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Recommendation on Feasibility for Onboard Refueling Loss Control

NOTICE

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I. Introduction

Refueling loss hydrocarbon emissions, estimated to be in the range of 4-5 g/gallon, can be controlled by use of control equipment at the service station (Stage II control) or by use of control equipment in the vehicle (onboard control). As required by the 1977 amendments to the Clean Air Act, the Emission Control Technology Division (ECTD) of EPA has reviewed and analyzed available data on the feasibility and desirability of onboard refueling loss control which will be discussed in this report. This information will be combined by the Office of Policy Analysis with available Stage II control information to provide the basis upon which the Administrator may choose the best of the two strategies.

II. Summary of Conclusions and Recommendations

Several hardware demonstrations and paper studies, Ref. 1, 2, have been conducted to determine the technical feasibility and cost effectiveness on onboard refueling loss control. Much of the current information is from the American Petroleum Institute (API) onboard demonstration program, Ref. 3. Other current information was obtained from motor vehicle manufacturers in response to a June 27, 1978 Federal Register (43FR 27892) request for relevant information. These demonstrations and analyses deal with the state-of-the-art emission control technology.

Analysis of this information supports the following conclusions:

1. Onboard refueling loss control is feasible for light-duty vehicles;

2. The most probable control system uses hydrocarbon adsorption on charcoal (the same strategy that is used for evaporative emission control);

3. Control effectiveness can be as high at 97% but depends especially upon the vehicle fillpipe/service station nozzle interface and upon control technology design;

4. An analysis of data from three fillpipe/nozzle concepts (fillpipe seals, nozzle seals, and combination fillpipe/nozzle seals) shows that the effectiveness of all three concepts is approximately equal. Durability effects have not been extensively evaluated, especially for the nozzle seal concept;

5. A vapor/liquid pressure relief valve is required to protect the integrity of the vehicle fuel tank during the refueling process. The pressure relief valve can be designed to function on the fuel nozzle, or it may be incorporated as part of the fillpipe

seal mechanism, which would be sealed-off by the fuel cap during vehicle operation. Durability effects have not been evaluated for either the fillpipe or nozzle pressure relief. ECTD recommends that the fillpipe/nozzle seal and pressure relief be located on the vehicle if onboard controls are required.

6. Cost to the consumer for control of refueling losses on light-duty vehicles will probably range around $17/vehicle. The $17 estimate does not include costs for a seal or pressure relief. Cost for a seal and pressure relief, if used on the vehicle, is estimated to be about $2.70. The cost of a seal on the nozzle should be the same as the cost for a Stage II nozzle. Except for the as yet undefined durability of the interface seal no maintenance costs are expected;

7. The feasibility of controlling refueling loss emission from gasoline fueled trucks and diesel fueled vehicles has not been evaluated to date. Technical feasibility and cost effectiveness of controlling these sources should be determined;

8. Minor increases in CO exhaust emissions seen for some of the vehicles can probably be controlled by minor changes to either the refueling loss control system or to the exhaust emission control system. The ability to certify a vehicle to a 3.4 g/mi CO standard to 50,000 miles should not be seriously impaired;

9. The use of a bladder in the fuel tank appears to be a viable alternative control strategy, but some problems exist and technical feasibility is yet to be demonstrated.

10. Considering the lead time needed for regulation development and review within EPA and the lead time required by the industry for development and application of technology, implementation of onboard controls cannot occur before 1983.

ECTD recommends that the choice between onboard control and Stage II control of refueling loss emissions be based upon the relative cost effectiveness of the two strategies for the same overall level of control and air quality considerations.

It is recommended that methods of reducing the cost of onboard refueling control systems be examined by considering tradeoffs between control system capacity and cost. It may be possible to sacrifice some capacity that is only required under infrequent conditions and achieve proportionately more significant cost savings.

The feasibility and desirability of control of refueling losses from light and heavy-duty gasoline fueled trucks and from diesel fueled vehicles should be considered. EPA should support the development of the bladder tank alternative for refueling loss control strategy. If regulations are to be developed for onboard refueling loss control, a certification test procedure must be developed.

III. Review of Available Information

The data and information summarized in this section are based on material submitted to EPA by the American Petroleum Institute and information received in response to a request for information (43FR 27892) published on June 27, 1978. The API material, Ref. 3, is the result of their most recent study to assess onboard technical feasibility and compare the cost effectiveness of onboard refueling controls and Stage II controls. This study was initiated at the urging of EPA. Respondents to the Federal Register notice include General Motors, Ford, and AMC. The API, GM, and Ford information contain data from tests with onboard control hardware. All respondents, with the exception of AMC, submitted information on the cost and the desirability of onboard control systems.

1. API Onboard Study

The API Onboard Control Study was structured to address questions regarding onboard feasibility which were posed to API in a December 1977 meeting with EPA. The API study consisted of three tasks: a vehicle concept demonstration, a fillpipe/nozzle concept demonstration, and a cost/benefit analysis. Exxon Research and Engineering Company and Mobil Research and Development Corporation were the API contractors for the vehicle concept demonstration. Atlantic Richfield Company was the API contractor for the fillpipe/ nozzle concept demonstration. Exxon R & E completed the cost/benefit analysis for API.

The vehicle concept modification task had the following design objectives:

1) Minimum 90% overall refueling vapor recovery.

2) No significant effect on exhaust emissions.

3) No significant effect on evaporative emissions.

4) Design should be durable, practical, and safe.

The fillpipe/nozzle demonstration had the following objectives:

1) 90% overall vapor control.

2) Compatible with existing vehicle population.

3) Compatible with existing Stage II nozzles.

4) Design should be durable, practical, and safe.

A review of the three API contractor's activities is presented below.

Test procedure guidelines for the API work were discussed at a meeting with API on March 15, 1978. Important procedural guidelines which resulted from that meeting are summarized as follows:

Fuel specification: Indolene unleaded test fuel was used for all exhaust, evaporative, and refueling loss measurements.

Dispensed fuel quantity: Test vehicles were refueled to 100% of capacity from a condition of 10% tank capacity.

Fuel tank temperature/Dispensed fuel temperature: The dispensed fuel temperature was selected to be representative of summer refueling conditions in Los Angeles during the month of August, or about 85°F. The fuel temperature in the tank was also selected to be 85°F. Thus, the refueling was isothermal.*

Purge Cycle: For the purposes of the API study, the only driving cycle which was used for purging the refueling loss canister is the LA-4 cycle.

Individually, these test procedure guidelines are considered to represent real world situations in a high oxidant forming location, e.g., Los Angeles during the month of August. Collectively, these guidelines imply that the API vehicles demonstrated the feasibility of onboard control systems in an approximate worst case condition. This reasoning is consistent with earlier EPA recommendations that API err on the conservative side during their study. For example, Exxon used the following test sequence to quantify the exhaust emissions interaction between the refueling control system and the exhaust emission control system:

1) Load ECS (Evaporative Control System) canister to breakthrough.

2) Condition the vehicle by driving 2 LA-4's.

3) Soak vehicle overnight.

4) Load RCS (Refueling Control System) canister to breakthrough.

*This represents a conservative situation as survey data, Ref. 4, show that nationwide dispensed fuel temperatures are typically lower than tank fuel temperatures, thereby representing a vapor shrinkage situation during the refueling process.

5) Condition the vehicle by driving 5 to 6 simulated city driving days (4.7 LA-4's with one hour hot soaks in between and a diurnal at the end of the day) to consume 90% of the fuel in the tank.

6) Drain the fuel tank.

7) Block RCS canister line.

8) Fill tank to 40%, unblock RSC canister lines.

9) Conduct diurnal evaporative test in SHED.

10) Drain tank to 10%.

11) Bring fuel tank liquid and vapor to equilibrium at 85°F (shake the vehicle to accelerate the equilibrium process).

12) Refuel the vehicle to 100% in SHED with 85°F fuel.

13) FTP

14) Hot soak evaporative test in SHED.

Obviously, these test procedures do not lend themselves to a routine laboratory certification test procedure. They do, however, permit an approximation of how an onboard control system would function in a severe "real-world" situation.

Exxon

Exxon assumed the responsibilty for modifying four test vehicles. Their vehicles included the following:

1978 Chevrolet Caprice

1978 Ford Pinto

1978 Plymouth Volare*

1978 Chevrolet Chevette

All vehicles are designed to comply with 1978 California exhaust and evaporative emission standards (.41 HC, 9.0 CO, 1.5 NOx, 6.0 Evap).

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* Vehicle subsequently dropped from test program because of high baseline NOx levels.

Table 1

FTP Exhaust and Evaporative Emissions - Caprice

		Exhaust (g/mi)				Evap. (g)		
		HC	CO	NOx		Diurnal	Hot Soak	Total
Baseline Configuration	n=4				n=3			
	Ave.	0.345	6.48	0.95		0.8	2.1	2.9
	S.D.	0.033	0.56	0.06		0.4	0.4	0.8
Modified Configuration	n=4				n=3			
	Ave.	0.338	7.10	0.86		1.1	2.1	3.1
	S.D.	0.010	0.59	0.05		0.3	0.2	0.4
Percent Change		-2	+10	-10				+7

Table 2

FTP Exhaust and Evaporative Emissions - Pinto

		Exhaust (g/mi)				Evap. (g)		
		HC	CO	NOx		Diurnal	Hot Soak	Total
Baseline Configuration	n=4				n=3			
	Ave.	0.187	1.70	0.77		1.0	2.5	3.5
	S.D.	0.021	0.10	0.01		0.2	0.3	0.4
Modified Configuration	n=4				n=3			
	Ave.	0.217	1.83	0.79		0.9	2.4	3.3
	S.D.	0.006	0.12	0.07		0.3	0.5	0.7
Percent Change		+16	+8	+3				-6

Table 3

FTP Exhaust and Evaporative Emissions - Chevette

		Exhaust g/mi)			Evap. (g)		
		HC	CO	NOx	Diurnal	Hot Soak	Total
Baseline Configuration	n=3				n = 4		
	Ave.	0.27	3.7	1.09	0.8	2.6	3.4
	S.D.	0.02	0.32	0.04	0.36	0.79	1.03
Modified Configuration	n=3						
	Ave.	0.26	3.6	1.13	0.3	1.2	1.5
	S.D.	0.05	0.28	--	0.08	0.15	0.15
Percent Change		-4	-3	+4			-56

*FTP + 3 Hot Start LA-4s

Table 4

Engine-Out Emissions - Caprice

		FTP (g/mi)			City Driving Day* (g)		
		HC	CO	NOx	HC	CO	NOx
Baseline Configuration	n=5						
	Ave.	1.28	26.42	1.17	41.86	733.86	38.68
	S.D.	0.05	0.72	0.04	2.00	39.27	1.17
Modified Configuration	n=5						
	Ave.	1.29	32.04	1.17	42.32	853.52	41.34
	S.D.	0.09	2.4	0.04	1.90	61.51	3.17
Percent Change		+1	+21	--	+1	+16	+7

*FTP + 3 Hot Start LA-4s

Table 5

Engine-Out Emissions - Pinto

		FTP (g/mi)		
		HC	CO	NOx
Baseline Configuration	n=4			
	Ave.	1.83	52.7	1.25
	S.D.	0.06	1.2	0.08
Modified Configuration	n=4			
	Ave.	1.77	60.1	1.12
	S.D.	0.09	0.8	0.04
Percent Change		-3	+14	-10

Table 6

Refueling Loss Measurements

		Potential HC (g)	SHED HC (g)	Percent Control Effectiveness
Caprice		93.4	0.4	
		91.0	0.4	
		89.3	0.3	
	Ave.	91.2	0.4	99
Pinto				
		51.0	1.0	
		59.3	1.3	
		53.1	1.1	
	Ave.	54.5	1.1	98
Chevette				
		62.5	0.5	
		65.5	1.5	
		60.1	1.1	
		64.6	1.6	
	Ave.	63.2	1.2	98

Table 7

Benzene Emissions

	Potential Benzene Emissions*SHED Measurements (ppm)	Measured Loss*SHED Measurements (ppm)
Caprice	3.0	<0.05
Pinto	2.7	<0.05

*All refueling at 85°F, RVP 9 lbs., Benzene content 0.7%.

