ORVR燃油系统设计及验证要求

Contents

Importance

- Direct impact on the final customer satisfaction;
  - No premature shut-offs
  - No spit-backs
  - Potential for improved comfort, for instance capless system

- Compliance with regulations, especially in the US

- Large portion of development cost associated to refueling within Inergy:
  - High cost of development: from 400 hours (when not responsible) up to 5000 lab hours
  - High differences from system to system
  - Large proportion of lab test failures are related to fill quality issues

Scope

- Describe typical ORVR and RVR (RVR=Refueling Vapor Recovery by gas station) architectures
- Covering gasoline and Diesel
- Concentrate here on the function
  - Physical characteristics of refueling ;
    applies to both plastic and metal pipes
  - Refer to specific processing trainings as regards manufacturing

- **Refueling basics**
- Refueling and hydrocarbon emissions
- Typical configurations
- Innovative refueling concepts

Definition of refueling

- To fill a certain fuel volume, corresponding at most to the capacity of the fuel system, while ensuring:
  - The evacuation of air and fuel vapor
  - The automatic shut off of the fuel nozzle

- Main constraints:
  - Vehicle environment
  - Regulations
    - Compatibility with multiple nozzle designs
    - Evaporative emissions (vapor generation, permeation)
  - « Round-off » capability
  - Proper sealing of filler pipe with cap after refueling
  - 360° nozzle position

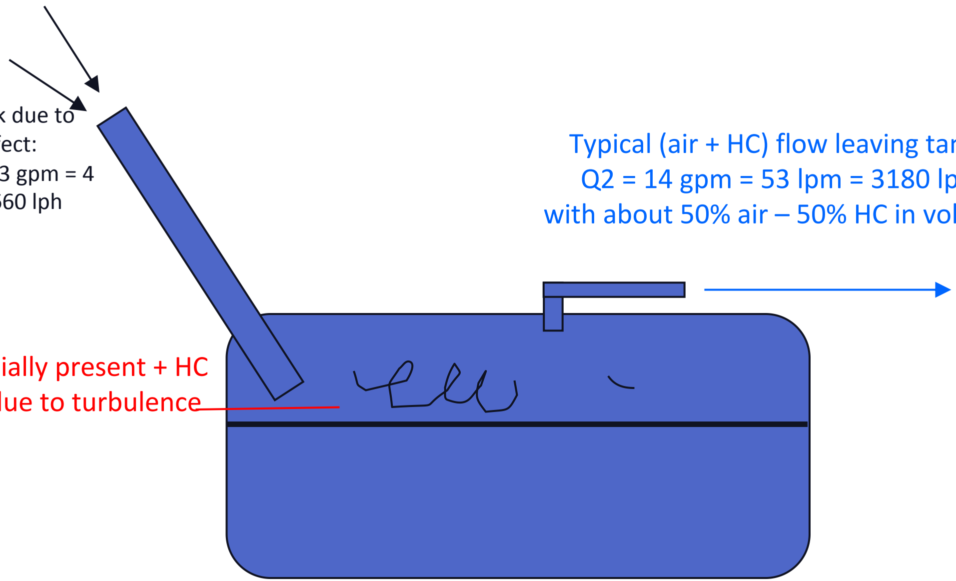
- How does it work ?
  - Example of European / Asian architectures

Refueling flows

Typical fuel flow entering tank:
Q1 = 10 gpm (gallons per minute) = 38 lpm = 2280 lph

Air flow entering tank due to nozzle venturi effect:
10 to 30% of Q1 ≈ 1 to 3 gpm = 4 to 11 lpm = 240 to 660 lph

Typical (air + HC) flow leaving tank:
Q2 = 14 gpm = 53 lpm = 3180 lph
with about 50% air – 50% HC in volume



Air + HC vapour initially present + HC vapor generation due to turbulence

HC = Hydrocarbon

Typical value of $[Q2]_{HC}/Q1$ = 1.3 gHC/liter of entering fuel (from 0.9 with mechanical seals to 1.8 in case of high turbulence and depending upon fuel/temperature)

Possible issues linked to refueling

- Possible issues:

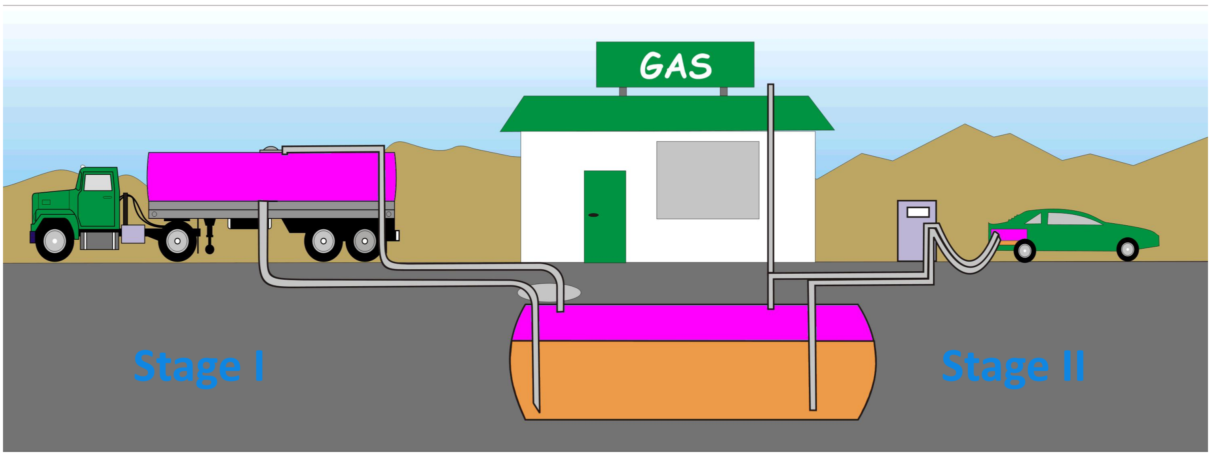
  - Premature shut off
  - Spit-back
  - Overfilling prevention
  - Acceptable fill quality with respect to
    - Fuel type
    - Fuel quality (RVP)
    - Fuel and tank temperatures
    - Fill flow rates

How does it work?

