BEAU DE ROCHAS

It was not until 1862 that the fundamental principles underlying the economical operation of the internal combustion engine were set forth by Beau de Rochas, a French engineer.

His paper set forth, first the conditions under which maximum economy could be obtained, namely:

1) Smallest possible surface - volume relation for the cylinder (large bore - short stroke) R.L.B.

2) Most rapid expansion possible. (Attained by Bourke cycle)

3) Maximum possible expansion. (Attained by Bourke cycle)

4) Maximum possible pressure at beginning of expansion process. (Total, Bourke cycle)

1) Suction during the outward stroke of the piston.

2) Compression during the inward stroke of the piston.

3) Ignition of charge at inward D.C. and expansion on outward stroke.

4) Exhaust during the next inward stroke of the piston.

(Note: One complete revolution of crank in a Bourke engine duplicates the above cycle twice.)

BOURKE ENGINE FUNCTION

The Bourke engine is the only real breakthrough in internal-combustion practice. The design, uses ported cylinders, cyclonic turbulating pistons to prevent loss of raw fuel to the exhaust, built-in ram induction manifolding, cylinders directly opposed and in a common plane, pistons secured to a rigid rod, explosions successively on each end, as a free piston engine, to compress in the opposing cylinder which permits the use of terrific compression ratios. There is no side loading on cylinder walls and the crankpin bearing is an annular, triple slipper type working in cooperation with the reverse cam effect which produces a rotary toggle action. A toggle action is used in machines where an increase of force is desirable for a lesser input. Most any compression is possible with the Bourke engine, the 400 cubic inch was 24 to 1.

The Bourke engine is not just another mechanical device to extract the energy from the carbon content of hydrocarbon fuels, and then waste most in heat ejection, but it is designed to use the carbon as a trigger to convert the hydrogen and oxygen to water. In combining the two, terrific forces are released. (See Sir Frederic Abel, Sir Humphrey Davy, Bunsen and others, their findings on hydrogen.)

The Bourke engine was designed, and built, based upon the findings of the above eminent scientists. It was built to extract the energy from the fuel in its entirety and not to pay a premium for additives, or to use unleaded fuel and have the hydrogen and oxygen combine to create a "ping" and ruin the engine, as happens in conventional engines.

Should the energy in any hydrocarbon fuel, in the quantities it is inducted into the cylinders, be released in its entirety in a conventional engine with all its side loading and dead strokes to be accelerated and decelerated, parts would be scattered far and wide. This was common to some diesels when the fuel was interrupted allowing the extremely lean mixture to create pressures sufficient to disintegrate the prime mover. (Now a kill devise is used on some to prevent that.)

Many misinterpreted the terrific acceleration characteristics of the Bourke engine and its ability to twist off shafts (impossible for conventional engines of the same displacement) as a fault. It is not a fault, it only indicates more energy being released from the same displacement; therefore, the much sought after goal of more energy from a pound of fuel was being realized. A more rugged drive end was indicated, adequate for an engine of four times the displacement of a Bourke .

About two and three-quarters centuries (275 years) ago, the idea of an internal combustion engine (motor) using gunpowder as the explosive element was first conceived by Abbe Hautefenille (in 1678), but the idea ended with its conception and it was not until the end of the 19th century that a practical combustion engine was made possible by Murdock, who discovered that a combustible gas could be distilled from coal. Numerous attempts were made to design an engine using this fuel; and in 1826, Brown constructed a gas-vacuum engine which was probably the first to do real work. About 1838, Barnett made the first attempt to compress the charge before explosion, and many patents followed with no material progress.

In 1860, the Lenoir Motor made its appearance in France, and many engines of this type were built and used in England and the United States. The Lenoir had the appearance of a double-acting, horizontal steam engine with simple slide valves driven by eccentrics, and designed so that the inside edges only uncovered the ports at the beginning of the stroke and admitted a mixture of air and gas to the cylinder. At half stroke, the valve closed and the charge was ignited by an electric spark from an induction coil. The fuel expanding behind the piston gave a pressure of 60 to 70 pounds per square inch. The exhaust opened at the end of the stroke and remained so during the return of the piston, so the products of combustion were entirely cleared from the cylinder. As the engine was double-acting, a similar cycle took place on the other side of the piston.

To make the combustion engine a commercial success, further improvement was necessary, and the Hugon Motor appeared in 1862. Shortly afterwards, Beau de Rochas presented his four-stroke cycle idea. To get a high economy, it was the belief that the gas must be compressed to high pressure before ignition; and to obtain this result, he proposed that the cycle of operation should occupy four strokes of the piston, or two complete revolutions of the crank.

This cycle was first put into actual operation in 1876 by Dr. Otto, and it is now universally known as the Otto cycle. When Otto assembled and operated his first successful four-stroke cycle engine, there was established a formula which was basically sound and was practical in every respect in view of the development of the state of the art at the time; but he did not foresee and could not provide for the enormous advances in metallurgy, chemistry, electricity, hydraulics, dynamics, etc., which of course, its development fathered.

In our rush forward, we have failed to take into account that, what was sound then, might have to be modified and revised to compensate for conditions and forces which have been created or accentuated due to the aforementioned advances which have brought internal combustion engine design to a dead end, from which there seems no way out, and there is no way out based upon the Otto formula. No further gains than are now being enjoyed can be foreseen. Actually, records indicate the only real advances in the last 20 years or more have been attained through the use of more expensive fuel.

Dr. Otto's formula was correct as related to the state of the art at the time, for all power generated was either by water wheel, windmills, animal powered treadmills, and some steam power, which were all of a very slow speed variety. Therefore, the formula did not have to take into consideration the destructive forces which are generated now in a high speed engine. Said forces have reached the point of disintegration in the present engines at extremely high revolutions, which high revolutions are so necessary if one wishes to crack existing speed records.

Horse power is a secondary consideration in breaking speed records. High revolutions per minute is a must. For example, take Slo Mo's propeller speed, where the horse power has been reduced from the engine shaft through gears to deliver about fifteen thousand rpm to the propeller with considerable loss in effective horse power.

The history of internal combustion to 1900 and a careful checking to date of all available data, as well as a very broad experience, uncovers absolutely nothing in the way of mechanical advances that were not known prior to 1900.

Every conceivable type of valve we know today had been tried. Overhead valves and hemispheric combustion chambers were old stuff. Compounding the stroke dates back to before 1890. Two opposed pistons in a cylinder with ports date back to circa, 1881. But no one as far as I can determine to 1900, was so naive as to try to produce a prime mover using the cam (wedge) in place of the crank (lever) to transfer reciprocation motion into rotary motion. Only during the first quarter of this century was this tried. The ancients knew their laws of mechanics. Our modern sophisticated generation, it seems, were more intent on producing something different, with not enough thought to improvements as to better fuel conversion. With the result, many queer cam engines were built during that period only to end up in the scrap, or as historical oddities. The designers should have known before their sketches were finished that no economy or dependable operation life could be expected from them.

Some of the better known cam engines were: the wobble plate, barrel cam, clover leaf (Marchetti), figure eight (Fairchild Caminez). The Knight sleeve valve was as good as any contemporary engine for slow rpms, but could not compete in manufacturing cost, weight and higher rpm for competition.

BOURKE CYCLE DIFFERENCES

For millions of years, the law of gravity was in force, yet it was only about two hundred and fifty years ago that Sir Isaac Newton discovered one of the most obvious of natural phenomenon. Therefore, it is not too strange that about one hundred years had to elapse after the invention of the four-stroke cycle engine before any basic improvement was made.

Therefore, with the advent of the Bourke cycle, it is going to be necessary for all of us, engineer and layman alike, to discard and forget much of what has been gospel up to this time. If we are to thoroughly grasp and understand the workings of this radical advance in internal combustion practice, practically every formula now in use must be discarded.

In conventional engines, the fuel must be tailored to suit the particular engine by a very costly cracking process, whereas in the Bourke cycle, the fuel is subjected to a series of cracking actions in the normal course of its introduction into the combustion chamber, and the lower grades of fuel are more compatible, the higher octanes are to be avoided.

Another belief which must be revised is that continuous high rpm is harmful and wasteful of fuel and parts. To the contrary in the Bourke cycle, the pistons and rods are always under pressure and operate in a straight line with no destructive inertial forces generated. Lack of connection between crankpin and connecting rods call for a different approach in design and balance of crankshafts. The overall design of the engines in general to obtain the greatest horse power with extreme economy and unbelievable low weight per H. P. calls for a new concept also.

Conventional engines are always thought of in multiples of one cylinder and are so grouped to usually deliver spaced impulses in a vain attempt at dynamic smoothness. The Bourke cycle can only be attained in groups of two cylinders; and inasmuch as any two-cylinder group is gyroscopically balanced, the progressive firing of cylinders in a multi-group assembly is not necessary for smoothness. In many applications, the simultaneous firing of half the cylinders (as in the six or eight cylinder grouping that is three or four cylinders at the same time) will deliver a much higher H. P. output per cubic inch displacement at any comparable rpm and at a lower fuel to H. P. hour ratio than any other known type of firing progression.

Mechanically, the Bourke engine is capable of high rpms not possible in any other type of reciprocating piston engine. Therefore, a revised approach to gear ratios and operating procedures must be made to take advantage of the extreme practical operating range. The Bourke cycle engine differs in many respects from other known engines, such as the two-stroke cycle, Otto (or four-stroke cycle), and the Diesel cycle which is but a modification of either of the above working with a constant pressure cycle, to create heat, with fuel injected under pressure and timed so that ignition will occur to best advantage.

All the above type engine cycles can be built in multiples of one-cylinder engines, that is, 1, 2, 3, 4, etc. The Bourke cycle is possible only in multiples of two cylinders, that is, 2, 4, 6, etc., because each rod is a rigid unit with a piston securely fixed to each end shuttling through an oil-filled (almost half full) sealed crankcase having a single throw crank, which is activated by, but not connected to, the rod which has a slotted opening in its center.

Each time the rod moves, a power impulse is delivered to the crank. Valving action is through a combination of cylinder and piston ports.

So much for the mechanics of the engine, as there are no more parts other than the two opposed cylinders.

The cycle starts by inducing a vacuum below a piston which vacuum activates a fuel injector, the vacuum cracks the fuel, then a high speed stream of air produces a turbulence, or a carbureted mixture can be inducted instead. This turbulating mixture is highly compressed and cyclonically transferred to the top or working side of piston, compressed, ignited, expanded against piston on power stroke and exhausted. The same cycle of events was occurring in the opposed cylinder, but in staggered sequence.

Any of the conventional means of ignition can be used successfully, such as electric ignition, glow plug, whichever suits the application.

Trucks and buses now using conventional diesel engines must maintain engine rpm regardless of vehicle speed. Whereas in a truck or bus powered with a Bourke engine, a lower gear ratio can be chosen to suit the hill, one that will allow for an increase in engine rpm to maintain road speed. This is possible because the H. P. of the Bourke engine increases progressively with rpm. Therefore, the necessary power to lift the load over the hill without loss of road speed is readily available.

The Bourke engine is nothing more than an apparatus to squeeze maximum power from each pound of hydrocarbon fuel by obtaining a hydrogen-oxygen reaction, using principles of combustion laid down by pioneer scientific investigators into hydrocarbon chemistry.

The burning of fuel is a chemical process, for which precise chemical equations can be written. Given a hydrocarbon fuel and the air which surrounds us, one has only hydrogen, carbon and oxygen to work with in devising combustion equations. Books of early researchers state clearly that one pound of carbon burned with oxygen will heat 8,000 pounds of water one degree C., but one pound of hydrogen similarly burned will heat 34,170 pounds of water a like amount. Also, the rate of expansion of the Hydrogen-Oxygen reaction is far greater than that of Carbon-Oxygen. Hydrogen-Oxygen expanding at the rate of 5,000 feet per second as against the Carbon-Oxygen rate of 25 to 75 feet per second.

In conventional internal combustion engines, fuel does not really explode — it burns progressively. Touch a match to some gun cotton standing in open air and it will burn harmlessly in a progressive manner. But ignite it with a percussive primer, as in a rifle cartridge, and a violent explosion results. Far more energy is released. A shock wave passing through a fuel makes it burn differently more powerfully. But, for generations, power plant engineers have been schooled to regard detonation as bad, and their work revolves around avoiding it. One authority wrote ".....no known engine is capable of utilizing such a violent force".

Furthermore, aviation engine designers have concentrated their efforts on reducing engine weight, while neglecting the greater benefits of reduced fuel weight obtained through substantially lower fuel consumption per horse power hour.

The obvious way to reduce fuel consumption is to use a leaner air-to-fuel mixture. Today's gasoline engines run on a mixture of about 15 parts of air to 1 part of fuel. The common diesel shows clearly that increasing the compression ratio allows the use of leaner mixtures. All diesels run leaner than gasoline engines and in some when idling, the mixture may be as lean as 1,000 parts of air to 1 of fuel. In the past, diesel engines have blown up from the explosive power that resulted from momentarily leaning out the mixture when tapering off the fuel to stop. For that reason, some of them are today fitted with kill devices which eliminate that brief period of danger.

Lean mixtures can develop vastly more power for a simple reason. The leaner the mixture, the more oxygen there is in the combustion chamber in relation to the amount of carbon and hydrogen. The richness of a conventional gasoline engine's mixture automatically limits the combustion process to a carbon-oxygen reaction. There is not enough oxygen for a hydrogen-oxygen combination and also the normal carbon-oxygen flame is not hot enough to initiate the hydrogen-oxygen reaction. Doping fuel with tetraethyl lead plus careful tailoring of temperatures and pressures prevents unwanted detonation that takes place in gasoline engines when limits are exceeded. In diesels, fuel is injected and burns as the piston moves away from top dead center, increasing cylinder volume and keeping heat and pressure within limits.

A gas has two specific heats, depending on whether it is kept at constant volume or constant pressure. During a power stroke in a conventional engine, combustion space volume steadily increases and the burning of fuel does not build up the pressure required to burn a very lean mixture. If combustion takes place in a closed vessel so that volume does not increase, only pressure can increase and that can raise temperatures high enough to cause a hydrogen-oxygen reaction in a lean mixture.

The Bourke engine is based on these scientific facts. In a conventional engine, the rate of piston travel, hence the period spent at TDC, is a direct and unalterable function of crank pin rotation and the designer must program his combustion process to suit. In the Bourke engine, the geometry of the scotch yoke mechanism permits the piston to remain at TDC longer — long enough for the extremely rapid hydrogen-oxygen combustion process to burn all the fuel before the downstroke really begins. Compression ratios up to 24 to 1 are used, which gives the high pressure and temperature needed to trigger the explosive combustion. When a cylinder fires, its piston acts as a projectile and the entire piston and rod assembly moves. As it moves, its kinetic energy is transmitted to the crankshaft.

Initial combustion temperature is higher than poppet valves could stand, but as the piston moves on its downstroke, cylinder volume increases. All the fuel has burned however, and cylinder walls are not seared with flame. Instead, the expanding gasses act just as scientific laws say they should — as a refrigerant. The pressure of still-burning fuel is not suddenly valved out to the atmosphere to make a loud noise. There is no exhaust flame throwing heat energy to waste — the engine's exhaust is so cool that a man could hold his hand close to the ports without harm.

The straight-line motion of the pistons eliminates piston slap; there is no valve clatter or gear whine; the exhaust is muted. The hydrogen-oxygen combustion does not produce carbon monoxide. As the pistons are interconnected, the crankshaft never feels their reciprocating forces, and counterbalancing is not needed. The action of the yoke is such that 100 percent balance is possible for the crankshaft; it spins as smoothly as a flywheel. You might guess that the engine would shake from piston action, but it does not because the twin piston assembly is free, can't transmit its reciprocating forces to the body of the engine, and also absorbs these forces within itself. It is simply thrown back and forth, explosion forces acting against momentum forces so that things are cancelled out, as in a free piston engine, which it is.

