history, its habits and its needs, that now constitute so large a part of our study, and is an acknowledged factor in practical agriculture.

American horticulture, still more obviously a branch of applied ecology, has already reached a stage of development in which it is hardly an exaggeration to say that desired forms are actually made to order, and some of the men who are contributing to this end are leading promoters of ecological investigations. They are the men we summon when we want to know the real basis of Mendel's laws and the ones who are teaching us from their own studies the course of contemporaneous evolution.

I have already referred to forestry as illustrating the extent and definiteness of application of ecological principles in a great practical industry. It is highly important, particularly in the United States, that this relation should be well understood. We are confronted in many of our states with peculiarly difficult problems of reforestation. Land that has been the greatest source of wealth to the state is now a wilderness, practically worthless until it is clothed again with forests. How this is to be accomplished is one of the serious economic problems that the present generation is called upon to solve. We are gaining the data in part through the suggestions of professional foresters, but there is imperative need of all the light that can be gained by critical and extended study of the natural succession of plant societies. It is fortunate that such studies have already attracted earnest and capable students, and it is fair to say that those who desire to render the state a permanent economic service can hardly find a better field, providing they are fitted for the task.

I make no apology for thus emphasizing the practical value of this branch of scientific work. Service, first wrung from the unwilling slave, then the free-will offering of the citizen and patriot, is now the honorable goal of the worker in science, and there is no higher end to be attained.

Speaking for botanists, I have taken into account only one side of ecological study, that which relates to the habits and adaptations of plants. The habits of animals can not be less interesting and important, and it is a matter of congratulation that zoologists are entering this field with enthusiasm and well-defined aims. We extend to them our hearty greetings for the new year and the new era of biological work. V. M. SPALDING.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SECTION D, MECHANICAL SCIENCE AND ENGINEERING.

TUESDAY MORNING, DECEMBER 30.

Electrical Engineering: J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

Electrical engineering is a branch of engineering which more than any other joins the scientific with the practical, and bases the latter more immediately on theoretical considerations and mathematical calculations. It differs widely in this respect from some other branches of engineering, and for this reason papers which might otherwise come to this section are easily included under the head of physics, just as formerly all papers of scientific affinities went together into one section. Now, since Section D has been in existence, a paper, say, on thermodynamics, has been considered suitable for it, for although its matter was really a branch of physics, its engineering connections would naturally bring it to us. Now, Section B is overloaded with papers and I would suggest that some effort be made to get into this section such papers as may properly be claimed under electrical engineering, interpreting it broadly if need be.

Stress: J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

Attention has often been called to the fact that in mechanics a confusion exists in the use of fundamental terms, which results in many cases from faulty definitions of the quantities employed.

Stress is one of the more recent terms, and a discussion of its meaning may lead to a better understanding of it.

An examination of authors shows that it is a general designation for tension, compression, shear, etc., in which authors agree; they differ, however, somewhat on minor points, so that the composite idea to be gained from a number of them is somewhat confused.

Its right to exist must depend upon its applicability to a definite thing in nature for which no better name exists, and we will attempt to show what this thing is.

When forces and moments are in equilibrium upon a material body, a state is produced therein which, viewed statically, is called a *stress,* and, viewed geometrically, a *strain.* Thus, if two equal and opposite forces of m pounds each, or, as we may express it, two forces m and $-m$ in the same line of action, be applied to the ends of a rope, a state of tension ensues therein. This is evident statically from its tendency to contract, and geometrically from its greater than normal length.

The following distinct points are to be noticed:

(*a*) It requires *two* equal and opposite forces to produce a tension, that is, it requires a 'couple,' and the definition of stress should be consistent therewith and with the following general conceptions:

A definite force applied at any point of a free body produces in one second a definite velocity of translation of its center of gravity. If a 'couple' of forces be applied, each neutralizes the translation of the other so that the center of gravity is unaffected. The forces of the 'couple' have, of course, parallel lines of action whose distance apart is the lever arm of the 'couple,' and the product of one of the forces by the lever arm is the moment, or torque, of the 'couple.' A definite torque produces a definite angular velocity, and may be neutralized by an equal and opposite torque so as to leave the body unaffected as to both translation and rotation. It is unscientific to exclude, as some authors do, from their definition of a 'couple' the case when the lever arm is zero; the 'couple' exists then as much as it ever does.