The Caprice is a conventional oxidation catalyst vehicle, while the Pinto is a three-way catalyst vehicle with feedback carburetor control. Vehicle descriptions and complete refueling loss control system descriptions are presented in Table A-1 and Figure A-1 of the Appendix. The refueling loss canisters in the Caprice, Pinto and Chevette are described as follows:

Vehicle	RCS Carbon Volume	Carbon Mass	Carbon Type*	Location
Caprice	5.0ℓ	1800 g	BLP-F3	Underhood
Pinto	3.0ℓ	1100 g	BLP-F3	Underhood
Chevette	3.0ℓ	1100 g	BLP-F3	Trunk

* Same carbon currently used for controlling evaporative emissions.

The Exxon exhaust and evporative emission test results which compare baseline and modified versions of the Caprice, Pinto and Chevette are summarized in Tables 1, 2 and 3. Engine-out data are summarized in Tables 4 and 5. Refueling loss effectiveness test results are summarized in Table 6. All Exxon refueling emission tests assumed a no-leak seal at the fillpipe/nozzle interface. In laboratory practice this was achieved with leak free connections from the fuel nozzle to the fillpipe.

Benzene emissions were measured during the refueling loss SHED tests with both the Caprice and Pinto. These results are summarized in Table 7. The Exxon data indicate that benzene control is directly proportional to refueling loss control effectiveness, although current benzene levels in the SHED are at the detectable limit of the instrumentation.

Table 8 presents Exxon's manufacturer cost estimates for onboard control systems for the 1978 Caprice and Pinto. These estimates do not include the costs for fillpipe sealing devices and pressure reliefs, and this hardware represents an additional cost of approximately $1.50 (manufacturer's cost) per vehicle. Exxon's cost estimates assume an estimated $.50 credit for downsizing the ECS canister, which in the two canister system, controls only carburetor losses. Exxon estimates the incremental cost of two-canister refueling control systems to range from $8.25 to $10.53. This estimate includes the above mentioned $.50 credit but does not include the $1.50 cost for the fillpipe seal and pressure relief. The corresponding cost range for single canister refueling control systems is $6.75 to $9.00. For light-duty trucks, Exxon estimates a cost range of from $12 (large single canister) to $20 (two separate refueling loss canisters or multistage purge systems).

Table 8

COST ESTIMATES FOR ONBOARD SYSTEMS[1]

	Caprice	Pinto
Charcoal[2]	$4.96	$3.03
Canister and Valves[3]	2.50	2.00
Tank Modifications[4]	0.50	0.50
Hoses and Tubing[5]	1.57	1.72
Assembling and Installing[6] @ $20.00/hr.	1.50	1.50
	$11.03	$8.75
Credit for Downsized Evaporative Control System[7]	$0.50	$0.50
	$10.53	$8.25

(1) Estimates are made for cost to manufacturer for large volume production.

(2) 1800 g for the Caprice canister, 1100 g for the Pinto canister at $1.25/lbm (Calgon BPL-F3 carbon).

(3) Plastic container and valves.

(4) Larger size float/roll-over valve.

(5) 3/4" vapor line from fuel tank to canister, 3/8" purge line. EPDM tubing for vacuum control lines.

(6) Additional 4.5 minutes labor at $20/hour.

(7) Reduced size evaporative control canister.

Exxon estimates the average cost for onboard control systems to be $9/vehicle. This is based on the following assumptions:

1) Onboard systems are designed to control refueling emissions from light duty vehicles with an average fuel tank size of 17 gallons refueled to 100% capacity from a condition of 10% tank capacity. The onboard systems are designed to control hydrocarbon emissions at a level of 6 g/gal.

2) 70% of light-duty vehicles and single tank light-duty trucks are assumed to use single canister (evap + refueling) systems.

3) 30% of light-duty vehicles and single tank light-duty trucks are assumed to use two canister systems.

4) Light duty trucks with dual or large fuel tanks constitute approximately 10% of the light-duty vehicle light-duty truck population.

In summary, Exxon finds that onboard refueling controls for light-duty vehicles are a technically feasible, practical, and cost effective alternative to Stage II vapor recovery. They are of the opinion that the same may also be said for light-duty trucks.

Mobil

Mobil R&D has modified a 1978 Pontiac Sunbird for control of refueling losses. This vehicle has a three-way catalyst with a feedback carburetor control system, and is certified for complaince with California exhaust and evaporative emission standards. This modified vehicle uses a single canister which contains 1550 grams of Calgon BLP-F3 carbon. The complete vehicle and refueling loss control system descriptions are presented in the Appendix. Table 9 presents comparisons of exhaust and evaporative emissions from the Sunbird for the baseline and modified configurations; a summary of the refueling emission data is presented in Table 10.

Similar to Exxon's findings, Mobil states that their test results have demonstrated that onboard controls are a feasible and desirable method of controlling refueling losses from light-duty vehicles and light-duty trucks.

Atlantic Richfield Company

One of the requirements for the operation of an effective refueling loss control system is the existence of a no-leak seal at the fillpipe nozzle interface. Atlantic Richfield (ARCO) has developed working prototypes of fillpipe seals and nozzles. ARCO has investigated three types of sealing systems. They included:

1) Modification of the vehicle fillpipe to achieve a seal when used with conventional lead-free nozzles.

Table 9

FTP Exhaust and Evaporative Emission Comparisons -- Sunbird

		Exhaust (g/mi)				Evap. (g)		
		HC	CO	NOx		Diurnal	Hot Soak	Total
Baseline Configuration	n=9				n=2			
	Ave.	0.39	6.41	0.98		0.87	1.12	2.00*
	S.D.	0.03	0.91	0.07		030	0.13	0.34
Modified Configuration	n=6				n=4			
	Ave.	0.40	6.35	0.99		0.72	1.27	2.11
	S.D.	0.03	0.74	0.03		0.23	0.37	0.56
Percent Change		+3	-1	+1				+6

* Includes five tests at low mileage where individual diurnal and hot soak results are not available.

Table 10

Refueling Loss Measurements -- Sunbird

Fuel Dispensed (gal)	HC Collected in Canister (g)*	Refueling Emissions SHED Measurements (g/gal)	Control Efficiency (%)
16.4	85	0.18	97
15.3	73	0.02	99
16.9	113	0.44	94
17.1	109	0.36	95

* Canister purged from a nominal working capacity load of 210 g.
Fuel of nominal 9 lbs. RVP.
8 gpm refueling rate, using modified Stage II nozzle.

2) Modifications to both the fillpipe and lead-free nozzle.

3) Modification of a Stage II vapor recovery nozzle.

A description of each type of seal and a summary of the durability data collected with each system are presented below:

Fillpipe seals: Two types of fillpipe seals have been examined. They are a rotary grease seal (similar to grease seals used on rotating machinery shafts), and a doughnut shaped seal. The material types for these two seals are a compounded nitrile and thermosetting urethane, respectively. More complete descriptions of these seals, including durability data, are found in Figure A-5 and Tables A-2 and A-3 of the Appendix. Appproximately thirty days of durability tests with both types of seals have demonstrated that the rotary seal is more effective, basically due to the absence of expansion problems when exposed to gasoline liquid and vapor atmospheres. The seal effectiveness of the prototype fillpipe and nozzle hardware are determined by a bench test apparatus which pressurizes a particular system and measures the resulting leak rates. Seal effectiveness calculations are determined by dividing the leak rate by a nominal fueling rate (assumed to be 7.5 gallons/min.). Durability tests conducted with the rotary seal have demonstrated that the rotary seal is effective after 700-1000 nozzle insertions, which correspond to the life of the vehicle.

Combination fillpipe/nozzle seals: These systems consist of connecting parts on both the fillpipe and nozzle. Figure A-6 is an example of a prototype design evaluated by ARCO. Durability test results with these systems are similar to results obtained with the rotary seal.

Nozzle Modification: Working prototypes of vapor recovery nozzles, modified for refueling loss control, have been developed by OPW and Emco Wheaton and evaluated by ARCO for effectiveness and durability. These nozzles are designed to seal on standardized fillpipes. The modified vapor recovery nozzles incorporate a pressure relief valve, which is located at the vapor return exit or cast into the nozzle body, which is designed to open at approximately 14-17 in. water pressure*, thereby permitting the nozzle to refuel onboard control vehicles and in-use vehicles. Nozzle durability data are very limited but one nozzle has been inserted and latched 7500 times, representatitve of a year's service at a high volume station, and showed a seal effectiveness of greater than 99%.

ARCO concludes that the preferred seal techniques are either the fillpipe seal method or the combination fillpipe/nozzle seal.

* Refueling loss control systems designed by Exxon and Mobil are designed to operate at fill pressures of less than 4 in. of water pressure.

No statements are made as to the desired location of the pressure relief mechanism.

2. Vehicle Manufacturer Comments

General Motors

GM's March 1978 submission to EPA, Ref. 5, presents a summary of their work on the control of diurnal evaporative emissions and refueling losses through the use of fuel tank bladders. Their information represents the most complete study of bladder tank feasibility known to EPA. Regarding bladder tank feasibility, GM admits bladder tanks have the potential for a substantial amount of emissions control, but they are of the opinion that the technical problems which must be solved before bladder tanks are capable of demonstrating the same degree of control effectiveness as carbon adsorption systems, do not permit this technology to be considered applicable in the same time frame as the other candidate control technologies, including Stage II control methods. The March 15 submission states that the major problem with controlling evaporative and refueling emissions with the bladder tank is the formation of gasoline vapor mixtures from dissolved air in gasoline. The temperature at which the vapor pressure of the dissolved air equals the partial pressure of air in the vapor space (bubble formation) is known to be very sensitive to the quantity of dissolved air in gasoline. Other design problems include pressure relief valves, and a puncture resistant fuel gaging indicator.

The March, 1978 submission presents calculations showing that the additional weight of the components of an onboard control system would cancel out any potential energy saving which would result from the combustion of the refueling vapors.

The June, 1978 submission, Ref. 6, is basically a cost effectiveness study comparing onboard and Stage II cost effectiveness.

GM's March, 1978 submission estimates the cost of typical carbon adsorption onboard control systems to range from $11 for single canister systems, to $15 for two-canister systems. The GM estimates represent costs to the consumer. The June, 1978 submission indicates that these figures must be increased by $5-$9 per vehicle to cover the costs for an enlarged vapor/liquid separator and additional carbon. Thus, GM's estimates are now $16-$24 per vehicle. These estimates do not include costs for fillpipe seals or pressure reliefs as GM assumes that this hardware would be part of the service station fuel dispensing equipment.

GM has stated that both onboard and service station controls are technically feasible methods of reducing refueling loss emissions. However, GM's cost effectiveness calculations find onboard controls to be much less cost effective than Stage II vapor recovery. Rather, GM emphasizes certain technical concerns which they say are not fully addressed by the API study. According to GM, these include API's unsubstantiated support for the onboard fillpipe seal and pressure relief (lack of adequate durability results), an unknown CO penalty for light-duty vehicles (no sensitivity data relating CO to test procedure differences), and unproven feasibility for trucks.

GM is of the opinion that accelerated laboratory durability tests are not sufficient to prove that proposed elastomer type seals will be effective in the extreme usage and environmental conditions of the real world, particularly when considering a ten year average lifetime for a light-duty vehicle.

Ford

Ford has submitted test results from four 1978 model year vehicles (three non-feedback systems and one feedback control system) modified for refueling loss control. These vehicles are described in detail in Table A-4 in the Appendix and in their submission to EPA, Ref. 7. The purge control systems for these vehicles are shown in Figures A-7 and A-8 in the Appendix.

Ford estimates the cost to the consumer of onboard controls to range from $15-$20. They note that the $15-$20 estimate does not include additional expense for such items as: packaging costs, incremental labor costs, or the costs for additional exhaust emission control, such as feedback control over a wider air/fuel ratio range.

Recent Ford material, Ref. 12, suggest that the cost of onboard systems may range from $30 to $253. The $30 estimate includes costs over the original $15-20 estimate, including costs for such items as vehicle modifications to package onboard systems, incremental assembly, and material substitution. The $253 estimate includes the cost for a feedback fuel system and electronic controls for vehicles which are not planned to be equipped with these control devices.

On the basis of their in-house test results, Ford has concluded that onboard controls are not technically feasible for light-duty vehicles.

