

## EXPLANATION OF THE RIEDLER CYCLE.

### PREAMBLE

All manifestations of energy are due to a relative unbalance of MASS-RATE.

Transmission of energy is due to impact from one molecular system to another.

To make practical efficient use of available energy created by such a relative unbalance during formation of the world requires that the energy released occurs close to the original ambient condition.

Hydrocarbons are composed of heavy carbon molecules bonded to very light hydrogen molecules. It must be assumed that all carbon-hydrogen formation were formed during exclusion of oxygen in cavities of the earth's crust at a MASS-RATE (temperature) equal to the energy released during oxidation. this fixes the temperature somewhere between 2000 to 3000 degrees F, and the corresponding pressure.

MASS-RATE increase can be achieved :

1. by reducing the distance between molecular structures of different density
2. by accelerating the molecular mass due to energy release by chemical rearrangement of the structure.

### THEORY

Knock or detonation during hydrocarbon oxidation (combustion) in internal combustion engines has been an unexplained perplexing phenomenon. Mr. Otto spent years trying to find an answer even on his atmospheric engine and before he invented the Otto cycle engine. He tried by mechanical means (spring loaded pistons etc) to overcome the destructive effect of the knock without success.

Dr. Diesel's first engine suffered from violent detonation

and after he succeeded in getting the engine to operate at all it was necessary during the exhibition in Munich to have the engine started an hour before the show opened since the knock was so terrifying that the visitors would leave the hall.

The author's first experience with knock, or detonation, dates back to 1915. In the following years it became more and more evident to him that the generally accepted explanation for detonation, namely, too rapid energy release (too much fuel burned) for the Otto cycle engine was erroneous. In 1939, in a paper presented at the Franklin Institute in Phila., he presented undisputed evidence that:

1. Vaporized fuel or pressure atomized fuel does not cause combustion if injected into high temperature air.
2. Since hydrocarbons crack at about 500 degrees F into  $H_2$ ,  $CH_4$  and carbon the violent pressure rise called detonation is caused by a lean hydrogen air mixture.
3. High speed photographs of combustion at Princeton University in 1942 showed that pressure vaporized fuel (gasoline) injected through a large acetylene welding torch does not react, (ignite) burn or is in any way disturbed by the high temperature.
4. Calculations at that time at Princeton seemed to prove that the energy released ~~through~~ from a lean hydrogen mixture is not large enough to cause piston burning, ring seizure or any of the other phenomena accompanying detonation. It was concluded that a reversal from  $H_2$  to  $2H$  was taking place. This would explain the succession of pressure waves always appearing on indicator cards and extremely high temperatures accompanying detonation ( plus 4500 degrees F).

In 1920 Dr. Bergius for the first time was able to

liquify coal by compressing coal dust at high temperature in an hydrogen atmosphere (adding hydrogen to the molecular structure). Since the advent of the Houdray process using high temperature plus a catalyst, without pressures another method was found to add hydrogen molecules to a hydrocarbon structure.

It is, therefore, quite evident that the hydrocarbon structure in any type of hydrocarbon (gasoline, fuel oil or heavier hydrocarbon liquids) is sensitive to mass acceleration. The bond between the hydrogen and carbon is weak and easily disturbed. By pressure atomization of fuel through small orifices at high pressure mechanical energy is used to accelerate the molecular structure facilitating the rupture of the bond. Since carbon oxidizes out of the solid at about 1600 degrees F it needs the hydrogen energy release for acceleration to the oxidation rate. If the bond is broken the carbon drops out and the hydrogen energy is wasted in rapid acceleration and deceleration so typical of detonation.

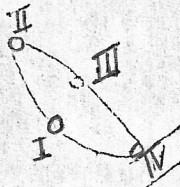
In 1936 Dr. Boerlage of Dutch Shell proposed that the only way of achieving combustion was not to destroy the bond but to oxidize the hydrocarbon molecules as a whole calling it hydroxylation.

Dr. Diesel was convinced that the ideal heat engine could be created by following the Carnot suggestion which were first published in 1824.

Carnot was the first one to show that the efficiency of a steam engine was direct proportional to the temperature drop between boiler and condenser. He proposed to work with air instead of steam to eliminate the boiler not being suitable for higher temperature. He explained that the air should be

compressed before new heat is added. The fuel should be added in small particles.

The schematic illustration of the Carnot cycle is as follows:



- 4:1 Isothermal - No increase in temperature.
- 1:2 Adiabatic - Increase in  $T_c$ . No heat added (No heat conducted away) at 2 highest  $T_c$ .
- 2:3 Heat added (combustion) - no increase in  $T_c$ . (Increase in volume) Isothermal expansion. No further heat added at 3.
- 3:4 Expansion adiabatic to 4 to starting  $T_c$ .

This process would be 100% efficient if we could expand to abs. 0 Or  $-273^{\circ}\text{C}$ . However, we can at best expect to go to  $+20^{\circ}\text{C}$ . Even expansion to this low point is not possible since it would for all practical purposes require too great an expansion ratio (large engine or compounding.)

