California Environmental Protection Agency

Air Resources Board

Gasoline Dispensing Facility (GDF)
Vacuum-Assist and Conventional Hose
Permeation Study

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Introduction

During July, August and September of 2009, California Air Resources Board (ARB) staff conducted testing to determine permeation rates of vacuum assist and conventional gasoline dispensing facility (GDF) hoses used in California. Staff was also interested in characterizing the effects of test fuel degradation on observed permeation rates.

Staff initially selected five nearly identical samples of vacuum assist style vapor recovery hose to undergo testing. Because a vacuum assist hose carries fuel against its outer hose wall, it is substantially similar to a conventional fuel hose when considering permeation performance. Therefore, for testing simplification, conventional hoses were assumed to permeate at the same rate as vacuum assist hoses. An additional vacuum assist hose used in previous 2004 ARB hose permeation testing was brought into the trial several weeks after the study began in order to help understand differences between observed permeation rates from current and previous ARB permeation testing. The hoses were filled with California summer blend commercial pump fuel (CaRFG 3 with 6% ethanol) and placed in a testing chamber where temperature was recorded continuously throughout the testing. Hoses were weighed daily over the course of the testing and permeation results were calculated from the observed mass losses.

ARB staff estimates, based upon observations within this paper, that average vacuum assist style and conventional GDF hoses, when subjected to an average temperature of 71.9°F (22.2°C), and filled with summer blend CaRFG 3 (pump fuel) with 6% ethanol, permeate at a rate of approximately 77.4 g/m^2/day. However, this can vary significantly for different manufacturer's constructions.

ARB staff observed that test fuel degradation (multi-constituent fuel change due to different constituents leaving the fuel at different rates), beyond a mass loss of approximately 5%, leads to a reduction of permeation rates. If not corrected for during testing, this will lead to an underestimation of actual emissions. It is possible that this effect may be present for test fuel degradations corresponding to fuel mass loss slightly lower than 5%, but temperature fluctuations in this area of the data set made this impossible to determine.

Note that permeation results are highly dependent upon temperature, permeate type (fuel type) and permeation barrier material (hose material type). ARB staff tested one type of fuel, used an uncontrolled temperature profile and did not prescribe hose materials in manufacturer hose constructions, therefore, ARB staff realizes that the results from this study provides the basis for a rough estimate of emissions from GDF hoses.

Background

It is part of ARB's mission to promote and protect the public health and welfare through the effective and efficient reduction of air pollutants. In carrying out this mission, ARB has sought to control hydrocarbon emissions at GDFs in California since 1975. Hydrocarbon emissions are reactive organic gases which can react in the atmosphere to form photochemical smog. Recently, ARB staff has identified GDF hoses as a source of uncontrolled reactive organic gas emissions due to gasoline's ability to permeate through common GDF hose materials.

California GDFs, which are permitted by the local air pollution control districts, in most cases must use vapor recovery style hose. Vapor recovery hose is different from conventional fuel delivery hose in that it has two paths: one for fuel delivery and the other for vapor return. There are two different styles of vapor recovery hose: balance and vacuum assist. For permeation purposes, vacuum assist hoses are similar to conventional fuel delivery hoses in that the liquid fuel is carried against the inside of the outer hose wall (Figure 1).