The engine burns straight fuel like any four-stroke cycle machine. As can be seen in the drawing, the crankcase is separated from the cylinder. Piston blowby does not go into the crankcase but is recirculated via incoming charges. Oil in the crankcase is not contaminated and lasts indefinitely. The cylinders and pistons are lubricated by small oil holes which leave a metered amount of oil between the pistons and walls. There is no poor idling or spark plug fouling such as is experienced when oil is mixed with two-cycle fuel. Each piston produces a power stroke on every revolution and as twin pistons are the foundation of the idea, there are two power impulses for every revolution. Any number of twin-piston power units can be bolted to a variety of bases to give power clusters of any desired output.

There is a reason for each and every detail. The engine can stand detonation pressures because there is no connecting rod angularity of crankpin bearings to suffer intolerable shock loads. Pistons have turbulating fins on them to impart tornado action to incoming charges.

This makes unburned charges rush past open exhaust ports without going out through them. Piston skirts are split and pre-loaded against the cylinder walls so there is heat transfer when the engine first starts. If pistons were a loose fit, their heads would overheat from detonation before the rest of the metal expanded enough to dissipate any heat into the cylinder walls; this, along with the coolness of incoming charges under the pistons, keeps the National Leather seals from scorching. Slipper type bearings in the yoke have large area and are made of shock-resistant alloy so they withstand destonation easily.

The Bourke engine will run on cheap fuels such as brown distillate. As for economy, a 30 cubic inch model rated at 76 H.P. at 10,000 rpm burned only one gallon per hour at 6,500 rpm. The engines have been run up to 2,000 hours without noticeable wear and have reached speeds of over 20,000 rpm without harm. The only apparent speed limitation is in the ability of an ignition system to produce sparks that fast. Bourke engines can run much faster without harm due to the absence of dead strokes and connecting rod side loads. For aviation use, high crankshaft rpm is desirable, as the torque curve is like that of a turbine and the engine may be geared down for propeller efficiency. This gives high output per pound of weight.

The engine prefers low grade petroleum fuels and these, in spite of their lower volatility, go through the carburetor effectively for a simple reason — there is a strong partial vacuum under the pistons as they move on the up-stroke, and when the cylinder wall ports open, this draws air-fuel mixture in with considerable velocity, then the 50 pounds transfer pressure and the turbulence do the rest to assure thorough carburetion. If the design and installation are correct, there is no carburetor icing. Both carburetors and fuel injectors have been used, the latter being a simple 50-cent item actuated by induced vacuum on the base side of the piston — these showed no signs of flutter at 15,000 rpm.

A mechanic with one five-sixteenths inch Allen wrench can top overhaul a Bourke 400 in only two hours. The engine has no gaskets to replace, and the piston rings serve only as pressure seals and not to locate a loose-fitting piston quickly enough during the warm-up period. They don't get much beating or burning and don't gum up quickly.

The curve of fuel consumption is like that of an electric motor's current consumption in that it follows the load applied and not the curve of revolutions per minute.

The Bourke cycle engine differs in many respects from other known engines, such as the two-stroke cycle, Otto (or four-stroke cycle) and the diesel cycle which is but a modification of either of the above working with a constant pressure cycle.

All the above type engines can be built in multiples of one-cylinder, that is 1, 2, 3, 4, etc. The Bourke cycle is possible only in multiples of two cylinders, that is 2, 4, 6, etc., because each rod is a rigid unit with a piston securely fixed to each end, shuttling through a partially oil filled, sealed crankcase. A single throw crank is activated by, but not connected to, the rod which has a slotted, perpendicular opening in its center which receives the crank pin.

Each time the rod moves, a power impulse is delivered to the crank. Valving action is through a combination of cylinder and piston ports.

The cycle starts by inducing a vacuum below a piston, which vacuum activates a fuel injector. The vacuum cracks the fuel, then a high speed stream of air produces a turbulance, or a carbureted mixture can be induced instead. This mixture is highly compressed and cyclonically transferred to the top or working side of the piston, compressed, ignited, expanded against piston on power stroke and exhausted. The same cycle of events was occuring in the opposed cylinder, but in staggered sequence.

Any of the conventional methods of ignition can be used successfully, such as electrical ignition, glow plug, or diesel pressure — whichever suits the application.

BOURKE CYCLE

(mono cycle, or one stroke cycle)

To those of you who have not been able to visualize the "Bourke-Cycle," here is a brief description and explanation.

The crankshaft is a standard single throw supported at each end by a two-row ball bearing of standard make. On the throw is a three-layer bearing. There is no connection between the crankshaft and the piston. The bearing rolls freely in the yoke. The yoke, rods and pistons, are to all intents and purposes, one solid part, and are rigid; no wrist pin or oscillating con rod action.

The case is sealed along the rod by a bushing and seal, and filled one half full of oil. Since the rod travels in a straight line the bushing and seal prevent any blow-by, oil dilution, etc., eliminating need for oil change.

Now let's follow a piston through one crank revolution: As the crank bearing rolls across the yoke the piston is stopped at the top of its stroke for a measurable degree of crank travel, holding the burning gases until they are consumed (no further flame) and the maximum of pressure is developed. At the same time the intake ports are opened by the piston skirt and the area between the piston and the seal (app. 30 cu. in.) has filled with fuel-air mixture. As soon as the crank reaches a position of mechanical advantage the piston is forced in, transmitting the energy to the crank through the yoke, closing the intake port and sealing the carbureted mixture under the piston, compressing the primary charge as the piston telescopes over the seal. At this point the window in the piston lines up with its transfer ports and the carbureted charge under high pressure is forced out of the primary chamber past the turbulating fin on the piston and into the cylinder head forcing the exhaust out the open exhaust ports. At this time the opposite piston is receiving its power impulse and is ready to start in, the crankshaft having completed 180 degrees of travel. Our original piston is, of course, being forced out toward the head, the transfer and exhaust ports are closed and the charge is being compressed at the same time. A vacuum is being created beneath this piston which draws in the fuel charge. About 90 degrees of crank travel before TDC ignition occurs and compression is continued. The air intake port is now open under piston allowing either carbureted fuel or air to mix with the injected fuel, as the case may be, beneath the piston. As head compression increases the fuel burns more rapidly, and a force, or cushion, is built up sufficient to stop the movement of the mass (pistons, rods and yoke) and as the crank moves across TDC the burning charge is completely consumed and a tremendous pressure is released to send the mass back, causing 180 degree crank rotation.

Since the same action takes place at the other end of the mass and since the forces generated are equal, the moving mass can be likened to a tennis ball being batted back and forth between two players. As the mass is not tied to the crankshaft it simply imparts the energy to it. No energy is absorbed from the crankshaft to complete the cycle.

Low grade fuels have proven the most satisfactory for the "Bourke-cycle." Its slow burning characteristics builds a cushion and its high heat potential is released at high compression while the piston is held at TDC and all fuel is completely burned. Since all heat is extracted at the top of the piston travel and the flame dies out, the rapid expansion of the gases during the in-stroke cools the gases, being, in fact, a refrigeration stroke. Paper matches held in the exhaust port will not light and the gases at the exhaust port feel only warm to the hand when all adjustments are correct. I have been using a mixture of three parts white gasoline to one part of stove oil, but you can vary it to suit your local fuels, altitudes, etc. Fuel consumption is approximately one gallon per hour. A consumption approaching two gallons per hour indicates too rich a mixture, and RPM and power will be lost.

I am using Bendix Scintilla mags, No.K2A-205, as used on Mercurys, they are guaranted to 4200 only, but by some modification I have been able to run the engine to extremely high RPM. Needless to say I did have replacement problems on the mags at those RPM, but they seem to hold up quite well down in the sensible range.

From the foregoing it is obvious that this engine must not be thought of as a reciprocating engine, it is in actuality a high pressure turbine, as the power curve indicates. However, it has the advantage of extreme economy which is not possible with a turbine, although RPM approaching those of a turbine should be possible if faster ignition can be devised, which appears to be the limiting factor.

I have built into this engine all the virtues, simplicity and trouble-free performance I knew how. The article in "Speed and Spray" is comprehensive, so you know of the thousands of hours of torture tests on torque stands, water brakes, river runs and automotive installations.

In conclusion: Are you to be one of the first to own one of these revolutionary, history making engines? If so the door of opportunity is open to you who are experimentally minded to aid in attaining that perfection we all desire. The basic simplicity of this engine makes that attainment possible.

Yours for better things in engines,

RUSS BOURKE

INTERNAL COMBUSTION

To thoroughly understand internal combustion the reader must realize that the fire created in a cylinder is not an act of destroying a fluid by burning, but the visual phenomenon of chemical combination of two or more elements to form, or create, another compound. He must realize that each chemical combination requires a special grouping of ingredients and conditions, and hydrocarbons being the most common fuel used we will discuss them here.

The "hydro" part of hydrocarbons is hydrogen and possesses a terrific latent power – note the Hydrogen Bomb. The carbon is puny in comparison. But both have the same needs in common, that is, an adequate supply of oxygen for combination. The carbon requires a much lower temperature to burn than does the hydrogen. The hydrogen-oxygen combination, as burned in the engine cylinder, requires 1800 degrees F. That high a degree of heat is not allowed to occur in conventional engines, thereby failing to extract the major force available in hydrocarbons.

The necessary action to produce an internal combustion cycle are extremely simple, but because of the search over the last century to attain smoother operation, fuel economy and better operating characteristics, many accessories have been attached to accessories, until today the present internal combustion engine enjoys a unique place amongst mechanical devices wherein it has more "gadgets" to make it better than it basically needs to function as a prime mover. The tragic part of all this is that engineers and laymen alike have erroneously come to accept all the trappings and gimmiks as a must. Therefore failing to recognize the simplicity of the real basic function which causes the wheels to turn.

The basic formula for internal combustion is as follows: Induct a combustible mixture, compress, ignite, expand and exhaust. That is internal combustion in its simplest terms.

The ram jet is the simplest of internal combustion engines, but it is also one of the most wasteful of fuel.

The Bourke Cycle engine is basically as simple as the ram jet but it is as different in all other ways as two things can be, being easy on fuel. Free of flame in the exhaust and with an extremely high H. P. output for fuel consumed.

The Bourke Cycle engine function is based upon the phenomenon commonly known as detonation. The normal rate of flame propogation is 25 to 75 feet per second, striven for in conventional engines, but the same fuel, when detonated, has a lineal speed of 4000 to 5000 feet per second, an enormous power increase if controlled. This is done in the Bourke engine by reducing the fuel to air ratio, that is, a leaner mixture controls the speed of burning, an excess amount of air is a must to obtain this controlled chemical conversion (known as association) to H_2O. This makes it possible to attain higher rpm as the resultant impact on the piston is not a pressure from the expanding burning gases, but is more like the shock which drives a rifle bullet. Kinetic energy is imparted to the piston-rod assembly which then imparts that energy through the crank while it is in a mechanically advantageous position.

All conventional engines have an rpm where the H. P. output and fuel economy are best and it is to be assumed that the Bourke Cycle is no exception in this regard. However all tests and runnings of the Bourke to date indicate a much higher rpm is possible as a peak.

The Bourke engine differs from conventional engines in that there is not the increased fuel to H. P. ratio as occurs when the rated rpm of a conventional engine is exceeded.

Higher rpm, within the safe operating limits of an engine, is to be preferred to a slow idle or lugging. Lugging causes heavy side loading on pistons and cylinder walls. The more rapidly the exhaust can be expelled and the less the side loading, both achieved through higher rpm, the cooler the engine will run, thus extending engine life and H. P. for fuel used.

TORQUE

The torque of a motor is its turning moment and it is generally expressed as the number of pounds of effort exerted at a radius of one foot. To find the horse power that is equivalent to a given torque and speed of rotation, the following formula may be used:

H = horse power
T = torque at one foot radius
R = revolutions per minute

$$H = \frac{T \times R \times 2 \times 3.1416}{33{,}000} = \frac{T \times R}{5252},\ T = \frac{H \times 5252}{R}$$

Torque, according to the dictionary, means twist. It is a term not fully understood and confusing as it is meaningless without modification or amplification.

Take, for example, two engines, each single cylinder of 100 cubic inch displacement and same cycle type of 100 pounds per square inch compression.

Engine Number 1 has 5-inch bore, 5-inch stroke, and a 12-inch long connecting rod.

Engine Number 2 has 4-inch bore, 8-inch stroke, and a 24-inch long connecting rod.

Engine Number 2 will produce a greater torque at low speeds, but Number 1 will produce more H.P. as it can run at much higher rpm and will be snappier with more rapid acceleration.

A low-speed, high-torque engine is ideal for constant duty, but the high speed engine is preferable where flexibility is required, because the usable torque is greater in the high speed engine as the formula above will show.

The same formula as regards to high torque and low speed is applicable to the Bourke engine although the Bourke engine does produce a greater torque per cubic inch than conventional engines. A high speed engine should not be used for low speed work. Heavy duty engines can be designed for that purpose.

KINETIC ENERGY GENERATED BETWEEN T. D. C. & B. D. C.

(Power Stroke)

$$F = \frac{W}{G} \cdot \frac{\pi\ 2}{900} \cdot N^2 \cdot (\frac{S}{2})$$

When F equals Kinetic Energy between T.D.C. & B.D.C.
W equals weight of reciprocating mass
N equals rpm
S equals stroke
G equals 32.2 feet/second^2

If W equals 50 pounds
N equals 2,000 rpm
S equals 1/3 ft.

$$F = \frac{50}{32.2} \cdot \frac{\pi\ 2}{900} \cdot (2{,}000)^2 \cdot \frac{(1/3)}{2} = 11{,}300 \text{ lbs.}$$

Please note: The equation gives only the force generated by one explosion: there are two of equal magnitude occurring at the same instant opposed (not directly). See Horizontal Four print.

BOURKE 400 VERSUS V8 400

An 8-cylinder, 4-stroke cycle engine of 400 cubic inches displacement has 4 power impulses per revolution of 50 cubic inches per cylinder or 200 cubic inches per revolution.

A 4-cylinder, 400 cubic inch Bourke engine delivers 2 impulses of 200 cubic inches per revolution or four times the volume per impulse and twice the volume per revolution (400 cubic inches).

It is, therefore, quite evident that an engine of the Bourke type is capable of a far higher torpue output at the same rpm than would a 4-stroke cycle engine of the same displacement.

BOURKE ENGINE

Dear Reader: Please bear with me, draw no conclusions, make no decisions either way, until you have twice carefully read all the data herein assembled. A great truth could be here clearly defined, unrecognized for about 100 years. The law of gravity was in force since time began, yet only about 250 years ago Sir Isaac Newton stepped into the Hall of Fame for seeing the obvious. The Hall of Fame is still open. WELCOME STRANGER.

* * * *

The vertical cross section of a complete two-cylinder unit shows clearly the fuel passages, the water passages, and the exhaust which have been indicated with arrows to aid in recognizing the various passages and to follow the cycles of which there are two complete cycles to one revolution of the crank, for each two-cylinder unit as follows: 2 intake, 2 compression, 2 power, 2 exhaust.

