ASTM 1216

Technical Data

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EXHIBIT 1 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
8" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	8.0	inches
10			Minimum Inside Diameter	7.60	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	12.59	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	1.0	ft.
16	H	=	height of soil above top of pipe	1.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	11.6	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32* R_w*B'* E'_s*(E_L\ I/D^3)]^{1/2}$	12.93	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000463	$in.^4/in.$
28	t		CIPP thickness	0.177	inch
29	t		CIPP thickness	4.5	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	12.59	psi
35			Calculated External Pressure (q_t) Capacity	12.93	psi
36			Percentage Difference	2.6%	
37			CIPP thickness	0.177	inch
38			CIPP thickness	4.5	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas F. Jones
6/25/93

R.H.

Norman Medgett
12-11-99

EXHIBIT 1 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
8" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	8.0	inches
10			Minimum Inside Diameter	7.60	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.77	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000151	in.^{4}/in.
28	t		CIPP thickness	0.122	inch
29	t		CIPP thickness	3.1	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.77	psi
36			Percentage Difference	0.4%	
37			CIPP thickness	0.122	inch
38			CIPP thickness	3.1	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas T. Jarvis
12/15/03

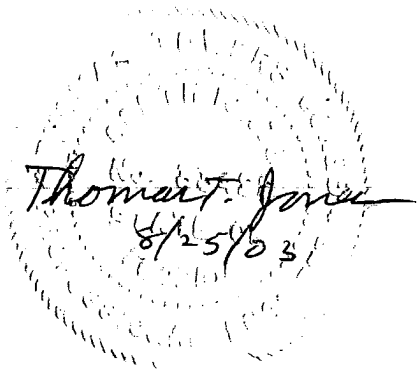
R.H

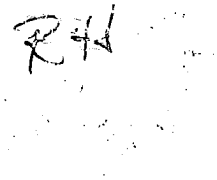
Dawn Medynski
12-11-03

EXHIBIT 1 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
8" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	8.0	inches
10			Minimum Inside Diameter	7.60	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	12.0	ft.
16	H	=	height of soil above top of pipe	12.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.98	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000237	$in.^4/in.$
28	t		CIPP thickness	0.142	inch
29	t		CIPP thickness	3.6	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	11.90	psi
35			Calculated External Pressure (q_t) Capacity	11.98	psi
36			Percentage Difference	0.7%	
37			~~CIPP thickness~~	0.142	inch
38			~~CIPP thickness~~	3.6	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





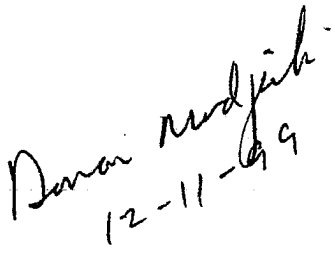


EXHIBIT 1 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
8" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	8.0	inches
10		Minimum Inside Diameter	7.60	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	16.0	ft.
16	H	= height of soil above top of pipe	16.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	16.36	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.000377	in.^{4}/in.
28	t	CIPP thickness	0.165	inch
29	t	CIPP thickness	4.2	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	15.86	psi
35		Calculated External Pressure (q_t) Capacity	16.36	psi
36		Percentage Difference	3.0%	
37		CIPP thickness	0.165	inch
38		CIPP thickness	4.2	mm
39				
40		**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas F. Jones
8/25/03

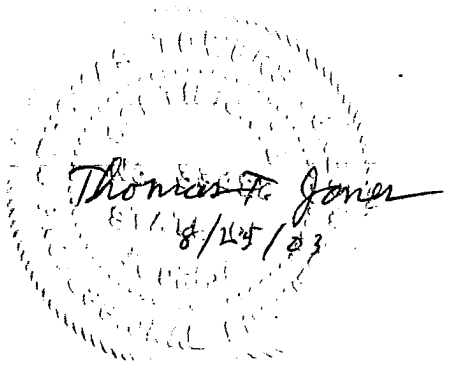
RH

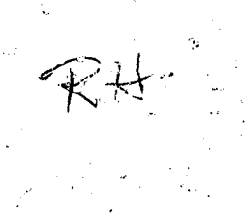
Donna Mostafa
12-11-99

EXHIBIT 1 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
8" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	8.0	inches
10		Minimum Inside Diameter	7.60	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	20.0	ft.
16	H	= height of soil above top of pipe	20.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	20.15	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.000495	in.^{4}/in.
28	t	CIPP thickness	0.181	inch
29	t	CIPP thickness	4.6	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	19.83	psi
35		Calculated External Pressure (q_t) Capacity	20.15	psi
36		Percentage Difference	1.6%	
37		CIPP thickness	0.181	inch
38		CIPP thickness	4.6	mm
39				
40		**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





