

Testing & Validation Fuels in Vehicle Development

Pat Y. Geng

General Motors Powertrain

Lutz Reichenbaecher and Albrecht Spangenberg

Haltermann Products

Don E. Burnett and Dennis Doerr

Chevron Phillips Chemical Co., LP

Copyright © 2008 GM Global Technology Operations, Inc. Published by SAE International with permission.

ABSTRACT

Because of the wide array of commercial or market fuels in use today, all components, engines, and vehicles must be vigorously tested to confirm emissions performance, driveability and material compatibility. To support the requirements of the modern global vehicle engineer, various testing and validation fuels are used to represent quality that ranges from good to poor for fuel that are currently in the market or that will be introduced into the market in the future. Testing and validation fuels have been developed specifically for emissions compliance testing to meet new environmental regulations in different parts of the world, vehicle performance and reliability needs. Demand for new testing and validation fuels will continue to grow. This paper reviews historical developments in vehicle testing, the development of testing and validation fuels, global fuel quality and trends, and describes the importance of using specialty fuels to develop robust designs that ensure vehicle performance, compliance and reliability in the global market place.

- 1) Emission certification fuels for mileage accumulation, legislated emissions compliance tests, and research and development.
- 2) Performance fuels to ensure vehicle performance and customer satisfaction
- 3) Durability fuels to screen materials and validate parts for robust design requirements

Blended reference fuels corresponding to these and other testing requirements must be available in different regions of the world to support the production, and supply of world class vehicles.

The challenge of building adequate flexibility into a vehicle so it operates efficiently on different commercial fuels while meeting or exceeding numerous regional emissions standards is significant. The underlying objective is to avoid having to modify a vehicle so that it will comply with a regional standard. The fewer modifications required while participating in the global market, the better.

Emissions standards and other requirements around the world are in place to protect the consumer. The standards or regulation development process generally starts with needs assessment, data collection, selecting the best level of performance needed to accomplish the desired goal, rule making, implementation, and enforcement. The vehicle engineer then strives to meet these standards or regulations without compromising vehicle drivability or performance. This is done by using a combination of well defined emission certification fuels and market representative test fuels.

The challenges facing a vehicle engineer would be significantly reduced if there was a single emissions standard for vehicles worldwide. One drawback to one size fits all emissions standards are prevailing weather patterns and temperature inversions in certain regions.

INTRODUCTION

As automobile companies pursue world wide markets, their products must be calibrated to meet emissions regulatory requirements and provide optimal drivability performance for the targeted region. Because fuel quality around the world varies and emission requirements are different from region to region, a combination of specific emissions certification fuels and market representative test fuels are required. Thus specialty testing and validation fuels are used to prepare vehicles that meet or exceed the regulatory and customer satisfaction requirements on a global basis.

Specialty testing and validation fuels are generally categorized into:



Documents

Document Sharing Hub

Population concentrations in large cities are another factor. In the U.S., Reformulated Gasoline (RFG) is required in some regions that don't meet prescribed emissions standards whereas other regions can use Conventional Gasoline which is easier to produce. It is an unnecessary burden to force regions that can meet the standards without it, to use the fuels required in RFG areas to meet Federal Emissions Standards.

In 1998, the World-Wide Fuel Charter was formed with the European Auto Manufacturers Association (ACEA), the Japan Auto Manufacturers Association (JAMA), the Alliance of Automobile Manufacturers, and the Engine Manufacturers Association (EMA) as members. In a 2000 publication, a read across table was published for ASTM, ISO, JIS, and some EN and CEC Tests Methods that are commonly used to certify gasoline and diesel fuel products¹. This was done to promote world-wide fuel harmonization, encourage the continued reduction of sulfur in fuels, and support the continued development of new engine and emissions control technology in Asia, Europe and North America.

There are other obstacles to having a single world wide fuel specification. Seasonal climate conditions require changes in fuel volatility. Some vehicles operating at high altitude have different octane requirements. With the advent of increased fuel mileage and fuel storage capacity, it is possible to go from a cold climate where 14 RVP High Volatility Fuel is required, to a more temperate climate where 9 RVP Fuel Low Volatility Fuel is required, on a single tank of fuel. Similarly, one can go from high altitudes where the octane requirements are lower, to a low altitude region where higher octane fuels are needed, without refueling. The vehicle has to continue operating flawlessly irrespective of what fuel is being used. This is one of the critical roles that computerized engine controls and On Board Diagnostics (OBD) Systems play as they interpret fuel, air density, temperature and other inputs, and make adjustments to optimize emissions and vehicle power performance.

