Integrating Vapor Recovery System in Fuel Circuit Layout

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Abstract*:*
Study report describes unique way of integrating Vapor Recovery System in Internal Combustion Engine and Hybrid vehicles by eliminating conventional Vapor purge circuit from Canister to E ngine. Introducing Vapor Recovery system in layout which converts Vapor to Liquid gasoline through forced convection method, which simplifies the complexity in Powertrain tunning.

Keywords*:* Tank Reservoir, Vapour tube, Roll Over Valve (ROV), Canister, Heat dissipation unit, EVAP emissions

1. Introduction

Petrol and Diesel emissions are a major focus in the automotive industry due to their impact on air quality and climate change. Both types of fuel emit various pollutants during combustion, b ut they differ in their composition and the types of emissions they produce. Petrol engines gene rally produce fewer pollutants than diesel engines, but they still emit a variety of harmful subst ances Carbon Dioxide (CO_2),Carbon Monoxide, Hydrocarbons, Nitrogen Oxides and Particulate Matter. In other hand Diesel engines are typically more fuel-efficient than petrol engines, but th ey produce higher amounts of certain pollutants, which can have more severe health and enviro nmental impacts. To reduce harmful emissions from both petrol and diesel engine various techn ologies are used:

Catalytic Converters: Found in petrol engines, catalytic converters reduce CO, HC, and NOx emissions by converting them into less harmful substances (CO_2 , nitrogen, and water).

Diesel Particulate Filters (DPF): These are used in diesel engines to trap particulate matter, re ducing PM emissions.

Selective Catalytic Reduction(SCR): This technology used in diesel engines to reduce NOx emis sions by injecting a urea-based solution into the exhaust system.

Exhaust Gas Recirculation(EGR): Both petrol and diesel engines may use this system to reduce NOx emissions by recirculating a portion of the exhaust back into the engine's combustion c hamber.

Compliance to vehicle emission norms as per Regulatory requirements [2,11], Passenger and co mmercial transport vehicles are mandatory to reduce overall vehicle emissions [1] and aiming t o reduce and meet zero emission of HC, NOX, and particulate matters from System to Vehicle level. To meet Regulatory commitments, Original Equipment Manufacturers (OEM) and suppliers are working in line with technology to optimize and improve the efficiency from complete fuel burning through fine tuned Engine ignition cycles to reducing usage of HC pollutants emitting p lastic sub substan-ce parts in Vehicle. Reducing hydrocarbon (HC) emissions is crucial for impr oving air quality and meeting environmental standards in the automotive industry. Plastic p arts in vehicles, especially those made from materials like polypropylene, nylon and polym ers play an important role in addressing these emissions. However, they can also contribute to HC emissions due to off-gassing or the absorption and release of gasoline vapors. Fortunately, manufacturers are using various strategies to minimize these emissions and improve vehicle perf ormance in an eco-friendly way. Evaporative Emission Control systems in the automotive industr y are designed to prevent the relea-se of fuel vapors into the atmosphere, which can contribut e to air pollution and smog. These vapors are a byproduct of gasoline evaporation, which can happen even when the car is off, particularly in hot weather.

The EVAP system captures these vapors and routes them to charcoal canister, where the vapors are stored temporarily. Then, when the engine is running, the vapors are purged from the cani ster and burned in the engine, reducing harmful emissions.

Key components of an EVAP system typically include [10]:

- Charcoal Canister: Absorbs and stores fuel vapors.
- Purge Valve: Allows stored vapors to be drawn into the engine for combustion
- Vent Valve:Prevents vapors from escaping into the atmosphere when vehicle is off.
- Fuel Tank Pressure Sensor:Monitors the pressure inside the fuel tank to ensure system is fun ctioning properly.

Global regulations for evaporative emissions follow the certification test flow [2,9]:

- The carbon vapor canister is prepared and loaded.
- Fresh fuel is added to the fuel system.
- The vehicle is preconditioned through a driving cycle.
- Hot soak test
- Running loss test
- Diurnal test

Some of the processes that cause evaporative emissions in vehicles are:

Diurnal emissions generated in the vehicle's fuel system are caused by changes in temperature throughout the day.

Emissions from the fuel system when a hot engine is turned off occur because of the residual heat volatilization factor of fuels.

Evaporative emissions while driving occur when the engine is operating normally.

Emissions at rest with a cold engine occur mainly due to permeation of the fuel system components.

Evaporative emissions during refuelling consist of vapor leaks from the fuel tank during the refuelling process; these occur while the vehicle is at the service stations.

Table 01. Breakdown of the different processes that contribute to evaporative emissions.

