Corvallis, Oregon,
May 20, 1937.

Professor H. R. Patterson,
Oregon State College,
Corvallis, Oregon.

Dear Sir:

I transmit herewith my senior seminar paper in conformance with the requirements for the Bachelor of Science degree in Wood Products.

This paper does not do more than touch upon the subject of wood saccharification, mentioning only the major factors concisely.

Respectfully submitted,
THE ECONOMIC PROBLEM OF CONVERTING PACIFIC NORTHWEST FOREST WASTE TO INDUSTRIAL ALCOHOL
THE ECONOMIC PROBLEM OF CONVERTING
PACIFIC NORTHWEST FOREST WASTE TO
INDUSTRIAL ALCOHOL

The idea of making ethyl alcohol from wood cellulose is not a revolutionary new discovery; H. Braconnet, a French chemist, first published a treatise on the hydrolysis of cellulose by sulfuric acid in 1819, but there have been no outstandingly significant developments since. Many independent investigators have worked on the subject from time to time, and the general chemistry of the reduction process is pretty well understood.

Before going ahead with a technical discussion of the chemistry of wood cellulose saccharification, it would be well to digress into the subject of wood structure so that we may better know what is the problem with which we are dealing.

WOOD STRUCTURE

Wood is far from a simple homogeneous mass; under the microscope, or even under a hand lens, it is seen to be a heterogeneous collection of regularly disposed cells. Higher magnification and special chemical treatment will reveal a far more complex basic structure than simple cells, whose very walls are made up of spirally disposed fibrils, composed in turn of elementary fusiform bodies.

We shall deal only with the cells per se, and the materials of which they are constructed. Roughly, the cells are hollow, cigar-shaped members, made up of cellulose, hemicellulose, pectins, carbohydrates, minerals and gums or resins. The individual cell walls have
lignin in them as well, and are cemented together with it. (The between-wall portion is designated the middle lamella.) All of the compounds named may be decomposed by one means or another, but the lignin is the most difficult to reduce to other organic compounds which we desire.

Technically, wood cells consist of protoplasm in the living cells (made up of cytoplasm, vacuoles, nucleus, nucleoli, and down to chromosomes if we care to be specific. The protoplasm is an insoluble proteid built up of the elements oxygen, hydrogen, carbon, nitrogen, sulphur and phosphorus.

The walls of new cells are almost pure cellulose \((C_6H_{10}O_5)_n\), but lignin, hemicellulose, etc., is later deposited as the cells mature. When the cells die, gums or resins are deposited in them.

Lignin is probably deposited on the micellae of the cell walls as a coating; i.e., on the fibrils or fusiform bodies. It is very probably a cement material physically.

Wood cells range in length from about 1.5 to 9 millimeters long, with an inside diameter of from .005 to .05 millimeters.

Wood averages about 1.54 in specific gravity; that is, the actual wall material. The lignin is less than 1.54 grams per cubic centimeter, while the cellulose is more than 1.54 gm./cc.

**NATURAL DECOMPOSITION**

In nature both lignin and cellulose are commonly decomposed by living organisms; our common Trametes pini, for instance, decomposes lignin slowly, while the various Polyporus and Lenzites rots are

*Thaysen & Bunker - "Chemistry section of Microbiology, etc."*
cellulose decomposers. The micro-organisms do not break down cellulose and lignin directly, but do so by secreting certain enzymes which do the actual work of decomposition. Older research by H. Schmitz shows that certain fungi secreted the enzyme, pectosinase, to dissolve the middle lamella. Certain bacteria work symbiotically with certain fungi to accelerate decomposition by some catalytic action, which would in itself be an excellent subject for original research. Insects such as termites which apparently digest cellulose, do so only with the aid of certain protozoa which inhabit their digestive tracts. Digestion without the aid of the enzymes which the protozoa secrete would be impossible.

Basically, then, and certainly roughly, we shall consider wood to be made up of cells, composed of cellulose, and cemented together by lignin. Both cellulose and lignin may be decomposed, and are both decomposed in nature. The ordinary decomposition products of both are: water, hydrogen, methane, carbon dioxide, etc.

