Assessment of Light Duty Vehicle

Evaporative Emission Control Technology

by

Eric Ellsworth

Environmental Protection
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I. Introduction: The current federal test procedure for evaporative emissions measurement for light duty vehicles, the canister method, is expected to soon be replaced with a revised test procedure which involves the use of a SHED (Sealed Housing for Evaporative Determination) to collect the evaporative emissions rather than the currently used activated carbon canister. The SHED test procedure was first proposed by the Department of Health, Education and Welfare in 1967 and later evaluated by General Motors. (Findings of GM's early evaluations were reported in SAE papers, numbers 680125 and 690502). This revised test procedure will have a major impact on the measured effectiveness of evaporative emission controls in use today on light duty vehicles. While the data available using the SHED test procedure (Fig. 1) (3) generally indicate excessive evaporative emissions, even from "controlled" vehicles, recent results indicate that there are a limited number of production vehicle types with evaporative control systems capable of passing the six gram standard which California has proposed for 1977 (Fig. 2). Most current devices in use consist of a storage canister used for the storage of evaporated hydrocarbons, and associated tubing which connect the major sources of evaporative emissions with the storage canister. (See Appendix A for a detailed review of the types of evaporative control systems currently being used by the automotive industry.) This report is an assessment of current control technology and is not intended to represent the technical limits of evaporative emission control. The report first addresses the basic sources of evaporative emissions, then discusses the influence of fuel composition, and finally addresses evaporative emission control from a total control system standpoint.

II. Leakage: Leakage of fuel system components occurs because of the deterioration of those components through abuse, poor material selection or improper manufacturing of components. The Department of Transportation has recently (effective September 1, 1975) introduced Federal Motor Vehicle Safety Standard (FMVSS) 301, for 1976 model year, which requires a vehicle's fuel system to maintain its integrity through a 30 mph crash and subsequent roll over. Compliance with this safety standard should result in an improvement to the integrity of fuel system components and their interfaces, so leakage may cease to be a significant source of evaporative emissions.

Abuse to the fuel system centers around the gas cap and its mating sealing surface on the filler neck. This is indicated in the EPA surveillance data gathered in the FY 73 program from Los Angeles and Denver. From random samples totaling 40 vehicles approximately five percent of the vehicles tested had leaks and these leaks were all at the gas cap.

During recent SHED testing at the EPA Motor Vehicle Emission Laboratory one vehicle in the 6 vehicle test fleet had a gas cap failure. In attempting to repair the vehicle, several gas caps had to be purchased in order to find one which did not leak. An inspection of the gas caps revealed a variance in distance from the locking lugs to the gasket. Caps displaying the greater distances were the ones which leaked because sufficient loads were not applied to the gasket to maintain a leak free joint. Variance from cap to cap could be the result of poor quality control at the manufacturing plant or improper tolerances as a result of the design.

To reduce the impact of inadequate quality control and tolerance stack-ups (the sum of tolerances on mating parts) General Motors has developed a new design gas cap which is used on many intermediate and full size vehicles beginning in the 1975 model year. This cap has two features which will improve its reliability. First, the gasket is made of a low durometer (soft) material. This provides a better seal because a soft material will conform to irregularities on the sealing surface more readily. Second, the cap has a torque limiting function which protects the soft gasket from excessive loads, thus extending the life of the gasket.

III. <u>Fuel Tanks</u>: The following equation is a mathematical simulation of vapor losses from a fuel tank due to thermal expansion and vapor pressure changes:

$$G = 454W \left[\frac{520}{690-4M}\right] \frac{\bar{p}}{P_a - \bar{p}} \left[\left[\frac{(P_t - p)\,v}{T}\right]_1 - \left[\frac{(P_t - p)v}{T}\right]_2\right] \qquad (4)$$

G = weight of hydrocarbons lost, g
W = condensed vapor density, lb/gal
M = molecular weight of hydrocarbon, lb/lb mol
p = vapor pressure of gasoline at T, psia
$\bar{p}$ = average vapor pressure, psia, $(p_1 + p_2) \div 2$
P = total pressure, psia
v = volume of vapor space, ft^3
T = vapor temperature, °F
1 = initial state
2 = final state
t = tank
a = atmosphere

By manipulation of total tank pressure, temperature, and vapor space terms for the final state expression, a reduction in tank losses can be achieved. When vapor space and temperature decrease, the amount of fuel evaporated decreases. An increase in tank pressure will result in a decrease in evaporative emissions.

To reduce fuel tank temperature, the exhaust system could be rerouted, fuel tanks could be relocated, a heat shield could be placed between the tank and the exhaust system, or the fuel tank could be insulated. The last option only produces the desired effect in short driving cycles. After an extended engine-on mode the insulation may result in the generation of equal or greater quantities of fuel vapor than the non-insulated fuel tank because the tank will cool off more slowly, thus maintaining the driving force for a longer period of time.

A fuel tank with internal baffles would generate fewer emissions than a conventional tank. These baffles should be placed perpendicular to the natural convection currents in the tank. By breaking up the convection currents a severe temperature gradient is established in the fuel tank with warm fuel on the bottom, cool fuel and cool fuel vapors at the top. The lower the vapor temperature, the smaller the evaporative losses (Fig. 3).

The vapor space could be reduced by using a fuel tank with a bladder which would contain the fuel (Fig. 4). As a tank is emptied the bladder would shrink and when it is filled the bladder would stretch to the maximum size allowed by the tank. By stretching the bladder to accommodate particular fuel fill; in essence, the fuel tank is always full. A full tank has no vapor space and very little evaporative losses (Fig. 5) (5).

Vehicles with fuel return lines have higher evaporative losses from the tank. As a result of the pumping process and exposure to engine compartment and exhaust heat, the temperature of the fuel in the return line is raised. When this hot fuel is injected into the tank, the temperature increase and the agitation create excessive losses.

All the control technology for steel fuel tanks can be applied to non-metallic tanks. Plastic fuel tanks are inherently insulated due to the material's low thermal conductivity. It should be noted that many plastics are porous and will allow gaseous hydrocarbons to escape. With the proper selections of materials or the proper surface treatment the porosity can be eliminated.

It is believed that the only fuel tank modification that has been discussed above that may have an adverse effect on vehicle performance is the elimination of fuel return lines. These lines are required on vehicles that have hot start problems or fuel injection. Relocation and rerouting can be most efficiently handled during a vehicle's styling change or new model design.

