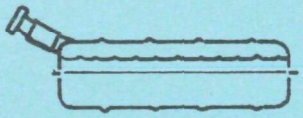

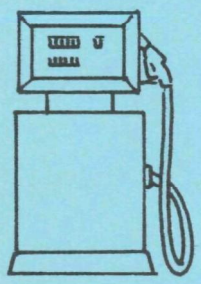

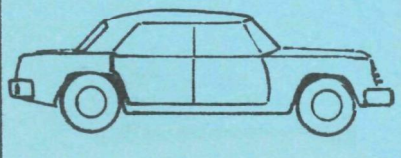

EPA-450/2-76-012

August 1976

FIELD EVALUATION OF RED JACKET VAPOR CONTROL SYSTEM

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA-450/2-76-012

FIELD EVALUATION OF RED JACKET VAPOR CONTROL SYSTEM

by

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

August 1976

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TABLE OF CONTENTS

	Page
ABSTRACT	iv
1.0 INTRODUCTION	1-1
2.0 SUMMARY AND DISCUSSION OF RESULTS	2-1
2.1 OVERALL RESULTS FOR RED JACKET SYSTEM	2-1
2.2 OVERALL RESULTS FOR VAPOR BALANCE SYSTEM	2-13
2.3 GENERAL COMMENTS ON TEST ACTIVITIES	2-25
3.0 CONTROL EQUIPMENT AND TEST INSTRUMENTATION	3-1
3.1 VAPOR CONTROL EQUIPMENT	3-1
3.2 TEST EQUIPMENT	3-4
4.0 TESTING AND ANALYTICAL PROCEDURES	4-1
4.1 PROCEDURES FOR REFUELING TESTS ON RED JACKET SYSTEM	4-1
4.2 PROCEDURES FOR REFUELING TESTS ON VAPOR BALANCE SYSTEM	4-3
4.3 AUXILIARY MEASUREMENT PROCEDURES	4-3
4.4 CALCULATION OF REFUELING TEST DATA	4-3
APPENDIX A - CALIBRATION DATA	A-1

ABSTRACT

Report describes field evaluation of a Red Jacket "Aspirator Assist" vapor control system and a comparison with results from a test of a vapor balance system. Two different measurement approaches are compared and a combination of the two methods is used to calculate hydrocarbon emissions.

Approximately 100 vehicles were used to test each system. Besides vapor measurements made during the vehicle refueling operations, vent pipe emissions were determined and added to the total emissions calculations.

Definition of Symbols and Abbreviations

EPA	Environmental Protection Agency
LRM	Leak Rate Method
gms	gram(s)
gal	gallon(s)
ΔT	Initial vehicle fuel temperature minus the average dispensed fuel temperature, °F.
ΣM_{pot}, ΣM_P	Sum of the potentially recoverable vapors from all refueling operations, grams
ΣM_{meas}, ΣM_M	Sum of the measured or captured vapors from all refueling operations, grams
ΣV_l, ΣV_L	Sum of the quantity of fuel dispensed into test vehicles, gallons
LEL	Lower Explosive Limit
HC	Hydrocarbons
Veh. No.	Vehicle number
Yr	Model year of vehicle
Gal. Disp.	Gallons of fuel dispensed into test vehicle
M/L_{meas}, M/L_M	Grams of vapor measured (captured) per gallon of fuel dispensed, one refueling
M/L_{pot}, M/L_P	Potential grams of vapor recoverable per gallon of fuel dispensed, one refueling
M_P	Total potential grams of vapor recoverable, one refueling; M/L_P x Gal. Disp.
M_M	Total grams of vapor measured (captured), one refueling
gpm	Gallons per minute
cm	Centimeter
psi	Pound per square inch
NDIR	Non-Dispersive Infrared
V/L	Ratio of volume of vapor measured (collected) to volume of liquid dispensed
°F	Degrees Fahrenheit

1.0 INTRODUCTION

The objectives of this program were to determine the performance characteristics of the Red Jacket "Aspirator Assist" Vapor Control System, perform comparative tests on a vapor balance system and to evaluate procedural modifications and alternative measurement techniques to those indicated in the proposed EPA Test Procedures for Stage II Gasoline Recovery.[1]

Vehicle refueling emission tests were conducted from February 12, through February 24, 1976. An operating service station located at 1200 East Imperial Highway, Brea, California, was provided by Union Oil Company of California for these tests. The station was originally equipped with a vapor balance control system using non-manifolded, two-inch vapor piping from the dispensing island to the underground tanks. Prior to testing, personnel from Red Jacket Division of Weil-McLain Co., installed their "Aspirator Assist" units in each dispenser and incorporated an additional shutoff valve to deactivate their system for evaluation of the vapor balance system.

Approximately 100 vehicle refueling tests were conducted on each of two control systems. Measurements were made of the vapor quantity returned to the underground tank, leak rate profiles, and underground tank vent emissions to allow calculation of overall Stage II refueling emission rates by three methods:

- Baseline Method
- Leak Rate Procedure
- Combination Method

Field work and the analysis and reporting of data were performed by Scott Environmental Technology, Inc., San Bernardino, California.

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[1] Federal Register, 40 CFR, Part 52, Thursday, October 9, 1975.

2.0 SUMMARY AND DISCUSSION OF RESULTS

2.1 OVERALL RESULTS FOR RED JACKET SYSTEM

Table 2-1 presents a summary of the emission results calculated for the Red Jacket System evaluation. As indicated, application of the Baseline Method (which is essentially the Proposed EPA Field Test Procedure for Stage II Control Systems applicable to Vapor Balance Systems)[1] resulted in the calculation of a negative emission rate at the dispensing island. The negative emission rate of -0.051 grams/gallon of dispensed fuel is due to the fact that a slightly greater amount of vapor (about 2 percent more) was collected on the non-baseline vehicles than would have been predicted from the Baseline regression curve.

Calculation of the emission rate at the dispensing island strictly via the Leak Rate Method resulted in 0.00007 grams/gallon. As indicated in the summary table, a total of 0.08 grams was emitted for the entire vehicle fleet. Only two of the 34 non-leak-tight vehicles exhibited a positive pressure at the fill neck interface during refueling, and in both cases the positive pressure lasted for a few seconds and then progressed to a negative reading. The remainder of the non-leak-tight vehicles (32 cases) exhibited negative fill neck interface pressure readings during the entire refueling operation.

The Combination Method of calculating the emission rate at the dispensing island resulted in an emission rate of 0.031 grams/gallon. This approach sums all of the individual Baseline Method emissions where the emission rate exceeds 1.0 grams/gallon with the individual Leak Rate Method results where the emission rate is less than 1.0 grams/gallon. The reasoning behind this approach is that the Baseline Method is potentially less precise for small leak rates and the Leak Rate Method is potentially less accurate for large leak rates. The bulk of emissions calculated by the Combination Method would be attributed to a 31.87 gram loss on Vehicle #1.

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(1) Federal Register, Vol. 40, No. 197, Thursday, October 9, 1975, pp. 47668 - 47685.

Table 2-1. SUMMARY OF EMISSION RESULTS
-RED JACKET SYSTEM-

Baseline Method:	
No. of Vehicles Tested	100
No. of Vehicles, data excluded	18
No. of Vehicles, data complete	82
No. of Baseline Vehicles	50
ΣM_{pot}, gms	4824.23
ΣM_{meas}, gms	4877.53
$\Sigma M_{pot} - \Sigma M_{meas}$, gms	- 53.30
ΣV_L, gallons	1035.56
Fleet Emission Rate, gms/gal (@ island)	- 0.051
Leak Rate Method:	
$\Sigma M_{emitted}$, gms (by Leak Rate Method)	0.08
ΣV_l, gallons	1035.56
Fleet Emission Rate, gms/gal (@ island)	0.00007
Combination Method:	
$\Sigma M_{emitted}$, gms	31.95
ΣV_l, gallons	1035.56
Fleet Emission Rate, gms/gal (@ island)	0.031
Vent Pipe Emissions:	
ΣM_{vented}, gms (@ vent pipe)	195.70
Total Gallons	2976.8
Vent Emission Rate, gms/gal	0.066
Fleet Averages:	
Avg. Vehicle Initial Fuel Temperature, °F.	73.6
Avg. Dispensed Fuel Temperature, °F.	65.5
Avg. ΔT, °F.	+ 8.1
Avg. V/L	0.92
Avg. M/L_{pot}, gms/gal	4.66
Avg. M/L_{meas}, gms/gal	4.71
Avg. Fill Neck Pressure, In. H_2O	- 0.31

Vent pipe emissions measured during the Red Jacket System evaluation averaged 0.066 grams/gallon. Adding the vent emission rate to the Combination Method calculated emission of 0.031 grams/gallon at the dispensing island gives an overall fleet emission rate of 0.097 grams/gallon for Stage II refueling emissions or 98 percent control efficiency.

2.1.1 Refueling Tests - Red Jacket System

One hundred vehicle refueling tests were performed in evaluation of the Red Jacket System. Table 2-2 presents the data for the individual vehicles. As indicated, data from eight refueling tests were not included in the calculations due to the fact that the nozzle had to be hand held, and data from ten other tests were excluded because ΔT could not be determined. Of the remaining 82 refueling operations, 50 were performed where a leak-tight refueling situation was determined by a zero flow indication with the Leak Rate Test System. These data were used to generate a least square fit regression equation of the form:

$$M/L_p = K + a\,\Delta T + b\,\Delta T^2 \text{ where:}$$

M/L_p = Potential recoverable vapor quantity in grams/gallon of dispensed fuel

K = Constant term

a & b = Regression coefficients

ΔT = Vehicle initial tank fuel temperature minus the average dispensed fuel temperature, °F.

One refueling, Vehicle #2, used in the calculation of the baseline regression equation exhibited an explosimeter reading of 0.5 LEL (lower explosive limit) for approximately the first five seconds of the refueling. Since the leak check performed after the refueling indicated a leak tight system, it is believed that the explosimeter reading was probably caused by a few drops of fuel spilled in the vicinity of the interface area during nozzle insertion or removal of the thermocouple which measures initial vehicle tank temperature.

Table 2-2. TEST RESULTS--INDIVIDUAL VEHICLES--RED JACKET SYSTEM

Veh. * No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
1	'74 Merc Benz	23.45	-10	0.81	86.08	3.67	117.95	5.03	31.87	0.00	(A)
2B	'73 Fiat 124	8.06	+10	1.01	42.08	5.22			0.00	0.00	(B)
3	'72 Chev. LUV		HAND HELD								(C)
4B	'74 Galaxie	17.09	+15	0.76	68.66	4.02			0.00	0.00	
5B	'73 Merc Benz	11.23	+ 2	0.98	57.00	5.08			0.00	0.00	
6B	'70 Impala	7.26	- 5	1.05	37.81	5.21			0.00	0.00	
7B	'74 Pinto	10.31	+ 8	0.97	52.46	5.09			0.00	0.00	
8B	'64 Impala	18.13	+ 8	1.06	95.15	5.25			0.00	0.00	
9B	'68 Pont. Wgn.	15.02	+20	0.72	61.85	4.12			0.00	0.00	
10	'63 Chev. P.U.	12.47	+ 9	1.06	61.21	4.91	61.00	4.90	-0.21	0.00	(D)
11	'70 Chev. P.U.	10.37	+16	0.94	50.31	4.85	43.86	4.23	-6.45	0.00	(E)
12B	'71 Vega	7.55	+18	0.76	35.28	4.67			0.00	0.00	
13	'65 Dodge Dart	13.65	+14	0.83	61.08	4.47	60.88	4.46	-0.20	0.00	
14B	'69 Ford Wgn.	16.07	+17	0.68	58.90	3.67			0.00	0.00	
15B	'70 Chev. ElCam.	13.65	+ 4	1.06	72.84	5.34			0.00	0.00	
16	'76 Honda Civic		HAND HELD								(C)
17	'65 Buick Specl.	13.08	+13	0.87	65.62	5.02	59.64	4.56	-5.98	0.00	
18B	'73 Datsun	7.67	+10	0.88	37.96	4.95			0.00	0.00	
19B	'70 Pont. Bonv.	10.46	+26	0.42	23.37	2.23			0.00	0.00	
20LT	'73 Toy. Celica		VEHICLE FUEL TEMP. NOT MEASURED								

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline car

(A) Explosimeter reading of 1.2 LEL for more than ten (10) seconds

(B) Explosimeter reading of 0.5 LEL for five (5) seconds

(C) Fill neck too small for nozzle to latch properly

(D) Explosimeter reading of 0.3 LEL for five (5) seconds

(E) Explosimeter reading of 1.2 LEL for ten (10) seconds

Table 2-2 (Continued). TEST RESULTS--INDIVIDUAL VEHICLES--RED JACKET SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
21B	'59 Ford F350	11.17	+ 9	0.91	58.26	5.22			0.00	0.00	
22	'71 Fiat		HAND HELD								(B)
23B	'68 Chev. ElCam.	13.78	+18	0.69	64.17	4.66			0.00	0.00	
24B	'69 Ford Wgn.	8.97	+ 7	0.98	49.71	5.54			0.00	0.00	
25B	'71 Galaxie	19.57	+ 5	0.98	114.31	5.84			0.00	0.00	
26	'74 Dodge Van	16.82	-10	1.23	94.77	5.63	84.60	5.03	-10.17	0.00	(C)
27B	'74 Fiat	7.19	-12	1.14	35.57	4.95			0.00	0.00	
28B	'73 Pinto Wgn.	10.04	+14	0.92	45.09	4.49			0.00	0.00	
29	'70 Chev. Cap.	14.63	+ 4	1.02	72.83	4.98	75.64	5.17	2.81	0.00	
30B	'72 Cad. Sedan	20.25	- 3	1.04	104.58	5.16			0.00	0.00	
31B	'71 Pont. LeMans	15.80	+13	0.89	73.11	4.63			0.00	0.00	
32	'68 Toronado	19.09	0	1.04	102.57	5.37	100.41	5.26	-2.16	0.00	
33B	'63 LeSabre Wgn.	15.75	+ 6	0.95	79.24	5.03			0.00	0.00	
34	'72 Fairlane	13.69	+12	0.90	72.26	5.28	63.66	4.65	-8.60	0.00	
35	'66 Mustang		VEHICLE FUEL TEMP. NOT MEASURED								
36	'70 Chev.	13.32	- 2	1.04	71.12	5.34	70.20	5.27	-0.92	0.00	
37	'74 Porsche 914		HAND HELD								(D)
38B	'73 Datsun P.U.	6.41	+ 8	0.82	26.55	4.14			0.00	0.00	
39	'74 Ford TowTrk.	15.96	+12	0.86	71.35	4.47	74.21	4.65	2.86	0.00	
40	'70 Chev. P.U.	9.67	+13	1.10	39.70	4.11	44.09	4.56	4.39	0.00	

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for more than ten (10) seconds

(B) No lip in fill neck for nozzle to catch

(C) Explosimeter reading of 0.6 LEL for thirty (30) seconds

(D) Nozzle would not enter fill neck sufficiently to unseat face seal from collar

Table 2-2 (Continued). TEST RESULTS--INDIVIDUAL VEHICLES--RED JACKET SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
41LT	'75 Dodge P.U.		VEHICLE FUEL TEMP. NOT MEASURED								
42	'65 Buick Spec.	10.91	+14	0.84	48.53	4.45	48.66	4.46	0.13	0.00	
43B	'70 Chev. Cap.	18.64	+11	1.05	82.50	4.43			0.00	0.00	
44	'69 Cutlass	16.17	+ 2	1.07	87.48	5.41	84.57	5.23	-2.91	0.00	
45B	'74 Torino	12.44	+ 7	0.84	56.74	4.56			0.00	0.00	
46LT	'73 Jag. E type		VEHICLE FUEL TEMP. NOT MEASURED								
47	'74 Corvette	9.04	- 2	0.98	40.62	4.49	47.64	5.27	7.02	0.00	(B)
48	'72 Impala	7.50	- 8	1.24	42.35	5.65	38.48	5.13	-3.87	0.00	(C)
49	'69 Riviera	7.47	-12	1.24	41.98	5.62	36.53	4.89	-5.45	0.00	
50B	'69 Impala	20.40	0	1.03	109.76	5.38			0.00	0.00	
51LT	'72 Galaxie		VEHICLE FUEL TEMP. NOT MEASURED								
52	'70 Toyota P.U.	9.18	-10	1.08	51.23	5.58	46.18	5.03	-5.05	0.01	
53B	'72 Pinto Wgn.	9.06	+ 9	0.80	37.38	4.13			0.00	0.00	
54LT	'73 Electra 225		VEHICLE FUEL TEMP. NOT MEASURED								
55B	'66 Mustang	8.88	+ 2	0.97	45.40	5.11			0.00	0.00	
56B	'72 Torino	19.10	0	1.13	113.55	5.95			0.00	0.00	
57B	'74 Volvo 164E	12.27	+ 8	0.99	65.05	5.30			0.00	0.00	
58	'74 Datsun 260Z		VEHICLE FUEL TEMP. NOT MEASURED								
59	'63 Cadillac		HAND HELD								(D)
60B	'70 Impala	15.83	+17	0.71	63.57	4.02			0.00	0.00	