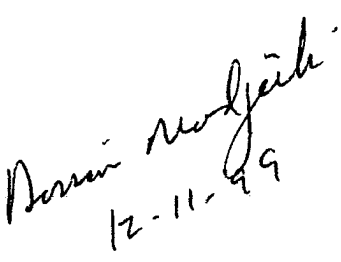
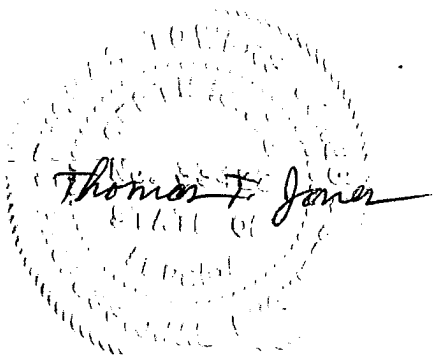


EXHIBIT 2 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
10" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	10.0	inches
10		Minimum Inside Diameter	9.50	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	12.19	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	1.0	ft.
16	H	= height of soil above top of pipe	1.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	11.2	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	12.50	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.000846	$in.^4/in.$
28	t	CIPP thickness	0.217	inch
29	t	CIPP thickness	5.5	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	12.19	psi
35		Calculated External Pressure (q_t) Capacity	12.50	psi
36		Percentage Difference	2.5%	
37		CIPP thickness	0.217	inch
38		CIPP thickness	5.5	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



Thomas F. Jones

R H

Dorian Nodjeh
12-11-99

EXHIBIT 2 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
10" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	10.0	inches
10			Minimum Inside Diameter	9.50	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.85	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000302	in.^{4}/in.
28	t		CIPP thickness	0.154	inch
29	t		CIPP thickness	3.9	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.85	psi
36			Percentage Difference	1.4%	
37			CIPP thickness	0.154	inch
38			CIPP thickness	3.9	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

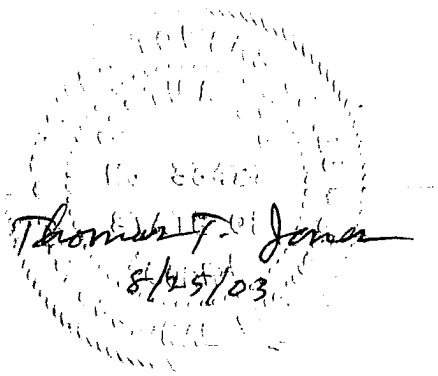
Thomas F. Jones
8/25/03

12-11-09

EXHIBIT 2 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
10" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	10.0	inches
10			Minimum Inside Diameter	9.50	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	12.0	ft.
16	H	=	height of soil above top of pipe	12.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.98	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000463	$in.^4/in.$
28	t		CIPP thickness	0.177	inch
29	t		CIPP thickness	4.5	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	11.90	psi
35			Calculated External Pressure (q_t) Capacity	11.98	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.177	inch
38			CIPP thickness	4.5	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



RH

12-11-99

EXHIBIT 2 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
10" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	10.0	inches
10			Minimum Inside Diameter	9.50	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	16.0	ft.
16	H	=	height of soil above top of pipe	16.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	16.12	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000715	$in.^4/in.$
28	t		CIPP thickness	0.205	inch
29	t		CIPP thickness	5.2	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	15.86	psi
35			Calculated External Pressure (q_t) Capacity	16.12	psi
36			Percentage Difference	1.6%	
37			CIPP thickness	0.205	inch
38			CIPP thickness	5.2	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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8/25/03

RH

Dana Modjeski
12-11-99

EXHIBIT 2 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
10" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	10.0	inches
10			Minimum Inside Diameter	9.50	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	20.0	ft.
16	H	=	height of soil above top of pipe	20.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N^*[32^* R_w{}^*B'^* E'_s{}^*(E_L\ I/D^3)]^{1/2}$	19.89	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000942	$in.^4/in.$
28	t		CIPP thickness	0.224	inch
29	t		CIPP thickness	5.7	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	19.83	psi
35			Calculated External Pressure (q_t) Capacity	19.89	psi
36			Percentage Difference	0.3%	
37			CIPP thickness	0.224	inch
38			CIPP thickness	5.7	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas T. Jones
8/28/03

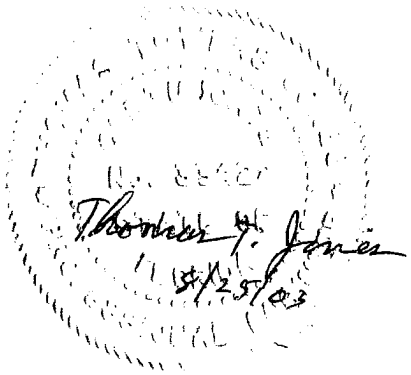
R+H

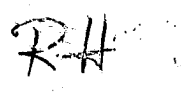
12-11-99

EXHIBIT 3 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
12" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	12.0	inches
10			Minimum Inside Diameter	11.40	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	11.89	psi
14	R_w	=	water buoyancy factor = $1 - 0.33 (H_w/H)$	0.67	
15	H_w	=	height of water above top of pipe	1.0	ft.
16	H	=	height of soil above top of pipe	1.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	10.9	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N^*[32^* R_w{}^*B'^* E'_s{}^*(E_L I/D^3)]^{1/2}$	11.94	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.001333	$in.^4/in.$
28	t		CIPP thickness	0.252	inch
29	t		CIPP thickness	6.4	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	11.89	psi
35			Calculated External Pressure (q_t) Capacity	11.94	psi
36			Percentage Difference	0.4%	
37			CIPP thickness	0.252	inch
38			CIPP thickness	6.4	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





