

HYDROGEN PERMEABILITY THROUGH TAPED AND UNTAPPED 'CLAM SHELL' CONTAINERS USED AT ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Terry J. Wickland
Nuclear Filter Technology L. L. C.

Donald F. Dustin Ph.D.
Safe Site of Colorado, L.L. C RFETS

ABSTRACT

At the Rocky Flats Environmental Technology Site, shredded HEPA filter media that is loaded with plutonium residues are stored in PVC bags, which are in turn stored inside protective polyethylene "clamshell" containers. The clamshell containers have two halves of approximately 4 liters in volume and when the two clamshell halves are threaded together, the container volume is about 7.15 liters. Because the containers are greater than 4 liters, it is suspected that the waste residues stored in clamshell containers will be wattage limited, and therefore restricted from shipment to the Waste Isolation Pilot Plant. The intent of the clamshell containers is to provide physical protection for the stored contents. The seam formed between the two clamshell halves is sealed with two to three layers of yellow Slipknot #44 poly Vinyl chloride (PVC) tape. Previous studies at Rocky Flats have shown the clamshell containers are neither air tight, nor water tight. This paper describes the method used to measure the hydrogen decay through the taped, and untaped clamshell containers. Gas samples were analyzed by a gas chromatograph with a thermal conductivity detector over a predetermined time at specified intervals. The hydrogen permeability of hydrogen has been measured at about 5.0×10^{-8} moles/sec/mole-fraction for a taped container and 2552×10^{-8} moles/sec/mole fraction for an un-taped container. The results are to be used by Rocky Flats Environmental Technology Site personnel to make decisions regarding on-site safe storage and possible combinations of treatments of packages for shipment and disposal at the Waste Isolation Pilot Plant (WIPP). Possible treatments of the clamshell containers include repackaging and ventilation with HEPA filters. This work is performed under Safe Sites of Colorado Sub-contract #SSC000401 BHS-041.

BACKGROUND

Hydrogen permeability through taped Volrath 88020 steel slip lid containers has been measured under previous Safe Site Contract 703384 and SSC000068. It was expected that the hydrogen diffusion rates would be much different because of the threads of the clamshell, the greater surface area of the container, and the fact that the clamshells have multiple layers of tape whereas the Volrath 88020 slip lid cans had only one layer. The diffusion rate of the slip lid Volrath 88020 cans with a single layer of PVC tape was measure at 1.2×10^{-7} moles/second/mol fraction. The WIPP TRUPACT II SAR section 1.3.5 requires a drum of transuranic waste to be vented with a filter that has a hydrogen diffusion rate of 1.9×10^{-6} Moles/Second/Mol Fraction. A non-filtered liner bag diffuses hydrogen gas at a rate of 5.6×10^{-7} mol/second/mole fraction.

PROCEDURE

The 12 clamshells were delivered by RFETS with tape applied by operators who normally processed the packages. Each of the 12 test clamshell were modified to allow gas sampling. The modifications included a brass valve fitting (Part # B-4P4T1) which is securely threaded into each end. To assure a tight seal and provide strength, two-part five-minute epoxy glue was applied around each fitting. In order to verify that the ball valves made a leak tight seal, each clamshell was pressurized to a about 3 inches of water column and the end inserted into a basin of water. The absence of bubbles indicated there were no macro leaks.

PHOTOGRAPHS

Photographs were taken of the Clamshells prior to the start of testing. The photographs are presented in the Photographs Section and represent the appearance of the tape on the top and bottom sides of each clamshell. Also shown in the photographs is Clamshell #6 (with no tape wrapped around it) which was not threaded completely, and as a result leaked hydrogen much more rapidly than the other clamshells. Clamshell #12 is shown which was wrapped in multiple layers of yellow PVC tape and was used to determine 'system losses'.

DETERMINATION OF TEST PERIOD

Since no prior knowledge existed about the hydrogen permeability through the clamshell packages, in the first phase of the test program three containers, two taped and one not taped, were tested in order to determine the appropriate test period for each configuration. The test period was determined to be 21 days for the taped configuration and about 0.5 hours for the un-taped configuration.

One 21 day test cycle, and one 27 day test was conducted on taped clamshells. Two 35 minute tests were conducted on each un-taped clamshell. Prior to the start of a hydrogen diffusion test, each clamshell container is purged with the test gas (NIST traceable 4% hydrogen, balance nitrogen), and samples are taken for analysis every 3 to 5 days. The valves installed in each clamshell allowed periodic samples to be taken for analysis.

