Gasoline Vapor Pressure & US RVP Control

Glenn W. Passavant

MWV

August 2015

Purpose & Overview

- Purpose of this presentation is to discuss gasoline vapor pressure, RVP, and the effect on vehicle evaporative emissions
  – Review key terms and concepts
  – Overview of current US program
  – Vehicle evaporative emission effects
  – Gasoline/alcohol blends
  – RVP and Emission Effects for Mexican Vehicles

Key Terms and Concepts

- Evaporation: - the change of phase from a liquid to a gas; the rate is strongly dependent on temperature
- Volatility – property of a liquid fuel which defines its evaporative characteristics.
- Volatile fuel is any fuel that is a gas at atmospheric pressure; gasoline, methanol, ethanol, natural gas, and LPG are volatile fuels.
- Volatile liquid fuel - a fuel that is liquid at atmospheric pressure and has an RVP higher than 2.0 psi - gasoline, ethanol, and methanol are good examples. Diesel fuel is not considered volatile.
- True Vapor Pressure (TVP) - is a common measure of the volatility. It is the absolute pressure of a vapor in thermodynamic equilibrium with its condensed phases in a closed container.
  - Vapor pressure increases exponentially as temperature increases. It depends on no other parameter.
  - Compounds with high TVPs have low boiling points.
- Partial pressure – the vapor pressure of any given component in a mixture; the TVP is the sum of the partial pressures of all gases in the mixture.
- Boiling point: the temperature where the TVP equals the external pressure.
  - Varies with atmospheric pressure, elevation, or fuel tank pressure. The boiling point of a mixture such as gasoline is when the sum of the partial pressures equals external pressure.
  - Mixtures such as gasoline often are referred to as having a “boiling range” not just a single boiling point.

Reid Vapor Pressure

- Reid Vapor Pressure (RVP) – is the absolute vapor pressure of a volatile fuel at 37.8C (100 °F) as evaluated using ASTM method D323A. For gasoline/oxygenate blends use ASTM D4953.
  - The term dry vapor pressure equivalent (DVPE) (ASTM D5191) is often used interchangeably. DVPE and RVP values for a fuel sample are close but not identical.
  - TVP and RVP are numerically very similar at 100 °F. However, at temperatures less than 100 °F RVP>TVP and at temperatures greater than 100 °F TVP>RVP.
  - ISO 3007-1999 is the RVP test procedure used in Europe.

- RVP is the most commonly used metric in discussing automotive gasoline vapor pressure and its regulation.

Gasoline and Gasoline Vapor

- Gasoline is a mixture of hydrocarbon substances of various formulas and widely-varying formula weights. Certain of its properties are subject to specification limits, but the composition is not. No two batches of gasoline are ever exactly alike.

- Not being a pure substance, gasoline has no single boiling point. Instead, the lighter fractions start boiling out at 90-100 °F, with more and more evaporated as the liquid temperature increases, until the final heaviest fractions evaporate in the 300-400°F range. This behavior creates what is sometimes called a “distillation curve”.

  - Although the molecular formula varies, it is close to $C_{7.4}H_{13.7}$ with a formula weight of 100 to 105 g/mole.

- Vapor pressure or RVP is a critical characteristic of gasoline

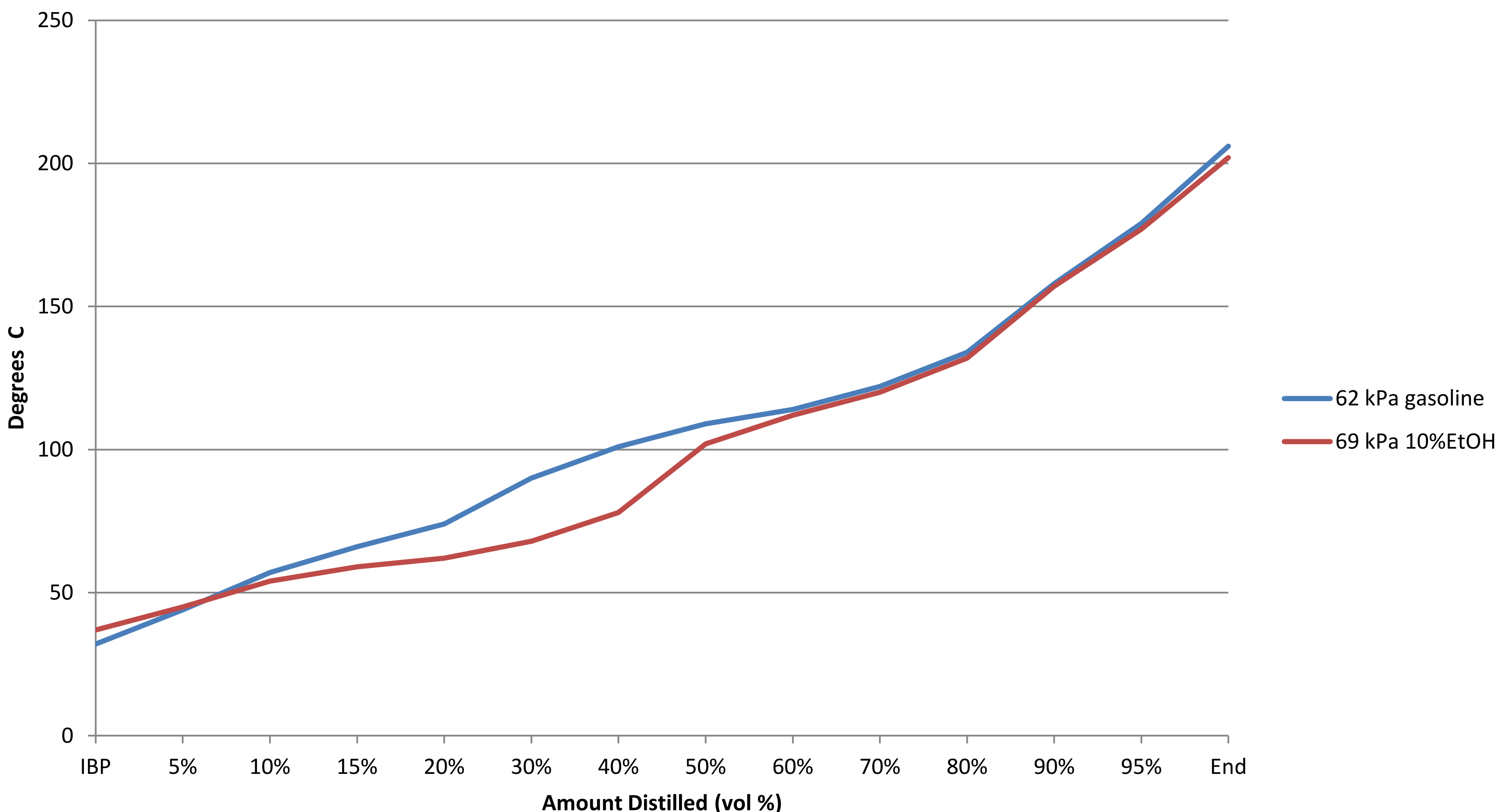
  - High RVP compounds are needed for vehicle starting and warm-up for spark-ignition engines.