It follows therefore that the maximum efficiency depends on how high the  $T_c$  at 2 is before the new heat is added.

Dr. Diesel's idea was to apply this cycle to a practical engine which approximately 70 years later was still a challenge to the motor industry. On Feb. 27, 1892 Dr. Diesel filed his first application for a German patent.

Dr. Diesel's second claim of his original patent D.R.P 67207, Feb. 8, 1892 reads as follows:

"Compression of the for combustion necessary air.....far beyond the present day practice so that the compression temp. is very much higher than the ignition temp. of the fuel. This compression can be adiabatic, or which is of great importance can first be isothermal and then adiabatic which would be the

optimum of this process."

His 4th claim..."Introduction of a specific calculated amount of fuel per stroke into the compressed quantity of air and in succession in in mathematic calculated quantity so that the combustion process is as close to isothermal as possible."

His fifth claim..."after combustion a close to adiabatic expansion of the gases (without cooling)."

His sixth claim..."Avoiding of cooling of the cylinder walls during combustion as well as during expansion."

In this patent Dr. Diesel used the original Carnot diagram for illustration.

On 27th of July 1892 the patent office proposed two claims which Dr. Diesel accepted almost verbatim:

Claim 1 reads as follows:

"Working process for internal combustion engines operating as follows: In a cylinder the working piston compresses air... to such an extent that the in this way generated TE is very much higher than the self ignition TE of the fuel used. Upon which beginning at top dead center the fuel is introduced so gradually so that combustion due to the expansion stroke of the piston and through this affected expansion of the air occurs without appreciable increase of pressure and TE, of which after stopping of the introduction of fuel the gases continue to expand."

Dr. Diesel's intention was to use 250 Atm. (3720 lbs.) as compression pressure following Carnot's reasoning for high efficiency namely the highest possible temperature drop. To fulfill the first phase of the Carnot process he was going to inject water during phase 4:1 (isothermal compression). From 1:2 adiabatic compression without cooling of the cylinder walls maximum rise in TE 2:3 introduction of fuel at rate of combustion

(isothermal) with no increase of TE but increase of volume.

3:4 adiabatic expansion.

The reason that Dr. Diesel's motor never operated and today's so called diesel engines do not even approach the so called Diesel cycle (combustion occurring with no increase of TE and PR but with increase of volume contrary to Otto cycle increase in TE and PR with no increase in volume," is that too radical mistakes were made.

1. Combustion material injected into a mass of high TE air does not oxidize (burn) since oxidation of a hydrocarbon is a chemical reaction which is only possible if a chemically correct mixture (stoichiometric) approximately 13:1 by weight is first established (see Franklin Inst. lecture, page 147, Feb. 1942 given at meeting held May 4, 1939). High speed moving pictures taken through combustion chamber (film available) shows no signs of combustion reaction as fuel enters high temperature air. This proves that isothermal combustion controlled by rate of introduction of fuel is impossible. Actually the idea that fuel has to be pressure atomized which was also Dr. Diesel's idea and upon which he spent several years is also radically wrong. This however, is still accepted by the industry and attempted in all commercial so called diesel engines.

At the Original high compression ratio proposed by Dr. Diesel (60:1 or 250 ATM) the air temperature at the end of compression would exceed the TE of chemical equilibrium so that under no circumstances combustion could occur. Later Dr. Diesel proposed compression ratios of 28:1 or 90 ATM (1330 lbs) or 800 degrees C. (1447 degrees F.), the thermal efficiency should be 68%. Dr. Diesel was never able to operate an engine success-

fully at even these lower pressures for above explained reasons, (Violent detonations.) until he abandoned the Carnot cycle completely, nullified his own patents and lowered his compression ratios to approx. 12:1 now generally raised to approx. 16:1 producing an Otto cycle injection engine.

Originally in all Dr. Diesel's papers and patent application he used the same diagram that Carnot had sketched in his papers.

In one of his dissertations he mentions that after calculating an indicator card for his engine that the characteristic was so completely different from Carnot's assumption. The calculated card as attached shows that for approximately 90% of the effective pressure stroke there is very little difference in the pressure rise for 6:1 to 18:1 compression ratio. The maximum rise occurs on the last 10% of the stroke. On the last 10%, however, the rise for 16:1 is approximately 600 lbs. while for 34:1 it is 1500 lbs. The rapid rate of compression of the mixture of air and liquid hydrocarbon particles is not a function of rotative speed of the engine but of the rapidly changing pressure characteristic of compression ratios above 30:1.

The rate of energy release (acceleration) in a hydrocarbon oxygen reaction depends:

1. on the energy supplied to the mixture to accelerate it to the point where the reaction produces an excess in energy.

2. at that point the rate increase depends on how much of the surplus energy is consumed to accelerate the non-participating masses.

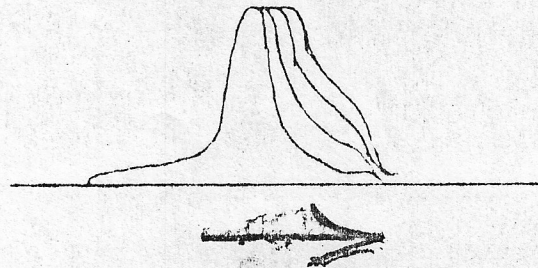
There are various means of supplying energy to a chemical reaction. One is to approach the mixture with a molecular structure at a higher rate which can either be electrical discharge or another chemical reaction which is in a high state of ~~high~~ acceleration.