IV. Air Induction System: The air induction system containing the air cleaner, carburetor and intake manifold is the next area that will be discussed from the aspect of reducing its contribution to overall evaporative emissions. The air cleaner is being utilized as a storage compartment for hydrocarbons emitted from the internal vents of the carburetor. The air cleaner is at best a poor storage compartment because its design allows high flows with minimum restriction. In a test run by the Air Resources Board of California a 1974 AMC Ambassador with air cleaner storage averaged 12 grams loss per SHED test. When the vehicle was modified by venting the carburetor bowl to the storage canister the losses were reduced to an average of 3.3 grams per test (3). The air cleaner's performance as an evaporative control device could be improved by including a filter element which would adsorb the hydrocarbons or restrict their flow out of the air cleaner. Internal baffling would be another method by which the evaporative emissions could be retarded from leaving the air cleaner (Fig. 6).

The conventional venturi carburetor is the most prevalent device for introducing fuel to achieve a combustible mixture. The internal vents of a carburetor provide many sources for fuel vapor to escape. Valves could be added which would close idle ports, off-idle ports, primary and secondary metering circuits and acceleration pump nozzle when the engine is off. This would force the fuel vapor through an external vent and into a storage canister. Reducing the number of passages in the carburetor by using a common passage would reduce the heated surface area of the fuel. The addition of an external bowl vent (certain carburetors in production have this feature) along with the reduction in number of internal passages and valving for these passages should be considered as a single system.

Carburetor losses can be lowered by lowering the temperature to which the carburetor is exposed (Fig. 7) (6). This reduction can be achieved by heat shielding, improved air flow through the engine compartment, and insulating the carburetor body. Heat shielding and insulating will have the same effects and drawbacks as discussed in the fuel tank section of this report. Increased air flow has an indirect effect by increasing heat dissipation, thus lowering peak operating temperatures and peak hot soak temperatures. Engine-off hot soak temperatures could be reduced by using a thermostatically-controlled electric fan to force air through the engine compartment.

Reducing fuel bowl volume lowers evaporative losses (6). As the quantity of fuel in the bowl decreases, the quantity of fuel which would be distilled at peak bowl temperature is reduced, which in turn is a reduction in overall carburetor losses (Fig. 8).

Plastic carburetor bodies are being used on a few late model vehicles. These plastic bodies may present unique problems due to permeability exhibited by some plastics and low thermal conductivity. If the proper material or surface treatment is not used, fuel vapor will escape through the walls of the carburetor body. The low thermal conductivity will tend to reduce peak carburetor bowl temperature which will reduce evaporative emission (Fig. 7), but the bowl will cool down more slowly. If this cool down time is long enough, the advantage gained by a lower bowl temperature will be nullified.

Carburetor sealing may become a major constitutent of the deterioration factor as all other sources are reduced and/or eliminated. As the vehicle ages, gaskets and seals in the carburetor will lose their resiliency and shafts running through the body of the carburetor will become worn causing loss of fuel vapor to the environment at these points.

Briefly looking at intake manifolds, they could be designed to help dissipate heat from the carburetor, and/or the manifold could be used as a storage chamber for hydrocarbons from the carburetor, thus reducing the load on the storage canister (Fig. 9).

Manufacturers are now offering types of fuel injection, electronic or mechanical, as options on certain models. This device may significantly reduce hydrocarbon losses from the induction system. The only problems that may need resolution are the requirement for a fuel return line, which was discussed in the tank section, and injector design. Currently, the injectors are on-off valves activated by an electronic or mechanical signal. If these injectors allow fuel to seep-by due to wear or poor design, the evaporation losses could be significant. However, the potential for complete control of hot soak losses exists with fuel injection systems.

Analytically, any modifications that are made to the venturi carburetors will require a major undertaking by the manufacturers. Changes to fuel flow and metering can affect exhaust emissions and vehicle performance. Other modifications mentioned, such as improved gasket life, the addition of baffles to an air cleaner and improved heat dissipation, will require less design and development because their impact on exhaust emissions and vehicle performance may be insignificant.

V. <u>Storage Canister</u>: A canister containing activated carbon is the primary storage device for the evaporative emission control system. Fuel vapors that are exposed to the activated carbon bed are adsorbed on the surface of the carbon. A secondary storage mechanism is residency. This occurs when carbon particles in an area are saturated and fuel vapor can no longer be adsorbed on the surface of the carbon. At this point, hydrocarbons remain in a gaseous state in the spaces between carbon particles. As the requirement for evaporative emission control increases, the capacity of the carbon canister will have to increase. One of the obvious ways to do this is to increase the quantity of activated carbon in the canister. Another way is to use a more efficient adsorber, one that will adsorb more grams of fuel vapor per gram of adsorbent.

Storage canisters may also be emitters of hydrocarbons. Open bottom canisters have a high concentration cloud of hydrocarbons at the bottom of the canister. This may be a result of heavier hydrocarbons drifting through the carbon bed. This situation can be remedied by placing a semipermeable membrane at the bottom of the carbon bed. The membrane would retard the flow of hydrocarbons from the bottom of the canister while allowing the fuel tank to breath and the canister to purge (Fig. 10). Another solution would be to install a bottom on the canister with a vent tube that has its opening at the same level as the top of the carbon bed (Fig. 11).

The emissions from a storage canister can be reduced, significantly in some cases, by providing for an adequate purging of the storage canister during the engine-on modes of vehicle operation. This purging of the storage canister will remove the hydrocarbons from the canister's carbon bed. If a storage canister experiences an inadequate purge it may not have sufficient capacity to retain all the fuel vapors generated after the engine is turned off. Inadequate purging may be a result of poor evaporative emission control system design and/or poor maintenance. Poor maintenance of the storage canister filter, if so equipped, will have a detrimental effect on storage canister purge rate. As the filter becomes clogged the air flow through that filter is reduced which in turn reduces the storage canister's purge rate.

It is believed that modification to the storage canister will have an indirect effect on vehicle exhaust emissions. Due to the increase in fuel vapors trapped, the purge rate of the canister will also have to be increased, which may cause HC and CO emissions to increase.

VI. Fuel: Gasoline is a mixture of various hydrocarbon compounds and additives. By changing the blend of the gasoline, its characteristics can be changed. Reid vapor pressure (RVP) and initial boiling point (IBP) are the two characteristics that have effects on evaporative emissions. As the RVP of a fuel decreases, the evaporative losses decrease (Fig. 12) (7). IBP has an inverse effect on evaporative losses. As the IBP increases, the evaporative emissions decrease.

