tire-miles were run by 2,157 tires which became unserviceable through Road Test operation and were junked. Table 3 gives an analysis of these 2,157 tires, by tire size, from which a computation was made of costs in cents per casing-mile. Cost per casing-mile of the 6.70×15, 4-ply and 7.00×16, 6-ply sizes, which were used on the 4-tire and 6-tire single-unit trucks, was about 0.05 cent per mile. This was only 29 percent of

TABLE 3

TIRE USAGE AND COSTS ON AASHO ROAD TEST RELATED TO REPRESENTATIVE TIRE COSTS BASED ON 2,157 TIRES JUNKED DURING TEST ENDED DECEMBER 3, 1960[1]

Item	Single-Unit Trucks		Tractor-Semitrailer Combinations						Total or Avg.
Loop—lane	2–1	2–2	3–1, 3–2	4–2	4–1	5–2, 5–1	6–2	6–1	—
Vehicle type code	2 (4-tire)	2 (6 tire)	2–S1, 3–S2	3–S2	2–S1	3–S2, 2–S1	3–S2	2–S1	—
Size of tire	6 70×15/4	7 00×16/6	7 50×20/10	9 00×20/10	10 00×20/12	11 00×20/12	12 00×20/14	12 00×24/14	—
Load per tire, (lb)	1,000	1,500	3,000	4,000	4,500	5,000–5,600	6,000	7,500	—
Axle weight [2], (lb)	2,000	6,000	12,000	16,000	18,000	20,000–22,400	24,000	30,000	—
Total number junked casings	54	82	595	303	129	475	305	214	2,157
Total number of recaps	87	123	842	605	241	1,065	491	337	3,791
Average recaps per casing	1 61	1 50	1 42	2 00	1 87	2 24	1 61	1 57	1 76
Cost-new tire, avg. dollars	15 05	28 95	55 40	75 65	95 90	112 95	156 10	167 15	—
Cost each recap, dollars	5 50	8 35	11 45	17 65	19 55	21 20	29 45	31 80	—
Total cost per casing, dollars	23 91	41 48	71 66	110 95	132 46	160 44	203 51	217 08	—
Avg. mi. per original tread	18,866	45,025	21,609	25,881	35,130	24,533	19,123	24,694	—
Avg. mi. per recap tread	17,584	31,206	17,604	18,863	21,457	18,088	18,606	21,895	—
Total mi. per casing	47,176	91,834	45,840	63,607	75,255	65,050	49,079	59,069	—
Cost per casing-mile, cents	051	045	156	174	176	247	415	368	—
Index-cost per casing-mile (10 00×20/12 = 100)	29 0	25 6	88 6	98 9	100 0	140 3	235 8	209 1	—
Total mileage junked casings (1,000)	2,548	7,530	27,275	19,273	9,708	30,899	14,969	12,641	124,842
Load per tire, ton	0 50	0 75	1 50	2 00	2 25	2 65	3 00	3 75	—
Cost per casing ton-mi., cents	0 102	0 060	0 104	0 087	0 078	0 093	0 138	0 098	—

[1] See footnote 1 in Table 1.

[2] For tandem axles these weights represent the weight of one axle.

the cost for the 10.00×20, 12-ply tire (Fig. 9). The cost of the 7.50×20, 10-ply tire used with 3,000-lb tire load was about 89 percent of that of the 10.00×20, 12-ply tire. The 9.00×20, 10-ply tire with a 4,000-lb tire load cost almost the same as the 10.00×20, 12-ply tire with a 4,500-lb tire load. The 11.00×20, 12-ply tire cost is shown as an average of the 5,000- and 5,600-lb tire loads and is 40 percent more costly than the base 10.00 tire. Increasing the tire load to 6,000 lb with the 12.00×20, 14-ply size tire increased the cost to 135 percent more than the 10.00 tire. The cost of the larger 12.00×24, 14-ply tire with a 7,500-lb tire load was about 109 percent more than the cost of the 10.00×20, 12-ply size tire with a 4,500-lb tire load (Fig. 9).

Whereas, the cost per casing-mile in cents increased generally as the load per tire increased, the cost per casing ton-mile remained rather constant at about 0 1 cent a ton-mile for each of the various sizes of tires used on the Test.

At the conclusion of vehicle operation, there were approximately 1,524 tires mounted on the vehicles plus 300 to 400 spare tires on the rack. Some of both of these categories had been recapped one or more times and could have represented some of the better performing tires. However, the group of 2,157 junked tires is of considerable size and it is reasonable to assume that the tires still in operation could be expected to follow a pattern of service closely similar to the service observed for the 2,157 tires. This assumption is based on the belief that there was a nearly constant number of long-life tires in service at any one time as evidenced by the low average recaps per casing ranging from 1.42 to 2.24, the 48,000- to 75,000-mi range (for heavier axle loads) of service per tire casing, and the average of 138,000 mi per vehicle.

Table 4 gives summary data for motor-fuel consumption, oil-added rates, and tire wear.

COMPONENT REPLACEMENTS

During the more than 2-yr operation of the AASHO Road Test certain component replacements became necessary to keep the 22 single-unit trucks and 104 tractor semitrailer combinations in running condition. Table 5 summarizes major component replacements.

