# COMPARISON OF ON-VEHICLE AND SERVICE STATION TECHNOLOGIES TO CONTROL VEHICLE REFUELING EMISSIONS IN BRAZIL

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**Manufacturers of Emission Controls Association**

2200 Wilson Boulevard | Suite 310 | Arlington, VA 22201 | (202) 296-4797

www.meca.org

Summary: Vehicle refueling emissions in Brazil can be controlled through either service-station based technology generally referred to as Stage II vapor recovery (Stage II) or vehicle-based Onboard Refueling Vapor Recovery (ORVR). A comparison of the control efficiency, cost, cost-benefit and implementation issues of the two approaches shows that ORVR offers advantages in terms of cost, payback to the vehicle owner, and health-based emission reductions. It is the superior approach.

The Brazilian Ministry of Labor Portaria 1.109 is an occupational health program designed to reduce exposure of service station attendants to the benzene in gasoline C refueling emissions.[1] The Portaria would require the use of the types of nozzles and vapor hoses used in Stage II systems to move the refueling vapor from an attendant's breathing zone. The technology envisioned in paragraph 14 of the Portaria is better termed "partial Stage II" technology, since it uses some of the hardware approaches used in "full Stage II" systems, but it provides no control of the refueling-related Volatile Organic Carbon (VOC) emissions which adversely impact local air quality.

IBAMA is now considering provisions for PROCONVE L7 which could require ORVR technology for new vehicles using gasoline C and E100. Based on experience in North America, ORVR provides control of 98% of refueling emissions.[2] When compared to the "partial Stage II" technology envisioned in the Portaria, ORVR is the superior approach for control of refueling emissions. ORVR technology provides benzene reductions for service station attendants during refueling. It reduces benzene vapor concentration in communities near to service stations, and it provides large VOC reductions for local and regional ambient air quality. ORVR is significantly more efficient than "partial Stage II" technology, the emission reductions are greater, its economic impact is far less, and it has a better cost-effectiveness.

Introduction: Vehicle refueling emissions are a significant contributor to the ozone air quality problems in Brazil. On average, for each liter of fuel (gasoline C/E100) dispensed to a passenger car or light commercial vehicle in Brazil, about 1 gram of VOC and 8 mg of benzene is emitted to the atmosphere.[a]

The purpose of air pollution control emission regulations is to protect the public health and welfare through improving air quality. Similarly, the purpose of occupational health regulations is to protect worker health. For some air pollution sources, such as vehicle refueling emissions, control techniques can improve ambient air quality for citizens and reduce exposures to benzene for service station attendants. Selection of the most effective and lowest cost control technique is critical in optimizing the health benefits and minimizing costs.

Since the PROCONVE vehicle exhaust hydrocarbon emission standards are now quite stringent, hydrocarbon vapors emitted during vehicle refueling and vehicle operation are among the most significant sources of air pollution. All gasoline vapor is photochemically reactive and contributes to the formation of ozone and secondary organic aerosols (particulate matter) in the atmosphere. Gasoline C contains about 1% benzene, which is a known human carcinogen.[3] Exposures to the benzene in gasoline refueling emissions are of concern for the health of service station attendants and those citizens who live near service stations. Control of refueling emissions can reduce community and occupational exposures to benzene as well as ozone and particulate matter concentrations in ambient air.

Service Station Controls: In September 2016, the Ministry of Labor released Portaria 1.109 designed to reduce the exposure of service station attendants to benzene vapor during refueling. Compliance with

[a] This is based on an average liter of volatile liquid fuel, which includes gasoline C at about 9 psi RVP, E100 at about 2.3 psi RVP and a gasoline C benzene content of about 1% by volume.

the Portaria requirements begins in September 2019 for new stations and phases-in over 10 years (beginning in September 2022) for existing stations. When fully implemented, the Portaria will apply at about 41,000 service stations across Brazil. Reducing exposure to refueling emissions is good policy and the Portaria has many good provisions. Paragraph 14 of the Portaria refers to Stage II technology, but this is a misnomer. The technical provisions in paragraph 14 are better termed as "partial Stage II" technology as it only calls for vapor capture at the fill pipe and transfer to the gasoline underground storage tank (UST). The provisions in paragraph 14 are likely to reduce attendant breathing zone concentrations, but the technology approach in the Portaria does not reduce any of the 70,000 metric tons of refueling-related VOCs or the 570 metric tons of refueling-related benzene released into the environment each year.[b]

