Comparative values of alcohol and gasoline for light and power.

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EXPERIMENT STATION

IOWA STATE COLLEGE
OF AGRICULTURE AND THE MECHANIC ARTS

AGRICULTURAL ENGINEERING SECTION

COMPARATIVE VALUES OF ALCOHOL AND GASOLINE FOR LIGHT AND POWER

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In the spring of 1906 the National Congress passed an act which became a law January 1, 1907, permitting the withdrawal from bond, tax free, of domestic alcohol, when denatured or rendered unfit for a beverage by the addition of certain materials repugnant to the taste and smell. A portion of this act reads as follows:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after January first, nineteen hundred and seven, domestic alcohol of such degree of proof as may be prescribed by the Commissioner of Internal Revenue and approved by the Secretary of the Treasury, may be withdrawn from bond without the payment of internal revenue tax, for use in the arts and industries, and for fuel, light and power provided said alcohol shall have been mixed in the presence and under the direction of an authorized Government officer, after withdrawal from the distillery warehouse, with methyl alcohol or other denaturing material or materials, or admixture of the same, suitable to the use for which the alcohol is withdrawn, but which destroys its character as a beverage and renders it unfit for liquid medicinal purposes; such denaturing to be done upon the application of any registered distillery in denaturing bonded warehouses specially designated or set apart for denaturing purposes only, and under conditions prescribed by the Commissioner of Internal Revenue with the approval of the Secretary of the Treasury."

The new law has aroused no little interest concerning the use of alcohol for fuel and light and not only has the Experiment Station been called upon to answer many inquiries, but also the subject has received much attention in the current literature of the day. The opinions advanced in these articles differ very much, and the fact has been made plain that very little reliable data concerning the subject is available. The Agricultural Engineering Section has for some time been conducting experiments to learn something of the value of this fuel for lamps and internal combustion engines, and this bulletin contains the results of the experimental work completed to date.

The alcohol used in these tests was grain or ethyl alcohol of approximately 188 proof or 94% purity by volume and was not
denatured. The gasoline was obtained from a local tank line and was the kind sold for stove and engine fuel.

The experimental work undertaken with alcohol and gasoline was for the purpose of making a comparison between (1) the heat value of the fuels, (2) their economy in the production of light, (3) their economy in the production of power, and (4) the relative safety of alcohol and gasoline for general use.

CALORIMETER TESTS.

Definition of the British Thermal Unit (B. T. U.)—The British thermal unit is defined as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. This value is definite enough for most practical purposes, however, in order to be precise, this one degree of rise is specified as being from 62 degrees to 63 degrees Fahrenheit. This is due to the fact that the specific heat of water varies somewhat at different temperatures.

Description of Calorimeter.—The calorimeter used is one known as the Parr Standard Calorimeter which is of the bomb type and is provided with an electric igniting device. The oxygen for supporting combustion in the bomb is furnished by sodium peroxide. A special accelerator composed of two parts of boric acid and one part potassium nitrate is used with the fuel. When making the tests the proper corrections were made for the heat of the accelerator and other chemical reactions, also the water equivalent of the instrument. Each determination was continued long enough to determine the rate of transfer of heat to the air, and the readings of the rise in temperature corrected accordingly. These separate calibrations were necessary because it was found impossible to keep the temperature of the room constant.

Method of Weighing Fuel.—The directions for using the calorimeter state that when liquid fuels are tested the weight of fuel used may be obtained by using a weighing flask with a dropper tube in the stopper. This method would not cause a perceptible loss in the case of heavy oils, but alcohol or gasoline is so volatile that the following method was resorted to. Small glass bulbs with a capillary tube attached were blown, weighed, filled with fuel, sealed and reweighed. Thus all losses by vaporization were prevented while reweighing and closing calorimeter. The glass of the bulb being inert did not in any way effect the results.

Heat Produced by the Union of Water and Sodium Peroxide. —As stated the alcohol contained about 6 per cent. of water by volume. This water reacts with the sodium peroxide generating heat rapidly enough when placed in the calorimeter to cause the charge to ignite at once. The rapidity of this action was prevented
by breaking only the capillary tube, leaving the bulb intact. When
the bomb was closed, it was shaken gently allowing the alcohol to
leave the bulb slowly. Thus the heat generated was given time to
be absorbed by the apparatus without raising any portion of the
charge to the ignition point. The bulb was finally broken by vio­
lently shaking the bomb and the whole was placed in the calori­
metric bath and constant conditions of temperature obtained be­
fore igniting.