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for more than ten (10) seconds

(B) Evaporative emission control canister inaccessible; not plugged for Leak Rate

(C) Explosimeter reading of 1.2 LEL for five (5) seconds

(E) Nozzle could not be inserted properly due to vehicle sheet metal interference

Table 2-2 (Continued). TEST RESULTS--INDIVIDUAL VEHICLES--RED JACKET SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
61	'66 Fairlane	14.32	+25	0.62	51.55	3.60	41.38	2.89	-10.17	0.00	
62B	'66 Chev. Capr.	8.19	0	1.03	39.25	4.79			0.00	0.00	
63B	'71 Chevelle	12.97	+21	0.61	44.70	3.45			0.00	0.00	
64B	'67 Dodge Van	19.09	+ 8	0.95	96.24	5.04			0.00	0.00	
65	'70 Chev. P.U.	9.90	+13	1.19	43.65	4.41	45.14	4.56	1.49	0.00	
66B	'73 Cadillac	19.58	+17	0.70	72.71	3.71			0.00	0.00	
67B	'71 Datsun	6.16	+12	0.84	28.88	4.69			0.00	0.00	
68	'75 BMW 2002	10.90	+23	1.22	32.93	3.02	35.32	3.24	2.39	0.00	(B)
69B	'74 Cont'l.	22.14	+20	0.70	87.18	3.94			0.00	0.00	
70	'74 Cadillac	13.60	+ 3	1.07	73.15	5.38	70.72	5.20	- 2.43	0.00	
71	'65 Chev. Wgn.	7.47	+11	1.13	30.58	4.09	35.41	4.74	4.83	0.00	
72	'74 Chev. P.U.		HAND HELD								(C)
73B	'73 Pon. Firebd.	13.26	+20	0.72	53.02	4.00			0.00	0.00	
74B	'72 Buick Cent.	17.56	+26	0.47	44.64	2.54			0.00	0.00	
75B	'69 Ford P.U.	16.28	+ 2	0.84	68.29	4.19			0.00	0.00	
76B	'71 Vega	7.65	+ 5	0.98	38.33	5.01			0.00	0.00	
77LT	'71 Fiat 124		VEHICLE FUEL TEMP. NOT MEASURED								
78B	'74 Cont'l.	13.33	+12	0.80	60.13	4.51			0.00	0.00	
79	'68 ElDorado	12.62	0	1.11	78.67	6.23	66.38	5.26	-12.29	0.00	
80LT	'75 Chev. Van		VEHICLE FUEL TEMP. NOT MEASURED								

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for more than ten (10) seconds

(B) Three-inch diameter fill neck, explosimeter reading of 0.6 LEL for twenty (20) seconds

(C) Sharp bend in fill neck prevented sufficient nozzle insertion to latch

Table 2-2 (Continued). TEST RESULTS--INDIVIDUAL VEHICLES--RED JACKET SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
81B	'73 Ford Trk.	17.95	+ 5	1.02	102.84	5.73			0.00	0.00	
82B	'73 Datsun P.U.	9.79	- 2	1.07	58.65	5.99			0.00	0.00	
83B	'72 Malibu	9.73	+ 7	0.92	47.66	4.90			0.00	0.00	
84	'72 Chev. Vega		HAND HELD								(B)
85B	'73 Cad. Eldo.	7.59	+ 3	0.98	36.02	4.75			0.00	0.00	
86	'69 Buick Riv.	7.59	+ 9	1.01	36.65	4.83	37.19	4.90	0.54	0.00	
87	'74 Dodge Van	17.59	+ 6	1.02	94.50	5.37	89.36	5.08	-5.14	0.00	(C)
88B	'67 Merc. Cgr.	9.77	- 1	1.01	50.11	5.13			0.00	0.00	
89B	'74 Monte Carlo	15.74	+21	0.68	57.91	3.68			0.00	0.00	
90B	'67 Mustang	7.59	+ 6	0.93	35.76	4.71			0.00	0.00	
91B	'67 Mustang	7.59	+28	0.47	17.92	2.36			0.00	0.00	
92	'66 Porsch 912		HAND HELD								
93	'66 Olds 98	13.03	+11	0.89	63.49	4.87	61.76	4.74	-1.73	0.07	
94	'66 Malibu	7.60	+14	0.92	38.98	5.13	33.90	4.46	-5.08	0.00	
95B	'70 Chev.	11.35	+23	0.55	35.56	3.13			0.00	0.00	
96	'70 Plym.	8.86	+ 9	0.96	47.26	5.33	43.41	4.90	-3.85	0.00	
97	'69 Olds Cut.	14.52	+13	0.96	76.38	5.26	66.21	4.56	-10.17	0.00	
98	'67 Olds Delta	12.14	+12	1.04	65.96	5.43	56.45	4.65	-9.51	0.00	
99	'69 Corvette	7.59	+ 2	1.26	38.99	5.14	39.70	5.23	0.71	0.00	
100LT	'70 Ford P.U.		VEHICLE FUEL TEMP. NOT MEASURED								

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for more than ten (10) seconds

(B) Vehicle rear bumper interference prevented sufficient nozzle insertion to latch

(C) Explosimeter reading of 0.6 LEL for ten (10) seconds

Figure 2-1 presents a graph of baseline refueling data for the evaluation of the Red Jacket System and the regression line computed.

Explosimeter measurements were made during all refueling tests using a Bacharach Model GP #500-011 Combustible Gas Indicator which is scaled 0 - 1.2 times the lower explosive limit (LEL) of a combustible gas. Assuming that gasoline vapors have an LEL of 1.5 volume percent, explosimeter readings of less than full scale can be multiplied by 1.5 to give the approximate percent volume concentration of gasoline vapors detected. The explosimeter probe tip was held approximately one centimeter from the interface of the fill neck and the nozzle face seal while circling the periphery of the connection. Table 2-3 presents a summary of calculated vapor losses as a function of explosimeter readings for the Red Jacket System tests.

All of the refueling tests commenced using the middle flow setting on the dispensing nozzle, approximately 6.1 gpm. Spitbacks were observed on vehicles #3 and #59, both of which were manually refueled (not refueled hands off) due to unusual fill neck characteristics which prevented normal latching of the nozzle.

2.1.2 Vent Pipe Emissions - Red Jacket System

Vent pipe emissions were monitored during the four test days concurrently with the refueling tests and during one overnight period. The overnight period ran from approximately 5 p.m. on February 17, 1976, to 8:30 a.m. on February 18, 1976. Table 2-4 shows the daily and overall calculated vent emissions. As indicated in the table, vent pipe emission rates were less than 0.10 grams/gallon of dispensed fuel except for the last test day. The largest emission rates were noted on February 12 and 20, on test days which immediately followed a bulk delivery. Previous experience indicated that during the 24-hour period following a bulk delivery a greater tendency to outbreath has been observed when the delivered fuel is significantly lower in temperature than the underground tank temperature. This is believed to be due to a net heat flow into the recently filled tank from the surrounding earth.

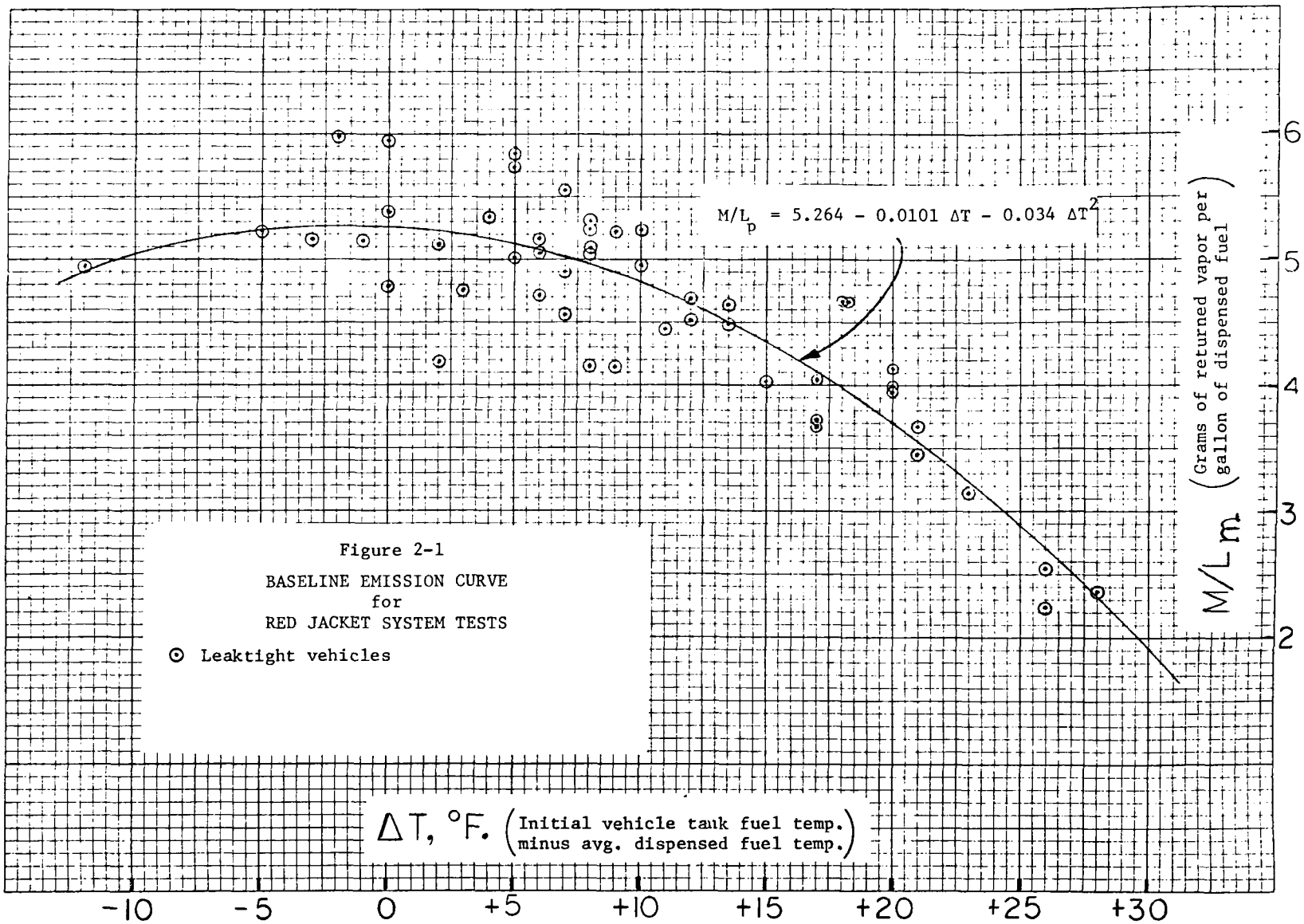


Figure 2-1

BASELINE EMISSION CURVE
for
RED JACKET SYSTEM TESTS

Table 2-3. CALCULATED VAPOR LOSSES BASED ON EXPLOSIMETER READINGS
-RED JACKET SYSTEM-

Veh. No.	Explosimeter Reading LEL	Explosimeter Reading Approx. Duration	Gal. Disp.	Vapor Loss, grams (A)	Vapor Loss, grams (B)
1	1.2	4 min.	23.45	52.26	52.26
2	0.5	5 sec.	8.06	0.00	0.00
10	0.3	5 sec.	12.47	0.00	0.00
11	1.2	10 sec.	10.37	27.05	2.70
26	0.6	30 sec.	16.82	26.24	4.83
48	1.2	5 sec.	7.50	0.00	0.00
68	0.6	20 sec.	10.90	9.62	1.82
87	0.6	10 sec.	17.59	32.12	1.90
				147.29	63.51

(A) Losses calculated using Table 8-1 of Proposed EPA Test Procedure for Stage II Operations at Vacuum Assisted Systems

(B) Losses shown in column (A) multiplied by percent of total dispensing time the explosimeter reading was observed

Table 2-4. SUMMARY OF VENT PIPE EMISSIONS
-RED JACKET SYSTEM-

Date	Total ft^3 Vented	Total Grams Vented	Total Gal. Disp.	Avg. Density gms/ft^3	Venting Rate gms/gal disp.	Notes
2-12	5.225	46.07	494.5	8.82	0.093	(A)
2-17	5.700	6.74	645.0	1.18	0.010	(B)
2-17	2.094	0.63	733.6	0.30	0.001	(C)
2-18	4.955	0.71	674.5	0.14	0.001	(D)
2-20	6.493	141.55	429.2	21.80	0.335	(A)
	24.467	195.70	2976.8*	8.00	0.066	

*Of the total 2976.8 gallons dispensed for these tests, 805.3 gallons (27%) were dispensed at the self-service islands and 2171.5 gallons (73%) were dispensed at the full-service islands.

(A) Bulk delivery within 24 hours prior to measurement period

(B) 7.60 grams weight increase on carbon canisters

(C) Emissions monitored overnight

(D) 2.30 grams weight increase on carbon canisters

During two of the test days, February 17 and 18, activated carbon canisters were mounted in series with the vent pipe monitoring system to capture the vented hydrocarbons. A comparison of the calculated emissions using volume and HC concentration measurements with the weight increase on the canisters indicated that the canister measurement method was approximately 0.9 and 1.6 grams higher for the two test dates respectively. Although the two techniques did not compare well on a percentage basis, the difference of 1.6 grams for an entire day (the worst case) amounts to only 0.002 grams/gallon difference for the venting rate.

On the first test day, February 12, unusual venting was observed at approximately 5 p.m., shortly after a refueling test. It was subsequently determined that the valve at the Dresser Meter inlet was not closed when the vapor hose was flushed with compressed air (see Section 4.1 for discussion of backflushing procedure). Approximately 1.25 cubic feet of air was forced into the underground tank vapor space which accounted for the unusual venting. The pressure was relieved on the underground tank, and 0.746 cubic feet of vapor passing the vent monitoring system was excluded from the calculation of vent emissions for that test period. Including this abnormal venting would result in an additional 0.73 grams vented yielding a venting rate of 0.095 grams/gallon for February 12. The overall venting rate for the entire test period would remain 0.066 grams/gallon.

2.2 OVERALL RESULTS FOR VAPOR BALANCE SYSTEM

Table 2-5 presents a summary of emission results calculated for the vapor balance system evaluation. As indicated, the Baseline Method calculations result in an emission rate of 0.258 grams/gallon at the dispensing island, the Leak Rate Method calculations indicate an emission rate of 0.100 grams/gallon at the island, and the Combination Method indicates 0.244 grams/gallon at the island. The vent pipe emission rate calculated was 0.035 grams/gallon. Summing the vent pipe emission rate and the Combination Method results gives an overall emission rate of 0.279 grams/gallon for Stage II refueling emissions or 94.2 percent control efficiency.

Table 2-5. SUMMARY OF EMISSION RESULTS
VAPOR BALANCE SYSTEM

Baseline Method:	
No. of Vehicles Tested	98
No. of Vehicles, data excluded	14
No. of Vehicles, data complete	84
No. of Baseline Vehicles	43
ΣM_{pot}, gms	5239.62
ΣM_{meas}, gms	4959.88
$\Sigma M_{pot} - \Sigma M_{meas}$, gms	279.74
ΣV_l, gallons	1084.20
Fleet Emission Rate, gms/gal (@ island)	0.258
Leak Rate Method:	
$\Sigma M_{emitted}$, gms	108.88
ΣV_l, gallons	1084.20
Fleet Emission Rate, gms/gal (@ island)	0.100
Combination Method:	
$\Sigma M_{emitted}$, gms	265.05
ΣV_l, gallons	1084.20
Fleet Emission Rate, gms/gal (@ island)	0.244
Vent Pipe Emissions:	
ΣM_{vented}, gms	124.64
Total gallons	3539.5
Vent Emission Rate, gms/gal (@ island)	0.035
Fleet Averages:	
Avg. Vehicle Initial Fuel Temperature, °F.	71.4
Avg. Dispensed Fuel Temperature, °F.	64.8
Avg. ΔT, °F.	+ 6.6
Avg. V/L	0.87
Avg. M/L_{pot}, gms/gal	4.83
Avg. M/L_{meas}, gms/gal	4.57
Avg. Fill Neck Pressure, In. H_2O	+ 0.08

2.2.1 Refueling Tests - Vapor Balance System

Of the 98 vehicles passing through the test lane, data from 14 vehicles were excluded from the overall fleet calculations. Four of these 14 vehicles required that the nozzle be hand held during refueling, and one vehicle required less than five gallons of fuel. Additionally, data from nine other tests were excluded because ΔT could not be determined. A total of 43 of the 84 remaining tests exhibited a leak-tight condition and were subsequently used to generate the Baseline regression equation.