It is generally agreed among occupational health professionals that occupational exposure to benzene should be no more than one-tenth to one ppm (8-hour time-weighted average) for a 40-hour work week and less for longer work shifts or longer work weeks. The program in the Portaria is likely to reduce benzene concentrations in the breathing zones for service station attendants who refuel vehicles. However, it may not in all circumstances lead to benzene exposures consistently below the recommended levels since vapor is not being captured, just transferred to the UST where, in the absence of VOC capture technology, it is likely to be leaked or vented back into the service station environment. A study by the US National Institute for Occupational Safety and Health (NIOSH) indicated no difference in overall service station attendant benzene exposures with or without Stage II controls.[4]

Portaria 1.109 as an Air Pollution Control Program: The "partial Stage II" technology required by the Portaria should not be confused as equivalent to the Stage I and Stage II programs needed for air pollution control at service stations. It will provide no refueling emissions control because it does not include control technology to prevent VOCs from being released from the UST and critical implementation provisions found in other environmental regulations designed to reduce air pollution from service stations.

First, regarding control technology, Stage I (for control of UST emissions during UST filling) and Stage II controls (for control vapors released during vehicle refueling) are both needed to contain the gasoline vapor at service stations. Brazil does not have requirements for Stage I vapor recovery to control UST emissions. The Portaria only requires technology to transfer refueling vapors from the fill pipe area to the UST. It does not require capture or containment of the refueling vapors in the UST. The refueling emission control effectiveness will be minimal for the technology envisioned in the Portaria because the captured vapor will leak from the UST or be released through the UST vent pipe.

Second, as implemented in the past in the US and now being phased-in in Europe, a worthwhile Stage II program will require government regulations and resources to address program implementation and in-use efficiency.[5,6] This includes new regulations covering items such as: certification of hardware systems, permitting of installations, periodic equipment inspections, performance tests to ensure proper operation, and government enforcement of compliance with the requirements. This will also require new government technical personnel at the Federal level or state level to oversee and enforce the program provisions. None of these implementation provisions are addressed in the Portaria.

Without these two requirements, the effectiveness of the Portaria as an air pollution control measure is very limited. It will not reduce benzene levels in the nearby community or refueling-related VOCs which

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[b] The national fuel volume weighting for gasoline C and E100 is from Brazil ANP for 2016 is about 70% gasoline C and 30% E100.

contribute to the formation of ambient ozone and particulate matter. Without government oversight, the implementation and in-use effectiveness of the "partial Stage II" as an occupational health measure is in doubt since the technology does not perform well if it is improperly installed or not maintained.

Another important consideration is the compatibility of the materials used in vapor recovery hardware with the fuel composition in Brazil. The experience in the US and Europe with testing and certifying Stage II equipment has been done on gasoline with an ethanol content of 10% or less. In the US, where there is E85, the E85 gasoline dispensers are exempt from Stage II because there are no certified Stage II components for E85 and most flexible fuel vehicles (FFVs) in the US are equipped with ORVR to control refueling emissions. Prior to certifying dispensing equipment and implementing the Portaria, Stage II components compatible with gasoline C will have to be developed and evaluated for durability.

<u>Onboard Refueling Vapor Recovery (ORVR)</u>: Evaporative and refueling emissions both arise from the motor vehicle fuel system. Since 1990, the Brazilian motor vehicle emission standard program (PROCONVE) has included requirements to control vehicle fuel evaporative emissions while the vehicle is parked. These requirements have become a bit more stringent over time, but overall have changed little for over 25 years. Motor vehicle and environmental protection interests in Brazil have been developing ORVR test procedures and related requirements for vehicle refueling emission control for several years. The ORVR test procedures would not require any significant facility upgrades.
ORVR technology involves the integration of the hardware used to control evaporative emissions and that needed to control refueling emissions into one control system commonly referred to as an integrated ORVR system. An integrated ORVR system for vehicles in Brazil would be a relatively simple extension of the hardware used in current evaporative systems. The key changes are fill pipe modifications to block refueling emission escape to the atmosphere and an increase in the size of the activated carbon canister to capture this refueling vapor. The other changes are minor component upgrades, on-vehicle hardware reconfigurations, and purge air calibration changes. ORVR has been required on vehicles in North America for 20 years and there have been over 300 million vehicles produced with ORVR. Beginning in July 2020, China requires ORVR for all new gasoline motor vehicles. Prior to 2020, essentially every manufacturer selling passenger cars or light commercial vehicles in Brazil will have experience with ORVR in either North America or China or both. The substantial manufacturing and in-use experience with integrated ORVR control systems allows several important observations regarding this approach.