DETERMINATION OF SYSTEM LEAKS

In order to verify system leak rates, especially to quantify leaks at the valve to clamshell joint, one clamshell was securely wrapped in yellow PVC tape, about 1/4" thick around the outside of the clamshell. The same was applied to each end of the clamshell. This isolate hydrogen leaks to the system and valve fittings and to some degree through the walls of the container.

Measurement over a period of 45 days showed these hydrogen losses to be about 20% of the measured leak rate though a clamshell. The hydrogen diffusion rate through the 'sealed' container was measured at $1.039 \text{ E-08 mol/s/mol fraction}$ with a standard deviation of $0.9 \text{ E-08 mol/s/mol fraction}$. Complete data including gas chromatograph outputs, and diffusion rate calculations are shown in Appendix-3.

HYDROGEN TEST SETUP

The schematic diagram on the following page shows the test set up. A certified mixture of 4.0% hydrogen gas with a balance of nitrogen is circulated by a peristaltic pump through the gas chromatograph and returned to the clamshell. An initial gas sample is taken, and then at even intervals as determined by the estimate made by the step "Determination of Test Period". A sample of the gas is injected into the detector for analysis. Seven samples are taken over the test period. The amount of hydrogen in the test vessel decays over time due to diffusion through the clamshell and threaded seal. The hydrogen diffusivity losses through the container, tubing, and connections has also been measured.

The chromatogram peak area is related to the amount of hydrogen in the container. The decay rate, or hydrogen diffusivity, D , through the assembly is given by:

$$D = PV/t RT \ln(H_o/H_t)$$

where P is atmospheric pressure, V is the volume of the vessel with connective tubing, t is elapsed time in seconds, R is the Ideal Gas Constant, and T is the temperature in Kelvin. The diffusion rate, D , is in Moles/Second / Mole Fraction (M/S/M Frac). The initial concentration of hydrogen given by the chromatogram peak area is H_o and the amount of hydrogen after time t is H_t .

The diffusion tests are conducted at the Nuclear Filter Technology Laboratory in Golden Colorado which is at an elevation of 6000 feet. Therefore P , the atmospheric pressure is adjusted down from 1 atmosphere to 0.81 atmospheres. The volume of the test container was measured by recording injected water volume until the vessel was full. The volume of the clamshell containers are 7154 milliliters. The volume of the clamshells was measured three times by metering in water until the container was full. The ideal gas constant is 0.08206 L-Atm / Mol-Kelvin. The tests were conducted in a temperature controlled room and was maintained at between 24 and 26 degrees centigrade. Temperature correction to 25.0 centigrade have been made.

Peak area data is transferred to a spreadsheet where the diffusion coefficient is calculated at each data point. An average of six diffusion coefficients are taken and reported as the diffusion rate, D' . The standard deviation of the mean is also calculated and reported as a result.

EQUIPMENT AND OPERATING PARAMETERS

The gas chromatograph used for the tests will be a Shimadzu GC 14A equipped with a 6 port "Event 91" valve. The detector is a thermal conductivity detector (TCD) and the column is a MS-5 A, 2.5 meter 80 X 100 molecular seive. Operating parameters of the GC are 100 C detector temperature, 110 C column and injector temperature, and 150 C TCD temperature. The current across the TCD is set at 70 milliamps. The data acquisition software used is Shimadzu EzChrome.

QUALITY ASSURANCE

The gas chromatography tests for hydrogen gas were conducted in accordance with DOE/WIPP Procedure 520.1 "Gas chromatography Determination Of Hydrogen And Methane in Waste Container Headspace" which is based on ASTM Method 1946-82. The key Quality Assurance elements derived from Procedure 520.1 and applied to the test described here are the use of National Institute of Standards and Technology (NIST) traceable standard gases for establishing a three point calibration curve. Calibration curves were run at the start of each day that tests were conducted. The minimum detection limit (MDL) of the thermal conductivity detector was measured in accordance with 40 CFR Pt. 136, app. B. The chromatograph peak area has been measured 14 times in response to the certified hydrogen gas concentration of 1.5% hydrogen. The MDL is estimated at 230 parts per million. The precision and accuracy of the test equipment proposed has been measured at less than 100 ppm.

Certificates of Conformance on NIST traceable gases and equipment are included in Appendix-9 of this report. The three point calibration curves taken at the beginning of a day of testing are included in Appendix -6.