American Motors

AMC has submitted a letter to EPA, Ref. 9, which states their concerns with the possible use of onboard controls. They state that packaging concerns, reduced quantities of purge air from downsized engines, and compliance with stringent evaporative emission standards are unresolved technical issues which have not been addressed by the API work to date.

AMC does not find that API has demonstrated light-duty vehicle technical feasibility.

IV. Analysis of Available Information

1. API Work

Exxon

Exxon R&E appears to have done a credible job in characterizing the components of a hydrocarbon adsorption system. An examination of the results from baseline tests and tests with the modified Pinto (3-way + feedback carburetor system) show small but finite increases in engine-out (14%) and tailpipe (8%) CO emissions. HC, CO, and NOx emissions are still well below statuatory emission levels for low mileage vehicles. Engine-out CO emissions from the Caprice are approximately 20% higher than baseline test results; tailpipe CO emissions are approximately 10% higher than the baseline results. No increase in tailpipe CO was observed during tests with the Chevette. Exxon suggests that differences in CO emissions for the Caprice and the Pinto can be further reduced by minor modifications to the refueling loss control system or the exhaust emission control system, although this has not been demonstrated.

Figure A-2 shows canister purge as a function of time. Although the data are bench test results, the results are also representative of actual control system purge data. It is significant to note that the refueling loss canister is essentially purged to its working capacity after three LA-4 driving days. This implies that the refueling control/exhaust emission interaction is likely to be less in a typical driving day than Exxon has measured using conservative test methods, which required running a cold start FTP immediately after a 90% refueling.

ECTD expects that refueling loss control systems will result in slightly higher CO feedgas levels. Exxon estimates that the average increases in CO feedgas between refuelings will be approximately 5% for non-feedback control systems and less than 3% for feedback control systems. ECTD has no other data concerning either the magnitude of the average CO feedgas penalty or the resulting effect on catalyst durability. It is ECTD's opinion that the Exxon estimates are reasonable and that these additional CO penalties will make it more difficult for vehicle manufacturer's to certify some engine/families to the 3.4 g/mi CO standard. The higher CO levels somewhat reduce the margin available to allow for exhaust system deterioration over 50,000 miles.

ECTD finds that light-duty vehicles equipped with onboard systems are capable of meeting a 2 gram evaporative emission standard.

An analysis of the control effectiveness of benzene emissions during refueling, Table 6, indicates that charcoal canisters can control in excess of 99% of the uncontrolled benzene emissions. Exxon conducted additional tests with the Caprice and Pinto using indolene test fuel with a high benzene content (4.2%). The results from these five tests with the modified vehicles support the earlier findings -- benzene emissions are controlled in excess of 99% during refueling.

Packaging refueling loss control systems is a difficult problem, but definitely not an insurmontable one. The refueling loss canister is located behind the rear seat and above the rear axle in the Caprice, and in the engine compartment of the Pinto. It is Exxon's opinion, and ECTD agrees, that it is possible for manufacturers to locate a refueling loss canister on downsized vehicles without major engine compartment or sheetmetal modifications.

The feasibility of refueling loss controls for light-duty trucks has not been evaluated by Exxon, but they are of the opinion that refueling loss control is feasible for light-duty trucks by using larger control systems and more sophisticated purging controls (refueling loss control canisters for each tank and/or two stage purging systems). It is ECTD's opinion that the control of refueling losses from light-duty trucks needs to be demonstrated, especially the ability to comply with a 2 g evap standard, before onboard controls are judged to be effective for these vehicles at the costs Exxon has estimated.

Table 8 shows Exxon's detailed manufacturer's cost estimates for refueling control systems which have two canisters. ECTD finds these cost estimates to be reasonable for onboard systems designed to control 100% of refueling emissions from 90% fill conditions. Exxon estimates the average manufacturer's cost for the light-duty truck and light-duty vehicle population to be about $9. That number is derived as follows:

	Assumed Average Cost	% of Population
One-cansiter vehicles*	$7.88	70
Two-canister vehicles*	$9.38	20
6,000 to 8,500 lbs. trucks**	$16.00	10
Weighted average	$9.00	

* Includes light-duty vehicles and light-duty trucks under 6000 GVW - average fuel tank size = 17 gal.
** Average fuel tank size = 35 gal.

The charcoal cost per gallon of tank volume is assumed to be about $0.20.

The $9 incremental manufacturer cost may be translated to a consumer cost estimate of $16.20 by multiplying the manufacturer's cost estimate by a factor of 1.8 (Ref. 10, EPA Report "Cost Estimations for Emission Control Related Components/Systems and Cost Methodology Description" by Rath and Strong, March 1978). The 1.8 factor is in general agreement with previous EPA studies, such as the EPA Report, Ref. 11, "Investigation and Assessment of Light-Duty Vehicle Evaporative Emission Sources and Control," June 1976, which used a manufacturer to consumer cost factor of 2.0. The $16.20 estimate is in good agreement with consumer cost estimates submitted by GM ($16-$24) and Ford ($15-$20). It is possible to further reduce the cost of an onboard system by trading off some degree of refueling loss control effectiveness.

Exxon has designed refueling loss control systems based on conservative criteria, and thus a different set of design criteria will afford reductions in the cost of onboard control systems. Texaco has submitted data (Figure A-11) Ref. 12, which relates the number of light-duty vehicle refuelings and the percent of tank fill. A reasonable design criterion is to size the refueling canisters to control 90% of nationwide refueling emissions. Calculations (Figure A-12) show that 90% control can be achieved by designing systems to control 100% of refueling emissions from fills to 63% of fuel tank volume. If onboard control systems are designed to control emissions from refueling to 63% of tank capacity rather than 90% of tank capacity, the Exxon estimate of $9 per vehicle can be reduced by $1.60 as the result of reduced charcoal quantity. This cost reduction is proportional to the reduction in carbon bed volume. The net effect of this design change is a cost reduction to the consumer of approximately $2.88. Changes in design specifications such as the 90% fill requirement may afford additional cost reductions for other control system components as well as a general reduction in the problem of packaging onboard control systems.

ECTD estimates the consumer cost of light-duty vehicle onboard control systems designed for maximum control effectiveness to be about $17. This estimate does not include an estimate for the cost of the fillpipe seal or pressure relief valve. The $17 estimate is based on Exxon estimates, which when translated to consumer costs, are in agreement with consumer cost estimates provided by GM and Ford.

Exxon estimates the manufacturer's cost for a fillpipe seal and onboard pressure relief valve to be approximately $1.50. ECTD estimates the consumer cost of an onboard fillpipe seal and pressure relief to be approximately $2.70.

Mobil

Comparisons of baseline and modified vehicle test results indicate that Mobil R&D is able to add refueling controls to the

1978 Pontiac Sunbird (3-way + feedback carburetor system) without adversely affecting exhaust or evaporative emissions. No changes in engine-out or tailpipe CO emissions are observed. Evaporative emissions are also unchanged, with both baseline and modified vehicle test results near the 2 g evaportive emission level.

It must be emphasized, however, that Mobil and Exxon use different test procedures for measuring the refueling control/ exhaust emission interaction. Mobil's test procedure consists of the following sequence of events:

1) Load canister to approximately one-half of working capacity.

2) Condition vehicle by driving two simulated city driving days (4.7 LA-4's with one hour hot soaks in between and a diurnal at the end of the day).

3) Drain fuel tank to 10% of volume.

4) Refuel to 90% of volume in SHED.

5) Conduct hot start emission test.

6) Soak vehicle for 11 hrs.

7) Conduct diurnal evaporative test in SHED.

8) FTP

9) Hot soak evaporative test in SHED.

Steps 1, 2, and 5 are the important differences between the test procedures used by Exxon and Mobil. Mobil starts their test sequence with a canister loaded to one-half of working capacity, versus a saturated condition for the Exxon procedure. Mobil purges the refueling loss canister with two LA-4 driving days, versus the Exxon method of purging by running a series of LA-4 driving days until the fuel tank reaches 10% of capacity. Mobil runs a hot start emission test prior to the FTP; no such additional conditioning is used in the Exxon test sequence. It is ECTD's opinion that the the Mobil test sequence, particularly the addition of a hot start exhaust emission test, will result in a less severe refueling control/exhaust emission interaction. This is due to the smaller quantity of hydrocarbon which is purged during the cold start FTP when using the Mobil test sequence. The actual emission sensitivity to various test procedure arrangements has not yet been determined.

Atlantic Richfield Company

ARCO states that the fillpipe modification approach and the combination fillpipe/nozzle seal concept are the preferred techniques for achieving a no-leak seal. This recommendation is not supported from an analysis of leak rate and durability data because the test results show that seal effectiveness among all three concepts are equal. Cost estimates for the three designs have not been submitted. ARCO is continuing to collect field durability data on their prototypes, but the lack of a more extensive durability demonstration under simulated conditions of real world usage makes it questionable to assume that their seals will function as well in the field as they have in the laboratory.

In particular, ARCO has not adequately addressed the issue of onboard pressure relief valves versus liquid pressure relief valves located on the fill nozzle. Pressure relief valves are necessary to prevent over-pressurization of the fuel tank in the event of a failure of the automatic shutoff on the fill nozzle. For the purpose of fuel tank integrity in the event of a vehicle crash, NHTSA recommends that the pressure relief not be located on the fuel tank. However, a relief valve might be incorporated safely with a fillpipe seal mechanism, which would be sealed-off by the fuel cap during vehicle operation.

The achievement of a safe and durable seal at the nozzle fillpipe interface is critical to the performance of an onboard refueling loss control system. ARCO has demonstrated that the effectiveness of fillpipe seals, combination seals and nozzle seals are equal; but, the design, locations, and durability of the pressure relief valve have not been adequately addressed.

Conceptually, a pressure relief may be designed to function properly when located on the vehicle or on the nozzle. However, if refueling losses are controlled on the vehicle, it is recommended that the fillpipe/nozzle seal and pressure relief valve also be located on the vehicle. Locating all parts of an onboard system on the vehicle will prevent the potentially serious problem of refueling a controlled vehicle without protection from overpressurization (no relief valve). Administrative and certification concerns also suggest that onboard controls are practical only if the seal and pressure relief are located onboard.

An alternative technique of achieving a seal at the fillpipe/nozzle interface is the liquid trap or submerged fill. This seal concept has not been adequately investigated. Submerged fill offers the potential for significant advantages in terms of simplicity of operation and durability (mechanical, magnetic, or elastomer type seals are avoided). It is ECTD's opinion that the submerged fill concept should be investigated. Submerged fill (and seal techniques investigated by ARCO) must be evaluated in the context of a complete refueling and evaporative emission control system. This includes incorporating features to provide adequate thermal expansion capability and rollover protection while still permitting normal safe refueling.

2. Vehicle Manufacturer Information

General Motors

General Motors has several reservations concerning the applicability of onboard controls, citing such things as: the uncertainty of the effectiveness of fillpipe/nozzle seals, potential cost increases associated with exhaust emission control systems which must be designed to control increased CO emissions, negative fuel penalties which are the result of this increased emission control, and the long lead time which is required to obtain a substantial reduction in atmospheric hydrocarbon and benzene loading. However, with the exception of GM's concern with using accelerated laboratory tests to assess fillpipe/nozzle seal durability, these reservations are not detailed in their submissions. GM has stated that refueling losses can be controlled on the vehicle (feasibility for trucks has not been demonstrated) or at the service station. GM's disagreements with controlling refueling emissions with onboard controls are primarily based on the issue of cost/effectiveness.

GM's March, 1978 submission to EPA presents a summary of their work on the control of diurnal evaporative emissions and refueling losses using fuel tank bladders.

It is EPA's opinion that the theoretical control effectiveness of evaporative and refueling loss emissions using bladder tank technology is high and that these problems can be solved. It is recommended that bladder tank feasibility be researched by funding a bladder tank hardware demonstration contract.

The March, 1978 submission presents calculations showing that the additional weight of the components of an onboard control system will cancel out any potential energy saving which results from the combustion of the refueling vapors. ECTD agrees with this analysis.