One other case (Vehicle #14) indicated a negligible leak rate of less than 0.007 cfm. For this vehicle the leak appeared to be at the junction of the fill neck and the tank. After the refueling operation liquid fuel was observed leaking under the vehicle, and it is believed that the fuel level in the fill neck was above the leak so that the Leak Rate Method was indicating a fuel leak rate rather than a vapor leak rate. This vehicle was considered a nonleaker in the calculations presented in the Summary Table 2-5. If Vehicle #14 is considered a leaker, the Baseline Method calculations would result in a Fleet Emission Rate (@ island) of 0.265 grams/gallon, and the Leak Rate Method and Combination Method results would remain unchanged due to the fact that the Leak Rate Method indicated a negligible leak and the Combination Method would not count this size leak (0.99 grams/gallon by the Baseline Method) as a large leak.

Table 2-6 lists the individual vehicle refueling test results, and Figure 2-2 presents a graph of baseline emission rates as a function of ΔT for the leaktight refueling cases.

Explosimeter measurements were made during all refueling tests. Table 2-7 presents a summary of the explosimeter data. Nineteen cases were observed, two of which were readings of approximately five seconds duration (on Vehicles 58 and 80). These explosimeter responses are believed to be caused by the presence of a few drops of fuel spilled in the proximity of the interface during nozzle insertion or during removal of the temperature probe. The Leak Rate Test performed on Vehicle #18, a 1969 Cadillac, yielded a very erratic pressure trace at 0.5 and 0.3 inches H_2O and no leakage at 0.1 inches H_2O. This is believed

Table 2-6. TEST RESULTS FOR INDIVIDUAL VEHICLES--VAPOR BALANCE SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
1B	'74 Pinto Wgn.	10.58	+12	0.73	37.84	3.58			0.00	0.00	
2B	'71 Olds 88	17.28	- 1	1.07	88.71	5.13			0.00	0.00	
3	'69 Chevelle	14.29	+ 3	0.91	64.63	4.52	75.59	5.29	10.96	8.44	
4B	'68 Ford P.U.	9.86	- 6	1.10	51.88	5.26			0.00	0.00	
5	'67 Plym. Belv.		VEHICLE FUEL TEMP. NOT MEASURED								
6	'74 Toy. Celica	11.09	+ 1	0.83	44.22	3.99	60.11	5.42	15.89	10.98	(A)
7B	'67 Chev. P.U.	7.47	+ 1	1.21	45.96	6.15			0.00	0.00	
8B	'71 Ford P.U.	17.65	+ 1	1.17	107.16	6.07			0.00	0.00	
9B	'71 Ford P.U.	18.89	+ 4	1.02	99.83	5.28			0.00	0.00	
10	'64 Mustang	17.04	+13	0.86	77.14	4.53	73.27	4.30	-3.87	0.00	(A)
11B	'74 Cont'l.	15.68	+ 9	0.85	72.74	4.64			0.00	0.00	
12	'74 Merc Benz	13.51	- 1	0.99	64.82	4.80	74.71	5.53	9.89	0.94	(A)
13B	'73 Merc Broughm	18.30	+11	0.86	84.32	4.61			0.00	0.00	
14LT	'64 Corvair	7.74	- 4	0.98	36.10	4.66			0.00	0.00	(C)
15	'73 Gran Torino	17.76	+11	0.87	83.38	4.69	80.63	4.54	-2.75	0.22	
16LT	'73 Maverick		VEHICLE FUEL TEMP. NOT MEASURED								
17	'70 Valiant	11.02	+ 5	0.91	52.99	4.81	56.53	5.13	3.54	0.00	
18	'69 Cadillac	20.33	+12	0.39	42.96	2.11	89.86	4.42	46.90	0.00	(B)
19	'71 Torino	15.40	+ 3	1.08	84.35	5.48	81.47	5.29	-2.88	0.00	(A)
20	'70 Olds Cutlass		VEHICLE FUEL TEMP. NOT MEASURED								

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for entire fill

(B) Explosimeter reading of 0.1 LEL for forty (40) seconds

(C) Presence of fuel dripping under car after fill indicated a leak at the base of fill neck; Leak test performed after refueling operation indicated negligible leakage (<0.007 cfm).

Table 2-6 (Continued). TEST RESULTS FOR INDIVIDUAL VEHICLES--VAPOR BALANCE SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
21	'74 MG Midget	7.10	+ 2	0.70	25.[illegible]3	3.57	37.99	5.35	12.66	6.81	(A)
22	'68 VW Sedan	9.09	- 1	1.04	4[illegible].12	5.40	50.27	5.53	1.15	0.00	
23	'69 Cont'l.	19.84	- 1	1.03	106.25	5.36	109.72	5.53	3.47	3.84	
24B	'71 Chevelle	9.90	+ 6	0.85	46.06	4.65			0.00	0.00	
25	'69 Plym. GTX	15.62	+10	0.81	71.98	4.61	72.79	4.66	0.81	0.00	
26	'72 Fiat 128		HAND HELD								(B)
27B	'71 Chevelle	9.31	+14	0.75	38.05	4.09			0.00	0.00	
28B	'73 Vega S/W	7.61	+ 7	0.89	35.64	4.68			0.00	0.00	
29	'72 Coronet	11.30	- 1	0.95	51.82	4.58	62.49	5.53	10.67	1.66	
30	'71 Satellite	16.01	+10	0.77	66.70	4.17	74.61	4.66	7.91	11.14	
31B	'71 Chevy P.U.	13.51	- 5	1.10	74.76	5.53			0.00	0.00	
32	'73 Merc Benz		HAND HELD								(C)
33B	'73 Olds 88	22.12	+ 2	1.00	112.00	5.60			0.00	0.00	
34B	'71 LTD	18.15	- 5	1.16	117.93	6.50			0.00	0.00	
35	'68 Chevelle	10.67	+ 5	0.79	48.25	4.52	54.74	5.13	6.49	2.37	
36	'70 Chevelle	7.86	+ 1	0.92	38.30	4.87	42.60	5.42	4.30	1.45	(A)
37B	'74 Dodge P.U.	17.23	+10	0.71	69.03	4.01			0.00	0.00	
38B	'71 Ford Wgn.	13.78	+12	0.69	51.31	3.72			0.00	0.00	
39B	'71 Pinto	8.79	+17	0.85	36.02	4.10			0.00	0.00	
40B	'74 Ford P.U.	8.97	+ 1	0.93	42.02	4.68			0.00	0.00	

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for entire fill

(B) Nozzle hand held; no lip for collar to catch

(C) Nozzle hand held; body sheet metal interference

Table 2-6 (Continued). TEST RESULTS FOR INDIVIDUAL VEHICLES--VAPOR BALANCE SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
41	'74 Ford P.U.		VEHICLE FUEL TEMP. NOT MEASURED								
42B	'73 Electra	17.07	+25	0.46	43.60	2.55			0.00	0.00	
43	'69 Fiat 124		SEE NOTES								(C)
44	'71 Chevelle	15.87	+ 6	0.87	74.00	4.66	80.14	5.05	6.14	2.61	
45	'69 Olds 88	15.08	+ 3	0.99	79.60	5.28	79.77	5.29	0.17	0.14	
46B	'67 Cougar	14.47	- 2	1.10	84.90	5.87			0.00	0.00	
47	Ford P.U.	14.95	+ 9	0.82	70.13	4.69	71.16	4.76	1.03	0.00	
48B	'72 Skylark	14.20	+12	0.78	63.66	4.48			0.00	0.00	
49	'73 Dodge Van	16.67	+10	0.64	60.54	3.63	77.68	4.66	17.14	4.78	(A)
50B	'74 Cont'l.	14.07	+13	0.73	61.56	4.38			0.00	0.00	
51	'63 GMC P.U.	14.80	- 7	0.99	80.23	5.42	84.66	5.72	4.43	2.25	(A)
52	'69 Cutlass	12.53	- 2	0.97	65.34	5.21	69.92	5.58	4.58	0.00	
53LT	'69 Merc. Wgn.		VEHICLE FUEL TEMP. NOT MEASURED								
54B	'73 Pinto	8.85	+ 8	0.91	44.31	5.01			0.00	0.00	
55	'69 Charger	10.26	- 3	0.97	52.04	5.07	57.66	5.62	5.62	.74	
56	'70 El Camino		VEHICLE FUEL TEMP. NOT MEASURED								
57B	'72 Chev. P.U.	17.66	- 2	1.14	104.95	5.94			0.00	0.00	
58	'68 El Dorado	10.32	+ 6	0.83	46.94	4.55	52.12	5.05	5.18	3.28	(D)
59	'55 Belair		SEE NOTES								(E)
60B	'71 Olds 88	17.88	+ 7	0.93	89.89	5.03			0.00	0.00	

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for entire fill

(B) Explosimeter reading of 0.4 LEL for fifteen (15) seconds

(C) No temperature obtained

(D) Explosimeter reading of 1.2 LEL for five (5) seconds

(E) Data not used; too few gallons dispensed

Table 2-6 (Continued). TEST RESULTS FOR INDIVIDUAL VEHICLES--VAPOR BALANCE SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
61	'65 Rambler	7.01	+14	0.77	31.45	4.49	29.23	4.17	-2.22	2.67	(A)
62LT	'60 Thunderbird		VEHICLE FUEL TEMP. NOT MEASURED								
63B	'72 Olds 98	13.26	+22	0.59	45.44	3.43			0.00	0.00	
64	'69 Opel Kadett	6.80	+12	0.88	29.80	4.38	30.06	4.42	0.26	4.30	(A)
65	'72 Merc Benz		HAND HELD								(B)
66	'67 Dodge Polara	15.49	+11	0.85	70.82	4.57	70.32	4.54	-0.50	0.00	
67	'71 Chevelle	16.02	+20	0.68	61.67	3.85	52.39	3.27	-9.28	0.38	
68B	'68 Dodge P.U.	10.99	+14	0.82	50.38	4.58			0.00	0.00	
69B	'68 Dodge P.U.	10.26	+13	1.34	52.48	5.12			0.00	0.00	
70B	'74 Torino	16.31	+ 8	0.89	84.14	5.16			0.00	0.00	
71B	'70 Fairlane	10.78	+18	0.63	41.52	3.85			0.00	0.00	
72B	'70 Datsun 1600	9.54	+13	0.76	41.08	4.31			0.00	0.00	
73	'74 Pinto	11.88	+18	0.77	49.94	4.20	42.77	3.60	-7.17	0.94	(A)
74LT	'74 AMC Matador		VEHICLE FUEL TEMP. NOT MEASURED								(C)
75	'69 Chry. Newpt.	9.77	+ 6	0.92	48.59	4.75	49.34	5.05	0.75	0.00	
76	'66 Malibu	7.59	+ 4	0.97	39.79	5.24	39.62	5.22	-0.17	0.19	
77	'75 BMW	7.59	- 2	0.91	32.17	4.24	42.35	5.58	10.18	0.00	(A)
78B	'65 Volvo 1225	10.38	- 5	1.10	55.45	5.34			0.00	0.00	
79	'73 Toy. Celica	9.42	- 7	0.91	41.67	4.42	53.88	5.72	12.21	3.63	(A)
80B	'74 Cont'l.	11.32	+ 9	0.76	48.73	4.30			0.00	0.00	(D)

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for entire fill

(B) Nozzle hand held; body sheet metal interference

(C) Explosimeter reading of 0.3 LEL for five (5) seconds

(D) Explosimeter reading of 0.2 LEL for five (5) seconds

Table 2-6 (Continued). TEST RESULTS FOR INDIVIDUAL VEHICLES--VAPOR BALANCE SYSTEM

Veh.* No.	Description	Gal. Disp.	ΔT	V/L	M_M	M/L_M	M_P	M/L_P	Indic. Loss B'Line	Indic. Loss LRM	Notes
81	'68 Ford P.U.	17.04	+ 1	0.82	70.06	4.11	92.36	5.42	22.30	20.53	(A)
82B	'69 Ford P.U.	15.36	+ 4	0.96	75.23	4.90			0.00	0.00	
83B	'67 Ford	10.62	+15	0.74	43.17	4.06			0.00	0.00	
84B	'69 T-Bird	16.74	+ 5	0.93	83.77	5.00			0.00	0.00	
85B	'71 Cont'l.	19.26	+22	0.63	65.86	3.42			0.00	0.00	
86	'68 Riviera	7.59	+ 7	0.88	32.34	4.26	37.65	4.96	5.31	9.49	
87	'70 Opel GT		VEHICLE FUEL TEMP. NOT MEASURED								(C)
88	'62 Electra	9.94	+ 1	0.72	37.43	3.76	53.87	5.42	16.44	1.79	(A)
89B	'73 Cont'l.	17.39	+21	0.58	56.72	3.26			0.00	0.00	
90B	'72 Vega	7.66	+14	0.88	35.30	4.61			0.00	0.00	
91	'70 Datsun P.U.	7.97	+ 4	0.78	32.02	4.02	41.60	5.22	9.58	1.94	(A)
92B	'69 LTD Wgn.	18.71	+ 2	1.07	104.65	5.59			0.00	0.00	
93B	'70 Firebird	14.02	+ 5	0.99	72.53	5.17			0.00	0.00	
94B	'71 Olds Wgn.	7.59	+25	0.20	8.07	1.06			0.00	0.00	
95	'74 Dodge Ambl.	15.17	+ 7	0.40	31.23	2.06	75.24	4.96	44.01	0.58	(B)
96	'70 Olds Wgn.	12.14	+ 2	0.97	60.81	5.01	65.07	5.36	4.26	0.44	
97B	'71 Chevelle	9.91	+ 2	0.96	49.77	5.02			0.00	0.00	
98	'68 El Dorado	7.25	+ 2	0.94	34.51	4.76	38.86	5.36	4.35	0.35	

* B = Baseline Vehicle; LT = Leak Tight Vehicle not used as Baseline Car

(A) Explosimeter reading of 1.2 LEL for entire fill

(B) Evaporative Emission Control Canister not accessible for plugging during LRM

(C) Dispensing stopped short of fill due to fuel leakage at junction of fill neck and tank

