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CONFIDENTIAL REPORT

Corrugated Fiberglass Well Casing And Cap Tests

for

GP Fiberglass Ltd.
Melfort Saskatchewan

by

Product Design & Development

Small Industry Services

SRC Publication No. 10177-1C00

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1 Introduction

GP Fiberglass Ltd, located near Melfort, Saskatchewan, manufacture 30-inch diameter corrugated well casing in 25 foot lengths and also fiberglass caps which fit over the end of the well casing. Each length of casing is provided with a serial number and associated with each serial number is production data including manufacturing times for each phase, amount and type of resin, amount and type of glass and catalyst used to manufacture the pipe.

The fiberglass well casing had been successfully manufactured and used. However, some clients have requested physical property data for the fiberglass components.

Mr. Gregg Phillips, President of GP Fiberglass Ltd., obtained the required test equipment and requested that all the tests be witnessed by engineering personnel from the Product Design and Development Group of the Saskatchewan Research Council. This report outlines the tests that were conducted and the data that was obtained on June 12, 2000 by Tony Kaminski, P. Eng, PhD, a principal engineer at the Saskatchewan Research Council in Saskatoon.

2 Objective

The objective of the tests was to obtain the following:

(1) load and stress data when the well casing is positioned vertically and loaded to failure
(2) load data when the well casing is positioned horizontally and loaded to failure
(3) load data when the cap is positioned on a vertical casing and loaded to failure

3 Test Procedure

Tests were conducted using both 1-ft and 3-ft lengths of well casing cut from pipes made on different days. The following data was obtained for both the well casing and well caps.

(1) component weight using a Toledo platform scale
(2) surface hardness using a Rex Model 1600 Type D gauge
(3) wall thickness using a Mitutoyo 8-inch digital micrometer
(4) product temperature using a infrared thermometer
(5) test time using a digital stop watch
(6) product length or diameter using a tape measure
(7) vertical test force using a CDK RL9000 100,000 lb capacity load cell with a Rice Lake Weighing System Model IQ + 355-2A indicator supplied by Norac Systems in Saskatoon

Each component was loaded using a 100-ton hydraulic press manufactured by Fasoli Industries Ltd., a Model 36-60-100 having a 36" x 60" bed. The vertical well casings were tested as shown in Figure 1.

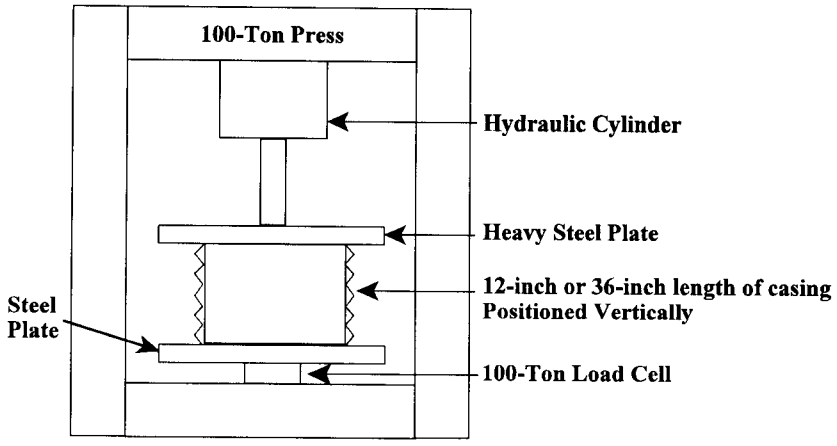


Figure 1: Vertical Loading of 30" Corrugated Well Casing

The well casing was also positioned horizontally as shown in Figure 2.

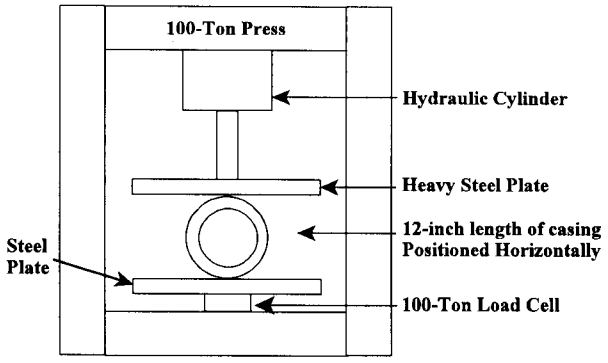


Figure 2: Horizontal Loading of 30" Corrugated Well Casing

The well casing caps were tested as shown in Figure 3.

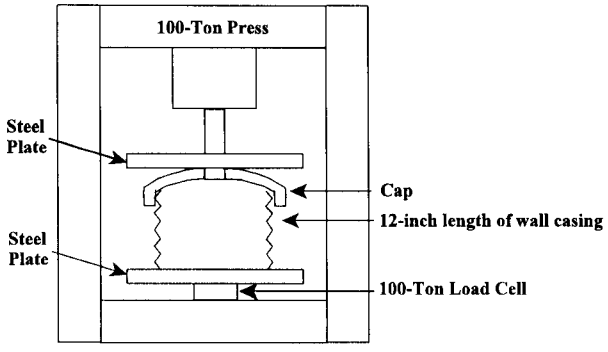


Figure 3: Vertical Loading of Well Casing Cap

The general test procedure consisted of the following:

(1) record serial number, weights, dimensions, temperature and hardness. The hardness was taken at the top of the corrugation
(2) mount the casing or cap in the press
(3) start stop watch, apply initial load and for casing tests measure distance between steel plates. For cap tests measure the distance from bottom of rim to upper steel plate. The sawed casing ends were somewhat irregular so the well casings were not uniformly loaded around the circumference
(4) increase load in varying increments and take length or diameter data between each load change
(5) record the maximum observed load prior to failure
(6) read time on stop watch
(7) perform calculations such as average wall thickness, average diameter and, in some cases, average wall stress

The well casing wall thickness varied considerably so four readings were taken of the minimum thickness found at the bottom of the corrugation when viewed from the outside of the casing. Four thickness readings were also taken at the top of the corrugation having the maximum wall thickness. The cap thickness varied also with four measurements made at the top around the 6 5/8 inch diameter hole where the wall thickness was about twice the thickness of the rim around the outside. Data sheets for all the tests are included in the Appendices.