Higher and Lower Heat Value.—In the combustion of gasoline
or alcohol the hydrogen of the fuel unites with oxygen forming
water. If this water passes off in the form of steam, it retains its
latent heat of vaporization. At atmospheric pressure the latent
heat of water amounts to 965 B. T. U. per pound. In determin­
ing the heat value of such fuels by the type of calorimeter used,
the water is retained and condensed, thus causing it to give up its
heat of vaporization. Results obtained in this way are termed
the higher heat values while the results of tests permitting the
moisture to pass off in the form of steam are termed the lower
heat values. The higher value is more often quoted, but the lower
value is the value more nearly realized in practice. In the follow­ing
table the higher heat values were obtained by tests while the
lower heat values were calculated from the higher values.

In the case of alcohol the heat of vaporization of not only the
water produced by combustion, but also the water originally in
the alcohol was substracted from the higher value to obtain the
lower value since this water must be converted into vapor or
steam and pass off as such.

For each value tabulated three satisfactory consecutive deter­
minations were made, and the two more nearly agreeing were
averaged.

| TABLE NO. I |
| HEAT VALUES |

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>93.67</td>
<td>7289</td>
<td>62.027</td>
<td>20060</td>
<td>121864*</td>
</tr>
<tr>
<td>Alcohol</td>
<td>.8212</td>
<td>12200</td>
<td>83521</td>
<td>10977</td>
<td>75124</td>
</tr>
</tbody>
</table>

*Lighter gasolines may have a heat value of 117000 or less.
Basing the "higher heat" value of gasoline as to weight and volume on 100%, it is to be noted from this table that the value of alcohol is 60.8% and 68.5 respectively, which is to say that on the same basis alcohol is 39.2% lower than gasoline by weight and 31.5% lower by volume than gasoline. It is further to be noted that the "lower heat value" for alcohol is 59.2% by weight and 66.4% by volume of the "lower heat value" of gasoline. Attention is called to the fact that unless a greater thermal efficiency can be secured in the use of alcohol in lamps and internal combustion engines, its consumption must necessarily be much greater.

The reason for the difference in heat values of gasoline and alcohol may be explained quite easily from a chemical standpoint. Gasoline is composed almost entirely of bodies belonging to an important series of compounds known as the paraffine series. This series has many derivatives such as its nitrogen, sulphur, and oxygen derivatives. The alcohols are a class of the oxygen derivatives of which ethyl alcohol is a member. In other words the alcohols may be said to represent the first stage of oxidation of the corresponding members of the paraffine series.

Composition of Fuels:*—The crude petroleum of the United States are largely made up of bodies of different densities composing the paraffine series. All these oils contain twice as much hydrogen plus two parts, as carbon and are represented by the general formula \( C_n H_{2n+2} \) where \( n \) may be any number from 1 to 32. The lower values of \( n \) represent gases while the higher values represent successively gasoline, naphthas, kerosene, heavier illuminating oils, lubricating oils of different grades and finally paraffine. It is stated by good authority that gasoline often contains bodies differing in formula from \( C_3 H_{18} \) to \( C_8 H_{18} \). The heavier ones or those of higher carbon content were formerly sold as naphthas, but under present market demands are included in gasoline; in fact most of the gasoline used in these tests was of such density as corresponds to \( C_8 H_{18} \).

The same series, with the addition of one part of oxygen, represents the class of derivatives known as the alcohols the general formula for which is \( C_n H_{2n+2}O \). The first in the class is wood or methyl alcohol \( C_1 H_4 O \) or as it is more often written \( C H_3 O H \); grain or ethyl alcohol is next \( C_2 H_5 O H \), followed by others the first few of which are usually distilled in small amounts with grain alcohol. The heaviest of the class is bee’s wax \( C_{30}H_{61}O H \).