Other concerted efforts have been made to arrive at standardized commercial fuels. In 1989, the Auto/Oil Air Quality Improvement Research Program (AQIRP) served as a major catalyst for the introduction of Reformulated Gasoline (RFG) in the U.S. The Coordinating Research Council (CRC), with strong support from the U.S. Environmental Protection Agency, the California Air Resources Board (CARB) and the Department of Energy (DOE), worked with the primary stake holders and member companies of the American Petroleum Institute (API) and the Society of Automotive Engineers (SAE), to develop a matrix of 144 test fuels designed to provide the best and worst possible emissions performance. These fuels which were blended by the Specialty Fuels Group of Chevron Phillips Chemical Company were used by AQIRP to develop an information base on fuel and vehicle effects on

emissions, in support of developing enhanced OBD and other engine management systems to significantly reduce emissions in accordance with new regulations being promulgated under the Clean Air Act. The specifications for Federal RFG Fuel were also established as a result of this effort. This program was the largest and most comprehensive project of this nature ever attempted².

More recently, the European Programme on Emissions, Fuels, and Engine Technologies (EPEFE) embarked on a similar effort based on cooperation between the European motor and oil industries to extend the information developed by AQIRP on fuels and engine technologies for the European continent. This resulted in additional data on the interaction between vehicle emissions control technology, fuel composition and the resulting emissions and impact on air quality. This supported subsequent Air Modeling, goal setting and the development of additional regulations to reduce emissions in pursuit of clean air³.

Similar gains toward reduced emissions have been accomplished by the Coordinating European Council (CEC) with their introduction of Euro I, II, III and IV Emissions Standards. The tailpipe and other emissions standards have been instrumental in driving the development of improved OBD Systems and Fuel Quality. Many industrialized countries are adopting various levels the CEC Emissions Standards along with aggressive goals to move toward the highest level of Euro V in as short a time period as possible. China, Japan, Korea, India and many other countries are implementing these CEC type standards in pursuit of reduced vehicle emissions and clean air.

The current trend is that variation in commercial transportation fuels continue to increase. In addition to regional variations in the composition of standard fuels, the use of various alternate fuels is increasing. Driven by rising conventional fuel costs, the expectation is that demand for flexible fuel vehicles and hybrids will continue to increase. The increasing use of alternate fuels world wide imposes additional challenges on the OEMs. Solutions and standards must be developed to insure that Flex Fuel vehicles provide seamless transitions from one power source to another. Adequate power must always be available to support passing, climbing, towing, merging into traffic, and sitting in traffic with the air conditioner and other accessories operating.

In addition to developing better emissions systems for vehicles sold domestically, the ability to develop and produce low emissions vehicles for export is critical to participating in global markets. In order to develop robust engine management systems that will perform flawlessly irrespective of region, climate, regulation or fuel type used, the design engineer will most often need access to the best and worse fuel the vehicle will use and operate as

ability to recreate the other test parameters in a controlled environment.

After the development work is complete, reference fuels from each destination country for the vehicle must be used to see if the vehicle can be certified. If the Fuel Handling and OBD system design can not pass the guidelines for tailpipe or diurnal emissions, it can not be sold in that country or region

U.S. authorities prescribed the use of reference fuels in emissions testing as early as the 1960s. Europe followed swiftly and soon the automotive industry introduced reference fuels not only for emissions testing but also in the development of lubricants and additives⁴. Today, engine and fluids development without such fuels is inconceivable. The number of ‘Legislative Fuels’ required by the authorities and ‘Research and Development Fuels’ fuels needed by the automotive industry grows steadily. The production of these test fuels within narrowly defined tolerances requires experience and considerable technical resources.

Prior to 1973 when crude oil was USD 3.00/barrel and gasoline was USD 0.30/gallon, there was little consideration given to the use of alternative fuels. Now the growing demand and diminishing supplies, limits in refining capacity and other (geo-political) factors affecting costs and supply have combined to generate significant interest in alternative fuels for transportation.

