MWV Specialty Chemicals

Future Evaporative and Refueling Emission Control Strategies for Mexico

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Background

- Evaporative emissions are hydrocarbons from gasoline vapors that vent from a vehicle that is parked or driven
- Evaporative controls and limits must be considered in addition to exhaust limit values
- Impacted by fuel RVP, fuel temperature, and ambient temperature
- Emission rate can also vary significantly with vehicle fuel system design characteristics
  - Fuel tank volume
  - Fuel delivery approach
  - Fuel system materials
  - Fuel system architecture and layout

Example of Refueling Emissions Using FLIR Camera

Categories of Evaporative Emissions

	SOURCE ON VEHICLE	CAUSE OF VAPOR GENERATION	UNCONTROLLED EMISSIONS FACTORS
DIURNAL	Tank vent, AIS	Daily temperature cycle	25-35 g/day
REFUELING	Filler pipe or tank vent	Displacement of vapor by liquid	5 g/gallon dispensed
RUNNING LOSS	Tank vent	Heat from engine, exhaust system, and road surface	13 g/hour driving
PERMEATION	Tank shell, hoses, connections	Diffusion through plastics	0.1 g/hour
HOT SOAK	Tank vent, crankcase	Latent engine and exhaust system heat	5-10 g/trip

- If evaporative emissions were uncontrolled, they would total about 34 kg/vehicle·year
- Equivalent to 50 liters (13 gallons) of liquid gasoline

Control efficiency of evaporative emissions primarily a function of canister capacity and in-use purge rate

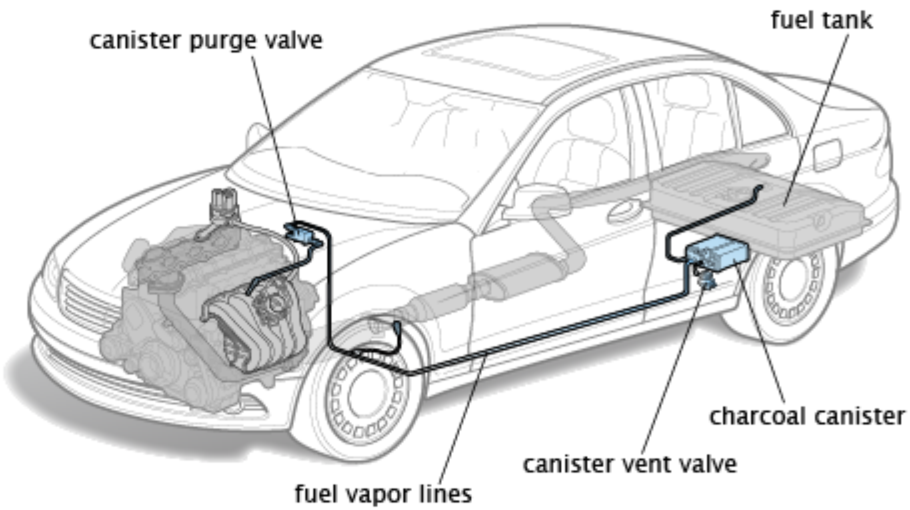


Image courtesy of ClearMechanic.com

Low Capacity
European Canister

High Capacity
U.S. Canister

- CANISTER
  - Filled with adsorbent charcoal
  - Stores gasoline vapors vented from tank until “purged” to engine
  - Canister vapor storage capacity a function of the charcoal type and canister volume
  - Automakers add enough capacity to meet the demands of the certification test
  - Higher canister capacity = lower diurnal emissions and running loss
  - Higher capacity also results in increased purge rate
- PURGE
  - When driving, the engine pulls air through the canister to remove gasoline vapors and use them as fuel in the engine – this regenerates the canister
  - Treats running loss, evaporative emissions during vehicle operation
  - Automakers calibrate when purge occurs and at what rate based on the demands of the certification test
  - High purge rates are needed to control emissions during low speed driving or short trips

Acronyms

- SHED = Sealed Housing for Evaporative Determination
- ORVR = Onboard Refueling Vapor Recovery
- HS = Hot Soak
- GDF = Gasoline Dispensing Facility
- EVR = California's Enhanced Stage II Vapor Recovery

Current US/California evaporative standards are very different from European standards

		Europe		United States / California			
Standard		**Euro 3-5**	**Euro 6 (Proposed)**	**Pre-Enhanced**	**Enhanced + ORVR**	**Tier 2 / LEV II**	**Tier 3 / LEV III**
Year Initiated		2000	2018	1981	1995	2004	2017
Diurnal + Hot Soak	24-hour SHED	2.0 g/d	None	2.0 g/d	None	None	None
	48-hour SHED	None	2.0 g/d	None	2.5 g/d	0.65 g/d	0.300 g/d
	72-hour SHED	None	None	None	2.0 g/d	0.50 g/d	0.300 g/d
Refueling	Stage II Recovery (controls on gasoline pump)	90+% efficiency at certification (80-90% of GDFs)	90+% efficiency at certification	90+% efficiency at certification (30% of GDFs)	90+% efficiency at certification (30% of GDFs)	90+% efficiency at certification (30% of GDFs)	California Only (EVR)
	ORVR (controls on vehicle)	None	None	None	0.20 g/gal (95% effic)	0.20 g/gal (95% effic)	0.20 g/gal (95% effic)
Running Loss		None	None	None	0.05 g/mile	0.05 g/mile	0.05 g/mile
In-Use Standard (In-Use Verification Program, In-Use Compliance Program)		None	None	None	48hr+HS, ORVR @10,000+ mi @50,000+ mi (+ one vehicle over 100k mi)	48hr+HS, ORVR @10,000+ mi @50,000+ mi (+ one vehicle over 100k mi)	48hr+HS, ORVR @10,000+ mi @50,000+ mi (+ one vehicle over 100k mi)
Useful Life Requirement		None	None	None	120,000 mi	120,000 mi	150,000 mi

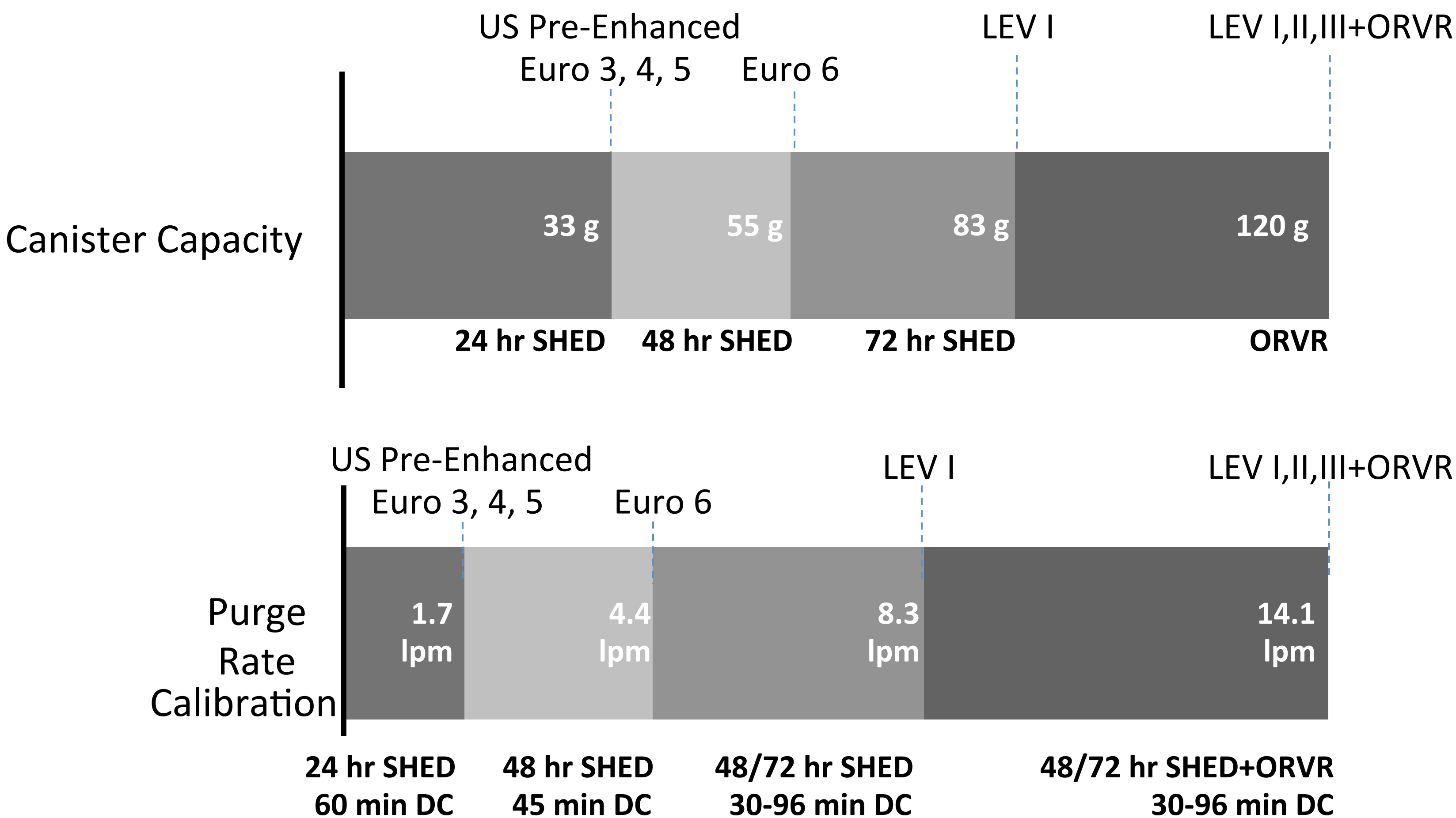
Emissions standards affect canister capacity and purge rates

	Certification Test Vapor Load	Certification Test Purge Time	Relative Canister Capacity	Relative Purge Rate
Euro 3-5	33 grams	60 min	1	1
Euro 6 (proposed)	55 grams	45 min	1.7	2.2
LEV II + ORVR	93 grams (120 grams)	30 min	3.6	7.3

Canister capacity ∝ net vapor load during cert. test
∝ vapor load rate during cert. test
∝ $1/SHED\ limit$

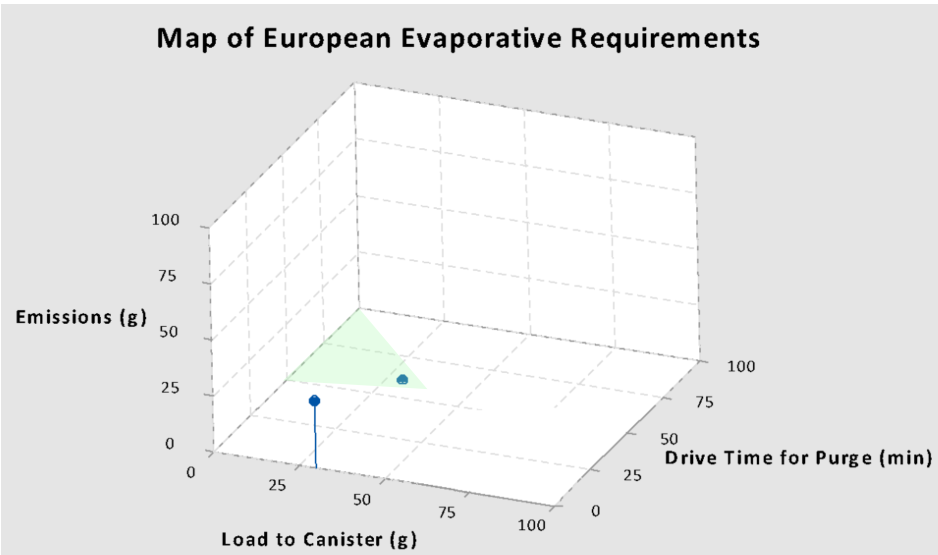
Purge rate ∝ canister capacity
∝ $1/drive\ cycle\ time$

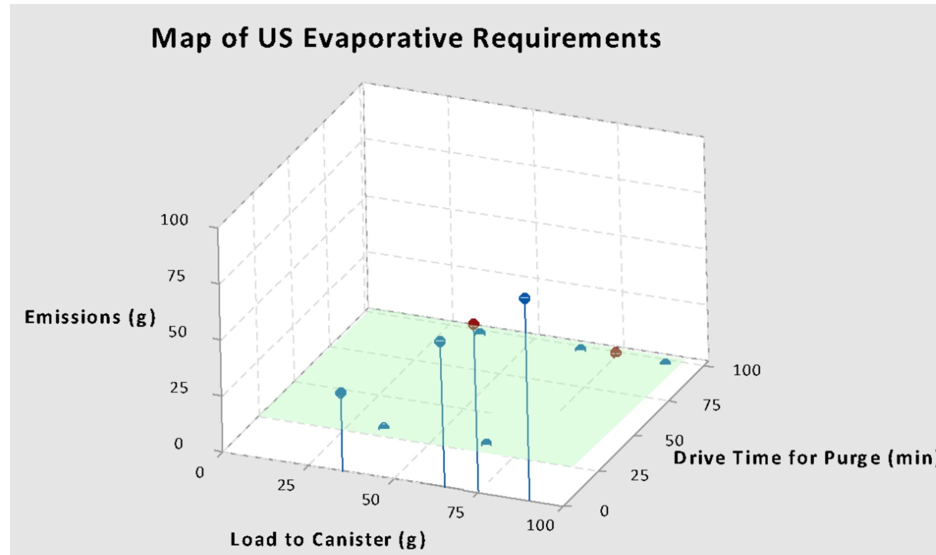
Introduction to Evaporative Technology Packages



The US regulates over a surface of conditions, while Europe only regulates at a single point.