4 Tests with Vertical Loading of 30-Inch Diameter Corrugated Well Casing

All these tests were conducted with the well casing positioned vertically in the hydraulic press as shown in Figure 1. The data sheets are contained in Appendix A. Summarized in Table 1 are the results of the eight tests that were conducted.

Table 1. Test Data with Vertical Loading of 30" Well Casing

Casing Length	Pipe Serial Number	Date of Manufacture	Average Wall Thickness	Fracture Load	Average Bending Stress in Wall
12"	199910203	October/99	.235"	35,000 lb	1,646 lb/in^2
	199910203	October/99	.226"	36,000 lb	1,767 lb/in^2
	199910203	October/99	.227"	38,000 lb	1,851 lb/in^2
	20000671	June 2000	.222"	34,800 lb	1,691 lb/in^2
	20000681	June 2000	.232"	33,000 lb	1,571 lb/in^2
	20000681	June 2000	.232"	38,000 lb	1,809 lb/in^2
36"	20000671	June 2000	.221"	33,500 lb	1,675 lb/in^2
	20000681	June 2000	.222"	33,200 lb	1,652 lb/in^2
Average Values			.227"	35,188 lb	1,708 lb/in^2

The eight tests with vertical loading of 30" diameter corrugated well casing showed the following:

(1) the casing samples had similar weight and wall thickness
(2) the maximum vertical fracture loads varied from 33,200 lb to 38,000 lb with an average value of 35,188 lb
(3) the casings typically fractured at the bottom of the corrugations having the lower wall thickness
(4) the average bending stress in the casing wall at failure varied from 1,571 lb/in^2 to 1,851 lb/in^2 with an average value of 1,708 lb/in^2
(5) the load data obtained with 12-inch lengths was similar to the load data obtained with 36-inch lengths
(6) the 12-inch casing length decreased about 5/16" in length prior to failure whereas the 36-inch casings decreased almost 3/4" in length prior to failure which represented about 2 to 2 1/2% of the casing length
(7) the surface hardness on top of the corrugations was typically 80 to 85 D for all the fiberglass components
(8) the test times varied from 2.5 to 10 minutes with an average time of 5.14 minutes

5 Tests with Horizontal Loading of 30-inch Diameter Corrugated Well Casing

All these tests were conducted with the well casing positioned horizontally in the hydraulic press as shown in Figure 2. The data sheets for these tests are provided in Appendix B. Summarized in Table 2 are the results obtained in the four tests that were conducted with 12-inch lengths of well casing.

Table 2. Test Data with Horizontal Loading of 12-inch Lengths of 30-inch Diameter Well Casing

Casing Length	Pipe Serial Number	Date of Manufacture	Average Wall Thickness	Fracture Load	Loading Per Inch of Length
12"	20000671	June 2000	.229"	840 lb	70 lb/in
	20000681	June 2000	.229"	850 lb	70.8 lb/in
	199910203	October/99	.228"	925 lb	77.1 lb/in
	199910203	October/99	.228"	1,045 lb	87.1 lb/in
Average Values			.229"	915 lb	76.3 lb/in

The 4 tests with horizontal loading of 12-inch lengths of 30-inch diameter well casing showed the following:

(1) the fracture loads varied from 840 to 1045 lbs with an average of 915 lbs which represented an average uniform loading of 76.3 lb/in of pipe length
(2) the casings had similar weights and wall thicknesses
(3) the fiberglass well casing, when subjected to horizontal loading, deforms at least 10 inches or over 30% of its diameter prior to fracturing along the severely bent sides
(4) the well casing deforms into an irregular shape due to side loading
(5) the average time for the casing tests was 4.72 minutes
(6) the surface hardness on the top of the corrugations typically varied from 80 to 90 D and were similar for all casing samples

6 Tests with Vertical Loading of Well Casing Caps

The casing caps were positioned on top of a 12-inch length of 30-inch diameter well casing and tested as shown in Figure 3. The following types of fiberglass caps were tested:

(1) molded fiberglass caps without a hole in the center
(2) molded fiberglass caps with a 6 5/8" diameter hole in the center
(3) prototype hand sprayed cap without a center hole
(4) prototype hand sprayed cap with a 6 5/8" diameter center hole

The data sheets for the 10 well cap tests are in Appendix C. The molded caps had a curved top with the dome height at the center being about 1 1/2 inches higher than the height around the outside rim. This non-uniform cap height made it impossible to use a flat steel plate to produce a uniform loading over the entire cap area which would more closely represent soil loading in a typical application. Ideally a special molded interface section is required between the flat steel plate and the dome surface of the cap.

Application of a vertical load on a cap using a flat steel plate resulted in vertical force being applied to only the center portion of the cap. If the top of the cap was relatively thin then the cap would flatten out and permit the load to be applied to the outside of the cap which is supported by the relatively strong well casing. If the top of the cap was relatively thick and stiff then application of a load only at the center of the cap would result in a high bending moment which could cause the bottom lip of the cap to crack due to excessive tensile stresses.

