Motor Fuels*

Vapor Tension and Other Characteristics of a Perfect Fuel

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THE gross heating value of a fuel is the total heat evolved by the complete oxidation of its combustible constituents, while when hydrogen is one of these it burns to water, the vaporization of which renders latent a portion of the heat evolved, and, if the steam escapes with the other products uncondensed, this heat is lost with it, and the net calorific value of the fuel is the total heat of combustion minus the latent heat of the water vapor formed.

In the internal combustion engine, the water formed by the combustion of the hydrogen of the gasoline all escapes as steam, so that it is the net calorific value that is the important factor.

In forming an estimate as to the value of a motor fuel, calorific value is by no means the most important thing to consider, as often it happens that the efficiency of the engine using it may be so increased, owing to the nature of the fuel allowing of high compression or other factors that tend to the better conversion of the heat units into power, that a fuel relatively poor in calorific value may be nearly equal to one of far higher thermal units in actual use.

There is, however, one point that always must be taken into consideration, and that is the vapor tension of a liquid intended for use as a motor fuel, as this governs its power of evaporation, and upon it depend ease in starting from cold and flexibility in running.

A good motor fuel must give off enough vapor at low temperatures to form an explosive mixture in the cylinders of a car that has been standing all night in a cold garage, as if it does not considerable time and much effort have to be expended in working the starting gear, so as to get a sufficient amount of combustion in the cylinder to raise it to the necessary temperature.

A good deal naturally depends on the form of carbureter used; but with any of fairly modern type a good spirit should give no trouble.

We have seen that when a crude oil is distilled the temperature is raised gradually, and that the fraction which comes over up to 150 deg. Cent. is called "benzine," and contains the most volatile portions of the oil. The next fraction coming over at from 150 deg. Cent. to 300 deg. Cent. is called "kerosene," and forms the ordinary illuminating oil. The lower fraction can be redistilled, and if the specific gravities and vapor tensions of these fractions be taken it will be found that the vapor tension falls as the specific gravity rises, as is shown in the following table obtained from the fractionation of an American oil:—

Specific Gravity.	Vapor Tension in Millimeters Water at 15 deg. Cent.
0.650	2,110
0.680	1,185
0.695	930
0.735	410
0.756	125
0.762	85
0.772	40
0.788	15
0.812	0

These figures make it clear that an oil of this last character, having a specific gravity of 0.812 (which would correspond to kerosene or lamp oil), cannot be used alone as a motor spirit, because on a day when the temperature was 15 deg. Cent. the engine if cold would never start, as no vapor would be given off to make the explosive mixture with air, and not only must vapor be given off but sufficient vapor to make an explosive mixture with the air in the cylinder.

The scientific methods of determining the vapor tension of a liquid upon which its volatility depends would be far too complicated for use by the ordinary observer; but he can form an equally sound judgment as to how far a motor fuel is likely to be satisfactory in starting and flexibility by means of a simple apparatus devised by Sir Boverton Redwood and Captain Thomson, whereby the relative volatility of various spirits could be determined, the object they had in view being the pressure the spirit might develop in a closed vessel on increase of temperature as bearing upon safety in storage and transport.

The apparatus consists of a thick-walled glass tube of small bore, about 30 inches long. The lower end of the tube is turned up and widens into a cylinder, about 6 inches long and 1 inch in diameter, the upper end of which terminates in a short length of glass tube. The long

tube is graduated in inches divided into tenths, and the wide cylinder is provided with two marks, the lower corresponding with the zero of the scale and the upper being placed at nine-tenths of the capacity of the cylinder above the lower mark.

