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ON FLINT'S INVESTIGATION OF THE NICARAGUAN WOODS.

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PRELIMINARY REMARKS. BY R. H. THURSTON.—It had long been a conviction of the writer that the tropical and semi-tropical countries of America possess a large number of valuable timber trees of which nothing is known by our engineers or builders, but which, for some of the more important purposes, as well as for ornamental and exceptional constructions, may have extraordinary value. As the process of stripping our own land of timber goes on, and as our pines and finer grades of timber trees become gradually more and more difficult and costly of procurement, the necessity will become more and more pressing of going into the more heavily forested countries nearer the equator for our supplies of lumber. It is thus becoming continually more important that we learn something of the resources of such countries, and especially of the useful qualities of the woods available for building purposes. A knowledge of the extraordinary strength, and of the other valuable properties of some of these timbers, will unquestionably, in time, lead to the opening of our markets to them, and to a trade that may prove to be of inestimable advantage to both purchaser and vendor. A few years more will see the great forests of the Northwest stripped of their best timber, and the supply will then be mainly drawn from the South and the Pacific Coast; but the enormous rate of growth of the country in population, and still more in manufactures, will sweep those districts clean at a rapidly increasing rate of destruction, and it will be found, probably much sooner than is now generally imagined, that we must look elsewhere for the enormous supplies demanded by our markets. The growth of this demand is a geometrical one.

That most remarkable of recent works on economical subjects, that romance of statistics, *Triumphant Democracy*, gives some striking facts abstracted from the last census. Mr. Carnegie finds that our lumber trade has quadrupled within the generation, the business now employing about 150,000 men, and producing nearly $250,000,000 worth of lumber. About $40,000,000 is invested in this trade in Michigan alone, and the three states, Michigan, Minnesota and Wisconsin cut, in the year 1880, over 7,000,000,000 feet of timber, in the form of marketable lumber, besides millions of feet in the shape of railroad ties and other minor products. It is estimated that the pine forests of the northwest will be gone in about twenty or twenty-five years; but the southern forests are of much greater extent. It is not certain that we shall very soon be entirely deprived of the light and comparatively soft growing woods; but their extinction would seem to be but a matter of time, and, as the lives of nations are counted, not a long time.

Mr. Jessup has collected for the New York Museum of Natural History some 400 varieties of North American woods, including very many which are of very great value for constructive purposes; some of these, as the sycamore, have not been as yet much used, but are now being found to have peculiar value for special purposes. The consumption of these hitherto neglected timbers will continually and rapidly increase. Others, as the live oak of our Gulf States, have been used exclusively for special purposes, as in ship-building, and have, by the progress of improvement in the art, been thrown out of use, to come in again at some later time in a way as yet unforeseen. The soft woods are those which, from their soundness and especially from the ease with which they can be worked, are in greatest demand, and, fortunately, they are those which have hitherto been most plentiful and cheap in our markets; but they are gradually becoming less accessible and more difficult of procurement; their cost is thus threatening to become seriously increased, and we are likely to be compelled to find ways of substituting the hard woods for the soft in our constructions. A century ago, oak was the most common of building timbers in the older countries of the world; it seems now possible that it, and the other hard woods, may, in time, again come into general use; but, if so, we must, after a time, go into the southern and neighboring states for such woods. Once we are brought to the use of such hard woods again, we shall, perforce, be brought to the construction of buildings capable of withstanding the teeth of time as effectively as did those of our ancestors of the middle ages.

We are to-day sending out into the markets of the world, annually, something like $30,000,000 worth, probably, of wood, in the form of manufactured articles mainly, particularly as furniture, and the time is coming when we shall supply a very large part of the world with its timber and manufactured wood products; but this will only hasten the day when we must look to the West Indies and to Central and Western America, perhaps to South America, for our own supplies.

It was considerations such as have been above outlined that led the writer, some years ago, to endeavor to secure such data relative to the useful qualities of the tropical and semi-tropical woods as would, in the course of time, prove useful to our own people as well as to the citizens of those neighboring countries to which we shall be likely to first look for our supplies of the heavier sorts of timber; for it will be seen that nearly all of the semi-tropical and tropical woods are of the hardier varieties and are distinguished rather by their hardness and strength than by lightness and ease of working—the peculiar qualities of the varieties of the coniferæ from which we obtain the greater part of our timber to-day. The first attempt to investigate these hard woods of the warmer latitudes in a systematic and satisfactory manner was probably that undertaken some ten or fifteen years ago by French engineers and naturalists studying the trees of New Caledonia. Later investigations of a similar character have been made, usually since the work directed by the writer about to be referred to as initiating his own researches, by British authorities, in India and in the Australasian colonies of Great Britain. The first systematic study of these classes of woods in America, so far as the writer has observed, was made at the suggestion and request of the writer by Mr. E. D. Estrada and published in Van Nostrand's *Magazine* for November and December, 1883. Recently, another investigation has been undertaken in the Mechanical Laboratory of the Sibley College, Cornell University, by Mr. Rufus Flint, the results of which will here be presented. Mr. Flint, although by descent on the father's side an American, is a native of Nicaragua, and, until coming into the United States to obtain his education, has been a resident of that country. Through his relatives and friends and assisted by the liberality of the Government, which allows such material to enter duty free, Mr. Flint has been able to secure a fine collection of the woods of Nicaragua, and thus to enter upon a research as important in its bearing upon the business interests of his own country and of the United States as that conducted by Mr. Estrada.

Examining the data thus secured by these investigators, we find that the tropical woods are distinguished by their extraordinary strength, elasticity, beauty of grain and durability. The few already known to us, such as mahogany, rosewood and some of the cedars, may be taken as illustrations of the several principal classes of timbers to be found in the forests of Central America and the Islands of the Caribbean Sea. These woods are all coming into demand very rapidly already, for house decoration, and in the construction of the finer grades of furniture, and an examination of the magnificent collection gathered at New York, by Mr. Jessup, will reveal the fact that we have but begun to make application of the enormous variety of woods which are readily obtainable and available for such purposes. These statements will be seen to be true of the woods of Central America here to be described, as well as of the Cuban woods already reported upon. In both cases, but a few of an immense number of woods have been taken for investigation; but these selected samples may be taken as illustrative of the whole product of this vast arboretum. The tropical trees attain enormous sizes, are extraordinarily solid, close and firm of grain, excel in the beauty and variety of their coloring, in fineness of texture, and especially in their wonderful durability, whether exposed to the corroding influence of the atmosphere, to the action of heat and moisture, or to the attacks of insects. Ironwood and lignum vitæ exemplify the first of these characteristics; mahogany, rosewood, tulipwood, and others, illustrate their beautiful color and grain; and the live oak and teak are good examples illustrating their power of resisting the action of oxygen and the attacks of the teredo and of the limnoria.

The investigations of the Central American woods were made in the several testing machines and the workshops of the Sibley College, and the results were reported to the writer in a paper presented in June last, the substance of which is here given. The report is so well written and so complete that it has been thought best to give the whole in the words of the observer. The figures have been very carefully checked, and are believed to be perfectly reliable throughout. The machines used had been standardized and were known to be practically exact, and it is thought that the data thus obtained, as here given, may be of real value to the profession, as well as to the two countries most nearly interested in the results of the research. The native nomenclature is given throughout. It was found difficult to obtain the botanical names of all these woods, and, in many cases, those obtained were subject to some question in consequence of the fact that the botanists seem to have had comparatively few opportunities of study of these woods; but the introduction of the timbers of these regions into our own markets will undoubtedly lead to the adoption of the nomenclature obtained in their homes, and no inconvenience will arise, it is thought, from the omission of the technical names.