  - RVP is controlled to reduce vapor lock concerns for fuel systems where they still exist.

  - Most of the RVP is provided by isomers of propane, butane, and pentane … butane is blended in various amounts to adjust RVP.

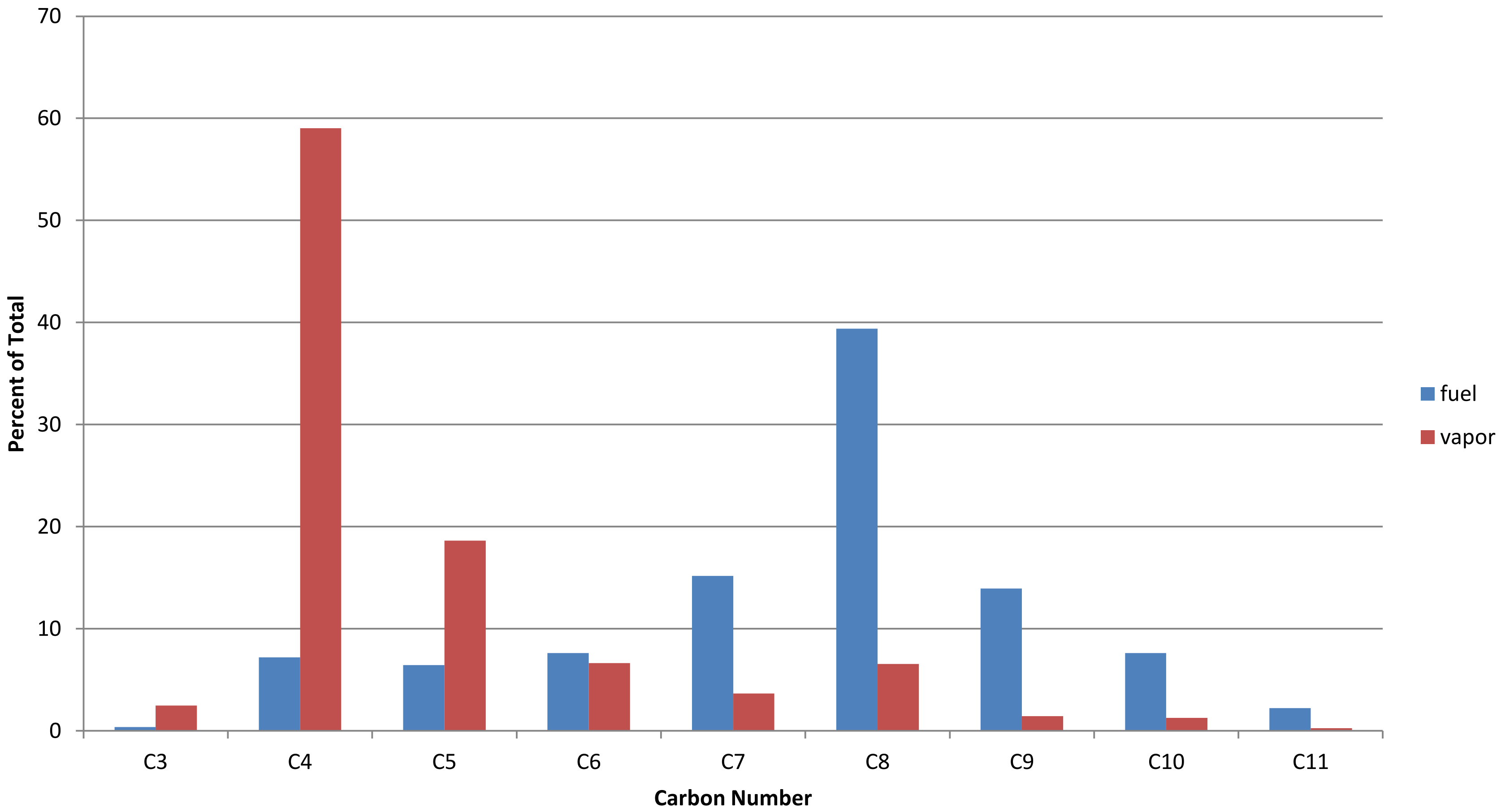
  - However, most of liquid gasoline itself is comprised of heavier molecular weight compounds such as larger chain alkanes and aromatics.

