MLGW
MEMPHIS LIGHT, GAS AND WATER DIVISION
Legal Department

January 24, 2012

Larry Borum, Chief
Gas Pipeline Safety Division
Tennessee Regulatory Authority
460 James Robertson Parkway
Nashville TN 37243-0505

Re: TRA Docket No. 08-00124

Dear Larry:

Pursuant to Memphis Light, Gas and Water's ("MLGW") letter to you of February 28, 2011, MLGW has completed its proposed testing of pipe samples by GTI Testing Laboratories which was overseen by MLGW's consultant in this matter, Dr. Gene Palermo. Both GTI's report and Dr. Palermo's report are enclosed for your review.

MLGW has now completed all three conditions set forth in your prior letter of January 18, 2011. It is MLGW's understanding that this brings to a conclusion all MLGW obligations required by the TRA and PHMSA as regards this waiver request. If this is not the case, please let me know at your earliest convenience.

Should either the TRA or PHMSA have any questions regarding the two enclosed reports, please let us know.

Very truly yours,

Fred E. Jones, Jr.
MLGW Staff Attorney

FEJ/fj

220 S. Main Street, Room 529, Memphis, Tennessee 38103
Telephone (901) 528-4343 Fax (901) 528-4991 email skipjones@mlgw.org

G T I   T E S T I N G   L A B O R A T O R I E S
1700 South Mount Prospect Road | Des Plaines, Illinois | 60018

Brian K. Spillar
Senior Engineer,
T: 847 768 0658   F: 847 768 0569
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12/29/2011

Dr. Gene Palermo
Palermo Plastics Pipe Consulting
654 Watershaw Drive
Friendsville, TN 37737
Ph: 865-995-1156
Fx: 865-995-0115
Cell: 703-201-8987
www.plasticspipe.com

Reference: GTI Testing Laboratories Batch Report 111106

Dear Dr. Palermo:

We have completed the elevated sustained pressure testing. We performed testing at 80°C/825 psi hoop stress/6000hr testing for six (6) pipe segments each for 4", 6", and 8" black PE 3408 pipe for a total of eighteen (18) samples.

Of the eighteen (18) segments there were two (2) failures observed:

1) 111106-005, 4" IPS. Failed in a ductile manner at 3178hrs.
2) 111106-017, 8" IPS. Failed in a brittle manner at 5961hrs.

The test results are presented in the attached tables and pictures. The appearance of extensive cracking of the inner surface of 111106-017 is not consistent with normal PE material behavior we have observed in the past. It is respectfully recommended that additional analyses be performed in order to determine their nature and cause of the cracking prior to placing the pipes into service.

Return of Post Test Specimens: The specimens will be retained in locked indoor storage for thirty (30) days from the completion of test program **at no charge**. At the end of this time the samples will be returned at 10% additional to the total project cost. Secure storage of the samples can be accommodated at GTI at the rate of **$10.00/per calendar day** from the standard thirty (30) hold.

Thank you for choosing GTI Testing Laboratories for your project needs. We pride ourselves in establishing long-term relationships with our clients. Should you have any questions, I can be reached at 847-768-0658.

Sincerely,

Brian K. Spillar
Senior Engineer

ACCREDITED
CERTIFICATE 2139-01

ASTM D1598 Long-Term Hydrostatic Test Results

Project:	02222.1.01 MLGW-Palermo 111106	Test Fluid:	
Update Date:		Tank Fluid:	
Manufacturer:		Requested By:	
Print Line:		Tested By:	

111106-006	2011	3	7	15	40	4.487	0.425	172	2011	11	16	10	10	6090.5	6090.5	822.0	80°C	3-25	Removed before failure.	5593.0	
111106-005	2011	3	7	15	40	4.489	0.425	172	2011	7	18	2	0	3178.3	3178.3	822.4	80°C	3-26	Ductile failure.	5593.0	
111106-004	2011	3	7	15	40	4.495	0.422	172	2011	11	16	10	10	6090.5	6090.5	830.0	80°C	3-28	Removed before failure.	5593.0	
111106-001	2011	3	7	15	40	4.495	0.425	172	2011	11	16	10	10	6090.5	6090.5	823.6	80°C	3-29	Removed before failure.	5593.0	
111106-003	2011	3	7	15	40	4.496	0.426	172	2011	11	16	10	10	6090.5	6090.5	821.6	80°C	3-30	Removed before failure.	5593.0	
111106-002	2011	3	10	16	25	4.485	0.425	172	2011	11	16	10	10	6017.7	6017.7	821.6	80°C	3-23	Removed before failure.	5593.0	
111106-008	2011	3	10	16	25	6.616	0.612	169	2011	11	16	10	10	6017.7	6017.7	829.0	80°C	3-24	Removed before failure.	6017.7	
111106-009	2011	3	10	16	25	6.616	0.614	169	2011	11	16	10	10	6017.7	6017.7	826.0	80°C	3-22	Removed before failure.	6017.7	
111106-010	2011	3	10	16	25	6.616	0.613	169	2011	11	16	10	10	6017.7	6017.7	827.5	80°C	3-20	Removed before failure.	6017.7	
111106-011	2011	3	10	16	25	6.616	0.614	169	2011	11	16	10	10	6017.7	6017.7	826.0	80°C	3-19	Removed before failure.	6017.7	
111106-013	2011	3	10	16	25	6.616	0.616	169	2011	11	16	10	10	6017.7	6017.7	823.1	80°C	3-18	Removed before failure.	6017.7	
111106-012	2011	3	10	16	25	6.616	0.616	169	2011	11	16	10	10	6017.7	6017.7	823.1	80°C	3-16	Removed before failure.	6017.7	
111106-016	2011	4	4	11	25	8.625	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.5	80°C	3-07	Removed before failure.	6031.2	
111106-021	2011	4	4	11	25	8.620	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.0	80°C	3-08	Removed before failure.	6031.2	
111106-017	2011	4	4	11	25	8.620	0.813	172	2011	12	8	20	40	5961.2	5961.2	825.8	80°C	3-09	Brittle slit failure .	6031.2	
111106-019	2011	4	4	11	25	8.625	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.5	80°C	3-10	Removed before failure.	6031.2	
111106-020	2011	4	4	11	25	8.625	0.813	172	2011	12	12	8	35	6045.2	6045.2	826.4	80°C	3-11	Removed before failure.	6031.2	
111106-018	2011	4	4	11	25	8.624	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.4	80°C	3-14	Removed before failure.	6031.2	

