NATIONAL CORRUGATED STEEL PIPE ASSOCIATION

Design data sheet

No. 18

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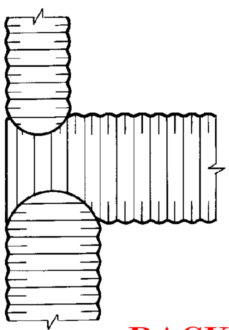
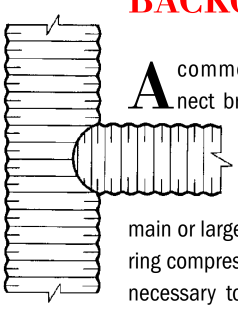


Pipe Reinforcement at Fittings and Intersections

BACKGROUND



A common practice in storm drain projects is to connect branch lines to the main line. Similarly, underground detention systems are often fabricated with several branches connected to a larger header or manifold. When a section of the main or larger pipe is cut away to make the connection, the ring compression capacity of the pipe is reduced. It is then necessary to evaluate the need for reinforcement of the main or larger pipe in order to re-establish adequate ring compression capacity. National Corrugated Steel Pipe Association (NCSPA) and the American Iron and Steel Institute (AISI) funded development of a software package to determine whether reinforcement is required and to provide a method for designing the reinforcement if required.

In Phase 1 of this project, finite element analysis was used to develop the method for determining whether reinforcement is required for an installation. The second phase of the program involved establishing reinforcement methods and the actual calculations of the reinforcement requirements for each method. This was done for main pipe diameters from 48 to 144 inch and branch pipe diameters from 24 inch up to the diameter of the main pipe. Main pipe with wall thickness from 0.064 in (16ga) to 0.168 in (8ga), and depths of cover of 10, 20 and 30 feet were considered.

The results of Phase 1 showed that the need for reinforcement increases with increasing branch diameter, increasing depth of cover and decreasing wall thickness. In Phase 2 of this effort, three methods were developed for providing the required reinforcement. The three methods are: (1) increasing the wall thickness of the main pipe, (2) mounting a saddle plate and branch stub assembly on the main pipe for connecting the branch, and (3) adding reinforcement around the direct connection of the branch pipe to the main pipe.

The culmination of this effort was the development of a fittings reinforcement software package called CSPFIT. This user-friendly software determines whether reinforcement is required and then considers the three possible solutions previously mentioned. The result is that the fabricator will have at least one, and possibly three reinforcement techniques to choose from if reinforcement is required. This Design Data Sheet will explain the design procedure in the event the fabricator or engineer desires a better understanding of the method for determining the need for and sizing the reinforcement.

GENERAL DESIGN ASSUMPTIONS

It is assumed that the main and branch pipes have been designed to the appropriate specifications and that the wall thickness specified is appropriate for the corrugation profiles, backfill material and installation methods specified. Backfill and live load pressures on the pipes must be thoroughly evaluated. The possibility of higher construction loads on the pipe, when the cover is shallow must also be considered in selecting the pipe wall thickness and corrugation. Structural design of the pipes should be in accordance with ASTM A796 and AASHTO Section 12.

It is further assumed that the branch pipe is adequately connected to the main pipe by direct welding or with a saddle branch that has been properly attached to the main pipe. Reinforcement members, welds and fasteners must be protected against corrosion to provide durability equal to or in excess of that of the pipes.

In addition to the design methods used in the CSPFIT software, there are alternative design methods for determining reinforcement. The intent of this software is not to eliminate these alternative methods. What is important is that these fittings situations be thoroughly evaluated to ensure pipe strength is not compromised. Nothing in this report should be construed as a prohibition against rational alternative design methods.

DESIGN PROCEDURE

STEP 1. DATA REQUIRED FOR DESIGN

Whether the design is performed using the tables and procedures provided in this Design Data Sheet or by use of the CSPFIT software, the following data must be available in order to evaluate the need for and design of the reinforcement.

- Main pipe diameter (in)
- Main pipe corrugation (in)
- Main pipe wall thickness (in)
- Branch pipe diameter (in)
- Branch pipe angle with main pipe (30 to 90 degrees)
- Main pipe height of cover (ft)
- Fill density (lb./cu ft)
- Live load (H20/H25)

Only the branch pipe angle and the live load items require further explanation. The designated angle is the acute angle between the pipes. If the branch intersects the main at 90 degrees, use the nominal diameter of the pipe. For connections with an intersection angle between 30 and 90 degrees, the effective opening in the main pipe equals the diameter of the branch divided by the sine of the acute angle. The effective branch diameter cannot exceed the main pipe diameter.

The CSPFIT software and the tables in this document, assume an H20 or H25 live load. If a live load other than H20 or H25 is expected, its impact is evaluated by converting that pressure to an equivalent dead load. The pressure on the main pipe, resulting from the added live load, should be determined in accordance with an appropriate design specification or by the engineer's best judgement. Once determined, the live load pressure is converted to an equivalent backfill depth by dividing by the fill density. The load on the main pipe is then the total of the backfill and the equivalent live load pressures.

STEP 2. ACHIEVING THE DESIGN

The purpose of this Design Data Sheet is to alert the user and engineering communities to the possible need for CSP fittings reinforcement. Corrugated steel pipe is the ideal product for installations such as underground detention systems that require fabricated fittings. Fitting reinforcement could be critical if the CSP installation is to perform as expected throughout its planned service life. ASTM Standard A998 defines the procedure for evaluating CSP fittings reinforcement.

This Design Data Sheet or ASTM A998 will provide the engineer with the information to determine whether CSP fittings on a project will require reinforcement. The project engineer will then be able to identify the specific fittings that require reinforcement. Selection of the means of reinforcement will be the responsibility of the fabricator of the fittings. If deemed necessary, the engineer may require that the fabricator submit a justification of the reinforcement method for review and approval by his office. Handling the fitting reinforcement design in this manner will result in the use of a reinforcement method best suited to the fabricator.