Typical Distillation Curves



SAE Paper 852116: “Volatility Characteristics of Gasoline-Alcohol and Gasoline-Ether Fuel Blends “

Example: Gasoline Vapor vs. Liquid (10.3 RVP ~70kPa)



SAE Paper 880712 : "Factors Influencing the Composition and Quantity of Passenger Car Refueling Emissions - Part II"

Why Control RVP? – O_3 Reactivity

- Ozone is formed through photochemical interactions of VOCs and NOx. Many different VOCs are emitted into the atmosphere, each reacting at different rates and with different reaction mechanisms.
- These differences in effects on ozone formation are referred to as the ozone "reactivity" of the VOCs and are quantified through RAFs.
- Ozone RAFs have been determined for each VOC.
- The lighter weight compounds which are dominant in gasoline vapor are moderately reactive. However, they represent such a large fraction of the total emission mass, that reducing lighter ends through RVP control is a major ozone reduction strategy.
- In this example, C3-C5 compounds represent 65% of ozone forming potential emissions from gasoline vapor.

Compound	mass % liquid*	mass % vapor*	CA ARB RAF**	mass vapor % wtd RAF
propane	0.06	1.9	0.49	0.65%
n-butane	5.27	47.6	1.15	38.30%
n-pentane	1.21	3.1	1.31	2.84%
n-hexane	1.28	0.9	1.15	0.72%
isobutane	0.45	6.1	1.23	5.25%
isopentane	4.92	17.6	1.45	17.86%
2,2-dimethylbutane	0.01	0.7	1.17	0.57%
2,3-dimethylbutane	2.2	2.6	0.97	1.76%
2-methylpentane	1.81	1.9	1.5	1.99%
3-methylpentane	1.28	1.2	1.8	1.51%
2,4-dimethylpentane	1.78	0.9	1.55	0.98%
3,3-dimethylpentane	3.79	1.2	1.2	1.01%
3-methylhexane	1.3	0.4	1.61	0.45%
2,2,4-trimethylpentane	9.12	2.2	1.2	1.85%
2,3,4-trimethylpentane	5.41	0.7	0.96	0.47%
methylcyclopentane	0.47	0.3	2.06	0.43%
2-methyl-1-butene	0.16	0.5	6.4	2.24%
cis-2-butene	0.07	0.5	14.24	4.98%
trans-2-butene	0.03	0.5	15.16	5.30%
cis-2-pentene	0.21	0.5	10.38	3.63%
toluene	18.01	2.3	4	6.44%
benzene	2.9	1.5	0.72	0.76%

* SAE Paper 860086: “Composition of Vapor Emitted from a Vehicle Gasoline Tank During Refueling”

** 17 CCR 94700 : “Maximum Incremental Reactivity Values for Compounds - 2010”

What Is Considered in Setting RVP Specifications?

- RVP is one of the gasoline characteristics that is specified in consensus standards (ASTM) and in some cases in government regulations.
  - Covers vapor pressure and vapor lock
  - Key factors are temperature and altitude

- Limits are established in terms of vapor-liquid ratio (D5188), vapor pressure (D5191), and distillation properties (D86).

- RVP for a given region varies based on temperature and altitude.
  - Regions are usually some political subdivision such as a state line or latitude/longitude coordinates
  - Incorporate allowance for refiner to retail distribution times
  - Incorporate regulatory limits as well as provisions such as ethanol blend waivers.

- Vapor pressure for a given batch of gasoline is finished by adding the needed amount of butane.
  - n-butane 52 psi RVP
  - Isobutane 71 psi RVP

- RVP control reduces upstream and mid-stream gasoline vapor emissions (distribution, storage) and vehicle emissions. In the US, the upstream/midstream emissions inventory for VOC is about the same as that for motor vehicle evaporative emissions.

Altitude/Elevation

- Vapor pressure increases exponentially with temperature.
- “Boiling” occurs when the vapor pressure equals atmospheric pressure.
- Additional consideration needed when setting RVP specifications for high altitude areas.
- Illustration of altitude effect.

Diurnal Emissions: 65 -105°F (9 RVP)			
City	Altitude	Pressure	g/gal of tank vapor space
Los Angeles	100 ft.	14.6 psi	4
Denver	5280 ft.	12.2 psi	6
Mexico City	7350 ft.	11.2 psi	6.5

-- Effect would be greater for 10% ethanol blend.

US REQUIREMENTS

Overview

- Traditionally, US refiners generally followed ASTM D4814 RVP recommendations.
- In mid 1980s, there was a gradual upward trend in US RVP which led to increased VOC emissions from the gasoline transportation and storage system as well as from vehicles.
- A five year long public policy debate ensued which involved refiners, auto industry, and government.
- This eventually led to California ARB and EPA volatility regulations for summer RVP (Apr15th-Sept15th). See 40 CFR 80.
- Ultimately, US Clean Air Act was amended to include not only these volatility provisions, but also: (http://epa.gov/OTAQ/fuels/gasolinefuels/volatility/standards.htm)
  - Reformulated gasoline (RFG) (based on model)
    - CAA mandatory and opt-in [part or all 17 states and DC; about 30% of summer consumption]
  - Mandatory RVP controls in some or part of 40 states (7-9 psi RVP)(~47-62kPa)
  - 1 psi RVP (6.9 kPa) waiver for 9-10% ethanol blends
    - US state may opt-out or enforce more stringent standard.
    - Waiver is not permitted for RFG.
    - It varies, but 55-60% of gasoline usually gets 1 psi waiver.
- RVP is controlled from refinery gate to retail. Base gasoline for alcohol blends needs to have low enough RVP so that blend still meets standard.

