UNDERSTANDING THERMAL EXPANSION AND PLACING EXPANSION JOINTS

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What We Will Discuss Today

- BRIEF INTRODUCTION TO THERMAL EXPANSION
- OVERVIEW OF EXPANSION JOINTS, ANCHORS AND GUIDES
- CALCULATE ANCHOR LOADS AND THERMAL EXPANSION
- PLACING EXPANSION JOINTS
- TIPS AND TRICKS TO REDUCE THE NUMBER OF GUIDES / JOINTS REQUIRED

What Is Thermal Expansion?

According to Merriam-Webster: “increase in linear dimensions of a solid or in volume of a fluid because of rise in temperature”

Hot systems (hot water, steam) will expand as they heat up

Chilled systems (chilled water) will contract as they get colder

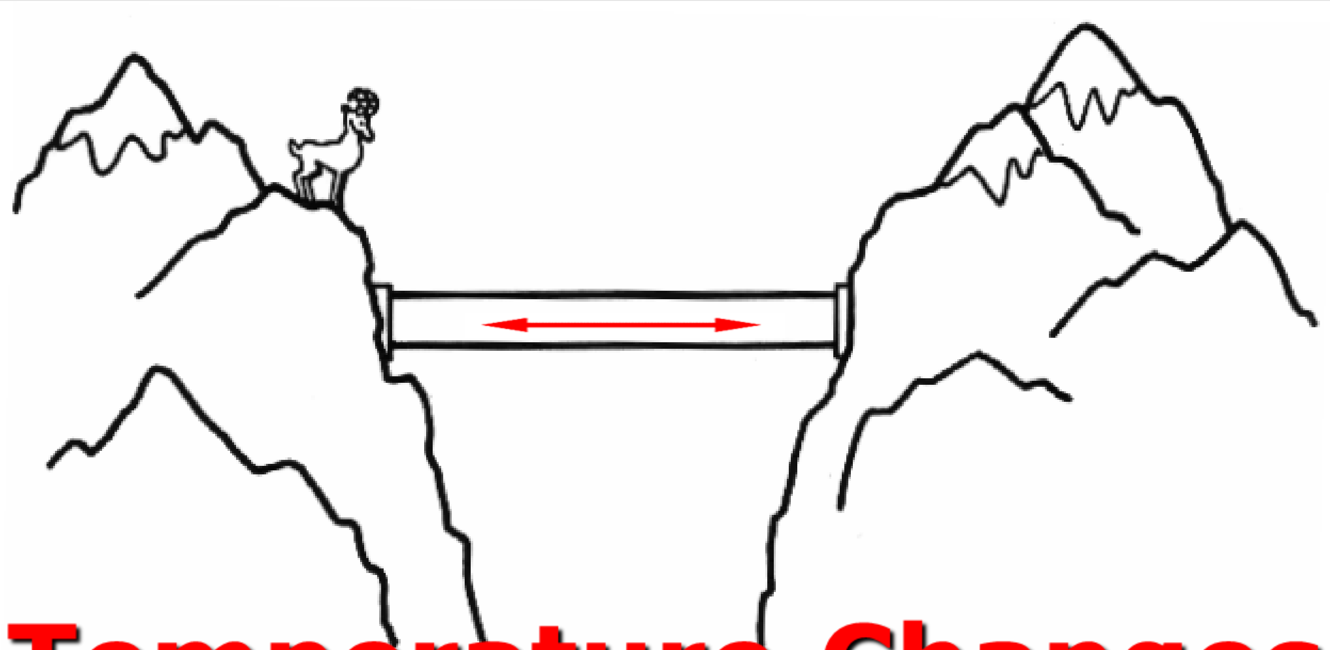
An expansion joint is used to absorb this expansion or used to absorb the contraction. The expansion joint moves so your whole system does not

What is an Expansion Joint?

An expansion joint is:

A device designed to safely absorb the heat-induced expansion and contraction of a piping system, to absorb vibration, or to allow movement due to ground settlement or earthquakes.

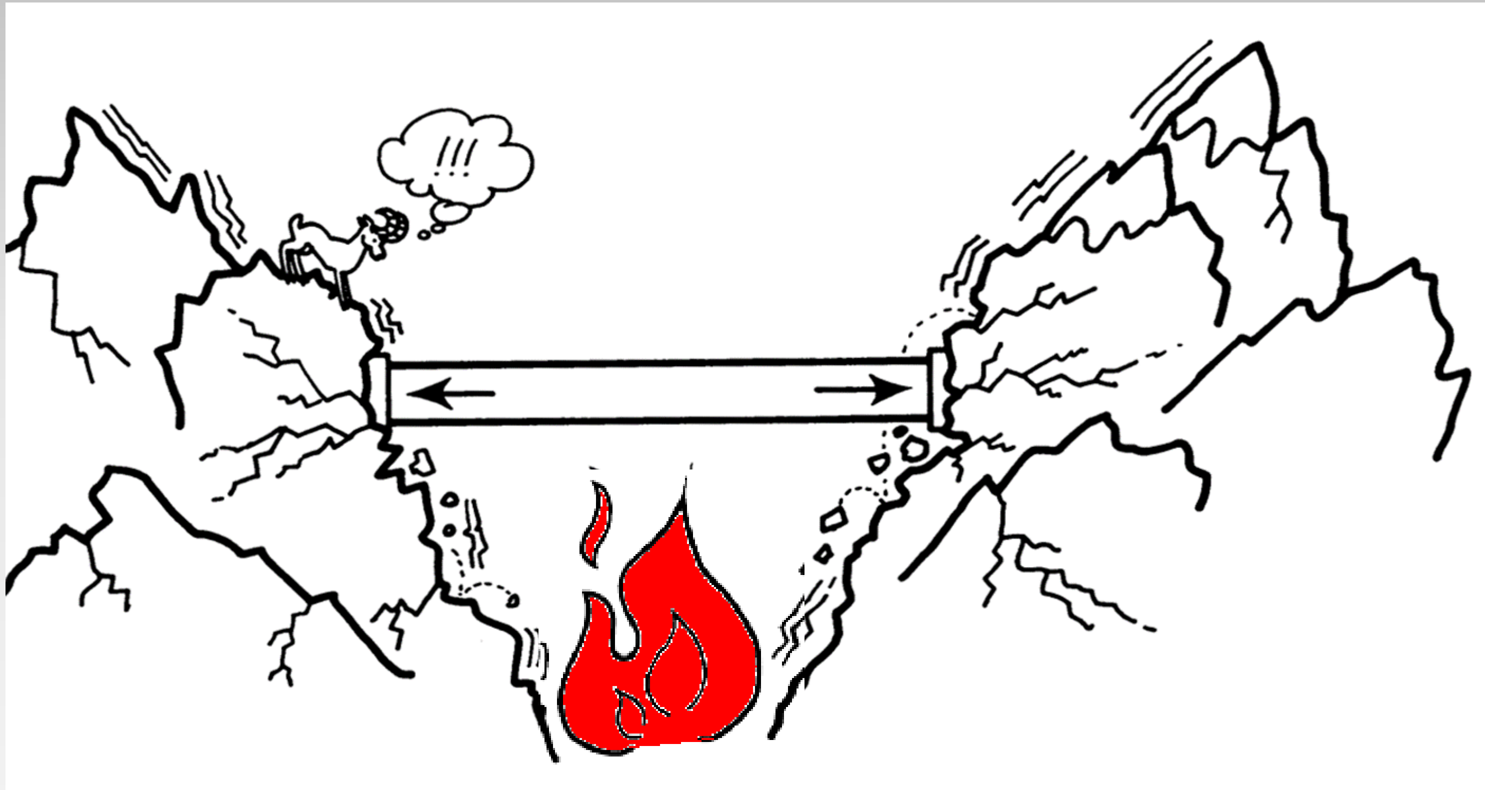
What happens when you heat up pipe?



Temperature Changes

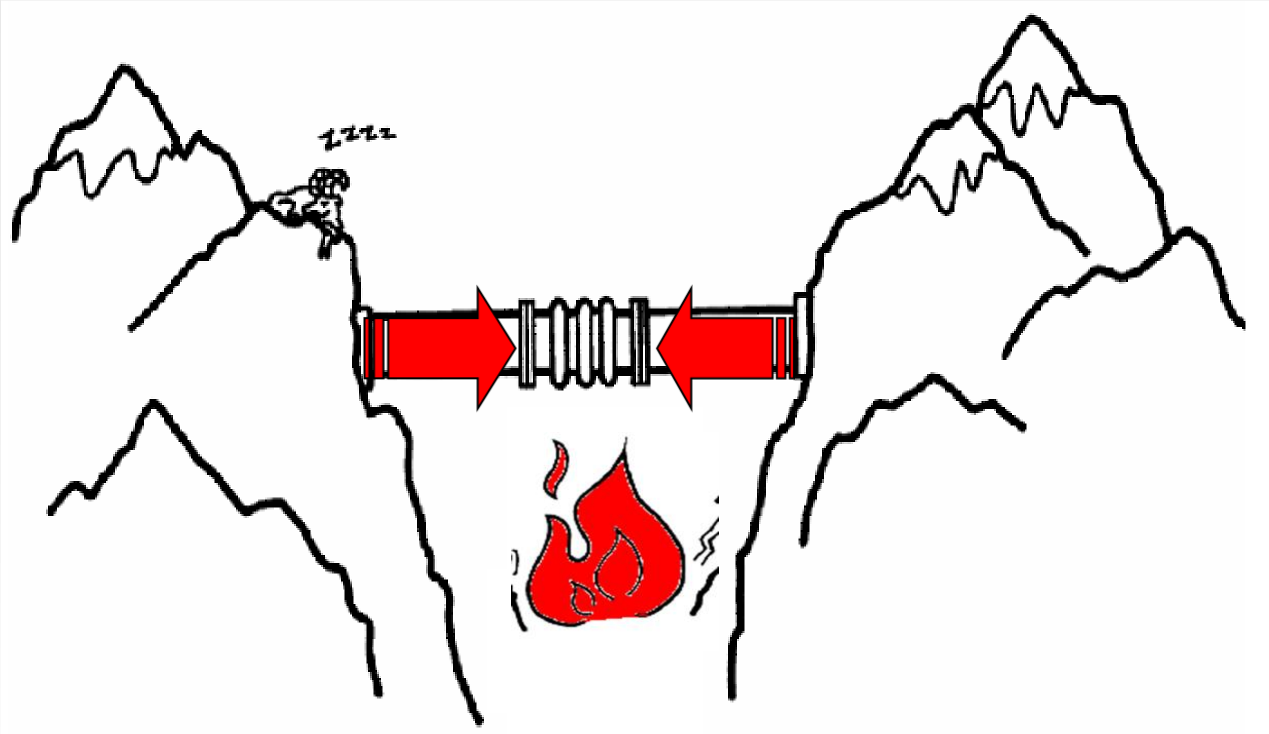
Pipe Expands

These forces are huge

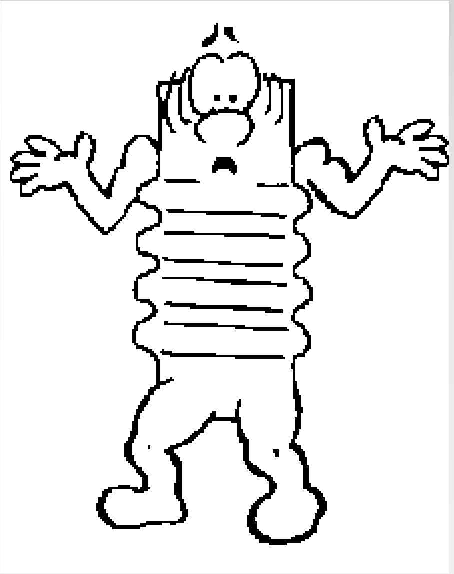


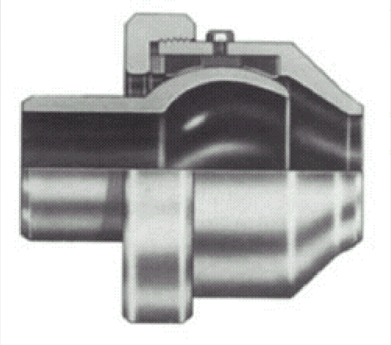
PIPE SIZE	FORCE EXERTED BY 100 FEET OF PIPE AT		
	$\Delta T = 200°$ $\Delta L = 1.52"$	$\Delta T = 340°$ $\Delta L = 2.7"$	$\Delta T = 420°$ $\Delta L = 3.42$
4	120,460 LBS	213,980 LBS	271,040 LBS
6	212,040	376,650	477,090
8	319,200	567,000	718,200
12	554,800	985,500	1,248,300

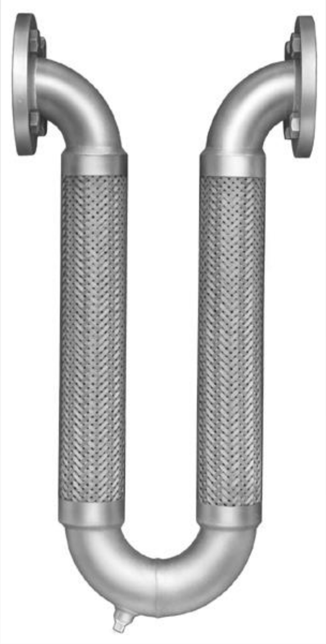
Expansion joints absorb the pipes expansion while the piping remains in its original position



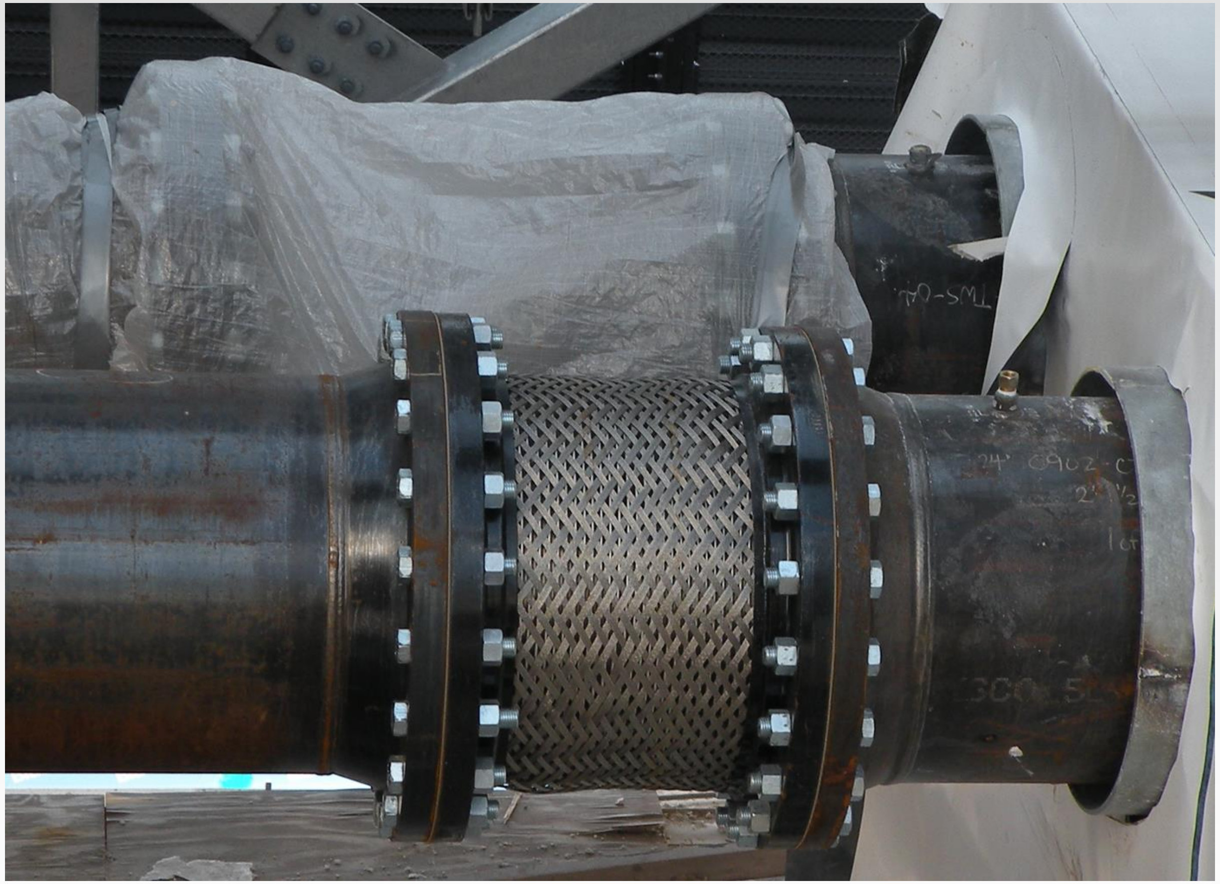
Which Expansion Joint do I use ?







Flex connectors are NOT expansion joints

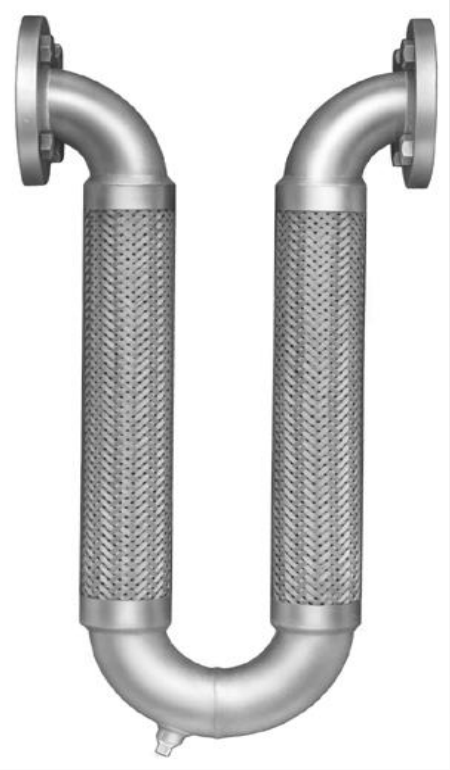


Types of Expansion Joints

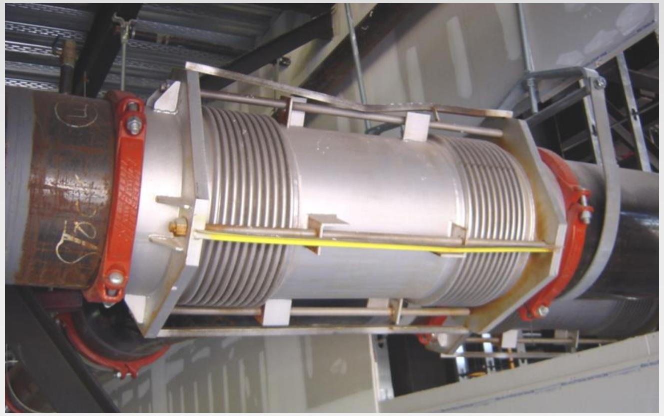
Internally Pressurized

Externally Pressurized

Flexible Pipe Loop



INTERNALLY PRESSURIZED JOINTS



High Corrugation Bellows

Features

High Corr. Design.

Hydraulically Formed.

Axial or angular movement only.

Advantages

Hydrostatic forming process develops lower stresses in the stainless steel bellows.

Very reliable. The hydrostatic forming process also tests the bellows to 5,000 PSI.

Disadvantages

Engineered product.

Low movement.

Must be anchored / restrained

Critical guiding requirements –If this joint is not guided properly, it is subject to squirm out.

Low Corrugation Bellows

Features

Low Corr. Design.

Mechanically Formed.

Axial or angular movement only. Can be used for lateral if used in pairs.

Advantages

Small face-to-face dimension

Low Cost

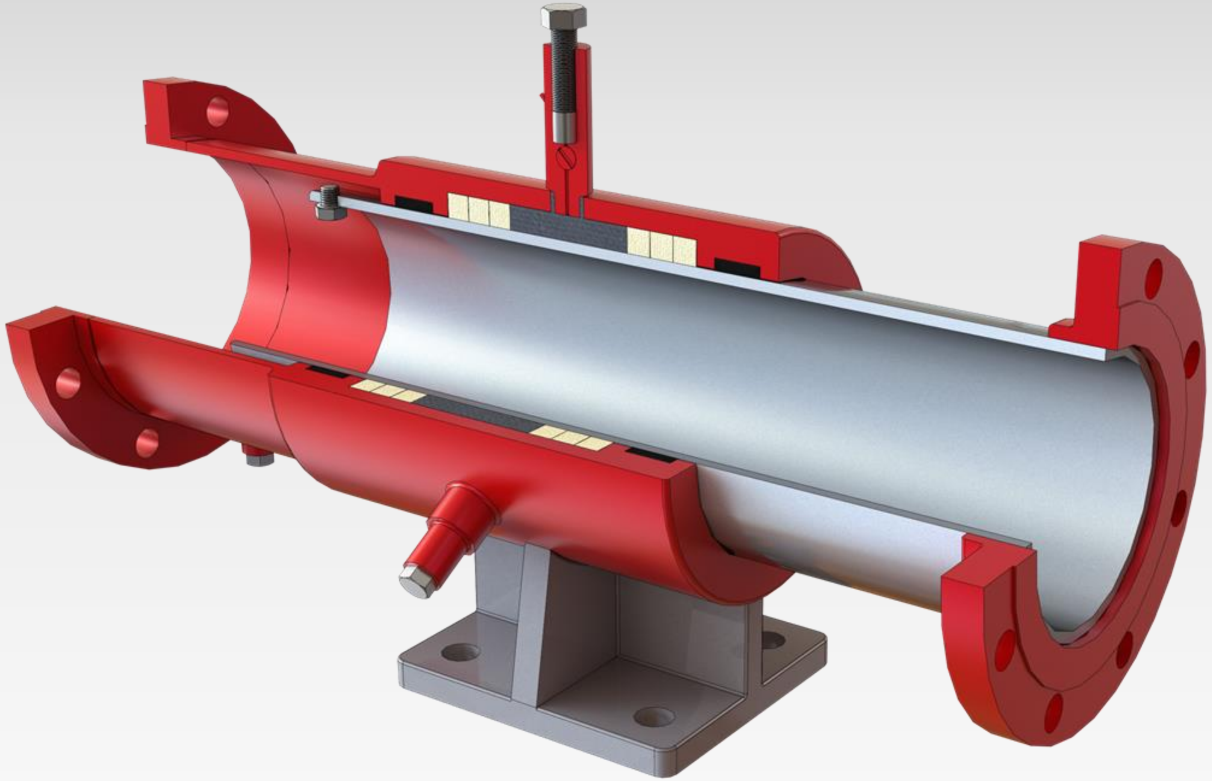
Disadvantages

Low movement

Must be anchored / restrained

Critical guiding requirements –If this joint is not guided properly, it is subject to squirm out.