A detailed study was made of 173 of the 246 engine replacements. Miles run at time of replacement were recorded for all engine replacements in 77 of the 127 vehicles used. These 77 vehicles, for the most part, had been operated from start to finish of the Road Test and do not include vehicles which were purchased after the Road Test had been in operation for a considerable time. There is a general trend with one exception (28,900-lb gasoline engine) toward fewer miles per engine

TABLE 4

SUMMARY OF VEHICLE OPERATING DATA FROM OPERATION OF SINGLE-UNIT TRUCKS AND TRACTOR-SEMITRAILER COMBINATIONS ON AASHO ROAD TEST, BY VARIOUS LOADED GROSS WEIGHTS, 1958-60[1]

Item	Single-Unit Trucks		Tractor-Semitrailer Combinations							
	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Diesel	Diesel	Diesel
Loop—lane	2–1	2–2	3–1	4–1	5–1	3–2	6–1	4–2	5–2	6–2
Vehicle type code	2 (4 tire)	2 (6 tire)	2–S1	2–S1	2–S1	3–S2	2–S1	3–S2	3–S2	3–S2
Number of vehicles	8	15	13	13	13	13	13	13	13	13
Engine displacement range (cu in.)	235–240	223–314	261–272	331–348	331–361	302–406	426–672	401–672	672–743	743
Net brake hp range	109–115	126–165	130–149	134–194	158–195	141–186	166–192	162–166	173–192	230–239
Axle test load (lb)	2,000	6,000	12,000	18,000	22,400	24,000	30,000	32,000	40,000	48,000
Loaded gross weight (lb)	4,200	8,200	28,900	42,600	51,600	54,800	70,100	74,000	89,800	108,600
Tare (empty) weight (lb)	3,600	4,600	12,300	14,700	15,800	19,000	22,600	23,800	26,900	31,900
Payload weight (lb)	600	3,600	16,600	27,900	35,800	35,800	47,500	50,200	62,900	76,700
Gross tons	2 10	4 10	14 45	21 30	25 80	27 40	35 05	37 00	44 90	54 30
Payload tons	30	1 80	8 30	13 95	17 90	17 90	23 75	25 10	31 45	38 35
Total veh-mi (1,000)	1,079	2,228	1,794	1,780	1,765	1,832	1,745	1,762	1,762	1,688
Total motor fuel (gal)	75,461	184,827	318,044	391,091	390,974	472,285	341,695	368,286	417,216	492,991
Total oil added (qt)	1,151	2,723	3,784	3,672	5,124	7,056	6,618	8,266	6,062	8,507
Total tire casings junked	54	82	595	129	475	595	214	303	475	305
Unit Computations:										
Motor fuel per veh-mi (gal)	0 070	0 083	0 177	0 220	0 222	0 258	0 196	0 209	0 237	0 292
Motor fuel per 1,000 gross ton-mi (gal)	33 30	20 24	12 24	10 33	8 60	9 42	5 59	5 65	5 28	5 38
Motor fuel per 1,000 payload ton-mi (gal)	233 33	46 11	21 33	15 77	12 40	14 41	8 25	8 33	7 54	7 61
Oil added per 1,000 mi (qt)	1 07	1 22	2 11	2 06	2 90	3 85	3 79	4 69	3 44	5 04
Oil per 1,000 gross ton-mi (qt)	0 51	0 30	0 15	0 10	0 11	0 14	0 11	0 13	0 08	0 09
Tire cost per casing-mi (cents)	0 051	0 045	0 156	0 176	0 247	0 156	0 368	0 174	0 247	0 415
Avg. mi per original tread	18,866	45,025	21,609	35,130	24,533	21,609	24,694	25,881	24,533	19,123
Avg. mi per recap tread	17,584	31,206	17,604	21,457	18,088	17,604	21,895	18,863	18,088	18,606
Avg. recaps per casing	1 61	1 50	1 42	1 87	2 24	1 42	1 57	2 00	2 24	1 61
Cost per casing ton-mi (cents)	0 102	0 060	0 104	0 078	0 093	0 104	0 098	0 087	0 093	0 138

Sources: Tables 1, 2, and 3.

[1] See footnote 1 in Table 1.

