to dark red, and on the component parts of corn (bran, germ and gluten), in all cases gave negative results for added color, tested under like conditions with the gluten feeds. The evaporated steep-water often gives a faint color reaction, similar to caramel (sugar) coloring, on the first wool sample.

The artificial coloring of feed-stuffs is contrary to the Federal Food Act and to many State Food Acts, unless it is specifically stated that the food product is artificially colored. The purpose of adding color to gluten feeds is only for deception, to make them appear better than they really are or to hide some inferiority, such as the use of rotten, burnt or fermented corn. The buyers of gluten feeds are fully aware that these products cannot be of absolutely uniform color or shade, due to variation in color of the raw material used, the corn. It cannot even be justly claimed that a high artificial color makes feeds more palatable, as it is very doubtful whether the esthetic taste or the idiosyncrasy of the animals have been sufficiently developed to discriminate between brown, grayish-brown or golden-yellow gluten feeds.

I wish to express my thanks to Messrs. Hills, Jenkins, Jordan, Voorhees, Wheeler and Woods, Directors of the Vermont, Connecticut, New York, New Jersey, Rhode Island and Maine Experiment Stations, for some of the samples gathered in their respective states and forwarded to me.

Nothing was known to me as to the history or as to the manufacturers of these samples of gluten feeds, they were submitted under identification marks only.

POSTAL TELEGRAPH BUILDING, CHICAGO.

[CONTRIBUTIONS FROM THE HAVEMEYER LABORATORIES OF COLUMBIA UNIVERSITY, No. 158.]

THE CALORIFIC POWER OF PETROLEUM OILS AND THE RELATION OF DENSITY TO CALORIFIC POWER.

BY H. C. SHERMAN AND A. H. KROPFF.

Received July 9, 1908.

The purpose of this paper is to put on record the calorific power of a considerable number of representative American petroleum oils and to point out an approximate relationship between the density and the calorific power of such oils.

While among the homologues of a given series of hydrocarbons, decreasing proportions of hydrogen might be assumed to involve an increase in density and decrease in heat of combustion or calorific power, it would not necessarily follow that such a relation would obtain for the mixtures of hydrocarbons which constitute the crude petroleums or their commercial products. Nor have we been able to find in the literature sufficient comparable data to give even an approximate expression of the quantitative relation to be expected between the density and the calorific power of petroleum products.

In a previous paper from this laboratory[1] it was shown that a fairly definite relation exists between the heat of combustion and the specific gravity in fatty oils, and data were then given for three petroleum oils in which also the decrease in calorific power with increasing density was fairly regular. Since that time one of us has had occasion at intervals to determine the calorific power of petroleum oils and the results have generally tended to confirm the impression that the relation between density and calorific power while not strictly quantitative for commercial oils, is yet sufficiently regular to be of some practical value. We have, therefore, thought it worth while to extend this investigation to include a careful determination and comparison of the heat of combustion and specific gravity in a variety of samples of known origin.

The samples of known origin were obtained during the summer and fall of 1907. Thirteen of these samples were kindly procured for us by Prof. C. F. Chandler through the courtesy of Mr. G. M. Sayboldt, of the Standard Oil Company; four by Prof. C. E. Lucke, from the De La Vergne Machine Company; six by Mr. T. T. Gray, chemist of the Tide-Water Oil Company; the remainder from various sources.

We desire to express our indebtedness to Professors Chandler and Lucke and Mr. Gray for the interest and assistance which greatly facilitated the collection of samples representing a wide variety of American fields and known to be typical of the petroleum oils now in use in this country.

We are also indebted to Mr. Emil Osterberg for assistance in securing a portion of the analytical data.

In the accompanying table are shown the data for 64 petroleum oils which have been so examined as to admit of comparison, with a statement of origin in all cases in which this was known. For convenience of comparison the oils are arranged in order of density and will be seen to vary from a medium light gasoline to a crude oil of exceptionally high specific gravity.