- Refueling basics
- **Refueling and hydrocarbon emissions**
- Typical configurations
- Innovative refueling concepts

Refueling and hydrocarbon emissions

- Regulations in 2 stages
  - Vapor recovery Stage 1 pertains to recapturing vapors during refueling of gas stations from tank vehicles
    - Not relevant for fuel system design
  - Vapor recovery Stage 2 specifies ways of limiting hydrocarbon emissions during refueling of vehicles from gas stations
    - Impact on fuel system



Stage II : emissions during refueling

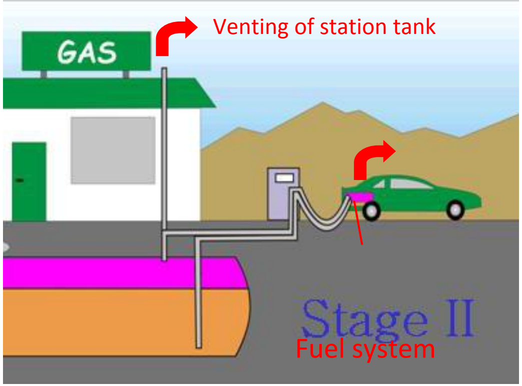
– Stage II aims at limiting hydrocarbons emissions during refueling from gas stations to vehicles

– Due to the refueling operation, fuel vapor can escape

- from the station venting system, due to the introduction of air or lean vapor in the station tank and fuel vapor pressure coming back to equilibrium
  - Typically 1 g/liter of fuel when air is sucked in gas station tank

  ➔ **Reduction thanks RVR (~ 0 g/l), condensation, membrane separation**

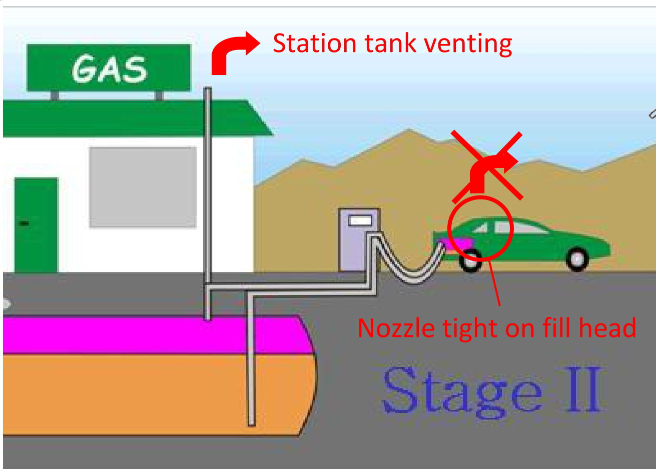
- from the fuel system (mostly through fill head) due to
  - Vapor displaced by the liquid fuel entering the vehicle tank
  - Vapor generated during refueling



➔ **Passive or active recovery (RVR) in gas station, or ORVR (on board of vehicle)**

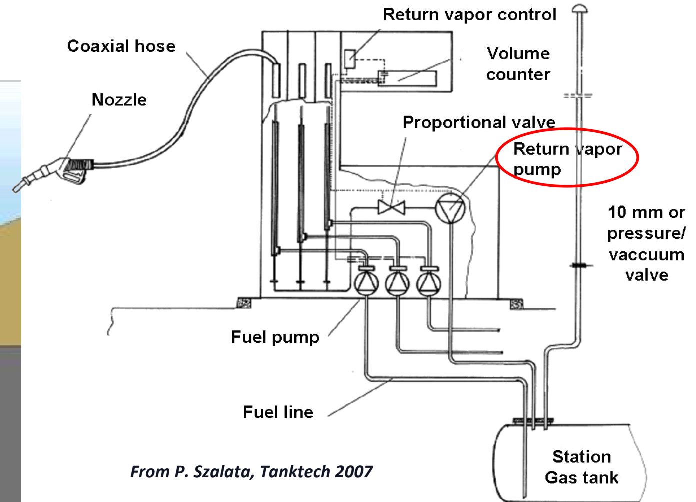
Emissions from the fuel system: RVR

- Vapor recovery with **passive system**
  - **Interface** between vehicle and nozzle made tight to recover vapor and send them to gas station tank



  - Still used in US, but disappearing (replaced by ORVR); also in Korea and China
  - Efficiency limited in practice due to the effort required on nozzle

- Vapor recovery with **active system**
  - **Pump sucking vapor** from vehicle to station gas tank

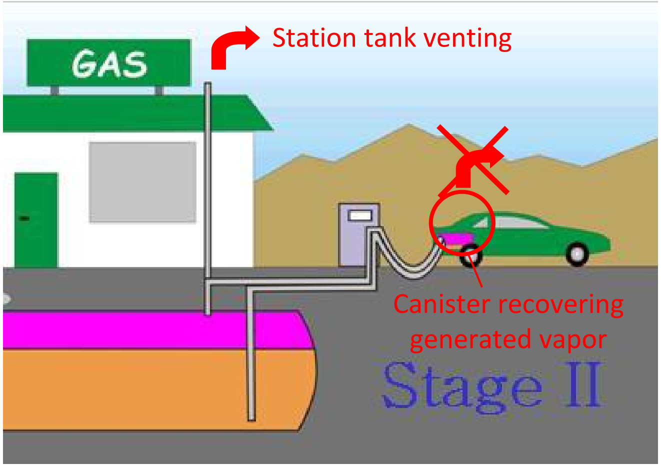


From P. Szalata, Tanktech 2007

  - Deployed (since 1992) in some European countries, under deployment in others
  - Efficiency : ≥ 85% (average on 8 vehicle types required in Germany)

Emissions from the fuel system: ORVR

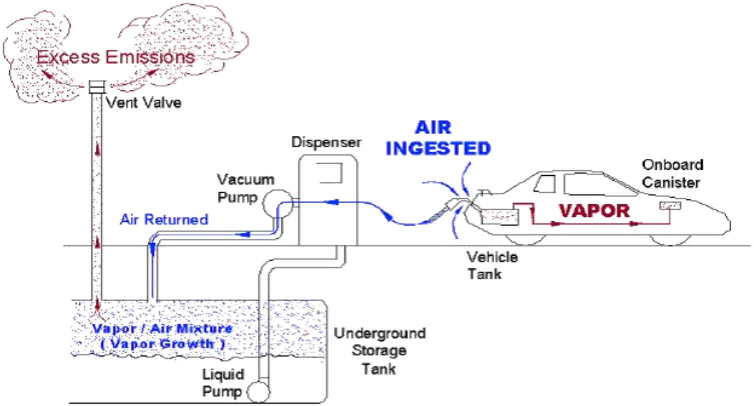
- On-board Refueling Vapor Recovery (ORVR)
  - Adsorption of vapor generated during refueling in large carbon canister

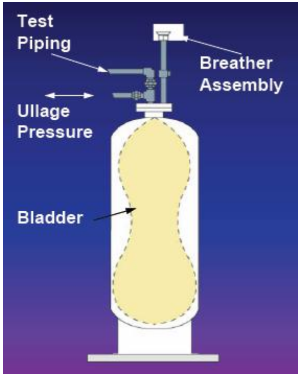


- Widespread in US
- Efficiency > 95% (limit at 0.2 g/gal = 0.053 g/l) but does not contribute to reduction of the emission from the gas station venting system

ORVR systems are incompatible with Phase II dispensing

- ORVR introduced in 1998.
- 100% of US vehicles include ORVR since 2000
- ORVR systems included on over 55% fleet miles
- ORVR refueling in stage 2 equipped stations adds excess venting emissions to environment.
- California requires dispensing stations to install controls and separator tank to prevent excess emissions





How does it work?

