The investigations of Douglas on "Weather Cycles in the Growth of Big Trees" and "A Method of Estimating Rainfall by the Growth of Trees," of Huntington on the climatic factor, and of Humphreys on the relation of volcanic dust to climatic changes, etc., appear to have been the chief inspiration and sources for this particular portion of the monograph.

This is a very new field for the modern student of plant succession. The author states that: "The interpretations of past vegetations rests upon two basic assumptions. The first is that the operation of climatic and topographic forces in moulding plant life has been essentially the same throughout the various geological periods. This is a direct corollary of the conclusions of Lyell as to geology, and of Huntington, Humphreys and others as to climatology. The second assumption is the one already quoted, namely, that the operation of succession as the developmental process in vegetation has been essentially uniform throughout the whole course of the geosere. From these two assumptions naturally follows a third to the effect that the responses of animals and man to climate and to vegetation, both as individuals and in groups, have remained more or less identical throughout geological time. As a consequence of Darwin's work, this has long been accepted for the individual, but as to the community it still awaits detailed confirmation by the new methods of zoecology. Further, if all these be accepted as necessary working hypotheses, it is evident that what is true of the parts must be true of the whole plexus of geological causes and biological responses in the past."

The attempt is then made to trace the successions through the various geological eras with their shifting climates and climaxes. But here again the details are so numerous and so many biological principles are involved that only first-hand examination of these chapters can give the reader an adequate conception of the matter handled in this way. In passing it is interesting to note that Clements has used vegetation rather than animal life as the basis for the recognition of eras of the geological record, somewhat after the fashion of Saporta (1881). Thus we read: Eophytic, Paleophytic, Mesophytic, Cenophytic.

These latter chapters should be particularly suggestive and stimulating to the animal ecologist and the paleo-ecologist as well as to others with an interest in the phenomena of living thing of past ages.

The bibliography of nearly a thousand titles, the most of which have been abstracted or noted somewhere in the text, is still another valuable part of the book. This is probably the most nearly complete collection of titles on succession and related phenomena available.

It may be said, after securing a bird's-eye view of the book as a whole, that Clements's monograph presents an invaluable summary of our knowledge of plant succession and that it must become at once the indispensable reference and guide for the student of vegetative cycles in all parts of the world.

Raymond J. Pool
The University of Nebraska

SPECIAL ARTICLES

RECENT INVESTIGATIONS OF TRACTIVE RESISTANCES TO MOTOR TRUCKS ON ROADS AND PAVEMENTS

An experimental investigation was carried on in the research division of the electrical engineering department, at the Massachusetts Institute of Technology, during the year 1915, under a fund contributed for researches on motor trucks, for the purpose of determining the tractive resistance of a motor delivery wagon with four wheels and solid rubber tires on various level urban roads and pavements. The complete report on this research was published in the *Proceedings of the American Institute of Electrical Engineers,* June, 1916.

By "tractive resistance" is meant the horizontal force necessary to apply to the truck in order to keep it at a constant speed in still air after deducting axle frictions and internal-mechanism losses. It is, therefore, the reactive force offered by the truck, assumed internally frictionless, in overcoming the road, tire and still-air resistances on a level surface. It may be expressed either in pounds weight per short ton of total moving mass, or in kilograms per metric ton, or in per cent. equivalent grade. Thus a 1 per cent. equivalent grade tractive resistance means that a car without axle friction or other internal mechanism losses would require to be pulled on a level road at a constant stated speed a force of 20 pounds per short ton of 2,000 pounds, in order to overcome the resistance of the tires, road-bed and still-air displacement. This force would obviously serve to propel the same vehicle up a 1 per cent. grade in the absence of tire, road-bed, still-air and internal frictions. At a given speed, therefore, this tractive resistance depends upon the wheel, the tire, and the road, and also on the air-displacement resistance of the truck.

The truck tested was a 1,000-lb. (450 kg.) electrically-propelled delivery wagon equipped with single solid rubber tires, one on each of the four wheels—the tire rating being 36 in. by 2½ in. (915 mm. by 63.5 mm.). The tests were made by running the car at, as nearly as possible, constant measured speed, in alternate directions, over selected lengths of standard roads in and near Boston. From the observed storage-battery outputs during these runs, the corresponding tractive resistances were evaluated after correcting for all losses internal to the truck mechanism, wind losses, grade and incidental accelerations. The internal losses of the truck mechanism from battery terminals to wheel spokes were determined from laboratory tests with the car raised from the ground on jacks, and by driving tested dynamos from the rear wheels.

The following is a summary of the results obtained as applying to urban roads with this truck between the speed limits of from 13 to 25 km. per hour (8 to 15.5 miles per hour).

1. The over-all efficiency of the test-truck mechanism between battery terminals and rear-wheel treads reached a maximum value of about 78 per cent., under the most favorable conditions.

2. The mechanical efficiency of transmission from motor shaft to rear-wheel treads, for the truck tested, shaft-driven through a single-reduction worm gear, was found as high as 90 per cent.

3. Under the conditions of these tests, the tractive resistance on level roads, in the absence of wind, is composed of (*a*) displacement resistance, (*b*) impact resistance and (*c*) air resistance.