In order to attempt to distribute the downward force of the hydraulic press over a larger area of the cap, some tests were conducted using the following modifications:

(1) a 17" diameter truck wheel having a 19 1/2" O.D. tire rim complete with an old tire positioned on top the cap
(2) adding two spacer rings each made by cutting up the tops of the well caps as shown in Figure 4

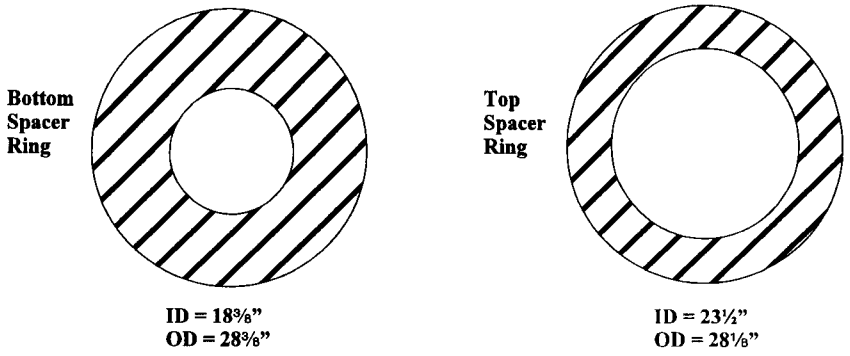


Figure 4: Two Fiberglass Spacer Rings Having Similar O.D.

(3) adding two fiberglass spacers with the bottom ring having a larger outside diameter as shown in Figure 5

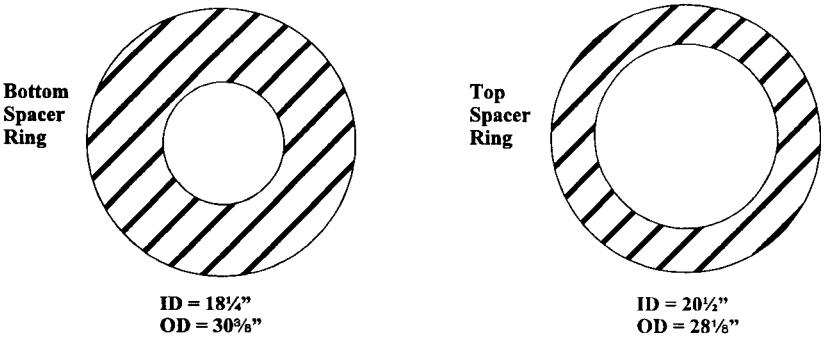


Figure 5: Two Fiberglass Spacer Ring With Larger Diameter Rings Positioned At Bottom

The fiberglass spacer rings were used to distribute the force on the well cap as shown in Figure 6.

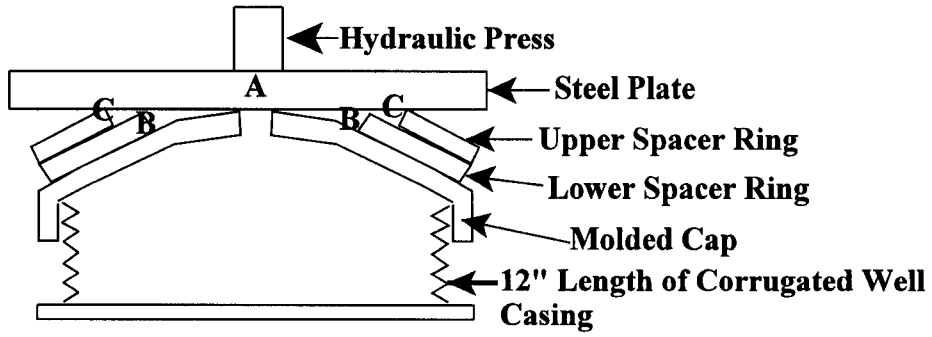


Figure 6: Distribution of Cap Loads Using Spacer Rings

With the spacer rings mounted as shown in Figure 6 the force of the hydraulic press was applied at points B and C in addition to A.

The results of the well cap tests are summarized in Table 3.

Table 3. Test Data with Vertical Loading of 30 5/8" OD Well Cap

Cap Identification	Cap Type	Average Thickness		Loading Configuration	Deflection Prior to Failure	Fracture Load
		Top	Rim			
Heavy Prototype made 10/99	Hand sprayed No hole	.376"	.334"	Center only	1.44"	27,000 lb (flattened, no fracture)
Heavy Prototype made 10/99	Hand sprayed 6 5/8" hole	.376"	.334"	Center only	1.31"	23,600 lb (cracked across center)
Light Prototype made 10/98	Hand sprayed 6 5/8" hole	.407"	.180"	Center only	1.88"	25,300 lb (flat at 5,000 lb)
Light Prototype made 12/98	Hand sprayed No hole	---	---	19 1/4" OD tire rim	1.94"	7,640 lb (cracked around top of cap rim)

2000060718 made 6/00	Molded 6 5/8" hole	.441"	.174"	Center only	.59"	3,100 lb - (rim cracked)
2000060719 made 6/00	Molded 6 5/8" hole	.466"	.183"	19 1/4" OD tire rim	2.69"	5,300 lb - (cap rim cracked)
20000607 made 6/00	Molded No hole	---	---	Center only	.75"	3,030 lb - (cap rim cracked)
2000060814 made 6/00	Molded 6 5/8" hole	.456"	.184"	Two fiberglass rings shown in Figure 4	.38"	14,600 lb - rim and top cracked
2000060807 made 6/00	Molded 6 5/8" hole	.408"	.179"	Two fiberglass rings shown in Figure 4	.38"	Started cracking between 12,500 lb and 27,400 lb
2000060723 made 6/00	Molded 6 5/8" hole	.472"	.185"	Two fiberglass rings shown in Figure 5	.19"	Initial failure at about 20,000 lb 22,900 max load applied

The results of the 10 well cap tests indicated the following:

(1) The hand sprayed caps had thicker rims and thinner tops so they would flatten out without the rim cracking and enabled the well casing to support loads of 23,600 to 27,000 pounds when loaded with a flat steel plate. The actual behavior under soil loading is unknown but the deflection data indicated that when the loads exceeded about 8,000 lbs there was generally no further deflection of the cap indicating that the load was being transferred to the casing.

