AMERON INTERNATIONAL

Bondstrand® Installation

FIBERGLASS PIPE GROUP

Installation of Suspended Bondstrand Pipe

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FP288A (1/97)

1 General

Designing the Bondstrand system

This guide contains general information for designing suspended Bondstrand piping systems. This information, in conjunction with good general engineering practice and the designer's good judgment, must all be applied to complete a successful and economical piping system.

The guide considers the following:

- Criteria for selecting Bondstrand products for a given application
- Expansion and contraction
- Span between supports and support location
- Connections to other materials and equipment
- Coating Bondstrand products
- Suggested details for guides, supports and anchors

While Bondstrand performs in many applications just like metallic systems, the designer must recognize some important differences:

- Bondstrand pipe weighs only about 1⁄7 as much as Schedule 40 carbon steel pipe. This means that pipe and piping assemblies even in 16-inch diameters can be lifted into place using any light lifting equipment. In the smaller diameters, no lifting equipment is necessary. This reduces on-site installation costs.
- The longitudinal modulus of Bondstrand is much less than that of carbon steel pipe — a characteristic that limits spans where deflection is important but also reduces thrust due to temperature change.
- Thermal expansion is 60% greater than for carbon steel. However, by taking advantage of the Bondstrand's flexibility, you can provide for this expansion economically, often without using expansion joints.
- Bondstrand fiberglass pipe requires protection against potential external abrasion or crushing at points where steel supports are located. Such protection is easy and economical.
- Effective modulus values vary with temperature. Recommended spans and estimated thrusts are given to help the designer detail his project for long-time operation at ambient and elevated temperatures.

Recognition of these and other differences dealt with in this guide is the key to successful installations. While this information is likely to prove most helpful to those designing Bondstrand systems for the first time, experienced Bondstrand customers will also find new and useful information.

Be aware that the reinforced thermosetting resin piping products offered by other manufacturers may differ significantly from Bondstrand. Resin systems, manufacturing processes and joining systems are important variables affecting the mechanical and physical properties of these products. The recommendations and suggestions given are based on Ameron's test and field experience and should be applied only to Bondstrand products.

Selecting Bondstrand pipe, fittings and adhesives

A choice of either epoxy or vinyl ester Bondstrand products is available for different chemical and thermal environments. For information to guide your selection, refer to the Bondstrand Corrosion Guide, FP132. This publication provides recommendations for different chemicals and other fluid materials, including food products, as well as guidance for selecting the appropriate Bondstrand adhesive.

Filament-wound versus molded products

In smaller pipe sizes, you have a choice between molded and filament-wound fittings. In general, filament-wound fittings should be used in applications where fittings in loops, turns or branches are intended to flex, where temperature changes exceed 100°F in restrained or blocked systems, or where the system is exposed to mechanical vibration or hydraulic surge. Filament wound fittings would be used, also, in systems where a liner is required. Some sizes and types of fittings are not available in both molded and filament-wound styles, so check the Bondstrand Fittings Dimensions, FP282, for availability when making your choice.

1 General (cont)

Energy savings

Remember when selecting pipe diameter that Bondstrand's low frictional values (Hazen-Williams C = 150) will reduce your pumping energy requirements compared to those for carbon steel pipe. In most systems these low frictional values will be maintained for the life of the system.

Note also that the slightly larger inside diameter of Bondstrand pipe compared to Schedule 40 or 80 carbon steel pipe, will further reduce your pumping costs. Handy charts in the Bondstrand engineering guides show the head loss expected for both pipe and fittings.

Insulated systems

Bondstrand may be insulated in the field. Bondstrand pipe is also available from many pipe insulators with efficient built-in insulation. If you use insulated Bondstrand, be sure to check your support spacings for the operating temperature to accommodate the added weight of the insulation and jacket.

Series 2000M-FP is manufactured with a factory applied, reinforced coating which provides impact resistance and thermal insulation in addition to its fire protection properties. Unless indicated otherwise, values presented in the tables for Series 2000 can be used for Series 2000M-FP.

Other application information

Where containment is required for your piping system, Ameron can supply Bondstrand II pipe with a variety of joining and performance options.

Ameron has prepared a number of publications with valuable information pertaining to specific types of service, including marine applications, fire protection systems and steam condensate returns. Just call your local Bondstrand distributor or your nearest Ameron sales office, and let us know your application. Give us the temperature, pressure, liquid or gas to be carried, and other pertinent conditions.

In addition, Ameron has computer programs for deflection and stress analysis of Bondstrand systems. For a nominal fee, Ameron Engineering Department will be pleased to utilize one of these programs to analyze your specific systems. Experience shows, however, that such analysis is required only for the more demanding or complicated conditions and that the generalized procedures presented herein will usually suffice.

2 Designing for expansion and contraction

General principles

Suspended pipe generally performs best where it is permitted to move freely. In these systems, anchors serve only to keep the pipe properly positioned between loops and turns. Center the anchor in the run between loops if possible. An anchor should be placed between loops and between loops and turns. Except for the one anchor per run, supports should carry the pipe and maintain the intended drainage slope but should not restrain the pipe against axial movement. At turns, the supports should also permit lateral movement. Supports should not fall directly on fittings.

If the piping system cannot be designed to move freely, see next section on DESIGNING FOR RESTRAINED SYSTEMS.

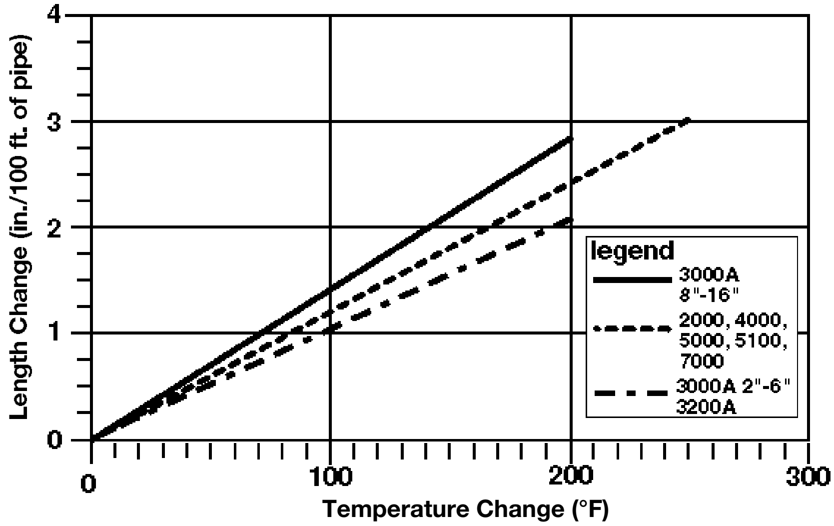
Pipe changes length in a free system as a result of changes in temperature and pressure. Since both can increase or decrease concurrently, the resulting changes in length must be combined for loop design. Length-change formulas and examples appear in Appendix A, but the following paragraphs will provide all you need for most pipeline designs.

2 Designing for expansion and contraction (cont'd)

Length change due to temperature

Tests show that the amount of linear expansion varies directly with temperature. Figure 1 shows the length change for Series 2000, 3000A, 3200A, 4000, 5000, 5100 and 7000 Bondstrand pipe.

Figure 1 **Length changes for Bondstrand Series 2000, 2000M-FP, 4000, 5000, 5100, 7000, 3000A, and 3200A**



Length change due to pressure

The amount of length change occurring because of internal pressure depends on wall thickness, diameter, Poisson's ratio and the effective modulus of elasticity in both axial and circumferential directions at the operating temperature. In Bondstrand pipe, some of these factors tend to cancel each other, and the correction becomes relatively simple. For each 100 feet in a straight, freely supported run of Bondstrand pipe (Table 1) provides length changes which are suitable throughout the indicated range of temperatures. You need only correct this value for the pressure of your system by using a direct pressure-ratio correction.

Table 1 **Length increase due to a 100 psi (7 bar) internal pressure in an unrestrained system.**

Values given for Series 2000, 2000M-FP and 4000 are valid to 250°F (121°C). Values for Series 3000A, 3200A, 5000, 5100 and 7000 are valid to 200°F (93°C).

Nominal Diameter		Inches per 100 feet of pipe (*mm per 100 m of pipe*) from 100 psi (*1 MPa*) internal pressure													
		Series 2000		Series 3000A		Series 3200A		Series 4000		Series 5000, 5100		Series 7000		Series 2000M-FP	
in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*
1	*25*	0.1	*11*	–	–	–	–	0.1	*14*	0.3	*37*	0.1	*10*	0.1	*11*
1.5	*40*	0.1	*18*	–	–	–	–	0.2	*23*	0.5	*60*	0.1	*16*	0.1	*18*
2	*50*	0.2	*23*	0.2	*27*	0.2	*27*	0.2	*29*	0.6	*77*	0.2	*20*	0.2	*23*
3	*80*	0.3	*36*	0.3	*39*	0.3	*39*	0.4	*46*	1.0	*122*	0.3	*32*	0.3	*36*
4	*100*	0.3	*35*	0.4	*49*	0.4	*49*	0.3	*42*	0.9	*110*	0.3	*32*	0.3	*35*
5	*125*	0.4	*44*	–	–	–	–	0.4	*53*	1.2	*140*	0.3	*40*	0.4	*44*
6	*150*	0.4	*54*	0.4	*53*	0.4	*53*	0.5	*64*	1.4	*170*	0.4	*49*	0.4	*54*
8	*200*	0.5	*63*	1.3	*158*	0.5	*66*	0.6	*74*	1.6	*195*	0.4	*48*	0.4	*52*
10	*250*	0.7	*80*	1.4	*165*	0.6	*69*	0.8	*94*	2.0	*247*	0.4	*49*	0.4	*52*
12	*300*	0.8	*96*	1.4	*168*	0.6	*70*	0.9	*112*	2.4	*295*	0.4	*49*	0.4	*52*
14	*350*	0.8	*100*	1.5	*176*	0.6	*74*	0.9	*107*	2.3	*282*	0.4	*50*	0.4	*52*
16	*400*	0.8	*100*	1.5	*182*	0.6	*76*	0.9	*107*	2.3	*281*	0.4	*50*	0.4	*52*

Anchoring for branches and valves

Both vertical and horizontal branches can add complexity to a system intended to move freely. Unless a branch can move both axially and laterally, such as a short stub-out to a nozzle or flexible hose connection, it will require special consideration to avoid undue bending stresses. Sometimes the best solution is to anchor both the branch and the run at the tee, accommodating the pipe length changes at turns or loops in each of the three connecting lines. For example, a vertical branch connecting to buried pipe may include a Z-loop; the tee may be rotated 90° to permit an L-loop; or the vertical line may be treated as a restrained pipe as described in Designing for Restrained Systems.

Valves should be anchored and supported directly, especially in diameters six inches and larger. Valve weight in the larger sizes and torque on valve handles in all sizes are the primary concerns. Generally, butterfly valves with manual lever handle actuators do not require separate supports. Other types of actuators can add too much torque or weight if they are not separately supported.

2 Designing for expansion and contraction (cont'd)

Using expansion loops

Loops are recommended for relieving longitudinal stress between anchors in a suspended pipeline. Table 2 gives minimum expansion loop dimensions for all Bondstrand pipe series. First, determine how much total length change due to temperature and pressure must be absorbed. Use the appropriate table for the pipe series you are using. Select the pipe diameter and total length change to determine the required leg length for a U-loop design. As an example, assume that a Series 2000 eight-inch line is installed and will change a total of two inches in length. Table 2 for Series 2000 and Series 4000 shows that the length of loop leg required to accommodate the length change is 9 feet (2.8m).

Loops should be horizontal whenever possible to avoid entrapping air or sediment and to facilitate drainage.

- For upward loops, air relief valves aid air removal and improve flow. In pressure systems, air removal for both pressure testing and normal operation is required for safety as well.
- For downward loops, air pressure equalizing lines may be necessary to permit drainage.
- In both cases, special taps are necessary for complete drainage.