Figure 1. Summary of Test Results for 111106

Sheet Revision: New
Work Instruction: PP-304

ASTM D2122 Pipe Measurement Sheet

Project:	MLGW 02222.1.01 111106			Temperature:	72°F
Date:	7-Mar-2011			Relative Humidity [%]:	49
Pipe Print Line:	6"IPS SDR11.0 DRISCOPLEX GAS PE3408 CEE ASTM D2513 KV22 H 0000 FEET K005 081306 PACK 0007				
Pipe Size:	6"	Nominal OD [in]: 6.625	OD Tolerance ± [in]: 0.011	Max. Out-of-Round [in]:	0.070
Pipe DR:	11	Min. Wall [in]: 0.602	Wall Tolerance + [in]: 0.072		

Nominal OD, OD tolerance, and Max. Out-of-Round are given in ASTM D 2513.
Minimum Wall thickness and wall tolerance are given in ASTM D 2513.

Table 1 - Wall Thickness **Measurment Tool Serial Number:** 3035021

111106-001	1	0.612	0.624	0.619	0.628	0.619	0.630	0.633	0.632	0.612	0.633	0.625	3.318	0.612	0.638	0.626	4.075
	2	0.614	0.622	0.623	0.632	0.628	0.636	0.638	0.628	0.614	0.638	0.628	3.762				
111106-002	1	0.614	0.628	0.634	0.636	0.626	0.631	0.622	0.623	0.614	0.636	0.627	3.459	0.614	0.636	0.625	3.459
	2	0.615	0.627	0.632	0.632	0.624	0.623	0.621	0.619	0.615	0.632	0.624	2.690				
111106-003	1	0.614	0.625	0.634	0.634	0.624	0.634	0.620	0.623	0.614	0.634	0.626	3.155	0.613	0.636	0.626	3.616
	2	0.613	0.626	0.636	0.635	0.623	0.630	0.624	0.623	0.613	0.636	0.626	3.616				
111106-004	1	0.614	0.629	0.634	0.636	0.625	0.633	0.625	0.625	0.614	0.636	0.628	3.459	0.614	0.636	0.627	3.459
	2	0.614	0.630	0.634	0.635	0.624	0.631	0.625	0.624	0.614	0.635	0.627	3.307				
111106-005	1	0.616	0.630	0.626	0.634	0.628	0.644	0.639	0.641	0.616	0.644	0.632	4.348	0.616	0.644	0.631	4.348
	2	0.619	0.627	0.629	0.634	0.627	0.637	0.637	0.631	0.619	0.637	0.630	2.826				
111106-006	1	0.616	0.622	0.621	0.635	0.627	0.640	0.638	0.631	0.616	0.640	0.629	3.750	0.616	0.640	0.629	3.750
	2	0.616	0.621	0.623	0.634	0.626	0.640	0.636	0.630	0.616	0.640	0.628	3.750				

Table 2 - Outside Diameter (to be measured within one-half pipe diameter or 2 in., whichever is closer, of the rounding equipment (if used) or pipe end.
Note: Do not use Pi Tape for these O.D. measurements. **Measurment Tool Serial Number:** 0036734

111106-001	1	N	6.610	6.578	6.607	6.635	6.647	6.604	6.578	6.647	6.614	0.069	1.043	5.364	6.577	6.647	6.611	5.359	0.065	0.983
	2	N	6.610	6.577	6.596	6.615	6.638	6.610	6.577	6.638	6.608	0.061	0.923	5.353						
111106-002	1	N	6.617	6.635	6.616	6.604	6.576	6.586	6.575	6.635	6.606	0.060	0.908	5.352	6.575	6.642	6.606	5.355	0.063	0.954
	2	N	6.618	6.642	6.621	6.608	6.578	6.576	6.576	6.642	6.607	0.066	0.999	5.359						
111106-003	1	N	6.574	6.615	6.660	6.627	6.614	6.589	6.574	6.660	6.613	0.086	1.300	5.361	6.574	6.660	6.613	5.360	0.083	1.248
	2	N	6.579	6.614	6.658	6.629	6.610	6.581	6.579	6.658	6.612	0.079	1.195	5.359						
111106-004	1	N	6.589	6.628	6.639	6.631	6.619	6.588	6.589	6.639	6.612	0.070	1.059	5.357	6.564	6.645	6.609	5.354	0.075	1.142
	2	N	6.564	6.581	6.638	6.645	6.622	6.582	6.564	6.645	6.605	0.081	1.226	5.351						
111106-005	1	N	6.650	6.604	6.632	6.647	6.644	6.577	6.577	6.650	6.626	0.073	1.102	5.362	6.577	6.655	6.625	5.363	0.071	1.064
	2	N	6.655	6.596	6.635	6.642	6.630	6.587	6.587	6.655	6.625	0.068	1.026	5.364						
111106-006	1	N	6.578	6.593	6.625	6.653	6.634	6.587	6.578	6.653	6.612	0.075	1.134	5.354	6.576	6.653	6.612	5.355	0.074	1.119
	2	N	6.576	6.595	6.627	6.649	6.638	6.584	6.576	6.649	6.612	0.073	1.104	5.355						