US ASTM Classifications for RVP and Distillation Temperature

D4814 – 13

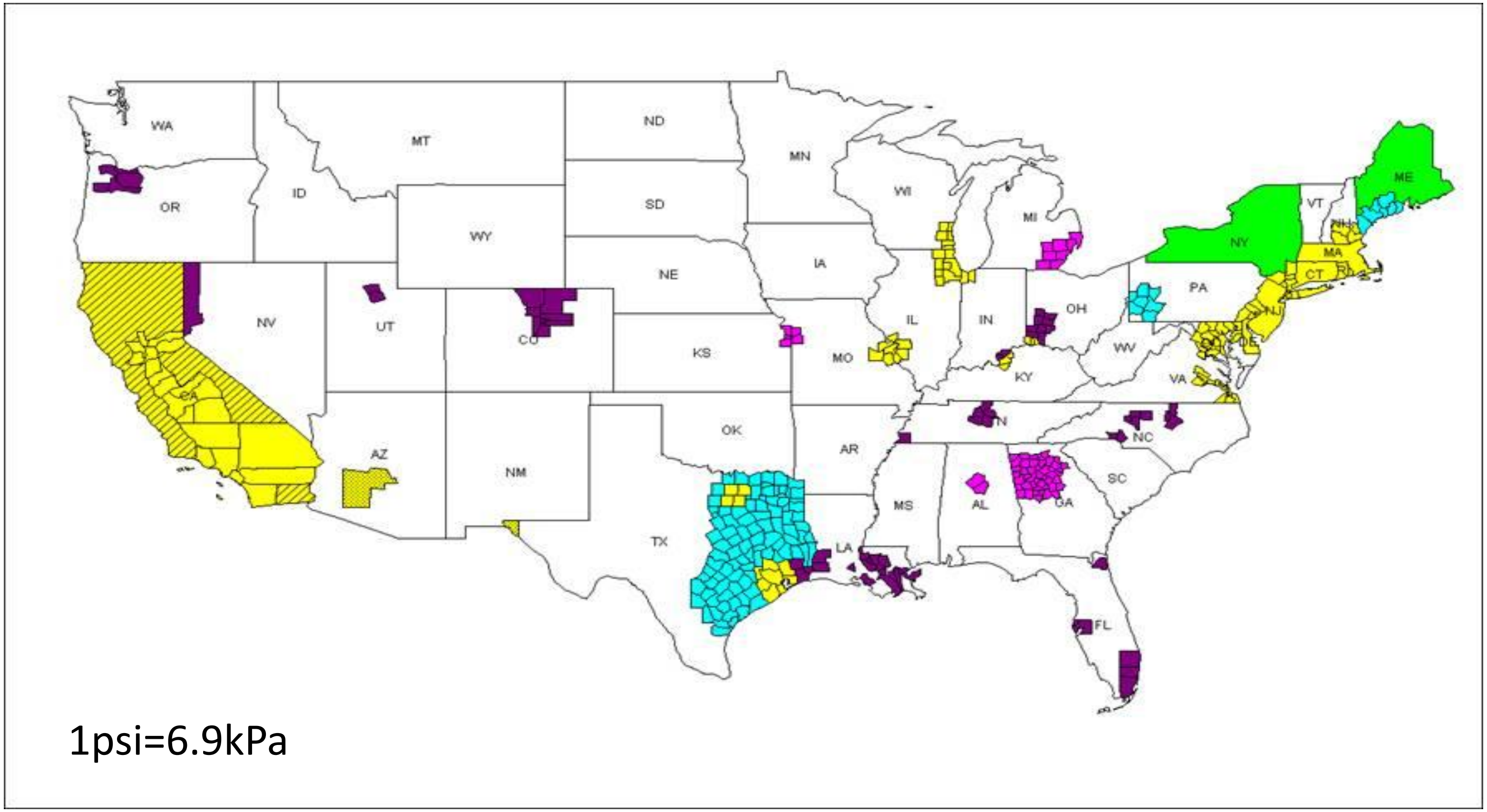
TABLE 1 Vapor Pressure and Distillation Class Requirements[A]

Vapor Pressure/ Distillation Class	Vapor Pressure,[B] at 37.8°C (100°F) max, kPa (psi)	Distillation Temperatures, °C (°F), at % Evaporated. max[C]					Distillation Residue, volume %, max	Driveability Index,[D] max, °C (°F) Derived[E,F]
		10 volume %, max	50 volume % min[G]	50 volume % max	90 volume %, max	End Point, max		
AA	54(7.8)	70.(158)	77(170.)	121(250.)	190.(374)	225(437)	2	597(1250.)
A	62(9.0)	70.(158)	77(170.)	121(250.)	190.(374)	225(437)	2	597(1250.)
B	69(10.0)	65(149)	77(170.)	118(245)	190.(374)	225(437)	2	591(1240.)
C	79(11.5)	60.(140.)	77(170.)	116(240.)	185(365)	225(437)	2	586(1230.)
D	93(13.5)	55(131)	77(170.)[H]	113(235)	185(365)	225(437)	2	580.(1220.)
E	103(15.0)	50.(122)	77(170.)[H]	110.(230.)	185(365)	225(437)	2	569(1200.)

TABLE 3 Vapor Lock Protection Class Requirements[A]

Vapor Lock Protection Class	Temperature, °C (°F) for a Vapor-Liquid Ratio of 20, min[B,C]	Special Requirements for Area V of D4814 Temperature, °C (°F) for a Vapor-Liquid Ratio of 20, min
1	54 (129)	60. (140.)
2	50. (122)	56 (133)
3	47 (116)	51 (124)
4	42 (107)	47 (116)
5	39 (102)	41 (105)
6	35 (95)	35 (95)

US RVP and Discussion of ASTM Texas (Apr-Oct)



CaRFG3 EPA RFG RVP 7.0 RVP 7.8 RVP 8.0 RVP 8.8 RVP 9.0 RVP 10.0

ASTM Texas	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
East 99° Long.		13.5	11.5			9			10	11.5		13.5
West 99° Long	13.5	11.5	10			9			10	11.5		13.5

VEHICLE EVAPORATIVE EMISSIONS

Categories of Evaporative Emissions

	SOURCE ON VEHICLE	**CAUSE OF VAPOR GENERATION**
DIURNAL	Tank vent, AIS	Daily temperature cycle
REFUELING	Filler pipe or tank vent	Displacement of vapor by liquid
RUNNING LOSS	Tank vent and canister vent	Heat from engine, exhaust system, fuel pump, and road surface
HOT SOAK	Tank vent, AIS	Latent fuel, engine, and exhaust system heat
PERMEATION	Tank shell, hoses	Diffusion through plastics

RVP has a Significant Effect on Vehicle Evaporative Emissions

- RVP, ambient temperature, elevation, elements of vehicle fuel and evaporative control system design, and driving patterns all affect evaporative emission rates.

