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Hybrid Engine (Stirling Engine + IC Engine + Electric Motor)

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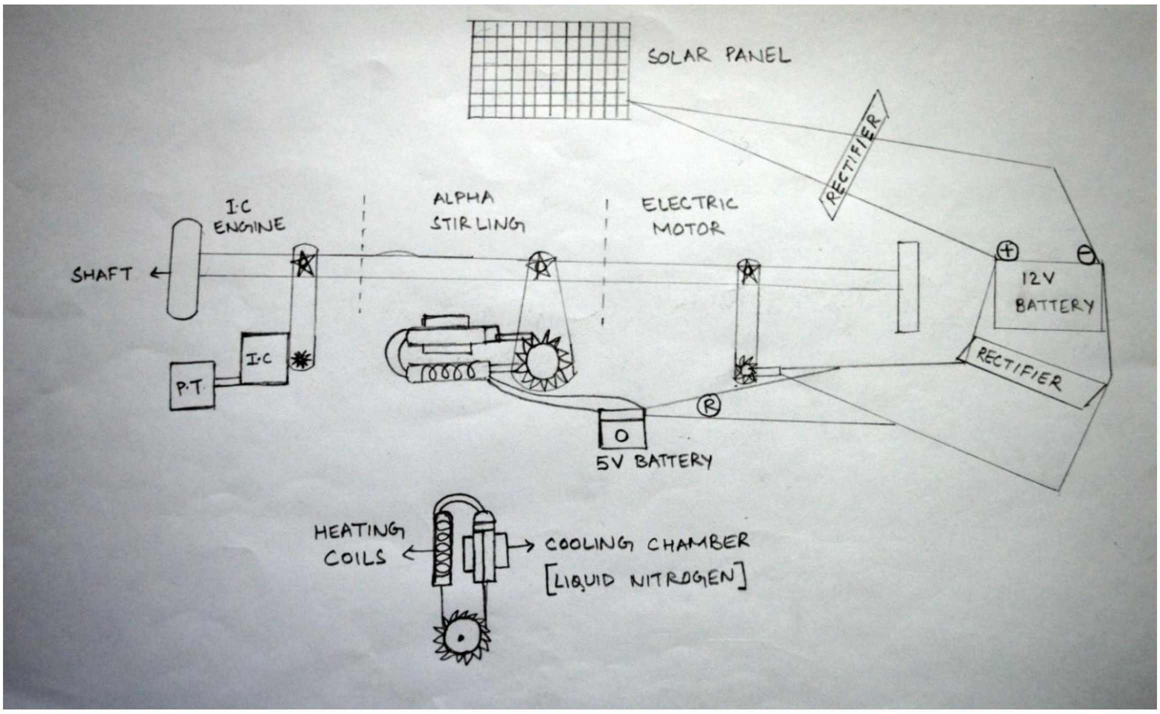
I. Introduction

Hybrid engine is a combination of Stirling engine, IC engine and Electric motor. All these 3 are connected together to a single shaft. The power source of the Stirling engine will be a Solar Panel. The aim of this is to run the automobile using a Hybrid engine.

II. Construction Of A Hybrid Engine



III. Components Of A Hybrid Engine

1. IC ENGINE
2. STIRLING ENGINE
3. ELECTRIC MOTOR
4. SOLAR PANEL
5. 12V & 5V BATTERY
6. SPROCKETS [6 nos.]
7. PETROL TANK
8. SHAFT
9. TYRES
10. CHAIN [3 nos.]
11. RESISTOR [2 nos.]
12. THERMOSTAT
13. HEATING COIL
14. LIQUID NITROGEN
15. BEARINGS

IV. Working Of Hybrid Engine

- The 3 engines are connected to the main shaft such that IC engine is placed first followed by Stirling engine in the middle and then the Electric motor.
- The Solar Panel is connected to the 12 volt car battery through a Rectifier and the energy is sent to the battery.
- Then the energy travels to the smaller battery which is connected to the Stirling engine through a heating coil.
- The small battery gives energy to the coil to heat up the cylinder.
- A cooling gasket is fixed to the other cylinder to fill up liquid nitrogen in it for cooling.