- This would be like certifying exhaust emissions at a single speed and engine load
- Load to canister drives canister capacity
- Combination of drive time and canister capacity drives purge rate





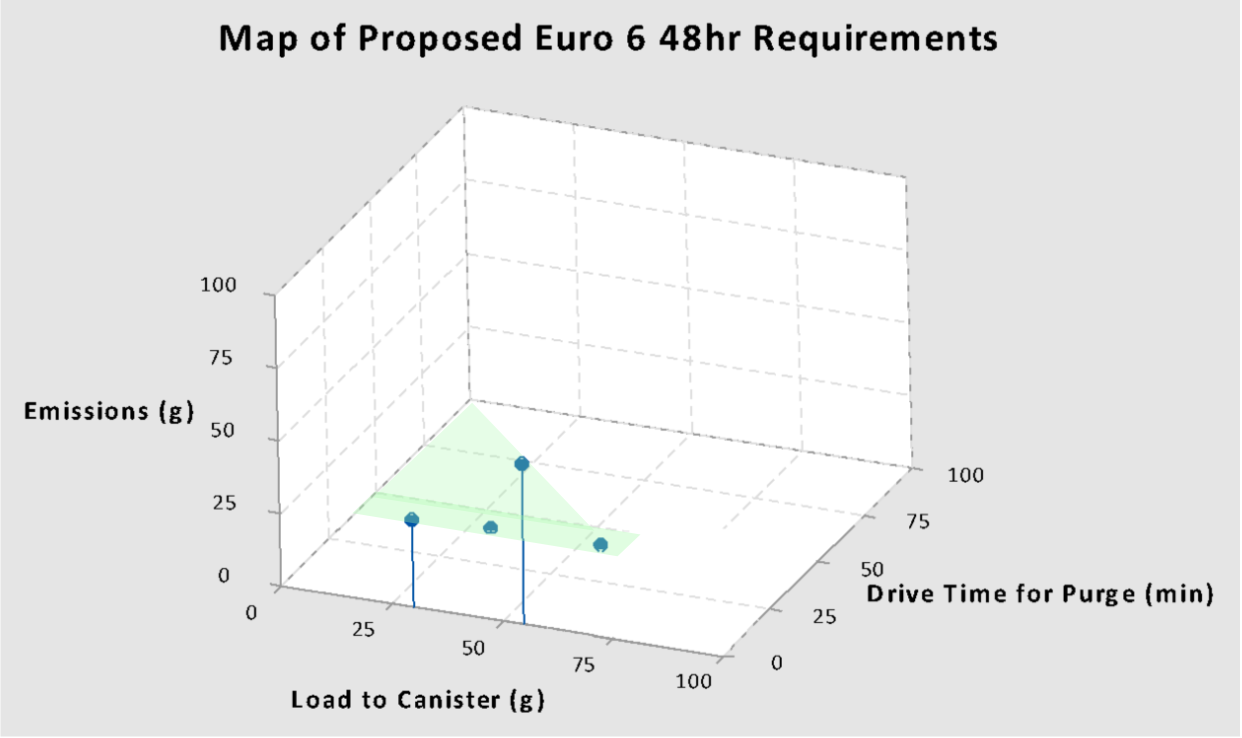
European requirements do not force vehicle controls during the following situations:

- Short driving events
- Long or high temperature driving events that can result in significant running loss
- Extended parking events or episodes of high vapor generation
- Refueling events (relies upon Stage II, which suffers from low efficiency, poor reliability)

The US test procedures work well because:

- They drive high canister capacity and refueling control
- Purge must be aggressive over short, slow driving conditions
- Running loss is controlled, and permeation is controlled through low SHED limits

If Europe adopts a 48-hr test with Euro 6, it will not lead to significant improvement



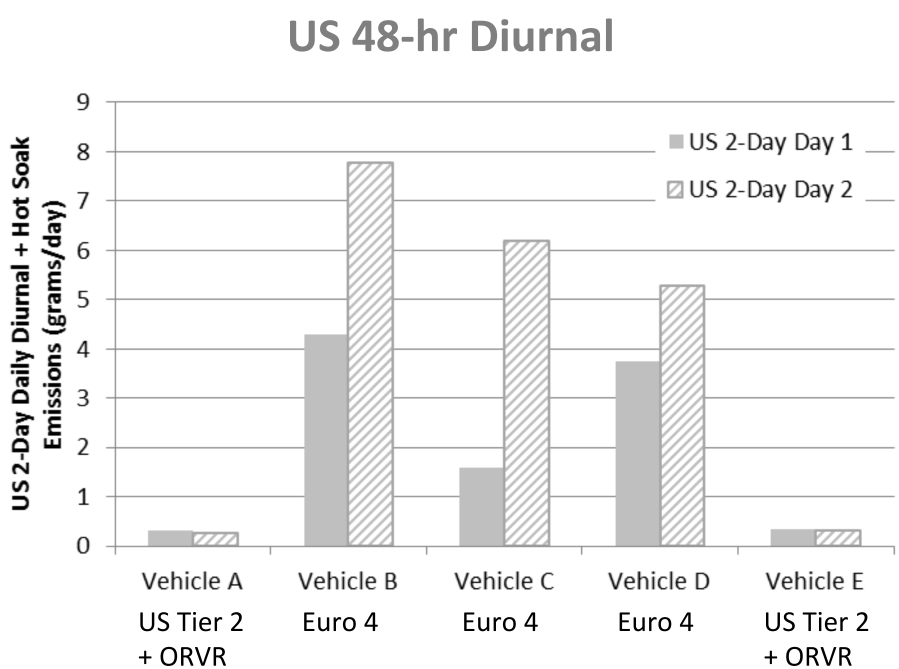
- Only two points on the conditions map
- High limits and low diurnal loading will not result in significant canister capacity increase
- High limits, moderate drive time, and low canister capacity will not increase purge rates sufficiently
- Extended drive times and high vapor loading conditions are not addressed
- Short, low-speed drive still not addressed

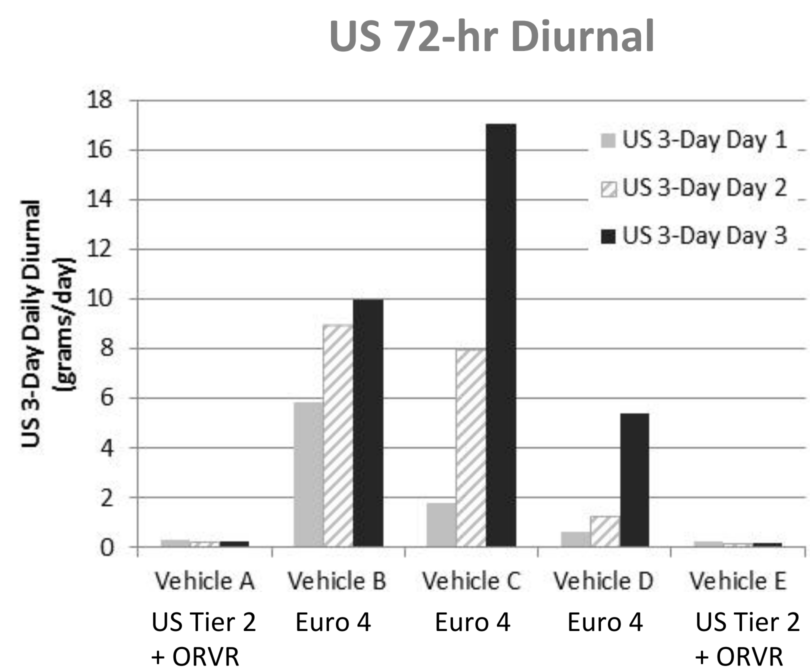
Additional evaporative technology package components based on certification standards

Technology Package		Euro 3-6	US Pre-Enhanced	LEV I+ORVR	LEV II+ORVR	LEV III+ORVR
Routing of Refueling Vapors to …	… Filler Pipe	✓ **No ORVR**	✓ **No ORVR**			
	… Canister			✓ **ORVR**	✓ **ORVR**	✓ **ORVR**
Tank Thermal Managem’t Approach	Recirculating Fuel Pump Results in high fuel temperatures Thermal management not addressed	✓ **No RL**	✓ **No RL**			
	On-demand Fuel Pump Minimizes pump energy heat Eliminates heat from recirculated fuel	✓	✓	✓ **0.05 g/mi RL**	✓ **0.05 g/mi RL**	✓ **0.05 g/mi RL**
	Tank Shielding, Insulation Reduces heat load from road,exhaust			✓ **0.05 g/mi RL**	✓ **0.05 g/mi RL**	✓ **0.05 g/mi RL**
Tank/Hose Material	Single layer HDPE, fluorinated High permeation rates Not durable over vehicle lifetime	✓ **2.0 g SHED**	✓ **2.0 g SHED**			
	Multilayer EVOH Minimizes tank permeation Durable			✓ **0.95 g SHED IUVP**	✓ **0.50 g SHED IUVP**	✓ **0.30 g SHED IUVP**
	Limited tank penetrations, low-permeation connections & welds Minimizes permeation through seams					✓ **0.30 g SHED IUVP**

A comparison of SHED emissions following the US 48-hour and 72-hour tests, which better represent typical driving conditions, suggest that:

- 24-hr emissions are 8-12 times higher for Euro 4 vehicles
- 48-hr emissions are 4-25 times higher for Euro 4 vehicles
- 72-hr emissions are 40 times higher for Euro 4 vehicles

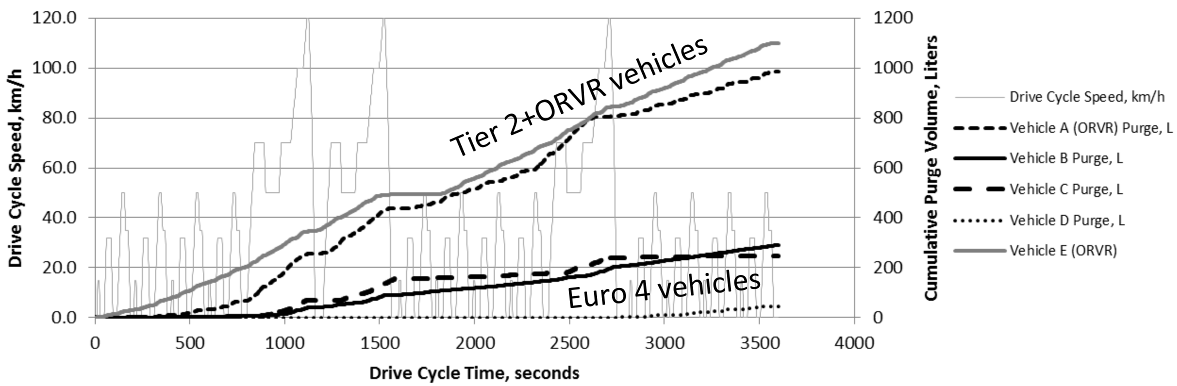




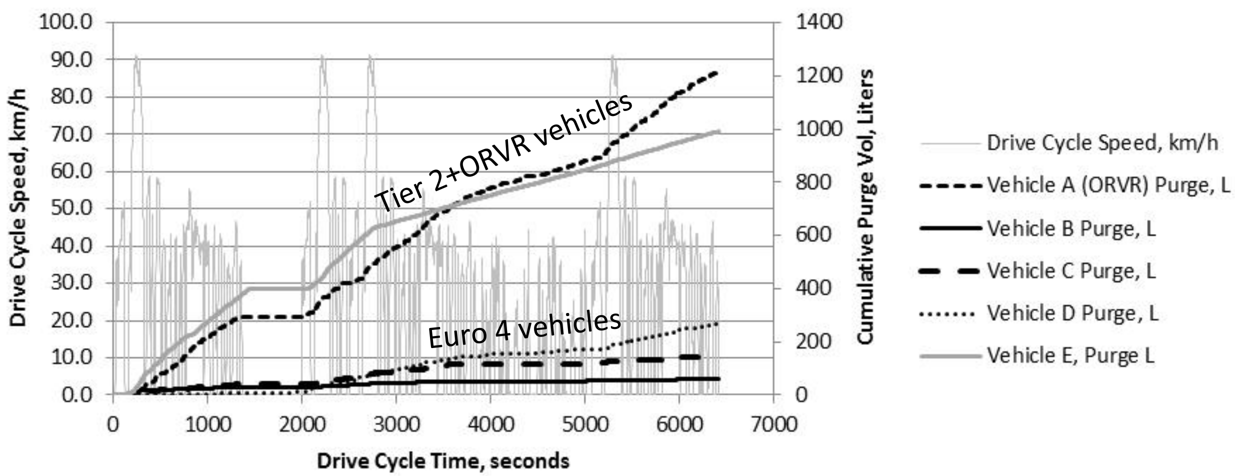
Conclusions: The lack of canister capacity and the insufficient purge over slow, high-transient drive cycles (typical of urban driving) on Euro 4 vehicles result in diurnal emissions about 20 times higher than levels typical for Tier 2+ORVR vehicles. Canister capacity and purge rates need to be increased to reduce emissions.

Purge Measurement Comparison Over NEDC and FTP

- Euro 4 vehicles are not robust across a range of driving conditions and experience very low or zero purge rates at low vehicles speeds of the FTP
- High running loss (evap emissions during driving) on some Euro 4 vehicles over the FTP
- Tier 2 vehicle maintained highest purge rates over both drive cycles and all conditions



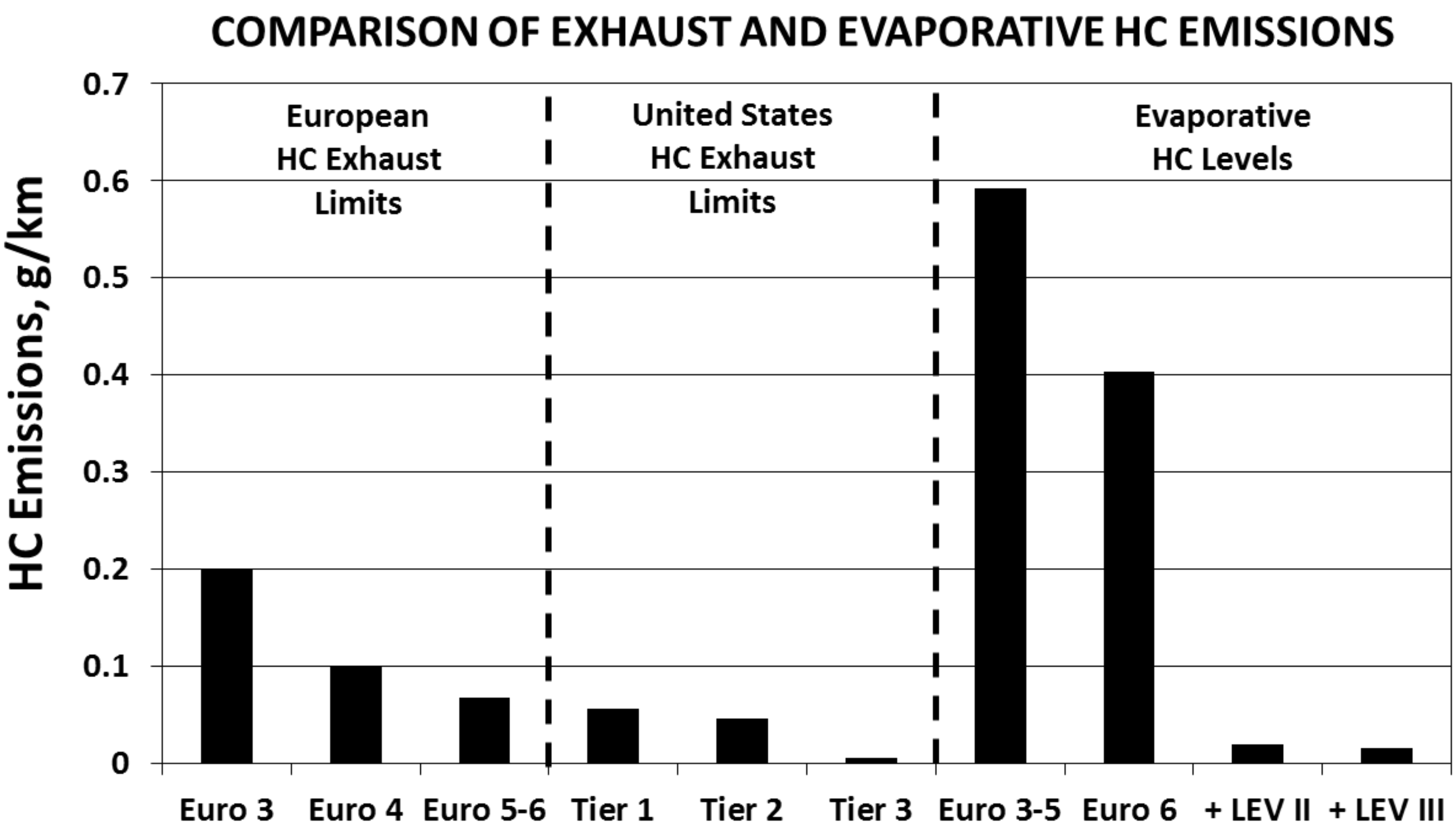
Over the NEDC, purge rate for Tier2 vehicles were 5-times higher than Euro 4 vehicles