DATA VALIDATION

In order to validate the test data, cell formulas are printed and have been reviewed. Cell formulas of spreadsheet calculations used for taped clamshells is presented in Appendix -7. Cell formulas of spreadsheet calculations used for un-taped clamshells is presented in Appendix -8. Also, hand calculations verified that the spreadsheet was transforming the data as expected. The spreadsheet calculations have been used in previous studies that have been published and subject to peer review.

SOURCE SURVEILLANCE

Representatives from Rocky Flats Environmental Site, Safe Sites of Colorado, including management, Quality Assurance, and engineering made planned and unplanned visits to Nuclear Filter during testing of clamshells.

RESULTS

A total of eleven clamshell were tested for each of the taped and un-taped configurations. The twelfth clamshell was used to determine system leaks during the duration of the tests which lasted 45 days. Hydrogen gas sampling, was begun on September 16 at 8:11 AM. The test duration for the first run of taped clamshell containers was 21 days. Six gas samples were taken over the period of the test at intervals between three to five days. The test duration for the second run of taped clamshell containers was 27 days. In the second test run of the taped clamshells, seven gas samples were taken over the period of the test at intervals between three to five days. The gas chromatogram outputs for each test sample for the taped clamshell run #1 is presented in Appendix-1. The gas chromatogram outputs for each test sample for the taped clamshell run #2 is presented in Appendix-2.

The un-taped clamshell containers were tested over two consecutive days. Seven gas samples were taken at five minute intervals over a 35 minute test period. The gas chromatogram outputs, and spreadsheet calculations for test run #1 of the un-taped clamshell is presented in Appendix-3. The gas chromatogram outputs, and spreadsheet calculations for test run #2 of the un-taped clamshell is presented in Appendix-4.

Table-1 shows complete data including GC output for each test sample of taped clamshells test run #1 including calibration slope, time, conversion to percent hydrogen, and the calculated hydrogen diffusivity coefficient. Table-2 shows complete data of the second run of taped clamshells. Table-3 shows the calculated hydrogen diffusivity coefficients for un-taped clamshells test runs #1 and #2. Table -4 below, provides a summary of test results showing the hydrogen diffusion coefficients for each taped and un-taped test run.

The Charts in the following section shows the hydrogen decay over time for each of the eleven clamshells tested. Clamshell #6 leaks H₂ very rapidly with respect to the other clamshells. A second pressure test of clamshell #6 determined there is not a macro leak in the fittings. It is possible to see a thin cut in the taped on Clamshell #6, combined with the fact that Clamshell #6 was not threaded completely, is responsible for a rapid hydrogen loss.