V. IC Engine Specifications

- Diameter of piston – 0.050228 mm
- Radius of bore – 0.25114 mm
- Bore length – 46 mm
- Stroke length – 42 mm
- Cubic capacity – 69.9 CC
- Type – 2 stroke

VI. Calculations(Ic Engine)

- Displacement = (π/4)(4.2)^2(4.6)*1 = 69.79 CC.
- Stroke = 4D/(π*B^2N) = 4.21 cm.
- Bore = 4D/(π*S*N) = 4.6 cm.
- Break mean effective pressure = 75.4*T/Disp. = 11.15 bar.
- Fuel consumption = V/T = 10.07 kg/hr
- Mass flow rate = (Vol*Spec gravity)/(Time*1000) = 0.002803 kg/sec
- Efficiency = BP/M.F.R*CV = 25%
- Torque = [(W*S)/1000]L = 5.6
- Power = 2.61KW @ 5000 RPM
- Angular speed = (2πN)/60
- Speed (N) = 4980 rpm
- Specific fuel consumption = Wt. of fuel/Power = 0.036 Kg/KW

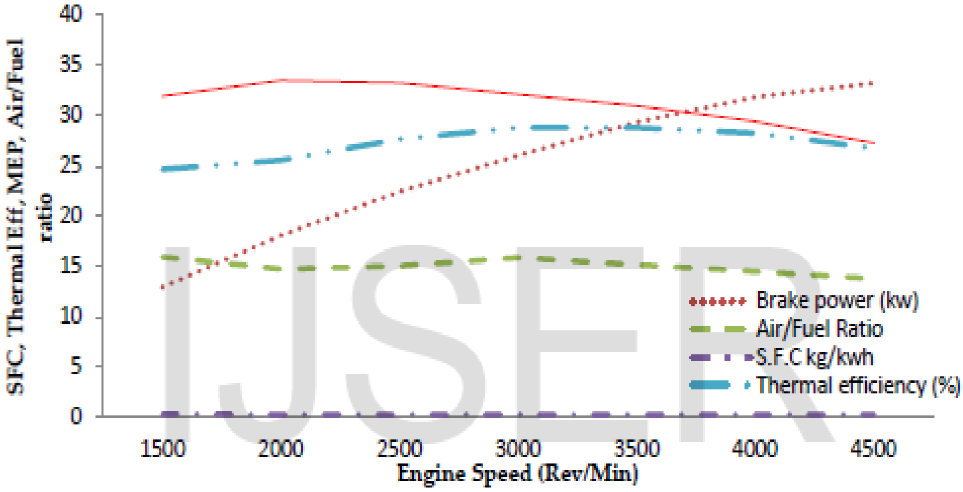


Fig. 2. A plot of engine speed in rpm against sfc, thermal efficiency, mep and air/fuel ratio for experimental results

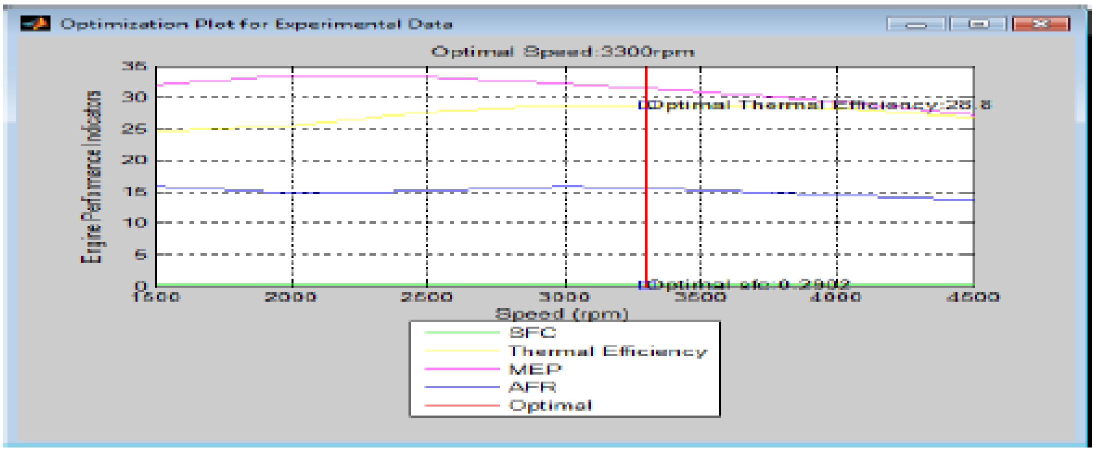
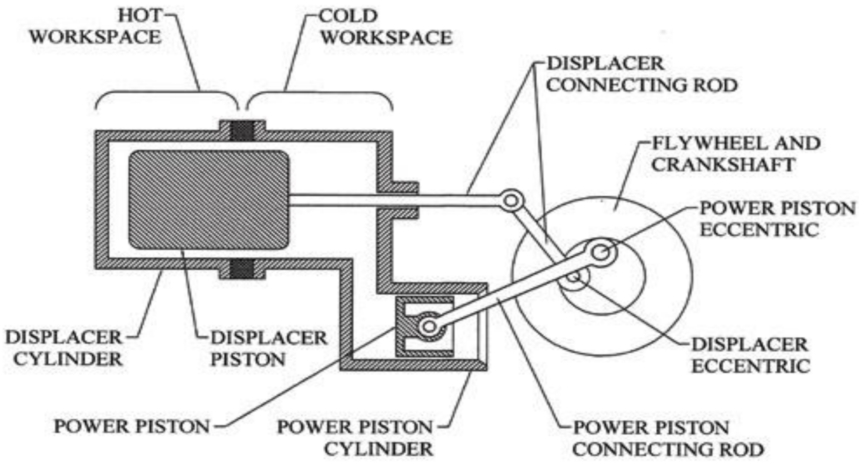