*The authors wish to acknowledge valuable assistance in the way of suggestions and the loan of apparatus by Professors L. G. Michael and W. P. Coover, Agricultural Chemists at Iowa State College.
The ratio of the heat value of carbon to hydrogen is about as seven to thirty, and alcohol has a higher ratio of hydrogen to carbon than gasoline. For this reason alcohol would have a slightly higher heat value were it not for the oxygen present in the compound. But on account of this oxidation which has taken place the alcohol generates less heat than does gasoline.

**TABLE II.**

**CONSTITUENTS OF ONE GALLON OF FUEL.**

<table>
<thead>
<tr>
<th></th>
<th>Gasoline</th>
<th>Alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>None</td>
<td>65 lbs.</td>
</tr>
<tr>
<td>Carbon</td>
<td>5.10 lbs.</td>
<td>3.23 &quot;</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>.97 &quot;</td>
<td>.82 &quot;</td>
</tr>
<tr>
<td>Oxygen</td>
<td>None</td>
<td>2.15 &quot;</td>
</tr>
<tr>
<td>Total</td>
<td>6.07 &quot;</td>
<td>6.85 &quot;</td>
</tr>
<tr>
<td>Combustible Material</td>
<td>6.07 &quot;</td>
<td>4.05 &quot;</td>
</tr>
<tr>
<td>Percent of Combustible Material</td>
<td>90 7</td>
<td>85.3</td>
</tr>
</tbody>
</table>

It is to be noted that the amount of combustible material in one gallon of alcohol is much less than the amount in one gallon of gasoline.
LAMP TESTS.*

The lamps were tested for their horizontal candlepower upon a standard Reichsanstalt photometer fitted with a flicker screen, in the photometer room of the Department of Electrical Engineering of the Iowa State College. The standard used was one of several regularly used for photometric testing by that depart-

![Lamp No. 1—Operated successfully with alcohol and gasoline.](image)

ment, and, after the tests were completed, it was sent to an electrical standardizing laboratory for calibration and was found to be accurately rated.

A flicker screen was used on account of the difference in color of the lights given off by the mantle and the standard lamp. By means of the flicker screen the two colors were blended, but a

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*The Agricultural Engineering Section wishes to acknowledge the valuable assistance in the lamp tests rendered by the Department of Electrical Engineering, Iowa State College, the Sun Vapor Street Light Company, the Best Street Light Company of Canton, Ohio, and Mr. A. B. Cox, representing the Pitner Pressure Lamp of Chicago, Illinois.*
difference in intensities of lights remained perceptible. The flicker photometer screen is considered by some good authorities to be susceptible of more accurate reading than any other.

The general appearance and features of the lamps used in the tests are shown in the various illustrations. Lamps Nos. 1, 2 and 3 are gravity lamps each using a clear pearl glass chimney $1\frac{7}{8}\times8$ inches and a four-inch mantle with $3\frac{1}{4}$ inches of the mantle exposed to heat.

Lamp No. 2—Operated successfully with alcohol and gasoline.

Lamp No. 1 was an over-head generator and had an average fuel head of $15\frac{3}{4}$ inches measured from center of generator to center of tank. The tube in which the fuel was gasified was coiled over the chimney.

Lamp No. 2 was also an over-head generator, had a fuel head of 21 inches and a straight generator tube provided with a hood which seemed to aid in the absorption of heat by the generator tube.

Lamp No. 3 was an underneath generator with a fuel head of
about 16 inches. This lamp would not generate or vaporize alcohol.

Lamp No. 4 was a wick gasoline lamp using same chimney and mantle as Nos. 1, 2 and 3. The fuel was conducted upward from the reservoir, by a wick, into a tube 5-16 inches in diameter. This tube terminated in a small opening at the top and was heated by conduction through a copper rod which extended upward into the flame within the mantle. In this way the heated tube vaporized the gasoline from the wick, generating sufficient pressure to force the proper amount of fuel up through the opening in the end of the tube to fill the mantle. There seems to be no reason why the copper heat-conductor could not be so designed as to conduct enough heat downward to evaporate the alcohol, but with the lamp tested, alcohol could not be generated or vaporized.

Lamp No. 5 was a pressure over-head generator lamp receiving its fuel through a hollow wire under pressure. This lamp
used a 5-inch mantle, 4 3/8 inches of which was exposed to heat supported upon a magnesia post in center of mantle. Four series of carefully conducted tests were made upon this lamp, and curves were plotted representing the data obtained in each series.