**CELLULOSE**

Cellulose is the framework of plant organisms; it is not found in animal structure. Cellulose is chemically a carbohydrate with a very heavy, complex molecule whose empirical formula is generally accepted as \((C_6H_{10}O_5)_n\), which means that the elements carbon, hydrogen and oxygen are assembled in the proportion of 6,10 and 5. How many atoms of each element are in the entire cellulose molecule is not yet known, but it is a relatively large amount. The most commonly accepted organic
chemistry formula diagram for cellulose is as follows:

\[
\begin{align*}
&\text{CH}_2\text{OH} \\
&\text{CH-}\text{O}---\text{X} \\
&\text{CH} \\
&\text{CHOH} \\
&\text{CH} \\
&\text{CHOH} \\
&\text{CH-}\text{O}---\text{X}
\end{align*}
\]

Cellulose is truly amorphous (i.e., it is non-crystalline), white in color, and insoluble in all simple solvents. It does not occur absolutely pure in nature, but is found nearly pure in certain seed hairs, notably in cotton. For our purpose it is enough to say that cotton represents pure cellulose, flax represents pecto-cellulose, and wood and jute represent ligno-cellulose, that being a simple way to denote the close association of organic compounds.

Müller, a German investigator, has carefully analyzed clean cotton to find the following composition of it:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>91.35%</td>
</tr>
<tr>
<td>Water</td>
<td>7.00%</td>
</tr>
<tr>
<td>Fatty substances</td>
<td>0.40%</td>
</tr>
<tr>
<td>Nitrogenous matter</td>
<td>0.50%</td>
</tr>
<tr>
<td>Ash</td>
<td>0.12%</td>
</tr>
<tr>
<td>Cuticular matter</td>
<td>0.63%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
Compared to cotton's more than 90% of cellulose, wood averages from about 30% to a little over 60% as follows:

<table>
<thead>
<tr>
<th>Wood</th>
<th>Percentage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech</td>
<td>45.47%</td>
<td>Müller</td>
</tr>
<tr>
<td>Birch</td>
<td>55.52</td>
<td>&quot;</td>
</tr>
<tr>
<td>Chestnut</td>
<td>52.64</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ebony</td>
<td>29.99</td>
<td>&quot;</td>
</tr>
<tr>
<td>Fir</td>
<td>56.99</td>
<td>&quot;</td>
</tr>
<tr>
<td>Linden (basswood)</td>
<td>53.09</td>
<td>&quot;</td>
</tr>
<tr>
<td>Scotch pine</td>
<td>53.27</td>
<td>&quot;</td>
</tr>
<tr>
<td>Spruce</td>
<td>53.00</td>
<td>Griffin and Little</td>
</tr>
<tr>
<td>Poplar</td>
<td>41.00</td>
<td>Reid</td>
</tr>
<tr>
<td>Poplar</td>
<td>62.77</td>
<td>Müller</td>
</tr>
<tr>
<td>Willow</td>
<td>55.72</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

In 1917, Bjorne Johnson, Swedish investigator, found the following percentages of cellulose in various woods:

<table>
<thead>
<tr>
<th>Wood</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black spruce</td>
<td>50.64%</td>
</tr>
<tr>
<td>Red spruce</td>
<td>51.80</td>
</tr>
<tr>
<td>White spruce</td>
<td>56.44</td>
</tr>
<tr>
<td>Balsam fir</td>
<td>50.98</td>
</tr>
<tr>
<td>Jack pine</td>
<td>49.24</td>
</tr>
<tr>
<td>Hemlock</td>
<td>47.00</td>
</tr>
</tbody>
</table>

Sulphite pulp was found by Griffin and Little to average about 81% cellulose in spruce pulp and 55% in poplar.