The June, 1978 submission is basically a cost effectiveness analysis comparing onboard controls with Stage II controls (balance displacement and vacuum assist systems). GM estimates that onboard control systems, effective with the 1982 model year, will range from $16 to $24. These figures are about $5 to $9 higher than the March, 1978 estimates due to higher estimates for larger canisters and a new vapor/liquid separator. GM assumes that the seal at the fillpipe/nozzle interface will be obtained using modified vapor recovery nozzles. GM does not include seal costs in its estimate. They assume these costs will be the same for either Stage II or onboard controls and, hence, leave these costs out of their analysis of both options. General Motor's onboard cost estimates are costs to the consumer. These estimates are based on costs for hydrocarbon adsorption systems which control evaporative and refueling emissions with one canister (cheapest) and systems which use two separate canisters for containing evaporative (diurnal and hot soak) and refueling emissions (most expensive). The GM cost estimates are consistent with Exxon's manufacturers cost estimates for onboard controls. As discussed earlier, it is possible to design cheaper refueling loss control systems by not providing 100% control of refueling emissions under worst case conditions. If the design criterion of 100% control for a 90% refueling is changed to 100% control for a 63% refueling, it is possible to reduce the required working capacity of the charcoal canister, thus reducing the average system cost to the consumer by about $3.00.

GM does not find that onboard controls are feasible for the 1982 model year, although their cost effectiveness analysis calculations are based on the assumption that onboard control could become effective beginning with the 1982 model year. It is ECTD's opinion that onboard refueling loss controls cannot be implemented prior to 1983 model year. GM did not comment on the feasiblity of refueling loss controls for light-duty trucks and heavy-duty gasoline powered vehicles.

Ford

Ford emphasizes that the refueling loss/exhaust emissions interaction is a function of the test procedure and that the differences between emissions interactions measured by Exxon and Mobil are due to test procedure differences. This statement is correct, although the actual emission sensitivity to the test procedure is unknown.

Ford attributes the high CO effects, which they have observed with both conventional oxidation catalyst systems and three-way plus feedback carburetor systems, to the presence of refueling loss controls. However, the reason for their high CO emissions is due to a non-optimally designed system for controlling the hydrocarbon purge rate. Ford uses a manifold vacuum controlled purge system, which results in cold start hydrocarbon loadings that are two to three times higher than results obtained with venturi vacuum controlled systems (Exxon system). This is the reason the Ford results are so high, particularly engine-out CO emissions. Ford maintains that refueling loss control systems produce peak enrichment effects equal to two air/fuel ratios, which is beyond the capability of their current feedback carburetor control system. Exxon has demonstrated, however, that venturi vacuum maintains the air/fuel ratio within the control limits of the feedback control system. Problems with the existing Ford feedback control system are likely to be the result of response time problems, not control range problems.

Some of Ford's concerns with onboard refueling control systems, such as packaging, weight of onboard systems, and the design of vapor/liquid separators have been examined during the API study and shown not to be significant problem areas. Other concerns with onboard controls, including system durability, onboard feasiblity for light and heavy duty trucks, and high altitude feasibility, have not been adequately addressed in any of the information submitted to ECTD. It remains ECTD's judgment that these issues need further examination, particularly before onboard controls are determined to be feasible for light and heavy-duty trucks. Although onboard durability data are not available, ECTD finds that onboard control systems should be as durable as current evaporative emissions control systems, which last for the lifetime of the vehicle.

Ford estimates the consumer cost of onboard controls for light-duty vehicles to range from \$30 to \$253. EPA estimates that the consumer cost of onboard control systems will be about \$20 (includes \$2.70 for the cost of an onboard seal and pressure relief).

American Motors

AMC's concerns with the use of onboard controls are addressed to the issues of exhaust and evaporative emissions interactions, feasiblity of vehicles using small engines, costs, and light-duty truck feasibility. With the exception of feasibility for light-duty trucks, AMC's concerns have been examined in detail by the API study. EPA's analysis of that data is that refueling loss controls are feasible for light-duty vehicles at a consumer cost of approximately \$17.

V. Conclusions

Feasibility

An Analysis of the available information has shown that onboard refueling loss controls are feasible for light-duty vehicles designed to meet low exhaust and evaporative emission standards (0.41 HC, 3.4 CO, 1.0 NOx and 2.0 Evap.). However, the feasibility for light-duty trucks, particularly the assurance that onboard control systems are compatible with a 2 gram evaporative emission standard, has not been established. Feasibility for heavy-duty gasoline vehicles has not been established.

An analysis of information and test data presented to EPA regarding the control of light-duty vehicle refueling emissions offers the following conclusions:

1. Onboard control systems in laboratory use situations can control in excess of 97% of the uncontrolled hydrocarbon refueling losses.

2. The same systems in laboratory use situations can control in excess of 97% of the uncontrolled benzene refueling losses.

3. Test results from two light-duty vehicles equipped with three-way catalysts, feedback carburetors, and prototype refueling loss systems show that tailpipe CO emissions range from a 0 to 8% increase.

Test results from the same vehicles show that engine-out CO emissions range from a 0 to 14% increase.

4. Emission data from two conventional oxidation catalyst equipped light-duty vehicles show that tailpipe CO emissions range from a 0 to 10% increase.

Data from one of the conventional oxidation catalyst vehicles show that engine-out CO emissions increase by 10 to 20%.

5. The addition of refueling loss controls to light-duty vehicles does not significantly affect evaporative emission losses.

6. Minor increases in CO exhaust emissions seen for some vehicles can probably be controlled by minor change to either the refueling loss control system or to the exhaust emission control system. However, the addition of refueling loss controls will likely make it more difficult to certify some vehicles to the 3.4 g/mi standard at 50,000 miles.

7. Onboard controls do not affect vehicle fuel economy.

8. Onboard controls do not affect vehicle driveability.

9. Refueling loss control systems for light-duty vehicles are estimated to add $17 to the vehicle sticker price. The $17 estimate does not include the costs associated with the fillpipe/nozzle seal or pressure relief valve. The consumer cost of a seal and pressure relief in the fillpipe is estimated to be about $2.70. The cost of a seal on the nozzle should be roughly the same as the cost for a Stage II nozzle. However, it is recommended that all components of an onboard control system be located on the vehicle.

Lead time

Onboard refueling loss control can be implemented for 1983 model year light-duty vehicles, provided that potential problem areas such as the design and development of effective fillpipe/nozzle seals and pressure relief valves do not require additional hardware demonstration programs. It is anticipated that the fillpipe/nozzle seal and the control feasibility for light and heavy-duty trucks are issues which can be resolved during the NPRM process.

ECTD estimates that a minimum of two years lead time will be required by manufacturers for development (purge system optimiza-

Figure 1

Lead Time

```
                                               Calendar Year
                                  1979      1980      1981      1982      1983
             Quarter:    | 3 4 | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 |

Develop Certification
Test Procedure              -------------

Continued Study of
Fillpipe/Nozzle Seal        -------------
Concepts

Decision on Seal               -   (Decision to publish service station nozzle
Concepts                            requirements or put seal on vehicle)

EIS, EIA, NPRM
Preparation                  --------

Publish NPRM                            -

Final Rule                                   -

Manufacturers
Lead Time                                    --------------------------| 1983 MY
```

tion, design and verification of fillpipe seal mechanisms) and production tooling changes (tooling associated with fabrication and relocation of new evaporative control components). These estimates are based in part upon data provided by manufacturers relating to carburetor tooling changes, and in part upon data supplied by GM relating to retooling changes for body panel modifications. Additional time will be required for EPA to develop a certification type test procedure and issue regulations, however, the certification procedure development can overlap the production tooling lead time. Therefore, the projection is that an NPRM can be published late in 1979 with final rules promulgated by 1980 with the earliest possible implementation date being 1983. (See lead time chart, Figure 1).

Compliance Costs

ECTD estimates that certifying light-duty vehicles for compliance with a refueling loss standard will require an additonal one-half person-year at the EPA-MVEL. This is based on an estimate of 100-150 refueling loss tests per year. Facility modifications/ equipment procurements will cost from $30K to $80K.

A potentially significant impact on refueling loss compliance costs is Inspection/Maintenance testing of light-duty vehicles. EPA has not developed, and is not aware of, a valid I/M test for determining the performance of evaporative emission control systems. Monitoring the performance of in-use refueling loss control systems will be difficult and cumbersome. At this time, it may be assumed that the onboard compliance costs associated with an I/M test will be equal to the cost of Stage II enforcement.

VI. Recommendations for Future Work

1. ECTD recommends that additional hardware testing be conducted to determine the optimal fillpipe-nozzle seal. Additionally, the operation and durability of a fillpipe or nozzle pressure relief must be demonstrated. The use of an onboard liquid trap seal (submerged fill) as an alternative to elastomer type seals should be investigated.

2. ECTD recommends that additional hardware testing be conducted to assess the feasibility of controlling refueling losses on light-duty trucks and heavy-duty gasoline powered trucks.

3. ECTD recommends that the need for controlling refueling losses from diesel powered vehicles be investigated since these vehicles are predicted to represent a substantial fraction of the entire motor vehicle population in the 1980's.

4. ECTD recommends that the bladder fuel tank be investigated as an alternative to carbon adsorption technology. It is ECTD's opinion that the theoretical control of evaporative and

refueling loss emissions with bladder tanks is high and that technical problems can be solved. It is recommended that bladder tanks feasibility be researched by funding a hardware demonstration contract.

5. Finally, ECTD recommends that methods of reducing the cost of onboard refueling control systems be examined. Such studies should be directed toward tradeoffs between level of control effectiveness and cost. It may be possible to sacrifice control capacity that is required under only infrequent conditions to achieve a proportionally more significant cost savings.

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5. "General Motors Commentary to the Environmental Protection Agency Relative to On-Board Control of Vehicle Refueling Emissions," March 1978.

6. "Suppplement to General Motors Commentary to the Environmental Protection Agency Relative to On-Board Control of Vehicle Refueling Emissions," June 1978.

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12. Texaco statement submitted to Paul Stolpman, July 18, 1978.

APPENDIX

The Appendix contains detailed descriptions and data from the test vehicles and fillpipe/nozzle seals which were used in the most recent testing and evaluation of refueling loss control systems.

Exxon

Table A-1 presents a description of all Exxon test vehicles. Figure A-1 is a schematic of the basic control system designed for the Chevrolet Caprice and the Ford Pinto. The refueling emissions (RCS) canister controls both refueling emissions and diurnal evaporative emissions; the evaporative emissions (ECS) canister controls carburetor hot soak losses. Exxon investigated several different purge mechanisms, including combinations of manifold vacuum and venturi vacuum, and two stage purge control valves controlled by fuel volume, but venturi vacuum, which is proportional to engine air flow, is the most effective purging method. Exxon's control system is designed to maintain the total purge air volume (RSC + ECS) equal to the purge air volume of the unmodified vehicle's evaporative control system.

The air bleed control valve, shown in Figure A-1, is necessary because the RCS canitser is purged more efficiently (higher hydrocarbon purge per unit volume of air) than the unmodified ESC system, thereby resulting in richer A/F mixtures. This air bleed may not be necessary for other vehicles with feedback carburetor controls.

Figure A-2 is a plot of the RCS canister purging as a function of time. These data are based on consecutive LA-4 driving days. As noted, the RCS system is purged at a rate of about 4 litres/min., which corresponds to a total canister purge volume of about 40 litres during an LA-4 driving cycle.

Mobil

Specifications for the vehicle Mobil has modified for refueling loss control are summarized as follows:

Vehicle: 1978 California Pontiac Sunbird

Engine Size: 151 cu. in. L-4

Interia Weight: 3000 lbs.

Emission Control System:
- Exhaust: 3-way catalyst with feedback carburetor, EGR
- Evaporative: Carbon canister

Fuel Tank Capacity: 18.5 gallons

The production vehicle is modified for controlling refueling emissions by enlarging the existing carbon canister, (one canister controls refueling, diurnal, and hot soak loss), enlarging the vapor line between fuel tank and canister, redesigning the vapor/liquid separator, and installing a purge control orifice between the canister and intake manifold. A schematic of the Sunbird's control system is shown in Figure A-3. Various flow control orifices were inserted in the canister purge line but best results are obtained with an orifice of 0.100 in. diameter. Mobil uses 1550 grams of Calgon BPL-F3 carbon for their control system, which assumes a 20% safety factor. This quantity of carbon is based on a 90% fill of the 18.5 gallon tank, and assumes a hydrocarbon loading of six grams per gallon of dispensed fuel. The working capacity of the canister is approximately 240 grams. The basic components of the canister control system are shown in Figure A-4. The ported vacuum purge control valve is from a 1978 Chevrolet Impala evaporative canister, while the two fuel tank vapor valves (two are used to reduce the pressure drop during the refueling operation) are carburetor bowl valves from a 1978 Impala. Using two fuel tank vapor valves results in fillpipe pressures as low as two inches of water pressure during refueling. The fuel tank vapor valves are also controlled by manifold vacuum such that the vapor valves are closed when manifold vacuum is present at the control port.

