TABLE V

AVERAGE TOTAL ANNUAL COST OF TRANSPORTATION IN DOLLARS PER MILE

This table shows the total cost of transportation on one mile of each type of road for the traffic densities listed at the head of the column It includes the amount paid in taxes, etc , for the up-keep of the road and the sums paid by the owners in vehicle operation costs The various items are obtained by adding the corresponding sums from Tables II and IV Table V gives a *true comparison of the relative values of the five types of road* and shows which type of road is economical for each traffic density It also shows the fallacy of considering the road costs without at the same time considering the relation of the type of road to the cost of vehicle operation

The table was calculated on the basis of 90 per cent of the traffic being passenger automobiles with an average weight of 1 35 tons, 5 per cent being pneumatic-tired trucks with an average weight of 2 tons and 5 per cent being solid-tired trucks with an average weight of 3 5 tons The width of roadway surface was assumed to be 18 feet for the paved surfaces and 22 feet for the other types The rate of interest was taken as 4 per cent The cost of bridges and culverts was not included because it varies so greatly in different areas

Average vehicles per day	100	250	500	750	1,000	1,500	2,500
Average tons per day	149	372 5	745	1,117 5	1,490	2,235	3,725
Ordinary earth	5,353	12,944	25,580				
Best earth	5,210	12,449	24,512	36,577	48,632		
Ordinary gravel	5,350	12,476	24,343	36,229	48,101	71,862	
Best gravel	5,183	11,778	22,792	33,808	44,821	66,837	110,885
Best Portland cement concrete	5,501	11,150	20,650	30,150	39,611	58,563	96,397

D

WIND RESISTANCE OF MOTOR VEHICLES

L E Conrad

Kansas State Agricultural College, Manhattan, Kansas

The investigation of wind resistance of motor vehicles was undertaken about three years ago by the Engineering Experiment Station, Kansas State Agricultural College, at the suggestion of the National Research Council, and assisted financially by the U S Bureau of Public Roads

As it was originally intended to use the natural winds for this purpose, the choice fell upon the Kansas State Agricultural College, partly because of the duration and intensity of the winds during the greater part of the year The method used in these tests consisted of measuring the average pull of the wind on a car supported on a platform which floated in a large tank An automatic device recorded the variations in pull, which were averaged by means of a planimeter Wind velocity was determined by means of anemometers, and its direction was found by weather vanes After a year's work the method was temporarily abandoned because of the extreme variability and gustiness of the natural winds, and a wind tunnel large enough to be used in testing full-sized cars was designed and built It is rectangular in cross section, 10 feet high by 12 feet wide at the throat, and enlarged to 10 feet 9 inches high by 13 feet 6 inches wide at the working section to compensate for the area occupied by a car A transition section leads from the working chamber to the fan, changing from a rectangle of the size mentioned to a circle 10 feet in diameter The original length was 37 feet The motor vehicles are placed on a freely swinging platform, which is essentially a part of the floor of the working section, and the pull required to return the platform to its zero position is taken as the measure of the force of the wind on the car at the given speed

Two wooden aeroplane propellers were combined and used as a 4-blade propeller, driven by a 55 H P direct current electric motor With this installation, it was possible to obtain a wind velocity of 18 miles per hour, but only for short times as the motor was seriously overloaded It was desired to attain higher speeds than this, and a tentative goal of 30 to 35 miles per hour was suggested A one-twelfth scale model of the large tunnel was built and extensive experiments carried out to determine the controlling influences on wind velocities and power input The design of fan was first considered, 2-, 4-, 8-, and 16-blade fans were tried out with blade angles varying from 15 degrees to 42 degrees and with various widths and cambers Records were kept of the wind velocity, fan speed, and power requirement through a wide range of values for each setting of each fan An 8-blade fan, of a design which could be most readily duplicated, produced a wind velocity of 35 miles per hour at 5,600 r p m with a net power input of 0 78 H P From this data it was thought that a similar fan might produce a like velocity in the large tunnel at about 460 r p m with 112 H P An 8-blade adjustable-pitch propeller was designed, built, and installed three weeks ago The hub is made of cast steel and the blades of cast aluminum alloy containing 8 per cent copper In a trial run, a wind velocity of 36 miles per hour in the working section was obtained at a propeller speed of 442 r p m with an input to the motors of 121 electrical horsepower This wind velocity corresponds to 67 miles per hour at the fan itself

In experiments with the model tunnel, the effect of exit cones or draft tubes was next investigated Draft tubes having side angles of 5 to 18 degrees and from 3 to 20 inches long (corresponding to feet on the large tunnel) were made and tested A tube with flaring sides was also tried The draft tube giving the best results was 12 inches long, diameter of small end 10 inches, and diameter of large end 14 14 inches As it was most convenient to set the motors in the draft tube, the condition was approximated in the model and an equal net volume obtained by increasing the diameter of the large end of the draft tube to 15½ inches This increase in size gave equally good results when an obstruction of size and shape corresponding to the motors and to their concrete base was put in the proper position With this draft tube in place it was found that a fan would produce a given air speed with approximately one-half the power input required when the draft tube was not used The effect of spinners, hydraucones, cores, and guide vanes was investigated but none was found to be beneficial

A draft tube 12 feet long with an exit end of 15 feet 6 inches diameter was built on to the original tunnel, making the total length about 50 feet The transition section and the draft tube were built of 20-gage sheet metal fastened to wooden frames and the remainder of the tunnel constructed of matched flooring

Two 55 H P direct current motors are connected directly to the fan by means of suitable flexible couplings, and speed regulation is obtained by a set of resistance grids and by field rheostats

The fan was first set with a blade angle of 35 degrees, but has since been changed to 30 degrees and 30 minutes, due to the maximum power output that was obtained from the motors at an unfavorably low speed

A spring balance for measuring the pull on the car has been made and installed The wind velocity is measured by means of a pitot tube and an inclined manometer In a trial run, the force exerted on a Dodge touring car at a wind velocity of 36 miles per hour was about 90 pounds, which represents a power consumption of over 8½ H P This figure is approximate as the platform resistance is not subtracted A device for lifting the car off the platform in order to obtain the effect of the wind on the platform itself has been perfected

The following investigations remain to be made

1 To determine the effect of the platform on the total pull for each type of car
2 To determine the error due to the fact that the wheels are stationary instead of turning
3 To determine the wind resistance of all available types of cars
4 To derive an empirical formula for the wind resistance in terms of the projected area of the car and its velocity

E

INVESTIGATION OF TIRE WEAR

W C McNown

University of Kansas, Lawrence, Kansas

This is the second progress report on Cooperative Test between the University of Kansas and the U S Bureau of Public Roads to determine the relation of road surface to tire wear

The first report made in the fall of 1923 was a discussion on the general