The examination of the Cuban woods, to which reference has been made, showed moduli of elasticity as deduced from the experiments on transverse stress and strain, varying from 1,500,000 to 2,500,000, British measure, the great majority of the dozen and a-half varieties studied ranging above 2,000,000, or equalling the stiffness of the Indian teak, and exceeding that of any known variety of our native timber, with the exception of an occasional sample of the strongest and stiffest of the choicest of Southern long-leaved, yellow pine. The figures for the best of the Cuban woods are above those of any known North American woods, exceeding their best figures by fifty per cent., nearly. Three-fourths of them are stiffer than the best teak. The moduli of rupture by transverse stress vary between 15,000 and 20,000 pounds per square inch, as a rule, in but one case falling to 8,000, and in several exceeding 20,000, the average being not far from 18,000. The densities average above that of water, and many samples exceed that unit by some twenty per cent. Quite a number of these woods have just the qualities which distinguish yellow pine of the finer grades; for example, Baria (*Cordia gerascanthoides*) and Caobilla (*Crotos lucidam*), as representing the lighter varieties, and Majagua (*Paritium elatum*), an even lighter and stronger wood; Dagame (*Colycophyllum candidissimum*), one of the most common of West Indian woods, weighing but fifty-six pounds per cubic foot, and having a modulus of rupture of 16,000 pounds.

Sabicu (*Mimosa adorantissima*) has just the weight of water, or a trifle less, and, with a modulus of elasticity of about 2,400,000, exhibits a modulus of rupture exceeding 20,000. A dozen of these varieties are higher in rank than the best building material found in our native forests.

The Central American woods, growing on a more widely distributed area, in a soil of less uniform character and in a greater variety of climate, are naturally of more widely differing character than those of Cuba. The high and dry atmosphere and more innutritious soil of the interior, and the rich bottom lands of the swampy regions of the coast, with every intermediate condition of soil, climate and exposure, produce timber of soft as well as hard varieties, of less as well as of greater strength or elasticity, and thus yield to the market a larger assortment of useful woods than could any insular district. The moduli of rupture, as determined by Mr. Flint, vary from 7,000 to nearly 30,000, and the moduli of elasticity from about 600,000 to about 2,500,000, usually approximating 2,000,000, the modulus of rupture commonly falling at about 22,000.

INTRODUCTION BY RUFUS FLINT, M.E.

The woods of Nicaragua, grown under the sunny sky of the Torrid Zone, and in the mountains, valleys and on the sandy shores of the Atlantic and Pacific Oceans, are many in number and of widely different character in nature, strength and color. Unrestricted in their growth, in the exuberant and wild forests and woods of the country they attain enormous sizes, and exhibit great strength and solidity.

As a general rule, they are of delicate hues and beautiful colors, exhibit extreme fineness of grain and have marked peculiarities in texture and general appearance.

The investigation of their strength and natural properties is a matter of great interest. With the facilities offered in the Mechanical Laboratory of Sibley College for complete investigation of the materials of construction, I have thought it advisable to conduct such an investigation of a few of the Nicaraguan woods so as to make known the characteristics, not only of those that have found their way into the markets of this country and of Europe, mainly because of their worth as dye woods or for ornament, but also some others, perhaps of better if not equally prized properties, which have yet remained unknown in the industries.

In undertaking this investigation, I hope to find results which may prove of value and interest to the artisans of my native land, and also aid in developing, to a certain extent, the commerce and industries of Nicaragua, by making some of its natural products known in the United States and Europe.

I have restricted myself to the study of those woods which are most used in engineering construction and decoration, leaving out the dye and other woods, which, perhaps, may be of equal interest and value, there being quite as many unknown, or at least unused, valuable woods and plants of this latter kind.

I was encouraged from the start by Prof. Thurston, who very kindly wrote to the Government of Nicaragua, asking for a collection of the most important woods of the country, expecting that its officials would take, or at least show, some interest, and thus secure a good collection of the woods. But unfortunately we were in this disappointed. It was by my father's interest, kindness and persistence, and through my friend Miguel Ugarte's active and courteous help, that I was supplied with as good a collection as could be obtained in the short time allowed to collect them. Steps were taken to get the woods, seasoned and sound, from persons engaged in working them, but they failed to obtain them. It is for this reason that the woods tested have not been entirely satisfactory, as they were cut green, and the men could not in most cases fell large trees to get the heart or the best of the wood; as a consequence, they checked on the way, and many of them were found to be knotty. The woods were collected in one month, within a circuit of three leagues, on the hills about Belen in the agricultural and chocolate-raising "Departmento," of Rivas, between Lake Nicaragua and the Pacific Ocean. Some few, obtained from a carpenter, are seasoned. My collection of fifty different varieties represent about half the number of the useful woods of the country.

The terms used may be thus defined: The modulus of rupture for tension is the force necessary to pull asunder a bar whose section is one square inch, when acting in the direction of the axis of the bar.

The modulus of rupture for compression is the pressure necessary to crush a piece of any material whose section is unity and whose length does not exceed about five times its diameter.

The modulus of rupture for transverse stress is the stress at the instant of rupture upon a unit of the section which is most remote from the neutral axis on the side which first ruptures.

The modulus of elasticity is a value which expresses the relation between the extension, compression, or other deformation of a bar, and the force which produces the deformation.

Resilience is a measure of the capacity of a material to resist shock, and its value is equal to the amount of energy expended, or the " work " performed in producing distortion or rupture.

GENERAL DESCRIPTION OF THE WOODS.

(1.) *Carbon.*—Extraordinarily solid, equalled only by the Piedra and the Quiebra-hacha. Is almost imperishable when used for posts, and is supposed to be very good for railroad ties. The tree attains a height of 30 feet, and measures 12 inches in diameter. Is common in most of the wooded districts. The wood is of a very fine grain, with peculiar dark streaks; very much like the mahogany in appearance and in color, but heavier and much handsomer. Is easy of working, and turns very smoothly.

(2.) *Cedro* (Cedar.)—The wood, on account of its peculiar properties, has found a place in all the markets abroad. In Nicaragua, it is found abundantly, and attains enormous sizes. Is used extensively for furniture, frames, book cases, etc. It is even used by the Indians for boats, which they work out entire from the trunk of the tree.

(3.) *Chaperno.*—Dark red color, turns and planes very smoothly. It has a fine grain and great strength and is susceptible of high polish. It is used extensively for cross pieces of drawers and tables. Is extremely durable. There are two varieties of this wood, black and white, as they are called respectively. The tree attains a height of forty feet.

(4.) *Chiquirin.*—Dark yellowish wood with a strong cedar smell. Is heavy, fine grained and planes smoothly. The tree attains a height of thirty feet, and one foot in diameter. It has various uses, is durable, and having odor is probably not subject to attacks by insects.

(5.) *Cortez.*—Extremely heavy and very fine-grained, of a very dark yellowish color. When broken in splinters, it gives off a fine yellow powder, which has similar properties to litmus; it turns bright red when mixed with soap water. It is a large tree like the Nacascolo. It is used in cabinet work, for framing, etc. The only place in which I can remember to have seen it growing is on a rocky hill at the foot of the volcano Mombacho, near the shore of Lake Nicaragua. The hill is covered with these trees, which, in the beginning of every spring, are a beautiful sight, being covered with yellow flowers.