Table 3 - Specimen length, and average OD along length.
Note: Use Pi Tape for these O.D. measurements. **Measurment Tool Serial Number:** 12100382

111106-001	38.00	6.615	6.616	6.618	6.616	6.617	6.615	6.618	6.616
111106-002	38.00	6.616	6.616	6.617	6.617	6.615	6.615	6.617	6.616
111106-003	38.00	6.617	6.617	6.616	6.615	6.616	6.615	6.617	6.616
111106-004	38.00	6.616	6.616	6.617	6.616	6.616	6.616	6.617	6.616
111106-005	38.00	6.616	6.616	6.616	6.615	6.615	6.615	6.616	6.616
111106-006	38.00	6.615	6.615	6.616	6.616	6.616	6.615	6.616	6.616

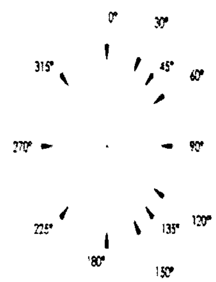

Table 4 - Dimensional Analysis Across Specimens

0.614	6.613	3.785	1.085	5.358

Input	Value above tolerance
Calculation	Value below tolerance

Thickness Range shall be within 12% when measured (ASTM D 2513).
Ovality shall not exceed 5% when measured (ASTM D 2513).