STEP 3. DETERMINE IF LONGITUDINAL REINFORCEMENT IS REQUIRED.

For this determination, refer to the tables of "Maximum Branch Diameters That Do Not Require Longitudinal Reinforcement". A separate table is provided for each of four corrugation depths (1/2-inch deep, 1-inch deep, 3/4" x 3/4" ribbed and 3/4" x 1" ribbed) and for backfill depths of 10, 20 and 30 feet.

These tables are based on earth load only, except for the 10-foot cover that includes an H20 loading. The branch pipe sizes listed under 10-foot cover were determined for covers ranging from 2 to 10 feet and an H20 loading. For cover less than 2 feet, determine the total pressure on the pipe by converting the live load pressure (including impact) to an equivalent depth of earth load and adding this value to the actual backfill depth.

If the diameter of the branch pipe exceeds the size listed in these tables, reinforcement is required. The following three reinforcement methods may be considered.

1. Increase wall thickness of main pipe, at point of connection.
2. Use a saddle plate for connection of the branch pipe.
3. Install reinforcement members around the branch to main connection.

A combination of any two of these methods may be the most economical solution in any particular circumstance. For example, a single step increase in wall thickness along with a saddle plate might be the ultimate solution.

However, increasing the wall thickness of the main (or header) pipe will usually be the most economical means of reinforcement. This solution increases material cost but essentially eliminates additional labor cost. The use of saddle plates or structural shape members require added material costs and also added labor costs. These costs can be extensive depending on the size and number of fasteners required. In addition to being an economical solution, the added wall thickness also increases the durability and structural capacity of the pipe and fittings.

To determine the required wall thickness, use the tables "Maximum Branch Diameters That Do Not Require Longitudinal Reinforcement". Select the appropriate table for the proposed corrugation and from this table locate the main pipe diameter. Find the minimum main pipe wall thickness that allows use of the branch pipe size being considered, at the appropriate cover depth.

Determination of the ability of a saddle plate to provide adequate reinforcement is best accomplished by the CSPFIT software. The CSPFIT program will automatically identify the thickness and size of saddle plate required. The program allows the user to try various combinations of pipe wall and saddle plate thickness.

If the use of a saddle plate or increased thickness of the main pipe is not deemed feasible, proceed to the subsequent steps to determine both the horizontal and circumferential reinforcement that may be required. These steps may be useful even if saddle plates or increased thickness seem to be the preferred method. By determining the extent of the fabricated reinforcement required, the costs of each of the three methods can be calculated and compared, and the most cost effective method chosen.

STEP 4. DETERMINE REQUIRED CROSS-SECTIONAL AREA FOR LONGITUDINAL REINFORCEMENT.

Any pipe with an opening cut out for a branch pipe can still carry some earth load. The tables on pages 8 through 11 give the cover depth H_{nlr} that a main pipe of given corrugation pattern and diameter, can support without longitudinal reinforcement for various branch pipe sizes. The tables on pages 6 and 7 define the incremental area of longitudinal reinforcement (A_{r10}) that is required for each additional 10 feet of cover beyond the H depth. Thus the minimum area of longitudinal reinforcing required (A_{rl}) for any depth of cover is calculated as:

$$A_{rl} = (A_{r10}/10)(H - H_{nlr})$$

where:

A_{rl} = Minimum cross-sectional area of longitudinal reinforcement (in^2)

A_{r10} = Incremental area of longitudinal reinforcement required for each additional 10 feet of cover beyond the H depth (in^2/10 feet)

H = Depth of cover over main pipe (ft)

H_{nrl} = Cover depth for which longitudinal reinforcement is not required (ft)

A_{rl} is the minimum cross-sectional area that must be provided for each of the longitudinal tension straps that are be attached to the main pipe, just above and just below the branch pipe opening. The strap can be fabricated from culvert sheet, bar stock, plate, angle or other structural shapes, all having a yield strength equal to A36 steel. For practical considerations, the reinforcement should not be less than a strap 3 inches wide by 0.138 inch thick (10 gage), which has an area of 0.40 in^2. When wide straps are required or small diameter pipes must be reinforced, it may be necessary to bend the strap longitudinally in order to achieve satisfactory connections.

If the main pipe is a ribbed configuration, the value calculated for A_{rl} in the previous paragraph must be multiplied by the appropriate factor from the following table to determine the minimum longitudinal reinforcement area for a ribbed pipe.

	Specified Thickness (in)			
Profile	**0.064**	**0.079**	**0.109**	**0.138**
3/4 x 3/4 x 7-1/2	1.4	1.3	1.1	1.0
3/4 x 1 x 11-1/2	1.9	1.7	1.4	-

Step 5. Determine the minimum length for the longitudinal reinforcement.

The required total length (L_{min}) of each reinforcement strap depends on the depth of cover as follows:

10 ft cover, L_{min} = 1.5 times branch diameter

20 ft cover, L_{min} = 2.0 times branch diameter

30 ft cover, L_{min} = 2.5 times branch diameter

The length of the longitudinal reinforcements should not exceed the length of the pipe if the reinforcements are placed inside the pipe. If fastened to the exterior of the pipe, the reinforcements must be shortened so as to avoid interference with the jointing system.

Step 6. Determine the required connection for the longitudinal reinforcement.

Each reinforcement must be attached to the main pipe with connections adequate to develop the required strength. Fasteners can be mechanical, such as self-tapping screws, bolts in punched holes or welds. The allowable load per fastener (q) should be based on standard specifications and/or manufacturers' literature. For mechanical fasteners, q must be based on shear or bearing, whichever is smaller. For welds, q must be based on the shear strength of the weld or the sheet, whichever is smaller. The fasteners should be spaced along the reinforcement in a uniform pattern.

The total number of fasteners (N_L) required for each longitudinal strap is:

$$N_L = 50{,}000\ A_r/q$$

where:

A_r is the cross section area of the reinforcement (in^2)

q is the allowable load per fastener (lbs.)