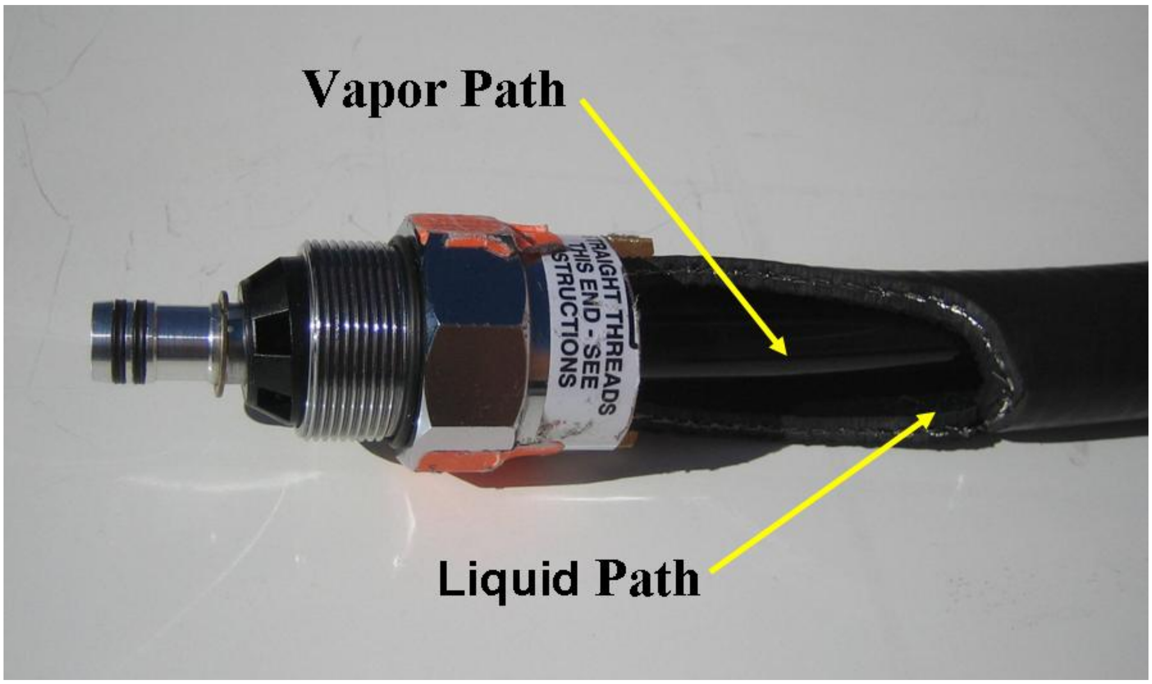


Figure 1 Vacuum assist style vapor recovery GDF hose showing vapor and liquid paths.

In 2004, ARB staff conducted a GDF hose permeation test as an initial attempt to try to estimate the amount of reactive organic gasses which were being emitted in California from GDF hoses.[1] That testing did not address test fuel degradation throughout the testing period and it did not characterize vapor concentrations in the balance hose vapor path. In 2008 ARB staff conducted a balance GDF hose permeation test to estimate permeation rates in these hoses for a saturated vapor[2]. The permeation test discussed in this paper is an attempt to more accurately estimate permeation emissions from vacuum assist and conventional style GDF hoses when controlling for the effects of fuel degradation.

Test Protocol

For approximately 60 days, from July 16th to September 14th of 2009, ARB staff conducted in-house gravimetric permeation testing of 6 vacuum assist style vapor recovery GDF hoses under non-controlled ambient conditions. The hoses were placed on racks within fuel storage cabinets in a fuel storage room throughout the testing (Figure 2). Hoses were removed from this environment daily only for the purpose of recording weight and refreshing fuel (dumping old test fuel in the hose and replacing with fresh test fuel). Time was recorded for all weighings during the test. Permeation rates were attributed to the weigh loss over each time period.

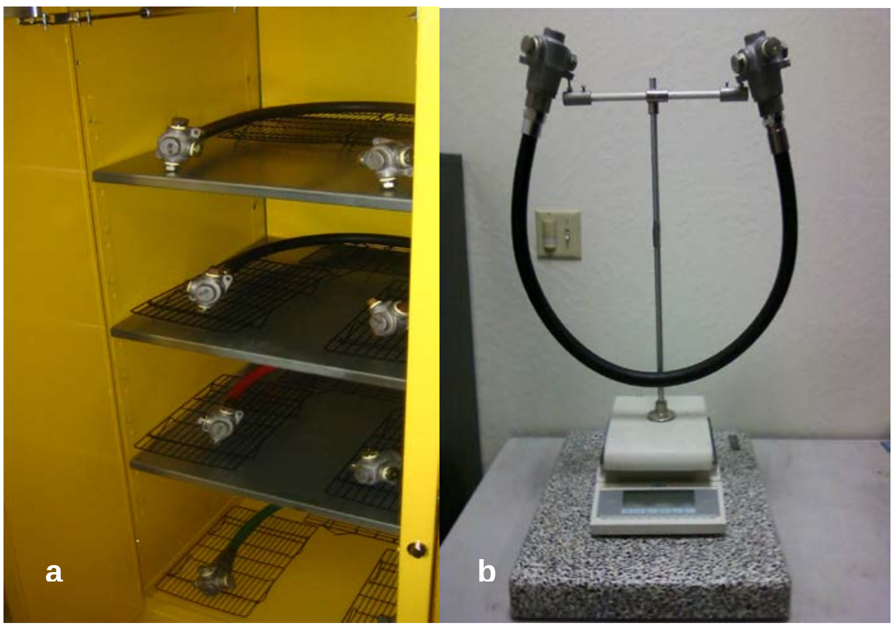


Figure 2 (a) Hoses in testing room. (b) Hose being weighed.

Testing room temperature was continuously recorded via a data logger over the course of the testing. Temperature was only controlled to the extend that building temperature controls limited the temperatures to diurnal swings of an average of 8.6 °F (4.8°C) at an average temperature of 71.9°F (22.2°C) throughout the testing. Testing data and average temperatures can be viewed in Attachment 1. Although it would have been preferable to control testing temperature more precisely, staff was able to observe clear trends in the data and draw conclusions.

Staff initially selected five nearly identical vacuum assist hoses for this testing. For the purpose of identification, these hoses were labeled V1 through V5. These hoses were each measured to be approximately 49 inches in length as measure from o-ring flange to o-ring flange. The average internal diameters were approximately 3/4 inches. The hoses had been used in a previous tests conducted by ARB staff in the summer of 2006 to observe fuel temperature profiles in GDF hoses. The hoses had been filled with summertime pump fuel and hung outdoors in various degrees of shade for approximately 3 months. Staff believes that this exposure was beneficial in that helped to precondition the hoses to behave more closely to hoses taken from actual service. Because the inner vapor path (Figure 1) of each hose was not of any importance in this permeation test, the inner path (hose) was removed from each sample.

