The righting of the power situation requires (1) the establishment of a comprehensive system of electric transmission lines to be administered as a common-carrier system like the railways. (2) The provision of such a system will necessitate the coordinated growth of central power stations in coal fields and at water-power sites, and in doing so will open to business enterprise a tremendous field of opportunity hitherto closed off from entry, and thus lead to the balanced development of the two major energy resources, coal and water-power. (3) The principle of multiple production, recognized and incorporated in national policy, will supplement the additional service gained through the organized employment of the electrical principle; applied to the production of coal-generated electricity, and, through the medium of municipal public utility plants, to the distributive employment of coal, this principle will effectively correlate the recovery of the commodity and energy values, so as ultimately to effect a full saving of the former and an increased gain of the latter, thus permitting a further relative diminution of the amount of fuel calling for transportation in bulky form. The first two points reduce themselves to a single issue, which is purely a business proposition to be handled by a business organization; the third item is more intangible and it is a matter of policy, which, therefore, can not be delegated or otherwise handled in objective fashion.

The provision of a common-carrier system of transmission lines, in brief, is the key to the whole problem. Its establishment will remove the retarding influence of high interest rates and antagonistic misunderstanding that has blocked water-power development, and will afford the point of departure from precedent in favor of coal-field generation of electricity. Owing to the magnitude of the issue and the manifold lines of progress directly at stake, the development will provide a nuclear point for the establishment of a constructive economic policy, needed not merely for the full development of this field but as well for proper unfoldment of the industrial possibilities of the country in general. As such a policy has not developed in the past because of economic sectionalism growing chiefly out of an unequalized development of the energy resources, the nationalization of industrial opportunity attainable through a balanced development of power supply will clear the path of the main obstruction to unified action.

Thus specific action in respect to establishing a common-carrier system adapted to the power needs of the country will not only go far toward solving the problem of transportation, but it will improve the fuel supply, correct the economic fallacy of drawing upon capital resources while neglectful of income, contribute to the recovery of the values now lost in the consumption of raw coal, lead to an adequate development of electrochemical activities, cut off a needless annual expenditure running well beyond the billion dollar mark, and constitute a potent contribution in the direction of stimulating the upgrowth of a constructive economic policy of national scope attuned to the needs of modern industrial development. It is believed that these results would involve national economies, offsetting in large part the cost of the war.

SPECIAL ARTICLES

THE COEFFICIENT OF EXPANSION OF LIVING TREE TRUNKS

THE present investigation was undertaken as a continuation of the work of the late Professor C. C. Trowbridge, of the Department of Physics, Columbia University, on the movements of the branches of trees, with the object of inquiring into the mechanism of these movements. Part of the work had been carried out in collaboration with Professor Trowbridge.

The measuring apparatus, as devised by him, consisted of a rod of invar, with four steel knobs set on short steel posts fitted into the rod near one end, at intervals of ninety degrees, and also with one or more small brass blocks in the form of square prisms, fitted over the rod at some distance from that end. A steel-pointed block and a conical steel socket were attached to the tree under investigation, and a measurement was made by holding one of the steel balls in the socket, and making a light scratch on the brass plate by gently drawing it over the steel point. A careful record was kept of the exact position on the brass plate of each of the scratches made, and the distances between them were measured under the microscope. In the tests made previous to the tree-trunk work, the instrument was found to be suitable for general laboratory work as well as

[1] C. C. Trowbridge, "The Thermometric Movements of Tree Branches at Freezing Temperatures," *Bulletin of the Torrey Botanical Club*, 43, No. 1, pp. 29–56, 1916.

for special types of investigation. Together with each measurement a reading was taken of the air temperature as given by a mercury thermometer attached to the tree, as well as the reading of one or more thermometers inserted into the tree to various depths.

Observations were made on a European linden tree (*Tilia europœa*), and a plane tree (*Platanus orientalis*), both on the campus of Columbia University. The observations extended from February 2 to May 19, 1917, and from December 22, 1917, to April 25, 1918. During the first winter, observations were made on both of these trees, but attention was confined to the linden tree alone during the second winter, as the same effects were observable here to a far more marked degree. During both winters, longitudinal and transverse measurements were made, a separate point and socket being used for each, and a longer rod being used for the longitudinal observations, as the longitudinal changes were, as a rule, much smaller in amount. An extended series of measurements was also made on the changes in the circumference of the tree and on frost cracks, during the second winter. Three interior thermometers were used in the first winter's observations, four in the second, one extending to a somewhat greater depth than the deepest of the previous winter. No observations were made during the summer, as it was found that at ordinary and high temperatures, the changes in dimensions were extremely slight. Observations were made from one to four times a day, and readings of the various thermometers were sometimes taken more frequently. During the winter of 1917–18, the writer made 109 sets of measurements, and about the same number during the preceding winter.