Longitudinal reinforcements may be fastened either to the inside or outside surfaces of non-ribbed pipe. The reinforcement members for pipe with corrugations consisting of circular arcs should be fastened to the pipe at the corrugation crests. For ribbed pipe with rectangular ribs, the reinforcement can most easily be fastened to the interior surface of the pipe with the connections spaced uniformly along the reinforcement members. If the reinforcement member must be fastened to the exterior of ribbed pipe, they must be connected to the ribs.

Step 7. Determine if circumferential reinforcement is required.

The tables labeled "Maximum Branch Diameters That Do Not Require Circumferential Reinforcement" (Page 12) identify the largest size branch pipe (d) that can be connected to a main pipe of known size and with a known cover depth, without circumferential reinforcement. For cover depths other than 10, 20 or 30 feet, determine the maximum branch pipe size by interpolating between the table values.

Step 8. Determine Required Cross-Sectional Area For Circumferential Reinforcement

If the size of the branch pipe exceeds the maximum size listed on the table on Page 12 for the appropriate condition, circumferential reinforcement is required. The minimum area of reinforcement (A_{rc}) is determined as follows:

$$A_{rc} = (HDd/96{,}000)(d-d_m)/d$$

where:

A_{rc} = Minimum cross-sectional area of circumferential reinforcement (in^2)

H = Depth of cover over main pipe (ft)

D = Diameter of main pipe (in)

d = Diameter of branch pipe (in)

d_m = Maximum diameter of branch pipe for which main pipe does not require circumferential reinforcing (in)

The circumferential reinforcement can be a strap from culvert sheet, or from bar, plate, angle, or other structural section, A36 steel or equivalent. It should extend the distance between the longitudinal reinforcements, but need not be connected to them. For practical considerations, the reinforcement should have a minimum thickness of 0.138 in. Generally, a flat strap should be connected with two lines of fasteners. Thus, the minimum strap width would be the corrugation pitch plus two edge distances if bolts or screws are used, or just the corrugation pitch if welds are used. For ribbed pipe consider a minimum width of 3 in.

Step 9. Determine the required connection for the circumferential reinforcement.

The total number of fasteners (N_c) required for each circumferential reinforcement is

$$N_c = 40{,}000\ A_{rc}/q$$

where:

A_{rc} is the cross section area of the circumferential reinforcement (in^2)

q is the allowable load per fastener (lbs.)

If the reinforcement is a flat strap of thickness "t", the circumferential spacing between fasteners must not exceed 44t. If the reinforcement is a rolled structural shape, the circumferential spacing between fasteners must not exceed 12 in. Use two lines of fasteners for a flat strap and either one or two lines of fasteners for a rolled structural shape.

The circumferential strap can be connected to the inside or outside of the pipe. The general considerations in Step 6 apply here also.

OTHER CONSIDERATIONS

Bulkhead Design

Bulkheads are fabricated from flat sheet and reinforced with structural angles or channels when required. They act as a diaphragm, reacting to the soil and live load pressures outside of the pipe. In cases where the pipe can be empty, the internal fluid force, acting outward against the backfill, is ignored.

Because they generally are reinforced in only one direction, bulkheads are often designed as a simply supported, uniformly loaded beam. In this case, assuming the beam's span is one pipe diameter, it must support the horizontal component of soil and live load pressures occurring at the center of the bulkhead.

A simple, conservative design can be done by first selecting a convenient bulkhead plate thickness and then checking for the necessary reinforcement. Follow these steps:

1. Maximum spacing between structural reinforcements:

$$S_{pa} = (143F_y t^2/(LL+DL)k_a)^{0.5}$$

2. Required section modulus for plate and reinforcement:

$$S \geq 0.00145(LL+DL)K_a(S_{pa}\text{-actual})D^2/Fy$$

Where:

t = thickness selected for the bulkhead plate (in)

F_y = the yield strength of the steel (psi)

LL = Live load pressure (psf) see highway live load tables in the NCSPA Green Book or Blue Book

DL = Dead load pressure (psf)

K_a = Active soil pressure coefficient for the native soil, outside the backfill zone
= .5 may be used as a conservative assumption

S_{pa} = the maximum allowable spacing between structural reinforcements (in)

S_{pa}-actual = the actual, selected spacing for reinforcements (in)

D = Pipe Diameter (in)

S = section modulus required (in^3/S_{pa}-actual)
= where reinforcements are bolted to the bulkhead plate use the added total of the section modulus of the structural plus that of the plate over the width Spa-actual. Where structural members are welded to the plate, the composite section modulus may be used.

Manhole Design

Manholes must be reinforced as a conventional tap-in per ASTM A998. However, the manhole barrel (riser) is typically located to one side so it aligns with the spring line of the pipe. This makes access easier. To avoid cumbersome reinforcement, etc., manholes should be located in complete pipe sections, not at tees, elbows or as part of other fittings.

The primary considerations beyond normal reinforcement of the mainline pipe are the drag down and live loads that can act on the manhole riser. Drag down loads occur when the backfill or embankment soil around the riser settles. Friction forces between the soil and the riser tend to hold the adjacent soil up essentially forcing the riser to support the soil's weight. These loads are too great to carry. They can collapse the riser, punch it through into the mainline pipe or over deflect the mainline pipe depending on conditions.

Drag down loads must be avoided by allowing the riser portion of the manhole to move with any soil settlement that occurs. Placing a slip joint just above the mainline pipe generally provides for this movement as long as the top of the manhole is also free to move.

Highway or other vehicular loads are also generally too great for the manhole barrel to carry. To avoid problems, manhole tops are typically concrete slabs that, like a footing, bear these loads out into the surrounding soil. The manhole barrel is provided with a slip connection to allow a few inches of relative vertical movement between the two.

NCSPA

REFERENCES

ASTM Standard A998, "Standard Practice for Structural Design of Reinforcements of Fittings in Factory-Made Corrugated Steel Pipe for Sewers and Other Applications," 1998.

Brockenbrough, R.L., "Reinforcement Requirements for Fittings in Corrugated Steel Pipe," National Corrugated Steel Pipe Association, 1995.