**CHEMICAL BEHAVIOR OF CELLULOSE**

While cellulose is commonly considered insoluble in simple solvents,
it reacts slightly with water and even air under the stimulus of certain catalysts in the proper conditions. Hydra-cellulose is produced by hydrolysis in water in the presence of weak acids or alkalies or by enzymes or ferments. Oxy-cellulose is produced in air by the action of certain bleaches. The action of oxy-cellulose is deleterious, especially on paper and cloth; it produces a deeper shade of coloring from the same dye vat, but the cellulose is rendered weak and brittle, and its whiteness deteriorates.

Hot zinc chloride dissolves cellulose to yield a viscous substance used for making vulcanized fiber, etc. Ammoniacal cupric oxide (Schweitzer's reagent) also dissolves cellulose; it is used to make waterproof Willesden canvas and paper. It also produces rayon when the treated cellulose is extruded through dies into a dilute acid bath. Schweitzer's reagent is made by dissolving copper hydroxide in ammonia.

Cellulose enters into the chemical composition of many common substances which we use daily without a thought of their origin. The mention of only a few will show how widely it is employed and how valuable it is to us:

Gunocotton, smokeless powder, celluloid, collodion, camera films, artificial silks (rayons), pyroxylin plastics, acetate fabrics, cellulose, carbohydrate stock foods, bromethyl furfural, Fabrikoid leather and many chemical derivations such as ethyl alcohol.
INTRODUCTION:

Alcohol is a name which has undergone an etymological evolution; derived from the two Arabic words, "al" and "kohl," meaning an impalpable powder used in the East for painting eyebrows, hence any fine powder. Its meaning synonymous with the liquid beverage ingredient is a recent addition.

Alcohol is not found in nature except in fermenting fruits and in the urine of diabetics and alcoholics. It is a colorless liquid at ordinary temperatures, is a thick, viscous liquid at -90°C, and it solidifies to a white mass at -130°C. When mixed with water, the mixture contracts in volume and rises in temperature, showing an affinity for H₂O. This affinity is so marked that water cannot be separated from alcohol entirely by distillation, there being always at least 5% of water in the purest distilled ethyl alcohol. Several anhydrous chemical compounds will remove the last traces of water, however, and are commercially used. Among them are quick-lime, baryta and anhydrous copper sulphate.

Aqueous alcohol may be detected by mixing it with benzene, carbon disulphide or paraffin oil. The mixture becomes turbid if there is more than the faintest trace of water in the alcohol.

A very accurate test of laboratory caliber is that of adding a small quantity of anthraquinone and sodium amalgam. Pure alcohol will be colored green while even a minute quantity of water will produce a red color.
Vice versa, to find traces of ethyl alcohol in water, convert the alcohol to ethyl benzoate by shaking with benzoyl chloride and caustic soda; or warm with iodine and potassium bromide to produce iodoform, (the odor is easily recognizable); or oxidize to an aldehyde by distilling it into a strong solution of sodium hydroxide. An aldehyde resin will be formed, producing a strong characteristic smell.

Ethyl alcohol has almost innumerable industrial, chemical and everyday uses; it is an excellent solvent for many solids, liquids, fats and waxes. Above 10% solution in water is an antiseptic; it is beneficial as a liniment, as a cleaning fluid, preservative, beverage, anti-knock component of motor fuel and as a chemical raw material for the manufacture of such products as ether, chloroform, iodoform, acetaldehyde, acetic acid, vinegar, dyes, varnishes, stains, oil cloth, leather cloths, soap, fulminates, powder, explosives and various pharmaceutics.

Approximately five million bulk gallons are used in the world annually, according to the encyclopedia Britannica.

Ethyl alcohol is easily distinguished from wood, or methyl, alcohol by several easily determined tests. There is a difference in taste, smell, specific gravity, chemical composition, boiling point, etc., as shown below.