Two complete series of tests with each fuel were made with Lamp No. 5 varying the pressure in the fuel supply tank. The results of these tests are shown graphically in Plates I. and II. In the first series of tests, an opening was used in the nozzle of the generator of such a size as to give an excess of fuel at 16 pounds pressure. In the second series of tests with gasoline, as shown in Plate II., the lamp was provided with a nozzle of such a size as to give an excess of fuel at 36 pounds pressure. In the alcohol test it was found impossible to generate as much fuel as could have been burned in the mantle. This is due to the fact that alcohol requires more heat for vaporization, and hence will
need a special lamp for high pressures. This explains the poor showing made by alcohol at high pressures as indicated by the curves.

A single test with a larger opening in the end of the generator tube and a hood to aid in generation gave 3505 candle power hours per gallon of alcohol at 33 pounds pressure as shown in Plate III. This shows graphically the maximum number of candle power hours per gallon of fuel obtained with each lamp tested.

Mention is to be made of the fact that the lamps using gasoline or alcohol produced a hissing noise which, however, was not objectionable in any case except with Lamp No. 5 with high pressure on fuel tank. Even this would not be noticed in factories and around machinery.

_Lamp No. 5—A pressure lamp which operated successfully with alcohol and gasoline. This lamp, as all others, was tested without a shade._

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A test was made of a kerosene lamp (No. 6) having a B & H burner with an inch and a half circular wick. This was to make possible a comparison between the mantle lamps and the common wick lamp using kerosene which is probably the most general illuminant for isolated dwellings.

Lamp No. 6—Kerosene Lamp.

### TABLE NO. III.

**LAMP TESTS.**

<table>
<thead>
<tr>
<th>Lamp No.</th>
<th>Fuel used</th>
<th>Duration of Test</th>
<th>Amt. of Fuel Used in Lbs.</th>
<th>Candle Power Developed</th>
<th>C. P. Hrs.</th>
<th>C. P. Hrs. per Pound</th>
<th>C. P. Hrs. per Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alcohol</td>
<td>2 Hours</td>
<td>.53</td>
<td>62.0</td>
<td>234.1</td>
<td>1571</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>2 &quot;</td>
<td>.79</td>
<td>90.6</td>
<td>298.3</td>
<td>1750</td>
<td></td>
</tr>
<tr>
<td>5 at 34 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.50</td>
<td>87.8</td>
<td>255.4</td>
<td>1657</td>
<td></td>
</tr>
<tr>
<td>5 at 33 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.31</td>
<td>51.2</td>
<td>435.1</td>
<td>2448</td>
<td></td>
</tr>
<tr>
<td>5 at 16 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.245</td>
<td>65.5</td>
<td>594.6</td>
<td>3530</td>
<td></td>
</tr>
<tr>
<td>5 at 16 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.292</td>
<td>300.0</td>
<td>749.9</td>
<td>4550</td>
<td></td>
</tr>
<tr>
<td>5 at 16 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.318</td>
<td>326.0</td>
<td>512.5</td>
<td>3065</td>
<td></td>
</tr>
<tr>
<td>5 at 16 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.341</td>
<td>320.0</td>
<td>435.6</td>
<td>2920</td>
<td></td>
</tr>
<tr>
<td>5 at 16 lbs.</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>.341</td>
<td>33.5</td>
<td>129.0</td>
<td>877</td>
<td></td>
</tr>
</tbody>
</table>

Davidson and King: Comparative values of alcohol and gasoline for light and power.
PLATE NO. 2

Light in candle power hrs. per gal. gasoline.

Alcohol consumption per hr.

Gasoline consumption per hr.

Candle power hrs. per gal. alcohol.

Candle power hrs. per gal. gasoline.

Fuel consumption in gal. per hr.

PRESSES IN POUNDS.