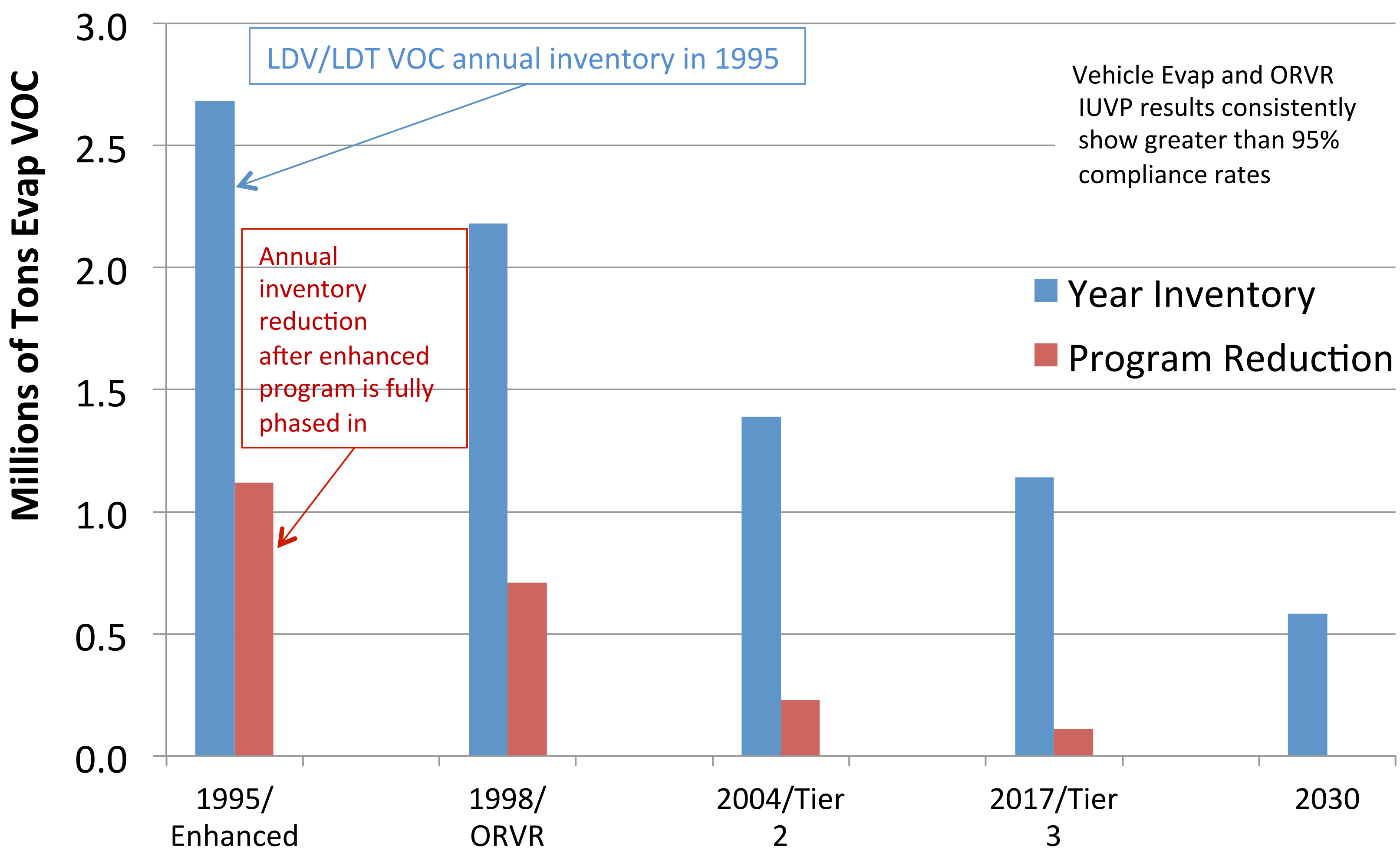
Over the FTP, purge rate for Tier 2 vehicles were 9-times higher than Euro 4 vehicles

Conclusion: Current Euro test procedures do not demand adequate purge. This affects in-use running loss, canister regeneration, and diurnal parking emissions. Europe's WLTP will help a little, but purge rates are primarily affected by the combination of canister capacity and drive cycle time.

In-use evaporative emissions on European certified vehicles are 30x higher than Tier 2 as well as 10x higher than Euro 5-6 exhaust

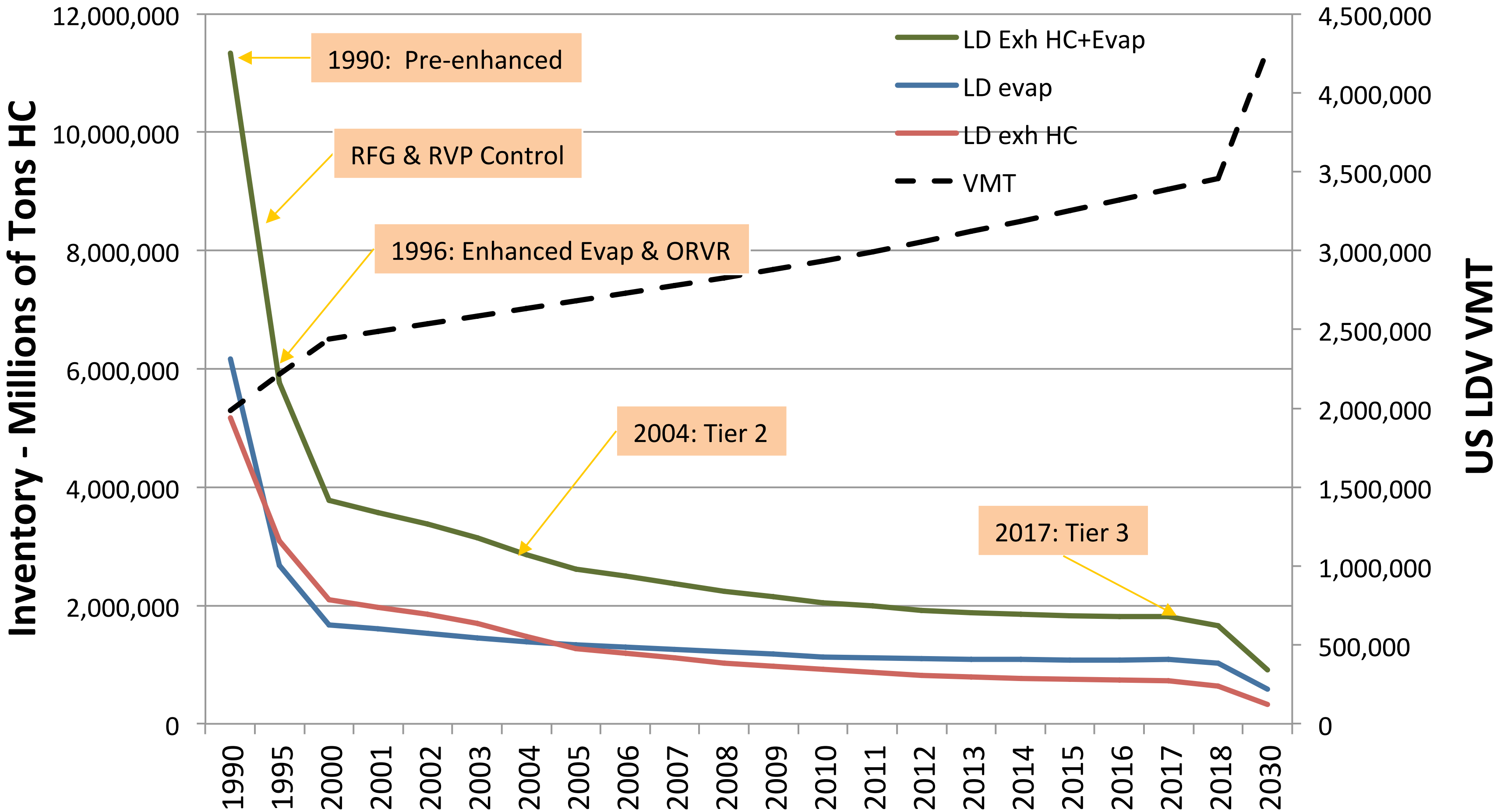


US LDV/LDT VOC Evaporative Inventory & Reductions from Fully Phased-in EPA/CARB Programs



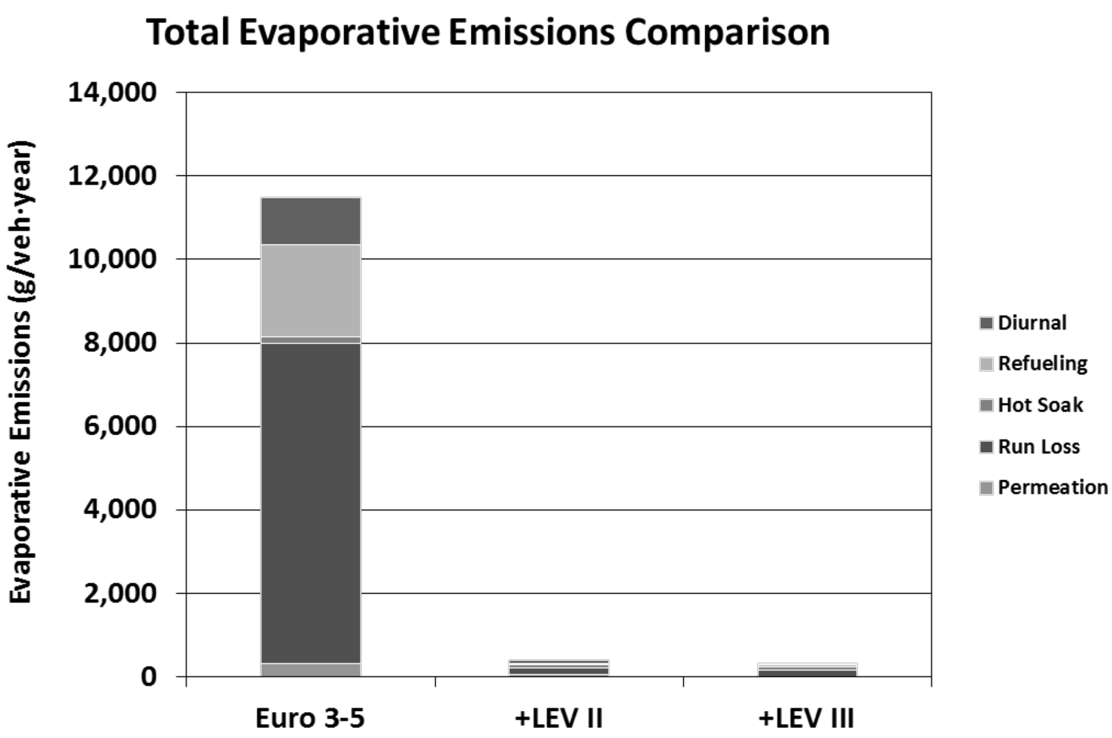
US LDV+LDT HC Inventory

HC Inventory is decreasing while VMT is increasing



Mexico Inventory

- Mexico has a Euro 4 evaporative standard
  - 60 min NEDC, 24-hour heat build, 2.0 g/d SHED limit
- About 50% (?) of LDVs sold in Mexico are designed to meet LEV II/Tier 2 standards and we assume that the matching evaporative controls are in place on those vehicles
- Weighted annual evap emissions ~5,500 g/vehicle·year (equivalent to 8 liters of liquid gasoline per year)



Emissions Depend on Temperatures and Gasoline RVP

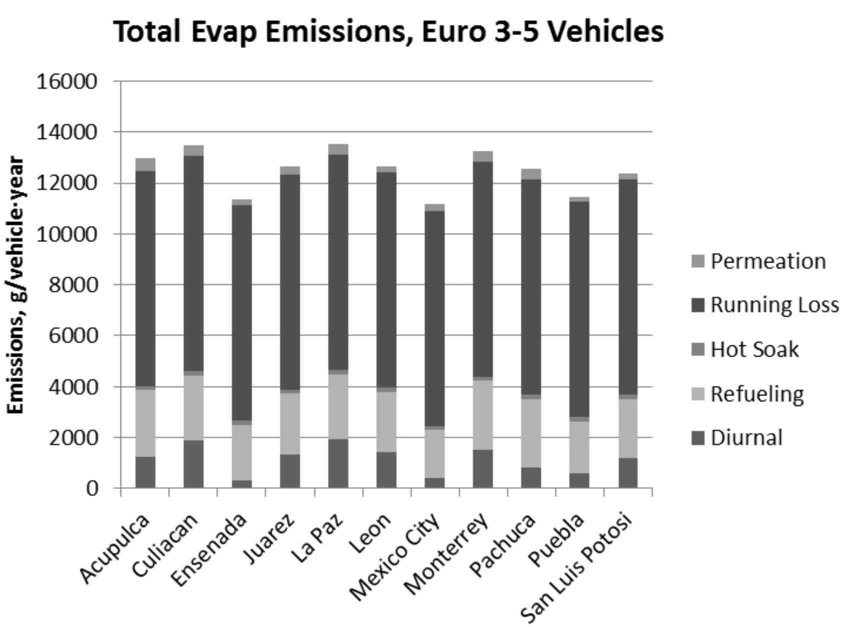
TABLA 4. CLASE DE VOLATILIDAD DE LAS GASOLINAS DE ACUERDO A LAS ZONAS GEOGRAFICAS Y A LA EPOCA DEL AÑO (1)