Ethyl alcohol, often known as grain alcohol from its derivation from grain mashes, has the well-known chemical formula \( \text{C}_2\text{H}_5\text{OH} \). It has a molecular weight of 46.05, a specific gravity of 0.789 at 20°C, and a melting point of \(-114°C\). It boils at 78.4°C, and is soluble in any proportion in water and ether. At 0°C, it weighs 0.791 grams
per cubic centimeter, or 49.4 pounds per cubic foot. It is known as absolute alcohol when above 99% pure. By common usage, 100% proof spirits equals 50% pure alcohol.

Methyl alcohol, often known as wood alcohol from its source by destructive distillation, has a chemical formula of CH₃OH, a molecular weight of 32.03, a specific gravity of 0.798 at 15°C. Its melting point is -97.1°C.; its boiling point is 66°C., and it is also infinitely soluble in water, ethyl alcohol or ether, or a mixture of them. It weighs 0.810 grams per cubic centimeter, or 50.5 pounds per cubic foot.

While methyl alcohol is poisonous to the human system in any quantity, ethyl alcohol is actually an easily assimilable food in small quantities. In large or even medium quantities, ethyl alcohol produces definitely toxic reactions. Even the fumes of methyl alcohol will affect the optic nerves, and may produce blindness.

REDUCTION METHODS:

Early in the present century it was found by several investigators, notably V. Omelianski and Y Khouvine, that certain anaerobic bacteria would decompose wood cellulose to form small quantities of ethyl alcohol as well as carbon dioxide, hydrogen, methane, butyric acid and acetic acid. A.H.C. van Senus concluded that the ethanol (ethyl alcohol) was not a direct decomposition product, but was rather the result of the action of nascent hydrogen on the acetic acid.

Very little progress has been made in the process of direct reduction of wood cellulose by bacteria, molds and fungi, but it appears that there is a good possibility for the discovery of a suitable com-
mercial process. At least there is a great deal of work being done on it.

As stated in the first paragraph of this paper, hydrolysis of cellulose was first noted in 1819 by H. Braconnet. Cellulose, sugars, and starches are so closely related that it is sometimes difficult to distinguish between them chemically except by the most accurate of analytical methods.

Note the similarity and relationship of the following organic compounds:

- Ethyl alcohol $\text{C}_2\text{H}_5\text{OH}$
- Cellulose $(\text{C}_6\text{H}_{10}\text{O}_5)_n$
- Starch $(\text{C}_6\text{H}_{10}\text{O}_5)_n$
- Sucrose $\text{C}_{12}\text{H}_{22}\text{O}_{11}$
- Dextrose $\text{C}_6\text{H}_{12}\text{O}_6$
- Levulose $\text{C}_6\text{H}_{12}\text{O}_6$

Hydrolysis of both starch and cellulose will produce sugars according to the following reaction: $\text{C}_5\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} = \text{C}_6\text{H}_{12}\text{O}_6$, which may be easily demonstrated by treating wood chips with hydrochloric or sulfuric acid, neutralizing the sugar-acid solution, then testing for sugar.

At the close of the 19th century Simonsen studied the effect of various concentrations of sulfuric acid, of pressure and of time on saccharification. His conclusions pointed to an optimum conversion at 0.5% sulfuric acid concentration, 9 atmospheres pressure and 15 minutes time in a mixture of five times as much liquid as wood.

During the first two decades of the 20th century, there were four commercial wood saccharification plants in this country, operating mainly in the southern pine territory.
One plant is described in U. S. Department of Commerce 22nd report of the National Committee on Wood Utilization. Sawdust was charged into brick-lined cylindrical retorts about twelve feet in diameter. From $\frac{3}{8}$ to 1% of the weight of sawdust was added in the form of dilute sulfuric acid. The mixture was then agitated and heated by direct steam at 120 pounds pressure. Maximum temperature was held to 335°F. Only an hour was required to complete each full charge. The residue was washed, pressed to dry out most of the water, and used as fuel for power and steam generation. The wood liquor, containing acid, sugar and other organic compounds was next neutralized with milk of lime in agitated tanks, then clarified by decanting and settling. Finally, the sugar solution was fermented by yeast and distilled. Very little foreign esters, acids and fusel oil came over with the ethanol.