But besides these kinematic effects, which may or may not be produced, we have the static effect on the body itself, and a body can not act as the medium for balancing forces or moments without assuming a state of stress, so that a 'couple,' whose dynamic effect is reduced to zero by reducing to zero its lever arm, still causes *stress* in the body. In a 'couple,' therefore, the *essential property* of the forces themselves is neutralized, and the dynamic or static properties of the couple alone remain.

A stress, therefore, is *not* a force, any more than a 'couple' is, although appropriately measured in pounds or similar unit used for forces.

(*b*) Another point of difference between a stress and a force is that a force is a vector having direction, while a stress has only a line of action. This is the more evident when we consider that changing the algebraic sign of a force reverses its direction, and that to produce one stress, say a tension, we require both the plus and minus forces, thus interfering with the idea of direction. A stress has only a line of action, and changing from plus to minus has nothing to do with direction, but means the change from tension to compression, which corresponds with a reversal of the signs of the forces producing the stress. A plus stress being tension, a minus stress is compression, with no change in the line of action.

(*c*) A stress may or may not be considered per unit of area. There is nothing in a stress to make it different from a force in that respect. All forces are actually distributed forces, and all stresses distributed stresses. A stress must be defined as to its inherent nature, and not as to a method of measuring it. Sometimes 'total stress' is required, and sometimes the 'intensity' of the stress, or stress per unit of area, just as we speak of weight or weight per cubic or square foot. That is, we may wish to speak of the tension in a beam or the tension per square inch.

An examination of authors shows the justice of these three points, although I am not aware that they have been distinctly and positively affirmed, and the importance pointed out of making them clear in defining the word stress.

A Systematic Method of Calculating the Dimensions of Dynamo-Electric Machines: Carl Kinsley, University of Chicago, Chicago, Ill.

The dimensions are so arranged that a set of three simultaneous equations give the relations existing between the diameter of the armature, its length and the number of conductors in the winding.

These equations are primarily made to depend upon considerations which will determine the satisfactory operation of the dynamo. The *first* equation is made to depend on the electromotive force desired. The *second* equation considers the rise in temperature allowable. The *third* equation determines the efficiency of the machine.

The intermediate assumptions, such as the area covered by the pole piece, affect the ultimate dimensions, but all unite in giving the essential features desired, namely, the electromotive force, rise of temperature and efficiency.

Exhibit of a New Mechanical and Metallurgical Product: C. A. Waldo, Purdue University, Lafayette, Ind.

The new product was shown in two forms. A thin spherical shell two and one half inches in diameter, with a hole one eighth inch in diameter through it, and a reproduction in thin sheet copper of a common quart whiskey bottle. Both products had neither seam nor weld and were not made by electro-deposition. This is accomplished by a new process not yet made public.

Comparative Ductility of Steel under Gradual and Impact Loading: W. K. Hatt, Washington, D. C.

This note describes the results of tests to determine the effect of rapidity of deformation in tension on the ductility of steel. Bars were tested: (1) Under a gradual loading of about ten minutes' duration, and (2) under one blow of a falling weight, causing rupture in from .01 to .05 of a second. The tests cover a range of steel from soft steel castings and boiler steel to hard tire steel. The material was all of good quality.

It is evident from the results that an increased ductility may be expected under impact conditions in the case of soft steel. There seems to be a tendency under impact to develop nodes of ductility in tension bars, and sometimes two or even three distinct necks are formed. This may account for the observed increase in ductility. The phenomenon may be explained by the assumption that the harder portions of the bar transmit the shock quickly, throughout the region that they occupy, to the softer parts where the shock is absorbed in producing deformation. The effect of low temperatures, for instance, is to elevate the elastic limit of steel, *i. e.,* to convert it, from the mechanical standpoint, into a harder steel; and when a bar that is partly frozen is broken in tension the frozen section suffers but little deformation under impact, while the other segments are stretched to the point of plasticity.

In case of harder steels, the indications are not so evident. It is difficult to obtain two bars cast from the same heat of steel that are of the same grain, and comparisons of individual bars are apt to be misleading. In general it may be said that the ductility under impact of hard steels may fall below that under gradual tests depending on influences not understood. There are differences of ductility under impact not detected by the gradual test.