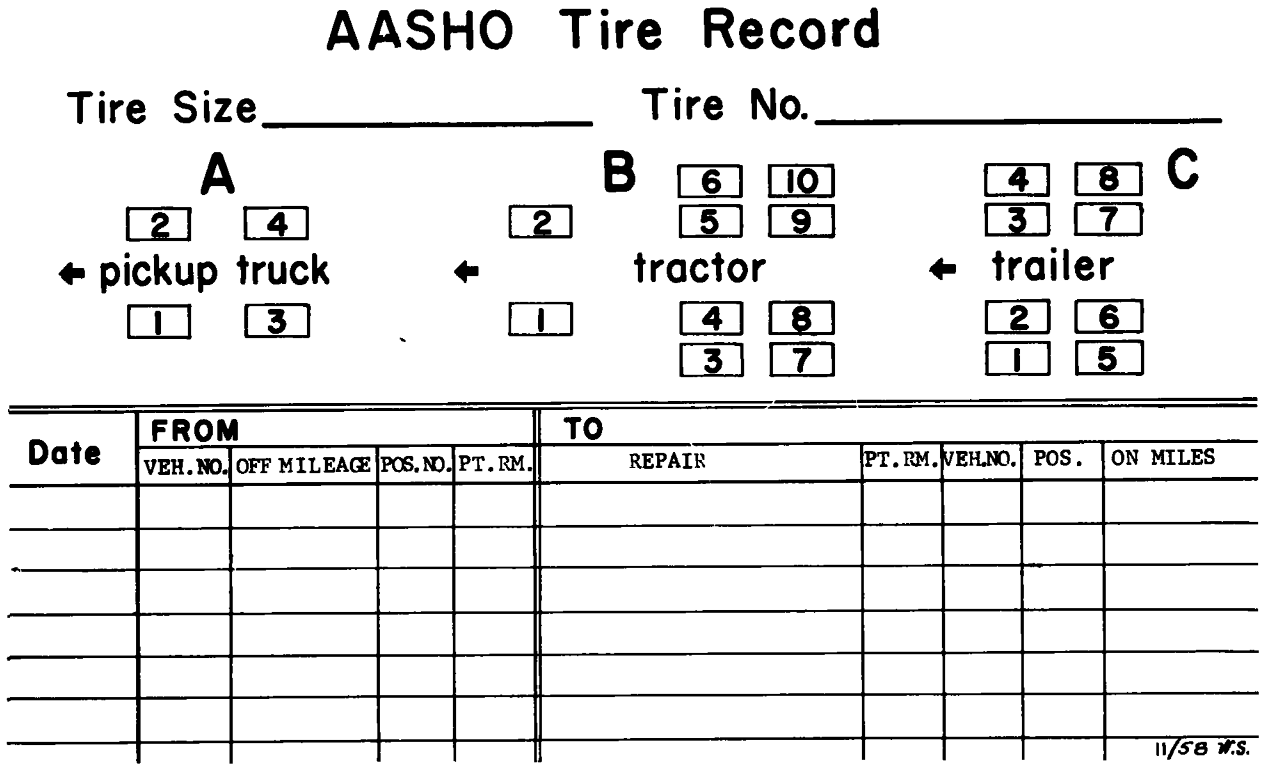
TABLE 5

TRUCK COMPONENT REPLACEMENT SUMMARY AT AASHO ROAD TEST OF SINGLE-UNIT TRUCKS AND TRACTOR-SEMITRAILERS BY TYPE OF FUEL USED, 1958-60[1]

Item	Single-Unit Trucks		Tractor-Semitrailer Combinations							
	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Diesel	Diesel	Diesel
Loop—lane	2–1	2–2	3–1	4–1	5–1	3–2	6–1	4–2	5–2	6–2
Vehicle type	2 (4 tire)	2 (6 tire)	2–S1	2–S1	2–S1	3–S2	2–S1	3–S2	3–S2	3–S2
No. of vehicles	8	15	13	13	13	13	13	13	13	13
No. of cylinders [2]	6	6–V8	6–V8	6–V8	6–V8	6–V8	6–6T	6T	6–6T	6T
Engine displacement range (cu in.)	235–240	223–314	261–273	331–348	331–361	302–406	426–672	401–672	672–743	743
Net brake hp range	109–115	126–165	130–149	134–194	158–195	141–186	166–192	162–166	173–192	230–239
Test axle load (lb)	2,000	6,000	12,000	18,000	22,400	24,000	30,000	32,000	40,000	48,000
Loaded gross weight (lb)	4,200	8,200	28,900	42,600	51,600	54,800	70,100	74,000	89,800	108,600
Total mi. driven (1,000)	1,079	2,228	1,794	1,780	1,765	1,832	1,745	1,762	1,762	1,688
Component replacements:										
Engine	2	14	39	15	38	60	14	16	19	29
Transmission	3	9	14	15	47	60	19	6	29	43
Power divider or rear end	2	24	11	11	15	22	4	8	11	5
Front springs	0	35	19	16	5	11	15	11	21	23
Rear springs	1	22	24	34	31	9	127	14	74	14
Clutch	7	20	34	25	93	51	12	9	37	31
Special study–engine replacements:										
Number of vehicles involved	2	7	11	6	11	8	8	7	8	9
Total mi at replacement (1,000)	210	707	982	587	1,157	1,114	725	774	682	752
No. of replacements	2	8	28	10	34	38	10	14	13	16
Mi per replacement (1,000)	105	89	35	59	34	29	72	55	53	47

[1] See footnote 1 in Table 1.

[2] 6T denotes a 6 cylinder turbo-supercharged engine.



AASHO Tire Record

Tire Size ________ Tire No. ________

A: pickup truck — positions 2, 4 / 1, 3

B: tractor — positions 2, 6, 10, 5, 9 / 1, 4, 8, 3, 7

C: trailer — positions 4, 8, 3, 7 / 2, 6, 1, 5

Date	FROM				TO				
	VEH. NO.	OFF MILEAGE	POS. NO.	PT. RM.	REPAIR	PT. RM.	VEH. NO.	POS.	ON MILES

11/58 W.S.

Figure 8.