The second winter's observations fully confirmed the earlier series, and added some new results. In regard to the transverse measurements, it was found that above 32° Fahrenheit there is a slight expansion with rise in temperature, while below that temperature the changes are far more marked. As the temperature falls below 32° Fahrenheit there is a very marked transverse contraction. The difference in the changes above and below freezing may best be illustrated by stating, in the case of the linden, that above the freezing temperature, the coefficient of expansion is nearly the same as that of dead wood, *i. e.*, of the order of 5×10^{-5}, while below freezing it is some fifty times as great.

The transverse change in dimensions of the tree, below freezing, usually lags behind the change in temperature of the bark by several hours at least, often as much as twenty-four hours. When there is a sudden change in the temperature of the bark, the contraction is rapid, but not synchronous. With a rise in temperature, the lag, as a rule, is relatively greater. It is probable that the temperature at a depth of four or five inches has little or no influence on the changes in transverse dimensions.

In the case of longitudinal measurements the fact was revealed that below the freezing temperature there is a minute but extremely definite *increase* in length with *fall* of temperature, and that above freezing, there is an equally minute *increase* with *rise* of temperature. At extremely low temperatures, near zero, Fahrenheit, however, there is a small *contraction* with fall of temperature, but when the temperature rises again, the expansion is extremely rapid, and by the time the temperature is again the same as before the drop, the tree is very much longer than previously.

In this series of measurements at very low temperatures, there is distinct evidence of two changes—thermal and physiological, apparently acting in opposite directions. At slightly higher temperatures the thermal change is not so much in evidence, and so, as a rule, only the physiological expansion with drop of temperature is observed. There is evidence of a lag of longitudinal expansion and contraction behind the temperature of the bark of the tree, but excepting at the lowest temperatures, the phenomenon is not clear cut, as in the case of the transverse measurements, and the details have not as yet been worked out.

A very extended series of measurements was made on the circumference of the linden tree, and it was found that, as a rule, the expansions and contractions were in the same direction as for the transverse measurements, but yet this was not always the case. The changes in circumference were found not to be proportional to the transverse measurements. After more than four months, when the temperature was much higher than at the time observations were begun, the circumference of the tree was still *smaller* than when the first observations were made. The method of making observations on the circumference consisted in measuring, with a pair of dividers, the distance between two scratches on a painted steel tape surrounding the tree, and continuously left in contact with it. When the series of observations was begun, two scratches were made, one on each of the two parts of the tape which lay, one directly above the other, and, as the circumference changed, the distance between these scratches was recorded. These measurements were made several times a day, and showed that the final contraction, which Grossenbacher[2] thought might possibly be due to an error in his measurements, is an actual experimental fact. Grossenbacher's observations were made at intervals of several weeks, and his tape was removed after each observation.

An equally extended series of measurements on frost cracks was made during the winter of 1917–18. It was found that during the coldest weather when the crack was open about three fourths of an inch, its depth at certain points was more than ten inches. Also, in addition to the large crack formed on the south side of the linden tree, another was formed on the north side toward the end of January, 1918, and the change in the width of the two cracks seemed to follow the same law, *i. e.,* the cracks became wider as the temperature fell, and narrower as it rose again.

From the measurements on the transverse changes, on the circumference and on frost cracks, the conclusion was reached that frost cracks are caused by a tearing apart of the tissue of the tree, due to a great *contraction.* Both the circumference and the transverse dimensions are much less when the crack is open than when it is closed, and the one is not proportional to the other.[3] Frost cracks are probably due to a difference in the coefficients of radial and tangential contraction of the tree, a difference which sets in at approximately 25° Fahrenheit (about 4 degrees below zero Centigrade). If the cells of the tree collapse in a tangential direction (a fact which was observed) and the changes along the medullary rays are not as great, then the tree will split open, due to the increased tension. If the cells again expand tangentially, the crack will close due to increased pressure, provided the radius may not change in dimensions at all, it may expand to a greater extent, or it may even contract; in any case the crack will close. The first or third of these cases would account for the observation that after the crack has closed, the circumference of the tree is less than before it opened. These conclusions are, however, tentative and approximate, due to the complications caused by the lag in the tangential direction, the temperature gradient through the tree, and other difficulties which must still be studied, before a more complete explanation can be given.

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THE DEPTH OF DOLOMITIZATION[1]

In a recent issue of the *American Journal of Science*,[2] there appeared an article by E. W. Skeats on "The Formation of Dolomite and its Bearing on the Coral Reef Problem." The author of this paper adopts the replacement theory of the origin of dolomite and presents

[2] J. G. Grossenbacher, "Crown-Rot of Fruit Trees, Field Studies," N. Y. Agricultural Experiment Station, Geneva, N. Y., Technical Bulletin, No. 23, September, 1912, pp. 35–37.

[3] Some similar conclusions were reached by a different method by Caspany, *Bot. Zeit.*, 15, 1857.

[4] Deceased.

[1] Published with the permission of the Director of the Iowa Geological Survey.

[2] Volume XLV., 4th Series, pp. 185–200, March, 1918.