The process, while commercially practical, did not utilize all of the cellulose in the wood because there was a natural equilibrium in the reaction beyond which the process could not go unless the temperature, pressure or acid concentration were increased, thereby introducing other technological difficulties.

More than 12 gallons* of ethyl alcohol from each cord of pine cordwood was easily recoverable.

The Forest Products Laboratory, at Madison, Wisconsin, found that optimum reduction occurred at 7$\frac{1}{2}$ atmospheres pressure, 20 minutes cook, 125 to 100 ratio of water to dry wood, 2$\frac{1}{2}$ to 100 ratio of acid to dry wood. About 22 to 30% of fermentable sugar was obtained from white spruce sawdust, and 30% from western larch.

*R.V. Williamson states that up to 50 gals. per ton of dry wood is possible.
Sherrard and Blanco analyzed the sugars from white spruce saccharification to be:

- mannose 37.7%
- glucose 29.3%
- xylose 13.3%
- arabinose 5.4%
- volative matter 7.3%

100.0%

Complete technological reduction need not be resorted to, since Willstatter and Zechmeister, German chemists, found that wood chips and concentrated hydrochloric acid might be mixed in equal proportions and allowed to stand only 24 hours at 15°C., following which a yield of 21.6% of sugar would be obtained. At 40°C., the percentage recovery of sugar increased to 23.5%.

One investigator* found the positive correlation between sugar yield and acid ratio to be as follows:

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Acid to Wood</th>
<th>% Sugar 15°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>44.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>54.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>66.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>67.2</td>
<td></td>
</tr>
</tbody>
</table>

The ultimate use of the sugars, whether from anaerobic fermentation as discussed previously, or chemical decomposition as discussed above, *Hagglund, Holzchemie (1923)
is for fermentation into ethyl alcohol.

HOW DOES THE PACIFIC NORTHWEST COME INTO THE PICTURE?

One of the most significant facts in connection with this subject of wood saccharification is that conifers lend themselves far more readily to reduction than do angiosperms, which is the exact reverse of the situation pertaining in destructive distillation.

Since our Pacific northwest is so heavily forested with soft-woods, it follows that we are in a favorable position in the matter of a possible saccharification industry. Our weed species such as lodgepole pine and overmature white firs would supply a tremendous amount of raw cellulose, while our sawmill and logging waste in the Douglas fir region alone would support a sizeable industry. This leads to the question of what we would do with all this alcohol if it were produced, since there seems to be no crying demand for alcohol at present except in some instances for cheaper beverages.

GASOLINE DILUTION – AN ECONOMIC NECESSITY

Few laymen have considered gasoline from other than the standpoint of its being an expensive item in their automobile operating budgets. They know that there are various grades of gasoline at varying prices, that the cheaper grades of gasoline detonate, or "ping" in their modern high-compression engines, and that good "ethyl" gasolines do not knock, or at least not appreciably. Beyond that, the laymen does not usually go.

The gasoline and oil problem is not individual; it is not local; it is not even national. It is world wide. For the past several decades much of the world strife has been the result of greed for oil resources by countries which do not own oil lands or whose oil lands have become
depleted. The oil supply of the world will probably not last over a few decades under the present drain, at least the quantity drained must soon be reduced. But in spite of the very depressing economic picture, a few grasping millionaire tycoons have lobbied against enforced gasoline "dilution" with alcohol to reduce the annual drain and to conserve natural resources. Not only do these oil interests lobby against measures which would benefit the countries economically and the farmers and timber holders individually, but they disseminate grapevine rumors to the effect that alcoholized gasoline is in truth adulterated, inferior gasoline. Such is far from the truth.

Alcohol-treated gasoline is far superior to the straight petroleum product; it is highly anti-knock; runs cooler and smoother, keeps a cleaner engine because it dissolves carbon and it allows very much higher compression engines. The normal compression ratio of about 6 to 1 may be safely raised to the remarkable value of 10 to 1 without knocking when about 33-1/3% of alcohol is added to the gasoline. Ordinary pump fuel, alcohol treated, is sold in the British Isles which will not knock on compression ratios up to 8 to 1. This definitely allows more power to be taken from the same size and weight of engine without loss of efficiency.* Flame propagation is slowed down by alcohol, which is part of the answer.