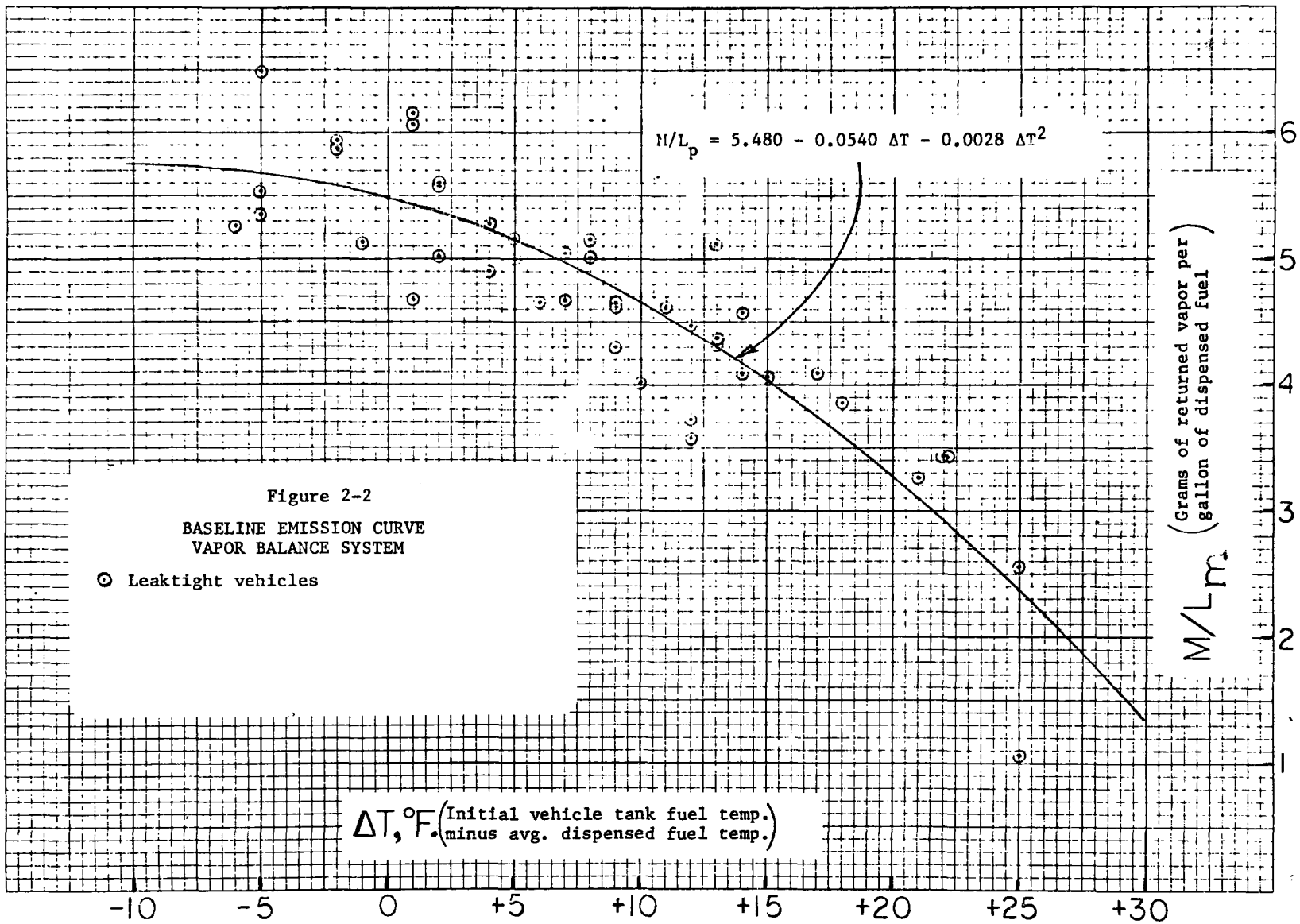


Figure 2-2

BASELINE EMISSION CURVE
VAPOR BALANCE SYSTEM

⊙ Leaktight vehicles

Table 2-7. CALCULATED VAPOR LOSSES BASED ON EXPLOSIMETER READINGS
-VAPOR BALANCE SYSTEM-

Veh. No.	Explosimeter Reading L.E.L.	Approx. Duration	Gal. Disp.	Vapor Loss, grams (A)	(B)
6	1.2	2 min.	11.09	26.25	26.25
10	1.2	3 min.	17.04	44.45	44.45
12	1.2	2 min.	13.51	32.44	32.44
18	0.1	40 sec.	20.33	10.96	2.26
19	1.2	2 min.	15.40	38.58	38.58
21	1.2	1 min.	7.10	17.78	17.78
36	1.2	1 min.	7.86	20.50	20.50
49	1.2	3 min.	16.67	46.65	46.65
51	1.2	2 min.	14.80	39.88	39.88
58	1.2	5 sec.	10.32	0.00	0.00
61	1.2	1 min.	7.01	20.46	20.46
64	1.2	1 min.	6.80	17.03	17.03
73	1.2	2 min.	11.88	32.63	32.63
77	1.2	1 min.	7.59	17.18	17.18
79	1.2	1 min.	9.42		
80	0.2	5 sec.	11.32	0.00	0.00
81	1.2	3 min.	17.04	41.80	41.80
88	1.2	1 min.	9.94	25.93	25.93
91	1.2	1 min.	7.97	20.38	20.38
				452.90	444.20

(A) Losses calculated using Table 8-1 of Proposed EPA Test Procedure for Stage II Operations at Vacuum Assisted Systems

(B) Losses shown in column (A) multiplied by percent of total dispensing time the explosimeter reading was observed

to be related to a fill neck design which is slightly submerged below the liquid level when the tank is filled.

All of the tests commenced using the middle flow setting on the dispensing nozzle, approximately 6.3 gpm. Spitbacks were observed on vehicles #26 and #65 both of which were manually refueled (not refueled hands off) due to unusual fill neck characteristics which prevented normal latching of the nozzle.

2.2.2 Vent Pipe Emissions - Vapor Balance System

Vent pipe emissions were monitored during four test days concurrently with refueling tests and during two overnight periods as shown in Table 2-8. During the overnight period on February 16, a bulk delivery of 4,085 gallons was made at approximately 5:30 p.m. The emission data for the bulk delivery indicated approximately 539 grams emitted for a Stage I emission rate of approximately 0.13 grams/gallon of delivered fuel. From approximately 6 p.m. that night until 8:30 a.m. the following morning the vent emission rate was 0.094 grams/gallon of dispensed fuel. All of the other daily vent emission rates, including the overnight period beginning at 5 p.m. on February 23, were lower ranging from 0.001 to 0.066 grams/gallon. The overall vent emission rate was 0.035 grams/gallon.

During the day of the 23rd the carbon canister measuring system was used in series with the vent pipe monitoring system. A 5.90 gram weight increase was observed which was approximately 4.7 grams less than the emissions calculated using volume and HC concentration data. Several times during this test period explosimeter readings of 0.05 LEL were observed at the outlet of the second canister (zero explosimeter readings had always been observed prior to this day). Since there is a constant flow of gas through the NDIR analyzer, HC vapors during an outbreathing event and cabinet air (to zero instrument) when no outbreathing is occurring, it is believed that previously trapped HC vapors were being slowly purged from the second canister during long periods when no outbreathing was occurring. This phenomenon resulted from the way the two measurement techniques were configured in relation to each other and is not necessarily a deficiency in the activated carbon material itself.

Table 2-8. SUMMARY OF VENT PIPE EMISSIONS
-VAPOR BALANCE SYSTEM-

Date	Total ft^3 Vented	Total Grams Vented	Total Gal. Disp.	Avg. Density gms/ft^3	Venting Rate gms/gal disp.	Notes
2-13	3.403	0.66	671.1	0.19	0.001	
2-16	9.203	39.36	591.7	4.28	0.066	
2-16	3.535	57.36	609.3	16.23	0.094	(A) (B)
2-23	7.366	10.37	532.3	1.41	0.019	(C)
2-23	4.029	14.43	602.2	3.58	0.024	(B)
2-24	4.065	2.46	532.9	0.60	0.005	
	31.601	124.64	3539.5*	3.94	0.035	

*Of the total 3539.5 gallons dispensed for these tests, 1205.6 gallons (34%) were dispensed at the self-service islands and 2333.9 (66%) gallons were dispensed at the full-service islands.

(A) Bulk delivery made during measurement period

(B) Emissions monitored overnight

(C) 5.90 grams weight increase on carbon canisters

2.3 ANALYSIS OF TEST METHODS

Two calculations of the quantity of gasoline vapor emitted were made for each refueling test. The Baseline Method essentially estimates the emission indirectly by predicting the total vapor quantity that should have been collected (by use of regression techniques) for comparison with the actual measured amount that was collected, the difference representing the quantity not collected (emitted). The Leak Rate Method estimates the quantity of vapors emitted directly by establishing a relationship between vapor leak rate and fill neck interface pressure (calibrating the size of the leak) and applying this data to the observed fill neck interface pressure during a refueling operation. With this approach the total quantity recoverable and the total quantity collected are not determined.

Both of the above approaches yield values for the amount of vapors emitted (not collected) at the dispensing island, and emissions at the underground tank vents must be quantified for adding to the losses at the island to determine the overall emission rate due to refueling of vehicles (Stage II operations). The Combination Method allows calculating the emission via both methods on each refueling test and computes the overall fleet emission rate by selectively using results from both methods.

From Tables 2-2 and 2-6 calculations of the quantity emitted by the two methods are shown to have a large discrepancy in many cases. Additionally, the occurrence of an explosimeter reading is often noticed simultaneously with a zero emission calculation by one or both calculating methods. Unfortunately, there exists no referee method with which one can determine the accuracy and precision of each method.

The regression equations for predicting the Baseline emission rates (shown graphically on Figures 2-1 and 2-2) had correlation coefficients of 0.88 and 0.89 and standard errors of 0.41 grams/gal. and 0.47 grams/gal. for the Red Jacket System tests and the Vapor Balance System tests respectively.

2.3.1 Interpretation of Data for Balance System Tests

Using the value for the standard error of 0.47 grams/gal. (for Balance System Tests) the following table shows the expected distribution of leaktight refuelings cases:

Number of Standard Errors	Band About Regression Line	Percent of Cases Included
0.67	±0.32 gms/gal.	50
1.00	±0.47 gms/gal.	68
2.00	±0.94 gms/gal.	95
2.13	±1.00 gms/gal.	97

This means that there is a 50-50 chance that the measured results for any individual refueling test will be greater than ±0.32 grams/gal. away from the regression line when there is no emission. Similarly, there is about a 3 percent chance that refueling results will be greater than ±1.00 grams/gal. away of the regression line or conversely about 97 percent of the time a refueling test that results in no emission should yield results that are within ±1.00 gram/gal. of the regression line.

Since the emission rate calculated for any non-leaktight vehicle is:

$$M/L_P - M/L_M = M/L_E$$

M/L_P = Potential grams of vapor recoverable per gallon of dispensed fuel

M/L_M = Measured grams of vapor collected per gallon of dispensed fuel

M/L_E = Emitted grams of vapor per gallon of dispensed fuel

and M/L_P has a standard error (variability) of ±0.47 grams/gallon for any one vehicle, then; $[M/L_P \pm 0.47] - M/L_M = [M/L_E \pm 0.47]$ for 68 percent of the leakers or $[M/L_P \pm 1.00] - M/L_M = [M/L_E \pm 1.00]$ for 97 percent of the leakers. Refueling tests which involve a small leak of 0.01 gram/gal. could potentially be quantified anywhere between -0.99 and +1.01 grams/gal. This explains the existence of negative emission values which are operationally impossible yet are often seen with this method and provides one explanation

for the discrepancy in emission values calculated by the Baseline Method and the Leak Rate Method. Although the potential errors associated with a single test are substantial, distributing the errors over 40 non-leaktight cases results in a fleet error of:

$$S_e/\sqrt{N} = 0.47/\sqrt{40} = 0.074 \text{ gms/gal}$$

Table 2-9 shows a comparison between the two calculation techniques for all of the non-leaktight refuelings arbitrarily segregated by small, medium-size and large leakers. For the 84 total tests, there were 44 leaktight cases and 40 non-leaktight cases (determined with the Leak Rate Test System). It is possible for a non-leaktight situation to result in no emission to atmosphere. This occurs when temperature conditions cause sufficient vapor shrinkage to effect a negative pressure in the vehicle fuel tank and fill neck during dispensing. As shown in the table the average small leak is approximately the same for both methods even though there are large discrepancies for any one vehicle. There is a 0.04 gram/gal. difference between the two methods which is not significant. Hence, one might conclude neither method is superior to the other in quantifying the emissions from a subfleet of vehicles which have small leaks.

For medium size leakers, the difference in the average emission rate calculated by the two methods is 0.85 grams/gal., and for large leakers the difference is 2.58 grams/gal. with the Baseline Method being higher for both groups. These differences are significant.

It is not possible to state with absolute certainty whether the Baseline Method is estimating the emissions higher than the "true" value or the Leak Rate Method is estimating low for the medium-size and large leakers. If one assumes that the Leak Rate Method results accurately estimate the loss, then the Baseline Method could potentially estimate the loss 1.00 gram/gallon higher and lower than the Leak Rate Method (due to statistical variability) 3 percent of the time. The data in Table 2-9 show that the Baseline Method estimates more than 1.00 grams/gallon higher in 10 percent of the 40 cases and never estimates more than 1.00 grams/gallon lower. Therefore, the Leak Rate Method probably underestimates the emission, and this error appears to be greater with larger size leaks.

Table 2-9. COMPARISON OF CALCULATED EMISSION RATES

SMALL EMITTERS
B'Line Loss < 1.00

Veh. No.	Emission Rate, gms/gal B'Line	LRM
3	+ 0.77	0.59
10	- 0.23	0.00
12	+ 0.73	0.07
15	- 0.15	0.01
17	+ 0.32	0.00
19	- 0.19	0.00
22	+ 0.13	0.00
23	+ 0.17	0.19
25	+ 0.05	0.00
29	+ 0.94	0.15
30	+ 0.49	0.70
35	+ 0.61	0.22
36	+ 0.55	0.18
44	+ 0.39	0.16
45	+ 0.01	0.01
47	+ 0.07	0.00
51	+ 0.30	0.15
52	+ 0.37	0.00
55	+ 0.55	0.07
58	+ 0.50	0.32
61	- 0.32	0.38
64	+ 0.04	0.63
66	- 0.03	0.00
67	- 0.58	0.02
73	- 0.60	0.08
75	+ 0.08	0.00
76	- 0.02	0.02
86	+ 0.70	1.25
96	+ 0.35	0.04
98	+ 0.60	0.05
Avg.	+ 0.22	0.18

MEDIUM SIZE EMITTERS
B'Line Loss 1.00 to 2.00

Veh. No.	Emission Rate, gms/gal B'Line	LRM
6	+ 1.43	0.99
21	+ 1.78	0.96
49	+ 1.03	0.29
77	+ 1.34	0.00
79	+ 1.30	0.38
81	+ 1.31	1.20
88	+ 1.66	0.18
91	+ 1.20	0.24
Avg.	+ 1.38	0.53

LARGE EMITTERS
B'Line Loss > 2.00

Veh. No.	Emission Rate, gms/gal B'Line	LRM
18	+ 2.29	0.00
95	+ 2.90	0.04
Avg.	+ 2.60	0.02

The relative contributions of the three subgroups of vehicles on Table 2-9 can be estimated by comparison with the total quantity of vapor involved as shown below.

Baseline Method Results:

Vehicles	Total Lost, gms	Total Collected, gms	% Lost
44 (no leak)	0.00	2754.52	0.00
30 (small leak)	72.43	1787.73	3.89
8 (medium leak)	116.40	343.44	25.31
2 (large leak)	90.91	74.19	55.06
84	279.74	4959.88	

The importance of precisely quantifying the vapor emissions from the large leakers is evident since a major portion of the total quantity emitted comes from just ten of the 40 non-leaktight cars. Although the Leak Rate Method appears to provide more useful information on the individual emissions rates from small leakers, there is little difference in the computation of the control system performance regardless of whether the Leak Rate Method data or the Baseline Method data are used for this entire subgroup. Therefore it is doubtful that the Combination Method of summing the losses is much different than using a straight Baseline Method. Operationally, the Leak Rate Test System is very useful for determining whether or not a leak-tight situation exists and would be recommended for this reason; however, the inability to quantify emission levels on the large leakers limits the utility of the Leak Rate Method.

2.3.2 Interpretation of Data for Red Jacket System Tests

Table 2-10 shows the comparison of calculated emission for the two methods on the Red Jacket System Tests. Of the 32 non-leaktight cases there was only one vehicle that did not fall into the small emitter subgroup. The average emission rate for the small emitters is -0.22 grams/gallon by the Baseline Method and 0.003 grams/gallon for the Leak Rate Method, the difference being significant. Although negative emissions are undefined, the formula $M/L_P - M/L_M = M/L_E$ can yield negative values for M/L_E if the quantity of vapor collected, M/L_M, for non-leaktight

Table 2-10. COMPARISON OF CALCULATED EMISSION RATES
-RED JACKET TESTS-

SMALL EMITTERS B'Line Loss < 1.00			MEDIUM-SIZE EMITTERS B'Line Loss 1.00 to 2.00		
	Emission Rate, gms/gal			Emission Rate, gms/gal	
Veh. No.	B'Line	LRM	Veh. No.	B'Line	LRM
10	- 0.02	0.00	1	+ 1.36	0.00
11	- 0.62	0.00			
13	- 0.20	0.00			
17	- 0.46	0.00			
26	- 0.60	0.00			
29	+ 0.19	0.00			
32	- 0.11	0.00			
34	- 0.63	0.00			
36	- 0.07	0.00			
39	+ 0.18	0.00			
40	+ 0.45	0.00			
42	+ 0.01	0.00			
44	- 0.18	0.00			
47	+ 0.78	0.00			
48	- 0.51	0.00			
49	- 0.73	0.00			
52	- 0.55	0.01			
61	- 0.71	0.00			
65	+ 0.15	0.00			
68	+ 0.22	0.00			
70	- 0.18	0.00			
71	+ 0.65	0.00			
79	- 0.97	0.00			
86	+ 0.07	0.00			
87	- 0.29	0.00			
93	- 0.13	0.07			
94	- 0.67	0.00			
96	- 0.43	0.00			
97	- 0.70	0.00			
98	- 0.78	0.00			
99	+ 0.09	0.00			
Avg.	- 0.21	0.003			

cases is consistently greater than the potential amount M/L_P. This might be expected if air is pulled in to the control system through the leak and causes vapor growth. Use of the Baseline Method on the Vapor Balance System requires that the negative values of M/L_E are summed with the positive values to cancel out the random errors, however, this approach does not appear feasible when air is ingested into the control system. The sum of the emissions from the "small leakers" totals approximately -85 grams of vapor which more than offsets the real losses that occurred on vehicles #52 and 93 as well as the 32 gram loss on vehicle #1. For this reason, use of Leak Rate Method results for small leakers combined with Baseline Method results for larger leakers yields a more realistic indication of the Red Jacket System performance.