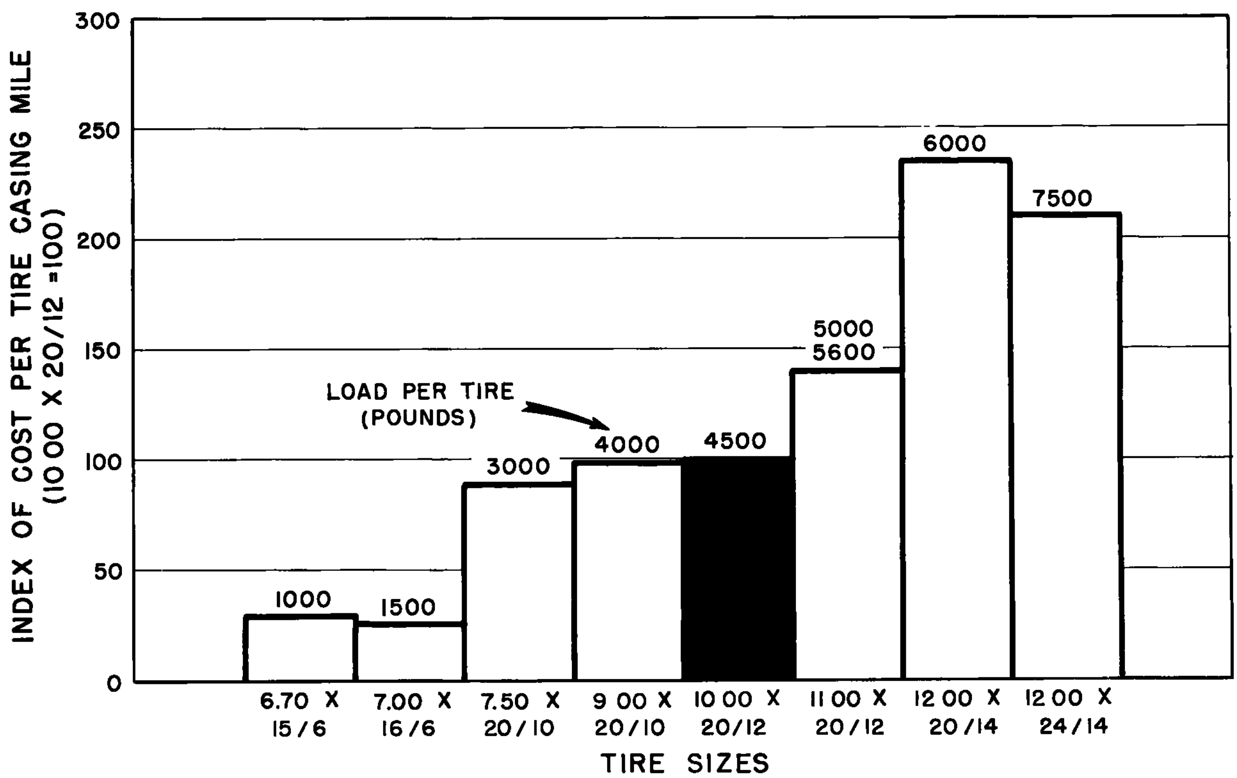


Figure 9. Tire casing cost per mile, AASHO Road Test.

replacement as loaded gross weight of vehicle increases (Table 5). Gasoline-powered combinations with loaded gross weight of 42,600 lb ran 59,000 mi per engine replacement as compared to 29,000 mi per engine replacement for the 54,800-lb combinations. Diesel-powered vehicles with loaded gross weight of 70,100 lb ran 72,000 mi per engine replacement as compared to 47,000 mi per engine replacement for diesel combinations weighing 108,600 lb.

TIRE-PRESSURE BUILDUP

As tire inflation pressure increases for a constant load the tire contact area with the road decreases thus producing an increase in unit pressures on the pavement. To provide data for analyzing this decrease in road contact area, a study of tire-pressure buildup resulting from road operation was made.

Tire pressures were taken at ambient air temperature at start of operation and after several 1½-hr intervals of driving. Ambient air temperature readings at tire height and air temperature readings 1 in. above rigid and flexible pavements were recorded for each tire air pressure reading. Tire air pressures were taken at left outside tires on each axle of 18,000-, 22,400-, 40,000- and 48,000-lb axle combinations and on both right and left outside tires on each axle of the 12,000-lb axle combination. Vehicles were run 19 out of each 24 hours (15 hours plus lunch and rest periods); hence, the beginning pressure reading at air temperature was made 5 hours after the last 19-hr period of operation. The air temperature range during this November 1960 tire-pressure study was 40 to 60 F with similar ranges in the surface temperatures. Tire position is designated numerically as given in Table 6 and Figure 8.

For 3 and 2 tire sizes, respectively, Tables 6 and 7 give the various tire pressure readings together with Tire and Rim Association recommended cold-tire air pressures at prevailing atmospheric temperatures. Also given are positions of tires, temperatures at start and after several 1½-hr periods of driving, approximate wheel loads of tires, and the percent cold-tire air pressures of Tire and Rim Association recommended pressures (see Appendix B).

Beginning cold-tire air pressures closely approximated pressures recommended by the Tire and Rim Association for each of three sizes of tires (Table 6). Deviation from recommended pressures cannot therefore be considered as a significant variable for tires in the 12,000-, 18,000-, and 22,400-lb categories. Temperature readings did not vary to any significant degree and hence temperature is also ruled out as a significant variable. Tire air-pressure buildup on the 2,250-lb front-axle wheel loads on the 12,000-lb single-axle vehicle amounted to less than 3 percent (2 psi), as compared to a buildup of more than 6 percent (5 psi) on the other 3,000-lb wheel loads. Tire air-pressure buildups on front axles of 18,000- and 22,400-lb single-axle vehicles amounted to 8 percent after 1½ hours of operation as compared with tire air-pressure buildups of 15 to 20 percent (11 to 15 psi) on other axles of these two vehicles. There was no appreciable buildup in air pressure after the first 1½ hours of operation for the three tire sizes.