Different engineers and college professors have variously referred to the Bourke-cycle as a ONE-STROKE-CYCLE, MONO-CYCLE, FREE PISTON ENGINE with power take-off and SOLID PRESSURE TURBINE. The pistons take the place of the buckets where a solid pressure is stored in the piston-rod-yoke mass working through the reverse cam effect of the parallel cooperating rod surfaces. The crank with its triple slipper bearing, the outer diameter of which must be the same as the stroke or slightly larger, which construction produces a rotary toggle effect which, with the necessary working clearances and large diameter of bearing sweeping across the flat surface of piston rod, produces a delayed piston reversal action that makes the hydrogen-oxygen combination possible without ping or injury to the engine.

I, too, am aware of what the book says the correct fuel to air mixture must be for an internal combustion engine of the piston, wrist pin and connecting rod, crankshaft type, for I was an instructor in the Air Service during World War I, and any student answering it otherwise rated a "goose egg". Later, in my extensive research of hydrocarbons, one thing became clear. The total potential of hydrocarbons could only be utilized in an engine which had no dead strokes, which created no shearing forces, had no single oscillating connecting rods to create dynamic unbalance and cylinder wall side loading that would, because of the terrific force, break the oil film and scuff piston and cylinder thus causing a hole to burn in head of piston -- a common occurance in conventional engines. It likewise makes clear that the higher the compression, the leaner the mixture can be. The pressures of a diesel cycle will ignite the fuel at 1,000 to 1 because of the heat and an excess of oxygen.

According to my sources of information, and they are most of the eminent scientists of the last century — Sir Humphry Davy, Sir Fredric Able, Bunsen, Pagé, Hiscox, Sir Dugald Clerk and others (I feel they were with out peer and my library has their works). I have never found an engine built since 1900 that shows any variation which wasn't known and tried prior to that time, excepting the N. S. U. Wankel.

The expansion rate of the hydrogen-oxygen reaction, according to my authority, is (quote) "5,000 feet per second as against the carbon-oxygen rate of 25 to 75 feet per second but is of no interest to a designing engineer for no known engine is capable of utilizing such a violent force". (end of quote)

If it were possible for me to use a standard 15 to 1 mix in a Bourke engine and cause all the hydrogen contained in a full charge to combine with oxygen, we would disappear in a cloud of chips. But Nature protects fools and children, it cannot combine for lack of oxygen. There is barely enough oxygen in a 15 to 1 mixture to permit the conversion to Carbon Dioxide; and in that mixture, two things are missing:

1) The temperature cannot reach 1800 F. which is what it takes to cause the Hydrogen-Oxygen combination.

2) The necessary excess of Oxygen is not present. Therefore, when the conditions are ideal to produce the Hydrogen-Oxygen cycle, there has to be only a minute amount of Hydrocarbon with an excessive amount of Oxygen, as in a true diesel engine at idle when the fuel to air could be about 1,000 to 1. But there are two reasons why the explosion in a diesel is not violent, they are:

1) Pressure-drop, and

2) Heat drop

To explain: the fuel is injected as the piston is moving away, causing a pressure drop and heat drop which are not indicated where a violent reaction is desired. In the Bourke engine, an early spark to trigger the carbon which is then compressed, while burning, causes a rapid heat and pressure rise. A delayed piston action over top center permits combination, which combination occurs with an instantaneous heat generation and no after-burn and acts on piston head as a shock, driving piston-rod assembly as a projectile of kinetic energy and the expanding hot (but not flaming) gas acts as a refrigerant.

If the engine were not made as a direct-opposed with a power impulse at each outer end of piston travel, but as an in-line or a "V", the violence of the power impulse would chop the crankshaft or push it into the ground.

This engine can, if no flywheel is used (flywheel would explode), rev. to extreme rpm without load and with no ill effect because the forces are equal and opposite and the load to be stopped is not greater than the force used to send it, and under load, the force needed to stop the piston is that generated minus the force absorbed in doing work.

Viewing the vertical cross section to follow the cycle: the left hand piston is at extreme outward position of compression ready to begin power stroke. Intake is under the piston, fuel-air mixture is being inducted by the vacuum created when piston traveling outward, and near end of its stroke uncovers the intake ports, charging the area between the bottom of piston head and crankcase with fuel-air mixture (note this area is about twice the area of the combustion area). As noted by viewing the right hand cylinder at the end of the power stroke, it is exhausting, and transferring the below-piston charge (about 50 pounds per square inch) to the combustion chamber ready for the compression stroke.

We have, in this engine, the four necessary functions: Intake, compression, power and exhaust as specified in 1862 by Beau de Rochas and crudely applied by Dr. Otto in 1876 where he interpreted that to mean the piston must make four strokes to complete a cycle which although varying widely from de Rochas' specification, nevertheless was the first successful prime mover to compete with the steam engine.

De Rochas also said:

1) The greatest possible cylinder volume with the least possible cooling surface.

2) The greatest possible rapidity of expansion.

3) The greatest possible expansion.

4) The greatest possible pressure at the commencement of the expansion.

5) Minimum of moving parts.

Now, let us see how the Bourke cycle meets these requirements.

1) Large bore, short stroke.

2) Safe high rpm.

3) Exhaust without heat, charge expanded in engine.

4) Straight line direct compression, extreme compression possible and no energy extracted from crankshaft.

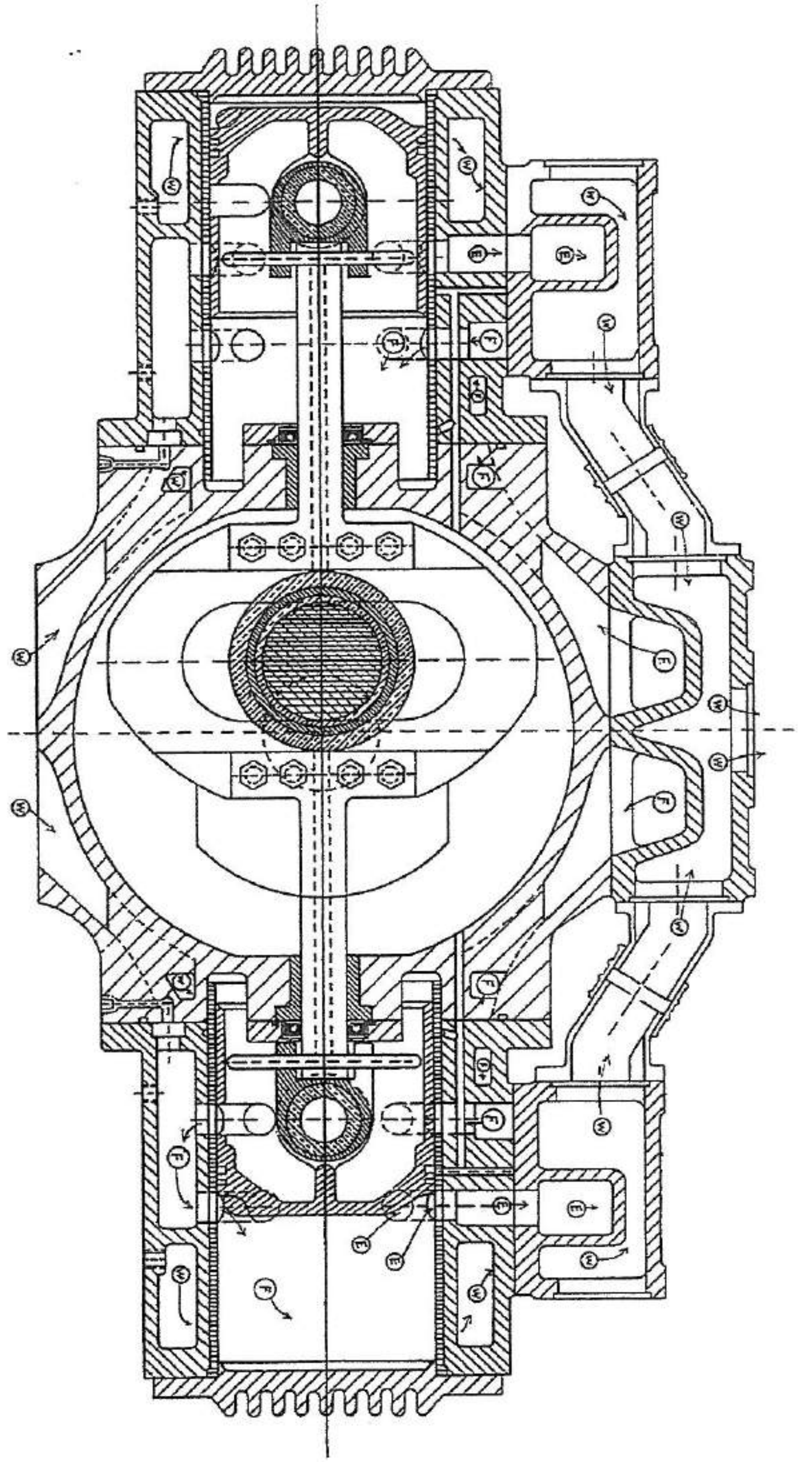
5) Cannot be less moving parts.

Now, let us look at the rod assemble which shows .000 run-out after assembly. Piston rod bearings are spaced 15½ inches apart, providing rigid no-cock alignment, and oil seals are National Leather. Outer and inner crankpin bearings are 18-22 Ampco, a highly shock resistant metal, center rings steel, hardened and ground.

Pistons, alloy — cam ground, relieved at piston pin hole, split skirt to transfer window, and preloaded to provide cylinder wall contact at all times for heat transfer and oil control. Otherwise, pistons will tie up, for they will not radiate until they touch, then it is too late, they will seize.

No rights or lefts, all parts that are for the same purpose are 100 percent interchangeable. All mating surfaces are metal to metal, no gaskets are used, only "O" rings where needed. All oil passages are rifle drilled. Water passages provide cooling for lower half of crankcase then courses through both sides of cylinder, around the upper part of the combustion chamber and to the exhaust manifold, thence to intake manifold water jacket area, and then to the radiator.

The exhaust gases are just below the temperature of the water so are used to help cool, and the intake manifold is water jacketed to prevent icing, and to pre-heat the fuel charge.



VERTICAL CROSS SECTION OF BOURKE 400

There are turbulating fins on the piston heads that spin the new charge in a whirlpool-like fashion and direct it against the cylinder head. This prevents raw fuel loss through the exhaust ports. The swirling circular motion directs the new charge to the semi-hemispheric cylinder head and because of the short elapsed time, it is held in the cylinder under plus atmospheric pressure even though the exhaust ports are open the the atmosphere.

The cylinder head having no contact with any working part is air-cooled for greater thermal efficiency.

Rods are hollow for greater rigidity and to provide better escape for any heat which could enter rod through piston pin.

Viewing the horizontal four-cylinder assembly, it shows that it is actually two,2-cylinder units coupled in tandem to form a four-cylinder, high-speed, high-torque, dynamically balanced power unit for heavy duty applications being light in weight and fully reversible.

Like the crank pin bearings, the mains are also slippers. All main bearings are of the triple slipper type and are interchangeable. The thrust washers are not. I developed this bearing because a ball bearing exploded in an early model — very tragic.

Note the cranks are coupled at 180 degrees, thereby producing two simultaneous power impulses every half revolution for high torque at the lower rpms, and extremely smooth operation with an added torque in the higher ranges, there being no dead strokes to cause it to peak at higher rpm in the upper ranges under load.

The outer rim of the crankshaft counterweights rotate in exactly the same arc as does the crank pin outer bearing rim, thereby maintaining a constant balance at all speeds; and as the rods are not connected to the crank or activated by it (except in starting), the rods take over as a free piston engine.

The slots in the piston saddle are to aid in preventing piston heat from traveling to the crank case.

See vertical cross section.

BOURKE CYCLE CHEMISTRY DEFINED

The following is based upon the findings of numerous eminent researchers and scientists of many countries which made it possible for me to evolve a different approach to successfully utilize hydrocarbons and other fluid and gaseous fuels to obtain a greater fuel to H.P. output than is now being enjoyed by the accepted method of power by compression and ignition of a charge of mixed air and fuel adjusted to burn at a speed of between 25 to 75 linear feet per second in the cylinder.

The above expansion, pressing like steam on the piston to cause rotation of the crank, produces power, but with such a waste in fuel.

To produce the above effect and prevent detonation in all conventional reciprocating engines, a fuel to air ratio on the fuel rich side or an additive to the fuel, such as tetraethyl lead is used to suppress the naturally violent reaction of combustion which would result in a conventional engine if high compression and leaner mixtures of undoctored fuel were used.

An improvement can be made in the economy of all conventional piston engines by slight modification of adjustments, but to obtain an even higher degree of economy a few changes must be made in the rod-crank linkage. Higher compression ratios are used and a modification of the cycle must be made to permit a fuller utilization of the latent forces that can be liberated under the Bourke formula.

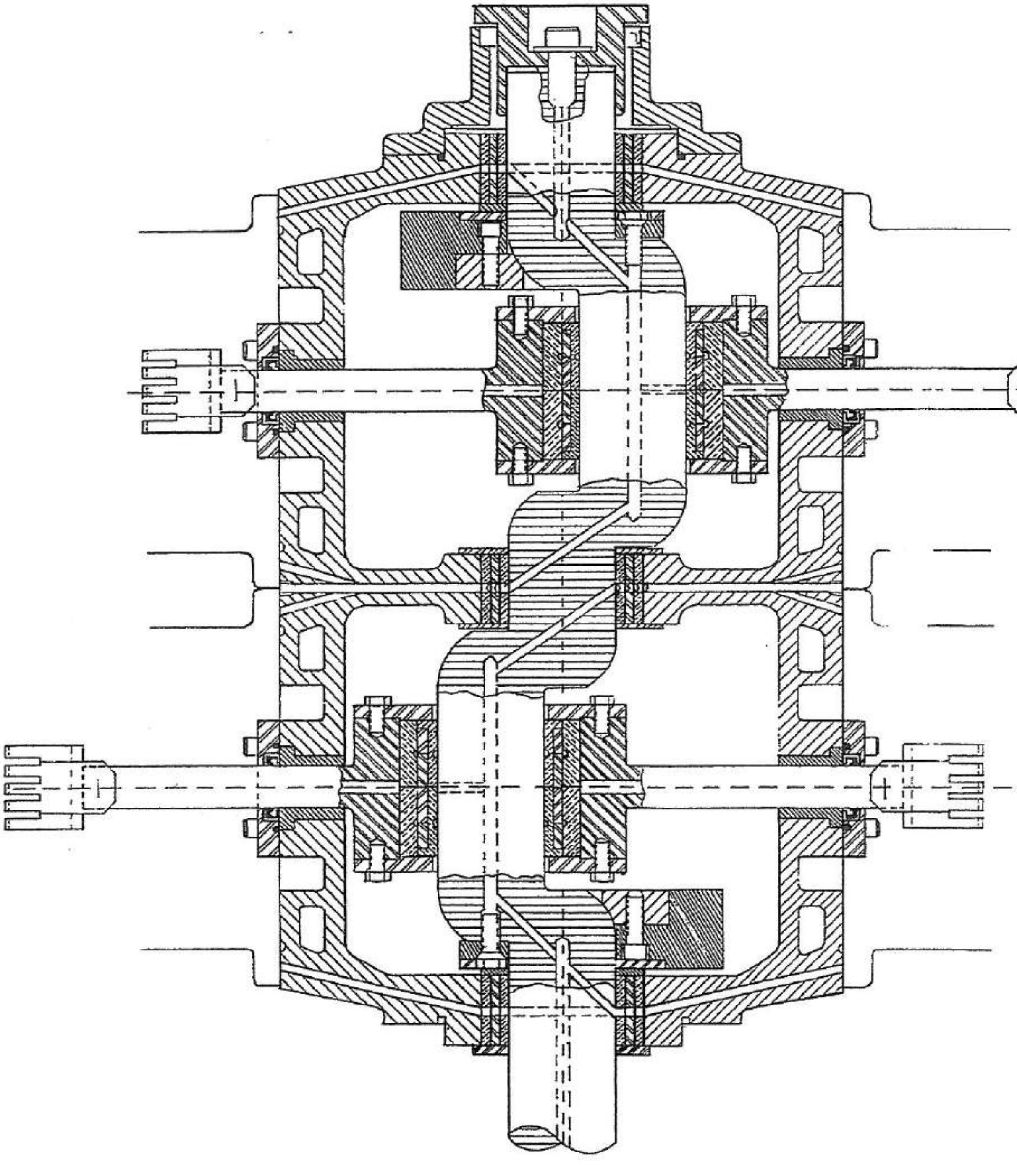
Working piston speeds should never be under 1500 feet per minute if full advantage of the inherent economy and potential of the Bourke formula is to be realized. This will be readily understood when the chemistry of the combustion cycle is studied and checked against the findings and formulas of record of the famous engineers and scientists of all the world.