Nicking the surface of a bar renders it less ductile under an impact test than under a gradual test. The shape of the cross-section and condition of surface have a minor influence. In the case of both hard and soft steels the ductility is greater when the bar is broken by a number of blows than when broken with one blow. Within ordinary limits the speed of delivery of a given amount of energy at one blow has no appreciable effect on the ductility. Low temperatures decrease the ductility more decidedly under impact than under gradual loading.

Cementation of Road Material and Elasticity of Clays: ALLERTON S. CUSHMAN, Bryn Mawr College, Bryn Mawr, Pa.

The method of testing the binding or cementing power of road materials was briefly described. It was pointed out that the cementing value was a phenomenon of the same nature as the plasticity of clays. Results obtained in the road material laboratory of the Department of Agriculture, seem to point to the fact that plasticity is dependent on a colloid condition of the particles. No sample has ever been met with that exhibited plasticity that did not contain water of combination, although many samples which contain water of combination do not exhibit plasticity. Only one sort of water of combination (the so-called Micellian water of Nageli and Van Bemmelen) is in any way a measure of plasticity. The inorganic colloids or so-called 'hydrogels' have been studied by Van Bemmelen. They are chiefly characterized by the peculiar structural relation they bear to water. They can be hydrated and rehydrated indefinitely unless by heating to too high a temperature the colloid structure is destroyed. Exactly the same phenomenon characterizes plastic clays and rock powders. The surfaces of roads are continually being powdered by the effect of traffic wear and weathering, and the particles are continually being cemented and recemented. If the material of the road lack plasticity, the particles blow and wash away too rapidly. The binding quality of such rocks as limestones and dolomites is a function of the hydrogel impurities present, usually either in the form of silicic acid or hydrated oxide of iron.

Topographical Work, U. S. Geological Survey: H. M. WILSON, Washington, D. C.

A verbal description of recent topographic work done by the U. S. Geological Survey, the extent of the same as far as completed being shown upon a map of the United States.

TUESDAY EVENING, DECEMBER 30.

Construction of Washington Monument and Library of Congress: BERNARD R. GREEN, Washington, D. C.

A description of the construction of the monument, illustrated by a series of photographs.

Rapid Primary Triangulation: John F. Hayford, Washington, D. C.

This paper is a statement of the results secured by a triangulation party on the 98th meridian triangulation in Kansas, Oklahoma, Indian Territory and Texas, during the season of 1902, and of the peculiarities of their methods. This triangulation is fully up to the primary standard degree of accuracy, and it is believed to be the most economical as well as the most rapid triangulation of its class yet executed.

Reaction versus Velocity as an Active Agent in Removing Bars: Lewis M. Haupt, Philadelphia, Pa.

Necessity for channels of larger capacity across ocean bars, to keep pace with the growth of vessels and commercial demands. Present resources of the engineer limited to concentration and dredging. Defects of this system, with illustrations.

Reaction, the cause of deep holes and channels, rather than mean velocities. Eddies which scour and those which deposit. Applications of reaction, as exemplified in nature, to effect similar results locally across ocean bars, illustrated. Great economy and efficiency of the single-reaction breakwater as compared with other methods in vogue.

WEDNESDAY MORNING, DECEMBER 31.

Notes on Comparative Designs of Metallic Arch Bridges: H. S. Jacoby, Cornell University, Ithaca, N. Y.

A comparison of the weights of three-hinged spandrel-braced arches for different heights of the crown hinge, ranging from the bottom to the top chords. The effect of variations in bridge specifications upon the weights of two-hinged arch ribs and spandrel-braced arches. The effect of different curves for the lower chord.

Road Material Laboratory: L. W. Page, Washington, D. C.

This paper describes different road-making materials and points out the wisdom of having them tested by laboratory methods before they are used in construction. The amount of traffic on one road may not require the same kind of material that another road should receive. The binding materials present with crushed rocks of various kinds have much to do with their value for surfacing roads. The road-material laboratory of the Agricultural Department makes these tests free and invites an inspection of the equipment and methods used in the examination of road material.

Agricultural Engineering: Elwood Mead, Washington, D. C.

Conditions of farm life and farm labor in the United States have undergone a revolution in the past fifty years. The shorter hours of labor and conditions of life in factories are having their influence on farm work. The farmer is compelled to do as the factories have done, substitute power for hand labor and use the most effective implements and machines. Application of power to farm work is taking new and significant form through the use of steam, gas and electricity as substitutes for animal power. Increasing importance of this evolution has attracted the attention of European countries, where institutions for the study and improvement of farm machinery are supported by the state.