Certain of the beginning air pressures (Table 7) for two tire sizes were from 5 to 17 percent (4 to 13 psi) below pressures recommended by the Tire and Rim Association. This underinflation undoubtedly resulted in higher than normal buildup in tire pressure due to an increased amount of flexing which causes higher tire temperatures.

The same tire size, 11.00×20, 12-ply, was used on the 22,400-lb single axle (Table 6) as was used on the 40,000-lb tandem (Table 7). There appears to be little difference in tire-pressure buildup for the 5,600-lb wheel load as compared with the 5,000-lb wheel load, both having an approximate 15 percent buildup (11 psi) at the end of 1½ hours of operation. The Tire and Rim Association recommendation for this size tire is a wheel load of 5,150 lbs. The front tractor axle carrying wheel loads of 3,100 lb (Table 6) had approximately half the air-pressure buildup as the front tractor axle carrying 4,500 lb (Table 7). For the tire sizes in Table 7, there is no appreciable tire-pressure buildup after 1½ hours of operation.

The results of these observations of tire pressures at the AASHO Road Test indicate that there is a significant buildup in tire pressure during operation. The increase of 10 to 12 psi above cold-air pressures imposes greater unit loads on highway surfaces by reducing the contact area between the tire and the pavement. This increase in unit loads will be of interest to highway design engineers.

REFERENCES

1. "Highway Statistics, 1959." U. S. Department of Commerce, Bureau of Public Roads, Washington, D. C., p. 26.
2. Kent, Malcolm F., "Fuel and Time Consumption Rates for Trucks in Freight Service." HRB Bull. 276, 1-19 (1960).
3. Saal, Carl C., "A Survey of Air Pressures of Tires Mounted on Trucks Operating in Everyday Traffic." *Public Roads,* 29:12, 269-278 (February 1958).

TABLE 6

TIRE PRESSURE BUILDUP ON AASHO ROAD TEST AFTER SEVERAL 1½-HR PERIODS OF OPERATION BY WHEEL POSITION, BY 3 TIRE SIZES, AND BY AMBIENT AND PAVEMENT TEMPERATURES, NOVEMBER 1960

Test Axle Weight	Vehicle No.	Tire Position	Wheel Load	T and R Assn. Recommendations: Weight	T and R Assn. Recommendations: Pressure	Tire Air Pressure: Cold Pressure Air-R-F [1]	Tire Air Pressure: At 1½ hr Air-R-F	Percent Buildup in 1½ Hr	Tire Air Pressure: At 3 Hr Air-R-F	Tire Air Pressure: At 4½ Hr Air-R-F	Tire Air Pressure: At 6 Hr Air-R-F	Percent Buildup	Percent Cold Pressure of T and R Recommendations
7.50×20/10:													
Air temp. (°F)	—	—	—	—	—	58–60–60	52–55–55	—	45–51–50	39–41–46	44–42–49	In 6 hr	—
4,500	—	1	2,250	2,980	75	76	78	2 6	76	74	77	1 3	101 3
12,000	—	2	3,000	—	—	76	78	2 6	77	76	78	2 6	101 3
12,000	—	3	3,000	—	—	78	82	5 1	81	80	81	3 8	104 0
12,000	—	6	3,000	—	—	76	82	7 9	81	80	83	9 2	101 3
12,000	—	1 TR	3,000	—	—	77	83	7 8	80	80	81	5 2	102 7
12,000	—	4 TR	3,000	—	—	78	84	7 7	84	83	86	10 3	104 0
Avg. tractor front axle	—	—	—	—	—	—	—	2 6	—	—	—	1 9	101 3
Avg. tractor 2nd axle	—	—	—	—	—	—	—	6 5	—	—	—	6 5	102 7
Avg. trailer 1st axle	—	—	—	—	—	—	—	7 7	—	—	—	8 4	103 3
10 00×20/12:													
Air temp. (°F)	—	—	—	—	—	60–60–61	57–57–58	—	55–54–53	59–54–55	60–56–56	In 6 hr	—
6,000	1	1	3,000	4,580	70	75	81	8 0	81	81	81	8 0	107 1
6,000	2	1	3,000	—	—	74	80	8 1	83	79	80	7 5	105 7
18,000	1	3	4,500	—	—	76	96	26 3	94	95	96	26 3	108 6
18,000	2	3	4,500	—	—	78	89	14 1	86	87	89	14 1	111 4
18,000	1	1 TR	4,500	—	—	70	83	18 6	82	83	84	20 0	100 0
18,000	2	1 TR	4,500	—	—	76	91	19 7	87	89	91	19 7	108 6
Avg. tractor front axle	—	—	—	—	—	—	—	8 1	—	—	—	8 1	106 4
Avg. tractor 2nd axle	—	—	—	—	—	—	—	20 1	—	—	—	20 1	110 0
Avg. trailer 1st axle	—	—	—	—	—	—	—	19 2	—	—	—	19 9	104 3
11 00×20/12:													
Air temp. (°F)	—	—	—	—	—	60–60–61	57–57–58	—	55–54–53	—	—	In 3 hr	—
6,200	1	1	3,100	5,150	75	74	81	9 5	78	—	—	5 4	98 7
6,200	2	1	3,100	—	—	74	79	6 8	76	—	—	2 7	98 7
22,400	1	3	5,600	—	—	73	81	11 0	77	—	—	5 5	97 3
22,400	2	3	5,600	—	—	73	87	19 2	82	—	—	12 3	97 3
22,400	1	1 TR	5,600	—	—	73	85	16 4	80	—	—	9 6	97 3
22,400	2	1 TR	5,600	—	—	75	88	17 3	82	—	—	9 3	100 0
Avg. tractor front axle	—	—	—	—	—	—	—	8 1	—	—	—	4 1	98 7
Avg. tractor 2nd axle	—	—	—	—	—	—	—	15 1	—	—	—	8 9	97 3
Avg. trailer 1st axle	—	—	—	—	—	—	—	16 9	—	—	—	9 5	98 7