- Refueling basics
- Refueling and hydrocarbon emissions
- **Typical configurations**
- Innovative refueling concepts

Typical configurations

- Europe:
  - Gasoline RVR system
  - Diesel

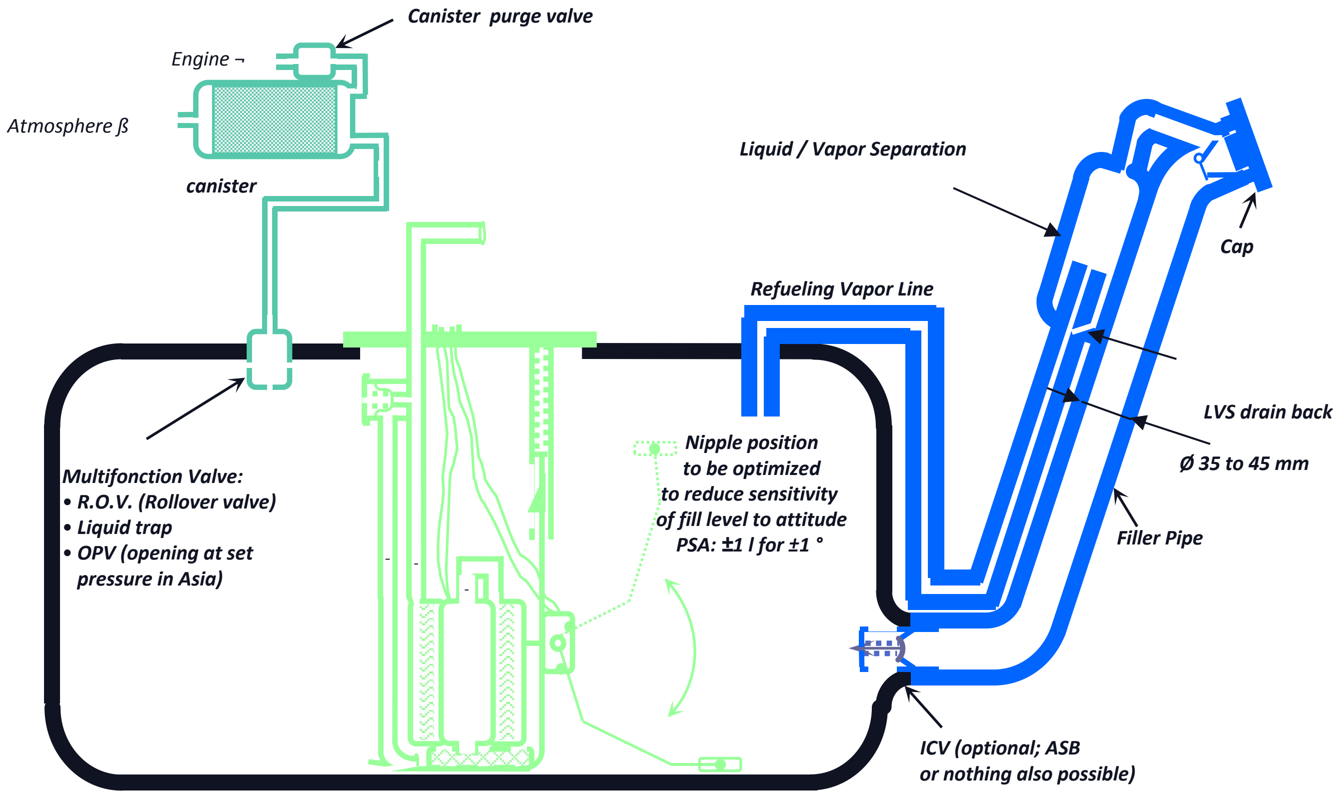
- US
  - Gasoline ORVR system

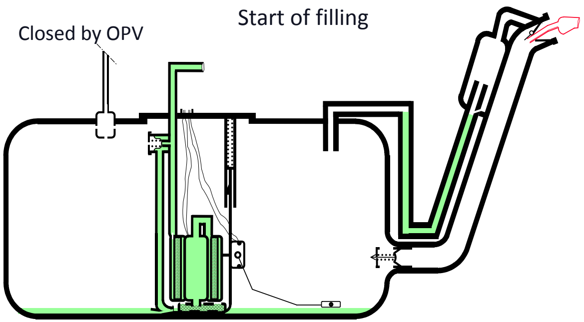
- ASIA
  - Gasoline RVR system (very similar to Europe)

- RVR = Refueling vapor recovery (through nozzle)

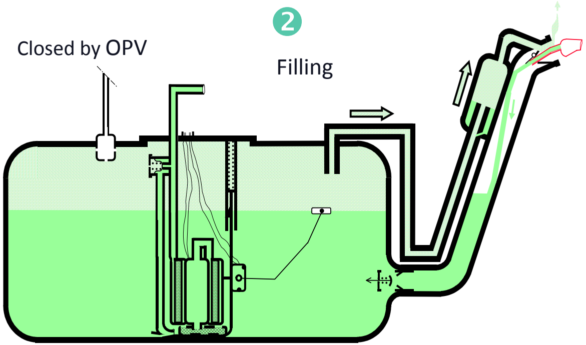
- ORVR = On-board refueling vapor recovery

Europe / Asia gasoline RVR





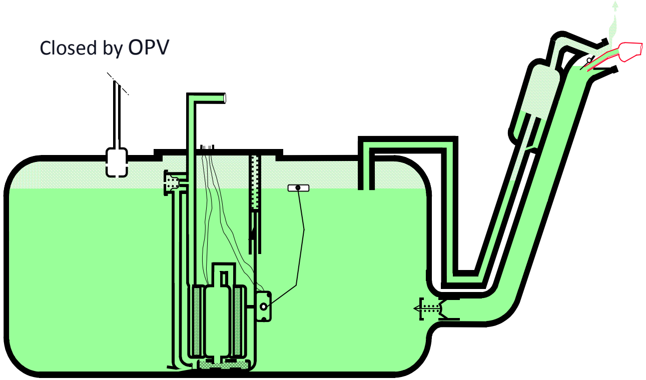
- Phase n°1:
  - Important vapor generation
  - High pressure level in case of filled syphon



- Phase n°2:
  - Stabilized conditions

❸

End of filling



– Phase n°3:
- Vapor line closed by fuel level
- Pressure increase in the tank (backpressure)
- Fuel ascent in the filler pipe and in the vapor line
- Shut-off (as the fuel level reaches the nozzle)