As a rule the specific gravities were determined by means of a pycnometer and the corresponding Baumé numbers are taken from the specific gravities according to the "American standard" table as given in *Van Nostrand's Chemical Annual, 1907*. The heats of combustion or calorific powers were in all cases determined by means of the Atwater-Mahler apparatus and method as described in our previous paper[2] and more fully by Atwater and Snell.[3]

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[1] Sherman and Snell, THIS JOURNAL, 24, 348 (1902).

[2] Sherman and Snell, *loc. cit.*

[3] THIS JOURNAL, 25, 659 (1903).

DENSITIES AND HEATS OF COMBUSTION OBSERVED AND CALCULATED.

No.	Specific gravity 15°/15°.	Baumé degrees.	Calories per gram.	B. T. U. per pound.	B. T. U. calculated.	Percentage error.	Description.
1	0.7100	67.2	11,733	21,120	20,938	—0.91	Gasoline
2	0.7175	65.1	11,327	20,389	20,854	+2.33	"
3	0.7200	64.4	11,404	20,527	20,726	+0.99	"
4	0.7709	51.6	11,132	20,038	20,314	+1.38	[1]
5	0.7830	48.8	11,121	20,018	20,206	+0.92	Kerosene
6	0.7850	48.35	11,119	20,014	20,194	+0.89	California refined
7	0.7945	46.2	11,128	20,030	20,098	+0.33	West Va. crude
8	0.7950	46.1	11,186	20,135	20,094	—0.20	Kerosene
9	0.7964	45.8	11,242	20,236	20,082	—0.76	[1]
10	0.8048	44.0	11,149	20,068	20,010	—0.29	Ohio crude
11	0.8059	43.7	11,143	20,057	19,998	—0.29	Penna. crude
12	0.8080	43.2	11,001	19,802	19,979	+0.88	California refined
13	0.8103	42.8	11,090	19,963	19,962	±0.00	Kansas refined
14	0.8237	40.0	10,981	19,766	19,850	+0.42	West Va. crude
15	0.8248	39.7	11,015	19,827	19,838	+0.05	California refined
16	0.8261	39.5	11,123	20,021	19,830	—0.95	West Va. crude
17	0.8321	38.2	10,972	19,757	19,778	+0.11	[1]
18	0.8324	38.2	10,990	19,782	19,778	—0.02	Penna. crude
19	0.8418	36.3	10,950	19,710	19,702	—0.04	Ohio crude
20	0.8421	36.25	10,997	19,795	19,698	—0.48	Indian Ter.
21	0.8436	36.0	11,069	19,924	19,690	—1.17	[1]
22	0.8466	35.4	10,936	19,685	19,666	—0.09	Indian Ter.
23	0.8500	34.7	10,953	19,715	19,638	—0.38	California refined
24	0.8510	34.5	10,958	19,724	19,630	—0.47	Kansas crude
25	0.8514	34.45	10,945	19,701	19,630	—0.35	[1]
26	0.8534	34.05	10,991	19,784	19,610	—0.86	[1]
27	0.8580	33.2	10,772	19,389	19,578	+0.95	Kansas crude
28	0.8597	32.8	10,766	19,379	19,562	+0.95	Illinois crude
29	0.8616	32.5	10,967	19,741	19,550	—0.95	[1]
30	0.8640	32.05	10,867	19,555	19,530	—0.12	California refined
31	0.8648	31.9	10,920	19,656	19,526	—0.65	Penn. fuel oil
32	0.8660	31.65	10,864	19,555	19,516	—0.19	Fuel oil
33	0.8670	31.5	10,850	19,530	19,510	—0.10	Penn. fuel oil
34	0.8690	31.1	10,852	19,534	19,494	—0.20	Indian Ter.
35	0.8708	30.8	10,919	19,654	19,482	—0.86	[1]
36	0.8712	30.7	10,879	19,614	19,478	—0.68	[1]
37	0.8745	30.1	10,752	19,354	19,454	+0.50	Kansas crude
38	0.8773	29.6	10,794	19,429	19,434	+0.03	Penn. fuel oil
39	0.8800	29.0	10,804	19,447	19,410	—0.18	Kansas crude
40	0.8807	29.0	10,797	19,435	19,410	—0.47	[1]
41	0.8810	28.9	10,797	19,435	19,406	—0.15	
42	0.8820	28.75	10,913	19,643	19,400	—1.22	[1]
43	0.8828	28.7	10,694	19,249	19,396	+0.73	Kansas crude
44	0.8833	28.5	10,819	19,474	19,390	—0.42	[1]
45	0.8860	28.0	10,808	19,454	19,370	—0.42	Indian Ter.