Candle power hrs. per gal. fuel.
PLATE NO. 3
CANDLE-POWER HOURS PER GALLON OF FUEL

<table>
<thead>
<tr>
<th>Lamp No.</th>
<th>Fuel</th>
<th>Pressure</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Gasoline</td>
<td>40 lbs.</td>
<td>4600</td>
</tr>
<tr>
<td>5</td>
<td>Alcohol</td>
<td>33 lbs.</td>
<td>3505</td>
</tr>
<tr>
<td>5</td>
<td>Gasoline</td>
<td>14 lbs.</td>
<td>3385</td>
</tr>
<tr>
<td>5</td>
<td>Alcohol</td>
<td>16 lbs.</td>
<td>2900</td>
</tr>
<tr>
<td>2</td>
<td>Gasoline</td>
<td></td>
<td>3180</td>
</tr>
<tr>
<td>2</td>
<td>Alcohol</td>
<td></td>
<td>1657</td>
</tr>
<tr>
<td>1</td>
<td>Gasoline</td>
<td></td>
<td>2948</td>
</tr>
<tr>
<td>1</td>
<td>Alcohol</td>
<td></td>
<td>1571</td>
</tr>
<tr>
<td>4</td>
<td>Gasoline</td>
<td></td>
<td>2155</td>
</tr>
<tr>
<td>3</td>
<td>Gasoline</td>
<td></td>
<td>2004</td>
</tr>
<tr>
<td>6</td>
<td>Kerosene</td>
<td></td>
<td>877</td>
</tr>
</tbody>
</table>
ENGINE TESTS.

Tests were made with three different makes of gasoline engines having ordinary compression pressures, each of which are in general use throughout Iowa. These tests were not as exhaustive as might have been desired from several standpoints, but a further continuation of the tests was not deemed advisable because the Section was unable to secure an engine designed specially for alcohol. And it was further found practically impossible to prop-

![Image of Engine No. 1](image_url)


erly alter the design, of any of the larger gasoline engines found in the laboratory, for the most advantageous use of alcohol.

But the work was carried far enough to show that alcohol probably would not come into successful competition with gasoline in the production of power, when the cost of alcohol per gallon is greater than that of gasoline, even in the special designed engine. Conditions under which alcohol will be able to compete
with gasoline will come about slowly and by the time such conditions exist, the Section expects to have secured enough experimental data upon which to base another more definite and technical bulletin.

The main series of tests were made upon Engine No. 1,* an eight horse power, four cycle, water cooled horizontal engine using a make and break igniter. A complete thermal efficiency test was not made. The temperature of the jacket water was taken merely to determine the condition under which the engine was working, but the amount used was not determined.

The brake horse power was determined by means of a Prony brake and a speed indicator, and the indicated horse power by the number of explosions and the area of the indicator cards. A device was designed for counting the number of charges exploded in the engine. Indicator cards were the means of determining the proper timing of all events of the cycle, and were taken quite frequently to determine the least opening of the fuel valve which would give a full card with high maximum pressure. The point of ignition was such as to give greatest area to indicator card. That is, the maximum pressure from the explosion of fuel was brought about at such a time as to give the line, showing the rise in pressure, a forward inclination of about 4 or 5 degrees. Igniter mechanisms of different designs require such variable lengths of time to act that the point of release of this mechanism is of little value.

Engine No. 2 was similar to No. 1 except that it was of the vertical type and rated at three horse power.

Engine No. 3 was a two horse power, two cycle, water cooled horizontal engine using a jump spark ignition.

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*Valuable assistance with the engine tests has been rendered the Section by the Lennox Machine Co., of Marshalltown, Iowa, for which we desire to express our appreciation.

†Gas Engines by F. R. Hutton.
## TABLE IV.

ENGINE TESTS.

<table>
<thead>
<tr>
<th>Engine No.</th>
<th>Kind of Fuel</th>
<th>Indicated H. P.</th>
<th>Brake H. P.</th>
<th>Gallons per Brake H. P. hr. at 20°c p'r Gal</th>
<th>Cost per H. P. hr. at 20°c p'r Gal</th>
<th>Compression Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gasoline</td>
<td>11.6</td>
<td>8.6</td>
<td>.142</td>
<td>.0284</td>
<td>51</td>
</tr>
<tr>
<td>1</td>
<td>Alcohol</td>
<td>11.6</td>
<td>8.6</td>
<td>.214</td>
<td>.0428</td>
<td>51</td>
</tr>
<tr>
<td>1</td>
<td>Gasoline</td>
<td>7.4</td>
<td>5</td>
<td>.18</td>
<td>.036</td>
<td>51</td>
</tr>
<tr>
<td>1</td>
<td>Alcohol</td>
<td>7.6</td>
<td>5.1</td>
<td>.241</td>
<td>.0482</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>Gasoline</td>
<td>2.7</td>
<td>3.27</td>
<td>.167</td>
<td>.0334</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>Alcohol</td>
<td>2.25</td>
<td>3.25</td>
<td>.226</td>
<td>.0452</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>Gasoline</td>
<td>2</td>
<td>2.21</td>
<td>.211</td>
<td>.0422</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>Alcohol</td>
<td>2</td>
<td>2.28</td>
<td>.284</td>
<td>.0568</td>
<td>62</td>
</tr>
</tbody>
</table>

