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Imagine if you can a slab fire which has been kept alive day and night almost continuously over a period of 55 years by the refuse from a single large sawmill. Try to realize that this is an actual mill operating in the redwood region of California and that it is only one of many mills of similar size. You can not then help wondering why so much potentially valuable material must be wasted.

In a country like this with its immense supplies of raw material and its relatively small population per unit area the answer is not easy. Distribution for fuel is prohibited by hauling costs. Smaller countries with fewer resources and more dense population, with highly specialized industries, with demands caused by a keener struggle for necessities and luxuries, have been driven to closer consideration of the question and have to a great extent solved it. For example, wood waste in the densely populated portions of Europe means sawdust, and not much of this relatively unimportant material is actually wasted. It finds use as fuel in natural form, in briquettes, and as gas resulting from distillation. In combination with binding and cementing substances such as glue, albumin, blood and resin it forms plastic materials, artificial wood and xylolith or woodstone. In cheap but often very durable linoleums it takes the place of cork, a more valuable tree product. Various processes of manufacture produce from sawdust oxalic acid, acetic acid, formalyn, tannin, dyes, grain alcohol, wood alcohol, oils, tar, charcoal, etc.

In the United States until quite recently wood waste has meant practically all of the wood produced by the forest which could not be converted into salable lumber and from such lumber into buildings, railroad cars, ties, vehicles, furniture, fixtures, barrels, boxes and so on down through the list to knobs for tea kettle lids and the dowels which are concealed in many larger wooden commodities. In terms of a tree the sum of these represents about one-third its volume. The other two-thirds constitute wood waste. Specifically, wood waste consists of stumps, tops, broken logs, inferior species and other material left in the woods, of sawdust, bark, slabs, edgings, trimmings, pooly sawn boards and lumber depreciated in seasoning, all incident to manufacture; of sawdust, shavings and blocks which do not find use when the lumber is remanufactured into things people need.

The refuse left in the woods is not only lost but becomes a menace to the remaining forest by harboring disease and insects and by serving as tinder which a stroke of lightning or

a careless camper, hunter or smoker may convert into a destructive fire. The refuse of a sawmill, except for the portion which can be used for fuel to drive the saws and other machinery, must be disposed of at the expense of the owner. A mill producing daily 100,000 feet board measure is not large as mills go, yet it is estimated that $10 is a fair average cost for destroying the waste from a day's cut. The total annual waste of all mills in the United States has been given as 36,000,000 cords or 4½ billion cubic feet, enough to make a solid cube one-fourth mile high. Naturally the intelligent, progressive lumberman desires very much to find a use for his waste raw material and considerable sums have been spent in experimentation looking toward means of accomplishing this.

Keen competition has reduced the profits on lumber until at times they have threatened to disappear entirely. Under these conditions the profits on by-products may play an important part in the advancement of wood-using industries now employing 10 per cent or over 1,000,000 of the country's wage earners, and having an annual output roughly valued at $2,000,000,000. The cutting of timber has progressed at three times the normal rate of growth and of the original 5,200 billion feet in our virgin forests, 2,300 billion feet have been removed. The danger of timber famine has been pointed out and has given rise to the widespread study of conservaton. This in turn has fostered utilization and we are on the way to doubling our forest resources by reducing waste. In 1914 the estimated wood waste used as pulpwood by our sawmills amounted to 330,000 cords valued at about $1,400,000. In the same year these mills consumed an estimated total of 4,290,000 cords valued at $36,800,000. The average cost per cord of wood delivered at mills of reporting concerns was $8.58; for wood waste only $4.25. The Forest Products Laboratory reports that one lumber company in the Lake States region claims the removal of 3 times the material from the forest and the employment of twice the number of men formerly employed in producing an equal amount of lumber. A progressive lumber company in Pennsylvania is securing from its waste a gross return of $124 per acre, or 34 per cent of the total gross return from its hemlock and hardwood logs.

Germany has accomplished more along the line of systematic development of forest resources than any other country. In the roll of honor the United States ranks second. No small part of this is due to the work done in the Forest Products Laboratory at Madison, Wisconsin, established in 1910 by the Forest Service of the Department of Agriculture in co-operation with the University of Wisconsin. Nowhere else in the world is there a laboratory of this kind so completely equipped. Its various sections specialize in investigations of the mechanical, physical and

chemical properties of woods, the value of various species for pulp and paper manufacture, the art of timber preservation to prolong its life, and the destructive agencies which cause decay and other kinds of depreciation. The drying of lumber by both natural and artificial means, testing of special preservatives and processes of preservation for individual species and for particular purposes, development of improved methods of pulp and paper manufacture and of wood distillation, and the practical application of results in the arts and industries are among its activities.

Sudden changes in commercial relations caused by the European war have given stimulus to numerous domestic industries. Some of these utilize forest products. Osage orange dye, produced from mill waste, has within the last year been developed as a substitute for fustic imported from Jamaica, Southern Mexico and Central America. Over $1,000,000 worth of this dye was produced in 1916 and osage orange has gained lasting commercial recognition as a dyewood.