Syphon in refueling vapor line

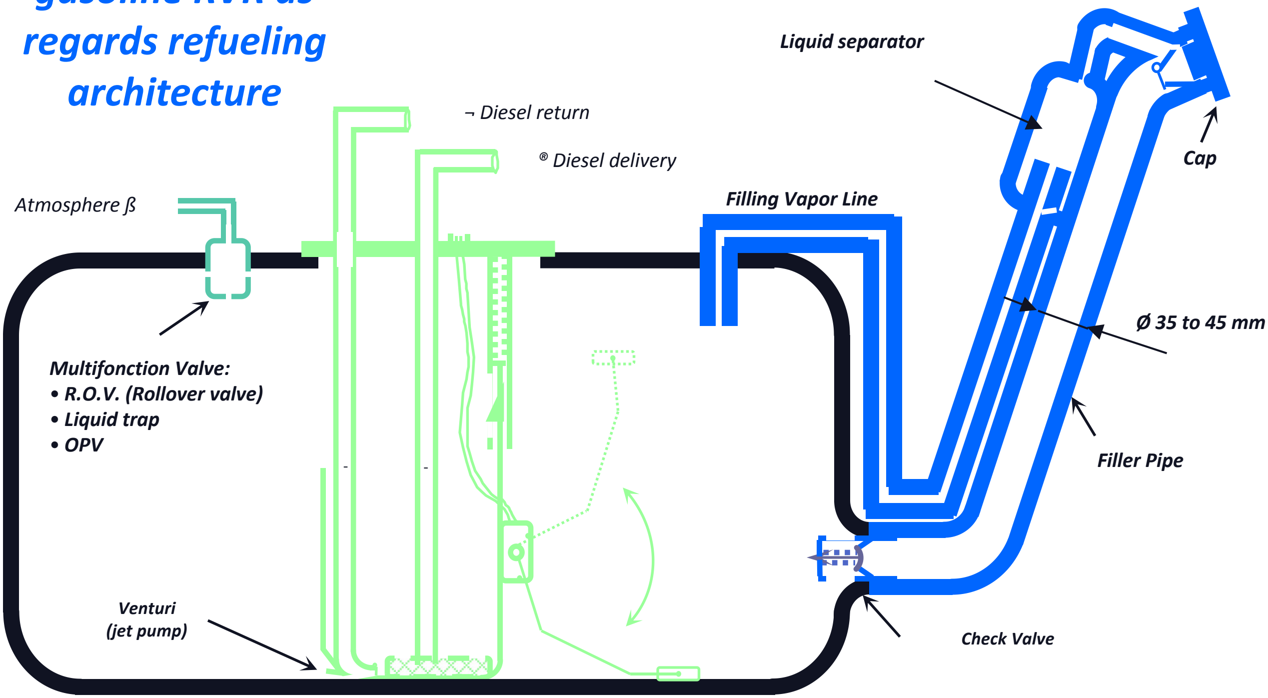
- Often imposed by vehicle architecture

- At start of refueling,
  - pressure build-up due to increased pressure drop (vapor bubbles through fuel);
  - can cause PSO if pressure build-up is sufficient to increase fuel level in filler pipe up to nozzle

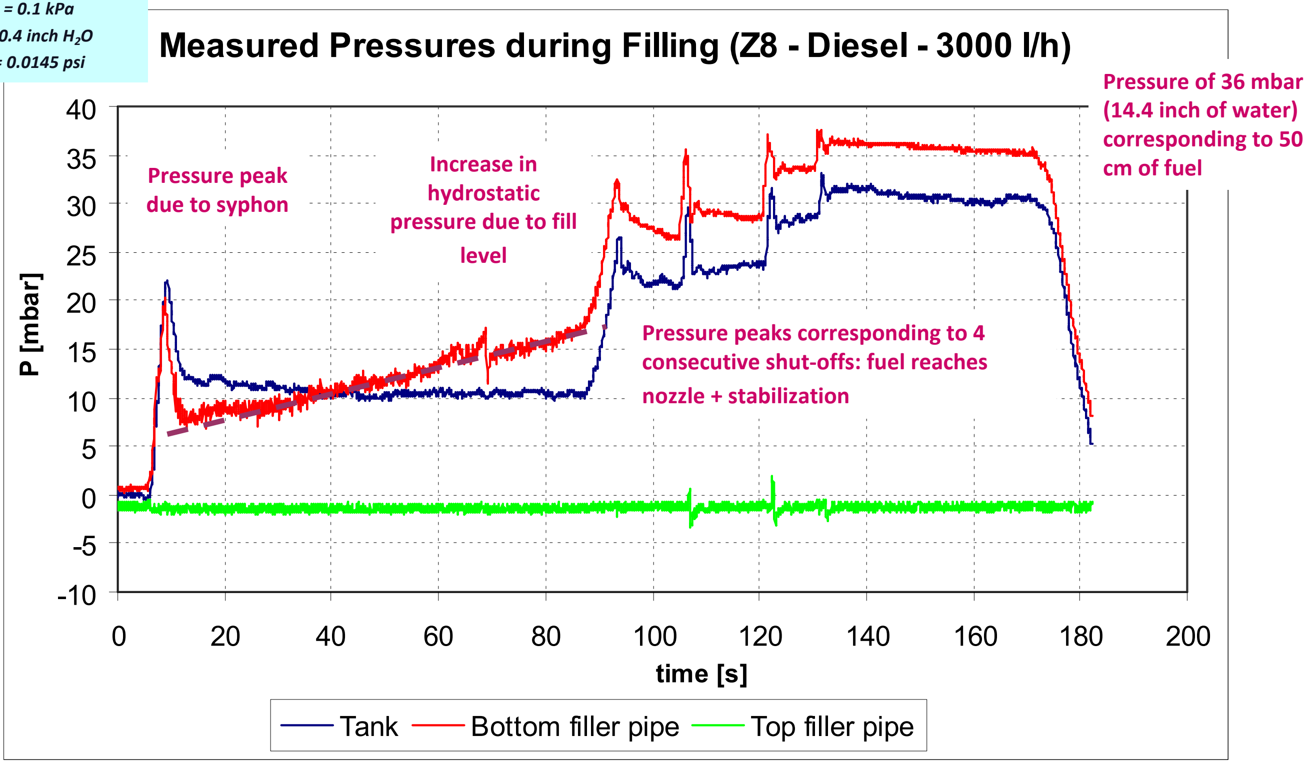
- Liquid fuel is pushed in liquid vapor separator

- Ways to reduce syphon impact
  - Separator as low as possible
  - Float valve protection
  - Reduce syphon volume

No difference with gasoline RVR as regards refueling architecture



1 mbar
= 0.1 kPa
= 0.4 inch H_2O
= 0.0145 psi



Differences Diesel-gasoline

- Physical properties

	Diesel	Gasoline
Kinematic viscosity (centistoke = 10^{-6} m^2/s)	3	0.5
Specific mass (kg/m^3)	830	740
Vapor pressure at 37.8°C (kPa/*psi*)	< 7 kPa *< 1 psi*	48-103 kPa *7-15 psi*

- Larger diameter of nozzle
  (≥ 23.6 mm for diesel & ≤ 21.3 mm for fuel)
- Higher flow rates

Differences Diesel-gasoline

- Foam provoked by Diesel fuel; possible issues:
  - Diesel foam can come out of filler pipe without provoking shut-off)
  - Specific foaming issue with high flow rate nozzles (trucks)
  - Foam can also lead to premature shut-off due to bubble entrainment in filling vapor line

- Consequences as regards tuning
  - Fill level can differ by 3 liters (5-6% of rated capacity) depending on foam generated by Diesel fuel
  - Problem to restart the filling with low diameter filler-pipe (25 mm)

- Consequences as regards design
  - Shorter refueling vapor line nipple with Diesel due to the presence of foam
  - Large diameter for the filler-pipe (>30mm)
  - Large diameter for the breathing line
  - Larger diameter for the filler-head guide

ORVR fuel system-"US" Specific Functions

- **O**n Board **R**efueling **V**apor **R**ecovery
  All the vapors displaced and generated during refueling have **to be stored on board:**