"Handbook of Steel Drainage & Highway Construction Products (Greenbook)," American Iron and Steel Institute, Washington, DC, 1994.

"Modern Sewer Design (Bluebook)," American Iron and Steel Institute, Washington, DC, 1995.

MAXIMUM BRANCH DIAMETERS THAT DO NOT REQUIRE LONGITUDINAL REINFORCEMENT**

MINIMUM COVER REQUIRED FOR MAIN AND BRANCH DIAMETERS *(Branch diameters are inches)*

2⅔" x ½" CORRUGATIONS

Wall Thickness		**.064"**			**.079"**			**.109"**	
Maximum Cover	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**
Main Diameter									
48"	48	36	24	48	42	30	48	48	36
60"				54*	36*	24*		42	36

**60" 16 gage main diameter not available. Use 54" main diameter.*

3" x 1" and 5" x 1" CORRUGATIONS

Wall Thickness		**.064"**			**.079"**			**.109"**			**.138"**			**.168"**	
Maximum Cover	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**
Main Diameter															
60"	42	24	18	54	30	24		42	30						
72"	36	24	18	48	24	18	54	36	24						
84"	30	18	18	42	24	18	54	30	24		42	30			
96"	30	18	12	36	24	18	48	30	18	54	36	24			
108"				36	18	12	42	24	18	42	30	24			
120"				30	18	12	42	24	18	48	30	24	54	36	24
132"							36	24	18	42	30	18	48	36	24
144"										42	24	18	48	30	24

¾" x ¾" x 7½" SPIRAL RIB PIPE

Wall Thickness		**.064"**			**.079"**			**.109"**			**.138"**	
Maximum Cover	**10'**	**20'**	**26'**	**10'**	**20'**	**29'**	**10'**	**20'**	**30'**	**10'**	**20'**	**30'**
Main Diameter												
48"	42	30	24	48	30	24	48	42	30			
60"	36	24		48	30	24	60	36	24			
72"				42	24		54	30	24			
84"							48	30	24	60	42	30
96"							42	24	18	54	36	30
108"										48	36	30

¾" X 1" x 11½" SPIRAL RIB PIPE

Wall Thickness		**.064"**			**.079"**			**.109"**	
Maximum Cover	**10'**	**20'**	**26'**	**10'**	**20'**	**29'**	**10'**	**20'**	**30'**
Main Diameter									
48"	42	30	24	48	30	24	48	42	30
60"	36	24		42	30	24	60	36	24
72"				36	24		48	24	24
84"				36	24		42	24	18
96"							42	24	18
108"							36	24	

**Note: Branch Diameters listed assume 90 degree Tee connections to the mainline. For Wyes and other conditions, increase the Branch Diameter to d/sinØ before entering the table. Ø is the acute angle of the pipe's intersection. d/sinØ is equal to the span of the main cut out.

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

INCREMENTAL REINFORCEMENT AREA (A_{R10}) FOR TENSION STRAPS (in) PER 10 FT COVER

0.064" Thickness

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
Main Diameter																	
48	.5	.7	1.0	1.3	1.8												
54	.5	.8	1.1	1.5	1.9	2.5											
60	.6	.9	1.2	1.6	2.1	2.7	3.3										
66	0.6	0.9	1.3	1.7	2.2	2.8	3.6	4.4									
72	0.7	1.0	1.4	1.8	2.4	3.0	3.8	4.6	5.7								
78	0.7	1.1	1.5	2.0	2.5	3.2	4.0	4.9	5.9	7.1							
84	0.8	1.1	1.5	2.1	2.7	3.4	4.2	5.1	6.2	7.5	8.9						
90	0.8	1.2	1.6	2.2	2.8	3.5	4.4	5.4	6.5	7.8	9.2	10.9					
96	0.8	1.2	1.7	2.3	3.0	3.7	4.6	5.6	6.8	8.1	9.6	11.3	13.2				
102	0.9	1.3	1.8	2.4	3.1	3.9	4.8	5.8	7.0	8.4	10.0	11.7	13.6	15.7			
108	0.9	1.3	1.9	2.5	3.2	4.1	5.0	6.1	7.3	8.7	10.3	12.1	14.1	16.2	18.7		
114	0.9	1.4	1.9	2.6	3.3	4.2	5.2	6.3	7.6	9.0	10.6	12.5	14.5	16.7	19.2	21.9	
120	1.0	1.4	2.0	2.7	3.4	4.3	5.4	6.5	7.8	9.3	11.0	12.9	14.9	17.2	19.8	22.6	25.6

0.079" Thickness

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138
Main Diameter																				
48	0.4	0.6	0.9	1.1	1.5															
54	0.5	0.7	0.9	1.3	1.6	2.1														
60	0.5	0.8	1.0	1.4	1.8	2.2	2.8													
66	0.6	0.8	1.1	1.5	1.9	2.4	3.0	3.6												
72	0.6	0.9	1.2	1.6	2.0	2.5	3.1	3.8	4.6											
78	0.7	0.9	1.3	1.7	2.2	2.7	3.3	4.1	4.9	5.8										
84	0.7	1.0	1.4	1.8	2.3	2.9	3.5	4.3	5.1	6.1	7.2									
90	0.7	1.1	1.4	1.9	2.4	3.0	3.7	4.5	5.4	6.4	7.6	8.8								
96	0.7	1.1	1.5	2.0	2.6	3.2	3.9	4.7	5.6	6.7	7.9	9.2	10.7							
102	0.8	1.2	1.6	2.1	2.7	3.4	4.1	4.9	5.9	7.0	8.2	9.5	11.1	12.7						
108	0.8	1.2	1.7	2.2	2.8	3.5	4.3	5.1	6.1	7.2	8.5	9.9	11.5	13.2	15.1					
114	0.8	1.2	1.7	2.3	2.9	3.6	4.5	5.4	6.4	7.5	8.8	10.2	11.8	13.6	15.5	17.7				
120	0.9	1.3	1.8	2.4	3.0	3.8	4.6	5.6	6.6	7.8	9.1	10.6	12.2	14.0	16.0	18.2	20.6			
126	0.9	1.3	1.9	2.4	3.1	3.9	4.8	5.8	6.9	8.1	9.4	10.9	12.6	14.5	16.5	18.7	21.1	23.8		
132	0.9	1.4	1.9	2.5	3.2	4.0	4.9	6.0	7.1	8.3	9.7	11.3	13.0	14.9	17.0	19.2	21.7	24.4	27.3	
138	1.0	1.4	2.0	2.6	3.3	4.1	5.1	6.1	7.3	8.6	10.0	11.6	13.4	15.3	17.4	19.7	22.3	25.0	28.0	31.2