To achieve the change in Reid vapor pressure and initial boiling point, the quantities of aromatics, paraffins, and olefins in the fuel will have to be changed. A typical low volatility fuel with an RVP of 6.8 psi and an IBP of 102°F compared to an average summer grade fuel would have a higher concentration of paraffins and olefins and a lower concentration of aromatics (7). This means a refinery may have to modify its cracking, reforming and blending. Particular modification will depend on the type of crude a refinery uses to produce gasoline. The effect of low volatility fuel on exhaust emissions is an increase in CO and HC (Fig. 13, 14). The fuel change would reduce evaporative losses on in-use vehicles significantly (Fig. 15).

VII. Control System: The evaporative emission control system which will be used by the automotive industry will contain a mix of component modifications (3). This mix will vary from manufacturer to manufacturer depending on the particular characteristics of individual components used by the manufacturers.

Examples of various systems which could be used in the control of evaporative emissions and their estimated incremental costs (costs over currently installed evaporative control systems) are listed below. Any one of these systems would impact only a moderate cost increase and would not require extensive lead times, i.e. could be available for 1978 model year (3). System I utilizes heat shielding and a high pressure fuel tank with a bladder to reduce the amount of fuel vapor generated, thus reducing the amount of vapor which must be stored and subsequently burned in the engine when the canister is purged. Systems II and III allow for greater production of fuel vapor which in turn requires more storage canister capacity. Also, the additional fuel vapor which is purged from the storage canister and burned in the engine will increase the burden on the engine's exhaust control system. System IV depends on a fuel modification to reduce the amount of fuel evaporated. The cost differentials indicated for the various systems are engineering estimates of component cost changes at the assembly plant.

- Vehicle Modification -

System I	Cost Differential	
• Screw on gas cap similar to ones used by General Motors	+	$ .25
• Steel fuel tank with a bladder and pressure setting of 30 inches of water	+	25.00
• Heat shielding between the exhaust pipe and the fuel tank		3.00
• Standard vapor-liquid separator		
• Air cleaner with baffles	+	.50
• Carburetor with an external bowl vent and heat shielding	+	1.00
• Closed bottom storage canister containing 700 gm of activated carbon	+	.15
• Manifold purge system for the storage canister		
TOTAL incremental cost impact per vehicle	+	29.90

System II		
• Screw on gas cap similar to ones used by General Motors with a pressure setting of 18 inches of water	+	$ .25
• Heat shielding between the exhaust pipe and fuel tank	+	3.00
• Vapor-liquid separator with a smaller orifice to increase tank pressure		
• Carburetor with reduced bowl capacity and external vent attached to a storage canister	+	.50

System II (cont.)			Cost Differential
• Two closed bottom storage canisters containing 700 grams of activated carbon each	+	$	3.00
• Manifold purge for both canisters			.50
TOTAL incremental cost impact per vehicle	+	$	7.25

System III			
• Improved gas cap gasket	+	$	.05
• Heat shielding between the exhaust pipe and fuel tank			3.00
• Carburetor with reduced bowl capacity, external bowl vent, and heat shielding	+		1.00
• One storage canister containing 1000 grams of activated carbon and intergral purge value (similar to Vega)	+		.75
• Manifold purge			
TOTAL incremental cost impact per vehicle	+		4.80

System IV			
• Improved gas cap gasket	+	$	.05
• Heat shielding between the exhaust pipe and fuel tank	+		3.00
• Carburetor with reduced bowl capacity and external vent attached to a storage canister	+		.50
• Closed bottom storage canister containing 700 grams of activated carbon	+		.15
• Manifold purge system			
TOTAL incremental cost impact per vehicle	+	$	3.70

NOTE: System IV requires the use of a low volatility fuel, RVP no higher than 6.8 psi, in conjunction with the vehicle modifications to achieve a reduced emission level.

VIII. Conclusion: Evidence indicates there exists sufficient evaporative control technology to control 90% of the generated evaporative emissions from a vehicle, thus allowing vehicles to meet an emission standard of from two to six grams using the SHED procedure, by model year 1978. It is reasonable to assume that the manufacturers will choose a system similar to system II and that the resultant incremental cost will be on the order of $7 per vehicle, with negligible operating and maintenance costs. From figure 1, the incremental emission reduction (from "controlled" vehicles) to be expected is approximately 1.8 to 2.3 grams per mile. Using $7 per vehicle and 2.0 grams per mile reduction, the cost effectiveness of such control would be $32 per ton, as compared to $437 per ton in going from federal 1975 light duty vehicle exhaust standard (1.5 g/mi) to the statuatory level (.4 g/mi) or $2020 per ton for light duty vehicle inspection/maintenance (8).

Appendix A

The following is an excerpt from the Phase I Task I report by Exxon from contract #68-03-2172.

CURRENT ATUOMOTIVE PRACTICE FOR CONTROL OF EVAPORATIVE EMISSIONS

In this section, the types of Evaporative Control Systems (ECS) used by the automotive industry to control evaporative emissions are reviewed.

A. Carburetor Evaporative Emission Control

The two modes of carburetor losses are running losses and hot soak losses. The running losses are controlled internally in the carburetor by venting from the carburetor bowl to the air intake of the carburetor via the balance tube, allowing carburetor running vapors to be burned in the engine. This is the case both when the bowl is vented to the carbon canister as well as when it is vented to the carburetor intake because the pressure in the intake is lower than that in the canister when the vehicle is running.

To control hot soak losses during engine shutdown, two basic systems are used. The first is storage of the vapors in the induction system during shutdown followed by eventual consumption in the engine after start-up. The hydrocarbon vapors move from the bowl into the carburetor intake through the balance tube and then into the carburetor throat and air cleaner. Because hydrocarbons are denser than air, they displace the air.

The second control system for hot soak losses uses both the induction system and a charcoal canister to store vapors. A line from the bowl to the canister diverts a portion of the vapors to this alternate storage. Vapors stored in the carbon canister are ultimately purged by a portion of engine combustion air which is drawn through the canister during operating modes.

B. Fuel Tank Evaporative Emission Control

In all cases, fuel tanks are "closed" systems (non-vented fill caps) which are connected to a vapor storage system through a vapor-liquid separator. The vapor-liquid separator reduces system load by returning condensed and entrained liquid to the tank. Three types of vapor storage techniques are used: (1) charcoal canister, (2) engine crankcase, and (3) an auxiliary tank.

C. Charcoal Canisters

The majority of ECS's use a charcoal canister to store the hydrocarbon vapors emitted from the fuel tank. In these system, all of the fuel tank vapors from both hot soak and running losses pass into the canister. A few systems, however, use a control valve which allows running loss vapors to bypass the charcoal bed and move directly to the engine, as will be described later.