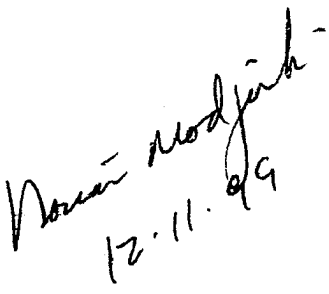
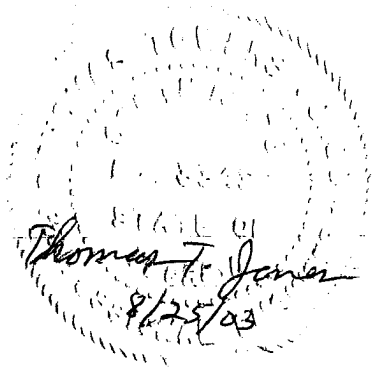


EXHIBIT 3 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
12" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	12.0	inches
10		Minimum Inside Diameter	11.40	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	8.0	ft.
16	H	= height of soil above top of pipe	8.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.8	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.91	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.000528	in.^{4}/in.
28	t	CIPP thickness	0.185	inch
29	t	CIPP thickness	4.7	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	8.73	psi
35		Calculated External Pressure (q_t) Capacity	8.91	psi
36		Percentage Difference	2.0%	
37		CIPP thickness	0.185	inch
38		CIPP thickness	4.7	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



R+t

Duncan Mudgett
12-11-09

EXHIBIT 3 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
12" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	12.0	inches
10			Minimum Inside Diameter	11.40	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	12.0	ft.
16	H	=	height of soil above top of pipe	12.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.98	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000801	$in.^4/in.$
28	t		CIPP thickness	0.213	inch
29	t		CIPP thickness	5.4	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	11.90	psi
35			Calculated External Pressure (q_t) Capacity	11.98	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.213	inch
38			CIPP thickness	5.4	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas T. Jones 8/25/03

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Donna Medgate 12-11-09

EXHIBIT 3 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
12" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	12.0	inches
10		Minimum Inside Diameter	11.40	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	16.0	ft.
16	H	= height of soil above top of pipe	16.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32* R_w*B'* E'_s*(E_L\ I/D^3)]^{1/2}$	15.97	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.001212	in.^{4}/in.
28	t	CIPP thickness	0.244	inch
29	t	CIPP thickness	6.2	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	15.86	psi
35		Calculated External Pressure (q_t) Capacity	15.97	psi
36		Percentage Difference	0.7%	
37		CIPP thickness	0.244	inch
38		CIPP thickness	6.2	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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Donna Medgitt 12-11-03

EXHIBIT 3 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
12" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	12.0	inches
10			Minimum Inside Diameter	11.40	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	=	water buoyancy factor = $1 - 0.33 (H_w/H)$	0.67	
15	H_w	=	height of water above top of pipe	20.0	ft.
16	H	=	height of soil above top of pipe	20.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N^*[32^* R_w{}^*B'^* E'_s{}^*(E_L I/D^3)]^{1/2}$	20.15	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.001671	$in.^4/in.$
28	t		CIPP thickness	0.272	inch
29	t		CIPP thickness	6.9	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	19.83	psi
35			Calculated External Pressure (q_t) Capacity	20.15	psi
36			Percentage Difference	1.6%	
37			CIPP thickness	0.272	inch
38			CIPP thickness	6.9	mm
39					
40			**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas T. Jones 8/25/03

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12-11-99

EXHIBIT 4 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
15" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	15.0	inches
10		Minimum Inside Diameter	14.25	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	11.09	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	1.0	ft.
16	H	= height of soil above top of pipe	1.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	10.1	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.28	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.002322	$in.^4/in.$
28	t	CIPP thickness	0.303	inch
29	t	CIPP thickness	7.7	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	11.09	psi
35		Calculated External Pressure (q_t) Capacity	11.28	psi
36		Percentage Difference	1.6%	
37		CIPP thickness	0.303	inch
38		CIPP thickness	7.7	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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8/25/03