Alcohol has an exceptionally high latent heat of vaporization. This means that it enters the engine at a lower temperature, and therefore, is heavier than straight gasoline. The heavier specific gravity of the charge amounts in principle to the effect of a supercharger on straight gasoline.

*A very definite loss in gasoline engine efficiency occurs when detonation begins.
With better thermal efficiency; i.e., less power loss through heat, there is less wear on exhaust valves and less tendency to "crack" the lubricating oil in the crankcase below the combustion chambers. And because alcohol actually dissolves carbon—carries it into colloidal suspension—the motor is kept free of the hard deposits of carbon which choke the valve seats, spark plugs and piston ring grooves of gasoline engines.

A noteworthy attribute of alcohol motor fuel is its capacity to absorb water to a limited extent and to take it through the carburetor and motor without noticeable effect. So pronounced is alcohol's affinity for water that fresh alcohol-gasoline in England will allow over a half pint of water to be poured into the ten gallon tank with no effect that is noticeable in the running of the engine. Most commercial gasoline is exposed to water through condensation, so this is no small factor.

Since alcohol treated motor fuels are even more anti-knock than are tetra-ethyl lead treated gasolines, the spark may be advanced with their use, and more speed, power and miles per gallon will result.

Just a few changes are necessary to switch from straight gasoline to a 20% or 30% alcoholized gasoline; either more manifold heat is supplied or a slightly richer mixture is used because the heavier specific gravity of the charge together with its high latent heat allows a heavier weight of air to be drawn into the cylinders.

IF ALCOHOL IS SO GOOD AS A MOTOR FUEL? WHY DO WE NOT USE IT NOW?

Only two things motivate against a general change-over in the United States from gasoline motor fuel to alcohol blends. First, the oil interest themselves are fighting the move, entirely for reasons
of personal gain. Secondly, the strongly entrenched tetra-ethyl lead interests are fighting any move which would put them out of business. Both are understandable motives, entirely in accord with our old economic philosophy of rugged individualism, but we are moving into an era of near socialism. We must consider legislation that will benefit the most people. We need legislation forcing dilution of motor gasoline with 20% of alcohol produced in this country. We need legislation providing for tax-free fuel alcohol.

It will be no simple process to get these bills through our legislatures. There are millions of dollars behind the oil lobbies; changes will have to come by gradually aroused public opinion.

ECONOMIC STATISTICS BEARING ON THE QUESTION:

The United States uses annually about seventeen billion gallons of motor gasoline, of which about 160 million gallons are used in Oregon. The Oregon figures for the past five years are given by the Oregon State Highway Commission as:

<table>
<thead>
<tr>
<th>Year</th>
<th>Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1931</td>
<td>155,447,825</td>
</tr>
<tr>
<td>1932</td>
<td>140,453,275</td>
</tr>
<tr>
<td>1933</td>
<td>155,213,833</td>
</tr>
<tr>
<td>1934</td>
<td>144,181,466</td>
</tr>
<tr>
<td>1935</td>
<td>159,077,140</td>
</tr>
<tr>
<td>1936</td>
<td>Not available</td>
</tr>
</tbody>
</table>

Thus it will be seen that Oregon uses less than one hundredth of the nation's total, and yet has the alcohol producing capacity to treat far more gasoline than Oregon can consume - an economic advantage since there are many states which couldn't supply their power alcohol requirements.
At 20% dilution, motor fuel would require over 3 billion gallons of additional alcohol a year, which would mean the opening up of an extensive new industry. Since we could probably get about 15 gallons* of alcohol per cord from Douglas fir waste, our estimated total Douglas fir annual waste of six million cords could supply a maximum of 90 million gallons, our 1\(\frac{1}{2}\) million cords of burned sawmill waste about 20 million gallons, and our waste lodgepole, etc., an indeterminate amount more. In addition, there could be much farm waste utilized - cull fruit, straw, dry corn stalks, etc. The source of power fuel would be almost unlimited, certainly replaceable, and economically sound.