Packed Joint



Features

A chrome plated slip tube

Can be repacked in service

Advantages

This joint can be used for very high pressure steam applications (1,000 PSI at 750^{o} F)

Can absorb very large amount of pipe expansion

Disadvantages

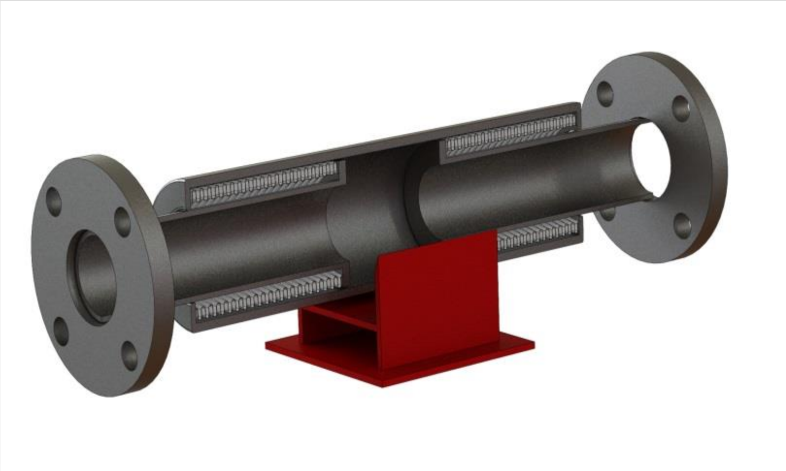
Maintenance Issues – The packed joint will need to be repacked over time

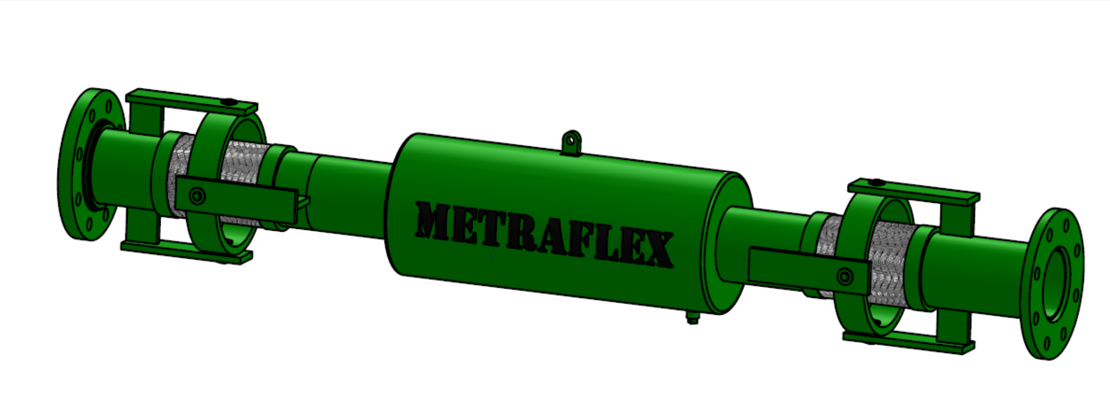
Anchoring issues – Develops high anchor loads

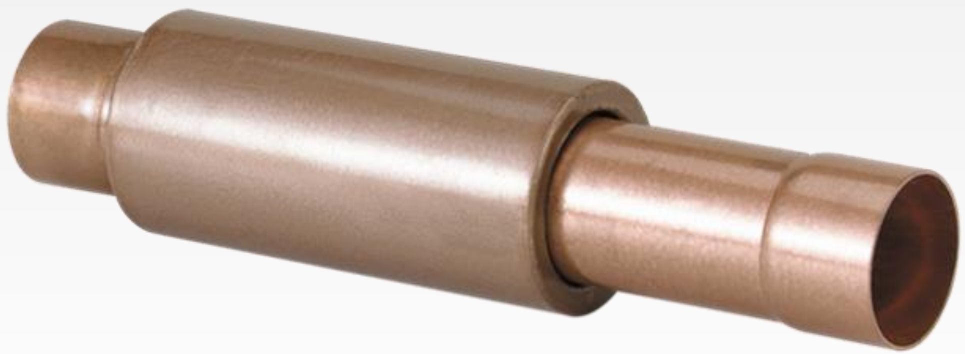
Guiding requirements are similar to bellows joints

Any damage to the chrome plated will cause leaking when the joint is cycled.

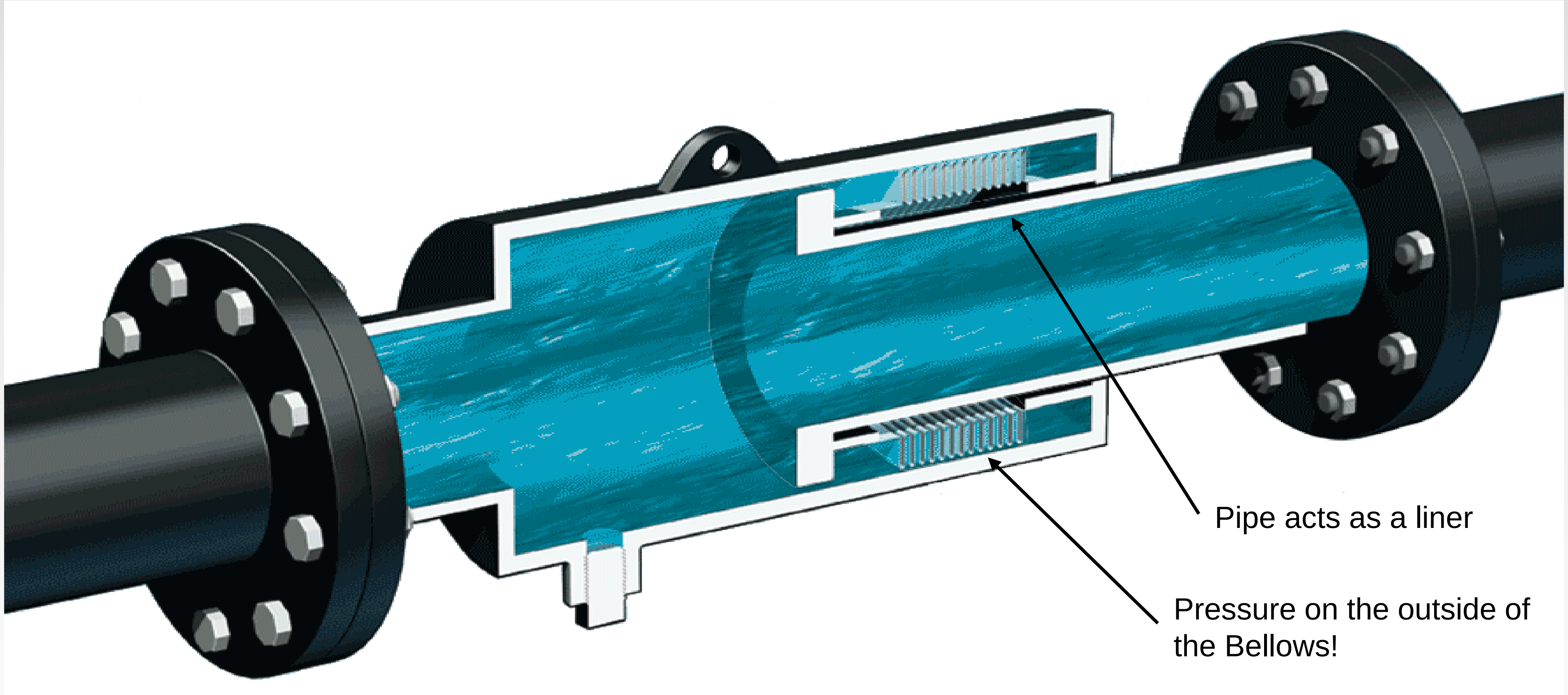
EXTERNALLY PRESSURIZED JOINTS







With an externally pressurized expansion joint, the pressure is external to the bellows allowing a longer, more stable bellows.



Externally Pressurized Bellows

Features

Built in liner – The pipe acts as a liner to protect the bellows.

Housing = Cover – The outer casing acts as a shield protecting the bellows.

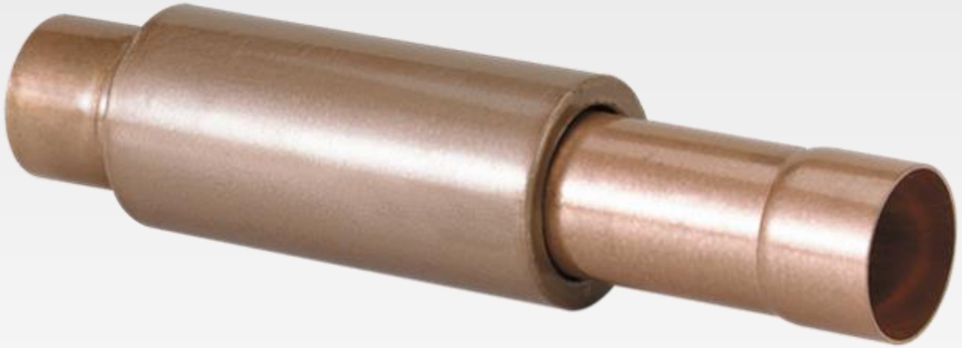
More movement – The pressure is on the outside of the bellows, this is a much more stable design than the internally pressurized bellows. Because of this, the bellows can have more corrugations and can be designed for more movement then an internally pressurized bellows.

Lower guiding requirements – The internal guide and the end plate both act as guides. The externally pressurized joint can be successfully installed without the first guide at four diameters from the joint

Very reliable – With the internal guides, pipe acting as a liner, and the casing acting as a shield, this is a very reliable joint.

Maintenance free

Copper Compensator



Copper version of a compensator

Features

Externally pressurized bellows.

Designs in 150 lb. class

Axial movement only.

Sweat Ends

Advantages.

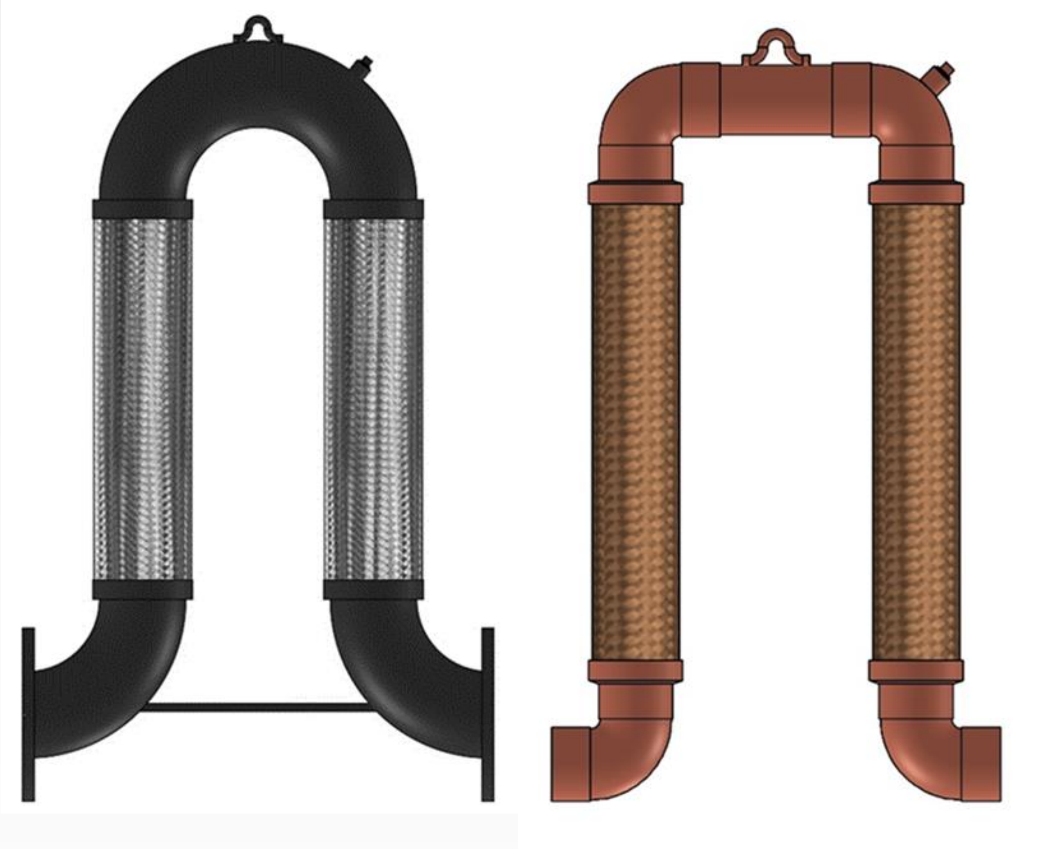
Built in liner – The pipe acts as a liner to protect the bellows.

Built in housing – The outer casing acts as a shield protecting the bellows.

Very reliable – With the internal guides, pipe acting as a liner, and the casing acting as a shield, this is a very reliable joint.

Maintenance free.

Flexible Pipe Loop



Features

Available large range of sizes

Available in Carbon steel, stainless steel, copper, and other alloys

Handles movement in any direction

Can be easily customized (smaller or larger movements)

Advantages

Lowest anchor loads of any expansion joint

Minimal guiding requirements

Ideal for use in seismic applications

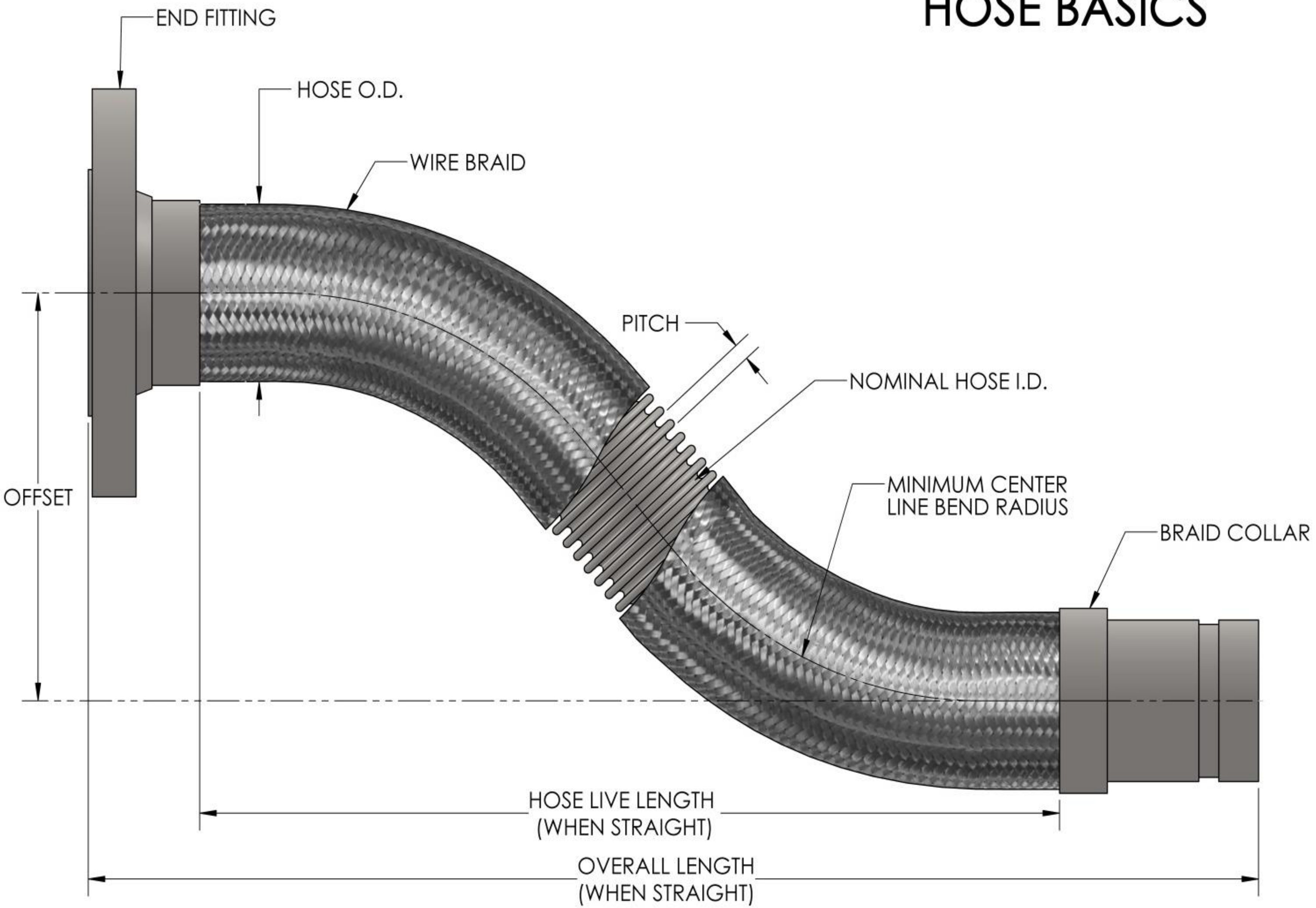
Available with UL, FM, CSA, and IAPMO listings

Maintenance free.

Disadvantages

B dimension

HOSE BASICS


END FITTING
HOSE O.D.
WIRE BRAID
PITCH
NOMINAL HOSE I.D.
MINIMUM CENTER
LINE BEND RADIUS
BRAID COLLAR
OFFSET
HOSE LIVE LENGTH
(WHEN STRAIGHT)
OVERALL LENGTH
(WHEN STRAIGHT)

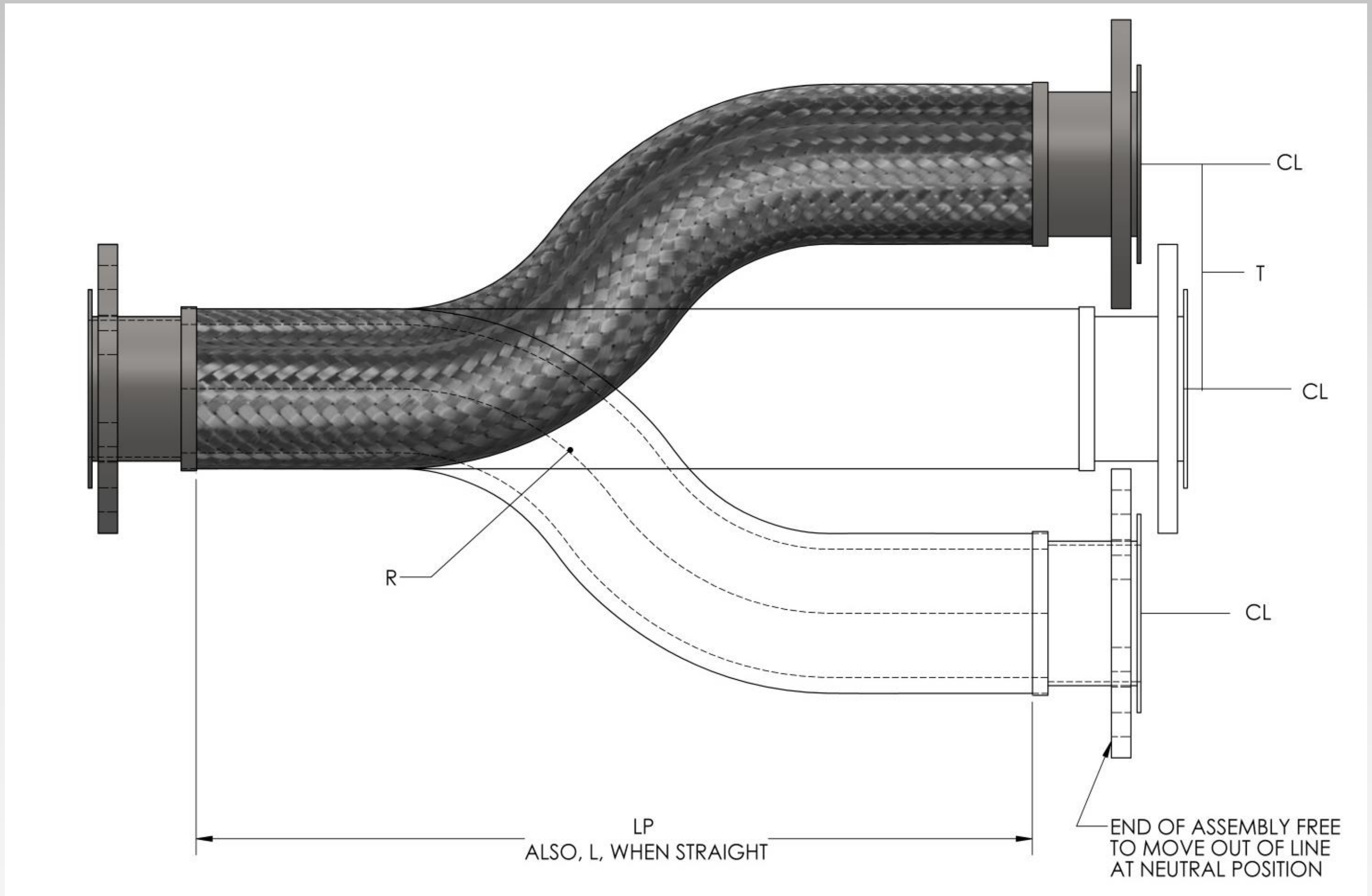
Stainless Steel

Size	Dynamic Bend Rad	Static Bend Rad	Seismic Bend Rad
1/2"	6	1.5	3.75
3/4"'	8	2.25	5.125
1"	9	2.75	5.875
1 1/4"	10.5	3.5	7
1 1/2"	12	4	8
2"	15	5	10
2 1/2"	20	8	14
3"	22	9	15.5
4"	27	13	20
6"	36	19	27.5
8"	40	20	30
10"	50	25	37.5
12"	60	30	45