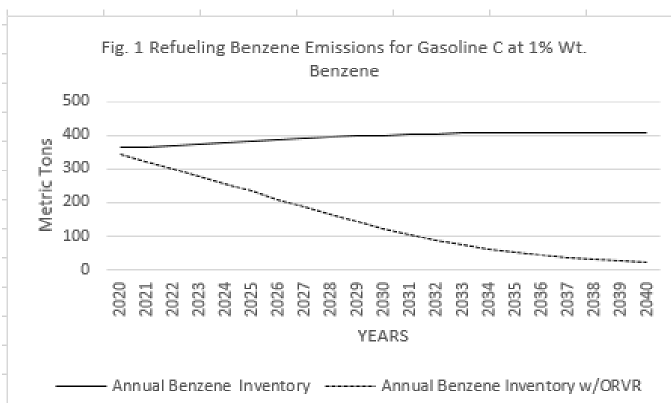
- Integrated ORVR systems capture essentially all refueling hydrocarbons including benzene. It provides control on the vehicle thus addressing service station attendant benzene exposures, community exposures to benzene, and ozone and particulate matter created by the refueling-related VOC emissions.
- ORVR technology works for gasoline C and E100 vehicles.
- US EPA data indicates that ORVR technology is 98% efficient in-use over the vehicle life.
- ORVR requires no new government programs. It fully fits with the current IBAMA type approval process for motor vehicle emissions.
- Integrated ORVR systems require no in-use maintenance or supplemental testing. System performance is monitored by the vehicle's existing onboard diagnostics (OBD) system.
- US test data shows that the improved vapor capture and purge capabilities of an integrated ORVR system provide technology to control up to 75% of the evaporative emissions not covered by the current PROCONVE standards.[7,8]

- Refueling and evaporative fuel vapors captured in the integrated ORVR system are purged during driving and used as fuel by the vehicle.
- Requirements of the ORVR test procedure will lead to vehicle designs which reduce fuel spillage during refueling at service stations.[9]

Comparison of In-Use Emission Reductions: There is no previous experience with "partial Stage II" technology as an emission control program. Vacuum assist-type Stage II nozzles can provide very good vapor capture at the fill pipe by drawing a greater air volume from around the fill pipe for each gallon of liquid dispensed (the air to liquid (A/L) ratio). An A/L of 1.2 or 1.3 would collect more vapor, but this increases the amount of vapor leaked or vented from the UST over that which would occur if the A/L ratio was near 1.0. Beyond this, experience with vacuum assist type nozzles in the US shows that without maintenance the A/L setting in the hardware drifts as the system is used and it must be recalibrated at least annually. The lack of Stage I hardware to control leaks and venting from USTs and the absence of any implementation and enforcement regulations addressing system performance prevent prediction of estimates of in-use efficiency for benzene control in the immediate service station area for "partial Stage II" technology. It is clear, however, that there will be little or no benzene reductions to promote health in the nearby community or refueling-related VOC control to reduce ambient ozone and particulate matter.

There is 20 years of experience with integrated ORVR systems in North America. Control of refueling emissions phases in as non-ORVR vehicles leave the fleet and ORVR vehicles enter the fleet. The figures below show benzene and refueling vapor reductions over time using fuel qualities, vehicle sales, fleet turnover and fuel economy values for Brazil and an ORVR efficiency of 98% as experienced in the U.S.

As seen in Figure 1, benzene emission reductions at Brazilian service stations from ORVR technology are substantial. These reductions translate directly into lower breathing zone concentrations for service station attendants and lower benzene exposures in nearby communities.



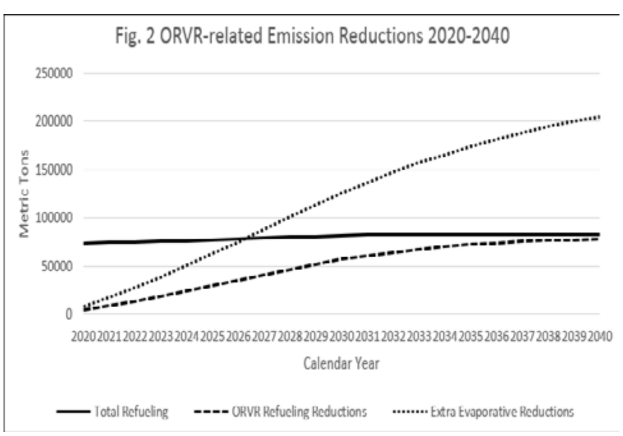




Figure 2 shows that refueling emission reductions are very substantial with control of over 1.2 million metric tons by ORVR. These decrease ozone and particulate matter in ambient air and help to address local and regional air quality concerns. The extra on-vehicle evaporative emission reductions from ORVR technology related to control of diurnal and running loss emissions not controlled by current PROCONVE requirements are 3 times those of refueling alone. These reductions come at no additional cost.