Processes contribute to evaporative emissions	Contribution in percentage
Fuel Tank Heating and Vaporization	30-40%
Fuel Tank Venting	20-25%

Fuelling Process	15-20%
Fuel System Pressure Changes	10-15%
Evaporation During Engine Warm-Up	5-10%
Hot Soak (Shutdown Conditions)	5-10%
Fuel System Leaks and Seals	5-10%

ICE vehicles run entirely on an internal combustion engine, which burns gasoline or diesel to power the car’s wheels. The engine generates mechanical power through the combustion of fuel in the engine’s cylinders.

HEVs combine an internal combustion engine with an electric motor and a battery. The electric motor assists the engine, especially during low-speed driving or when starting from a stop, improving fuel efficiency. The battery is charged through regenerative braking (which recovers energy while braking) and the engine. HEVs cannot be plugged in to recharge; they rely solely on the engine and regenerative braking for battery power.

PHEVs are a step up from HEVs and combine an internal combustion engine with a much larger electric motor and a rechargeable battery that can be plugged into an electrical outlet. PHEVs can run on electricity alone for short distances, after which the gasoline engine kicks in to extend the driving range. The vehicle can typically be charged via a standard home outlet or a fast charger. PHEVs can be driven solely on electric power for daily short trips, and when the battery is depleted, the internal combustion engine takes over.

Table 02. Emission types in ICE, HEV and PHEV vehicle.

Emission Type	ICE	HEV	PHEV
CO_2	High	Moderate	Low (on electric mode)
NO_x	High	Moderate	Low (on electric mode)
PM	High (diesel)	Moderate	Low
CO	High	Moderate	Low
HC	High	Lower	Low

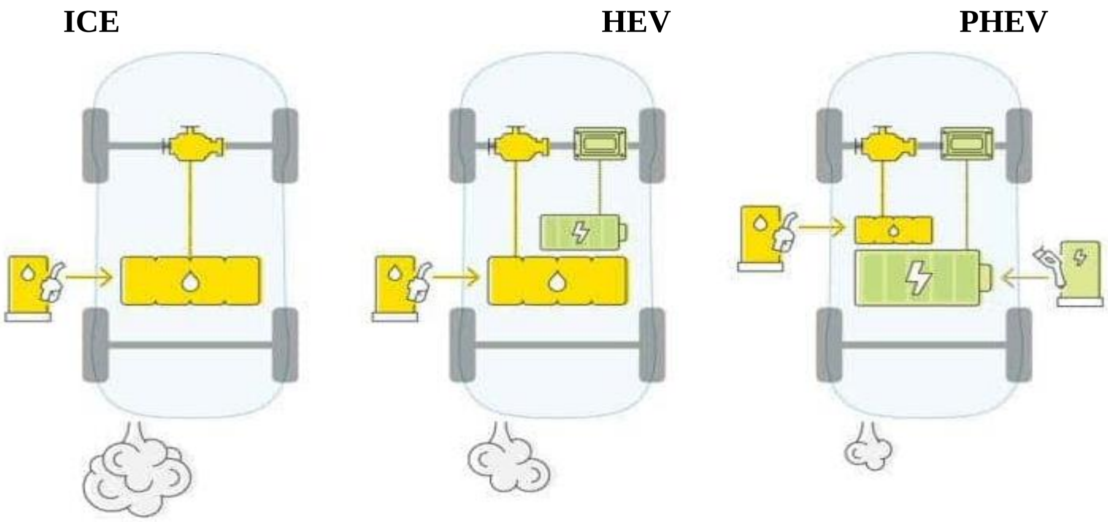

Figure 01 – ICE, HEV and PHEV vehicle configuration

OEMs are looking forward to drive upcoming projects With Battery pack (Hybrid and Plug-in hybrid) or Fuel cells or Hydrogen technology which is drastically reduce tail pipe & over all vehicle emissions. In Hybrid and Plug-in hybrid technology Vehicle could drive mostly on battery sources compare with conventional ICE vehicle, this conditions even applicable in both Series and Parallel vehicle configuration.

In ICE &Hybrid vehicles, during engine driving mode to avoid EVAP emissions fromfuel system, Canister which assembled in vehicle adsorbs vapor from Tank reservoir, and it burned in engine through Purge cycle. In hybrid, vehicle driving at electric mode, due to Gasoline nature of vaporization property, Fuel in reservoir vaporizes, and it get's stored in canister until it reaches holding capacity. There after it starts to emit to atmosphere. In current trends, Numerous advancements in battery chemistry, which is increasing battery cells range, vehicle can be able to drive in electric mode higher and declining the usage of Fuel in both HEV and PHEV vehicles. It further increasing EVAP emissions from Fuel system layout to environment. To reduce EVA-P emissions and meet regulatory requirements in ICE & Hybrid vehicles, Introducing unique Vapor Recovery System in Fuel layout which operates independent to Engine cranking (ON) condition.