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

INCREMENTAL REINFORCEMENT AREA (A_{R10}) FOR TENSION STRAPS (in) PER 10 FT COVER

0.109" Thickness

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
48	0.4	0.5	0.7	0.9	1.2																
54	0.4	0.6	0.8	1.0	1.3	1.6															
60	0.4	0.6	0.9	1.1	1.4	1.7	2.1														
66	0.5	0.7	0.9	1.2	1.5	1.9	2.3	2.8													
72	0.5	0.7	1.0	1.3	1.6	2.0	2.5	2.9	3.5												
78	0.6	0.8	1.1	1.4	1.8	2.2	2.6	3.1	3.7	4.4											
84	0.6	0.9	1.2	1.5	1.9	2.3	2.8	3.3	3.9	4.6	5.4										
90	0.6	0.9	1.2	1.6	2.0	2.4	2.9	3.5	4.2	4.9	5.7	6.6									
96	0.6	1.0	1.3	1.7	2.1	2.6	3.1	3.7	4.4	5.1	6.0	6.9	7.9								
102	0.7	1.0	1.3	1.7	2.2	2.7	3.3	3.9	4.6	5.4	6.2	7.2	8.2	9.4							
108	0.7	1.0	1.4	1.8	2.3	2.9	3.4	4.1	4.8	5.6	6.5	7.5	8.6	9.8	11.1						
114	0.7	1.1	1.5	1.9	2.4	3.0	3.6	4.3	5.0	5.8	6.7	7.8	8.9	10.1	11.5	12.9					
120	0.8	1.1	1.5	2.0	2.5	3.1	3.8	4.4	5.2	6.1	7.0	8.1	9.2	10.5	11.9	13.4	15.0				
126	0.8	1.1	1.6	2.1	2.6	3.2	3.9	4.6	5.4	6.3	7.3	8.3	9.5	10.8	12.2	13.8	15.5	17.3			
132	0.8	1.2	1.6	2.1	2.7	3.3	4.0	4.8	5.6	6.5	7.5	8.6	9.8	11.2	12.6	14.2	15.9	17.8	19.8		
138	0.8	1.2	1.7	2.2	2.8	3.4	4.1	5.0	5.8	6.8	7.8	8.9	10.2	11.5	13.0	14.6	16.4	18.3	20.3	22.5	
144	0.8	1.3	1.7	2.3	2.9	3.5	4.3	5.1	6.0	7.0	8.1	9.2	10.5	11.9	13.4	15.1	16.8	18.8	20.9	23.1	25.5

0.138" Thickness

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
78	0.5	0.7	1.0	1.2	1.5	1.9	2.2	2.6	3.1	3.6											
84	0.5	0.8	1.0	1.3	1.6	2.0	2.4	2.8	3.3	3.8	4.4										
90	0.6	0.8	1.1	1.4	1.7	2.1	2.5	3.0	3.5	4.1	4.7	5.4									
96	0.6	0.9	1.1	1.5	1.9	2.2	2.7	3.1	3.7	4.3	4.9	5.6	6.4								
102	0.6	0.9	1.2	1.5	1.9	2.4	2.8	3.3	3.9	4.5	5.2	5.9	6.7	7.6							
108	0.6	0.9	1.3	1.6	2.0	2.5	3.0	3.5	4.1	4.7	5.4	6.2	7.0	7.9	8.9						
114	0.7	1.0	1.3	1.7	2.1	2.6	3.1	3.6	4.2	4.9	5.6	6.4	7.3	8.3	9.3	10.4					
120	0.7	1.0	1.4	1.8	2.2	2.7	3.3	3.8	4.4	5.1	5.9	6.7	7.6	8.6	9.6	10.8	12.1				
126	0.7	1.0	1.4	1.8	2.3	2.8	3.4	4.0	4.6	5.3	6.1	7.0	7.9	8.9	10.0	11.2	12.5	13.9			
132	0.7	1.1	1.5	1.9	2.4	2.9	3.5	4.2	4.8	5.5	6.3	7.2	8.2	9.2	10.3	11.6	12.9	14.3	15.8		
138	0.7	1.1	1.5	2.0	2.5	3.0	3.6	4.3	5.0	5.8	6.6	7.5	8.5	9.5	10.7	11.9	13.3	14.7	16.3	18.0	
144	0.8	1.1	1.6	2.0	2.6	3.1	3.7	4.4	5.2	6.0	6.8	7.7	8.7	9.8	11.0	12.3	13.7	15.2	16.8	18.5	20.3

0.168" Thickness

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
114	0.6	0.9	1.2	1.5	1.9	2.3	2.8	3.2	3.7	4.3	4.9	5.6	6.3	7.1	7.9	8.8					
120	0.6	0.9	1.3	1.6	2.0	2.4	2.9	3.4	3.9	4.5	5.1	5.8	6.6	7.4	8.2	9.2	10.2				
126	0.6	0.9	1.3	1.7	2.1	2.5	3.0	3.6	4.1	4.7	5.3	6.0	6.8	7.6	8.5	9.5	10.6	11.7			
132	0.7	1.0	1.3	1.7	2.2	2.6	3.1	3.7	4.3	4.9	5.6	6.3	7.1	7.9	8.9	9.9	10.9	12.1	13.3		
138	0.7	1.0	1.4	1.8	2.2	2.7	3.2	3.8	4.5	5.1	5.8	6.5	7.3	8.2	9.2	10.2	11.3	12.5	13.7	15.1	
144	0.7	1.0	1.4	1.9	2.3	2.8	3.4	4.0	4.6	5.3	6.0	6.8	7.6	8.5	9.5	10.5	11.7	12.9	14.2	15.6	17.0