2.3.3 General Comments on Test Procedures

The Combination Method appears to be an acceptable measurement technique for determining the refueling emission characteristics of a fleet of vehicles. This program was performed primarily to obtain information on measurement and calculation techniques. Certain data were deleted from the computation of fleet emission rates to maintain as much consistency in test operations as possible. Due to the fact that the value of ΔT is needed to exercise Baseline Method calculations, measurement of the vehicle tank fuel temperature is required whereas it is not essential to Leak Rate Method calculations. It is doubtful that excluding vehicles (after the fact) when this temperature data is not available would affect the determination of system performance.

The inability to measure the fuel tank liquid temperature was usually caused by obstructions in the fill neck or tank that prevented the probe from being fully inserted. Sensing of fuel tank skin temperature may provide an acceptable alternate method for determining tank liquid temperature. Tank vapor space measurements do not coincide with the liquid temperature and disagree the most at extreme ΔT situations. The vapor temperature should not be used to calculate ΔT.

Although there appears to be little if any difference in usefulness between the Baseline Method and the Combination Method, the advantages of the Combination Method are apparent to the test personnel. They are:

(a) By leak checking all refueling operations, accurate assessment of the frequency of leaktight cases can be made and the sample size of baseline vehicles is maximized.

(b) The use of a rotameter set for conducting the Leak Rate Test allows the operator to quantify the existence and size of the leak with more speed and accuracy than the previously proposed techniques using positive displacement meters.

(c) The existence of a leaktight situation is determined with the actual dispensing nozzle inserted, not with a force fitted rubber stopper.

Combustible gas meters used for this program gave a full scale response in the presence of 1.8 percent gasoline vapors and have a sample pump flow rate of approximately 0.06 cfm. Since refueling vapors are often 45 percent hydrocarbons, a vapor leak rate of 0.0024 cfm could theoretically give a full scale response; however, because vapor leaks usually do not emanate from round orifices at the fill neck interface, a vapor leak rate of about 0.01 cfm or about 1 percent of vapors displaced with a gasoline dispensing rate of 7.5 gpm is sufficient to give a full scale reading. The instrument may also detect the presence of a few drops of spilled fuel. However, of the 106 leaktight refuelings that were recorded during this program, only three exhibited any reading in the explosimeter. For these three cases, no explosimeter reading was full scale nor was longer than 10 seconds. These data would indicate that liquid droplets do not cause the explosimeter method to over-estimate to a significant degree.

In spite of the great sensitivity of the explosimeter, data from these tests show the explosimeter can provide a reasonably accurate quantification of vapor losses at the fill neck. From data on Table 2-3, the vehicle refueling emissions for the Red Jacket system are calculated to be 0.061 grams/gallon after including the time factor. This compares with 0.031 grams/gallon calculated using data from the combination method. The

difference is small when compared with the proposed EPA standard of 0.4 grams/gallon and suggests that vapor control systems with high collection efficiency would not be seriously penalized by use of time factored explosimeter procedure. Without the time factor, the emissions are 0.142 grams/gallon.

The inability of the Leak Rate Method to quantify large leaks properly is probably due to the extremely low pressures associated with large gaps and the criticality of the pressure sensing location at these low pressures. Vapor emissions from vehicle tank vents are usually underestimated by the Leak Rate Method due to the pressure sensing location not being at the source of the leak, the tank head space.

3.0 CONTROL EQUIPMENT AND TEST INSTRUMENTATION

3.1 VAPOR CONTROL EQUIPMENT

The test site was an operating service station located at 1200 East Imperial Highway in Brea, California, and was an independently owned franchise of the Union Oil Company of California. It was located approximately one block from a freeway offramp and had a reported monthly throughput of 80,000 gallons operating 24 hours per day. Figure 3-1 shows a schematic of the service station vapor control piping. As shown, there were four self-serve dispensers and four full-serve dispensers at the station. All of the refueling tests were performed using leaded Premium grade fuel to allow testing the greatest number of vehicles per day. Since the test equipment was not installed on an unleaded dispenser, most 1975 and 1976 vehicles were not evaluated.

3.1.1 Red Jacket "Aspirator Assist" Vapor Control System

The Red Jacket System is comprised of a modulating diverter valve, a calibration valve and an aspirator assembly for each dispenser. Figure 3-2 presents a schematic of the system configuration evaluated. This system is intended to be used in conjunction with a non-manifolded vapor piping installation. During dispensing operations a portion of the fuel is diverted by the modulating valve before it enters the meter. The amount of fuel diverted (which is in proportion to dispensing rate) is directed through a preadjusted calibration valve to the injector assembly effecting a reduced pressure in the vapor hose. A mixture of collected vapors and diverted fuel (liquid) return to underground tanks through the vapor piping. No vapor processing equipment is used on the underground tank vent pipe.

For the test program all of the non-test dispensers were equipped with Emco Wheaton A-300 vapor recovery dispensing nozzles and 3/4" inside diameter black synthetic rubber vapor hoses.

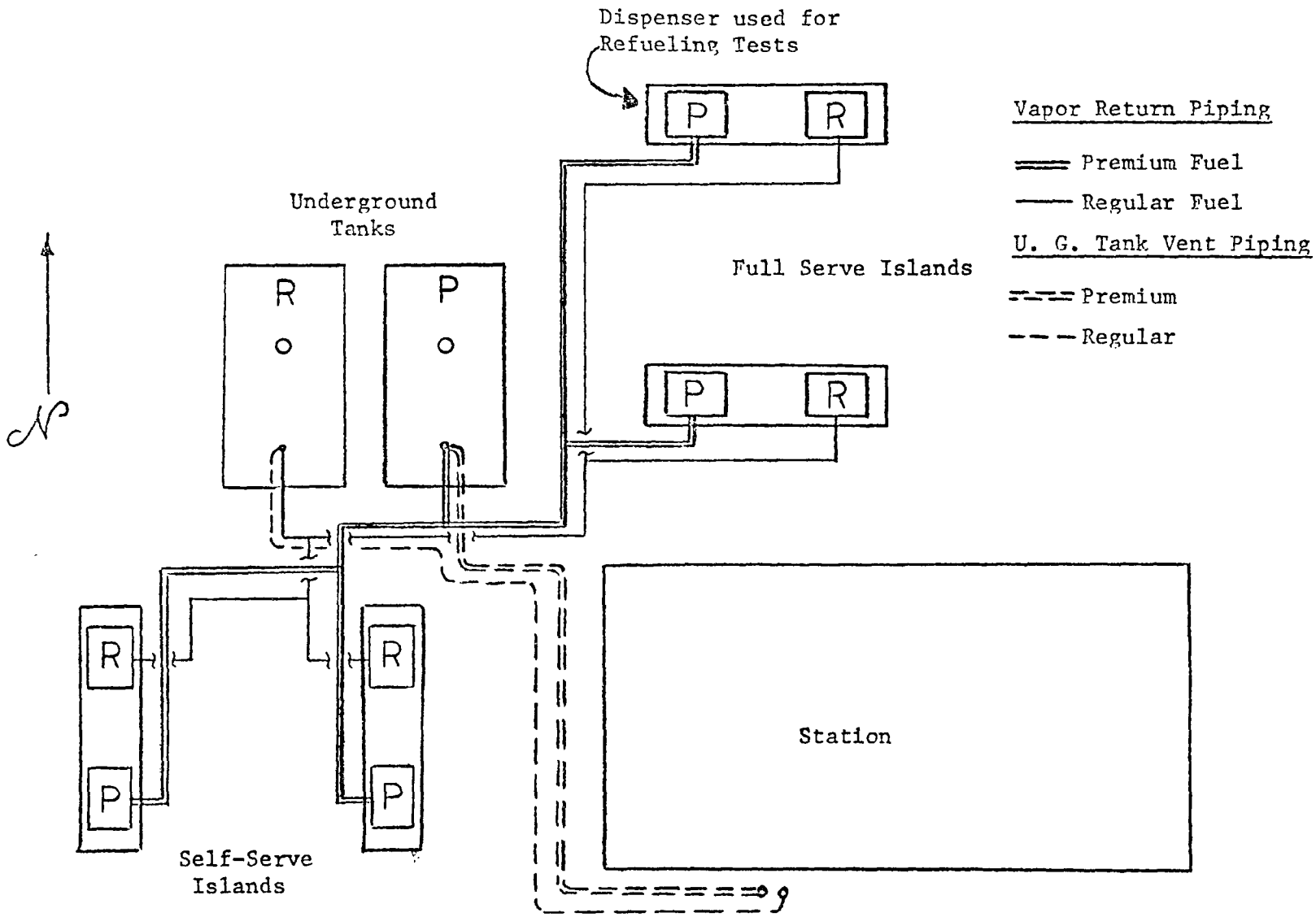


Figure 3-1. SCHEMATIC OF VAPOR CONTROL SYSTEM PIPING

1. Product Piping
2. Vapor Return Piping
3. Modulating Valve
4. Shutoff Valve (to deactivate Red Jacket System for Balance System tests)
5. Calibration Valve
6. Aspirator Assembly
7. Vapor Collection Hose
8. Product Hose
9. Dispenser Metering Assembly
10. Sealing Type Vapor Recovery Nozzle

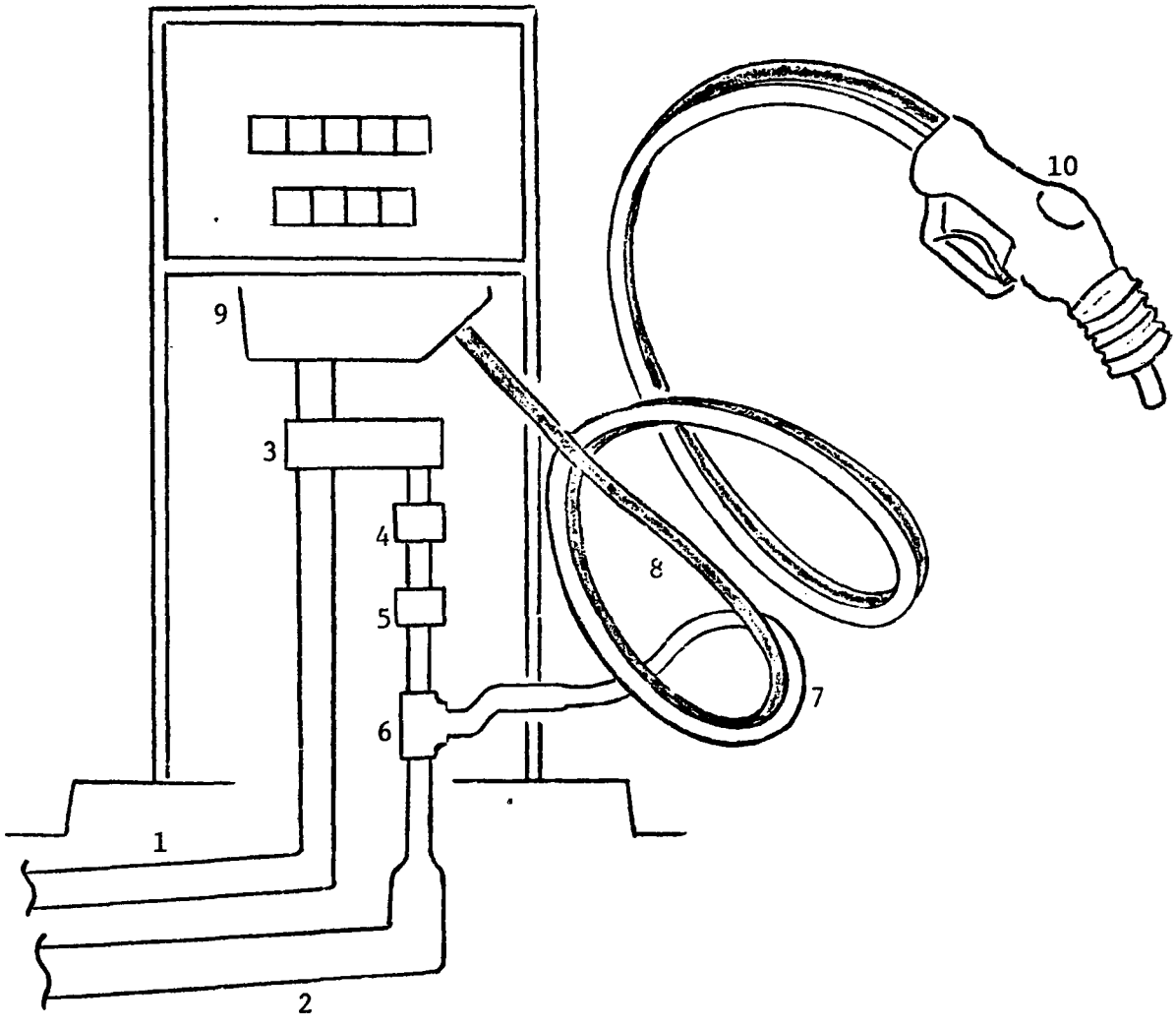


Figure 3-2. SCHEMATIC OF RED JACKET "ASPIRATOR ASSIST" INSTALLATION

3.1.2 Vapor Balance Control System

Tests performed in evaluation of the vapor balance control system were performed by simply closing the additional valve added in the diverted fuel piping. The same dispensing nozzles and vapor hoses were used with collected vapors being directed through the deactivated aspirator units.

3.2 TEST EQUIPMENT

3.2.1 Refueling Test Equipment

As mentioned previously, the Emco Wheaton A-300 vapor recovery nozzle was used for all testing. The nozzle was modified by installing a 1/8-inch stainless steel pressure sensing tube for monitoring fill neck interface pressure. Coupler fittings were fabricated for attachment at the product inlet and vapor outlet of the nozzle to allow measurement of dispensed fuel temperature and hydrocarbon concentration. Figure 3-3 shows a schematic of the Emco Wheaton test nozzle.

Vapors returned from the nozzle were directed through a Dresser (Roots Type) Model 1.5 M meter to the underground vapor piping. The analytical and monitoring equipment was mounted in a Chevrolet Van parked parallel and adjacent to the test lane. Figure 3-4 shows a schematic of the test apparatus for performing the refueling tests and the monitoring/analytical system.

Dispensed fuel temperature and metered vapor temperature were continuously monitored on a Leeds & Northrup strip chart recorder. Fill neck interface pressure was continuously monitored via a Setra pressure transducer (scaled +2.5 to -2.5 inches H_2O) in conjunction with a Texas Instruments strip chart recorder. Gasoline vapor hydrocarbon concentration was determined by pulling the vapor sample from the nozzle vapor coupler at approximately 290 cc/min. using a stainless steel Metal Bellows pump. Analyses of vapors were accomplished using a Beckman 315-A non-dispersive infrared analyzer modified to measure high level HC concentrations of 0 - 100 percent propane equivalent and was recorded continuously on the Texas Instruments strip chart recorder.