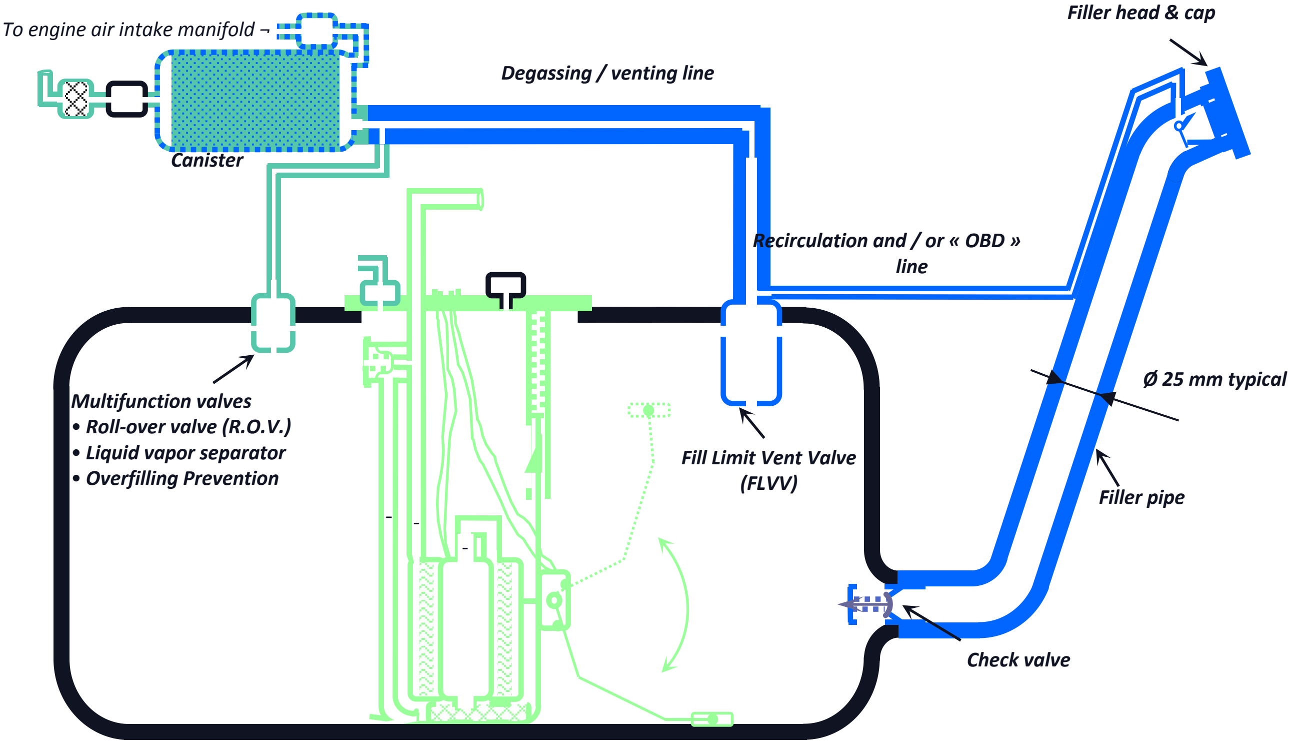
- Maximum allowed emission: 0.053 g/l of fuel added (0.2 g/gal) (in standard configuration, typical emissions are between 1 and 1.5 g/l)

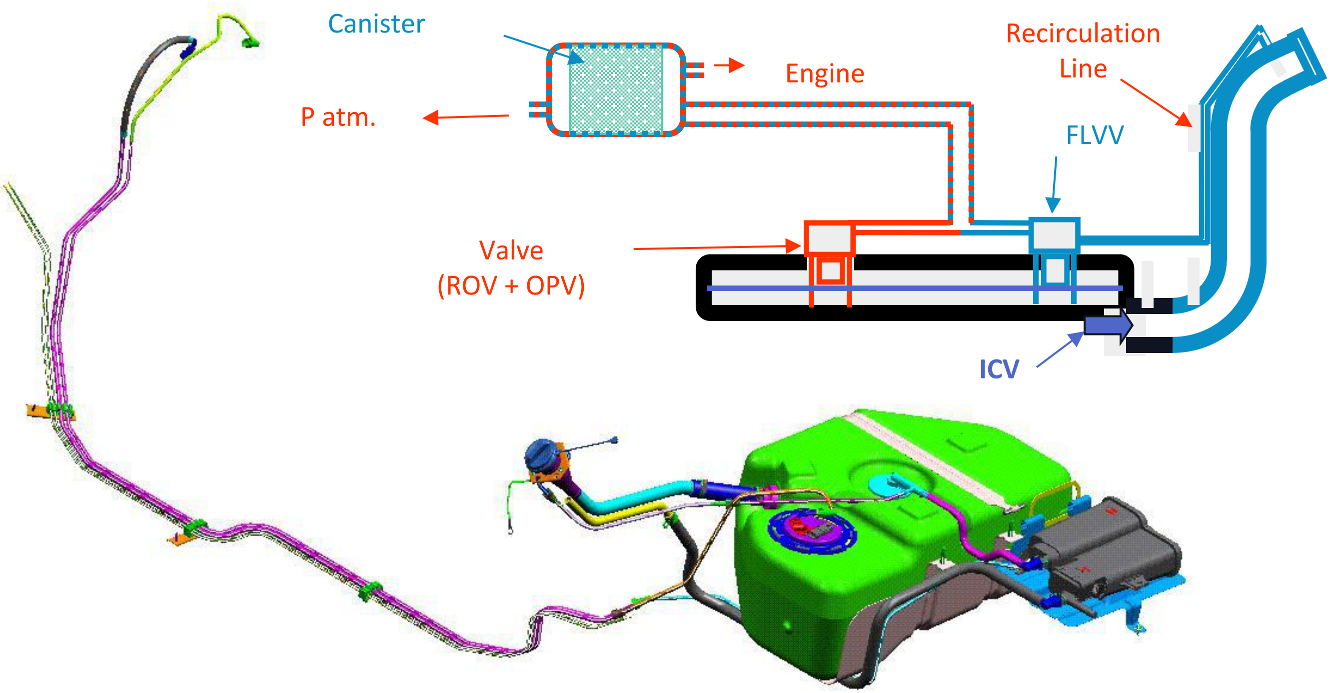
  - For flow rates from 4 to 10 gal/min (15 to 38 l/min)
  - Impact on design

- Typical requirement given by OEMs: 0.04 g/gal to 0.10 g/gal, with sometimes restrictions on canister loads (1.2 g/l)