The agricultural colleges of this country have in recent years given serious attention to this subject. A committee on methods of teaching agriculture has formulated a course in the subject which has been published in Bulletin 45, on pages 6 and 7, of the Office of Experiment Stations. One difficulty confronting the colleges is the lack of classified and verified information.

The interest shown in this subject shows that the time is ripe for further action.

The Mechanical Problems of a New Ore-producing Territory: C. A. WALDO, Purdue University, Lafayette, Ind.

A recently discovered copper and silver district in the Pan-Handle of Oklahoma is thirty miles distant from railroad transportation. The problem is to secure power to concentrate the ore at the mine. Electric power generated by the water of a stream twenty miles distant may be used, or gas engines adapted to the use of Texas oil may be more practicable.

The Metric System: J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

The advocates of the metrical system are pushing it more than it is worth. If its opponents would get up a *system* of their own there would be less chance of its success. Its main advocates are scientific rather than practical men, who make use of the less important parts of the system.

Taking up these points in reverse order, we remark that the less important part of any system of weights and measures is that which this designation indicates, with measures restricted to those of capacity. Measures of length form the most important part of any system. Measures of quantity and weights of different kinds often exist, and are in common use together without difficulty, though in scientific work involving accurate calculations trouble may result. Now, those who advocate a legal compulsory introduction of the metrical system are mainly interested in this end of it, and have little idea of it from the other and more important one. Standards of length lie at the foundation of all our important and accurate manufacturing and engineering work, and an examination of the necessities of this work, in both its theoretical and practical parts, shows that a change to the metrical system would be not only very expensive, but detrimental. It is difficult to estimate the cost of a change from the inch, with its multitudinous ramifications throughout the mechanical world, to metrical units; it would be enormous, and what advantages has metrical measure that the inch may not have, and much more? As to the size of it, the meter has nothing better to offer; and as to its subdivisions that into sixteen parts is far better that that into ten, except for certain purposes of calculation, and here the right thing to do is not to change to ten, but to so improve calculation by sixteenths as to make it also better than reckoning by tenths. This leads to the next point, or that of a system of calculation by sixteenths which shall be superior in all points to that by tenths.

The doubts that one may have as to the possibility of this are illusory, and mainly founded on the mistaken idea that the advantage of the so-called decimal system has anything to do with the number ten. 'Decimal' is a misnomer. 'Digital' would be quite as good, but neither touches the system itself, which consists in the values of the consecutive places, units place, tens place, etc., being in geometrical progression. The system would exist and have its characteristic advantages with any number as the ratio of this progression.

Now, sixteen is in many ways a better number than ten, and the change to a system having sixteen as its ratio or root would be such a change as a Chinaman has to make in adopting a European language with its methods of writing and printing and reckoning. A Chinaman might not understand if he were told that his language was inferior, say, to German, any more than a devotee of the meter can see that his idol is at most a poor stick lacking in the proportions needed for common measurements.

The next or first point follows from this, which becomes clearer as the matter is further examined, and the peculiar collateral advantages of sixteen are appreciated. To do this fully will require another paper, but some of them may be mentioned in the hope of eliciting comment and discussion.

The Drainage Problems of Irrigation: C. G. ELLIOTT, Washington, D. C.

A new problem confronts the owners of irrigated lands. The leakage from canals, and over-irrigation by users of water, have destroyed the productiveness of land by producing saturation of soils in certain localities, and resulting alkali conditions. Well-directed drainage operations will reclaim such lands and protect those which are threatened with the evil.

Second Law of Thermodynamics: J. BURKITT WEBB, Hoboken, N. J.

Various attacks have been made on this second law, and in a recent one by Jacob T. Wainwright, of Chicago, of which I shall not attempt a full criticism, there are some peculiarities, two of which may be worthy of remark.

In the first place the writer seems ignorant of, or avoids, Rankine's work in this direction, which, to my mind, contains the best statement and proof of the law, in no way touched by his remarks.

The proof is like a nutritious nut—crack the shell, or, failing that, gnaw through it, and you have a perfect kernel, the living germ of the second law, from which so much valuable fruit has sprung.