In use a short length of stout rubber tubing is wired to the tube at the top of the cylinder so as to cover it entirely and project about ¼-inch above it. Mercury is poured into the cylinder up to the lower mark, and care is taken that the mercury thread in the capillary tube is not broken. Enough of the liquid under test is poured into the cylinder to fill it well up to the upper mark, and the apparatus is clamped vertically in a vessel of water at 50 deg. Fahr. After sufficient time has elapsed to allow of this temperature being attained by the apparatus and its contents, the level of the liquid is corrected, if necessary, and the rubber tubing is closed by a pinch cock screwed up very firmly just above the top of the glass tube, the open end of the india-rubber tube being further closed by a glass stopper. The whole apparatus is immersed above the top of the rubber tube in water at 50 deg. Fahr. The temperature of the water is raised very slowly by means of a rose burner, and its temperature read by means of a thermometer immersed in it, unequal heating being avoided as far as possible by any form of mechanical stirrer. As the temperature of the water rises the height of the column of mercury in the capillary tube is read off at every 5 deg. Fahr. rise of temperature in the liquid, the heat being so regulated that this rise takes about ten minutes, and is continued to 100 deg. Fahr.

In this way, a comparison can be made between the vapor pressures of various suggested substitutes for gasoline as long as they are of the same kind of hydrocarbon, as we know that the best gasolines on the market, give only just the necessary starting power on a cold morning, and that anything that gives a vapor pressure less than that will give rise to trouble in starting, the pressure being a very fair measure of the trouble that would be experienced.

In the following table are given the pressures exercised by Pratt's "Perfection," benzol, alcohol, and pentane:—

VAPOR PRESSURE IN INCHES IN MERCURY.

Temperature deg. Fahr.	Pentane.	Pratt's Spirit.	Benzol.	Alcohol.	A.	B.
55	1.4	0.7	0.1	0.3	0.4	1.0
60	2.0	1.4	0.7	1.1	1.1	2.6
65	3.8	2.6	1.5	1.8	1.9	4.2
70	5.8	3.6	2.5	2.7	2.8	6.4
75	8.0	4.8	3.5	3.6	3.8	8.9
80	10.4	5.9	4.5	4.7	4.9	10.9
85	13.1	7.1	5.5	5.75	6.2	13.4
90	15.9	8.2	6.4	6.9	7.1	15.6
95	18.9	9.3	7.3	8.0	8.1	17.6
100	22.3	10.5	8.4	9.2	9.0	20.5

Taking the figures in the table, we know by experience that Pratt's spirit with an air temperature of 60 deg. Fahr. starts from cold without any trouble, and so also would the benzol and the two cracked spirits marked A and B, but nothing one could do would make the alcohol start at that temperature, although it is showing a higher vapor pressure than the benzol, and this is due to the percentage of combustible vapor in the mixture in the cylinder that will explode with electrical ignition. In the case of the benzol it needs only 2.7 per cent of vapor to give explosion, while with alcohol there must be at least 4 per cent, so that although its vapor pressure is higher than that of benzol it does not vaporize sufficiently quickly to reach the larger proportion of vapor needed.

When gasoline or other combustible vapors are mixed with air the maximum of chemical action—that is, the complete oxidation of the carbon and hydrogen of the combustible into carbon-dioxide and water vapor—gives the greatest energy of explosion. This point is a fixed and unalterable ratio of the vapor to air, and varies only with variation in the composition of the combustible body. On each side, however, of the percentage of vapor that gives the maximum effect there is a range over which the mixture is still explosive, although gradually diminishing in power the further the percentage of vapor is from the correct mixture, until points are reached above and below which the mixture is non-explosive.

The percentage over which the mixture is explosive is called the "explosive range," and varies slightly according to the method of ignition, and figures that have been given for electrical ignition are:—

EXPLOSIVE RANGE OF AIR-VAPOR MIXTURES WITH ELECTRICAL IGNITION.

	Per Cent	Range Per Cent.
Acetylene.....	3.2 to 52.2	49.0
Ethylene.....	4.2 to 14.5	10.3
Alcohol.....	4.0 to 13.6	9.6
Ether.....	2.9 to 7.5	4.6
Benzol.....	2.7 to 6.3	3.6
Gasoline.....	2.5 to 4.8	2.3

Although when ignited by a flame a still smaller proportion is combustible with explosion.