An additional vacuum assist hose, labeled V6 was added on Day 19 of the testing. The reason for this addition was that hoses V1 through V5 were permeating at a rate significantly lower than previous vacuum assist hoses observed by ARB staff. Therefore, staff introduced hose V6 into the trial, which had been used in previous ARB permeation testing, to try to detect any possible control errors that staff was not aware of. Hose V6 was also a vacuum assist hose, but from a different manufacturer than hoses V1 though V5. Hose V6 permeated at rates consistent with its performance in previous ARB testing. This demonstrated to staff that there were no undetected control errors within the testing. Hose V6 was measured to be approximately 54 inches in length as measure from o-ring flange to o-ring flange. The average internal diameter was approximately 3/4 inches. As with samples V1 through V5, the inner vapor path (hose) was removed from V6.

On July 16, 2009, approximately 15 gallons of California summer blend commercial pump fuel (CaRFG 3) was purchased from a local station of a major brand name retailer to use as test fuel. The fuel was dispensed into three 5 gallon low permeation ARB certified portable fuel containers. The test fuel was weighed throughout the testing to control for any fuel degradation not related to the hose permeation testing. Further, fuel samples were collected before and after testing for laboratory analysis to observe differences in test fuel due to permeation.

On Friday, July 17th, the first day of testing, each of the hoses was weighed empty, then filled with 0.5 liters of test fuel (approximately 90% of each hose's capped volume). The hoses were immediately capped after filling, then weighed. The hoses were placed in the testing room and allowed to precondition for approximately 4 days, at which point they were pulled from the testing room and their weights recorded. These weighings were repeated daily throughout the testing which terminated on September 14th, 2009. In a few instances, due to resource constraints, daily weighings were missed. In these cases, the weight loss was averaged over the effected period.

It was staff’s intent during this testing to try to control for fuel degradation when determining the steady state permeation rate by keeping fuel loss within each hose to less than 2%. At day 7 of testing, staff determined that some hoses were approaching 2% fuel loss. Therefore, staff emptied and refilled each hose with approximately 0.5 liters of fuel, then placed them back in the testing room. Staff continued to control for fuel degradation to 2% fuel loss in this manner for hoses V1 through V5 until day 27 of the testing. From this point, staff determined that there was sufficient data to estimate steady state permeation for hoses V1 through V5, so staff began to experiment with controlling fuel degradation to various levels of fuel loss until day 39. After this point, fuel refreshing was discontinued for hoses V1 through V5. Due to an unexpected spike in the fuel loss on hose V6 on day 32, Staff continued controlling fuel degradation to 2% in this sample until day 46. After this point, fuel refreshing was discontinued for hose V6 as well.

Fuel refreshing for of all six hoses generally took about 1.5 hours. In order to correct for this time in which permeation was not being measured, time that elapsed between taking the weight of all of the hoses before fuel refreshing and taking the weight of all of the hoses after fuel refreshing was omitted from permeation calculations so as not to underestimate emissions.

Throughout the testing, the hose caps were inspected daily, both visually and by smell, for fuel leaks so as to avoid biasing permeation rates with weight loss due to leakage. In a few cases, leaks were detected and followed up with immediate corrective action by staff.

On day 10, strong gasoline odor was detected at the threads for hose sample V5. It can also be observed from the graph (Attachment 2) that hose V5 was loosing weight at a much higher rate than the other hoses at this point. Staff tightened the cap threads for V5 which appears to have had the effect of reducing the weight loss from hose V5 back to the levels of hoses V1 through V4.

On day 20, strong gasoline odor was detected at the threads for hose sample V6. This can also be observed from the graph (Attachment 3) showing a spike in the weight loss data for hose V6 at this point. Staff tightened the cap threads on V6 which resulted in an immediate and significant decrease in weight loss from this hose.

On day 21, when uncapping hose V2 in the process of performing fuel refreshing, staff broke an o-ring seal. Staff immediately installed a new replacement o-ring. However, staff noted that the new o-ring had a slightly smaller material diameter, resulting in a looser fit in the o-ring seat. Staff noted that for next several weeks of testing, weight loss measurements were erratic and typically significantly exceeded the weight loss of all of the other hoses (Attachment 2). This effect seemed to go away after day 38 of the testing which also corresponds closely to the time that fuel refreshing was stopped for this hose. Because staff determined the steady state permeation rate for hoses V1 through V5 before the o-ring broke on hose V2, this incident is largely interesting in that it provides an opportunity for observation of how an o-ring defect may generate emissions.

No further episodes of leakage were detected throughout the testing.