[1] Air-R-F denotes temperature readings taken of air surrounding vehicle and 1 in. above rigid (R) and flexible (F) type pavements.

TABLE 7

Tire Pressure Buildup on AASHO Road Test After Several 1½-Hr Periods of Operation by Wheel Position, by 2 Tire Sizes, and by Ambient and Pavement Temperatures, November 1960

Test Axle Weight	Vehicle No.	Tire Position	Wheel Load	T and R Assn. Recommendations: Weight	T and R Assn. Recommendations: Pressure	Tire Air Pressure: Cold Pressure Air-R-F [1]	Tire Air Pressure: At 1½ hr Air-R-F	Percent Buildup in 1½ Hr	Tire Air Pressure: At 3 Hr Air-R-F	Tire Air Pressure: At 4½ Hr Air-R-F	Tire Air Pressure: At 6 Hr Air-R-F	Percent Buildup	Percent Cold Pressure of T and R Recommendations
11:00×20/12:													
Air temp. (°F)	—	—	—	—	—	49–53–52	52–56–58	—	51–56–57	50–54–56	—	In 4½ hr	—
9,000	1	1	4,500	5,150	75	65	76	16 9	77	76	—	16 9	86 7
9,000	2	1	4,500	—	—	67	79	17 9	79	78	—	16 4	89 3
40,000	1	3	5,000	—	—	73	83	13 7	84	84	—	15 1	97 3
40,000	2	3	5,000	—	—	74	83	12 2	83	83	—	12 2	98 7
40,000	1	7	5,000	—	—	72	86	19 4	87	86	—	19 4	96 0
40,000	2	7	5,000	—	—	78	90	15 4	90	89	—	14 1	104 0
40,000	1	1 TR	5,000	—	—	75	88	17 3	89	87	—	16 0	100 0
40,000	2	1 TR	5,000	—	—	75	88	17 3	88	87	—	16 0	100 0
40,000	1	5 TR	5,000	—	—	79	93	17 7	93	92	—	16 5	105 3
40,000	2	5 TR	5,000	—	—	77	88	14 3	88	87	—	13 0	102 7
Avg. tractor front axle	—	—	—	—	—	—	—	17 4	—	—	—	16 7	88 0
Avg. tractor tandem axle	—	—	—	—	—	—	—	15 1	—	—	—	15 1	99 1
Avg. trailer tandem axle	—	—	—	—	—	—	—	16 7	—	—	—	15 4	102 0
12:00×20/14:													
Air temp. (°F)	—	—	—	—	—	45–48–50	55–57–60	—	56–58–63	54–55–60	49–53–53	In 6 hr	—
12,000	1	1	6,000	6,020	80	81	87	7 4	87	87	87	7 4	101 3
48,000	1	3	6,000	—	—	66	74	12 1	76	75	75	13 6	82 5
48,000	1	7	6,000	—	—	67	76	13 4	78	77	77	14 9	83 8
48,000	1	1 TR	6,000	—	—	66	90	36 4	92	91	91	37 9	82 5
48,000	1	5 TR	6,000	—	—	70	75	7 1	78	77	76	8 6	87 5
12,000	2	1	6,000	—	—	76	85	11 8	88	86	86	13 2	95 0
48,000	2	3	6,000	—	—	78	86	10 3	88	86	86	10 3	97 5
48,000	2	7	6,000	—	—	79	86	8 9	88	87	87	10 1	98 8
48,000	2	1 TR	6,000	—	—	79	87	10 1	89	88	89	12 7	98 8
48,000	2	5 TR	6,000	—	—	80	90	12 5	92	91	91	13 8	100 0
Avg. tractor front axle	—	—	—	—	—	—	—	9 6	—	—	—	10 2	98 1
Veh 1 avg. tandem axle	—	—	—	—	—	—	—	16 7	—	—	—	18 2	84 1
Veh 2 avg. tandem axle	—	—	—	—	—	—	—	10 5	—	—	—	11 8	98 8

[1] Air-R-F denotes temperature readings taken of air surrounding vehicle and 1 in. above rigid (R) and flexible (F) type pavements.