Another way of causing molecular acceleration is to reduce the distance of travel (pressure) or vice versa the rate can be reduced by increasing the distance. A hydrocarbon reaction already in the stage of combustion can be stopped if the distance is increased at a rate greater than the chemical energy released. Vice versa, if the distance is reduced at a greater rate than the reaction can follow the energy release is retarded and if this process is continued to a point where the rate is equal to the chemical equilibrium no energy can be released until the distance is increased to the point where the energy release is effective.

At this point it should be mentioned that there is no information available as to what actually occurs at the point of highest pressure. There seems to be two opinions:

1. That the chemical reaction does not occur until the pressure is dropped.
2. that the chemical reaction is fully completed and stored until it is effective.

Indicator cards taken of this process show the following characteristic:





Either one of the two above mentioned processes would give the same indicator card.

The new process which we have developed for all practical purposes conforms as close as is practically possible to the Carnot cycle. Using the same original diagram as used by Carnot and Dr. Diesel it operates as follows:

A cylinder and piston which on the sides exposed to combustion and compression TE are coated with very thin material (.003") of very bad heat conductivity and (Alum. oxide hard coating) backed up, however, with a very good conductor (Aluminum) to avoid heat accumulation. Injecting of a combustible material in large droplets avoiding atomization (injection pressure approx. 200 lbs.) at bottom of stroke after closing of the exhaust ports (#4.) Approaching isothermal compression up to #1 (90% of the stroke or 250 lbs approx.) Compressing air mixed with liquid hydrocarbon droplets at rapid rate compression ratio 34:1, maximum pressure 1700 lbs., 1700 degrees F approx.) which is close to chemical equilibrium (CO to CO<sub>2</sub> reaction cannot occur at approx. 2000 degrees F.) into insulated chamber so that even if combustion is completed energy release can only start after piston moves over dead center dropping temperature into a range where the stored energy due to the chemical reaction can be utilized. Thus heat release depends on increased volume only to #3. (isothermal) after which gases expand adiabatic to #4.

Compression ratio might vary with engine design and size since process depends on TE at top dead center. 34:1 was determined experimentally on 3-1/2 x 2-1/2" engine. To prove above analysis compression ratio was raised gradually to 43:1 at which TE no combustion could occur since TE was too high for the process.

The material presented at the Franklin Institute lecture, which was the culmination of six years of concentrated research work proved among other things that detonation was caused by:

1. vaporization of the fuel either by mechanical means or
2. vaporization due to the fuel being exposed to high temperatures (long duration).

Mr. Charles Lawrance, inventor of the Whirlwind engine, which made Col. Lindberg's flight possible was the only one to recognize the importance of the new approach.

Mr. Lawrance had set out to duplicate his success with the Whirlwind engine by developing a radial diesel aircraft engine. At the time the author met Mr. Lawrance after the Franklin Institute lecture Mr. Lawrance had built and tested an air cooled overhead valve two stroke engine, a water cooled engine of the same design, a sleeve valve engine in consultation with Mr. Ricardo and a single loop scavenging engine with exhaust control permitting 100% supercharging. All these engines were complete failures due to violent detonation.

After applying the author's method of injection as described in patent #2,244,874 and using the injection valves patent #2,250,364 excellent performance resulted completely free of detonation as documented by the attached indicator cards D-104 and D-105 dated 2/22/43.

The injection system produced a spray without atomization at all speeds and loads. At all loads and speeds the duration was 8 to 10 degrees crank angle. For best performance injection started at  $38^{\circ}$  B.T.C. The valve had 8 holes of .8 mm dia. and an orifice length of 3.5 mm. Maximum injection pressure

of 1200# at point of impact and a line length of 21" with an inside diameter of 3 mm.

These cards already show the way for the new cycle since injection occurred and was completed when the cylinder pressure was only 100# and energy release didn't manifest itself until 10° before T.C. (see card D-104).

It took another seven years of research and development of a new injection system and fuel valves which produced approximately the same spray characteristics but at a injection pressure of only 200# per square inch instead of 1200# per square inch. This new injection system is capable of maintaining the same characteristic up to 12,000 injections per minute.

#### RESUME

Hydroxylation or oxidation of hydrocarbon without cracking is the only way to achieve clean combustion without detonation.

1. You can not inject hydrocarbon into compressed air and by so doing initiate hydroxylation without cracking.
2. You can not control hydrocarbon oxidation and energy release by rate of injection (diesel).
3. You can cause hydroxylation and avoid cracking by introducing large liquid hydrocarbon particles into air without vaporization at atmospheric pressure prior to compressing the mixture.
4. You can compress this mixture without energy release to its chemical equilibrium (34:1 approx.)
5. You can control energy release by rate of expansion which in a reciprocating becomes automatic.