Loops using 90° elbows absorb length change better than those using 45° elbows. Unlike a 90° turn, a 45° turn carries a thrust component through the turn which can add axial stress to the usual bending stress in the pipe and fittings. Alignment and deflection are also directly affected by the angular displacement at 45° turns and demand special attention for support design and location.

A 45° elbow at a free turn with the same increment of length change in each leg will be displaced 86% more than a 90° elbow. The relative displacement in the plane of a loop is also more of a problem. Figure 2 illustrates the geometry involved. Design information is not provided because it is beyond the scope of this manual and loops with 45° elbos are generally not recommended. Consult Ameron if a situation requires the use of 45° elbows.

Figure 2 **Comparison of displacement in 90° vs. 45° elbows caused by a unit length change**

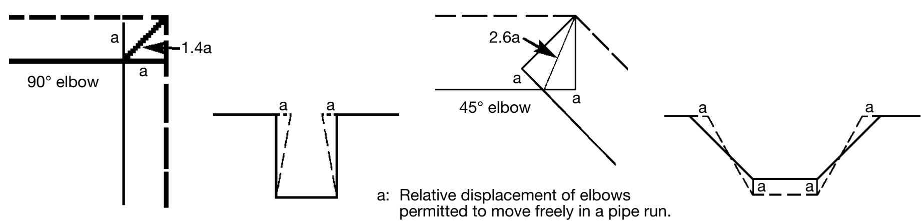


Table 2 **Expansion loop design:** Length of loop leg required to accommodate listed length changes

Nominal Pipe Size in.	*mm*	Series 2000 and Series 4000 length change (in./*mm*) 1.0/*25* ft	*m*	2.0/*50* ft.	*m*	3.0/*75* ft.	*m*	4.0/*100* ft.	*m*	5.0/*125* ft.	*m*
1	*25*	3	*1.0*	4	*1.3*	4	*1.3*	5	*1.6*	6	*1.9*
1.5	*40*	3	*1.0*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*
2	*50*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*	7	*2.2*
3	*80*	4	*1.3*	6	*1.9*	7	*2.2*	8	*2.5*	9	*2.8*
4	*100*	5	*1.6*	6	*1.9*	8	*2.5*	9	*2.8*	10	*3.1*
5	*125*	5	*1.6*	7	*2.2*	8	*2.5*	10	*3.1*	11	*3.4*
6	*150*	5	*1.6*	8	*2.5*	9	*2.8*	10	*3.1*	12	*3.7*
8	*200*	6	*1.9*	9	*2.8*	10	*3.1*	12	*3.7*	13	*4.0*
10	*250*	7	*2.2*	9	*2.8*	12	*3.7*	13	*4.0*	15	*4.6*
12	*300*	7	*2.2*	10	*3.1*	12	*3.7*	14	*4.3*	16	*4.9*
14	*350*	8	*2.5*	11	*3.4*	13	*4.0*	15	*4.6*	17	*5.2*
16	*400*	8	*2.5*	11	*3.4*	14	*4.3*	16	*4.9*	18	*5.5*

Nominal Pipe Size in.	*mm*	Series 5000 and 5100 length change (in./*mm*) 1.0/*25* ft	*m*	2.0/*50* ft.	*m*	3.0/*75* ft.	*m*	4.0/*100* ft.	*m*	5.0/*125* ft.	*m*
1	*25*	2	*0.7*	3	*1.0*	4	*1.3*	4	*1.3*	5	*1.6*
1.5	*40*	3	*1.0*	4	*1.3*	5	*1.6*	5	*1.6*	6	*1.9*
2	*50*	3	*1.0*	4	*1.3*	5	*1.6*	6	*1.9*	6	*1.9*
3	*80*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*	7	*2.2*
4	*100*	4	*1.3*	5	*1.6*	7	*2.2*	8	*2.5*	8	*2.5*
5	*125*	4	*1.3*	6	*1.9*	7	*2.2*	8	*2.5*	9	*2.8*
6	*150*	5	*1.6*	7	*2.2*	8	*2.5*	9	*2.8*	10	*3.1*
8	*200*	5	*1.6*	7	*2.2*	9	*2.8*	10	*3.1*	11	*3.4*
10	*250*	6	*1.9*	8	*2.5*	10	*3.1*	11	*3.4*	13	*4.0*
12	*300*	6	*1.9*	9	*2.8*	11	*3.4*	12	*3.7*	14	*4.3*
14	*350*	7	*2.2*	9	*2.8*	11	*3.4*	13	*4.0*	14	*4.3*
16	*400*	7	*2.2*	10	*3.1*	12	*3.7*	14	*4.3*	15	*4.6*

2 Designing for expansion and contraction (cont'd)

Table 2 **Expansion loop design:** Length of loop leg required to accommodate listed length changes

Nominal Pipe Size in.	*mm*	Series 2000M-FP and Series 7000 length change (in./*mm*) 1.0/*25* ft	*m*	2.0/*50* ft.	*m*	3.0/*75* ft.	*m*	4.0/*100* ft.	*m*	5.0/*125* ft.	*m*
1	*25*	3	*1.0*	4	*1.3*	4	*1.3*	5	*1.6*	6	*1.9*
1.5	*40*	3	*1.0*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*
2	*50*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*	7	*2.2*
3	*80*	4	*1.3*	6	*1.9*	7	*2.2*	8	*2.5*	9	*2.8*
4	*100*	5	*1.6*	6	*1.9*	8	*2.5*	9	*2.8*	10	*3.1*
5	*125*	5	*1.6*	7	*2.2*	8	*2.5*	10	*3.1*	11	*3.4*
6	*150*	5	*1.6*	8	*2.5*	9	*2.8*	10	*3.1*	12	*3.7*
8	*200*	6	*1.9*	9	*2.8*	10	*3.1*	12	*3.7*	13	*4.0*
10	*250*	7	*2.2*	10	*3.1*	12	*3.7*	13	*4.0*	15	*4.6*
12	*300*	8	*2.5*	10	*3.1*	13	*4.0*	15	*4.6*	16	*4.9*
14	*350*	8	*2.5*	11	*3.4*	13	*4.0*	15	*4.6*	17	*5.2*
16	*400*	8	*2.5*	12	*3.7*	14	*4.3*	16	*4.9*	18	*5.5*

Nominal Pipe Size in.	*mm*	Series 3000A length change (in./*mm*) 1.0/*25* ft	*m*	2.0/*50* ft.	*m*	3.0/*75* ft.	*m*	4.0/*100* ft.	*m*	5.0/*125* ft.	*m*
1	*25*	–	–	–	–	–	–	–	–	–	–
1.5	*40*	–	–	–	–	–	–	–	–	–	–
2	*50*	3	*1.0*	3	*1.0*	4	*1.3*	5	*1.6*	5	*1.6*
3	*80*	3	*1.0*	4	*1.3*	5	*1.6*	5	*1.6*	6	*1.9*
4	*100*	3	*1.0*	5	*1.6*	5	*1.6*	6	*1.9*	7	*2.2*
5	*125*	–	–	–	–	–	–	–	–	–	–
6	*150*	4	*1.3*	5	*1.6*	6	*1.9*	7	*2.2*	8	*2.5*
8	*200*	4	*1.3*	6	*1.9*	7	*2.2*	8	*2.5*	9	*2.8*
10	*250*	5	*1.6*	6	*1.9*	8	*2.5*	9	*2.8*	10	*3.1*
12	*300*	5	*1.6*	7	*2.2*	8	*2.5*	9	*2.8*	10	*3.1*
14	*350*	5	*1.6*	7	*2.2*	9	*2.8*	10	*3.1*	11	*3.4*
16	*400*	6	*1.9*	8	*2.5*	9	*2.8*	11	*3.4*	12	*3.7*

Nominal Pipe Size in.	*mm*	Series 3200A length change (in./*mm*) 1.0/*25* ft	*m*	2.0/*50* ft.	*m*	3.0/*75* ft.	*m*	4.0/*100* ft.	*m*	5.0/*125* ft.	*m*
1	*25*	–	–	–	–	–	–	–	–	–	–
1.5	*40*	–	–	–	–	–	–	–	–	–	–
2	*50*	3	*1.0*	3	1.0	4	*1.3*	5	*1.6*	5	*1.6*
3	*80*	3	*1.0*	4	1.3	5	*1.6*	5	*1.6*	6	*1.9*
4	*100*	3	*1.0*	5	1.6	5	*1.6*	6	*1.9*	7	*2.2*
5	*125*	–	–	–	–	–	–	–	–	–	–
6	*150*	4	*1.3*	5	1.6	6	*1.9*	7	*2.2*	8	*2.5*
8	*200*	4	*1.3*	6	1.9	7	*2.2*	8	*2.5*	9	*2.8*
10	*250*	5	*1.6*	7	2.2	8	*2.5*	9	*2.8*	10	*3.1*
12	*300*	5	*1.6*	7	2.2	9	*2.8*	10	*3.1*	11	*3.4*
14	*350*	6	*1.9*	8	2.5	9	*2.8*	11	*3.4*	12	*3.7*
16	*400*	6	*1.9*	8	2.5	10	*3.1*	11	*3.4*	13	*4.0*

Expansion joints

Instead of a loop, an expansion joint may be used to relieve longitudinal stress. The type selected must be fairly flexible, such as a Teflon bellows which is activated by the thrust of low modulus materials (see Note , Table 3).

Supports for expansion joints must be carefully designed and placed to maintain controlled deflection. Besides adding weight, most of these joints act as partial structural hinges which afford only limited transfer of moment and shear. Where the expansion joint relies on elastomers or thermoplastics for strength, the structural discontinuity or hinging effect at the joint increases with increases in temperature.

When using an expansion joint in a pipeline carrying solids, consider the possibility that it may stiffen or fail to function due to sedimentation in the expansion joint. Failure of the expansion joint may cause excessive pipe deflection.

3 Designing for restrained systems

Caution: In restrained systems, pipe fittings can be damaged by faulty anchoring or by untimely release of anchors. Damage to fittings in service can be caused by bending or slipping of an improperly designed or installed anchor. Also, length changes due to creep are induced by high pressures or temperatures while pipe is in service. When anchors must later be released, especially in long pipe runs, temporary anchors may be required to avoid excessive displacement and overstress of fittings.

General principles

The layout of a system occasionally makes it impossible to allow the pipe to “move freely.” Sometimes it may be necessary to block certain runs of an otherwise free system. In a fully restrained pipe (blocked against movement at both ends), the designer must deal with thrust rather than length change. Both temperature and pressure produce thrust which must be resisted at turns, branches, reducers and ends. Knowing the magnitude of this thrust enables the designer to select satisfactory anchors . Remember that axial thrust on anchors is independent of anchor spacing. Formulas and examples are found in Appendix B.

In practice, the largest compressive thrust is normally developed on the first positive temperature cycle. Subsequently, the pipe develops both compressive and tensile loads as it is subjected to temperature and pressure cycles. Neither compressive nor tensile loads, however, are expected to exceed the thrust on the first cycle unless the ranges of the temperature and pressure change.

Thrust due to temperature

In a fully restrained Bondstrand pipe, length changes induced by temperature change are resisted at the anchors and converted to thrust. The thrust developed depends on the thermal coefficient of expansion, the cross-sectional area, the modulus of elasticity and the temperature change, Δt. Table 3 gives the maximum axial thrust in anchored lines for each series of Bondstrand pipe at three elevated temperatures. The table assumes a fully relaxed initial pipe length at 60°F, with short-time modulus of elasticity values as shown.