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

COVER DEPTH (H_{NLR}) FOR WHICH NO LONGITUDINAL REINFORCEMENT IS REQUIRED (Depth in Feet)

0.064" Thickness 2⅔" x ½" Corrugation

Branch Diameter	24	30	36	42	48	54
Main Diameter						
48	37.4	27.5	22.2	17.9	13.8	

0.064" Thickness 3" x 1" and 5" x 1" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102
Main Diameter														
48	32.4	22.5	17.2	13.9	11.9									
54	28.8	20.0	15.3	12.4	10.5	9.7								
60	25.9	18.0	13.7	11.2	9.5	8.7	7.0							
66	23.6	16.4	12.5	10.1	8.6	7.9	6.4	5.3						
72	21.6	15.0	11.5	9.3	7.9	7.2	5.9	4.8	4.1					
78	19.9	13.9	10.6	8.6	7.3	6.7	5.4	4.4	3.8	3.2				
84	18.5	12.9	9.8	8.0	6.8	6.2	5.0	4.1	3.5	2.9	2.5			
90	17.3	12.0	9.2	7.4	6.3	5.8	4.7	3.9	3.3	2.7	2.4	2.1		
96	16.2	11.3	8.6	7.0	5.9	5.4	4.4	3.6	3.0	2.6	2.2	1.9	1.7	
102	15.3	10.6	8.1	6.6	5.6	5.1	4.1	3.4	2.9	2.4	2.1	1.8	1.6	1.4

0.079" Thickness 2⅔" x ½" Corrugation

Branch Diameter	24	30	36	42	48	54
Main Diameter						
48	48.2	36.3	29.6	21.6	16.6	
54	42.8	32.2	26.3	19.2	14.8	11.7

0.079" Thickness 3" x 1" and 5" x 1" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
Main Diameter																	
48	40.7	28.8	22.3	18.3	15.8												
54	36.2	25.6	19.8	16.3	14.0	11.7											
60	32.6	23.0	17.8	14.7	12.6	10.5	8.5										
66	29.6	20.9	16.2	13.3	11.5	9.5	7.8	6.4									
72	27.1	19.2	14.8	12.2	10.5	8.7	7.1	5.9	4.9								
78	25.0	17.7	13.7	11.3	9.7	10.7	6.6	5.4	4.5	3.8							
84	23.3	16.4	12.7	10.5	9.0	7.5	6.1	5.0	4.2	3.6	3.1						
90	21.7	15.3	11.9	9.8	8.4	7.0	5.7	4.7	3.9	3.3	2.9	2.5					
96	20.4	14.4	11.1	9.2	7.9	6.6	5.3	4.4	3.7	3.1	2.7	2.4	2.1				
102	19.2	13.5	10.5	8.6	7.4	6.2	5.0	4.1	3.5	2.9	2.6	2.2	2.0	1.7			
108	18.1	12.8	9.9	8.2	7.0	5.8	4.7	3.9	3.3	2.8	2.4	2.1	1.9	1.6	1.5		
114	17.1	12.1	9.4	7.7	6.7	5.5	4.5	3.7	3.1	2.6	2.3	2.0	1.7	1.6	1.4	1.3	
120	16.3	11.5	8.9	7.3	6.3	5.2	4.3	3.5	3.0	2.5	2.2	1.9	1.7	1.5	1.3	1.2	1.1

0.109" Thickness 2⅔" x ½" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66
Main Diameter								
48	69.1	53.2	39.2	28.9	22.0			
54	61.4	47.3	34.8	25.6	19.6	15.5		
60	55.3	42.6	31.4	23.1	17.6	14.0	11.3	
66	50.3	38.7	28.5	21.0	16.0	12.7	10.3	8.5

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

COVER DEPTH (H_{NLR}) FOR WHICH NO LONGITUDINAL REINFORCEMENT IS REQUIRED (Depth in Feet)

0.109" Thickness 3" x 1" and 5" x 1" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
48	56.6	40.7	32.1	26.9	22.0																
54	50.3	36.2	28.5	23.9	19.6	15.5															
60	45.3	32.6	25.7	21.5	17.6	14.0	11.3														
66	41.2	29.6	23.3	19.6	16.0	12.7	10.3	8.5													
72	37.7	27.2	21.4	17.9	14.7	11.6	9.4	7.8	6.6												
78	34.8	25.1	19.8	16.6	13.6	13.2	8.7	7.2	6.1	5.2											
84	32.3	23.3	18.3	15.4	12.6	10.0	8.1	6.6	5.6	4.8	4.1										
90	30.2	21.7	17.1	14.3	11.7	9.3	7.5	6.2	5.3	4.5	3.9	3.3									
96	28.3	20.4	16.1	13.5	11.0	8.7	7.1	5.8	4.9	4.2	3.6	3.1	2.8								
102	26.6	19.2	15.1	12.7	10.4	8.2	6.6	5.5	4.6	3.9	3.4	2.9	2.6	2.3							
108	25.2	18.1	14.3	12.0	9.8	7.8	6.3	5.2	4.4	3.7	3.2	2.8	2.5	2.2	1.9						
114	23.8	17.1	13.5	11.3	9.3	7.4	5.9	4.9	4.1	3.5	3.0	2.6	2.3	2.1	1.8	1.7					
120	22.6	16.3	12.8	10.8	8.8	7.0	5.6	4.7	3.9	3.3	2.9	2.5	2.2	2.0	1.8	1.6	1.4				
126	21.6	15.5	12.2	10.2	8.4	6.7	5.4	4.4	3.7	3.2	2.7	2.4	2.1	1.9	1.7	1.5	1.3	1.2			
132	20.6	14.8	11.7	9.8	8.0	6.3	5.1	4.2	3.6	3.0	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.2	1.1		
138	19.7	14.2	11.2	9.4	7.7	6.1	4.9	4.1	3.4	2.9	2.5	2.2	1.9	1.7	1.5	1.4	1.2	1.1	1.0	0.9	

