UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CAMPUS D'ALCOI

Modificación de un motor de baja cilindrada para mejorar la eficiencia con el empleo de etanol utilizado en la Shell Eco-Marathon

---

MEMORIA PRESENTADA POR:

David Bocanegra Sánchez

GRADO DE *INGENIERÍA MECÁNICA*

Convocatoria de defensa: *Septiembre del 2016*

RESUMEN

En este proyecto se realizara un estudio y modificación de un motor de baja cilindrada para mejorar la eficiencia con el empleo de etanol para la competición Shell Eco-Marathon, en el cual pretendemos consumir la menor cantidad de combustible ya que en esta competición se mide el grado de eficiencia energética alcanzado.

El proyecto se concreta en reducir el consumo de combustible de un motor térmico de cuatro tiempos.

RESUM

En este projecte es realitzara un estudi i modificació d'un motor de baixa cilindrada per a millorar l'eficiència amb l'ocupació d'etanol per a la competició Shell Eco-Marathon, en el qual pretenem consumir li menor quantitat de combustible ja que en esta competició es mesura el grau d'eficiència energètica aconseguit.

El projecte es concreta a reduir el consum de combustible d'un motor tèrmic de quatre temps.

ABSTRACT

In this Project we are going to study and modify a small cylinder capacity engine. It will be made to improve efficiency in the use of ethanol for the Shell Eco-Marathon competition, in which we pretend to consume the least amount of fuel because in this competition, we will measure the level of energy efficiency achieved

The project focuses on reducing the fuel consumption of a four-stroke internal combustion engine.

AGRADECIMIENTOS

Para empezar, agradecerles a mis padres todo el apoyo y esfuerzo que me han dado a lo largo de mi vida universitaria.

Dicen que los mejores amigos los conoces en la universidad y que razón tiene ese dicho, gracias a todos, he vivido los mejores años de mi vida a vuestro lado, tanto en la universidad, en viajes y viviendo en piso de estudiantes junto a vosotros.

Agradecer al personal y profesorado de la Escuela Politécnica Superior de Alcoy todo el apoyo, enseñanza y atenciones durante estos largos años.

No puedo olvidarme de la familia que he conseguido gracias al equipo IDF, aquí dentro he conocido auténticas personas y vivencias únicas.

Por ultimo dar las gracias a una persona que ya no está entre nosotros y que me enseño mucho dentro de la competición Shell Eco-Marathon y en las prácticas de empresa que hice con él. Gracias José Miralles por todo lo que me enseñaste sobre la Shell y sobre la vida. Estés donde estés te mando un abrazo.

INDICE

Capítulo 1: INTRODUCCÍON

1.1 ANTECEDENTES

Como mejora del vehículo prototipo de bajo consumo IDF 16 se ha decidido cambiar el motor Honda GX25, el cual se ha usado desde hace muchos años, por un Honda GX35. Ya que este año se va a realizar la competición en un circuito urbano y no en un circuito real. Quedándose el motor de 25c.c. corto.

1.2 OBJETIVO

Utilizar el motor de 35 c.c. y dejar el 25 c.c., ya que pensamos que el aumento de cilindrada puede favorecer la reducción del consumo.

Modificaremos el motor cambiándole el pistón y añadiremos un sistema inyección.

1.3 ESTRUCTURA

El proyecto se divide en 8 capítulos.

- **Capítulo 1: INTRODUCCIÓN**
  Explicación del proyecto y la forma en que va a ser desarrollado y estructurado.

- **Capítulo 2: LA COMPETICIÓN**
  Exposición del prototipo, el equipo y la competición Shell Eco-Marathon

- **Capítulo 3: CARACTERISTICAS MOTORES**
  Exposición de los motores, diferencias, su uso, precios, características, etc.

- **Capítulo 4: MODIFICACIONES EN EL MOTOR**
  Explicación de los cambios realizados en el motor.

- **Capítulo 5: PRUEBAS Y RESULTADOS**

  Exposición de los ensayos realizados en tablas comparativas de los cambios y mejoras en el motor.

- **Capítulo 6: CONCLUSIONES**

  Principales conclusiones obtenidas al realizar los ensayos.

- **Capítulo 7: BIBLIOGRAFÍA**

  Compilación de las reseñas recurridas para la realización del proyecto.

- **Capítulo 8: ANEXOS**

  Recopilación de documentos, planos, libros, considerados de importancia o interesantes para la comprensión, justificación o complementación del proyecto.

Capítulo 2: LA COMPETICIÓN

2.1 SHELL ECO-MARATHON

La Shell Eco-Marathon es una competición única que desafía a los estudiantes de todo el mundo a diseñar, construir y conducir el coche más eficiente del mundo. Con tres eventos anuales en Asia, América y Europa donde los equipos compiten para ver quién es el que menos energía o combustible gasta en un recorrido determino y en un tiempo máximo.

La Shell Eco-Marathon es el futuro de la movilidad, buscando los límites de la eficiencia de la energía y el combustible.

2.1.1 LOS PROTOTIPOS

En la competición hay dos tipos de vehículos, los Prototipos y los Urban Concept.

Los prototipos:

Son vehículos de 3 ruedas que se centran en la innovación y optimización del combustible o energía utilizados.

Los Urban Concept:

Vehículos adaptados a las competencias de un coche de calle, ya que están homologados para circular por la ciudad.

Tanto los dos tipos de vehículos se diferencian por el tipo de energía o combustible empleados:

- Gasolina
  Gasolina sin plomo 95, de los más utilizados en la Shell por su bajo precio y la facilidad de sus motores.
- Diésel
  No es de los más usados ya que los motores son de grandes dimensiones comparados con los de gasolina.
- Etanol
  Es el que nosotros usamos en el IDF 16, conocido como alcohol etílico, se obtiene del procesamiento de materia de origen renovable de ciertas plantas con azúcares (caña de azúcar, remolacha, etc.). La eficiencia energética es menor que en diésel y gasolina.
- Gas
  Se usa el GNC, que usa la transformación del gas natural por procesos catalíticos y obtienen combustibles con cero contaminantes.
- Biodiesel
  Es un líquido que se obtiene a partir de lípidos naturales como aceites vegetales o grasas animales.
- Eléctricos
  Dentro de los eléctricos los vehículos son alimentados por pilas de hidrógeno o baterías de litio.

2.1.2 REGLAMENTACIÓN

La reglamentación de la Shell Eco-Marathon es el talón de Aquiles de todos los equipos que van, ya que son muy exigentes y pasar las inspecciones técnicas antes de salir a pista es uno de los grandes logros para los equipos.

La normativa se resume en un conjunto de normas centradas en la seguridad del piloto, el diseño del vehículo y la seguridad en el circuito.

Toda la normativa se encuentra expuesta en el ANEXO A: Normativa de la Shell Eco-Marathon.

Destacamos los apartados que hacen referencia al motor en general, el Artículo 59: Propulsión nos cita:

> El tipo y diseño de los motores de combustión interna no se limitan, sin embargo, se debe ejecutar sólo en el combustible proporcionado por los organizadores y no debe consumir ningún tipo de aceite del motor. (Motores de 2 tiempos No están permitidos).

En el Artículo 60: Otras fuentes de energía a bordo cita:

> Se exponen varias normas la cual destacaremos que solo se puede usar las baterías para el autoarranque, el encendido, el inyector, la instrumentación, la bocina y sistemas de gestión electrónica.

En el Artículo 64: Motor de Arranque cita:

> Está totalmente prohibido que el motor de arranque eléctrico proporcione propulsión hacia adelante en el vehículo.

En resumen en este proyecto podemos realizar los cambios que queramos en el motor siempre y cuando el motor solo consuma etanol y solo sea propulsado por este mismo.

2.1.3 CLASIFICACIÓN

La competición consiste en cada equipo tiene cinco mangas clasificatorias durante 2 o 3 días, en la cual la mejor marca obtenida será la elegida. La marca obtenida se expresa en KM/L de gasolina, ya que al haber tantos tipos de combustibles usados se realiza esta conversión para juntar todas las marcas de los equipos.

Las marcas van variando año tras año, ya que cambian de circuitos, a veces son circuitos urbanos, circuitos de carreras, óvalos, con desniveles, climas, etc.

El cálculo de la gasolina se realiza usando el poder calorífico neto, que representa la cantidad de energía liberada por unidad de masa o volumen de combustible durante la combustión completa produciendo vapor y dióxido de carbono. Se calculan multiplicando la masa real del poder calorífico por la densidad del combustible a 15ºC.

Estos son los valores típicos del poder calorífico en base masa para los diferentes combustibles utilizados.

TIPOS DE ENERGIA	PODER CALORIFICO POR MASA (KJ/KG)
Gasolina 95	42.900
Diésel	42.600
Etanol	26.900
Gas licuado	44.000
Hidrógeno	119.930
CNG	50.016

Toda la normativa sobre la clasificación y cálculos de resultados se encuentran en el Artículo 54: Resultados Clasificación, dentro del ANEXO A: Normativa de la Shell Eco-Marathon.

2.2 EL EQUIPO

Somos el equipo IDF Eco-Marathon de la Universidad Politécnica de Valencia Campus de Alcoy y este nuestro prototipo actual:

Diseñado por todos los integrantes del equipo y perfeccionado con el paso de los años, este Prototipo se trata de un monocasco de fibra de carbono tan extremadamente rígido que cumple las unciones de carrocería y chasis. Todo el conjunto pesa 11 kg, siendo el más aerodinámico posible y, además, fabricado en una sola pieza.

Nuestra historia comienza en el 2006 cuando un grupo de alumnos se inscribió en la European Shell Eco-Marathon con la ayuda de nuestro actual Team Maneger Vicente Colomer.

Desde el año 2010 cuando personalmente me incorpore al equipo Vicente me ha transmitido su incalculable pasión y empeño, siendo para mi más que un profesor, un gran amigo.

Para la competición de 2017 tendremos un motor diseñado hasta la última pieza por el equipo, fabricado con la ayuda del IDF (Instituto de Diseño y Fabricación). Con esto motor se espera batir nuestra marca y superar los 1500km/l.

2.3 MARCAS

Estos son nuestros pasos a través de los años:

AÑO: 2006
CIRCUITO: Nogaro (Fr)
MARCA: 250 km/l
En tan sólo dos meses de preparación

AÑO: 2007
CIRCUITO: Nogaro (Fr)
MARCA: No hubo marca, debido a que no hubo categoría Ethanol
Diseño y fabricación de segundo vehículo

AÑO: 2008
CIRCUITO: Rockingham (UK)
MARCA: 633 km/l
2ª Posición Ethanol

AÑO: 2009
CIRCUITO: Lausitz (Ger)
MARCA: 548 km/l
2ª Posición Ethanol
Comienza patrocinio SEUR

AÑO: 2009
CIRCUITO:Murcia (ESP)
MARCA: 492 km//l
I Solar Race
1° Posición

AÑO: 2010
CIRCUITO: Lausitz (Ger)
MARCA: 0 km
Diseño y fabricación del tercer vehículo

AÑO: 2011
CIRCUITO: Lausitz (Ger)
MARCA: 891 km/l
3° Posición Ethanol

AÑO: 2011
CIRCUITO: Madrid (ESP)
MARCA: 256 km/l
1° Posición
Madrid EcoZity

AÑO: 2012
CIRCUITO:Rotterdam (Ne)
MARCA: 831 km/l
5° Posición

AÑO: 2012
CIRCUITO:Murcia (ESP)
MARCA: 722 km/l
3° Posición
III Murcia Solar Race

AÑO: 2013
CIRCUITO:Rotterdam (Ne)
MARCA: 973km/l
6° Posición Ethanol

AÑO: 2013
CIRCUITO: Valencia (ESP)
MARCA: 957 km/l
1° Posición
Green Prix VLC

AÑO: 2014
CIRCUITO: Rotterdam (Ne)
4ª Posición Ethanol
1048 km/l

CIRCUITO: Valencia (ESP)
MARCA: 785 km/l
1ª Posición
Shell Eco-Marathon Valencia

CIRCUITO: Murcia (ESP)
MARCA: 709 km/l
4ª Posición
IV Murcia Solar Race
Premio al Mejor Diseño

AÑO: 2015
CIRCUITO: Rotterdam (Ne)
4ª Posición Ethanol
829 km/l

AÑO: 2015
CIRCUITO: Rockingham (UK)
1° Posición Ethanol
4° Posición Clasificación Gnral.
1294 km/l

Reunión con nuestro Rector Francis Mora y la Vicerrectora Victoría Vivancos

Durante años los alumnos hemos ido cambiando, pero siempre se ha mantenido presente el trabajo constante ya que nuestros objetivos son mejorar las marcas obtenidas en competiciones pasadas y superar los nuevos retos. Es un trabajo muy duro a la hora de conseguir excelentes resultados en una prueba con tanta competencia internacional. Por este motivo, además de las competiciones organizadas por Shell, participamos en diversos eventos nacionales como: Murcia Solar Race, Madrid EcoZity, Green Prix de Valencia y Shell Eco-Marathon Valencia.

2.4 PATROCINADORES

El propio Campus de Alcoy de la UPV siempre ha sido uno de nuestros apoyos esenciales. Este nos ha facilitado el taller donde trabajamos y otro para llevar a cabo mecanizados en el vehículo y salas donde reunirnos. Además, la oportunidad para la propia universidad y el resto de sponsors de presentar el vehículo en múltiples de actos públicos.

El Instituto de Diseño para la Fabricación y Producción Automatizada (IDF) es la estructura de investigación de la universidad donde nos encontramos integrados. Éste nos aporta gran parte del soporte técnico, véase mecanizados con CNC, utillaje para fabricación, etc.

En el sector privado, la empresa principal es SEUR. Su fundación nos proporciona todo el soporte logístico en las competiciones a las que asistimos. Y su apoyo no es solo a nosotros, es a todos los equipos españoles y portugueses, que se encargan de todo el transporte a las competiciones.

Estos tres son los patrocinadores que más nos aportan pero también contamos con las ayudas de:

2.5 REPERCUSIÓN MEDIÁTICA

Desde nuestro arranque, hemos sabido cómo destacar y lo hemos logrado de una forma sobresaliente, consiguiendo una repercusión mediática muy destacable. Hemos aparecido en los telediarios, prensa (escrita y digital), radio, innumerables artículos, internet, tales como:

TV: La Sexta Noticias, Antena 3 Noticias, TVE, TVE Noticias, Cuatro en el Hormiguero, TV5 Germany, TF1 France, TV Azteca México.

RADIO: COPE, Cadena Ser, RNE, Radio Alcoy, etc.

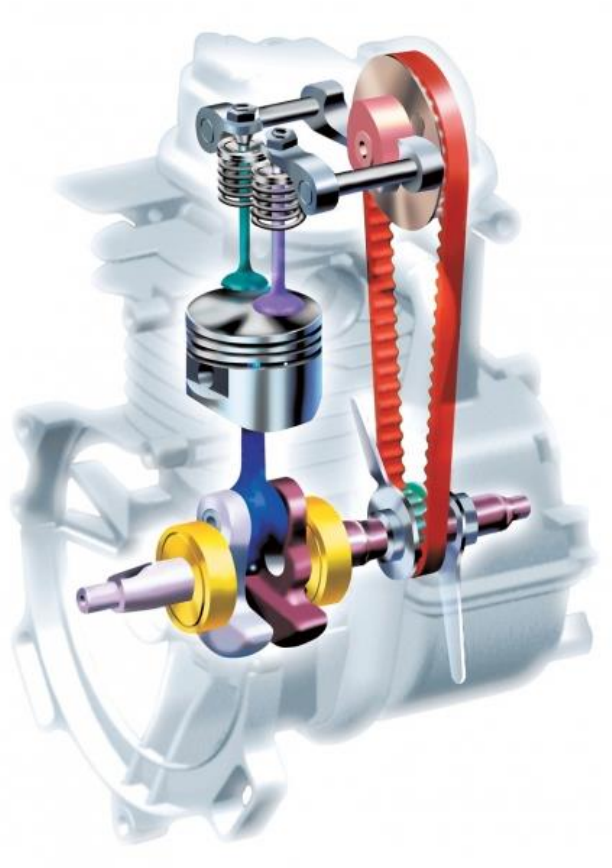
PRENSA: EL País, El Mundo, ABC, Levante, Auto Bild Magazine, Marca Motor, Las Provincias, etc.

INTERNET: EuroSport, UPV, La Vanguardia, 20 Minutos, El Nostre Digital, Universia, Europress, etc.

Capítulo 3: CARACTERÍSTICAS MOTORES

Los Motores Honda GX35 y GX25 son prácticamente iguales, solo cambian la cilindrada. Son motores de 4 tiempos con un cilindro vertical, refrigerado por aire y árbol de levas en cabeza (OHC) tienen sus árboles de levas colocados en la culata sobre la cámara de combustión.

La disposición de árbol de levas en cabeza se basa en estas ventajas para reducir el número de componentes del tren de válvulas permitiendo que sean más ligeros y resistentes, con lo que el motor en general es más compacto y ligero.



Mediante la combinación de un balancín en forma de L y un árbol de levas de una sola leva se ha hecho posible colocar la polea de distribución en un lado de la culata, de manera que la altura total del motor se puede reducir en comparación con un motor de árbol de levas convencional.

La correa de distribución en configuración de aceite, lubrica alrededor de la leva y las válvulas se realizan por el aceite que gira con la correa.

El carburador que monta incorpora una bomba de aceleración. Por mediación de un corte en la válvula rotativa de aceleración, la bomba inyecta gasolina directamente al chiclé principal del carburador, cada vez que se acelera desde la posición inicial.

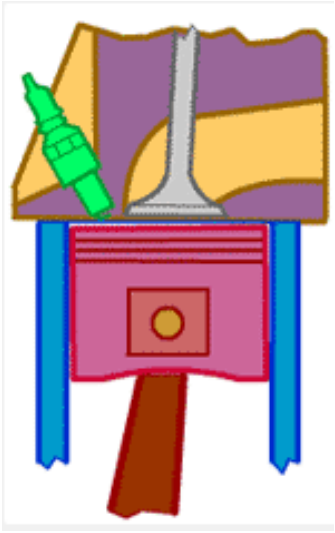
Junto con la reducción de peso de las piezas rotativas del motor (plato magnético), la inyección de esta cantidad extra de gasolina durante la aceleración, da como resultado una respuesta rápida de la aceleración, comparable a la de los motores de 2 tiempos.

Toda esa tecnología permite inclinar el motor hasta los 360º. Permite tener un alto rendimiento potente y silencioso. Por estas razones es uno de los motores más usados como propulsores para cortacéspedes, bombas, generadores y otros equipos que son fabricados por innumerables fabricantes de todo el mundo.