2. Working principle

ICE/Hybrid Vehicle in Idle/driving/Parking scenario, Gasoline in tank reservoir vaporized due to impact of environment temperature. Once it reaches certain pressure, vaporized gas in tank pass through Roll Over Valve to canister and it will be adsorbed by activated carbon in Canister module. During vehicle Battery switched on condition, battery source could initiate Vapor Recovery System (VRS) [5,8] through SCU.

Refer detailed working layout in figure 02.

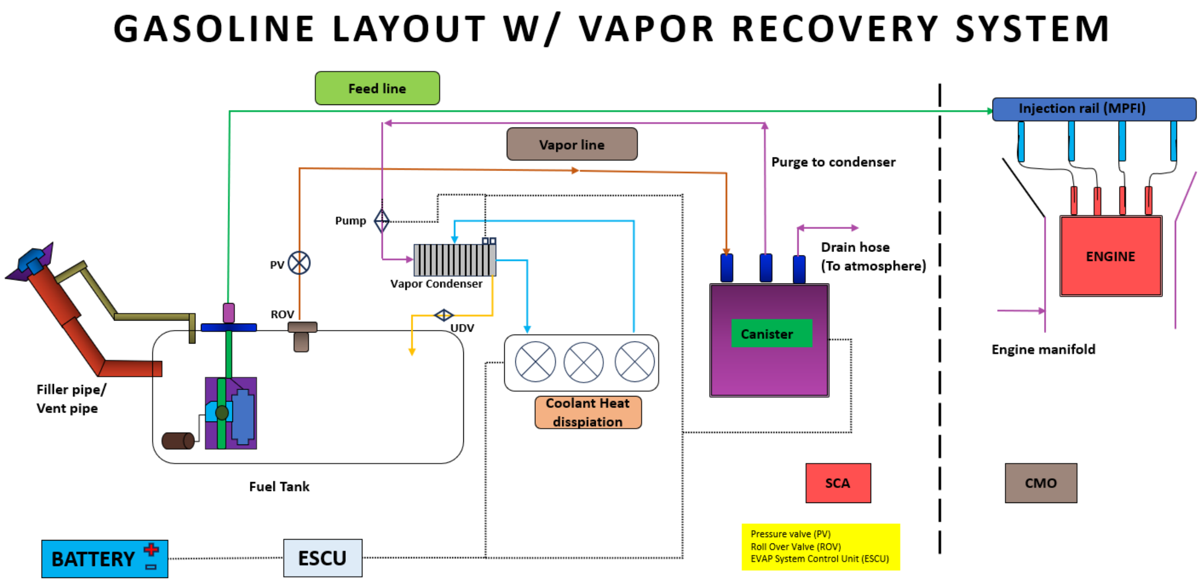

Figure 02 Vapor recovery System integrated in Gasoline Fuel circuit.

EVAP System Control (ESCU) operates the Pump, which pulls enriched carbon vapor from canister and passes through vapor condenser under forced convection process, vapor phase changes to Liquid gasoline, which eventually returns to tank reservoir through Uni Directional Valv

e (UDV).Coolant temperature can be maintained by Heat dissipation unit and monitored by ESC U.
As per figure 02, Vapor recovery system operates only when there is enough HC charge load c anister to be practically & economically viable to reduce battery consumption. Coolant used in Vapor recovery system monitored by preset temperature values through System control Unit (SC U). Once Coolant reached preset temperature, coolant dissipation unit convert high temperature coolant to low temperature. Above layout efficiently returns liquid gasoline to tank reservoir and it reduces fuel vaporization by maintaining ambient temperature. Vapor Recovery System functi oning independent on Engine burning cycle.

3. Conclusion:

Vapor Recovery System has potential to limit and reduce EVAP emissions significantly Vs C onventional Gasoline layout which lacks Vapor conversionin to reusable fuel and as a by-produc t needs additional complex purging circuit andits management for safe disposal inside ICE Co mbustion Chamber. The Demonstration of this idea as POC will surely require advance studies related to thermal (Heat and Mass Transfer) Science, Material Science and New Biofuels. Final ly developing an economically feasible VRS working concept model, with high efficiency and low ene-rgy consumption remains challenge and provide opportunity for undertaking future stu-di es from here.

4. Benefits

- Vapor Recovery System integrating on conventional vapor layout in vehicle which benefits to eliminate existing vapor purge line from canister to Engine assembly.
- Vapor Recovery System independent on Engine purge cycle. In ICE / Hybrid vehicle, Syste m Recover Vapors without dependent on combustion Engine funct-ion.
- Reducing the complexity of engine tunning since there is no intake of fuel vap-ors to engin e from canister.
- By Eliminating purge vapor loading, there is a substantial potential to reduce loading of pr ecious metals on the CATCON.
- Elimination of Canister Purge Circuit helps to reduce the permeation of fuel va-por through materials.

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