Test Results

It was staff's intent to determine the steady state permeation rate for vacuum assist and conventional hoses when using CaRFG 3 with 6% ethanol for a given temperature. For the purposes of this paper, steady state permeation is loosely defined as a permeation rate which appears to change very little when testing conditions (temperature and test fuel composition) are held constant. Because temperature was not able to be controlled precisely, staff needed to monitor the data as it was generated closely to make this determination and only an approximate determination could be made. Technical papers published by the Society of Automotive Engineers (SAE) suggest that a change in temperature of 1°C typically results in a permeation change of approximately 10%.[3,4] Also, as discussed earlier, staff attempted to control test fuel composition by refreshing the fuel within the hoses before 2% fuel loss occurred. Note that 2% limit is the limit given in SAE's most rigorous test procedure for low permeation fuel hoses, SAE J1737.[5]

Staff calculated daily permeation rates for each hose by dividing the daily weight loss by the hose's internal surface area. Staff calculated the internal hose surface areas of V1 through V5 to be approximately 115.5 in^2 (0.074 m^2). Staff calculated the internal hose surface area of V6 to be approximately 127.2 in^2 (0.082 m^2).

Staff determined that steady state conditions were best represented for hoses V1 through V5 from testing days 11 through 18, where average fuel mass loss did not exceed 1.2% (Attachment 2) and the average daily temperature varied by 2.5°F (1.4°C). The average steady state permeation rate of hoses V1 to V5 during this period was calculated to be 59.0 g/m^2/day.

Determining steady state for V6 was complicated by a spike in the percent fuel loss from days 29 through 33 (Figure 3). From past testing staff would have expected to see the permeation rate plateau at day 29, where we see the trend from the preceding day peak at approximately 101.9 g/m^2/day. Staff then expected this to be followed by a slight decline. However, due to resource constraints, staff was not available to perform fuel refreshing at this point, although weighing data was collected. This disturbance in fuel composition due to fuel degradation caused a steep drop in the permeation rate of V6. From the data, staff determined that steady state conditions were best represented for hose V6 from testing days 29 through 46, where except for the spike from days 29 to 33 average fuel mass loss did not exceed 2% and the average daily temperature varied by 0.5°F (0.3°C). Staff determined that the best way to estimate steady state permeation rate for this period would be to average the rates at the beginning (101.9 g/m^2/day) and end (89.6g/m^2/day) of this period. From this method, staff determined that the average steady state permeation rate of hose V6 during this period was 95.9 g/m^2/day.

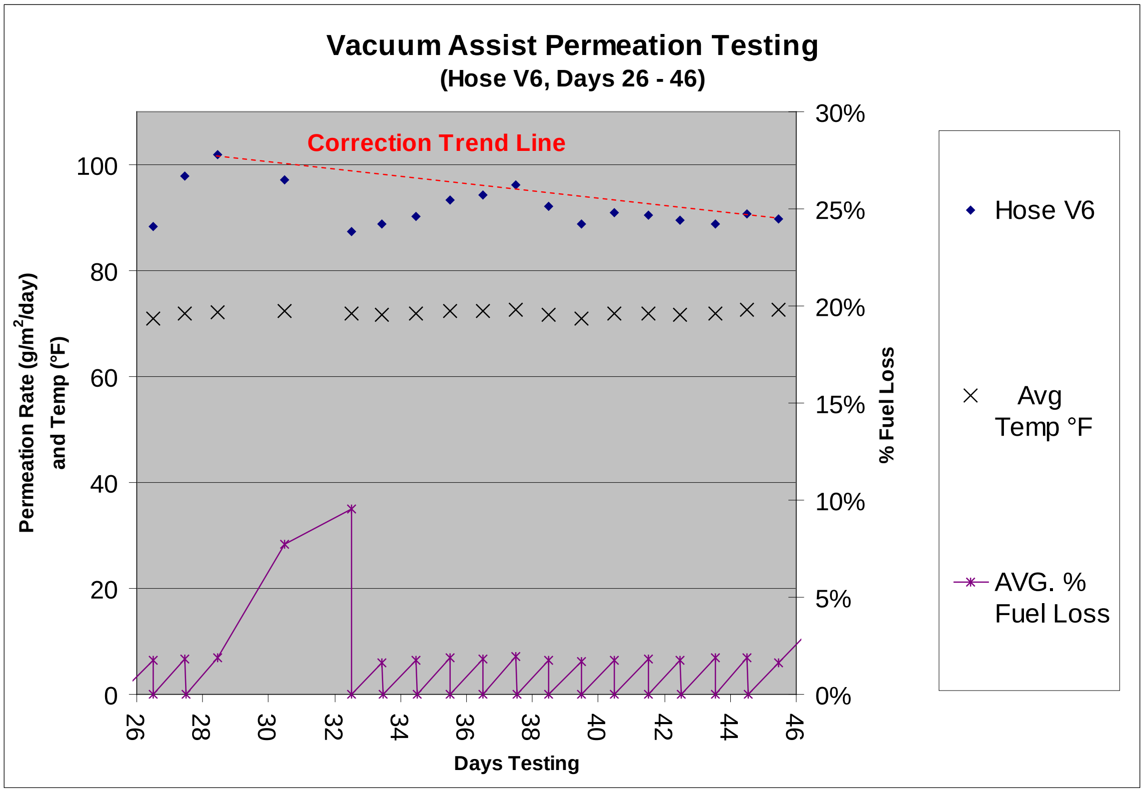


Figure 3 Trend line correction for hose V6 to estimate steady state permeation rate.