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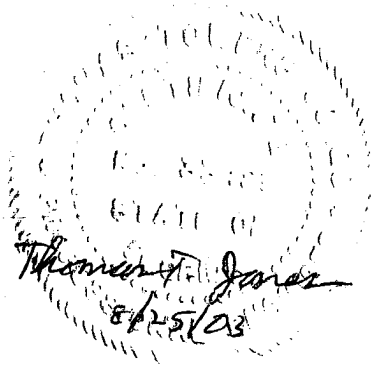
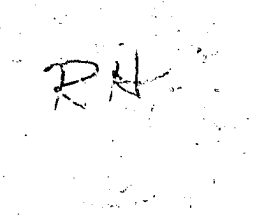
12-11-99

EXHIBIT 4 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
15" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	15.0	inches
10			Minimum Inside Diameter	14.25	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.74	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.000992	in.^{4}/in.
28	t		CIPP thickness	0.228	inch
29	t		CIPP thickness	5.8	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.74	psi
36			Percentage Difference	0.1%	
37			CIPP thickness	0.228	inch
38			CIPP thickness	5.8	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





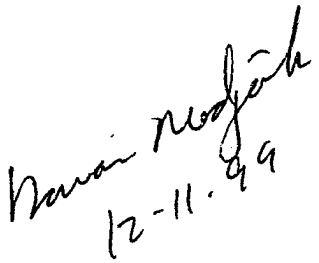
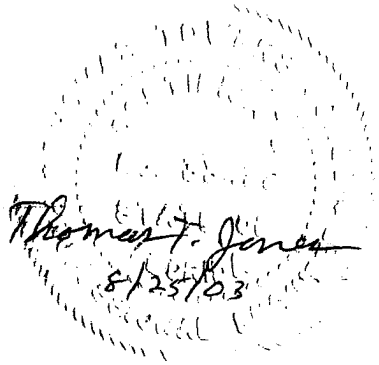
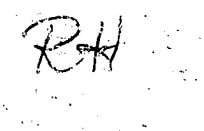


EXHIBIT 4 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
15" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	15.0	inches
10		Minimum Inside Diameter	14.25	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	12.0	ft.
16	H	= height of soil above top of pipe	12.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	12.11	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.001599	in.^{4}/in.
28	t	CIPP thickness	0.268	inch
29	t	CIPP thickness	6.8	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	11.90	psi
35		Calculated External Pressure (q_t) Capacity	12.11	psi
36		Percentage Difference	1.8%	
37		CIPP thickness	0.268	inch
38		CIPP thickness	6.8	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





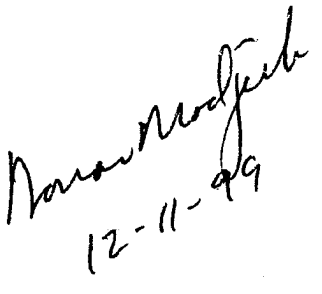
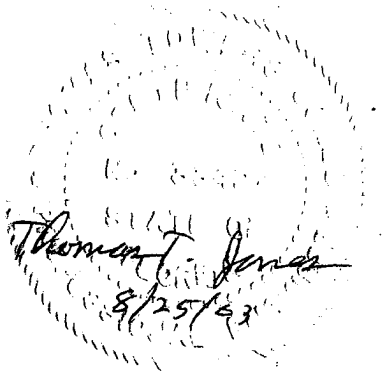


EXHIBIT 4 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
15" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	15.0	inches
10			Minimum Inside Diameter	14.25	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	16.0	ft.
16	H	=	height of soil above top of pipe	16.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	16.12	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.002413	$in.^4/in.$
28	t		CIPP thickness	0.307	inch
29	t		CIPP thickness	7.8	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	15.86	psi
35			Calculated External Pressure (q_t) Capacity	16.12	psi
36			Percentage Difference	1.6%	
37			CIPP thickness	0.307	inch
38			CIPP thickness	7.8	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



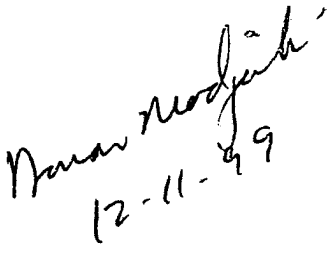
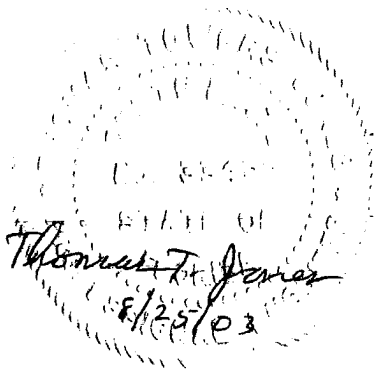
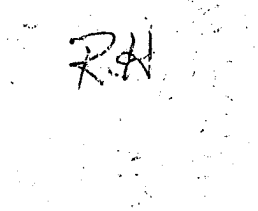