(2) The molded caps had relatively thick domes and thinner rims which would crack when loads exceeding about 3,000 lbs were applied only at the center of the cap.

(3) Placing a 19 1/4" OD truck rim on the molded cap increased the load carrying capacity of the cap to about 5,300 lb before the cap rim cracked.

(4) Placing two fiberglass spacer rings to distribute the loading on the top of the cap enabled the cap to carry loads up to about 20,000 lbs before failure.

(5) There was considerable variation on the amount of cap deflection prior to failure. Deflection varied from about 1/4" for the molded caps with two support rings to almost 2" for the lighter hand sprayed caps.

(6) The presence of a 6 5/8" diameter hole at the center of the cap did not appear to significantly affect the support capability of the cap when loaded using a steel plate.

(7) Normally the failure of the molded caps resulted from rim failure which then propagated up along the top.

(8) Increasing the thickness of the rim increases the load carrying capacity of the cap considerably. Perhaps it would be advantageous to use a uniform thickness for the top and rim of the cap.

(9) The loading configuration on the cap plays a very important role in determining the maximum load that the cap can support. Laboratory tests should be conducted simulating loading similar to what would be expected in the field.

7 Summary and Conclusions

A total of 22 laboratory tests were conducted on sections of 30-inch diameter corrugated fiberglass casings and fiberglass well caps using an instrumented hydraulic press. The components were well molded and there was generally good repetition of the test data. The results of these tests showed the following:

(1) well casings positioned vertically can support maximum vertical loads of 33,200 to 38,000 lbs which represented average bending stress in the casing wall of 1,571 lb/in^2 to 1,851 lb/in at the time of failure

(2) well casings positioned horizontally can support maximum concentrated vertical loads of 70.0 to 87.1 lb/inch of pipe length at failure

(3) the maximum vertical load a fiberglass well cap can support varied greatly with the loading configuration and varied from about 3,100 to 20,000 pounds. Well cap strength can be increased by increasing the thickness of the rim

APPENDIX A

Data Sheets for 8 Tests with Vertical Loading of 30-inch Diameter Well Casing

WELL CASING TEST DATA

19991020 3 Pipe Serial Number #1 of 12 Date of Manufacture Oct 26, 1999

Date of Test June 12/ 2000 Temperature 70°F

Weight of Resin 329 LB. Weight of Glass 72.5 LB.

Pipe Length 25 Ft - 4"

Pipe Diameter Outside 29 5/8" Inside 28"

Corrugation Pattern Depth .81" Spacing 2 5/8"

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .196"	2 .203	3 .193	4 .189

Average .195"

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum)

1 .273	2 .276	3 .275	4 .278

Average .275"

.235"

Test Sample

Length 12" Weigth 14 lb - 7 1/2 oz

Sample Orientation Vertical X OR Horizontal _____

	LOAD	LENGTH / DIAMETER	DEFLECTION
1	275	12 1/8	
2	1345	12 1/32	
3	3085	11 31/32	
4	6900	11 15/16	
5	10,360	11 29/32	
6	15,475	11 27/32	
7	20,400	11 26/32	
8	25 000	11 25/32	
9	29,400	11 24/32	
10	35,000	Major Fracture	
11			
12			
13			
14			
15			
16			
17			
18			
19			

No Air Space

initial crack

Collected Data

Average Diameter 28.81"

Average Cross Section Area 21.27 in^2

Maximum Compression Stress 1646 lb/in^2

Start test 12:07 pm Finshed 12:17 pm Total Time 10 minuts

Hardness on top corrigation 80-85 D

WELL CASING TEST DATA

199910203 Pipe Serial Number #2 of 12 Date of Manufacture Oct 20/1999

Date of Test June 12/ 2000 Temperature 78° F

Weight of Resin 329 ~~LB~~ LB. Oct Weight of Glass 720 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 1/2 Inside 28

Corrugation Pattern Depth _____ Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .186	2 .185	3 .193	4 .189	Average .188

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum)

1 .262	2 .257	3 .286	4 .276	Average .263

.226

Test Sample

Length 12' Weigth 14 lb 0z

Sample Orientation Vertical X OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	340	12 1/16	
2	2125	12	
3	4760	11 31/32	
4	8100	11 30/32	
5	11,375	11 29/32	
6	15,500	11 28/32	
7	18,400	11 27/32	
8	20,600	11 26/32	
9	23,425	11 25 3/32	
10	27,200	11 27/32	
11	31,000	11 24/32	
12	36,000	Quick-	
13			
14			
15			
16			
17			
18			
19			

Flat at top
No Air Bubbles

Collected Data

Average Diameter 28.75

Average Cross Section Area 20.37 in²

Maximum Compression Stress 1767 lb/in²

Start test 1:16 pm Finshed 1:23 Total Time 7min -20 Sec

Hardness on top corrigation 80 D

WELL CASING TEST DATA

199910203 Pipe Serial Number N3812 Date of Manufacture Oct 20/1999

Date of Test June 12/ 2000 Temperature 75°

Weight of Resin 329 LB. Weight of Glass 72.5 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 9/16 Inside 28

Corrugation Pattern Depth .83 Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1	2	3	4	Average
.182	.173	.183	.185	.181

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .227

1	2	3	4	Average
.258	.284	.259	.291	.273

Test Sample

Length 12" Weigth 14 lb - 4 oz

Sample Orientation Vertical X OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	285	12 1/32	
2	3970	11 31/32	
3	6755	11 30/32	
4	9965	11 29/32	
5	13500	11 28/32	
6	18,310	11 27/32	
7	22,250	11 26/32	
8	27,100	11 25/32	
9	30,500	11 24/32	
10	34,000	11 23/32	
11	38000	Failure	
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28.78

Average Cross Section Area 20.53

Maximum Compression Stress 1851 lb/in

Start test _____ Finshed _____ Total Time 4 min - 12 sec

Hardness on top corrigation 80 D

WELL CASING TEST DATA

2000671 Pipe Serial Number — Date of Manufacture June 7/2000

Date of Test June 12/ 2000 — Temperature 73°F

Weight of Resin 332 LB. — Weight of Glass 73 LB.