Charcoal is used in the manufacture of black powders and in driving bullets from shrapnel. It is also indispensable in the production of certain high grade steels required for guns and armor plate. The nitrate fibres used in nitrocellulose powders must be treated with a solvent and acetone, made from acetic acid, a hardwood distillation product, is employed for this purpose. Without acetone, procured largely from this country, Great Britain could not produce the cordite used by her soldiers on the battlefield. In this connection it may be interesting to note that a study by the Laboratory experts of the operating methods in a destructive distillation plant resulted in one case in increased yields of products valued at $15,000 annually. Another investigation resulted in the use of spent tanbark in the manufacture of patent roofing to the extent of 160 tons per week. The value of the bark has thereby increased from 60 cents to $2.50 per ton. The tanning industry now handles over 1,000,000 cords of waste per year. Some of this will be used in making sheathing paper, carpet liners, bottle wrappers, deadening felts and similar articles for daily use.

Formaldehyde, the universal disinfectant, is manufactured on a commercial scale entirely from wood alcohol. It would be difficult to estimate how many human lives are saved by preventing the spread of contagious diseases with this effective enemy of the germ. The agriculturist finds a use for it in disinfecting seeds, thus assuring a greater food crop.

For 5 years the Laboratory has been working on the production of grain alcohol from wood. In this time the yield has been raised and the cost of production lowered. Waste material of coniferous species has been found to give higher yields than do hardwoods. Chemical analysis of certain woods, notably western larch, has shown them to be especially rich in a water

solution material, galactan, which, converted into fermentable sugars, constitutes raw material for grain alcohol. Larch sawdust, hydrolyzed under pressure with acids, yields sufficient sugar to produce 35 gallons to the ton. Spruce sawdust yields 25 gallons. Probably 40,000,000 gallons of denatured alcohol were used in the United States in 1916, and huge quantities were exported. Grain alcohol from wood is no longer a mere possibility; it is today being manufactured in a large plant located in the South and using mill waste of southern yellow pine. Thus Mark Twain's statement that the country would never go dry as long as every table leg was good for a jag seems to be verified. Nor is this all. Galactan in oxidation yields large quantities of muric acid, a substitute for tartaric acid in the manufatcure of baking powder, an industry in which large quantities of tartaric acid are employed. Hydrolyzed galactan becomes galactose, which, with the addition of a small amount of alkali and subjection to heat, is transformed into a fine sweet syrup.

Seven billion pounds of artificial silk made from wood are used annually in this country. This material goes into silk sweaters, hose, neckties, fancy braids and millinery. It is merely cellulose reduced chemically to a gelatinous substance known as viscose. Some of the tough sausage casings now in use are also made of viscose, and this substance will undoubtedly find a great many uses. In Germany, since cotton is no longer obtainable in sufficient quantities, soft, artificial cotton is made from wood cellulose for surgical purposes.

Another interesting field of research for the utilization of wood waste and one giving promise of unusually important commercial results has to do with the manufacture of kraft paper and its remanufacture into a great variety of products. Kraft is a very tough paper because the action of the chemical used for reducing the wood to pulp is not severe enough to seriously weaken the fibres. Its natural color is brown, but it can be dyed easily by adding color to the pulp. In the form of tough, heavy wrapping paper it enters every home. Longleaf pine, western yellow pine, sugar pine, redwood, white fir, red fir, and a number of other species yield excellent kraft. It is used for large envelopes, book covers, imitation leather, especially that employed in the furniture industry, cardboard and matting suit cases, etc., and if cost of leather continues to go up we may eventually wear wooden shoes made from specially prepared kraft. Like most papers it is usually made up in the form of wide sheets which are wound on cores into large rolls. These rolls are cut into long ribbons or strips of varying widths which are in turn fed into spinning machines for the production of yarns and reeds. Sometimes the paper is gummed and coated with cotton fleece before spinning and the yarn so produced is used in the manufacture of cheap towels and napkins. One

of the largest single uses of spun paper in the United States lies in the production of so-called fibre rugs. These may be made entirely of paper or of paper and cotton or wool. The total daily output of such rugs is probably in excess of 100 tons.

Paper furniture is now a common article of commerce and its use should increase greatly. The reeds are usually made from heavy paper, stiffened by various processes, and when woven over wooden frames and coated with shellac, they produce an excellent substitute for other reeds.

Rope and cord made from kraft alone or from kraft with a core of hemp or sisal are finding considerable favor. Cheapness, smoothness, uniform strength and size are the points in which they excel other cords. European manufacturers are producing clothesline, sash cord, driving reins, skipping ropes, web straps for surcingles, and a variety of articles from paper twine. Floor mattings, stair runners, imitation burlaps for wall coverings, tapestries, and bagging to replace jute are other products. Eventually paper yarn will be woven into cloth to be used in making cheap clothing for rough work. Binder twine from paper to replace that made from imported fibres is another possibility of economic importance in our industrial development. Insulating tubing for electric wires, both for use under ground and overhead, is made partly from paper, as is also pipe for carrying liquids.

As a means of reducing wood waste by bringing wood users together the Office of Industrial Investigations of the Forest Service has opened a wood waste exchange. The co-operators now number over 500, many of whom have reported successful purchases or sales of wood waste through the Exchange. Thus a man desiring blocks for brushes may find that he can obtain cheaply for this purpose material which in another industry is waste.

Forest products investigations covering comparatively few years have opened our eyes to the uses of today and the immense possibilities of the future. The consumption of forest products is increasing, and the degree to which wood waste contributes to these products is the degree by which we are approaching the very remote goal—complete utilization. As the value of the tree is increased closer application of correct forest management is made possible. With this comes the assurance of steady supply and the consequent development of wood-using industries.