APPENDIX A

AASHO Road Test Revised Schedules
(Effective July 1, 1960)

Schedule A 1000–0505

1st Shift		Minutes	Schedule A 1000–0505	2nd Shift		Minutes
Drive	1000–1130	90		Drive	1940–2110	90
Break	1130–1145			Break	2110–2125	
Drive	1145–1315	90	Week starts	Drive	2125–2255	90
	1315–1355	Meal	1940 hrs. Sun.	Break	2255–2310	
Drive	1355–1525	90	Week ends	Drive	2310–0040	90
Break	1525–1540		1925 hrs. Sat.		0040–0120	Meal
Drive	1540–1640	60		Drive	0210–0220	60
Break	1640–1655			Break	0220–0235	
Drive	1655–1740	45		Drive	0235–0320	45
Break	1740–1755			Break	0320–0335	
Drive	1755–1840	45		Drive	0335–0420	45
Break	1840–1855			Break	0420–0435	
Drive	1855–1925	30		Drive	0435–0505	30
		450				450

Schedule B 1530–1035

1st Shift		Minutes	Schedule B 1530–1035	2nd Shift		Minutes
Drive	1530–1700	90		Drive	0110–0240	90
Break	1700–1715			Break	0240–0255	
Drive	1715–1845	90	Week starts	Drive	0255–0425	90
	1845–1925	Meal	1530 hrs. Sun.	Break	0425–0440	
Drive	1925–2055	90	Week ends	Drive	0440–0610	90
Break	2055–2110		1035 hrs. Sat.		0610–0650	Meal
Drive	2110–2210	60		Drive	0650–0750	60
Break	2210–2225			Break	0750–0805	
Drive	2225–2310	45		Drive	0805–0850	45
Break	2310–2325			Break	0850–0905	
Drive	2325–0010	45		Drive	0905–0950	45
Break	0010–0025			Break	0950–1005	
Drive	0025–0055	30		Drive	1005–1035	30
		450				450

Schedule C 2030–1535

1st Shift		Minutes	Schedule C 2030–1535	2nd Shift		Minutes
Drive	2030–2200	90		Drive	0610–0740	90
Break	2200–2215			Break	0740–0755	
Drive	2215–2345	90	Week starts	Drive	0755–0925	90
	2345–0025	Meal	2030 hrs. Sun.	Break	0925–0940	
Drive	0025–0155	90	Week ends	Drive	0940–1110	90
Break	0155–0210		1535 hrs. Sat.	Break	1110–1125	
Drive	0210–0310	60		Drive	1125–1225	60
Break	0310–0325				1225–1305	Meal
Drive	0325–0410	45		Drive	1305–1350	45
Break	0410–0425			Break	1350–1405	
Drive	0425–0510	45		Drive	1405–1450	45
Break	0510–0525			Break	1450–1505	
Drive	0525–0555	30		Drive	1505–1535	30
		450				450

APPENDIX B

Tire Data

Tire Size and No. of Plys	AASHO Specifications				Tire and Rim Association Standards		
	Loop	Lane	Test Load (lb) Axle Load	Test Load (lb) Per Tire	Load (lb)	Inflation (psi)[1]	Rim
6 70×15/4[2]	2	1	2,000	1,000	1,065	24	4.5K
7 00×16/6		2	6,000	1,500	1,580	45	5.5F
7 50×20/10	3	1	12,000	3,000	2,980	75	6.0
7 50×20/10		2	24,000	3,000	2,980	75	6.0
10 00×20/12	4	1	18,000	4,500	4,580	75	7.5
9 00×20/10		2	32,000	4,000	4,120	75[3]	7.0
11 00×20/12	5	1	22,400	5,600	5,150	75	8.0
11 00×20/12		2	40,000	5,000	5,150	75	8.0
12 00×24/14	6	1	30,000	7,500	6,780	80	8.5
12 00×20/14		2	48,000	6,000	6,020	80	8.5

[1] Taken with tires at approximately the prevailing atmospheric temperatures, and do not include any inflation buildup due to vehicle operation.

[2] Tubeless tire—Tire and Rim Association standard inflation pressure is 28 psi for 1,065-lb load.

[3] The Tire and Rim Association standard inflation pressure is 70 psi for a recommended maximum load of 3,960 lb. This tire was operated at 75-psi inflation pressure and the data given for this pressure are at a load of 4,120 lb.

APPENDIX C

Measures of Validity for AASHO Road Test Vehicle Operating Data

The observed values of motor-vehicle fuel and oil consumption rates recorded at the AASHO Road Test are shown in Tables 1, 2, and 4. The curves which have been fitted to these observed values are shown in Figures 2 through 7. These curves are of the form $Y = ax^b$ which, when expressed for solving by logarithms, is of the form $\log Y = \log a + b \log X$. A program was written for the 1401 IBM computer which fitted a straight line to the logarithms of the observed values. The antilogarithms of the computed logarithmic values, when plotted on coordinate paper, result in curved lines.

The unbiased standard error of estimate represented by the symbol S was first computed in logarithmic values. When the logarithmic values of S are added to and subtracted from the logarithmic values of Y, two parallel and equidistant bands are formed contiguous to the fitted logarithmic line. When the computed values forming the logarithmic parallel lines are converted to antilogarithms, the bands defined by the unbiased standard error of estimate are not equidistant to the computed line.

The values of ± 1 standard deviation from each computed value, at selected loaded gross weights as shown in the following, indicate the boundaries within which 68 out of 100 of the actual values would be expected to fall. Similar computations can be made of boundaries representing $\pm$ 2 and 3 standard deviations from each computed value within which 95 and 99.7 percent of the observed values respectively would be expected to fall.