Measured By: Peter P. Mulligan

Figure 2. Test Specimen Dimensions, 111106

Figure 3. Ductile Failure of 111106-005

Figure 4. Slit (Brittle Failure) of 111106-017

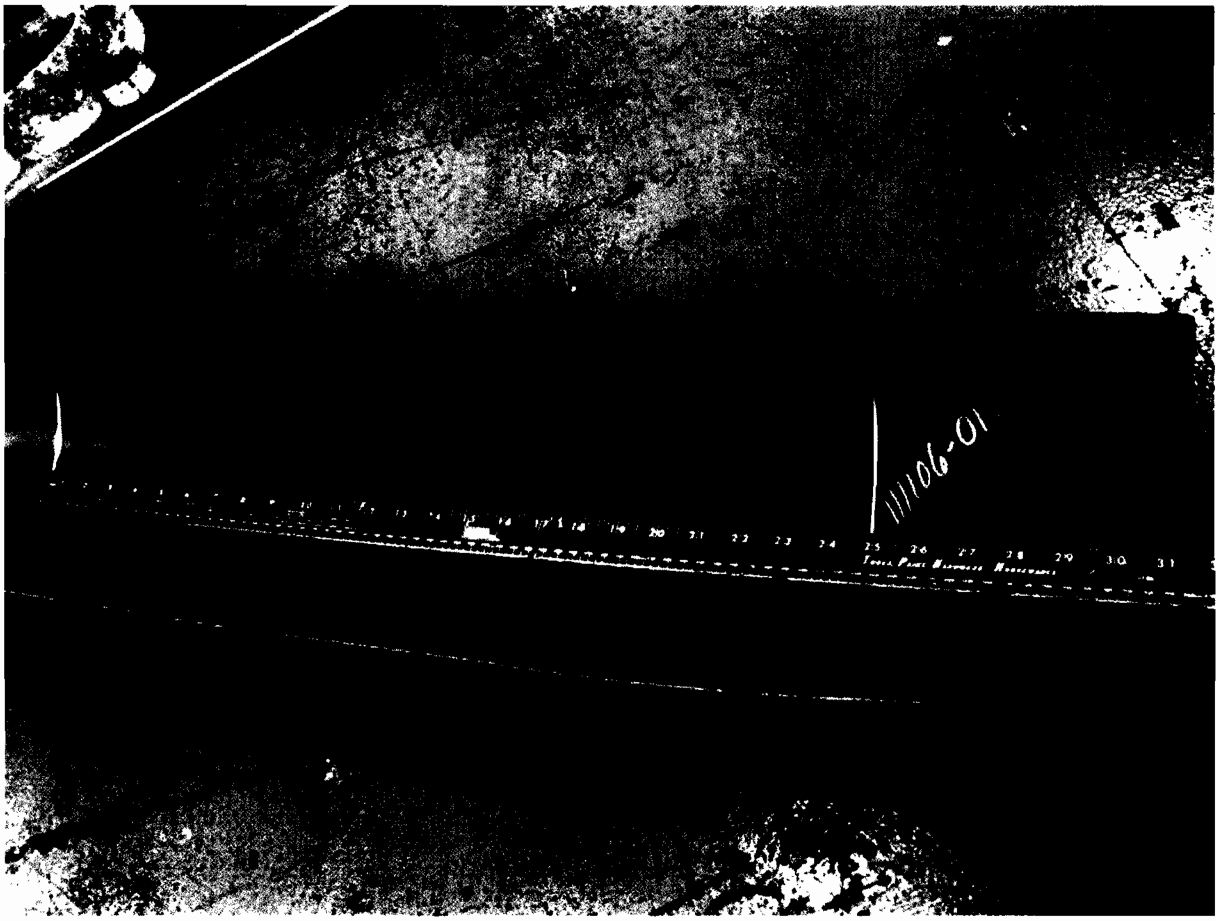

Figure 5. Pipe Inner Wall Surface, Slit (Brittle Failure) of 111106-017

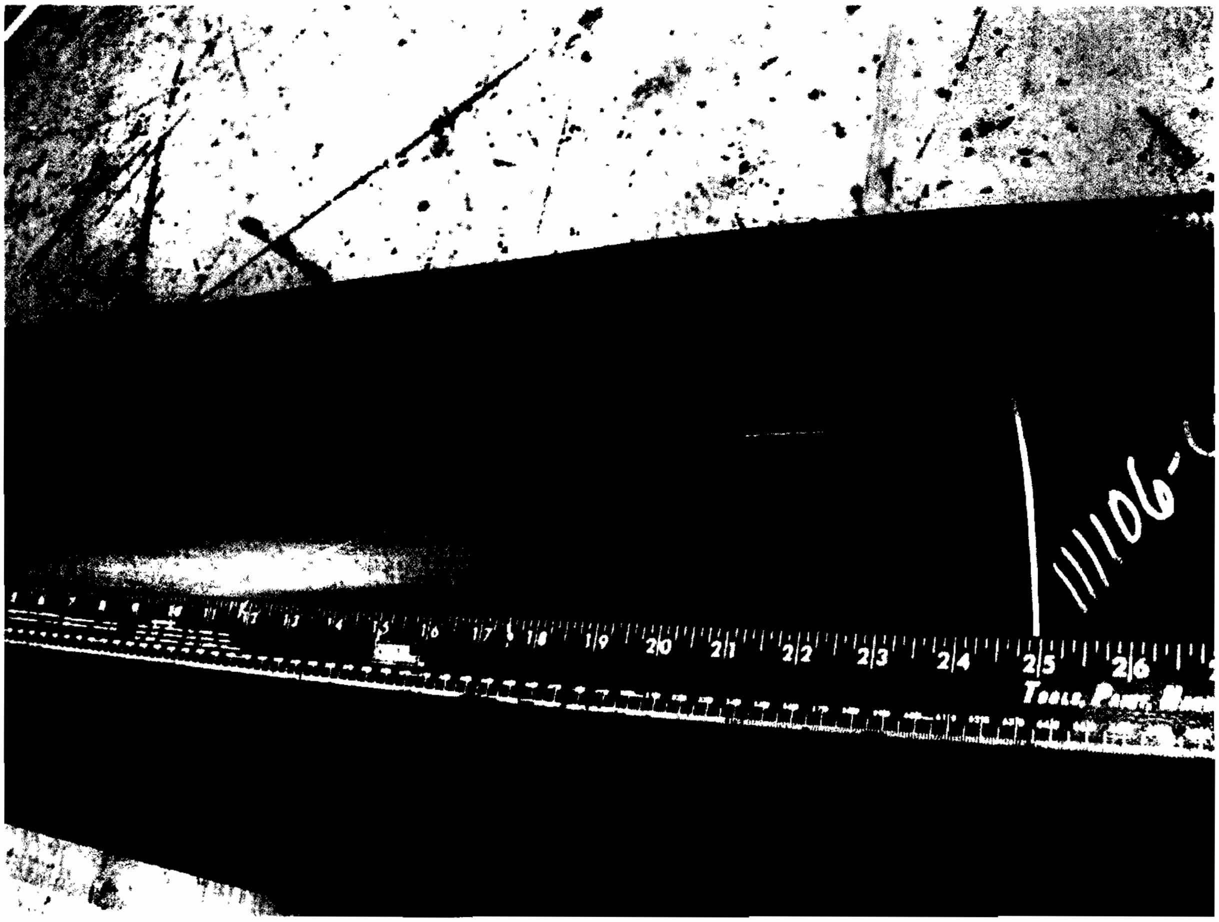

Figure 6. Pipe Inner Wall Surface, Slit (Brittle Failure) of 111106-017

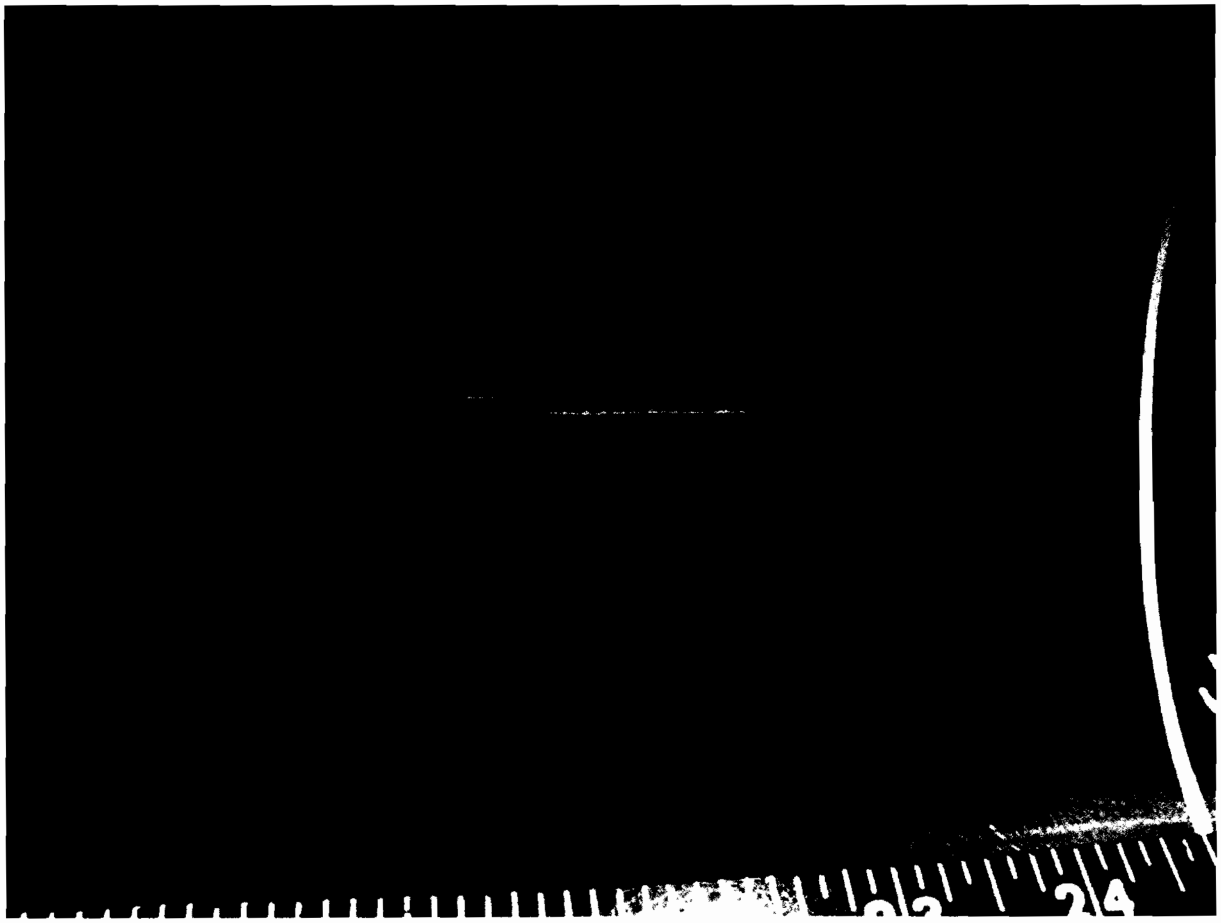

Figure 7. Pipe Inner Wall Surface, Slit (Brittle Failure) of 111106-017

End of Report

Palermo Plastics Pipe (P^3)
Consulting
Dr. Gene Palermo
www.plasticspipe.com

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Fax: 865-995-0115

"Elevated Temperature Testing of UV-Exposed HDPE Pipe As Requested by PHMSA"

Report Prepared for MLGW

By

Dr. Gene Palermo

1/23/2012

"Elevated Temperature Testing of UV-Exposed HDPE Pipe As Requested by PHMSA"

I. Summary

Elevated temperature sustained pressure testing completed by the Gas Technology Institute (GTI) confirms that ultra-violet (UV) radiation has no effect on the long-term performance of black HDPE pipe that Memphis Light Gas Water (MLGW) stored outdoors for several years. One pipe sample failed in the normal inside-to-outside crack propagation direction after 5961 hours at 80°C and 825 psi, which confirms linearity of the 23°C ductile regression line to 340 years based on the industry-accepted Bidirectional Shift Factors. Using the MLGW average annual ground temperature of 15°C (60°F), linearity of the ductile