Atlantic Richfield Company

Figure A-5 shows the fillpipe seal which ARCO has developed and tested for durability. Tables A-2 and A-3 are typical of the durability results obtained with this seal. Figure A-6 is an example of a prototype combination fillpipe/nozzle seal which has been developed and evaluated by ARCO.

Ford

The vehicles which Ford has used for refueling loss testing are shown in Table A-4. A single 4.35 l canister is used in the Mustang, while a duel canister system, 829 ml and 3.4 l, are used for controlling carburetor vapors and diurnal/refueling losses, respectively, in the Pinto. The purge systems for the Mustang and the Pinto are shown in figures A-7 and A-8.

Figures A-9 and A-10 are plots of canister loading versus test procedure sequence. These plots indicate that Ford's refueling loss control system is quite sensitive to the particular test procedure which is used to quantify the refueling control/exhaust emission interaction.

Table A-1

Vehicle Descriptions

Make	Model	Engine Displacement/ Configuration	Control Systems	Fuel Tank Capacity (gallons)
Chevrolet	Caprice	5.0 litre (305 CID)/V-8	Ox. Cat., AIR, EGR	21.0
Ford	Pinto	2.3 litre (140 CID)/L-4	3-Way, Ox. Cat., AIR, EGR	13.0
Plymouth	Volare	3.7 litre (225 CID)/L-6	Ox. Cat., AIR, EGR	18.0
Chevrolet	Chevette	1.6 litre (98 CID)/L-4	Ox. Cat., AIR, EGR	12.5

Table A-2

FILLPIPE MODIFICATION

ROTARY SEAL-CR 7538

LEAK RATE AS AFFECTED BY

FILLNECK PRESSURE AND WEAR

NO. OF SPOUT INSERTIONS	TYPE SPOUT	CUMULATIVE INSERTIONS	FT^3/MIN LEAK * @ 5" W.C.	@ 15"
0		0	0	0.001
100	Smooth	100	0	0.001
100	Rough	200	0	0.001
100	Smooth	300	0	0.001
100	Rough	400	0	0.001
100	Smooth	500	0	0.001
100	Rough	600	0	0.001
100	Smooth	700**	0	0.001
100	Rough	800	0	0.002
100	Smooth	900	0	0.002
100	Rough	1000	0	0.002

* Leak rate average of six nozzle insertions.

** Expected number of insertions during vehicle life.

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7/13/78

Table A-3

FILLPIPE MODIFICATION

ROTARY SEAL-CR 7538

EFFECT OF LIQUID AND VAPOR GASOLINE SOAK ON SEAL ID AND LEAK RATE*

HOURS OF LIQUID SOAK	TOTAL WEEKS OF VAPOR SOAK	SEAL ID,IN.	FT^3/MIN LEAK** @ 5" WC	@ 15" WC
0	0	.712	0	0
16	0	.712	0	0
35	0	.711	0	0
-	2	.705	0	0
-	3	.699	0	.001
-	4	.701	0	.001
-	5	.703	.001	.001
-	6	.698	0	0
-	7	.693	0	.001
-	8	.691	.001	.002

* Vapor and liquid soak at 72°F.

** Leak rate average of nine nozzle insertions.

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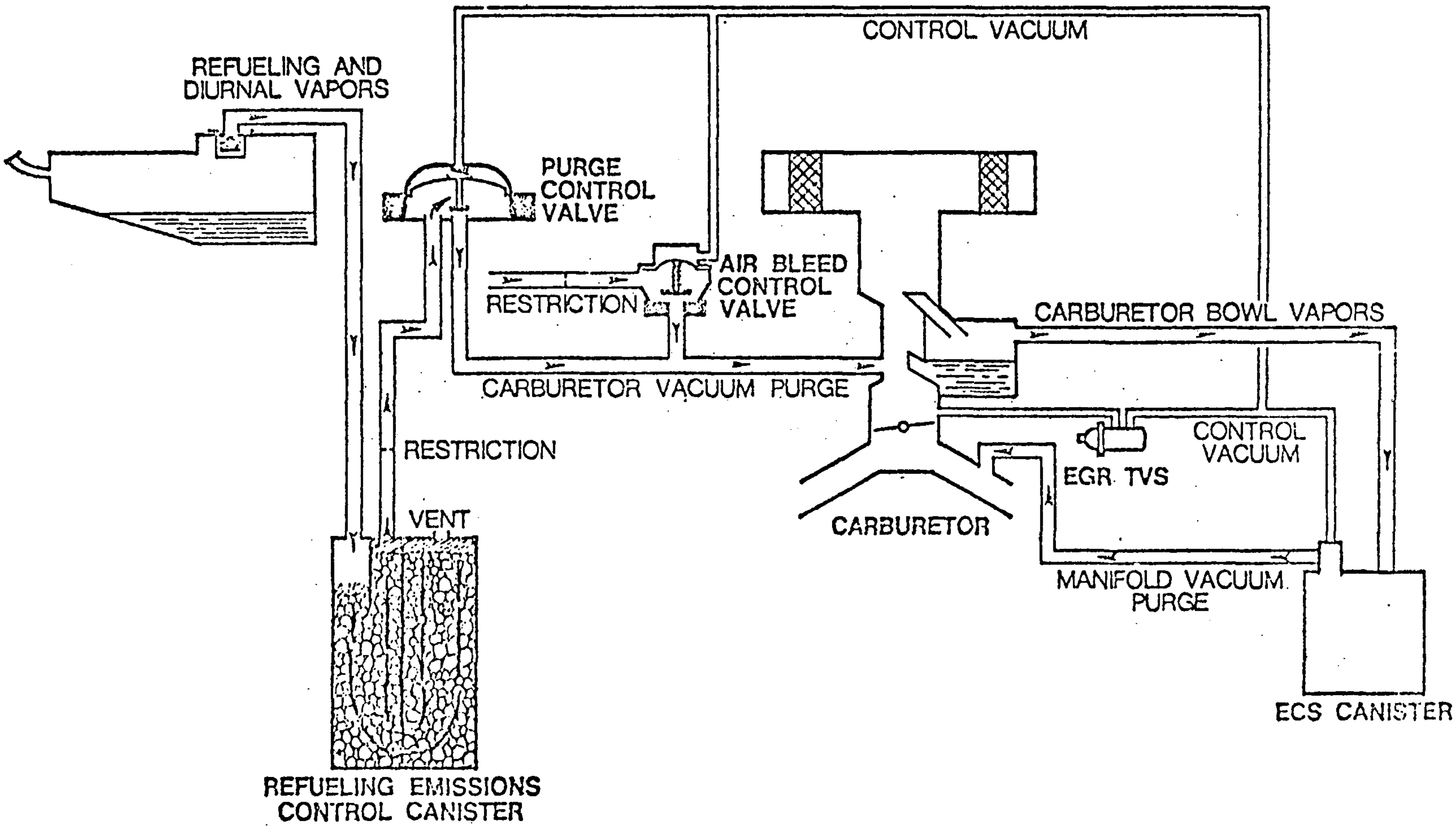
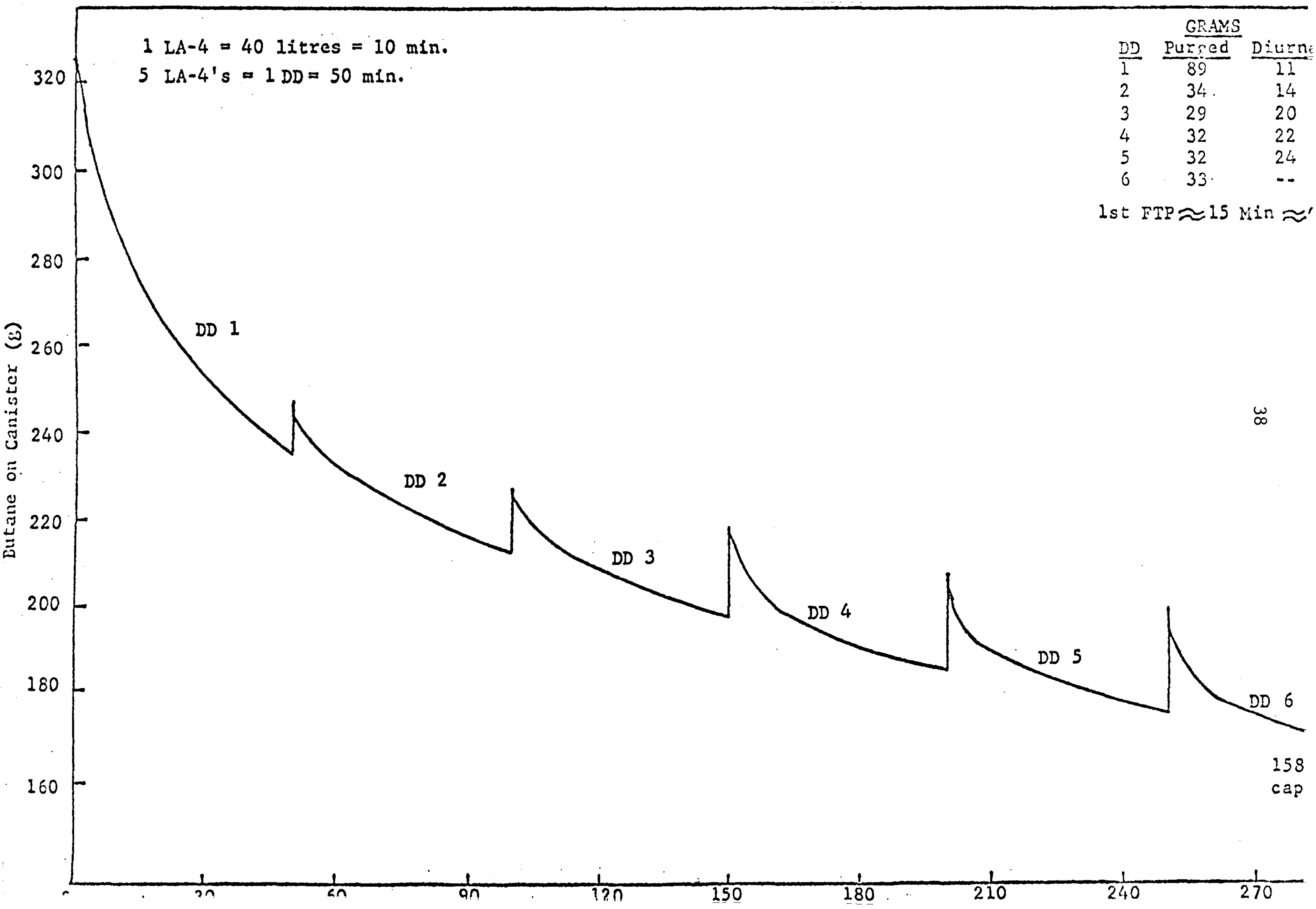
Figure A-1

EVAPORATIVE AND REFUELING EMISSIONS CONTROL SYSTEMS



PURGE @ 4 LITRE/MIN. WITH DIURNAL ADDITIONS
ADSORPTION TO 35 g. FROM BREAKTHROUGH

3.5 litre Canister (BPL-F3)