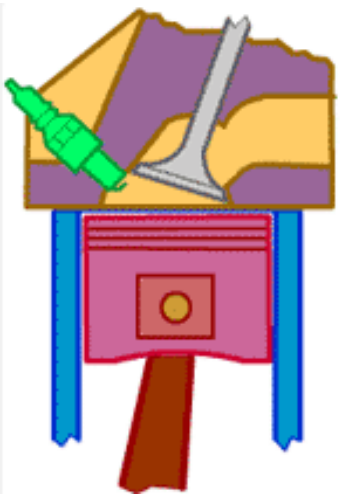
3.1 MOTOR HONDA GX25

	UNIDAD	GX35
ANCHO	mm	221
LARGO	mm	192
ALTO	mm	230
PESO	Kg	2.78
CAPACIDAD	litros	3.25

TIPO MOTOR	UNIDAD	GX25
Cámara de combustión		Tipo Bathtub
Desplazamiento	Cm3	25.0
Calibre por carrera	Mm	35 x 26
Potencia máxima	kW/rpm	0.72 / 7000
Par máximo	Nm/ rpm	1.0 / 5500
Consumo	g/kWh	340
Ratio de compresión		8.0
Ajuste de válvula Admisión	Mm	0.08+-0.02
Ajuste válvula (escape)	Mm	0.11 ± 0.02
Ralentí	Min-1	3100 ± 200
Máxima velocidad	Min-1	10000
Nivel sonoro	dBA7 1m	85

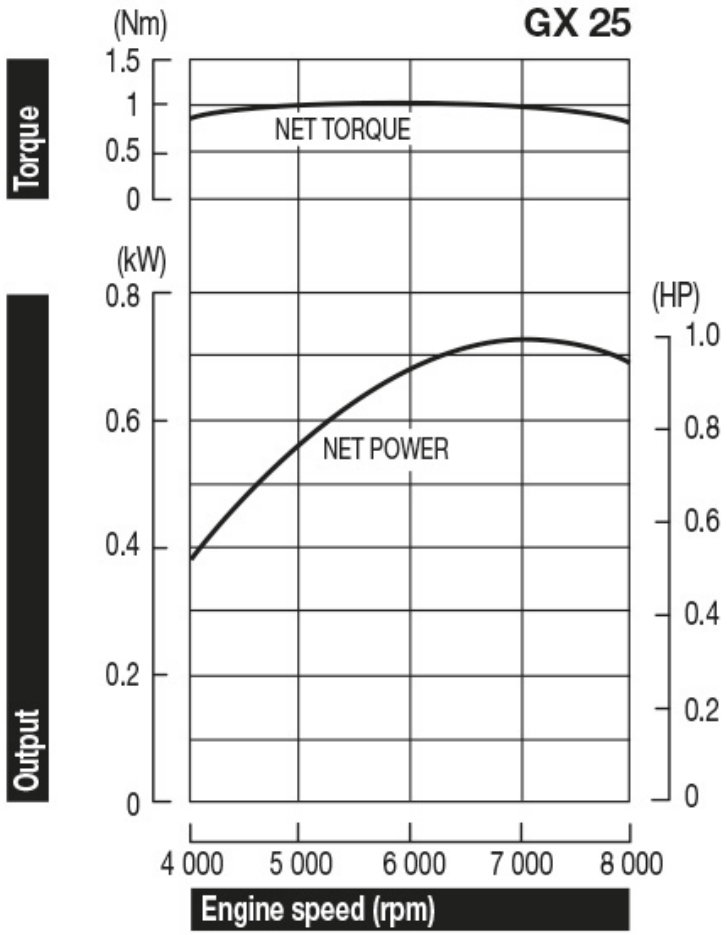


La cámara de combustión es tipo BATHTUB que significa que las válvulas se mueven en línea con el pistón.

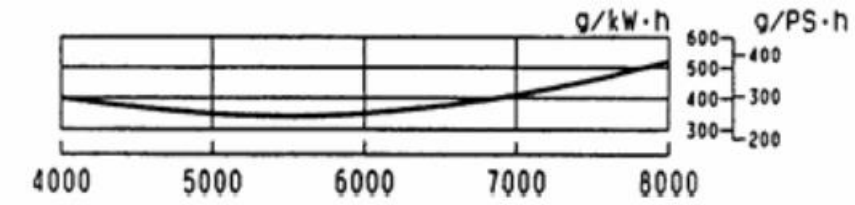


Hay otro tipo de cámara de combustión denominada WEDGE en el que las válvulas se mueven en ángulo con respecto al pistón.

Curvas de rendimiento:



Consumo utilizando gasolina, aquí ya podemos ir observando que el motor donde menos consume es a 5500 RPM.

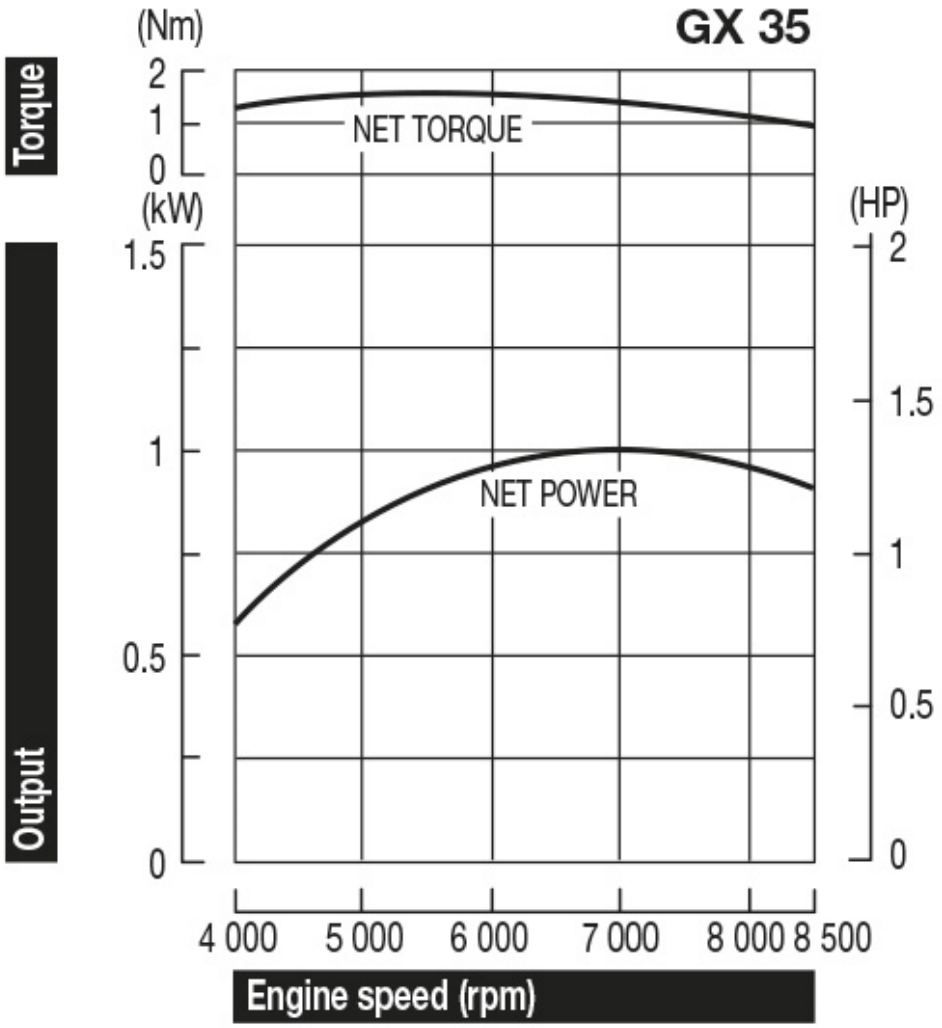


3.2 MOTOR HONDA GX35

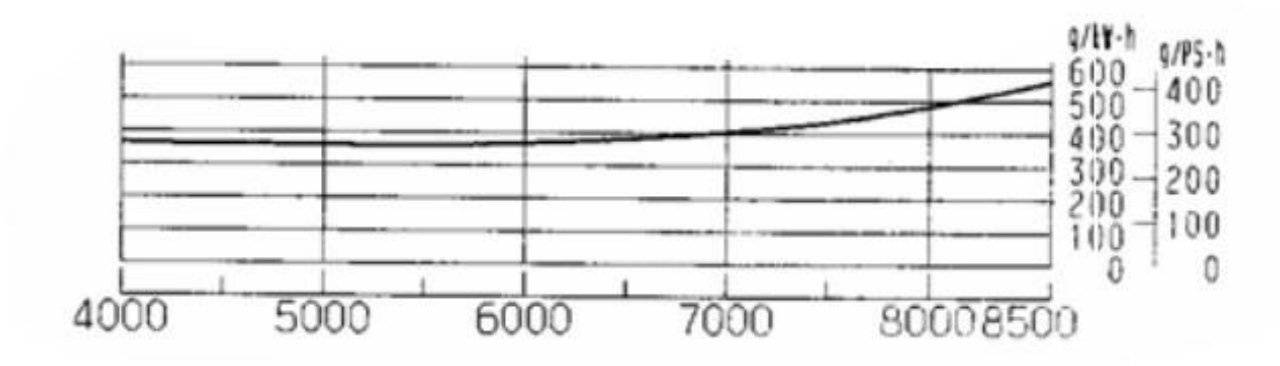
	UNIDAD	GX35
ANCHO	mm	234
LARGO	mm	198
ALTO	mm	240
PESO	Kg	3.33
CAPACIDAD	litros	3.88

TIPO MOTOR	UNIDAD	GX25
Cámara de combustión		Tipo Bathtub
Desplazamiento	Cm3	35.8
Calibre por carrera	Mm	39 x 30
Potencia máxima	kW/rpm	1.0/7000
Par máximo	Nm/rpm	1.6/5500
Consumo	g/kWh	360
Ratio de compresión		8.0
Ajuste de válvula Admisión	Mm	0.08 ± 0.02
Ajuste válvula (escape)	Mm	0.11 ± 0.02
Ralentí	Min-1	3100 ± 200
Máxima velocidad	Min-1	10000
Nivel sonoro	dBA7 1m	89

Curvas de rendimiento



Consumo gasolina, podemos ir observando que el motor donde menos consume es a 5000 RPM como en el gx25.



3.3 DIFERENCIAS

Los motores son prácticamente iguales, pero nos decantamos por el motor Gx35 porque con un aumento mínimo de consumo especifico (tan solo 20g/kWh) conseguimos prácticamente duplicar el par motor (de 1 del GX25 a 1.6 del GX35) y lo más significativo es que la curva de consumo especifico entre las 4000 y 6500 rpm se mantiene casi plana en el GX35 mientras que en el GX25 el consumo aumenta si nos pasamos del punto óptimo de consumo,

Capítulo 4: MODIFICACIONES EN EL MOTOR

4.1 PISTÓN

Lo primero que realizamos es sustituir el pistón del motor GX35 por el del motor GX31, el cual tiene el mismo diámetro pero tiene una altura mayor, haciendo que la relación de compresión aumente.

Pistón del motor GX31

En esta imagen observamos el pistón del motor GX35 unido a la biela y cigüeñal y a la derecha el pistón G31.

Para la sustitución del pistón debemos realizar un rebaje en la parte superior para que el pistón no toque con la culata ya que en los motores de combustión interna hay que mantener una determinada distancia entre la parte superior del pistón y el inicio de la cámara de combustión para que la combustión sea idónea.

En la imagen de abajo indicamos el material eliminado mediante un proceso de torneado.

Características Motores Honda GX35 y GX31

Motor Honda GX35

D: Diámetro del pistón (Bore) D = 39 mm

L: Carrera del pistón (Stroke) L = 30 mm

v_0: Volumen de la hendidura de la cabeza del pistón Honda GX35: v_0=0.8cc

SQUISH del pistón motor Honda GX35: SQUISH = 1.8 mm

V: Cilindrada del motor Honda GX35: V = 35.83 cc

R: Relación volumétrica del motor Honda GX35: R = 8:1

Peso del pistón del motor Honda GX35: 37.2 gf

Motor Honda GX31

D: Diámetro del pistón (Bore) D = 39 mm

L: Carrera del pistón (Stroke) L = 26 mm

h: Mayor altura del pistón del Honda GX31 respecto del GX35: h = 1.53mm

Peso del pistón del motor Honda GX31: 42.2 gf

Peso del pistón del motor Honda GX31 con la cabeza recortada: 39.7 gf

El volumen de la cámara de combustión del motor Honda GX35 será:

$$R = \frac{V + v}{v} \rightarrow v = \frac{V}{R - 1} = \frac{35.83}{8 - 1} = 5.12cc \ (1)$$

Si sustituimos el pistón del motor Honda GX35 por el del GX31, teniendo en cuenta que este último no tiene hendidura en su cabeza y que, además, es

más alto que el primero, entonces la expresión 1 se puede escribir como sigue:

$$v - v_\theta - \pi 10^{-3}\left({}^{D}/_{2}\right)^2 h - \pi 10^{-3}\left({}^{D}/_{2}\right)^2 \Delta_h = \frac{V}{R+1} \rightarrow$$

$$v - v_\theta - \pi 10^{-3}\left({}^{D}/_{2}\right)^2 (h - \Delta_h) = \frac{V}{R-1} \quad (2)$$

Siendo Δ_h la longitud en mm a recortar al pistón GX31 para ajustar la Relación de compresión (R) del GX35, sustituyendo valores en la expresión 2, tendremos:

$$5.12 - 0.8 - 10^{-3}\pi\left({}^{39}/_{2}\right)^2 (1.35 - \Delta_h) = \frac{35.83}{R-1} \rightarrow$$

$$\Delta_h = \frac{30}{R-1} - 2.268$$

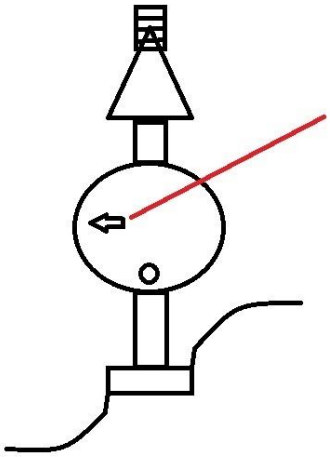
Cálculo del incremento de altura

Eficiencia del motor GX35 en función de su compresión.

COMPRESIÓN	EFICIENCIA
8	51.7%
9	53.65%
10	55.33%
11	56.79%
12	58.11%

De subir de 8 a 11 ganaríamos un 5.09% de rendimiento.

A la hora de montar el pistón debemos montarlo como indica la siguiente imagen.



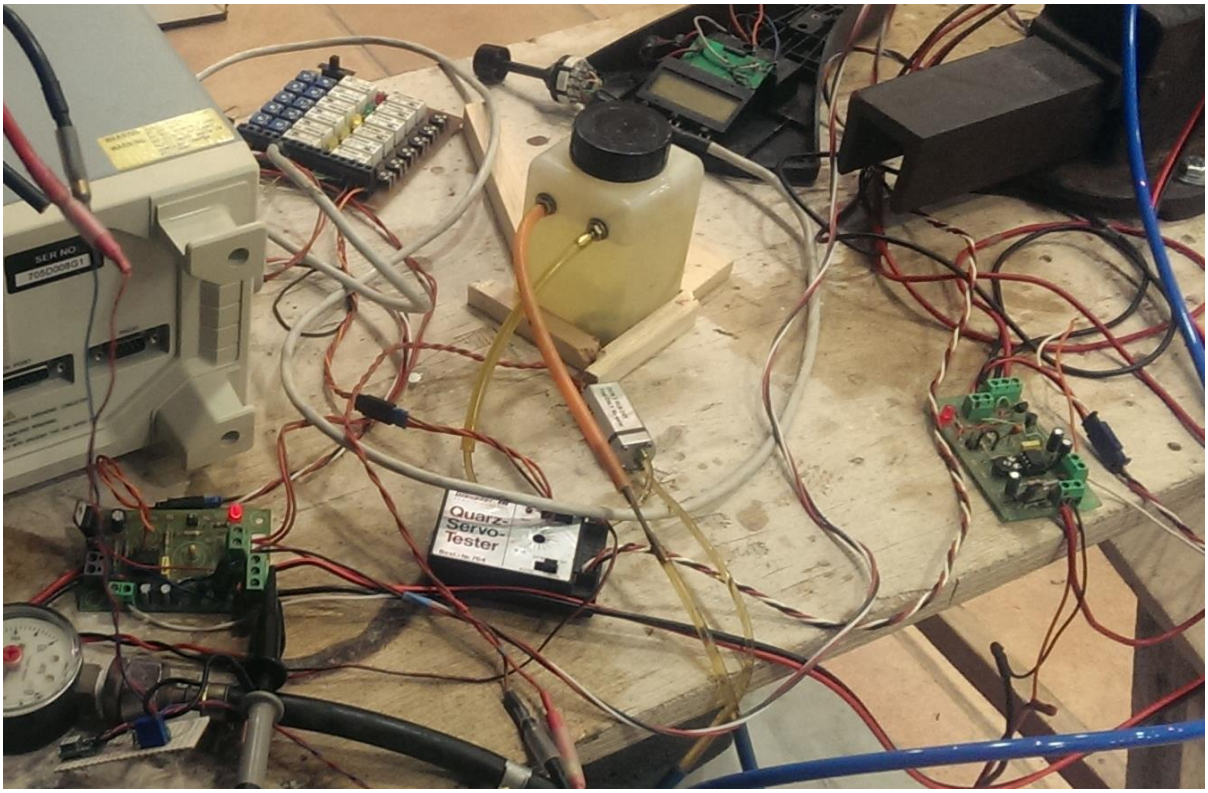
Posición del piston respecto el cigüeñal

4.2 INYECCION

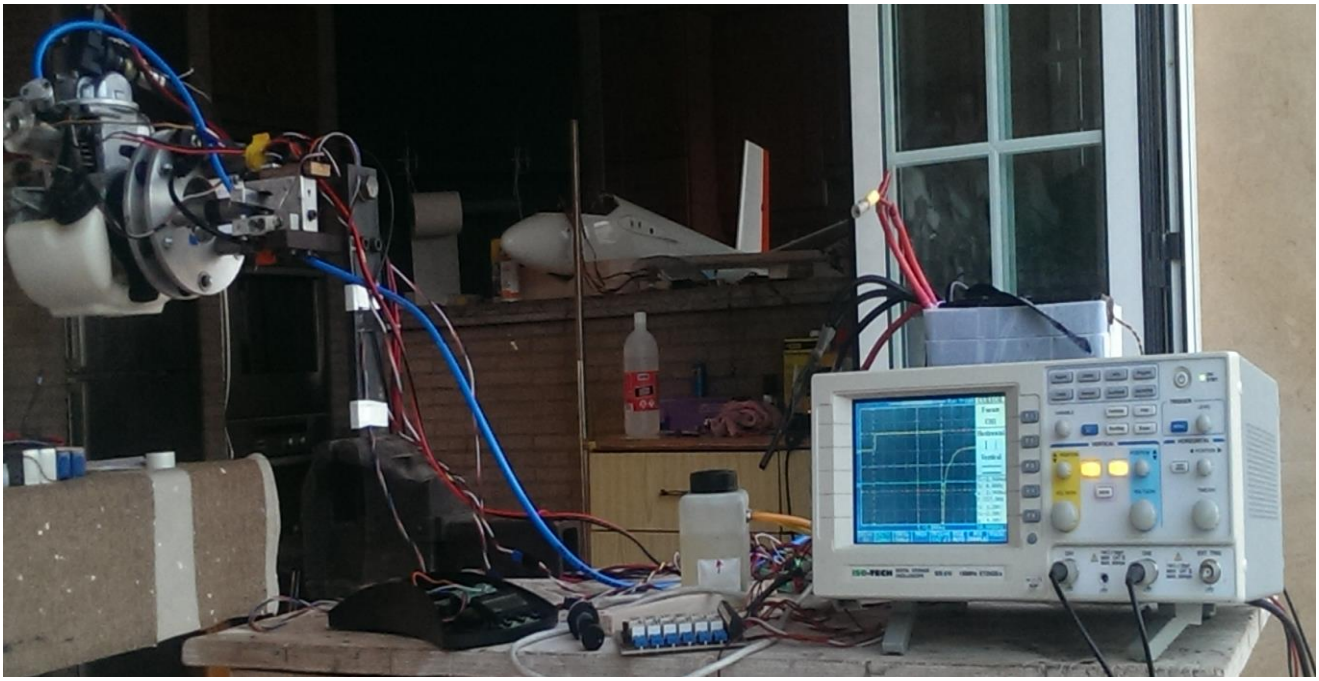
Diseñado por mi tutor José Miralles.