Bronze

Size	Dynamic Bend Rad	Static Bend Rad	Seismic Bend Rad
1/2"	7	1.5	4.25
3/4"'	8	2.25	5.125
1"	10	3	6.5
1 1/4"	12	3.5	7.75
1 1/2"	13.5	4	8.75
2"	17	5	11
2 1/2"	22	8	15
3"	24	12	18
4"	26	14	20

Centerline Bend Radius in Incehs	Intermittent Offset Motion Max Distance From Centerline in Inches								
	1"	1.5"	2"	3"	4"	5"	6"	8"	10"
5	6	7	7.75	10.25	12.25	13.5	15	18	20.5
6	6.25	7.5	8.25	10.75	12.75	14.25	16	19	21.5
7	6.75	8.25	9.25	11.5	13.5	15.25	17	19.75	23
8	7	8.75	10	12.5	14.5	16.25	18	21.5	24.25
9	7.5	9.25	10.75	13.25	15.25	17	19	22.5	25.5
10	8	9.75	11.25	13.75	16	18	20	23.5	26.5
11	8.25	10.25	11.75	14.5	16.75	18.75	20.75	24.5	27.5
12	8.5	10.5	12.25	15	17.5	19.5	21.5	25.5	28.75
13	9	10.75	12.75	15.75	18	20.25	22.5	26.25	29.75
14	9.25	11.25	13.25	16.25	18.75	21	23.5	27.25	30.75
15	9.75	11.75	13.5	16.75	19.25	21.75	24.25	28	31.75
16	10	12.25	14	17.25	20	22.5	25	29	32.75
17	10.25	12.5	14.5	17.75	20.5	23.25	25.5	29.75	33.5
18	10.5	13	15	18.25	21.25	24	26	30.5	34
19	10.75	13.25	15.25	18.75	21.75	24.5	26.75	31.25	35
20	11	13.5	15.75	19.25	22.5	25	27.5	32.25	36.25
22	11.5	14	16.25	20	23.25	25.75	28.5	33.5	37.5
24	12	14.5	17	20.75	24	26.5	29.5	34.75	39
26	12.5	15	17.5	21.5	25	27.75	30.75	36	40.25
28	13	15.75	18.25	22.5	26	29	32	37.5	41.5
30	13.5	16.5	19	23.5	27.25	30.5	33.5	39	43.75
35	14.5	18	20.75	26.25	29.5	32.75	36	42	47
40	15.5	19	22	27	31.25	35	38.5	44.75	50
45	16.5	20.75	23.5	28.5	33.25	37	41	47.5	53
50	17.5	21.5	24.75	30	35	39	43	50	56
60	19	23.25	27	33	38.25	43	47	54.5	61
70	20.5	25.25	29	35.5	41.5	46	51	58.75	65.75
80	22	27	31	38	44	49.5	54	62.75	70
90	23.5	28.5	33	40.5	46.75	52	57.25	66.25	74.25
100	24.5	30	35	42.5	49.25	55	60.5	69.75	78.25



FORMULA: $L = \sqrt{6RT + T^2}$

$Lp = \sqrt{L^2 - T^2}$

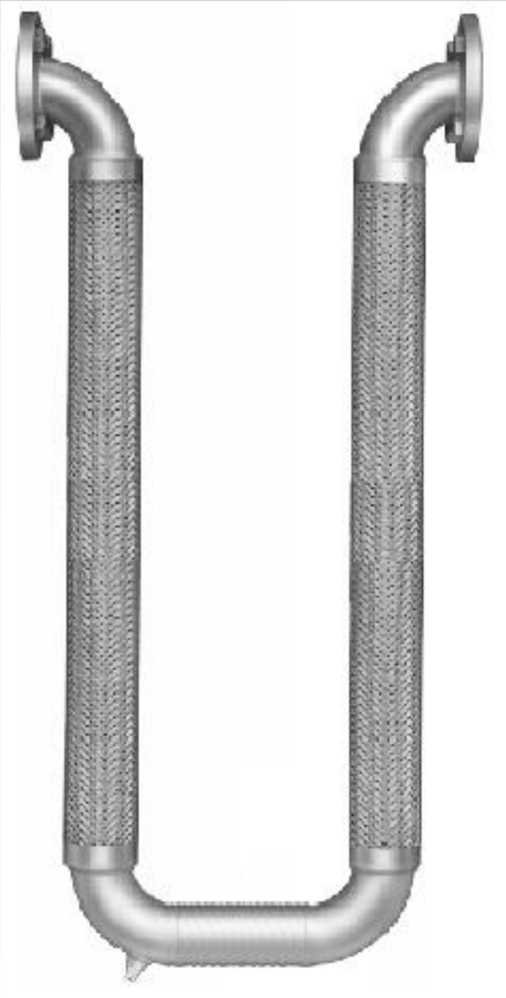
L = Live Hose Length (inches)

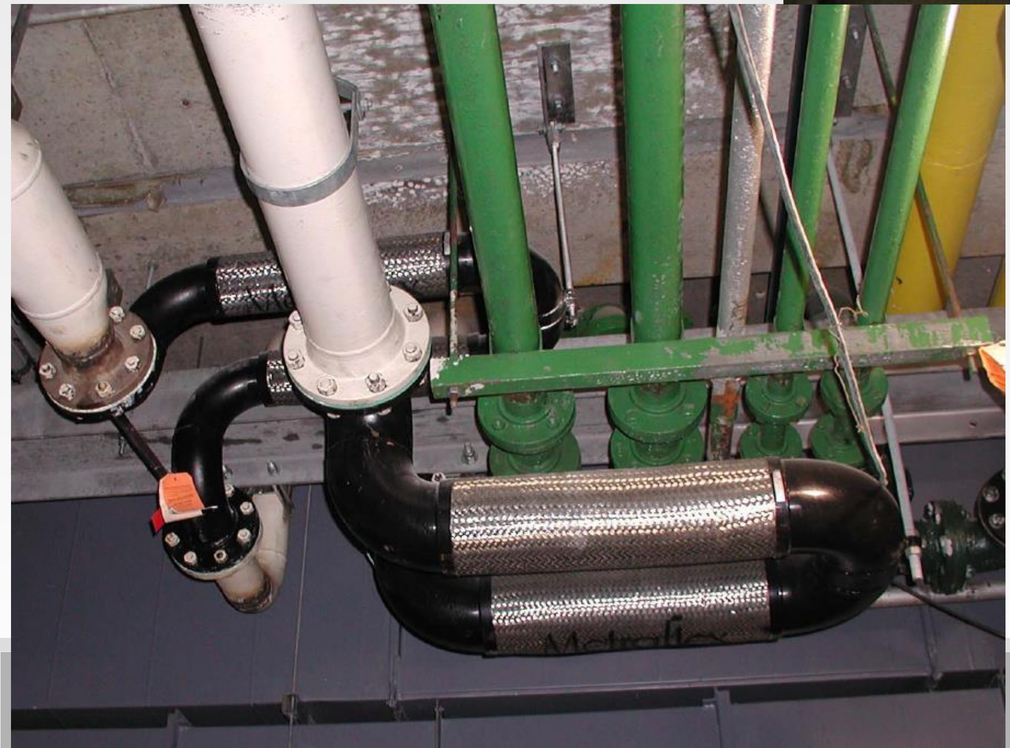
Lp = Projected Live Hose Length (inches)

R = Minimum Centerline Bend Radius for constant flexing (inches)

T = Offset Motion to one side of Centerline (inches)

Virtually any amount of movement





Anchor Load (Thrust Load) Calculation

18” Externally Pressurized Joint

Operating at 125 PSI

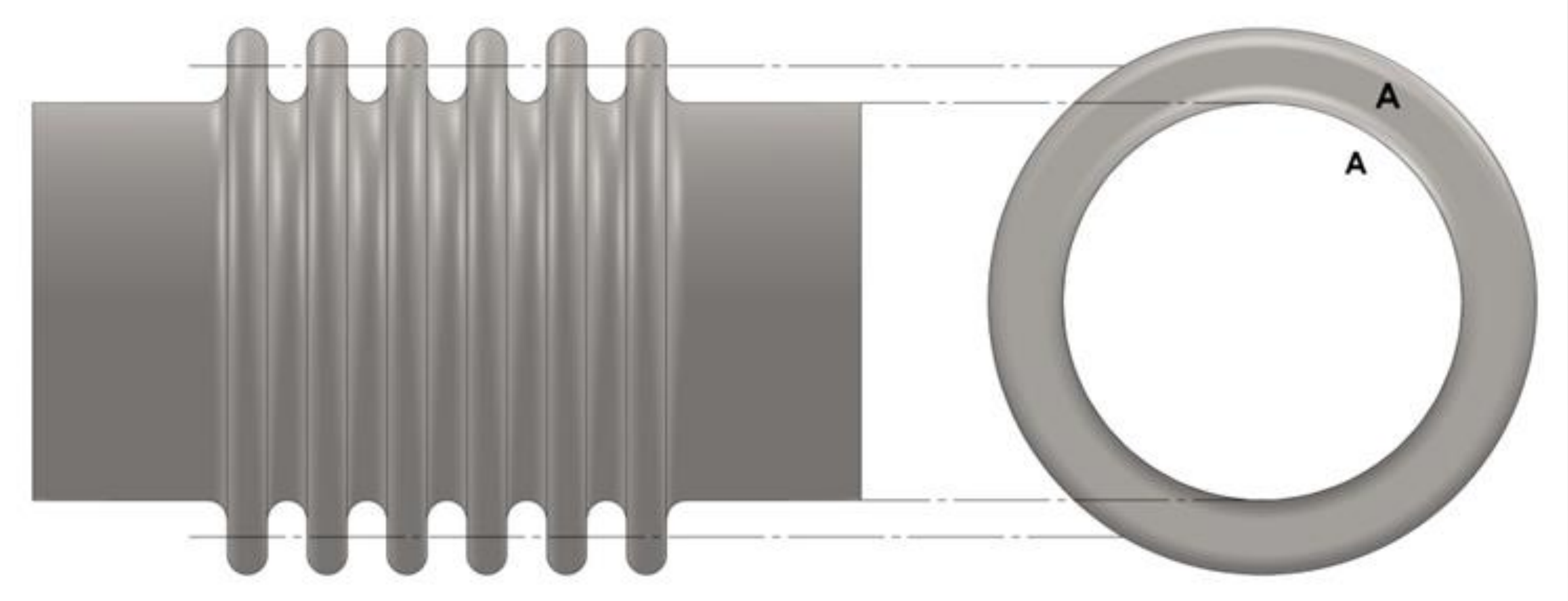
42,250 lbs Thrust Load

42,250 lbs = 3 African Bush Elephants

Pressure Thrust

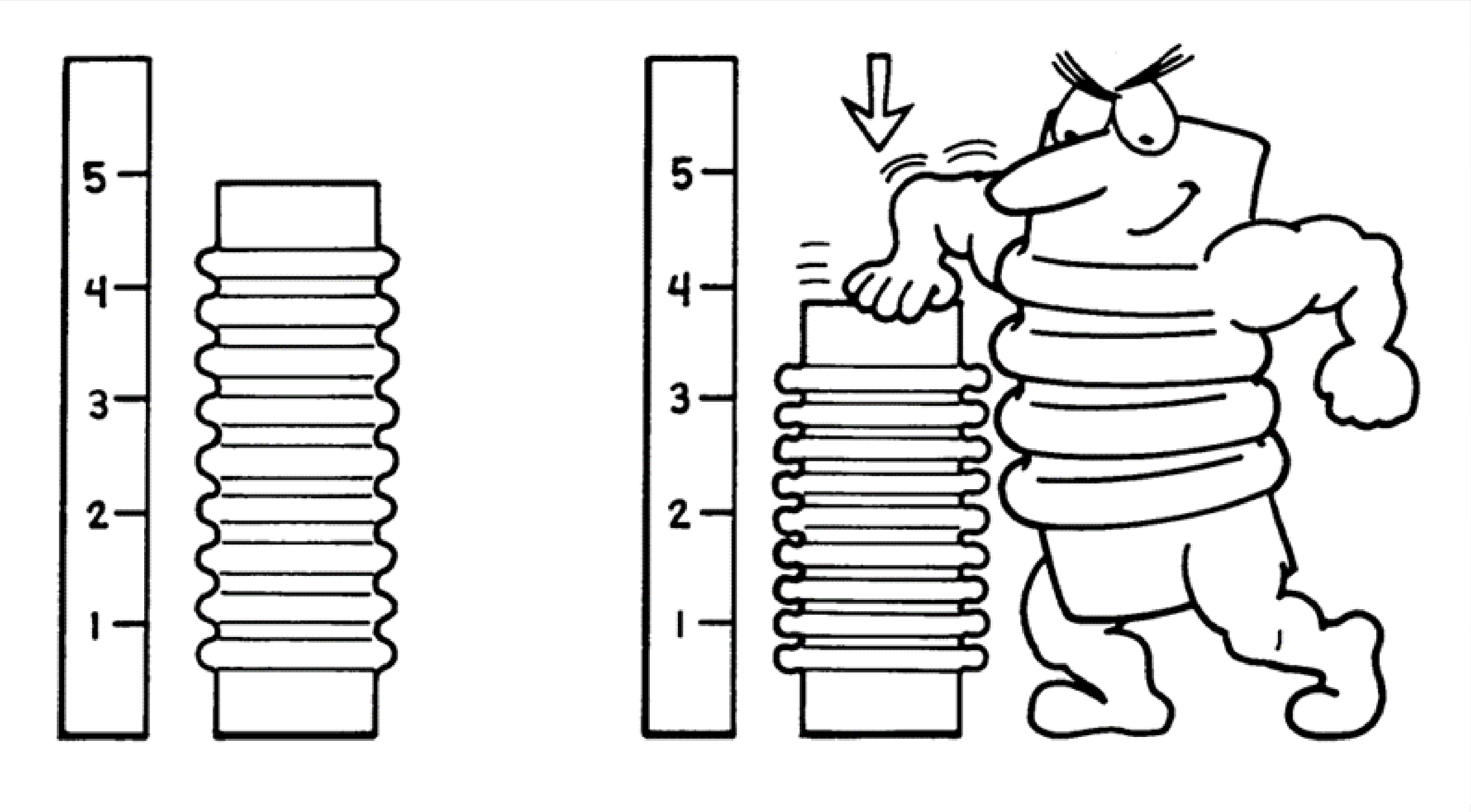
Pressure X effective area (Use the highest pressure possible, often the test pressure).

The effective area of a bellows is often over looked. The effective area can be found by calculating the area of the "mean" diameter of the bellows.

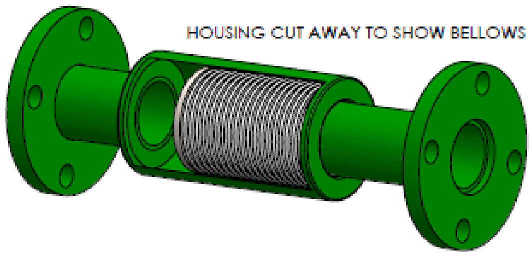


Deflection Load Published Spring Rate X movement of the joint

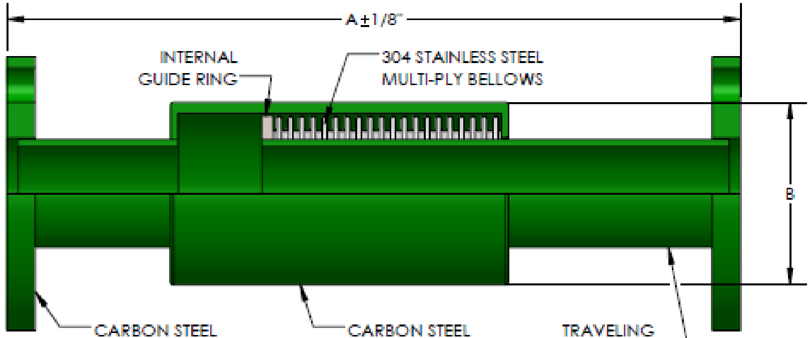
The deflection load is the force it takes to bend the stainless steel bellows



MODEL HPF3
HIGH PRESSURE
EXTERNALLY PRESSURIZED
EXPANSION COMPENSATOR



DESIGN DATA
TEMPERATURE: 750° (399°C)
PRESSURE: 175 PSI (1206 kPa)
TEST PRESSURE: 250 PSI (1809 kPa)
AXIAL COMPRESSION: 3" (80mm)
AXIAL EXTENSION: 1/2" (13mm)



THIS EXPANSION JOINT IS DESGINED FOR AXIAL MOVEMENT ONLY. PIPE MUST BE PROPERLY GUIDED AND ANCHORED PER THE RECOMMENDATIONS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION.

QTY	PART NUMBER	PIPE SIZE		A	B	EFFECTIVE AREA (in²)	SPRING RATE (lb/in)	WEIGHT	PROJECT INFORMATION
		INCH	MM						
	HPF30075	3/4"	20	17-1/8"	2-3/8"	1.5	58	9	
	HPF30100	1"	25	17-1/8"	2-1/2"	2.1	63	12	
	HPF30125	1-1/4"	32	17-1/8"	3"	3.3	52	13	
	HPF30150	1-1/2"	38	18-1/8"	3-1/2"	4.3	82	15	
	HPF30200	2"	50	18-1/8"	4"	6.3	117	20	
	HPF30250	2-1/2"	65	19-3/8"	5"	8.8	132	31	
	HPF30300	3"	80	19-7/8"	5-1/2"	13.1	161	36	
	HPF30400	4"	100	19-7/8"	6-5/8"	20.8	341	49	

NSF 372 - LEAD FREE
The wetted surface of this product contacted by consumable water contains less than one quarter of one percent (0.25%) of lead by weight. Material complies with state codes and standards, where applicable, requiring reduced lead content.

CUSTOMER:____________________
PROJECT:____________________
ENGINEER:____________________

REV.	DATE

2323 W. HUBBARD ST.
CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

MODEL HPF3
HIGH PRESSURE EXPANSION COMPENSATOR

DRAWN BY: DKISH	DATE: 9/3/2015
APPROVED: JC	DATE: 9/3/2015
SCALE: N/A	DRAWING NUMBER: HPF3

(Max Pressure X Effective Area) + (Spring Rate X Movement)

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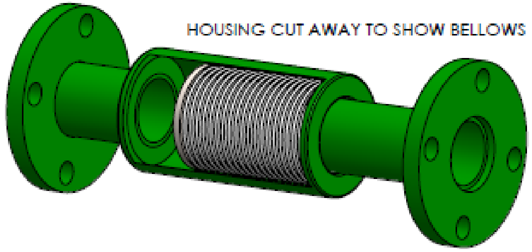
HPF30400
150 PSI Test Pressure
2” Axial Compression

MODEL HPF3
HIGH PRESSURE
EXTERNALLY PRESSURIZED
EXPANSION COMPENSATOR



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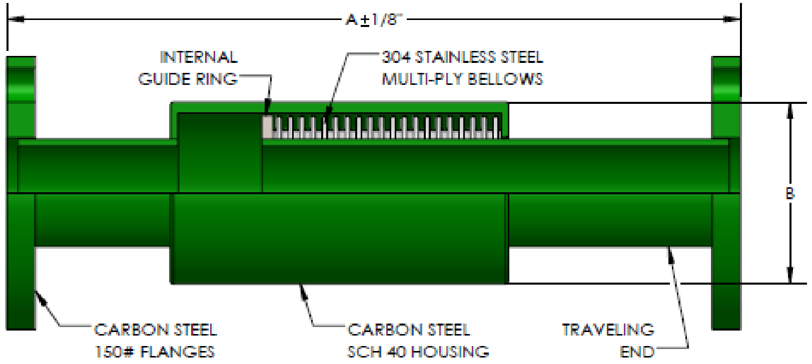

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HIGH PRESSURE EXPANSION COMPENSATOR

DRAWN BY: DKISH	DATE: 9/3/2015
APPROVED: JC	DATE: 9/3/2015
SCALE: N/A	DRAWING NUMBER: HPF3

(Max Pressure X Effective Area) + (Spring Rate X Movement)

(150 psi X 20.8 sq in) + (341 lbs X 2") = 3,802 lbs

QTY	PART NUMBER	PIPE SIZE		A	B	EFFECTIVE AREA (in²)	SPRING RATE (lb/in)	WEIGHT	PROJECT INFORMATION
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	HPF30200	2"	50	18-1/8"	4"	6.3	117	20	
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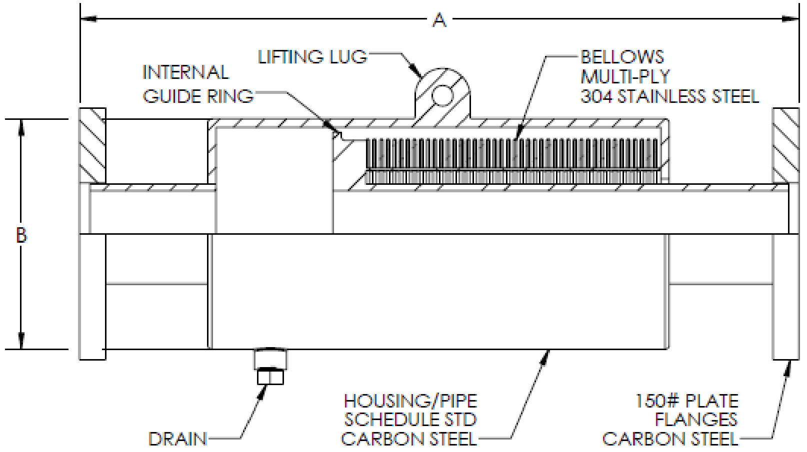
	HPF30400	4"	100	19-7/8"	6-5/8"	20.8	341	49	

HPF30400
150 PSI Test Pressure
2" Axial Compression

Friction Load = Weight of Pipe + Weight of Water X 0.3

METRAFLEX METRAGATOR
150 PSI, 4" AXIAL COMPRESSION, FLANGED
EXTERNALLY PRESSURIZED EXPANSION JOINT



THE EXPANSION JOINT IS DESIGNED FOR AXIAL MOVEMENT ONLY. PIPE MUST BE PROPERLY GUIDED AND ANCHORED PER THE RECOMMENDATIONS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION.