The charcoal canister system functions via an adsorption-regeneration process. Hydrocarbon vapors are adsorbed on the surface of the activated carbon for storage purposes. Later the vapors are desorbed from the surface by passing a portion of engine combustion air through the charcoal bed. This regeneration, or purging process, is necessary to restore the capacity of the bed for further hydrocarbon storage.

There are several types of carbon canisters in use. They may be classified by the method of introducing purge air to the bed and by the technique for the handling of running vapors. In most cases, purge air enters the bed through the open bottom of the canister as illustrated in Figure 3. A replaceable filter is used to prevent dust contamination. A second type of canister in use has a sealed bottom with an air inlet on top. In many canisters, running vapors as well as hot soak emissions pass into the carbon bed. In others, a purge valve is used which allows running vapors to bypass the carbon bed.

D. Purge Systems

There are three general types of purge systems for regeneration of carbon beds. These systems can purge to: (1) the air cleaner, (2) the carburetor, and (3) the Positive Crankcase Ventilation valve (PCV). Units purging to the air cleaner generally utilize the pressure drop through the air cleaner and inlet system to draw purge air through the canister. One system utilizes the velocity of the air in the air cleaner snorkel to pull air through the carbon bed. Purging to the carburetor is the most popular technique. A port at the idle position is most often used so that at idle the purge rate will be very low but will increase as the throttle is opened. The third type of purge is to the PCV system. With this system, a purge valve is used which permits only tank running vapors to reach the engine at idle. As the throttle is opened from idle, engine vacuum opens the purge valve on the canister so that both tank running vapors and stored vapors in the bed are drawn into the engine via the purge air stream.

E. Summary of Techniques for Evaporative Emission Control

1. Carburetor Bowl Emissions To:
   - Induction system only
   - Both induction system and charcoal bed canister

2. Fuel Tank Emissions To:
   - Charcoal bed
   - Auxiliary Tank
   - Engine crankcase

3. Carbon Canister:
   - Open or closed bottom
   - All vapors enter the bed
   - Running vapors bypass bed

4. Purges To:
   - Air cleaner
   - Carburetor
   - PCV

5. Other

IV. CLASSIFICATION OF SYSTEMS

Evaporative Control Systems have been divided into two general categories: (1) those using a charcoal canister, and (2) those using a system other than a charcoal canister for storage of fuel tank vapors. Over 98% of the 1973-1975 vehicle population utilize a charcoal canister. These systems have been further typed according to carburetor storage and type of canister purge. This is shown in Figure 5. Systems not using a charcoal canister may use the engine crankcase or a small auxiliary tank for storage.

A further subdivision is by the style of canister. A description of the charcoal canisters used by each U.S. manufacturer is given in Table 1.

V. SURVEY OF ECS's IN USE

A cross section of about 120 vehicles from the 1973-1975 car population has been used in this survey of evaporative control systems in current use. In addition to describing the ECS, the fuel system components which affect their function such as proximity of fuel tank to a tank have also been surveyed. This survey covered all families of engines from each U.S. manufacturer and the leading foreign-manufactured cars. All told, this group is representative of at least 99% of the vehicles in the 1973-1975 car population. The results from this survey are shown in Table 1.

CHARCOAL CANISTERS ON U.S. CARS

Manufacturer	No.	No. of Tubes	Tube Designation			Remarks
			Inlet	Outlet	Other	
General Motors	1	2	Tank	Purge		
	2	3	Tank Carburetor Bowl	Purge		
	3	3 (purge valve)	Tank	Purge	Vacuum for Purge Valve	
	4	4 (purge valve)	Tank Carburetor Bowl	Purge	Vacuum for Purge Valve	
Chrysler	1	3	Tank Carburetor Bowl	Purge		Carburetor Bowl sometimes not used (Same as GM-2)
	2	4 (purge valve)	Tank Carburetor Bowl	Purge	Vacuum for Purge Valve	(Same as GM-4)
Ford	1	2	Tank	Purge		500 gms
	2	2	Tank	Purge		300 gms
American Motors	1	2	Tank	Purge		
	2	3	Tank Carburetor Bowl	Purge		

References for Evaporative Losses

1. Martens, S.W.; Thurston, K.W., "Measurement of Total Vehicle Evaporative Emissions" SAE Transaction 680125, 1967.

2. Martens, S.W., "Evaporative Emissions Measurement with the SHED - A Second Progress Report" SAE Transaction 690502, 1968.

3. Statements given before the Environmental Protection Agency Waiver Hearing on the California 1977 Light Duty Evaporative Emission Standards, May 28, 1975.

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5. Patterson, D.J. and Heneim, N.S., "Emissions from Combustion Engines and Their Control", Ann Arbor Science Publishers, 1972.

6. Koehl, W.J., Jr., "Mathematical Models for Predictionof Fuel Tank and Carburetor Evaporative Losses", SAE Transaction 690506, 1969.

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8. "Examination of Interim Emission Control Strategies for Heavy Duty Vehicles" prepared by Emission Control Technology Division of the Office of Mobile Source Air Pollution Control May 30, 1975.

9. "Investigation and Assessment of Light Duty Vehicle Evaporative Emission Sources and Control", Phase I Task I 68-03-2172.

10. "Study of the Interaction of Fuel Volatility and Automotive Design as they Relate to Driveability", CPS 22-69-66.

11. California Air Resources Board, Los Angeles County A.P.C.D., Western Oil and Gas Association Modification Its Potential as an Air Pollution Control Measure in Los Angeles County".

12. Muller, H.L.; Kay, R.E. and Wagner, T.O., "Determining the Amount and Composition of Evaporatives Losses from Automotive Fuel Systems", SAE Transaction 660407, 1966.