Because there are no construction standards that favor one design of vacuum assist hoses over another, staff has determined that it is appropriate to use the average of these rates when estimating uncontrolled permeation emissions from vacuum assist and conventional hoses. By averaging the permeation rates of the two different vacuum assist hose constructions considered, staff estimates the uncontrolled steady state permeation rate for vacuum assist hoses to be 77.4 g/m^2/day for the testing conditions. Because conventional hoses are substantially similar to vacuum assist hoses when considering permeation, staff also estimates that 77.4 g/m^2/day is the uncontrolled permeation rate for conventional GDF hoses as well.

Fuel Analysis

Samples of both the original test fuel and spent test fuel were taken and subjected to laboratory analysis. The purpose of this testing was to observe any constituents that may permeate at higher rates than the average constituent, as this information may prove valuable for future permeation analysis. Due to a lack of testing resources, the fuel was only examined for criteria which ARB performs active enforcement. The results of the analysis are given in Table 1.

Table 1: Test Fuel Analysis

Test criteria	Original Test Fuel	Spent Test Fuel	Units	Test Method
Ethanol	5.4	2.2	%V	ASTM D4815-99
Toluene	6.82	5.31	%W	ASTM D5580-00
Benzene	0.630	0.428	%V	ASTM D5580-00
E-Benzene	1.62	1.45	%W	ASTM D5580-00
m,p - Xylene	6.26	5.38	%W	ASTM D5580-00
o - Xylene	2.25	2.39	%W	ASTM D5580-00
Olefins	3.5	3.4	%V	ASTM D6550-00 (modified)
Total Aromatics	26.8	25.1	%V	ASTM D5580-00
C9+ (carbon chains of 9 or greater)	13.1	13.5	%W	ASTM D5580-00
Sulfur	5	60	ppm	ASTM D5453-93
Specific Gravity	0.747	0.749		ASTM D4052-96
RVP (Reid Vapor Pressure)	6.74	6.22	PSI	13 CCR Section 2297
T50 (Temp at which 50% boils off)	215	221	°F	ASTM D86-99
T90 (Temp at which 90% boils off)	313	321	°F	ASTM D86-99

An important observation is that 68% of the ethanol permeated out during the test period while only 22% of the overall test fuel was lost through permeation. This observation is consistent with other studies that have shown ethanol tends to permeate at a higher rate than other fuel constituents.[6,7]

A striking observation is that sulfur appears to have increased in concentration by over 1100% during the testing. This increase is not consistent with a simple concentration increase for a non-permeating constituent corresponding to a 22% total loss in fuel. Therefore, staff assumes that this may be due to sulfur entering the fuel from the hose material.

Another noteworthy observation is that 47% of the benzene permeated out during the test period while only 22% of the overall test fuel was lost through permeation. Since Benzene is listed by the EPA as a Toxic Air Pollutant, and is a known carcinogen, it is important to note that not only can this substance be emitted into the atmosphere via permeation, but that is appears to permeate at a higher rate than many other fuel constituents.

Another observation that staff drew from this permeation study is the overall importance of controlling for fuel degradation, or test fuel composition. The final mass loss data taken for hoses V1 through V5 in this study shows an average permeation rate of 33.3 $g/m^2/day$. This average rate also corresponds to a total average fuel loss from these hoses of 22.1% by mass. With a fuel loss of only 22.1%, the permeation rate has fallen from its steady state permeation rate of 59.0 $g/m^2/day$ by more than 44% (Attachment 2). A similar trend can also be seen for V6 (Attachment 3) Such a large percent change in permeation rate corresponding to a much smaller percent loss in fuel mass greatly highlights the importance of controlling for fuel degradation when reporting steady state permeation rates.

Conclusion

Based upon the testing data discussed in this paper, ARB staff estimates that the liquid, and saturated vapor, steady state permeation rate for vacuum assist style GDF hoses is 77.4 $g/m^2/day$ when using CaRFG 3 summer blend fuel with 6 % ethanol at an average temperature of 71.9°F (22.2°C). ARB staff also observed that to avoid under reporting of steady state permeation rates during testing, test fuel degradation should be minimized to the greatest extent possible. Staff observed that fuel loss within the sample of over 5% of the total fuel mass led to lower permeation rates due to fuel degradation. ARB staff further observed that ethanol permeates at a much greater rate than many of the other fuel constituents which make up CaRFG 3 summer blend fuel. This may be an especially important consideration in light of many proposals to increase ethanol content in fuels nationwide. Although these observations offer valuable insight into the understanding of emissions from GDF hoses, ARB staff concludes that these numbers are conservative. ARB staff intends to do a larger and more rigorously controlled GDF hose permeation test in the near future to better estimate actual statewide emissions from this source.