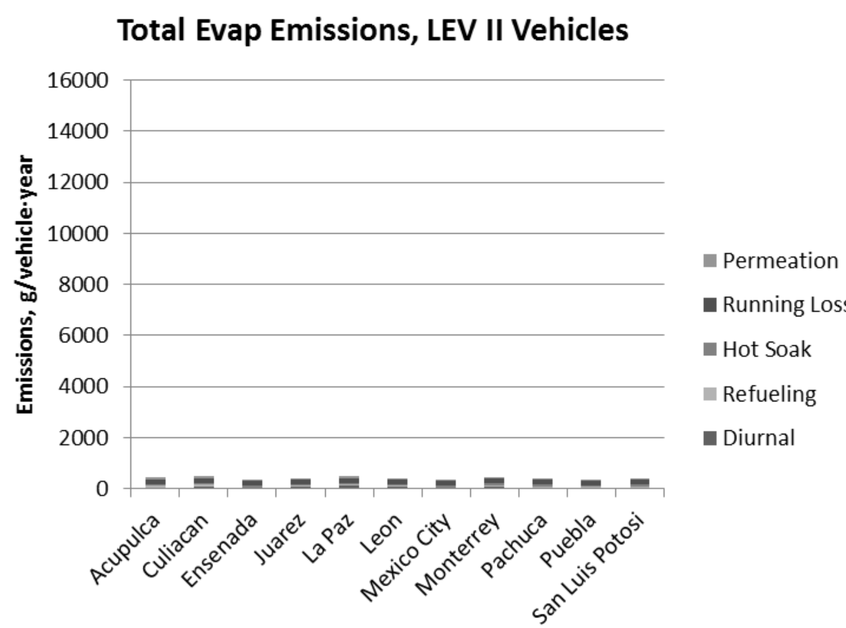
MES	Noreste	Centro-Noreste	Sureste	Bajio	Pacifico				Centro	ZMVM y ZMG	Monterrey
					Z1	Z2	Z3	Z4			
Enero	C-3	C	B	C	B	B	B	B	C	AA-3	C
Febrero	C-3	C	B	C	B	B	B	B	C	AA-3	C
Marzo	B-2	B	B	B	B	B	B	B	B	AA-2	B
Abril	B-2	B	B	B	B	B	B	B	B	AA-2	B
Mayo	B-2	B	A	B	A	B	B	B	B	AA-2	B
Junio	A-1	A	A	A	A	A	A	A	A	AA-2	B
Julio	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 1. ESPECIFICACIONES DE PRESION DE VAPOR Y TEMPERATURAS DE DESTILACION DE LAS GASOLINAS

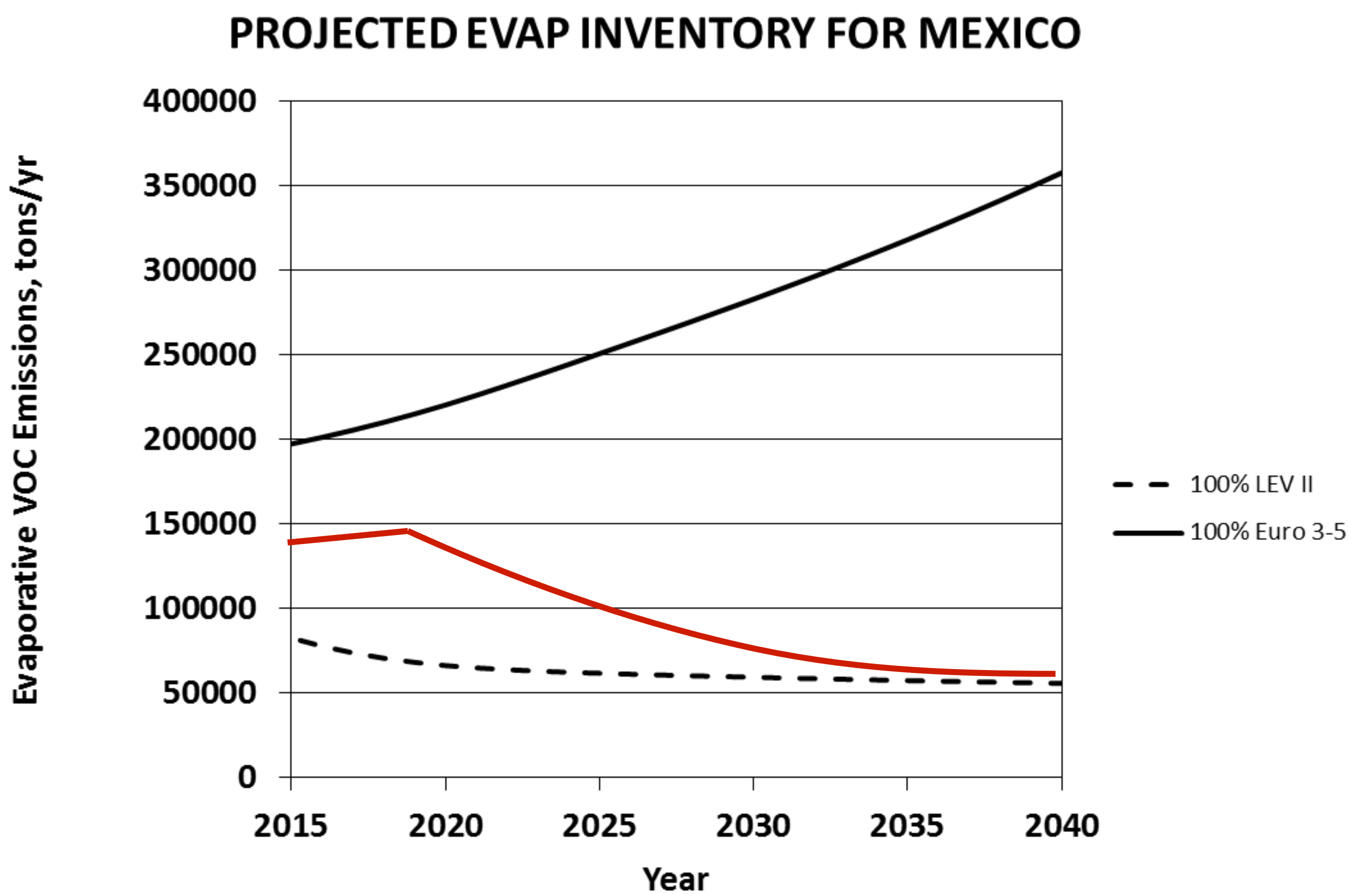
SEGUN LA CLASE DE VOLATILIDAD

		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)



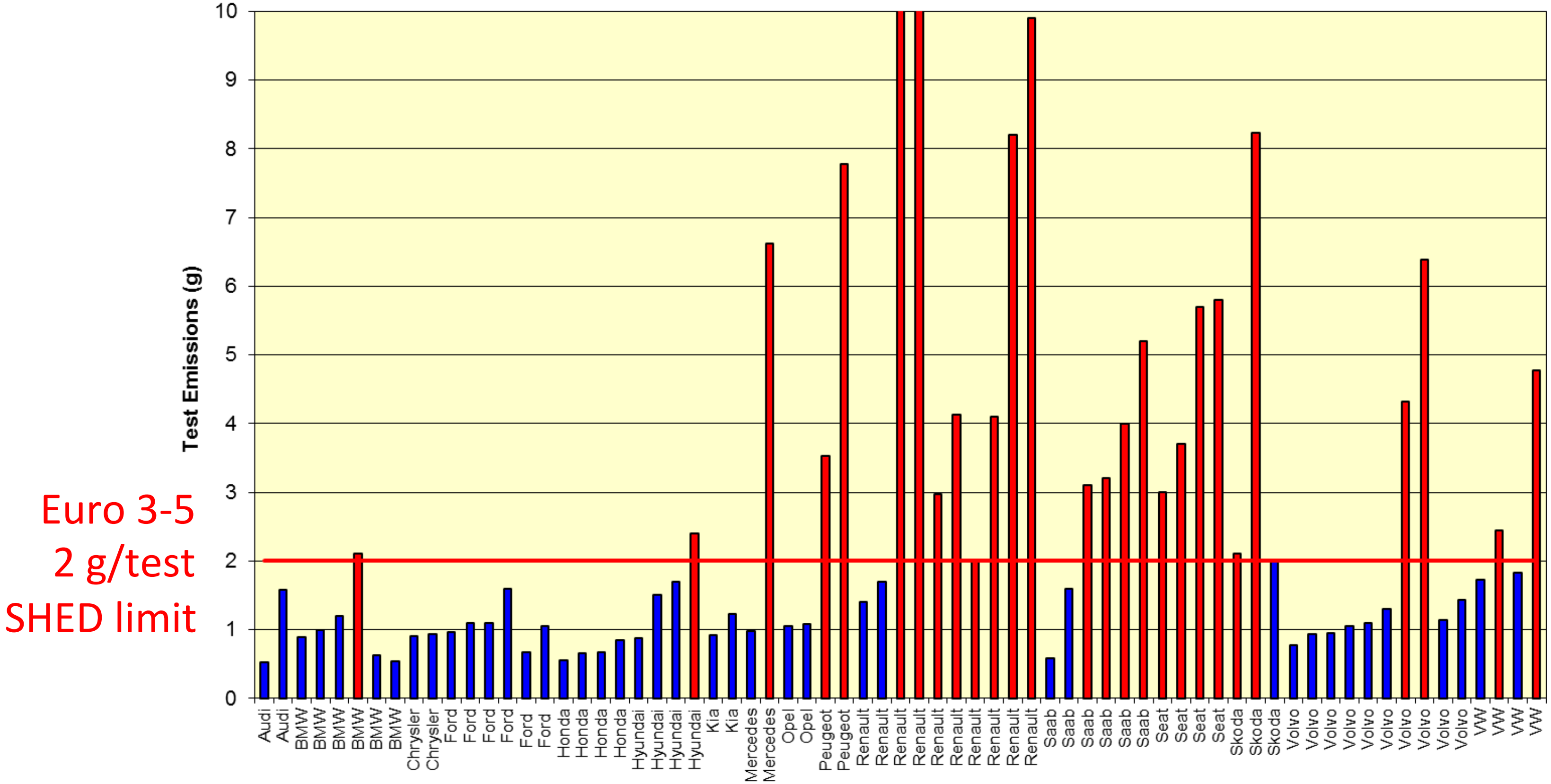


LEV II evaporative requirements will reduce future VOC inventories by over 150,000-200,000 tonnes/year



30% of European in-use vehicles do not meet 2 g/test SHED limit due to canister aging. Over 98% of US vehicles meet SHED limits because of in-use standards and IUVP

27 out of 69 in-use European vehicles tested by Vagverkett did not meet the 2 g/d certification limit



Cost Overview of US Program

Program	Phase-in Years	Test Procedures	Other	New Vehicle Cost	Fuel Recovery Credit
Conventional pre-enhanced	1978-1981	SHED Diurnal: 24-hr test, 1 hour heat build 60-84°F for HS+DI.	SHED test replaced carbon trap method. Standard was 2 g/test.	~$32	-$42
Enhanced Evap	1995-1999	Upgraded test procedures for diurnal and hot soak (HS+DI): 48 and 72 hour tests with 12 hour 72-96°F heat build	Added running loss test procedures and standards and spitback test procedure and standards	$15	-$51
ORVR	1998-2006	Refueling	LDV,LDT, HDGV	$13	-$15
Tier 2/MSAT	2004-2010	More stringent HS+DI standards	E10 durability; forced some control of permeation	$5	-$5
Tier 3	2017-2022	“Zero evap” HS+DI	E10 test fuel, canister bleed, and leak test	$16	-$10

Automaker cost to convert Euro 5 to Tier 2+ORVR = $33 per vehicle
Fuel recovery credit for converting Euro 5 to Tier 2+ORVR = $71 per vehicle

LEV II and LEV III Evaporative Phase-In Schedules

LEV II

Model Year	Minimum Certification %
2004	40%
2005	80%
2006	100%

LEV III

Model Year	Minimum Certification %
2018	60%
2020	80%
2022	100%

Evaporative and Refueling Emission Test Procedures

Glenn W. Passavant

Evaporative Emission Program

- Control started in early 1970s with first generation of diurnal and hot soak emissions standards. These were based on an ineffective test procedure known as the "carbon trap" method.
- Significant upgrade was made in changing to SHED based test procedure in 1978; a 2.0 g/day hot soak+ diurnal emission standard was implemented for the 1981 model year.
  - This was expanded to heavy-duty gasoline vehicles for the 1985 model year.
  - Notable shortcoming of this test was the 1 hour length of the heat build and the limited fuel tank heat build interval (60-84°F).
- After more than a decade of no change, since the mid 1990s there have been several significant changes in the scope of the program, upgrades to the test procedure requirements, and increases in the stringency of the standards.
- Major developments over the past decades
  - Move to SHED test from canister trap test
  - Increases in stringency for diurnal and hot soak … LEVIII includes "zero evap" standards.
  - Upgrade of diurnal requirements (longer heat build periods (12 hour), more extensive diurnal temperature cycles, and multi-day evaluations
  - Addition of new requirements (ORVR, running loss, canister bleed, SHED rig, leak)
  - Fuel quality specifications (vapor pressure, oxygenate).

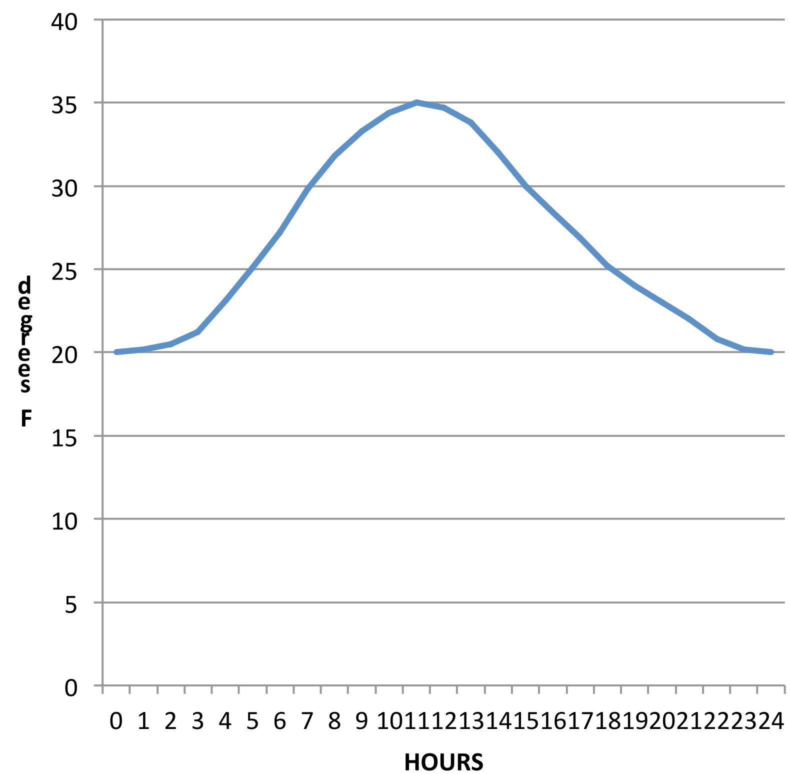
Current European Type IV Evaporative Requirements

European evaporative emission program test requirements

- Addresses only hot soak + diurnal
- 24 hour test
- 12 hour heat build 68°F to 95°F
- Fuel vapor pressure: 56 – 60 kPa
- 2.0 g/test limit: based on sum of hot soak + diurnal measurements

Overall, relatively weak in comparison to current US EPA/ California evaporative program

Type IV Diurnal Temperature Cycle



Overview

- Four basic vehicle fuel system vapor emission test modes we will discuss today.
  - Evaporative diurnal (US 2-day (48 hour) and 3-day (72 hour); Europe 1 day)
  - Evaporative hot soak
  - Evaporative running loss
  - Refueling (which includes spit back)
- Three special tests
  - SHED rig
  - Canister bleed
  - Leak

- Each of the test procedures involves measuring fuel vapor emissions over basic test cycles which involve combinations of key parameters and comparing measured results to applicable standards/limits.
  - US is now transitioning from Tier 2/LEV II to Tier 3/LEV III.
- Evaporative emission standards do not address non-fuel emissions such as from tires and other vehicle components made of rubber and plastic compounds.