Hemos descartado del motor el sistema de alimentación a carburador, ya que añade un consumo superior al motor que aumenta con el número de revoluciones, por lo que es sustituido por un sistema de inyección en el que contralaremos en todo momento la cantidad de combustible añadida.

Este sistema de inyección era controlado mediante una centralita analógica con potenciómetros, todo diseñado por mi tutor en prácticas, José Miralles.



Nos ayudábamos de un osciloscopio para medir la señal del avance de encendido y poder ajustarla mejor.



Capítulo 5: PRUEBAS Y RESULTADOS

Todos los ensayos han sido realizados 3 veces cada uno de ellos, y los resultados indicados en las tablas se han obtenido realizando la media de las tres medidas.

5.1 PRIMERAS PRUEBAS

PRUEBAS CON MOTOR HONDA GX35

Lo primero a realizar, es un rodaje de 4 horas al motor Honda GX 35 con aceite 10w40.

ENSAYO POTENCIA MOTOR: GX35 SIN MODIFICAR

HÉLICE APC 16X16 Y APC 16X14P

FUERZA SOBRE LA BALANZA (gramos fuerza)	**Silenciador de escape**	**Filtro de admisión**	**R.P.M**	**Hélice**	**POTENCIA NETA EN EL EJE DEL MOTOR P_n(W) $P_n=M\cdot RPM\cdot Pi/30$**
1600	Si	Si	5700-5800	16x16	947
1650	No	Si	5800-5900	16x16	957
1650	Si	No	5800-5900	16x16	957
1700	No	No	6000	16x16	1017
1750	Si	Si	6300-6400	16x14P	1163
1750	Si	No	6400-6500	16x14P	1182
1800	no	No	6600-6700	16x14P	1253

ENSAYO CONSUMO ESPECIFICO MOTOR HONDA GX35

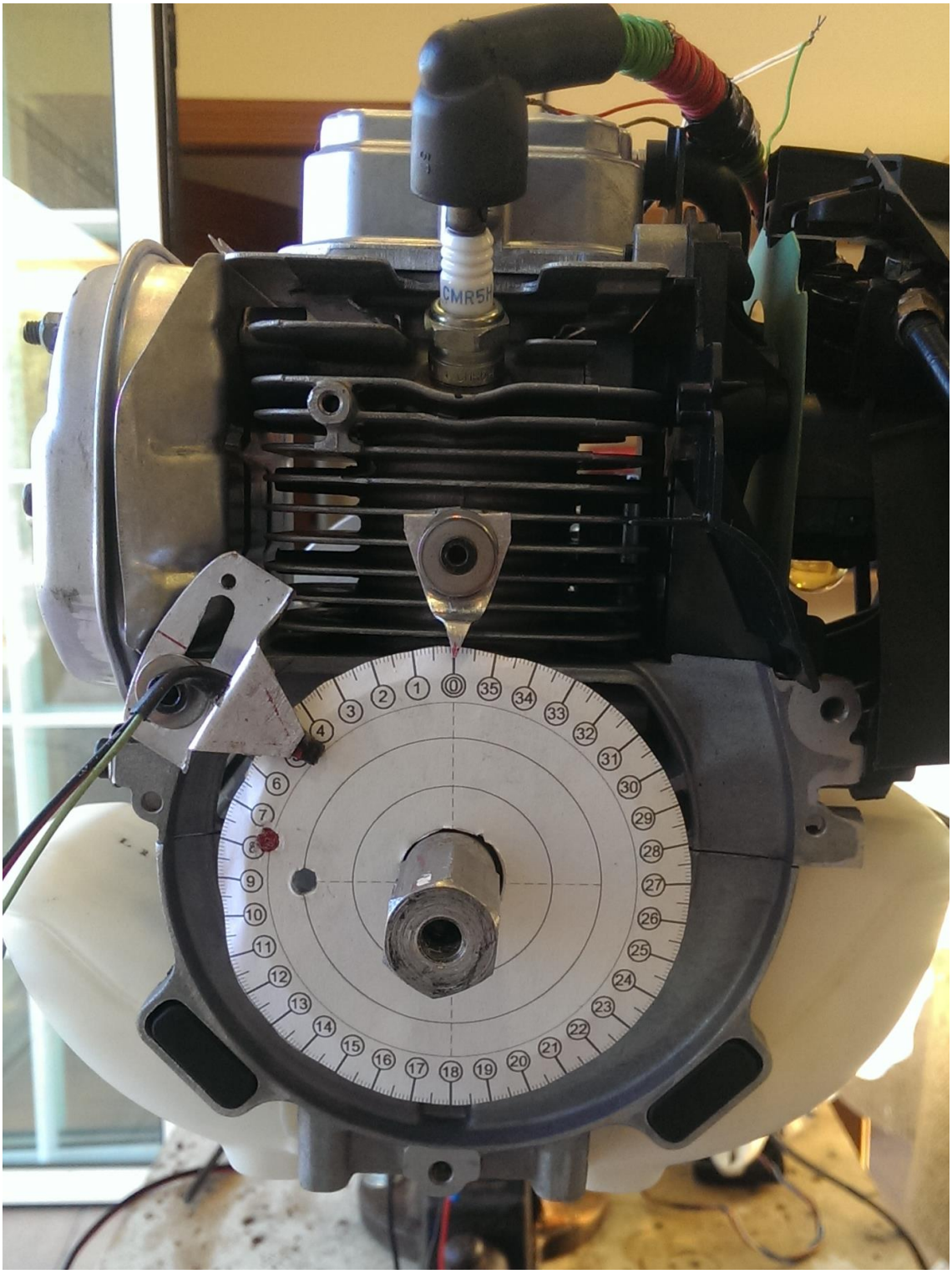
SIN MODIFICAR, SIN FILTRO Y SIN SILENCIADOR

GASOLINA 98 Y AVANCE DE IGNICIÓN 25º

HÉLICE	**R.P.M**	**CANTIDAD DE COMBUSIBLE**	**TIEMPO MARCHA MINUTOS**
APC 16x16	5000-5100	100 c.c.	14:25
APC 16x16	5000-5100	100 c.c.	14:15
APC 16x16	5000-5100	100 c.c.	13:55

Hemos puesto aceite 5w30, hemos colocado el pistón modificado del Motor Honda GX31. Realizamos un volante para el motor y la hélice para colocar el imán y el sensor Hall. En estas pruebas usamos carburador.

Después de varias pruebas a distintos puntos de avance y viendo las rpm máximas que lograba sacar el motor***, el mejor punto de avance es el 25,*** que rinde unas 6200-6300 R.P.M con una fuerza sobre la balanza de 1900 Nm.

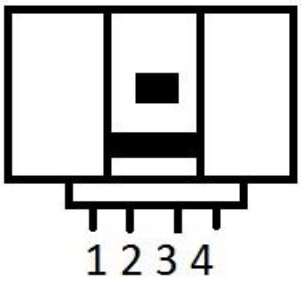


Sistema de indicación de avance

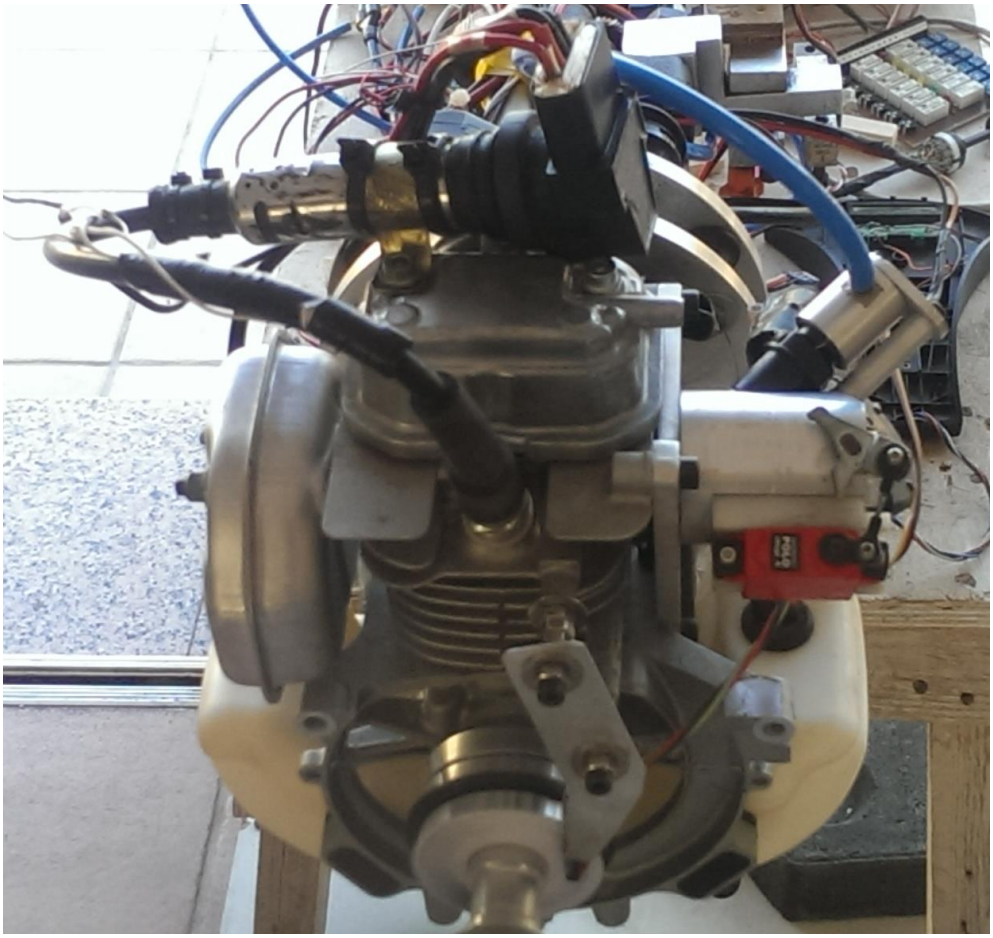
Utilizamos una lámpara estroboscópica y este esquema para poder ver dónde está el avance y poder ir cambiándolo.

Hemos puesto una Bobina VW AG con un circuito hecho por mi tutor de prácticas José Miralles, el motor ha llegado a hacer puntas de 6500rpm.

ESQUEMA BOBINA



1) A CHASIS (NEGRO)
2) A ELECTRÓNICA (NEGRO)
3)12+v (ROJO)
4)TTL (ROJO)



5.2 SEGUNDAS PRUEBAS

ENSAYO POTENCIA MOTOR: GX35 MODIFICADO

HÉLICE APC 16X16 Y APC 16X14P

AVANCE 25º

FUERZA SOBRE LA BALANZA (gramos fuerza)	**Silenciador de escape**	**Filtro de admisión**	**R.P.M**	**Hélice**	**POTENCIA NETA EN EL EJE DEL MOTOR P_n(W) $P_n=M\cdot RPM\cdot Pi/30$**
1700	Si	Si	6000-6100	16x16	1077
1725	No	Si	6100-6200	16x16	1092
1725	Si	No	6100-6200	16x16	1092
1750	No	No	6200-6300	16x16	1107
	Si	Si	6600-6700	16x14P	
1837	No	No	6900-7000	16x14P	1337

ENSAYO CONSUMO ESPECIFICO MOTOR HONDA GX35

MODIFICADO, SIN FILTRO Y SIN SILENCIADOR

GASOLINA 98 Y AVANCE DE IGNICIÓN 25º

HÉLICE	**R.P.M**	**CANTIDAD DE COMBUSIBLE**	**TIEMPO MARCHA MINUTOS**
APC 16x16	5000-5100	100 c.c.	16:35
APC 16x16	5000-5100	100 c.c.	16:40
APC 16x16	5000-5100	100 c.c.	16:10
APC 16x16	5000-5100	100 c.c.	16:16
APC 16x16	5000-5100	100 c.c.	16:18
APC 16x16	5000-5100	100 c.c.	16:12
APC 16x16	5000-5100	100 c.c.	16:38

Estas pruebas tienen una FUERZA SOBRE LA BALANZA DE 1300 Nm

Y una POTENCIA NETA EN EL EJE DEL MOTOR de 687

Vamos a colocar el ***sistema de inyección*** al motor Honda G35 Modificado, el motor funciona perfectamente y con un avance a 25 llega a 6300 R.P.M y se mantiene constante.

También vamos a colocar un imán en el árbol de levas y medimos con el osciloscopio, las diferencias son claras:

ENSAYO CONSUMO ESPECIFICO MOTOR HONDA GX35

MODIFICADO, SIN FILTRO Y SIN SILENCIADOR

CON INYECCIÓN E IMÁN ARBOL LEVAS

GASOLINA 98 Y AVANCE DE IGNICIÓN 25º

HÉLICE	**R.P.M**	**CANTIDAD DE COMBUSIBLE**	**TIEMPO MARCHA MINUTOS**
APC 16x16	5000-5100	100 c.c.	17:05
APC 16x16	5000-5100	100 c.c.	17:17
APC 16x16	5000-5100	100 c.c.	17:05

Inyección en Osciloscopio nos da un PULSO DE INYECCIÓN de 4.600 ms a 6300 R.P.M

Con una fuerza sobre la Balanza 1280 gf (la balanza es de torsión)

Potencia = 571,1 W

5.3 TERCERAS PRUEBAS

PRUEBAS CON MOTOR HONDA GX25

Vamos a realizar los ensayos con queroseno e inyección electrónica.

Primero probamos el motor con gasolina 95, pero vimos que este motor tenía un problema de compresión entorno 100-200 R.P.M menos. Pero al realizar el ensayo con queroseno el motor volvió a funcionar bien, se ve que el queroseno al parecerse al diésel ha lubricado el motor o algún aro y el motor vuelve a funcionar bien.

ENSAYO CONSUMO ESPECIFICO MOTOR HONDA GX25

MODIFICADO, SIN FILTRO Y SIN SILENCIADOR

CON INYECCIÓN E IMÁN ARBOL LEVAS

QUEROSENO Y AVANCE DE IGNICIÓN 26º

HÉLICE	R.P.M	CANTIDAD DE COMBUSIBLE	TIEMPO MARCHA MINUTOS
APC 16x16	5000-5100	100 c.c.	19:37

REPETIMOS ESTE MISMO ENSAYO PERO CON GASOLINA 95

HÉLICE	R.P.M	CANTIDAD DE COMBUSIBLE	TIEMPO MARCHA MINUTOS
APC 16x16	5000-5100	100 c.c.	19:44

REPETIMOS ESTE MISMO ENSAYO PERO CON AVANCE A 27.5º Y GASOLINA 95 Y CON UN PULSO DE 2740x2 ms

HÉLICE	R.P.M	CANTIDAD DE COMBUSIBLE	TIEMPO MARCHA MINUTOS
APC 16x16	5000-5100	100 c.c.	19:25

Por último probamos la hélice APC 16x14P

FUERZA SOBRE LA BALANZA (gramos fuerza)	Silenciador de escape	Filtro de admisión	R.P.M	Hélice	POTENCIA NETA EN EL EJE DEL MOTOR P_n(W) $P_n=M\cdot RPM\cdot Pi/30$
1100	No	No	5000-5100	16x14P	

El peso muerto del motor es 155 y hemos llegado a subir el motor a 5700-5800 R.P.M

Nota:

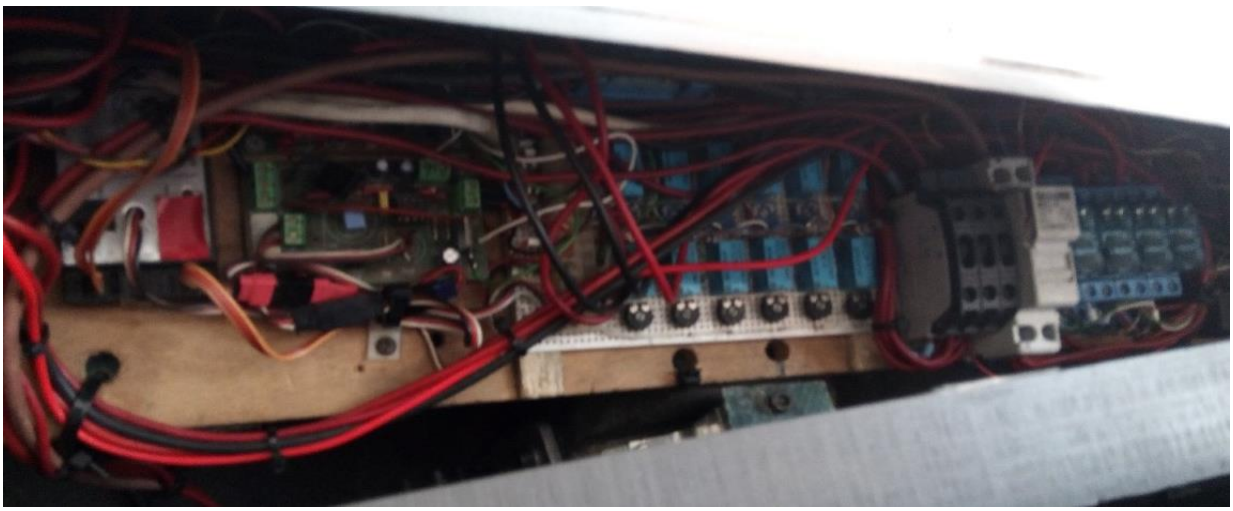
Probamos unas Micro turbinas en el motor HONDA GX25, el motor de casa daba unos 4800-4900 R.P.M con un avance a 28º, es decir, para este motor no funciona. Estas Micro turbinas sí que pueden ir bien en aeromodelismo

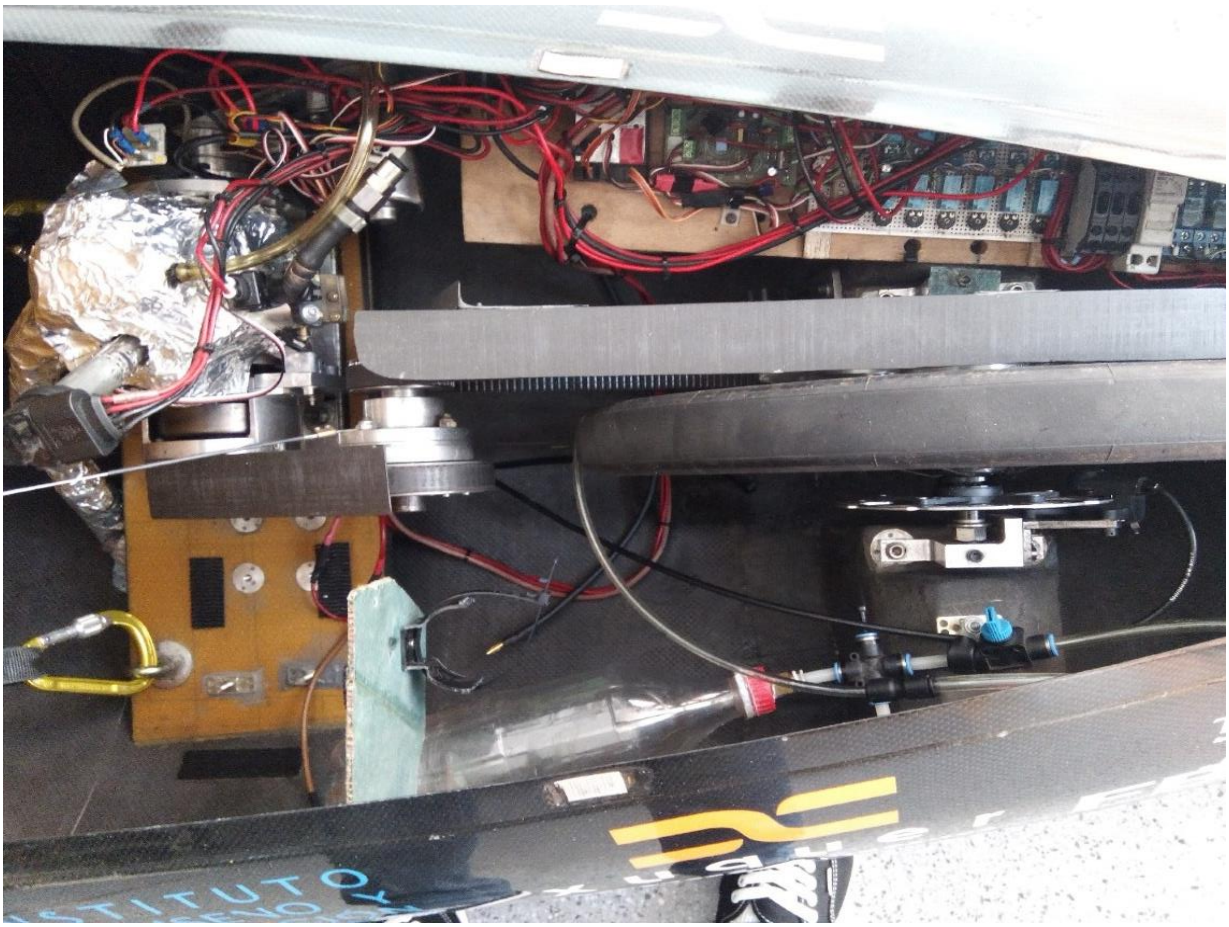
Todas estas pruebas las realice en periodo de prácticas en la empresa Medavia S.L.