DD	GRAMS Purged	Diurna[l]
1	89	11
2	34	14
3	29	20
4	32	22
5	32	24
6	33	--

Figure A-3

ONBOARD SYSTEM TO CONTROL REFUELING EMISSIONS

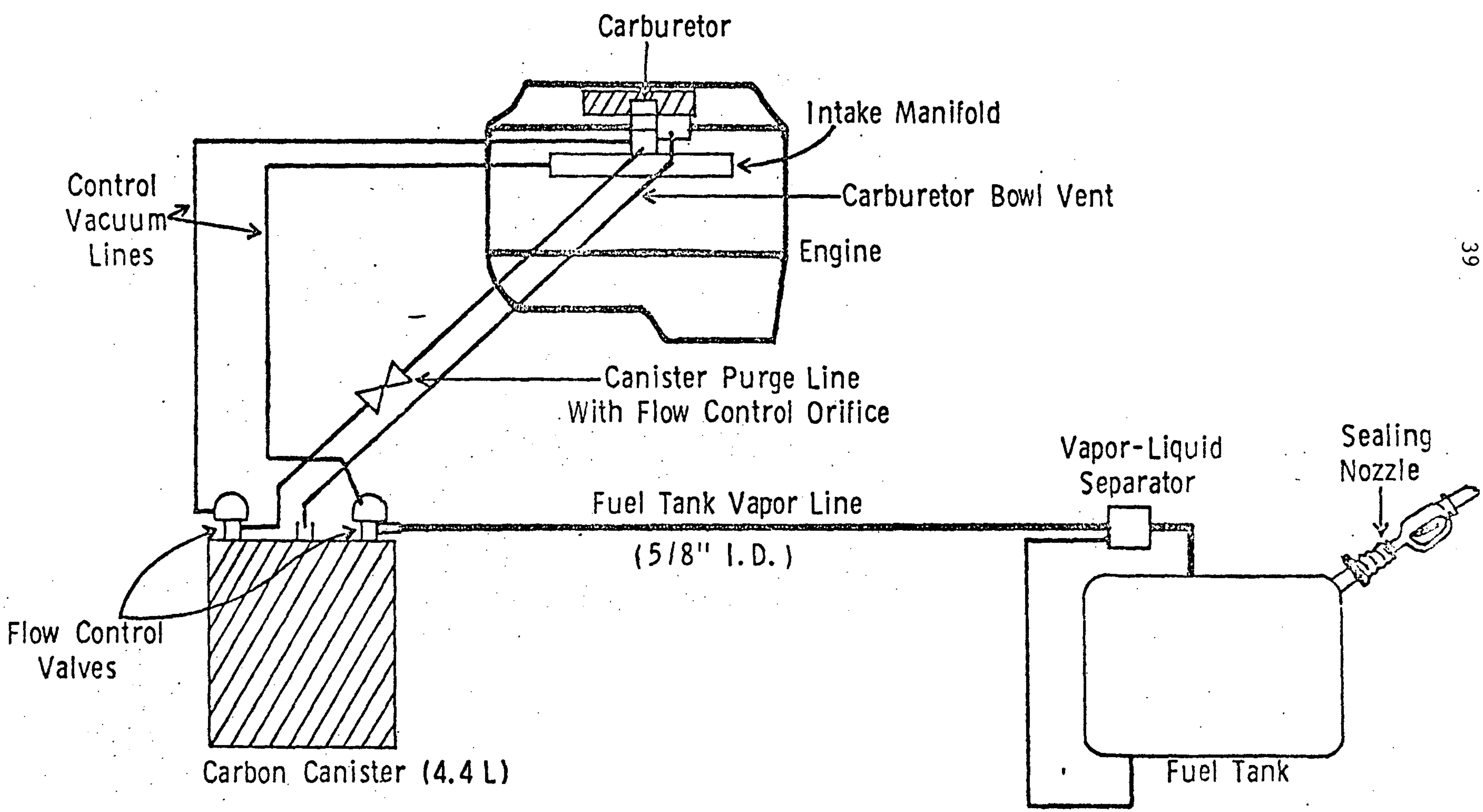


Figure A-4

Refueling System Carbon Canister

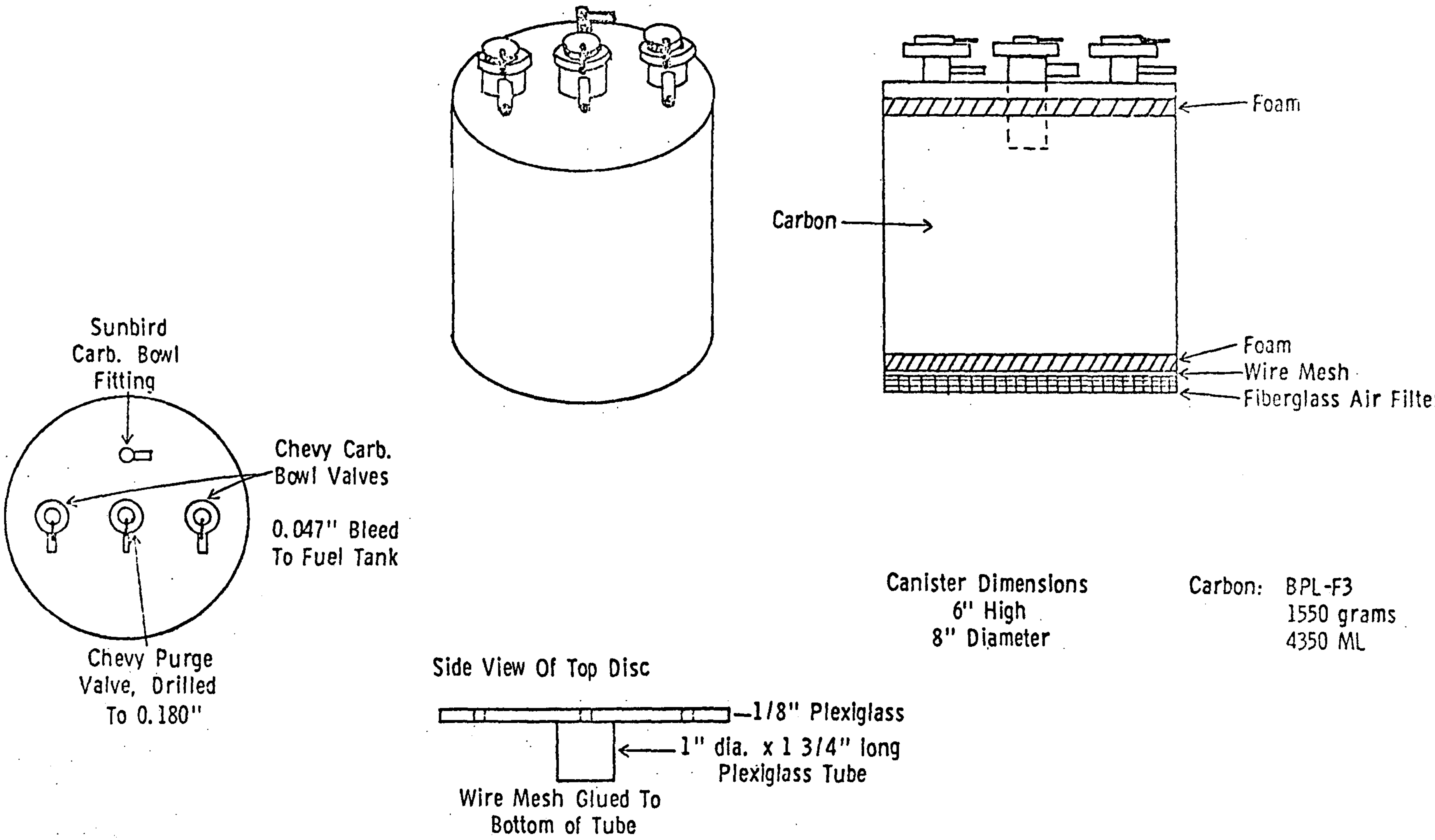
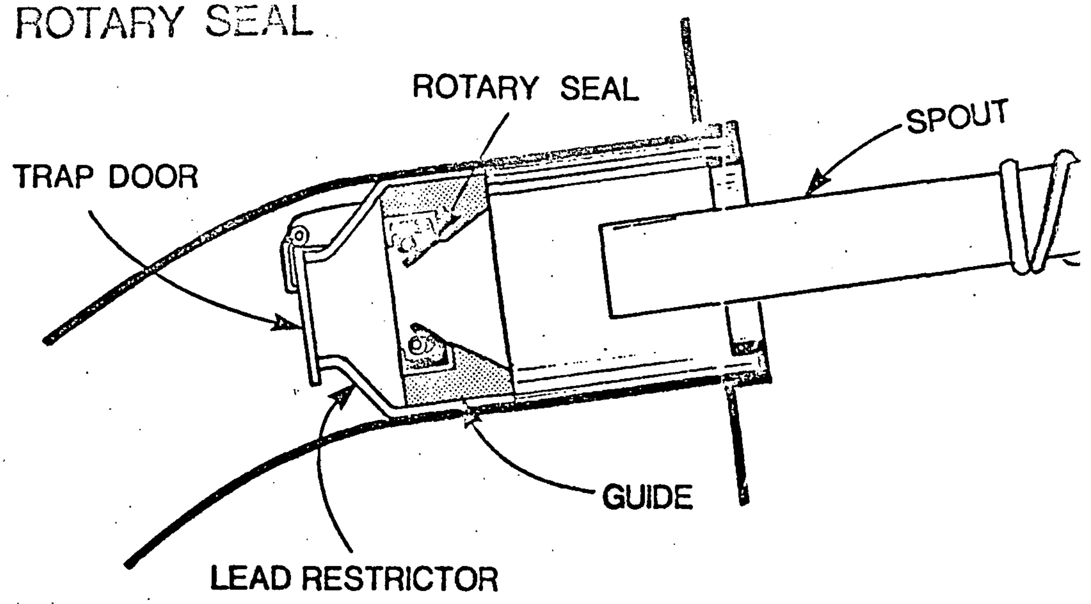