Estimated Emissions Impact of an 8 kPa Difference in RVP for Vehicles Meeting Current Mexican Evaporative Emission Standards (2.0 g/test hot soak + diurnal)

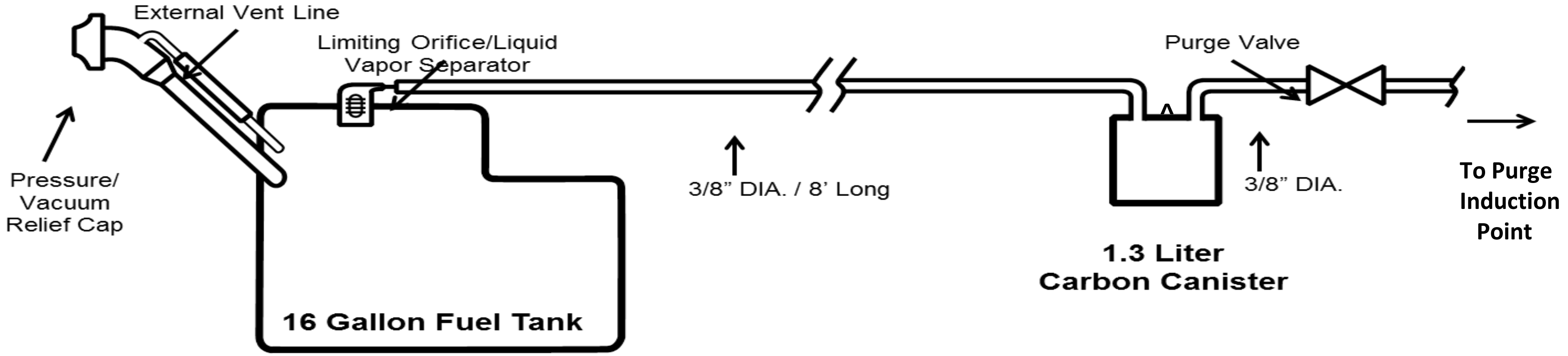
Evaporative Emission Category	Emissions at 56 kPa	Emissions at 64 kPa	% change	
Diurnal (65-105°F) g/gal of vapor space	3.3	4.3	31%	SAE 892089
Refueling g/gal of fuel dispensed	3.8	4.3	13%	SAE 2010- 01-1279
Running Loss g/km	0.11	0.18	60%	SAE 931191
Hot Soak g/test (75°F) LDV PFI	0.34	0.36	6%	EPA 420-R-01-026
Permeation	No relationship with RVP			

Certification vs. In-use RVP

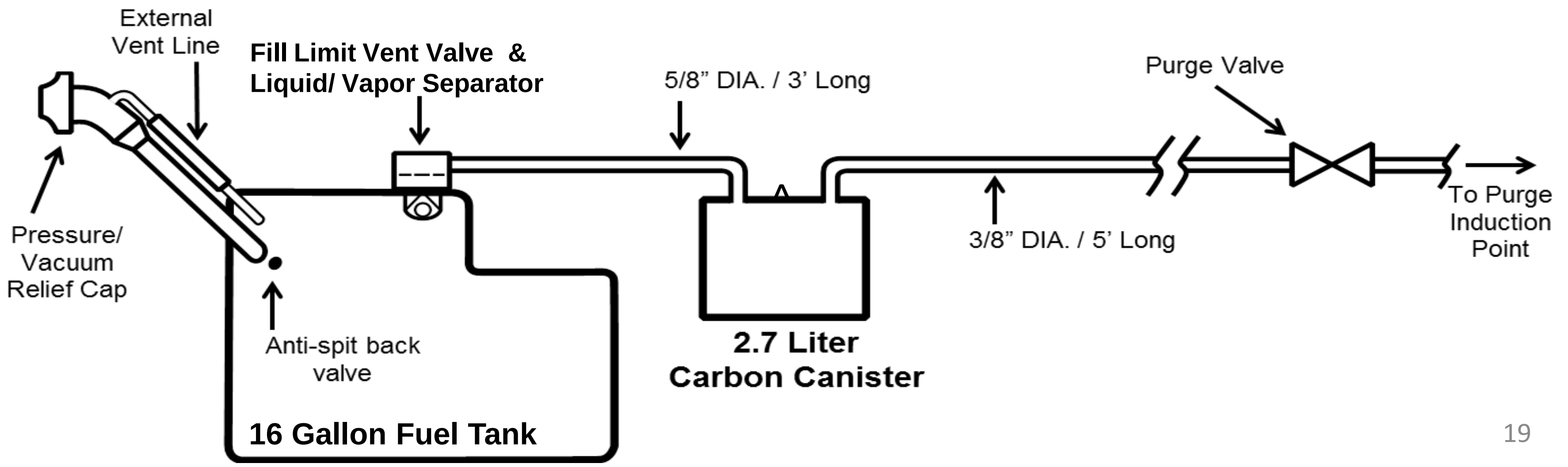
- KEY PRECEPT: The US EPA and California ARB view vehicles and fuels as a system in the context of emission control. Fuel quality impacts emissions and the performance of emission control systems.
  - RVP and ambient and fuel temperatures are the key predictors of vehicle evaporative and refueling emission rates.
- It is very important that the RVPs and temperatures specified in the emission test procedures lead to control systems which perform well in-use even as these temperatures and RVPs vary over the year.
    - Especially critical for canister capacity and purge strategy
    - Purge effectiveness is sensitive to elevation since air density is lower at higher altitudes
- US Tier 2 and LEV II test procedures (RVP & temperature requirements) for ORVR and evaporative emissions control were selected to be consistent with expected in-use RVP and temperature profiles.
  - The RVP and ambient/fuel temperature values in the test procedures together with the driving cycles will force the needed vehicle system design features including hardware and calibrations.
  - Thus, control is achieved as in-use RVPs decrease and ambient/fuel temperatures increase (Spring-Summer) and as in-use RVPs increase and ambient/fuel temperatures decrease (Fall-Winter).
- To maximize reductions action is needed to improve test procedures and adopt more stringent vehicle evaporative and refueling emission standards.