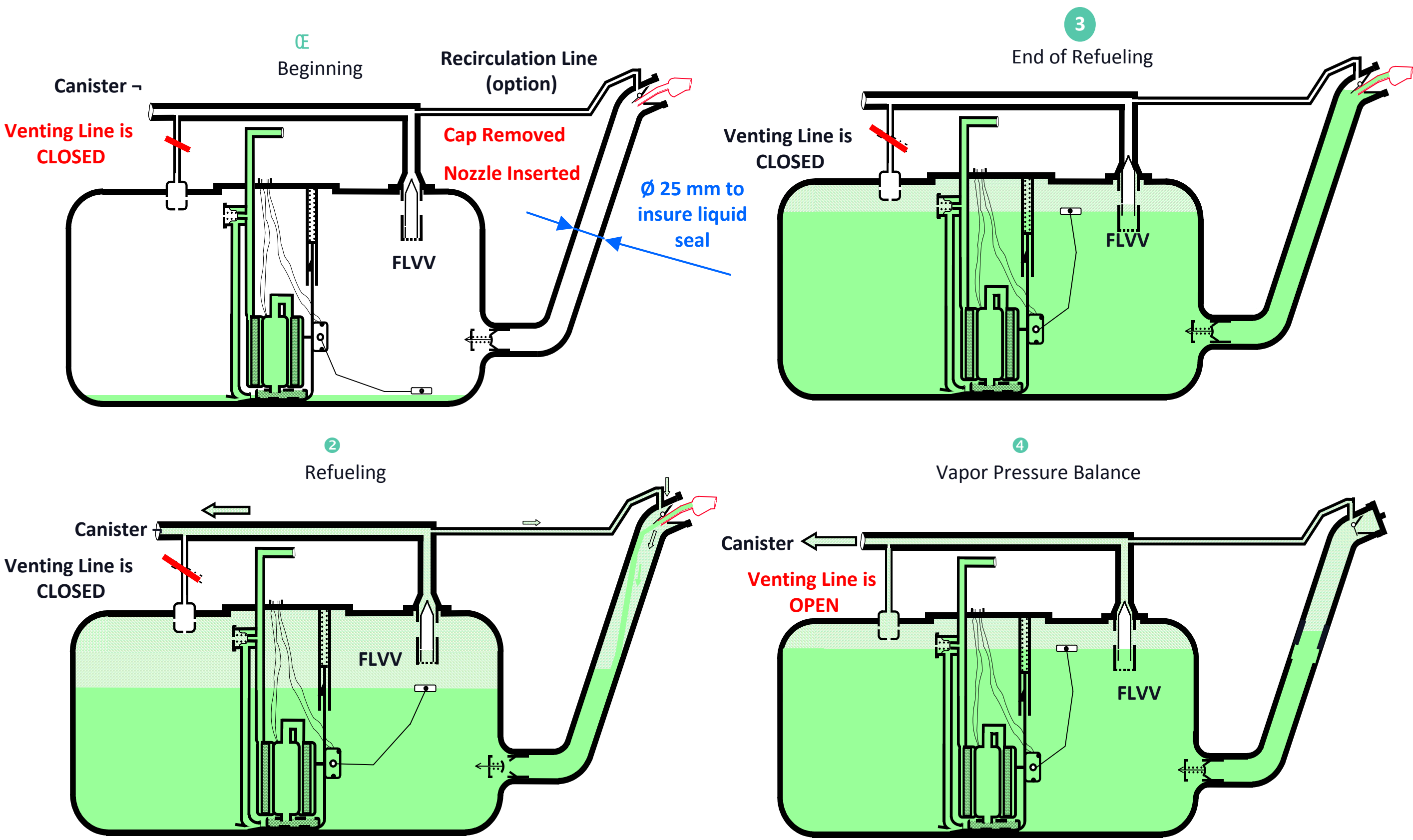
- Leak Detection (OBD)
  - Recirculation line to have communication between filler head and vapor dome

ORVR - Standard architecture




Canister
Engine
P atm.
Recirculation
Line
FLVV
Valve
(ROV + OPV)
ICV

Refueling of ORVR Systems



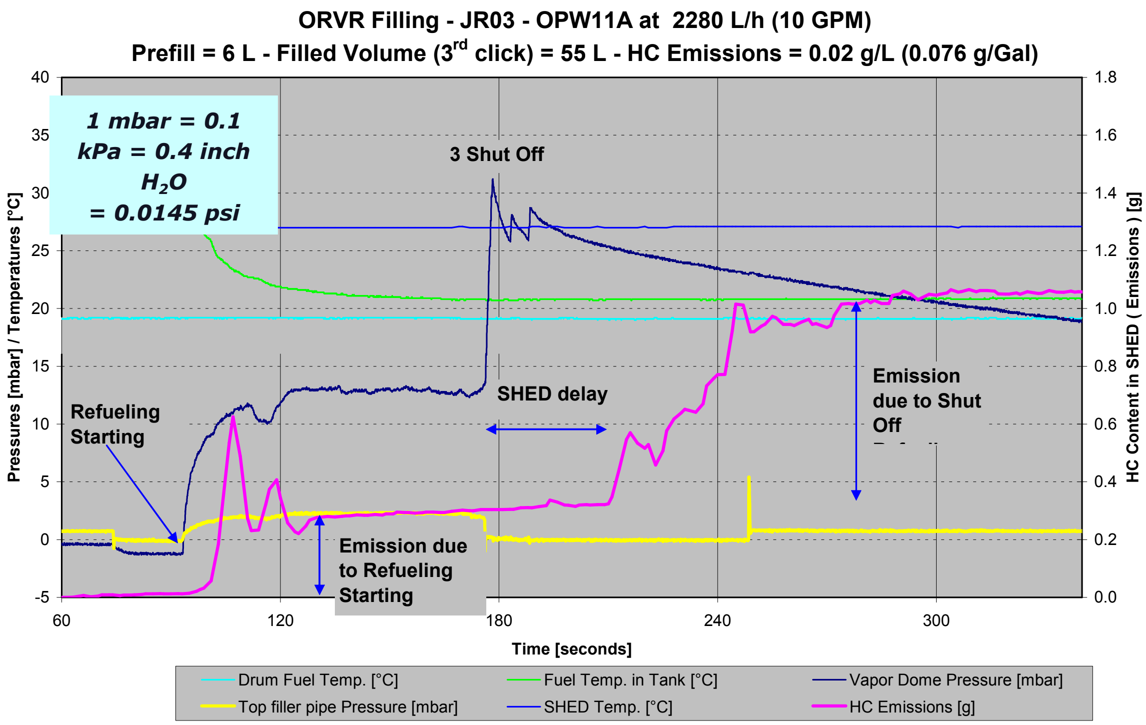
- Refueling emissions are measured in an ORVR SHED
- ORVR SHED accommodates vehicle refueling through the wall
- Hydrocarbons escaping the vehicle are contained in the sealed SHED. The concentration is measured with a FID.