For a successful Bourke cycle of combustion, the following, in order, must be obtained. A violent induction of an extremely lean fuel to air mixture (lean in fuel) reduces it to atomic particles. Carbon in the fuel is used to trigger chemical changes in the process of combustion. Hydrogen from the fuel combines with oxygen from the air, after the compressing of the burning carbon raises the temperature to 1800 degrees F. The combination occurs with a violent 5,000 feet per second detonation to form water, $H2O$. Mechanical utilization of this process increases the torque and permits higher rpm with less heat losses to the cylinder wall and exhaust, for the flame has died out.

Because of a more rapid flame front before the piston starts its power stroke, the expansion of the hot gas — but not flaming gas — causes refrigeration during the power stroke. The air to fuel ratio is in excess of air. therefore, the exhaust is free of carbon monoxide.

The piston is not moved on its power stroke by expansion of the flame as in conventional engines but by a timed shock effect that imparts kinetic energy to the piston and rod assembly, as does powder to a projectile from a gun, thereby instantly storing most all force generated into a moving mass which then transfers said force to the crank over a 180 degrees of crank travel producing a flat torque unlike the impulse curve as would occur if the piston were impelled by an expanding gas with a progressive and rapid pressure drop.

This cycle in an engine can, and should, be run with a compression pressure far higher than is commonly used. All laboratory tests prove a far greater output for the same volume of fuel. Higher compression pressure, which is known to create detonation, is the sought for condition in



HORIZONTAL CROSS SECTION OF BOURKE 400

in the Bourke formula and predetermines the point where detonation occurs and permits complete expansion of all fuel, with the release of all energy to the movement of the piston, thereby transmitting the major portion of the force into rotary motion and emitting a temperature of under 200 degrees F. from the exhaust.

In conventional engines, the fuel must be tailored to suit the particular engine by a very costly cracking process, whereas in the Bourke cycle, the fuel is subjected to a series of cracking actions in the normal course of its induction into the combustion chamber. The lower grades of fuel are more compatille. The higher octanes are to be avoided.

Another belief which must be revised is that continuous high rpm is harmful and wasteful of fuel and parts. To the contrary, in the Bourke or modified Bourke cycle, the pistons and rods are always under pressure in one direction.

In the Bourke cycle engine proper, there is no side loading, and destructive inertial forces are not generated. In the Bourke modified cycle side loading does exist, but the destructive inertial forces referred to are cancelled out. Such a modified cycle is described under the next heading.

The over-all design of engines, in general, to obtain the greatest H.P. with extreme economy and unbelievable low weight per H. P. will call for a new concept also.

Conventional engines are always computed in multiples of one cylinder and are so grouped to usually deliver spaced impulses in a vain attempt at dynamic smoothness. The Bourke cycle can only be attained in groups of two cylinders, and inasmuchas any 2-cylinder group is dynamically balanced. the progressive firing of cylinders in a Bourke multi-group assemble is not necessary for smoothness.

In most cases involving 4 and 8 cylinder engines firing half the cylinders at one time, that is 2 or 4 will deliver a much higher H.P. output per cubic inch of displacement per rpm and at a lower pound of fuel per H. P. hour than firing the cylinders one at a time, that is, progressively.

Mechanically the Bourke engine is capable of high rpm and live, which is not possible in any other type of reciprocation engine (piston engine). Therefore, a revised approach to gear and operation procedures must be made to take advantage of the extreme practical operation range.

The destructive inertial forces referred to are cancelled out. Such a modified cycle is described under the next heading.

CYCLES

The Bourke cycle is based upon an entirely different concept than that accepted for the Otto or four-stroke cycle or for the two-stroke cycle. The above mentioned engines were an attempt to duplicate the characteristics of the steam engine then so widely used. Because of the then state of the art, 200 rpm was the top rpm desired. That was not difficult to do in early internal combustion engines where no pre-compression was created, but the cost per H. P. hour of fuel was excessive until Beau de Rochas' theory was recognized some 14 years after publication. When recognized, the engines and their components of that day were modified to create, not what Beau de Rochas had envisioned, but a complicated, complex mechanism requiring two complete crank revolutions, gear trains, cams, springs, etc., and, in the process, did depart from the simple concept intended and so ably described by Beau de Rochas.

The Bourke cycle is the Beau de Rochas dream, mechanically devised in its entirety, but simplified beyond his wildest dreams.

Although the Otto cycle is now thought to be the practical, complete embodiment of the Beau de Rochas theory, it was not so considered in his day (according to the available historic data), but a crude compromise.

If the mechanical efficiency of our present Otto cycle engines is computed from the B. T. U. in the fuel consumed as against the actual performance in miles per gallon or pounds of fuel per H. P. hour, they leave an awful lot to be desired.

Until the first quarter of this century, the inefficiencies were freely admitted, but, later on, due to our inability to correct the inherent faults, a campaign of misleading advertisement has been carried on to the point where engineers and laymen alike have come to accept out present power plants as perfection. They thought that no other avenue looking toward better fuel conversion should be examined.

In the 1920's and 1930's, an enormous number of trick engines were built, but not one of them eliminated the dead strokes, the one basic requirement without which real economy cannot be obtained. They all adhered to cycles in which dead strokes existed.

The presence of dead strokes in a slow engine is of not much concern, but a hydrocarbon engine is just approaching the ideal combustion process when the inertia forces of shock, piston and rod reversal, on the dead stroke or strokes of the cycle become greater than the expansive force of the the charge, causing a rapid increase in the fuel consumption and a steep fall-off in H. P. This point arrives at about 50 percent of potential output of any conventional engine of the 2 and 4-stroke cycle types.

Engines of the above type give their best economy and a longer life when run at their rated rpm, but show excessive wear shorter life if worked at lower rpm with a higher fuel per H. P. hour resulting.* Disintegration will soon result if run near, or above, 100 percent of potential.

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*See Fig. 1

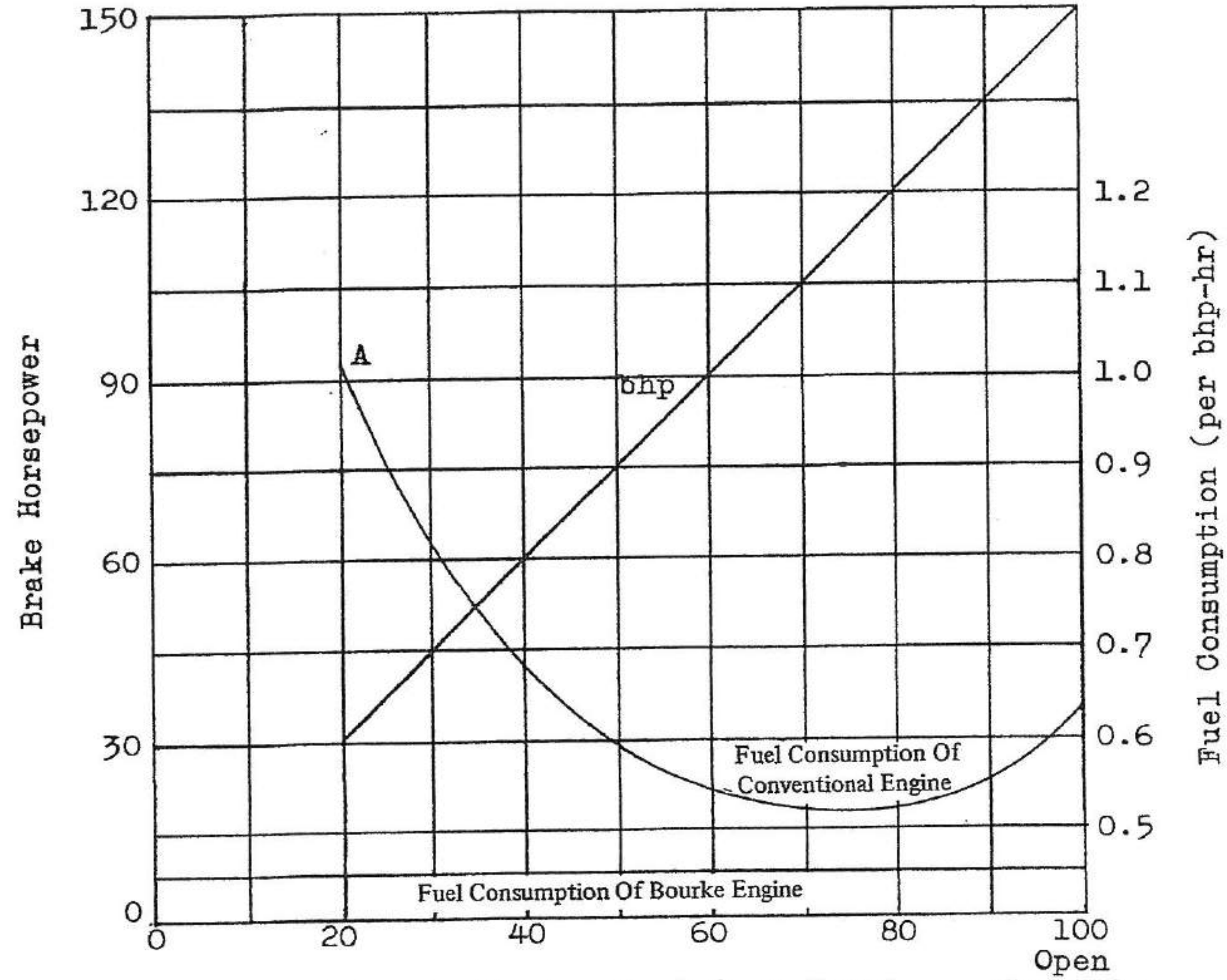


Fig. 1. Engine Load (per Cent)

BEILITZER

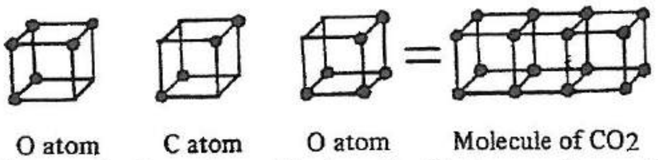
Part of a letter from Mr. Beilitzer:

About your motor I only wrote to my 2 friends, but it is possible that one may have written you.

I'm still after the combustion and have found a new step. Practically it is not new, but new it is. Russ you have it in your motor. You know that I'm after the exhaust gases, temperature, pressure, volume, and chemical process. I know you have CO_2 in your exhaust and other products. I would call it a little atomic engine in your motor. Now listen, an atom and electron combine with excessive combustion or oxidation with a powerful reaction, as in your motor, is like the Bohr's hypothesis. When an electron falls from one orbit to another nearer the nucleus (in the cylinder) the atom emits radiant energy. The amount emitted being the difference between the sum of the kinetic and potential energies of the nucleus system before and after the transition takes place. According to Planck's quantum hypotheses, the frequency of the radiation is given by the relation

$$h\nu = E_1 - E_2 \text{ or } \nu = (E_1 - E_2)/h$$

where h is the Planck's Constant, ν = the frequency of the radiation and E_1 and E_2 are the energies before and after the transition.

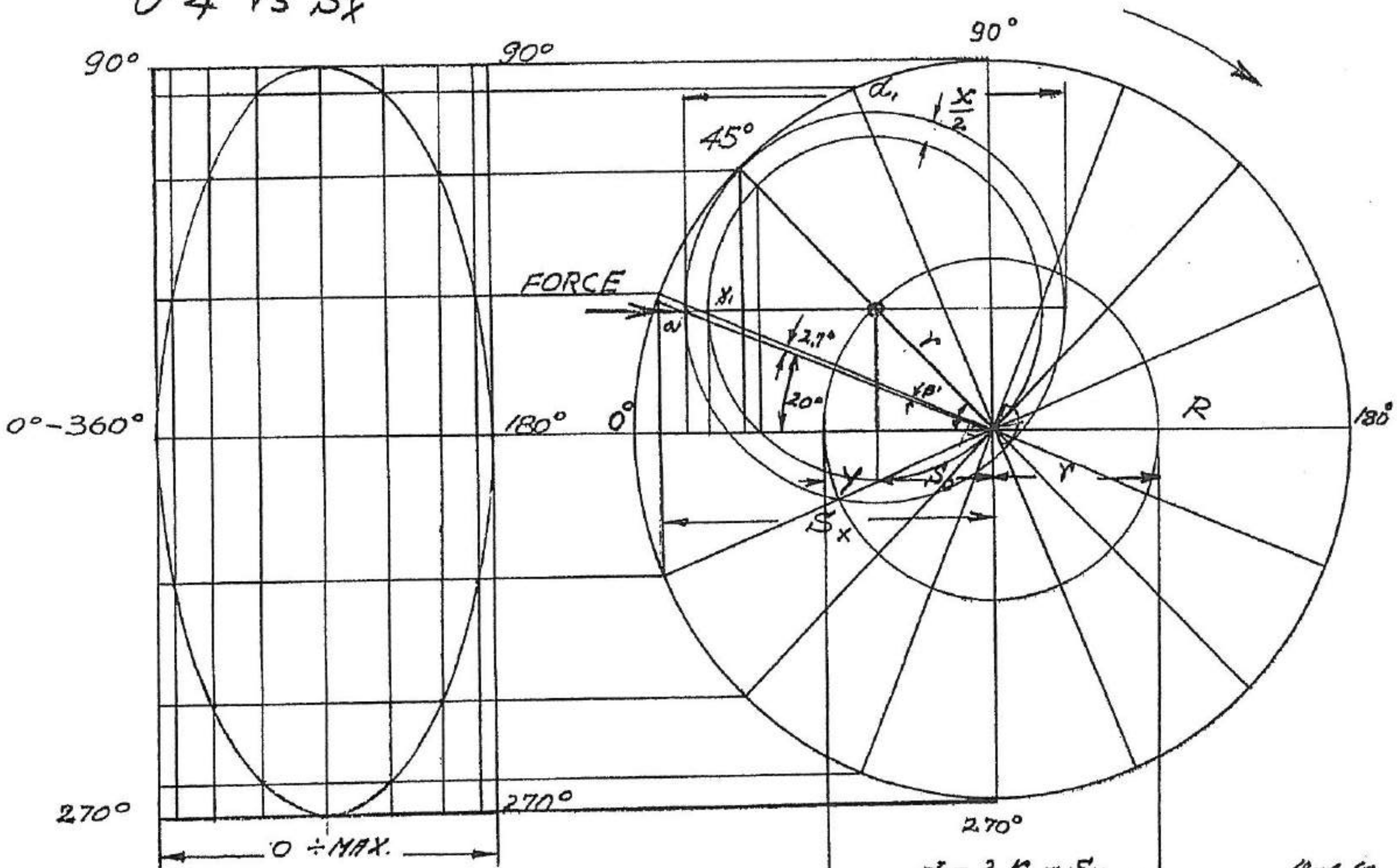


Here is the formation of carbon dioxide from carbon and oxygen.