Fig. 3. Plot of engine speed in rpm against sfc, thermal efficiency, mep and a/f ratio for experimental results

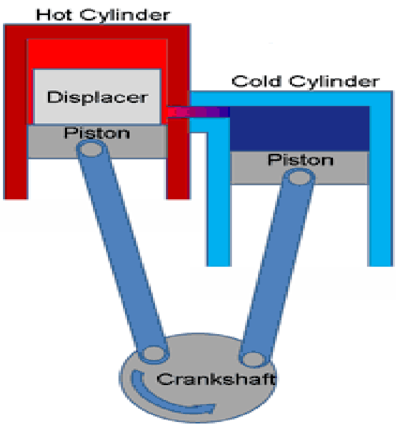
VII. Stirling Engine

CONSTRUCTION AND WORKING



VIII. Stirling Engine Heat Source

SOLAR PANEL



STIRLING ENGINE SPECIFICATION

5.1.5.1.2 Sample Engine Specifications

In order to check equations which look quite different, it was decided to specify a particular engine and then determine if the work integral checks. The specification decided upon was:

$$M(R) = 10.518\ J/K$$
$$TH = 600\ K$$
$$TC = 300\ K$$
$$VL = VK = VP = RD = 40\ cm^3$$
$$HD = CD = 0$$
$$AL = 90^{\circ}$$

TR is defined a number of ways, depending how it is defined in the analytical equation that is being checked. It may be:

(1) Arithmetic mean (Walker)

$$TR = (TH + TC)/2 = 450\ K$$

(2) Log mean, most realistic

$$TR = (TH - TC)/\ln(TH/TC) = 432.8\ K$$

(3) Half volume hot, half volume cold (Mayer)

$$\frac{1}{TR} = \frac{1}{2(TH)} + \frac{1}{2(TC)}$$

$$TR = 400\ K$$

The above sample engine specification is for a gamma engine. For a beta engine assume in addition that VM = 0. Then:

$$CD = 0 - 40\left(1 - \frac{\sqrt{2}}{2}\right) = -11.715\ cm$$

5.1.5.2 Dual Piston Engines

5.1.5.2.1 Engine Definition and Sample Engine Specifications

The nomenclature for engine internal volumes and motions are described in Figure 5-9. Also given in Figure 5-9 are the assumed values for the sample case. The following equations describe the volumes and pressures.