QTY	PART NUMBER	PIPE SIZE NPS	PIPE SIZE MM	A (in)	B (in)	EFF. AREA (in²)	SPRING RATE (lb/in)	NOTES
	GAT04SF0200	2	50	25	5.5	13.2	183.0	
	GAT04SF0250	2.5	65	25	5.5	13.2	183.0	
	GAT04SF0300	3	80	24	6.5	20.8	343.0	
	GAT04SF0400	4	100	25	8.5	36.0	200.0	
	GAT04SF0500	5	130	25	10.75	46.4	235.0	
	GAT04SF0600	6	150	25.5	12.75	58.9	269.0	
	GAT04SF0800	8	200	28.25	14	88.8	332.0	
	GAT04SF1000	10	250	27	16	124.6	400.0	
	GAT04SF1200	12	300	27	18	166.6	463.0	

DESIGN DATA
TEMPERATURE: 700°F (370°C)
PRESSURE: 150 PSI (1034 KPa)
TEST PRESSURE: 225 PSI (1551 KPa)
AXIAL MOVEMENT: 4" COMPRESSION (100 mm)

NOTE: ANCHOR LOAD = (MAX PSI X EFFECTIVE AREA) + (SPRING RATE X MOVEMENT)

MILITARY SPECS:
CONFORMS TO MIL-E-17813H AND ASTM-F-2934

REV.	DATE

2323 W. HUBBARD ST.
CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

METRAFLEX METRAGATOR, 150 PSI, 4" AXIAL COMPRESSION, FLANGED

DRAWN BY: DKISH DATE: 6/1/2015
APPROVED: ZB DATE: 6/2/2015
SCALE: N/A DRAWING NUMBER: GAT04SF

CUSTOMER:____________________
PROJECT:____________________
ENGINEER:____________________

Now You Try !!!

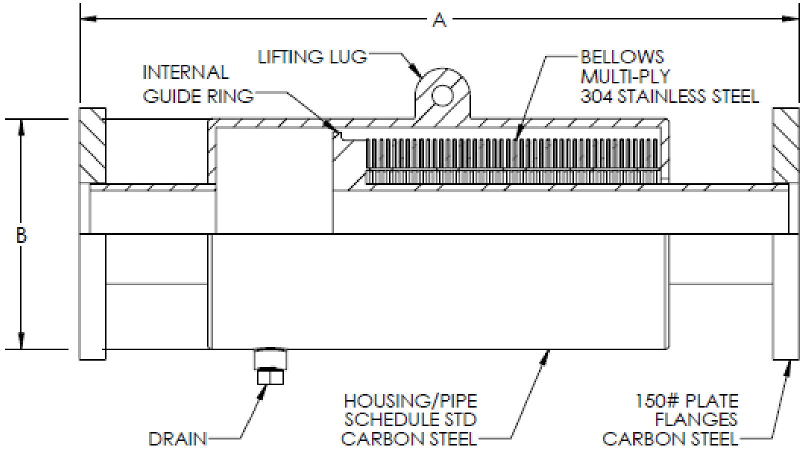
125 PSI Test Pressure
4" Axial Compression

Thrust Load = _________ LBS

EFF. AREA (in²)	SPRING RATE (lb/in)
13.2	183.0
13.2	183.0
20.8	343.0
36.0	200.0
46.4	235.0
58.9	269.0
88.8	332.0
124.6	400.0
166.6	463.0

(Max Pressure X Effective Area) + (Spring Rate X Movement)

METRAFLEX METRAGATOR
150 PSI, 4" AXIAL COMPRESSION, FLANGED
EXTERNALLY PRESSURIZED EXPANSION JOINT



THE EXPANSION JOINT IS DESIGNED FOR AXIAL MOVEMENT ONLY. PIPE MUST BE PROPERLY GUIDED AND ANCHORED PER THE RECOMMENDATIONS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION.

QTY	PART NUMBER	PIPE SIZE		A (in)	B (in)	EFF. AREA (in^2)	SPRING RATE (lb/in)	NOTES
		NPS	MM					
	GAT04SF0200	2	50	25	5.5	13.2	183.0	
	GAT04SF0250	2.5	65	25	5.5	13.2	183.0	
	GAT04SF0300	3	80	24	6.5	20.8	343.0	
	GAT04SF0400	4	100	25	8.5	36.0	200.0	
	GAT04SF0500	5	130	25	10.75	46.4	235.0	
	GAT04SF0600	6	150	25.5	12.75	58.9	269.0	
	GAT04SF0800	8	200	28.25	14	88.8	332.0	
	GAT04SF1000	10	250	27	16	124.6	400.0	
	GAT04SF1200	12	300	27	18	166.6	463.0	

DESIGN DATA
TEMPERATURE: 700°F (370°C)
PRESSURE: 150 PSI (1034 KPa)
TEST PRESSURE: 225 PSI (1551 KPa)
AXIAL MOVEMENT: 4" COMPRESSION (100 mm)

NOTE: ANCHOR LOAD =
(MAX PSI X EFFECTIVE AREA) +
(SPRING RATE X MOVEMENT)

MILITARY SPECS:
CONFORMS TO MIL-E-17813H AND ASTM-F-2934

REV. DATE

2323 W. HUBBARD ST.
CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

METRAFLEX METRAGATOR, 150 PSI,
4" AXIAL COMPRESSION, FLANGED

DRAWN BY: DKISH DATE: 6/1/2015
APPROVED: ZB DATE: 6/2/2015
SCALE: N/A DRAWING NUMBER: GAT04SF

CUSTOMER:__________
PROJECT:__________
ENGINEER:__________

Now You Try !!!

125 PSI Test Pressure

88.8 sq. in. X 125 PSI = 11,100 lbs

4” Axial Compression

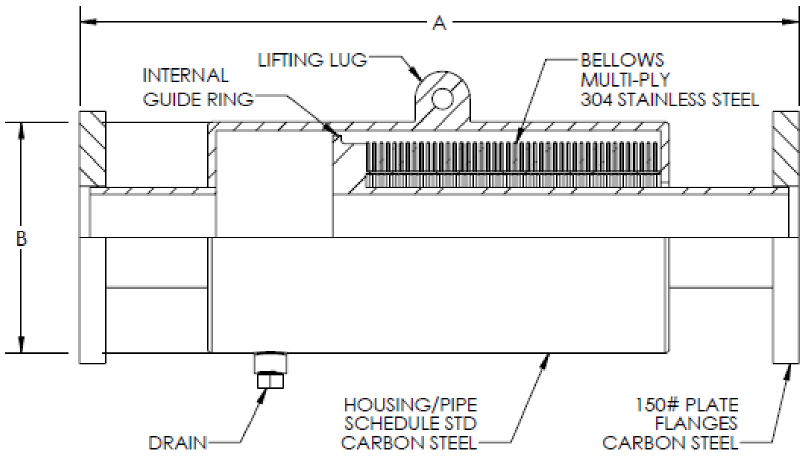
332 lb/in X 4” = 1,328 lbs

Thrust Load = 12,428 LBS

EFF. AREA (in^2)	SPRING RATE (lb/in)
13.2	183.0
13.2	183.0
20.8	343.0
36.0	200.0
46.4	235.0
58.9	269.0
88.8	332.0
124.6	400.0
166.6	463.0

(Max Pressure X Effective Area) + (Spring Rate X Movement)

METRAFLEX METRAGATOR
150 PSI, 4" AXIAL COMPRESSION, FLANGED
EXTERNALLY PRESSURIZED EXPANSION JOINT



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QTY	PART NUMBER	PIPE SIZE NPS	PIPE SIZE MM	A (in)	B (in)	EFF. AREA (in^2)	SPRING RATE (lb/in)	NOTES
	GAT04SF0200	2	50	25	5.5	13.2	183.0	
	GAT04SF0250	2.5	65	25	5.5	13.2	183.0	
	GAT04SF0300	3	80	24	6.5	20.8	343.0	
	GAT04SF0400	4	100	25	8.5	36.0	200.0	
	GAT04SF0500	5	130	25	10.75	46.4	235.0	
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	GAT04SF0800	8	200	28.25	14	88.8	332.0	
	GAT04SF1000	10	250	27	16	124.6	400.0	
	GAT04SF1200	12	300	27	18	166.6	463.0	

DESIGN DATA
TEMPERATURE: 700°F (370°C)
PRESSURE: 150 PSI (1034 KPa)
TEST PRESSURE: 225 PSI (1551 KPa)
AXIAL MOVEMENT: 4" COMPRESSION (100 mm)

NOTE: ANCHOR LOAD =
(MAX PSI X EFFECTIVE AREA) +
(SPRING RATE X MOVEMENT)

MILITARY SPECS:
CONFORMS TO MIL-E-17813H AND ASTM-F-2934

REV.	DATE

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CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

METRAFLEX METRAGATOR, 150 PSI,
4" AXIAL COMPRESSION, FLANGED

DRAWN BY: DKISH DATE: 6/1/2015
APPROVED: ZB DATE: 6/2/2015
SCALE: N/A DRAWING NUMBER: GAT04SF

CUSTOMER:____________________
PROJECT:____________________
ENGINEER:____________________

Let's Try Another !!!

125 PSI Test Pressure

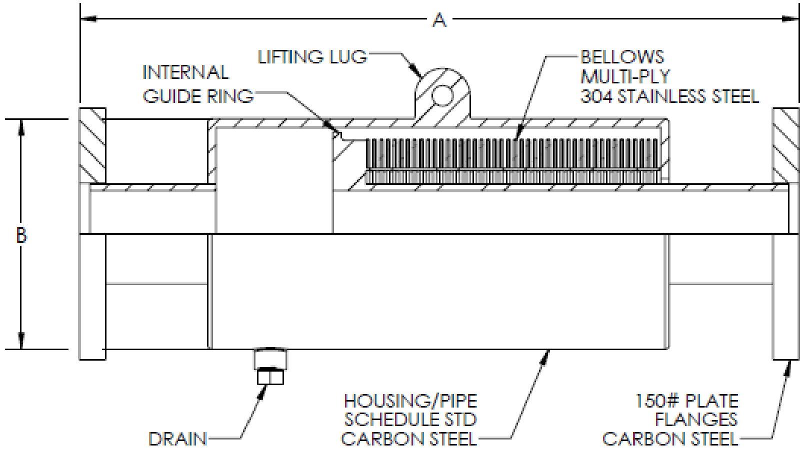
4" Axial Compression

Thrust Load = ________ LBS

EFF. AREA (in^2)	SPRING RATE (lb/in)
13.2	183.0
13.2	183.0
20.8	343.0
36.0	200.0
46.4	235.0
58.9	269.0
88.8	332.0
124.6	400.0
166.6	463.0

(Max Pressure X Effective Area) + (Spring Rate X Movement)

METRAFLEX METRAGATOR
150 PSI, 4" AXIAL COMPRESSION, FLANGED
EXTERNALLY PRESSURIZED EXPANSION JOINT



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QTY	PART NUMBER	PIPE SIZE NPS	PIPE SIZE MM	A (in)	B (in)	EFF. AREA (in²)	SPRING RATE (lb/in)	NOTES
	GAT04SF0200	2	50	25	5.5	13.2	183.0	
	GAT04SF0250	2.5	65	25	5.5	13.2	183.0	
	GAT04SF0300	3	80	24	6.5	20.8	343.0	
	GAT04SF0400	4	100	25	8.5	36.0	200.0	
	GAT04SF0500	5	130	25	10.75	46.4	235.0	
	GAT04SF0600	6	150	25.5	12.75	58.9	269.0	
	GAT04SF0800	8	200	28.25	14	88.8	332.0	
	GAT04SF1000	10	250	27	16	124.6	400.0	
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DESIGN DATA
TEMPERATURE: 700°F (370°C)
PRESSURE: 150 PSI (1034 KPa)
TEST PRESSURE: 225 PSI (1551 KPa)
AXIAL MOVEMENT: 4" COMPRESSION (100 mm)

NOTE: ANCHOR LOAD =
(MAX PSI X EFFECTIVE AREA) +
(SPRING RATE X MOVEMENT)

MILITARY SPECS:
CONFORMS TO MIL-E-17813H AND ASTM-F-2934

REV.	DATE

2323 W. HUBBARD ST.
CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

METRAFLEX METRAGATOR, 150 PSI,
4" AXIAL COMPRESSION, FLANGED

DRAWN BY: DKISH DATE: 6/1/2015
APPROVED: ZB DATE: 6/2/2015
SCALE: N/A DRAWING NUMBER: GAT04SF

CUSTOMER:________________________
PROJECT:________________________
ENGINEER:________________________

Let's Try Another !!!

125 PSI Test Pressure

166.6 sq. in. X 125 PSI = 20,825 lbs

4" Axial Compression

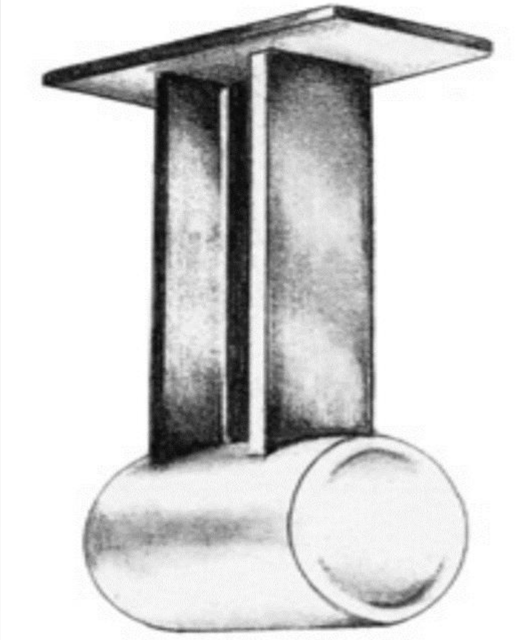
463 lb/in X 4" = 1,852 lbs

Thrust Load = 22,677 LBS

EFF. AREA (in²)	SPRING RATE (lb/in)
13.2	183.0
13.2	183.0
20.8	343.0
36.0	200.0
46.4	235.0
58.9	269.0
88.8	332.0
124.6	400.0
166.6	463.0

(Max Pressure X Effective Area) + (Spring Rate X Movement)

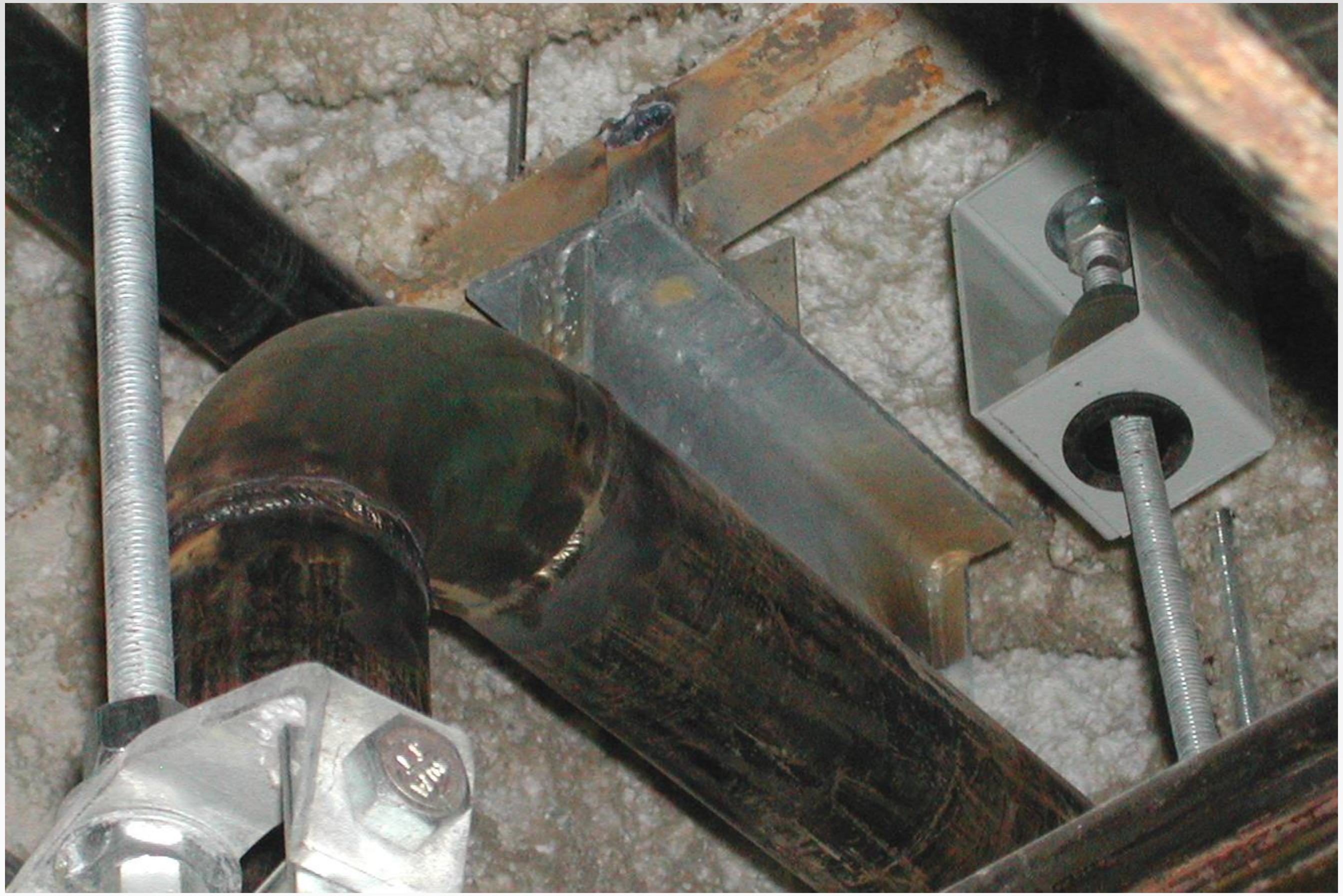
Prefabricated Anchors



*Anchor loads must be predetermined by manufacturer

Part No.	Bottom to Pipe	Top to Base	Width Plane View	Bottom Plate/ Side View	Mounting Bolt Hole Centerline/ Side View	Mounting Bolt Hole Size	Working Loads (lbs)
PAPI0150	5.25	11.82	10.00	8.00	6.00	0.62	2,200
PAPI0200	5.12	11.93	10.00	8.00	6.00	0.62	2,200
PAPI0250	5.38	13.43	12.00	8.00	6.00	0.62	5,750
PAPI0300	5.12	13.49	12.00	8.00	6.00	0.62	5,750
PAPI0400	5.25	14.62	13.00	10.00	8.00	0.88	7,150
PAPI0500	5.25	15.72	14.00	10.00	8.00	0.88	9,100
PAPI0600	5.25	17.26	16.00	12.00	10.00	1.12	12,800
PAPI0800	6.50	20.64	18.50	12.00	10.00	1.12	17,500