Now. . . . .

CRANKSHAFT-RELATION AND FORCE ∡ to: CRANK-PIN ∡
at: 45°

θ°∡ vs S_x



$d = 2r = S_x$

or: $r + S_o + Y = d$

$Y = S_x - r - S_o$

$d_1 = 2r + X$; $D = 2R$ or: $d_1 + R - \frac{x}{2}$

12-4-67

S_x = DISPLACEMENT $\boxed{S_o = r \times \cos\beta}$

$S_{x_{45^\circ}} = Y = r - S_o$

CRANK-Sh.-BEARING $= \frac{X}{2}$; $X = \frac{X+X}{2}$

" SHAFT-RADIUS $= R$; $D = 2R$

" " " $= r$; $d = 2r$

" " PIN " $= r$; $d_1 = 2r + X$

" " " DIM. $= d_1 + X$

" " " ∡ at: 45° shown θ

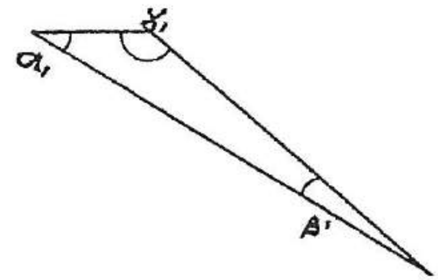
FORCE ∡ at: 45° = 20°

WEDGE-TRIANGLE

$a_1 = 20°$ (= FORCE ∡ 20°)

$\beta_1 = 2.7°$

$\gamma_1 = 157°$



WEDGE-TRIANGLE at: 0° & 180°

CHANGE AS A STRAIGHT LINE = R

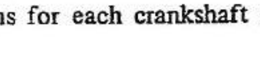
Total DISPLACEMENT = S_X

$S_{X_{45°}} = Y = r - S_0$

Y = DISPLACEMENT of PISTON-Tr.; EXPRESST in: Inch or mm

$S_0 = r \times \cos\theta$; $\cos 45° = .707$

θ = CRANKSHAFT ∡°; as shown: β45°

⟶ FORCE-DIRECTION: 

Included you will find the explanation that you need I made this diagram as shown at 45° crankshaft ∡ . It shows how the FORCE is related. This diagram fits any engine also the formulas. Be sure the CRANK-RADIUS AND BEARING RADIUS are in relationship. The WEDGE-TRIANGEL is invisable and changes from 0° to 180° as a line and is practically 0°. It is max. at 90° and 270°. At 45° and 225° position and at 135° and 315° negative from the view FORCE DIRECTION. The bearing makes two motions for each crankshaft revolution.

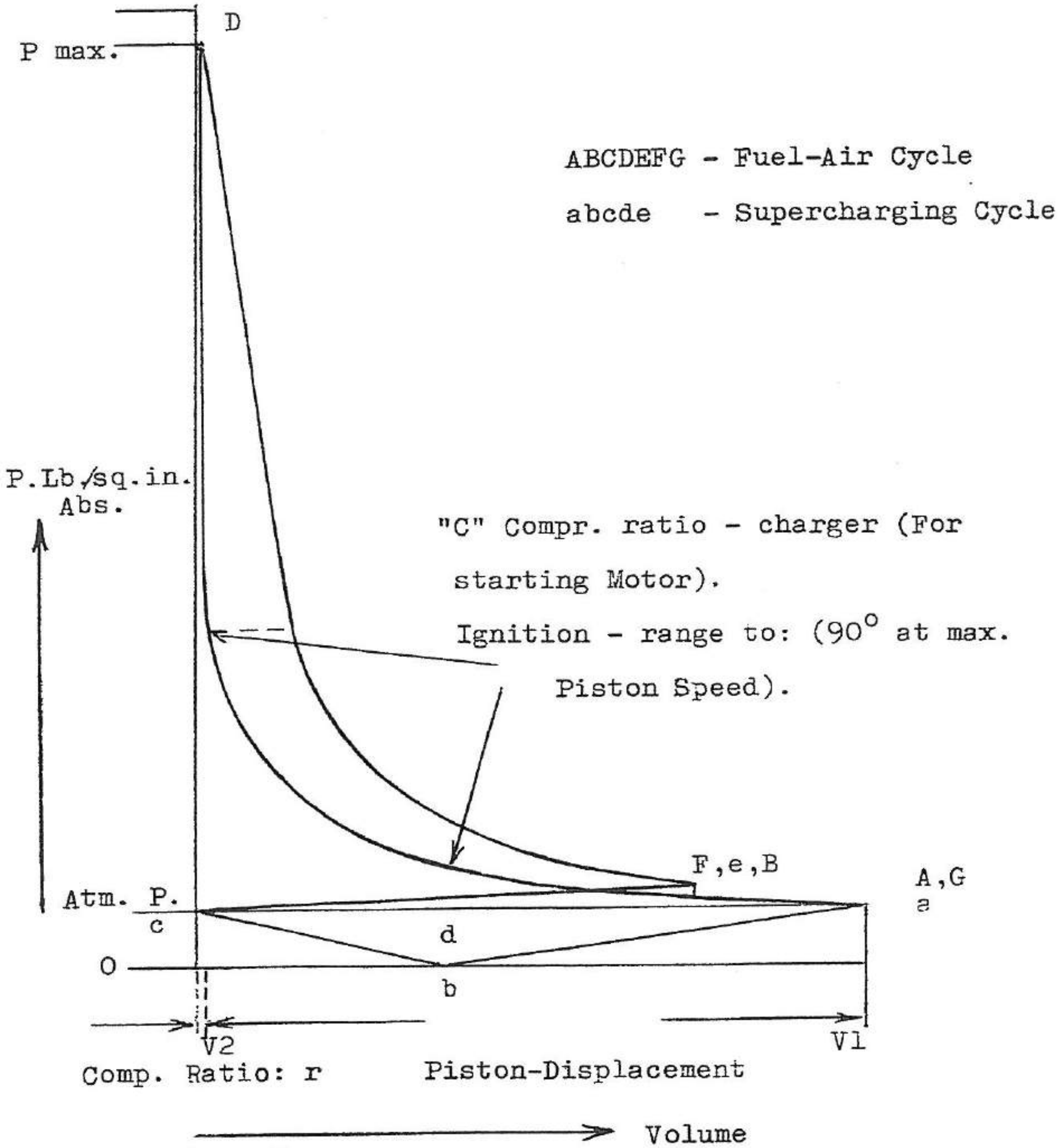
EXPLONATION To:

CRANKSHAFT-RELATION & FORCE ∡ to: CRANK-PIN ∡

12-14-57

THE BOURKE * CYCLE

High Speed Internal Combustion Engine



$$r = \frac{V^1 + V^2}{V^2}$$

Design by; William H. Bielitzer

Perhaps we are now ready for the Bourke Engine, or better yet, now that we have hopped up every Detroit engine to the point of self-destruction, the Bourke Engine is now ready for us. It may not be the last word in design, for designs will be forever improved upon, but at least it is a step in the right direction.

All the lost energies present in the four-stroke engine have been put to work; like a Judo expert that makes use of his adversary's strength and momentum, Bourke has made every last motion in the engine perform a needed operation.

The engine and its functions are simplicity personified, yet the engineering and development involved are by no means simple. It is of the opposed cylinder, one stroke cycle (Bourke-cycle). Cooperative pistons are connected to one rigid connecting rod that shuttles through an oil-filled sealed crankcase. (oil level ½)

There are only two moving parts in the engine:

1) the piston connecting rod, and

2) the crankshaft

All other parts usually found in the conventional engine have been discarded.

There is no flywheel as the crankshaft is dynamically balanced for all speeds and is not connected solidly with piston-rod assembly. Operated through a streamlined, high-speed version of the "Scotch Yoke", all kinetic and inertial forces generated by the piston-rod assembly are used directly for charging and compression. The forces delivered to the crank are then one-directional and permit a greater power output with almost instantaneous acceleration under load.

In summing up the operation of this all-new engine, we discover quite a number of outstanding features:

1. A reduction of moving parts to complete the cycle.

2. No dead strokes to absorb power.

3. Reduction of weight as no flywheel, camshaft, cam gears or valves are necessary. No gaskets are used, only "O" rings where needed.

4. A far greater power output for any given displacement as the Bourke engine can be operated at much higher rpm without appreciable fall-off. Naturally, no valve float as there are no valves in the Bourke cycle.

5. There is an absence of both shearing stresses and cylinder wear as the pistons operate in a straight line. Rings, serving as compression seals only, are made of low tension material and cause very little wear.

6. The engine has no mechanical sounds and can be run clock or counter-clockwise. All parts are interchangeable and there is no need of specialized tools or machinery to manufacture it.

7. The Bourke cycle operates on low quality fuel with practically no exhaust fumes, no flame, and very little heat.

The question in everyone's mind is "how many horses will it deliver?" The H. P. is limited only by the number of rpms obtainable and the only mechanical part of the engine which limits reasonable rpm is the ignition system.

These facts are all very interesting, but the thing that will be of primary interest to the engine user everywhere is the fact that these two-cylinder opposed units can be bolted together in clusters to achieve an engine of almost any displacement desired.

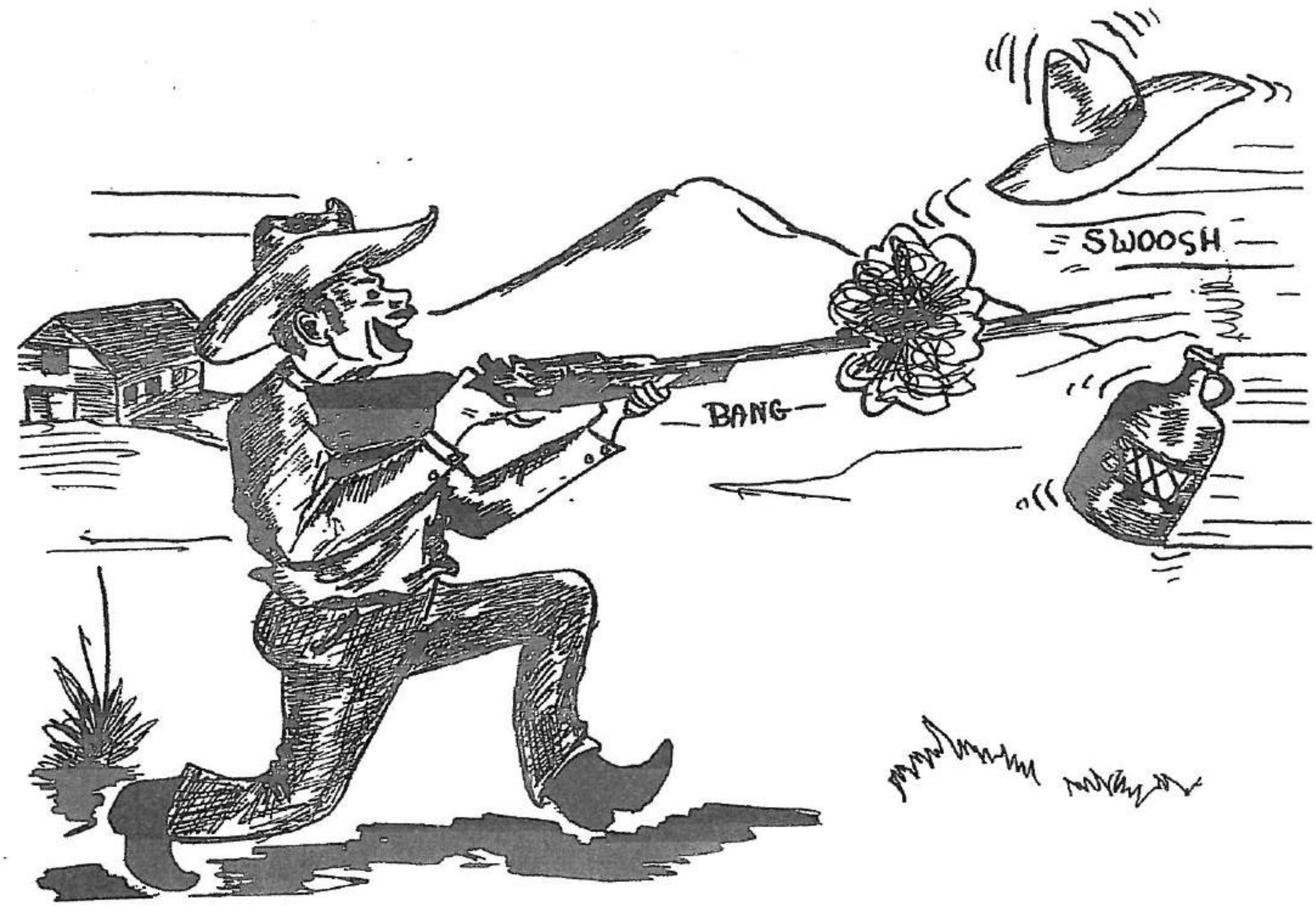
Bourke's sole aim was to design and build an economical engine that would take advantage of the power losses in conventional engines. Practical economy was the designer's prime requisite. It can be manufactured cheaply, can be run for exceptionally long periods of time without need of being torn down, and it is economical to operate.

OUT OF TRAGEDY THE BOURKE ENGINE WAS BORN

In 1932 we were running a stock ranch, herefords, in Sonoma County, California in the very top of Sonoma Mountain, an extinct volcano that through the ages had eroded to a beautiful valley having many cold springs flowing year around which then converged to flow over Whitney Falls hidden away in dense timber and brush on the Valley of the Moon side of the mountain. In an earlier era the falls were a mecca for hikers from the surrounding valleys as a week-end expedition. Water falls are a rarity in Sonoma County. Also an unsurpassed view of the San Francisco Bay and Farallone Islands was an extra treat. At one's feet the Petaluma, Santa Rosa and Sonoma Valleys were stretched out in geometric paterns, always a patchwork of varying colors depending on the season. The location was surrounded on all sides by highly developed civilization, with access being difficult because of the extreme steepness of the mountain sides. It was a wild area abounding in deer. The deer were an ever present magnet for hunters.

Cattle raising and deer hunting are not conducive to profitable cattle ranching. So I did not allow hunting. There are always some who will take any chances and go to any lengths to bag a deer, legal or otherwise, and therein were the ingredients that started the Bourke engine on its way.

In late July I had just completed cutting, baling and storing two hundred and fifty tons of beautiful oat and vetch hay in the feed barn as winter food for the stock. Deer season opened on August 1st and during the season two other riders and myself patrolled the ranch to keep out poachers. A few minutes past midnight on August 5th, the



SHERIFF OF THE MOUNTAIN

dogs wakened us with an alarming bark. From our bedroom window we saw fire blazing in the door of the barn as someone lighted papers in the door of the barn and ran into the timber. The house was five hundred feet from the barn and during the time consumed in getting into overhalls and boots and to the barn the flames had swept through the peak of the barn. All chance of saving the contents was gone, so my wife and I concentrated on saving the major part of the corrals and the horse barn that contained forty tons of the same hay, and to keep the flames from spreading into the range land. After three days and nights Mrs. Bourke and I, totaly exhausted, claimed victory. By then my nerves were really ragged. The slaming of a door, or the barking of the dogs would cause me to jump. Necessity, however, drove us to greater efforts as a new feed barn was needed and corrals had to be rebuilt before the snows came, this we did. Then to relax, as I was afraid I would crack up if the tension and shock could not be erased. I told my wife I was going to build the engine I had hoped some day to have time to build. I had a nice lathe and other tools that a home lightplant supplied with power.