Pipe Length 25'-4"

Pipe Diameter — Outside 29 9/16 5/8 — Inside 28

Corrugation Pattern Depth _____ — Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1	2	3	4	Average
.191	.177	.182	.172	.181

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .225

1	2	3	4	Average
.265	.253	.272	.258	.262

Test Sample

Length 12" — Weigth 14 lb - 5 ~~oz~~

Sample Orientation — Vertical X — OR — Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	300	12 1/8	
2	3220	12 1/32	
3	6550	12	
4	9700	11 31/32	
5	13,230	11 29/32	
6	16,665	11 29/32	
7	18,765	11 28/32	
8	23,910	11 28/32	
9	27,100	11 27/32	
10	30,100	11 26 2/32	
11	34,800	Broke	
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28.80

Average Cross Section Area 20.58

Maximum Compression Stress 1691 lb/in²

Start test 1:44 pm — Finshed _____ — Total Time 5 min

Hardness on top corrigation 80-85 D

WELL CASING TEST DATA

20000681 Pipe Serial Number — Date of Manufacture JUNE 8/ 2000

Date of Test June 12/ 2000 — Temperature 75°F

Weight of Resin 333 LB. — Weight of Glass 73 LB.

Pipe Length 25'4"

Pipe Diameter — Outside 29 3/4-29 1/2 — Inside 28

Corrugation Pattern Depth .79 — Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1	2	3	4	Average
.185	.176	.192	.186	.185

(232)

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum)

1	2	3	4	Average
.264	.284	.290	.287	.280

Test Sample

Length 12" — Weigth 14 lb - 4 oz

Sample Orientation — Vertical X — OR — Horizontal _____

	LOAD (lb)	LENGTH / ~~DIAMETER~~	DEFLECTION
1	485	12 1/8	
2	3000	12 1/16	
3	6150	12	
4	10,350	11 31/32	
5	15,190	11 30/32	
6	19,900	11 29/32	
7	22,600	11 28/32	
8	26500	11 27/32	
9	33,000	11 26/32	
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28,87

Average Cross Section Area 21,0 in²

Maximum Compression Stress 1571 lb/in²

Start test 1:55 — Finshed _____ — Total Time 2 min - 30 sec

Hardness on top corrigation 75-80 D

WELL CASING TEST DATA

20000687 Pipe Serial Number — Date of Manufacture JUNE 8/2000

Date of Test June 12/ 2000 — Temperature 77°F

Weight of Resin 333 LB. — Weight of Glass 73 LB.

Pipe Length 25'-4"

Pipe Diameter — Outside 29 5/8 — Inside 28

Corrugation Pattern Depth .181" — Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1	2	3	4	Average
.187	.180	.186	.190	.186"

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .232

1	2	3	4	Average
.269	.285	.279	.282	.279

Test Sample

Length 12" — Weigth 14 lb-6 oz

Sample Orientation — Vertical X — OR — Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	430	12 4/16	
2	3515	12 3/16	
3	6615	12 2/16	
4	7520	12"	
5	15,320	11 31/32	
6	18,030	11 30,5/32	
7	21,510	11 30/32	
8	25,200	11 29/32	
9	29080	11 28/32	
10	38~~000~~	Failure	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28,81

Average Cross Section Area 21,00 in²

Maximum Compression Stress 1809 lb/in²

Start test _____ — Finshed _____ — Total Time 4 minutes

Hardness on top corrigation 80-85 D

WELL CASING TEST DATA

20000671W Pipe Serial Number Date of Manufacture JUNE 7/2000

Date of Test June 12/ 2000 Temperature 74°F

Weight of Resin 3.32 LB. Weight of Glass 73 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 5/8 Inside 28

Corrugation Pattern Depth 1 8/ Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (~~Minimum~~ minimum) (~~Maximum~~)

1 .185	2 .154	3 .184	4 .192	Average .179"

Wall Thickness - Top of Corrugation (~~Minimum~~ Maximum) (~~Maximum~~) (.221)

1 .262	2 .267	3 .268	4 .258	Average .264

4½ 9

Test Sample

Length 36" Weigth 43 lb 3½ 7

Sample Orientation Vertical X OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	450	36 1/16	
2	3050	36	
3	6500	35 15/16	
4	9240	35 29/32	
5	13,030	35 25/32	
6	16,700	35 23/32	
7	23,885	35 10/16	
8	25,000	35 9/16	
9	29,400	35 9/16	
10	33,500	Failure	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28.81

Average Cross Section Area 20.00

Maximum Compression Stress 1675 lb/in²

Start test 2:12 pm Finshed _____ Total Time 3 min 37 sec

Hardness on top corrigation 80-85 D

(.64)

WELL CASING TEST DATA

20000681 Pipe Serial Number — Date of Manufacture JUNE 8/2000

Date of Test June 12/ 2000 — Temperature 75°F

Weight of Resin 333 LB. — Weight of Glass 73 LB.

Pipe Length 25'-4"

Pipe Diameter — Outside 29 5/8 — Inside 28

Corrugation Pattern Depth .187 — Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .188	2 .159	3 .174	4 .184

Average .176

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .222

1 .264	2 .265	3 .274	4 .269

Average .268

Test Sample

Length 36" — Weigth 43 1/2 lb

Sample Orientation — Vertical X — OR — Horizontal _____ 5½

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	660	36 3/16	
2	3640	36 1/16	
3	6920	35 15/16	
4	10,030	35 14/16	
5	13,745	35 12/16	
6	17,890	35 11/16	
7	21,035	35 9/16	
8	25,100	35 7/32	
9	28,330	35 7/16	
10	33,200	Failure	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28.81

Average Cross Section Area 20.09

Maximum Compression Stress 1652 lb/in²

Start test 2:23 — Finshed _____ — Total Time 4min-30sec

Hardness on top corrigation 80-85 D

APPENDIX B

Data Sheets for 4 Tests with Horizontal Loading of 30-inch Diameter Corrugated Well Casing

Seam top and bottom

WELL CASING TEST DATA

200006-71-H Pipe Serial Number

Date of Manufacture June 7/2000

Date of Test June 12/ 2000

Temperature 78°F

Weight of Resin 332 LB.