Simple Steel Anchor

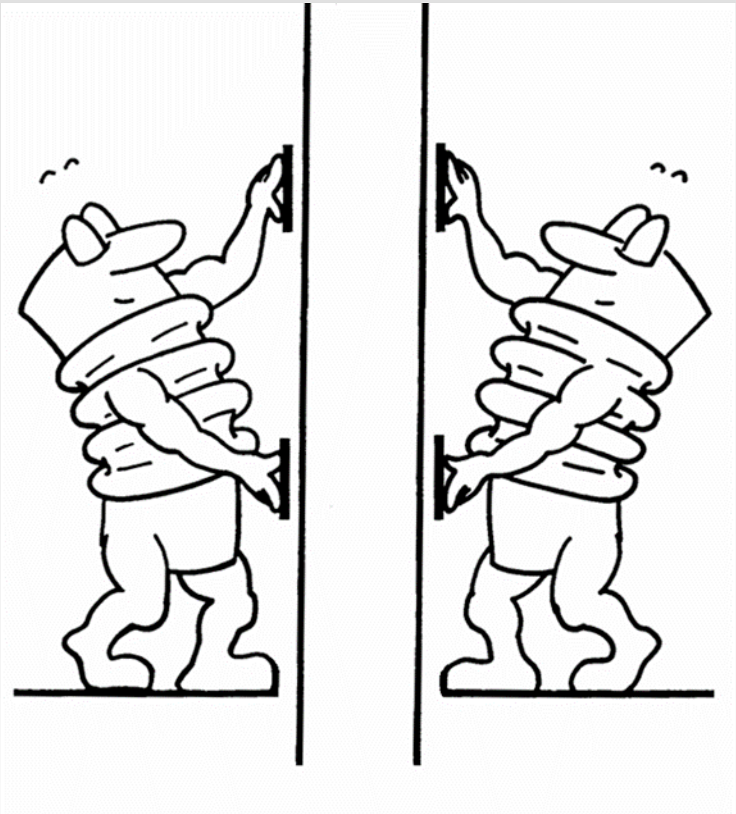


Complex Steel Anchor

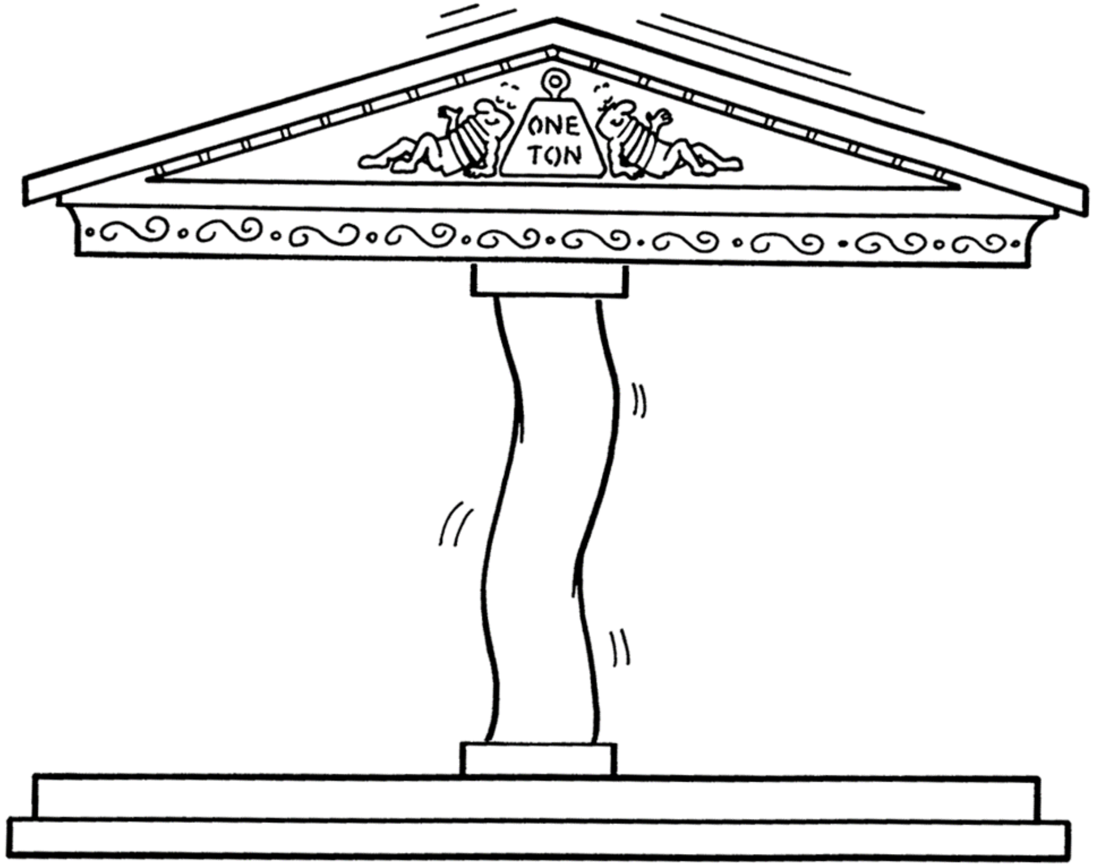
No Anchors

Incorrectly Designed Anchors

Guiding



Column strength of pipe



PIPE SIZE	MAXIMUM LOADS AT LENGTHS OF		
	200 FT	100 FT	50 FT
4	359 LBS	1,437 LBS	5,748 LBS
6	1,396	5,585	22,341
8	3,602	14,410	57,641
12	13,864	55,454	221,820

CONCENTRIC PIPE GUIDE SPACING

* Data Per Expansion Joint Manufacturers Association

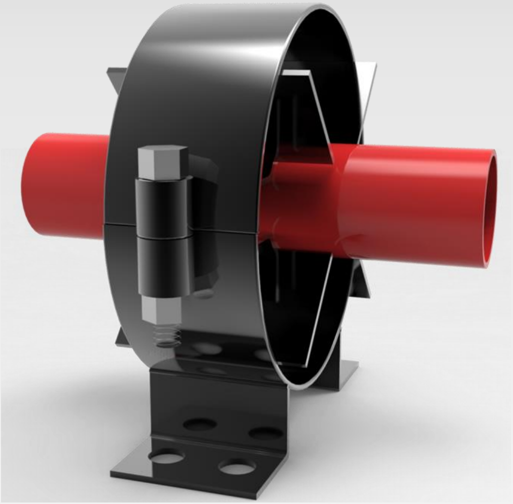
Pipe Size	Maximum Distance To 1st Guide	Approx. Distance Between 1st to 2nd Guide	Approximate Distance Between Additional Pipe Guides (In feet)			
			@ 50 PSI	@ 100 PSI	@ 150 PSI	@ 300 PSI
1"	4"	1'4"	21'	15'	12'	10'
1-1/4"	5"	1'5"	23	17	13	12
1-1/2"	6"	1'9"	28	20	17	13
2"	8"	2'4"	32	23	18	15
2-1/2"	10"	2'11"	35	28	22	20
3"	1'	3'6"	38	28	23	17
3-1/2"	1'2"	4'1"	45	35	27	19
4"	1'4"	4'8"	52	38	31	22
5"	1'8"	5'8"	63	45	38	25
6"	2'	7'	68	48	40	28
8"	2'8"	9'4"	87	62	45	38
10"	3'4"	11'8"	107	75	60	48
12"	4'	14'	118	85	70	50
14"	4'8"	16'4"	122	88	72	55
16"	5'4"	18'8"	137	96	80	60
18"	6'	21'	145	105	85	65
20"	6'8"	23'4"	160	118	90	70
24"	8'	28'	181	125	105	75

4, 14, 40

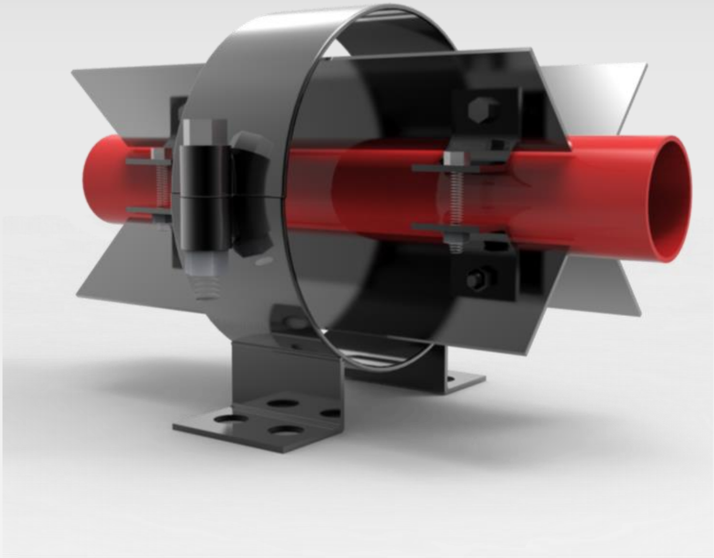
Pipe Diameters

Traditional Pipe Alignment Guides

Spider Type



Standard



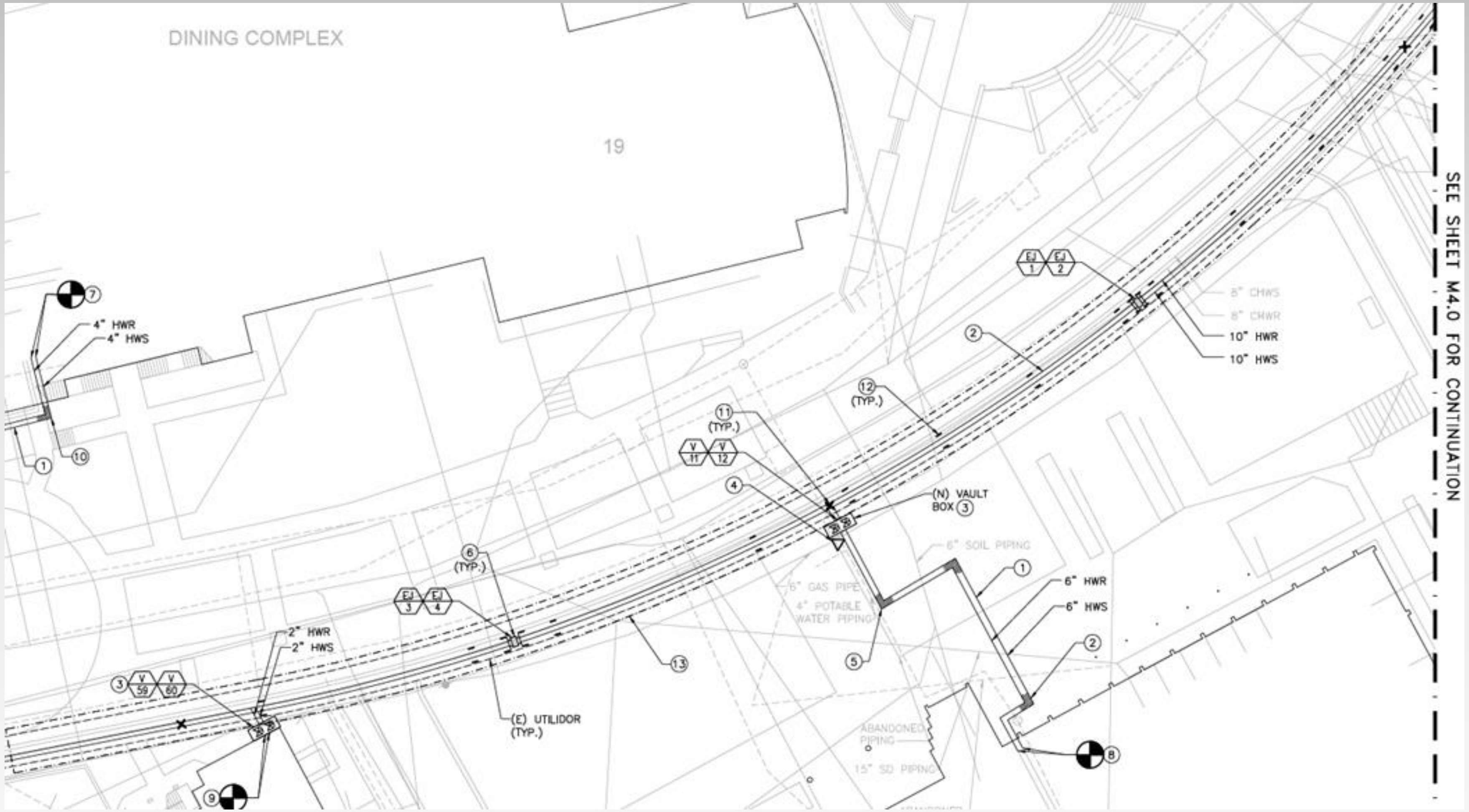
Extended Spider Type
(for larger movements)

Slide Guides

Standard

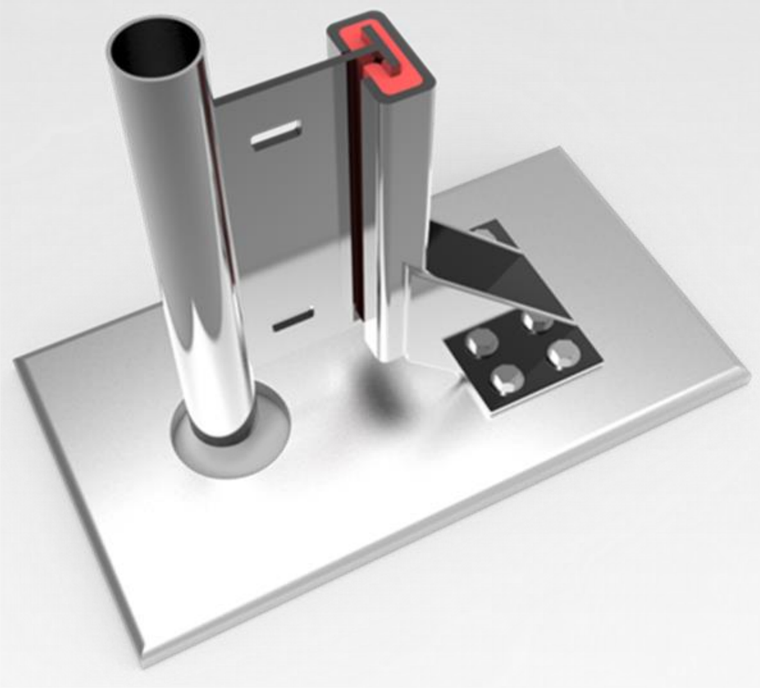
Pre-Insulated

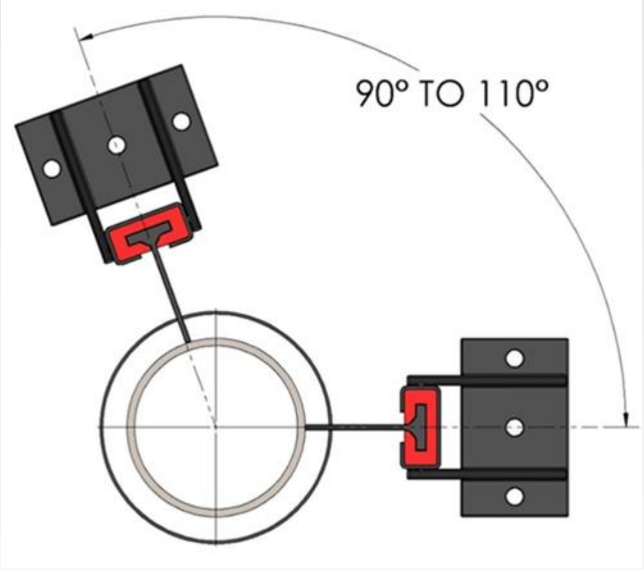
<u>Rated to restrain both the lateral loads and dead load of the pipe</u>



USE SLIDE GUIDES FOR CURVED PIPE

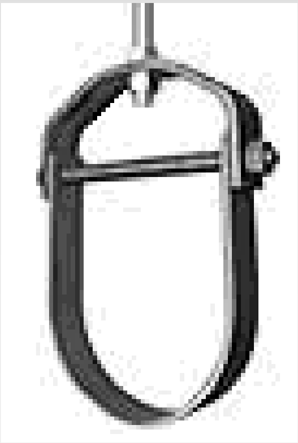
Riser Guide



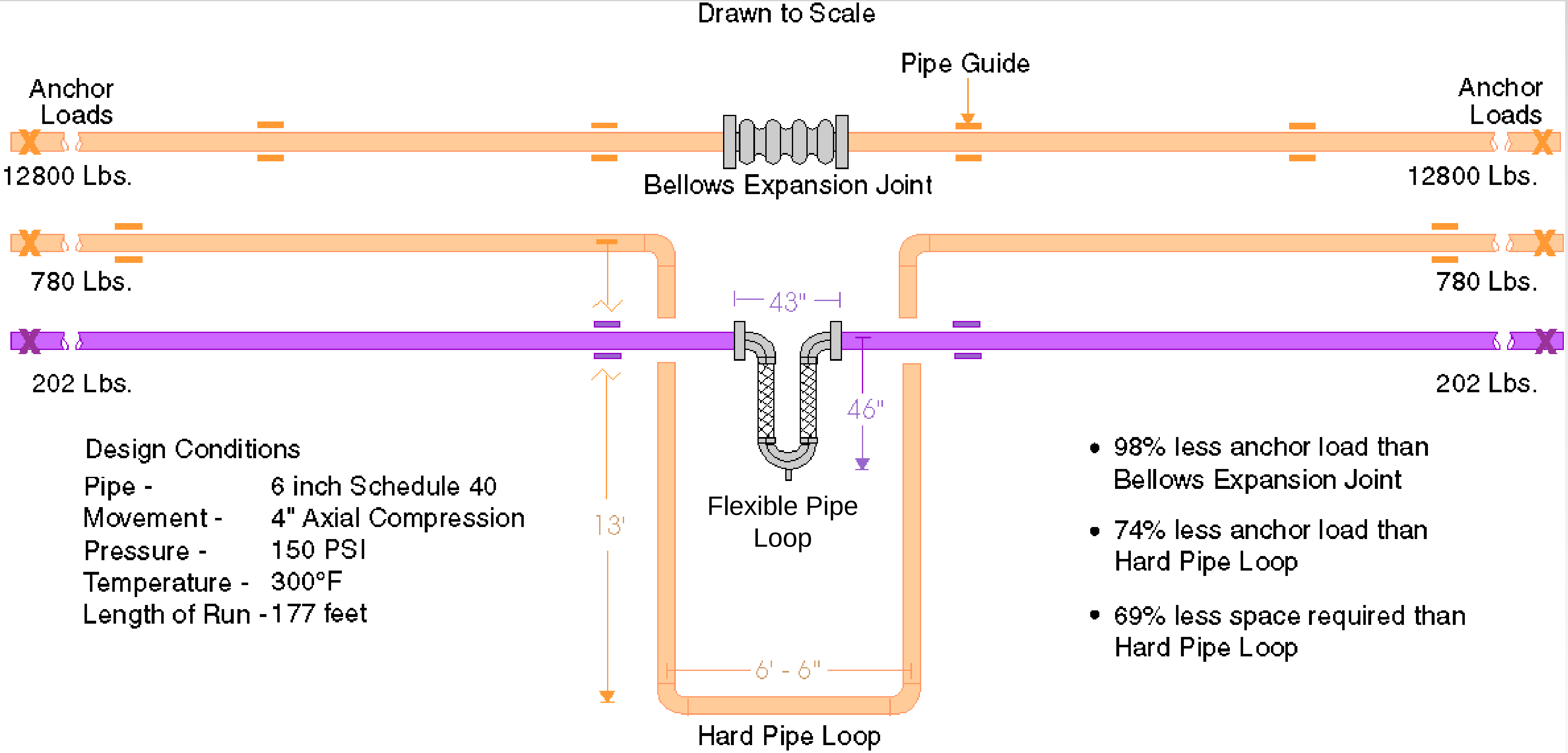


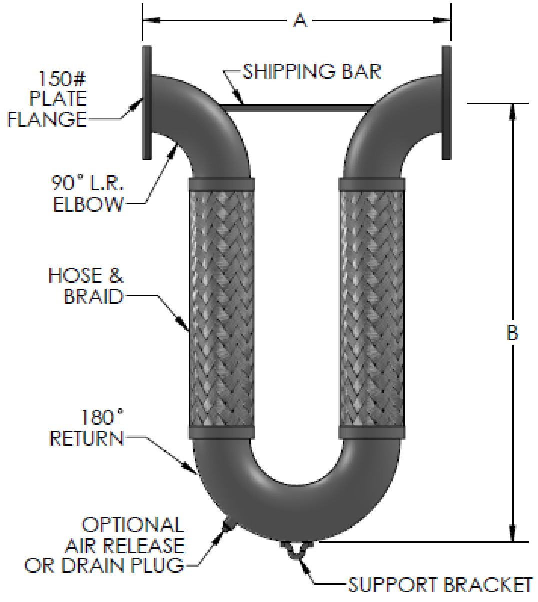
No Guides

Could these be used as guides?



The flexible pipe loop is also smaller and has less anchor load than a hard pipe loop





MATERIALS OF CONSTRUCTION*

END FITTINGS - CARBON STEEL - SCH 40/STD WT
HOSE & BRAID - STAINLESS STEEL - 300 SERIES
90° ELBOW - CARBON STEEL - SCH 40/STD WT
180° RETURN - CARBON STEEL - SCH 40/STD WT
*OTHER MATERIALS AVAILABLE

NSF 372 - LEAD FREE

The wetted surface of this product contacted by consumable water contains less than one quarter of one percent (0.25%) of lead by weight. Material complies with state codes and standards, where applicable, requiring reduced lead content.

NOTE: METRALOOPS 2" AND LARGER INSTALLED IN ANY ORIENTATION OTHER THAN HANGING DOWN *MUST* HAVE THE 180° RETURN SUPPORTED. (SEE INSTALLATION INSTRUCTIONS.)

CONTACT FACTORY FOR ADDITIONAL SIZES AND MOVEMENTS. ALL DIMENSIONS IN INCHES.

QTY	SIZE	MODEL	MVMT	A	B	PSI*	WT (LBS)	SPRING FORCE**	PROJECT INFO
	2	MLF80200	+/- 4	14.5	24.5	500	24	78	
	2.5	MLF80250	+/- 4	16	28.25	387	36	83	
	3	MLF80300	+/- 4	18.5	30	288	50	90	
	4	MLF80400	+/- 4	24.5	35.375	232	69	120	
	5	MLF80500	+/- 4	30.5	40.25	191	101	186	
	6	MLF80600	+/- 4	36.5	45.375	165	163	202	
	8	MLF80800	+/- 4	48.5	53.5	212	309	260	
	10	MLF81000	+/- 4	60.5	63.25	175	484	283	
	12	MLF81200	+/- 4	72.5	72.75	160	666	390	

120 lbs VS 3,802 lbs

260 lbs VS 12,482 lbs

*Working pressure listed is the rating at 70° F. Contact factory for other pressure ratings at other temperatures and for steam applications.