The Climate summit held at Bali in autumn 2007 also demonstrates the growing political pressure on industrial nations to review their use of Fossil Fuels and Green House Gas Emissions. The current trend is to move more aggressively towards the use of renewable energy sources with a smaller emissions footprint from Volatile Organic Compounds (VOC’s). These new sources are considered more environmental friendly but they create both opportunities and challenges for OEMs. Powertrain and vehicle management systems must now be able to take on a larger variety of energy sources without sacrificing performance and regulatory emission requirements.

BACKGROUND

Controlled blending for specialty testing fuel activities can be traced back to the year 1910. At that time the reduction of exhaust emissions played practically no role. “The best and most economic fuel for automobiles and engines of any kind”, as it was then claimed in advertisements, happened to be benzene which was produced from coal.

Figure 1 Benzol Poster



Subsequently, the fuel market has seen many changes and vehicle performance standards have increased significantly. These factors combined to create a need for specially blended test fuels that represent a wide spectrum of reference fuels and development fuels.

This includes the production of Diesel, Gasoline, and Jet Fuel for the following applications:

Table 1 Application for Test and Validation Fuels

Types	Examples
Engine Development	Low octane fuels, Cetane fuels, Heating value fuels, Hot/Cold Weather Volatility.
Lubricant and Additive Development	Sludge fuels, Keep Clean. Clean Up, Lubrication, Performance, Nozzle Coking, Inlet Valve Sticking, Inlet Valve Deposits, Ring Sticking, Piston Cleanliness, Bore Polish, Fuel Economy.
Durability Testing	Mileage accumulation, material compatibility
Emission Testing and Certification (Gasoline)	EEE and UTG 96 (aka Indolene®), CARB Phase II, CEC RF-02 to CEC RF-08
Certification (Diesel)	ULS 7 – 15 ppm, Euro IV, Type Approval, Homologation
Production Calibration	RVP, Density, Octane, Conformity of Production (CoP)
Validation for export Markets	Country specific fuels

Testing and Validation Fuels can range from efficient running extremely clean fuels with low emissions and deposit forming ability, to fuels that perform poorly in an engine, yield poor emissions and create deposits in an engine. Both types of fuels are needed to support on going design and development efforts to improve vehicle fuel economy, emissions, and reliability. They are also needed to validate compliance with the emissions and other performance guidelines established for the vehicle and to support the development of air quality models to predict the impact of reduced emissions. They are also

used in an attempt to recreate problems experienced by consumers in the field, in a controlled environment in order to develop solutions

Some Test Fuels are used to challenge engine octane requirements, drivability responses, cold start and operating ability, and hot weather (Diurnal Fuel) handling ability. The OBD System is also programmed to make sure that emissions are properly controlled in all possible operating modes. Some worst case test fuels are designed to identify and exploit weaknesses in either system. This allows the engineer to make changes in his design or operating parameters to overcome the impact of the worst case fuel. Other Test Fuels are designed to be used to validate that the vehicle is performing to meet or exceed regulatory requirements.

Since most manufactures are global, emissions and performance improvements must be obtained irrespective of differences in weather and road conditions, driving styles and fuel quality on a world wide basis. Otherwise, appropriate modifications must be made on a regional basis to pass the required certification tests.

It is not enough though to certify a vehicle when it is new. There are also requirements that an audit on emissions and mileage be performed when a vehicle is well on into its service life. This is to insure that the OBD and Fuel Handling Systems are rugged and reliable enough to withstand the challenges of use in extreme hot and cold weather and moderate to severe operating conditions for extended periods of time and continue to perform enough to pass the required emissions and other tests. If vehicle does not pass the audit, OEM can be fined.

The modern OEM Vehicle Engineer has an ongoing requirement to have access to "Tomorrows Fuels Today". Ultimately, some Fuel Cell Vehicles could require a totally sulfur free hydrocarbon fuel especially to support the on board generation of hydrogen. Catalytic Converter development will continue to benefit greatly from lower sulfur fuels and other emission reduction strategies and technology. While the Auto and Oil industries have worked well together in the past, the question of where the next major improvement will come from continues to be asked - Will the breakthrough come from new engine technology or from a new fuel?