Indicator card from Engine No. 1 using gasoline. 200 pound spring. M. E. P. 85.

Indicator card from Engine No. 1 using alcohol. 200 pound spring. M. E. P. 85.6.

**Note:** The gas engine indicator is an instrument for recording the pressures in the engine cylinder at all points to the stroke of the piston. The indicator cards or diagrams shown above are samples of the cards obtained by a gas engine indicator during the tests.
TABLE V.
THE AMOUNT OF AIR REQUIRED FOR COMBUSTION

| Cu. ft of Air per | Grain Alcohol | Wood Alcohol | Denatured Alcohol | Gasoline | Kerosene
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pound of fuel</td>
<td>98.9</td>
<td>71.1</td>
<td>96.4</td>
<td>166.3</td>
<td>164.3</td>
</tr>
<tr>
<td>Gallon of fuel</td>
<td>676.</td>
<td>489.</td>
<td>661.</td>
<td>1008.</td>
<td>1117.</td>
</tr>
<tr>
<td>1000 B. T. U.</td>
<td>8.92</td>
<td>8.72²</td>
<td>8.88</td>
<td>8.96</td>
<td>8.96</td>
</tr>
<tr>
<td>1000 C. P. Hrs. with Max. economy with lamp</td>
<td>233.</td>
<td>219.</td>
<td>1267.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 C. P. Hrs. with Min. economy with lamp</td>
<td>430.</td>
<td>502.</td>
<td>1268.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Air was taken as weighing .08074 pounds per cubic foot, "Kent."

2Jones’ Elements of Physical Chemistry

3Kerosene is made up of several compounds, but the specific gravity of the kerosene used corresponds to that of C₁₄H₂₀, therefore the kerosene was considered as such.
RELATIVE AMOUNTS OF AIR USED.

The amount of air consumed by different illuminants has recently received considerable attention and the subject is of great importance, for houses are not as a rule, too well ventilated. The fuels are of such a nature that the relative amount of air consumed per pound or per thousand candle power hours, as shown by our tests, may be calculated quite accurately. Gasoline is made up of several slightly different oils; and different gasolines may differ considerably in density, etc., but they differ only slightly in the amount of air consumed per pound (not more than 2% from lightest to heaviest gasoline) and vary in a like manner in the amount of heat given off. Therefore, for any gasoline the amount of air consumed per B. T. U. will not vary more than 1%. With alcohol the variation is greater. Wood alcohol requires about 72% of the amount of air required per pound for grain alcohol, but generates about 77% as much heat per pound as grain alcohol, therefore the amount of air used per B. T. U. is for wood alcohol only 93% of same amount for grain alcohol. As the ingredients of denatured alcohol, as specified by the Rules and Regulations governing the denaturing of alcohol, are one hundred parts grain alcohol, ten parts wood alcohol and one-half of one part benzine, the amount of air required for the combustion of the same may be calculated very closely. The amount of air required for kerosene will also be included in the table.

SAFETY.

The relative danger from fire connected with the use of these two fuels may be considered in two ways: (1) The flash point or temperature at which the fuel vaporizes sufficiently to form an explosive mixture at a certain distance from the exposed surface, (2) the relative difficulty of extinguishing the flame of either while burning.

Flash Point.—The flash point is determined by various methods, but perhaps the method most widely used in the United States is the one specified by the Iowa State Board of Health, and which was followed in the tests upon these fuels. The flash point as determined by these rules is the lowest temperature at which sufficient vapor is given off to be ignited by a small flame, whose greatest dimension is less than \( \frac{1}{4} \) inch, passed over the surface of the oil at a distance of \( \frac{3}{8} \) inch. The lowest flash point allowed by the State Board of Health for illuminating oils burned from the exposed end of a wick is 105 degrees F.
94% Alcohol flashed at 58.5 degrees F.
90% Alcohol flashed at 58 degrees F.
64°C B. Gasoline flashed at 15.4 degrees F.