Hot Volume

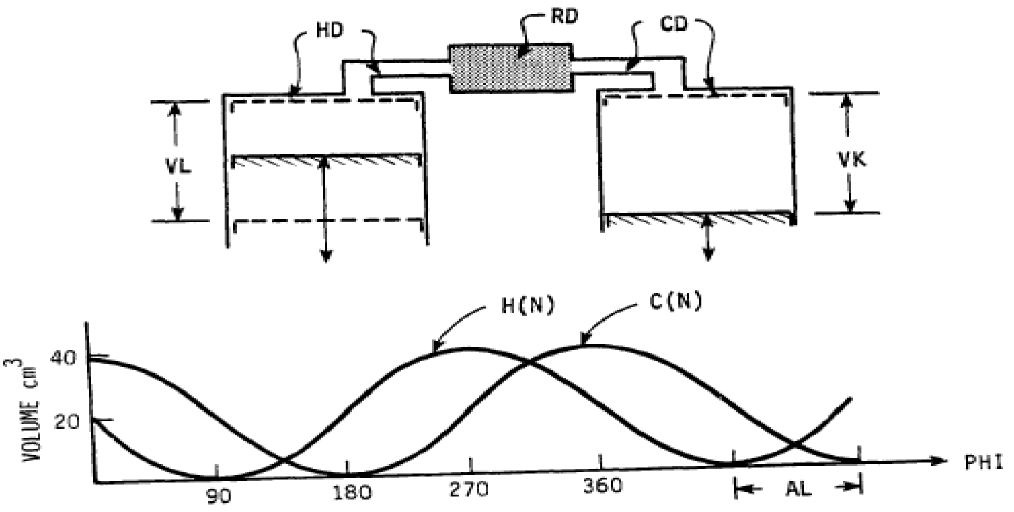
$$H(N) = \frac{VL}{2}\left[1 - \sin(F)\right] + HD \qquad (5\text{-}32$$

Cold Volume

$$C(N) = \frac{VK}{2}\left[1 - \sin(F - AL)\right] + CD \qquad (5\text{-}33$$

Total Volume

$$V(N) = H(N) + C(N) + RD \qquad (5\text{-}34$$



Symbol	Definition	Units	Assumed Values
HD	hot dead volume	cm^3	0
RD	regenerator dead volume	cm^3	40
CD	cold dead volume	cm^3	0
VL	hot piston live volume	cm^3	40
VK	cold piston live volume	cm^3	40
TH	effective hot gas temperature	K	600
TC	effective cold gas temperature	K	300
TR	effective regenerator gas temp.	K	450
M	engine gas inventory	g mol	1.265
R	gas constant	J/g mol·K	8.314
M(R)		J/K	10.518
P(N)	common gas pressure	MPa	to be calculated
F	crank angles	degrees	
ND	crank angle increment	degrees	(ND)(N) = 360
AL	phase angle	degrees	N = interger

Figure 5-9. Dual Piston Engine Nomenclature and Assumptions for Sample Case.

Engine Pressure

$$P(N) = \frac{(M)(R)}{\frac{H(N)}{TH} + \frac{C(N)}{TC} + \frac{RD}{TR}} \qquad (5\text{-}35$$

5.1.5.2.2 Numerical Analysis

Using the assumed values given in Figure 5-9, Equations 5-32 to 5-35 were evaluated for F = 0, 30, 60 ... 360. The results were:

F Degrees	V(N) cm^3	P(N) MPa
0	100.0	41.2
30	87.3	45.7
60	72.7	54.4
90	60.0	67.6
120	52.7	83.0
150	52.7	91.9
180	60.0	86.1
210	72.7	71.2
240	87.3	57.0
270	100.0	47.3
300	107.3	41.9
330	107.3	39.9
360	100.0	41.2

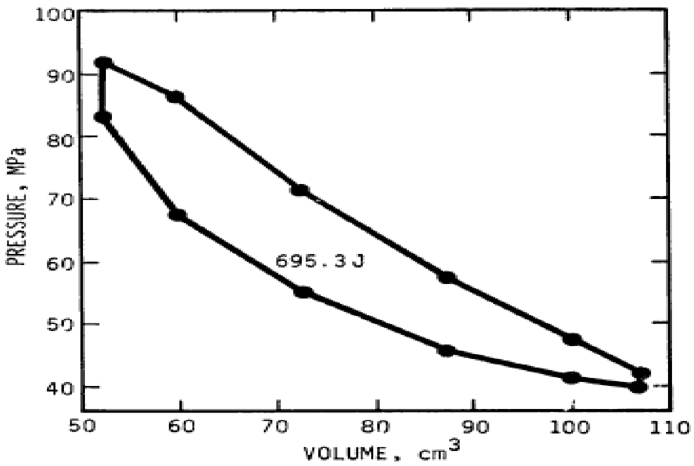


Figure 5-10. Work Diagram for Dual Piston Sample Case (ND = 30°).

5.2.2 Efficiency Prediction

Efficiency of a Stirling engine is related to the cycle efficiency of a Stirling engine which is the same as the Carnot efficiency, which of course is related to the heat source and heat sink temperatures specified. Section 4 gives all the information available on well-designed Stirling engines which have not been fully disclosed and shows how the quoted efficiencies of these engines relate to the Carnot efficiency.