Of late, researchers are working to introduce Advanced Combustion Engines in pursuit of additional emissions and fuel economy improvements. It is noteworthy that the successful introduction of this technology will almost certainly require a step change improvement in fuel quality.

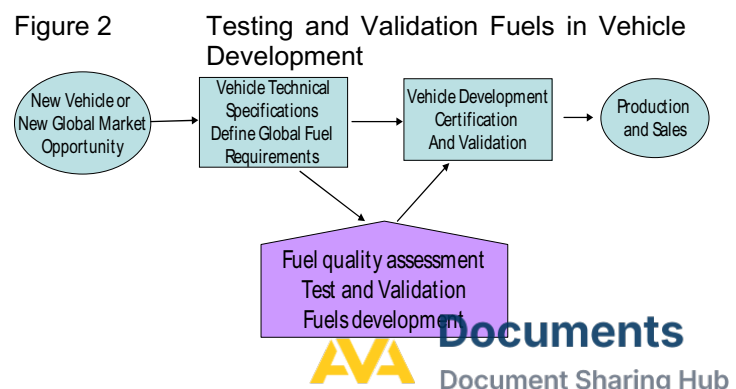
Bio-fuels are also making inroads and industry is developing performance standards and product specifications that will enable vehicle makers to confirm they can continue to provide warranty protection on the engine, fuel handling system, and OBD. Each variation and type of Alternate Fuel must be tested independently and in combination with conventional and other alternate fuels. Each fuel variable must be submitted to the same regimen of operating cycles and climate conditions. Test Fuels are also being developed for this sector so that engine and vehicle manufacturers can continue to do extensive testing to continue to provide warranties on their vehicles, validate the improvements in various engine configurations and improve their engine and OBD designs to better exploit the opportunities generally associated with alternate fuels.

Specifications of fuels are usually compromised between how the fuel can be processed and what end users want to accomplish. Thus, there are very few fuel specifications that are perfect in every respect. It is an ongoing but necessary requirement that fuel producers and distributors maintain quality in the market place but this can also be a source of disagreement among stakeholders. Therefore some testing and validation fuels are created to be representative of the largest percentile of market fuels possible. In other instances, a 95% Fuel is of higher quality than all except 5% of fuels in the applicable market being studied.

Chemical resistance and compatibility testing is a requirement for vehicle hardware. This is critical to avoid premature failures of vehicle components. Efforts are made to avoid component failure in view of the potential for consequences related to safety, environmental, warranty, quality ratings, and reputation. Testing and validation fuels are blended to standardized specifications to simulate poor quality market fuels for use in accelerated testing to simulate use over the expected vehicle service life..

In summary, a robust vehicle design process is based on performance requirements established by OEMs and applicable regulatory organizations, with strong consideration given to the intend use of the vehicle.

This process can be outlined in the flowchart in Figure 2



Development of testing and validation fuels in the US is more or less in line with the evolution of engine technology developments. For example, reference fuels were developed and supplied in the early 1950's to establish the octane number for gasoline and the cetane value of diesel fuel. Values were established based on the use of Primary Reference Fuel Isooctane with a Research Octane Number (RON) and Motor Octane Number (MON) of 100, and Primary Reference Fuel n-Heptane with a RON and MON value of 0.

A CFR (Co-ordinating Fuel and Equipment Research Committee) Knock Engine is used to determine when a test fuel will knock by blending corresponding Octane Number Reference Fuels that knock above and below the fuel being tested to establish the octane value of the fuel being tested. The RON is a measure of a fuels resistance to premature detonation or auto-ignition under mild driving conditions and light to medium loads. The MON is a measure of a fuels resistance to premature detonation or auto-ignition during severe high speed or high load driving. For example a high load is exerted on the engine when proceeding at a high rate of speed from a dead stop.

These products are still used for this purpose. Octane Values are recognized worldwide with ASTM D2699 and D2700 covering RON and MON Octane Analysis in the US and DIN EN ISO 5163 and 5164 covering MOZ and ROZ analysis in Europe.

Diesel Fuels are ranked by Cetane Number (ASTM D 613 or DIN ISO 5165) and Cetane Index (ASTM 976 or DIN ISO 4264, and ASTM D 4737) values. In general, a diesel fuel with a higher value auto-ignites easier on the power stroke. This also translates to smoother engine operation compared to a diesel fuel with a low cetane value, and improved combustion and emissions. The Cetane Number is obtained using a test apparatus similar to the CFR Octane Test Machine. The Cetane Index is a calculated value based on the specific gravity and 50% (or other) boiling range of the fuel.