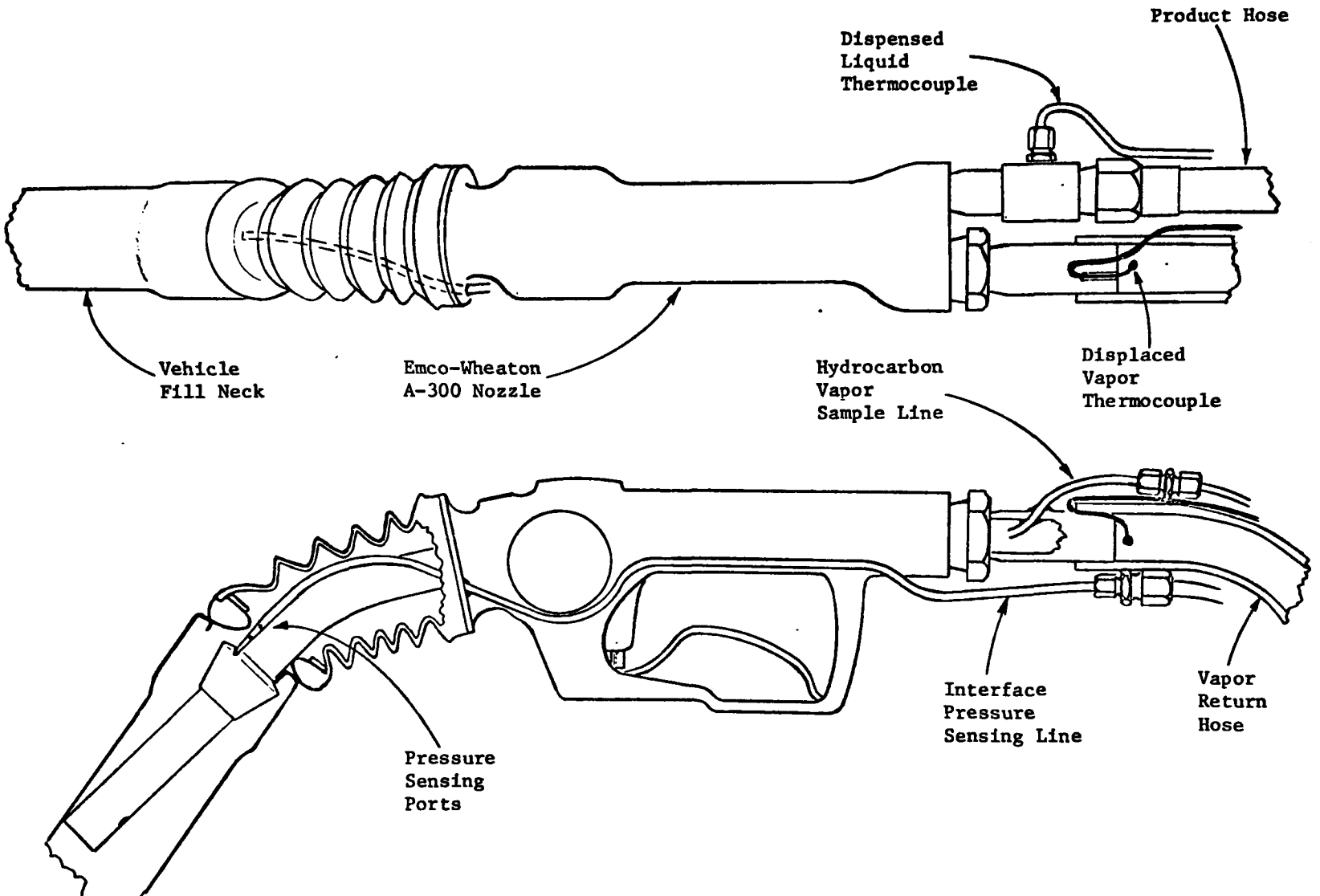


Figure 3-3. INSTRUMENTED VAPOR RECOVERY NOZZLE

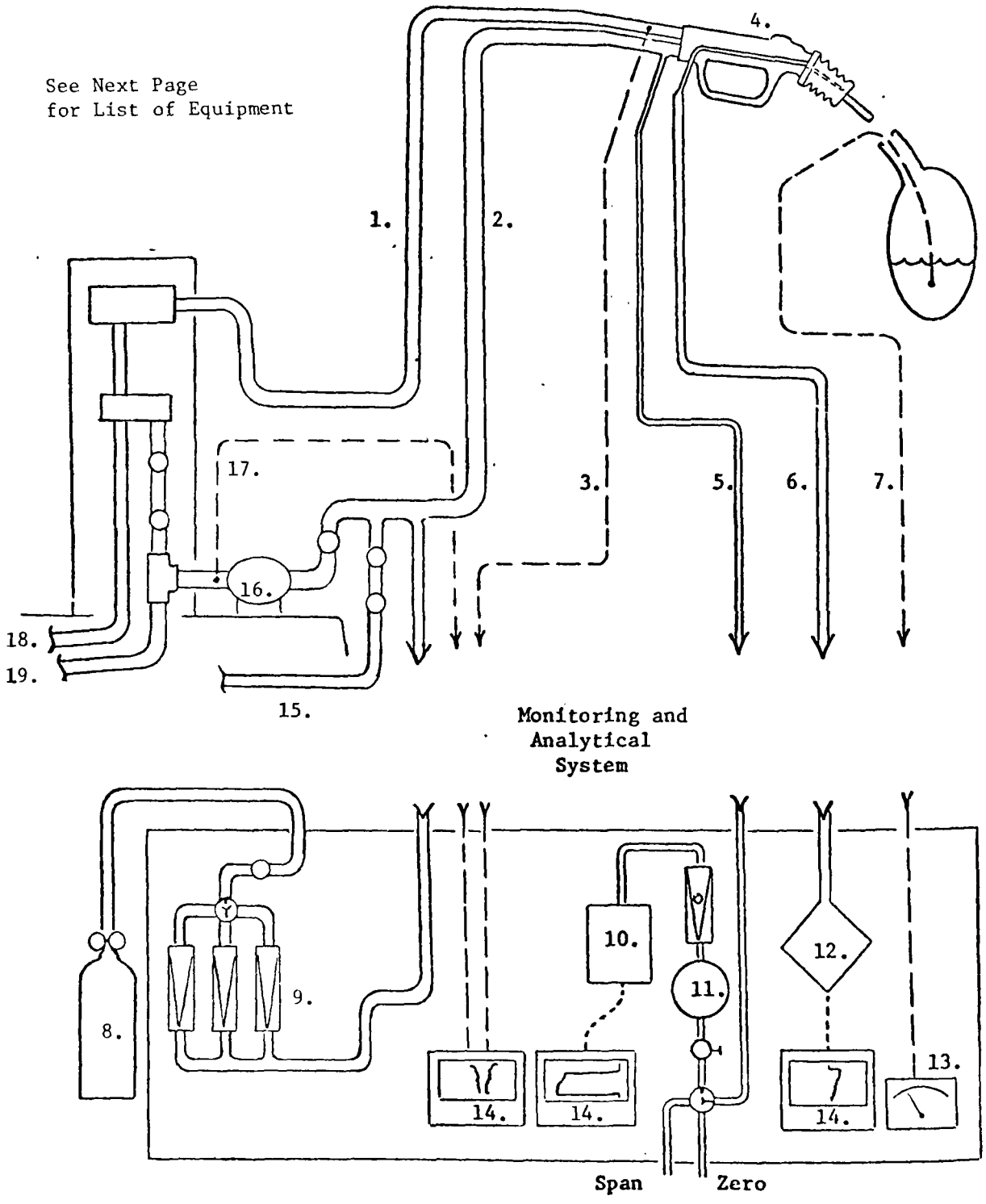


Figure 3-4. SCHEMATIC OF EQUIPMENT AND INSTRUMENTATION FOR REFUELING TESTS

TEST EQUIPMENT AND INSTRUMENTATION

1. Product Hose
2. Vapor Hose
3. Dispensed Fuel Temperature Thermocouple
4. Vapor Recovery Nozzle
5. Hydrocarbon Vapor Concentration Sample Line
6. Nozzle Interface Pressure Sample Line
7. Vehicle Tank Fuel Thermocouple
8. Propane Cylinder
9. Leak Rate Test System
10. Infrared Type Analyzer for HC Concentration
11. Sample Pump
12. Pressure Transducer
13. Pyrometer
14. Strip Chart Recorder
15. Compressed Air Line for Flushing Vapor Hose
16. Dresser Meter
17. Returned Vapor Temperature Thermocouple
18. Product Supply Piping
19. Vapor Return Piping

Vehicle initial tank temperature was determined via thermocouple sensor using a squeeze bulb to draw fuel up a 1/4-inch nylon syphon tube which contained the thermocouple.

A compressed air line was attached to the vapor collection hose for backflushing of the hose and nozzle vapor passages during the Red Jacket System tests.

The Leak Rate Test was performed by using a pressurized cylinder of propane connected to a pressure regulator, flow control valve and four-way selector valve. The selector valve was plumbed to three calibrated rotameters (in parallel). With this configuration the leak rate characteristics of a vehicle/dispensing nozzle connection could be determined by closing the valve at the inlet to the Dresser Meter and flowing propane into the vapor collection hose and vehicle tank. The flow rate was adjusted to establish the desired fill neck interface pressure (monitored via the pressure transducer), and the leak rate is determined directly from the rotameter reading. Appendix A shows the Leak Rate Test flow rates at the various rotameter readings.

3.2.2 Vent Pipe Emission Monitoring Equipment

Premium grade fuel was used during all of the dispensing tests. Underground tank vent emissions were monitored by directing the vapors to an Automatic Vent Pipe Monitoring System (AVPMS) as shown schematically on Figure 3-5. The AVPMS was designed to direct all outbreathing through a solenoid valve and an American DTM-325 dry test meter. Analysis of vented vapors was accomplished by drawing a sample from the outlet fitting of the DTM through a stainless steel Metal Bellows pump and pumping into a Beckman 315-A analyzer modified to detect 0 - 100 percent HC levels (propane equivalent). Inbreathing of ambient air was controlled by a second solenoid valve so that the DTM was bypassed. Control of the venting solenoids and the inbreathing solenoid was via paired Dwyer pressure switches adjusted to actuate the solenoid valves at +0.19 and -0.19 inches H_2O pressure respectively.

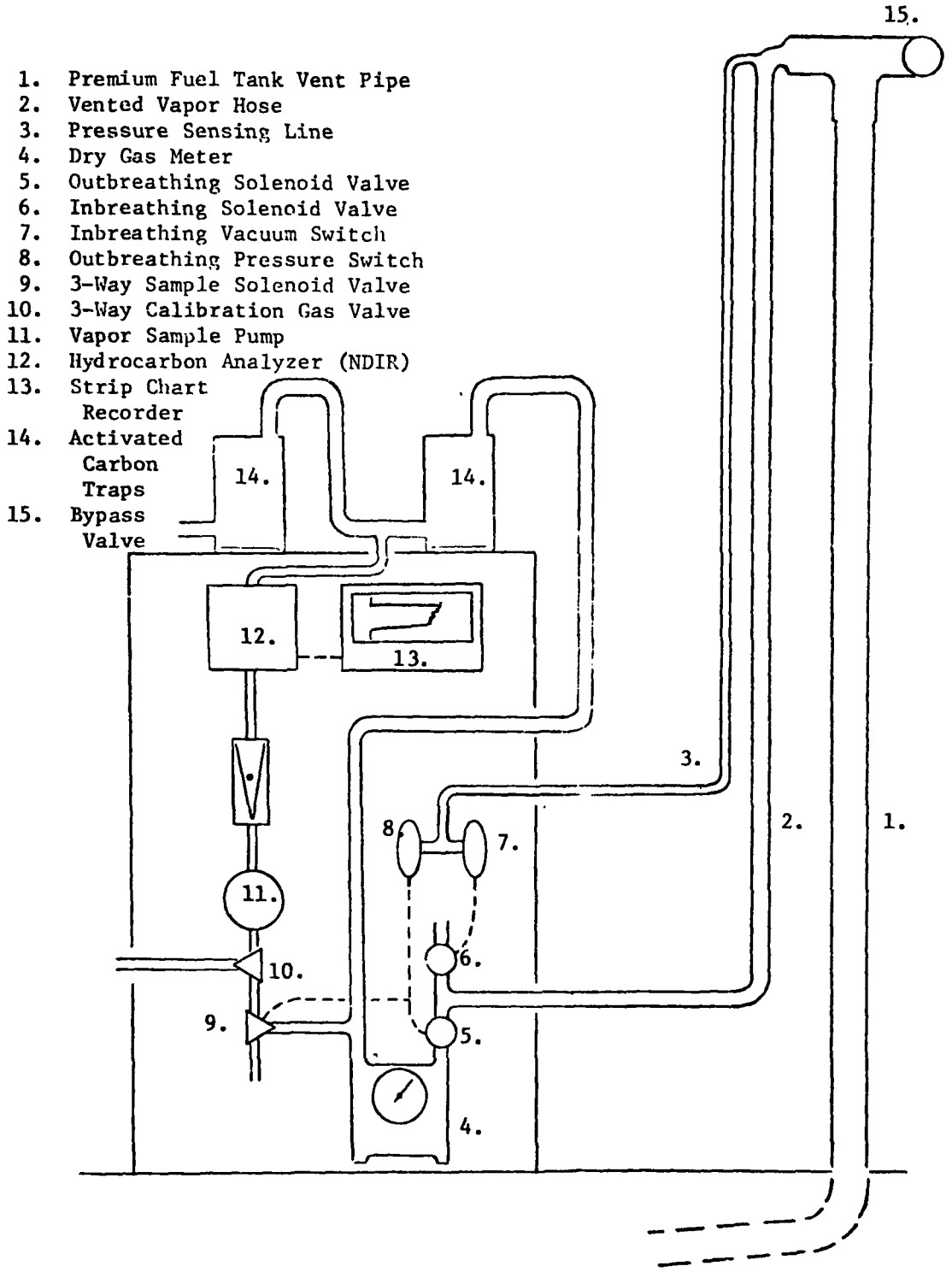


Figure 3-5. AUTOMATIC VENT PIPE MONITORING SYSTEM

Additionally, data was sought to determine if vent emissions could be quantified via entrapment on activated carbon. Two canisters each containing approximately 500 grams of "Darco" 4-12 mesh virgin activated carbon were connected to the AVPMS as shown in Figure 3-5 so that all vented gas passing through the dry gas meter and the hydrocarbon analyzer would be directed to the canisters. The canisters were weighed at the beginning and end of each test period using an Ohaus 700 triple beam balance.

4.0 TESTING AND ANALYTICAL PROCEDURES

4.1 PROCEDURES FOR REFUELING TESTS ON RED JACKET SYSTEM

Presented below is a list of steps conducted to perform one refueling test on the Red Jacket system:

(a) Insert temperature probe in vehicle tank using squeeze bulb to pull fuel up the tube until thermocouple is fully wetted.

(b) Record initial vehicle tank liquid temperature as well as test number, vehicle make, model year, body style, license number, ambient temperature and barometric pressure.

(c) Zero Dresser Meter revolution counter and open valve at inlet to meter.

(d) Insert dispensing nozzle and prelatch the trigger at the desired flow rate.

(e) Activate hydrocarbon analyzer sample pump, place selector valve in "sample" position, and activate strip chart recorders to monitor dispensed fuel temperature, returned vapor temperature, hydrocarbon concentration and fill neck interface pressure.

(f) Approximately ten seconds after activating sample pump, energize dispensing pump and mark all strip charts when fuel flow begins.

(g) Probe the periphery of the nozzle face seal interface with the vehicle fill neck with a combustible gas detector maintaining a distance of one centimeter from the interface.

(h) Record the Dresser Meter revolution count at five gallon intervals.

(i) At the completion of refueling operation mark the strip charts accordingly, close valve at meter inlet and place dispensing pump lever in "off" position.

(j) Record total gallons dispensed, total cost, cost/gallon, final revolution counter reading, combustible gas meter readings, and

note any premature nozzle shut offs--spillage--spitback and/or any unusual events. The dispensing nozzle should remain inserted in vehicle.

(k) If the vehicle has an evaporative emission control system, plug or clamp the lines from the vehicle tank to the control system.

(l) Adjust the Leak Rate Test System propane flow control valve to obtain 0.5 inches H_2O pressure at the nozzle interface and select appropriate size rotameter depending on the flow rate. Use a higher pressure setting in pressures greater than 0.5 inches H_2O were observed during refueling.

(m) If flow control valve can be closed and pressure holds, system is tight and Leak Rate Test is complete.

(n) If a leak is present at the high pressure setting, determine flow rate from rotameter calibration table and repeat Leak Rate Test at 0.3 and 0.1 inches H_2O pressure.

(o) Advance strip chart approximately one half inch at each pressure setting used to obtain record and record leak rates.

(p) Upon completion of Leak Rate Test, close propane flow control valve, remove dispensing nozzle from vehicle, install fill neck cap and unplug evaporative emission line on vehicle.

(q) Close valve leading to pressure transducer and manually hold dispensing nozzle sealing disc off of tapered collar by compressing bellows.

(r) Slowly open compressed air flow control valve backflushing vapor hose and nozzle passages.

(s) Energize hydrocarbon analyzer sample pump and monitor concentration of gas being flushed.

(t) When concentration falls below 5 percent (as propane), close compressed air flow control valve and open propane flow control valve on Leak Rate Test System and flow a sufficient volume of propane to displace the air in the vapor hose and nozzle passage.

(u) Close propane flow control valve, release the nozzle bellows, and open valve leading to pressure transducer. Place hydrocarbon analyzer selector valve to zero air position.

4.2 PROCEDURES FOR REFUELING TESTS ON VAPOR BALANCE SYSTEM

The steps conducted to perform one refueling test on the vapor balance system were identical to those listed previously except that steps (q) through (u) were omitted.