Why Four Test Modes?

- Each of the basic test modes addresses a different evaporative emissions regime and serves a different purpose.
  - Diurnal: addresses fuel tank vapors emitted when a vehicle is parked. These are caused by either daily ambient or driving related fuel temperature changes as well as permeation through fuel system materials.
    - 48 hour -- addresses short distance driving/two-day parking – assures rigorous canister purge
    - 72 hour – addresses longer term parking – often results in control over more than 3 days
  - Hot soak: addresses fuel vapor emitted from the fuel system and engine air induction system immediately after vehicle is parked.
  - Running loss: addresses fuel vapor emitted from the fuel system when vehicle is in operation.
  - Refueling: addresses hydrocarbon vapor emissions from fuel tank when vehicle is being refueled (vapor displacement) and reduces spit back spillage. ORVR requirement dictates total canister hydrocarbon capture capacity.
- The SHED rig, canister bleed, and leak tests are specialized tests designed to address one or more specific types of emission regimes not fully captured by the four basic tests. These become especially important as evaporative emission standard values approach zero.

US Fuel Vapor Emission Standards

	Tier 2/LEV II					PZEV	Tier 3/LEV III[5]			
	LDV	LLDT	HLDT	LHDGV	HHDGV	LDV/LDT/MDV	LDV/LDT1	LDT2	HLDT/MDPV	L/HHGDV
	phased-in 2004-2010					thru 2017: CA & 177 states	phase-in 2017-2022			
Diurnal+Hot Soak				CA/EPA	CA/EPA					
LA 2-day (g/test)	0.65	0.85	1.15	1.25/1.75	1.25/2.3	0.35/0.50/0.75	0.300	0.400	0.500	0.600
LA 3-day (g/test)	0.50	0.65	0.90	1/1.4	1/1.9	0.35/0.50/0.75				
HA 2-day (g/test)[1]	0.95	0.95	1.20	1.75	2.30		0.65	0.85	1.15/1.25	1.75/2.3
HA 3-day (g/test)[1]	1.20	1.20	1.50	1.40	1.90					
Bleed (g/test)[2]							0.020	0.020	0.020	0.030
SHED rig (g/test)[3]						~0	~0	~0	~0	~0
Running loss (g/mi)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Refueling (g/gal)[4]	0.20	0.20	0.20	0.20		0.20	0.20	0.20	0.20	0.20

[1] EPA only

[2] low altitude only

[3] CA only

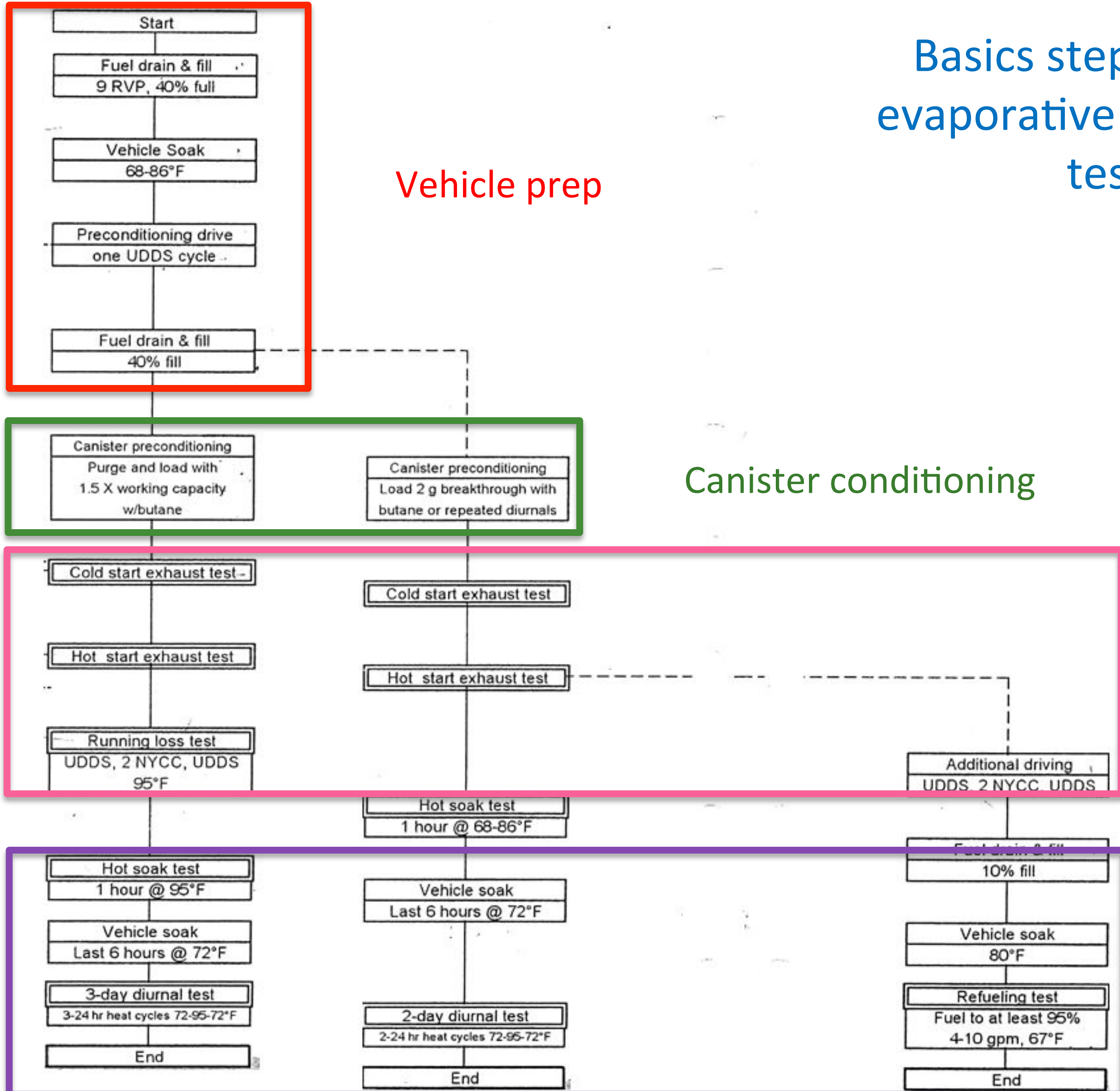
[4] complete vehicles only

[5] useful life: 15 yrs/150,000 miles

Basic Components of Each Cycle

- Vehicle preparation
- Control system preparation (canister pre-conditioning)
- Pre-conditioning vehicle driving
- Conduct emission test in SHED
- Variables may include:
  - Test fuel specifications: (fuel RVP, ethanol)
  - Temperatures (fuel, lab ambient, diurnal, test cell)
  - Canister pre-conditioning
  - On-vehicle pre-conditioning and emission generation driving cycles

Basics steps of vehicle evaporative and refueling testing



Evap & Refueling Test Fuels

Test	RVP	Ethanol	Applicability	Comment
CA LEV II	7.0	Oxygenate use based on predictive model	Low altitude only	RFG 2 – eliminated after 2014 MY
EPA Tier 2	7.8	n/a	High altitude	30 ppm S
EPA & CA LEV II refueling	9.0	n/a	All altitude	
CA LEV III evap, bleed, rig, & optional refueling	7.0	10%	Low altitude only	RFG 3/ 10 ppm S
EPA Tier 3 refueling	9.0	10%	All altitude	Indolene/10 ppm S
EPA Tier 3 evap	7.8	10%	High altitude	10 ppm S

Test Temperatures

<table>
<tr><th colspan="3">Test</th><th>Test Spec</th></tr>
<tr><td colspan="3">CA 48 hr... hot soak</td><td>68-86°F</td></tr>
<tr><td colspan="3">CA 48 hr... diurnal</td><td>65-105°F</td></tr>
<tr><td colspan="3">CA running loss</td><td>105°F</td></tr>
<tr><td colspan="3">CA 72 hr... hot soak</td><td>105°F</td></tr>
<tr><td colspan="3">CA 72 hr... diurnal</td><td>65-105°F</td></tr>
<tr><td colspan="3">CA canister bleed</td><td>65-105°F</td></tr>
<tr><td colspan="3">CA fuel/evap system SHED rig (48 & 72 hr...)</td><td>65-105°F</td></tr>
<tr><td>EPA refueling</td><td>Td = 67°F;Tt=80°F</td><td>CA refueling (optional)</td><td>Td = 79°F;Tt=80°F</td></tr>
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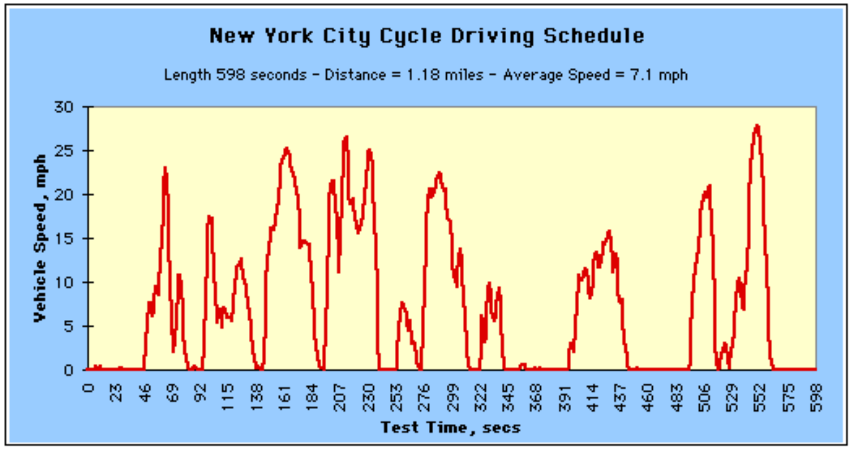
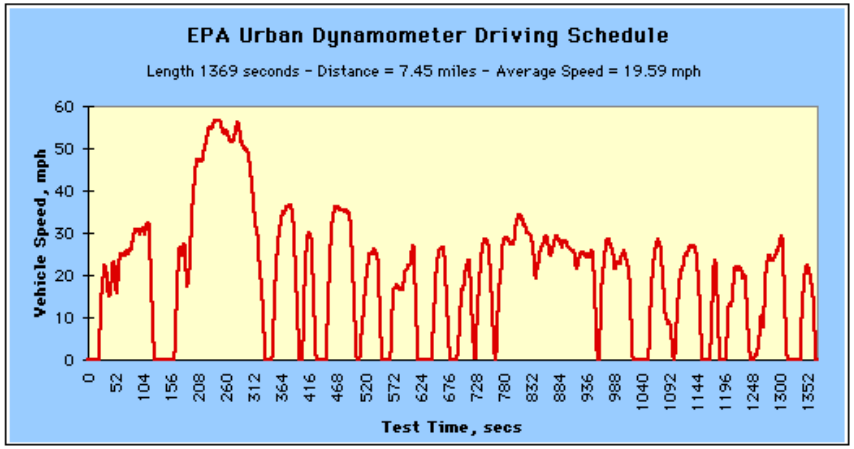
Basic Driving Cycles

NYCC – New York City Cycle



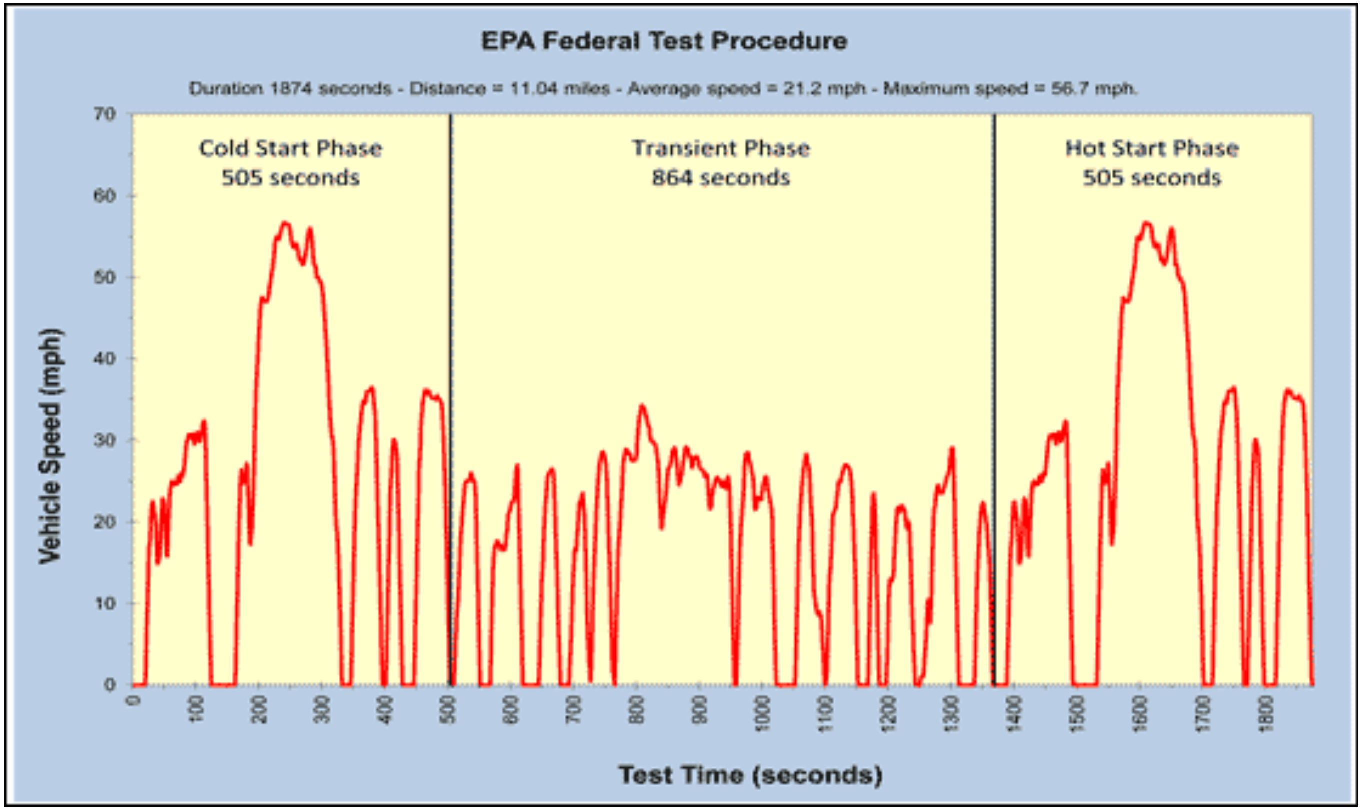
UDDS Urban Dynamometer Driving Schedule – LA4