The simplicity of the proof makes the nut hard cracking for some. He holds that evidently heat is of such a simple, homogeneous nature that all its differential elements must have the same effect, and, further, that all the infinitesimal elements of temperature must have equal effects, which last is analogous to the statement that when the camel's back breaks each element of weight has the same effect—the first straw being equal with the last in the actual catastrophe. From this the division of each element of heat by its absolute temperature and the second law follow easily.

Secondly, the author's claim that Clausius's proof is faulty (as I pointed out years ago) is correct. Clausius proves the form of his function on the principle that in a reversible cycle all natural working substances must be equally efficient, and then attempts to define the function exactly by discussing the properties of a perfect gas—a theoretical working fluid which does not exist in nature. The proof, therefore, fails in default of a further investigation showing that the absence of the natural properties which a theoretically perfect gas lacks does not vitiate the result.

Theory, Construction and Use of a Pressure-tube Anemometer: A. F. ZAHM, Catholic University, Washington, D. C.

The present paper describes the design and use of a pressure-tube anemometer whose observed readings conform to those required by theory. The instrument consists of a double-pressure nozzle connected with a differential pressure-gauge. One nozzle transmits the direct impact of the air, while a side nozzle gives the static pressure of the current at the same point. Their difference is theoretically proportional to the velocity-head, and serves to determine the velocity of the air when its density is known. To prove the agreement of the theoretical and actual pressures sustained by the nozzles, the following facts are experimentally established:

(1) The pressure on the direct impact nozzle is proportional to the total head; (2) the pressure on the side nozzle equals the true static pressure of the point; (3) the differential pressure is proportional to the true velocity head, since the velocity

calculated therefrom equals the known velocity of the air; (4) the differential pressure varies exactly as the square of the velocity, as required by theory. The air velocities employed ranged from five to thirty miles an hour, and the pressure gauge was graduated to millionths of an atmosphere. The experiments were conducted in a tunnel through which air was drawn with uniform velocity and direction, its velocity being measured simultaneously by the pressure-tube anemometer and by a balloon anemometer. In the latter device a toy balloon drifting through the tunnel cuts two pencils of light thrown squarely across its path at an interval of ten feet, the time between the cutting of the sheets of light being determined photographically. The average wind-speed determined by means of the pressure-tube anemometer agrees with the average determined by the standard, or balloon anemometer, accurately to less than one per cent. Examples are also given of the use of the pressure-gauge for measuring static pressures from one millionth of an atmosphere upwards.

Hydrographic Work of the U. S. Geological Survey: H. A. PRESSEY, Washington, D. C.

The work of the Survey in measuring the flow of all the important streams in the country is described, and the great value of the results to industrial projects pointed out.

Friction in Ball-bearings: M. J. GOLDEN, Purdue University, Lafayette, Ind.

The paper describes an apparatus used to determine the friction of ball-bearings of different sizes at different speeds. It was shown that at high speeds ball-bearings fail entirely. Ball-bearings for ordinary pressures and speeds give a loss by friction less than that of an ordinary bearing poorly lubricated, but not much less than a finely polished and thoroughly lubricated bearing.

Errors in Analyses of Furnace Gases Shown by Computation: WILLIAM KENT, Passaic, N. J.

It is shown by arithmetical computation based on the analyses of a certain coal that the analysis of the gas from the chimney, as reported by the chemist, must be in error. With such an analysis it is impossible to compute a heat balance in a boiler test with any approach to accuracy.

Heat Exchanges Within the Steam-engine: R. H. THURSTON, Cornell University, Ithaca, N. Y. (Not read.)

The method of heat exchange in the steam-engine cylinder, which results in serious wastes of heat and proportional reduction of the efficiency of the machine, has been considered an obscure phenomenon. The experiments made by Professor Dwelshauvers-Dery and by M. Duchesne indicate that the cylinder wall takes the temperature of the steam as long as it is covered with moisture; but when the wall is dry it may hold a temperature considerably in excess of that of the steam in contact with it. During expansion and compression of steam in the cylinder there is a constant interchange of heat, which accounts for the varying efficiency of the steam as a motor. Experiments conducted at Sibley College of Cornell University sustain these deductions. The experiment is described and results shown graphically.

ELWOOD MEAD,
Secretary.

SECTION E, GEOLOGY AND GEOGRAPHY.

SOME forty-five papers were offered to Section E for reading at the Washington meeting. On account, however, of the conflict with the meeting of the Geological Society of America, all the papers of the Section E program were accepted by the