regression line is substantiated to 812 years. An additional 16 black HDPE pipe samples were on test at the same conditions for over 6000 hours. In addition, the normal inside-to-outside crack propagation direction is further confirmation that UV radiation had no effect on the long-term performance of the black pipe stored outdoors by MLGW.

II. Background

Memphis Light Gas Water (MLGW) had stored black HDPE gas pipe outdoors for several years and then installed this pipe in their natural gas distribution piping system. The plastic piping industry understands that black pipe (with 2% carbon black) can be stored outdoors indefinitely with no damage from UV radiation. However, as the ASTM D2513 standard only recognized an outdoor storage of two years, MLGW submitted a waiver to PHMSA with two requests – 1) allow the installed black HDPE pipe that had been subjected to several years outdoor storage to remain in service, and 2) allow current black HDPE pipe stored outdoors for several years to be installed.

MLGW received a letter from Mr. Larry Borum, Chief Gas Pipeline Safety Division of the Tennessee Regulatory Authority (TRA), responding to their waiver – see Appendix A. MLGW requested that Dr. Gene Palermo of Palermo Plastics Pipe Consulting review this letter, and provide guidance on conducting the requested testing. As per point number 2 of this letter, PHMSA would like for MLGW to conduct the 80°C sustained pressure test at a stress of 825 psi for a time of 6000 hours, as shown below.