EXHIBIT 4 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
15" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	15.0	inches
10			Minimum Inside Diameter	14.25	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	20.0	ft.
16	H	=	height of soil above top of pipe	20.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32* R_w*B'* E'_s*(E_L\ I/D^3)]^{1/2}$	20.06	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.003235	in.^{4}/in.
28	t		CIPP thickness	0.339	inch
29	t		CIPP thickness	8.6	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	19.83	psi
35			Calculated External Pressure (q_t) Capacity	20.06	psi
36			Percentage Difference	1.2%	
37			CIPP thickness	0.339	inch
38			CIPP thickness	8.6	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





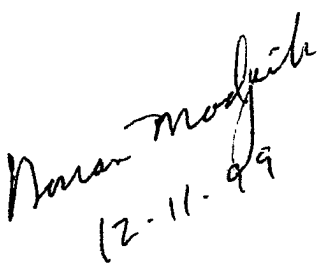


EXHIBIT 5 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
18" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	18.0	inches
10		Minimum Inside Diameter	17.10	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	10.39	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	1.0	ft.
16	H	= height of soil above top of pipe	1.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	9.4	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	10.48	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1+4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.003465	in.^{4}/in.
28	t	CIPP thickness	0.346	inch
29	t	CIPP thickness	8.8	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	10.39	psi
35		Calculated External Pressure (q_t) Capacity	10.48	psi
36		Percentage Difference	0.8%	
37		CIPP thickness	0.346	inch
38		CIPP thickness	8.8	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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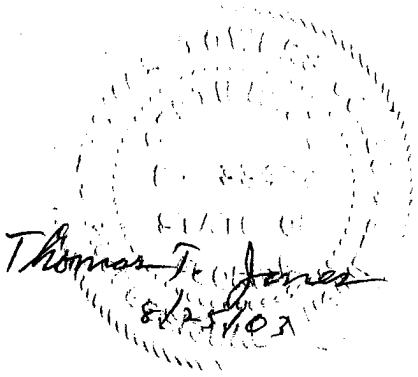
EXHIBIT 5 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
18" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	18.0	inches
10			Minimum Inside Diameter	17.10	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.81	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.001744	in.^{4}/in.
28	t		CIPP thickness	0.276	inch
29	t		CIPP thickness	7.0	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.81	psi
36			Percentage Difference	1.0%	
37			CIPP thickness	0.276	inch
38			CIPP thickness	7.0	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



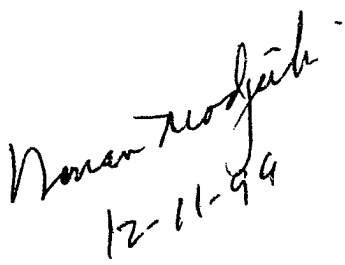
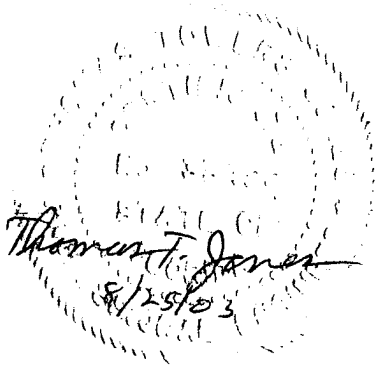
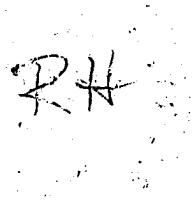


EXHIBIT 5 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
18" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	18.0	inches
10			Minimum Inside Diameter	17.10	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	12.0	ft.
16	H	=	height of soil above top of pipe	12.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.98	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.002703	$in.^4/in.$
28	t		CIPP thickness	0.319	inch
29	t		CIPP thickness	8.1	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	11.90	psi
35			Calculated External Pressure (q_t) Capacity	11.98	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.319	inch
38			CIPP thickness	8.1	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