RESULTS THAT MIGHT BE EXPECTED:

One of the most far reaching results that might accrue from the legislative enactments referred to hereinbefore is the change it would make in the availability of stands of excellent mature timber located too far from the mill for profitable logging for lumber alone. Extra income from alcohol production would swing hundred of thousands of acres of unprofitable lands to a profitable category. The United States Forest Service estimates that over half of Oregon's timber is now economically unavailable - in zones 2 and 3 - representing an actual loss to log. The effect of changing a large part of this Cascade Mountain timber to Zone 1 would be to increase materially the wealth of Oregon, to increase the expected life of logging and lumbering projects, and to provide more employment here.

The time will come when this move will be necessary; the time has already come when we should raise the cry for its adoption.

*See footnote on Page 11.
BIBLIOGRAPHY
References Used in Study

1. Chemical Utilization of Wood.
   U.S. Dept. of Commerce publication.


   Expt. Sta. publication; C.W. Kline, author.

4. Encyclopedia Brittanica.

5. Encyclopedia Americana.


7. The Microbiology of Cellulose, Hemicelluloses, Pectin and gums.
   Thaysen and Bunker.


RUNS A MOTOR CYCLE ON HALF DOZEN FUELS

Pole Demonstrates Invention That Permits Use of Kerosene, Alcohol or Even Olive Oil.

A motor cycle first consumed gasoline. After a run with that the tank was merely drained and refilled with kerosene, then fuel oil, then alcohol in quick succession. The motor cycle performed about the same each time, doing easily about fifty miles an hour.

The inventor says the motor will run just as well on soybean oil and operate even on olive oil, though the low caloric value of olive oil makes it uneconomic. He claims cheap performance with all other fuels including soybean oil and believes he has solved a problem of countries lacking petroleum but producing alcohol, such as Italy, France and Germany, or soy beans such as Japan and Poland. An Italian observer watched the demonstration. The inventor has also installed his invention on the motor of a French standard automobile, which has run, he says, more than 60,000 miles.

The invention substitutes for the carburetor what is termed an "injector." This piece, made by a local watch factory, together with a special injector pump, is apparently the heart of the invention. It also requires a special piston. The motor appears to be no heavier than an ordinary motor.
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Cheap and reliable transportation for Cane, Sugar Mill Supplies

These engines can be furnished for operation on Gasoline, Crude Oil or Philippine Alcohol.

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The New Studebaker Trucks are now built to use alcohol instead of gasoline, a saving to you of 45% on fuel. We now have a limited stock on hand, and are prepared to demonstrate and prove to you the saving you can make with Studebaker Trucks.

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RUGGED ---

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Truck-built to meet the needs of modern truck and bus operators. Sturdily constructed; dependable to operate. Powered with the Famous "221" GMC valve-in-head Engine

Alcohol burning—Optional

Pacific Commercial Company
Cebu — Iloilo — Manila
An azeotropic mixture with a vapour pressure higher than the separate constituents is produced when alcohol and benzole are added to petrol. In consequence this type of motor spirit has an unusually high initial volatility ensuring quick-starting at all times.

The gain in overall volatility shortens the warming-up period and is an important factor in ensuring mixture stability at low induction temperatures.

The high latent heat of alcohol cools the charge, and this is the prime requisite for improvement in volumetric efficiency. An alcohol blend has the advantage that this can be done without detriment to distribution of the mixture owing to the inherent stability of the cooled charge.

Alcohol controls and cushions the power stroke by reducing the rate of pressure rise. An alcohol blend possesses the highest octane number of any motor spirit. It is more than an anti-knock—it is anti-shock owing to shock-loading being absent, which in turn means absence of vibration and noise.