(6.) *Granadillo-negro.*—Wood very much esteemed for interior decoration, on account of its handsome dark color, fineness of grain and ease of working. The tree attains a height of thirty feet, and is found on the shores of the rivers which flow into the eastern side of Lake Nicaragua.

(7.) *Gauchipilin.*—Fine grained wood of a light yellowish color, heavy and tough. The tree attains a height of 30 or 40 feet, and has a diameter of 15 inches. It is irregularly branched. Much used by the artisans for durable work, as it resists moisture for years. It is also used for telegraph poles and railroad ties. Is abundant all over the country.

(8.) *Guapinol.*—The tree is nearly as large as the Jenisero, and its branches large but more erect. The wood is of a light mahogany color, long grained, but very compact, heavy and tough. Is used almost exclusively for cylinders of sugar cane mills, while the teeth moving them are made of guachipilin, guayacan or other similar wood.

(9.) *Guayabo de Monte.*—Attains a height of sixty feet, is of irregular diameter, and seldom over two feet above the lateral roots, acting as braces, which support the trunk. It has a fine grain and is very tenacious. The test made probably does not show full strength, as it was an inferior sample. It is used for small masts and the weather streaks of boats. According to Mr. D. L. Murray, who preferred it above all others for launch guards, it resists wear and tear better than any other wood.

(10.) *Guiliguiste.*—A wood unknown to commerce. Has a light brown color in the heart, is fine and fibrous of grain. It ran above the average in compression. It is not as durable as the other hard woods, but from its beautiful grain and color, and from its ease of working, it would seem that it should be used for interior house work. The tree is small, growing only about 30 feet high, with a diameter from 15 to 18 inches.

(11.) *Jenisero*.—One of the most useful trees, and one of the largest in the country. Attains a height of 90 feet, with 7 in diameter, and its large branches cover a space of over 100 feet in diameter. In Nagarote, a town in the Departmento de Leon, at the junction of one of its streets with the large road from the western departmentos, there is a Jenisero whose branches cover a circumference of 348 feet (about 9,498 feet area); it is 90 feet high, and has a circumference of 21 feet at 4 feet from the ground, according to Senor F. Guerreo Baster.

The wood has a light to dark color, and a peculiar grain; it is open and wide in the annual rings, but very compact between. It is used for cart wheels, lasting for years without tires on clay soil. Used also by the carpenters in various ways. Its fruit is eaten by the cattle, and is used to sour the milk. It is fairly well distributed over the country.

(12.) *Jicaro-Sacaguacal*.—Attains a height of 20 feet, and a diameter from 10 to 12 inches. Common on marshy land. It is of a nearly white color and very tough, used in saddlery and for boat-knees. Resists moisture, and is durable in salt water. The shells of its fruits, after being worked, are used by the natives for drinking vessels. They carve them very beautifully and artistically.

(13) *Laurel*.—Dark color, light, strong and elastic wood and very easy of working. There are two varieties, male and female, as they are popularly called. Used mostly in frames for cots, and for work where elasticity is required. The dark kind is preferable. Both have a spicy smell. The tree attains a height of 40 feet, and a diameter from 8 to 12 inches, seldom over 8.

(14.) *Lligualtil*.—This is one of the trees having many peculiar natural properties. Its fruits have a rich fragrance and flavor, and when green give out a coloring substance. From its bark a bluish and sometimes a purple substance is obtained, and from its sap thirty per cent. sugar may be obtained; is one of the most elastic woods found in Nicaragua. It is used for drum hoops, canes, etc. The tree seldom attains a height of twenty feet, and about twelve inches in diameter.

(15.) *Madera-Negra*.—One of the most useful trees found in Nicaragua, not only on account of its durability, strength and excellency for fire wood, giving out intense heat; but also from its method of growth. It is about the only tree used to shade the chocolate trees. It has a rapid growth, and is early produced from the seed. Mostly used for railroad ties, posts for houses, fence posts, foundations, etc. Has a dark, yellowish color in the heart, is fine grained, heavy and tough. It grows with oblong cavities wasting a good deal of the wood when being dressed. However, straight logs, 1 foot square and 30 feet high can be obtained.

(16). *Madrono.*—There are two kinds, white and dark. It has a fine grain, and is heavy. Its strength may be seen from the tests in torsion and by transverse stress. Its growth is irregular and branching.

(17.) *Mahogany.*—This is too well known to demand description. In Nicaragua it is fairly well distributed. The best and most valuable is exported to a considerable extent from the Mosquito territory, where it grows abundantly, and to its fullest size. It is also found along the Pacific Coast in considerable quantities

(18.) *Moran.*—Solid and fine grained wood of a beautiful yellow color. After it has been turned, it looks as if it had been polished; planes very easily. It is exported in great quantities as a dye-wood. Is often used for columns. Attains a height of from 30 to 35 feet. and a diameter of from 12 to 18 inches.

(19.) *Nacascolo.*—The wood is extremely heavy, very fine grained, and of a handsome dark color. Its toughness is shown by the test in torsion. The fruit is known by the names of *Nacascolo* or *Dividi*, and used for dyeing purposes when dry. It is one of the largest of hard-wood trees. Its trunk, although irregular in growth, and seldom over twenty feet to the point where it branches, is 6 feet in diameter. It attains a height of 60 feet, and is found more abundantly on the Atlantic Coast. Is an excellent wood for railroad ties.

(20.) *Nancite.*—Has a soft pink color, fine grain and works very easily. The tree is small, grows on arid hills, and seldom attains 30 feet height. Its bark is used for tanning, and its fruits are to the Nicaraguenses what cherries are to the North Americans.

(21.) *Nispero.*—It may be said that there are two kinds, wild and cultivated. Large fruit tree of a thick and handsome foliage. The trunk is straight and free from limbs. The tree attains a height of 60 feet and a diameter of 2 feet. It is abundant all through the country in farms near the towns and in the wild forests. Exclusively used for wharves, bridges and posts. Resists moisture equal to any of the hard woods, and is said to petrify in the water. The wood is of an exceedingly fine grain, has a beautiful red color, and is very easy working. It behaved the best of any under compression, bulging out considerably before showing any sign of shearing or split.

(22.) *Oja-tostada.*—Has a very light pink color, is fine grained and light. It is one of the most elastic and tough woods tested, as may be seen from the tests by transverse stress and by compression. It is very good for light and strong constructions.

(23.) *Palo de Arco.*—The sample tested planed easily in parts, and in parts less readily, probably on account of being green. Is hard, has a fine grain, and a light red color. It is used for construction where easy of access. It grows along the coast, and in the coast range of mountains, attaining a height of 30 feet and 15 inches in diameter.

(24.) *Piedra.* (Stone.)—Has a fine grain, is heavy and strong, of a yellowish color in the sap, and deep red in the heart. Turns very smoothly and is one of the hardest and heaviest woods known and yet not difficult to turn or plane. The tree attains a height of 40 feet, and has a diameter of from 15 to 18 inches. It is imperishable. Used in many places for pillars and transverse beams of houses on farms distant from towns where it is easy of access. Is abundant on the hills along the coast on the Pacific slope. There are two varieties. It is an excellent wood not only for interior decoration or for heavy furniture on account of its beautiful color and fineness of grain, but also for heavy constructions, as for foundations for engines or heavy machinery.