FTP75 Exhaust Emission Cycle

FTP = US Federal Test Procedure

UDDS (cold exhaust)+10 minute soak+ first 505 of UDDS (hot exhaust)



US Emission Test Drive Cycle Characteristics

Emission Cycle	Driving (after canister preconditioning)	Time	Distance	Avg Speed	% time idle	Avg Speed w/o idle	% time non-idle cruise & accel
2-day	FTP	1874 sec/31.2 min	11.04 mi	21.2 mph	19.0%	26.38 mph	46.4%
RL	UDDS + 2 min. idle+ 2 NYCC +2 min. idle+ UDDS + 2 min. idle	4294 sec/71.6 min	17.26 mi	14.47 mph	30.1%	21.13 mph	39.4%
3-day	FTP+RL	6168 sec/ 102.8 min	28.3 mi	16.52 mph	26.75 %	22.55 mph	41.5%
ORVR	FTP+RL	6168 sec/ 102.8	28.3 mi	16.52 mph	26.75 %	22.55 mph	41.5%

LEV III 48 hr… hot soak + diurnal

- Vehicle and system preparation
  - Fuel drain and 40% fill (CA 7RVPE10)
  - 6 hr. minimum soak at (68-86°F)
  - Vehicle LA-4 dyno prep at 68-86°F
  - Fuel drain & 40% fill
  - 12-36 hr. soak at 68-86°F
  - Load canister to 2g breakthrough @ 40 g/hr. using 50-50% butane/nitrogen
- Pre-conditioning dyno driving
  - FTP at 68-86 °F
- Conduct hot soak emission tests in SHED
  - 1 hour hot soak test 68-86°F
  - Measure hydrocarbon emissions using Flame Ionization Detector (FID)
- Conduct diurnal emission tests in SHED
  - 6-36 hr. soak; last 6 hours at diurnal initial temp (65°F CA)
  - 2-day diurnal (65- 105°F CA)
  - Measure hydrocarbons (HC) after each 24 hr. period using FID
- Calculation of results
  - Correction measurement results for ethanol
  - Sum hot soak and largest of two diurnal measurements
  - Compare to standard

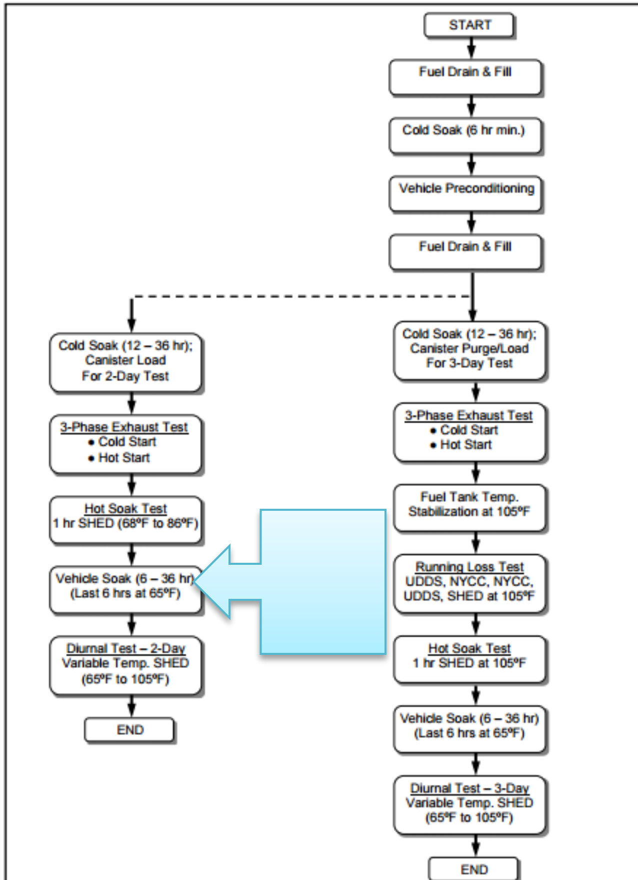
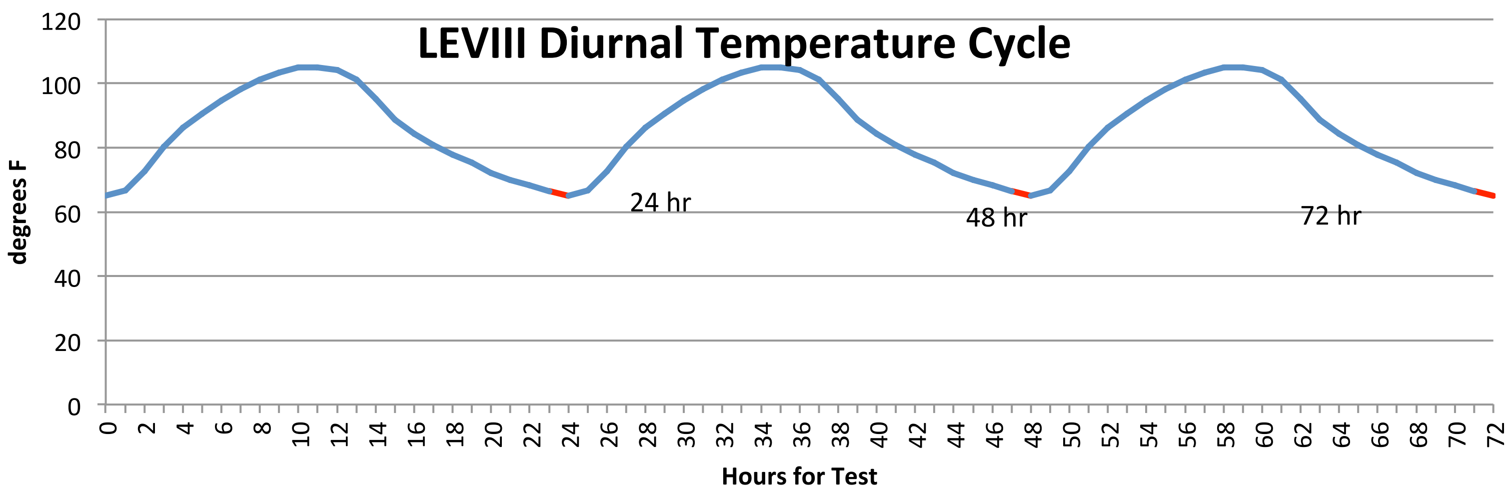


Figure 2: Test Procedure for 2001 and Subsequent Model Motor Vehicles

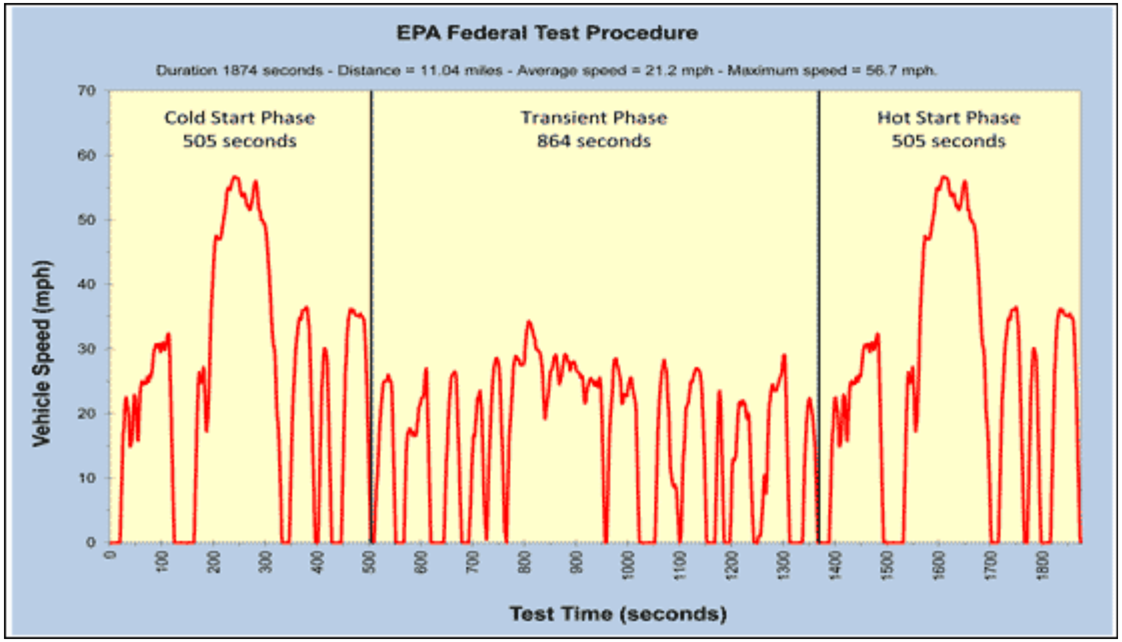
LEV III Diurnal Test Conditions

Tank Fill: 40%; Test Fuel RVP: 7 psi (48 kPa)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12
(°F)	65.0	66.6	72.6	80.3	86.1	90.6	94.6	98.1	101.2	103.4	104.9	105.0	104.2
Hour	13	14	15	16	17	18	19	20	21	22	23	24	--
(°F)	101.1	95.3	88.8	84.4	80.8	77.8	75.3	72.0	70.0	68.2	66.5	65.0	--



Purge for 48 hour diurnal + hot soak FTP (31.2minutes)



LEV III Running Loss

- Running loss test is an element of 72-hr test but can be done alone
- Vehicle and system preparation
  - Fuel drain and 40% fill (CA 7 RVPE10)
  - 6 hr. minimum. soak (68-86°F)
  - Vehicle LA-4 dyno prep at 68-86°F
  - Fuel drain & 40% fill (CA 7 RVPE10)
  - 12-36 hr.... soak at 68-86°F
  - Purge canister 300 BV; Load canister to 1.5 x WC @ 15 g/hr. using 50%- 50% butane/nitrogen
- Pre-conditioning driving
  - FTP at 68-86°F
- Running Loss Test
  - 1-4 hr. soak (to achieve 105°F CA)
  - Running loss test and measurement (start at test cell and fuel temperature of 105°F CA)
  - Can be run in special SHED with vehicle chassis dyno (enclosure method) or on vehicle chassis dyno in lab (point source method)
    - For enclosure method measure emissions in SHED ; for point source method us sum of integrated point source measurements
    - During the test, fuel tank temperatures must track the profile developed for the vehicle model for a very hot summer day under the environmental conditions and driving cycles specified in the regulations.
- Calculation of results
  - Measurement of hydrocarbon (HC) by Flame Ionization Detector (FID)
  - Correction for ethanol
  - Comparison to standard

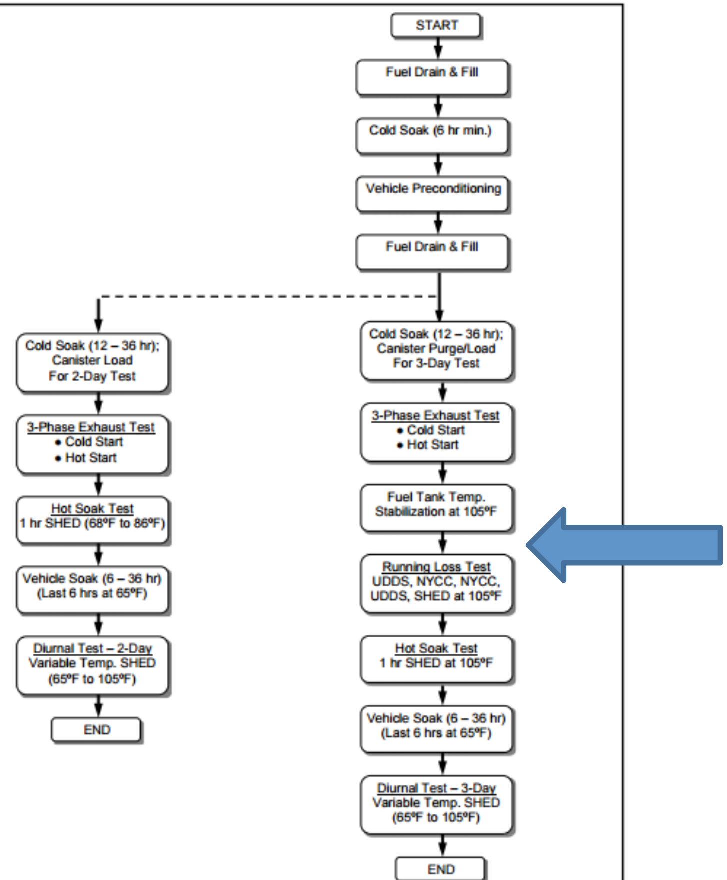
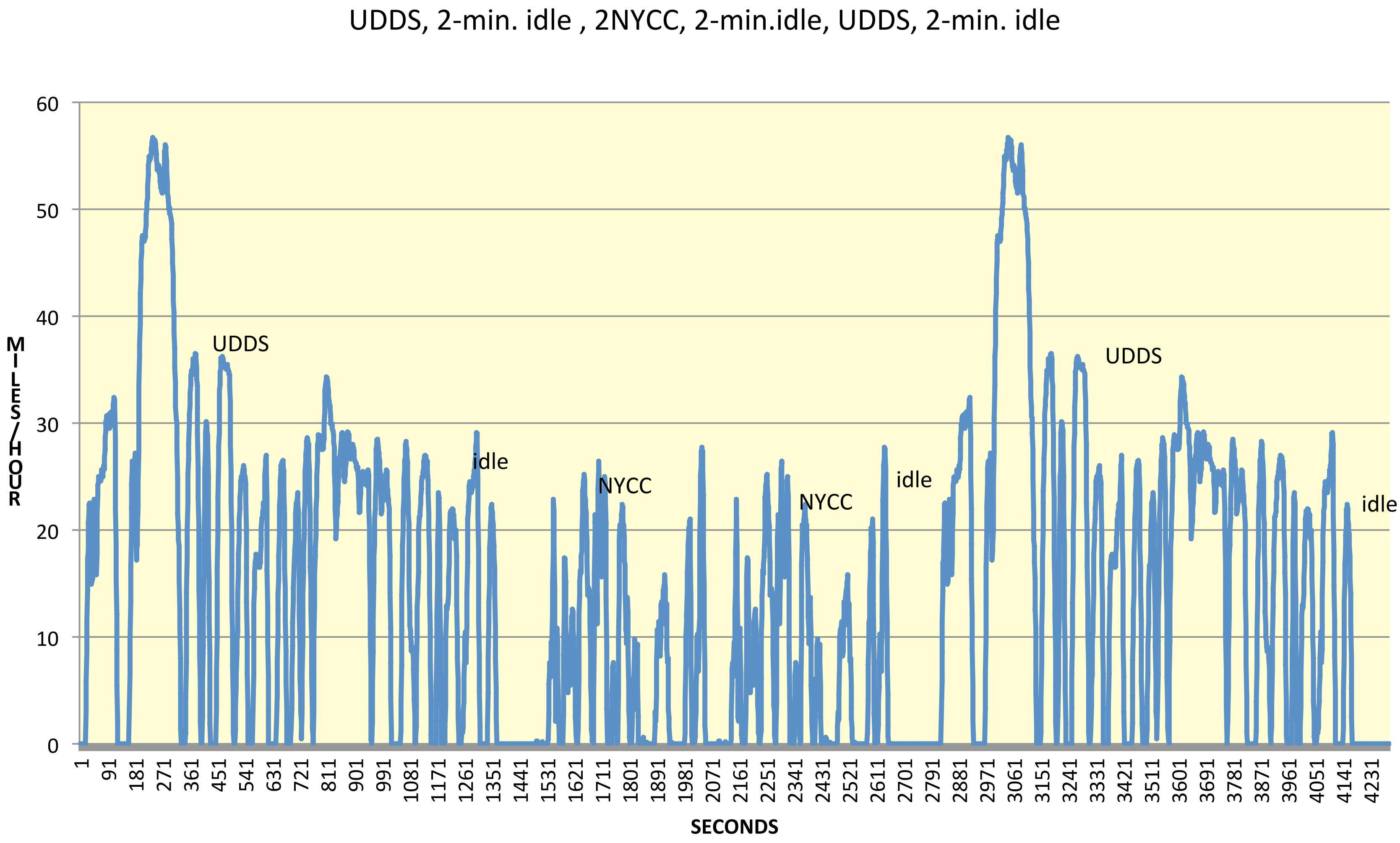