It is quite evident that the wider the range over which the spirit employed will form an explosive mixture, the more elastic will be the proportion of air, and we all know the trouble caused when a sudden change in heavy traffic stops the engine by throwing the mixture outside the explosive limits.

Another test which it is essential to make with a motor spirit is a fractional distillation, in order to ascertain the proportion of hydrocarbons present in it vaporizing at a sufficiently low temperature to ensure a complete combustion in the cylinder, and with spirit of the ordinary character 90 per cent ought to distill over below 150 deg. Cent.; but it must be remembered that this does not always apply to gasoline substitutes.

In carrying out a fractional distillation of this character great care has to be exercised in standardizing the method to be employed, as the results found by various observers in a fractionation of the same spirit differ widely, unless the same method of procedure and apparatus are adopted. Probably the most satisfactory method is to take a short-necked Jena glass flask, into the neck of which is fitted a five-bulb Young dephlegmator, in the top of which is placed a thermometer so arranged that the bulb is just below the level of the side tube. A uniform rate of distillation throughout the run must be maintained, and the temperature is noted at which the first drop leaves the end of the side tube. From that moment, the volume collected through each 10 cubic centimeters should be noted, and the distillation carried up to 150 deg. Cent., unless the bulk of the liquid has passed over below that temperature.

When distilling mixtures such as are to be found in some gasoline substitutes, the distillation results, if plotted out, will generally give a very good idea of what the constituents are, which can be confirmed by taking the specific gravities of the main fractions. In the following table the fractionation of Pratt's spirit is shown as an example of a true gasoline:—

FRACTIONATION OF PRATT'S SPIRIT.

Specific gravity.....	0.7088
First drop.....	30°C.
Below 50°C.....	1.50 per cent
" 60°.....	7.25 "
" 70°.....	19.25 "
" 80°.....	28.75 "
" 90°.....	42.25 "
" 100°.....	57.25 "
" 110°.....	70.25 "
" 120°.....	79.50 "
" 130°.....	86.50 "
" 140°.....	91.00 "

It must, however, be clearly grasped that in many gasoline substitutes it is possible to use mixtures in which some fractions distill as high as 250 deg. Cent. if sufficient spirit distilling below 100 deg. Cent. is present to give ease in starting and the necessary flexibility in working.

When gasoline was first introduced it seemed probable that its high volatility, and the fact that the vapor it gave off was highly inflammable and formed a violently explosive mixture when mixed with air, might threaten its use, but experience has shown that the accidents due to it have not been nearly so numerous as it was feared they might be. One knows from experience that on a warm summer's day the vapor comes off so rapidly that a tin left open soon undergoes a serious diminution in volume, and that the spirit has such a wonderful penetrative power, and is so liable to creep, that the smallest fault in a screw-cap or plug leads to a slight leakage, with the result that in places where the gasoline is stored, slight leakage and evaporation into the air are constantly occurring, and as 2½ per cent of the vapor in the air forms an explosive mixture of maximum strength, while 1.6 per cent is still explosive when ignited by flame, strict precautions should be taken to protect such places from becoming an active source of danger. Probably the factor which gives the greatest danger is that the weight of the gasoline vapor is so far above that of air that it

* Abstract from a lecture delivered before the Royal Society of Arts.

spreads and flows over a flat surface in much the same way that a liquid would do, and as a pint of it poured on the floor will give sufficient vapor to cover 80 square feet with inflammable vapor to a sufficient thickness if ignited at any point to carry the flame back to the point of leakage, it is clear that the floor level is the one which should be specially considered in precautions to minimize danger, and a strong floor draught is one of the most important factors of safety that can be provided.