2. The 80 degree C (80°C) test **(ASTM D2513-09a)** must be performed for samples of the 4-inch, 6-inch and 8-inch pipe which have been most exposed to UV. To confirm the performance of the PE pipe materials in question, follow 5.6.2 (Procedure II) of ASTM D2837-08 **(or most current version referenced through ASTM D2513-09a)**. The test conditions are to be taken from Table 3 of D2837-08, or for a PE material with an HDB of 1600 psi, a test hoop stress of 825 psi and a test temperature of 176°F (80°C). The linear extrapolation of the stress regression curve to 438,000 hours (50 years) is substantiated when the log average failure time of the test specimens at 176°F (80°C) surpasses 6,000 hours.

This testing would assure PHMSA, TRA and MLGW that black PE 3408 pipe that has been stored outdoors for several years will have a 73°F ductile regression line, which is linear for at least 438,000 hours (50 years). Per the referenced ASTM D2837 Section 5.6.2, the 80°C stress rupture test would be conducted at a hoop stress of 825 psi for at least 6000 hours. The Gas Technology Institute (GTI) was asked to conduct this 80°C stress rupture testing on behalf of MLGW.

The plastic pipe industry has determined that this 6000-hour test is actually quite conservative, as only 200 hours at 80°C and 825 psi hoop stress is required to validate the Hydrostatic Design Basis at 73°F by demonstrating linearity to 100,000 hours (11 years). Using the well-accepted Bidirectional Shift Factors, a running time of 6000 hours at 80°C and 825 psi actually shifts to 342 years at 73°F (23°C) or 850 years at 60°F (15°C), which is the average annual ground temperature at MLGW. See Appendix 2 for an explanation of these Bidirectional Shift Factors. As such, this 6000-hour test actually "substantiates" linearity for 850 years, which is considerably longer than the requested 50 years.

MLGW collected the appropriate 4", 6" and 8" pipe samples that had been exposed to the most UV radiation from several years of outdoor storage, and shipped them to GTI for testing. Here are the print lines for these three pipe sizes:

4" - 4"IPS SDR11 POLYPIPE 6810 GAS PE3408 CEE ASTM D2513 API 15LE X37L43 5GC 04 DEC 05

6" - 6"IPS SDR11.0 DRISCOPLEX GAS PE3408 CEE ASTM D2513 KV22 H 0000 FEET K005 081306 PACK 0007

8" - 8"IPS SDR11 POLYPIPE 6810 GAS PE3408 CEE ASTM D2513 API 15LE X46L43 7GA 06DEC05

III. Elevated Temperature Test Results

A. Data from Gas Technology Institute (GTI)

GTI subjected all the 4", 6" and 8" black HDPE pipe samples to sustained pressure testing in accordance with ASTM D1598 at a temperature of 80°C and a stress of 825 psi. The data are summarized in the table below:

ASTM D1598 Long-Term Hydrostatic Test Results

Project:	02222.1.01 MLGW-Palermo 111106	Test Fluid:		Requested By:	
Update Date:		Tank Fluid:		Tested By:	
Manufacturer:					
Print Line:					

111106-006	2011	3	7	15	40	4.487	0.425	172	2011	11	16	10	10	6090.5	6090.5	822.0	80°C	3-25	Removed before failure.	5593.0	
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111106-002	2011	3	10	16	25	4.485	0.426	172	2011	11	16	10	10	6017.7	6017.7	821.6	80°C	3-23	Removed before failure.	5593.0	
111106-008	2011	3	10	16	25	6.616	0.612	169	2011	11	16	10	10	6017.7	6017.7	829.0	80°C	3-24	Removed before failure.	6017.7	
111106-009	2011	3	10	16	25	6.616	0.614	169	2011	11	16	10	10	6017.7	6017.7	826.0	80°C	3-22	Removed before failure.	6017.7	
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111106-017	2011	4	4	11	25	8.620	0.813	172	2011	12	8	20	40	5961.2	5961.2	825.8	80°C	3-09	Brittle slit failure .	6031.2	
111106-019	2011	4	4	11	25	8.626	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.5	80°C	3-10	Removed before failure.	6031.2	
111106-020	2011	4	4	11	25	8.625	0.813	172	2011	12	12	8	35	6045.2	6045.2	826.4	80°C	3-11	Removed before failure.	6031.2	
111106-018	2011	4	4	11	25	8.624	0.812	172	2011	12	12	8	35	6045.2	6045.2	827.4	80°C	3-14	Removed before failure.	6031.2	

All of the pipe samples tested (six samples for each of three pipe sizes) exceeded 6000 hours of testing at 80°C and 825-psi hoop stress with two exceptions. There was one ductile failure at 3178 hours in a 4" pipe sample and there was a slit failure at 5961 hours in an 8" pipe sample. These two samples are discussed below.

B. Pipe Sample with a Ductile Failure

When conducting the validation or substantiation tests per ASTM D2837, it is possible to obtain a premature ductile failure. The reason for this is that the test stresses were based on the 23°C ductile regression lines for several PE materials that were then shifted to 80°C using the same Bidirectional Shift Factors. When testing at these high stresses, such as 825 psi, it is possible to obtain ductile failures. ASTM D2837 accounts for this by allowing the testing to be conducted at a lower stress for a longer time as shown below.