The data used to determine the extra evaporative emission reductions from ORVR technology are derived from US EPA emission factors for vehicles with the same type of evaporative emission control technology now used on vehicles in Brazil under PROCONVE L6.[c] The extra evaporative reductions capability of ORVR technology are documented in SAE paper 900155 and an EPA technical report.[7,8]

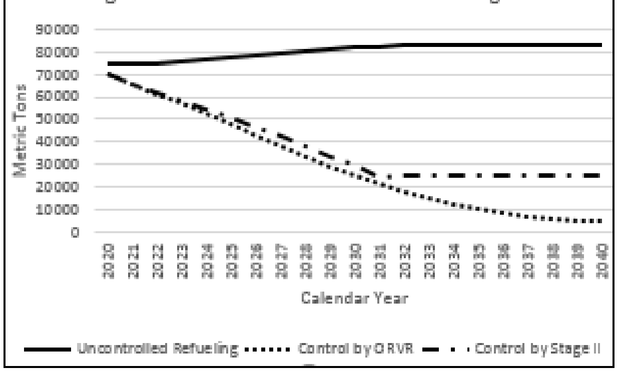


Fig 3.Emission Reductions: ORVR vs Full Stage II

Partial Stage II technology would provide few, if any, metric tons of refueling emission reductions. There is substantial experience with “full” Stage II in the US. These “full” Stage II programs include Stage I and strong implementing Stage II regulations in addition to all Stage II hardware. The state of California in the US has a long-standing and comprehensive “full Stage II” program. Data gathered in that program indicates that refueling control in-use efficiency is about 70% even with Stage I controls, comprehensive implementing regulations, and diligent enforcement of the requirements.[a] Figure 3 compares ORVR with a “full Stage II’ program for Brazil (using the Portaria phase-in for Stage II) and considering only the refueling portion of the vehicle evaporative emissions. Reductions from ORVR technology (which include VOCs and benzene) would be greater than with “full Stage II” initially and in each subsequent year during the phase-in. When fully phased-in, ORVR reductions are 28 percentage points greater than for “full Stage II.”

Comparison of Costs and Cost-Benefit: Using standard regulatory impact analysis practices, it is possible to compare the costs and cost benefit of “partial” and “full Stage II” and ORVR. As was the case for the emission reduction analysis, this assessment covers the period 2020-2040 and is based on the Portaria phase-in for service station controls and normal fleet turnover for ORVR. The cost for implementation is based on experience and data from the US (adjusted to 2017) and uses a 3% net present value. [d,d] Table 1 compares the costs and cost-benefit for ORVR to the “partial Stage II” and “full Stage II” programs. The assessment for “full Stage II’ does not include Stage I costs or the additional government resources and ongoing costs related to the stronger implementing regulations. Most noteworthy here is the difference in initial and net costs for ORVR versus Stage II. For ORVR, the recovered fuel vapor from refueling and evaporative emissions provides a net savings to the vehicle owner.

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[c] “Evaporative Emissions from On-road Vehicles in MOVES2014,” EPA 420-R-14-014, September 2014.

[d] API report 1645, “Stage II Vapor Recovery Systems Operations & System Installation Costs,” August, 2002.

| Table 1: Cost and Cost-Benefit Comparison for Partial and Full Stage II and ORVR (2020-2040) | | | | |
|---|---|---|---|---|
| Analytical Element | Partial Stage II | ORVR in PROCONVE | | Full Stage II |
| Units Impacted | 40809 service stations | 72.96 million vehicles | | 40809 service stations |
| Total Initial Cost* | $4.4 billion USD | $1.4 billion USD | | $4.4 billion USD** |
| Fuel Recovery Credits* | ~0 | $4.8 billion USD | | $0.6 billion USD |
| Net cost | $4.4 billion USD | $3.4 billion USD (savings) | | $3.8 billion USD** |
| Recovery credits/ Initial Cost | ~0 | 2.20 | | 0.14 |
| Total Emission Reductions | ~0 cannot be quantified | 5.3 million metric tons | | 0.58 million metric tons |
| | | | | |
| COST/BENEFIT | | | | |
| Initial Cost* /Emission Reduction | Undefined | $260/metric ton | | $7500 /metric ton |
| Net cost*/Emission Reduction | Undefined | savings | | $6700/metric ton |
| *net present value; **does not include costs for Stage I hardware or Stage II enforcement | | | | |