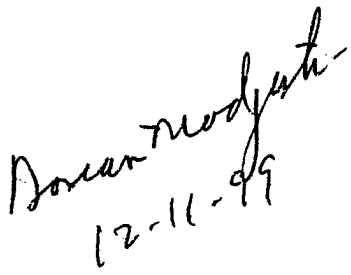


EXHIBIT 5 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
18" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	18.0	inches
10			Minimum Inside Diameter	17.10	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	16.0	ft.
16	H	=	height of soil above top of pipe	16.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N^*[32^* R_w{}^*B'^* E'_s{}^*(E_L\ I/D^3)]^{1/2}$	15.97	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.004090	$in.^4/in.$
28	t		CIPP thickness	0.366	inch
29	t		CIPP thickness	9.3	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	15.86	psi
35			Calculated External Pressure (q_t) Capacity	15.97	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.366	inch
38			CIPP thickness	9.3	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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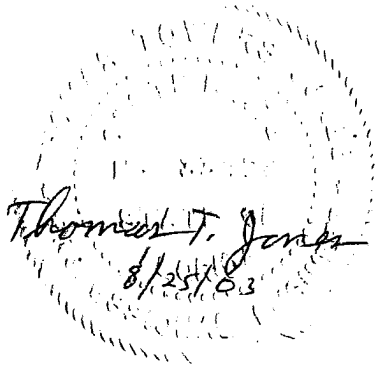
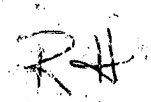
EXHIBIT 5 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
18" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	18.0	inches
10		Minimum Inside Diameter	17.10	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	20.0	ft.
16	H	= height of soil above top of pipe	20.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32* R_w*B'* E'_s*(E_L\ I/D^3)]^{1/2}$	20.00	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.005557	$in.^4/in.$
28	t	CIPP thickness	0.406	inch
29	t	CIPP thickness	10.3	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	19.83	psi
35		Calculated External Pressure (q_t) Capacity	20.00	psi
36		Percentage Difference	0.9%	
37		CIPP thickness	0.406	inch
38		CIPP thickness	10.3	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





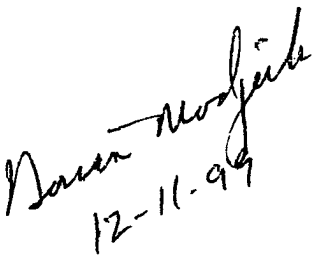


EXHIBIT 6 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
21" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	21.0	inches
10			Minimum Inside Diameter	19.95	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	9.89	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	1.0	ft.
16	H	=	height of soil above top of pipe	1.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	8.9	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32* R_w*B'* E'_s*(E_L\ I/D^3)]^{1/2}$	9.92	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.004934	in.^{4}/in.
28	t		CIPP thickness	0.390	inch
29	t		CIPP thickness	9.9	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	9.89	psi
35			Calculated External Pressure (q_t) Capacity	9.92	psi
36			Percentage Difference	0.3%	
37			CIPP thickness	0.390	inch
38			CIPP thickness	9.9	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

Thomas T. Jones 8/25/03

Nasar Mudgil 12.11.09

EXHIBIT 6 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
21" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	21.0	inches
10			Minimum Inside Diameter	19.95	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.87	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1+4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.002804	in.^{4}/in.
28	t		CIPP thickness	0.323	inch
29	t		CIPP thickness	8.2	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.87	psi
36			Percentage Difference	1.6%	
37			CIPP thickness	0.323	inch
38			CIPP thickness	8.2	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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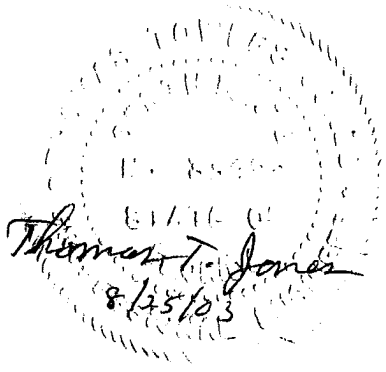
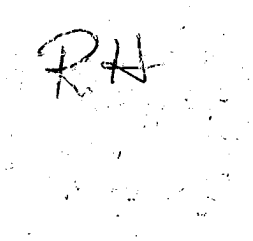
EXHIBIT 6 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
21" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	21.0	inches
10		Minimum Inside Diameter	19.95	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	12.0	ft.
16	H	= height of soil above top of pipe	12.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	12.08	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.004360	$in.^4/in.$
28	t	CIPP thickness	0.374	inch
29	t	CIPP thickness	9.5	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	11.90	psi
35		Calculated External Pressure (q_t) Capacity	12.08	psi
36		Percentage Difference	1.5%	
37		CIPP thickness	0.374	inch
38		CIPP thickness	9.5	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





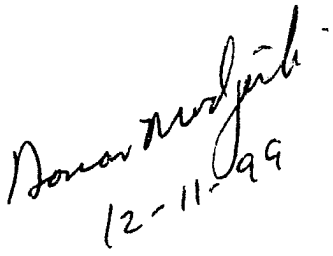
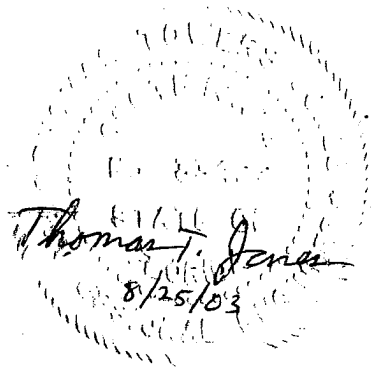


EXHIBIT 6 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
21" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	21.0	inches
10		Minimum Inside Diameter	19.95	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	16.0	ft.
16	H	= height of soil above top of pipe	16.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	16.08	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.006586	$in.^4/in.$
28	t	CIPP thickness	0.429	inch
29	t	CIPP thickness	10.9	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	15.86	psi
35		Calculated External Pressure (q_t) Capacity	16.08	psi
36		Percentage Difference	1.4%	
37		CIPP thickness	0.429	inch
38		CIPP thickness	10.9	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.