[1] Obtained by fractional distillation of commercial fuel or gas oils; Nos. 4, 25, 36, 44 and 52 were the successive fifths from one sample; Nos. 9, 21, 26, 29, and 42 from a second; Nos. 17, 35, 40, 46 and 50 from a third.

DENSITIES AND HEATS OF COMBUSTION OBTAINED AND CALCULATED (*Continued*).

No.	Specific gravity 15°/15°.	Baumé degrees.	Calories per gram.	B. T. U. per pound.	B. T. U. calculated.	Percentage error.	Description.
46	0.8862	28.0	10,762	19,372	19,370	—0.01	[1]
47	0.8900	27.3	10,788	19,418	19,342	—0.39	Indian Ter.
48	0.8914	27.1	10,690	19,242	19,332	+0.45	Texas crude
49	0.8970	26.1	10,753	19,355	19,294	—0.31	
50	0.9007	25.4	10,755	19,359	19,267	—0.47	[1]
51	0.9050	24.7	10,682	19,228	19,238	+0.05	
52	0.9065	24.45	10,751	19,352	19,228	—0.63	[1]
53	0.9066	24.4	10,605	19,089	19,226	+0.69	Kansas crude
54	0.9087	24.1	10,712	19,282	19,213	—0.35	
55	0.9114	23.6	10,724	19,303	19,194	—0.55	Kansas crude
56	0.9137	23.2	10,571	19,028	19,178	+0.76	Texas crude
57	0.9153	22.95	10,692	19,246	19,168	—0.39	Texas crude
58	0.9155	22.9	10,560	19,008	19,166	+0.80	Texas crude
59	0.9158	22.9	10,318	18,572	19,166	+2.58	California crude
60	0.9170	22.7	10,613	19,103	19,157	+0.28	Fuel oil
61	0.9179	22.5	10,433	18,779	19,150	+1.94	California crude
62	0.9182	22.5	10,547	18,985	19,149	+0.83	California crude
63	0.9336	20.0	10,600	19,080	19,048	—0.16	Texas crude
64	0.9644	15.2	10,327	18,589	18,858	+1.42	California crude

It will be seen that throughout the range of oils included in the table there is a general tendency toward a fairly regular decrease in calorific power as the specific gravity increases and the Baumé numbers decrease.

In the cases in which an approximate estimate of the calorific power is most likely to be useful, the expression of density in terms of the Baumé scale and of calorific power in British thermal units per pound will probably be most common.[2] By grouping the samples falling within certain limits of Baumé density and plotting the average figures, it was found that the approximate average relation between Baumé density and calorific power in B. T. U. may be expressed as follows:

$$\text{B. T. U.} = 18{,}650 + 40\,(\text{Baumé} - 10).$$

This formula was then applied to the data of the individual samples. In the column headed "B. T. U. calculated" and "percentage error" are given for each sample the calculated British thermal units and the percentage difference between the calculated and the determined values.

It will be seen that the difference between the calorific power as determined in the bomb calorimeter and as calculated from the formula here proposed is usually small. In only one-ninth of the cases is the difference greater than 1 per cent., in only one-thirtieth is it greater than 2 per

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[1] Obtained by fractional distillation of commercial fuel or gas oils—Nos. 4, 25, 36, 44 and 52 were the successive fifths from one sample; Nos. 9, 21, 26, 29, and 42 from a second; Nos. 17, 35, 40, 46 and 50 from a third.

[2] It should perhaps be noted that the heavier oils with lower calorific power per gram or per pound would show higher calorific power *per gallon* than the light oils.

cent.; in no case is it as great as 3 per cent. The samples examined were all believed to be of fair average commercial purity; the discrepancies might readily be larger in oils grossly contaminated with water or suspended matter, but the majority of such cases could probably be recognized by superficial examination.