Weight of Glass 73 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 5/8 Inside 28"

Corrugation Pattern Depth _____ Spacing _____

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1	2	3	4	Average
.179	.189	.185	.185	.185

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .229

1	2	3	4	Average
.273	.276	.270	.271	.273

Test Sample

Length 12" Weigth 14lb 5oz

Sample Orientation Vertical _____ OR Horizontal X

	LOAD	~~LENGTH~~ / DIAMETER	DEFLECTION
1	101b	29 5/8	
2	145	28 1/2	
3	220	27 3/4	
4	300	26 3/4	
5	375	25 15/16	
6	440	25 1/8	
7	520	24 1/4	
8	640	23 1/8	
9	695	22 3/8	
10	785	21 5/8	
11	825	20	
12	840 Cracked		
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter 28.81"

Average Cross Section Area _____

Maximum Compression Stress _____

Start test 4:28 Finshed 4:32 Total Time 4 minutes

Hardness on top corrigation 80-90 D

WELL CASING TEST DATA

20000681 Pipe Serial Number — Date of Manufacture JUNE 8/2000

Date of Test June 12/ 2000 — Temperature 78°F

Weight of Resin 333 LB. — Weight of Glass 23 LB.

Pipe Length _____

Pipe Diameter — Outside 29 5/8 — Inside 28

Corrugation Pattern Depth .81 — Spacing 2 5/8

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .183	2 .183	3 .192	4 .193

Average .188"

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum)

1 .262	2 .283	3 .265	4 .270

Average .270"

Test Sample

Length 12" — Weigth 14 lb 7 oz

Sample Orientation — Vertical _____ OR Horizontal X

	LOAD	~~LENGTH~~ / DIAMETER	DEFLECTION
1	16	29 7/16	
2	110	28 5/8	
3	210	27 1/2	
4	310	26 1/2	
5	365	25 11/16	
6	450	24 7/16	
7	530	23 1/2	
8	605	22 1/2	
9	685	21 3/4	
10	730	21 1/4	
11	785	20 1/2	
12	850	Crushed	
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section Area _____

Maximum Compression Stress _____

Start test _____ Finshed _____ Total Time 5 min 55 sec

Hardness on top corrigation 85-90 D

Seam top and bottom

WELL CASING TEST DATA

199910203 Pipe Serial Number #5 & 12 Date of Manufacture Oct 20/1999

Date of Test June 12/ 2000 Temperature 76°F

Weight of Resin 329 LB. Weight of Glass 725 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 5/8 Inside 28"

Corrugation Pattern Depth .181 Spacing 2 5/8"

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .187	2 .189	3 .195	4 .188

Average .190

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .228

1 .263	2 .265	3 .272	4 .267

Average .267

Test Sample

Length _____ Weigth 14 lb

Sample Orientation Vertical _____ OR Horizontal X

	LOAD	~~LENGTH~~ / DIAMETER	DEFLECTION
1	10 lb.	29 9/16"	
2	130 lb	28 3/4	
3	230	27 13/16	
4	320	26 7/8	
5	395	25 7/8	
6	485	25	
7	575	24"	
8	630	23 1/4"	
9	715	22 1/8"	
10	925	Cracked in half	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section Area _____

Maximum Compression Stress _____

Start test 5:02 pm Finshed _____ Total Time 5 min 46 sec

Hardness on top corrigation 85-90 D

Seams on Side

WELL CASING TEST DATA

199910203 Pipe Serial Number 6 & 12 Date of Manufacture Oct 20/1999

Date of Test June 12/ 2000 Temperature 78°

Weight of Resin 329 LB. Weight of Glass 225 LB.

Pipe Length 25'-4"

Pipe Diameter Outside 29 5/8 Inside 28"

Corrugation Pattern Depth _____ Spacing 2

Wall Thickness - Bottom of Corrugation (Minimum) (~~Maximum~~)

1 .181	2 .187	3 .183	4 .191	Average .186

Wall Thickness - Top of Corrugation (~~Minimum~~) (Maximum) .228

1 .268	2 .260	3 .278	4 .277	Average .271

Test Sample

Length 12" Weigth 14lb 4oz

Sample Orientation Vertical _____ OR Horizontal X

	LOAD	~~LENGTH~~ / DIAMETER	DEFLECTION
1	10	29 9/16	
2	130	28 7/16	
3	245	27 9/16	
4	340	26 3/4	
5	420	26	
6	505	25 3/16	
7	595	24 3/8	
8	685	23 1/4	
9	750	22 1/2	
10	1045	broke at Seam Center	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section Area _____

Maximum Compression Stress _____

Start test 5:09 pm Finshed _____ Total Time 3 min-12 sec

Hardness on top corrigation 85-90 D

APPENDIX C

Data Sheets for 10 Tests with Vertical Loading on Well Caps Positioned on Well Casing

~~Good~~ Heavy cap - sprayed by hand - 12 hole in center

WELL CAP TEST DATA

Prototype Pipe Serial Number

Date of Manufacture Oct, 1999

Date of Test June 12/ 2000

Temperature 83°F

Weight of Resin _____LB.

Weight of Glass _____LB.