Figure 1

Model Year	Diurnal (g/phase)	Hot Soak (g/phase)	Total (g/test)	g/mi equiv.	Percent Imp	Cert Std. (g/test)	Avg Loss (g/test)
	SHED Results					Canister Result	
57-69	26	15	41	2.8	0	None	-
70-71	18	12	30	2.1	25	6	-
72	14	12	26	2.0	28	2	-
73	16	15	31	2.5	11	2	.5
78 (Calif)	1 (est)	5 (est)	6 (std)	.7 (est)	75	-	-
Possible	.4 (est)	1.6 (est)	2 (std)	.23 (est)	92	-	-

Figure 2

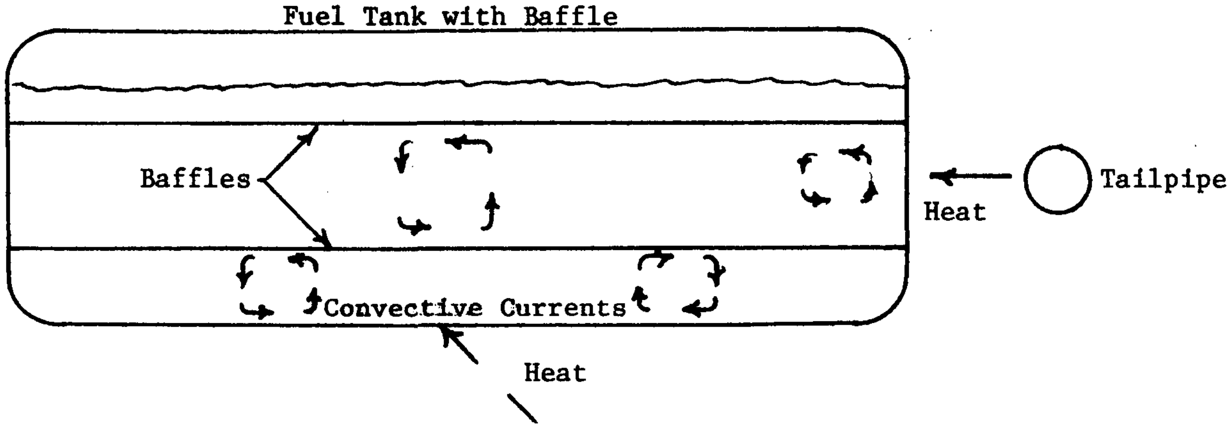
Vehicles passing 6 gram per test, proposed California SHED Standard

Vehicle	No. of Test	Diurnal	Hot Soak	Total	
1975 Vega 140-2BBL	3	.4	1.5	1.9	*
1975 Camaro 350-2BBL	3	.5	4.6	5.1	*
1975 VW Beetle 97-FI	3	1.0	2.5	3.5	*
1972 Pontiac 2BBL	1	.35	4.25	4.6	3
1972 Chevrolet	1	.15	5.28	5.43	3
1974 Ambassador (modified)	2	1.1	2.1	3.2	3
1975 Coupe DeVille 500-FI	2	.25	1.07	1.32	3
1975 Omega 260-2BBL	2	.49	3.89	4.38	3
1975 Olds 350-4BBL	22	2.85	2.60	5.45	3
1975 Olds 455-4BBL	16	1.27	3.83	5.10	3
1975 Vega 140	7	.3	1.0	1.3	3
1975 VW Sedan 1600-FI	1	1.4	2.9	4.3	3
1975 VW Rabbit	NA	NA	NA	4.3	3
1975 VW Type 1	NA	NA	NA	5.0	3
1975 Chry. Type SS22 360-2BBL	9	1.50	1.22	2.72	3
1975 Chry. Type VS29 360-HP	1	.28	1.94	2.22	3
1975 Chry. Type VH23B18-2BBL	1	.31	2.96	3.27	3
1975 Chry. Type RV41 318-2BBL	1	.62	4.20	4.82	3
1975 Chry. Type DH41	1	1.71	3.73	5.44	3

NA - not available
* - testing done at MVEL
3 - reference 3

Figure 3

Fuel Tank with Baffle



Fuel Tank without Baffle

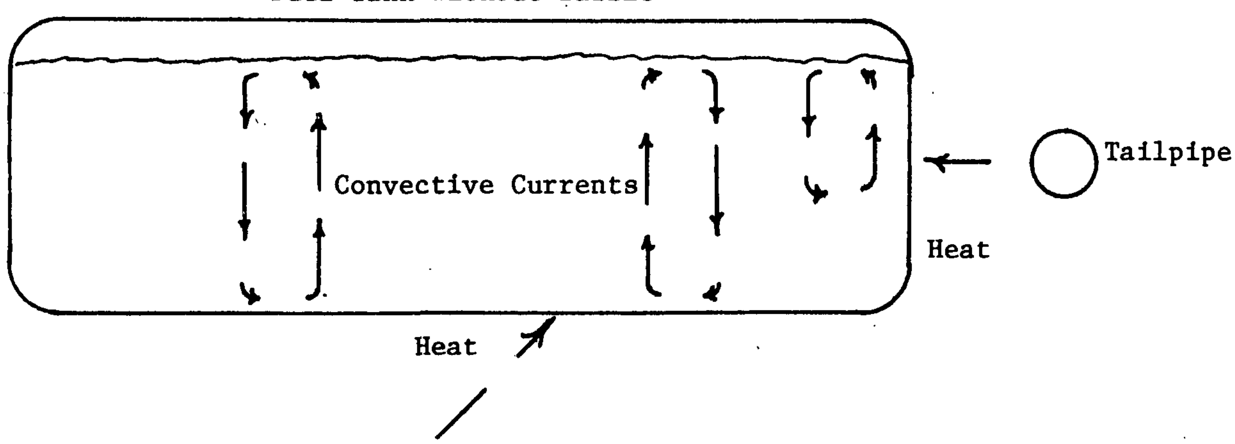


Figure 4

Fuel Tank with Bladder

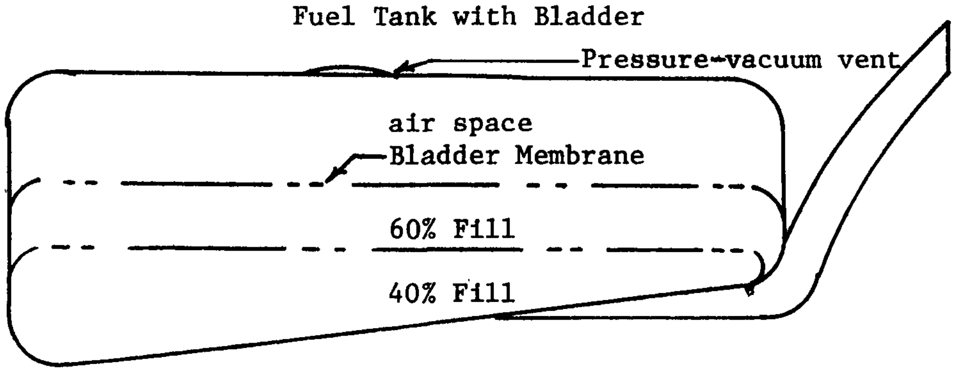
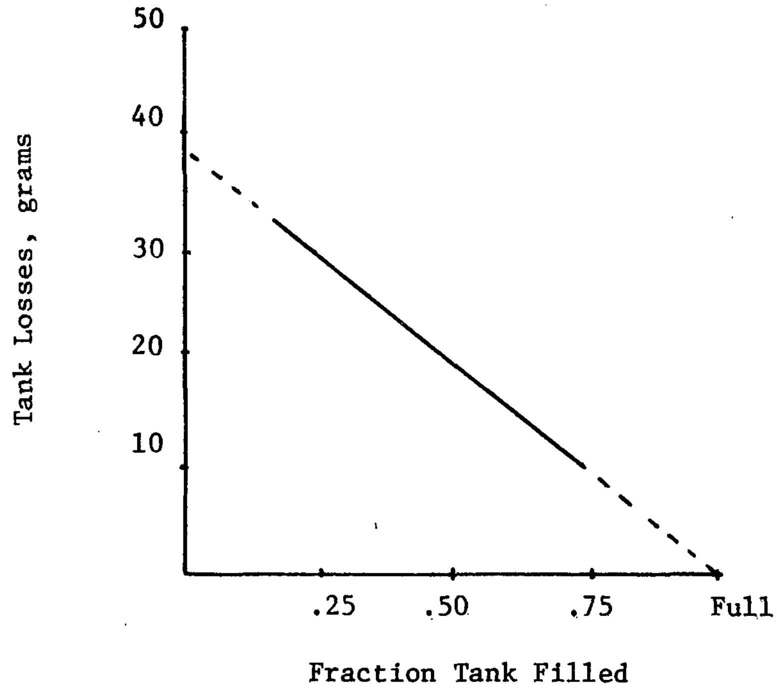