Evaporative System Technology Upgrade

Pre-enhanced Evaporative Control System



Integrated ORVR/Tier 2 Evaporative Control System

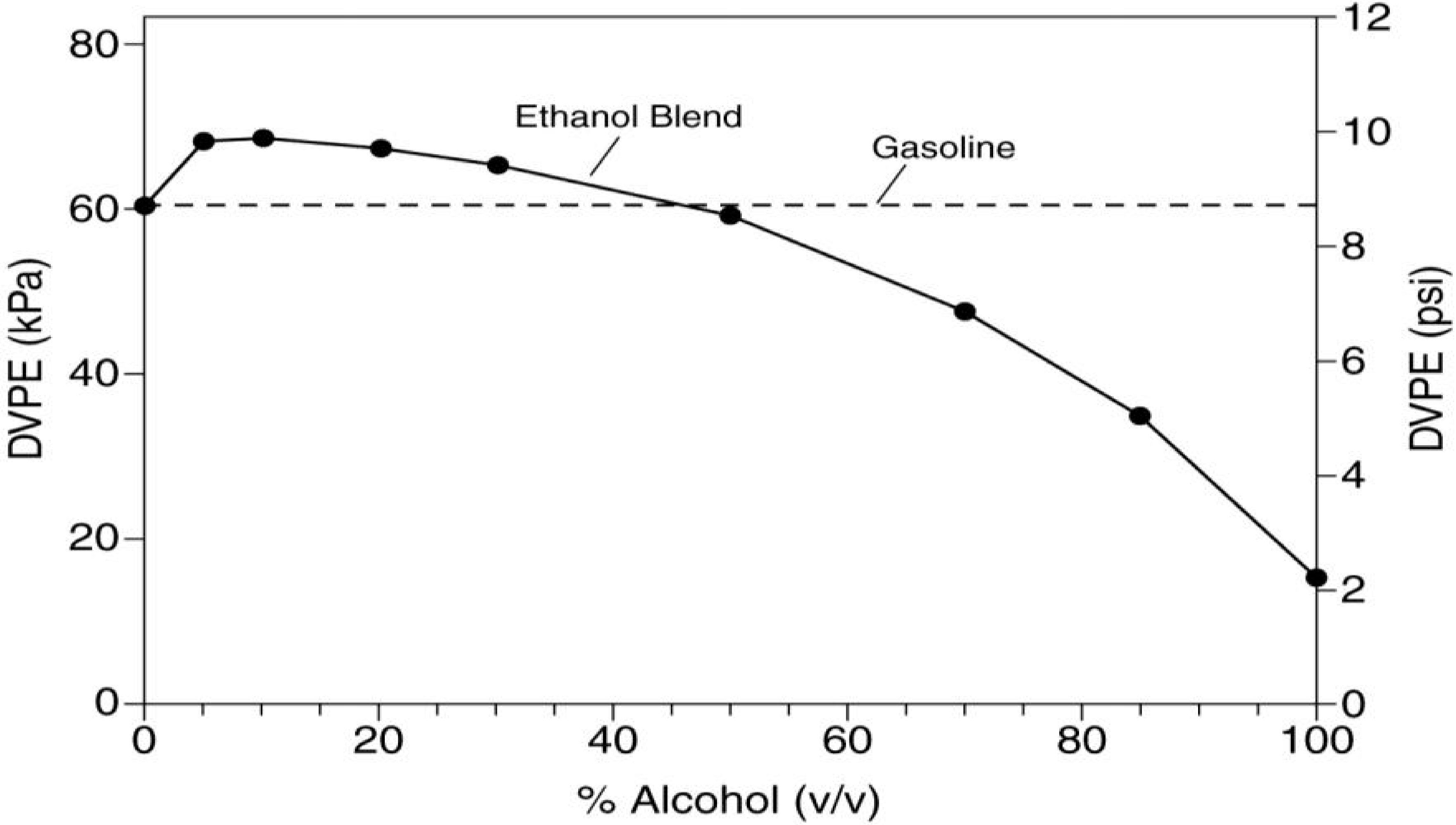


GASOLINE/ALCOHOL BLENDS

Gasoline/Alcohol Blends

- Alcohols (ethanol, methanol, TBA) and ethers (ETBE & MTBE) gasoline blends were evaluated and marketed in the 1980s.
    - Fuel demand and energy security
    - Octane enhancer (ethanol octane blending value is about 112)
    - Environmental protection & legislative mandates (cold CO, Reformulated Gasoline, Renewable Fuels)
- Today the most common blend in North America is gasoline/ethanol blended at 6-10%. In the US today it is very close to 10%.