Carlqvist, et. al (77 al) give the following formula for well optimized engines operating on hydrogen at their maximum efficiency points.

$$\eta_{eff} = \frac{P_{net}}{E_F} = \left(1 - \frac{T_C}{T_H}\right) \cdot C \cdot \eta_H \cdot \eta_M \cdot f_A \qquad (5\text{-}42$$

where

η_{eff} = overall thermal or effective efficiency

P_{net} = net shaft power with all auxiliaries driven

E_F = fuel energy flow

T_C, T_H = compression - expansion gas temperature, K

C = Carnot efficiency ratio of indicated efficiency to Carnot efficiancy, normally from 0.65 to 0.75. Under special conditions 0.80 can be reached.

η_H = heater efficiency, ratio between the energy flow to the heater and the fuel energy flow. Normally between 0.85 and 0.90.

η_M = mechanical efficiency, ratio of indicated to brake power. Now about 0.85 should go to 0.90.

f_A = auxiliary ratio. At maximum efficiency point f_A = 0.95.

Thus the most optimistic figures:

$$\eta_{eff} = \left(1 - \frac{T_C}{T_H}\right)(0.75)(.90)(.90)(.95) = \left(1 - \frac{T_C}{T_H}\right)(0.58)$$

5.2.3 Power Estimation by First-Order Design Methods

Some attempts have been made to relate the power actually realized in a Stirling engine to the power calculated from the dimensions and operating conditions of the engine using the applicable Schmidt equation. Usually, the actual power realized has been quoted to be 30-40% of the Schmidt power (78 ad, p.100). However, the recommended way of estimating the Stirling engine power output is to use the Beale number method as described by Walker (79 y). To quote from Walker, "William Beale of Sunpower, Inc. in Athens, Ohio, observed several years ago that the power output of many Stirling engines conformed approximately to the simple equation:

$$P = 0.015\ p \times f \times V_o$$

where .

P = engine power, watts
p = mean cycle pressure, bar
f = cycle frequency of engine speed, hertz
V_o = displacement of power piston, cm^3

"This can be rearranged as $P/(pfV_o)$ = constant. The equation was found by Beale to be true approximately for all types and sizes of Stirling engines for which data were available including free piston machines and those with crank mechanisms. In most instances the engines operated with heater temperatures of 650 C and cooler temperatures of 65 C.

"The combination $P/(pfV_o)$ is a dimensionless group that may be called the Beale number. It is self-evident that the Beale number will be a function of both heater and cooler temperatures. Recent work suggests the relationship of Beale number to heater temperature may be of the form shown in Figure 5-18 by the full line. Although for the sake of clarity the relationship is shown as a single line, it must of course be understood that the relationship is a gross approximation and particular examples of engines that depart widely may be cited. Nevertheless, a surprisingly large number of engines will be found to lie within the bounds of the confidence limits (broken lines) drawn on either side of the proposed relationship. Well designed, high efficiency units with low cooler temperatures will be concentrated near the upper bound. Less well designed units of moderate efficiency with high cooler temperatures will be located at the lower extremity.

"It should be carefully noted that the abcissa of Figure 5-18 is absolute temperature, degrees Kelvin; engines with the hot parts made of conventional stainless steels (say 18-8) will be confined to operate at temperatures limited to the region indicated by the line A-A. High alloy steels for the hot parts will permit the elevation of heater temperature to the limit of B-B. Above this temperature ceramic components would likely be used in the heater assembly."

Figure 5-18 is the best information generated by Walker and his students based upon information available to them, both proprietary and non-proprietary.