This same comparison was made in a different way. The fuels were maintained at the same temperature, 79 degrees F., and the same amount of surface exposed to air, and were tested to find how near a small flame could be brought to the surface of each before the vapor ignited, care being taken to prevent drafts. The average distance for gasoline was 17-16 inches, and for alcohol was 1 inch. These tests indicate greater safety in the use of alcohol. This fact must not encourage carelessness, but should simply be taken to indicate that less danger is involved in the use of alcohol than in the use of gasoline.

**EXTINGUISHING THE FLAME**

The best and about the only practical method of extinguishing a gasoline flame is to smother it, and this is often impossible on account of there being nothing at hand for the purpose. A gasoline flame cannot be extinguished by applying water, for the gasoline will float and the use of water simply spreads the flame.

With alcohol these conditions are reversed as the alcohol flame is more easily extinguished, due to the fact that alcohol vaporizes less rapidly, and also to the fact that alcohol and water mix in all proportions which raises the flash point of the alcohol.

The following mixtures of alcohol and water were made and tested as to their inflammability:

**TABLE VI.**

**INFLAMMABILITY OF ALCOHOL.**

<table>
<thead>
<tr>
<th>No.</th>
<th>% Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>94</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
<td>70</td>
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<td>7</td>
<td>65</td>
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<td>8</td>
<td>60</td>
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<tr>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>
The first six solutions above flashed at room temperature 70 degrees F. The richer solutions, however, burned very freely with a steady flame. Numbers 7, 8, 9 and 10 burned quite freely, but in order to ignite them it was necessary to touch the liquid with the flame, thus generating enough vapor to support combustion. It was necessary to heat No. 11 to about 110 degrees F. before it could be ignited, but it burned for some time. No. 12 was heated nearly to the boiling point before it could be ignited, after which it burned only a short time, showing that a 25% solution is about as weak as will burn at ordinary temperatures. In other words, if enough cold water be added to burning alcohol to reduce it to 25% purity, the flame will cease.

**SUMMARY.**

The following is a summary of the results of the experimental work as far as completed in regard to the comparative values of alcohol and gasoline in the production of light and power.

1. The higher heat value of 94% alcohol is but 68 to 71% that of gasoline.
2. The lower heat value (the value more nearly attained in practice) of 94% alcohol is but 66% to 69% that of gasoline.
3. When used for the production of light, 94% alcohol will produce from 53% to 85% as much light as an equal volume of gasoline.
4. Alcohol of 94% purity must be sold for from eleven to seventeen cents per gallon to compete with gasoline for lighting purposes at twenty cents per gallon (the present retail price of gasoline in Ames).
5. Alcohol, when used in a generator lamp, will produce from two to four times as many candle power hours as kerosene in a wick lamp.
6. It was found impossible to soot the mantels of any of the lamps with alcohol.
7. Alcohol of 94% purity, when used in engines designed for gasoline, has but 68% to 85% the value of gasoline in the production of power.
8. To compete with gasoline at twenty cents per gallon for use in gasoline engines, 94% alcohol must be sold for from thirteen to seventeen cents per gallon and 90% alcohol from eleven to fifteen cents per gallon.
9. None of the engines could be started readily with alcohol, although a few could be started with less difficulty than others.
10. After having once been started with gasoline and warmed up, the carburetors as designed for gasoline vaporized the alcohol successfully, except in one instance.

11. No doubt the gasoline carburetor can be readily changed to permit the use of alcohol as well as gasoline in the same engine.

12. Experimental work does not include tests of the special designed alcohol engine which should show better economy in the use of alcohol.

13. Gasoline cannot be used readily in a special designed alcohol engine using high compression on account of pre-ignition.

14. The odor of the exhaust of an engine when using alcohol is not as unpleasant as when using gasoline.

15. Alcohol is much more pleasant to handle.

16. There is much less danger from fire when using alcohol than when using gasoline owing to the fact that alcohol does not vaporize as readily as gasoline and its flame may be extinguished with water.