5.4 PRUEBAS EN LA UNIVERSIDAD POLITECNICA DE VALENCIA CAMPUS DE ALCOY

Nuestro prototipo siempre ha llevado una centralita electrónica analógica con potenciómetros, el cual después de muchos años decidimos cambiarla por una ECU.

La centralita que usábamos era idéntica a la diseñada por José Miralles, pero montada en nuestro vehículo de tal manera:





Este año hemos instalado una ECU DTA Fast S40pro (Centralita Electrónica Programable) en el motor para realizar pruebas con etanol en el Motor GX35, ya que obtendremos un mayor control sobre la regulación del motor, los resultados obtenidos son las siguientes tablas:

TIEMPOS DE INYECCIÓN

En esta tabla podemos observas dos ejes, en el vertical aparecen las Revoluciones del motor desde 800 rpm hasta las 8800 y en el eje horizontal aparece la abertura de la Mariposa, nosotros siempre vamos a mariposa abierta (aunque esto se puede modificar), pero para controlar el lugar del mapa utilizamos un potenciómetro en el manillar que simula la apertura de nuestra mariposa.

Los tiempos de inyección son muy largos porque se inyecta etanol y se necesita compensar su falta de poder calorífico en comparación con el de la gasolina que es 2 veces mayor aproximadamente.

La DTA nos pedirá unos datos específicos del motor, entre ellos estos son los dientes que tiene la rueda fónica y los que le faltan, así como decir a cuantos dientes se encuentra el TDC (PUNTO MUERTO SUPERIOR) que es donde comienza el proceso de combustión.

Con los dientes que teníamos menos los grados de avance que pusimos en el mapa de ignición tratamos de que se ajustara a 27ºGrados, que es el punto ideal donde debe hacer la explosión de mezcla.

Las revoluciones a las que tiene que ir el motor durante la competición son a 5000 rpm que es cuando está en su punto óptimo.

Fuel Map Edit ms

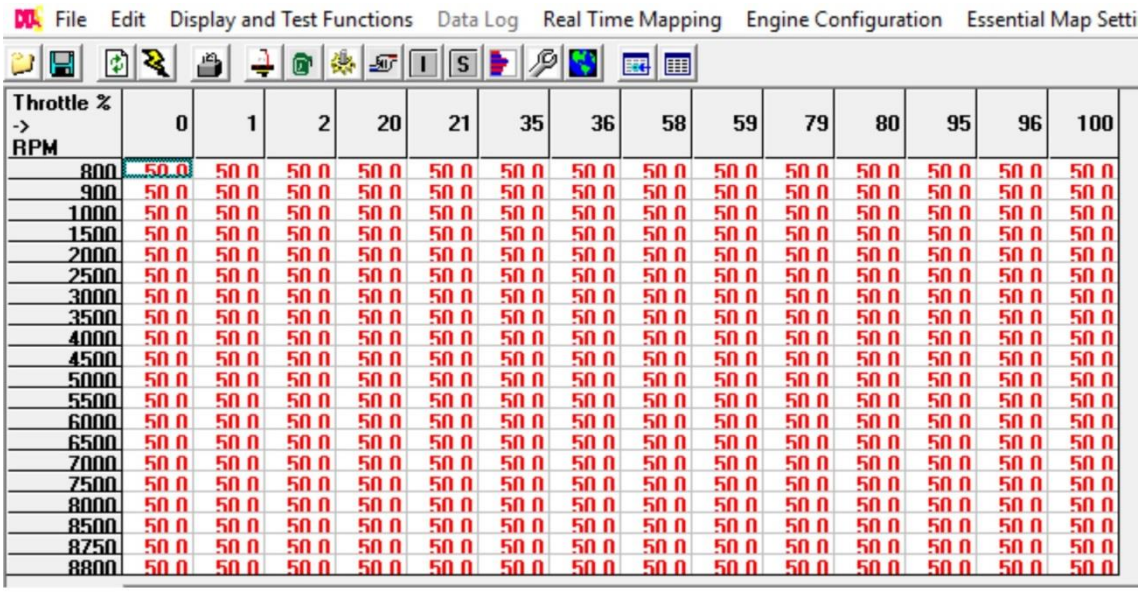
Throttle % -> RPM	0	1	2	20	21	35	36	58	59	79	80	95	96	100
800	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
900	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
1000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
1500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
2000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
2500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
3000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
3500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
4000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.00	15.00
4500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	14.60	14.60
5000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.50	15.50
5500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	15.50	15.50
6000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
6500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
7000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
7500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
8000	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
8500	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
8750	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00
8800	12.00	12.00	12.00	12.00	13.00	13.00	14.00	14.00	14.50	14.50	15.50	15.50	13.00	13.00

Graph

AVANCE DEL ENCENDIDO

La chispa tiene que ser siempre igual, o puede modificarse al inicio ya que hay técnicas de detonación en diferentes momentos para arrancar más rápido el motor ya que no siempre queda en la misma posición el pistón al apagarse.

La DTA nos dice que el avance está a 50, que significa que es el avance en grados de la chispa.



Throttle % -> RPM	0	1	2	20	21	35	36	58	59	79	80	95	96	100
800	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
900	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
1000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
1500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
2000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
2500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
3000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
3500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
4000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
4500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
5000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
5500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
6000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
6500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
7000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
7500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
8000	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
8500	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
8750	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
8800	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0

Capítulo 6: CONCLUSIONES

6.1 VENTAJAS DEL SISTEMA DE INYECCIÓN

Gracias al sistema de inyección conseguimos aumentar la eficiencia del motor, ya que está más tiempo arrancado con la misma cantidad de combustible.

6.2 VENTAJAS DE CAMBIAR EL PISTON

Al aumentar la relación de compresión en los motores de combustión interna, aumenta su eficiencia, por lo que utilizar un pistón que aumente la relación de compresión de nuestro motor a priori ya debería resultar ventajoso.

Las pruebas del motor sin modificar comparadas con las modificadas se observa una mejora en la reducción del consumo de combustible, que se traduce en un descenso del consumo de combustible, o en nuestro ensayo, en un aumento de la duración del tiempo de trabajo del motor utilizando el mismo volumen de combustible. Que es el objetivo de la competición Shell Eco-Marathon.

6.3 RESUMEN

La combinación del aumento de relación de compresión y la utilización del sistema de inyección conseguimos mejorar los resultados obtenidos en las pruebas.

El empleo de este motor puede resultar el medio con el que consigamos aumentar la marca del IDF16.

6.4 MEJORAS PENDIENTES

Este proyecto ha servido para comprobar el funcionamiento de las mejoras en el motor GX35 pero aún queda su acoplamiento en el vehículo y ver su comportamiento real en un circuito.

Capítulo 7: BIBLIOGRAFÍA

Honda Engines, "Manual técnico del producto GX25/35"

Robert Bosch GmbH, Bobina de encendido 0 986 221 023

Shell
www.shell.com/energy-and-innovation/shell-ecomarathon.html

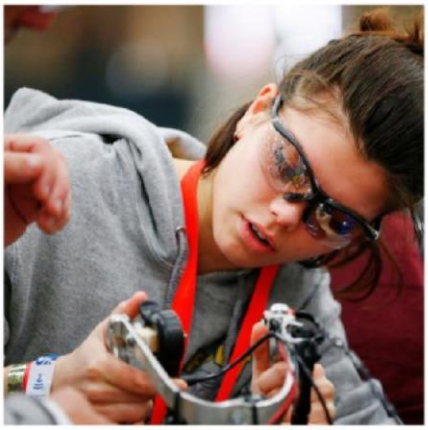
Motores de combustión interna alternativos
Payri González, Francisco

Capítulo 8: ANEXOS

Incluimos la normativa de la Shell Eco-Marathon

2016 Oficial Rules, Chapter 1

2016 Oficial rules, Chapter 2 no ha sido incluida ya que trata sobre los padocks, circuito, normas de convivencia, etc…



SHELL ECO-MARATHON

2016 OFFICIAL RULES

CHAPTER I

Shell
Eco-marathon

FOREWORD

Dear Shell Eco-marathon competitors, friends and enthusiasts, Welcome to Shell Eco-marathon!

I am pleased to announce the Shell Eco-marathon 2016 Global Rules, which continue to provide the foundation for one of the world's leading student engineering competitions.

Listening to many of your comments and suggestions during the past 12 months, my Tech Team colleagues and I have clarified many articles and added four brand-new Tech Tips which will help you to better understand these rules and their purpose.

In 2016, the Shell Eco-marathon Europe family will move to London, UK following four highly successful years in Rotterdam, the Netherlands. The capital of the UK will be our host for the next few years. Moreover, I am excited to announce that London will be the backdrop for our first Shell Eco-marathon World Championship, with selected teams from Europe, Asia and Americas. More information will be available soon.

This season will also mark the 10th edition of Shell Eco-marathon Americas, which will once again take place in Detroit, MI, USA. Over 100 teams are expected to take to the track on the iconic streets of the Motor City.

For the third year, Shell Eco-marathon Asia will take centre stage at Rizal Park in Manila, the Philippines. With the well-known set-up, I look forward to seeing competitors improve their previous results for ultimate performances on track.

It cannot be stressed enough that the success of Shell Eco-marathon is based on the creativity, ingenuity, hard work and dedication of its student participants. This spirit is at stake when overly enthusiastic and ambitious faculty staff, parents or professionals take over the project, rather than providing steer and advice only. I'd like to remind all participants that Shell Eco-marathon is an academic student engineering competition, aiming to inspire students and teach technical and non-technical skills. My team and I will strengthen our efforts to challenge participants on their design choices and test their knowledge on all functional parts of their vehicles. Faculty advisors will not be allowed to join this process. The Organisers reserve the right to withhold technical inspection approval for teams which show substantial knowledge gaps over the design of their vehicle and the functional principles of its component parts.

That being said, I wish all participants a successful and safe Shell Eco-marathon season and look forward to seeing you at one of our events in 2016.

Norman Koch

Shell Eco-marathon Global Technical Director

TABLE OF CONTENTS

1. ORGANISATION

ABOUT THE RULES

a) The full Rules for Shell Eco-marathon 2016 events in Asia, the Americas and Europe are comprised of the Shell Eco-marathon Official Rules 2016 Chapter I, hereinafter referred to as "Official Rules" (this document) and the specific Chapter II of the region where Shell Eco-marathon takes place, which can be downloaded from the 'For Participants' section of the Shell Eco-marathon website once available.

b) It is the responsibility of every participating team to ensure the full Rules are read and understood. In order to highlight rule changes and aid the understanding of frequently misunderstood rules several tools have been used in this document:

c) Text set in red indicates a change/addition/amendment to the previous year's Rules.

d) Text set in italic indicates a note or explanation of the rule above to aid its understanding.

e) Links are used throughout this document to improve navigation.

f) Hyperlinks to Tech Tips videos are used throughout this document to explain certain rules and illustrate acceptable and non-acceptable solutions.

g) In this document functions and roles are defined as follows:

h) 'Organisers' – the specific Shell company that organises the Shell Eco-marathon event in a particular region as named in Chapter II, and all persons acting on its behalf.

i) 'Team' – group of individuals with a team name and one vehicle that has been accepted for entry to the Shell Eco-marathon competition.

j) 'Participant' – member of a Team.

k) 'Team Manager' – a Participant that has been appointed on the event registration document as single focal point for his/her team towards the Organisers.

l) 'Faculty Advisor' – a professional staff member of the educational institute which the Team represents

m) 'Race Director' – person appointed by the Organisers, who is responsible to manage and sanction all on-track activities.

n) 'Track Marshall' – person appointed by the Race Director to act on his/her behalf, in particular to ensure on-track safety and observe on-track rule compliance.

o) 'Fuel Marshall' – person appointed by the Organisers, works as member of the technical team and supervises fuelling activities in line with the requirements of these rules.

p) 'Technical Director' – person appointed by the Organisers, who is responsible to ensure the technical standards and integrity of the Shell Eco-marathon competition.

Article 1: ACCEPTANCE

a) Applications to enter the competition must be made via the online registration tool on the Shell Eco-marathon website to the Organisers who will accept Teams based on the quality of the proposed entry. All decisions by the Organisers regarding the acceptance of Teams are final.

b) By fact of their entry, Participants accept all provisions of the Official Rules and agree to abide by all decisions made by the Organisers. The Organisers reserve the right to add, modify or delete any article of the Official Rules. In such an event, the Teams will be notified. The Organisers are solely empowered to pronounce on cases not provided for in the Official Rules.

c) The Organisers reserve the right to modify, postpone or cancel the competition for any reason including for reasons of force majeure due to, including but not limited to, adverse or extreme weather conditions, the occurrence of a natural disaster, acts of terrorism or safety concerns. No claims for compensation will be accepted.

d) The Participant is aware that photo, audio and video recordings will be made of the event. By entering the Shell Eco-marathon, the Participant permanently relinquishes all rights in respect of these photos, audio and video recordings, which are made by third parties, the Organisers and its affiliates. Shell companies may use said photos, audio and video material for internal and external communications and own presentations (including but not limited to promotions, advertising, internet presence, TV and radio reports and press reports).

Article 2: ENTRIES

a) For each entry, a Team Manager, a Driver and a Faculty Advisor must be designated. A Reserve Driver may also be designated.

b) The Team Manager must be a student member of the team currently enrolled at the institution. In case all team members are legal minors, the Faculty Advisor has to act as Team Manager.

c) The Team Manager can only be responsible for one vehicle. He/she may also be a Driver for that vehicle, but only for that vehicle.

d) The Team Manager is the Team's sole official liaison with the Organisers. All information will be addressed to him/her. For the purposes of the project, he/she will be responsible for the Team, must speak on behalf of the Team and must be able to understand and speak English.

e) The eligibility criteria for Drivers are detailed in the relevant section of Chapter II. The Driver and Reserve Driver must be students of the educational institution in question. The Driver and the Reserve Driver for one vehicle cannot be the Driver or Reserve Driver for another vehicle. Both must be able to speak and understand English.

f) Each interested Team must apply to compete in the regional Shell Eco-marathon event closest to their home country. Attendance at another Shell Eco-marathon event outside its home region is subject to decision of the relevant regional organising committee.

Article 3: TRACK ACCESS CONDITIONS

During both the practice runs and the competition, all vehicles must comply with the technical and safety rules of the event. Whenever the track is entered, the vehicle body must be in place and bear all the competition numbers, sponsor stickers and Shell logos required by the Official Rules.
Organisers will supply these numbers and logos.

Article 4: IDENTIFICATION

a) Logos, official sponsor stickers and racing numbers must be fixed to the vehicle body in accordance with the diagram provided (see Chapter II) such that they can be clearly read during any public presentation, in promotional films and on all photographs.

b) Under no circumstances may the Shell logos, the sponsor stickers or racing numbers be modified, either on the vehicle or on any other documentation. It is prohibited to cut the stickers supplied by the Organisers. Their dimensions are as follows:

i. For each side and for the front of the vehicle: a Shell logo, 20 x 21.5 cm. ii. For each side and for the front of the vehicle: racing numbers, 20 x 26 cm.

iii. For each side, on the lower part of the body: a sponsor sticker, 77 x 8 cm.

c) A mandatory 10 cm space must be left free on all four sides of the Shell logo.

d) Any other sponsor names/logos must be smaller than the Shell logo. Each sponsor sticker must fit within a maximum area of 400 cm^2 (empty space included).

e) The trademarks or logos of tobacco companies and alcoholic drinks producers are prohibited. Trademarks and logos of other energy companies and direct competitors to event sponsors require the prior written approval of the Organisers. This rule applies to all vehicles and all team members' apparel.

f) In the event of a breach of this rule, the Organisers reserve the right to remove any sponsor logos.

g) All vehicles are subject to the Organisers approval concerning these provisions.

Article 5: COMPLIANCE

a) Only those vehicles that comply with the present Official Rules are allowed to participate. No vehicle will be allowed on the track for practice or competition until the Organisers have approved it. The decisions of the Organisers are final in all matters concerning the compliance of vehicle design and construction with the present Official Rules.

b) The Organisers reserve the right to rescind vehicle approval upon further or more detailed checks. The Organisers must be notified of any modifications to the vehicle after inspection. Non-compliance with this rule will lead to vehicle disqualification.

c) Vehicles complying with all safety rules but not with some of the other technical rules will not qualify for the competition, however may be allowed on the track for practice or demonstration at the discretion of the Technical Director.

Article 6: PROTESTS

The Team Manager is the only person authorised to lodge protests. Protests must be brought to the attention of the Technical Director via the results desk. Depending on the nature protests must be lodged within the following times:

a) Vehicles: before track closure on the current day

b) Team and Driver behaviour: within 30 minutes following the end of the attempt.

c) Results: within 1 hour after the result of an attempt has been posted.

Article 7: DISPUTES

In the event of any disputes, all decisions made by the Race Director are binding and final.

Article 8: PENALTIES

a) Non-compliance with the driving rules will result in a formal warning, invalidation of the best overall attempt or disqualification of the Team, depending on the severity of the breach.

b) The Organisers will exclude, disqualify or otherwise penalise any Participant who, in the judgement of the Race Director, has gained an unfair advantage as a result of any breach of these Official Rules, hindrance of other Participants, departure from the normal course, or any act or omission capable of misrepresenting performance, especially with regard to fuel consumption or method of propulsion.

c) During the competition, the Driver or the Team Manager must report to the Organisers any movement made or attempted by means other than the vehicle's own motive power. In such an event, the attempt in question will not be taken into account. If this type of incident is not reported, all the Team's attempts will be invalidated.

d) The Organisers will apply the following penalties:

1st infraction: Formal warning

2nd infraction: Best overall attempt invalidated at the end of the competition 3rd infraction: Immediate Team disqualification.