Figure 5

Losses vs Volume of Fuel



Reference (5)

Figure 6

Air Cleaner with Internal Baffles

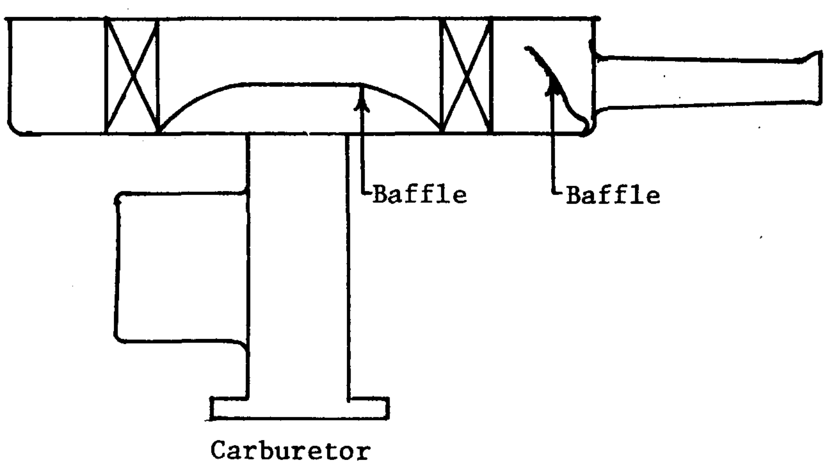
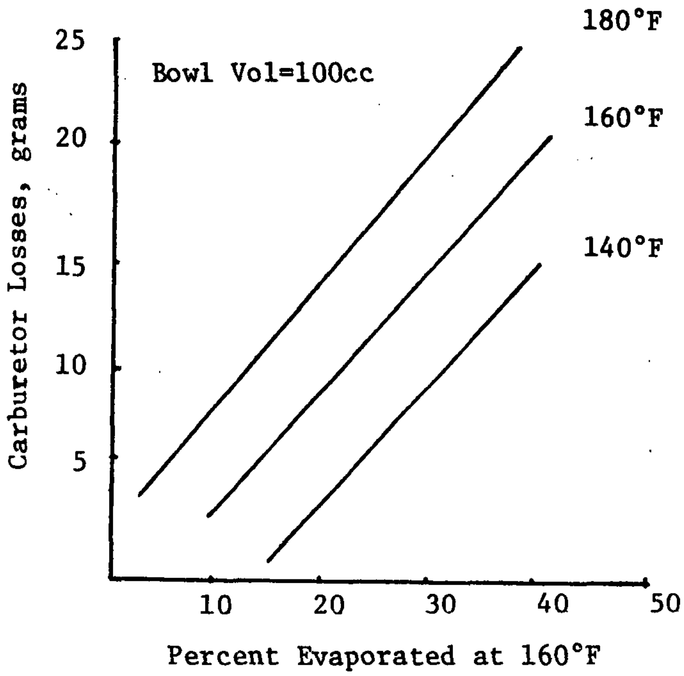


Figure 7

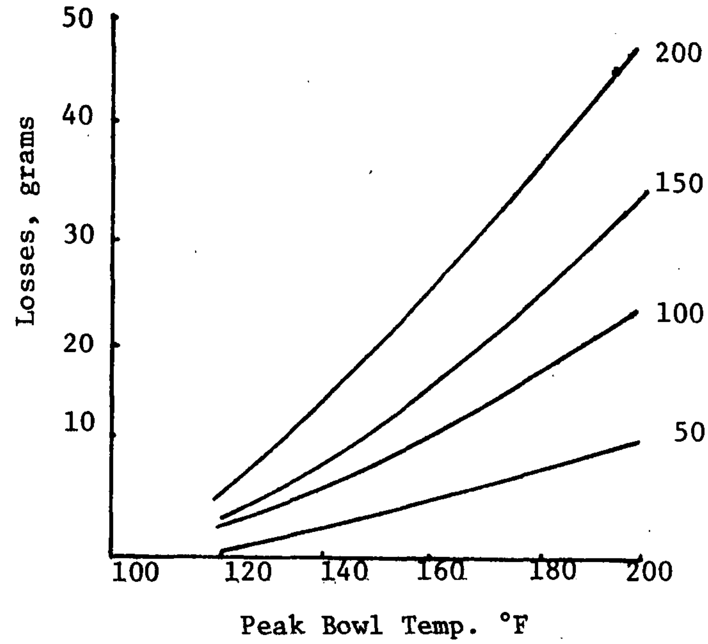
Losses vs Peak Bowl Temp



Reference (6)

Figure 8

Losses vs Bowl Vol., cc



Reference (6)