Figure 2: Test Procedure for 2001 and Subsequent Model Motor Vehicles

Purge for Running Loss Driving (71.6 min)



LEV III 72 hr… hot soak + diurnal

- Vehicle and system preparation
  - Fuel drain and 40% fill (CA 7 RVPE10)
  - 6 hr. min. soak (68-86°F)
  - Vehicle LA-4 dyno prep at 68-86°F
  - Fuel drain & 40% fill (CA 7 RVPE10)
  - 12-36 hr… soak at 68-86°F
  - Purge canister 300 BV; Load canister to 1.5 x WC @ 15 g/hr. using 50%- 50% C_4H_{10}/N_2
- Pre-conditioning driving
  - FTP at 68-86°F
- Running Loss Test
  - 1-6 hr. soak (105°F CA)
  - Running loss test and measurement (start at 105°F CA)
- Conduct hot soak emission tests in SHED
  - 1 hour hot soak test (100-110° F CA)
  - Measurement of hydrocarbon (HC) by Flame Ionization Detector (FID)
- Conduct 3-day diurnal emission tests in SHED
  - 6-36 hr. soak; last 6 hours at diurnal initial temp (65°F CA)
  - 3-day diurnal (65- 105°F CA)
  - Measure hydrocarbons (HC) after each 24 hr. period using FID
- Calculation of results
  - Correction measurement results for ethanol,
  - Sum hot soak and largest of three diurnal measurements
  - Compare to standard

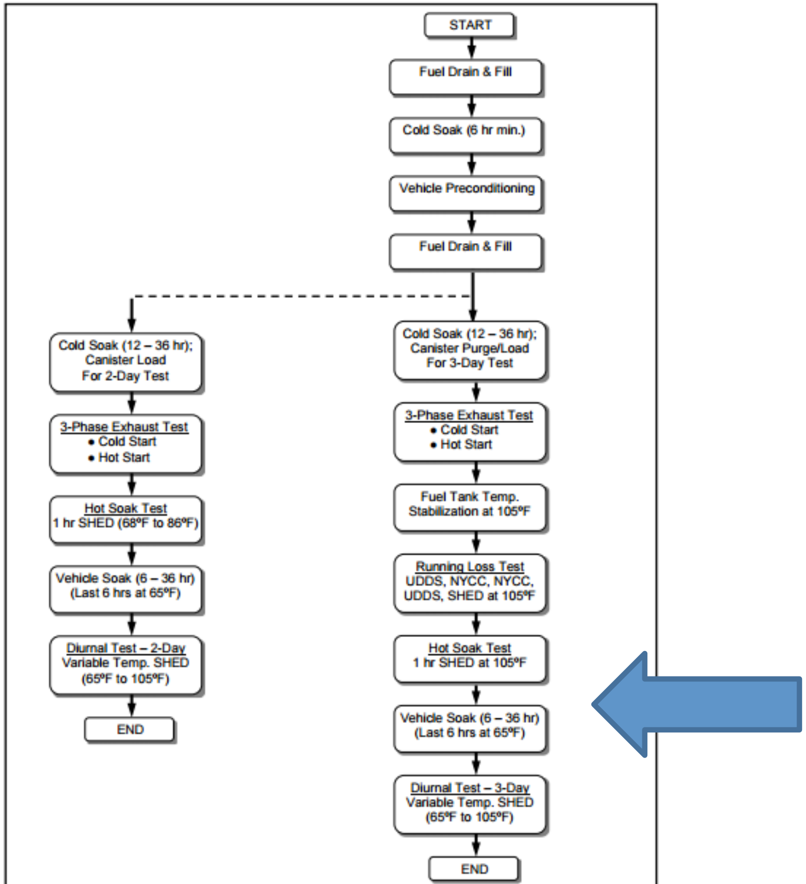
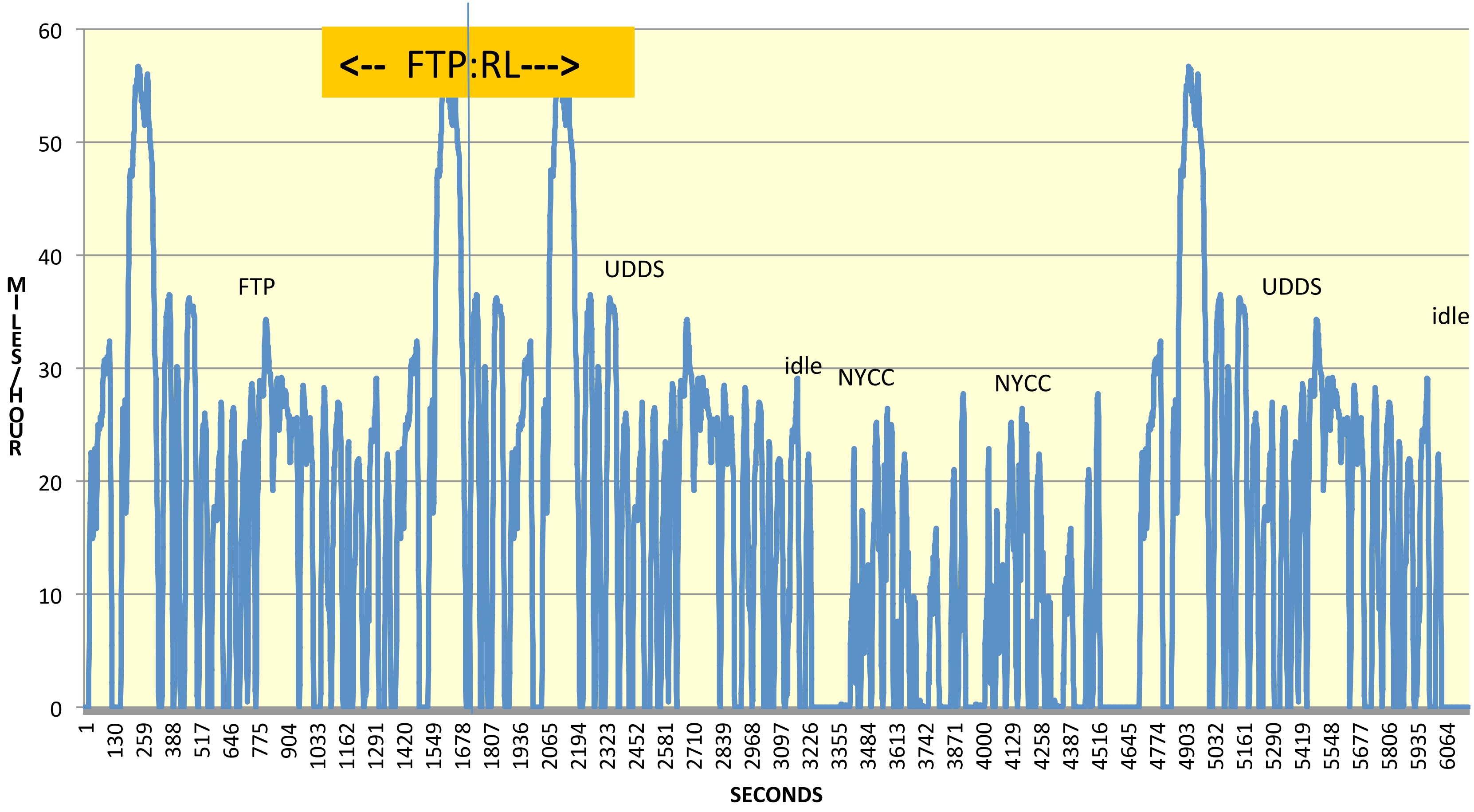


Figure 2: Test Procedure for 2001 and Subsequent Model Motor Vehicles

Purge for 72 hr diurnal test (102.8 min) --- Cumulative Driving



Refueling

- Refueling is controlled by Onboard Refueling Vapor Recovery System (ORVR)
- Two basic approaches
  - Integrated; refueling and evaporative vapors share common carbon canister and related vapor and purge lines
    - Some PHEVs use only a refueling canister
  - Non-integrated; refueling and evaporative vapors use different carbon canister and related vapor and purge lines
- California and EPA have the same test procedure

Refueling

- Vehicle and system preparation
  - Fuel drain and 40% fill (9RVPE10)
  - 6 hr. minimum. soak (68-86°F)
  - Vehicle LA-4 dyno prep at 68-86°F
  - Fuel drain & 40% fill (9RVPE10)
  - 12-36 hr. soak at 68-86°F
  - Purge canister 300 BV; Load canister to 2g breakthrough @ 40 g/hr. using 50-50% C_4H_{10}/ N_2
- Pre-conditioning driving
  - FTP at 68-86°F
  - 0-1 hr. soak (68-86°F)
  - Additional pre-conditioning driving UDDS, 2 NYCC, UDDS at 68-86°F
- Conduct emission tests in SHED
  - Disconnect canister
  - Drain and fill to 10%
  - 6-24 hr.... soak (77-83°F)
  - Reconnect canister
  - Refueling test: dispense fuel at a temperature of 65.5-68.5°F at 9.5 -10.1 gal/min. until at least 95% full.
- Calculation of results
  - Measurement of hydrocarbon (HC) by Flame Ionization Detector (FID)
  - Correction for ethanol not required
  - Comparison to standard

- For non-integrated system additional driving is from 95% full to as low as 10% full (drive down uses repeated UDDS cycles).

- Manufacturers may certify using Federal or California test fuels, but EPA will only accept results for EPA test fuel results

- There is a separate US EPA fuel dispensing spit back test and standard.
  - This requirement is waived for ORVR vehicles since any premature nozzle shut-off during the refueling test must be restarted and any fuel spit back during the refueling test is considered as a refueling emission for compliance purposes.

- PHEVs/HEVs
  - Refueling test is adjusted slightly to accommodate unique operating characteristics of the se vehicles
  - Off vehicle charge capable hybrids: repeat drive cycle until 85% fuel drawdown maximum or canister is sufficiently purged
    - Similar to non-integrated systems