Another critical Reference Fuel is Aviation Check Fuel which measures power ratings for Reciprocal Piston Engines based on RON and Supercharge Rating Values.

ASTM through Section 1E on Combustion Materials provides oversight to review and update test precision on Reference Fuel Test apparatus and procedures. Other activities include coordinating Reference Fuel Certifications requiring multiple tests by the National Exchange Group (NEG), new test development, and editorial and other amendments on existing tests.

In 1968, the Coordinating Research Council (CRC) issued one of its first reports on "The Effects of Gasoline Properties on Carburetor and PC Valve Deterioration"

(CRC Project CAPE 2-68. This non-profit organization directs various engineering and environmental studies on the interaction between vehicles and petroleum products based on committee goal setting. The current Sustaining Members of CRC are the American Petroleum Institute (API), the Society of Automotive Engineers (SAE) and automobile manufacturers (General Motors, Ford Motor, Chrysler, Toyota, Volkswagen, and Honda)..

The U.S Congress in 1970 passed the Clean Air Act that empowered the US Environmental Protection Agency to be the primary custodian for the enforcement of Clean Air Standards. Early milestones included mandating that OBD type systems be able to tell vehicle owners when the EGR System needed to be serviced in 1971, eliminating the use of TEL in commercial gasoline in 1973, implementing the use of catalytic converters on all gasoline powered vehicles in 1975, and increasing emission standards that in effect created a quick transition to Throttle Body, and then Port Fuel Injectors.

In 1975, the Energy Policy and Conservation Act implemented Corporate Average Fuel Economy (CAFE) standards and required the Department of Transportation to administer the standards and the Environmental Protection Agency to administer fuel economy test procedures. When first implemented, passenger cars averaged about 18 mpg. Current 2008 MY rules set a CAFE standard of 27.5 mpg for automobiles and 22.5 mpg for light trucks. However, as a result of the Energy Independence and Security Act of 2007, CAFE standards will be steadily increasing in order to achieve a combined car and truck industry average of 35 mpg in 2020

The Clean Air Act of 1970 made EPA responsible for certification and enforcement of emissions standards for new vehicles. EPA's compliance program includes in-use testing of vehicles during their useful life. If an emissions noncompliance is identified, a manufacturer could be subject to an expensive emissions recall

A common test fuel is used for Emissions and CAFE testing in spark ignition engines. The Unleaded Test Gasoline 96 RON (UTG-96) test fuel specifications are outlined in the Code of Federal Regulations (CFR). Specifications for UTG-93 and UTG-91 are also included in support of emissions testing for small 2 and 4 cycle engines.

The specifications for Unleaded Gasoline are defined by ASTM D 4814. It defines Reid Vapor Pressure, volatility and characteristics to be used in certain regions of the U.S., based on weather conditions and altitude. Refiners are free to determine the Keep Clean and Clean up detergent additives they want to use and to give their fuel a market or brand name.

Diesel Fuels in the U.S. are governed by ASTM D-975. For both gasoline and diesel fuels, the specifications are being expanded to cover mixtures with bio-fuels such as E-10 (90% gasoline with 10% ethanol) and B-5 (95% diesel fuel with 5% biodiesel)..

In 1978, legislation was also passed to support the use of Hydrocarbon Gasoline with 10% ethanol which was referred to as Gasohol. While it's use was considered optional, it was an early effort to introduce renewable fuels into the supply chain and promote clean air.

In 1990, Amendments to the Clean Air Act tied Air Quality of a State or Region to a requirement to use Gasoline containing 2.0 wt % oxygen in the summer and 2.7 wt% oxygen in the winter months. Other changes were made to the fuel as well, all with the intent to reduce the formation of ozone precursors like NOx, VOC and CO emissions from the tail pipe emissions of spark ignition engines.

In 1999, the Auto/Oil Air Quality Research Improvement Program, (AQRIP) administered by the CRC on the best engine reduction technology available at the time identified the formulation that provided the best emissions performance. This work led to the introduction of Phase II Reformulated Gasoline also known as Federal RFG, and another important base line test gasoline, RF-A Industry Average Test Fuel.