The reason why so few accidents happened in the past is due to the high temperature needed to ignite the vapor either alone or mixed with air, and a long series of experiments made in the early days of the use of gasoline showed that the vapor could not be ignited by the glowing spark on a splint of wood, a red-hot piece of coke, or a shower of sparks from a flint and steel; and from experiments which I have made since I think we may safely

assume that the ignition point is in the neighborhood of 1,200 deg. Cent., and it is this which has safeguarded its use. How often have we seen the careless chauffeur filling the tank of his car with spirit while at the same time smoking a cigarette, a proceeding which, had the igniting point been as low as that of any ordinary combustible, such as paper, wood or coal, would have led to disaster.

The necessary temperature to cause ignition, although never reached by a glowing body, is attained with the smallest of flames, the temperatures of which are practically all higher than 1,200 deg. Cent., and the throwing down of a lighted match on a surface over which gasoline vapor is flowing has caused many serious fires.

The high ignition point of the explosive mixture of gasoline and air also explains the necessity for a higher density spark for igniting the mixture in the cylinder.

The volume of vapor yielded by a sample of gasoline depends upon its composition, the variation which exists between the various constituents being shown in the following table:—

VOLUME OF VAPOR FROM GASOLINE HYDROCARBONS.

	Specific gravity.	Boiling-point.	Cubic Feet of Vapor	
			Per Gallon.	Per pound.
Pentane.....	0.626	37.6°C.	31.2	4.9
Hexane.....	0.664	69°	27.7	4.1
Heptane.....	0.700	98°	25.7	3.7
Octane.....	0.719	118°	22.6	3.1
Nonane.....	0.741	136°	20.8	2.9

So that the higher the specific gravity the lower will be the gas yield.

The Zodiacal Light

Theories as to It's Cause, and It's Place in the Solar System

THE theory that the zodiacal light is a nebulous ring surrounding the sun is, for the most part, no longer held. It was Baron von Humboldt's theory and Sir John Herschel wrote: "I cannot imagine upon what grounds Humboldt persists in ascribing to it the form of a ring encircling the sun." For dynamical and optical reasons we believe this theory to be untenable.

The theory that it is a solar appendage has received more support and in fact remains the theory most generally accepted. It was originated by Giovanni Domenico Cassini at the Royal Observatory, Paris, about 1685. But it is hard to conceive what form such an appendage can take reaching out from the sun to a distance exceeding the earth's orbit. At Pike's Peak in 1878 during a solar eclipse Professor Langley observed the long coronal streamers extending to a distance estimated at 10,000,000 miles, and the question has been asked: May not the corona in increasingly attenuated form extend 93,000,000 miles? Apart from the fact that the appearance of the Zodiacal Light does not correspond with that of the corona, Laplace declared that the sun's atmosphere "can extend no farther than to the orbit of a planet whose periodical revolution is performed in the same time as the sun's rotary motion on its axis, i. e., only $\frac{1}{8}$ of Mercury's distance from the sun." There is no evidence that the coronal streamers extend even to the orbit of Mercury.

Moreover, if the Zodiacal Light is a solar appendage of the kind supposed, reaching forth unbrokenly from the sun, it must create a resisting medium involving Mercury, Venus, the earth and the moon and of this there is no evidence. A variant of this theory invokes Arrhenius's doctrine of light-pressure, by which it is surmised that streams of electrons expelled from the photosphere are light-borne to a distance just exceeding the earth's orbit and there held in unstable equilibrium. This is a fanciful speculation and, without prejudice to the applicability of Arrhenius's doctrine to the relationship between solar electrical action and terrestrial magnetism, it may be stated that there is no evidence that the zodiacal light can be thus accounted for. The conception of a lenticularly-shaped envelope, which is usually connected with the solar appendage theory, arose in my opinion, from the lenticularly-shaped appearance of the zodiacal light as frequently observed. But this conception is rendered valueless by the fact that *the illuminated part of the Zodiacal Light band does not exhibit the whole of the Zodiacal Light band material at any one and the same time.*

The third outstanding theory to account for the Zodiacal Light is that it is an earth ring, comparable, say, to the "crape" ring of Saturn.