2. SAFETY

Article 9: SAFETY RULES

a) As with any Motorsport activity there should be an understanding that certain inherent risks will be present. Recognising and controlling these risks are vital for the well-being of people and local surroundings. Safety is an essential consideration for the Organisers. These Rules are to protect all individuals and surrounding areas and are in no way intended to curtail the spirit of the competition. Any activity deemed unsafe or outside of the spirit of the event will be met with appropriate action by the event Organisers.

b) Therefore, compliance with safe driving and sporting rules, as well as any instructions given by Track Marshals is mandatory for everyone. All Participants must comply with the safety measures and must notify Organisers about any anomalies or incidents. In the event that dangerous conditions are present leave the area immediately. During the event the paddock area will be monitored by the Organisers to assist Teams to comply with safe practices.

c) The Race Director is responsible for and has the final authority in determining the safe conditions for track operations in regards to weather.

d) Non-compliance with any of these Rules may lead to disqualification from the competition at the sole and absolute discretion of the Organisers.

DRIVING RULES

Article 10: DRIVING KNOWLEDGE AND TEST

a) Only the registered Driver and the Reserve Driver will be authorised to drive the vehicle.

b) Drivers may be questioned about their knowledge of the driving rules during inspection. The Organisers reserve the right to deny track access to Drivers with insufficient knowledge of the Rules.

c) Driving on-track: In the interest of safety it is important that Drivers learn and apply smooth and predictable driving techniques, e.g. thinking well ahead, avoiding sudden directional changes, and being fully aware of other vehicles around them.

Article 11: DRIVING UNDER THE INFLUENCE OF ALCOHOL/ILLEGAL SUBSTANCES

a) Driving under the influence of any alcohol and or illegal substance(s) is forbidden. This applies to all Drivers and Reserve Drivers entering the track.

b) Procedures for alcohol or substance testing are detailed in Chapter II.

c) Any breach will be penalized in line with Article 8: and the following additional penalties:

   i. Any alcohol and/or substance related breach of the rules will be treated at least as '2nd infraction' of the Team, even if no prior violation has occurred.

ii. In addition, the affected Driver is immediately banned from track access as long as he/she is under the Influence. A Reserve Driver may substitute the Driver if he/she is eligible to drive.

iii. Any second alcohol and/or substance related infraction will lead to the immediate disqualification of the entire Team.

Article 12: BRIEFING

The attendance of the daily Drivers' Briefing is mandatory for the Team Manager and all registered Drivers every day. Failure in attending these Briefings by the Team Managers and Drivers will disqualify the team from practicing and/or competing that day.

Article 13: ACCESS TO THE TRACK AND TEST LAP

a) Vehicles must pass a safety inspection prior to accessing the track for practice runs. A safety sticker will be clearly affixed once the vehicle has passed the inspection.

b) For practice runs on both, the test track and the competition track, only vehicles with a safety sticker will be allowed on the track.

c) For the competition, only vehicles with safety and technical inspection stickers will be allowed to compete.

d) The Organisers will allow opportunity for Team Managers and Drivers to inspect the track, i.e. before any vehicles are allowed on the track. For further details please refer to Chapter II.

e) After pre-start measurements have been completed, teams must be ready to start their attempt within two minutes or return to the paddock.

Article 14: PUSHING THE VEHICLE

At no time on the race track are drivers allowed to push their vehicle or have it pushed, including to start the run or to cross the finish line

Article 15: RACE DIRECTION

It is forbidden to drive in reverse gear or to drive against the race direction.

Article 16: RADIO COMMUNICATION

The use of hand-held communications is forbidden in the vehicle. However, the use of a "hands-free" kit is allowed as long as both hands of the driver remain on the steering system.

Article 17: OVERTAKING

Drivers are required to give clear passage for other vehicles wishing to overtake.

a) Drivers in overtaking vehicles must sound their horn and pass with caution. The Driver of the overtaking vehicle is responsible for the safety of the manoeuvre.

b) Drivers of the vehicles being overtaken must use their mirrors and must not change course suddenly.

c) On the track, overtaking is authorised on both the right and the left, as long as the abovementioned safety rules are followed.

Article 18: BREAKDOWNS AND OTHER INCIDENTS

a) Intentional stopping on the track is forbidden unless it is required by the competition, e.g. for UrbanConcept vehicles.

b) The Driver is allowed 30 seconds to attempt to re-start the vehicle from within its driving position.

c) If a vehicle breaks down or is involved in a minor disabling accident on the track, the Driver must immediately make every attempt to drive the vehicle to the side of the track and wait in the vehicle for the Track Marshalls to arrive.

d) In an emergency, the Driver must get out of the car and wait in a safe place off the track for the Track Marshalls to arrive and recover him/her and the vehicle.

e) It is forbidden to carry out repairs on the track. In the event of a flat tyre, even when near the starting line, a new start will not be granted for the attempt in question.

Article 19: OFF-TRACK VEHICLE MOVEMENTS

a) All vehicles must be parked inside the designated paddock area or directly in front of it. When off the track, vehicles must be moved without the use of the engine. They must be pushed or pulled. Test-driving in the paddock area is forbidden.

b) Track Marshals will notify the Race Director of any breaches and any unsafe or unfair behaviour.

DRIVER & EQUIPMENT

Article 20: DRIVER WEIGHT

a) The minimum Driver Weight is: Prototype vehicles – 50 kg
UrbanConcept vehicles – 70 kg

b) The Driver Weight is defined as the weight of the person driving the vehicle including full driving gear and communication devices. If the Driver Weight does not meet the minimum weight requirement ballast needs to be fitted to the vehicle. This ballast must be provided by the Team, in form of scuba diving weights or rectangular metal plates. No other form of ballast is permitted. Any ballast must be effectively secured to the vehicle chassis to ensure Driver safety in the event of collision or roll-over, and it must be easily detachable for weighing.

c) Drivers (in full driving gear, including communication devices) and their ballast may be weighed before or after each attempt. A weight loss of up to 1 kg during an attempt will be tolerated.

Article 21: HELMETS

a) For practice and competition, Drivers must wear full-face or three quarter helmets suitable for motorsport activities. Bicycle/riding/skating type helmets are not permitted. Helmet labels must be clearly readable. Helmets worn by all Drivers will be subject to inspection.

b) All helmets must be affixed with a face shield (or visor). The face shield (or visor) must cover all of the face down to the chin. Tinted face shields or sun glasses to be worn under the face shield are permitted. The helmets must correctly fit the Driver and be secured by a chin strap.

Article 22: DRIVER CLOTHING

a) All Drivers must wear a racing suit as the outermost layer of clothing (fire retardant). Casual clothing and street wear are not permitted. Wearing synthetic clothes or underwear is strictly forbidden for Drivers when seated in their vehicle.

b) Gloves (covering all fingers fully) and shoes are required and must be provided by the team; bare feet or socks only are prohibited.

Article 23: DRIVER COMFORT

Please note that in the event of hot weather conditions high temperatures could be attained inside the vehicle, potentially affecting Driver comfort and/or causing heat stress.

a) It is recommended to properly ventilate the inside of the vehicle to provide cooling to the Driver.

b) It is recommended to provide sufficient drinking liquids to the driver for the duration of an attempt. If fluid containers are provided to the driver(s), these containers must be hands free, e.g. camelback style or bottles secured inside the driver's compartment with flexible feed straw.

c) It is recommended to equip the vehicle with an effective sunscreen.

d) The Organisers reserve the right to restrict individual driving time by any means at their sole discretion, e.g. shortening the distance, requesting driver change (pit stop), limit maximum number of attempts per driver per day, etc.

TEAM SAFETY EQUIPMENT

Article 24: EQUIPMENT AND MATERIALS

Teams are required to provide and use the following at the event: a)

Gloves for general work: leather or canvas material.

b) Gloves for fuel or motor oil handling: Chemical resistant.

c) Safety glasses for all Team members. (Disposable types are permitted).

d) Hearing protection for all Team members. (Approved Earplugs or muffs).

e) Duct tape to secure any cords or cables lying on the pit floor.

f) Lift stands or appropriate raised platform for vehicle tuning and repairs.

g) Own tools and materials.

h) Each Team must provide an extinguisher for their pit area with a minimum extinguishing capacity of 1 kg in addition to the vehicle's extinguisher suitable for "ABC" class of fires. The extinguisher must be accessible in the Team's specific pit area. The extinguisher must be full (i.e. never used) and have a manufacturing or expiry date. If the extinguisher does not have an expiry date the unit will be acceptable (i.e. valid) if it was manufactured within the past three years. Any extinguisher beyond the expiry period that has been re-inspected and tagged with an official dated recertification will also be permitted.

i) Effective equipment suitable to mitigate and/or control Lithium-based battery fires must be used during battery charging whether the battery is charged in or outside of the vehicle. The equipment

must prevent or contain the spread of any fire or battery event during charging. Equipment that may be used includes:

j) A battery charging bag that is designed for containment of a Lithium battery fire, or

k) A fire proof blanket that can be placed over AND under the battery being charged. The blanket must be of sufficient size to fully cover and contain any potential fire or battery event.

ATTENTION

Review all sections of the Official Rules as they contain further safety matters specific to the topic.

3. VEHICLE DESIGN

3A – GENERAL

Article 25: VEHICLE DESIGN

a) During vehicle design, construction and competition planning, participating Teams must pay particular attention to all aspects of safety, i.e. Driver safety, the safety of other Team members and spectator safety.

   i. Prototype vehicles must have three or four running wheels, which under normal running conditions must be all in continuous contact with the road.

   ii. UrbanConcept vehicles must have exactly four wheels, which under normal running conditions must be all in continuous contact with the road. A fifth wheel for any purpose is forbidden.

b) Aerodynamic appendages, which adjust or are prone to changing shape due to wind whilst the vehicle is in motion, are forbidden.

c) Vehicle bodies must not include any external appendages that might be dangerous to other Team members; e.g. pointed part of the vehicle body. Any sharp points must have a radius of 5 cm or greater, alternatively they should be made of foam or similar deformable material.

d) Vehicle body panels must be rigid with an appropriate stiffness not to be prone to changing shape due to wind.

e) The vehicle interior must not contain any objects that might injure the Driver during a collision.

f) Windows must not be made of any material which may shatter into sharp shards. Recommended material: Polycarbonate (e.g. Lexan)

g) Any cover of the energy compartment (engine/motor/transmission/battery, etc.) should be easy to open for quick inspection access.

h) All parts of the drive train, including fuel tank, hydrogen system components, etc. must be within the confines of the body cover.

i) All objects in the vehicle must be securely mounted. Bungee cords or other elastic material are not permitted for securing heavy objects like batteries.

j) All vehicles must have a solid floor and frame that prevents any part of the driver's body from contacting the ground.

k) All vehicles (including Prototypes) must be fully covered. Open top vehicles are not allowed. Vehicles that look like bicycles, tricycles or wheelchairs are not acceptable.

l) The Organisers may provide any team with telemetry equipment and request them to install it in their vehicle for the purpose of competition monitoring and result calculation. In this case the main housing of the telemetry equipment will need to be installed inside the vehicle and the team must provide a hole in the body of the vehicle of no more than15 mm for the passage of cables to one or more outside antennae which will need to be attached outside on top of the vehicle.

Teams will be informed during technical inspection if such an installation is required and receive further installation guidelines. To ensure competitive fairness all teams in a particular energy class and vehicle category will have to install identical equipment.

Article 26: CHASSIS/MONOCOQUE SOLIDITY

a) Teams must ensure that the vehicle chassis or monocoque is designed wide and long enough to effectively protect the driver's body in the case of collisions or rollovers. The Organizers will exclude any vehicle whose construction is deemed to be dangerous.

> A monocoque is a construction that supports structural load by using an object's external skin as opposed to using a frame.

b) The vehicle chassis must be equipped with an effective roll bar that extends 5 cm around the driver's helmet when seated in normal driving position with the safety belts fastened.

> If this position impairs the driver visibility it will be deemed that the roll bar is not adequate. The effectiveness of the roll bar and driver's visibility will be validated simultaneously, i.e. the driver must not be in such position that he or she must raise their head or torso above the roll bar to pass the visibility test.

c) This roll bar must extend in width beyond the driver's shoulders when seated in normal driving position with the safety belts fastened.

> It is permissible to either use a tubular or panel type roll bar. If a 'tubular roll bar' is used, it must be made of metal. A panel roll bar is the rigid partition separating the cockpit from the engine compartment. Such a panel roll bar must be an integral part of the vehicle chassis or integrated in a monocoque.

d) Any roll bar must be capable of withstanding a static load of 700 N (~ 70 kg) applied in a vertical, horizontal or perpendicular direction, without deforming (i.e. in any direction).

Article 27: PROPULSION AND ENERGY STORAGE SYSTEM ISOLATION

a) A permanent and rigid Bulkhead must completely separate the vehicle's propulsion and energy storage systems from the driver's compartment.

> This means engines, fuel cells, fuel tanks, batteries (both propulsion and auxiliary), hydrogen cylinders, Super Capacitors, etc. must be placed outside the driver's compartment behind the bulk head. The purpose of this bulkhead is that in the event of a fuel leak or fire, it prevents liquids and/or flames and/or smoke reaching the driver. Pay particular attention to avoid any gaps and holes between the body and the bulk head. It is recommended to seal gaps with materials such as metal/aluminium sheeting or aluminium tape.

b) This bulkhead must be of fire retardant material and construction.

c) The bulkhead must effectively seal the driver's compartment from the propulsion and fuel system.

d) The bulkhead must prevent manual access to the engine/energy compartment by the driver.

e) If holes are made in the bulkhead to pass through wires, cables, etc. it is essential that the wires/cables are protected by a grommet or similar protective material to prevent chafing or damage. All gaps/holes must also be filled.

Article 28: VISIBILITY

a) The Driver must have access to a direct arc of visibility ahead and to 90° on each side of the longitudinal axis of the vehicle. This field of vision must be achieved without aid of any optical (or electronic) devices such as mirrors, prisms, periscopes, etc. Movement of the Driver's head within the confines of the vehicle body to achieve a complete arc of vision is allowed.

The driver's helmet must be 5 cm below the roll bar at all times.

b) The vehicle must be equipped with a rear-view mirror on each side of the vehicle, each with a minimum surface area of 25 cm² (e.g. 5 cm x 5 cm). The visibility provided by these mirrors, and their proper attachment, will be subject to inspection. An electronic device must not replace a rear-view mirror.

c) In technical inspection visibility will be checked in order to assess on-track safety by using 60 cm high poles spread out every 30° in a half-circle, with a 4 m radius in front of the vehicle.

d) For UrbanConcept vehicles wet weather visibility is also mandatory (see Article 52:).

Article 29: SAFETY BELTS

a) The Driver's seat must be fitted with an effective safety harness having at least five mounting points to maintain the Driver securely in his/her seat. The five independent belts must be firmly attached to the vehicle's main structure and be fitted into a single buckle, specifically designed for this purpose. The mounting points should be fitted so that the belts will self-align with the direction of the load.

b) The safety harness must prevent any upward or forward motion of the driver's torso. Any slack in the harness must be adjusted by using the seat belt length adjuster. The adjustor must be located as close as possible to the connection point. The crotch strap mounting point should be behind the chest line and the topmost straps should be at an angle of at least10° below the shoulder line.

c) The safety harness must be worn and fastened at all times to prevent the driver from having any free movement when the vehicle is in motion.

d) The fitness for purpose of the harness and its fitting will be evaluated during technical inspection. For Prototype cars this will be done by raising the vehicle with the Driver on board using the safety harness buckle as the lifting point, this must be capable of withstanding 1.5 times the Driver's weight.

e) The Urban Concept vehicle safety harness must be specifically manufactured for motorsport use (e.g. certified or compliant with FIA standards).

Article 30: VEHICLE ACCESS

a) It is imperative for Drivers, fully harnessed, to be able to vacate their vehicles at any time without assistance in less than 10 seconds.

b) Prototype vehicles must be equipped with a sufficiently large opening for the cockpit. The driving position must be designed so that emergency services can easily extract the Driver from his/her vehicle, if necessary.

c) For Prototype vehicles, the said opening may be enclosed wholly or partly by means of hinged, detachable and/or folding doors, provided that a release mechanism is easily operable from inside and that the method of opening from the outside is clearly marked by a red arrow and does not require any tools.

d) For UrbanConcept vehicles, the opening release mechanism must be easily and intuitively operable from the inside and the outside of the vehicle. The method of opening from the outside must be clearly marked by a red arrow and must not require any tools.

e) It is forbidden to use adhesive tape to securely close the Driver's opening from the outside.

Article 31: HORN

a) Each vehicle must be equipped with an electric horn mounted towards the front of the vehicle, in such a manner that is effectively audible to other vehicles and track marshals. With the vehicle in normal running condition, it must emit a sound greater than 85 dBA when measured 4 meters horizontally from the vehicle.

b) The horn must have a high tone (pitch) of equal or greater than 420 Hz.

Article 32: ON-BOARD FIRE EXTINGUISHER

a) Each vehicle must be fitted with a fire extinguisher (ABC or BC type). All Drivers must be trained in the use of said fire extinguisher. This extinguisher must have a minimum extinguishant capacity of 1 kg (2 lb for US application); equivalent size extinguishers are not permitted. The extinguisher must be full (i.e. never used) and have a manufacturing or expiry date. If the extinguisher does not have an expiry date the unit will be acceptable (i.e. valid) if it was manufactured within the past three years. Any extinguisher beyond the expiry period that has been re-inspected and tagged with an official dated recertification will also be permitted.

b) Plumbed-in extinguishers may be located in the engine compartment and must discharge into the engine compartment. Triggering systems must be located within the cockpit and be operable by the Driver in his/her normal driving position.

c) Hand held extinguishers must be located within the cockpit and be accessible to the Driver once they have vacated the vehicle. These should be securely mounted to prevent movement while driving/braking. In the event of a fire, Drivers should first exit the vehicle and then if possible, remove the extinguisher and attempt to extinguish the fire if safe to do so.

d) The on-board fire extinguisher does not replace the need for an adequate fire extinguisher for the team's garage area.

Article 33: DRIVER POSITION

For safety reasons, the head-first driving position is prohibited. The driver position should be such that the helmet is 5 cm below the roll bar AND that the visibility for the driver is unimpaired at the same time.

Article 34: CLUTCH AND TRANSMISSION

a) All vehicle propulsion must be achieved only through the friction between the wheels and the road.

b) All vehicles with internal combustion engines must be equipped with a clutch system.

c) For centrifugal/automatic clutches the starter motor speed must always be below the engagement speed of the clutch.

d) For UrbanConcept only: The vehicle must have 'idling capabilities', i.e. the vehicle must remain stationary with the engine running.

e) For manual clutches the starter motor must not be operable with the clutch engaged. An interlock is required to facilitate this functionality.

f) Please refer to Article 64: regarding starter motor requirements.

g) The installation of effective transmission chain or belt guard(s) is mandatory.

This is required to protect driver or technician when working on the car in the event of the chain or belt breaking. It must be made of metal or composite material rigid enough to withstand a break.

Article 35: EXHAUST SYSTEM

a) The exhaust gases must be evacuated outside the vehicle body.

b) Exhaust pipes must not extend beyond the rear or the side of the vehicle body.

c) All vehicles are expected to comply with reasonable environmental standards, e.g. amount of smoke and odour emitted.