In 2005, a Renewable Fuels mandate was signed into law which dropped the Oxygenate Requirement for Summer and Winter RFG in favor of a escalating requirement for the sale of renewable fuels that targets sales o 7.5 billion gallons by 2012.

More recently, further reductions of sulfur content in both gasoline and diesel have occurred. Gasoline sulfur has been reduced from approximately 450 ppm down to a range of 40 to 50 ppm in non-oxygenated fuels and less than 20 ppm in oxygenated gasoline. On road Ultra Low Sulfur or Diesel 2007 is now limited to 7 – 15 ppm.

In 1975, California was one of the first states to form a State Air Resources Board (CARB). Now each of the 50 states in the U.S has a State Environmental Agency. California has been at the point on several fuel related air quality initiatives and remains a recognized leader in the establishment and enforcement of aggressive emissions reduction targets. The Clean Air Act allows only California to set new vehicle emissions standards, but other states may copy California's standards if certain conditions are met. The Clean Air Act also allows CARB to regulate fuels and fuel additives, but the authority of other states to regulate fuels and additives is limited. Notable CARB accomplishments include requiring the use of specifications in line with the top 95% of Market Fuels (95 Percentile Fuels) by limiting the

aromatic content of diesel fuels to 10% as defined in their Tier 2 2004 Diesel Fuel Specification, adopting the use of Reformulated Gasoline with ethanol, known as California Phase III Reformulated Fuel, and eliminating the use of MTBE in favor of ethanol along with 16 other states in the U.S.

Figure 3 Timeline of Development of Certification Fuels and Engine Technology

Diesel - Engine Technology		Certification Diesel Fuel	Gasoline-Engine Technology		Certification Gasoline
- Indirect Injection	1993 EURO I	CEC RF-03-A-84 S < 500 mg/kg	- Catalytic converter	1993 EURO I	CEC RF-08-A-85 S < 400 mg/kg
- Mechanical Pump			- Lambda Sensor		
- Exhaust Gas Recirculation	1996 EURO II		- Electronic Fuel Injection	1996 EURO II	
- Oxidation Catalyst		CEC RF-06-99 S < 300 mg/kg Polycyclic Aromatics 3 – 6 %m/m	- Multipoint Fuel Injection		CEC RF-02-99 S < 100 mg/kg Aromatics max. 40 % v/v
Direct Injection	2000 EURO III		- On Board Diagnostic (OBD)	2000 EURO III	
- Turbo					
- Common Rail		CEC RF-06-03 S < 10 mg/kg Polycyclic Aromatics 3 – 6 %m/m	- Exhaust Gas Aftertreatment Improvement	2005 EURO IV	CEC RF-02-03 S < 10 mg/kg Aromatics max. 35 % v/v
- Advanced Common Rail	2005 EURO IV				
- Diesel Particulate Filter		CEC Code tbd S < 10 mg/kg FAME Content 4,5 - 5,5 %v/v	- Homogenous Charge Compression Ignition (HCCI)	2009 EURO V	CEC Codes tbd S < 10 mg/kg Various EtOH contents
- NOx Trap	2009 EURO V				

In Europe, Specialty Fuels Blenders started responding to industry needs for testing and validation fuels as early as 1968. Initially, this was in response to U.S. legislation that established emissions targets engine manufacturers had to meet in order to obtain certification for their cars. Until then, non U.S. based OEMs had imported an American test fuel which was used to optimize the ignition timing of the export models with respect to CO-emissions. Test activities increased to such an extent that OEMs had to look for a European supplier of the test fuel. Thus one the first tightly specified fuel called, Indolene 30 was developed and subsequently supplied to European OEMs. This fuel was blended to the appropriate specifications to support vehicle testing for CO Emissions.

In order to stay abreast of new developments, European Test Fuel suppliers joined the DKA (Deutscher Koordinierungs-Ausschuss), the German national organization within the Coordinating European Council (CEC) for the Development of Performance Tests for Transportation Fuels, Lubricants and other Fluids. It was soon established that in addition to the American emission tests needed for export vehicles, a second set of European certification fuels would be needed for

vehicles that would be certified for use in Europe. This was a result of differences in climate and fuel quality, as well as the desire for independence. As a result the first “Informal CEC-sponsored Meeting” took place at the Paris Airport January 22, 1969.