**Spring force: The total force (Lbs) required to move the Metraloop its full rated movement for 150 PSI @ 70°F.

CUSTOMER:________________

PROJECT:________________

ENGINEER:________________

REV. 1 SUPPORT BRACKET CHANGE DATE 2/5/2015

Metraflex for pipes in motion

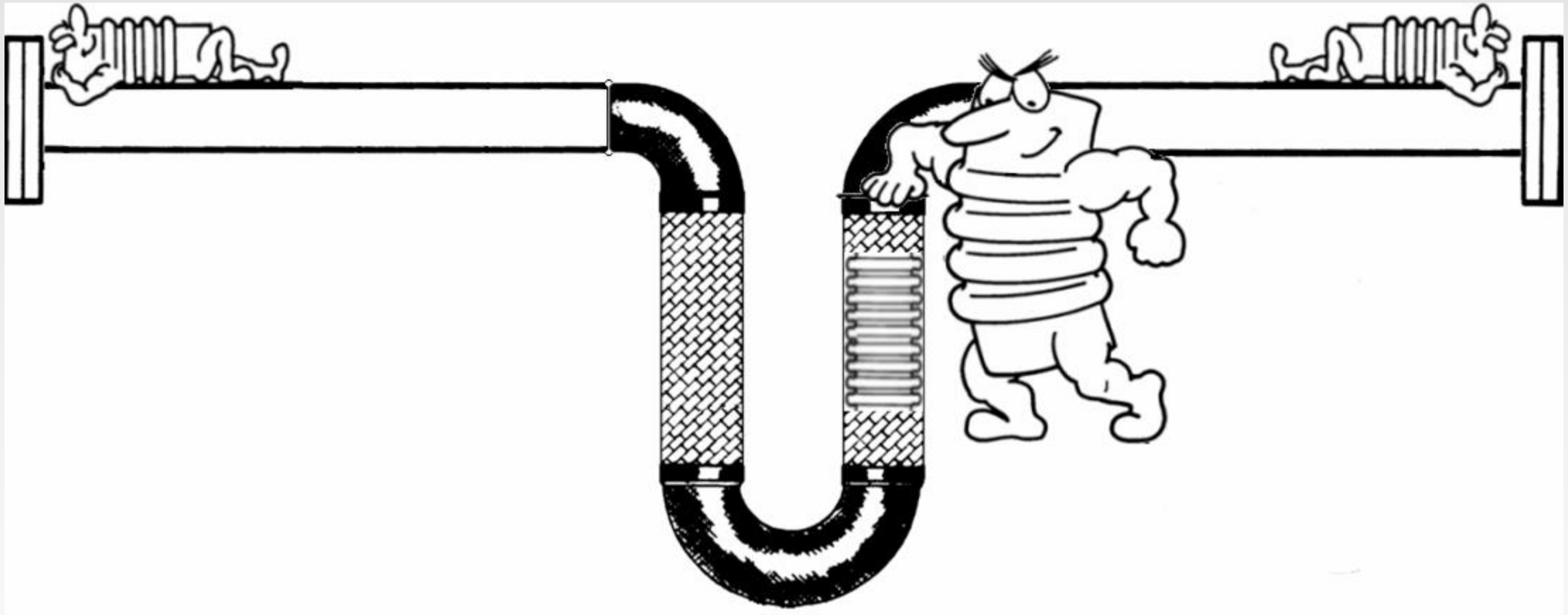
2323 W. HUBBARD ST.
CHICAGO, IL 60612
TEL: 312-738-3800
FAX: 312-738-0415
WWW.METRAFLEX.COM

METRALOOP®

FLANGED, +/- 4" MOVEMENT

DRAWN BY: DKISH DATE: 10/29/2014
APPROVED: JC DATE: 10/29/2014
SCALE: NONE DRAWING NUMBER: MLF8-REV1

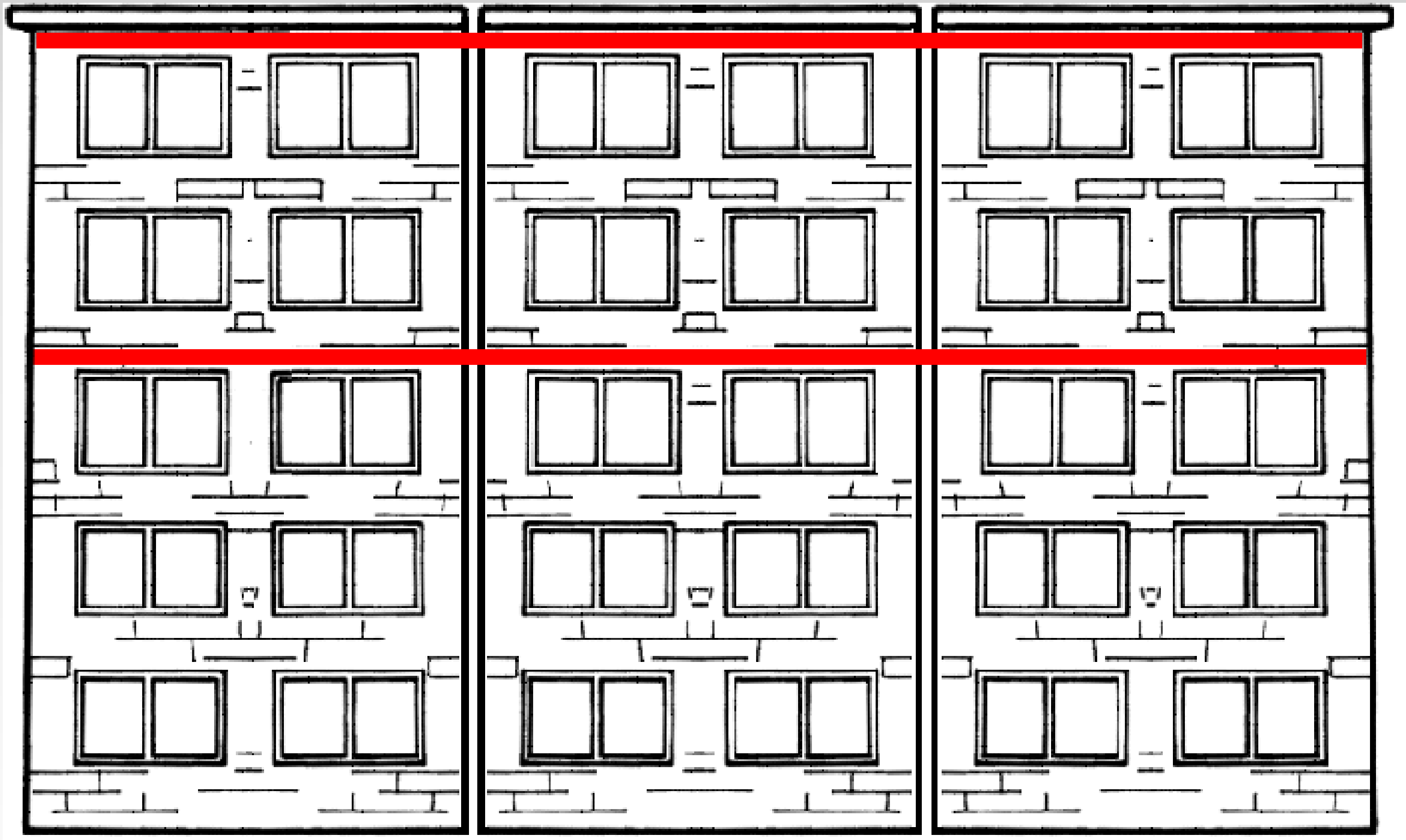
On a flex loop the braid is the anchor



Flexible Loops can use light weight anchor clamps

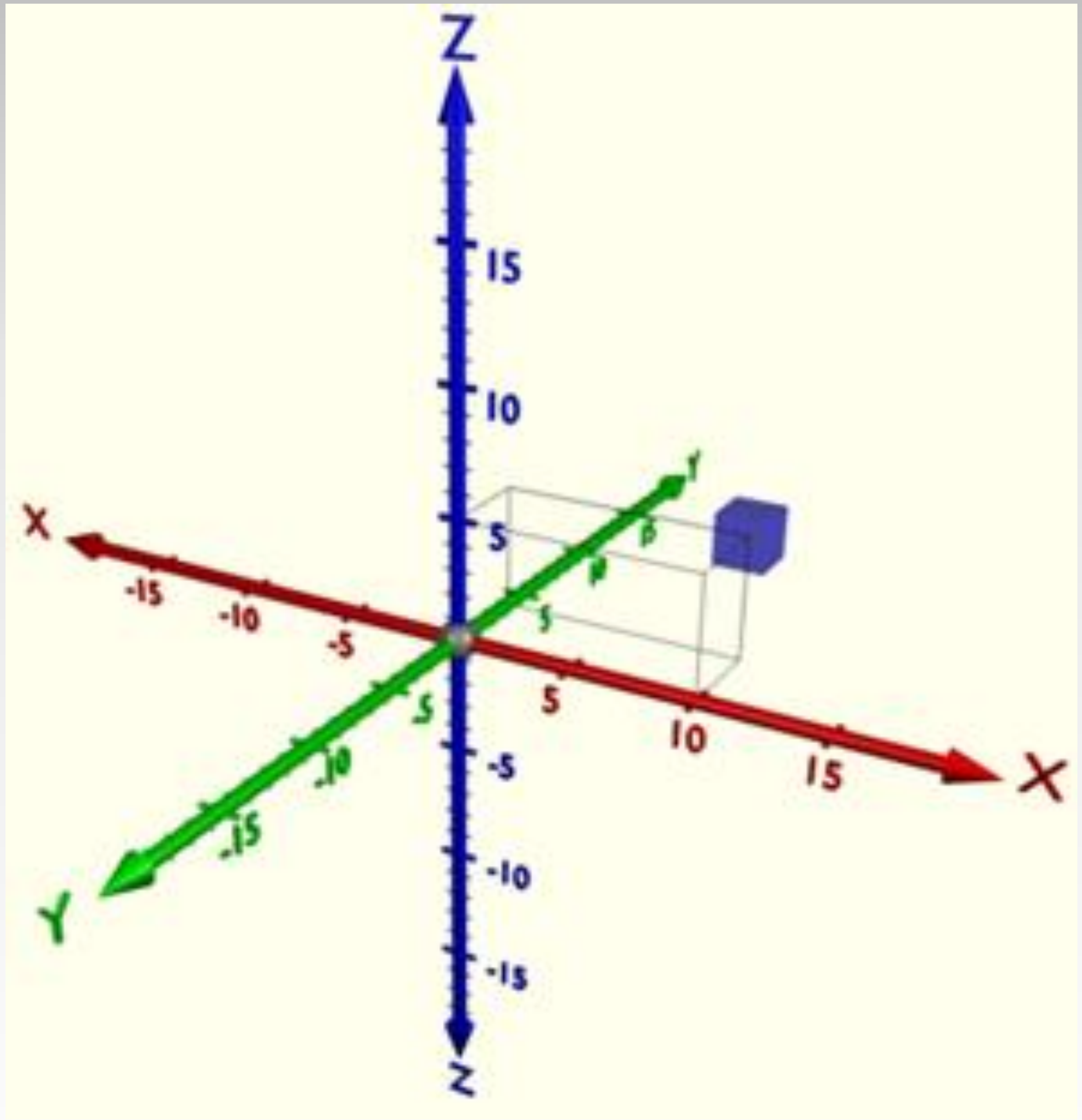
*Anchor loads must be predetermined by manufacturer

A building's seismic joints (before)



A building's seismic joints (after)

A building's seismic joints (after)


Z
15
10
5
-5
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X
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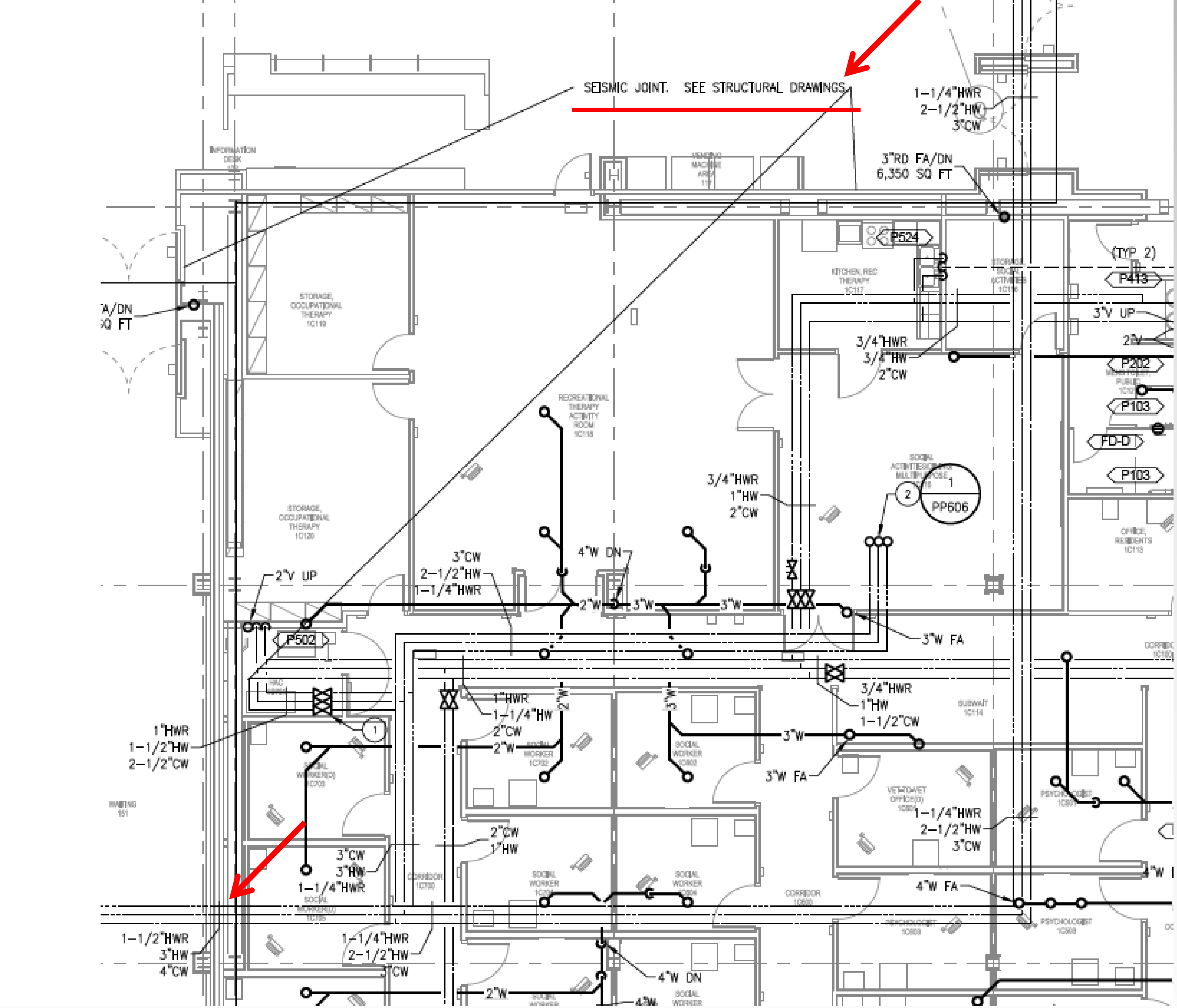
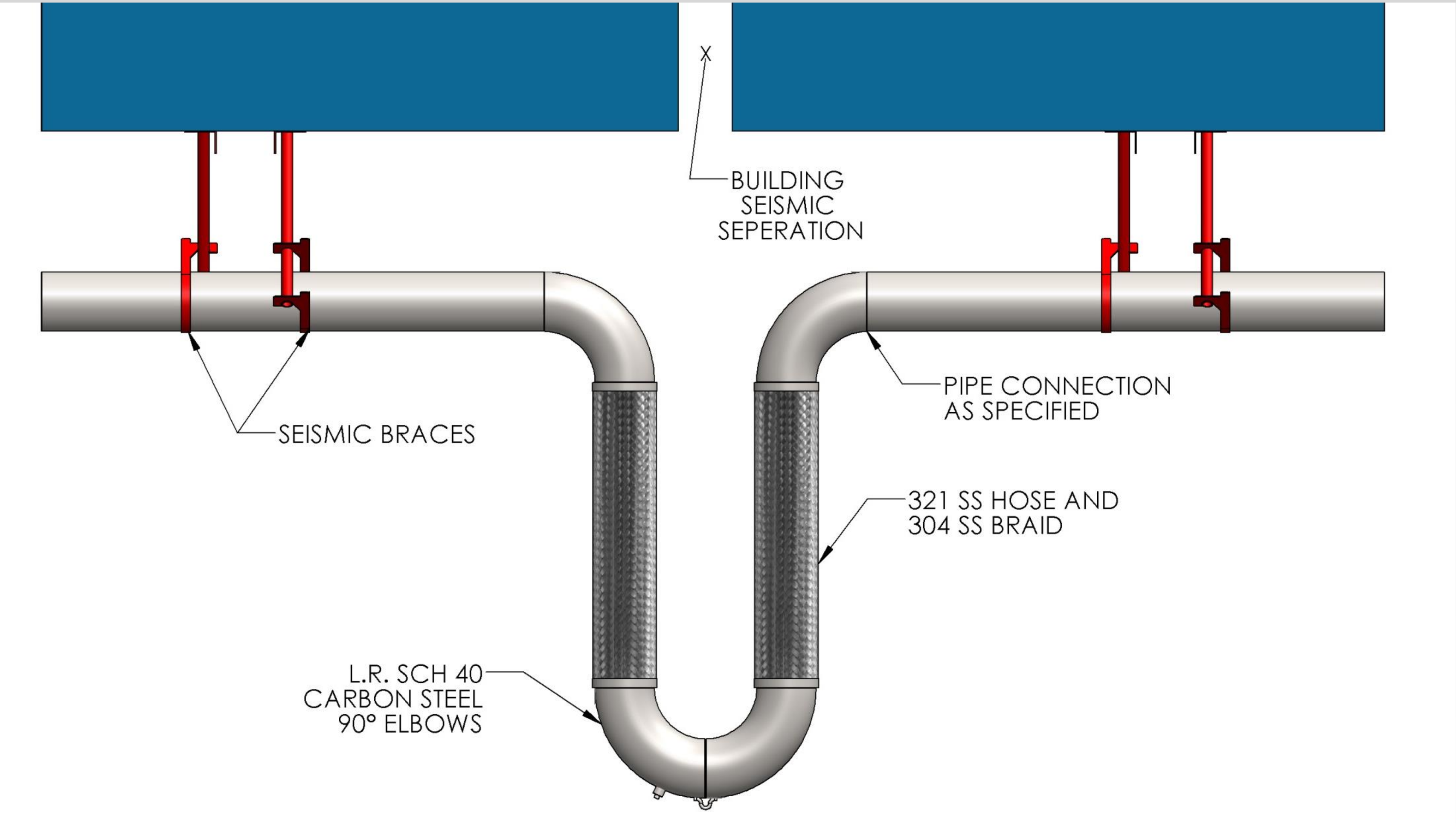
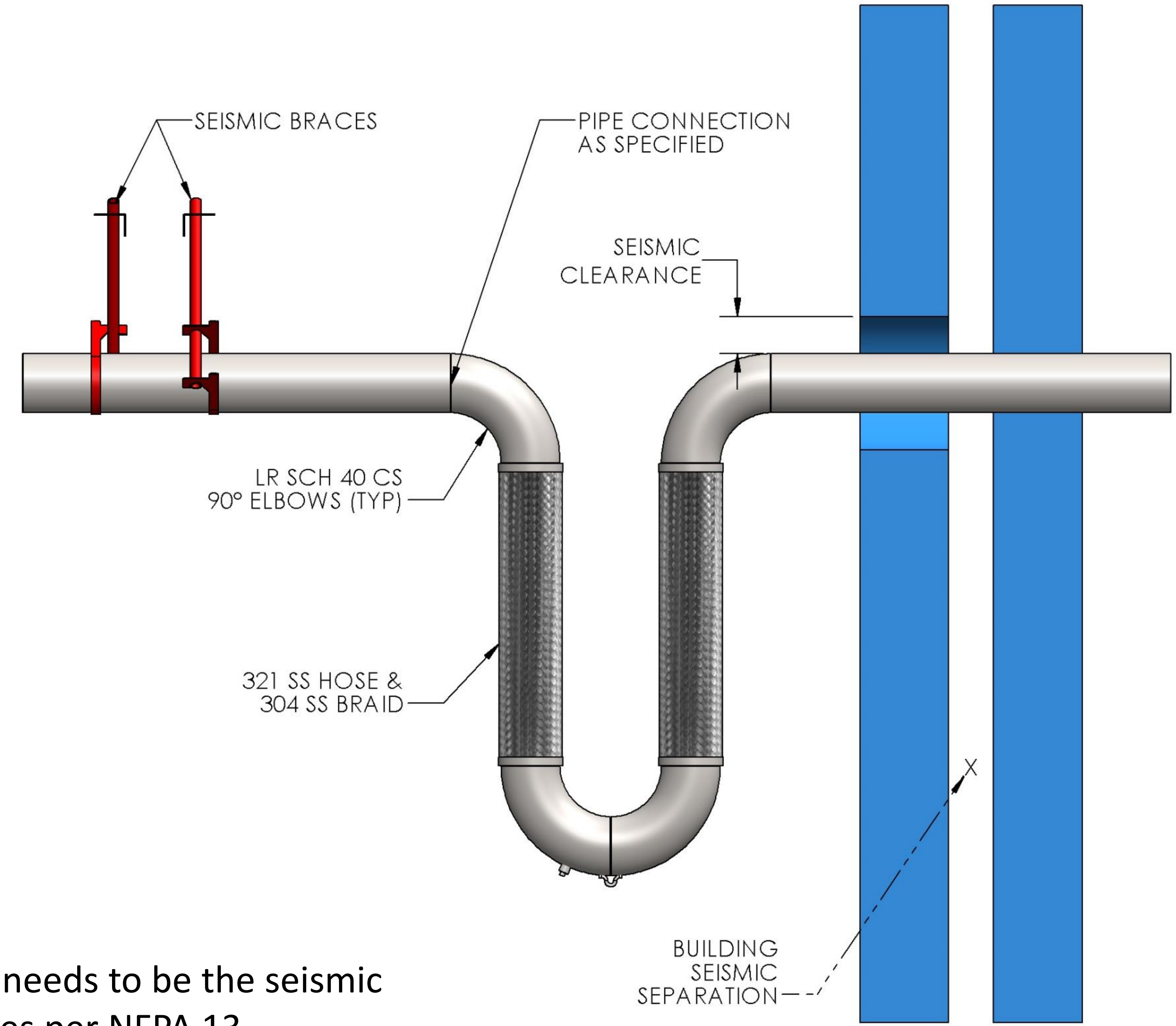