(25.) *Pochote.*—Tree of enormous dimensions. The wood is similar to the cedar, but much softer. It is used, however, in housework for doors, walls, floors, shingles, etc.

(26.) *Quiebra-hacha* (axe-breaker). There are two kinds, red and black. The latter, which was tested in three ways, is a most wonderfully tough wood. It has a color and appearance like the black-walnut, and its grain is similar to that of the oak. It planes beautifully smooth, and has a pleasing appearance, on account of its dark streaks. The red kind, which grows very straight and spreads considerably, reaches a height of 50 feet, and from 12 to 15 inches diameter. The dark kind, which spreads still more, seldom attains a height of 40 feet. Their name, axe-breaker, indicates their toughness; for in cutting or felling them, the axe is often broken. In cutting the samples received, two axes were nicked to the extent of one-half to three-fourths of an inch. The wood is durable and used for ties, poles, etc., and in posts for houses. One piece that had been for sixty-seven years in a clay soil was found still sound when sawed. The tree is common throughout the state.

(27) *Quita-Calson*.—Its powder acts as a purgative. The tree attains a height of 30 or 35 feet, branching at 15 or 20 feet from the trunk, and often has a diameter of 2 feet. It is abundant along the coast. It is used for boards where not exposed to the weather; it will not resist moisture.

(28.) *Roble*.—Light colored wood of a curly and beautiful grain. It is pink in color and used in house-building. The tree has exceedingly large leaves, 14 inches long and about 7 inches wide, is often 50 feet high, and from 12 to 15 inches diameter. Is abundant along the coast.

(29.) *Ron-ron*.—This is one of the largest of hard-wood trees growing on the shores of the rivers of the Departmento of Chontales on the Atlantic slope. It reaches a height of 50 or 60 feet, and often a diameter of 3 feet. Dark, fine-grained wood, strong, heavy and durable. Is used in cabinet work, turns very easily, and is susceptible of polish. It turns dark with age.

(30.) *Tempisque*.—This tree is of historical interest in Nicaragua, and is one of the largest found in the tropical forests. It attains a height of seventy-five feet or more. The trunk is irregular and seldom reaches twenty feet to the beginning of the largest branches. It has a diameter of 6 feet. The wood is fine grained, hard and very excellent for desks and other articles of cabinet work. Like the mahogany, it turns dark in a few years, and is equally durable. The cattle eat its fruit.

(31.) *Tiguilote*.—Light wood, grows about 30 feet high, and over 12 inches in diameter; good wood for carriages. It is used for fence posts, it easily roots when set with care, thus making a permanent fence and a pretty grove.

(32.) *Zapotillo*.—Of a light mahogany color, has a fine grain, and is light. Attains a height of 40 feet and 1 foot in diameter. It is not very much used.

(33.) *Zopilote* (Buzzard).—Coarse, long-grained wood, but of compact layers when viewed in cross-section. It has a greenish color. Turns and planes fairly well. The wood is used only in neighborhoods where more useful woods are scarce. When unexposed or when well seasoned and protected with paint, it would probably be a valuable wood, as it ran above the average in torsion, was among the highest in compression, and stood well under transverse stress. It attains a height of about 40 feet and 1 foot in diameter.

The Transverse Stress tests were made in the Transverse testing machine of the Messrs. Fairbanks, designed for Prof. Thurston. It consists of a Fairbanks' scale combination with a pointer and beam at the end to secure perfect balance. The whole machine rests upon a wooden frame; upon the platform rests a cast iron cross beam, and upon this slide the supports, which are set and secured by bolts at the required distance apart. The test piece is placed upon the mandrels, which rest on the supports set at the required distance. The loads are put in the scale, and equilibrium is established by the elastic resistance of the piece offered against the pressure transmitted through the screw and pressure block by means of the lever. The screw passes through a nut, and terminates in a sliding piece. The cast iron columns serve as guides to the pressure block. The whole is made stable by wrought iron braces bolted to the wooden frame. The deflections of the piece are measured by the linear advance of the screw, by means of a graduated wheel. The pitch of the screw was found to be equal to 0·33297 inches, and the wheel was graduated into 333 equal divisions, thus reading to $\frac{1}{1000}$ of an inch, with an error of 0·0001 of an inch. The pointer clamped to the screw is placed over the starting division in each case, and after the wheel has been turned and equilibrium established, the reading is taken. This is a very convenient way of reading the deflections, giving the difference directly. The test pieces were planed by hand by an expert, Mr. Kerr, and afterwards measured by means of a micrometer screw reading to $\frac{1}{1000}$ of an inch.

With all the data required, we obtained the results in the same way as in compression tests, by plotting the curve to each test, with loads as ordinates and the deflections as abscissas. This gives the elastic limit more exactly than in any other way. It also shows at a glance the behavior, strength, elasticity, etc., of the material tested.

DETAILS OF TRANSVERSE STRESS TESTS.

(1.) *Carbon.*—28-inch supports. Green sample from the sap, and with a few small knots on top. Like the other, it broke just after having brought the beam up by its elastic resistance, under 650 pounds, and deflected 1·011 inches. Remained unbroken.

(2.) ——— ———.—25-inch supports. A very well seasoned piece, but slightly weakened by a knot where it first gave way. The first rupture occurred at 950 pounds on the weak part. The second under 1,150 pounds with a long and several other small splinters on tension side. Total deflection, 1·687 inches.

(3.) *Chaperno.*—24-inch. A very good sample as regards soundness and seasoning. Cross grained. Broke under 3,700 pounds, with a deflection of 0·496 inch. Broke gradually in small splinters from the bottom side upwards, and crushed slightly on top also.

(5.) *Cortez.*—24-inch. A large sample from near the heart. Excepting two knots on thickness and bottom sides respectively, and checked on sap line on top, it was a fine sample. Its toughness is shown by its behavior under load. Reached the elastic limit at 2,500 pounds, broke at 4,300 pounds, with a deflection of 0·443 inch. Second rupture occurred under 4,650, with a deflection of 1·3975 inch. By diminishing the loads it might have given more ruptures without breaking completely. Broke in several adhering splinters on tension side.

(7.) *Guachipilin.*—11-inch supports. Good sample. The first rupture occurred under 1,800 pounds load with 0·462 inch deflection. After the first rupture it showed a good deal of elasticity in resisting the loads and gradually ruptured slightly under 2,050 pounds. The reason we took this latter for the rupturing load is on account of the behavior after the first rupture, which latter was very light, and on account of a weak point. Both ruptures were very light splinters, and the piece might have shown still more tenacity if the load had been diminished. But here, as in most cases, we were after first rupture only. Almost any kind of wood will behave in the same way if so treated, unless it is very brittle.

(8.) *Guapinol.*—24-inch supports. An inferior sample, knotty near the middle, checked on top, and with a few worm holes. Broke under 1,600 pounds with a deflection of 0·699 inch and with a few splinters on tension side.

(9.) *Guayabo de Monte.*—24-inch supports. The test piece was planed from a green limb. It was checked and knotty on either side of middle line in tension side. The first rupture occurred on account of cross-grain at 660 pounds, with a deflection of 0·477 inch. Ruptured with only one splinter across the bottom side.

(11.) *Jenisero.*—24-inch. Broke at 1,600 pounds, with a deflection of 0·426 inches. When under 1,600 pounds load, brought the scale up when pulling the lever arm, but immediately afterwards broke suddenly in two splinters. It evidently is very brittle.