Comparison of Other Program Characteristics: Table 2 lists a variety of additional factors comparing "partial Stage II" and ORVR. Most noteworthy is the significant difference in cost the lack of true refueling emission reductions from the "partial Stage II" approach, and the private sector and government resources needed for even a "partial Stage II" program. Also, note that any Stage II program would have a significant and ongoing cost impacts on small business gasoline distributors through initial capital costs and maintenance.

| Table 2: Comparison of Other Program Characteristics | | |
|---|---|---|
| Program Element | Partial Stage II | ORVR in PROCONVE |
| Requires new government programs and resources | Yes | No, uses current PROCONVE Type approval program |
| Training of operators and users | Yes | None |
| Oversight of operations by government | Needs new program | No new program |
| Hardware maintenance needed | Yes | Minimal |
| Inspections and operational tests needed | Yes | No |
| Continuous performance monitoring | No | Uses current onboard diagnostics system |
| Implementation rate and scope | Progressive and nationwide | Progressive and nationwide |
| Refueling control efficiency | Unknown but near zero | 98% |
| Extra evaporative control | None | Yes |
| Development and installation | Outsourced contractors | Auto manufacturers |
| Fuel recovery credits | If any, to service station | To car owner |
| Cost to Brazilian economy | $4.4 billion | -$3.6 billion (savings) |
| Impacted entities | Over 40,000 service stations | About 20 auto manufacturers |
| Impact on small business | Yes, ongoing | No |

Conclusions:

- Control of refueling emissions is needed to protect worker health and address local air quality.
- Portaria 1.109 has many good provisions, but this occupational health program is not a substitute for a more comprehensive PROCONVE program for controlling vehicle-related refueling emissions to improve ambient air quality.
- "Partial Stage II" technology as envisioned in the Portaria is likely to reduce benzene concentrations in service station attendant breathing zones. However, ORVR can reduce benzene concentrations in service station attendant breathing zones, benzene in the nearby community, and VOCs which contribute to ambient ozone and particulate matter.
- ORVR is significantly more efficient and effective than either "partial Stage II" or "full" Stage II. ORVR has a demonstrated full-life in-use efficiency of 98% with no maintenance. Even a "full" Stage II program is at best about 70% efficient.

- Without a comprehensive regulatory program and diligent field enforcement, the "partial Stage II" program will capture few, if any, vapors.
- ORVR can be implemented with few additional government resources.
- ORVR can provide control at virtually no cost to the Brazilian economy or the vehicle owner. There is a net economic difference of $8 billion USD over 20 years between ORVR and Stage II.
- ORVR has no impacts on small business gasoline distributors.
- Implementing ORVR technology through PROCONVE L7 is clearly and wholly superior to Stage II.

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[1] Brazil, Ministry of Labor, Minister's Office, Ordinance 1.109, September 20, 2016.

[2] US EPA, "Air Quality: Widespread Use for Onboard Refueling Vapor Recovery and Stage II Waiver," 77 Fed Reg 28777, May 16, 2012.

[3] http://transportpolicy.net/index.php?title=Brazil:_Fuels:_Diesel_and_Gasoline, last down loaded August 9, 2017.

[4] Hartle, R. "Exposure to Methyl tert-Butyl Ether and Benzene Among Service Station Attendants and Operators," Environmental Health Perspectives Supplements 101 (Suppl. 6): 23-26 (1993).

[5] US EPA, "Technical Guidance Stage II Vapor Recovery Systems for Control of Vehicle Refueling Emissions at Gasoline Dispensing Facilities – Volume II: Appendices," EPA 450/3-91-022b, November, 1991.

[6] European Commission Directive 2009/126/EC on Stage II Petrol Vapor Recovery during Refueling of Motor Vehicles at Service Stations, October 2009.

[7] Musser, G. et al, "Improved Design of Onboard Control of Refueling Emissions," SAE technical paper 900155, 1990.

[8] US EPA, "Application of Onboard Refueling Emission Control System to a 1988 Ford Taurus Vehicle," EPA-AA-SDSB, 91-06, 1991.

[9] US EPA, "Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Refueling Emission Regulations for Light-Duty Vehicles and Light-Duty Trucks; Final Rule," 59 FR 16272, April 6, 1994.