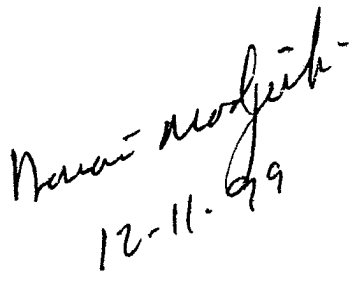
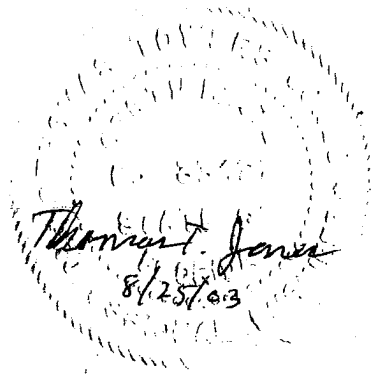
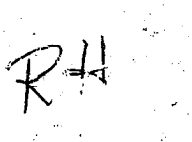


EXHIBIT 6 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
21" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	21.0	inches
10			Minimum Inside Diameter	19.95	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	20.0	ft.
16	H	=	height of soil above top of pipe	20.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	19.96	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.008787	$in.^4/in.$
28	t		CIPP thickness	0.472	inch
29	t		CIPP thickness	12.0	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	19.83	psi
35			Calculated External Pressure (q_t) Capacity	19.96	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.472	inch
38			CIPP thickness	12.0	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





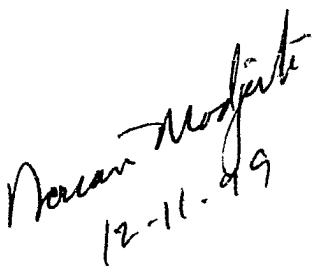
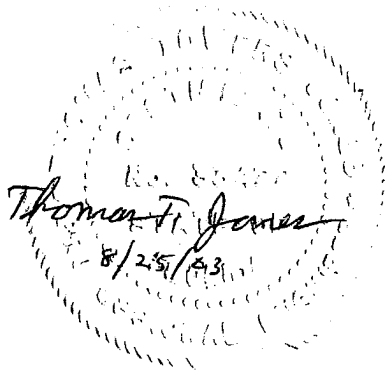
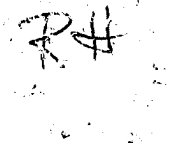


EXHIBIT 7 - A
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
24" DIAMETER, 1 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	24.0	inches
10		Minimum Inside Diameter	22.80	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	9.39	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	1.0	ft.
16	H	= height of soil above top of pipe	1.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	8.4	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	9.51	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.21	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.006769	in.^{4}/in.
28	t	CIPP thickness	0.433	inch
29	t	CIPP thickness	11.0	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	9.39	psi
35		Calculated External Pressure (q_t) Capacity	9.51	psi
36		Percentage Difference	1.3%	
37		CIPP thickness	0.433	inch
38		CIPP thickness	11.0	mm
39				
40		**CIPP Properly Sized Given Input Variables**		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.





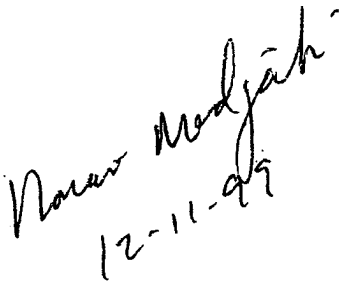


EXHIBIT 7 - B
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
24" DIAMETER, 8 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	24.0	inches
10			Minimum Inside Diameter	22.80	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	8.73	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	8.0	ft.
16	H	=	height of soil above top of pipe	8.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.8	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	8.77	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.30	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.004090	$in.^4/in.$
28	t		CIPP thickness	0.366	inch
29	t		CIPP thickness	9.3	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	8.73	psi
35			Calculated External Pressure (q_t) Capacity	8.77	psi
36			Percentage Difference	0.4%	
37			CIPP thickness	0.366	inch
38			CIPP thickness	9.3	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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EXHIBIT 7 - C
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
24" DIAMETER, 12 FT. DEPTH, 5 % SHAPELOSS