Works Cited

[1] California Air Resources Board (CARB), "GDF Hose Permeation Study Review", 29, Oct. 2007, <http://www.arb.ca.gov/vapor/gdfhe/gdfpermreport07.pdf>.

[2] California Air Resources Board (CARB), "Gasoline Dispensing Facility (GDF) Balance Hose Permeation Study", 19, June 2008, <http://arb.ca.gov/vapor/gdfhe/arb_gdf_balancehose_permeation_report_08_posted.pdf>.

[3] Fuel Filler Pipe Assembly Design Practice to Meet Low Evaporative Emission Requirements: SAE J2599. Society of Automotive Engineering Surface Vehicle Recommended Practice, REV. APR 2003, pp. 12.

[4] Lockhart, M., Nulman, M., Rossi, G., Estimating Real Time Diurnal Permeation from Constant Temperature Measurements. Society of Automotive Engineering, Technical Paper 2001-01-0730, pp. 4.

[5] SAE J1737:Test Procedure to Determine the Hydrocarbon Losses from Fuel Tubes, Hoses, Fittings, and Fuel Line Assemblies by Recirculation. Society of Automotive Engineering Surface Vehicle Recommended Practice, REV. NOV 2004, pp. 12.

[6] Baltz, Gene F., Effects of Alcohol Extended Fuels on the Rate of Fuel Hose Permeation. Society of Automotive Engineering, Technical Paper 880709, pp. 2.

[7] Hutchins, T. G., Rate of Fuel Permeation – Test Procedure Study. Society of Automotive Engineering, Technical Paper 820406, pp. 4.

Attachment 1

GDF Vacuum Assist Hose Testing Data

Date	Mass Loss (grams)						Fuel Mass Following Fuel Refreshing (grams)						Time of Permeation Period (days)		Average Temp (℃)
	Hose V1	Hose V2	Hose V3	Hose V4	Hose V5	Hose V6	Hose V1	Hose V2	Hose V3	Hose V4	Hose V5	Hose V6	Hoses V1 - V5	Hose V6	
16-Jul	N/A	N/A	N/A	N/A	N/A	N/A	367.94	369.77	365.88	373.09	370.54	N/A	N/A	N/A	N/A
17-Jul	0.23	0.04	0.19	1.62	1.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.69	N/A	25.32
18-Jul						N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	
19-Jul						N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	
20-Jul						N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	
21-Jul	0.08	0.07	0.49	0.15	1.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.01	N/A	23.06
22-Jul	0.42	0.4	1.17	0.47	1.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	N/A	21.84
23-Jul	1.24	1.17	1.94	1.35	2.41	N/A	387.84	385.92	385.15	392.67	391.73	N/A	1.07	N/A	21.44
24-Jul	4.47	4.5	5.34	4.55	6.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.92	N/A	22.02
25-Jul						N/A	392.19	390.68	389.88	395.27	397.07	N/A		N/A	
26-Jul	3.43	3.43	3.78	3.38	5.96	N/A	392.83	391.43	390.5	396.51	398.21	N/A	1.00	N/A	22.57
27-Jul	3.42	3.6	3.74	3.42	4.12	N/A	391.34	390.92	389.41	396.11	397.84	N/A	0.88	N/A	23.18