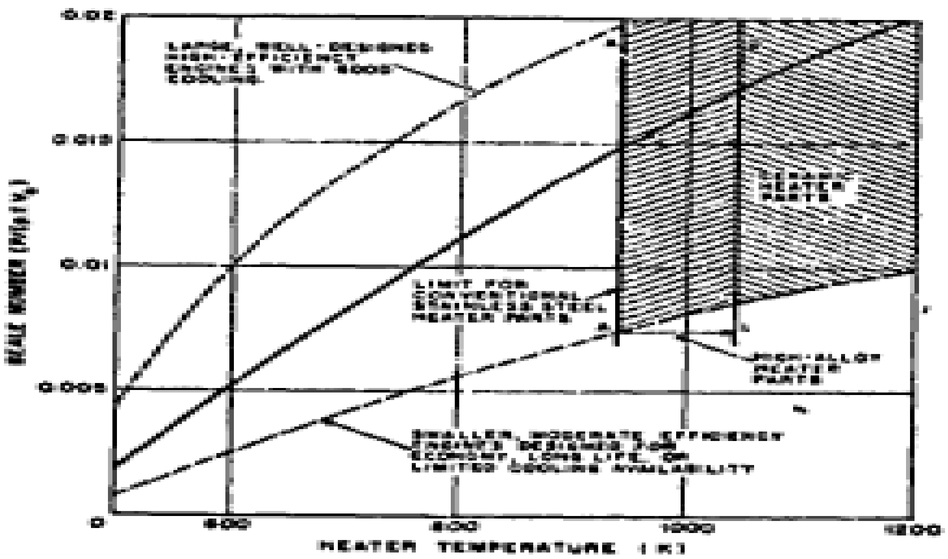
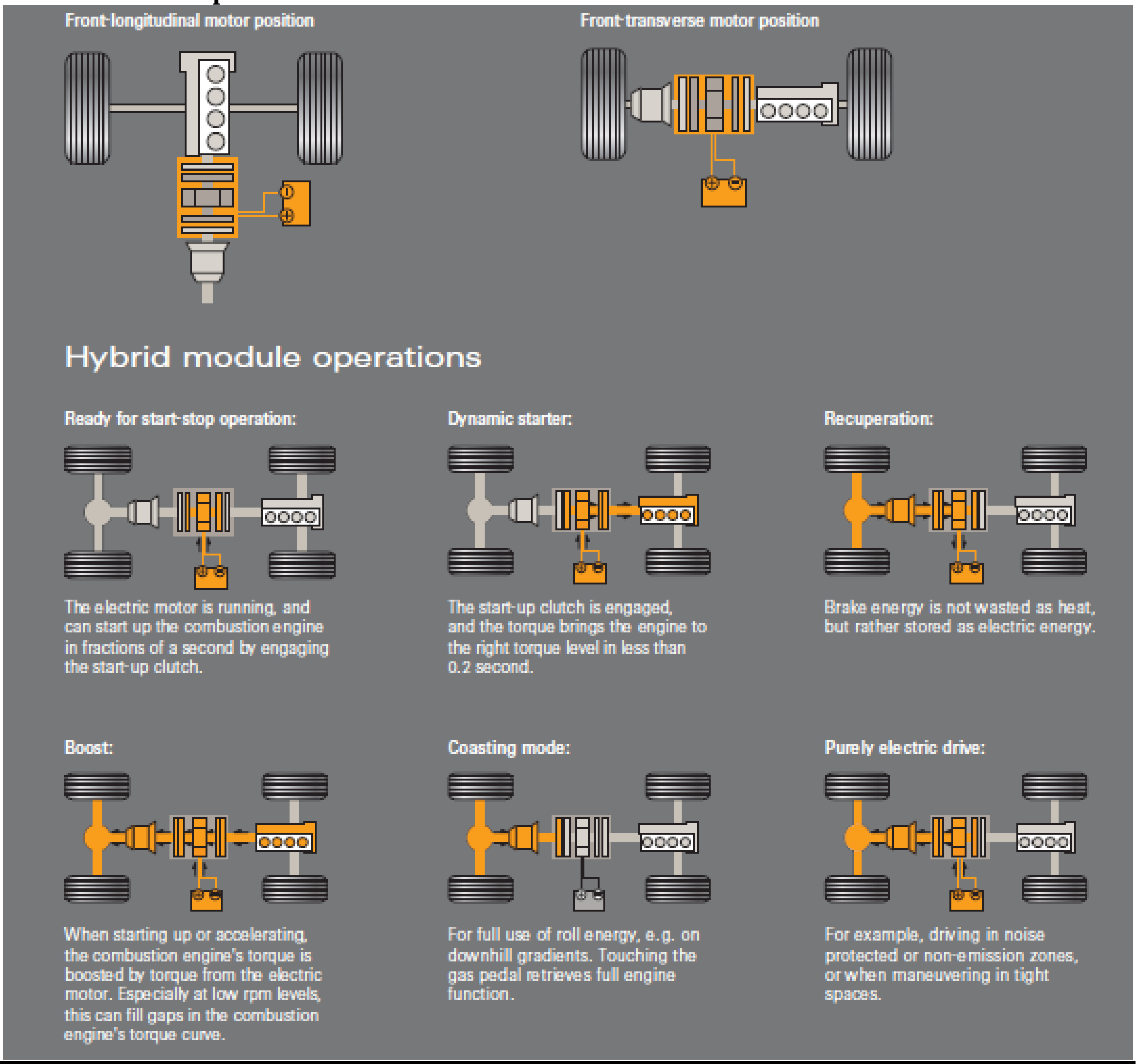