Table 3 Initial temperature-induced thrusts (pounds-force) in fully restrained Bondstrand pipe at various operating temperatures

Nominal Diameter		Initial Temperature Induced Thrusts (pounds-force) in a Fully Restrained Bondstrand Pipe at Various Operating Temperatures													
		Series 2000			Series 2000M-FP & Series 7000			Series 3000A	Series 3200A	Series 4000			Series 5000 & 5100		
in.	mm	150°F	200°F	250°F	150°F	200°F	250°F	200°F	200°F	150°F	200°F	250°F	140°F	170°F	200°F
1	25	880	1070	1210	880	1070	1210	–	–	730	880	1000	490	560	370
1.5	40	1300	1560	1780	1300	1560	1780	–	–	1060	1280	1460	710	810	540
2	50	1610	1940	2200	1610	1940	2200	1850	1850	1310	1580	1800	870	1000	660
3	80	2390	2890	3290	2390	2890	3290	2890	2890	1950	2350	2670	1300	1490	980
4	100	3980	4800	5470	3980	4800	5470	3800	3800	3410	4110	4680	2270	2610	1730
5	125	4940	5950	6780	4940	5950	6780	–	–	4220	5090	5800	2820	3230	2140
6	150	5920	7130	8120	5920	7130	8120	7420	7420	5060	6100	6940	3370	3860	2560
8	200	8600	10370	11800	10430	12570	14310	8160	10000	7480	9010	10260	4980	5710	3780
10	250	10760	12970	14760	16250	19590	22300	12030	14750	9340	11260	12820	6230	7140	4720
12	300	12780	15410	17540	22850	27540	31350	16350	20040	11100	13380	15230	7400	8480	5610
14	350	14770	17810	20270	26450	31880	36290	20060	24600	13880	16730	19040	9250	10600	7020
16	400	19090	23020	26200	34590	41700	47470	25140	30820	18000	21700	24700	12000	13750	9100

Nominal Diameter		Initial Temperature Induced Thrusts (*Newtons*) in a Fully Restrained Bondstrand Pipe at Various Operating Temperatures													
		Series 2000			Series 2000M-FP & Series 7000			Series 3000A	Series 3200A	Series 4000			Series 5000 & 5100		
in.	*mm*	*65°C*	*93°C*	*121°C*	*65°C*	*93°C*	*121°C*	*93°C*	*93°C*	*65°C*	*93°C*	*121°C*	*60°C*	*77°C*	*93°C*
1	25	3890	4720	5390	3890	4720	5390	–	–	3210	3900	4450	2170	2500	1640
1.5	40	5710	6930	7910	5710	6930	7910	–	–	4680	5680	6490	3160	3640	2390
2	50	7070	8580	9800	7070	8580	9800	8200	8200	5780	7010	8000	3900	4490	2940
3	80	10540	12800	14610	10540	12800	14610	12790	12790	8580	10410	11880	5790	6670	4370
4	100	17540	21290	24300	17540	21290	24300	16860	16860	15020	18230	20820	10140	11680	7660
5	125	21740	26390	30130	21740	26390	30130	–	–	18600	22570	25770	12550	14460	9480
6	150	26050	31610	36090	26050	31610	36090	32910	32910	22260	27020	30840	15020	17300	11340
8	200	37880	45970	52480	45900	55710	63600	36170	44330	32920	39950	45610	22220	25590	16780
10	250	47360	57480	65610	71570	86860	99150	53360	65390	41130	49920	56990	27760	31970	20960
12	300	56280	68310	77980	100590	122080	139370	72510	88870	48860	59300	67690	32970	37980	24900
14	350	65040	78940	90110	116440	141320	161330	89000	109080	61110	74160	84660	41240	47490	31140
16	400	84070	102030	116470	152320	184850	211030	111520	136670	79250	96180	109800	53480	61590	40380

Note: in tables above, thrusts are calculated assuming a fully relaxed initial length at 60°F (*16°C*) and short term modulus of elasticity values as follows. For 2 - 6 inch Series 3000A, use modulus of elasticity values from Series 3200A. Coefficient of thermal expansion is 10×10^{-6} in./in./°F (*18×10^{-6} mm/mm/°C*) for all but Series 3000A and 3200A which are 8.5×10^{-6} in./in./°F (*15.3×10^{-6} mm/mm/°C*) for 2 - 6 inch Series 3000A and all Series 3200A sizes, and 12×10^{-6} in./in./°F (*21.6×10^{-6} mm/mm/°C*) for 8 - 16 inch Series 3000A.

	Modulus of Elasticity													
	Series 2000			Series 2000M-FP & Series 7000			Series 3000A	Series 3200A	Series 4000			Series 5000 & 5100		
10^6 psi	1.6	1.2	1.0	1.6	1.2	1.0	1.3	2.3	1.6	1.2	1.0	1.2	1.0	0.5
GPa	11.03	8.55	7.17	11.03	8.55	7.17	8.97	15.52	11.03	8.55	7.17	8.28	6.90	3.59

3 Designing for restrained systems (cont'd.)

Thrust due to pressure

Thrust due to internal pressure in a suspended but restrained system is theoretically more complicated. This is because in straight, restrained pipelines with all joints bonded, the Poisson effect produces considerable tension in the pipe wall. As internal pressure is applied, the pipe expands circumferentially and at the same time contracts longitudinally. This tensile force is important because it acts to reduce the hydrostatic thrust on anchors at turns.

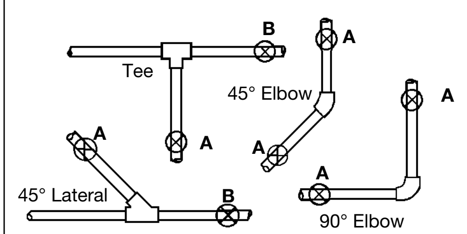
For the designer of a restrained Bondstrand pipeline, however, the problem can be greatly simplified. Table 4 provides the recommended design thrusts and locations for anchors at various fittings.

Table 4 **Thrust at anchors due to 100 psi (690 kPa) internal pressure in restrained Bondstrand systems**

Thrust at Anchors Due to 100 psi (*690 kPa*) Internal Pressure in Restrained Bondstrand Systems							
Nominal Pipe Size		Series 2000/4000/7000		Series 5000/5100		Series 3000A/3200A	
in.	*mm*	lb-force	*N*	lb-force	*N*	lb-force	*N*
1	*25*	50	*225*	45	*170*	–	–
1.5	*40*	115	*515*	115	*440*	–	–
2	*50*	180	*810*	190	*725*	240	*1060*
3	*80*	420	*1865*	460	*1755*	540	*2400*
4	*100*	695	*3085*	755	*2900*	915	*4070*
5	*125*	1080	*4805*	1200	*4605*	–	–
6	*150*	1565	*6955*	1765	*6760*	2000	*8895*
8	*200*	2680	*11925*	3035	*11710*	4045	*11995*
10	*250*	4220	*18780*	4830	*18645*	6365	*28320*
12	*300*	5990	*26645*	6890	*26640*	8890	*39545*
14	*350*	7215	*32100*	8305	*32105*	11535	*51320*
16	*400*	9425	*41935*	10855	*41965*	15070	*67035*

Notes:

1. Pipe anchors (A) such as shown in figure 8, Section 8 are used in restrained systems at each end of a run and just before a change in direction, and must resist the tabulated thrusts.
2. Pipe anchors (B) such as shown in figure 7, Section 8 are light-duty in-line anchors usually located between two pipe anchors (A) or midway between loops or turns in systems not restrained.
3. Pipe anchors (A and B) at elbows and branches should be located a distance of five to ten times the pipe diameter from the bend. Other anchor locations may require a flexibility analysis.
4. No appreciable thrust on anchors is developed due to internal pressure in the pipe at in-line reducers.



Using guides for alignment control

A suspended line which is restrained from movement may need extra supports or guides to maintain alignment, especially when the pipeline is exposed to a wide temperature range. Guides as shown in Figure 6 may permit the pipe to move axially but not laterally. Without guides, restrained pipe may not deflect uniformly and, in some cases, may deflect excessively. Tables 5 to 9 (Tables 10 to 14 for metric) give recommended guide spacing to avoid buckling deflection between anchors.

Supplying this lateral support by using guides at the normal support locations or even at every other support is often sufficient, especially in the larger diameters. To check, compare the recommended span for your operating temperature as determined from the section entitled SUPPORT LOCATIONS AND SPANS with the guide spacings from Tables 5 to 9 (Tables 10 to 14, metric). Be sure that guide and support spacing meet both requirements.

As an example for determining guide spacing, assume that a three-inch Bondstrand Series 2000 line is installed at 70°F and is to operate at 250°F (ΔT = 180°F). Table 5 shows that guides should be installed at intervals of 7 feet.

3 Designing for restrained systems (cont'd.)

Table 5 **Maximum guide spacing (ft.) required for temperature change (°F)**

Bondstrand Series 2000 & 4000

Nominal Pipe Size		Degrees of Temperature Change (°F)																		
in.	*mm*	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	*25*	11	7	6	5	5	4	4	4	4	3	3	3	3	3	3	3	3	2	2
1.5	*40*	16	11	9	8	7	6	6	6	5	5	5	5	4	4	4	4	4	4	4
2	*50*	19	14	11	10	9	8	7	7	6	6	6	6	5	5	5	5	5	5	4
3	*80*	29	21	17	15	13	12	11	10	10	9	9	8	8	8	8	7	7	7	7
4	*100*	38	27	22	19	17	15	14	13	13	12	11	11	10	10	10	9	9	9	9
5	*125*	47	33	27	23	21	19	18	17	16	15	14	14	13	13	12	12	11	11	11
6	*150*	56	40	32	28	25	23	21	20	19	18	17	16	16	15	15	14	14	13	13
8	*200*	74	52	43	37	33	30	28	26	25	23	22	21	20	20	19	18	18	17	17
10	*250*	92	65	53	46	41	38	35	33	31	29	28	27	26	25	24	23	22	22	21
12	*300*	110	78	63	55	49	45	41	39	37	35	33	32	30	29	28	27	27	26	25
14	*350*	120	85	70	60	54	49	46	43	40	38	36	35	33	32	31	30	29	28	28
16	*400*	138	98	80	69	62	56	52	49	46	44	42	40	38	37	36	35	33	33	32

Table 6 **Maximum guide spacing (ft.) required for temperature change (°F)**

Bondstrand Series 5000 & 5100

Nominal Pipe Size		Degrees of Temperature Change (°F)																		
in.	*mm*	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	*25*	10	7	6	5	5	4	4	4	3	3	3	3	3	3	3	3	2	2	2
1.5	*40*	15	11	9	8	7	6	6	5	5	5	5	4	4	4	4	4	4	4	3
2	*50*	19	13	11	9	8	8	7	7	6	6	6	5	5	5	5	5	5	4	4
3	*80*	28	20	16	14	13	12	11	10	9	9	9	8	8	8	7	7	7	7	6
4	*100*	36	26	21	18	16	15	14	13	12	12	11	11	10	10	9	9	9	9	8
5	*125*	45	32	26	23	20	18	17	16	15	14	14	13	13	12	12	11	11	11	10
6	*150*	54	38	31	27	24	22	21	19	18	17	16	16	15	15	14	14	13	13	12
8	*200*	71	50	41	36	32	29	27	25	24	22	21	21	20	19	18	18	17	17	16
10	*250*	89	63	51	44	40	36	34	31	30	28	27	26	25	24	23	22	22	21	20
12	*300*	106	75	61	53	47	43	40	37	35	33	32	31	29	28	27	26	26	25	24
14	*350*	116	82	67	58	52	47	44	41	39	37	35	34	32	31	30	29	28	27	27
16	*400*	133	94	77	66	59	54	50	47	44	42	40	38	37	36	34	33	32	31	31