Table #1 - Taped Clamshell Run #1

CLAM SHELL CONTAINER TEST HYDROGEN DIFFUSION WORK SHEET						
PERCENT OF HYDROGEN GAS IN TAPED CLAM SHELL CONTAINERS						
	RUN-1	RUN-1	RUN-1	RUN-1	RUN-1	RUN-1
	SAMPLE-1	SAMPLE-2	SAMPLE-3	SAMPLE-4	SAMPLE-5	SAMPLE-6
CAL. SLOPE	35536214.97	34918242.18	33895244.90	33302839.46	34294979.59	33243979.59
TIME MIN.	0	4242	11611	17220	23082	30232
Time (Days)	0	3	8	12	16	21
CLAM #1	4.041%	3.742%	3.296%	2.990%	2.619%	2.430%
CLAM #2	4.073%	3.823%	3.450%	3.225%	2.911%	2.788%
CLAM #3	4.045%	3.836%	3.426%	3.261%	2.932%	2.819%
CLAM #4	4.058%	3.843%	3.428%	3.262%	2.950%	2.825%
CLAM #5	4.045%	3.925%	3.570%	3.454%	3.237%	3.167%
CLAM #6	4.028%	1.617%	0.265%	0.000%	0.000%	0.000%
CLAM #7	4.038%	3.656%	3.070%	2.785%	2.395%	2.152%
CLAM #8	4.029%	3.886%	3.563%	3.431%	3.157%	3.031%
CLAM #9	4.028%	3.803%	3.404%	3.261%	2.961%	2.826%
CLAM #10	4.044%	3.863%	3.481%	3.352%	3.097%	3.007%
CLAM #11	4.022%	3.789%	3.347%	3.192%	2.899%	2.770%
GAS CHROMATOGRAM PEAK OUTPUT AREA						
CLAM #1	1435922	1306686	1117330	995852	898330	807852
CLAM #2	1447437	1334945	1169538	1073928	998345	926692
CLAM #3	1437286	1339597	1161162	1086076	1005409	936999
CLAM #4	1442065	1342028	1161843	1086482	1011657	939026
CLAM #5	1437486	1370645	1210016	1150210	1110182	1052710
CLAM #6	1431247	564543	89947	0	0	
CLAM #7	1435096	1276602	1040541	927628	821197	715279
CLAM #8	1431656	1356963	1207652	1142609	1082527	1007709
CLAM #9	1431368	1327803	1153872	1086035	1015461	939608
CLAM #10	1437126	1348919	1179767	1116150	1062208	999498
CLAM #11	1429096	1322963	1134360	1063170	994250	921015
H2 DIFFUSION COEFFICIENT CALCULATIONS						
	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	AVERAGE
	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST
	MOLE / S	MOLE / S	MOLE / S	MOLE / S	MOLE / S	MOLE / S
	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.
CLAM #1	7.14E-08	6.92E-08	6.90E-08	7.41E-08	6.64E-08	7.00E-08
CLAM #2	5.90E-08	5.64E-08	5.35E-08	5.74E-08	4.95E-08	5.52E-08
CLAM #3	4.92E-08	5.65E-08	4.93E-08	5.50E-08	4.72E-08	5.14E-08
CLAM #4	5.06E-08	5.74E-08	5.00E-08	5.45E-08	4.73E-08	5.20E-08
CLAM #5	2.80E-08	4.25E-08	3.62E-08	3.81E-08	3.20E-08	3.54E-08
CLAM #6	8.49E-07	9.25E-07				8.87E-07
CLAM #7	9.26E-08	9.32E-08	8.51E-08	8.94E-08	8.22E-08	8.85E-08
CLAM #8	3.35E-08	4.18E-08	3.68E-08	4.17E-08	3.71E-08	3.82E-08
CLAM #9	5.36E-08	5.72E-08	4.84E-08	5.26E-08	4.63E-08	5.16E-08
CLAM #10	4.26E-08	5.10E-08	4.31E-08	4.56E-08	3.87E-08	4.42E-08
CLAM #11	5.55E-08	6.25E-08	5.29E-08	5.60E-08	4.87E-08	5.51E-08
					AVERAGE	1.2987E-07
					STDEV	2.5154E-07

Table #2 - Taped Clamshell Run #2

CLAM SHELL CONTAINER TEST HYDROGEN DIFFUSION WORK SHEET							
PERCENT OF HYDROGEN GAS IN TAPED CLAM SHELL CONTAINERS							