4.3 AUXILIARY MEASUREMENT PROCEDURES

The following lists measurements performed intermittently throughout each test day:

(a) Disconnect nozzle interface pressure sensing line and check transducer zero pressure setting on recorder three times daily.

(b) Using pure propane check span setting on hydrocarbon analyzer three times daily.

(c) Calibrate dispensed fuel thermocouple and returned vapor thermocouple against reference thermometer at two bath temperatures bracketing the expected range of operation at the beginning of each test day.

(d) Collect one quart sample of fuel from dispensing nozzle shortly after last test vehicle of day each time a bulk delivery is made. Seal tightly and store in cool place until Reid Vapor Pressure analysis of fuel is obtained.

4.4 CALCULATION PROCEDURES

The following example calculation procedures were applied to each vehicle for both the evaluation of the Red Jacket System and the Vapor Balance System:

<u>Example Data Measurements (Baseline Method)</u>

T_v; Veh. init. fuel temp . . . . . 66° F.

T_d; Avg. dispensed fuel temp. . . . . 63° F.

Example Data Measurements (Baseline Method)

T_r; Returned vapor temp. . . . . 60° F.

P_a; Barometric pressure . . . . . 29.86 in. Hg

$; Total gasoline purchase $9.56

GC; Cost per gallon $0.669

REV; Total revolutions on Dresser Meter . . 156

C_r; Avg. HC concentration of ret'd. vapor. 71.0% (as propane)

F ; Calibration factor for Dresser Meter . 0.0111 ft^3/rev.

Calculated Values (Baseline Method)

V_r; Returned vapor volume, ft^3

V_l; Dispensed liquid volume, gallons

V/L; Vapor volume to liquid volume ratio

M_r; Total mass of returned hydrocarbons, grams

M/L_r; Mass of returned hydrocarbons to dispensed liquid volume ratio, grams/gallon

V_{rs}; Standard returned vapor volume, ft^3

$$\Delta T_{v-d} = T_v - T_d = 66 - 63 = +3° \text{ F.}$$

$$V_l = \$/GC = 9.56/0.669 = 14.29 \text{ gal.}$$

$$V_r = REV \times F = 156 \times 0.0111 = 1.732 \text{ ft}^3$$

$$V_{rs} = \frac{17.71 \times V_r \times P_a}{T_r + 460} = \frac{17.71 \times 1.732 \times 29.86}{60 + 460} = 1.761 \text{ ft}^3$$

$$M_r = 51.7 \times V_{rs} \times C_r = 51.7 \times 1.761 \times 0.71 = 64.64 \text{ grams}$$

$$M/L_r = M_r/V_l = 64.64/14.29 = 4.52 \text{ grams/gal.}$$

$$V/L = V_r/V_l = 1.732 \times 7.48/14.29 = 0.907$$

Calculated Values (Leak Rate Method)

OHCL; Observed total hydrocarbons leaked, grams

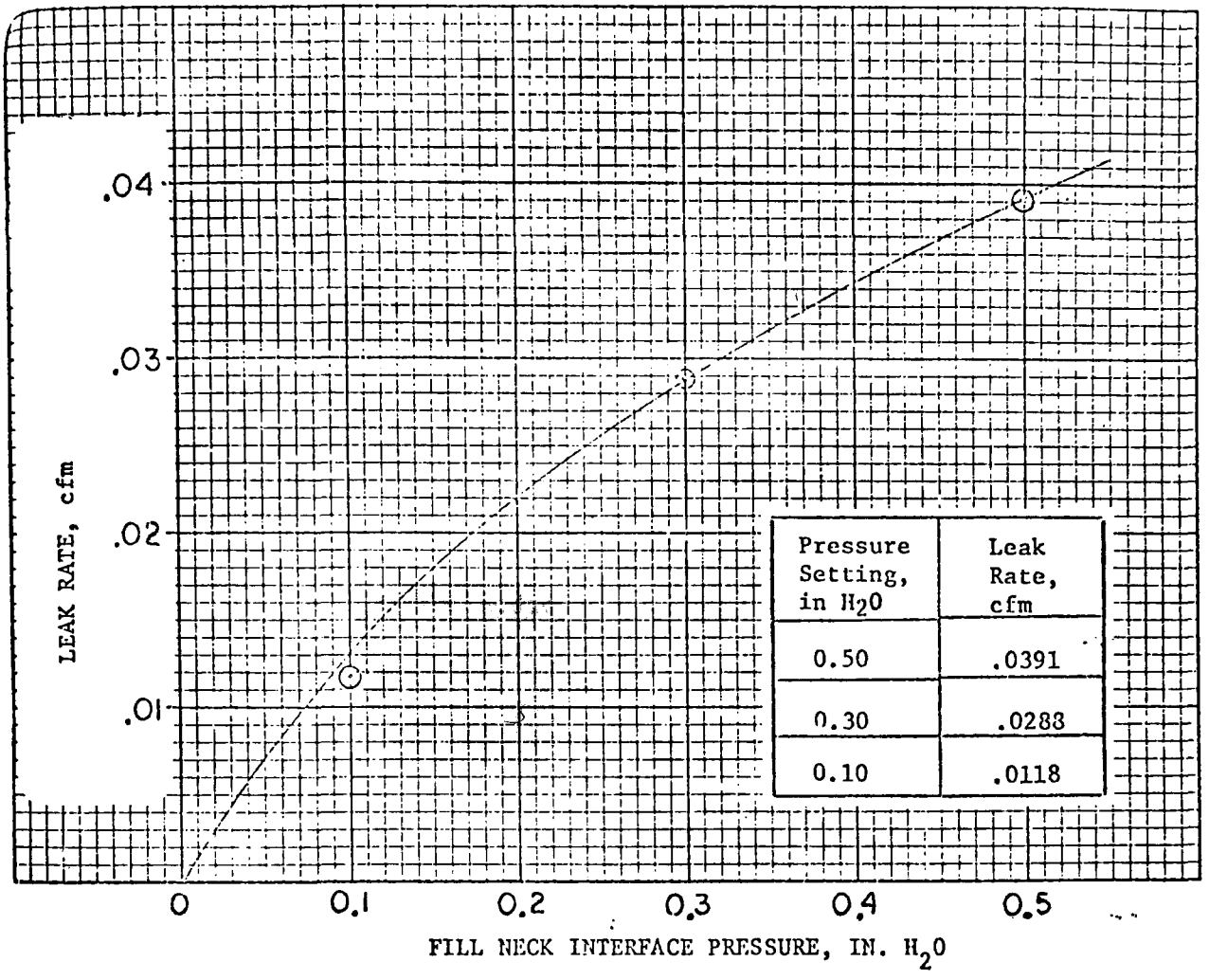
CHCL; Total hydrocarbons leaked corrected to 70° F. and 29.92 inches Hg, grams

HCLR; Hydrocarbons leaked per gallon of dispensed fuel, grams/gallon

$$CHCL = \frac{17.71 \times OHCL \times P_a}{T_r + 460} = \frac{17.71 \times 1.044 \times 29.86}{60 + 460} = 1.06 \text{ grams}$$

$$HCLR = CHCL/V_l = 1.06/14.29 = 0.07 \text{ grams/gallon}$$

EXAMPLE DATA MEASUREMENTS (LEAK RATE METHOD)



Pressure Setting, in H_2O	Leak Rate, cfm
0.50	.0391
0.30	.0288
0.10	.0118

Time Interval	Time, Min.	Avg. Press.	Leak Rate, cfm	HC % P ÷ 100	Dens. Factor*	HC Loss, Grams
1	.25	.13	.0160	.630	51.7	.130
2	.25	.12	.0150	.710	51.7	.138
3	.25	.10	.0130	.740	51.7	.124
4	.25	.10	.0130	.770	51.7	.129
5	.25	.10	.0130	.780	51.7	.131
6	.25	.09	.0120	.795	51.7	.123
7	.25	.08	.0108	.795	51.7	.111
8	.25	.08	.0108	.810	51.7	.113
9	.10	.08	.0108	.810	51.7	.045
	2.10					1.044

*Density factor for propane of 51.7 grams/ft^3 @ 70° F. & 1 atmosphere

Calculation of Fleet Emissions (Baseline Method)

ΣM_r; Sum of all the returned hydrocarbons from test vehicles (excluding hand-held cases)

ΣM_p; Sum of all the potentially recoverable hydrocarbons from same test vehicles (obtained from regression analysis)

ΣM_{vp}; Sum of all the emissions vented from underground tank supplying product under test

ΣV_s; Sum of all the fuel dispensed from underground tank supplying product under test

$(M/L)_{e'}$; Hydrocarbon emission rate (@ dispensing island), grams/gallon

$(M/L)_{e''}$; Hydrocarbon emission rate (@ underground tank vent pipe), grams/gallon

$(M/L)_e$; Overall hydrocarbon emission rate for Stage II

$(M/L)_{e'}$; $\frac{\Sigma M_p - \Sigma M_r}{\Sigma V_1}$

$(M/L)_{e''}$; $\Sigma M_{vp}/\Sigma V_s$

$(M/L)_e$; $(M/L)_{e'} + (M/L)_{e''}$

Calculation of Fleet Emissions (Leak Rate Method)