SEISMIC JOINT. SEE STRUCTURAL DRAWINGS.
1-1/4"HWR
2-1/2"HW
3"CW
3"RD FA/DN
6,350 SQ FT
P524
(TYP 2)
P413
3"V UP
P202
P103
FD-D
P103
3/4"HWR
3/4"HW
2"CW
3/4"HWR
1"HW
2"CW
PP606
3"CW
2-1/2"HW
1-1/4"HWR
4"W DN
2"V UP
P502
2"W
3"W
3"W
3"W FA
3/4"HWR
1"HW
1-1/2"CW
1"HWR
1-1/4"HW
2"CW
2"W
1"HWR
1-1/2"HW
2-1/2"CW
3"W
3"W FA
1-1/4"HWR
2-1/2"HW
3"CW
2"CW
1"HW
3"CW
3"HW
1-1/4"HWR
4"W FA
1-1/2"HWR
3"HW
4"CW
1-1/4"HWR
2-1/2"HW
3"CW
4"W DN
2"W

Per NFPA 13

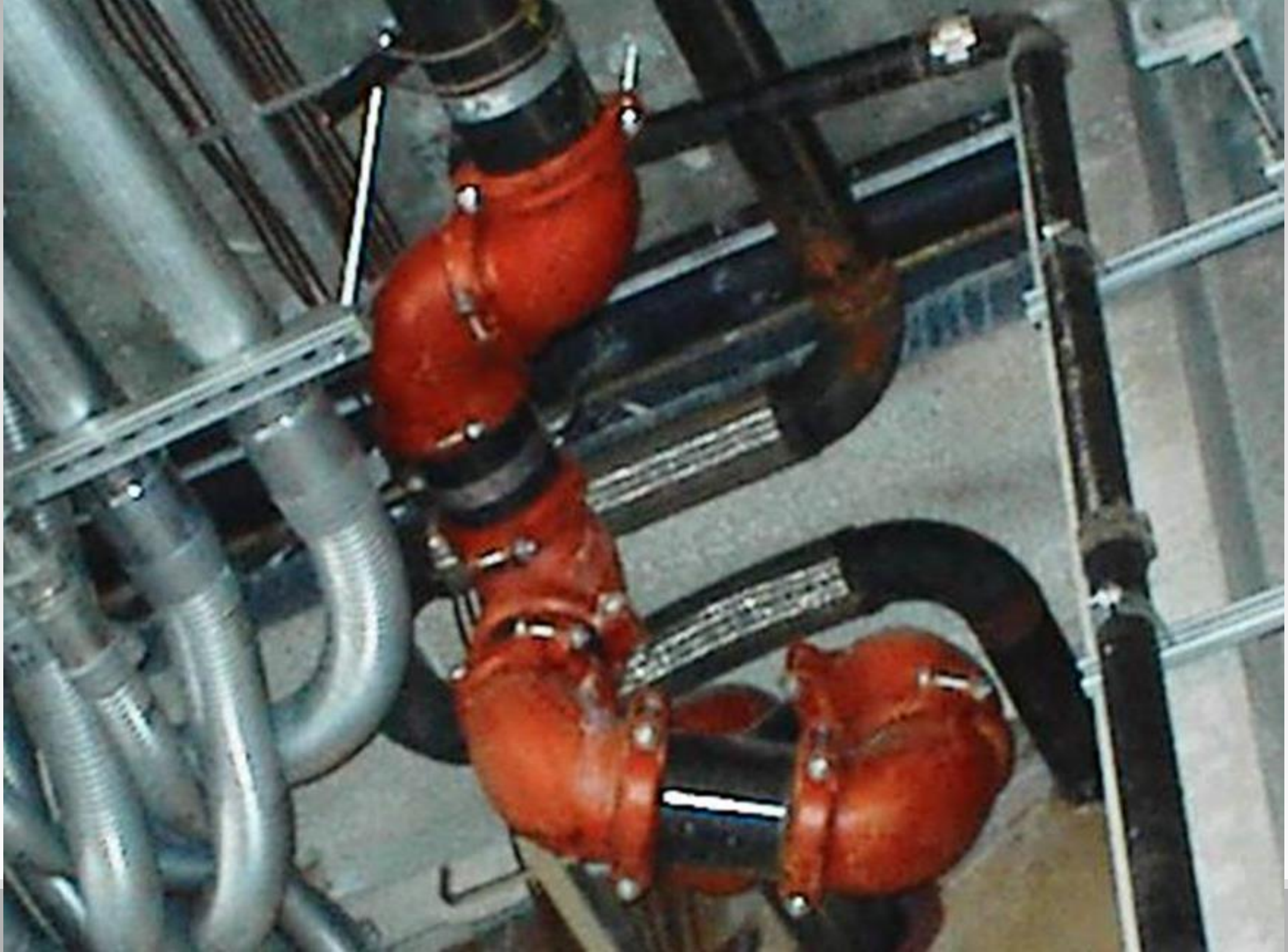
Each seismic brace can be no farther than 6 feet from the seismic separation.

The seismic device (flexible loop) can be no farther than 2 feet from the seismic separation.

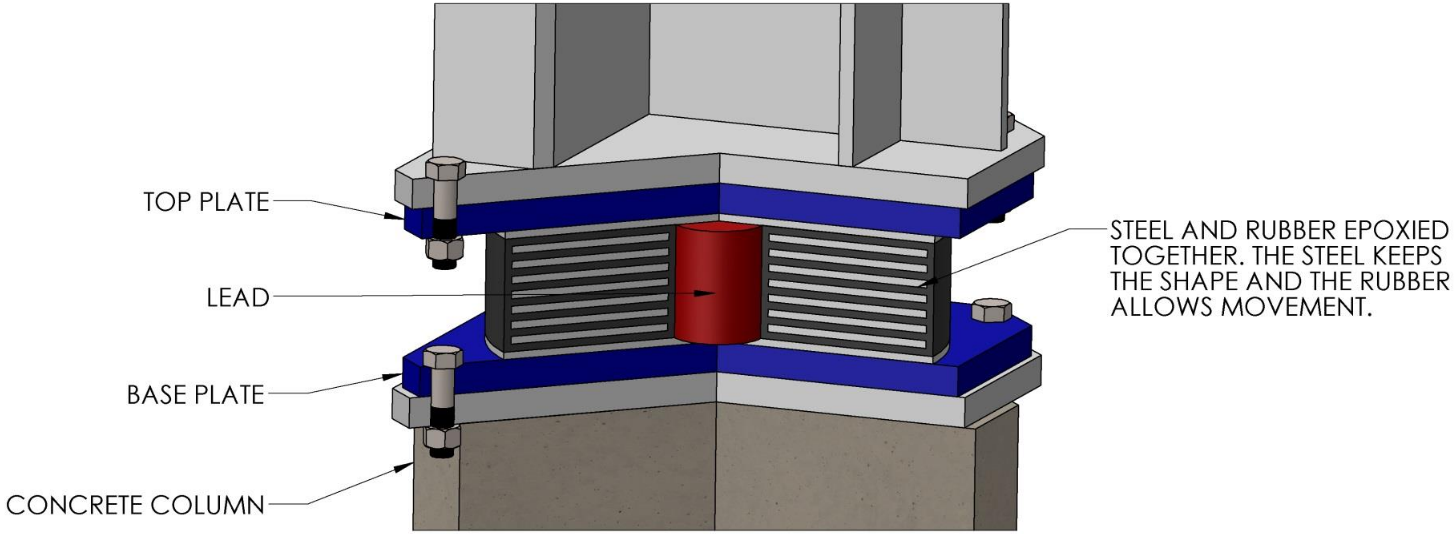




The seismic clearance needs to be the seismic movement plus 2 inches per NFPA 13.



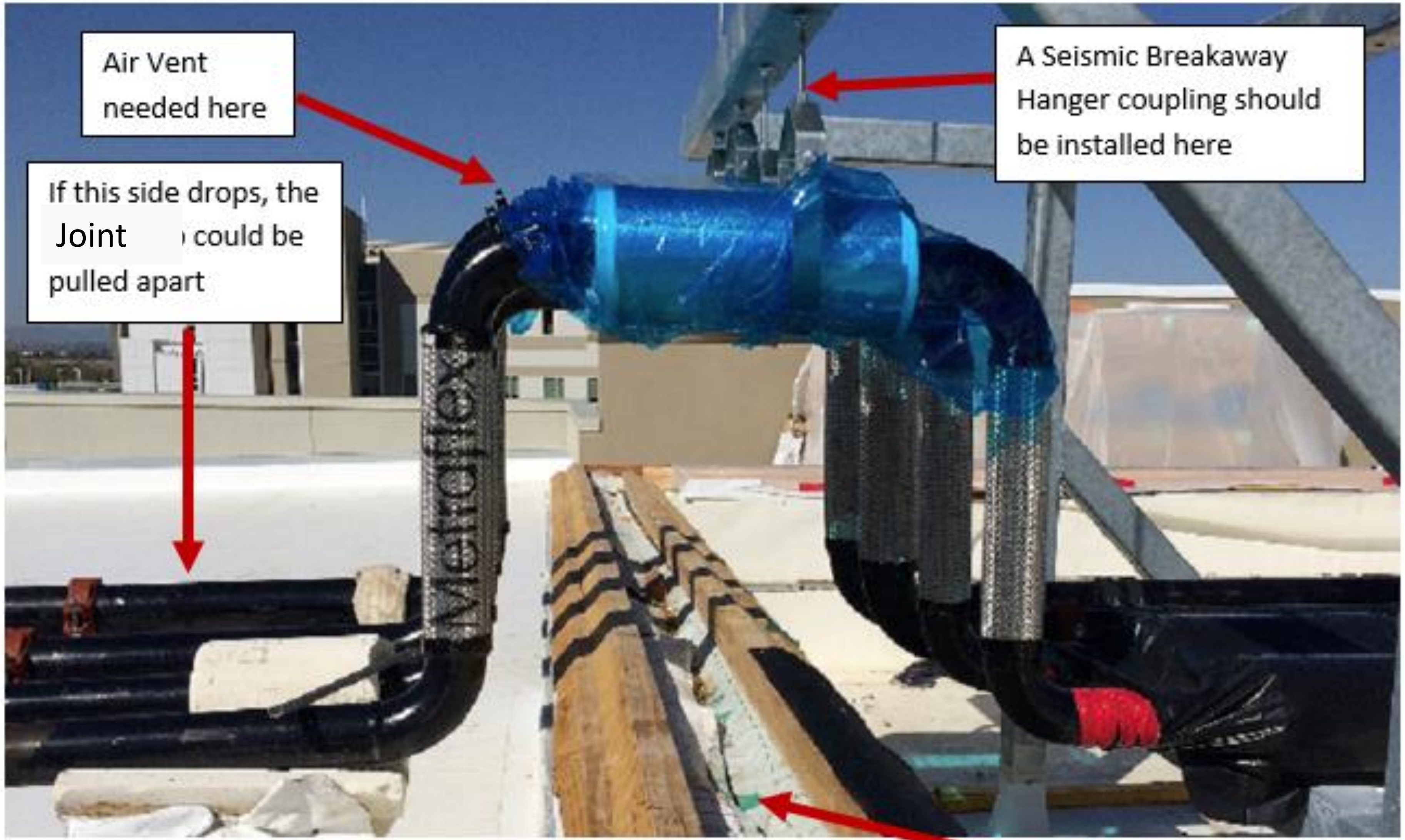
BASE ISOLATOR CLOSE UP



BASE ISOLATION SYSTEM

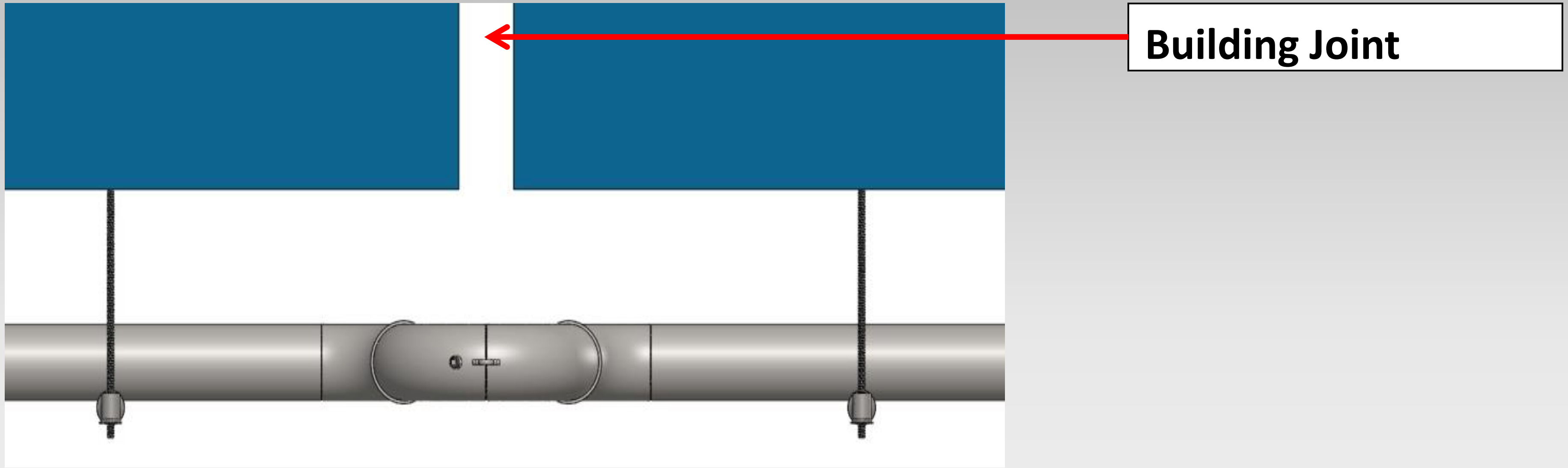

Metraflex
FIRELOOP


SANITARY WASTE

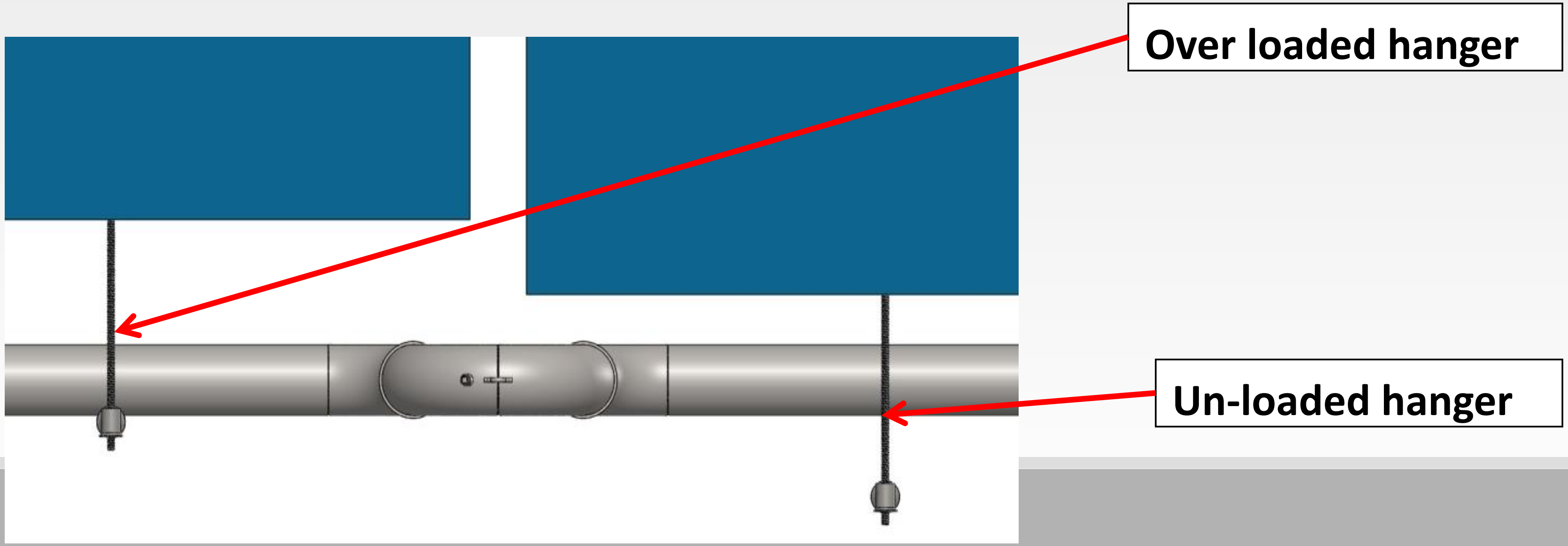


Picture 10. Seismic Example 1

Before Settlement

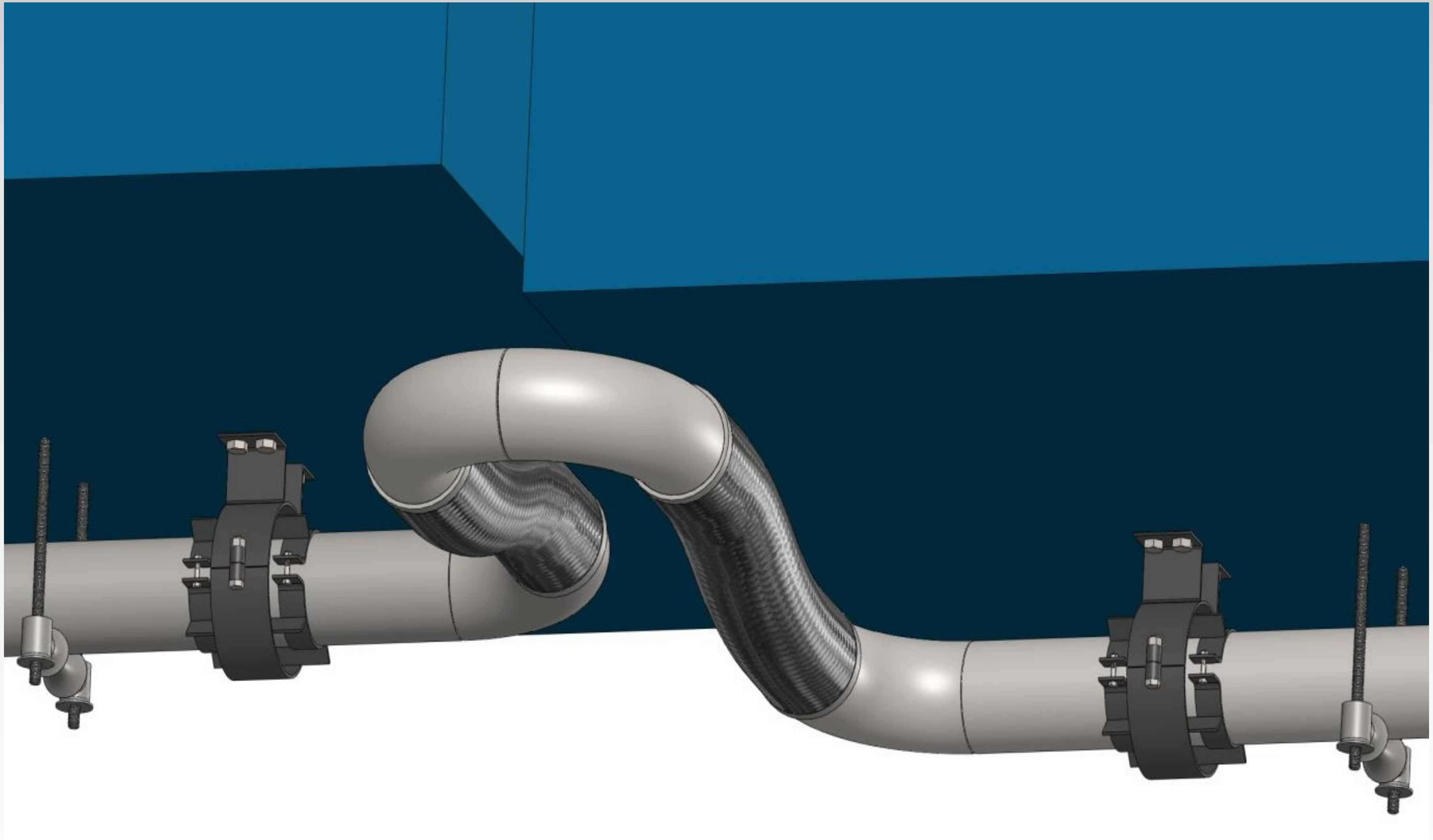


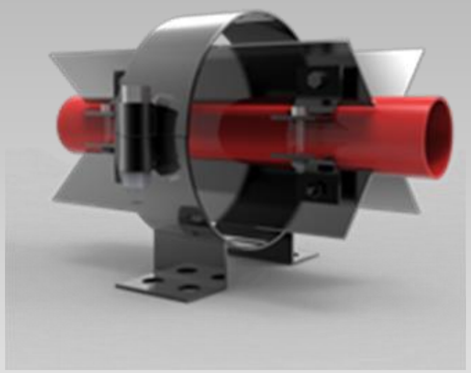
After Settlement



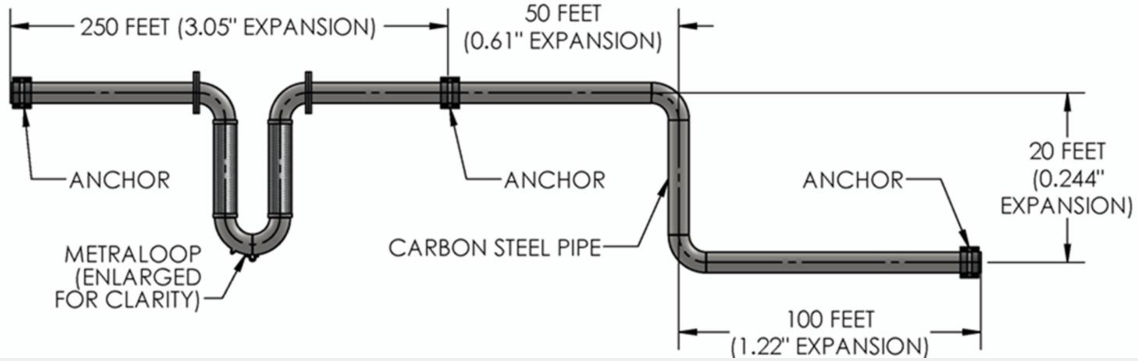
Correct Installation

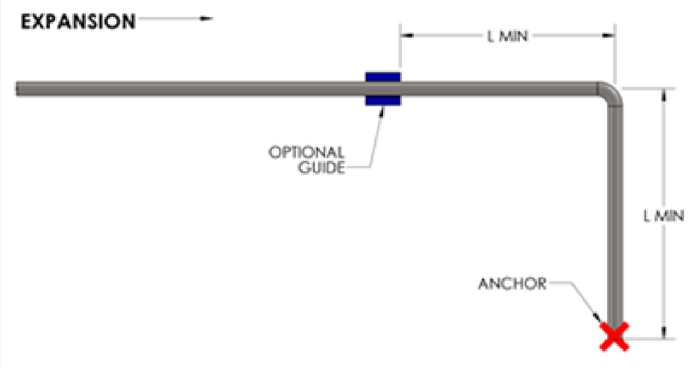
Building Settlement and Combined Seismic and Thermal