Pipe Length _____

Pipe Diameter Outside 30 3/4"

Inside _____

Corrugation Pattern Depth

Wall Thickness - (Top of Cap) ~~(Minimum)~~ ~~(Maximum)~~

.437	.3125	.3125	
1 7/16	2 5/16	3 5/16	4 .442

Average .376

Wall Thickness - (Lip of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1 .249	2 .378	3 .393	4 .317

Average .334

Test Sample

Length _____

Weigth 25 lb

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / DIAMETER	DEFLECTION
1	255 lb	4 11/16"	
2	1245 lb	4 1/2	
3	2240	4 1/4	
4	3395	3 15/16	
5	5555	3 3/4	
6	7935	3 1/2"	
7	15,100	3 5/16	
8	19425	3 1/4	
9	24,030	3 1/4	
10	27,000	3 1/4	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

4:07 pm

3 min 8 sec

Heavy hand sprayed well cap with 6 5/8" diam. center hole

WELL CAP TEST DATA

Prototype Pipe Serial Number — Date of Manufacture Oct 1999

Date of Test June 12/ 2000 — Temperature 78

Weight of Resin _____LB. — Weight of Glass _____LB.

Pipe Length _____

Pipe Diameter — Outside 30 3/4 — Inside _____

Corrugation Pattern Depth

Wall Thickness - (Top of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1	2	3	4

Average .326

Wall Thickness - (Lip of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1	2	3	4

Average .334

Test Sample

Length _____ — Weigth 24 1/2 lb.

Sample Orientation — Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	2651b.	4 9/16"	
2	1035	4 7/16	
3	1445	4 3/16	
4	1755	4 1/8	
5	2445	3 15/16	
6	3430	3 7/8	
7	4520	3 5/8	
8	5345	3 1/2	
9	6900	3 7/16	
10	9350	3 3/8	
11	18,800	3 1/4	
12	23,600	3 1/4	
13	L	Cracked across center	
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

Hand sprayed, lighter - thinner wall cap

WELL CAP TEST DATA

~~Prototype~~ Pipe Serial Number

Date of Manufacture Dec 1998

Date of Test June 12/ 2000

Temperature 76°F

Weight of Resin _____LB.

Weight of Glass _____LB.

Pipe Length _____

Pipe Diameter Outside 30 3/8"

Inside _____

Corrugation Pattern Depth

Wall Thickness - Top of Cap ~~(Minimum) (Maximum)~~

1 .244	2 .302	3 .440	4 .649

Average .407

Wall Thickness - Lip of Cap ~~(Minimum) (Maximum)~~

1 .186	2 .181	3 .165	4 .186

Average .180

Test Sample

Length _____

Weigth 20½ lb

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	200	5 3/16	
2	1015	5 1/8	
3	2195	4 7/8	
4	3320	4 5/8	
5	3915	4 7/16	
6	4300	4 1/8	
7	4400	3 13/16	
8	4200	3 9/16	
9	4900	3 3/16	
10	8020	3 5/16	
11	16,170	3 5/16	
12	25,300	3 5/16	
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

Light hand sprayed cap without hole and 19¼" OD tire rim sitting on top

WELL CAP TEST DATA

#Prototype Pipe Serial Number

Date of Manufacture Dec, 1998

Date of Test June 12/ 2000

Temperature 78°

Weight of Resin _____LB.

Weight of Glass _____LB.

Pipe Length _____

Pipe Diameter Outside _____ Inside _____

Corrugation Pattern Depth

Wall Thickness - Top of Cap (Minimum) (Maximum)

1	2	3	4

Average _____

Wall Thickness - Lip of Cap (Minimum) (Maximum)

1	2	3	4

Average _____

Test Sample

Length _____

Weigth _____

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	2001b	10⅞"	
2	2360	9 9/16"	
3	4900	9 5/16"	
4	6625	9 3/16	
5	7640	8 15/16	
6		Cracked circumferentially	
7		around top of rim	
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

4:35 pm.

WELL CAP TEST DATA

20000 60718

#_____ Pipe Serial Number

Date of Manufacture JUNE 7/2000

Date of Test June 12/ 2000

Temperature 75

6 5/8" Hole

Weight of Resin 16 LB.

Weight of Glass 3 LB.

Pipe Length _____

Pipe Diameter Outside 30 5/8"

Inside _____

Tested 6 in 1 ft length of pipe

Corrugation Pattern Depth

Wall Thickness - (Top of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1 .436	2 .437	3 .445	4 .446

Average .441"

Wall Thickness - (Lip of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1 .177	2 .174	3 .172	4 .173

Average .174

Test Sample

Length _____

Weigth 21 lb - 1/2 oz

Sample Orientation

Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	21b	4 17/32	
2	1060	4 5/16	
3	1630	4 1/4	
4	1975	4 6/32	
5	2390	4 4/32	
6	2955	3 30/32	
7	3100	Failure	
8			
9			
10	1,540		
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section 702 in²

Maximum ~~Compression~~ Bearing Stress 4442 lb/in²

Dome Height = 1 1/2"

Hardness 80-85 D

2:56 pm

4 1/2 minutes

Tested with 19½" OD Tire Rim Setting on Well Cap (17" Truck Rim with old tire)

WELL CAP TEST DATA

2000060719 Pipe Serial Number

Date of Manufacture JUNE 7/2000

Date of Test June 12/ 2000

Temperature 70°F

Weight of Resin 16 LB.

Weight of Glass 3 LB.

Pipe Length _____

Pipe Diameter Outside 30¼"

Inside _____

Corrugation Pattern Depth

Wall Thickness - Top of Cap ~~(Minimum) (Maximum)~~

1	2	3	4	Average
.467	.474	.459	.464	.466

Wall Thickness - Lip of Cap ~~(Minimum) (Maximum)~~

1	2	3	4	Average
.172	.196	.174	.191	.183

Test Sample

Length _____

Weigth 22lb - 4½ oz

Sample Orientation

Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	185	11 3/16"	
2	1070	11 5/16	
3	2985	11 3/16	
4			
5	4200	9 3/4	
6	5300	Cap Cracked at rim	
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

3:49 pm.