The subject of the meeting was: “Reference Gasoline for Emissions Type Approval Tests”. From this meeting, the first CEC specifications for reference fuels were developed with the following designations:

ERF / G30, also called “Indolene®” (according to US-specs)

ERF / G1, (specification adapted to European conditions)

These fuels were so-called “certification fuels”.

Soon after, the first reference Diesel fuel was defined.

The designation was:

ERF / D1, (for Diesel exhaust smoke measurement)

The testing activities which then followed provided early insights into the effects of varying fuel quality on exhaust emissions. Before long the experience gained was utilized in the development of additional and increasingly sophisticated engine tests. Soon tightly specified fuels were also demanded by the automotive industry for “non-emission testing”, for example for lubricant or additive development testing. Today reference fuels with certain tightly specified properties are an essential element of engine development. The CEC Reference Fuel Manual alone currently defines some forty fuels for a variety of applications.

CEC was formed in November 1963 with the primary objective of developing performance tests for the evaluation of transportation fluids (fuels, lubricants, coolants, and so on). CEC is legally registered in Belgium as a non-profit organization. Membership of CEC comprises representatives from the oil, motor, additive and associated industries⁵

As part of the CEC test procedures the fuels to be used are defined in dedicated specifications.

In addition to the chemical and physical requirements on the fuel, performance criteria measured in the engine also can be defined. As an example please see the specification of CEC-RF-89-T-96 where an inlet valve deposit (IVD) engine test according to CEC test procedure F-20-98 is mandatory.

Table 2 Specifications of Testing Fuel for IVD
CEC Experimentation Fuel RF-89-T-96 (Fuel Economy Gasoline)

Parameter	Method	Unit	Min.	Max.
RON	EN 25164-1993		95	
MON	EN 25163-1993		85	
Sensitivity			report	
Density at 15 °C	EN ISO 12185	kg/m³	725	745
Reid Vapour Pressure	EN 12	kPa	65	75
Distillation	EN ISO 3405			
I.B.P		°C	report	
- 70 °C		% v/v	25	35
- 100 °C		% v/v	43	65
- 180 °C		% v/v	85	
F.B.P		°C		215
Residue		% v/v		2
Hydrocarbon Analysis	ISO 3837			
Olefins		% v/v	10	14
Aromatics		% v/v		40
Saturates		% v/v	balance	
Benzene	EN 12177	% v/v		5
Lead Content	EN 237	g/l		5
Sulphur Content	ISO 4260	% m/m		0.04
Phosphorus Content	ASTM D 3231	g/l		0.0013
Solvent Washed Gum	EN ISO 6246	mg/100		4
Copper Corrosion	EN ISO 2160			1
Oxidation Stability	EN ISO 7536	min.	480	
Alcohol and other Oxygenates	ASTM D 4815	% v/v		0.1
Carbon Content	ASTM D 3343	% m/m	to report	
Hydrogen Content	ASTM D 3343	% m/m	to report	
Carbon/Hydrogen Ratio	ASTM D 3343		to report	
Hydrogen/Carbon Ratio	ASTM D 3343		to report	
Net Heating Value	ASTM D 3338	MJ/kg	to report	
Net Heating Value	ASTM D 3338	Btu/lb	to report	
Inlet Valve Deposit	CEC-F-20-T-96	mg/Cyl.	max. 25	

Additive 600 mg/kg

Other regions have not felt it was necessary to develop the comprehensive requirements that are in place in North America and Europe. The other regions have opted to build on what is known and apply it for their vehicles destined for the rest of the world in order to meet clean air requirements while sustaining economical development.

GLOBAL MARKET FUEL QUALITY AND EMISSION REQUIREMENTS

Due to variations in the composition of crude oil and the levels of refinery technology available in different regions and countries, the specifications that fuels are produced to may vary. In some countries, the high olefin content of the fuel is a well recognized characteristic of gasoline produced in the region. It is well known that fuels with high olefin content may have poor stability depending on fuel storage and handling conditions. There is also a strong link between high olefin content and fuel intake system deposits.

The following chart shows the olefin content from a Gasoline Survey taken in the summer of 2007 (SGS Worldwide Gasoline Surveys 2007).