Up at six each morning, the necessary chores were soon cared for, from then on until two o'clock every night chips would fly. At last the Silver Eagle was born and ran on my birthday, Oct. 29. But all stock carburetors I tried were incapable of being adjusted lean enough until I found a single jet carburetor with the jet on the engine side of the butterfly and a linkage to raise and lower the needle for different throttle positions made a miracle come true, a correct mixture through-out the range. There was no flame from the exhaust and the exhaust was just warm to the hand. The fuel economy was beyond belief. It was then mounted, on the back of a pickup and proundly taken to the University of California campus. Professor Belter who was then head of Engineering was contacted. He was shown the prints and the functions explained and then invited to the front of the building where the engine would be run and disassembled to prove it being exactly as the prints indicated. Quote from Professor Belter, "We tried to build one just like it, no use wasting your time and mine it cannot possibly run, good day Mr. Bourke." end of quote. That was the beginning of a long list of refusals by engineers and professors to even step out of their door to see it run. Next was the engineer at Hall Scott who refused to step out of the office door to see it. I was desirous of having some performance tests run as requested of me by the War Department, so I went to the president of Hall Scott, Mr. Ross, and he authorized the tests be run, which we did, but the head engineer never came near the test lab during that time. No positive conclusions as to horsepower were made, because the engine was an air-cooled model and no means for cooling was available. However, after seeing it run everyone in the plant, including the president, were all for building the engine, but the head engineer said it was a ported cylinder engine and they were no good and never would be. In my anger I said, "General Motors was no two bit outfit and they were building and selling two stroke cycle diesels." Then I put on my hat and left, which did not help me. I was beginning what was to be an endless trail of rebuffs by engineers and college professors who refused to even look at it. It is only of late that the real reason has been explained to me. The Bourke cycle of operation is reduced to a law and not theory. This would put many designing engineers out of lucrative employment, and reduce the engine repair business to a fraction of its present size.

RANCH HOUSE ON THE SONOMA MT. 1932

25 H. P. 4 CYL. RADIAL ENGINE USING 4 - 1½ H. P. MAYTAG CYLINDERS

LET US GET ON THE BALL

Being momentarily house-bound with a minor ailment, I have been re-reading some back issues of Hot Rod Magazine. In the September, 1960 issue, page 79, is an article by Ralph Jennings -- "High Performance Has A Hot Heart". I found it very interesting to re-read, and, but for modern phraseology, the text, finding and conclusions, are identical to that published by Sir Dugald Clerk in his 1896, eighth edition of "The Gas and Oil Engine", page 79, chapter 5.

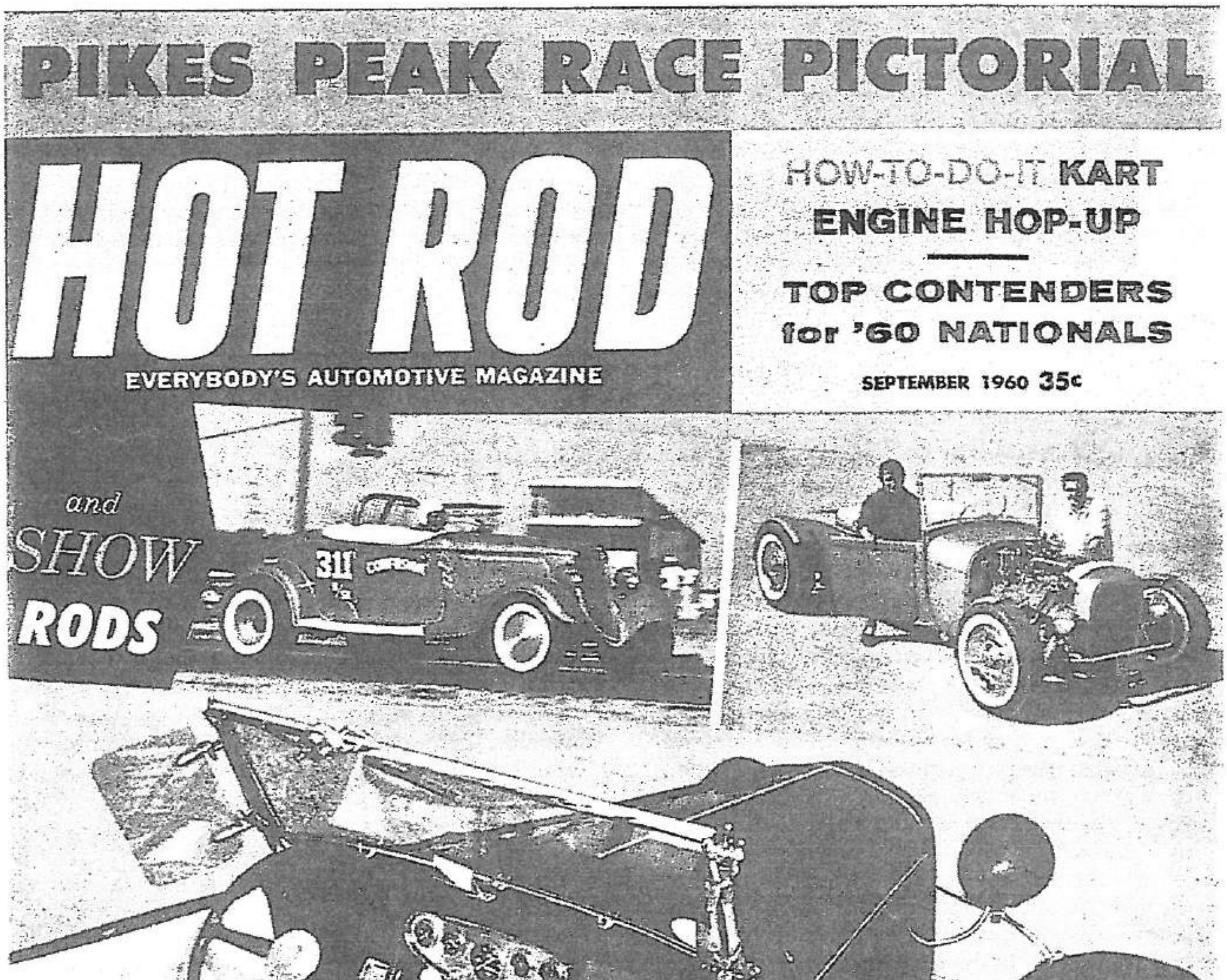
Now that is what I call real progress! It was noted, with regret, that Mr. Jennings also failed to give us the answer we all seek, that is, how to transform this terrific energy we purchase with every gallon of gasoline into more miles per dollar. Maybe too many of us find it more exciting to look through the wrong end of the telescope.

Mr. Jennings did not claim to have the answer, or intimate there was anyone he knew of who did, but perhaps he thought, his article might awaken a genius, and I hope it does, for there could be "gold" in "them thar cylinders".

Our present efforts to attain economy with turbines, free piston engines and the Wankel, seems somehow like trying to make a feast of pheasant feathers and ignoring the meat. True, a windmill is very economical power, when Nature supplies the air movement, but can be costly when produced through fuel conversion for much of the condition toward economy cannot be produced or controlled.

I think the hour is long since overdue for us to stop and review what we have in the way of an engine, how we obtained it, who contributed and how much. Also why isn't there another name that can even stand in the shadow of Dr. Ott. For although he borrowed Alphonse Beau de Rocha's formula some fourteen years after it was published, his greatness resides in the fact that he did build, with some modifications, but not improvements, an internal combustion engine that to this day no one has been able to improve so that greater economy might be enjoyed from each pound of fuel consumed.

His engine, built about 1876, had overhead valves with hemispheric combustion chamber, so do not let some of the clever ad writers mislead you into believing that their engineering staff has brought Utopia to your door in the form of exotic shaped pistons, hemispheric heads, with "squish this and squash that" shape combustion area. They claim to do most everything so much better than the



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High Performance Has a Hot Heart .... Ralph Jennings Page 79 competitor, with the competitor also claiming, with just as much truth, or lack of it, the same advantages.

Just to keep the record straight, check those records and you will find we do not enjoy as economical fuel to horse power ratio as Dr. Otto's engine did in the 1890's with unadorned gasoline, and now some of our engines are such Puima Donnas they wouldn't attempt a backfire without some fancy alphabetical additive in their fuel.

We could make quite a list of names that have crossed our horizon since I assisted in my first major engine overhaul in 1905: Ford, Apperson, Kettering, Cole, Durant, Olds, Chevrolet, Chrysler and Cord are but a few who come readily to mind, who have contributed much to the success of the automobile, but not one of them, or any other, can lay claim to any advance in the basic internal combustion art which Dr. Otto did not have in use prior to 1890.

Here we are in 1961, and to this day there is no one who can come forward with proof as to why the energy, so successfully produced in the cylinder head (thermal efficiency) refuses to appear as more than a token effect at the flywheel and what can be done to correct that condition.

APPRAISING ENGINE EFFICIENCY

Perhaps the time has come for engineers and scientists specializing in internal combustion engines to make an agonizing appraisal of their shortcomings so real progress might be realized. A review of the age and state of the art reveals; Huygens – 1680, gunpowder; Robert Street – 1794, gaseous mixtures; Otto – 1876, gave us the 4-stroke cycle, beyond which we have made no real progress. Better ignition, better oil and fuels, finer materials, and greater grouping of cylinders have in no way eliminated any of the basic faults which were inherent in the first engine built by Dr. Otto in 1876. They all have exactly the same working parts per cylinder, four-strokes per cycle, of which only one produces power. Such engines can only enjoy a semblance of dynamic smoothness and then only at one speed. Also, they will use more fuel while operating at one quarter load than when working at rated rpm and H. P. (i.e., ½ pound of fuel at rated H. P. – 1 pound of fuel at ¼ load).

Operational speeds must be reduced as piston displacement per cylinder increases, thereby reducing the operational flexibility and performance characteristics which can only be obtained through rpms. The performance of any world record holder will bear this out, for maximum horse power was developed far short of the rpm at which the speed record was made.

Two things must be done before any hopes can be held for an economical, effective prime mover:

1) First, eliminate all parts and strokes that do not add to effectiveness, and recognize the obvious fact that operational piston speeds below 1,500 feet per minute are useless from a power standpoint and are frightfully wasteful of fuel.

2) Second, extract more of the inherent power available in Hydrocarbons, instead of adding lead, etc., to dampen the enormous potential that can be extracted from the Hydrogen which is now ejected in the exhaust because a standard gas to air mix leaves no oxygen available for combination.

All fuel to H. P. tests made in the last 90 years only tend to prove one thing conclusively – that the devices used to convert Hydrocarbons to useful work are extremely wasteful. But, to date, no one has come forward with an acceptable answer as to why the thermal conversion in the cylinder head 90+ percent only appears as a token effect at the flywheel.

To attempt an understanding of this perverse performance, let us graph a complete cycle of a one-cylinder, four-stroke cycle engine and see if the areas of loss can be noted and once pinpointed, a possible remedy could be devised.

To correct an appreciable portion of these losses, a rearrangement of the configuration of the parts, a radical change in the firing order, to increase torque and reduce vibration, and a new cycle which uses natural forces for induction and exhaust must be introduced. The results of the change over will produce an engine which (in effect) will eliminate three strokes of the piston (that equals a one-stroke cycle). Such a change should total more H. P. per pound of fuel and longer operating life at higher rpms. And the strange part of the above is, the stock parts available from standard commercial engines are all that is needed to assemble such a power plant, and have been available since Dr. Otto's day.

The Lewis Engine (1896), Franklin Engine and the Dempsey cycle (circa, 1920), if the aforementioned engines or others using the constant pressure cycle had been correctly appraised, a savings of at least 20% in fuel could have been enjoyed. In recognizing that a truly efficient engine is reluctant to idle, real progress could have been made. Only negative work can be obtained (braking) by idling – it only makes for inefficiency and engine abuse, creates dangerous carbon monoxide, oil pumping and dilution, carbon deposits and excessive cylinder wear. All of the foregoing being the price we insist on paying just to say, "See how slow my engine will idle!" The fuel consumption per hour will be more idling than would be used cruising at a legal speed for the same length of time. In my opinion, and my experience bears it out, our engineers' biggest errors have been attempting to obtain too much swept volume, volumetric efficiency, horse power per cubic inch, etc. while it is universally known to anyone connected with engines in any way that no engine is capable of over 60 percent of capacity for any length of time and still be servicable.

All the foregoing can be certified if anyone would care to carefully study the findings of Dugald Clerk, Gardner D. Hiscox, M. E., Pagé, or any standard text books on internal combustion published before 1920. Also, the specifications and operating instructions of any commercial engine now on the market, which cautions that over 60% of capacity is to be avoided.

In my opinion along that line, further gains than are now being enjoyed are not possible.

Our President was not wearing his baby shoes at his inauguration, so why should we expect a 1965 engine to run in shoes fitted when it was 100 years younger? We cannot, in a four-stroke cycle, have all the virtues which we set up before us as we settle down to design an engine, so we set the following standard and there is where we start to get lost.

1) Low weight per H.P.
2) High torque at low rpm.
3) High volumetric efficiency.

The above are all very nice, but needs of this period in our history are for an engine that will deliver a higher rpm over extended periods and one with a power curve that does not start to tumble when it has just hit about half the revolutions you need. (See the results of the 1965 Indianapolis Race.)

An engine with a low fuel consumption per H. P. hour and a high performance per pound of fuel, the preceeding refer to two dissimilar conditions and are more correctly referred to as pounds of fuel per H. P. hour and miles per gallon.

I say they are dissimilar and should not be referred to in comparison. Take two engines exactly the same, mount one in a tug boat and its full operating time is a test of fuel per H. P. hour; whereas with its twin, installed in a pleasure car, the fuel consumed is measured against miles per gallon or miles per hour and has no true relationship to H. P. generated, because an automobile engine will consume more fuel going down a hill at any given speed in high gear than it will use to climb the same hill in the same gear at the same speed. Ridiculous, but true! Try it.

By recognizing and evaluating the foregoing and applying a sound approach chemically and mechanically to the problems, much progress could be made.

IMPORTANT FACTORS IN ENGINE DESIGN

There are various factors which must be considered in designing a conventional engine, and many of those factors are controlled by natural laws, and the designer must know these laws to stay within his limitations if he would avoid costly errors.

Take bearing surfaces for example. The greater the torque, the larger the crankshaft to resist distortion. The circumference then becomes greater, thereby forcing an rpm reduction to stay below critical bearing speed.

Weight and stroke of piston cannot safely exceed certain natural limits (feet per minute travel and inertia generated by piston and rod weight).

Rod length and weight is extremely important in high-speed versus low-speed, high torque disign. For high speed, the rod should be as short and light as possible, which reduces inertia weights and forces thus cutting down vibration, but a short rod increases cylinder wall shearing stresses and upper cylinder wear and increases destructive piston speeds at top dead center.

Long rods, to be ideal, would be infinite in length and without weight. This would eliminate cylinder wear and produce slow speed piston travel at top dead center, but they have weight so a compromise is necessary and the length is chosen where the weight and strength will withstand the rpm and torque for which it will be used. An engine with long rods can run smoothly only at top speed, but is more economical on fuel.