By "displacement resistance" is meant that portion of the tractive resistance which depends on the lack of resilience of a smooth road surface and of the wheel-tire material; *i. e.*, on the energy losses due to inelastic displacement of tire and road-surface materials.

By "impact resistance" is meant that portion of the tractive resistance which depends on the lack of smoothness of the road surface, and which is due to the impacts given to the moving vehicle by the irregularities of the road.

By "air resistance" is meant that portion of the tractive resistance due to air pressure on the moving vehicle necessary to displace the air in the absence of wind.

4. The displacement resistance varied from 0.85 per cent. equivalent grade, for a hard smooth asphalt or bituminous concrete, to 1.6 per cent. for a very soft tar-macadam road, and was practically constant, for all speeds considered, on any given road.

5. The impact resistance increases with the velocity, with the total weight of vehicle, and with increasing road-surface roughness. In these tests, the impact resistance of good asphalt or bithulithic or other smooth pavement, was practically negligible, and reached its highest values (about 1.5 per cent. equivalent grade at a speed of 20 km. per hr. (12.4 miles per hr.) on granite-block roads with sand filled joints, and on badly worn macadam pavements. The rate of increase of impact resistance with speed was most marked on the roughest roads.

6. At the vehicle speed of 20 km. (12.4 miles) per hour, the air resistance for the vehicle tested, assumed to be dependent only on the speed, was roughly 0.11 per cent. equivalent grade; *i. e.*, from 4 per cent. of the high-

est, to 12.5 per cent. of the lowest, total tractive resistance.

7. The following urban pavements are enumerated in the order of their desirability for vehicle operation from the point of view of tractive resistance at 20 km. (12.4 miles) per hr., as found in this investigation. (1) asphalt, (2) wood block, (3) hard smooth macadam, (4) brick block, (5) granite block with cement-filled joints, (6) cinder, (7) gravel, (8) granite block with sand-filled joints.

8. The equivalent grade at 20 km. (12.4 miles) per hr. of a badly worn city macadam road, was found to be nearly three times as great as that of the best asphalt road tested. This means, at this speed, a consumption of energy at wheel treads, of nearly three times as much on level poor macadam roads as on good level asphalt roads.

9. Increasing the gross weight of the vehicle by 12 per cent. through load, was found to have no effect on tractive resistance within the observed speed limits for smooth roads in good condition; but on rough roads, a distinct increase in tractive resistance with this extra weight was observed.

10. The presence of a layer of dust, say one cm. thick, on a fair macadam road, was found to increase the equivalent grade of tractive resistance, at a speed of 20 miles (12.4 km.) per hr., from 1.17 to 1.32 per cent.

11. A freshly tarred and therefore very soft tar-macadam road was found to have an increased tractive resistance equivalent grade, at substantially all tested speeds, of about 0.5 per cent. The tires in this case sank about 0.8 inch (2 cm.) into the road-bed, the gross car weight being 2,140 kg. (4,710 lb.).

12. The total range of tractive resistance equivalent grade covered in the tests, was from 0.93 per cent. on the best asphalt road, at lowest speed, to 2.7 per cent. on the worst macadam road, at nearly the highest speed.

13. The results indicate, as has already been pointed out by other observers, the importance of constructing and maintaining smooth, hard and clean roads, from the point of view of tractive resistance. Low tractive resistance means small gasoline consumption for gasoline trucks, and a reduced electricity expense or greater daily mileage with electric trucks.

14. Other problems which are of practical importance to vehicle designers and operators, and which require further investigation are the following:

(*a*) Tractive resistances on country roads.

(*b*) Tractive resistances to vehicles with different wheel tires.

(*c*) Tractive resistances of urban roads at low speeds from 0 to 10 miles per hour (16 km. per hr.).

(*d*) Tractive resistances at speeds higher than 15 miles per hour (24 km. per hr.).

(*e*) Tractive resistances for high-capacity trucks.

15. The results of the tests here reported have been found to be in substantial agreement with those obtained by other observers employing somewhat different methods; but the analysis of tractive resistance into its components here presented appears to be new, and is recommended for use in similar investigations or tests.

16. The writers are indebted to Mr. Thomas A. Edison and also to the Gould Storage Battery Co. for funds by which the research was made possible.

A. E. KENNELLY,
O. R. SCHURIG
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
CAMBRIDGE, MASS.

SOCIETIES AND ACADEMIES

THE BIOLOGICAL SOCIETY OF WASHINGTON

THE 563d meeting of the society was held in the assembly hall of the Cosmos Club, Saturday, January 13, 1917, called to order by President Hay at 8 P.M., with 45 persons in attendance.

On recommendation of the council Dr George W. Field, Biological Survey, was elected to membership.

President Hay announced the membership of the Publication Committee; C. W. Richmond, J. H. Riley, Ned Dearborn, W. L. McAtee; and the membership of the committee on communications: Wm. Palmer, Alex. Wetmore, R. E. Coker, L. O. Howard, A. S. Hitchcock.

Under the heading of brief notes W. L. McAtee and Alex. Wetmore called attention to the presence