(18.) *Moran.*—15-inch supports. A very sound and beautiful natural-colored piece of wood. Ruptured in light splinters under 2,600 pounds, with a deflection of 0·432 inches. Remained unbroken and could have still shown tenacity in successive ruptures.

(20.) *Nancite.*—32-inch supports. A good sample. Broke square on tension side, in two pieces, and very suddenly, after having offered elastic resistance to 2,200 pounds, and deflected 1·0765 inches.

(23.) *Arco.*—24-inch. Straight-grained sample, with two knots on bottom side. Broke at 2,000 pounds, with a deflection of 0·679 inches. Second rupture occurred under 1,100 pounds load, with a deflection of 1·116 inches. Ruptured with close splinters on tension or bottom side.

(26.) *Quiebra hacha negro.*—25-inch supports. Excepting a light streak of sap wood on bottom side, where it first gave away, it was a very sound sample. Its first rupture occurred when under 2,450 pounds, with a deflection of 1·693 inches. A second rupture occurred at 2,550 pounds, with a sudden crash and with a deflection of 2·080 inches. It is worth observing that the second rupture occurred with a larger stress than in the first one. The very finely intermingled narrow and regular splinters across the bottom side very fairly exhibit the high tenacity, ductility, as I may be allowed to say, and the uniformity of strength, cohesion and grain of this peculiar wood. Its rupture could very well be taken as the standard rupture of tough woods.

(27.) *Quita-Calson.*—21-inch supports. Season-checked on top,

TESTS BY TRANSVERSE STRESS.

	Wood.	Dist'nce between supports l	Depth h	Breadth b	Stress. E. Limit P	Stress. Rupture P'	Deflection at— E. Limit. d	Deflection at— Rupture. d'
		in.	in.					
1	Carbon, ...	28	1·235	1·470	300	650	0·392	1·011
2		25	1·225	1·215	500	1050	0·478	1·354
3	Chaperno, ...	24	2·000	1·994	2800	3700	0·36	0·496
4	Chiquirin, ...	24	1·772	1·779	1800	2400	0·420	0·611
5	Cortez, ...	24	1·740	1 745	2500	4300	0·443	1·073
7	Guachipilin, ...	12	1·237	1·237	1200	2050	0·277	0·761
8	Guapinol, ...	24	1·498	1·498	900	1600	0·335	0·699
9	Guayabo de Monte, . .	24	1·495	1·495	300	710	0·157	. .
11	Jenisero, ...	24	1·742	1·742	1000	1600	0·426	0·810
13	Laurel blanco, ...	28	1·775	1·730	1400	2150	0·139	0·265
14	Lligualtil, ...	30	1·218	1·218	300	750	0·552	3·284
18	Moran, ...	15	1·627	1·620	1600	2600	0·237	0·432
20	Nancite, ...	32	1·98	1·983	1200	2200	0·4385	1·076
22	Oja-tostada, ...	24	1·239	1·239	400	850	0·352	1·656
23	Palo de Arco, ...	24	1·459	1·492	1200	2000	0·382	0·679
26	Quiebra-hacha-negro, .	25	1·479	1·473	1200	2450	0·395	1·693
27	Quita-calson, ...	21	1·224	1.225	400	750	0·322	0·811
28	Roble, ...	30	1·772	1·768	1000	1600	0·615	1·217
30	Tempisque, ...	24	0·995	0·978	300	700	0·459	1·605
32	Zapotillo, ...	28	1·734	1·734	900	2100	0·318	1·139
33	Zopilote, ...	11	1·225	1.233	1450	2550	0·202	0·462
34	Guacuco, ...	30	1·48	1·480	500	1170	0·438	1·526
35	Escobillo, ...	30	1·745	1·741	0800	1850	0·216	0·826

	Wood.	Stress in outermost Fibre per Square Inch, at— E. Limit. $p=\frac{3\,Pl}{2\,bh^2}$	Stress in outermost Fibre per Square Inch, at— Rupture. $p'=\frac{3\,P'l}{2\,bh^2}$	Total Elastic Resilience $U=\frac{Pd}{2}$	Modulus of Elasticity. $E=\frac{Pl^3}{48\,d\,I}$
		lbs.			
1	Carbon, ...	5613	12162	58	1514400
2		10272	21571	119	1824400
3	Chaperno, ...	12575	16617	504	1672500
4	Chiquirin, ...	11600	15467	378	1496300
5	Cortez, ...	17025	29294	553	2119800
7	Guachipilin, ...	11411	19490	166	614550
8	Guapinol, ...	12206	21699	150	1858400
9	Guayabo de Monte, ...	3232	7649	23	1322000
11	Jenisero, ...	6803	6803	213	879780
18	Moran, ...	8385	13624	189	815100
20	Nancite, ...	7409	13583	263	1456500
22	Oja-tostada, ...	7571	16088	70	1665500
23	Palo de Arco, ...	13602	22670	229	2342900
26	Quiebra-hacha-negro, ...	13966	28514	237	2490200
27	Quita-calson, ...	6865	12872	64	1280300
30	Tempisque, ...	11154	26026	68	2344600
33	Zopilote, ...	12479	22730	141	1017100

and knotty on either side of middle line on the thickness side. Broke just under 750 pounds, with 0·811 inches deflection.

(33.) *Zopilote.*—11-inch supports. With a knot near one support gave away by shearing at the place when under 2,550 pounds. Stopped the test at this point and took this as the rupturing load.

The compression tests were made on the Olsen machine of 14,000 pounds capacity. The machine consists of four columns bolted to a plain cast-iron bed, and supporting on top a plate, in the middle of which one end of the test piece, if for tension, or the rod which holds the measuring apparatus are held by means of steel wedges.

Through the four angles of this bed and through those of that below pass four screws. To these latter is secured a plate, which pulls or compresses the piece, as the case may be. The plate rests upon four knife edges, on three beams or levers, and their ends rest together upon a link hung from knife-edges on each side of another beam, which latter is linked to the end of the scale in the same way. The machine is very sensitive. The scale is divided into divisions of five pounds. The load is applied by means of a crank or a lever, turning a central wheel geared to four others, one on each screw. A powerful leverage and a steady vertical motion of the plate is obtained. The deflections were measured by means of micrometer screws, using the electrical contact. I quote Prof. Thurston's full description of the instrument:

"The instrument consists essentially of two very accurately-made micrometer screws, working snugly in nuts secured in a frame which is fastened to the head of the specimen by a screw clamp. It is so shaped that the micrometer screws run parallel to and equidistant from the neck of the specimen on opposite sides. A similar frame is clamped to the lower head of the specimen, and from it project two insulated metallic points, each opposite one of the micrometer screws. Electric connection is made between the two insulated points and one pole of a voltaic cell, and also between the micrometer screws and the other pole. As soon as the micrometer screw is brought in contact with the opposite insulated point, a current is established, which fact is immediately revealed by the stroke of an electric bell placed in the circuit. The pitch of the screws is 0·02 of an inch, and their heads are divided into 200 equal parts; hence a rotary advance of one division on the screw head produces a linear advance of one ten-thousandth (0·0001) of an inch.