	RUN-2	RUN-2	RUN-2	RUN-2	RUN-2	RUN-2	RUN-2
	SAMPLE-1	SAMPLE-2	SAMPLE-3	SAMPLE-4	SAMPLE-5	SAMPLE-6	SAMPLE-7
CAL. SLOPE	33243979.59	33109974.15	33025751.02	33230692.52	33921042.18	31494463.95	31617020.41
TIME MIN.	0	4242	11611	17220	23082	30232	38892
Time (Days)	0	3	8	12	16	21	27.01
CLAM #1	4.042%	3.894%	3.362%	3.062%	2.829%	2.537%	2.244%
CLAM #2	4.055%	3.912%	3.573%	3.325%	3.148%	2.915%	2.672%
CLAM #3	4.073%	3.912%	3.591%	3.342%	3.167%	2.953%	2.722%
CLAM #4	4.088%	3.922%	3.603%	3.395%	3.216%	3.011%	2.780%
CLAM #5	4.072%	3.973%	3.717%	3.588%	3.369%	3.253%	3.094%
CLAM #6	4.068%	1.593%	0.281%	0.047%	0.000%	0.000%	0.000%
CLAM #7	4.093%	3.789%	3.212%	2.908%	2.467%	2.288%	1.932%
CLAM #8	4.080%	3.928%	3.620%	3.399%	3.027%	3.007%	2.793%
CLAM #9	4.081%	3.927%	3.603%	3.489%	3.006%	2.992%	2.777%
CLAM #10	4.098%	3.946%	3.668%	3.328%	3.151%	3.152%	2.964%
CLAM #11	4.082%	3.917%	3.555%	3.328%	2.969%	2.947%	2.710%
GAS CHROMATOGRAPH PEAK OUTPUT AREA							
CLAM #1	1343853	1265394	1117369	1017647	959636	799096	709401
CLAM #2	1348130	1289444	1187308	1104887	1067712	918066	844956
CLAM #3	1353935	1295171	1193261	1110499	1074432	930010	860715
CLAM #4	1359015	1298411	1197376	1128222	1090769	948373	879052
CLAM #5	1353625	1315542	1235057	1192185	1142711	1024456	978165
CLAM #6	1352475	527283	93494	15638	0	0	
CLAM #7	1360821	1254559	1067452	966396	836943	720577	610760
CLAM #8	1356258	1300613	1202893	1129632	1026800	947028	883045
CLAM #9	1356741	1300180	1197165	1159310	1019778	942315	878049
CLAM #10	1362250	1306498	1218860	1105765	1068903	992808	937019
CLAM #11	1356977	1296866	1181345	1105765	1007018	928291	856945
H2 DIFFUSION COEFFICIENT CALCULATIONS							
	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	
	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST	DIFF CONST
	MOLE / S	MOLE / S	MOLE / S	MOLE / S	MOLE / S	MOLE / S	MOLE / S
	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	MOLE FRAC.	AVERAGE
CLAM #1	3.47E-08	6.26E-08	6.36E-08	6.10E-08	6.08E-08	5.98E-08	5.71E-08
CLAM #2	3.35E-08	4.31E-08	4.55E-08	4.33E-08	4.31E-08	4.23E-08	4.18E-08
CLAM #3	3.75E-08	4.28E-08	4.53E-08	4.30E-08	4.20E-08	4.09E-08	4.19E-08
CLAM #4	3.87E-08	4.29E-08	4.26E-08	4.11E-08	3.99E-08	3.91E-08	4.07E-08
CLAM #5	2.28E-08	3.10E-08	2.90E-08	3.24E-08	2.93E-08	2.79E-08	2.87E-08
CLAM #6	8.73E-07	9.08E-07	1.02E-06				9.34E-07
CLAM #7	7.19E-08	8.24E-08	7.84E-08	8.66E-08	7.60E-08	7.62E-08	7.86E-08
CLAM #8	3.52E-08	4.07E-08	4.18E-08	5.10E-08	3.98E-08	3.85E-08	4.12E-08
CLAM #9	3.59E-08	4.24E-08	3.60E-08	5.23E-08	4.05E-08	3.91E-08	4.10E-08
CLAM #10	3.51E-08	3.77E-08	4.77E-08	4.49E-08	3.42E-08	3.29E-08	3.88E-08
CLAM #11	3.84E-08	4.70E-08	4.68E-08	5.45E-08	4.25E-08	4.16E-08	4.51E-08
						AVERAGE	4.55E-08
						STDEV	1.351E-08