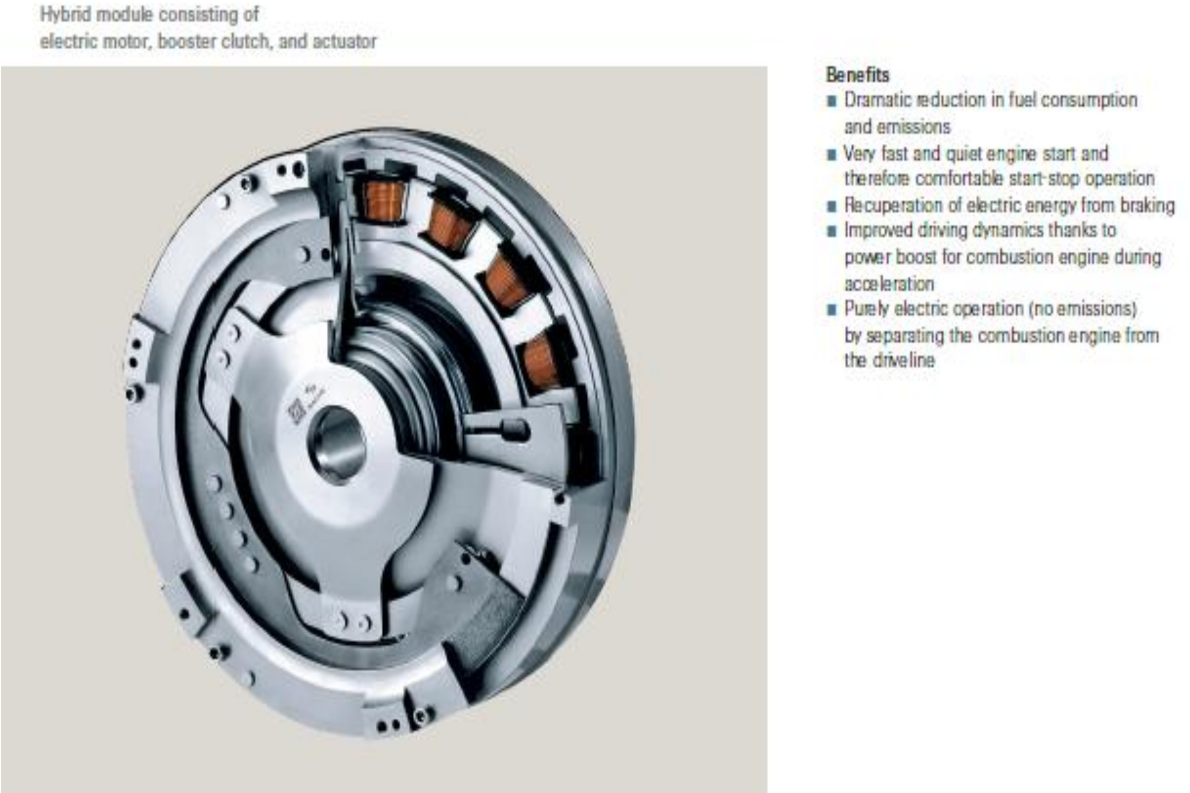
Figure 5-18. Beale Number as a Function of Heater Temperature.

IX. Electric Motor

Installation Concept And Overview



	Passenger car		
	Mild hybrid	Full hybrid	PlugIn hybrid
Power [kW]	4–20	20–70	50–100
Torque [Nm]	100–250	100–500	100–500
Voltage [V]	42–450	120–650	250–650
External diameters [mm]	240–325	240–345	240–345
Electric active length [mm]	50–80	55–105	55–105
Fuel reduction	up to 15%	up to 30%	up to 50%
Functions	Generator Start-stop Boost Recuperation	Generator Start-stop Boost Recuperation Electric drive operation	Generator Start-stop Boost Recuperation Electric drive operation
Electrical range [km]		1...5	15...45



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