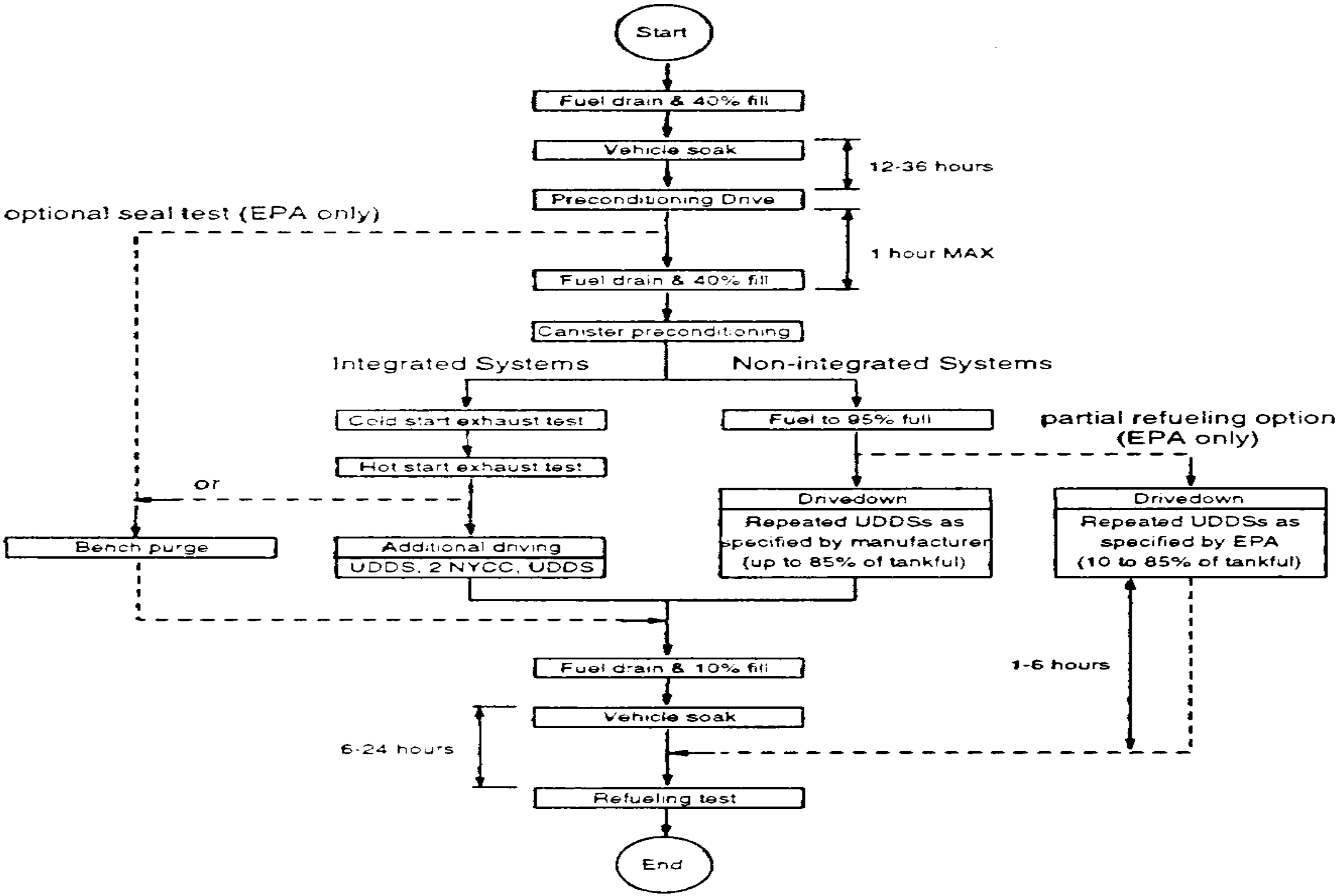
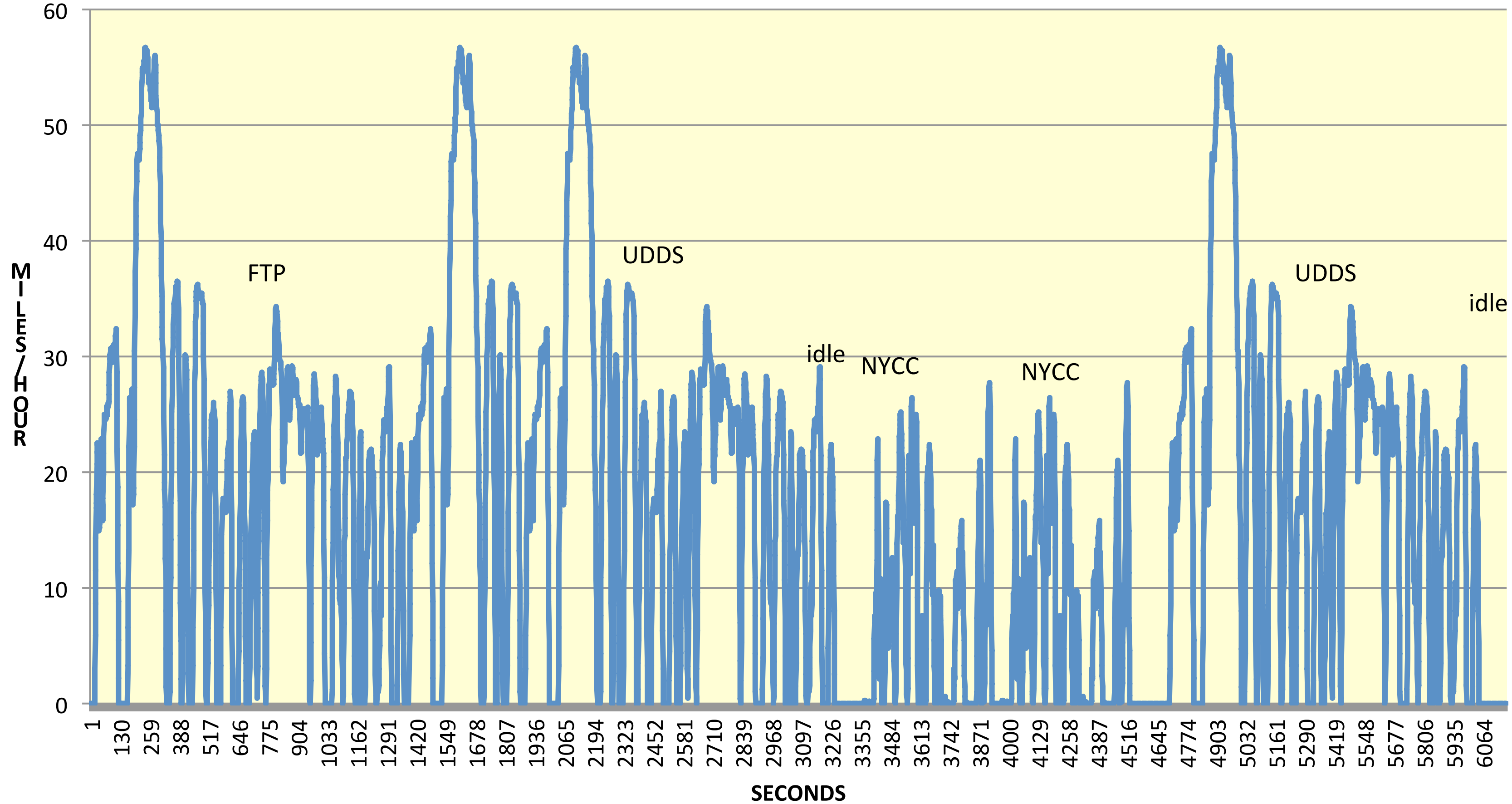


Figure B98-12: Refueling Test Sequence

ORVR - purge for integrated refueling/ evaporative systems (102.8 min)



Fuel/Evaporative System SHED Rig Test for CA

- Full vehicle test in a SHED measures fuel and non-fuel HC. Purpose is to set a ceiling on fuel HC
- First set in place in CA as part of PZEV, maintained in LEV III but not included in Tier 3 except as transitional option.
- The “fuel only” emissions test plan includes the testing of two fuel system rigs, one of which is never exposed to any fuel ("dry" rig), and the other is exposed to fuel ("wet" rig). These rigs will undergo both three-day and two-day diurnal plus hot soak tests .

<u>Basic Test Procedure Components</u>

1. Build two rigs with components seeing liquid fuel or vapor. (list provided)
2. Stabilize rig components for break-in, (fuel contact for components, thermal cycling, canister load & purge, fuel contact for permeation and temperature)
3. Bake to remove non-fuel background for both rigs.
4. Conduct Dry Rig, Wet Rig and Dry Rig Tests for 2 and 3-day diurnal and hot soak
5. Test result = wet rig-dry rig avg.

- Test very hard to replicate and enforce.

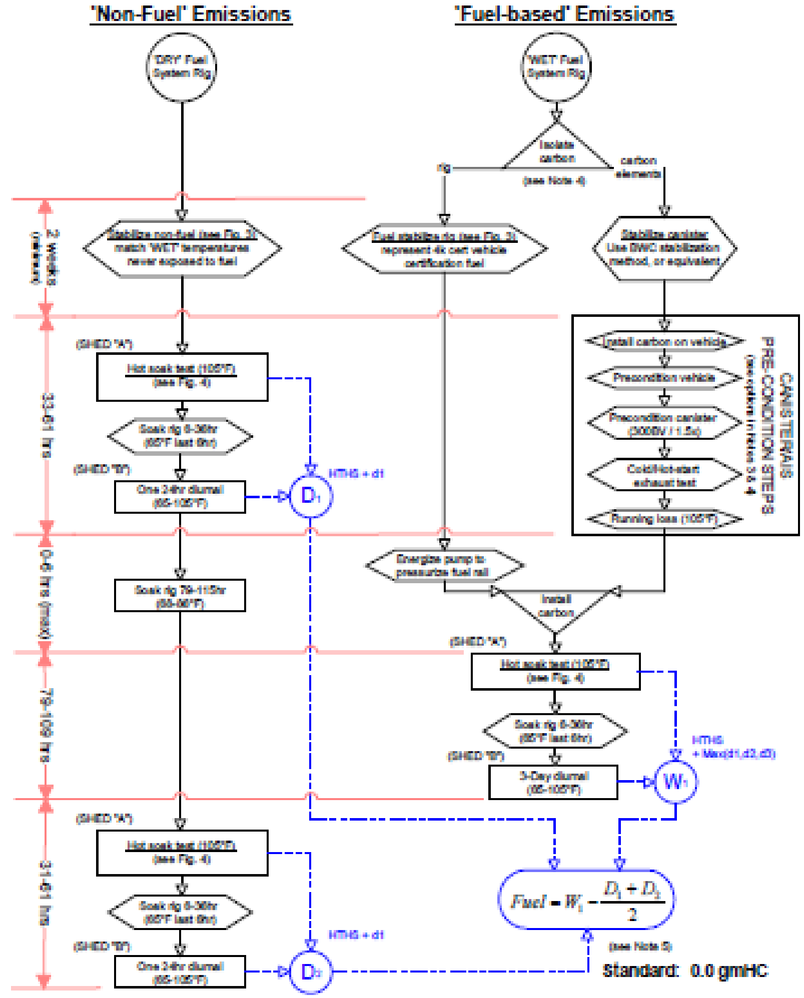


Figure 1: Test Rig 3-Day Evaporative Test Procedure[1]

Canister Bleed Test – LEVIII

Background

- Fuel/vapor control system SHED rig test is costly and cumbersome
- Manufacturers and suppliers put forth an alternative for LEV III … the canister bleed test
- Not a full vehicle test. Does not directly address non-fuel emissions or non-canister emissions but standard is less than one-half of that for SHED rig
- Test is replicable and standard can be enforced

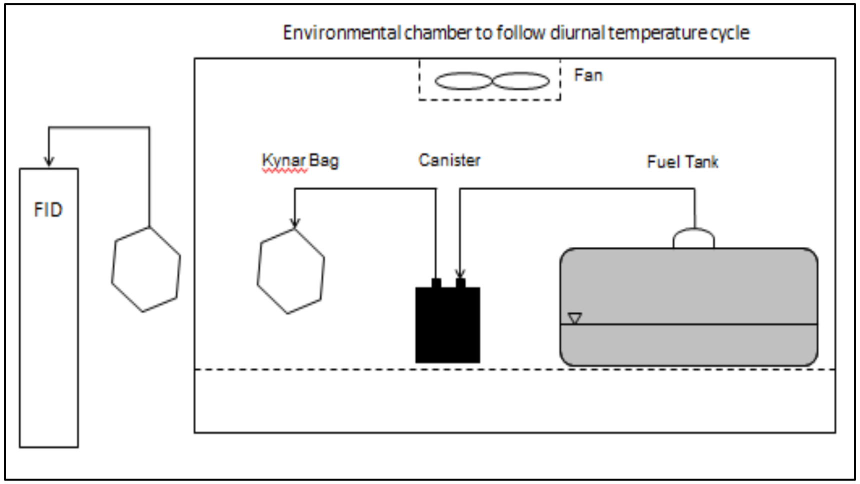
Basics of Test Procedure

- Canister stabilization
- Canister aging: Complete at least 10 GWC cycles with 50% gasoline vapor and purge 300 BV at 0.8 cubic feet per minute
- Fuel tank drain/fill to 40%
- Canister preconditioning
- Fuel tank/canister test rig set-up
- Conduct two-day diurnal test (different procedures depending on whether bag or SHED is used)
- Result is highest of the two day of measurements; no correction for ethanol
- Canister emissions must be ≤0.020 g/day for passenger cars and light trucks.

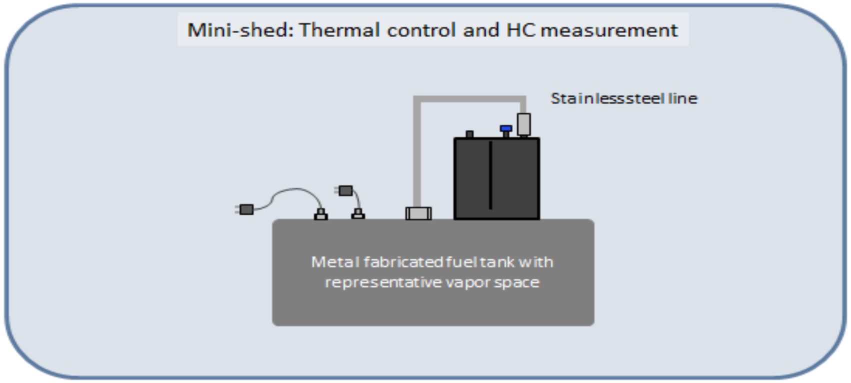
Basic Canister Bleed Test Set-up

- Two basic methods for isolating and measuring canister bleed emissions.
  - Bag method
  - SHED method
- Detailed procedures developed and published by US Council on Automotive Research (US CAR)

Bag method



SHED method



Leak Standard

- LEV III also incorporates a prohibition against any orifices with a cumulative diameter of greater than 0.20”.
  - Arise from micro-cracks, poor connections, in fuel and vapor control systems.
  - Leaks are significant sources of hot soak and running loss emissions.
  - This was included because the OBD requirement calls for detection of these “leaks” in-use but does not prohibit them.
- Manufacturers may attest to compliance at certification since vehicle would fail hot soak + diurnal and/or running loss emission standards during certification testing if it had a leak.
  - Manufacturers may also use test procedure in Code of Federal Regulations
- Enforced in-use through in-use verification program using OBD system and/or official test procedure.
- SAE has now developed a recommended practice in this area.

High Altitude

- LEV II and LEV III does not contain high altitude evaporative standards … there are requirements in Tier 2 and Tier 3 for both low and high altitude testing and separate standards.
  - For EPA high altitude is 4,000 ft.
- Low altitude purge calibrations result in slightly less efficient purge efficiency at higher altitude.
- EPA accommodates for this through two means:
  - Use of a lower vapor pressure test fuel, consistent with local conditions.
  - A slight upward adjustment in the level of the hot soak + diurnal emission standards. No adjustment for other standards.
- High altitude test conditions and standards may require further consideration for Mexico since many cities are at high altitude.

Conclusions

- Evaporative and refueling emissions from current new vehicles sold in Mexico are significant. They impact both $PM_{2.5}$, haze, and ozone air quality.
- Adoption of LEV II standards covering vehicle evaporative and refueling emissions would significantly reduce these emissions.
  - These standards have been fully phased-in in California and the US for five years.
  - Many current models sold in Mexico have the technology needed to meet these levels. The LEV II standards could be implemented in Mexico in the near term.
  - Based on US experience the cost savings related to fuel capture and re-use in the vehicle engine surpass the new hardware cost.
- LEV III would provide even more reductions in the post 2017 time frame; the phase-in in the US is not complete until 2022.