APPENDIX C (Continued)

Vehicle Operating Expense Items and Types of Engines	Loaded Gross Vehicle Weights (lb)						Coefficients of Correlation
	4,200	28,900	54,800	70,100	89,800	108,600	
(*a*) MOTOR FUEL PER VEHICLE MILE (gal)							
Gasoline engines $Yc = 0\ 0295X^{0.5282}$ (X = gross wt. in 1,000 lb)							
+1*S*	0 069	0 190	0 266				
Computed	0 063	0 174	0 244				0 989
−1*S*	0 058	0 160	0 224				
Diesel engines $Yc = 1\ 0048X^{0\ 8724}$ (X = gross wt. in 1,000 lb)							
+1*S*				0 206	0 257	0 303	
Computed				0 196	0 244	0 288	0 961
−1*S*				0 187	0 232	0 274	
(*b*) MOTOR FUEL PER 1,000 GROSS AND PAYLOAD TON-MILES (gal)							
Gasoline engines: Gross ton-miles $Yc = 42\ 3788X^{-0\ 4702}$ (X = gross tons)							
+1*S*	32 37	13 07	9 67				
Computed	29 90	12 07	8 94				0 991
−1*S*	27 61	11 15	8 25				
Payload ton-miles $Yc = 247\ 086X^{-0.9076}$ (X = gross tons)							
+1*S*	183 70	31 89	17 84				
Computed	126 01	21 88	12 24				0 953
−1*S*	86 45	15 01	8 40				
Diesel engines: Gross ton-miles $Yc = 8\ 7138X^{-0.1243}$ (X = gross tons)							
+1*S*				5 68	5 51	5 38	
Computed				5 60	5 43	5 30	0 762
−1*S*				5 52	5 35	5 23	
Payload ton-miles $Yc = 18\ 8045X^{-0.231}$ (X = gross tons)							
+1*S*				8 53	8 06	7 71	
Computed				8 27	7 81	7 47	0 873
−1*S*				8 02	7 57	7 24	
(*c*) OIL ADDED PER 1,000 VEHICLE MILES (qt)							
Gasoline engines $Yc = 0\ 4991X^{0.4444}$ (X = gross wt. in 1,000 lb)							
+1*S*	1 04	2 45	3 25				
Computed	0 94	2 23	2 96				0 935
−1*S*	0 86	2 03	2 69				
Diesel engines $Yc = 1\ 0592X^{0.3098}$ (X = gross wt. in 1,000 lb)							
+1*S*				4 44	4 80	5 09	
Computed				3 95	4 27	4 53	0 365
−1*S*				3 51	3 79	4 03	
(*d*) OIL ADDED PER 1,000 GROSS TON-MILES (qt)							
All vehicles $Yc = 0\ 6272X^{-0.5046}$ (X = gross tons)							
+1*S*	0 515		0 141	0 124		0 100	
Computed	0 431		0 118	0 104		0 084	0 958
−1*S*	0 362		0 099	0 087		0 070	

DISCUSSION

O. K. Normann, Bureau of Public Roads.—I think it has been demonstrated that this project has been a tremendous cooperative effort between industry, the universities, and the highway engineers. And I would like to have Mr. Kent explain how industry might use this information.

Kent.—There would be two rather distinct ways industry would be interested in these data. The first is in the cost and design of vehicles. This Road Test was actually a test of vehicles as well as a test of pavements and bridges. There were limits set that were above those that are used in highway operation—the 30,000-lb single and the 48,000-lb tandem axles. Conceivably, we should have had stronger vehicles or heavier vehicles to operate in tests of higher axle loads. The vehicles were commercial vehicles similar to those running on the highway in 1958. So the Road Test data will give some indication of what industry may have to do if it is ever called upon to operate heavier axle loads. There is no inference in this paper that we are going to have heavier axle loads, but in the event that that was deemed feasible, there would be some indication from the data of the vehicle costs to be expected and the vehicle components which industry would, of necessity, have to strengthen. In AASHO Test Report 3, there is a listing of component replacements that were made—engine replacements, transmissions, springs, power dividers or rear ends and others. So the AASHO Road Test gave some indication of the particular points of the vehicles which were not quite strong enough, in some instances, to carry the heavier axle loads.

The second angle is cost of operation. We do not operate on public highways now with some of the heavier loads operated on the Road Test. It would be difficult to determine, without guidance from the Road Test, the increased amounts of motor fuel, extra tire wear and other costs which are attributable to these heavier loads.

Louis Marick, U. S. Rubber Co.—It would be interesting if some comments were made on the total number of recaps, for example, that were used in the test. They went to rather high figures and could be of interest to quite a few of the people here. It would point out the durability of a tire carcass and mention has been made of the severity of the wear which occurred on the turnarounds. Most of the people in the room are aware of the great increase in wear-rate on turns as against a straight-ahead driving. So, at the moment, the only thing I would like to bring out is the tire serviceability from the standpoint of recaps. W. C. Johnson who is the tire industry representative on the Advisory Committee during the past year may have some additional comment.

Kent.—Due to the fact that this was scheduled as a 20-min presentation, it was not possible to report all of the data. You spoke of the total number of recaps. I believe the average recaps per casing will give a good understanding of what occurred at the Road Test. You may have the idea that all tire casings were recapped five or more times. Some few were but one must average in with those multi-recapped casings the tire casings which were not recapped at all—casings which became unserviceable while operating with original tread—and of course casings which were recapped less than five times. The average recaps per casing range was 1.4 for the 7.50 × 20/10 tire to 2.2 for the 11.00 × 20/12 tire. These were averages, by size of tire, which were used in computing the total cost per casing.