By using the word "comparable" it is not intended that the Zodiacal Light band corresponds in every respect to the crape ring of Saturn. Variety in similarity appears to be Nature's method. Saturn's ring system is situated in the line of the planet's equator. The Zodiacal Light band follows the line of the ecliptic and maintains with respect to the Sun's illumination a uniform appearance the year round, but as viewed by an observer on a fixed station the light changes in direction and intensity in the course of the year, according as the angle made with the horizon is more oblique or more nearly approaches a right angle. The points of resemblance suggested by the word "comparable" are (1) that, like Saturn's "crape ring," the Zodiacal Light band is a planetary ring and (2) that, like the crape ring, it is well-nigh transparent.

After the famous Leonid display of 1833, a discussion arose on the possibility of the Zodiacal Light being the origin of meteors. In the course of that discussion J. C. Houzeau contributed a paper to the *Astronomische Nachrichten* in which (as the result of his own observations) he argued that the causes of the Zodiacal Light

may be "more local than has been hitherto supposed." A few months ago a well-known English astronomer, knowing of my interest in Zodiacal Light investigation, wrote me that no definite, stable results can be obtained concerning the place of the Zodiacal Light in the Solar System "until we have a continuous series of observations on both sides of the equator." Presumably he was not aware that such a series had been made. From April 2, 1853, to April 12, 1855, Sundays excepted, for every day of good observing weather, the Rev. George Jones, A. M., U. S. N., chaplain of the U. S. Japan Expedition, made observations of the Zodiacal Light. His report, comprising notes made at the time of each observation, accompanied by carefully drawn charts, was published by authority of Congress as a government document and forms volume III of the report of the U. S. Japan Expedition under the command of Commodore W. C. Perry. Under no better conditions could a series of observations possibly be made, and the length of time, extending over two years, in both the eastern and western hemispheres, north and south of the equator, from 41 degrees 50 minutes north (near Hakodadi, Japan), to 53 degrees 38 minutes south. (Straits of Magellan), permitted of as diversified a study of the Zodiacal Light as could be desired. Of the 328 observations reported and charted, 148 were made in the tropics. On each chart is marked the horizon line for each observation (sometimes three or four on the same evening or morning); the ecliptic line is marked, also the place of the sun on the ecliptic below the horizon showing the angle between the sun and the horizon; the outline of the stronger part of the light for each observation is drawn with reference to conspicuous stars or planets and a dotted line surrounding this shows the extent of what Chaplain Jones calls the Diffuse Light spreading North and South of the stronger band as far as he could see it.

Among other interesting special features of his report we note the shifting of the Zodiacal Light, as projected against the starry sky, from hour to hour; but always along the ecliptic; the gegenschein visible in the east in the evening; the Moon Zodiacal Light in the evening in the east prior to moonrise; the joint Sun and Moon Zodiacal Light, seen in the west in the evening, the moon being at first quarter; the simultaneous eastern and western Zodiacal Lights, seen in favorable latitudes, the cone of light reaching up from both east and west horizons about midnight, the eastern light growing stronger as the western light fails; the pulsations of the light due either to atmospheric conditions or to commotions in the Zodiacal Light band material; the varying brightness of the gegenschein sometimes well-defined, at other times quite elusive and much elongated, due to change of angle of reflection in the course of the year.

While strenuously resolved not to begin his observations with any preconceived theory of the place of the Zodiacal Light in the Solar System, Chaplain Jones states that after a few month's observations, strive as he might, he could not banish the thought that it is an earth ring and this thought ripened into conviction by the time the cruise ended.