"A vertical scale, divided into fiftieths of an inch, is fastened to the frame of the instrument, and set very close to each screw head and parallel to the axis of the screw; these serve to mark the starting point of the former, and also to indicate the number of revolutions made. By means of this double instrument, the extensions can be measured with great certainty and precision, and irregularities in the structure of the material, causing one side of the specimen to stretch more rapidly than the other, do not diminish the accuracy of the measurements, since half the sum of the extensions indicated by the two screws is always the true extension caused by the respective loads."

The size of test pieces advised for compression varies with different authorities, the limit of the ratio of the length to the diameter being five times the diameter. The compression test should crush the piece down or shear it at 45°, but even with the ratio used—the length equal to twice the diameter, as given and used by Prof. Thurston—the piece showed a slight buckling in some cases.

We have obtained the results, from each test by plotting a curve, taking the loads as ordinates and the deflections as abscissas. In this way we see the behavior of the piece at a glance, by the curve, and find the elastic limit very accurately. This latter was obtained by drawing a straight initial line when necessary, and taking it as the point where the curve leaves the line.

We have given not only the results derived from the most common formula used in designing, or used indirectly, but also the original data of size of test piece, the actual loads, unit strains and stresses as they may be found convenient in some cases and for further information if desired. The formulæ from which the results were derived are set at the head of the tables.

TESTS BY COMPRESSION.

	Name.	Original Length.	Original Diameter.	Final Length.	Stress. E. Lim.	Stress. Maxim.	Stress. Break'g	Strain. E. Limit.	Strain. Maxim.	Strain. Breaking.
2	Cedar, ...	1·656	0·844	1·6273	2100	2300	2300	0·0189	0·0289	0·0289
5	Cortez, ...	1·625	0·828	1·5815	5500	8100	8100	0·0224	0·0435	0·0435
6	Granadillo-negro, . .	1·552	0·729	1·4733	4000	6500	6070	0·0115	0·0307	0·0795
7	Guachipilin, ...	1·583	0·732	1.5546	3000	5000	5000	0 0102	0 0289	0·0289
9	Guayabo de Monte, . .	2·235	1·125	2·1893	6000	8500	8500	0·0191	0·0460	0·0460
11	Jenisero, ...	1·506	0·794	1·4632	3000	4000	4050	0·0179	0·0341	0·0432
14	Lligualtil, ...	1·609	0·828	1·5157	4200	6325	6325	0·0178	0·0804	0·0936
15	Madera-negra, ...	1·609	0·812	1·5416	5500	6700	6650	0·0326	0·0574	0 0677
16	Madrono, ...	1·625	0·812	1·5638	4800	6600	6000	0·0156	0·0335	0 0612
21	Nispero, ...	1·625	0·828	1·5760	3500	7000	7000	0 0142	0·0490	0·0490
22	Oja-tostada, ...	1·218	1·0859	2·1573	5000	8000	7800	0·0130	0·0316	0·0613
26	Quiebra-hacha, . . .	1·625	0·8281	1·5776	5400	8600	8375	0·0225	0·0864	0·0474
27	Quita-calson, ...	2·224	1·119	2·1743	5000	8000	7600	0·0130	0·0318	0·0495
29	Ron-ron, ...	1·625	0·828	1·1823	4200	5900	5900	0·0165	0·0427	0·0427
31	Tiguilote, ...	2·219	1·126	1·1941	3800	5000	5000	0·0164	0·0251	0·0251
36	Guanacaste, ...	1·-969	0·817	1·5560	3000	3700	3700	0·0135	0·0409	0 0409

	Wood.	Unit Stress. E. Limit. $p=\frac{P}{F}$	Unit Stress. Maxim. $p'=\frac{P'}{F'}$	Unit Stress. Breaking. $p''=\frac{P''}{F''}$	Unit Strain Elastic Limit. $e=\frac{\lambda}{L}$	Modulus of Elasticity. $e=\frac{p}{e}$	Modulus of Resilience $U=\frac{p\lambda}{2L}$
1	Carbon, ...	5600	9800	9585	0 0069	804860	19
3	Chaperno, ...	2100	11500	11500	0·0035	593540	3
8	Guapinol, ...	7800	12000	12000	0·0074	1051600	28
10	Guiliguiste, ...	6000	8800	8800	0·0067	882940	20
12	Jicaro-sacaguacal, .	4000	7800	7800	0·0096	414020	19
20	Nancite, ...	6000	8000	8000	0·0072	824340	21
21	Nispero, ...	5600	10275	10000	0·0077	723550	21
21	Nispero, ...	7000	14000	14000	0·0087	801050	30
33	Zopilote, ...	7200	10800	10500	0 0099	721370	35

	Wood.	Unit Stress.			Unit Strain Elastic Limit.	Modulus of Elasticity.	Modulus of Resilience
		E. Limit. $p=\frac{P}{F}$	Maxim. $p'=\frac{P}{F}$	Breaking. $p'=\frac{P''}{F}$	$E=\frac{\lambda}{L}$	$E=\frac{p}{e}$	$U=\frac{p\lambda}{2L}$
2	Cedro, ...	4200	4600	4600	0·0114	367190	18
5	Cortez, ...	11000	16200	16200	0·0137	797990	75
6	Granadillo-negro, .	8000	13000	12140	0·0074	1080300	29
7	Guachipilin, ...	6000	10000	10000	0·0064	931470	19
9	Guayabo de Monte, .	6000	8500	8500	0·0085	702180	25
11	Jenisero, ...	6000	8000	8100	0·0118	504880	35
14	Lligualtil, ...	8400	12700	12650	0·0110	759440	46
15	Madera-negra, . . .	11000	13400	13300	0·0202	543010	111
16	Madrono, ...	9600	13200	12000	0·0096	1000000	46
21	Nispero, ...	7000	14000	14000	0·0087	801050	30
22	Oja-tostada, ...	5000	8000	7800	0·0058	853320	14
26	Quiebra-hacha, . . .	10800	17200	16740	0·013846	780000	74
27	Quita-calson, . . .	5000	8000	7600	0·0058	855310	14
29	Ron-ron, ...	8400	11800	11800	0·0101	827270	42
31	Tiguilote, ...	3800	10000	10000	0·0073	514210	14
36	Guanacaste, ...	6000	7400	7400	0·0084	709730	25

	Wood.	Original.		Final Length.	Stress.			Strain E. Limit.
		Length. L	Diameter D	L	E. Limit. P	Maxim. P'	Breaking. P''	λ
1	Carbon, . . .	2·2421	1·128	2·1562	5600	9800	9585	0·0156
3	Chaperno, . .	2·2611	1·1245	2·2096	2100	11500	11500	0·0080
8	Guapinol, . .	2·2516	1·3115	2·2036	7800	12000	12000	0·0167
10	Guiliguiste, .	2·2515	1·128	2·2012	6000	8800	8800	0·0153
12	Jicaro-sacagua-cal, ...	1·625	0·8437	1·5534	2000	3900	3900	0·0157
20	Nancite, . . .	2·2532	1·1292	2·2238	6000	8000	8000	0·0164
21	Nispero, . . .	2·2611	1·1235	1·9522	5600	10275	10000	0·0175
21	Nispero, . . .	1·625	0·8281	1·5760	3500	7000	7000	0·0142
33	Zopilote, . . .	2·2704	1·126	2·2143	7200	10800	10500	0·0180

The torsion tests were made in the autographic testing machine of Prof. Thurston: It consists of two angle frames united at their vertices by a cast-iron rod and rigidly bolted to a heavy cast-iron bed, thus making the machine very firm. These two angles have the bearings in line with the jaws or wrenches which hold the piece to be tested by means of steel wedges put from opposite sides. The test piece is put in line before securing it rigidly between the jaws, by means of centres in each jaw, one resting on a spiral spring and the other turned by a screw which projects out of the frame, thus enabling to place the piece symmetrically and directly in line with the axis of rotation.