Figure A-5

FILL PIPE MODIFICATIONS
ROTARY SEAL



FILL PIPE MODIFICATIONS
ROTARY SEAL

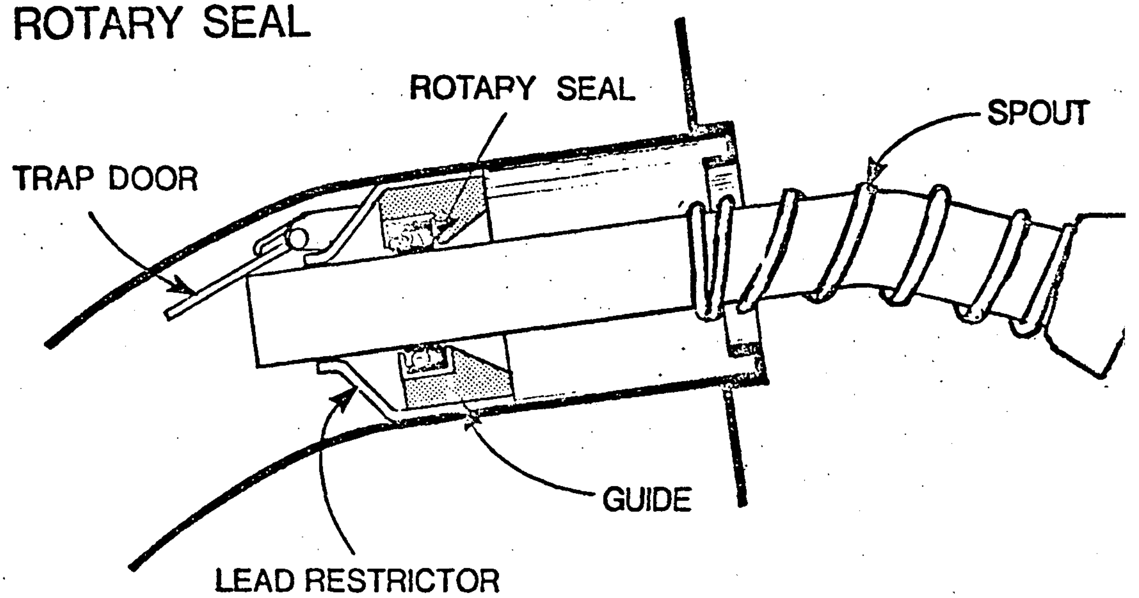
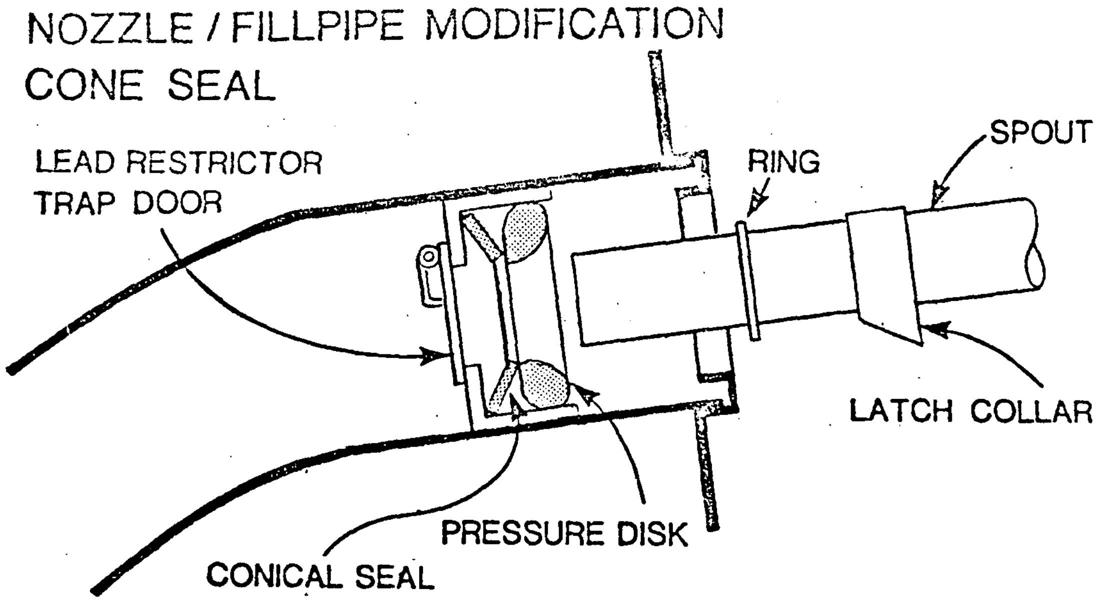
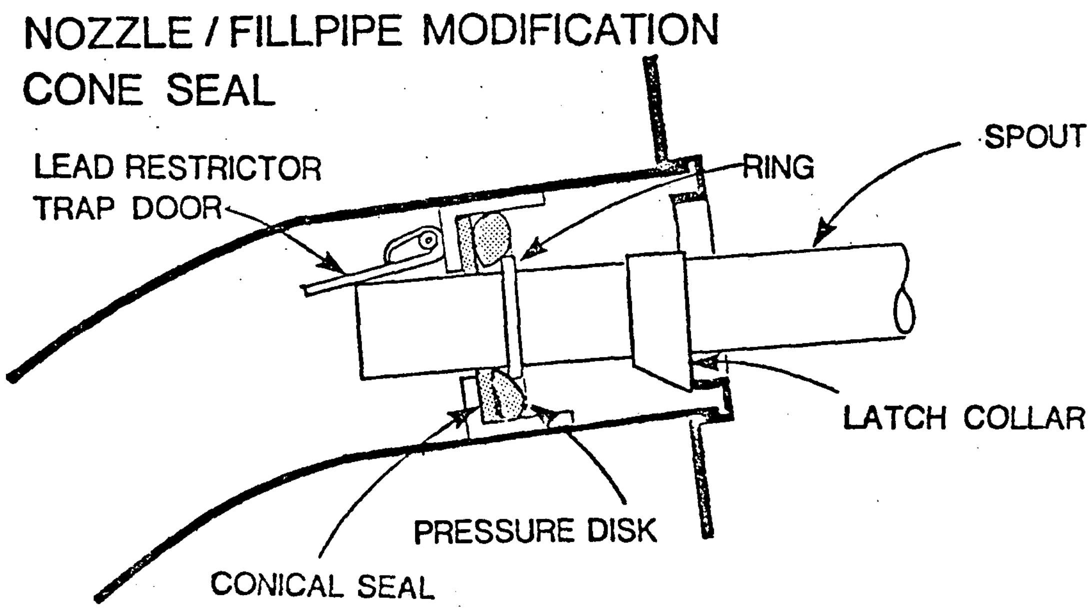


Figure A-6


NOZZLE / FILLPIPE MODIFICATION
CONE SEAL
LEAD RESTRICTOR
TRAP DOOR
RING
SPOUT
LATCH COLLAR
PRESSURE DISK
CONICAL SEAL


NOZZLE / FILLPIPE MODIFICATION
CONE SEAL
LEAD RESTRICTOR
TRAP DOOR
RING
SPOUT
LATCH COLLAR
PRESSURE DISK
CONICAL SEAL

ON BOARD VAPOR RECOVERY SYSTEM

Mustang 8Z18 & 8Z19
System A

VACUUM ACTUATED PURGE VALVE AND TANK VAPOR INLET VALVES ARE SIMILAR TO CURRENT PURGE VALVES

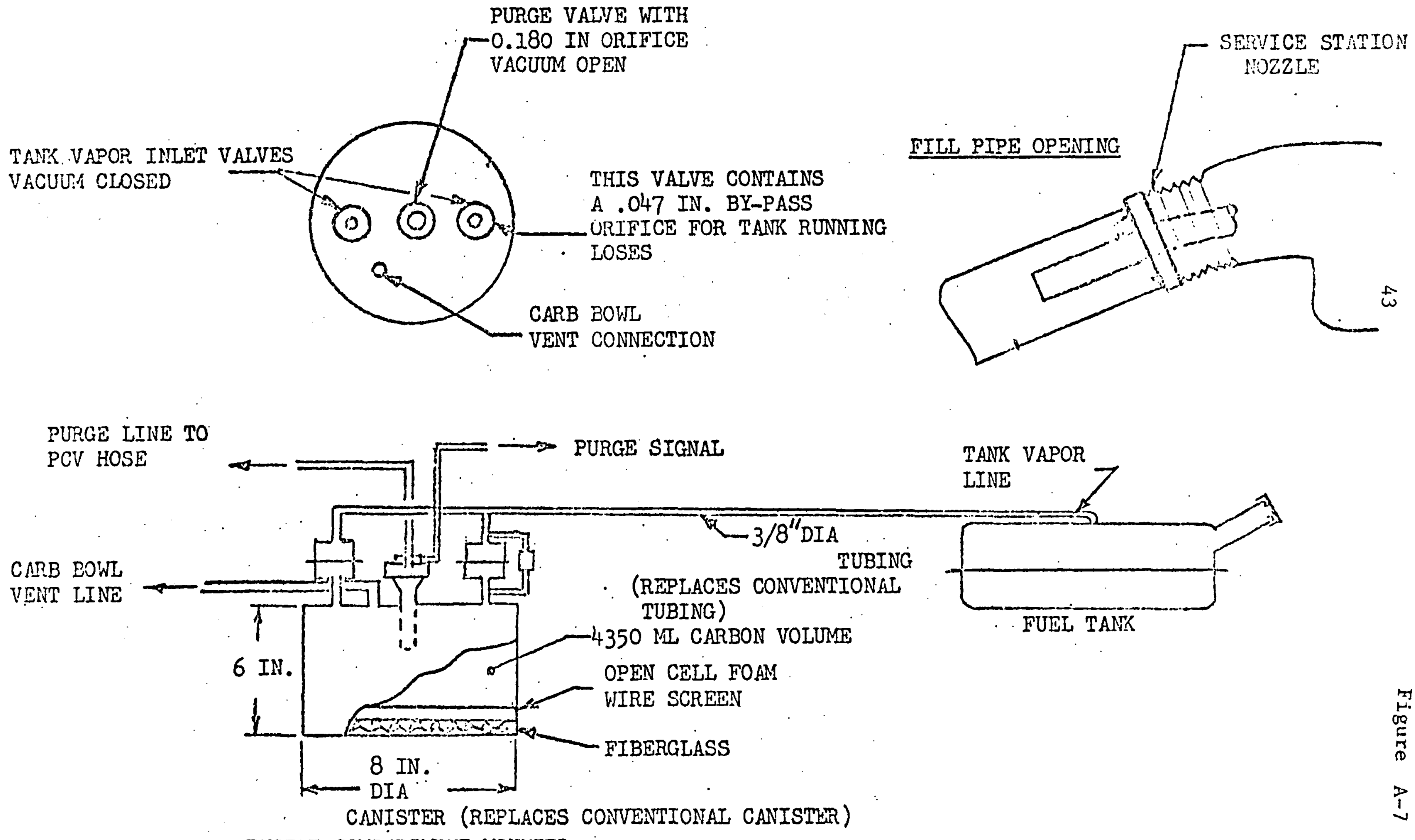


Figure A-7

ON BOARD V[illegible]ECOVERY SYSTEM
PINTO 8E79 & 8E124
System B

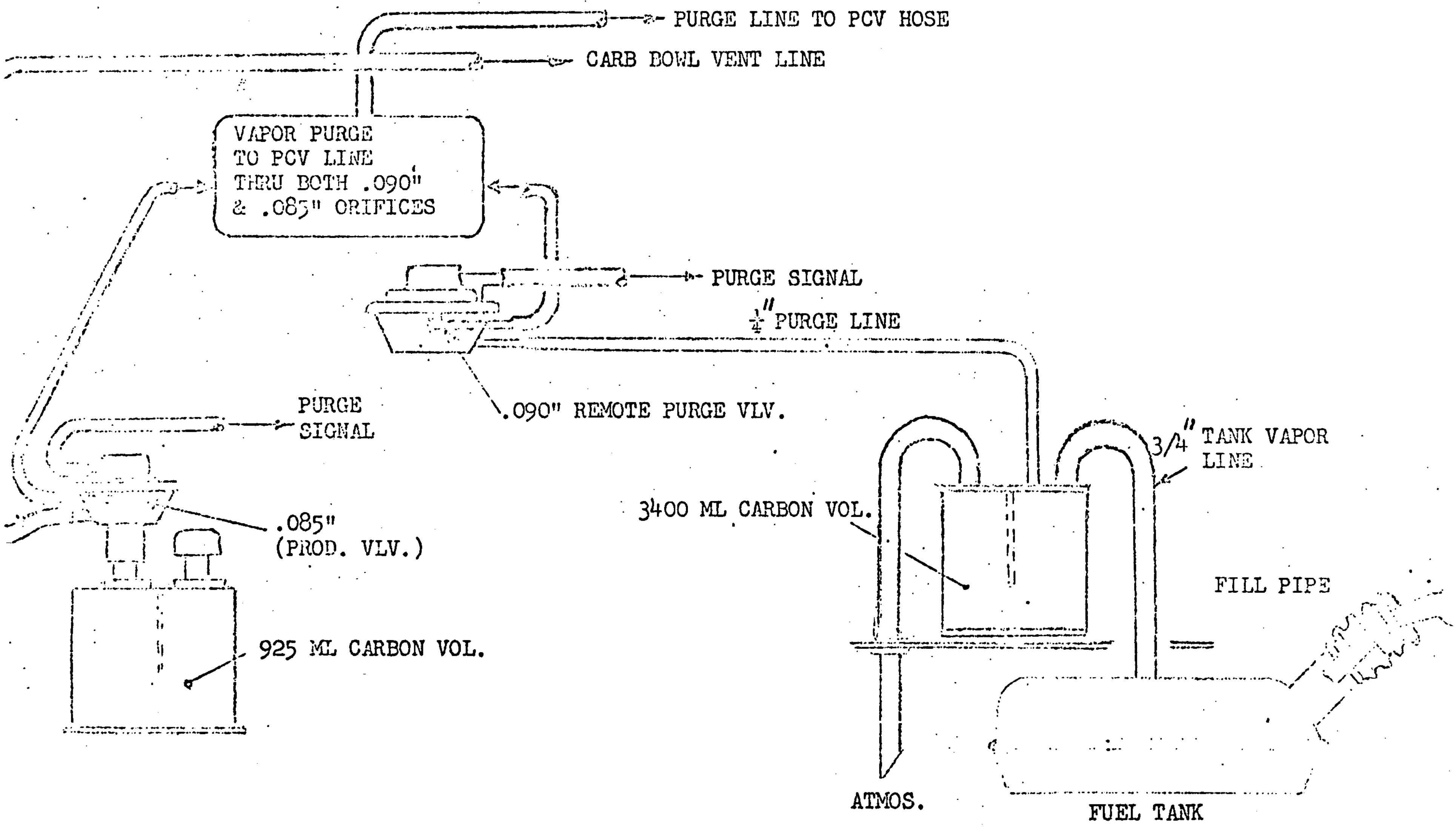
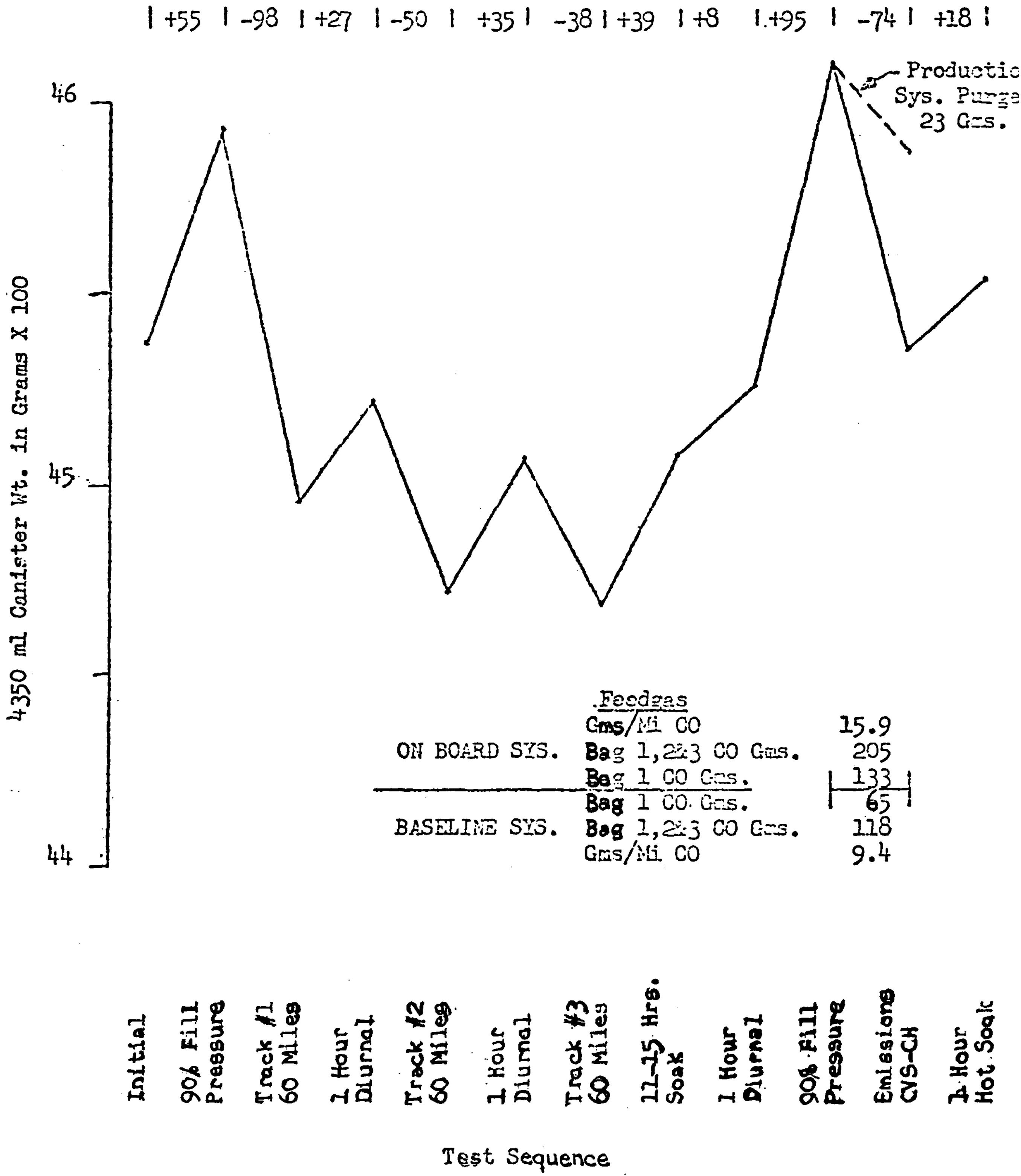