1.26E-07
2.68E-07

Table-3 Un-Taped Clamshells containers, Run #1 and 2

<u>2 DIFFUSION COEFFICIENT CALCULATIONS</u>			
	E-05 Moles / Second/Mole Fraction		
	No Tape	No Tape	
	RUN-1	RUN-2	
CLAM #1	2.156	2.302	
CLAM #2	0.690	0.973	
CLAM #3	1.084	1.108	
CLAM #4	2.150	2.234	
CLAM #5	3.481	3.440	
CLAM #6	9.052	9.804	
CLAM #7	2.093	1.708	
CLAM #8	2.590	2.490	
CLAM #9	6.237	6.325	
CLAM #10	3.100	3.521	
CLAM #11	1.613	1.760	
AVERAGE	3.113	3.242	
STDV	2.461	2.634	

AVERAGE 2.59 2.58 } WITHOUT #6
 STDV 1.55 1.56 }

TABLE -4 SUMMARY OF RESULTS

TABLE -4 SUMMARY OF RESULTS

Clamshell Container	Taped Run #1 H2 Diffusion Rate E-08 (Mol / S/ Mol Frac)	Taped Run #2 H2 Diffusion Rate E-08 (Mol/ S/ Mol Frac)	Un-Taped Run #1 H2 Diffusion Rate E-05 (Mol / S/ Mol Frac)	Un-Taped RUN #2 H2 Diffusion Rate E-05(Mol/S/ Mol Frac)
CLAM #1	7.00	5.66	2.16	2.30
CLAM #2	5.52	4.17	0.69	0.97
CLAM #3	5.14	4.21	1.08	1.11
CLAM #4	5.20	4.10	2.15	2.23
CLAM #5	3.54	2.89	3.48	3.44
CLAM #6	88.70	93.40	9.05	9.80
CLAM #7	8.85	7.90	2.09	1.71
CLAM #8	3.82	4.17	2.59	2.49
CLAM #9	5.16	4.14	6.24	6.33
CLAM #10	4.42	3.99	3.10	3.52
CLAM #11	5.51	4.58	1.61	1.76
If Clamshell #6 is eliminated from calculations:				
AVERAGE	5.41	4.55	2.52	2.58
STDEV	1.55	1.35	1.55	1.56
If clamshell #6 is included in calculations:				
AVERAGE	12.99	12.67	3.11	3.24
STDEV	25.4	26.8	2.46	2.63

Because Clamshell # 6 is considered a statistical outlier (greater than 3 sigma difference from the mean) the average diffusion rates and standard deviation are shown with, and with out clamshell #6 included.