RVP Effects of Ethanol



Effects of Ethanol on Vapor Emissions

- Ethanol can be blended three ways:
  - Splash blend: ethanol increases fuel volume and RVP
  - RVP control: ethanol replaces fuel volume but butane blending is modified to account for RVP effect
  - Matched volatility: butane blending and distillation curve are modified to get same overall distillation temperatures
    - Note: Ethanol MW is 46; butane is 58… ethanol RVP 2.0 psi

Central Issue for Vehicle Emissions is Volatility of E10 Blend

Category	Evaporative	Running Loss	Refueling	Sources
Splash Blend	25%	28%	5%	SAE 892089, SAE 931991
RVP Control	- -	22%	--	SAE 2010-01-1279
Matched Volatility	--	- -	- -	SAE 861556

Permeation

- Permeation is the migration of fuel hydrocarbons through plastic/elastomer materials in the fuel system. Sometimes referred to as resting losses.
  - Most common in plastic fuel tanks and fuel lines.
  - Varies directly with fuel temperature, wetted fuel system surface area, soak time, and molecular diameter. Not RVP dependent.
- Permeation occurs with both gasoline and gasoline/alcohol blends.
- For highway motor vehicles there are no specific standards or test procedures. Permeation emissions occur in the SHED tests; they are most notable in diurnal measurements. Fuel systems with gasoline/ethanol blends have larger permeation related emissions than gasoline alone.

Model Year	Tank Volume	Tank Material	Average Diurnal Emissions g/day (65-105°F 40% fill) Ethanol Blend	Gasoline	g/day difference	% greater
1978	18.1	metal	3.74	2.44	1.33	53
1985	13.2	metal	4.67	1.77	2.9	164
1989	16	metal	2.63	0.82	1.81	221
1991	17	metal	2.25	1.91	0.34	34
1993	23	plastic	4.89	3.55	1.34	37
1997	20	plastic	2.25	1.13	1.12	99
1999	13.2	metal	1.37	0.33	1.04	315
2000	20	plastic	1.43	0.58	0.85	146
2001	15.8	metal	0.76	0.22	0.54	245
			2.67	1.42	1.25	+88%

Source: Fuel Permeation from Automotive Systems CRC Project E-65

Commingling

- Commingling is the mixing of gasolines of different composition.
  - This is mostly an issue for motor vehicle fuel tanks, when the vehicle owner buys gasoline at different stations with different amounts of ethanol.
  - Effect varies with relative amounts of residual tank or dispensed fuels and their ethanol content.
  - Most notable effect on RVP is when E0 gasoline (such as RFG) is mixed with a blend as E10. The RVP of the fuel in the tank can increase by about 1 psi (10%).*
  - Also an issue for flexible fuel vehicles (FFVs) using E85. US EPA requires FFVs to certify refueling emissions using 10 psi RVP (69kPa) E10 fuel.

*SAE 940765: "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels"

Vapor Reactivity

- Fuel vapor composition for gasoline/ethanol blends is different than that of gasoline.
- Overall ozone reactivity is slightly better for ethanol blends versus gasoline.
  - Without RVP control the total mass of emissions for ethanol blend greater, leading to overall greater ozone reactive emissions to atmosphere.

	$gO_3/gVOC$	$gO_3/gVOC$	$gO_3/gVOC$
	9 psi RVP Gasoline	Splash blend E10	RVP controlled E10
Composite Reactivity	1.06	1.03	1.02
Mass Adjusted			
Composite Reactivity	1.06	1.29	1.02
% difference vs. gasoline		+25%	-4%

SAE paper 912429: "Composition and Reactivity of Fuel Vapor Emissions from Gasoline-Oxygenate Blends"

% of vapor mass	9 psi RVP	10% ethanol	10% ethanol
Compound	gasoline	splash blend	RVP control
Ethanol	0	7.15	6.86
Benzene	2.28	1.91	0.94
Toluene	2.71	2.09	1.65
Ethane	0.03	0	0
Propane	0.83	0.75	0.3
Isobutane	4.75	4.39	3.58
Isobutene	0.12	0.11	0
N-butane	39.23	36.58	33.74
trans-2-butene	0.52	0.48	0.46
cis-2-butene	0.26	0.24	0.22
3-methyl-1-butene	0.35	0.32	0.34
isopentane	24.93	23.69	26.16
2-methyl-1-butene	0.67	0.62	0.66
n-pentane	6.92	6.33	7.27
trans-2-pentene	1.15	1.07	1.15
cis-2-pentene	0.6	0.55	0.59
2-methyl-2-butene	1.56	1.44	1.59
2-2 dimethyl butane	0.36	0.35	0.42
3-methyl-1-pentene	0.25	0.23	0.26
2,3-dimethylbutane	2.31	2.21	2.55
2-methylpentane	2.05	1.95	2.27
3-methylpentane	1.21	1.15	1.32
2-methyl-1-pentene	0.21	0.16	0.17
n-hexane	0.9	0.82	0.93
trans-2-hexene	0.11	0.09	0.11
3,3 dimethyl-1-pentene	0.13	0.1	0.13
2,2 dimethylpentane	0.36	0.3	0.33
methylcyclopentane	0.94	0.84	0.94
2,3 dimethylpentane	1.49	1.4	1.54
3-methylhexane	0.29	0.27	0.28
2,2,4 trimethylpentane	2.11	1.96	2.2
n-heptane	0.14	0.13	0.13
2,4,dimethylhexane	0.24	0.2	0.34

RVP and Emission Effects for Mexican Vehicles

A Few Observations

- ASTM
  - Current ASTM specifications for Mexico have a structure like those for US.
  - Note that draft requirements look a bit better in that they replace kPa ranges by maximum values for each of the four classes. No mention of D,E.
  - They have no specific category for 48kPa which would be equivalent to that for California certification fuel (CA RFG3)
    - Current US ASTM points to regulations for those requirements.
    - Tier 2 uses 62 kPa (Class A). Tier 3 uses 62kPa with E10.
- Certification versus in-use requirements for fuel properties.
  - Moving forward, it is very important to remember that the certification fuel properties and vehicle test procedures must achieve good control with in-use conditions and fuels.
    - Be sensitive to relationship between purge volume, air density, and fuel RVP for high altitude regions.
- Gasoline/alcohol blend effects
  - The RVP effects of ethanol or any other alcohol must also be considered in certification and in-use RVP specifications to maximize control.