The Bourke engine is subject to the same natural laws governing all other types of piston engines, In designing an engine of the Bourke type, first determine what is required of it, now much H. P. at what rpm and then the number of cylinders can be determined to meet the H. P. demand. Unlike a conventional engine, a multiple group of cylinders is not necessary for dynamic smoothness.

It is quite obvious an engine for a racing car turning 10,000 rpm would have to differ in bore and stroke, etc., from an engine designed to power a transport truck.

Many of the destructive forces found in a connecting rod, wrist pin motor do not exist in a Bourke type, thereby permitting a greater range of performance for any given type.

THE BOURKE SLIPPER BEARING

In 1953 my Portland, Oregon neighbor, Bob Ramsby, told his brother-in-law, Tiny Wright, an executive at Iron Fireman about my engine and of the high rpm it would turn. Iron Fireman was by then a subsidiary of Boeing Aircraft. Tiny Wright then told three Boeing engineers of the engine and its speed but they scoffed at him saying that no bearing was capable of turning at such a high speed. Bob Ramsby asked my permission to demonstrate the engine to Tiny and the Boeing engineers.

Tiny Wright and the three engineers from Boeing then came to my home on S. W. 63rd Ave. for the demonstration. They stood by awe struck as I accelerated one of the stock 30 cu. in. Engines up to 15,000 rpm., and there were some very red faces when I showed my triple slipper bearing.

In 1958, articles began to appear in trade journals and magazines, such as Western Flying and Design News (Nov. 10, 1958), picturing and describing the bearing which Boeing had developed and which they had been five years in developing. My wife looked back in her Day Book and found that it had been five years since I had demonstrated to Tiny Wright and the Boeing engineers.

Until they started using my bearing in jets, every day we would read of a jet mysteriously exploding in the air. It was either not known, or not admitted to the public, that the type bearing they were using failed.

Of late many Flight Engineers have visited here and one and all are most enthusiastic over the life saving virtues of the triple slipper bearings now used on the jets main bearing; even though many many blades are missing on overhaul, they do not explode or vibrate unduly.

MECHANICAL POWERS

November, 1951

The following dicourse on mechanical powers is the most important chapter to you, the reader, if you are to correctly and thoroughly understand the forces generated, how translated into energy and delivered to the flywheel in the form of usable power with a minimum of loss. The writer begs of you to read and reread this portion until all phases are absolutely clear in your mind, for if it is not, the balance of this article will only serve as entertainment and will in no way fit you to design and build an engine which could extract more usable energy from a pound of fuel; the purpose of this article would be lost.

Many people think there are 5 mechanical powers, which are as follows: the lever, the screw, the inclined plane, the wedge, and the pulley; whereas there are only 2 mechanical powers — the lever and the wedge. The wedge, the screw, and the inclined plane are the same in principle. The screw is simply a cylinder with an inclined plane wrapped around it, and, of course, an inclined plane and a wedge are the same. The pulley is but another form of the lever. Really, only two forms of mechanical power exist.

The various forms of lever are, crowbar, pulley, gear, and crankshaft. The outstanding feature of the lever principle is the fact that power can be transmitted freely, with mathematical values, in both directions. Pulleys and gears are continous levers; a crankshaft is a rotating lever.

Wedges in some of their forms are, the screw-thread, inclined plane, cams, wobble plate, and gear worm. Cams and wobble plates are continous rotary wedges; and a gear worm, although not a continous rotary wedge, does produce the same effect when mated to a worm gear (also known as a worm wheel), but reverts to a pure wedge when used with a rack or sector.

The outstanding difference of the wedge, cam, inclined plane, wobble plate, gear worm and screw-thread is that they are capable of exerting great force in proportion to the input of energy and, therfore, an input of great force in reverse has little effect. The reason is quite easily noted as all forces are to a dead center.

There are many forms of cams too numerous to enumerate.

Note carefully the following: Wind wheels, airplane propellers, helicopter rotors, turbine blades, boat props, supercharger and vacuum fans, and worm gears (not to be confused with gear worm) are all a lever-wedge combination. The crankshaft, rod combination used in the Bourke engine is an unusual combination of the lever, the wedge and the reverse cam principles, and so designed and combined to produce a rotary toggle effect that embodies all the best features of each in a high-speed, completely dynamically balanced means of transforming reciprocating motion into rotary motion with a minimum of loss.

EDUCATION OF ENGINEERS

One of our greatest errors in the education of engineers is the lack of a thorough grounding in basic chemistry to acquaint the student with the fact that all actions and reactions are controlled by immutable laws; that nothing can be destroyed, only changed, and that changes can only occur when the conditions are tailored to produce the pre-determined results through chemistry or using the two Mechanical Powers in their most advantageous manner for mechanical conversion — the wedge for extreme pressure and the lever principle for conversion into usable rotary power.

If our engineers of today had been so trained we would not now be saddled with so many wierd devices designed to circumvent errors that have been compounded one error to another error, creating what our mechanics refer to as a "bug". A bug does not have a background of entomology, it is just a reproduction of some predecessors error, proving that the only thing we learn from History is that we learn nothing from History.

One of the biggest contributions Professors, Editors and Publishers could provide for future development would be to refuse to publish anything by anyone who did not correctly use the terms one-stroke cycle, two-stroke cycle and four-stroke cycle, in their correct and total discriptive terminology. Instead, they use the confusing two-stroke, two-cycle, four-stroke, four-cycle or refer to the four-stroke cycle as the four cycles. Four cycles require sixteen strokes of the piston to complete four cycles in a four-stroke cycle engine.

Practically every text book printed since 1921 uses these terms so loosely that I have encountered College Professors visiting here who could not define for me the meaning of the terms. The head Engineer from one of our great colleges, on loan to the Atomic Energy Commission did not know the meaning of the term "Thermal Efficiency" as referring to internal combustion.

THEORY

For too long a time, the word "theory" has been accepted in internal combustion practice as a basic law. Webster defines it as "speculation"; Funk and Wagnalls says "a proposed explanation designed to account for any phenomenon", and Russ Bourke calls it a crutch to support a lame idea. I do not wish to be critical, but for about 100 years, the theories on which we base our conclusions and design our engines have brought us to a point where, if any progress is to be enjoyed, a reexamination of our approach must be made, for aside from better materials, finer manufacturing techniques, improved electrical systems, advances in fuels, multi-cylinders with shorter stroke for smoother output, and improved balancing, still leaves us with exactly the same device that Dr. Otto successfully built and operated in the 1870's. Of course, we use a higher compression. At that time, Dr. Otto hadn't heard of tetraethyl lead, but he knew what high compression could do to an engine that was built with oscillating connecting rods and dead strokes, so our chemists emasculated the fuel potential to fit, instead of the engine being modified to extract the total force inherent in hydrocarbons.

If we dispassionately examine our approach to engine development, the incongruity becomes quite apparent.

Experience proves that no engine is capable of over 60 percent of capacity performance and live. In the face of that we still try for volumetric efficiency, deeper breathing, larger valves, supercharging, etc., none of which produce more horse power per pound of fuel but just the opposite, that is, more pounds of fuel per horse power hour.

The avowed goal, for over one hundred years, has been more H. P. per pound of fuel, but our progress has been more H. P. per pound of engine and more H. P. per cubic inch of engine. That is desirable for some uses and would be highly commendable if the reduction in fuel consumption followed the same curve, but just the reverse is true. Let me illustrate that lightness alone is not the answer, the reverse could be.

If an aircraft engine of 200 H. P.
at one pound per H. P. weighs . . . . . . 200 lbs.

Standard consumption uses ½ pound
fuel per H. P. hour (100 pounds fuel
per hour). Ten hours would use . . . . . 1000 lbs.

Takeoff weight engine and fuel . . . . . . 1200 lbs.

If an aircraft engine of 200 H. P.
at two pounds per H. P. weighs . . . . . . 400 lbs.

If engine were improved to use ¼
pound fuel per H. P. hour (50 pounds
fuel per hour). Ten hours would
consume . . . . 500 lbs.

Takeoff weight engine and fuel . . . . . 900 lbs.

Based on the above, which would you consider the most desirable?.

Now, as you can see, the engine weight, whether light or heavy, is a fixed amount and the difference would account for very little fuel load (additional fuel load), but a reduction in fuel consumption by one-half would almost double the cruising range with the same total engine and fuel load.

Any standard commercial engine, on test, will show on a cylinder head pressure gauge the total pounds per square inch exerted on the piston head at TDC, and were that force delivered to the flywheel, the H. P. per pound of fuel would be startling. But, the force generated in the head is not translated into usable power at the flywheel, thus proving that better fuel and fuel systems, supercharging, ram charging, larger valves or valves placed in different arrangement, cannot and has not plugged the hole through which the bulk of that energy, so efficiently produced in the head, is syphoned off before it can be delivered as work.

Wouldn't it appear we are trying to carry water in a leaky bucket? If it were a leaky bucket we were dealing with, a means would soon be found to plug the leaks, we would not punch more holes!

You can see by the above how ridiculous are the rumors and claims that this carburetor or that carburetor or injection systems will increase the performance to (dash-dash) miles per gallon. Or we hear the claims that some oil company didn't want a certain carburetor on the market and bought it up and put it on the shelf, or that this accessory or that accessory will increase the mileage.

If the engine on which any carburetor or accessory has been installed shows a marked improvement in fuel economy over the stock item it replaced, it just proves the item replaced was out of adjustment for some reason or other as leaded fuels do affect permanent adjustments and humans are not infallible. Therefore, invariably when such a switch is made, it makes us feel that the plugs, ignition, and timing should be sharpened up, which we do; and as the ignition always loses its fineness with time, it alone could have caused the difference you will note upon starting with the new set-up.

When one seriously examines all the fabulous and revolutionary engines that have crossed our horizon in the past 50 years, the startling thing is, one finds nothing new, just a different approach to produce the same effect with a less effective means. We are all still attempting to make an internal combustion engine function as a steam engine on an expanding gas, instead of recognizing that hydrocarbons permitted to combine normally are violent, and converted as a violent power source, could reduce the fuel consumption per H. P. to a marked degree and eliminate carbon monoxide from the exhaust.

I will not now take your time in outlining some of the reasons why the conventional four-stroke cycle is far below its potential, as it is now built, suffice to say, we are striving for performance characteristics that serve no purpose in this modern day.

PARTS WERE AVAILABLE AND BETTER ENGINES COULD HAVE BEEN BUILT FOR THE PAST 100 YEARS

Dear Reader: Having just received my first Social Security check, it was cruelly brought to my attention that I am one of the 10 percent who have survived to collect, and at 65, one's chances to continue for long enjoying this Heaven-Sent Bountiful Bonus grows slimmer as the days accelerate more rapidly into yesterdays.

Because of all the knowledge on Internal Combustion I have been so fortunate to acquire during a most colorful lifetime, countless members of Experimental Aircraft Association that have visited me here have insisted that it would be nothing short of criminal negligence for me to go on to my reward without leaving a complete, written manuscript on the writings and findings of those Illustrious Scientists which made it possible for me to assemble the hardware to make the dream of Beau de Rochas (1862) a reality.

By bringing into being the Bourke Cycle Engine we have become, among the elite of Internal Combustion Engineers, the most controversial subject since the stratified charge theory of Dr. Otto in the last half of the last century.

Now do not misunderstand me, not all have closed their minds and refused to check on the validity of my research, for about six schools of higher learning having checked my references have in the past twelve months initiated projects to build a Bourke Cycle.

During the early 1950's, my health was impaired and my wife was blind and helpless with crippling arthritis and I had the entire care for her comfort. At that time quite a barrage of uncomplimentary things were published about the engine and myself in various magazines by parties claiming to be speaking for the engineering profession.

This aroused my ire, so I did design, at that time, and build a group of engines using standard stock parts, parts that have been available since 1873 and they showed a startling improvement over anything in use. The reason was to prove that better engines could be produced if only the parts were correctly assembled to take advantage of the natural phenomena of chemistry and dynamics. Aided by the two mechanical powers, the lever and the wedge, and other phenomena that we all know of but fail to use because they are so obvious.

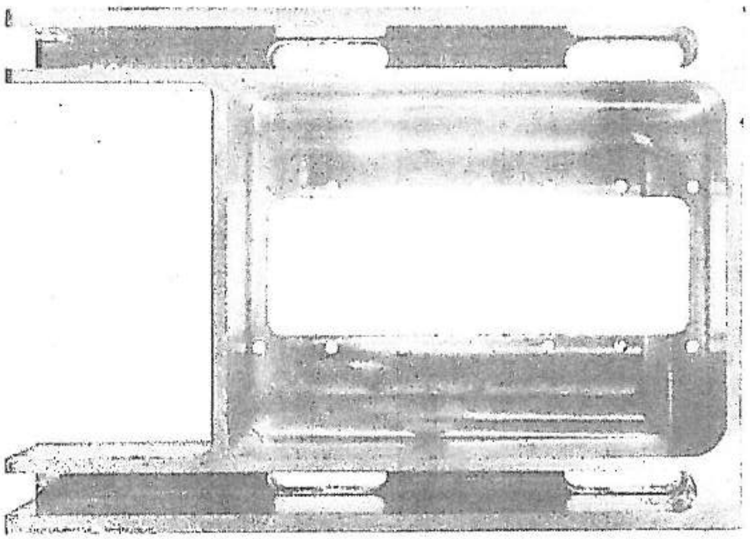
One of the primary causes that started Internal Combustion practice to lose its way is the sloppy way some of our educators and technical writers insist on mis-naming the type of engine being referred to and thereby planting confusion in the minds of those who might otherwise aid in developing something better. Four stroke cycle and two stroke cycle are two terms rarely seen in print in our modern text books and I have noted in some articles by our better known writers in popular automotive magazines that when referring to the four strokes of a cycle they use the term, the four cycles. To me, that is confusing and would erect a barrier to anyone seeking to cure the ills that are so obvious in all our present engines.

In the following pages are a few modifications I have tested for fuel to H. P. with quite startling results. I shall try to give a complete explanation to justify the unorthodox arrangements shown, but most of them will be quite obvious to anyone with any knowledge of mechanics.

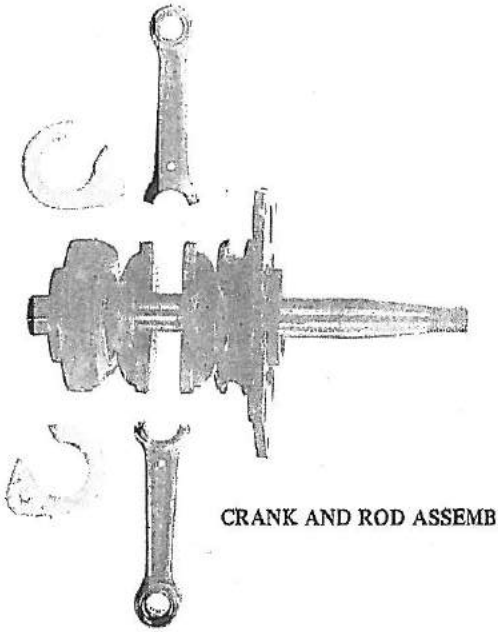
The crankcase lubricated conversion of a two-stroke cycle needs no explanation.

The Volkswagon-type engine converted to a two-stroke cycle with valves uses fuel injection through the intake valve seat and takes advantage of ram tube effect which I have used in all my engines since 1932, and which has recently been made standard intake on some popular American cars.