Σ CHCL; Sum of the corrected total hydrocarbons leaked

$(M/L)_{e'}$; Σ CHCL/Σ V_1

$(M/L)_{e''}$; Σ M_{vp}/Σ V_s

$(M/L)_e$; $(M/L)_{e'} + (M/L)_{e''}$

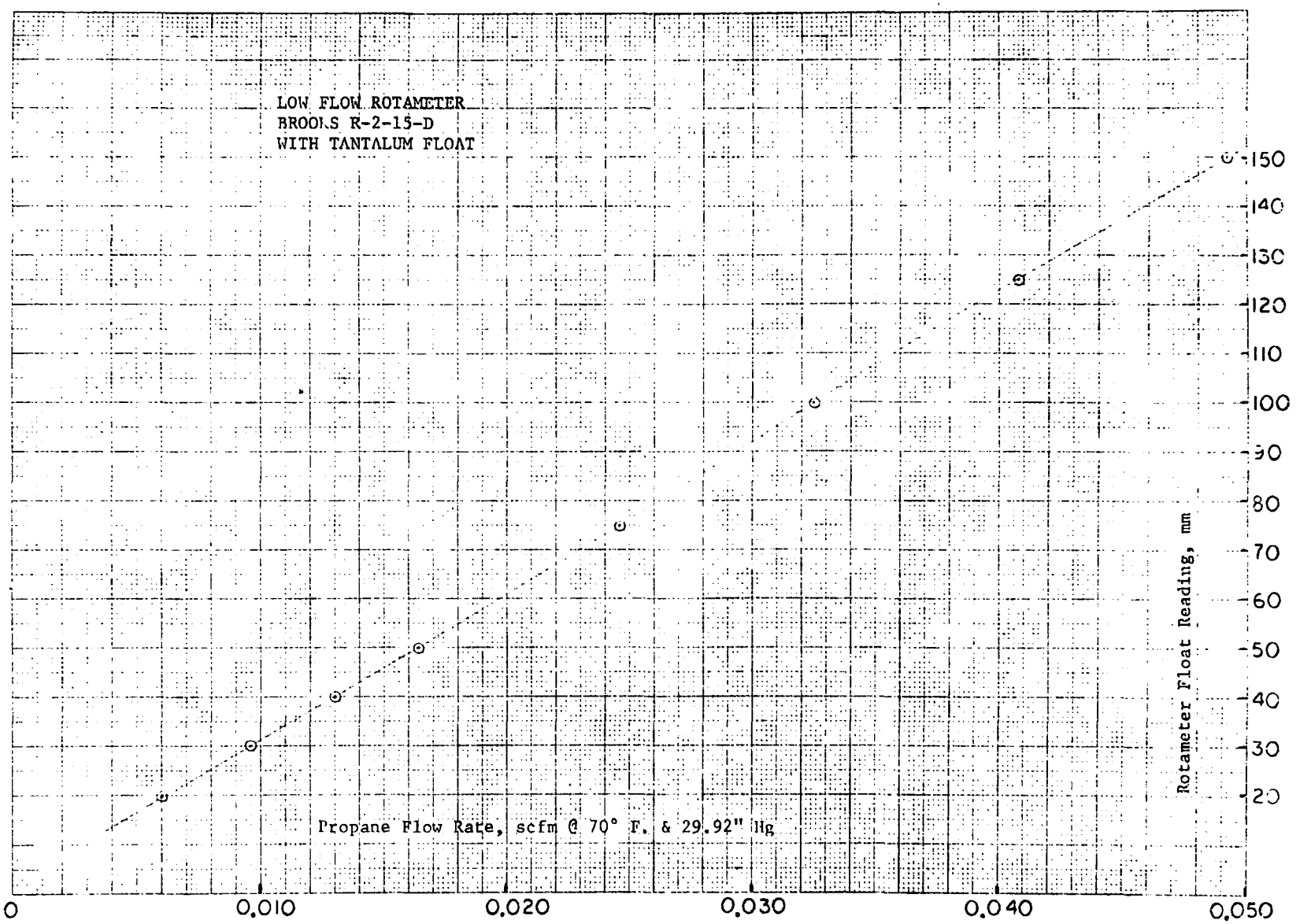
APPENDIX A

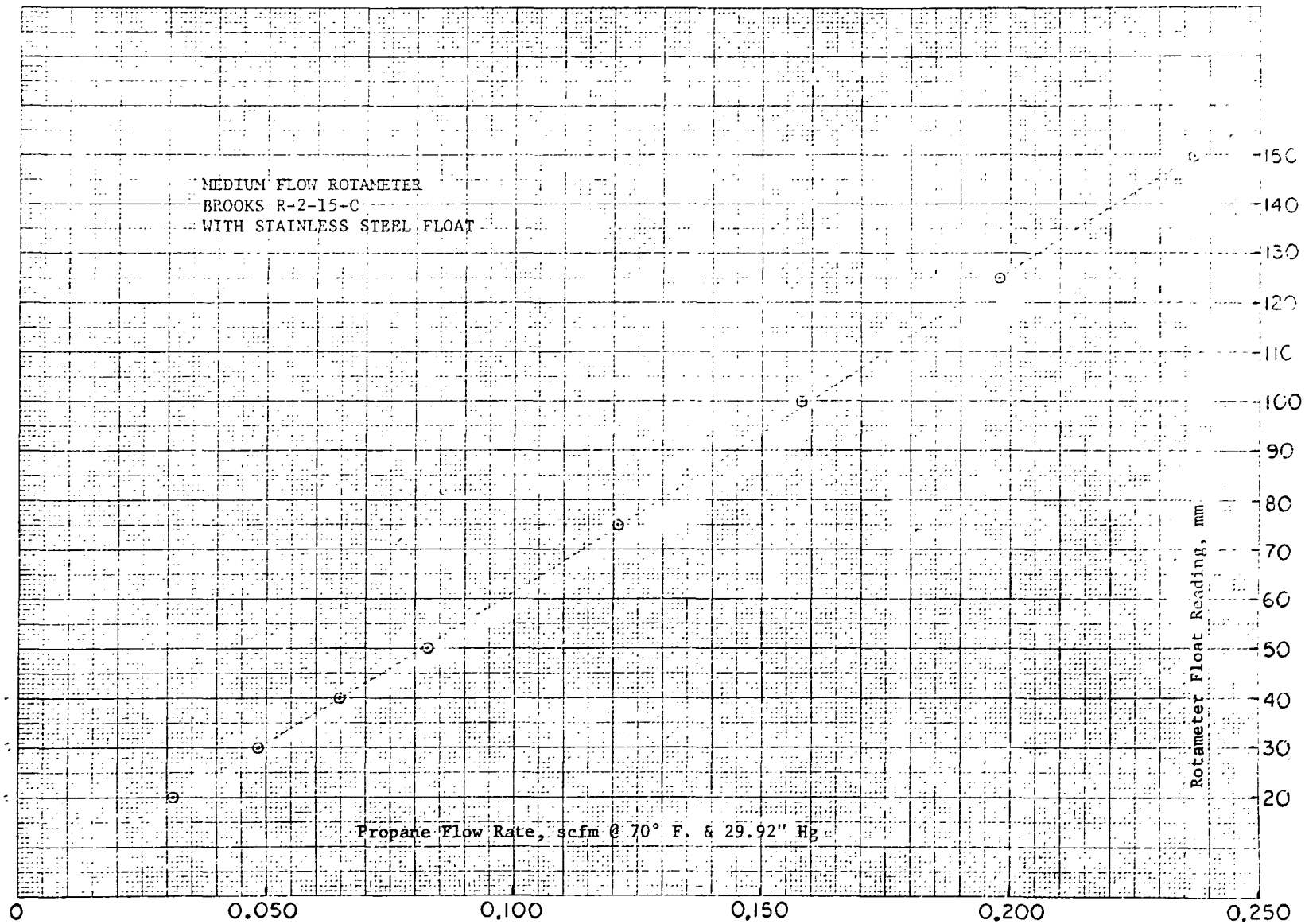
Calibration Data

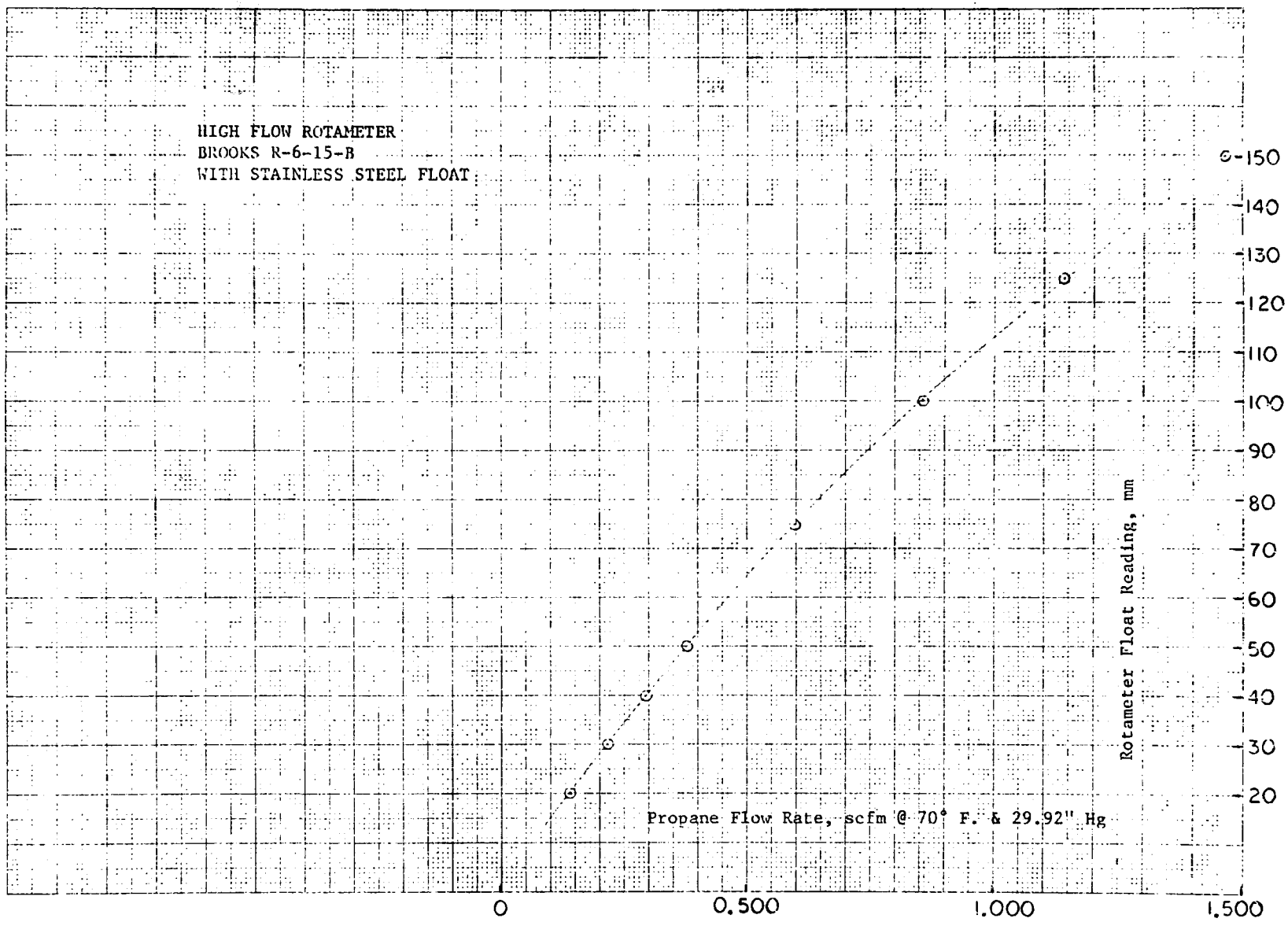
CALIBRATION DATA FOR
DRESSER 1.5 METER
(MODIFIED BY RED JACKET WITH OPTICAL REVOLUTION COUNTER)

	Test 1	Test 2
Observed Total Flow on American DTM-200 Dry Test Meter, ft^3	8.373	2.114
Dresser Meter Revolutions	752	188
Cubic Feet/Revolution	0.01113	0.01124
Nominal Flow Rate, GPM	7.85	2.62

NOTE: The calibration check was performed with the Dresser Meter in series (downstream) from the American DTM-200 Dry Test Meter. Air was flowed through both meters at approximately 68° F. and 28.96 inches HG pressure. The nominal flow rates represent expected gasoline vapor flow rates when fuel is dispensed using the middle and slow latch setting of an automatic dispensing nozzle.


LOW FLOW ROTAMETER
BROOKS R-2-15-D
WITH TANTALUM FLOAT
Propane Flow Rate, scfm @ 70° F. & 29.92" Hg
Rotameter Float Reading, mm
0
0.010
0.020
0.030
0.040
0.050
20
30
40
50
60
70
80
90
100
110
120
130
140
150


MEDIUM FLOW ROTAMETER
BROOKS R-2-15-C
WITH STAINLESS STEEL FLOAT
Propane Flow Rate, scfm @ 70° F. & 29.92" Hg
Rotameter Float Reading, mm
0
0.050
0.100
0.150
0.200
0.250
20
30
40
50
60
70
80
90
100
110
120
130
140
150


HIGH FLOW ROTAMETER
BROOKS R-6-15-B
WITH STAINLESS STEEL FLOAT
Rotameter Float Reading, mm
150
140
130
120
110
100
90
80
70
60
50
40
30
20
Propane Flow Rate, scfm @ 70° F. & 29.92" Hg
0
0.500
1.000
1.500

FLOW RATE TABLE--Rotameter #R-2-15-D; tant. float ser. #003

mm*	scfm**
24	.0073
5	.0076
6	.0080
7	.0083
8	.0086
9	.0089
30	.0092
1	.0095
2	.0098
3	.0101
4	.0104
35	.0108
6	.0111
7	.0114
8	.0117
9	.0120
40	.0124
1	.0127
2	.0131
3	.0134
4	.0137
45	.0141
6	.0144
7	.0147
8	.0150
9	.0153
50	.0157
1	.0160
2	.0163
3	.0166
4	.0169
55	.0172
6	.0176
7	.0179
8	.0183
9	.0186
60	.0189
1	.0192
2	.0195
3	.0198
4	.0201
5	.0204

mm*	scfm**
66	.0207
7	.0210
8	.0214
9	.0217
70	.0220
1	.0223
2	.0226
3	.0229
4	.0232
75	.0235
6	.0238
7	.0241
8	.0245
9	.0248
80	.0251
1	.0254
2	.0257
3	.0260
4	.0263
85	.0266
6	.0269
7	.0272
8	.0275
9	.0278
90	.0281
1	.0284
2	.0287
3	.0290
4	.0293
95	.0296
6	.0299
7	.0302
8	.0305
9	.0308
100	.0311
1	.0314
2	.0317
3	.0320
4	.0323
105	.0326
6	.0330
7	.0333

mm*	scfm**
108	.0336
9	.0339
110	.0342
11	.0345
12	.0348
13	.0351
14	.0355
115	.0358
16	.0361
17	.0364
18	.0367
19	.0370
120	.0373
1	.0376
2	.0380
3	.0383
4	.0386
125	.0389
6	.0392
7	.0395
8	.0398
9	.0402
130	.0406
1	.0409
2	.0412
3	.0415
4	.0418
135	.0422
6	.0425
7	.0428
8	.0431
9	.0434
140	.0438
1	.0441
2	.0445
3	.0448
4	.0451
145	.0454
6	.0457
7	.0460
8	.0464
9	.0467
150	.0471

*Reading at top edge of ball float
**Scfm of propane @ 70° F.

2-4-76
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FLOW RATE TABLE--Rotameter #R-2-15-C; st. st. float ser. #002

mm*	scfm**
24	.0383
5	.0400
6	.0417
7	.0434
8	.0451
9	.0468
30	.0485
1	.0501
2	.0518
3	.0534
4	.0551
35	.0567
6	.0584
7	.0600
8	.0617
9	.0633
40	.0650
1	.0666
2	.0683
3	.0699
4	.0716
45	.0732
6	.0749
7	.0765
8	.0782
9	.0798
50	.0815
1	.0831
2	.0848
3	.0864
4	.0881
55	.0897
6	.0914
7	.0930
8	.0947
9	.0963
60	.0980
1	.0996
2	.1010
3	.1026
4	.1042
5	.1058

mm*	scfm**
66	.1074
7	.1090
8	.1107
9	.1124
70	.1140
1	.1155
2	.1171
3	.1196
4	.1212
75	.1227
6	.1243
7	.1258
8	.1274
9	.1289
80	.1295
1	.1310
2	.1326
3	.1341
4	.1357
85	.1372
6	.1388
7	.1403
8	.1419
9	.1434
90	.1450
1	.1465
2	.1480
3	.1495
4	.1510
95	.1525
6	.1540
7	.1555
8	.1570
9	.1585
100	.1600
1	.1615
2	.1630
3	.1645
4	.1660
105	.1675
6	.1690
7	.1705

mm*	scfm**
108	.1720
9	.1735
110	.1750
11	.1765
12	.1780
13	.1795
14	.1810
115	.1825
16	.1840
17	.1855
18	.1870
19	.1885
120	.1900
1	.1916
2	.1932
3	.1948
4	.1964
125	.1980
6	.1996
7	.2012
8	.2028
9	.2044
130	.2060
1	.2075
2	.2090
3	.2105
4	.2120
135	.2135
6	.2150
7	.2165
8	.2180
9	.2195
140	.2210
1	.2227
2	.2244
3	.2261
4	.2278
145	.2295
6	.2312
7	.2329
8	.2346
9	.2363
150	.2380

*Reading at top edge of ball float
**Scfm of propane @ 70° F.

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FLOW RATE TABLE--Rotameter #R-6-15-B; st. st. float ser. #001

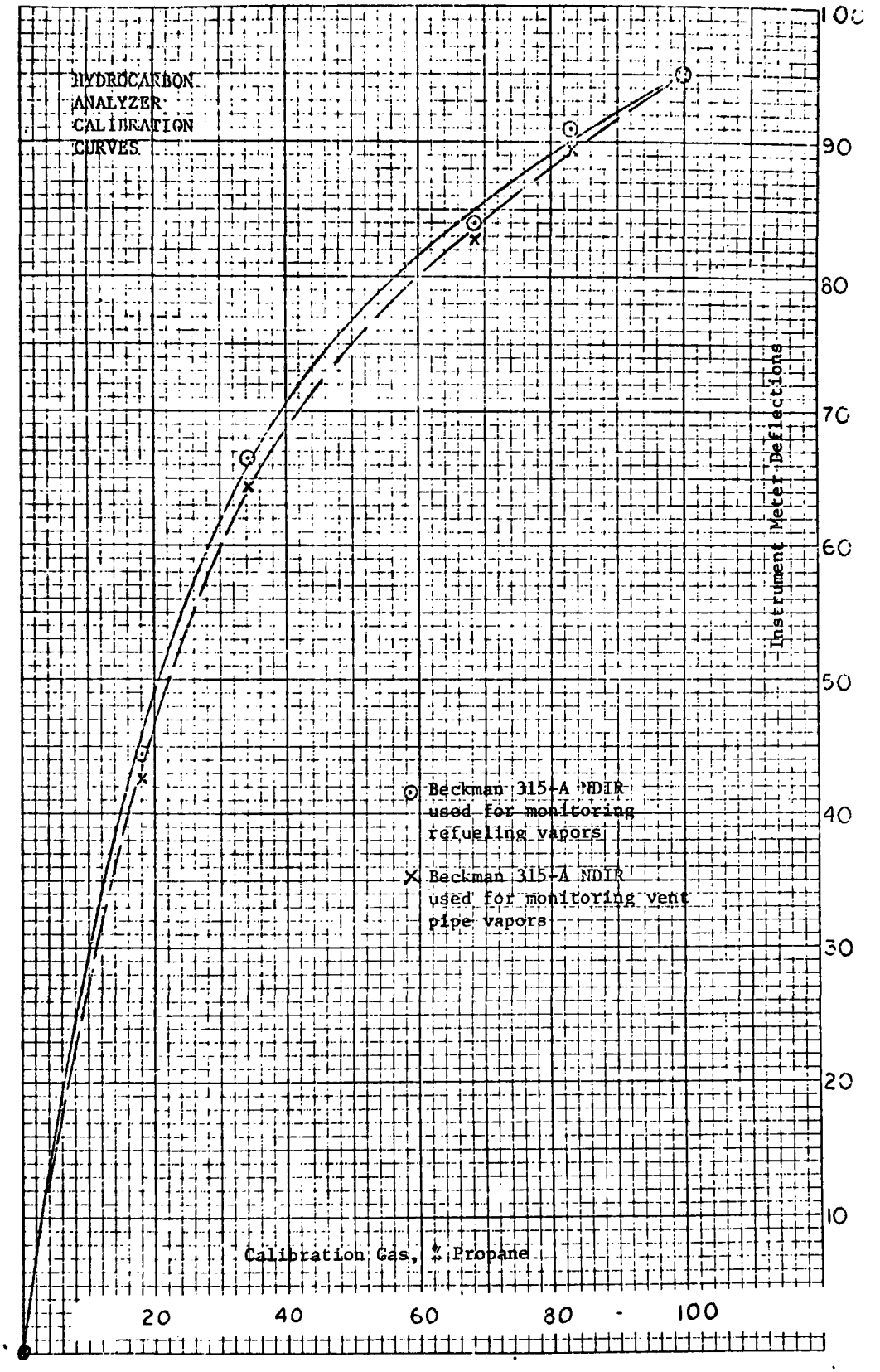
mm*	scfm**
24	.167
5	.175
6	.183
7	.191
8	.199
9	.207
30	.215
1	.223
2	.231
3	.239
4	.247
35	.255
6	.263
7	.271
8	.279
9	.287
40	.295
1	.303
2	.311
3	.319
4	.327
45	.335
6	.343
7	.351
8	.359
9	.367
50	.375
1	.383
2	.392
3	.400
4	.409
55	.417
6	.426
7	.434
8	.443
9	.451
60	.460
1	.469
2	.478
3	.487
4	.496
5	.505

mm*	scfm**
66	.514
7	.523
8	.532
9	.541
70	.550
1	.559
2	.569
3	.578
4	.588
75	.597
6	.607
7	.616
8	.626
9	.635
80	.645
1	.655
2	.665
3	.675
4	.685
85	.695
6	.705
7	.715
8	.725
9	.735
90	.745
1	.755
2	.766
3	.776
4	.787
95	.797
6	.808
7	.818
8	.829
9	.839
100	.850
1	.861
2	.872
3	.883
4	.895
105	.906
6	.917
7	.928

mm*	scfm**
108	.940
9	.951
110	.962
11	.974
12	.986
13	.998
14	1.011
115	1.023
16	1.035
17	1.047
18	1.060
19	1.072
120	1.084
1	1.096
2	1.109
3	1.121
4	1.134
125	1.146
6	1.159
7	1.171
8	1.184
9	1.196
130	1.209
1	1.221
2	1.234
3	1.246
4	1.258
135	1.270
6	1.283
7	1.295
8	1.308
9	1.320
140	1.333
1	1.346
2	1.359
3	1.372
4	1.385
145	1.399
6	1.412
7	1.425
8	1.438
9	1.451
150	1.464

*Reading at top edge of ball float
**Scfm of propane @ 70° F.

2-4-76
MJM


HYDROCARBON
ANALYZER
CALIBRATION
CURVES
Beckman 315-A NDIR
used for monitoring
refueling vapors
Beckman 315-A NDIR
used for monitoring vent
pipe vapors
Calibration Gas, % Propane
Instrument Meter Deflections
10
20
30
40
50
60
70
80
90
100
20
40
60
80
100

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Report describes field evaluation of a Red Jacket "Aspirator Assist" vapor control system and a comparison with results from a test of a vapor balance system. Two different measurement approaches are compared and a combination of the two methods is used to calculate hydrocarbon emissions.

Approximately 100 vehicles were used to test each system. Besides vapor measurements made during the vehicle refueling operations, vent pipe emissions were determined and added to the total emissions calculations.

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