Present-day astronomers are generally agreed that the Zodiacal Light is at no great distance from the earth; that, as is said, there is something "familiar" about it. A careful perusal of Chaplain Jones's data, illustrated by his charts, leads one—no less than he was led when actually making the observations—to the conclusion that the theory of the Zodiacal Light being an earth-ring fits the facts more fully than any other theory. Especially the relation of the reflected moonlight in the eastern evening sky to the Zodiacal Light band; the presence at midnight of both eastern and western lights; the uniformly broad base of the light along the horizon, narrowing and sometimes tapering toward the observer's meridian circle; all of these facts considered in connection with the laws of the reflection of light argue a circularly or elliptically curved band at no remote distance from the earth, from which the light is reflected according to the angle of incidence.

Why, then, it may be asked, has not Chaplain Jones's conclusion won acceptance?

It is my judgment that the theory of a ring of nebulous or meteoric matter surrounding the earth was held untenable because, if the Zodiacal Light band were such a ring, the light would be *strongest directly behind the earth* as in the case of the full moon. It is, I venture to believe, this consideration which has led astronomers to reject the earth ring theory. Can this crucial objection be removed? It is unanimously conceded that there is a dimming of the Zodiacal Light directly behind the earth. At times nothing can be seen of it, at other times the gegenschein can be made out. The question naturally arises: Why is the Zodiacal Light dimmed (at times invisible), right behind the earth? My answer is: *The earth's shadow falls athwart it.* The Zodiacal Light lies along the ecliptic—i. e. runs along the signs of the zodiac, the zodiacal constellations;—therefore, if within the range of the earth's shadow, it must thereby be dimmed. Lying on the ecliptic, the central part, so to speak, of the Zodiacal Light band is *exactly in the place of a full moon totally eclipsed.*

This, I beg to submit, is an adequate explanation of the reason why the Zodiacal Light is not strongest directly behind the earth. Accepting this reasonable explanation the crucial objection to the earth ring theory is demolished and the theory itself is strengthened to the point of demonstration. Further objection may be urged that if the Zodiacal Light band be an earth-ring the illumination should be strong and clear-cut right to the point where the earth's shadow intervenes. In considering this objection I suggest that allowance should be made for the penumbra section of the earth's shadow which should have the effect of *diminishing* the brilliancy of the Zodiacal Light as it approaches the umbra. The persistence of the light through the penumbra and even into the umbra, though dimly and more narrowly, as reported from observations in the tropics seems to indicate that the Zodiacal Light material may be more agglomerated along the axis of the band.

On account of the feeble intensity of the light spectroscopic examination is very difficult and a specially designed spectroscope—such as Dr. Michie Smith's at Kodaikanal—is desired. Recent work by Professor Fath at Lick and Mt. Wilson corroborates previous examinations to the extent of affirming that the light is reflected sunlight.

It may therefore be affirmed that the theory of the Zodiacal Light being a planetary ring is in good standing and that the preponderance of evidence is in its favor.—*Rev. W. E. Glanville in Popular Astronomy.*

Zeppelin Bombs

THE incendiary bomb used by the Germans in their raids on London, as a rule, is conical, of 10-inch diameter at the base, wrapped round with tarred rope and having a metal handle at the apex. The base is a flat cup, onto which a pierced metal funnel is fitted, having the ignition device and handle fitted at the top. The funnel is generally filled with thermit. The latter, upon ignition, generates intense heat, and by the time of the concussion has taken the form of molten metal, having the extraordinary high temperature of over 5,000 deg. Fahr. The molten metal is spread by the concussion. Outside the funnel is a padding of a highly inflammable or resinous material, bound on with an inflammable form of rope. The resinous material creates a pungent smoke. There is generally some melted white phosphorus in the bottom of the cap, which develops nauseous fumes. In some cases celluloid chippings are added, and occasionally a small quantity of gasoline.

1 By "directly behind the earth" is meant the point of the sky exactly opposite to the sun, e. g., at midnight.