> 5.6.2.3 If a temperature/stress condition in the tables results in a premature ductile failure for a particular PE material, the stress at that temperature may be lowered by 15 %. The corresponding required time for this lowered stress is then six times the value in the table. For example, when validating an HDB of 1600 psi at 73°F, if testing at 80°C/825 psi results in ductile failures, lower the stress to 700 psi and retest. The required time to validate using this condition is now 1200 h. If ductile failures still occur, the stress may be lowered to 595 psi and the corresponding time is increased to 7200 h.

In this case, we are trying to determine if UV radiation from several years of outdoor exposure has affected the long-term performance of HDPE pipe. This premature ductile failure was not due to any effects from UV radiation. It is common for a premature ductile failure to occur with some PE materials due to the high stresses that are used – such as 825 psi. Therefore, I do not believe that any additional testing needs to be done as a result of this ductile failure to demonstrate that UV radiation has no effect on the long-term performance of this black HDPE pipe.

C. Pipe Sample with a Slit Failure

One of the pipe samples failed in 5961 hours, which is just below the requested 6000 hours. This pipe sample failed in a normal manner for PE pipe, meaning a crack initiated on the inside pipe surface and propagated to the outside pipe surface. Keep in mind that the purpose of this test was to determine if there were any effects of UV radiation from outdoor storage on the long-term performance of the black HDPE pipe. I have personally conducted 80°C testing on non-black pipe that had been exposed to several years of outdoor exposure. If UV radiation has degraded the outside surface of outdoor exposed pipe, there are two key observations in the test – 1) the failure mode will be a crack that initiates on the outside pipe surface (in the degraded area) and propagates to the inside pipe surface, and 2) the failure time will be lower compared to standard pipe.

In this case, the failure mode was the standard inside-to-outside crack propagation direction. This indicates that there was no degradation on the outside pipe surface that would change the failure mode to an outside-to-inside crack propagation direction. Furthermore, the request from PHMSA was to substantiate the 23°C ductile regression line to 50 years. As shown below, this test result of 5961 hours actually substantiates linearity of the 23°C ductile regression line to 340 years, based on the Bidirectional Shift Factors.

Bidirectional Shift Factors

Reference Conditions		**Shifted Conditions**	
Temperature (Tr) = C	80	Temperature (T) = C	23
Stress (Sr) = psi	825	Stress =	S
Failure time (tr)= hours	5,961	Failure time =	t

at = exp(-0.109(T-Tr))

at = 499.1965969

bt = exp(0.0116(T-Tr))

bt = 0.516231485

Sr = S X bt

S = Sr/bt

S = 1598 psi
11.02 MPa

tr = t/at

t = tr X at

t = 2975710 hours
340 years

If we take into account the fact that the average annual ground temperature in Memphis is 15°C, this test result of 5961 hours actually substantiates linearity of the 15°C ductile regression line to 812 years, as shown below.

Bidirectional Shift Factors

Reference Conditions		**Shifted Conditions**	
Temperature (Tr) = C	80	Temperature (T) = C	15
Stress (Sr) = psi	825	Stress =	S
Failure time (tr)= hours	5,961	Failure time =	t

at = exp(-0.109(T-Tr))			bt = exp(0.0116(T-Tr))		
at =	1193.923235		bt =	0.47048086	
Sr = S X bt			tr = t/at		
S = Sr/bt			t = tr X at		
S =	1753	psi	t =	7116976	hours
	12.09	MPa		812	years

Therefore, I do not believe that any additional testing needs to be done to demonstrate that UV radiation has no effect on the long-term performance of this black HDPE pipe. The failure mode was the standard inside-to-outside crack propagation direction, and the failure time of 5961 hours validates linearity at the MLGW ground temperature to 812 years, which is well above the 50 years requested by PHMSA.

IV. Conclusion

Elevated temperature sustained pressure testing completed by the Gas Technology Institute (GTI) confirms that ultra-violet (UV) radiation has no effect on the long-term performance of black HDPE pipe that Memphis Light Gas Water (MLGW) stored outdoors for several years. One pipe sample failed in the normal inside-to-outside crack propagation direction after 5961 hours at 80°C and 825 psi, which confirms linearity of the 23°C ductile regression line to 340 years based on the industry-accepted Bidirectional Shift Factors. Using the MLGW average annual ground temperature of 15°C (60°F), linearity of the ductile regression line is substantiated to 812 years. An additional 16 black HDPE pipe samples were on test at the same conditions for over 6000 hours. In addition, the normal inside-to-outside crack propagation direction is further confirmation that UV radiation had no effect on the long-term performance of the black pipe stored outdoors by MLGW.

Appendix 1

TENNESSEE REGULATORY AUTHORITY

460 James Robertson Parkv
Nashville, Tennessee 37243-0

January 18, 2011

Mr. Brent Haywood, P.E.
Vice President – Technical Services
Memphis Light, Gas, and Water
220 South Main Street
Memphis, Tennessee 38103

Re: Docket 08-00124, Petition of Memphis Light Gas and Water for a Waiver to Permit the Continued Use of Plastic Piping, which is in service and had a Storage Period in Excess of 2 Years prior to Installation.