Table 7 **Maximum guide spacing (ft.) required for temperature change (°F)**

Bondstrand Series 2000M-FP & 7000

Nominal Pipe Size		Degrees of Temperature Change (°F)																		
in.	*mm*	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	*25*	11	8	6	6	5	5	4	4	4	3	3	3	3	3	3	3	3	3	3
1.5	*40*	16	12	9	8	7	7	6	6	5	5	5	5	5	4	4	4	4	4	4
2	*50*	20	14	12	10	9	8	8	7	7	6	6	6	6	5	5	5	5	5	5
3	*80*	31	22	18	15	14	13	12	11	10	10	9	9	8	8	8	8	7	7	7
4	*100*	40	28	23	20	18	16	15	14	13	13	12	11	11	11	10	10	10	9	9
5	*125*	47	33	27	23	21	19	18	17	16	15	14	14	13	13	12	12	11	11	11
6	*150*	59	42	34	30	27	24	22	21	20	19	18	17	16	16	15	15	14	14	14
8	*200*	79	56	45	39	35	32	30	28	26	25	24	23	22	21	20	20	19	19	18
10	*250*	99	70	57	50	44	41	38	35	33	31	30	29	28	27	26	25	24	23	23
12	*300*	119	84	69	59	53	49	45	42	40	38	36	34	33	32	31	30	29	28	27
14	*350*	128	91	74	64	57	52	48	45	43	40	39	37	36	34	33	32	31	30	29
16	*400*	146	104	85	73	65	60	55	52	49	46	44	42	41	39	38	37	36	35	34

Table 8 **Maximum guide spacing (ft.) required for temperature change (°F)**

Bondstrand Series 3000A

Nominal Pipe Size		Degrees of Temperature Change (°F)																		
in.	*mm*	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	*25*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1.5	*40*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	*50*	21	15	12	10	9	8	8	7	7	6	6	6	6	5	5	5	5	5	5
3	*80*	31	22	18	15	14	12	12	11	10	10	9	9	8	8	8	8	7	7	7
4	*100*	40	28	23	20	18	16	15	14	13	13	12	11	11	11	10	10	10	9	9
5	*125*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	*150*	59	42	34	30	26	24	22	21	20	19	18	17	16	16	15	15	14	14	14
8	*200*	64	45	37	32	29	26	24	23	21	20	19	18	18	17	16	16	15	15	15
10	*250*	81	57	47	40	36	33	30	28	27	25	24	23	22	22	21	20	20	19	18
12	*300*	96	68	55	48	43	39	36	34	32	30	29	28	27	26	25	24	23	23	22
14	*350*	109	77	63	55	49	45	41	39	36	34	33	31	30	29	28	27	26	26	25
16	*400*	125	88	72	62	56	51	47	44	42	39	38	36	35	33	32	31	30	29	29

Table 9 **Maximum guide spacing (ft.) required for temperature change (°F)**

Bondstrand Series 3200A

Nominal Pipe Size		Degrees of Temperature Change (°F)																		
in.	*mm*	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	*25*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1.5	*40*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	*50*	21	15	12	10	9	8	8	7	7	6	6	6	6	5	5	5	5	5	5
3	*80*	31	22	18	15	14	12	12	11	10	10	9	9	8	8	8	8	7	7	7
4	*100*	40	28	23	20	18	16	15	14	13	13	12	11	11	11	10	10	10	9	9
5	*125*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	*150*	59	42	34	30	26	24	22	21	20	19	18	17	16	16	15	15	14	14	14
8	*200*	76	54	44	38	34	31	29	27	25	24	23	22	21	20	20	19	18	18	17
10	*250*	96	68	55	48	43	39	36	34	32	30	29	28	27	26	25	24	23	23	22
12	*300*	114	80	66	57	51	46	43	40	38	36	34	33	32	30	29	28	28	27	26
14	*350*	130	92	75	65	58	53	49	46	43	41	39	37	36	35	33	32	31	31	30
16	*400*	148	105	86	74	66	61	56	52	49	47	45	43	41	40	38	37	36	35	34

3 Designing for restrained systems (cont'd.)

Table 10 Maximum guide spacing (m) required for temperature change (°C)

Bondstrand Series 2000 & 4000

Nominal Pipe Size		Degrees of Temperature Change (°C)																		
in.	mm	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	25	3.2	2.2	1.8	1.5	1.5	1.2	1.2	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
1.5	40	5.0	3.5	2.8	2.5	2.0	2.0	1.8	1.8	1.5	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.0	1.0	1.0
2	50	6.2	4.2	3.5	3.0	2.8	2.5	2.2	2.0	2.0	1.8	1.8	1.8	1.5	1.5	1.5	1.5	1.5	1.2	1.2
3	80	9.2	6.5	5.2	4.5	4.0	3.8	3.5	3.2	3.0	2.8	2.8	2.5	2.5	2.5	2.2	2.2	2.2	2.0	2.0
4	100	12.0	8.5	7.0	6.0	5.2	4.8	4.5	4.2	4.0	3.8	3.5	3.5	3.2	3.0	3.0	3.0	2.8	2.8	2.8
5	125	15.0	10.5	8.5	7.5	6.5	6.0	5.5	5.2	5.0	4.8	4.5	4.2	4.0	4.0	3.8	3.8	3.5	3.5	3.2
6	150	18.0	12.8	10.2	9.0	8.0	7.2	6.8	6.2	6.0	5.5	5.2	5.0	5.0	4.8	4.5	4.5	4.2	4.2	4.0
8	200	23.5	16.5	13.5	11.8	10.5	9.5	8.8	8.2	7.8	7.2	7.0	6.8	6.5	6.2	6.0	5.8	5.5	5.5	5.2
10	250	29.5	20.8	17.0	14.8	13.2	12.0	11.0	10.2	9.8	9.2	8.8	8.5	8.0	7.8	7.5	7.2	7.0	6.8	6.8
12	300	35.2	24.8	20.2	17.5	15.8	14.2	13.2	12.2	11.8	11.0	10.5	10.0	9.8	9.2	9.0	8.8	8.5	8.2	8.0
14	350	38.5	27.2	22.2	19.2	17.2	15.8	14.5	13.5	12.8	12.0	11.5	11.0	10.5	10.2	9.8	9.5	9.2	9.0	8.8
16	400	44.2	31.2	25.5	22.0	19.8	18.0	16.8	15.5	14.8	14.0	13.2	12.8	12.2	11.8	11.2	11.0	10.8	10.2	10.0

Table 11 Maximum guide spacing (m) required for temperature change (°C)

Bondstrand Series 5000 & 5100

Nominal Pipe Size		Degrees of Temperature Change (°C)																		
in.	mm	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	25	3.2	2.2	1.8	1.5	1.2	1.2	1.2	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
1.5	40	4.8	3.2	2.8	2.2	2.0	1.8	1.8	1.5	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
2	50	6.0	4.2	3.5	3.0	2.5	2.2	2.2	2.0	2.0	1.8	1.8	1.8	1.5	1.5	1.5	1.5	1.2	1.2	1.2
3	80	9.0	6.2	5.0	4.5	4.0	3.5	3.2	3.0	3.0	2.8	2.5	2.5	2.5	2.2	2.2	2.2	2.0	2.0	2.0
4	100	11.5	8.2	6.8	5.8	5.0	4.8	4.2	4.0	3.8	3.5	3.5	3.2	3.2	3.0	3.0	2.8	2.8	2.8	2.5
5	125	14.5	10.2	8.2	7.2	6.5	5.8	5.5	5.0	4.8	4.5	4.2	4.0	4.0	3.8	3.8	3.5	3.5	3.2	3.2
6	150	17.2	12.2	10.0	8.5	7.8	7.0	6.5	6.0	5.8	5.5	5.2	5.0	4.8	4.5	4.5	4.2	4.0	4.0	4.0
8	200	22.8	16.0	13.0	11.2	10.0	9.2	8.5	8.0	7.5	7.0	6.8	6.5	6.2	6.0	5.8	5.5	5.5	5.2	5.0
10	250	28.5	20.0	16.2	14.2	12.8	11.5	10.8	10.0	9.5	9.0	8.5	8.0	7.8	7.5	7.2	7.0	6.8	6.5	6.5
12	300	33.8	24.0	19.5	16.8	15.0	13.8	12.8	12.0	11.2	10.5	10.0	9.8	9.2	9.0	8.8	8.2	8.0	8.0	7.8
14	350	37.2	26.2	21.5	18.5	16.5	15.2	14.0	13.0	12.2	11.8	11.2	10.8	10.2	9.8	9.5	9.2	9.0	8.8	8.5
16	400	42.5	30.0	24.5	21.2	19.0	17.2	16.0	15.0	14.0	13.5	12.8	12.2	11.8	11.2	11.0	10.5	10.2	10.0	9.8

Table 12 Maximum guide spacing (m) required for temperature change (°C)

Bondstrand Series 2000M-FP & 7000

Nominal Pipe Size		Degrees of Temperature Change (°C)																		
in.	mm	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	25	3.5	2.5	2.0	1.8	1.5	1.2	1.2	1.2	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8
1.5	40	5.2	3.5	3.0	2.5	2.2	2.0	1.8	1.8	1.8	1.5	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.0	1.0
2	50	6.5	4.5	3.8	3.2	2.8	2.5	2.2	2.2	2.0	2.0	1.8	1.8	1.8	1.8	1.5	1.5	1.5	1.5	1.5
3	80	9.8	6.8	5.5	4.8	4.2	4.0	3.5	3.2	3.2	3.0	2.8	2.8	2.5	2.5	2.5	2.2	2.2	2.2	2.2
4	100	12.8	9.0	7.2	6.2	5.5	5.0	4.8	4.5	4.2	4.0	3.8	3.5	3.5	3.2	3.2	3.0	3.0	3.0	2.8
5	125	15.0	10.5	8.5	7.5	6.5	6.0	5.5	5.2	5.0	4.8	4.5	4.2	4.0	4.0	3.8	3.8	3.5	3.5	3.2
6	150	19.0	13.2	11.0	9.5	8.5	7.8	7.0	6.5	6.2	6.0	5.5	5.5	5.2	5.0	4.8	4.8	4.5	4.2	4.2
8	200	25.2	17.8	14.5	12.5	11.2	10.2	9.5	8.8	8.2	7.8	7.5	7.2	7.0	6.5	6.5	6.2	6.0	5.8	5.8
10	250	31.8	22.5	18.2	15.8	14.2	13.0	12.0	11.2	10.5	10.0	9.5	9.0	8.8	8.5	8.0	7.8	7.5	7.5	7.2
12	300	38.0	27.0	22.0	19.0	17.0	15.5	14.2	13.5	12.5	12.0	11.5	11.0	10.5	10.0	9.8	9.5	9.2	9.0	8.8
14	350	41.0	29.0	23.8	20.5	18.2	16.8	15.5	14.5	13.5	13.0	12.2	11.8	11.2	11.0	10.5	10.2	9.8	9.5	9.2
16	400	47.0	33.2	27.0	23.5	21.0	19.0	17.8	16.5	15.5	14.8	14.0	13.5	13.0	12.5	12.0	11.8	11.2	11.0	10.8

Table 13 Maximum guide spacing (m) required for temperature change (°C)

Bondstrand Series 3000A

Nominal Pipe Size		Degrees of Temperature Change (°C)																		
in.	mm	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1.5	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	50	6.5	4.5	3.8	3.2	2.8	2.5	2.2	2.2	2.0	2.0	1.8	1.8	1.8	1.8	1.5	1.5	1.5	1.5	1.5
3	80	9.8	6.8	5.5	4.8	4.2	4.0	3.5	3.2	3.2	3.0	2.8	2.8	2.5	2.5	2.5	2.2	2.2	2.2	2.2
4	100	12.5	9.0	7.2	6.2	5.5	5.0	4.8	4.5	4.0	4.0	3.8	3.5	3.5	3.2	3.2	3.0	3.0	3.0	2.8
5	125	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	150	19.0	13.2	10.8	9.5	8.5	7.8	7.0	6.5	6.2	6.0	5.5	5.2	5.2	5.0	4.8	4.8	4.5	4.2	4.2
8	200	20.5	14.5	11.8	10.2	9.0	8.2	7.8	7.2	6.8	6.2	6.0	5.8	5.5	5.2	5.2	5.0	4.8	4.8	4.5
10	250	25.8	18.2	14.8	12.8	11.5	10.5	9.8	9.0	8.5	8.0	7.8	7.2	7.0	6.8	6.5	6.2	6.2	6.0	5.8
12	300	30.5	21.5	17.5	15.2	13.5	12.5	11.5	10.8	10.0	9.5	9.2	8.8	8.5	8.0	7.8	7.5	7.2	7.0	7.0
14	350	35.0	24.8	20.0	17.5	15.5	14.2	13.0	12.2	11.5	11.0	10.5	10.0	9.5	9.2	9.0	8.8	8.2	8.2	8.0
16	400	40.0	28.2	23.0	20.0	17.8	16.2	15.0	14.0	13.2	12.5	12.0	11.5	11.0	10.5	10.2	10.0	9.5	9.2	9.0