Given a taped clamshell, and assuming #6 **is omitted** from the data set, the mean hydrogen diffusion rate for a taped clamshell container is 5.00 E-08 mol/s/mol fraction with a standard deviation of 1.48 E-08 mol/s/mol frac.

Given a taped clamshell, and assuming #6 **is Included** with the data set, the mean hydrogen diffusion rate for a taped clamshell container is 12.82 E-08 mol/s/mol fraction with a standard deviation of 25.37 E-08 mol/s/mol frac.

Given an un-taped clamshell, and assuming #6 **is omitted** from the data set, the mean hydrogen diffusion rate for a taped clamshell container is 2.55 E-05 mol/s/mol fraction with a standard deviation of 1.52 E-05 mol/s/mol frac.

Given an un-taped clamshell, and assuming #6 **is Included** with the data set, the mean hydrogen diffusion rate for a taped clamshell container is 3.18 E-05 mol/s/mol fraction with a standard deviation of 2.49 E-05 mol/s/mol frac.

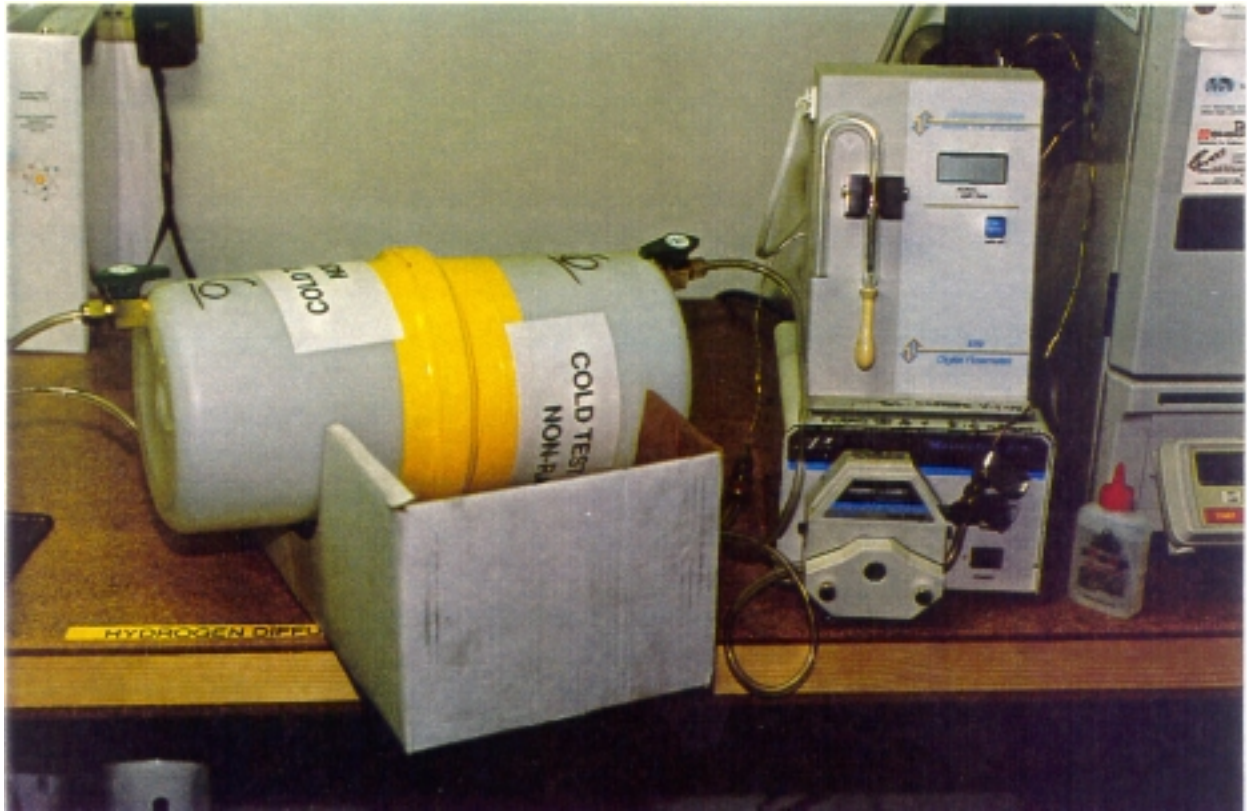
CONCLUSION

The hydrogen diffusivity rate through taped and un-taped clamshell containers have been measured. The hydrogen permeability rate through a taped clamshell container is 5.0×10^{-8} mole/second/mole/fraction. The hydrogen permeability rate through an un-taped clamshell container is 2552×10^{-8} mole/second/mole/fraction. The Rocky Flats Environmental Technology Site utilizes clamshell containers for storing shredded HEPA filter media that is loaded with plutonium residues. The hydrogen diffusion rate coefficients as measured and reported in this study are very low with respect to other package configurations. As a result, the waste packages that utilize the clamshell containers will have to be treated by ventilation with a filter, or at a minimum repackaged so that wattage limits are not exceeded.

The study reported here was conducted under Rocky Flats Environmental Technology Site PO SC000401 BHS1.



Photograph #1 - Shows the hydrogen gas test stand with the Gas Chromatograph, Computer, Peristaltic pump and several Clam Shells.

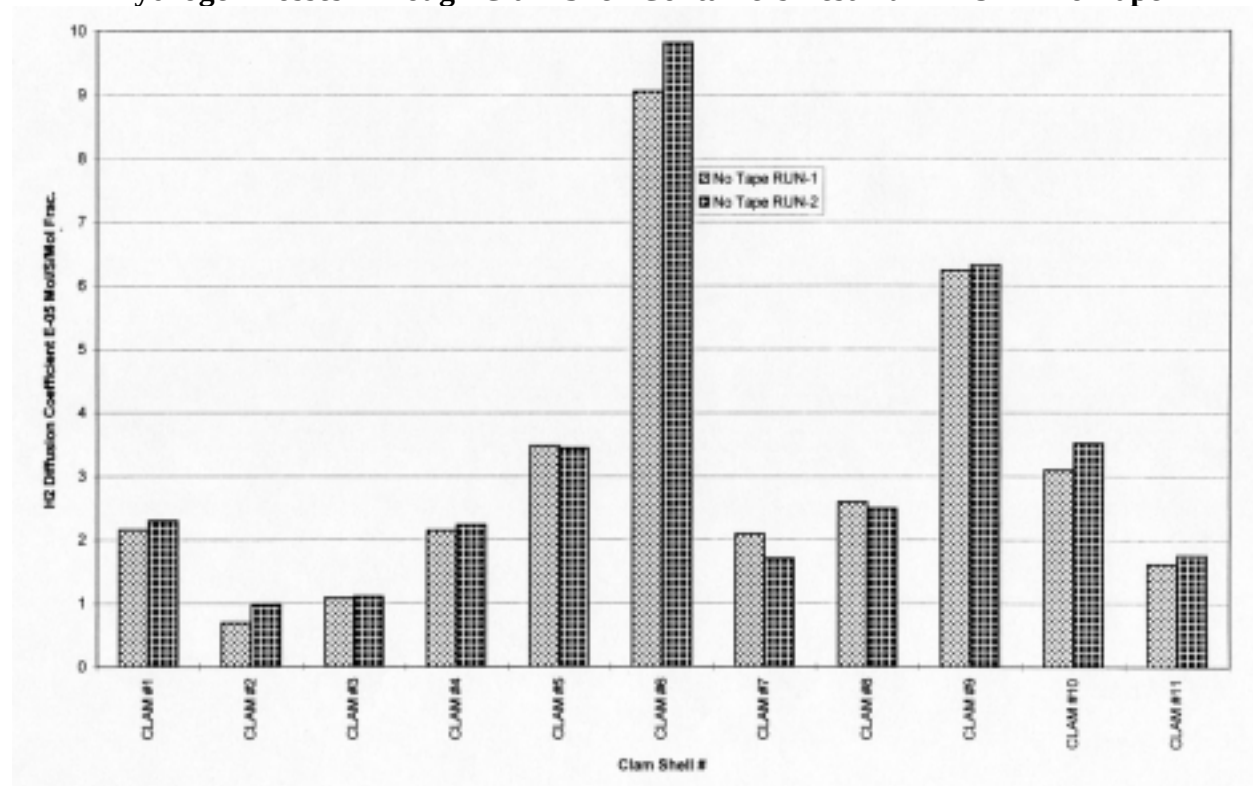


Photograph #2 - shows a close up view of Clam Shell #6 connected to peristaltic pump suring a hydrogen gas sample.