Dear Mr. Haywood:

The Gas Pipeline Safety Division (GPSD) of the Tennessee Regulatory Authority (TRA) is in receipt of a letter dated December 15, 2010 from the Pipeline and Hazardous Materials Safety Administration (PHMSA) in response to the above referenced waiver request. A copy of the PHMSA letter accompanies. The letter contains no objections to the order of 49 CFR 192.7 as specified in the TRA submission dated August 19, 2010, however, it does include three (3) conditions as follows:

1. The operator must remove and discard a minimum of two times the diameter in length of all polyethylene (PE) pipe ends that have been stored outdoors at any time without properly fastened end-caps. This is due to UV exposure at these ends, which may be greater than exposure at other points in the pipe.
2. The 80 degree C (80°C) test **(ASTM D2513-09a)** must be performed for samples of the 4-inch, 6-inch and 8-inch pipe which have been most exposed to UV. To confirm the performance of the PE pipe materials in question, follow 5.6.2 (Procedure II) of ASTM D2837-08 **(or most current version referenced through ASTM D2513-09a)**. The test conditions are to be taken from Table 3 of D2837-08, or for a PE material with an HDB of 1600 psi, a test hoop stress of 825 psi and a test temperature of 176°F (80°C). The linear extrapolation of the stress regression curve to 438,000 hours (50 years) is substantiated when the log average failure time of the test specimens at 176°F (80°C) surpasses 6,000 hours.
3. All pipe must be inspected for surface damage including cuts, gouges, scratches, and similar imperfections. Any pipe segments with surface damage penetrating greater than 10 percent (10%) of the wall thickness must be removed.

01-24-11A11:15 RCVD

Telephone (615) 741-2904, Toll-Free 1-800-342-8359, Facsimile (615) 741-5015
www.state.tn.us/tra

According to Mr. Richard Sanders of PHMSA, these conditions are applicable to stored pipe. The GPSD is in agreement with these conditions and requests that MLGW provide a schedule for completing the testing as set forth in condition 2 by letter within sixty (60) after receipt of this letter. Upon completion MLGW shall provide a copy of the test results to the GPSD.

We appreciate MLGW's continuing patience and work relative to the resolution of this issue. Should you have any questions or wish to discuss any issues or concerns, please contact us.

Sincerely,

Larry K. Borum

Larry K. Borum, Chief
Gas Pipeline Safety Division

cc: Richard Collier, TRA General Counsel
TRA Docket File #08-00124

Appendix 2

Bidirectional Shift Factors (BSF)

Dr. Carl Popelar introduced the Bidirectional Shift Factors in the early 1990's. He used stress rupture data from several unimodal medium-density PE materials, unimodal high-density PE materials and also bimodal high-density materials. He found that the stress rupture data for all these PE materials could be shifted into one master curve. He also determined the equations to be used when data are to be shifted from one temperature to another temperature. Using these equations there is a corresponding bidirectional shift in both the hoop stress and the time when the temperature is shifted. Here are the equations that Dr. Popelar developed based on about 50 different stress rupture datasets for a variety of PE materials.

$$a = \exp [-0.109 (T - T_R)]$$

$$b= \exp [0.0116\ T - T_R)]$$

where the Temperature (T) and the arbitrary reference temperature (T_R) are in degrees Celsius.

When the coefficients a and b are known, the hoop stress (S) and the failure time (t) are calculated from the following equations.

$$S(T_R) = S(T) \times b$$

$$t(T_R) = t(T) / a$$

As an example, we have determined that at a test temperature of 80°C and test hoop stress of 600 psi, the failure time (or running time) is 1000 hours. We would like to know the corresponding hoop stress and time at 20°C.

In Example Calculation 1 shown on the next page, the above test conditions shift from a stress of 600 psi to a stress of 1203 psi and from a time of 1000 hours to a time of 79 years, when the temperature is shifted from 80°C to 20°C. Note that when shifting from a high temperature to a lower temperature, the stress is shifted to a higher stress and the time is shifted to a higher time. Since both stress and time are shifted, the method is referred to as a bidirectional shift. Of course, we can also shift from a low temperature to a higher temperature, as shown previously in Figure 2, when the shift was from 23°C to 80°C. This BSF calculation is shown in Example Calculation 2.

Example Calculation 1 – Shift From 80°C to 20°C

Popelar Shift Factors

Reference Conditions		Shifted Conditions	
Temperature (Tr) = C	80	Temperature (T) = C	20
Stress (Sr) = psi	600	Stress =	S
Failure time (tr)= hours	1,000	Failure time =	t

at = exp(-0.109(T-Tr))			bt = exp(0.0116(T-Tr))		
at =	692.2866		bt =	0.498576	
Sr = S X bt			tr = t/at		
S = Sr/bt			t = tr X at		
S =	1203.428	psi	t =	692286.6	hours
	8.299505	Mpa		79.02815	years

Example Calculation 2 – Shift From 23°C to 80°C

Popelar Shift Factors

Reference Conditions		Shifted Conditions	
Temperature (Tr) = C	23	Temperature (T) = C	80
Stress (Sr) = psi	1600	Stress =	S
Failure time (tr)= hours	100,000	Failure time =	t

at = exp(-0.109(T-Tr))			bt = exp(0.0116(T-Tr))		
at =	0.002003		bt =	1.937115	
Sr = S X bt			tr = t/at		
S = Sr/bt			t = tr X at		
S =	825.9704	psi	t =	200.3219	hours
	5.696347	Mpa		0.022868	years