A light high speed engine with high torque for its size demonstrating extremely smooth operation characteristics and startling fuel economy is the "Bourke-H", made of all easily obtained stock parts. The crankcase is fabricated. It has a wet sump and cannot pump oil, and will run clock or counter-clockwise. It is also capable of operation on the Hydrogen cycle because the arrangement of parts and the conformation produce a one-stroke cycle effect and makes a flywheel unnecessary for its smooth operation. The preceeding explosion directly compresses the charge for the next impulse in the opposed cylinder by the twin rod arrangement eliminating the need for stored energy in a flywheel with its accompanying destructive twisting of the

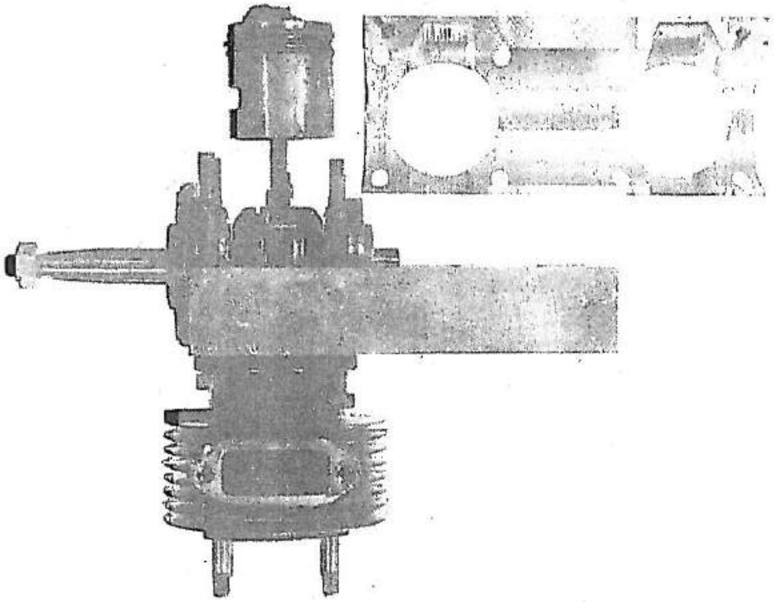


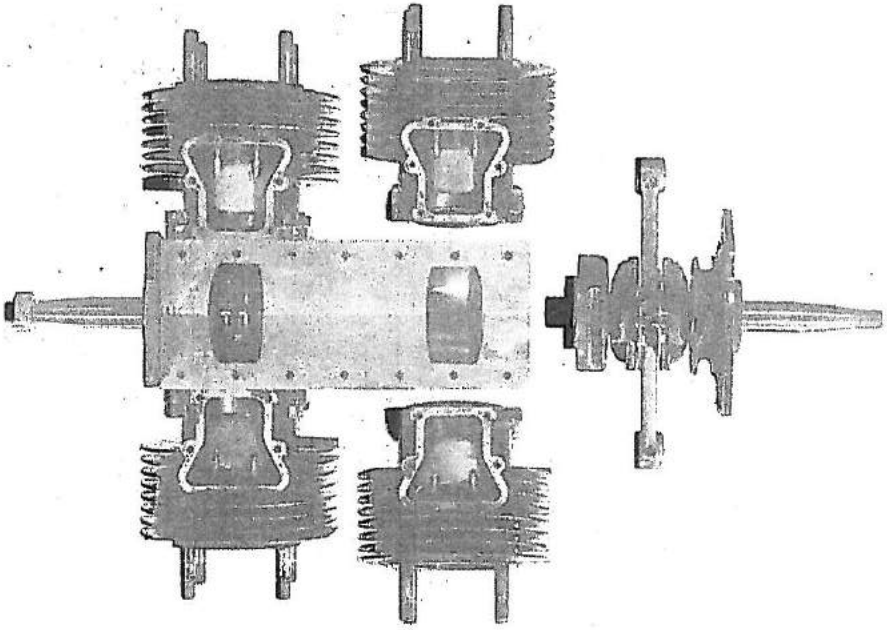
INTAKE MANIFOLD, OIL PAN, AND PART OF BASE



CRANK AND ROD ASSEMBLY

THE TWO CRANKSHAFTS ARE CONNECTED WITH A COUPLING





PARTS OF A MODIFIED BOURKE ENGINE BEING MADE BY THE PUBLISHER crank at each impulse and dynamic balance is held more constant because the 180 degree crankpins with two opposed rods to a pin are creating the same varying forces on each side of crank center line.

There will be those who insist a couple is set up by this, but for the record I might state that the only crank where no couple is created is a single throw, and the couple effect can be minimized by correct crankshaft design and balance.

The crankshaft as shown in the sketch is two cranks, each from a single cylinder engine that the cylinder, piston and connecting rod were parts of. They are coupled as shown for stiffness and to give a gyroscopic effect to aid in cancelling any couple that might develope.

Both ends of the crank are power ends to be coupled to a jack shaft by gear reduction or timing belts. This engine is capable of safe rpm higher than present commercial engines. The rpm at the clutch or power-take-off should be reduced to suit the stock equipment and for safety. The H. P. output would twist the shaft if all power was delivered from only one end of the crankshaft.

An interesting engine that takes advantage of some natural phenomena is a four-stroke cycle engine converted to a two-stroke cycle and retaining the valves instead of using ports. It doubles the number of impulses, takes advantage of the positive oiling of four-stroke cycle practice, eliminates mixing oil and gasoline and stops fouling of plugs as it cannot pump oil past the rings. It can be made from any standard garden variety engine as an experimental project to acquaint oneself with the project before taking on a full scale conversion.

The camshaft must be modified, that is, take off the intake cam and put on another lobe on the exhaust 180 degrees out of phase. Each lobe must be ground to permit 90 degrees of exhaust, opening 45 degrees before and closing 45 degrees after BDC. The intake valve spring is to be replaced by a light spring that will be opened by the air pressure in the intake manifold and the vacuum caused by the exhaust blow-out. The exhaust spring can be about half the pressure of a standard exhaust spring, for the valves cannot float because they are both forced to their seats by compression.

This engine will not be as volumetrically efficient as it was when it was a four-stroke cycle but the doubling of the impulses will make it smoother running and it will deliver more H. P. per pound of fuel and the total output of the engine will be increased over its original factory rating.

The fuel is to be injected through the intake valve seat just before it closes to prevent escape of unburned fuel to the exhaust.

Take most any two-stroke cycle engine of the two port variety, plug up or close with a blind gasket the transfer passage where it joins the crankcase, remove the carburetor and reed valve, attach a metal tube from the opening where the reed valve was to a point in line with the upper transfer port. Within this tube a neoprene, or other suitable flexible tube is placed that will withstand oil and heat. Attach a metal tube to the cylinder in line with the transfer passage, and on the opposite end fit the reed valve and carburetor to register with the area surrounding the flex tubing.

ECONOMY

Changes to be made on standard motor vehicles (gasoline powered) that will reduce the gasoline consumption at least 25 percent:

Raise the head compression beyond the safe pressure that a full throttle will give, then provide restrictions in the intake ports to permit only enough air to bring the cylinder to original compression pressure when operating at full throttle at operating rpm, which modification will give a much higher idle pressure producing greater economy at idle and cruising.

Modify spark advance to have greater advance range and to work in concert with foot throttle instead of as now.

Adjust spark to be at full retard when foot is off throttle. At the end of throttle travel (½ pedal), a heavier spring comes into play increasing pressure needed to advance spark (full pedal) giving top rmp at full throttle. Spark locks advanced until foot is removed from throttle pedal, permitting high cruising efficiency.

Install a large-volume spring-loaded air bypass on intake manifold connected through air cleaner and preheated over exhaust manifold to open only upon rapid deceleration and downhill travel on closed throttle. Connect a preloaded gear pump to driveshaft for downhill braking.

FUEL CONSUMPTION OF ENGINES AT SLOW IDLE

It may be awfully late, but you should know that a gasoline engine at slow idle (400 to 500 rpm) will consume nearly as much fuel per hour as it would moving your car down a smooth highway at a legal speed.

Your engine will use more fuel descending a hill than it will use to climb that same hill, in the same gear and at the same speed.

A standard four-stroke cycle engine becomes a brake when the throttle is closed, and is acting as a vacuum pump. That is costly on fuel, until the engine is operating at its optimum rated efficiency.

Real fuel economy will never be attained until all engines are a constant pressure cycle, which means no completely closed throttle valve and the idle will be controlled by retarding the spark and a correct fuel mixture. A Diesel engine is a constant pressure cycle. Each time air is taken in, the cylinder is completely filled with air and only the correct amount of fuel is introduced for the required horse-power demands of that moment.

As long as the fuel supplied to the cylinder is off the correct mixture (kept on the lean side) there will be no carbon monoxide in the exhaust gases. The driver of a Diesel should always shift to a lower gear if engine will not accelerate in the gear it is in, as exhaust is smokey and engine is lugging.

SCIENTISTS FINDINGS

The following, based upon Gay-Lussac's Laws and the findings of Professor Bunsen, Sir Humphrey Davy, Sir Frederic Abel, Mallard and Le Chatelier, Berthelot and Vielle, Professor Andrews and Favre and Silberman:

With hydrogen and oxygen, three volumes before combination becomes two volumes after combination with $C\text{-}H_4$ and O; also C_2H_4 and O, the products of combustion are equal to the volume of mixture. With Carbonic Oxide (CO) and oxygen three volumes before, become two volumes after combination.

Mallard and Le Chatelier's findings on the velocity of flame in diluted mixtures show the rates of ignition, or inflammation are measures of inflammability, and are the rates for constant pressure; the rates for constant volume are very different, and the problem is a more complex one. Inflaming at the closed end of the tube, they found even very dilute mixtures gave a sharp explosion, and in the case of the true explosive mixture of hydrogen, the velocity became 1000 meters per second instead of 20.

Messrs. Berthelot and Vielle have proved that under certain conditions, even greater velocities than these are possible. The conditions, however, are abnormal and the generation of Mr. Berthelot's EXPLOSIVE WAVE is exceedingly undesirable in a gas engine. It is generated by inflaming a considerable portion of the mixture at once and so causing the transmission of a shock from molecule to molecule of uninflamed mixture. This shock causes an ignition velocity nearly as rapid as the actual mean velocity of the gaseous molecules at the high temperature of combustion. The difference between this almost instantaneous detonation and the ordinary flame propagation may be compared to similar differences in the explosion of gun cotton, discovered by Sir Frederic Abel.

Gun cotton lying loosely and open to the air will burn harmlessly if ignited by a flame. Indeed, a considerable portion may be laid upon the open hand and ignited by a flame without the smallest danger. The same quantity in the same position, if fired by a percussive detonator, will occasion the most violent explosion. The nature of the shock given to the gun cotton by the detonator causes a transmission of the kind of vibration necessary to cause its instantaneous resolution into its component gases. The explosive wave in gases seems to originate under like conditions. The shock velocity for the true explosive mixture of hydrogen and oxygen is 2,841 meters per second.

Sir Dugald Clerk, observing the above (quote), "The experiments are very interesting and important from a physicist's standpoint; but, fortunately for the inventor dealing with gas engines, the EXPLOSIVE WAVE is not easily generated in a gas engine cylinder; if it were, it would be impossible to run the engine without shock and hammering. The velocity which concerns the engineer is that due to inflammability, and expansion produced by inflaming – the velocity, in fact, with which the inflamation spreads through a closed vessel." (end of quote)

It might here be noted that no explosion sound is audible in an engine cylinder. When a ping or hammering is heard, it is the result of the explosive force. Because of the necessary running clearances and angularity of the connecting rod, the shock created crushes the oil film and permits metal to strike metal like a rattle.

Taking an average of Favre and Silberman and Andrews' results, we find the inflamable gases used in gas engines evolve upon complete combustion in the following amounts of heat:

1) Unit weight of hydrogen completely burned
to H_2O evolves 34,170 heat units.
2) Unit weight of carbon burned to CO_2 evolves
8,000 heat units.

3) Unit weight of Carbonic Oxide completely
burned to CO_2 evolves 2,400 heat units

That is, one pound weight of hydrogen burned completely to water will evolve as much heat as would raise 34,170 pounds of water through one degree C.

One pound of carbon in burning to carbonic acid evolves as much heat as would raise 8,000 pounds of water through one degree C.

Gases have two different specific heats, depending upon whether heat is applied while the gas is kept at constant volume, or at constant pressure; both are required in dealing with gas engine problems. The specific heat at constant volume is sometimes known as the true specific heat; in taking the specific heat at constant pressure, the gas necessarily expands and so does work on the external air; this specific heat is therefore greater than the former by the amount of work done.

At constant volume that is, burning in a closed vessel so that the volume cannot increase, but only the pressure, the temperature should be greater as the specific heat at constant volume is less.

The highest temperature produced by hydrogen burning in oxygen, combustion at constant volume or explosion, has been determined by Bunsen, also Mallard and Le Chatelier.

As the theoretic calculation shows, with no dissociation, the temperature of 9,000 degrees C. is possible.

The highest maximum it is possible to assume from Bunsen's experiments is 3,800 degrees C.; from Mallard and Le Chatelier's 3,500 degrees C.

That there is an enormous difference between heat temperature actually gotten and that which should be possible if no limit existed, dissociation is assumed to be partly the cause for the difference.

On general principles, the greater difference between the heat of combustion and the heat of exhaust is the relative measure of heat turned into work which represents the degree of efficiency without loss during expansion. The temperature of the exhaust on a Bourke engine at the ports is just warm to the hand.

CHEMISTRY

MATTER and ENERGY

In considering the process of combustion in air, attention was directed mainly to the materials involved: the oxygen, carbon, sulphur, etc., and to the products of the reaction, such as carbon dioxide and sulphur dioxide. The definition of combustion, however, as a chemical change accompanied by the emission of heat and light, clearly indicates that there is another aspect of the process to which consideration must be given. Heat and light are forms of energy, and energy may be defined as work or the capacity for doing work. Combustion, therefore, must be considered not merely as a process whereby matter is transformed but as a process in which energy is set free, a process which can be utilized for the performance of work. In combustion of ordinary fuels, indeed, this aspect of the process is the most important.

Although the association of energy with chemical change is made very obvious to us in connection with the process of combustion, it is also found in connection with all chemical changes. Every chemical system, every collection of substances which can spontaneously undergo chemical change, represents a certain amount of potential energy, and the material change which we observe, and which constitutes what we call a chemical reaction, is merely the outward sign of the conversion of so much potential energy (chemical energy) into other forms of energy – heat energy, light energy, electrical energy or some other form of energy.

Although in the process of combustion, heat is evolved, it must not be thought that all chemical change is accompanied with an evolution of heat. In some cases, the initial substances possess less energy than the final products, and the chemical change therefore takes place with absorption of heat.

Energy, that is to say, must be supplied to the initial substances in order that they may pass into the final products of change.

We distinguish, therefore, between exothermal reactions or reactions accompanied by evolution of heat, and endothermal reactions or reactions accompanied by absorption or taking in of heat energy.

From the law of conservation of energy, it follows that the change in energy which accompanies a chemical change or transformation of matter is, for a given weight of the reaction substances and under specified conditions, constant and definite in amount.

When carbon (e.g. charcoal) is burned in air or in oxygen so as to form carbon dioxide, 96,700 calories of heat energy are liberated for every gram-atomic weight (12 grams) of carbon burned; and this fact is represented by writing the equation for the process in the form:

$$C + O_2 = CO_2 + 96{,}700 \text{ cal.}$$

The heat evolved, 96,700 cal., is called the heat of combustion of carbon (in the form of charcoal), or the heat of formation of carbon dioxide, and is the amount of heat liberated when 1 gram-molecule (44 grams) of carbon dioxide is formed by the combustion of carbon.

The equation for the combustion of carbon shows that 12 grams (1 gram-atom) of carbon require, for complete