Table 14 Maximum guide spacing (m) required for temperature change (°C)

Bondstrand Series 3200A

Nominal Pipe Size		Degrees of Temperature Change (°C)																		
in.	mm	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
1	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1.5	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	50	6.5	4.5	3.8	3.2	2.8	2.5	2.2	2.2	2.0	2.0	1.8	1.8	1.8	1.8	1.5	1.5	1.5	1.5	1.5
3	80	9.8	6.8	5.5	4.8	4.2	4.0	3.5	3.2	3.2	3.0	2.8	2.8	2.5	2.5	2.5	2.2	2.2	2.2	2.2
4	100	12.5	9.0	7.2	6.2	5.5	5.0	4.8	4.5	4.0	4.0	3.8	3.5	3.5	3.2	3.2	3.0	3.0	3.0	2.8
5	125	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	150	19.0	13.2	10.8	9.5	8.5	7.8	7.0	6.5	6.2	6.0	5.5	5.2	5.2	5.0	4.8	4.8	4.5	4.2	4.2
8	200	24.2	17.2	14.0	12.0	10.8	9.8	9.0	8.5	8.0	7.5	7.2	7.0	6.8	6.5	6.2	6.0	5.8	5.8	5.5
10	250	30.8	21.8	17.8	15.2	13.8	12.5	11.5	10.8	10.2	9.5	9.2	8.8	8.5	8.0	7.8	7.5	7.2	7.2	7.0
12	300	36.5	25.8	21.0	18.2	16.2	14.8	13.8	12.8	12.0	11.5	11.0	10.5	10.0	9.8	9.2	9.0	8.8	8.5	8.2
14	350	41.5	29.2	24.0	20.8	18.5	16.8	15.5	14.5	13.8	13.0	12.5	12.0	11.5	11.0	10.8	10.2	10.0	9.8	9.5
16	400	47.5	33.5	27.5	23.8	21.2	19.2	18.0	16.8	15.8	15.0	14.2	13.8	13.0	12.5	12.2	11.8	11.5	11.0	10.8

4 Spans and support locations

Span recommendations

Recommended maximum spans for Bondstrand pipe at various operating temperatures are given in Table 15. These spans are intended for normal horizontal piping arrangements, i.e., those which have no fittings, valves, vertical runs, etc., but which may include flanges and non-uniform support spacings. The tabular values represent a compromise between continuous and simple spans. When installed at the support spacings indicated in Table 15, the weight of the pipe full of water will produce a long-time deflection of about ½ inch, which is usually acceptable for appearance and adequate drainage.

Fully continuous spans may be used with support spacings up to 20 percent greater than those shown in Table 15; in simple spans, support spacings should be 20 percent less than those shown in Table 15.

For this purpose, continuous spans are defined as interior spans (not end spans), which are uniform in length and free from structural rotation at supports. Simple spans are supported only at the ends and are hinged or free to rotate at the supports. Special conditions described below are not covered.

The pipe is assumed to be free to move axially. Suspended piping, which is restrained or anchored against longitudinal movement, represents a special case and guides may be required as discussed under the previous section, Use of Guides for Alignment .

Table 15 Recommended maximum support spacings in feet for Bondstrand pipe at various operating temperatures (fluid specific gravity=1.0)

Nominal Pipe Size		Series 2000				Series 2000M-FP				Series 4000				Series 5000			
		up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 200°F	*67°C to 93°C*
in.	*mm*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*
1	*25*	10.2	*3.1*	8.9	*2.7*	8.7	*2.7*	7.6	*2.3*	9.7	*3.0*	8.7	*2.7*	9.4	*2.9*	5.6	*1.7*
1.5	*40*	11.4	*3.5*	10.0	*3.0*	10.4	*3.2*	9.1	*2.8*	10.8	*3.3*	9.7	*2.9*	10.4	*3.2*	6.2	*1.9*
2	*50*	12.2	*3.7*	10.7	*3.2*	11.1	*3.4*	9.7	*3.0*	11.5	*3.5*	10.3	*3.1*	11.0	*3.4*	6.6	*2.0*
3	*80*	13.9	*4.2*	12.2	*3.7*	12.9	*3.9*	11.3	*3.4*	13.1	*4.0*	11.7	*3.6*	12.5	*3.8*	7.5	*2.3*
4	*100*	15.8	*4.8*	13.8	*4.2*	14.9	*4.5*	13.0	*4.0*	15.2	*4.6*	13.6	*4.1*	14.4	*4.4*	8.6	*2.6*
5	*125*	16.8	5.1	14.7	*4.5*	15.9	*4.9*	14.0	*4.3*	16.1	*4.9*	14.4	*4.4*	15.5	*4.7*	9.3	*2.8*
6	*150*	17.7	*5.4*	15.5	*4.7*	16.9	*5.2*	14.8	*4.5*	17.0	*5.2*	15.2	*4.6*	16.2	*4.9*	9.7	*3.0*
8	*200*	19.6	*6.0*	17.2	*5.2*	19.8	*6.0*	17.3	*5.3*	18.9	*5.8*	16.9	*5.1*	18.0	*5.5*	10.8	*3.3*
10	*250*	20.8	*6.4*	18.2	*5.6*	22.3	*6.8*	19.5	*6.0*	20.1	*6.1*	17.9	*5.5*	19.2	*5.8*	11.5	*3.5*
12	*300*	21.8	*6.7*	19.1	*5.8*	24.5	*7.5*	21.5	*6.5*	21.0	*6.4*	18.8	*5.7*	20.1	*6.1*	12.0	*3.7*
14	*350*	22.7	*6.9*	19.9	*6.1*	25.5	*7.8*	22.3	*6.8*	22.3	*6.8*	19.9	*6.1*	21.3	*6.5*	12.8	*3.9*
16	*400*	24.2	*7.4*	21.2	*6.5*	27.2	*8.3*	23.8	*7.3*	23.8	*7.3*	21.3	*6.5*	22.7	*6.9*	13.6	*4.2*

Nominal Pipe Size		Series 5100				Series 7000				Series 3000A				Series 3200A			
		up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 99°C*	up to 150°F	*up to 66°C*	151°F to 210°F	*67°C to 99°C*
in.	*mm*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*
1	*25*	8.1	*2.5*	5.6	*1.7*	10.1	*3.1*	8.9	*2.7*	–	–	–	–	–	–	–	–
1.5	*40*	9.0	*2.7*	6.2	*1.9*	11.4	*3.5*	9.9	*3.0*	–	–	–	–	–	–	–	–
2	*50*	9.5	*2.9*	6.6	*2.0*	12.4	*3.8*	10.8	*3.3*	12.8	*3.9*	11.9	*3.6*	12.8	*3.9*	11.9	*3.6*
3	*80*	10.8	*3.3*	7.5	*2.3*	14.3	*4.4*	12.5	*3.8*	14.5	*4.4*	13.5	*4.1*	14.5	*4.4*	13.5	*4.1*
4	*100*	12.4	*3.8*	8.6	*2.6*	16.2	*4.9*	14.2	*4.3*	15.6	*4.8*	14.6	*4.4*	15.6	*4.8*	14.6	*4.4*
5	*125*	13.4	*4.1*	9.3	*2.8*	17.2	*5.2*	15.1	*4.6*	–	–	–	–	–	–	–	–
6	*150*	14.0	*4.3*	9.7	*3.0*	18.2	*5.5*	15.9	*4.8*	18.7	*5.7*	17.4	*5.3*	18.7	*5.7*	17.4	*5.3*
8	*200*	15.6	*4.7*	10.8	*3.3*	20.8	*6.4*	18.3	*5.6*	16.8	*5.1*	15.7	*4.8*	20.0	*6.1*	18.6	*5.7*
10	*250*	16.6	*5.1*	11.5	*3.5*	23.3	*7.1*	20.4	*6.2*	18.6	*5.7*	17.3	*5.3*	22.2	*6.8*	20.6	*6.3*
12	*300*	17.4	*5.3*	12.0	*3.7*	25.3	*7.7*	22.2	*6.8*	20.2	*6.2*	18.8	*5.7*	24.0	*7.3*	22.3	*6.8*
14	*350*	18.4	*5.6*	12.8	*3.9*	26.2	*8.0*	23.0	*7.0*	21.3	*6.5*	19.8	*6.0*	25.3	*7.7*	23.6	*7.2*
16	*400*	19.6	*6.0*	13.6	*4.2*	28.0	*8.5*	24.6	*7.5*	22.6	*6.9*	21.0	*6.4*	26.8	*8.2*	25.0	*7.6*

Support spacings for special conditions

Piping designers may calculate deflections or determine support spacings for their own particular geometry and loadings using the effective beam stiffness factors given in Appendix C. In such an analysis, the effects of non-uniform spacing, turns and branches, vertical or inclined runs, special joints which may act as a hinge, heavy liquids, external loads such as insulation, thrust in restrained lines and dynamic loads may be considered, often using a computer program.

4 Spans and support locations (cont'd)

Loads on hangers and supports

Table 16 gives maximum service loads for horizontal piping on hangers and supports. Do not exceed the total support or hanger load given in the table for sustained operation.

Table 16 Permissible service loads as limited by hanger and support details, horizontal piping

Nominal Diameter in.	*mm*	Load on Support Fitted to Lower 180° (lbs) Maximum per linear inch	Maximum per support
1	*25*	100	100
1.5	*40*	100	120
2	*50*	100	160
3	*80*	100	200
4	*100*	100	200
5	*125*	100	200
6	*150*	130	330
8	*200*	200	600
10	*250*	340	1050
12	*300*	400	1430
14	*350*	650	1720
16	*400*	800	2320

Support locations

Supports that permit pipe movement are usually under pipe, not under fittings. Be sure that pipe movement is not obstructed either axially or laterally by a flange or fitting near the support. In general, supports may be located at convenient nearby structures, just as for steel pipe, provided the support spacings indicated in Table 15 are not exceeded.

Anchors on pipe are indicated in Table 4 for restrained piping. Except at flanged connections, above-ground anchors are usually found on pipe rather than fittings. Anchors in lines free to move should be located where necessary to control movement into loops or turns. See Figures 7 through 10 for typical anchor details.

Supports for vertical runs

Install a single support anywhere along the length of a vertical pipe run more than about ten feet long. See Figure 10 for suggested details. If the run is supported near its base, use loose collars as guides as shown in Figure 10b, spaced as recommended in Table 17.

Table 17 Minimum guide spacing (feet) for vertical runs supported from the bottom

Series	Pipe Diameter Inches	Fluid Temperature (°F) 100	150	200	250
2000, 4000	1, 1.5	20	15	10	10
	2, 3, 4, 5	25	20	15	10
	6, 8, 10, 12, 14, 16	30	25	20	15
3000A, 3200A	2, 3, 4, 6,	25	20	15	†
	8, 10, 12, 14, 16	35	30	25	†
5000, 5100	1, 1.5	20	15	10	†
	2, 3, 4, 5	25	20	10	†
	6, 8, 10, 12, 14, 16	30	25	15	†

† not recommended

Vertical runs less than ten feet long may usually be supported as part of the horizontal piping. In either case be sure the layout makes sufficient provision for horizontal and vertical movement at the top and bottom turns.