28-Jul	3.83	3.93	4.13	3.75	4.2	N/A	393.09	391.99	390.56	396.99	398.85	N/A	0.90	N/A	23.20
29-Jul	3.83	3.88	4.13	4.24	4.34	N/A	392.96	392.09	391.04	396.50	399.43	N/A	0.93	N/A	22.69
30-Jul	3.94	3.87	4.08	3.95	4.29	N/A	392.71	392.32	391.50	397.52	400.02	N/A	0.94	N/A	22.02
31-Jul	4.01	4	4.17	3.98	4.64	N/A	392.88	392.09	393.14	395.80	399.82	N/A	0.97	N/A	21.80
1-Aug	4.18	4.09	4.24	4.26	4.51	N/A	391.20	391.85	390.84	397.06	398.18	N/A	0.96	N/A	22.81
2-Aug	4.2	4.23	4.81	4.24	4.92	N/A	390.96	391.83	389.52	396.40	398.00	N/A	0.96	N/A	22.52
3-Aug	3.9	3.86	4.55	3.81	4.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.91	N/A	22.18
4-Aug	4.17	4.2	4.76	4.23	5.22	N/A	392.89	391.47	390.23	396.44	396.55	381.08	1.02	N/A	21.65
5-Aug	3.98	4.03	4.39	4.03	4.6	2.02	N/A	N/A	N/A	N/A	N/A	N/A	0.94	0.94	22.36
6-Aug	3.7	3.81	4.15	3.7	4.17	0.03	390.22	388.16	388.24	395.29	393.79	390.37	0.97	0.97	20.90
7-Aug	3.86	4.22	4.2	3.84	4.23	0.16	N/A	N/A	N/A	N/A	N/A	N/A	0.98	0.98	21.00
8-Aug	3.81	4.19	4	3.78	4.03	1.13	390.20	387.84	388.23	396.37	393.78	N/A	1.00	1.00	21.23
9-Aug	3.65	4.5	3.79	3.64	3.82	3.8	N/A	N/A	N/A	N/A	N/A	N/A	0.91	0.91	21.79
10-Aug	3.96	4.35	4.11	3.96	4.26	5.97	389.06	388.24	387.78	393.17	392.81	406.27	1.01	1.01	21.63
11-Aug	3.68	4.69	4.04	3.62	3.97	6.22	N/A	N/A	N/A	N/A	N/A	406.56	0.91	0.91	21.43
12-Aug	3.91	3.91	4.03	3.91	4.12	7.07	N/A	N/A	N/A	N/A	N/A	406.71	1.00	0.98	21.68
13-Aug	3.76	4.42	3.95	3.86	3.92	7.45	387.95	385.73	387.27	392.63	392.98	404.81	0.95	0.93	22.21
14-Aug	3.71	5.23	4.04	3.57	4.09	7.59	N/A	N/A	N/A	N/A	N/A	N/A	0.91	0.91	22.29
15-Aug	11.94	12.67	12.23	12.11	12.42	23.72	N/A	N/A	N/A	N/A	N/A	N/A	2.98	2.98	22.46
16-Aug							N/A	N/A	N/A	N/A	N/A	N/A			
17-Aug							N/A	N/A	N/A	N/A	N/A	N/A			
18-Aug	3.86	3.88	4.04	3.94	4.18	7.38	386.47	386.63	384.44	390.68	390.10	401.55	1.03	1.03	22.22
19-Aug	3.39	5.74	3.9	3.52	3.84	6.51	386.22	387.26	386.27	392.08	391.12	401.60	0.89	0.89	22.01
20-Aug	3.63	4.91	4.09	3.65	4.13	7.15	387.83	384.34	385.58	393.00	392.52	403.68	0.96	0.96	22.22
21-Aug	3.78	8.31	4.14	3.81	4.15	7.52	N/A	N/A	N/A	N/A	N/A	402.06	0.98	0.98	22.38
22-Aug	3.83	5.32	3.94	3.85	3.93	7.36	N/A	N/A	N/A	N/A	N/A	401.34	0.97	0.95	22.46
23-Aug	4.02	4.6	4.16	4.06	4.32	7.88	N/A	N/A	N/A	N/A	N/A	400.98	1.02	1.00	22.53
24-Aug	3.6	3.63	3.78	3.57	3.78	7.04	N/A	N/A	N/A	N/A	N/A	401.68	0.95	0.93	22.06
25-Aug	3.61	3.65	3.79	3.65	3.77	6.91	N/A	N/A	N/A	N/A	N/A	400.37	0.98	0.95	21.63
26-Aug	3.62	3.6	3.8	3.65	3.9	7.08	N/A	N/A	N/A	N/A	N/A	398.38	0.98	0.95	22.21
27-Aug	3.67	3.65	3.87	3.62	3.84	7.12	N/A	N/A	N/A	N/A	N/A	397.39	1.00	0.96	22.17