Vibrationless power and flash acceleration have been achieved without loss in thermal efficiency, as the calorific value of the alcohol blend is made equal to that of plain petrol.
McCormick-Deering
TRACTORS

MODEL T-20 DRAWBAR HORSEPOWER 25
" TA-40 " 40

While the McCormick-Deering T-20 TracTracTor is designed to operate economically and efficiently on either kerosene or alcohol without any change in the engine, the TA-10 is ESPECIALLY DESIGNED TO BURN PHILIPPINE ALCOHOL and will not operate satisfactorily on any other class of fuel.

McCormick-Deering TracTracTors are THE LOWEST PRICED TRACTORS taking into consideration: Drawbar Horsepower; Weight in terms of durability and strength; and Superior mechanical features.

We invite you to investigate thoroughly the McCormick-Deering.

INTERNATIONAL HARVESTER COMPANY
OF PHILIPPINES
154 Marques de Comillas—Manila
BRANCHES: Iloilo—Bacolod—Cebu—Davao—Legaspi—Tacloban

Spend to Save
Motor Trucks

Powered with Engines especially designed to burn ALCOHOL.

These Facts have been proven:

They are absolutely Dependable—
They are more Economical—
They are free from Carbon—
There is no loss of Power—

We shall be pleased to make a demonstration at any time, and one demonstration will convince you.

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Tel. 2-22-85
# Plymouth Alcohol Locomotives

**Eighty-Two (82) in Operation, and under Order, in the Philippine Islands**

Among the users in the Philippine Islands are:

<table>
<thead>
<tr>
<th>Company</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asturias Sugar Central</td>
<td>One (1)</td>
</tr>
<tr>
<td>Binalbagan Estate</td>
<td>Five (5)</td>
</tr>
<tr>
<td>Calamba Sugar Estate</td>
<td>One (1)</td>
</tr>
<tr>
<td>Central Azucarera de Bais</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Central Azucarera de Calatagan</td>
<td>Two (2)</td>
</tr>
<tr>
<td>Central Azucarera del Danao</td>
<td>One (1)</td>
</tr>
<tr>
<td>Central Azucarera Don Pedro</td>
<td>Four (4)</td>
</tr>
<tr>
<td>Central San Isidro</td>
<td>One (1)</td>
</tr>
<tr>
<td>Central Luzon Milling Co.</td>
<td>Two (2)</td>
</tr>
<tr>
<td>Central Santos-Lopez</td>
<td>Seven (7)</td>
</tr>
<tr>
<td>Hind Sugar Co.</td>
<td>Two (2)</td>
</tr>
<tr>
<td>Isabela Sugar Co.</td>
<td>Two (2)</td>
</tr>
<tr>
<td>Kabankalan Sugar Co.</td>
<td>One (1)</td>
</tr>
<tr>
<td>Lopez Sugar Central Mill Co.</td>
<td>Five (5)</td>
</tr>
<tr>
<td>Ma-ao Sugar Central Co.</td>
<td>Two (2)</td>
</tr>
<tr>
<td>Mount Arayat Sugar Co.</td>
<td>One (1)</td>
</tr>
<tr>
<td>Ormoc Sugar Co.</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Pampanga Sugar Mills</td>
<td>One (1)</td>
</tr>
<tr>
<td>Pampanga Sugar Development Co.</td>
<td>Six (6)</td>
</tr>
<tr>
<td>Paniqui Sugar Mills</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Philippine Starch and Sugar Co.</td>
<td>Three (3)</td>
</tr>
<tr>
<td>Talisay-Silay Milling Co.</td>
<td>Two (2)</td>
</tr>
<tr>
<td>De la Rama Centrals</td>
<td>Eight (8)</td>
</tr>
<tr>
<td>Vidaurrazaga Hermanos</td>
<td>One (1)</td>
</tr>
<tr>
<td>Julio Ledesma</td>
<td>One (1)</td>
</tr>
</tbody>
</table>

"The Standard of the Philippines"

**Sole Agents**

**KOPPEL (PHILIPPINES) INCORPORATED**

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