Fuel dispensing cart

Refueling nozzle through the SHED wall—booted for operator arm (not vapor recovery)

Refueling Emissions with ORVR

(37.8 lpm)

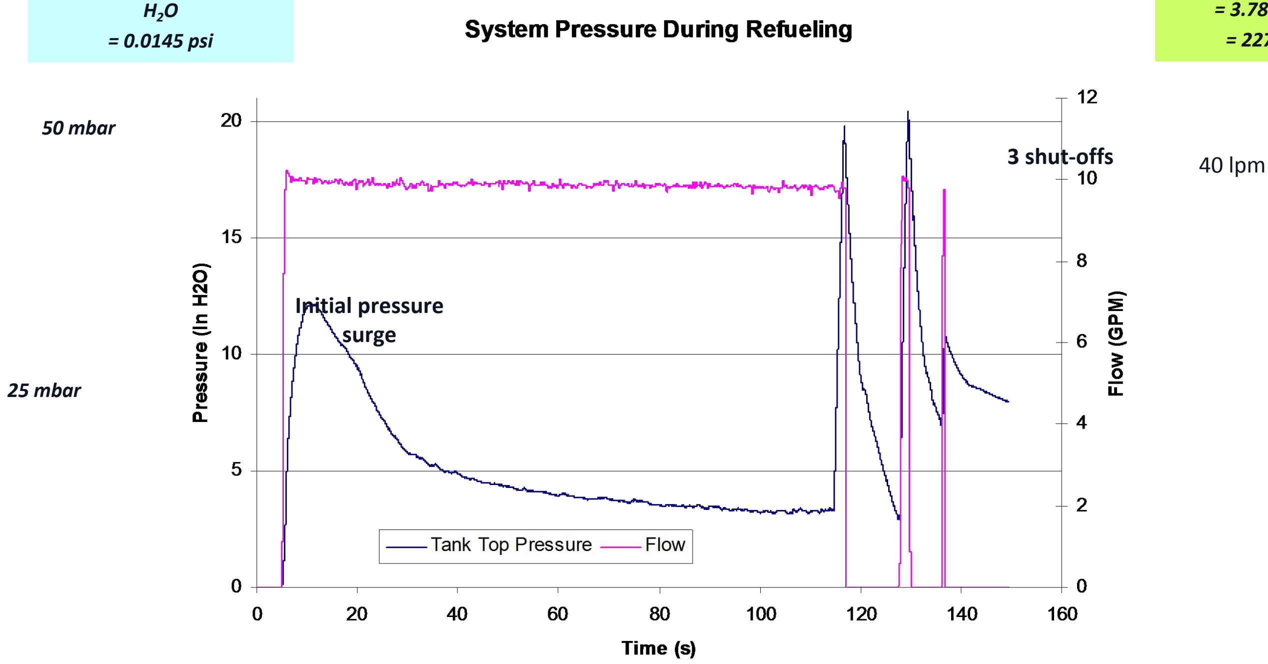


Note: for EPA, total emission = 1 shut off + 1 minute

Evolution of pressure during refueling (ORVR system)

1 mbar = 0.1 kPa = 0.4 inch H_2O
= 0.0145 psi

1 gpm
= 3.785 lpm
= 227 lph



Comparison of typical current architectures

Function	ORVR architecture	RVR architecture
Guide the fuel into the tank	**Liquid seal**, small diameter (inner diameter of 25 mm)	Large diameter (inner diameter of 35 to 45 mm)
Relieve the vapor during refueling	Into a **large canister** (1.8 to 4.5 l) with specific charcoal Recirculation line optional (reduction of canister load)	Into the atmosphere at the filler head thru breathing line Liquid trap management by liquid –vapor separator
Over Filling Prevention	Venting usually closed during refueling except FLVV **Fuel closes the FLVV** at the end of refueling, pressure increases in the tank, fuel rises in the filler pipe to reach the nozzle edge	Venting usually closed during refueling **Fuel closes the breathing line** at the end of refueling, pressure increases in the tank, fuel rises in the filler pipe to reach the nozzle edge.
Safety	Tank tightness: ROV & ICV Leak detection: OBD II	System tightness: ROV Measure to avoid running without cap (link between chassis and cap, keys blocked on when open)
HC recovery (legislation)	Limited emissions during refueling : **ORVR** (Max 0.2 g/gal or 0.053 g/l) RVR stage II still in use	**RVR stage II** (in some countries / stations) Small canister (0.7 to 1.2 l) used for venting flow only

ORVR Design (1/2)

- Filler pipe design must not allow vapor to escape during filling
  - Liquid seal with typical pipe internal diameter of 25 mm
  - Alternatively mechanical seal

- ORVR control valve (FLVV) must allow the vapor to exit the tank and control the fuel shut off level

- Vent line to the canister must allow vapor flow with minimum pressure drop

- Recirculation used to reduce canister loading (reduction of air entrainment and vapor generation) and/or for OBD

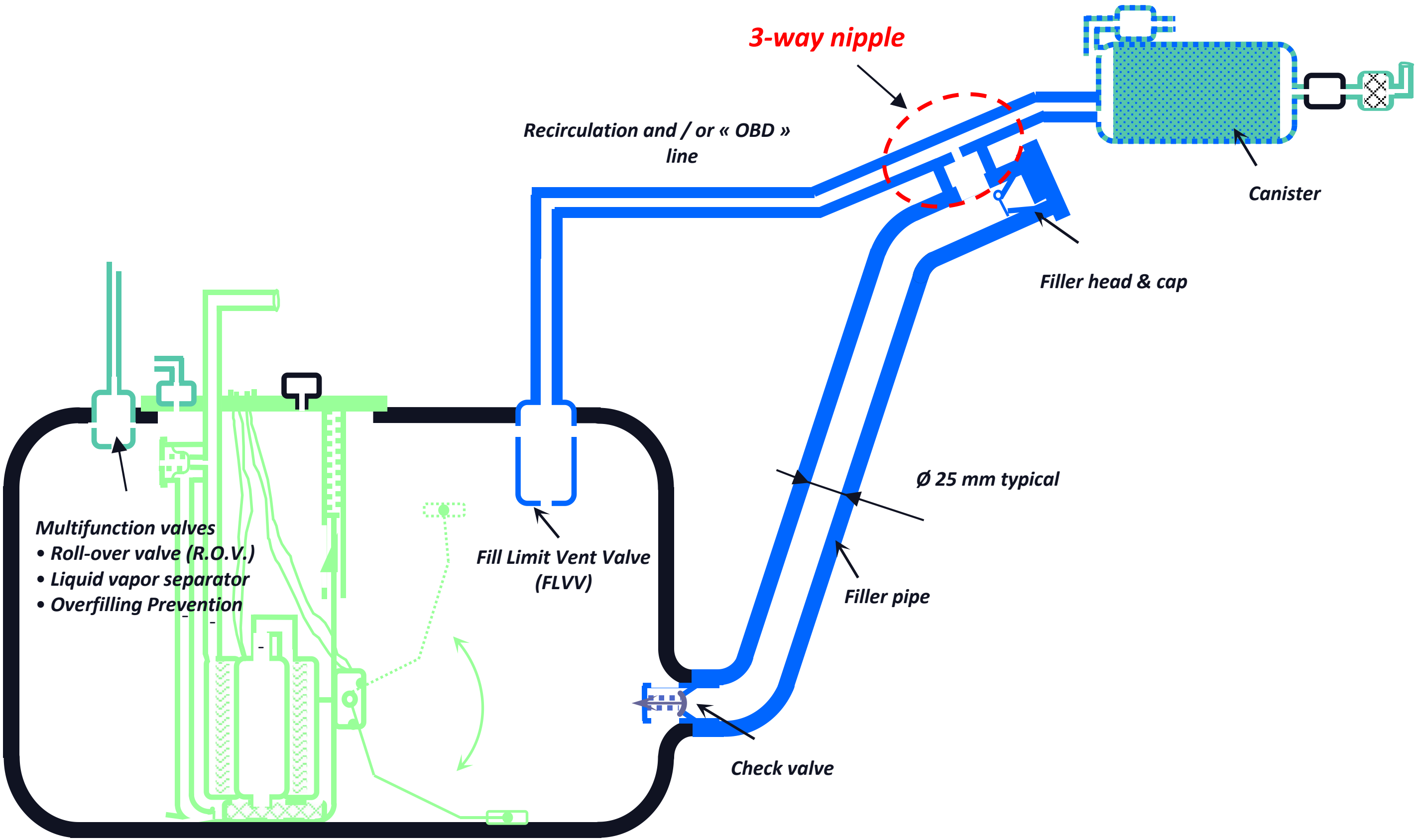
ORVR Design (2/2)