Figure A-8

Procedure #2 Set 2
Mustang 5.0L (8Z18) 1978 49 States
Date 7-17-78 Test 29

Figure A 9

——— 4350 ml Canister, Tank & Carb. Bowl w/.180" Purge Orifice
| | Grams of Vapor Purged (–), Absorbed (+)



Procedure #3 Set 2
Mustang 5.0L (8Z19) 1978 49 States
Date 7-8 & 9-78 Test #14, 15
——— 4350 ml Canister, Tank & Carb. Bowl Vapors w/.180" Purge Orifice
| |Grams of vapor, Purged (-), Absorbed (+)

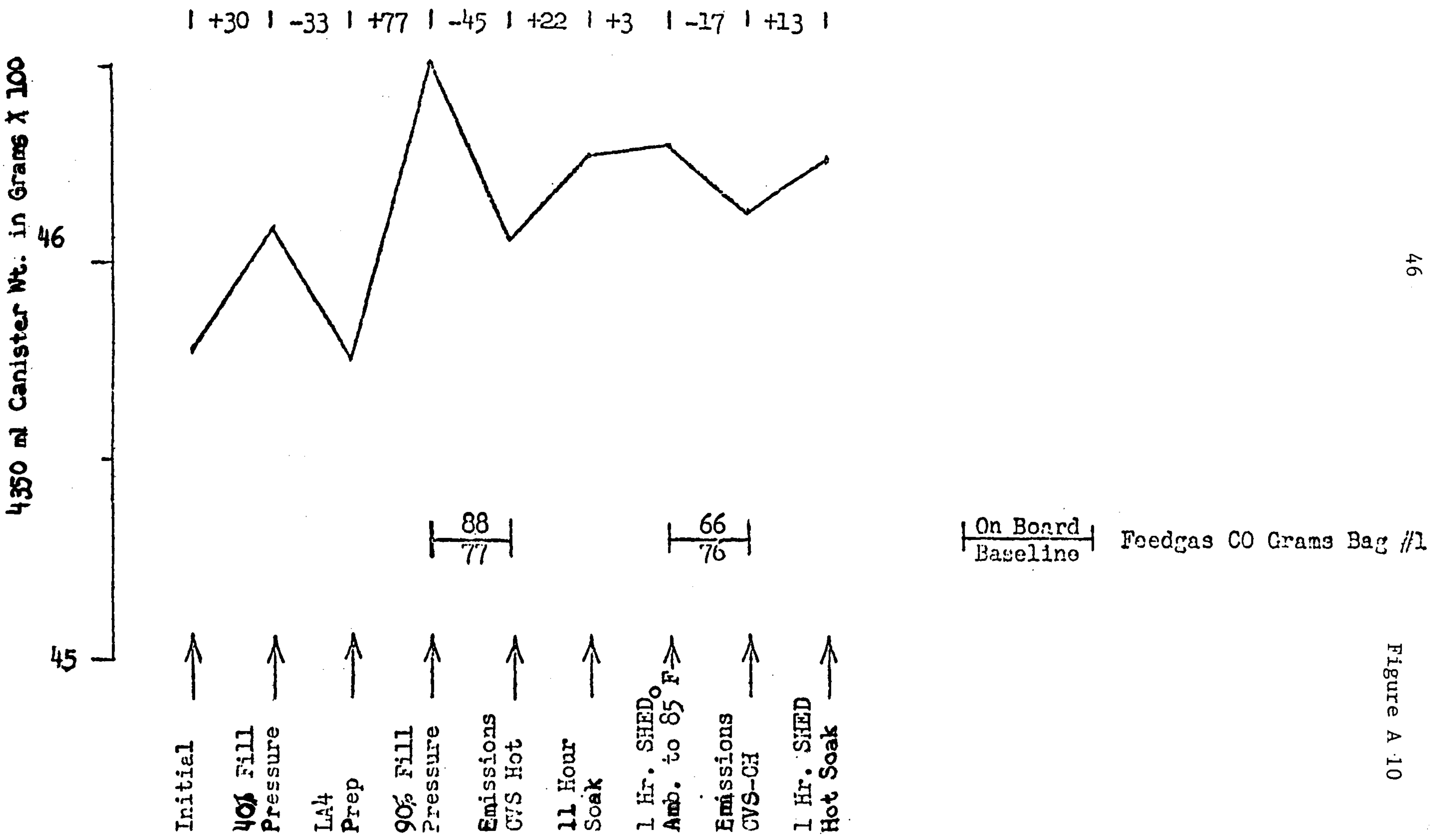


Figure A 10

Figure A-11

DISTRIBUTION OF GASOLINE PURCHASES

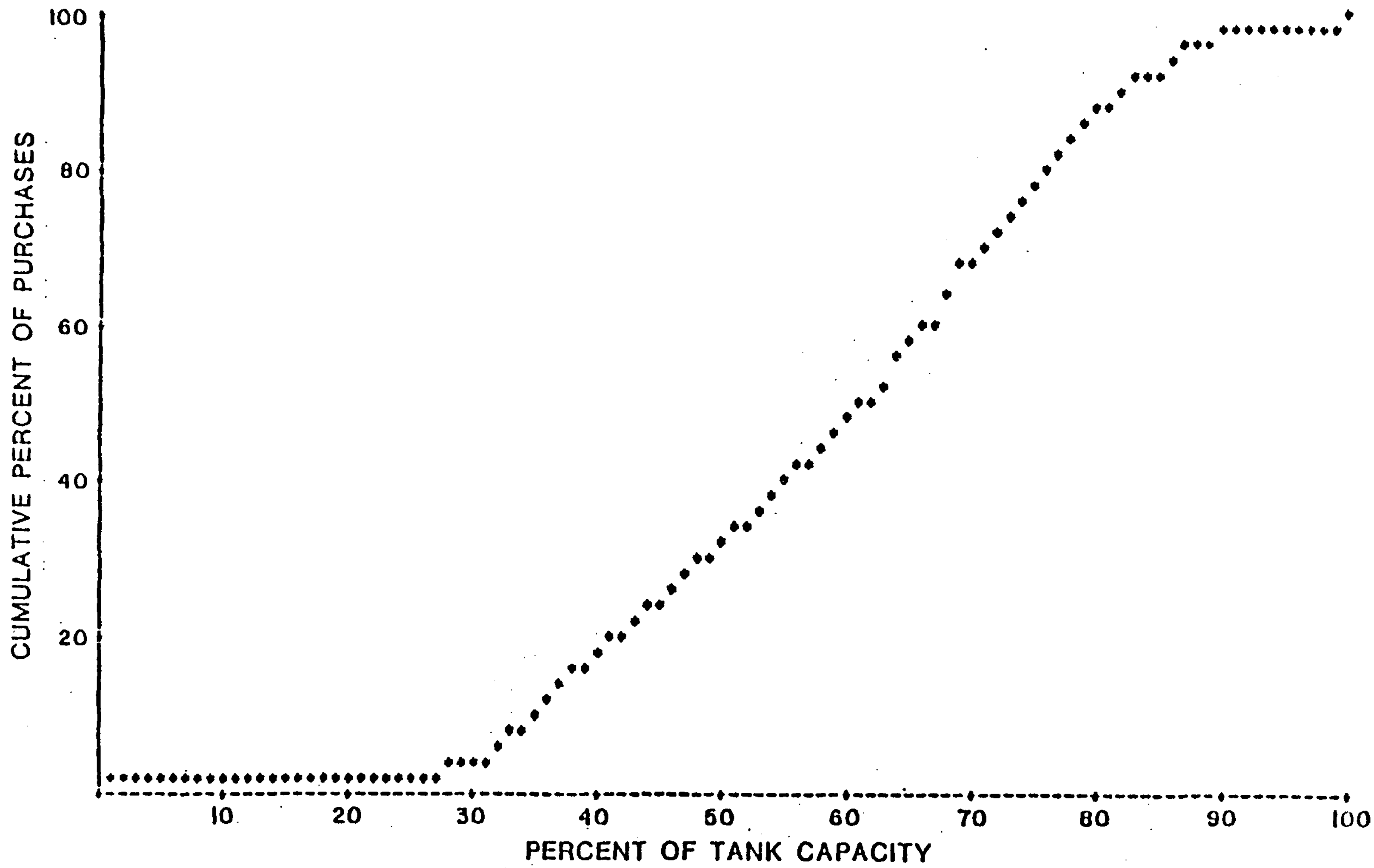


Figure A-12

REFUELING EMISSIONS CONTROLLED