Accommodate length changes in vertical pipe runs by allowing free movement of fittings at either top, bottom or both. For each 1/8 inch of anticipated vertical length change, provide 2 feet of horizontal pipe between the elbow and the first support, but not less than 6 feet nor more than 20 feet of horizontal pipe.

Treat columns more than 100 feet high (either hanging or standing) as special designs. Support and provision for length change are important. The installer should be especially careful to avoid movement due to wind or support vibration while joints are curing.

5 Connections to other materials

Connections to other piping

Where possible, connect Bondstrand to either metallic or thermoplastic piping using flanges drilled to the 150 psi standards of ANSI B16.5. Bondstrand filament-wound epoxy flanges and Bondstrand heavy-duty molded flanges may be bolted directly against raised-face steel flanges These flanges also seal well against lined steel configurations. All flanges, including Bondstrand standard molded flanges, epoxy and vinyl ester, provide sealing against flat-faced flanges. Use a full-faced ⅛-inch thick elastomer with a Shore A hardness of 60 ±5 for best results .

Flanged valves and other equipment are frequently supplied with different flange facings. The configuration of these facings may vary widely. Unless it has been demonstrated that these facings are compatible with the face of Bondstrand flanges, consult Ameron Fiberglass Pipe Group Engineering Department.

Where Bondstrand is connected to metallic pipe, securely anchor the metallic pipe at the point of connection so that expansion and contraction or weight of the metal line is not transferred to the Bondstrand line.

Small-diameter metallic connections

Outlets for instrumentation are best made using orifice flanges with ½-inch orifices. Threaded reducer bushings mounted in saddles, blind flanges and fittings plugs offer connections up to 1½-inches in diameter for a wide range of applications. The most commonly used metal bushing material is Type 316 stainless steel, but Ameron can furnish other materials on special order.

Gravity flow connections

There are different ways to make gravity-flow connections to floor drains, cast iron pipe, etc. For example, a four-inch by six-inch tapered body reducer will enlarge the receiving end of a Bondstrand four-inch pipe and serve as a packing chamber for the cast iron end of a floor drain or other fitting.

Conversely, Bondstrand pipe can be packed and sealed into a cast iron bell. In any case, avoid packing materials which must be applied at temperatures above 200°F. Mechanical couplings are available through other manufacturers to connect Bondstrand to clay, concrete, cast iron or other non-metallic pipe.

6 Connections to equipment

Equipment vibration

Bondstrand pipe will safely absorb vibration from pumping or other conditions if (1) stresses are controlled within reasonable limits, and (2) pipe is protected from external abrasion by saddles or sleeves where it contacts supports and other objects. In general, pipeline vibration is severe only when the generating frequency is at, or near, the natural resonance frequency of the pipeline. This frequency is a function of the support system, layout geometry, temperature, mass, and pipe stiffness, and is often difficult to predict.

There are two principal ways to control stress caused by vibration. You can usually observe the stability of the system during initial operation and add restraints or supports as required to reduce effects of equipment vibration. Where necessary, guides illustrated in Figure 6 will effectively hold pipe from lifting or moving laterally.

In special cases where source vibration is excessive (such as that resulting from pumps running unbalanced), an elastomeric expansion joint or other vibration absorber should be considered. If an expansion joint is considered, refer to EXPANSION JOINTS.

Connections to tanks

The wall flexure of a tank as it is filled and emptied produces movements at nozzles which must be accommodated in the design. These movements can be absorbed by a loop or turn, or by an expansion joint. Avoid direct, straight-line connections between tanks.

7 Other design considerations

Coating Bondstrand

Exposure to direct sunlight will eventually degrade the surface of Bondstrand piping. Although no failures are known to have resulted from this superficial degradation, it does cause a dull, grey appearance which many users wish to avoid.

Ameron products are available to prevent or arrest this effect, or for color coding. Based on studies at the factory, a five-mil single coat of Ameron Amershield® single coat polyurethane protective coating will provide suitable protection for either epoxy or vinyl ester pipe and fittings.

Adhesion of the coating is improved by delaying the application until the pipe surface has begun to weather. Pipe must be thoroughly cleaned before applying the coating.

For further information on chemical resistance, coverage rates, equipment and application procedures for coatings, contact Ameron's Protective Coatings Division.

Electrical properties

Bondstrand pipe offers high resistance to stray electrical currents, a common cause of corrosion around valves and pumps. Table 18 gives the results of tests on Bondstrand pipe in a clean, as manufactured, condition at room temperature. Obviously, electrical properties, especially surface resistivity, are greatly affected by contamination and atmospheric conditions .

Table 18 Electrical properties of Bondstrand Series 2000, 3000A, 3200A, 4000, 5000 and 5100 pipe

Property	Value	ASTM Test Method
Dielectric constant, at 1 KHz for a 0.22-inch thickness	5.9	D150
Dissipation factor, at 1 KHz for a 0.22 inch thickness	0.016 - 0.021	D150
Dielectric strength, by the short-time test using ¼-inch electrodes in oil for a 0.23-inch thickness, volts per mil	>230	D149
Dielectric breakdown voltage, by the short-time test using ¼-inch electrodes in oil for a 0.23-inch thickness, kv	>53.4	D149
Surface resistivity, ohms	10^{10} to 10^{12}	D257
Volume resistivity, for a 0.22-inch thickness	10^{14} to 10^{15}	D257

Note: All material was tested as manufactured and at room temperature.

High-velocity flow of fluids having low electrical conductivity, such as petroleum distillates, can generate significant amounts of static electricity. In buried pipe these charges are slowly dissipated. Be sure to ground projections or metal appurtenances, especially near discharge nozzles, filters, valves and other areas of high turbulence. Use saddles instead of elastomeric pads at supports to obtain better grounding.

Bondstrand Series 7000 pipe includes electrically conductive elements in the pipe wall which, when properly grounded, prevent accumulation on the exterior of the pipe of dangerous levels of static electricity produced by the flow of fluids inside the pipe.

Entrapped gases

As in all piping systems, high points in the system will trap air or other gases. Trapped gases may create a hazard during test and operation of the system, and may restrict flow or drainage. It is recommended that air release valves be used at high points to permit bleeding out trapped air or other gases. See SMALL-DIAMETER METALLIC CONNECTIONS for suggested method of mounting.

Steam condensate

Good drainage helps avoid water hammer in steam condensate lines. For further information, see our Bondstrand Guide for Steam Condensate, FP468, available from your local distributor.

Heat tracing

Heat tracing may be needed to prevent freezing in cold weather or to maintain flow of viscous fluids at ambient temperature.

Wrap heat tracing helically to avoid the pipe deflection caused by heating one side of the pipe. Heat tracing should be directly on the pipe and within the insulation. Do not exceed maximum trace temperatures of 250°F for epoxy products or 200°F for vinyl ester products, and use the maximum trace temperature for the design of the piping system.

8 Detailing the supports

The following paragraphs describe and illustrate the different methods and devices used to support Bondstrand pipe and fittings in a suspended system.

Because outside diameters of Bondstrand pipe are the same as those for iron pipe size (IPS) standards, standard pipe supports and hangers often may be used for Bondstrand piping systems. Occasionally, larger supports as given in Table 19 are required to fit over elastomeric pads or saddles, especially at anchors.

Table 19 Recommended nominal hanger sizes for Bondstrand pipe

Note: Dimensions shown in parentheses are recommended inside diameters of anchoring device or support, and provide for a ¼-inch elastomeric pad thickness or a 9⁄16-inch Bondstrand saddle thickness.

Nominal Diameter		Bare Pipe or with Sheet Metal Wrapper		With Elastomeric Pad		With Two Bondstrand 180° Support Saddles	
in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*
1	*25*	2	*50*	–	–	–	–
1.5	*40*	2	*50*	–	–	–	–
2	*50*	2	*50*	2½	*63.5*	3	*75*
3	*80*	3	*75*	3½	*88.9*	4	*100*
4	*100*	4	*100*	(5)	*(125)*	5	*125*
5	*125*	5	*125*	(6)	*(150)*	6	*150*
6	*150*	6	*150*	(7⅛)	*(181)*	(7⅞)	*(200)*
8	*200*	8	*200*	(9⅛)	*(232)*	(9⅞)	*(251)*
10	*250*	10	*250*	(11¼)	*(286)*	(12)	*(300)*
12	*300*	12	*300*	(13¼)	*(337)*	(14)	*(350)*
14	*350*	14	*350*	(14¾)	*(375)*	(15½)	*(394)*
16	*400*	16	*400*	(16¾)	*(425)*	(17½)	*(445)*

Clamping forces

Support styles that clamp the pipe, are generally not recommended to ensure that clamping forces do not crush the pipe. Local crushing could result from a poor fit, and all-around crushing could result from over-tightening .

Where the pipe must be held tightly at the support, mount a pair of 180° support saddles between clamp and pipe for the ultimate in strength and long life. In some cases with Bondstrand 2000 or 4000, a ¼-inch thick elastomeric pad (Shore A durometer hardness 60 ± 5) placed between clamp and pipe is a suitable alternative.

Space between pipe

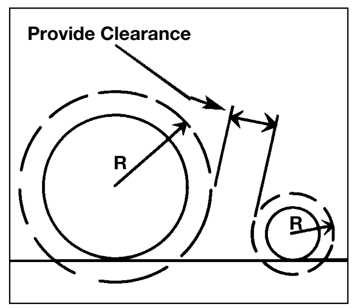
In multiple runs, allow clearance for flanges and other fittings having a diameter greater than the pipe. Table 20 shows the outside radius of standard Bondstrand products. Add space between pipe runs to accommodate length changes at loops and turns. Insulate as necessary to avoid direct exposure to hot pipe or other heat sources.

Table 20 Radius for determining piping clearance requirements for multiple runs

Notes:

1. Provide additional clearance between pipe runs to accommodate length changes at loops and turns.
2. Provide additional clearance where Bondstrand saddles are used for branching, or where Bondstrand maintenance couplings or other special joining systems are used.

Nominal diameter		Fittings Radius, R		Flanges Radius, R	
in.	*mm*	in.	*mm*	in.	*mm*
1	*25*	1¼	*32*	2½	*64*
1.5	*40*	1½	*38*	2¾	*70*
2	*50*	1¾	*44*	3	*76*
3	*80*	2¼	*57*	3¾	*95*
4	*100*	2¾	*70*	4½	*114*
5	*125*	3¼	*83*	4¾	*121*
6	*150*	3¾	*95*	5½	*140*
8	*200*	4¾	*121*	6¾	*171*
10	*250*	6¼	*159*	8	*203*
12	*300*	7¾	*197*	9½	*241*
14	*350*	9	*229*	11	*279*
16	*400*	10½	*267*	13	*330*



Supports permitting pipe movement

Supports allowing pipe to move with relative freedom include:

- hangers which are free to move laterally or longitudinally with the pipe,
- fixed supports over which pipe must slide, allowing longitudinal movement and often lateral movement, and
- guides which permit longitudinal movement of the pipe but restrain lateral movement.

Hangers are free to move on their hanger rods and allow considerable longitudinal and lateral movement. Hanger types include band, ring or clevis type (Figure 3), or roller types (Figure 4) with the roller either suspended freely or held rigidly in a frame.

Fixed supports permit the pipe to move longitudinally and, in some cases, laterally. An ordinary pipe rack made of steel angle is a typical fixed support permitting both longitudinal and lateral movement. Figure 5 shows some typical types of fixed support. Pipe resting in fixed supports requires protection from external abrasion, as described below.