Figure 9

Intake Manifold Storage

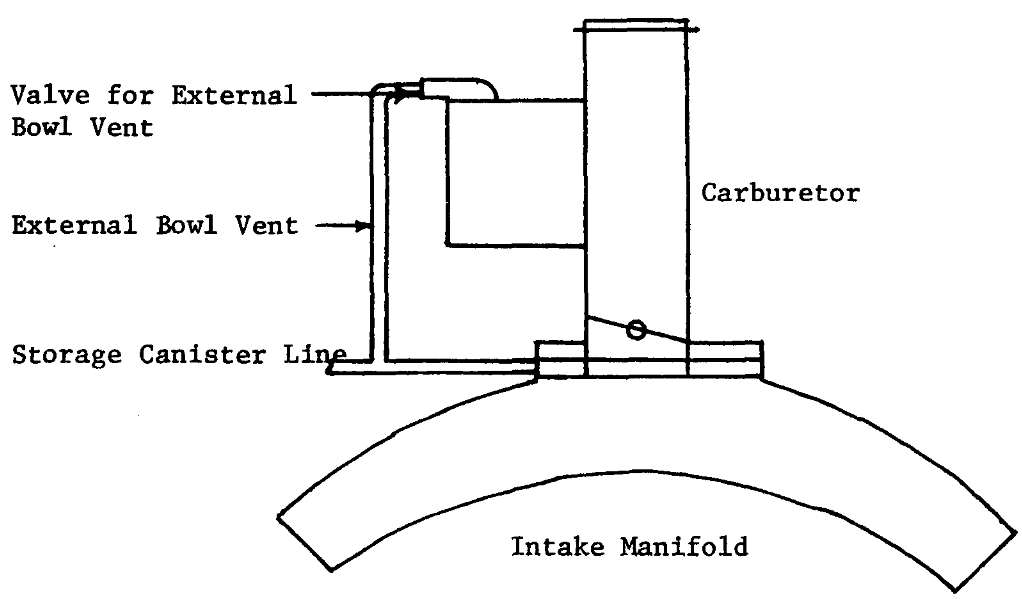


Figure 10

Carbon Canister with Semipermeable Membrane

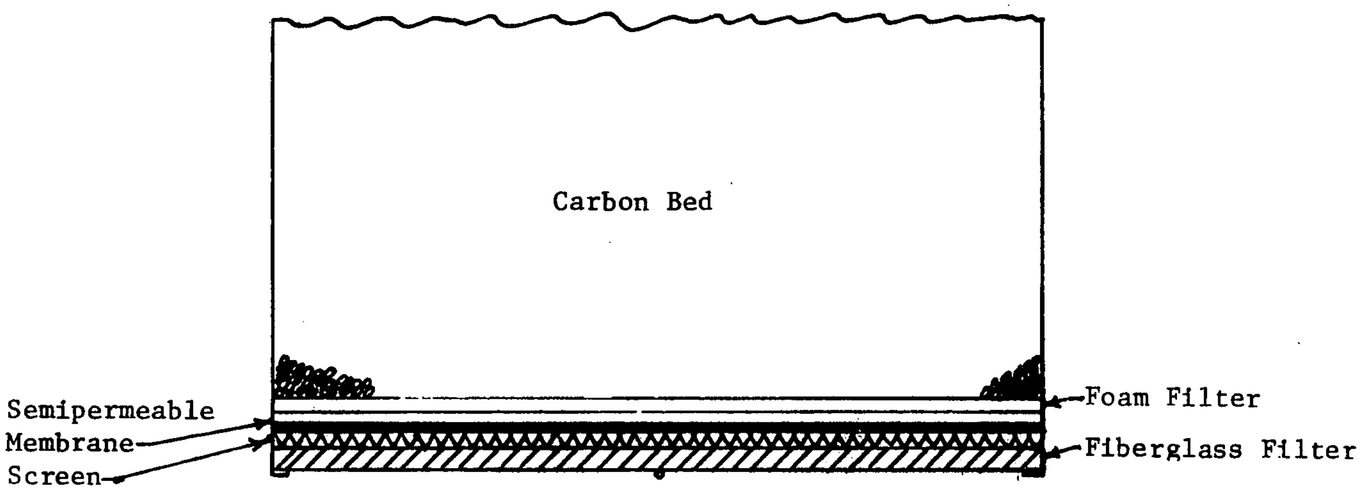


Figure 11

Storage Canister with Bottom

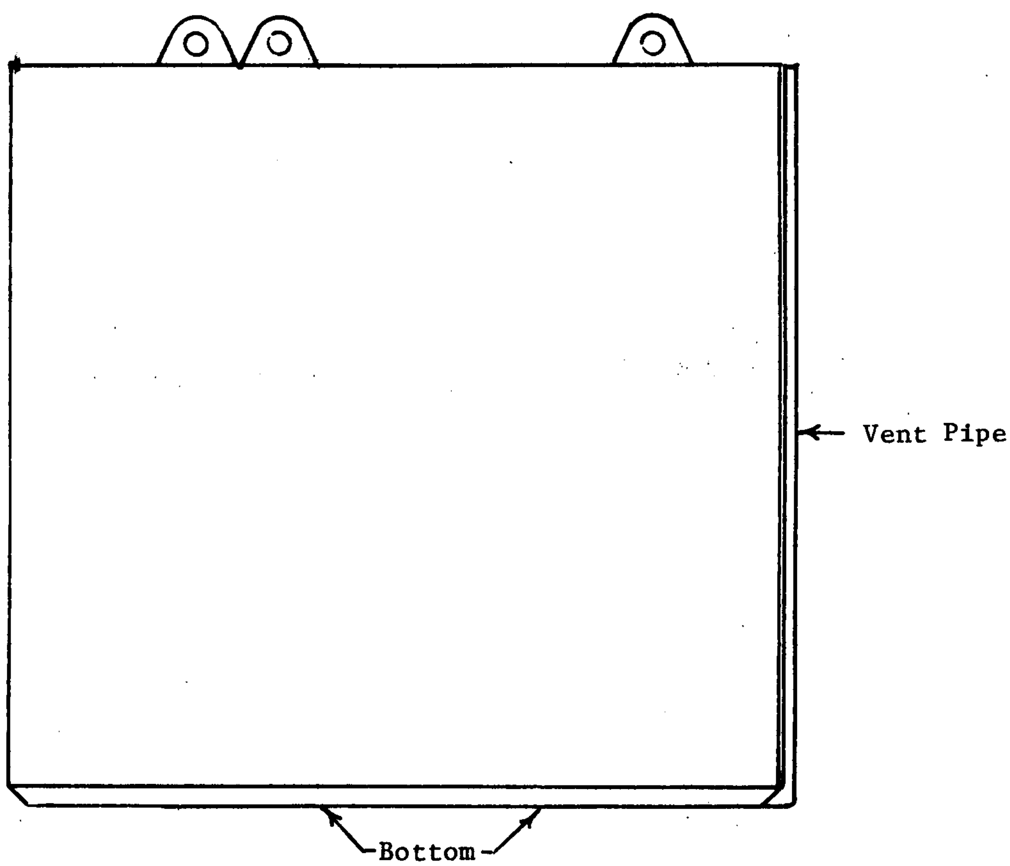
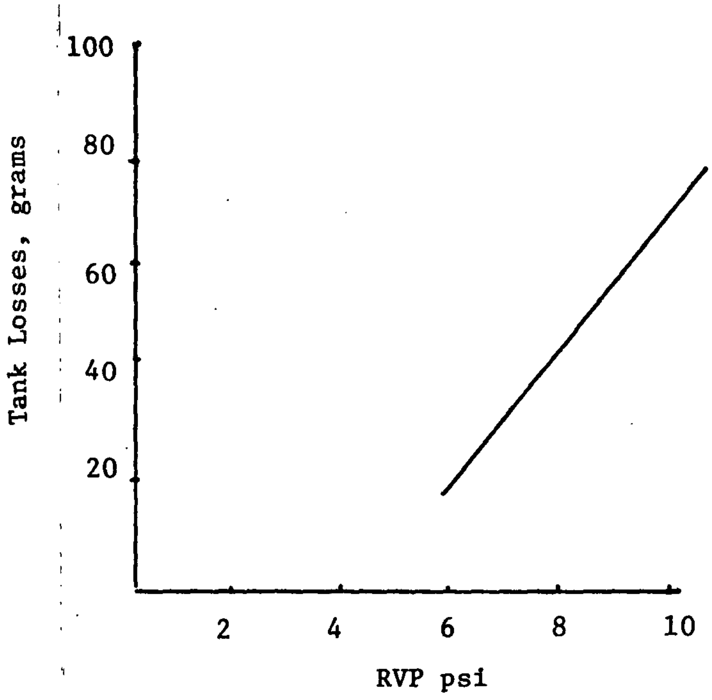