In view of the number of samples examined and the fact that about half of them were selected as representative of the products of the principal oil-fields of the United States, while the remainder were taken at random from commercial sources, it would seem safe to infer that for commercially pure samples of ordinary American petroleum oils, varying from heavy crudes to gasoline, the calorific power may be predicted from the density with about as close an approximation to accuracy as is usually obtained in calculating fuel values from chemical analyses.

If it be desired to estimate the calorific power in terms of calories per gram, or to base the estimate upon specific gravity, or both, it need only be remembered that calories per gram × 1.8 = B. T. U. per pound, and that specific gravity $= \dfrac{140}{130 + B^\circ}$, according to the standard used in obtaining the Baumé figures here given; or the following estimate may be used, which being obviously only an approximate indication, is perhaps less likely to be misleading than is a formula:

A	specific	gravity	0.7 –0.75	indicates	about	11,700–11,350	calories.
A	"	"	0.75–0.8	"	"	11,350–11,100	"
A	"	"	0.8 –0.85	"	"	11,100–10,875	"
A	"	"	0.85–0.9	"	"	10,875–10,675	"
A	"	"	0.9 –0.95	"	"	10,675–10,500	"

Of the 63 samples here examined which fall within these limits of specific gravity, only two fall outside of the indicated range of calorific power by as much as 100 calories, and only seven by as much as 50 calories.

Summary.

Sixty-four samples of petroleum oils, ranging from heavy crude oil to gasoline, and representing the products of the principal oil fields of the United States, were examined for calorific power by combustion in oxygen in the Atwater-Mahler bomb calorimeter with results ranging from 10318 to 11733 calories per gram, or 18572 to 21120 British thermal units per pound.

In general the decrease in calorific power with increase in specific gravity was fairly regular, so that the relation between the two may be expressed approximately by means of a simple formula. When the calorific powers calculated from the densities by means of this formula were compared with those actually determined, it was found that in one-ninth of the cases the difference was greater, and in eight-ninths it was

less than 1 per cent.; in only one-thirtieth was it greater than 2 per cent.; in no case was it as great as 3 per cent.

While it is obviously improbable that an exact quantitative relation should exist, it is believed that from the data here given the calorific power of commercially pure petroleum oils may be predicted from the density with a sufficient approach to accuracy for many practical purposes.

SODIUM CHLORIDE, C. P.

By Frank O. Taylor.

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Ordinarily it is considered a very simple thing to obtain sodium chloride in a state of great purity, and this is perfectly true on a small scale such as would be used in laboratory. When it comes to a manufacturing basis where several hundred pounds would be handled at a time, the problem is altogether different, for containers used in manufacturing operations are of necessity different in material from those which would be used for preparing a very pure product in small quantity.

My attention was directed to this in an attempt to purchase large quantities of exceptionally pure sodium chloride, particularly such as would produce a solution as free as possible from any floating particles, the idea being that this solution was to be used for physiological salt solution, where, in many cases, it would be injected into the body intravenously. Samples of C. P. sodium chloride obtained from a number of chemical manufacturing houses, while in almost all cases free from the usual impurities of sodium chloride such as calcium, magnesium, sulphates, etc., yet invariably showed a very marked trace of insoluble matter when the salt was dissolved in water. Some of this was evidently particles of dust which were present as a mechanical impurity, while other particles bore no resemblance to impurities of this character and seemed to be connected with the chemical character of the salt.

For the purpose of instituting comparison between the different samples of sodium chloride, the residue remaining on strongly heating this insoluble matter was taken as a standard. This, of course, did not show the amount of the organic particles occurring as mechanical impurities, but, as will be seen, these organic particles are not the most important, and the inorganic and nonvolatile portion of the insoluble matter is the best criterion of the purity of the sodium chloride in this respect. For carrying out these tests 50 grams of salt were dissolved in distilled water of exactly the same purity as that described below, the solution filtered through an ashless filter, the filter washed carefully free from chlorides and then incinerated and the ash heated to strong redness in a platinum crucible, after which it was