Article 36: SOUND LEVEL

a) The sound level of the vehicle must not exceed 90 dBA when measured 4 metres away from the vehicle.

Maximum sound levels will be measured and recorded at the start line and teams exceeding the permissible level will be notified with a request for correction within a reasonable timeframe.

Article 37: EMERGENCY SHUT-DOWN

a) The purpose of the emergency shutdown system is to disable the propulsion system of the vehicle. Different types of propulsion systems require different measures to accomplish this:

b) Spark ignition engines (gasoline, ethanol, CNG) will require the emergency shutdown mechanism to shut down the ignition. It is not necessary to isolate the accessory battery. In addition, for CNG powered vehicles the emergency shut-down system must also cut off the flow of gas.

c) Compression ignition engines (diesel, GTL) will require the emergency shutdown mechanism to shut off the fuel or air flow. It is not necessary to isolate the accessory battery.

d) For Battery Electric vehicles the emergency shutdown mechanism must provide a physical isolation of the propulsion battery from the vehicle electrical system. If relays are used, the relays must be a normally open contact type. The use of a power controller or other logic systems to drive an isolation device is not permitted.

e) For Hydrogen vehicles see e).

f) There must be both an internal and an external shutdown mechanism.

   i. The internal emergency shutdown mechanism is for driver operation and can be designed in any effective way.

   ii. The external emergency shutdown mechanism must be at the rear of the vehicle and permanently installed on a non-detachable part of the bodywork.

   iii. A red arrow (on a white background) at least 10 cm long and 3 cm wide at the widest point must be positioned on the vehicle body to indicate clearly the exterior position of the emergency shutdown actuator.

g) The following external emergency shutdown mechanisms must be used for the following propulsion energy types:

   i. Compression ignition engines (diesel, GTL) – latching red push button or push/pull red lever ii.

   All other propulsion energy types – latching red push button

h) In addition to the above devices, all vehicles must be equipped with a "dead man's safety device" or sometimes referred to as "operator presence control." The purpose for this device is to ensure that in case the driver becomes incapacitated the vehicle's propulsion power is automatically disengaged (i.e. returns to an idle condition). This device may consist of a spring loaded hand operated accelerator or foot pedal lever. An electric dead man switch is permissible as long as the switch is located on the steering wheel. If an electric dead-man switch is used the driver must directly (for example by thumb or index finger) engage the switch at all times while driving.

   i. This device is a separate switch from the required "emergency shut-down" mechanisms identified in section (c).

   ii. If an ICE Prototype vehicle is designed with a WOT (wide open throttle) operation the deadman switch must switch off the ignition system.

Article 38: ADDITIONAL INSPECTIONS

a) After passing technical inspection, the replacement and/or alteration of the engine, any vehicle wiring, or any other vehicle part must be re-approved by the Organisers.

b) After any significant incident to the vehicle, it must be re-inspected.

c) At any time, the Organisers may perform unannounced inspections on the vehicles.

3B – PROTOTYPE GROUP

Article 39: DIMENSIONS

a) The vehicle maximum height must be less than 100 cm.

b) The vehicle track width must be at least 50 cm, measured between the midpoints where the tyres of the outermost wheels touch the ground.

c) The ratio of maximum height divided by track width must be less than 1.25.

d) The vehicle wheelbase must be at least 100 cm.

e) The maximum total vehicle width must not exceed 130 cm.

f) The maximum total length must not exceed 350 cm.

g) The maximum vehicle weight, without the Driver is 140 kg.

h) None of the body dimensions above must be achieved by design singularities such as 'stuck-on' appendages or cut-outs.

Article 40: NOT USED

Article 41: TIRES, WHEELS, AXLES AND WHEEL HUBS

a) All types of tires and wheels are allowed.

b) Any type of wheel rim may be used. Rims must be compatible with the dimensions of the selected tires in order to satisfy safety standards.

Teams must take into account the fact that bicycle wheels are not generally designed to support substantial lateral cornering forces, such as may be found in Shell Eco-marathon vehicles at certain speeds.

The wheel axles must be designed for cantilever loads (like in wheel chairs) rather than for load distributed equally on both sides (like in bicycles).

c) Wheels located inside the vehicle body must be isolated from the Driver by a bulkhead.

d) Any handling or manipulation of wheels by the Driver is forbidden from the moment the vehicle is at the starting line until it crosses the finish line.

e) All installations must be carried out in a way that there is no likelihood of the wheels coming into contact with other parts of the vehicle (i.e. cables, wires, hoses, and engine compartment components like batteries, etc.). These must be safely mounted/secured so that they cannot interfere with the turning wheel during driving and cause accidents.

Article 42: TURNING RADIUS AND STEERING

a) Only front wheel steering is permitted. If the Organisers are not satisfied with the effectiveness and/or control of a vehicles steering system, this vehicle will be removed from the competition.

b) The turning radius must be 8 m or less. The turning radius is the distance between the centre of the circle and the external wheel of the vehicle. The external wheel of the vehicle must be able to follow a 90° arc of 8 m radius in both directions.

c) Electrically operated indirect steering systems are permitted providing they are operated by a steering wheel or similar (rotary potentiometer), joystick operation is not permitted. When electronic steering systems are used, then in event of release of the steering wheel by the driver or electrical failure, the vehicle should revert to the straight ahead position.

d) A vehicle handling course may be set up in order to verify the following when the vehicle is in motion: driver skills, turning radius and steering precision. In particular, the Organisers will verify that steering is precise, with no excessive play.

Article 43: BRAKING

a) Vehicles must be equipped with two independently activated brakes or braking systems; each system comprising of a single command control (lever(s) working together or foot pedal), command transmission (cables or hoses) and activators (callipers or shoes).

b) One system has to act on all front wheel(s), the other on all rear wheel(s). When braking on two steering wheels at the front, two activators (callipers or shoes) have to be used (one on each wheel), commanded by only one command control. In addition, the right and left brakes must be properly balanced.

c) The rear system must work on each wheel, unless they are connected by a common shaft in which case they can have a single system.

d) It must be possible to activate the two systems at the same time without taking either hand off the steering system. Foot control is recommended.

e) The effectiveness of the braking systems will be tested during vehicle inspection. The vehicle will be placed on an incline with a 20 percent slope with the driver inside. The brakes will be activated each in turn. Each system alone must keep the vehicle immobile.

f) During practice or competition runs the brakes must be protected against any adjustments by the driver. The effectiveness of the protection to ensure compliance will be evaluated during technical inspection and rechecked before entering the track. In addition, vehicles will be checked at the finish area. Any protection system that has been compromised will invalidate that run and a penalty may be issued by the Organisers.

g) The use of a hydraulically controlled braking system is highly recommended.

Cable operated systems are allowed as long as they are effective and pass the brake test.

3C – URBANCONCEPT GROUP

Article 44: DEFINITION

Under the name “UrbanConcept”, Shell offers an opportunity to design and build energy efficient vehicles that are closer in appearance to today’s production type passenger cars. UrbanConcept vehicles must comply with the specific rule of the Shell Eco-marathon for this group. One particular feature of this group is that vehicles competing in this group will require “stop & go” driving.

During all practice and competition driving at Shell Eco-marathon events only one person (the Driver) is allowed inside UrbanConcept vehicles, regardless of the number of seats installed.

Article 45: DIMENSIONS

a) The total vehicle height must be between 100 cm and 130 cm.

b) The total body width, excluding rear view mirrors, must be between 120 cm and 130 cm.

c) The total vehicle length must be between 220 cm and 350 cm.

d) The track width must be at least 100 cm for the front axle and 80 cm for the rear axle, measured between the midpoints where the tyres touch the ground.

e) The wheelbase must be at least 120 cm.

f) The Driver's compartment must have a minimum height of 88 cm and a minimum width of 70 cm at the Driver's shoulders.

g) The ground clearance must be at least 10 cm with the driver (and necessary ballast) in the vehicle.

h) The maximum vehicle weight (excluding the Driver) is 225 kg.

i) None of the body dimensions above must be achieved by design singularities such as 'stuck-on' appendages or cut-outs.

Article 46: VEHICLE BODY

a) Teams are requested to submit technical drawings, photographs or animations of their entire vehicle design to the Organisers for approval at their earliest opportunity.

This is strongly recommended to avoid upsets by failing the technical inspection at the event on grounds of design non-compliance.

b) The body must cover all mechanical parts whether the vehicle is viewed from the front, the rear, the sides or from above. However, the wheels and suspension must be fully covered by the body when seen from above and up to the axle centre line when seen from front or rear. The covering for the wheels and suspension must be a rigid integral part of the vehicle body.

c) It is prohibited to use any commercially available vehicle body parts.

d) Access to the vehicle by the Driver must be as easy and practical as typically found in common production type passenger cars. The "door" opening must have a minimum dimension of 500 x 800 mm. This means a rectangular template of this dimension must be able to pass through the door opening in the vertical plane.

e) Any access opening mechanisms (e.g. doors) must be firmly attached to the vehicle body (e.g. by means of hinges, sliding rails, etc.). Adhesive tape, Velcro, etc. are not permitted for this purpose.

f) The vehicle must have a roof covering the Driver's compartment.

g) A windscreen with effective wiper(s) is mandatory. Please refer to Article 52:.

h) Luggage space must be available for a rectangular solid box with dimensions of 500 x 400 x 200 mm (L x H x W). This space must be easily accessible from the outside and must include a floor and sidewalls to hold the luggage in place when the vehicle is moving. The luggage must be supplied by the Participant and must be placed in this space during the competition.

i) Vehicle bodies must not include any external appendages that might be dangerous to other Team members; e.g. sharp points must have a radius of 5 cm or greater, alternatively they should be made of foam or similar deformable material.

j) A towing hook or ring is mandatory at the front of the vehicle. It can be rigid or flexible (cable or strap). If it is rigid, it must be placed fully under the body for safety reasons. Alternatively, it may be retractable or removable as in a regular car but should be easily accessible. It must be used to tow the vehicle in case of breakdown on the track. It must have a traction resistance equivalent to the weight of the vehicle and have an opening width of at least 3 cm.

Article 47: TURNING RADIUS AND STEERING

a) Vehicle steering must be achieved by one system operated with both hands using a turning motion. It must be precise, with no play or delay.

b) Steering must be achieved using a steering wheel or sections of a wheel with a diameter of not less than 25cm.

c) Steering bars, tillers, joysticks, indirect or electric systems are not permitted.

d) The turning radius must be 6 m or less. The turning radius is the distance between the centre of the circle and the external wheel of the vehicle. The external wheel of the vehicle must be able to follow a 90° arc of 6 m radius in both directions.

e) A vehicle handling course may be set up in order to verify the following when the vehicle is in motion: driver skills, turning radius and steering precision. In particular, the Organisers will verify that steering is precise, with no excessive play.

Article 48: WHEELS

a) The rims must be between 15 to 17 inches in diameter.

b) The wheels located inside the vehicle body must be made inaccessible to the Driver by a bulkhead. Any handling or manipulation of the wheels is forbidden from the moment the vehicle arrives at the starting line until it crosses the finish line.

Article 49: TYRES

The choice of tyres is free as long as they are fitted on the type and size of rims recommended by their manufacturers and have a minimum tread of 1.6 mm. The tyre/rim assembly must have a minimum width of 80 mm, measured from tire sidewall to tire sidewall. The width is measured with the tyre fitted on its rim at its rated pressure.

Caution:

- The manufacturer's size indications should not be taken as measure, as the width of the rim directly impacts the width of the rim/tyre assembly.

- It is strongly recommended to use flat profile tyres designed for four wheels vehicles or light trailers, not round/triangular profile tyres used for mopeds or motorbikes.
- It may be necessary to use a 90 mm tire to achieve the above-mentioned measure.

Article 50: LIGHTING

The vehicle must have a functional external lighting system, including: a)

Two front headlights

b) Two front turn indicators

c) Two rear turn indicators

d) Two red brake lights in the rear

e) Two red rear lights (may be combined with the brake lights)

f) The centre of each headlight unit must be located at an equal distance and at least 30 cm from the longitudinal axis of the vehicle.

g) The mandatory red indicator light for the self-starter operation must be separate from any of the above (see c).

Article 51: BRAKING

a) The vehicle must be equipped with a four-disc hydraulic brake system, with a single brake pedal, which has a minimum surface area of 25 cm².

b) The brakes must operate independently on the front and rear axles or in an X pattern (i.e. right front wheel with left rear wheel, and left front wheel with right rear wheel).

c) A single master cylinder may be used, provided that it has a dual circuit (two pistons and dual tank).

d) The effectiveness of the brake system will be tested during vehicle inspection. The vehicle must remain immobile with the Driver inside when it is placed on a 20 percent incline with the main brake in place. Moreover, a dynamic inspection may be performed on the vehicle-handling course.

e) A parking brake function is required in order to keep the car stationary during technical inspections and fuel measurements. It must provide a brake force of at least 50 N.

f) Wet weather capability is mandatory (see Article 52:).

Article 52: WET WEATHER RUNNING

a) During weather conditions of light rain/drizzle, the UrbanConcept vehicles (only) may be required to drive on the track during competition with approval from the Race Director. Therefore, all UrbanConcept vehicles must be adequate for running under such conditions.

b) The vehicle must be equipped with an effective electric windscreen wiper arm assembly typically found in a production car.

c) The operation of the wiper assembly must be activated by an independent switch easily accessible to the driver.

d) The wiper operation must provide the driver a clear view.

e) The vehicle must be adequately ventilated to prevent driver's compartment from fogging.

f) The vehicle's electrical system must be suitable for wet weather conditions (e.g. will not malfunction during wet conditions).

g) Tyres must have a minimum tread of 1.6 mm (see Article 49:).

h) The vehicle's brake effectiveness may be re-inspected before and/or after any run.

i) The effectiveness of the vehicle to run in wet conditions will be evaluated during the initial inspection phase.

4. ENERGY SOURCES

4A – GENERAL

Article 53: ENERGY TYPES

Vehicles may only use any one of the following energies: a)

Internal Combustion:

i. Shell FuelSave Unleaded 95 (Europe and Asia)/Shell Nitrogen Enriched (US) Gasoline.* ii. Shell FuelSave Diesel (Europe)/Shell Diesel (Asia and US).

iii. Ethanol E100 (100% Ethanol)** iv. Shell Gas to Liquid (100% GtL)**

v. CNG***

* The gasoline and diesel provided by the Organisers during the competition are the Shell fuels prevalent in the local market where the event takes place. For testing and tuning purposes in the team's home countries where Shell fuels may not be available it is recommended to use the locally available Unleaded 95 (87 US) or Diesel instead. ** Ethanol E100 and Shell Gas to Liquid will be ranked jointly in one prize category called 'Alternative Fuels' on an energy content corrected basis.

*** The fuel provided by the Organiser for the CNG category will be pure Methane. b)

Electric Mobility:

i. Hydrogen. ii. Battery Electric.

Article 54: RESULTS CALCULATIONS

a) All live results displayed at on-site monitors as well as the internet during the competition are provisional until verified und published by the Organisers after the completion of the event, usually within 3 days after the event.

b) Results for the Internal Combustion Category will be expressed in kilometres per litre (km/l) (i.e. theoretical distance covered using energy of gasoline equivalent) corrected to a temperature of 15 °C on a tank-to-wheel basis.

c) Regardless of the fuel used, the ranking will be determined from this equivalent consumption of gasoline. This calculation will be performed using the net calorific value (NCV), which represents the quantity of energy released per unit mass or volume of fuel during complete combustion yielding steam and carbon dioxide.

d) Typical NCV values (mass basis) for different fuels are given in the table below. The NCV values (vol.) at 15 °C are calculated on the day of competition by multiplying the actual mass-based NCV by the fuel density at 15 °C

ENERGY TYPE	NCV BY MASS (kJ/kg)

Shell FuelSave Unleaded 95 (Europe and Asia), Shell Nitrogen Enriched (US) Gasoline	42,900
Shell FuelSave Diesel (Europe), Shell Diesel (Asia and US)	42,600
Ethanol E100	26,900
Gas to Liquid	44,000
Hydrogen	119,930
CNG	50,016

For example, if a distance of 1,000 km is covered with one litre of Shell FuelSave Diesel, whose corresponding energy is 35,660 kJ (if we assume a fuel density of 0.83716 kg/l at 15 °C), this represents 0.0280 km covered per kJ. Since the energy from one litre of Shell FuelSave Unleaded 95 is 32,010 kJ (if we assume a fuel density of 0.74616 kg/l at 15 °C), this corresponds to a corrected distance of 896 km (rounded to the nearest unit). The final result for a vehicle having covered 1,000 km with one litre of diesel fuel (at the reference temperature of 15 °C) will thus be 896 km for the equivalent of 1 litre of Shell FuelSave Unleaded 95 (also at the reference temperature of 15 °C).

e) Results for Battery Electric vehicles will be expressed in kilometres per kilowatt hour (km/kWh) and will be determined by using a joulemeter supplied by the Organisers.

f) Fuel Cell vehicles will use a flow meter to measure the H_2 consumed. The results will be calculated using the NCV of H_2 listed above and expressed in km/m^3 hydrogen.

g) The results for hybrid vehicles will be expressed based on the primary energy used.

Article 55: FUELS SUPPLY & HANDLING

a) Only the fuels listed in Article 53: as provided to the Participants by the Organisers during the event, are authorised for use during practice and competition.

b) Supplies adequate for practice and competition will be made available to all teams at the event.

c) No additives may be added to the fuel. Only the energy derived from the combustion of the fuel in the presence of air alone within the engine system may be used for forward propulsion. No other material that could serve as engine fuel may be used at any time during the event.

d) Participants handling fuel must wear safety glasses and chemically resistant gloves.

e) No additives, catalysts, water injection, or fuel treatment devices are allowed.

Article 56: NOT USED

Article 57: VEHICLE ELECTRICAL SYSTEMS

a) For safety reasons, the maximum voltage on board of any vehicle at any point must not exceed 48 Volts nominal and 60 Volts max (this includes on-board batteries, external batteries, Super Capacitors, fuel cell stack, etc.).

Battery definition: A 'battery' is defined as a source of electrical energy, which has exactly two connectors and comes as a single unit. This single unit may contain more than one sub-unit.

b) For all vehicles only one on-board battery is allowed. For ICE and hydrogen fuel cell vehicles this is the accessory battery (see i). For battery electric vehicles this is known as the propulsion battery.

c) If Lithium-based batteries are used, Battery Management Systems (BMS) tailored to this chemistry must be installed to control and protect the battery against risk of fire. The BMS must provide cell balancing and overvoltage protection during off-track charging. For E-mobility vehicles, the additional requirement of cell level over-discharge, over-current and over-temperature must be provided as part of the on-vehicle system. The BMS must AUTOMATICALLY isolate the battery, without operator intervention, if a limit or out of range condition is reached on any of the above parameters. For Lithium-based accessory batteries, the BMS cell balancing and overvoltage protection may be contained as part of the off-board charger. The maximum capacity of any Lithium-based battery used in any propulsion energy class vehicle is 1,000 Wh. For batteries not rated in Wh, the Wh rating is calculated by multiplying the amp-hour rating of the battery by its nominal voltage. Protection for Lithium-based battery charging, whether in or out of the vehicle must be provided, see Article 24(i).

d) Any Lithium based battery must be equipped with a metal tray under the battery suitable to prevent the battery, in the event of a fire or battery event, from burning through the vehicle body and dropping to the ground.

e) All batteries and Super Capacitors must be short circuit protected. Protection may be in the form of a fuse, fusible link, or a current interrupting device (circuit breaker). Automatic reclosing current interrupting devices are not allowed. Short circuit protection devices must be located on the positive conductor and as close as possible to the battery or Super Capacitor itself. The rating of the short circuit protection device must be such that the battery or Super Capacitor will be able to supply enough short circuit current at all times to open the device. For vehicles with a starter motor, the starter motor cable is NOT required to be protected.

f) For safety reasons, both the positive and negative circuits of the propulsion battery or Super Capacitors must be electrically isolated from the vehicle frame.

g) All vehicle electrical circuits must be protected against electrical overload. Overload protection may be in the form of fixed current limits within electric controllers or by the insertion of individual circuit fuses. For Internal Combustion vehicles, overload protection is required for the motor controller, ignition system, and other accessory load electrical circuits.

h) The accessory battery (see i) must maintain a negative ground.

i) The accessory battery provides for all allowed electrical needs such as safety devices (horn, windscreen wipers, lights, hydrogen sensors, hydrogen relays and hydrogen shutdown valve),

ignition, fuel injection control, starter motor, and ventilation/cooling fan for the driver. For Internal Combustion vehicles only the accessory battery may also be used for engine management systems.