Current ASTM for Mexican Gasoline

TABLA 4. CLASE DE VOLATILIDAD DE LAS GASOLINAS DE ACUERDO A LAS ZONAS GEOGRAFICAS Y A LA EPOCA DEL AÑO (1)

MES	Noreste	Centro-Noreste	Sureste	Bajío	Pacífico				Centro	ZMVM y ZMG	Monterrey
					Z1	Z2	Z3	Z4			
Enero	C-3	C	B	C	B	B	B	B	C	AA-3	C
Febrero	C-3	C	B	C	B	B	B	B	C	AA-3	C
Marzo	B-2	B	B	B	B	B	B	B	B	AA-2	B
Abril	B-2	B	B	B	B	B	B	B	B	AA-2	B
Mayo	B-2	B	A	B	A	B	B	B	B	AA-2	B
Junio	A-1	A	A	A	A	A	A	A	A	AA-2	B
Julio	A-1	A	A	A	A	A	A	A	A	AA-3	B
Agosto	A-1	A	A	A	A	A	A	A	A	AA-3	B
Septiembre	B-2	B	A	B	A	A	A	A	B	AA-3	B
Octubre	B-2	B	B	B	B	B	B	B	B	AA-3	C
Noviembre	C-3	B	B	C	B	B	B	B	C	AA-3	C
Diciembre	C-3	C	B	C	B	B	B	B	C	AA-3	C

TABLA 3. ZONAS GEOGRAFICAS DE DISTRIBUCION DE GASOLINA

Zona		Descripción (1)
Noreste		CE Cadereyta, TAD: Cd. Juárez, Chihuahua, Durango, Gómez Palacio, Matehuala, S.L.P., Santa Catarina, Sat. Monterrey, N. Laredo, Reynosa, Sabinas, Saltillo, Parral.
Centro-NE		TAD Cd. Madero, Cd. Mante, Cd. Valles, Cd. Victoria, Poza Rica, San Luis Potosí
Sureste		Campeche, Escamela, Jalapa, Mérida, TAD Pajaritos, Ver., Perote, Suptcia. Veracruz, CE Progreso, Puebla, Tehuacán, Tierra Blanca, Veracruz, Villahermosa, Tabasco.
Bajío		Aguascalientes, El Castillo, El Salto, Irapuato, León, Morelia, Uruapan, Zacatecas, Zamora, Tepic.
Centro		TAD Cuautla, Cuernavaca, Iguala, Pachuca, Toluca, Celaya, Querétaro. TAD 18 de Marzo Azcapotzalco, TS. Oriente A., TS Sur Barranca del Muerto, TS Norte S. Juan Ixhuatepec, Tula.
Pacífico	Z1	Acapulco, Colima, Lázaro Cárdenas, Manzanillo Term., Oaxaca, Oax., Salina Cruz, Tapachula, Tuxtla Gutiérrez
	Z2	Culiacán, Mazatlán
	Z3	Guamúchil Suptcia. V., Guaymas, La Paz, Navojoa, Topolobampo.
	Z4	Cd. Obregón, Ensenada, Hermosillo, Magdalena, Mexicali, Nogales, Rosarito (Tijuana).

(1) CTT (Centro de Transportación Terrestre) CE (Centro Embarcador)

TAD (Terminal de Almacenamiento y Distribución) TS (Terminal Satélite)

TABLA 1. ESPECIFICACIONES DE PRESION DE VAPOR Y TEMPERATURAS DE DESTILACION DE LAS GASOLINAS

SEGUN LA CLASE DE VOLATILIDAD

		CLASE DE VOLATILIDAD (1)			
Propiedad	Unidad	AA	A	B	C
Presión de Vapor Reid (2)	kPa (lb/pulg^2)	45 a 54 (6.5 a 7.8)	54 a 62 (7.8 a 9.0)	62 a 69 (9 a 10.0)	69 a 79 (10 a 11.5)

WORKING PROPOSAL 2014

Properties

Propiedad	Unidad	Clase de volatilidad (1) AA(3)	A	B	C
Presión de Vapor (2)	kPa (lb/pulg2)	54 (7.8)	62 (9.0)	69 (10.0)	79 (11.5)
Temperaturas de destilación:					
Temperatura máxima de destilación del 10%	°C(4)	70	70	65	60
Temperatura de destilación del 50%	°C	77 a 121	77 a 121	77 a 118	77 a 116
Temperatura máxima de destilación del 90%	°C	190	190	190	185
Temperatura máxima de ebullición final	°C	225	225	225	225
Residuo de la destilación, valor máximo	% vol	2	2	2	2

Regions

Zona	Estados
Norte	Nuevo León, Chihuahua, Durango, Coahuila, Tamaulipas, San Luis Potosí.
Sureste	Veracruz, Campeche, Puebla, Tabasco, Yucatán, Quintana Roo.
Centro	Aguascalientes, Jalisco, Guanajuato, Michoacán, Zacatecas, Morelos, Tlaxcala, Estado de México, Distrito Federal, Hidalgo, Querétaro.
Pacífico	Baja California, Baja California Sur, Sonora, Sinaloa, Nayarit, Colima, Guerrero, Oaxaca, Chiapas.

Specification by Region and Month

MES	Norte	Sureste	Centro	Pacífico	ZMVM y ZMG	ZMM
Enero	C-3	C	C	C	AA-3	C
Febrero	C-3	C	C	C	AA-3	C
Marzo	B-2	B	B	B	AA-2	B
Abril	B-2	B	B	B	AA-2	B
Mayo	B-2	B	B	B	AA-2	B
Junio	B-2	A	A	A	AA-2	B
Julio	B-2	A	A	A	AA-3	B
Agosto	B-2	A	A	A	AA-3	B
Septiembre	B-2	B	B	B	AA-3	B
Octubre	B-2	B	B	B	AA-3	B
Noviembre	C-3	C	C	C	AA-3	C
Diciembre	C-3	C	C	C	AA-3	C

Closing

Thank you for your kind attention.

Glenn W. Passavant

MWV

glenn.passavant@mwv.com

+1-517-759-9369