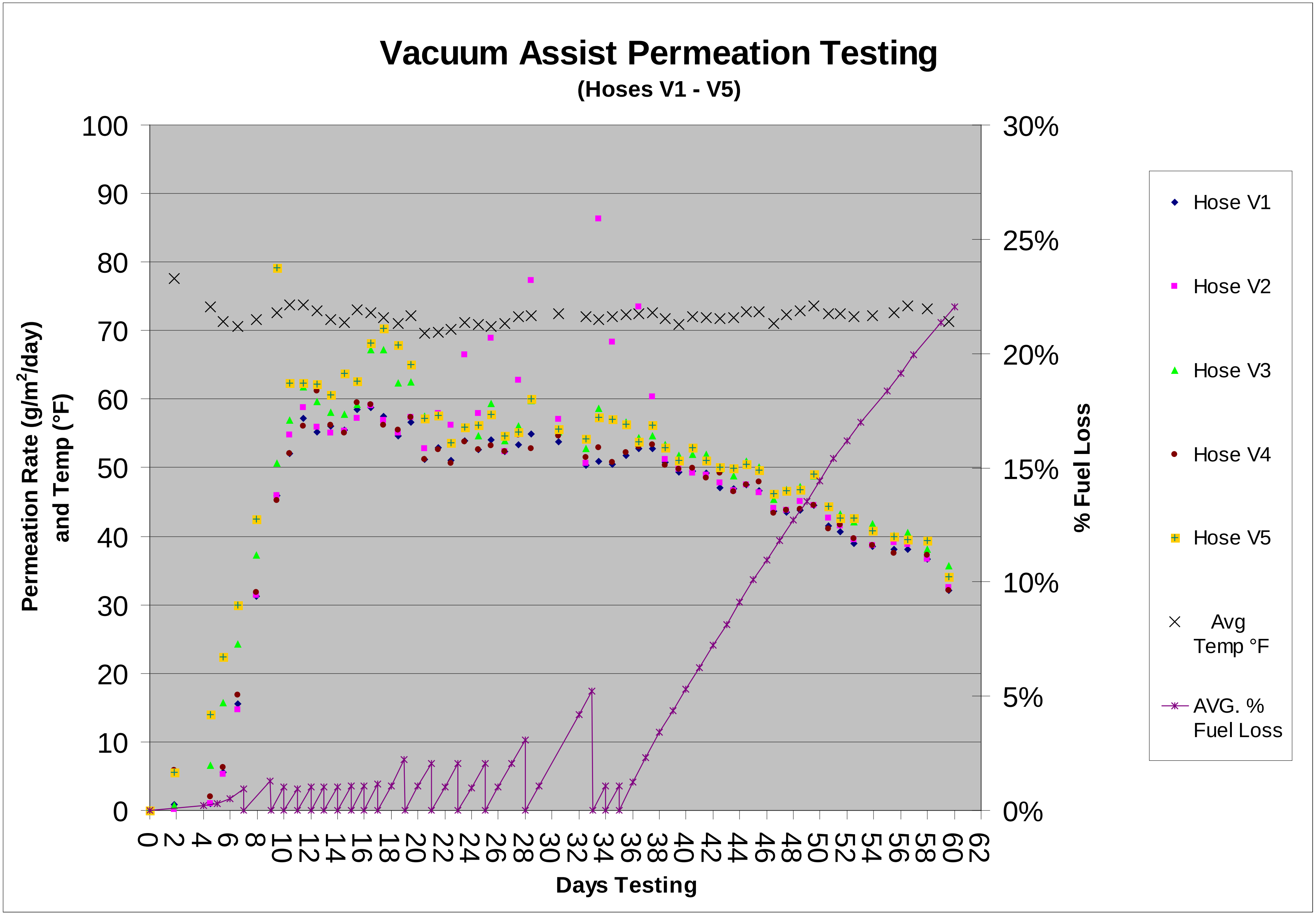
Attachment 1

28-Aug	3.44	3.49	3.64	3.59	3.68	6.97	N/A	N/A	N/A	N/A	N/A	398.03	0.98	0.95	22.09
29-Aug	3.79	3.77	3.95	3.76	4.07	7.55	N/A	N/A	N/A	N/A	N/A	397.65	1.09	1.04	22.15
30-Aug	3.67	3.67	3.94	3.67	3.94	7.53	N/A	N/A	N/A	N/A	N/A	396.73	1.04	1.01	22.62
31-Aug	3.19	3.17	3.42	3.28	3.42	6.52	N/A	N/A	N/A	N/A	N/A	N/A	0.92	0.88	22.62
1-Sep	3.29	3.32	3.42	3.27	3.51	7.15	N/A	N/A	N/A	N/A	N/A	N/A	1.01	1.01	21.71
2-Sep	3.29	3.31	3.54	3.31	3.56	7.25	N/A	N/A	N/A	N/A	N/A	N/A	1.02	1.02	22.41
3-Sep	3.18	3.27	3.43	3.19	3.42	7.02	N/A	N/A	N/A	N/A	N/A	N/A	0.98	0.98	22.72
4-Sep	3.34	3.34	3.66	3.34	3.71	7.29	N/A	N/A	N/A	N/A	N/A	N/A	1.01	1.01	23.11
5-Sep	3.72	3.82	3.98	3.68	4	8.05	N/A	N/A	N/A	N/A	N/A	N/A	1.20	1.20	22.49
6-Sep	2.83	2.89	3.01	2.9	3	6.11	N/A	N/A	N/A	N/A	N/A	N/A	0.94	0.94	22.51
7-Sep	3.02	3.06	3.26	3.07	3.33	6.54	N/A	N/A	N/A	N/A	N/A	N/A	1.04	1.04	22.27
<u>8-Sep</u>	5.11	5.12	5.53	5.12	5.44	10.91	N/A	N/A	N/A	N/A	N/A	N/A	1.78	1.78	22.35
<u>9-Sep</u>							N/A	N/A	N/A	N/A	N/A	N/A			
10-Sep	2.97	3.05	3.13	2.93	3.14	6.33	N/A	N/A	N/A	N/A	N/A	N/A	1.05	1.05	22.55
11-Sep	2.98	3.04	3.18	3.1	3.12	6.33	N/A	N/A	N/A	N/A	N/A	N/A	1.05	1.05	23.13
<u>12-Sep</u>	5.36	5.36	5.57	5.44	5.79	11.2	N/A	N/A	N/A	N/A	N/A	N/A	1.96	1.96	22.85
<u>13-Sep</u>							N/A	N/A	N/A	N/A	N/A	N/A			
14-Sep	2.68	2.72	2.98	2.68	2.87	5.6	N/A	N/A	N/A	N/A	N/A	N/A	1.12	1.12	21.84

Note: All positive mass numbers indicate mass loss.

_____ Underlined dates indicate dates for which mass loss was taken over multiple dates.

Attachment 2



Attachment 3