0.138" Thickness 3" x 1" and 5" x 1" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
78	45.8	33.7	27.2	21.9	16.7	13.2	10.7	8.8	7.4	6.3											
84	42.5	31.3	25.2	20.3	15.5	12.3	10.0	8.2	6.9	5.9	5.1										
90	39.7	29.2	23.6	18.9	14.5	11.5	9.3	7.6	6.4	5.5	4.7	4.1									
96	37.2	27.4	22.1	17.8	13.6	10.7	8.7	7.2	6.0	5.1	4.4	3.9	3.4								
102	35.0	25.8	20.8	16.7	12.8	10.1	8.2	6.7	5.7	4.8	4.2	3.7	3.2	2.8							
108	33.1	24.4	19.6	15.8	12.1	9.6	7.8	6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.4						
114	31.3	23.1	18.6	15.0	11.4	9.1	7.3	6.0	5.1	4.3	3.7	3.2	2.9	2.5	2.3	2.0					
120	29.8	21.9	17.7	14.2	10.9	8.6	7.0	5.7	4.8	4.1	3.6	3.1	2.7	2.4	2.2	1.9	1.8				
126	28.3	20.9	16.8	14.4	10.4	8.2	6.6	5.5	4.6	3.9	3.4	2.9	2.6	2.3	2.1	1.8	1.6	1.5			
132	27.1	19.9	16.1	13.7	9.9	7.8	6.3	5.2	4.4	3.7	3.2	2.8	2.5	2.2	2.0	1.7	1.6	1.4	1.3		
138	25.9	19.1	15.4	13.1	9.5	7.5	6.1	5.0	4.2	3.6	3.1	2.7	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.1	
144	24.8	18.3	14.7	12.6	9.1	7.2	5.8	4.8	4.0	3.4	3.0	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0

0.168" Thickness 3" x 1" and 5" x 1" Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144
Main Diameter																					
114	38.6	28.9	23.6	17.7	13.5	10.7	8.6	7.2	6.0	5.1	4.4	3.8	3.4	3.0	2.7	2.4					
120	36.7	27.5	22.4	16.8	12.8	10.1	8.2	6.8	5.7	4.9	4.2	3.6	3.2	2.9	2.5	2.3	2.1				
126	35.0	26.1	21.4	16.0	12.2	9.7	7.8	6.5	5.4	4.6	4.0	3.5	3.1	2.7	2.4	2.2	2.0	1.8			
132	33.4	25.0	20.4	15.3	11.7	9.2	7.5	6.2	5.2	4.4	3.8	3.3	2.9	2.6	2.3	2.1	1.9	1.7	1.5		
138	31.9	23.9	19.5	14.6	11.2	8.8	7.1	5.9	5.0	4.2	3.7	3.2	2.8	2.5	2.2	2.0	1.8	1.6	1.5	1.4	
144	30.6	22.9	18.7	14.0	10.7	8.4	6.8	5.7	4.7	4.0	3.5	3.1	2.7	2.4	2.1	1.9	1.7	1.5	1.4	1.3	1.2

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

COVER DEPTH (H_{NLR}) FOR WHICH NO LONGITUDINAL REINFORCEMENT IS REQUIRED (DEPTH IN FEET)
SPIRAL RIB PIPE

0.064" Thickness ¾" Depth Corrugation

Branch Diameter	24	30	36	42	48	54	60
Main Diameter							
48	30.4	20.5	15.2	11.9	9.9		
54	27.0	18.3	13.5	10.6	8.8	7.5	
60	24.3	16.4	12.1	9.6	7.9	6.7	5.9

0.064" Thickness 1" Depth Corrugation

Branch Diameter	24	30	36	42	48	54	60	66
Main Diameter								
48	29.7	19.8	14.4	11.2	9.1			
54	26.4	17.6	12.8	10.0	8.1	6.8		
60	23.7	15.8	11.5	9.0	7.3	6.1	5.3	
66	21.6	14.4	10.5	8.1	6.6	5.6	4.8	4.3

0.079" Thickness ¾" Depth Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78
Main Diameter										
48	37.7	25.8	19.3	15.3	12.8					
54	33.5	22.9	17.1	13.6	11.4	9.8				
60	30.2	20.6	15.4	12.3	10.2	8.8	7.9			
66	27.4	18.7	14.0	11.2	9.3	8.0	7.1	6.4		
72	25.1	17.2	12.8	10.2	8.5	7.4	6.5	5.9	4.9	
78	23.2	15.8	11.9	9.4	7.9	10.0	6.0	5.4	4.5	3.8

0.079" Thickness 1" Depth Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84
Main Diameter											
48	36.6	24.7	18.2	14.2	11.7						
54	32.5	21.9	16.1	12.7	10.4	8.9					
60	29.3	19.7	14.5	11.4	9.4	8.0	7.0				
66	26.6	17.9	13.2	10.4	8.5	7.2	6.3	5.7			
72	24.4	16.4	12.1	9.5	7.8	6.6	5.8	5.2	4.7		
78	22.5	15.2	11.2	8.8	7.2	8.8	5.4	4.8	4.4	3.8	
84	20.9	14.1	10.4	8.1	6.7	5.7	5.0	4.5	4.1	3.6	3.1