The outer end of one of the jaws is connected to a worm-wheel, the rotation to which is imparted through the worm by means of the crank. The other jaw carries the pendulum, to which is connected, a little below the jaw, the pencil which is held by a spring, tight against the sides of the guide curve. This curve is made so that when the pencil rolls on it, in virtue of the swinging of the pendulum through the test piece, the ordinates which are recorded upon a cross-section paper carried by a drum on the opposite jaw or on the one connected to the worm wheel, are proportional to the moments about the axis of the test piece. The machine, by the tracing of a simple curve, tells all the characteristics of the test piece. The circumference of the drum is equal to thirty-six inches, and the inches in the paper are divided into ten equal parts, thus making each inch of paper equal to 10°. The vertical lines are also divided in inches and each into tenths.

When the piece is secured between the clamps, the crank is turned by hand with a uniform motion and a slow rotation, interrupted only by the rupturing of the piece, is given to it, causing the pendulum to swing up on one side. This measures the resistance to torsion of the test piece which is recorded autographically in the paper.

To make these tests, we took off the bob from the pendulum, as it offers too large a moment for the torsional resistance of the woods for the size of test piece used. Before making the tests, we found the necessary constants of the machine to work out the results of tests, as follows: The pendulum without the bob was supported horizontally by a column, which rested on a scale. Thus, the maximum moment of the pendulum was weighed, and the corresponding ordinate in the curve observed:

Lever arm, ...	48 inches.
Weight of column with lever arm, ...	52·75 pounds.
" supporting columns.	21·5 "
" lever arm, or pendulum, ...	31·25 "
Hence maximum moment, ...	1,500 inch-pounds.

Maximum ordinate traced by the pencil, or ordinate corresponding to horizontal position of the pendulum — 4·3 inches. Therefore, one inch of ordinate = 348·837 inch-pounds.

We found the friction of the machine by means of a delicate spring balance, attached at a distance of fifty inches from the centre of suspension. The pendulum was pulled just far enough to overcome friction alone. After several trials, it was found to be equal to 0·25 pounds. Thus, the friction of the machine is 12·5 inch-pounds, which friction is added, in every case, to the moments recorded by the pencil.

The absolute errors in the size of the test pieces vary by excess from above one-thousandth ($\frac{1}{1000}$) of an inch up to a little above one-hundredth (0·01) of an inch.

We have put down the moments at the elastic limit and at the maximum before rupture; also the angles of torsion at the elastic limit, maximum before rupture, and final rupture with the corresponding elongations of the outermost fibres for the first three angles. As a matter of detail, we have observed those which reached the final rupture with a higher moment after the first rupture, and those that did not offer a higher resistance. The names used express the character of the four critical points to which a material is subjected under an increasing stress.

Not being able to put in the strain diagram, we have endeavored to write out for illustration the behavior of several pieces under stress, and their mode of rupture as concisely as possible in the details of torsion tests. These may be more valuable than the numerical results. The torsion tests give a better and more general idea of all the properties of strength and elasticity of the woods than any other test, as, in this case, they are compelled to write for themselves their "own story."

DETAILS OF TORSION TESTS.

(1.) *Carbon.* $d = 0{\cdot}6271$.—Test piece turned from a large sample near the heart. Very sound in the turned part. Elastic limit, maximum and rupture occurred under the same moment. From this and by breaking in two splinters it shows it is a brittle wood. It reached a moment at the latter points of 200·87 inch-pounds, at an angle of $7^\circ{\cdot}5$ and gave away completely at $13^\circ{\cdot}2$ with no higher moment. Its curve was at 45° from the axis of angles and was short-wavy all along.

(2.) ————.—With a short wavy and parabolic curve reached its elastic limit at $7^\circ{\cdot}11$ under a moment of 186 inch-pounds, and reached a maximum of 190 inch-pounds moment, which kept constant for about 8°, when it came down and ruptured. Fairly regular stiff rupture.

(3) *Chaperno.* $d = 0{\cdot}6278$.—Turned from a large sample and very sound piece. It rose with a 45° wavy curve up to 104·9 inch-pounds when it reached the elastic limit. Went up to a maximum of 124·128 inch-pounds, which kept constant until final rupture, splintered at 17°·3.

(5.) *Cortez.* $d = 0{\cdot}6278$.—Turned from a large sample near the heart. Very sound piece. It rose with a 45° curve and slightly wavy but uniform, reaching the elastic limit at 214·82 inch-pounds at an angle of 5°·9. Ruptured at 28° and splintered at 41°, reaching afterwards a higher moment, which kept constant till final rupture. Fibrous and stiff rupture, shearing a plug of same cross section as the turned part from the shoulder.

(8.) *Guapinol.* $d = 0{\cdot}5645$.—With a slightly parabolic curve at 45° angle, reached its elastic limit at 6° with a 183 inch-pounds moment, which kept constant until first rupture and reached a little higher moment before final rupture. Gave away with wide fibrous splinters.

(12.) *Jicaro-sacaguacal.*—The test piece was turned from a green limb. It rose with a parabolic line and very much inclined toward the axis of strains reaching at the elastic limit a moment of 103·2 inch-pounds. Reached a higher moment, which kept constant until final rupture at 155°, when it completely broke irregular and stiff.

(13.) *Laurel.* $d = 0{\cdot}631$.—Dark color. With a low sloping curve, but uniform, reached the elastic limit at 4° angle and under a moment of 82·268 inch-pounds. This was its maximum resistance and kept constant until ruptured at 20°. Uniform square rupture around the shoulders without projecting splinters. Gave way entirely at 105° angle.

(17.) *Mahogany.* $d = 0{\cdot}6358$.—A very sound piece, turned from a large sample. It rose with a long wavy line up to 78·779 inch-pounds, its elastic limit at 3° angle. Reached a higher moment of 82· inch-pounds at 6°·7 when it ruptured. It splintered at a still little larger moment at 27°·6. Fibres wide and stiff, and rupture irregular.

(18.) *Moran.* $d = 0{\cdot}6256$.—A very sound piece. With a curve above 45° angle with the axis of strains reached its elastic limit at 2° under a moment of 82·27 inch-pounds, which kept constant for 1·5, when it rose to 88·95 inch-pounds moment, and gave away for the first time. However, it still reached about twice as large a moment which kept constant till final rupture. Fibrous and tough rupture.

(24.) *Piedra* (Stone). $d = 0{\cdot}6257$.—A piece turned from near the heart and very sound. It rose with a parabolic short wavy line up to the elastic limit, when it had a moment of 227 inch-pounds at an angle of $9^\circ{\cdot}7$ It reached a maximum moment of 228·7 inch-pounds at an angle of 11°, and very soon lowered its moment to 221·8 inch-pounds, which kept constant until it splintered at 50°. Wide splinters and stiff rupture, but square around the shoulders.

(26.) *Quiebra-hacha.* $d = 0{\cdot}6268$.—A very sound piece. It rose with a parabolic curve above 45°, with the axis of strains up to 166 inch-pounds moment, its elastic limit, and kept reaching higher and higher moments by regular intervals up to a maximum after first rupture of 319·479 inch-pounds without giving way completely. Brushy, regular break and very tough.