Line No.			Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**			
9		Mean Inside Diameter	24.0	inches
10		Minimum Inside Diameter	22.80	inches
11				
12	**II. Estimated External Pressure (q_t) on Pipe**			
13	q_t	= $0.433H_w+wHR_w/144+W_s$	11.90	psi
14	R_w	= water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	= height of water above top of pipe	12.0	ft.
16	H	= height of soil above top of pipe	12.0	ft.
17	w	= soil density	120.0	lb/ft^3
18	W_s	= live load*	0.0	psi
19				
20	**III. Calculated External Pressure (q_t) Capacity**			
21	q_t	= $C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	11.98	psi
22	C	= ovality reduction factor	0.64	
23	q	= percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24		Minimum Inside Diameter) / Mean Inside Diameter		
25	N	= factor of safety	2.0	
26	B'	= coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.35	inch-pound units
27	I	= moment of inertia of CIPP = $t^3/12$	0.006406	$in.^4/in.$
28	t	CIPP thickness	0.425	inch
29	t	CIPP thickness	10.8	mm
30	E'_s	= modulus of soil reaction	1,000	psi
31	E_L	= long-term modulus of elasticity for CIPP	400,000	psi
32				
33	**IV. Summary & Conclusion**			
34		Estimated External Pressure (q_t) on Pipe	11.90	psi
35		Calculated External Pressure (q_t) Capacity	11.98	psi
36		Percentage Difference	0.7%	
37		CIPP thickness	0.425	inch
38		CIPP thickness	10.8	mm
39				
40		CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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EXHIBIT 7 - D
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
24" DIAMETER, 16 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	24.0	inches
10			Minimum Inside Diameter	22.80	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	15.86	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	16.0	ft.
16	H	=	height of soil above top of pipe	16.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	15.97	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.41	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.009696	in.^{4}/in.
28	t		CIPP thickness	0.488	inch
29	t		CIPP thickness	12.4	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	15.86	psi
35			Calculated External Pressure (q_t) Capacity	15.97	psi
36			Percentage Difference	0.7%	
37			CIPP thickness	0.488	inch
38			CIPP thickness	12.4	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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8/15/03

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12-11-03

EXHIBIT 7 - E
CIPP LINER THICKNESS CALCULATIONS
FULLY DETERIORATED GRAVITY PIPE CONDITION
24" DIAMETER, 20 FT. DEPTH, 5 % SHAPELOSS

Line No.				Inputs/ Calculations	Units
8	**I. Host Pipe Dimensions**				
9			Mean Inside Diameter	24.0	inches
10			Minimum Inside Diameter	22.80	inches
11					
12	**II. Estimated External Pressure (q_t) on Pipe**				
13	q_t	=	$0.433H_w+wHR_w/144+W_s$	19.83	psi
14	R_w	=	water buoyancy factor = 1 - 0.33 (H_w/H)	0.67	
15	H_w	=	height of water above top of pipe	20.0	ft.
16	H	=	height of soil above top of pipe	20.0	ft.
17	w	=	soil density	120.0	lb/ft^3
18	W_s	=	live load*	0.0	psi
19					
20	**III. Calculated External Pressure (q_t) Capacity**				
21	q_t	=	$C/N*[32*R_w*B'*E'_s*(E_L\ I/D^3)]^{1/2}$	19.93	psi
22	C	=	ovality reduction factor	0.64	
23	q	=	percentage of ovality of original pipe = 100 x (Mean Inside Diameter -	5.0	%
24			Minimum Inside Diameter) / Mean Inside Diameter		
25	N	=	factor of safety	2.0	
26	B'	=	coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units,	0.48	inch-pound units
27	I	=	moment of inertia of CIPP = $t^3/12$	0.013076	in.^{4}/in.
28	t		CIPP thickness	0.539	inch
29	t		CIPP thickness	13.7	mm
30	E'_s	=	modulus of soil reaction	1,000	psi
31	E_L	=	long-term modulus of elasticity for CIPP	400,000	psi
32					
33	**IV. Summary & Conclusion**				
34			Estimated External Pressure (q_t) on Pipe	19.83	psi
35			Calculated External Pressure (q_t) Capacity	19.93	psi
36			Percentage Difference	0.5%	
37			CIPP thickness	0.539	inch
38			CIPP thickness	13.7	mm
39					
40			CIPP Properly Sized Given Input Variables		

Note: * Source: Concrete Pipe Design Manual, American Concrete Pipe Association, Seventh Printing October 1987, p. 163.

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EXHIBIT 8
SUMMARY OF MINIMUM SECTIONAL LINER THICKNESS (MM)

Diameter (Inches)	Depth of Pipe in Feet				
	1 - 4 Ft.	>4 - 8 Ft.	>8 - 12 Ft.	>12 - 16 Ft.	>16 - 20 Ft.
8	4.5	3.1	3.6	4.2	4.6
10	5.5	3.9	4.5	5.2	5.7
12	6.4	4.7	5.4	6.2	6.9
15	7.7	5.8	6.8	7.8	8.6
18	8.8	7.0	8.1	9.3	10.3
21	9.9	8.2	9.5	10.9	12.0
24	11.0	9.3	10.8	12.4	13.7

Note: Based on Exhibits 1-A - 1-E, 2-A - 2-E, 3-A - 3-E, 4-A - 4-E, 5-A - 5-E, 6-A - 6-E, & 7-A - 7-E.

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