- Canister must be larger to hold all HC from filling and have low restriction

- Roll over/crash protection
  - Venting system must be leak tight (FLVV + ROVs)
  - Required by some customers in case of filler pipe rupture

    - Sealed Internal Check Valve is required inside the filler neck

- 3 typical ORVR architectures
  - Standard: the most widespread
  - With 3-way nipple: more and more used
  - Without recirculation line: seldom

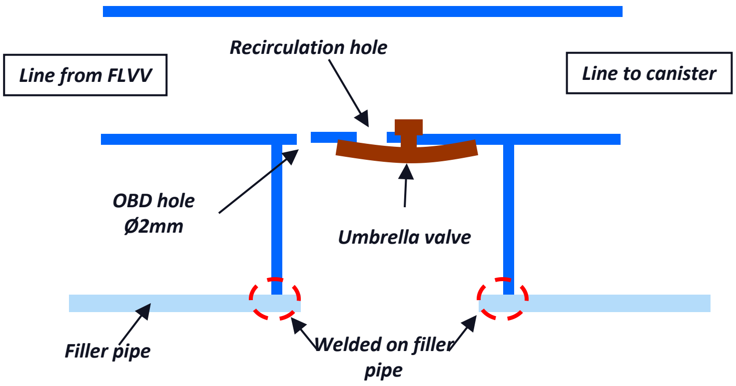

3-way nipple
Recirculation and / or « OBD » line
Canister
Filler head & cap
Ø 25 mm typical
Filler pipe
Check valve
Fill Limit Vent Valve (FLVV)
Multifunction valves
• Roll-over valve (R.O.V.)
• Liquid vapor separator
• Overfilling Prevention

ORVR – Architecture with 3-way nipple (2/2)

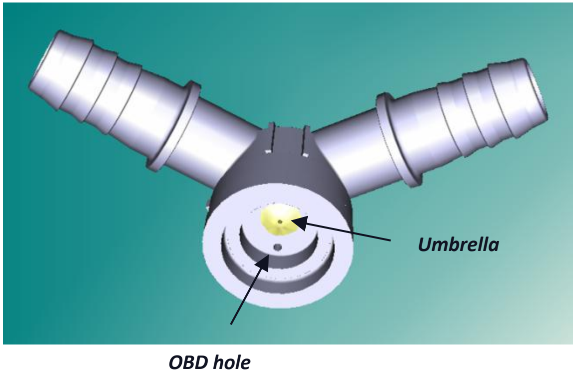
– Functions ensured by 3-way nipple

- Connection between filler pipe, line from FLVV and line to canister
- Recirculation of air in the filler pipe > the recirculation ratio can be adjusted by the size of the hole(s) and the umbrella valve
- OBD diagnostic: hole ≥ Ø2mm

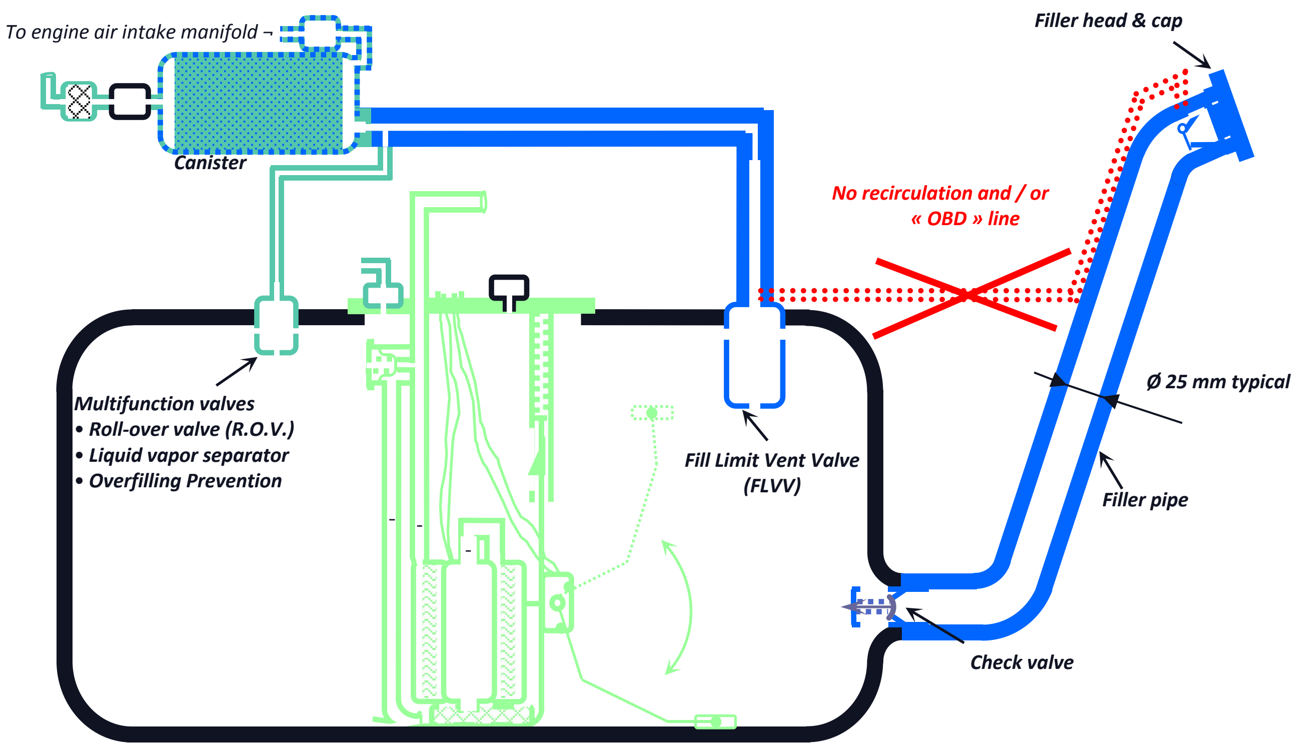
Typical 3-way nipple design



Example: PL6 US 3-way nipple



ORVR – Without recirculation line



ORVR architectures – Pros / Cons

Criteria	**Standard**	**3-way nipple**	**No recirculation line**
Canister loading	+	+	-
Compatibility with RVR architecture	-	+	-
OBD	+	+	-
Projects (examples)	GM Epsilon 2; BMW PL2	BMW E88 BMW PL6; Audi D4	Porsche C2/C4; Mercedes A/B Class

- Architectures with 3-way nipple are more and more used in Europe:
  - Architecture standardization + components prices
  - Be careful about ECE canister loading during refueling (BMW, Porsche)

➔ pressure drop between nipple and canister thanks to additional valve or restriction

- Architectures without recirculation lines often due to insufficient place in car environment