(29.) *Ron-ron*.—Dry and sound piece. Rose with a straight line up to 82·26 inch-pounds moment at an angle of $1^\circ{\cdot}5$, and kept a constant moment till final rupture. Broke with brittle fracture in two pieces, without showing any fibre.

(32.) *Zapotillo.*—The test-piece turned from a large sample, $d = 0{\cdot}6258$ inch; had a small knot on one end, but very sound otherwise. It reached its maximum at the elastic limit at an angle of $5^\circ{\cdot}5$ from the origin, rupturing with the same moment at angle of 9°. It kept a constant moment for about 80°, when it reached a little higher moment holding it till final rupture. Fibrous rupture.

(33.) *Zopilote.*—At first rose with a straight line below 45°, and turned parabolic near and after the elastic limit. First ruptured at 28° angle under a 106 inch-pounds moment and raised it slightly, keeping the latter constant for over 160. A very thready and tough rupture.

TESTS BY TORSION.

Wood.	Moments of Torsion in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
	E. Limit.	Max. before Rupt.	E. Lim	Max. before Rupt.	First Rupt.	Elastic Limit.	Maximum before Rupture.
	$(P_s)_E$	$(P_s)_M$	a	a_1	a_2	$p^s = \frac{2}{\pi r^3} \times (P_s)_E$	$p_s = \frac{2}{\pi r^3} (P_s)_M$
2 Cedar, . .	43·89	45 63	3·6	8·4	8·4	915	952
5 Cortez, . .	68·3	71·80	3·3	19·	27·5	1424	1497
7 Guachipilin,	82·2. 8	148·54	2·6	49·	49·	1716	3098
9 Guayabo de Monte, .	54·36	64·82	4·5	5·5	26·5	1133	1352
13 Laurel-macho, .	68·31	71·8	2 8	4·1	4·1	1424	1497
15 Madera-negra, .	141·57	141·57	3·6	13·4	17·4	2953	2953
16 Madrono, .	99·71	103·19	4·5	29·	35 0	2080	2152
19 Nacascolo,	145·06	145·06	2·4	2·4	16·1	3026	3026
20 Nancite, .	61·34	68·3	2·7	12·	12·	1279	1424
21 Nispero, .	103·89	193·89	7·2	5·	9·5	4044	4044
22 Oja-tostada,	52·616	54·36	2·7	14·5	19·5	1097	1133
25 Pochote, .	47·38	50·87	5 0	5·8	5·8	988	1061
26 Quiebra-hacha (yellow),	152·03	152·03	5·0	5·	9·3	3171	3171
28 Roble, . .	54·36	54·36	3·3	3·3	12·	1133	1133
31 Tiguilote, .	33 43	43·87	5·4	17·5	17·5	697	915
36 Guanacaste,	68·31	71·8	2·25	3·2	3·2	1424	1497

Wood.	Moments of Torsion in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
	E. Limit	Max. before Rupture	E. Limit	Max. before Rupture	First Rupture	Elastic Limit.	Maximum before Rupture.
	$(P_s)_E$	$(P_s)_M$	a	a_1	a_2	$p_s = \frac{2}{\pi r^3} (P_s)_E$	$p_s = \pi r^3 (P_s)_M$
1 Carbon, . .	200·8	200·8	7·5	7 5	7·5	4190	4190
2	186·92	190·4	7·11	8·5	8·5	3899	3972
3 Chaperno, .	104 9	124 1	3·4	5·7	7·3	2189	2589
5 Cortez, . .	214·8	214·8	5 9	5 9	28·0	4481	4481
7 Mahogany,	78·7	82·2	3·0	6·7	6·7	1643	1716
8 Guapinol, .	183·4	183·4	6·0	18·2	18·2	3826	3826
12 Jicaro-saca-guacal, .	103·2	110·1	20·	22 0	22·0	2153	2298
13 Laurel, dark,	82·2	82·2	4 0	4 0	20·0	1716	1716
18 Moran, . .	82·2	88 9	2·0	4·2	4 2	1716	1855
24 Piedra, . .	227·0	228 7	9·7	11·0	11·	4736	4772
26 Quiebra-hacha, . .	166·	166·0	8·0	8·0	8·0	3463	3463
29 Ron-ron, .	82·2	82·2	1·5	23 5	23·5	1716	1716
32 Zapotillo, .	99·7	99·7	5·5	5·5	9·0	2080	2080
33 Zopilote, .	94·4	106·6	5·7	28 0	28·0	1971	2225

	Wood.	Extension of outer Fibre. E. Limit.	Max. before Rupture.	First Rupture.	Modulus of Elasticity.	Total Elastic Resistance.
		$\lambda = \sqrt{1 + \alpha^2 (0{\cdot}000029747)} - 1$			$E_s = \frac{(P_s)E}{\alpha} \times \frac{l}{I_p}$	$\frac{(P_s)E \times \alpha}{2}$
2	Cedar, . . .	. . .	. . .	. . .	46635	1
5	Cortez, . . .	. . .	. . .	. . .	79161	2
7	Guachipilin, .	. . .	. . .	. . .	152358	2
9	Guayabo de Monte, . .	. . .	. . .	. . .	46203	2
13	Laurel-macho,	. . .	. . .	. . .	93310	1
15	Madera-negra,	. . .	. . .	. . .	150407	4
16	Madrono, . .	. . .	. . .	. . .	84748	4
19	Nacascolo, .	. . .	. . .	. . .	231175	3
20	Nancite, . .	. . .	. .	. .	86893	1
21	Nispero, . .	. . .	. . .	. . .	102997	12
22	Oja-tostada, .	. .	. . .	. . .	74533	1
25	Pochote, . .	. . .	. . .	. . .	36243	2
26	Quiebra-hacha (yellow), .	. . .	. . .	. . .	116297	6
28	Roble, . . .	. . .	. . .	. . .	63003	1
31	Tiguilote, . .	. . .	. . .	. . .	23678	1
36	Guanacaste, .	. . .	. . .	. . .	116119	1

	Wood.	Extension of outer Fibre. E. Limit.	Max. before Rupture.	First Rupture.	Modulus of Elasticity.	Total Elastic Resistance.
		$\lambda = \sqrt{1 + \alpha^2 (0{\cdot}000029747)} - 1$			$E_s = \frac{(P_s)E}{\alpha} \times \frac{l}{I_p}$	$\alpha = \frac{(P_s)E \times \alpha}{2}$
1	Carbon, . . .	. . .	. . .	. . .	102440	13
2		. . .	. . .	. . .	100551	11
3	Chaperno, . .		. . .	. . .	118050	3
5	Cortez, . . .	. . .	. . .	. . .	139270	11
8	Guapinol, . .	. . .	. . .	. . .	116920	9
12	Jicaro-sacaguacal, . .	. . .	. . .	. .	19735	18
13	Laurel (dark),	. . .	. . .	. . .	78663	2
17	Mahogany, .	. . .	. . .	. . .	100440	2
18	Moran, . . .	.	. . .	. .	157330	1
24	Piedra, . . .	. . .	. . .	. . .	89522	19
26	Quiebra hacha,	. . .	. . .	. . .	79363	11
29	Ron-ron, . .	. . .	. . .	. .	209750	1
32	Zapotillo, . .	. . .	. . .	. . .	69339	04
33	Zopilote, . .	. .	. . .	. . .	63390	4