The capacity of the accessory battery must be sufficient to power all the accessory loads with a sufficient safety margin. An accessory battery load analysis will be reviewed during technical inspection to validate sufficient battery capacity. The accessory battery is not allowed to power compressors, blowers, engine cooling systems or motors.

j) The Organisers reserve the right to request Teams to install one joulemeter, intended to measure the quantity of energy provided by the accessory battery. If this amount of energy exceeds the power typically required to operate the starter motor, horn and safety devices the competitor will be disqualified.

k) Both propulsion and accessory batteries must be installed outside of the driver's compartment behind a bulk head.

l) The following devices may be powered by batteries other than the propulsion or accessory battery provided they use built-in or small capacity batteries: radio communication system, GPS system, data loggers excluding engine management units, driver ventilators.

m) All electrical/electronic enclosures built and populated by the teams must be made of transparent material or at least have a transparent cover to allow the technical inspectors to view the contents.

Note: Beginning with the 2017 season, the Organisers intend to include all on-vehicle energy supplied by the vehicle battery in the calculation of fuel economy results. A joulemeter will be installed by the Organisers on every vehicle between the vehicle battery and the vehicle electrical system.

With this change, several existing restrictions will be removed. Technologies that the automotive industry is working on to improve fuel economy such as electric oil pumps, electric cooling system pumps, turbochargers with external oil pumps, will now be allowed. For prototype vehicles clutches will no longer be required. Vehicles with hybrid powertrains will no longer be required to isolate the hybrid electrical system from the vehicle battery.

Electric fuel pumps will continue to be prohibited.

Article 58: TECHNICAL DOCUMENTATION

a) Competitors need to provide technical documentation in 2 stages:

i. Prior to the event during the online submittal process (see b).
This documentation serves only to verify that the teams have an understanding of the Rules.

Online approval in no way constitutes a pre-approval for the Technical Inspection phase. ii. At the event (see c)

This should be a precise technical description of the vehicle. During technical inspection, the documentation will be compared against the vehicle. Deviations between the technical

documentation and the vehicle will be required to be reconciled prior to passing technical inspection.

b) Technical Documentation – prior to event.

i. Competitors must provide, through the online submittal process, documentation on the vehicle energy supply and propulsion system. It is not necessary to submit detailed component specifications or electrical schematics as part of the online submittal process. ii. Energy supply block diagram

The online submitted energy supply block diagram and associated text description must contain information describing the energy flow and component function for the vehicle energy systems. Specific items to be included in the block diagram for each energy category are listed below:

- ICE (liquid fuels): engine, fuel tank, fuel line, carburetor/injector, pressure relief valves, pressure regulators, pressure gauge, compressed air bottle, vehicle cut-off mechanism
- ICE (CNG) : Engine, pressure regulator, cylinder, solenoid valve, fuel line, vehicle cut-off mechanism
- H2 : Fuel cell, cylinder, solenoid valve, pressure regulator, flow meter, motor controller, motor, super capacitor, vehicle cut-off mechanism
- BE : Motor, battery/BMS, fuse, wiring, e-stop switches, motor controller, vehicle cut-off mechanism

iii. Propulsion system block diagram

The online submitted propulsion system block diagram and associated text description must contain information describing the propulsion mechanism for each energy category below:

- ICE/CNG : Engine/Motor to road (engine, transmission, clutch, wheel, motor, super capacitor, motor controller)
- H2 : Motor to road
- BE : Motor to road

c) Technical Documentation – at event (to be reviewed during Technical Inspection)

i. Competitors must have available for inspection with the vehicle printed documentation describing selective technical aspects of the vehicle. The printed documentation must be bound and divided into the following sections. The specific required sections for each energy category are defined below.

ICE (liquid and CNG) energy category

- Energy Supply Diagram
- Propulsion System Diagram
- Electrical Schematic
- Hybrid System +
- Battery/BMS ++

Battery Electric energy category

- Energy Supply Diagram (Electrical Schematic)
- Propulsion System Diagram
- Battery/BMS
- Motor/Motor Controller

Hydrogen category

- Energy Supply Diagram
- Propulsion System Diagram
- Fuel Cell
- Electrical Schematic
- Motor/Motor Controller
- Super Capacitor +
- Battery/BMS ++

+ If included in the vehicle

++ If a Lithium-based accessory battery is included in the vehicle ii. The minimal

contents of each of the above required sections are defined below.

- Energy Supply Diagram: include updated diagrams and associated descriptive text as defined in Article 58 (b) above.
- Electrical Schematic: provide a vehicle level schematic showing all vehicle wiring and associated components and connections. The schematic should include component values such as voltage levels and fuse ratings. Schematics of components such as the engine management system or fuel cell controller are not required in this section.
- Hybrid System: include manufacturers' component specifications at the lowest level of purchased components. Include diagrams describing the power flow into and out of the hybrid system. Include super capacitor documentation (see the Super Capacitor section below.
- Battery/BMS: (For Lithium-based batteries only) Provide battery/BMS manufacturer component specifications at the lowest level of purchased components. At minimum, the battery documentation should include cell chemistry, cell electrical characteristics, cell series or parallel configurations, battery voltage, and current ratings. The BMS data MUST include:

    1. Cell over-voltage and under-voltage protection limits
    2. Battery over-current limit (not required for accessory battery)
    3. Operation of cell balancing (how and when)
    4. Battery over-temperature limit (not required for accessory battery)

5. How the BMS will protect the battery when an over-voltage, under-voltage, over-current or over-temperature condition is reached, i.e. how will the BMS protect or isolate the battery, in the case of Battery Electric Vehicles, when these limits are reached?

- Motor/Motor Controller: Provide motor/motor controller manufacturers component specifications at the lowest level of purchased components. For Battery Electric Vehicles, include design documentation on the purpose built motor controller. The documentation may contain control flow diagrams, motor controller and sub-component schematics and PC board layouts if PC boards were used. Also include software documentation if software was written as part of the motor controller development.
- Fuel Cell: Provide fuel cell manufacturers component specifications at the lowest level of purchased components. This should also include the surface area of the fuel cells, rated power and voltage.
- Super Capacitors: Provide super capacitor manufacturers component specifications at the lowest level of purchased components. At a minimum, include super cap system rated voltage and max current.

4B – INTERNAL COMBUSTION ENGINES (LIQUID FUELS)

Article 59: PROPULSION

The type and design of the internal combustion engines are not restricted, however they must run only on the fuel provided by the Organisers and must not consume any engine oil (2 stroke engines are not allowed).

Article 60: OTHER ON-BOARD ENERGY SOURCES

a) For all fuel categories, stored electrical or pneumatic energy not replaced during the competition by the engine may only be used for the self-starter, the ignition, the injector, the instrumentation, the horn and electronic management systems.

b) Fuel pumps are permitted for all fuels provided they are mechanically driven by the engine only.

c) It is permitted to pressurise the liquid fuel tanks, in order to feed the engine, only under the following conditions:

   i. Pressurisation is done by means of a translucent compressed air bottle fitted with a safety valve set to 5 bars maximum – or the lower operation pressure of the vehicle system.

   ii. The system must include a standard valve as used for car tires in order to enable verification/control of the pressure setting for the safety valve. iii. The said pressurisation is done in the starting area by means of an air pump.

   iv. The Driver must not modify the pressure during the competition.

d) Auxiliary energy sources (chemical, latent energy from phase changes, etc.) are not permitted.

e) If the engine temperature is regulated, the said regulation should be limited to the use of pure, un-pressurised water as coolant. The external regulation temperature of the engine (for engines thus equipped) is limited to 100 °C.

f) It is forbidden to use a battery-powered electrical pump to ensure oil or water circulation in the engine, except in cases where this pump is only used when the engine is being started.

Article 61: FUEL TANKS (WITH THE EXCEPTION OF HYDROGEN AND CNG)

a) The vehicle must be equipped with only one of the following approved fuel tanks supplied by the Organisers:

   Tank capacities: Prototype: 30, 100 or 250 cc

   UrbanConcept: 30, 100, 250 or 350 cc

b) Only tanks bearing a clearly visible stamp proving its “APAVE”* certification compliance can be used for pressurised systems.

   *APAVE tests fuel tanks and certifies their ability to withstand a pressure of five bar.

c) The fuel tank has to be mounted in an accessible and zero degree vertical position which allows in-situ filling with a burette of approx. 1 metre height.

d) The fuel tank must be mounted in a way that its top is at least 5 cm below the roll bar.

e) The fuel tank cap, whether it is leak proof or not (drilled), must be in place at all times during the competition. For gravity fed systems a small (<3 mm) hole must be drilled in the centre of the cap to allow air to enter the tank, hence allow fuel out!

f) Fuel return lines must be fed into the fuel feed line below the fuel tank. However, the return line can only be fitted to the fuel cap if the engine was originally equipped with a manual priming pump and this return line and the pump have not been modified.

g) Competitors must equip their vehicle with clear fuel lines which are not prone to expansion when pressurised (max. internal diameter 8 mm).

h) For pressurised fuel systems the hoses connecting the pressure bottle with the fuel tank cap must be flexible (do not need to be Rilsan/Nylon type) to allow easy connection and in order to prevent side loading to the tank necks.

Article 62: FUEL SYSTEM

a) Participants must provide a description and a precise technical drawing of the fuel supply system from tank to engine.

b) This system must be designed in such a way that it can be completely drained and refilled before the competition.

c) The fuel line between the tank and the engine must not include any additional elements (no additional filters). A second valve directly at the bottom of the fuel tank is tolerated.

d) For diesel engines, a cut-off solenoid valve is required.

e) Any fuel system including a float chamber (carburettor) must be fitted with a drain valve at the bottom of the carburettor to partially drain the chamber during Technical Inspection to ensure that the fuel level goes down in the tank.

Note: Engines with carburettors will no longer be allowed from 2017 onwards.

f) The air intake manifolds must not contain any fuel (or be able to accumulate any fuel) or blowby gas when the vehicle is on the starting line prior to departure. Blowby gas must not be recycled during the competition but has to be collected in a specific canister for environmental protection.

Blowby gas: gas inside the engine (in particular, oil vapours, unburnt gas or gas in the combustion chamber that has not been evacuated in the exhaust). This gas is usually recovered at the intake manifold. This is known as blowby gas re-circulation.

g) The fuel system must be easily accessible for inspection and measurements.

h) It must be possible to set the fuel supply system to atmospheric pressure for measurement of the fuel level. The pressurisation system must be equipped with a pressure gauge and normal running pressure must be clearly marked on the gauge.

i) The standard fuel consumption measurement method for liquid fuels is by volumetric replacement of the fuel consumed and temperature corrected fuel (including temperature correction).

j) The fuel consumption of gasoline and ethanol powered vehicles which have achieved more than 1500 km/l (3528 mpg) in the past will be measured gravimetrically. At the start a Fuel Marshal will fill the fuel system and then the entire fuel system (including tank, injector, pipes, carburettor) will be weighed on a precision balance. All these components must be compact and easily detachable for weighing purposes. After completion of a successful run, the entire fuel system will be de-installed and weighed again on the same balance. This handling of the fuel system, including mounting to and dismounting from the vehicle and transporting it to the weighing room must be performed by a competent team member who has a valid garage access pass. The entire process of handling the fuel system will be supervised by a Fuel Marshal who will also perform the weighing will which needs to be witnessed by a Team Member.

k) Fuel is a volatile product. Therefore, it is not allowed to artificially increase the fuel system temperature, which would lead to the formation of vapour locks. Conversely, cooling or refrigeration of the fuel below ambient temperature is also prohibited.

Article 63: VEHICLES USING HYBRID TECHNOLOGY

a) A Super Capacitor is the only allowed energy storage device for hybrid vehicles. Mechanical or hydraulic energy storage is not permitted. The use of any battery in the hybrid propulsion system is forbidden.

b) This capacitor must be the only source of stored energy for the electric motor driving the vehicle.

c) Two connectors must be installed safely outside the vehicle to allow the voltage measurement on the starting line. These must be labelled “Super Capacitor Voltage”.

d) The state of charge of the Super Capacitor will be checked before and after each run by measuring its voltage. The voltage registered after the run must be at least equal to the voltage registered before the run. In the event of the contrary, the Super Capacitor must be re-charged by running the engine until its voltage is equal to the voltage registered before the run. The time required to recharge the Super Capacitor by running the engine after the competition is added to the recorded time of the relevant run.

e) As per Article 57: an accessory battery can be used to power the starter, the ignition, the injector, the instrumentation, the horn and electronic management systems.

f) The entire electric circuitry must be correctly fused to prevent overloading any of its parts. This fuse needs to be clearly identified in the technical drawings and easily visible and accessible for Technical Inspection (see Article 57:).

Article 64: STARTER

a) An electric starter may be used during the competition, provided that it can operate only when the ignition and fuel systems are activated.

b) It must be clearly established that the starter is never capable of providing any forward propulsion to the vehicle.

c) Starter light: A clearly visible red indicator light, equivalent in its luminescence to a 21 W light bulb, must be installed on the rear of the vehicle and must be clearly visible from both sides of the track in order to signal any operation of the starter motor.

d) In the event that Track Marshals report the repeated or intensive use of the electric starter by a Team, the Organisers reserve the right to order an immediate inspection of the vehicle and to install a joulemeter to measure starter energy used. If any non-compliance is observed, the Team will be penalised accordingly.

e) At the start, the starter and hence the starter light must be extinguished by the time the rear wheel of the vehicle crosses the start line. Failing to comply will invalidate the run and count towards the maximum number of attempts.

4C – ELECTRIC PROPULSION

Article 65: FUEL CELL POWERED VEHICLES

a) Fuel system

i. Participants must provide a description and a precise technical drawing of the fuel supply system.

ii. The fuel system must be easily accessible for inspection and measurements.

iii. The fuel cell must run by itself. The electricity needed for temperature regulation, fan, compressor, electronic management system for the fuel cell and the electric motor must be supplied by the fuel cell and not by the accessory battery.

iv. The hydrogen system must be designed as follows:

H_2 cylinder → Pressure regulator directly attached to the cylinder → Emergency shutdown valve directly attached to the outlet of the pressure regulator → Flow meter → Fuel Cell

v. The flow meter must be fixed at the inlet of the fuel cell. Both must be at the same pressure.

b) Hydrogen cylinders

i. FC-powered vehicle must use a compressed hydrogen cylinder, referred to hereafter as a cylinder, as provided by the Organisers during the entire event. Only one cylinder may be fitted to a vehicle at any time.

ii. Cartridges and any other means of hydrogen storage are not permitted.

iii. For Prototypes vehicles, the following cylinders will be provided:

Europe: B04 cylinder, 0.4 litre of hydrogen at 200 bar (7 cm/33 cm) 1.4 kg

Americas: Exchange cylinder ~ 152 bar
5.3" X 17.1" (13.5 cm x 43.4 cm), 8.6 lbs. (3.9 kg)

Asia: Catalina MD cylinder, 2.9 litre of hydrogen @139 bar (11.1 cm x 42.4 cm), 2.4 kg

iv. For UrbanConcept vehicles, the following cylinders will be provided:

Europe: B1 cylinder, 1 litre of hydrogen at 200 bar
(10 cm x 35 cm) 2.57 kg
and
B04 cylinder, 0.4 litre of hydrogen at 200 bar
(7 cm/33cm) 1.4 kg

Americas: Exchange cylinder ~ 152 bar
5.3" X 17.1" (13.5 cm x 43.4 cm), 8.6 lbs. (3.9 kg)

Asia: Catalina MD cylinder, 2.9 litre of hydrogen @139 bar (11.1 cm x 42.4 cm), 2.4 kg

v. Cylinders must be installed on the vehicle under the supervision of a Fuel Marshal. Participants are not allowed to keep any cylinders in their possession overnight. Upon arrival at the circuit, Team Managers must contact the Fuel Marshal, who will organise all relevant logistics. c) Ventilation

The vehicle body must allow for ventilation at the highest point of the fuel cell compartment, providing an orifice with a minimum opening of 5 cm^2. Another 5 cm^2 opening must be provided at the highest point of the driver compartment.

d) Hydrogen detector

i. A hydrogen sensor must be installed in the fuel cell compartment, near the main ventilation orifice mentioned above. This hydrogen sensor must drive the emergency shutdown valve and relay mentioned below. The trip level of the hydrogen sensor must be tuned to 25% of the LEL (Lower Explosive Limit) of hydrogen, i.e. 1% of hydrogen in air. A test will be carried out during the technical inspection.

For commercial Fuel Cells with integrated H_2 detector it is still required to fit a H_2 sensor as described above.

ii. The reset of the hydrogen detector, i.e., the hydrogen sensor and its electronics, must be done manually via a switch located in the fuel cell compartment. This switch must not be accessible by the Driver from the cockpit.

e) Emergency shutdown valve and relay

i. The hydrogen supply circuit must be equipped with a solenoid emergency shutdown valve. This valve must be normally closed in the absence of electricity.

ii. The power supply to the motor must be automatically cut off at the same time as the above emergency shutdown valve is activated. This is to be achieved by a suitable fail-safe relay.

iii. This valve and relay must be activated by any of the following three scenarios:

1. Through hydrogen detection as explained above
2. Through the emergency push-button located on the outside of the vehicle. A red arrow (on a white background) at least 10 cm long and 3 cm wide must be positioned on the vehicle body to clearly indicate the place of this emergency push-button. (Note: It must not be part of the detachable bodywork used to allow driver access)
3. Through another emergency push-button, accessible by the Driver in driving position iv. In case of activation by one of these three scenarios, the valve and relay must act simultaneously.

v. These three scenarios will be tested during Technical Inspection and before each attempt.

f) Pipes and connections of the hydrogen circuit

i. In all cases, piping and connectors of the hydrogen circuit must be designed for hydrogen use. The Team Manager must be able to present during the technical inspection the technical data sheets from the manufacturer of these piping and connectors to show that they are suitable for hydrogen use.