Guides (Figure 6) restrict translational movement but may permit longitudinal and rotational movement. Guides are recommended for lines which are subject to side-loads or uplift. Examples include lines subjected to pressure surges, lines emptied and filled during operation, and lines (especially when empty) which can be lifted or moved by wind or other external loadings. Use guides on vertical runs (see Table 17).

8 Detailing the supports (cont'd)

Though no significant longitudinal movement is involved, guides are normally required for restrained systems at spacings given in Table 5 through 14. An inexpensive guide for most applications is a light-duty U-bolt, double-nutted to restrict horizontal and vertical movement but which permits free longitudinal movement.

Abrasion protection must be provided to protect the pipe where it slides through a fixed support or guide. Choose a material compatible with the service environment and budget. Some recommended protective methods include:

- Bondstrand saddles, which provide a clean, corrosion-free surface acting as a stiffening saddle for the pipe. Saddles are bonded to the pipe. In eight-inch pipe and larger, light-duty abrasion protection can be provided by bonding a half section of the same pipe to the line pipe.
- elastomeric material such as rubber or neoprene. This material may be either bonded in place or held by the clamping force of the support device.
- galvanized sheet metal, bonded or banded to the pipe, where the environment is not too corrosive. Recommended minimum metal gauge is:

  2- through 6-in. pipe: 16 gauge (0.0598)

  8- through 16-in. pipe: 10 gauge (0.1345)

Abrasion protection must be firmly bonded or banded to the pipe wherever movement is possible between the pipe and the support.

Supports that anchor pipe

Pipe in a straight run is usually anchored by clamps or split rings. Light anchors intended only to hold pipe in position between loops or turns in a free system may be fixed supports, as shown in Figure 7.

Supports required to resist length changes in restrained systems generally require the use of saddles. Saddles are recommended where pipe is to be held by ring clamps (Figure 8). Bonded saddles also may be used as a shear key along with a loose anchoring ring.

Valves and pumps in Bondstrand lines must be supported independently. Figure 9 shows how supports may be bolted to a flange to support weight, to resist thrust and torque, and to provide electrical grounding.

Vertical pipe runs are usually anchored using bonded saddles or flanges resting on a suitably reinforced and mounted guide or riser clamp (Figure 10).

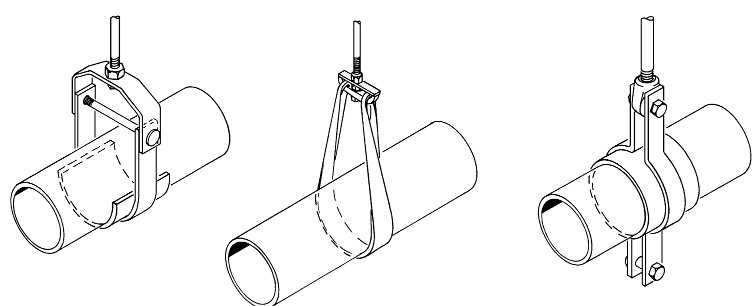


Figure 3 **Pipe hangers**
clevis, band, and ring type

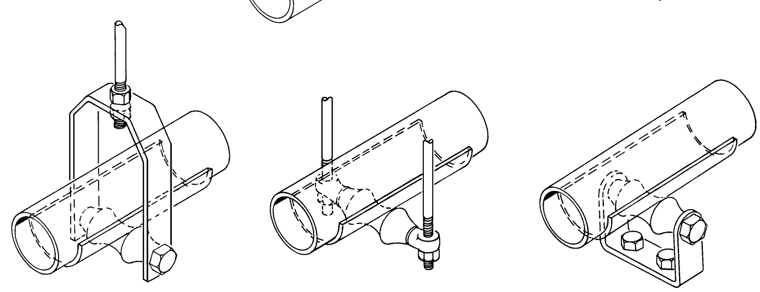


Figure 4 **Pipe hangers**
roller type

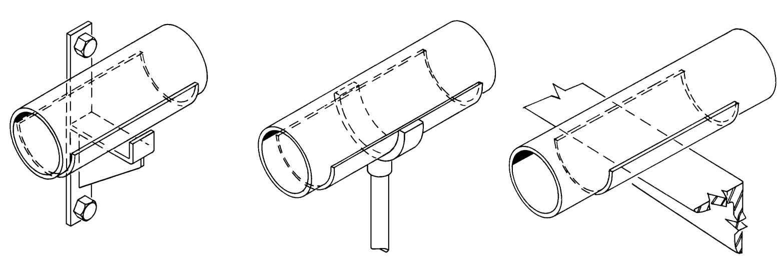


Figure 5 **Typical types of fixed supports**

8 Detailing the supports (cont'd)

Figure 6 **Supporting and guiding pipe**

a. pipe collar, loose fit

b. pipe clamp, loose fit

c. U-bolt, double nutted, loose fit

d. portable

notes:

1. Elastomeric pads are suitable in restrained systems where movement is negligible.
2. Bondstrand saddles or metal wrappers are suitable if pipe can move longitudinally as in vertical runs.

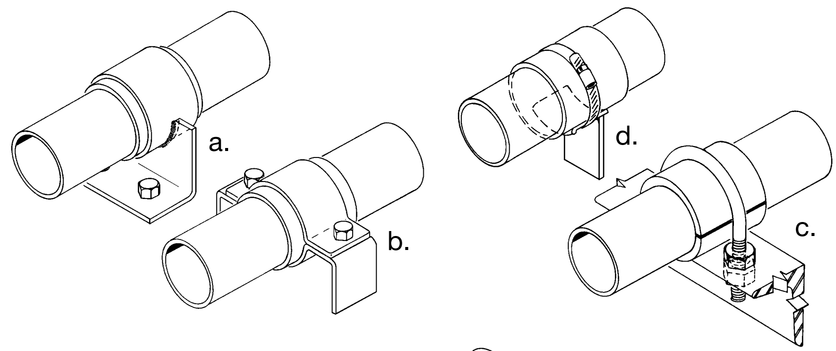


Figure 7 **Light duty anchors for free systems shown with two 180° Bondstrand saddles**

a. anchor chair

b. split ring anchor

c. strap anchor

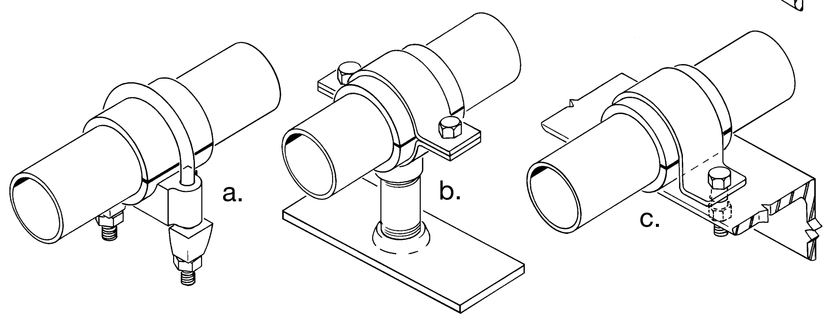


Figure 8 **Anchors for restrained pipe**

1 Two 180° Bondstrand saddles each side of clamp

2 Elastomeric pad

3 One 180° Bondstrand saddle each side of clamp

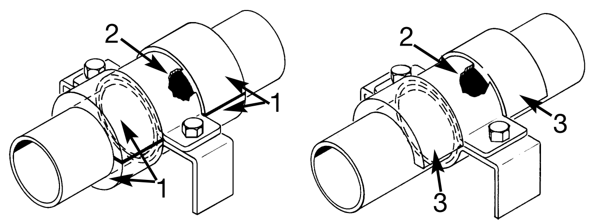


Figure 9 **Valve support and anchor**

Note:

1. Increase 45° angle to 60° to include 4 bolts on sizes 10 to 16 inches.

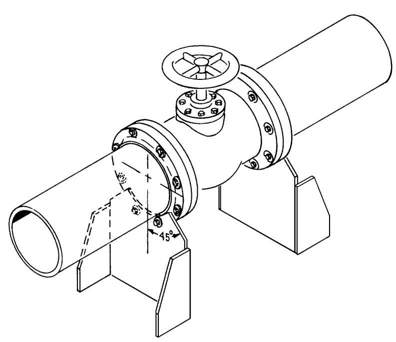
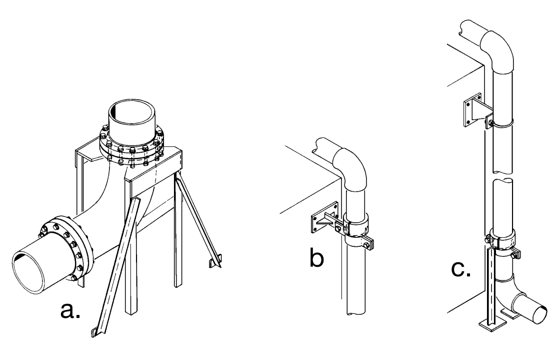


figure 10 **Support for vertical pipe runs**

a. base support for flanged column

b. support for hanging column

c. support for standing column: pipe guided by steel support for loose fit



9 Appendix A

Formulas for Calculating Length Change (with examples)

Thermal Expansion in Unrestrained Pipeline

Thermal expansion of a free Bondstrand pipeline is expressed by:

$$\frac{\Delta L}{L} = \alpha \Delta T \quad \text{where}$$

ΔL =change in length, in.
α =coefficient of thermal expansion, in./in./°F
L =length of pipeline, in.
ΔT =change in temperature, °F

Here is an example of calculating ΔL due to temperature. Assume that ΔT = 150°F, and α = 10 x 10^{-6} in./in./°F, then

$$\frac{\Delta L}{L} = 10 \times 10^{-6}(150) = 0.0015$$ in./in. of pipe or 1.8 in./100 ft. of pipe

Length Change with Pressure in Unrestrained Pipeline

The length of pipe in a free pipeline will change as internal pressure is applied to the line. The amount of change is reduced by the Poisson effect and is calculated for a free pipeline with closed ends by:

$$\frac{\Delta L}{L} = \frac{p\,\overline{ID}^2}{4tE_\ell D_m}\left(1 - 2m_{\ell c}\frac{E_\ell}{E_c}\right) \quad \text{where}$$

L =length of pipe, in.
p =internal pressure, psi
$\mu_{\ell c}$=Poisson's ratio
E_c =circumferential modulus of elasticity, psi
E_ℓ =longitudinal modulus of elasticity, psi
D_m =mean diameter of pipe wall, in.
$\overline{ID}$ =inside diameter of pipe wall, in.
t =thickness of pipe wall, in.

Here is an example of calculating ΔL due to pressure. Assume that

p= 100 psi, $\overline{ID}$ = 6.26 in., t= 0.180 in., D_m = 6.44 in., E_ℓ = 1.6 x 10^6 psi,

E_c= 3.6 x 10^6 psi, and $\mu_{\ell c}$ = 0.56

$$\frac{\Delta L}{L} = \frac{100(6.26)^2}{4(0.180)(1.6 \times 10^6)(6.44)}\left[1 - 2(0.56)\left(\frac{1.6}{3.6}\right)\right] =$$

0.00027 in./in. of pipe or 0.32 in./100 ft. of pipe

Notes:
Poisson's ratio for filament-wound structures depends on the ratio of the relative modulus of elasticity in the two directions under consideration. Both moduli are basically dependent on their orientation with respect to the glass fibers.

All three values, E_ℓ, E_c, and $\mu_{\ell c}$, used in this equation vary with temperature.

As indicated in Table 1, the effect of temperature on length change due to pressure within normal operating ranges is negligible.

Appendix B Formulas for Calculating Thrust

Thrust Due To Temperature Change in a Blocked Line

The thrust due to temperature change in a system fully restrained against length change is calculated by:

$$P = a\Delta TA_w E_\ell = a\Delta TE_\ell (pD_m t)$$

where P = thrust, lbf
α = coefficient of thermal expansion, in./in./°F
ΔT = change in temperature, °F
E_ℓ = longitudinal modulus of elasticity, psi
A_w = cross-sectional area of the pipe wall, in.^{2}
D_m = mean diameter of the pipe wall, in.
t = thickness of pipe wall, in.