0.109" Thickness ¾" Depth Corrugation

Branch Diameter	24	30	36	42	48	54	60	66	72	78	84	90	96	102
Main Diameter														
48	51.6	35.7	27.1	21.9	18.5									
54	45.9	31.8	24.1	19.5	16.5	14.4								
60	41.3	28.6	21.7	17.5	14.8	13.0	11.3							
66	37.5	26.0	19.7	15.9	13.5	11.8	10.3	8.5						
72	34.4	23.8	18.1	14.6	12.4	10.8	9.4	7.8	6.6					
78	31.8	22.0	16.7	13.5	11.4	13.2	8.7	7.2	6.1	5.2				
84	29.5	20.4	15.5	12.5	10.6	9.3	8.1	6.6	5.6	4.8	4.1			
90	27.5	19.1	14.5	11.7	9.9	8.6	7.5	6.2	5.3	4.5	3.9	3.3		
96	25.8	17.9	13.6	11.0	9.3	8.1	7.1	5.8	4.9	4.2	3.6	3.1	2.8	
102	24.3	16.8	12.8	10.3	8.7	7.6	6.6	5.5	4.6	3.9	3.4	2.9	2.6	2.3

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

COVER DEPTH (H_{NLR}) FOR WHICH NO LONGITUDINAL REINFORCEMENT IS REQUIRED (DEPTH IN FEET)
SPIRAL RIB PIPE *(continued)*

	0.109" Thickness 1" Depth Corrugation														
Branch Diameter	**24**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	**90**	**96**	**102**	**108**
Main Diameter															
48	49.7	33.8	25.2	20.0	16.6										
54	44.2	30.1	22.4	17.8	14.8	12.7									
60	39.8	27.1	20.2	16.0	13.3	11.5	10.1								
66	36.2	24.6	18.3	14.5	12.1	10.4	9.2	8.3							
72	33.1	22.6	16.8	13.3	11.1	9.5	8.4	7.6	6.6						
78	30.6	20.8	15.5	12.3	10.2	12.2	7.8	7.0	6.1	5.2					
84	28.4	19.3	14.4	11.4	9.5	8.2	7.2	6.5	5.6	4.8	4.1				
90	26.5	18.0	13.4	10.7	8.9	7.6	6.8	6.1	5.3	4.5	3.9	3.3			
96	24.9	16.9	12.6	10.0	8.3	7.2	6.3	5.7	4.9	4.2	3.6	3.1	2.8		
102	23.4	15.9	11.9	9.4	7.8	6.7	6.0	5.4	4.6	3.9	3.4	2.9	2.6	2.3	
108	22.1	15.0	11.2	8.9	7.4	6.4	5.6	5.1	4.4	3.7	3.2	2.8	2.5	2.2	1.9

	0.138" Thickness ¾" Depth Corrugation														
Branch Diameter	**24**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	**90**	**96**	**102**	**108**
Main Diameter															
78	40.9	28.8	22.3	18.3	15.8	13.2	10.7	8.8	7.4	6.3					
84	37.9	26.8	20.7	17.0	14.6	12.3	10.0	8.2	6.9	5.9	5.1				
90	35.4	25.0	19.3	15.9	13.7	11.5	9.3	7.6	6.4	5.5	4.7	4.1			
96	33.2	23.4	18.1	14.9	12.8	10.7	8.7	7.2	6.0	5.1	4.4	3.9	3.4		
102	31.2	22.0	17.0	14.0	12.0	10.1	8.2	6.7	5.7	4.8	4.2	3.7	3.2	2.8	
108	29.5	20.8	16.1	13.2	11.4	9.6	7.8	6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.4

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*

MAXIMUM BRANCH DIAMETERS THAT DO NOT REQUIRE CIRCUMFERENTIAL REINFORCEMENT

All CSP Except Spiral Rib Pipe

Thickness	**.064**			**.079**			**.109**			**.138**			**.168**		
Fill Heights	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
Main Diameter															
48	48	30	18	48	48	30	48	48	48						
54	48	30	18	54	42	30	54	54	48						
60	48	30	18	60	42	24	60	60	48						
66	48	30	18	66	42	24	66	60	42						
72	48	24	18	66	42	18	72	60	42						
78	48	24	18	66	36	18	78	60	42	78	78	60			
84	48	18	18	60	36	18	84	60	36	84	78	60			
90	48	18	18	60	30	18	90	60	36	90	78	54			
96	48	18	18	60	30	18	90	54	30	96	78	54			
102	48	18	18	60	24	18	90	54	30	102	78	54			
108				60	24	18	90	54	24	108	78	48			
114				60	24	18	90	48	24	114	78	48	114	96	66
120				60	18	18	90	48	18	114	72	42	120	96	66
126							90	48	18	114	72	42	126	96	66
132							90	42	18	114	72	36	132	96	60
138							90	42	18	114	66	30	138	96	60
144										114	66	30	144	90	54

¾" x ¾" x 7½" Corrugated Spiral Rib Pipe

Thickness	**.064**			**.079**			**.109**			**.138**		
Fill Heights	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
Main Diameter												
48	30	18	12	42	30	18	48	48	42			
54	30	18	12	42	24	18	54	54	36			
60	30	18	12	42	24	18	60	54	36			
66				42	24	18	66	54	36			
72				42	18	18	72	48	30			
78				42	18	18	78	48	30	78	78	60
84							78	48		84	78	60
90							78	48		90	78	54
96							78	42		96	78	54
102							78	42		102	78	54
108										108	78	48

¾" x 1" x 11½" Corrugated Spiral Rib Pipe

Thickness	**.064**			**.079**			**.109**		
Fill Heights	**10**	**20**	**30**	**10**	**20**	**30**	**10**	**20**	**30**
Main Diameter									
48	18	12	12	30	18	18	48	36	24
54	18	12	12	30	18	18	54	36	24
60	18	12	12	30	18	12	54	36	18
66	18			30	18	12	54	36	18
72				30	18	12	54	30	18
78				30	18	12	54	30	18
84				24			54	24	18
90							54	24	12
96							54	24	12
102							54	18	12
108							54	18	12

Note: *Blank entries indicate cases not investigated. For intermediate branch diameters, or intermediate covers, interpolate or select the lower branch diameter. For branch angles other than 90 degrees (but no less than 30 degrees), use the span (major dimension of opening cut in main pipe for branch pipe) rather than the branch diameter.*