The use of PTFE pipes is recommended. PU tubing should not be used as this tends to leak. ii. If the pressure in the hydrogen circuit is higher than 1.5 bar absolute (=0.5 bar above

atmospheric pressure) piping must be made of steel and connectors must be screw/compression type.

iii. If the pressure in the hydrogen circuit is lower than 1.5 bar absolute (= 0.5 bar above atmospheric pressure) flexible piping and unscrewed connectors are accepted.

iv. PTFE (Teflon) sealing tape must not be used because it can damage the flow meter. In any case Participants are responsible for damage to the flow meter due to wrong connections. g) Purge pipe

If a purge pipe is needed, its end must be located outside the vehicle.

h) Measurements and Equivalencies

i. The consumption of hydrogen is measured by an embedded flow meter. The flow meter will be checked/calibrated by the Organisers before Technical Inspection.

ii. The flow meter must be purchased from the Organisers.

iii. The volume of hydrogen consumed is posted in normal litres. The display of the flow meter must be easy to read from outside the vehicle, when the vehicle body is closed. It must be inaccessible by the Driver in normal driving position.

iv. The serial number on the hydrogen flow meter must not be covered or removed. i) Oxygen and air reserves

The use of non-replaced oxygen or compressed air reserves is forbidden.

j) Super Capacitors

i. If an embedded electric storage device is part of the power-train, it must be of capacitor type, referred to hereafter as 'Super Capacitor'. Other types of embedded electric storage device (Pb, NiMh, etc. batteries) are forbidden.

ii. The state of charge of the Super Capacitor will be checked before and after each run by measuring the Super Capacitor voltage. Two measurement points (Super Capacitor voltage + and – a labelled "Super Capacitor voltage") must be installed outside the vehicle to allow the voltage measurement on the starting line.

iii. The voltage registered after the run must be at least equal to the voltage registered before the run. In the event of the contrary, the Super Capacitor must be re-charged by running the fuel cell until their voltage is equal to the voltage registered before the run. The additional time required to recharge the Super Capacitor by running the fuel cell after the competition is added to the recorded time of the relevant run

iv. The maximum Super Capacitor voltage must not exceed that referenced in a). k) External starter battery

i. An external battery can be used on the starting line to start the fuel cell system. As soon as the vehicle starts to move, this battery must be unplugged.

ii. If an external battery is used, two connectors must be installed outside the vehicle to allow a quick connection and fuel cell system start on the starting line. These external connectors must be securely fastened to the vehicle.

iii. As mentioned in i) it is mandatory to power the hydrogen detector and the horn using the accessory battery. This battery must also power the emergency shutdown valve, relay and lighting system for UrbanConcept vehicles.

l) Electrical circuit/Electronics

i. All wiring associated with the accessory battery circuit must be clearly distinguishable from the propulsion system by physical isolation or the use of different wire colours.

ii. A fuse must be installed on the positive terminal of the fuel cell stack. Its melting current (expressed in Amps) must be less than the active area (expressed in square centimetres) of one cell of the stack. For instance, if the active surface of one cell of a 20 cell stack is 60 cm^2, the melting current of the fuse must not exceed 60 A.

iii. If a Super Capacitor is used in the circuit, a fuse must be installed on the positive terminal of the Super Capacitor pack. The fuse rating must be less than or equal to the maximum usable power divided by the rated voltage.

m) Other equipment

Compressors, fans and coolers for the fuel cell system must be powered by the fuel cell or Super Capacitor, not by the accessory battery (see Article 57:i).

Article 66: NOT USED

Article 67: BATTERY ELECTRIC VEHICLES

a) The drive train in the 'Battery Electric' category is restricted to a maximum of one electric storage device, and up to two electric motors, with associated control units. The electric motors may be purchased, purchased-and-modified, or purpose-built. The motor controller MUST be purpose-built for the Shell Eco-marathon. Modifications to purchased motor controllers or the use of purchased motor controller evaluation kits are not acceptable. Motor controllers built from sub-components such as single-board computers, power stages, etc. are encouraged. If a motor controller is built incorporating one or more single printed circuit boards (PCBs), the text "SEM" needs to be included in the mask of the PCB etching.

b) Only Lithium-based batteries are permitted as electric storage devices.

c) The vehicle must be equipped with a Battery Management System (BMS) to control and protect the battery against risk of fire as defined in Article 57:.

Any BMS for propulsion batteries must provide an AUTOMATIC isolation of this battery in the event of any measured parameters getting out of their designed range.

d) The Lithium-based battery and any accessory circuits are subject to the maximum voltage defined in a).

e) Participants are required to present electrical schematics at Technical Inspection.

f) All batteries must be placed outside the Driver's compartment behind the bulkhead and securely mounted. Bunge cords or other elastic materials are not permitted for securing the battery.

g) All vehicles must be equipped with one joulemeter located between the battery and the motor controller(s) to measure the vehicle propulsion energy consumption.

h) The Organisers will provide the joulemeter for the duration of the event.

i) The joulemeter must be positioned so that the display can be easily read and reset from the outside of the vehicle without the removal of any vehicle body components. It is acceptable to access the joulemeter from outside the vehicle though a hinged door.

j) The joulemeter must be inaccessible to the Driver in his or her normal driving position.

k) All electrical circuits must be protected as defined in Article 57:g.

l) On the starting line, Fuel Marshals will reset the joulemeter to zero, and then the vehicles will have access to the track to start their attempt under the same distance and time conditions as specified for their respective vehicle class.

m) At the finish line, Fuel Marshals will read the joulemeter display.

n) All 'Battery Electric' vehicles which complete a successful run will be classified in descending order of fuel economy, expressed in km/kWh.

4D – INTERNAL COMBUSTION (GASEOUS FUEL)

Article 68: CNG

CNG vehicles must comply with all rules of Section 4B INTERNAL COMBUSTION (LIQUID FUELS) as described in Articles 59, 60, 63 and 64. In addition the following rules apply: a) The CNG system must be designed as follows:

Methane cylinder/cartridge → Regulator assembly provided by the Organisers → hose → injector

Only the use of injectors is permitted. The use of vaporisers is not allowed. b)

Gas cylinder

i. The following cylinders will be provided:

Asia: Catalina MD cylinder, 2.9 litre, 70 bar (11.1 cm x 42.4 cm), 2.4 kg

Americas: Catalina MD cylinder, 2.9 litre, 70 bar (11.1 cm x 42.4 cm), 2.4 kg

Europe: Cylinder, 2.0 litre, 70 bar (10 cm x 41 cm), 1.5 kg

ii. For safety reasons, the cartridge/cylinder must not exceed a temperature of 50°C at any time. To prevent high temperature the cartridge/cylinder must not be installed above the battery, directly exposed to solar radiation and close to the exhaust system.

iii. Cylinders must be installed on the vehicle under the supervision of a Fuel Marshal. Participants are not allowed to keep any cylinders in their possession overnight. Upon arrival at the circuit, Team Managers must contact the Fuel Marshal, who will organise all relevant logistics.

c) Technical Inspection/Measurement

The fuel system must be easily accessible for inspection and measurements. The gas consumption will be measured gravimetrically. At the start a Fuel Marshal will weigh the entire fuel system (including cylinder/cartridge, pressure regulator, shut down valve, hose and injector). All these components must be compact and easily detachable for weighing purposes. After completion of a successful run, the entire fuel system will be de-installed and weighed again on the same balance. This handling of the fuel system, including mounting to and dismounting from the vehicle and transporting it to the weighing room must be performed by a competent team member who has a valid garage access pass. The entire process of handling the fuel system will be supervised by a Fuel Marshal who will also perform the weighing will which needs to be witnessed by a Team Member.

d) Methane detector

i. A methane sensor must be installed in the energy compartment, near the main ventilation orifice mentioned below. This Methane sensor must drive the emergency shutdown valve and relay mentioned below. The trip level of the methane sensor must be tuned to 25% of the LEL (Lower Explosive Limit) of methane, i.e. 1% of methane in air.

ii. The reset of the methane detector must be done manually via a switch located in the energy compartment. This switch must not be accessible by the Driver from the cockpit.

e) Pressure regulator/Shut down valve

i. The vehicle must be equipped with only the approved pressure regulator and shut down valve assembly provided by the Organisers. This equipment will be available from the Shell Eco-marathon e-shop.

ii. The maximum outlet pressure is limited to 3 bar absolute.

iii. This system include a safety valve, the discharge line must be installed to evacuate outside the vehicle and towards the ground.

iv. Emergency shutdown valve and relay

v. The shutdown valve is normally closed in the absence of electricity.

vi. The power supply to the ignition/injection must be automatically cut off at the same time as the above emergency shutdown valve is activated. This is to be achieved by a suitable failsafe relay.

vii. This valve and relay must be activated by any of the following three scenarios:

1. Through methane detection by the methane sensor
2. Through the emergency push-button located on the outside of the vehicle
3. Through another emergency push-button, accessible by the Driver in driving position viii. In case of activation by any of these scenarios, the valve and relay must act simultaneously.

ix. These three scenarios will be tested during Technical Inspection and before each attempt. f) Ventilation

The vehicle body must allow for ventilation at the highest point of the energy compartment, providing an orifice with a minimum opening of 5 cm^2. Another 5 cm^2 opening must be provided at the highest point of the driver compartment.

g) Pipes and connections of the gas circuit

i. In all cases, piping and connectors of the gas circuit must be designed for Methane use. The Team Manager must be able to present during the technical inspection the technical data sheets from the manufacturer of these piping and connectors to show that they are compatible for Methane use.

ii. Hoses and connectors must resist at a pressure of 9 bar absolute, 3 times maximum operating pressure of 3 bar absolute (proof is required).

Article 69: NOT USED

5. AWARDS AND PRIZES

5A – ON-TRACK AWARDS

Article 70: AWARD OVERVIEW AND PRIZES

All on-track prizes and trophies below are awarded twice, once for Prototype and once for UrbanConcept vehicles.

SHELL ECO-MARATHON ON-TRACK AWARD	ASIA AMERICAS	EUROPE	COMMENT
Shell FuelSave / Shell Nitrogen Enriched Gasoline Winner	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
Shell FuelSave / Shell Nitrogen Enriched Gasoline Runner-up	$1,000	€750	Prize Money only
Shell FuelSave / Shell Nitrogen Enriched Gasoline 3rd place	$500	€375	Prize Money only
Shell FuelSave Diesel Winner	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
Shell FuelSave Diesel Runner-up	$1,000	€750	Prize Money only
Shell FuelSave Diesel 3rd place	$500	€375	Prize Money only
Alternative Fuel Winner (E100+GtL)	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
Alternative Fuel Runner-up	$1,000	€750	Prize Money only
Alternative Fuel 3rd place	$500	€375	Prize Money only
CNG	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
CNG Runner-up	$1,000	€750	Prize Money only
CNG 3rd place	$500	€375	Prize Money only
Battery-electric Winner	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
Battery-electric Runner-up	$1,000	€750	Prize Money only
Battery-electric 3rd place	$500	€375	Prize Money only
Hydrogen Fuel Cell Winner	$2,000	€1,500	Prize Money, Trophy, on-stage Winners Ceremony
Hydrogen Fuel Cell Runner-up	$1,000	€750	Prize Money only
Hydrogen Fuel Cell 3rd place	$500	€375	Prize Money only

5B – OFF-TRACK AWARDS

Participating teams may choose to apply for a maximum of two Off-track Awards; or for three if one application is for the Safety Award.

Applications for all Off-track Awards must be relevant for and related to the work carried out for the Shell Eco-marathon project. Previous award winners cannot re-apply on the basis of the same vehicle design, innovation, communications or safety campaign. Submission must be clearly different from previous winning applications.

Applications for all Off-track Awards must be made in English language.

In order to submit an application for a Shell Eco-marathon Off-track Award, the required documents must be uploaded using the online team registration system. Please refer to Chapter II of the Shell Eco-marathon 2016 Rules of your regional event for the applicable submission deadline.

For all awards, the juries will make their first selection based on the submission received prior to the competition. All teams shortlisted for an award may then receive a visit by the judges during the event and are required to make a team member available to them at their request. The judges may ask further questions, wish to see particular evidence or discuss the team's submission in more detail.

By submitting an Off-track Award entry the Team agrees for the Organisers to publish their entry as deemed necessary to recognise the achievement and provide coaching to other Teams.

Teams cannot apply for the "Perseverance & Spirit of the Event" award.

Article 71: AWARD OVERVIEW AND PRIZES

All off-track prizes and trophies below are awarded once. Winners will receive the respective prize money, as well as a trophy on-stage during the Awards Ceremony.

SHELL ECO-MARATHON OFF-TRACK AWARD	ASIA AMERICAS	EUROPE
Communications Award	$2,000	€1,500
Vehicle Design Award Prototype	$2,000	€1,500
Vehicle Design Award UrbanConcept	$2,000	€1,500
Technical Innovation Award	$2,000	€1,500
Safety Award	$2,000	€1,500
Perseverance & Spirit of the event Award	$2,000	€1,500

Article 72: COMMUNICATIONS AWARD

Objective

To run the most impactful and successful integrated Communications campaign showing the efforts to promote the team ahead of the Shell Eco-marathon competition in 2016. The winner will be the team that demonstrates best the continuous communicational and promotional activities of the team on the road to Shell Eco-marathon (SEM) competition. a) Overview

An integrated Communications campaign, using different media channels and engagement activities, is integral for students to promote their teams ahead of Shell Eco-marathon. Participating teams are required to create, run and evaluate a communications plan with various activities to show the team's trajectory ahead of the competition.

When preparing the campaign, teams are encouraged to use a wide range of media channels, from traditional media (press, radio and TV), to online tools (websites, blogs) or social media networks (Facebook, Twitter, YouTube, Instagram etc.).

The winner will be judged on the quality and creativity of the content, the volume of activity as well as the impact (potential reach) of the campaign (i.e. media impressions; website visits; YouTube video views; Facebook likes; event attendance, etc.).

As we evaluate the team's trajectory before Shell Eco-marathon, the application should indicate when the campaign is launched and run, and should include planned activities after the submission deadline.

Remember that engaging with the Shell Eco-marathon online and social media channels are also an important part of the campaign. Teams applying to the Communications Award are invited and expected to join the regional SEM Facebook groups, follow SEM on Twitter, and use the #SEM2016 hashtag whenever possible.

Teams must note that the effectiveness of the Communications campaign will be judged in activities related to Shell Eco-marathon only. This includes, for instance, the unveiling of the vehicle, press conferences, photos or videos of the team and the car, or any social media activity. Participation in other competitions without a clear reference to Shell Eco-marathon will not be taken into consideration.

In order to be eligible for the Shell Eco-marathon Off-Track Communications Award, the team must have successfully passed Technical Inspection.

b) How to participate

Participation in this competition is voluntary. Teams interested in applying to the Off-Track Communications Award must submit an application via the online Team Registration web site. This application must consist of one (01) document (.pdf format) that should be simple and straightforward, and should contain:

1. Communications Plan: A short summary (no more than 500 words) indicating the main idea, objectives, strategy and timeline of the Communications Campaign.

2. Impact Analysis: A summary report (no more than 500 words) evaluating the success of the Communications Campaign compared with its objectives. Teams should also submit the main results (numbers) gathered throughout the campaign (e.g. event attendees, media impressions; video views; social media likes and shares; re-Tweets; etc.).

3. Campaign portfolio: Teams should collate and share all (or the best) examples of their campaign. This includes, for instance: press clips; event photos and footage; posters and brochures; creative infographics; websites links; social media channels (Facebook, Twitter, Instagram, Google+, YouTube, Tumblr, Vimeo, Vine etc.); blog posts; screen shots of social media posts; links to YouTube, Vimeo or Vine videos, etc.

Article 73: NOT USED

Article 74: VEHICLE DESIGN AWARD

a) Objective

This prize recognises innovative design research and execution and will be awarded to the team, which presents the most original and coherent vehicle in terms of aesthetics, ergonomics, technical feasibility, choice of materials and eco-friendliness. Each of these five criteria will be weighted equally in the Jury's decision. Due to their non-comparable designs there will be one award each for the Prototype and UrbanConcept categories.

b) Overview

Teams are required to describe their design approach, the basis for their research, factors which make this design special and issues and solutions encountered during the vehicle production process. Photographs, drawings and / or animations must be included to illustrate the process. Teams shortlisted for the Award will be visited by the Jury during the event to answer further question and present their vehicle.

In order to be eligibility for this Award the winning team must have at least one valid competition attempt, i.e. the team must have a result on the score board.

c) How to participate

Application for this award is voluntary. Teams interested in winning the Vehicle Design Award must submit a summary in .pdf format which does not exceed 1,500 words plus photographs, drawings or animations. This document must contain as a minimum the following information:

- Description of the original design idea the team wanted to develop and why
- Four images of the vehicle (photographs or drawings) which represent the car, such as:
- 3/4 front perspective view
- 3/4 rear perspective view
- direct Front view
- direct Rear view
- Side view

- Top view
- Cockpit view
- A brief project timeline and overview of the team structure and work allocation ■ When was this vehicle registered for the first time for Shell Eco-marathon?
- What are the new developments this year (if registered before)?
- Details about research and tests done to prove the vehicle's energy-efficiency
- Details about vehicle safety and driver ergonomics aspects
- Details about the eco-friendly materials used and how well they can be recycled
- The weight of the car and details on how the team managed weight reduction

Article 75: TECHNICAL INNOVATION AWARD

a) Objective

This award is presented to the Team which demonstrates outstanding technical ingenuity along with optimal use of new materials, components and inventions in their drive train, chassis, body, instrumentation and tyres.

b) Overview

Teams will be required to explain their innovative concept, its features and its benefits, how it relates to the Shell Eco-marathon competition and the potential it has for 'real world' application. Teams are strongly encouraged to consider all intellectual property developed in conjunction with the Shell Eco-marathon programme as valuable assets and seek professional advice about its protections through patents or trademarks before publishing.

In order to be eligibility for this Award the winning team must have at least one valid competition attempt, i.e. the team must have a result on the score board.

c) How to participate

Application for this award is voluntary. Teams interested in winning the Technical Innovation Award must submit an application in .pdf format which is not to exceed 1,500 words plus photographs, drawings or animations as applicable.

Article 76: SAFETY AWARD

a) Objective

This award aims to highlight the importance of structural, process and behavioural safety in the Shell Eco-marathon programme and encourages all participating teams to actively consider and implement safe practices in their daily work. It challenges all team to review established practices, inspect tools and equipment as well review their procedures in order to implement changes which lead to higher safety standards.

b) Overview

In order to win the award, the team must demonstrate excellent understanding of safe design concepts and the application to their car and the manufacturing process. Furthermore, the winning team must be able to demonstrate safe working practices as well as an overall proactive approach to their own and other people's safety at the event. In their submission the team will also explain which changes they have implemented to achieve higher standards of safety.

In order to be eligibility for this Award the winning team must have successfully passed technical inspection.

c) How to participate

Application for this award is voluntary. Teams interested in winning the Safety Award must submit an application in .pdf format which is not to exceed 1,500 words plus supporting photographs, documents, drawings or animations as applicable.

Article 77: PERSEVERANCE AND SPIRIT OF THE EVENT AWARD

This Award is presented to the team which, in the opinion of the Organisers, symbolises best the spirit and values of Shell Eco-marathon through their actions, which can involve but are not restricted to:

- Overcoming great obstacles in order to attend the Shell Eco-marathon;
- Mastering exceptional challenges while participating in the Shell Eco-marathon;
- Supporting other participants to help them overcoming significant challenges or obstacles;
- Keeping high spirits, showing outstanding resilience, resolve and resourcefulness.
- Teams cannot apply for this award.

Article 78: INTELLECTUAL PROPERTY

Any work performed in the preparation of vehicles for use in the Shell Eco-marathon programme may result in the creation of intellectual property. Teams are encouraged to consider all intellectual property created during the Shell Eco-marathon programme as valuable assets, and to seek professional advice about its protections prior to any submission to the Organisers, publication or public usage.