Hydrogen Permeability Through Taped and Untaped "Clam Shell" Containers Used at Rocky Flats Environmental Technology Site

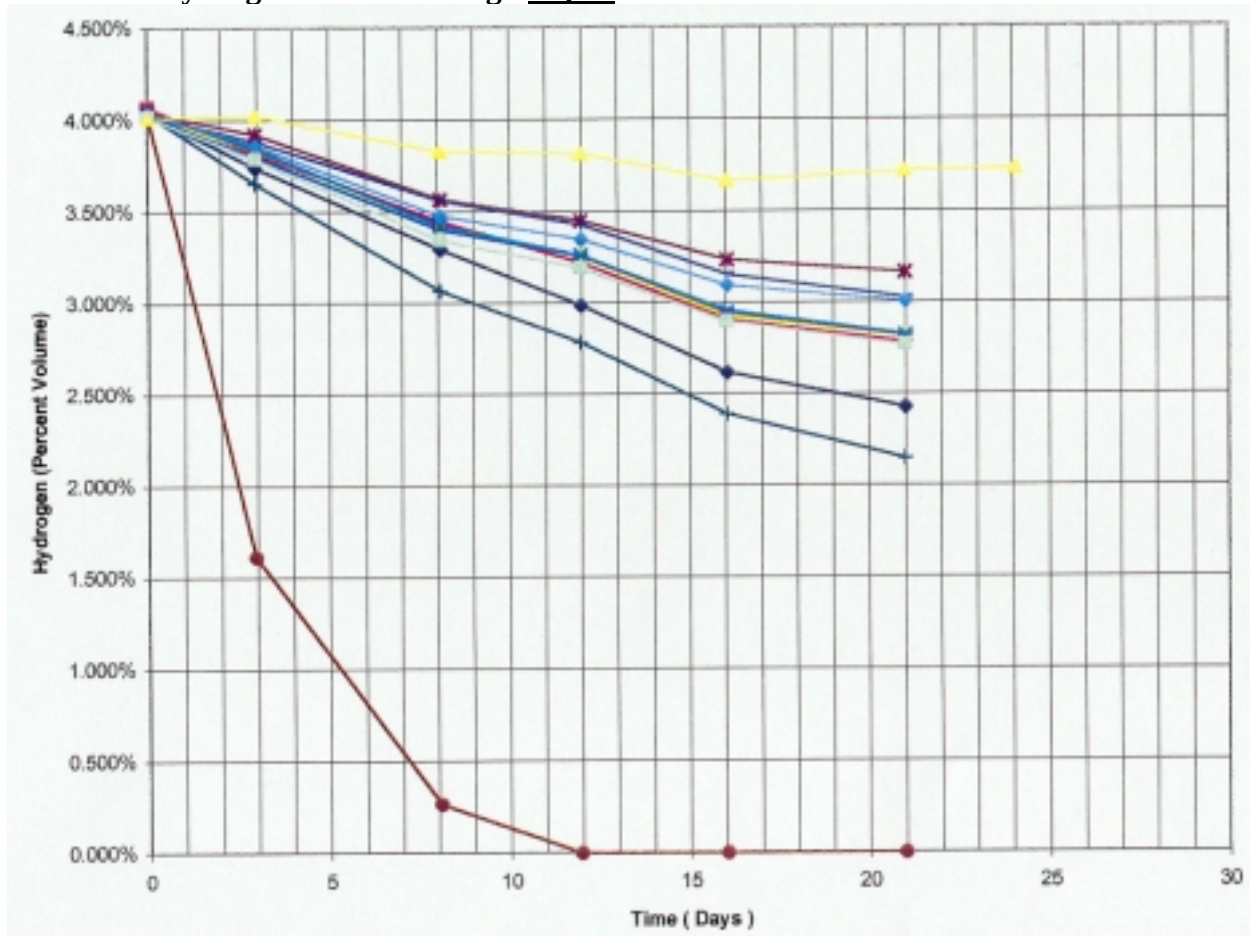
Chart-3

Hydrogen Losses Through Clam Shell Containers Test Run #1 & #1 No Tape



Hydrogen Permeability Through Taped and Untaped "Clam Shell" Containers Used at Rocky Flats Environmental Technology Site
Chart-4

Hydrogen Losses Through Taped Clam Shell Containers Test Run #1



Hydrogen Permeability Through Taped and Untaped "Clam Shell" Containers Used at Rocky Flats Environmental Technology Site Chart-5

Hydrogen Losses Through Taped Clam Shell Containers Test Run #2