For example:
$\alpha = 10 \times 10^{-6}$ in./in./°F, ΔT = 150°F, t = 0.18 in., D_m = 6.44 in.,
and $E_\ell = 1.6 \times 10^6$ psi
then $P = (10 \times 10^{-6})(150)(1.6 \times 10^6)[3.14(6.44)(0.18)] = 8,740$ lbf

Thrust Due To Pressure in a Blocked System

In a fully restrained system, calculate the thrust between anchors induced by internal pressure using:

$$P = \frac{\pi p D_m \overline{ID}}{2}\left(\frac{E_\ell}{E_c}\right)(-\mu_{\ell c})$$

where p = internal pressure, psi
E_c = circumferential modulus of elasticity, psi
$\mu_{\ell c}$ = Poisson's ratio

For example, assume that
$\overline{ID}$ = 6.26 in., D_m = 6.44 in., p = 100 psi, $E_\ell = 1.6 \times 10^6$ psi,
$E_c = 3.6 \times 10^6$ psi, and $\mu_{\ell C}$ = 0.56
then $P = \frac{3.14(100)(6.44)(6.26)}{2}\left(\frac{1.6}{3.6}\right)(-0.56) =$ 1,575 lbf (tension)

Thrust Due To Pressure on a Closed End

Where internal pressure on a closed end exerts thrust on supports, calculate thrust using:

$$P = \frac{p\,\overline{ID}^2}{4}p$$

For example, if there is 100 psi in a 6-inch (6.26 in.) pipe, thrust is

$$\frac{3.14(6.26)^2}{4} \times 100 = 3,080 \text{ lbf}$$

Stress in the pipe is given in each of the above cases by:

$$f = \frac{P}{A_w}$$

where f = longitudinal stress, psi

In the last example,

$$f = \frac{3,080}{3.64} = 845 \text{ psi}$$

Formula for Calculating Support Spacings for Uniformly Distributed Load

Suspended pipe is often required to carry loads other than its own weight and a fluid with a specific gravity of 1.0. Perhaps the most common external loading is thermal insulation, but the basic principle is the same for all loads which are uniformly distributed along the pipeline. The way to adjust for increased loads is to decrease the support spacing, and conversely, the way to adjust for decreased loads is to increase the support spacing. An example of the latter is a line filled with a gas instead of a liquid, and longer spans are indicated if deflection is the controlling factor.

For all such loading cases, support spacings for partially continuous spans with a permissible deflection of 0.5 inch are determined using:

$$L = 0.258\sqrt[4]{\frac{(E\,I)}{w}}$$

where L = support spacings, ft.
(EI) = beam stiffness, lb•in^2 (from Table C2)
w = total uniformly distributed load, lb/lin in.

For example, calculate the recommended support spacing for 6-inch Bondstrand Series 2000 pipe full of water at 200°F:

$$L = 0.258\sqrt[4]{\frac{16,000,000}{(0.25 + 1.1)}} = 15.1 \text{ ft.}$$

When using metric units the formula becomes:

$$L = 1.24\sqrt[4]{\frac{(EI)}{w}}$$

where L = support spacings, m
(EI) = beam stiffness, N•m^2 (from Table C2)
w = total uniformly distributed N/m

9 Appendix C (cont'd)

Table C1 Values for use in calculating support spacings

Nominal Pipe Size		Uniform Weight of Pipe									
		Series 2000/4000		2000M-FP		5000		7000		3000A/3200A	
in.	*mm*	lb/in	*N/m*	lb/in	*N/m*	lb/in	*N/m*	lb/in	*N/m*	lb/in	*N/m*
1	*25*	0.03	*5.8*	0.09	*16*	0.03	*5.8*	0.04	*7.3*	–	–
1.5	*40*	0.06	*10*	0.12	*20*	0.06	*10*	0.08	*13*	–	–
2	*50*	0.08	*13*	0.17	*29*	0.08	*15*	0.08	*15*	0.04	*7.3*
3	*80*	0.10	*18*	0.24	*42*	0.13	*22*	0.10	*18*	0.06	*10*
4	*100*	0.17	*29*	0.35	*61*	0.20	*35*	0.17	*29*	0.08	*15*
5	*125*	0.22	*38*	0.44	*77*	0.22	*38*	0.22	*38*	–	–
6	*150*	0.25	*44*	0.53	*92*	0.29	*51*	0.25	*44*	0.16	*28*
8	*200*	0.36	*63*	0.78	*136*	0.42	*73*	0.43	*76*	0.26	*45*
10	*250*	0.45	*79*	1.10	*193*	0.52	*90*	0.68	*118*	0.38	*66*
12	*300*	0.53	*93*	1.38	*241*	0.62	*108*	0.92	*160*	0.51	*89*
14	*350*	0.62	*108*	1.52	*266*	0.73	*127*	1.08	*190*	0.63	*109*
16	*400*	0.79	*139*	2.13	*372*	0.93	*163*	1.42	*248*	0.78	*137*

Nominal Pipe Size		Uniform Weight of Fluid					
		S.G.=1.0		S.G.=1.3		S.G.=1.6	
in.	*mm*	lb/in	*N/m*	lb/in	*N/m*	lb/in	*N/m*
1	*25*	0.3	*5.6*	0.04	*7.3*	0.05	9.0
1.5	*40*	0.8	*14*	0.10	*18*	0.12	22
2	*50*	0.12	*22*	0.16	*28*	0.20	*35*
3	*80*	0.29	*51*	0.38	*67*	0.47	*82*
4	*100*	0.49	*85*	0.63	*111*	0.78	*136*
5	*125*	0.76	*134*	0.99	*174*	1.2	214
6	*150*	1.1	*195*	1.4	*253*	1.8	*312*
8	*200*	1.9	*336*	2.5	*437*	3.1	*537*
10	*250*	3.0	*532*	3.9	*691*	4.9	*851*
12	*300*	4.3	*757*	5.6	*985*	6.9	*1212*
14	*350*	5.2	*913*	6.8	*1187*	8.3	*1461*
16	*400*	6.8	*1193*	8.9	*1551*	10.9	*1909*

Table C2 Effective beam stiffness values for use in calculating support spacings

Nominal Pipe Size		Effective Beam Stiffness Factor, EI (million lb in²)•*EI (kN m²)*															
		Series 2000				Series 2000M-FP				Series 4000				Series 5000			
in.	*mm*	up to 150°F	*67°C to 121°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 200°F	*67°C to 93°C*
1	*25*	0.16	*0.46*	0.09	*0.27*	0.16	*0.46*	0.09	*0.27*	0.13	*0.38*	0.08	*0.24*	.011	*0.33*	0.01	*0.04*
1.5	*40*	0.52	*1.5*	0.30	*0.87*	0.52	*1.48*	0.30	*0.87*	0.42	*1.21*	0.27	*0.77*	0.36	*1.04*	0.05	*0.13*
2	*50*	1.0	*2.8*	0.58	*1.7*	1.0	*2.8*	0.58	*1.7*	0.80	*2.3*	0.51	*1.5*	0.69	*2.0*	0.09	*0.25*
3	*80*	3.3	*9.5*	1.9	*5.6*	3.3	*9.5*	1.9	*5.6*	2.7	*7.6*	1.7	*4.8*	2.3	*6.6*	0.29	*0.85*
4	*100*	9.2	*26*	5.4	*16*	9.2	*26*	5.4	*16*	7.8	*22*	5.0	*14*	6.7	*19*	0.86	*2.5*
5	*125*	18	51	10	*30*	18	*51*	10	*30*	15	*43*	9.5	*27*	13	*37*	1.6	*4.7*
6	*150*	30	*87*	18	*51*	30	*87*	18	*51*	26	*74*	16	*47*	22	*63*	2.8	*8.1*
8	*200*	76	*217*	45	*128*	93	*268*	55	*158*	65	*187*	41	*119*	55	*159*	7.1	*20*
10	*250*	148	*426*	87	*251*	231	*664*	136	*391*	128	*366*	81	*233*	109	*312*	14	*40*
12	*300*	250	*716*	147	*421*	465	*1334*	273	*784*	214	*615*	136	*391*	182	*523*	23	*67*
14	*350*	348	*999*	205	*587*	624	*1790*	367	*1053*	325	*934*	207	*593*	276	*791*	35	*102*
16	*400*	590	*1693*	347	*996*	1066	*3061*	627	*1800*	554	*1590*	352	*1010*	468	*1342*	60	*173*

Nominal Pipe Size		Series 5100				Series 7000				Series 3000A				Series 3200A			
		up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 121°C*	up to 150°F	*up to 66°C*	151°F to 250°F	*67°C to 99°C*	up to 150°F	*up to 66°C*	151°F to 210°F	*67°C to 99°C*
in.	*mm*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*	ft.	*m*
1	*25*	.011	*0.33*	0.01	*0.04*	0.18	*0.50*	0.10	*0.30*	–	–	–	–	–	–	–	–
1.5	*40*	0.36	*1.04*	0.05	*0.13*	0.57	*1.6*	0.34	*0.97*	–	–	–	–	–	–	–	–
2	*50*	0.69	*2.0*	0.09	*0.25*	1.1	*3.2*	0.65	*1.9*	1.1	*3.1*	0.81	*2.3*	1.1	*3.1*	0.81	*2.3*
3	*80*	2.3	*6.6*	0.29	*0.85*	3.7	*11*	2.2	*6.3*	3.8	*11*	2.8	*8.1*	3.8	*11*	2.8	*8.1*
4	*100*	6.7	*19*	0.86	*2.5*	10	*29*	5.9	*17*	8.3	*24*	6.2	*18*	8.3	*24*	6.2	*18*
5	*125*	13	*37*	1.6	*4.7*	19	*56*	11	*33*	–	–	–	–	–	–	–	–
6	*150*	22	*63*	2.8	*8.1*	33	*96*	20	*56*	36	*104*	27	*78*	36	*104*	27	*78*
8	*200*	55	*159*	7.1	*20*	100	*288*	59	*169*	40	*115*	30	*86*	80	*230*	60	*173*
10	*250*	109	*312*	14	*40*	245	*704*	144	*414*	94	*270*	70	*202*	188	*539*	141	*404*
12	*300*	182	*523*	23	*67*	488	*1400*	287	*824*	180	*516*	135	*387*	360	*1032*	270	*774*
14	*350*	276	*791*	35	*102*	653	*1873*	384	*1102*	287	*824*	215	*618*	574	*1648*	431	*1236*
16	*400*	468	*1342*	60	*173*	1110	*3185*	653	*1873*	471	*1353*	354	*1015*	943	*2706*	707	*2030*

Notes

Notes

11 Health and safety information

Toxicity of adhesive

Hardener: Irritating to the skin, eyes and respiratory tract: toxic orally; may cause sensitization.

Resin: . May be mildly irritating to skin and eyes; may cause sensitization.

Handling precautions for adhesive

Hardener: Do not get in eyes, on skin or clothing. Avoid breathing vapor. Wash thoroughly after handling. When handling in the field, wear gloves and eye protection. When handling in bulk quantities, wear rubber gloves, rubber apron and NIOSH approved respirator.

Resin: Avoid contact with eyes, skin or clothing. When handling in the field, wear gloves and eye protection. Wash thoroughly after handling.

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For calls originating outside the continental U.S.
202-483-7616 -Washington D.C. collect

First aid for adhesive users

In case of contact

Eyes: Immediately flush with plenty of water for at least 15 minutes. Call a physician.

Skin: Wash with water and soap if available.

Clothing: Remove contaminated clothing and wash before reuse.

Inhalation: Remove to fresh air. Give oxygen or artificial respiration if necessary.

Ingestion: If hardener is swallowed and person is conscious, give plenty of water or milk to drink. **Do not induce vomiting.** Call a physician.

Important notice

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