Hardness 80-85 D

Well Cap W/o Hole in Center

WELL CAP TEST DATA

#2600607 Pipe Serial Number

Date of Manufacture _____

Date of Test June 12/ 2000

Temperature 87°F

Weight of Resin _____LB.

Weight of Glass _____LB.

Pipe Length _____

Pipe Diameter Outside _____ Inside _____

Corrugation Pattern Depth

Wall Thickness - Top of Cap (Minimum) (Maximum)

1	2	3	4

Average _____

Wall Thickness - Lip of Cap (Minimum) (Maximum)

1	2	3	4

Average _____

Test Sample

Length _____ Weigth _____

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / DIAMETER	DEFLECTION
1	1000	4 9/16"	
2	1400	4 5/16"	
3	2140	4 5/32	
4	3030	3 13/16	
5		Rim Cracked	
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

3:20 pm

Molded cap with 6 5/8" hole and two spacer rings on top to enable more uniform loading at the top

WELL CAP TEST DATA

20000608 No 14 Pipe Serial Number

Date of Manufacture JUNE 8/2000

Date of Test June 12/ 2000

Temperature 73°F

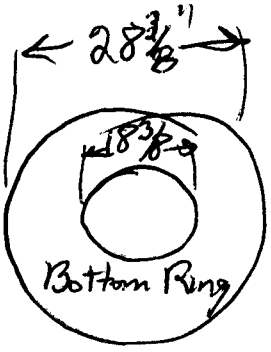
Weight of Resin 16 LB.

Weight of Glass 3 LB.

Pipe Length _____

Pipe Diameter Outside 30 5/8"

Inside _____



Corrugation Pattern Depth

Wall Thickness - ~~Top of Cap~~ (~~Minimum~~) (~~Maximum~~)

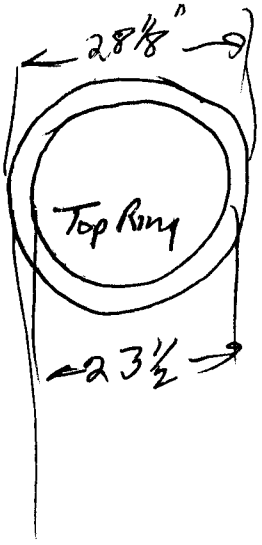
1 .460 ~~.480~~"	2 .450	3 .467	4 .456

Average .456"

Wall Thickness - Lip of Cap (~~Minimum~~) (~~Maximum~~)

1 .182	2 .179	3 .191	4 .183

Average .184"



Test Sample

Length _____

Weigth 22.5 lb

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	650 lb	4 3/4"	
2	940	4 5/8"	
3	1100	4 5/8"	
4	2170	4 3/16"	
5	5000	4 1/2"	
6	6945	4 3/16	
7	9930	4 1/8	
8	12,170	4 1/8	
9	14,600	cracked at various locations	
10		on lip and top	
11			
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

Hardness = 85-90D Time: 2 minutes

Molded cap with 6 5/8" hole and two spacer plates - 28 3/8 x 18 3/8 plus 23 1/2 x 28 1/8)

WELL CAP TEST DATA

20000608 Rice 7

_____ Pipe Serial Number

Date of Manufacture JUNE 8/2000

Date of Test June 12/ 2000

Temperature 80°F

Weight of Resin 16.5 LB.

Weight of Glass 3 LB.

Pipe Length _____

Pipe Diameter Outside 30 5/8"

Inside _____

Corrugation Pattern Depth

Wall Thickness - (Top of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1 .421 ~~.190~~	2 .413 ~~.201~~	3 .397 ~~.126~~	4 .397 ~~.199~~	Average .408"

Wall Thickness - (Lip of Cap) ~~(Minimum)~~ ~~(Maximum)~~

1 .190	2 .174	3 .176	4 .174	Average .179

Test Sample

Length _____

Weigth 20 lb

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / ~~DIAMETER~~	DEFLECTION
1	230	4 3/16	
2	730	4 1/16	
3	1015	4 1/16	
4	2105	4 3/8	
5	4430	4 5/16	
6	7000	4 5/16	
7	9100	4 1/4	
8	10,300	4 1/4	
9	12,500	4 3/16	
10	started cracking		
11	27,400		
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

Hardness = 85D

Molded cap with 6 5/8" hole with two spacer plates 18 1/4 x 30 3/8" (Bottom) and 23 1/2 x 28 1/8" Top

2000 06 07 (23)

WELL CAP TEST DATA

#_____ Pipe Serial Number

Date of Manufacture JUNE 7/2000

Date of Test June 12/ 2000

Temperature 75°F

Weight of Resin 16 LB.

Weight of Glass 3 LB.

Pipe Length _____

Pipe Diameter Outside 30 3/4 00 Inside _____

Corrugation Pattern Depth

Wall Thickness - (Top of Cap) (Minimum) (Maximum)

1 .469	2 .465	3 .480	4 .474	Average .472

Wall Thickness - (Lip of Cap) (Minimum) (Maximum)

1 .174	2 .193	3 .173	4 .198	Average .185

Test Sample

Length _____ Weigth 23 lb

Sample Orientation Vertical _____ OR Horizontal _____

	LOAD	LENGTH / DIAMETER	DEFLECTION
1	145 lb	4 5/8	
2	770	4 19/32	
3	1410	4 9/16	
4	2405	4 17/32	
5	3750	4 17/32	
6	4950	4 17/32	
7	8710	4 1/2	
8	11,300	4 7/16	
9	12,400	4 7/16	
10	22,900	Fracture	
11	about	20,000 initial fracture	
12			
13			
14			
15			
16			
17			
18			
19			

Collected Data

Average Diameter _____

Average Cross Section _____

Maximum Compression Stress _____

Hardness = 85D