Figure 12

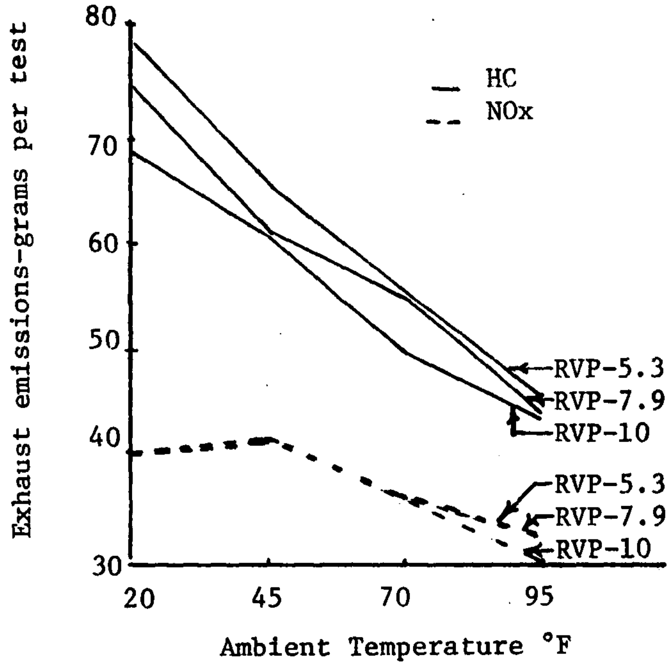
Losses vs RVP



Reference (5)

Figure 13

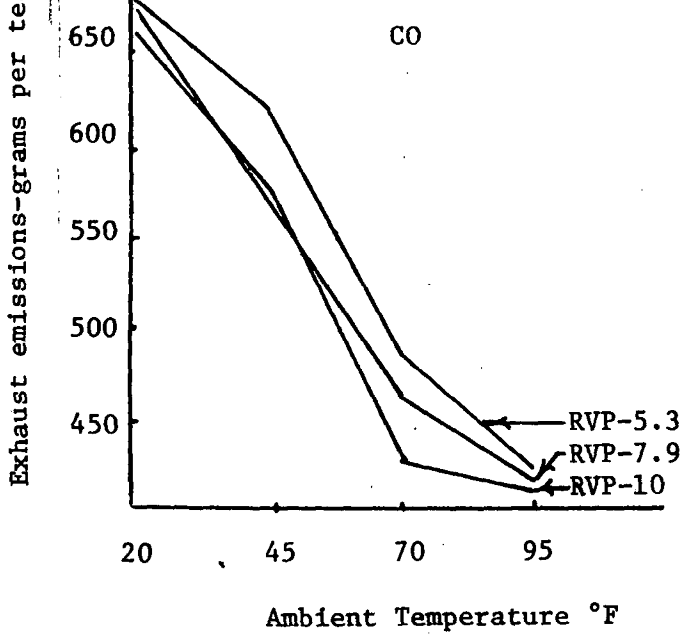
Effect of RVP on NOx & HC



Reference (11)

Figure 14

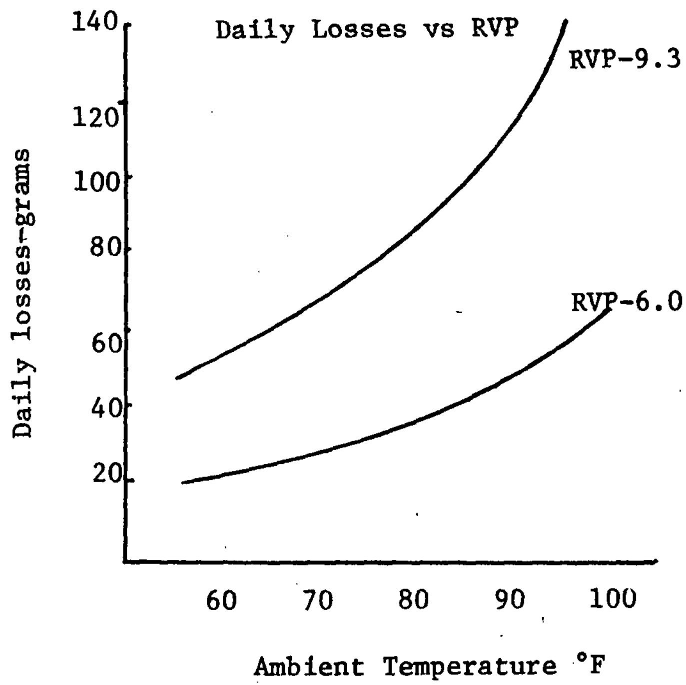
Effect of RVP on CO



Reference (11)

Figure 15

Daily Losses vs RVP



Reference (7)

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