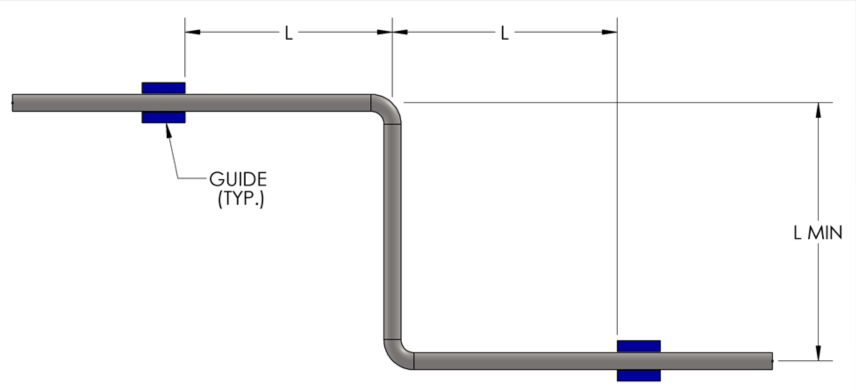


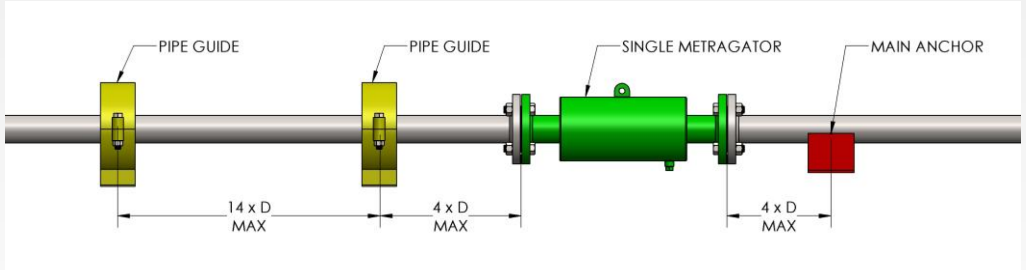


Calculating Thermal Expansion







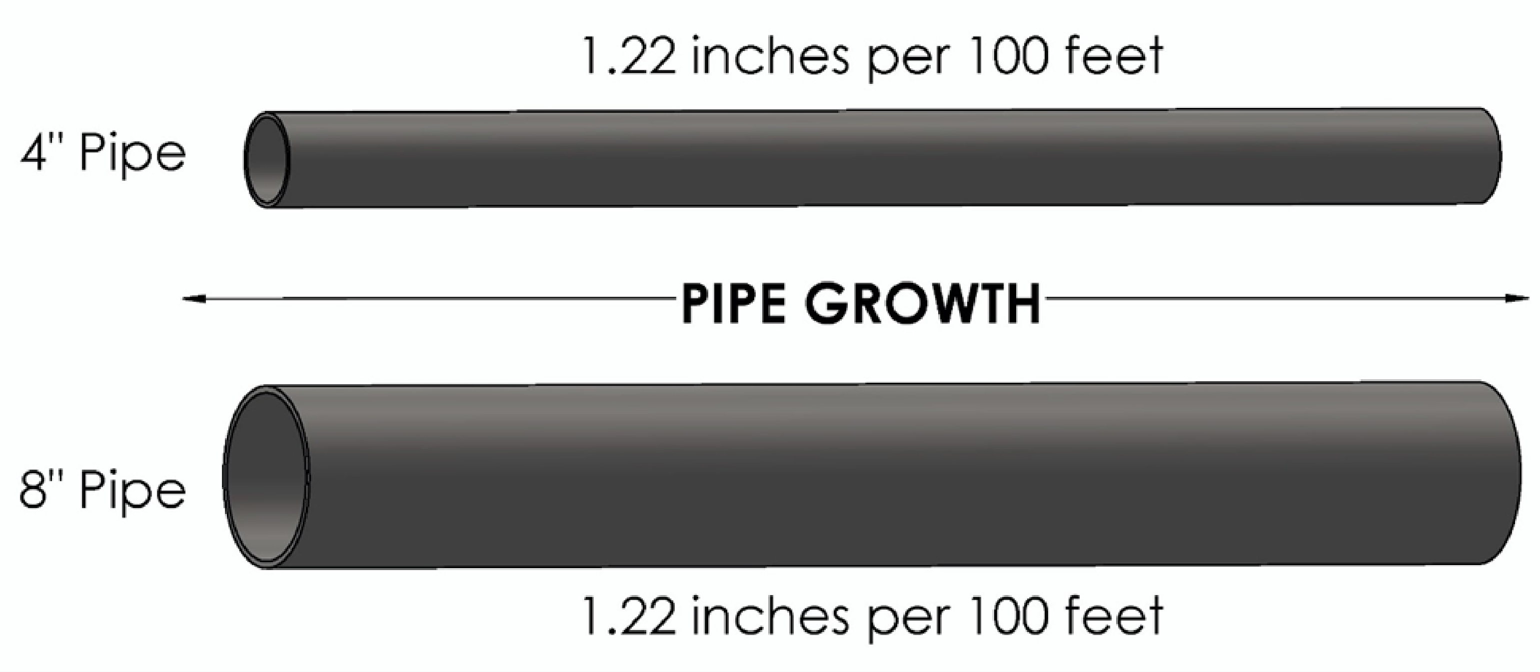


Similar Metals

Will expand (and contract) at the same rate regardless of the pipe size

Hot Water Example

40° F 200° F



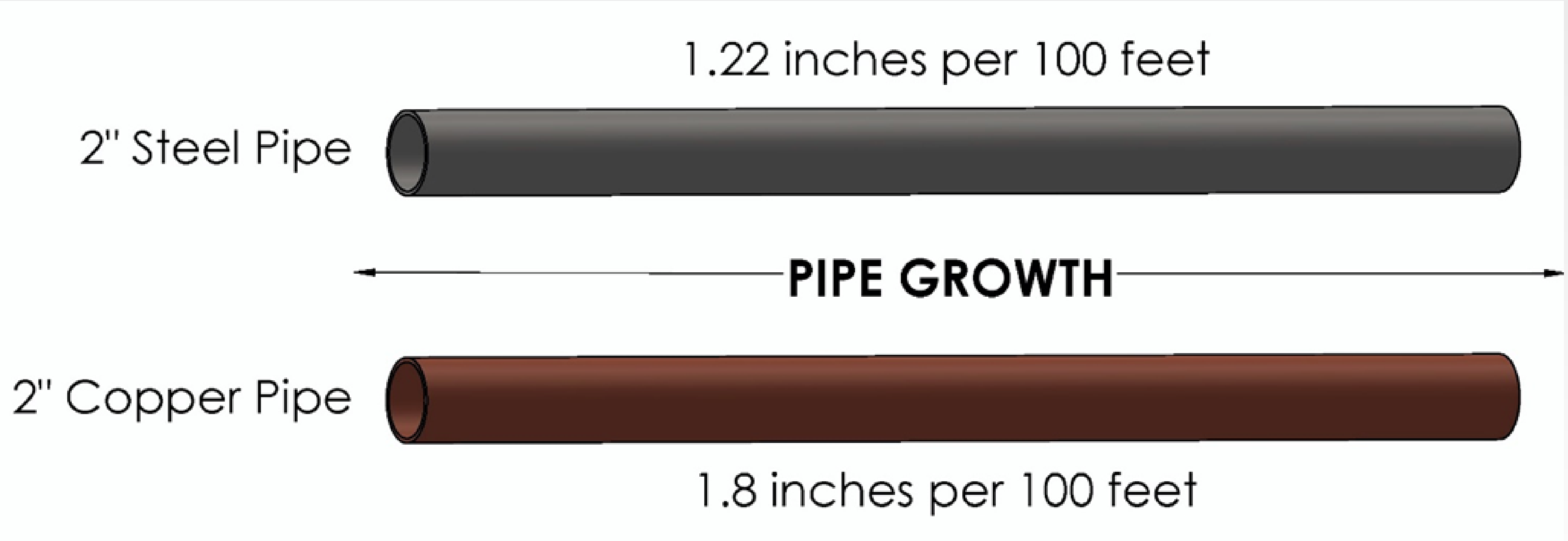
Note: ***But the anchor Thrust Loads will vary depending on the pipe size***

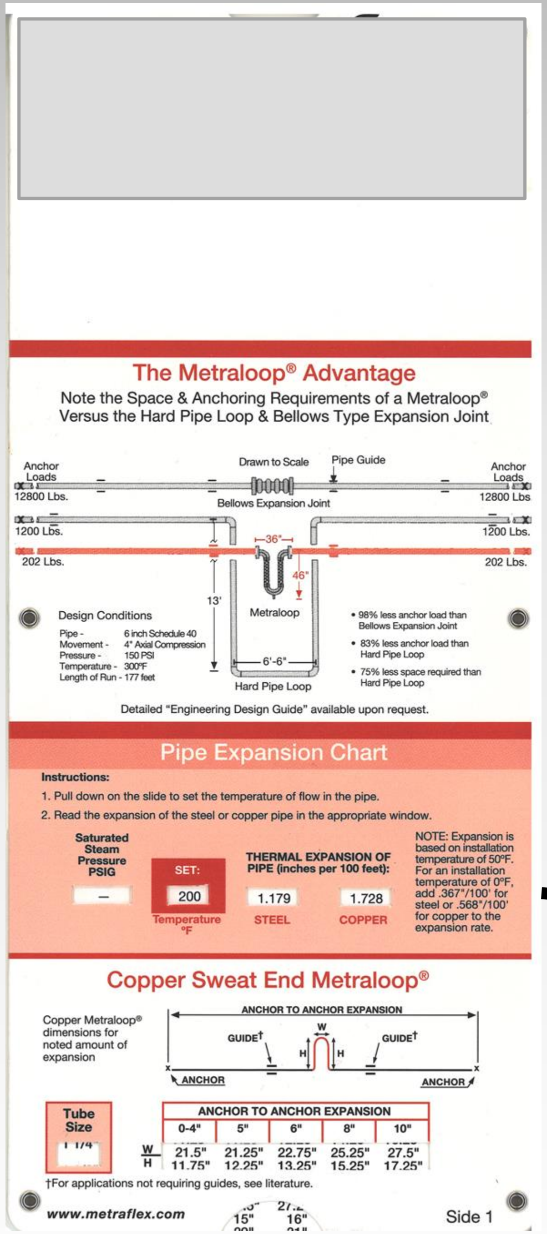
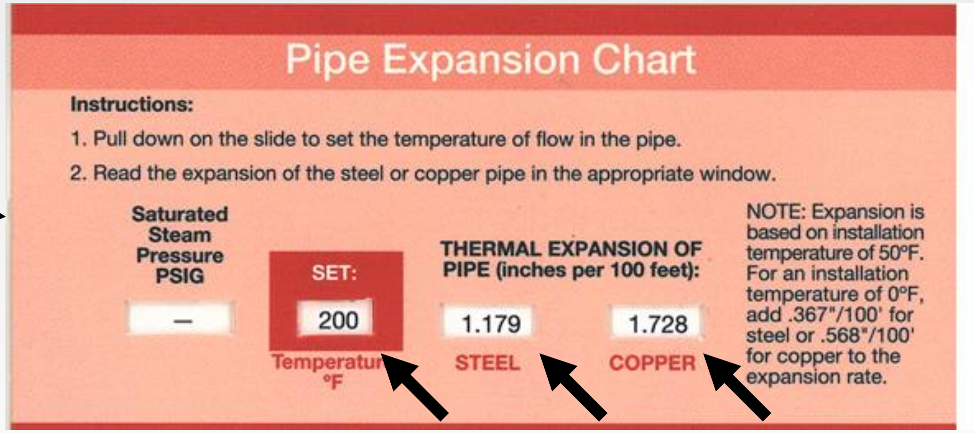
Different Metals

Will expand at different rates at the same temperature change

Hot Water Example

40° F 200° F




The Metraloop® Advantage
Note the Space & Anchoring Requirements of a Metraloop® Versus the Hard Pipe Loop & Bellows Type Expansion Joint
Anchor Loads
Drawn to Scale
Pipe Guide
Anchor Loads
12800 Lbs.
Bellows Expansion Joint
12800 Lbs
1200 Lbs.
1200 Lbs.
202 Lbs.
202 Lbs.
36"
46"
13'
Metraloop
Design Conditions
Pipe - 6 inch Schedule 40
Movement - 4" Axial Compression
Pressure - 150 PSI
Temperature - 300°F
Length of Run - 177 feet
6'-6"
Hard Pipe Loop
• 98% less anchor load than Bellows Expansion Joint
• 83% less anchor load than Hard Pipe Loop
• 75% less space required than Hard Pipe Loop
Detailed "Engineering Design Guide" available upon request.
Pipe Expansion Chart
Instructions:
1. Pull down on the slide to set the temperature of flow in the pipe.
2. Read the expansion of the steel or copper pipe in the appropriate window.
Saturated Steam Pressure PSIG
–
SET:
200
Temperature °F
THERMAL EXPANSION OF PIPE (inches per 100 feet):
1.179
STEEL
1.728
COPPER
NOTE: Expansion is based on installation temperature of 50°F. For an installation temperature of 0°F, add .367"/100' for steel or .568"/100' for copper to the expansion rate.
Copper Sweat End Metraloop®
Copper Metraloop® dimensions for noted amount of expansion
ANCHOR TO ANCHOR EXPANSION
GUIDE†
W
H
H
GUIDE†
ANCHOR
ANCHOR
Tube Size
ANCHOR TO ANCHOR EXPANSION
0-4"
5"
6"
8"
10"
W
H
21.5"
21.25"
22.75"
25.25"
27.5"
11.75"
12.25"
13.25"
15.25"
17.25"
†For applications not requiring guides, see literature.
www.metraflex.com
Side 1

Pipe Expansion Chart
Instructions:
1. Pull down on the slide to set the temperature of flow in the pipe.
2. Read the expansion of the steel or copper pipe in the appropriate window.
Saturated Steam Pressure PSIG
–
SET:
200
Temperature °F
THERMAL EXPANSION OF PIPE (inches per 100 feet):
1.179
STEEL
1.728
COPPER
NOTE: Expansion is based on installation temperature of 50°F. For an installation temperature of 0°F, add .367"/100' for steel or .568"/100' for copper to the expansion rate.

To Calculate Expansion

1 Determine design temperature – for example 200° F.

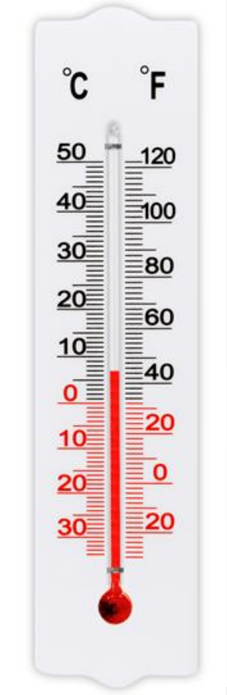
2 Establish installation temperature - For example 50° F

3 Find the expansion rate per 100 feet –
1.179” / 100 feet for steel – 1.728” / 100 feet for copper

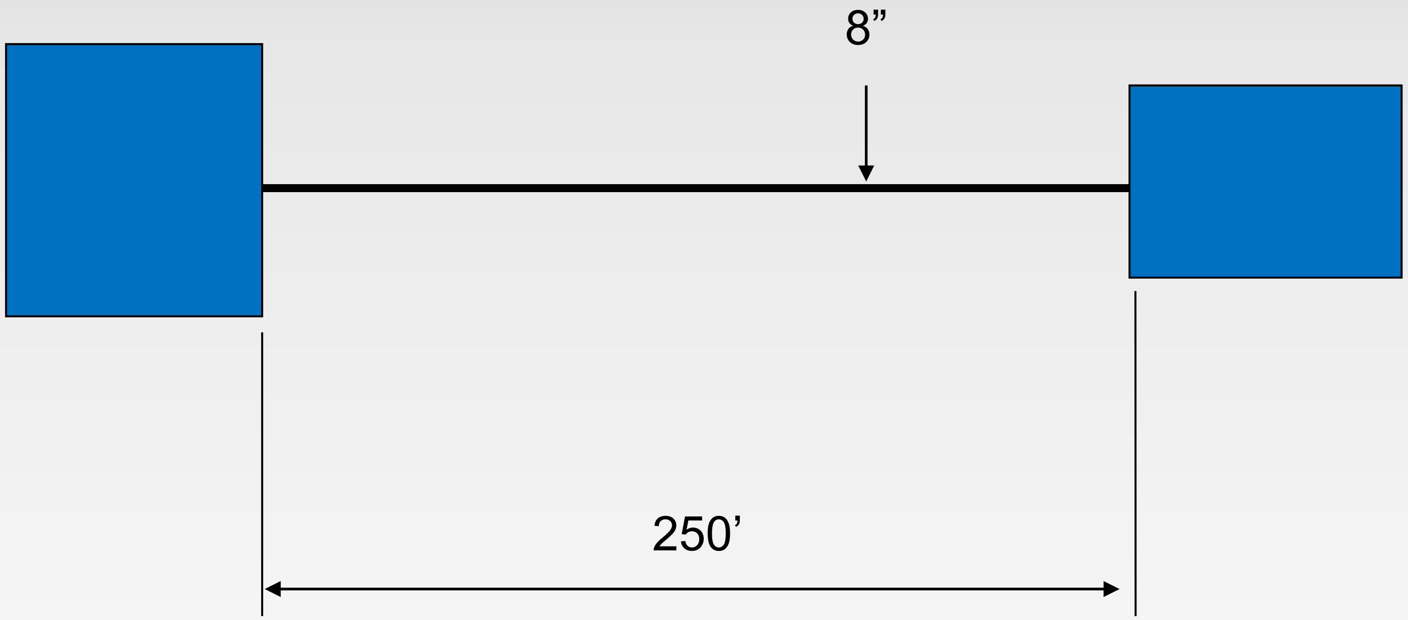
4 Determine the length of pipe run – for example 165 feet

5 Multiply the expansion rate by the length.
(165 / 100) X 1.179 = 1.94” Expansion

6 If the joint is for both thermal and seismic, the values must be added together!

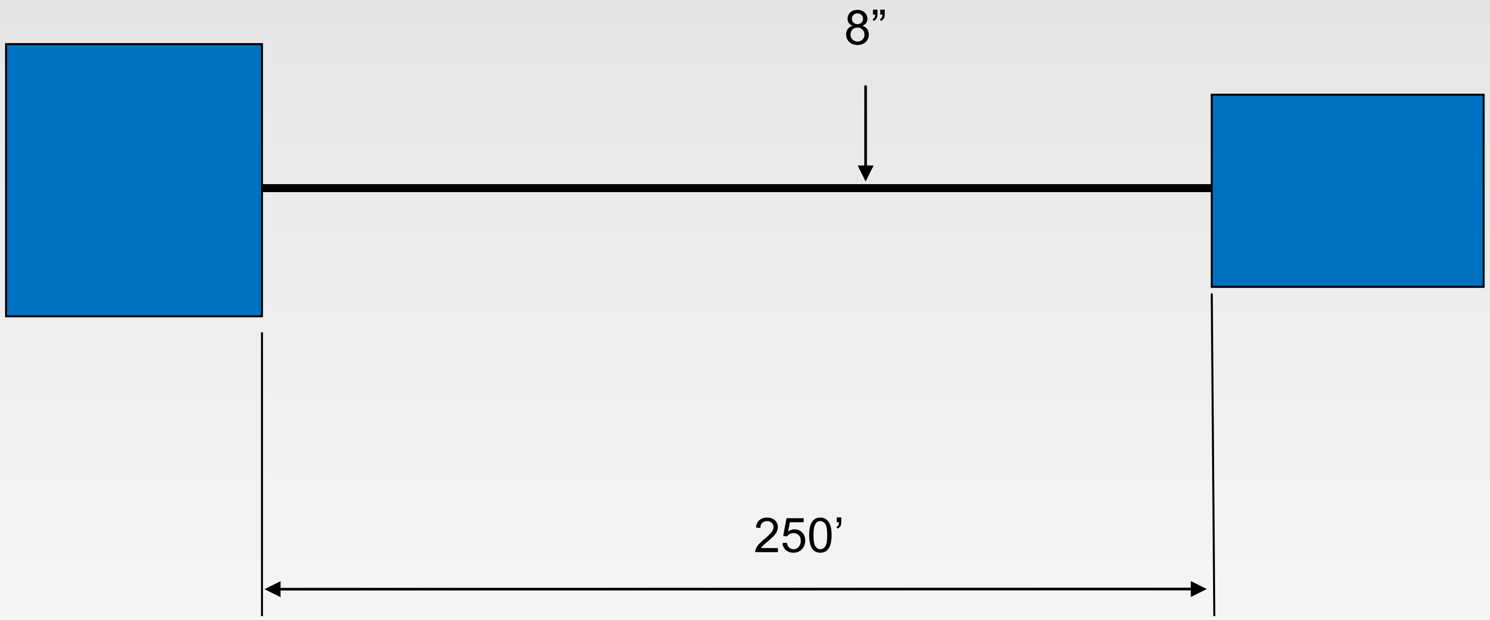


Lets Start With Determining The Pipe Size and Pipe Dimensions



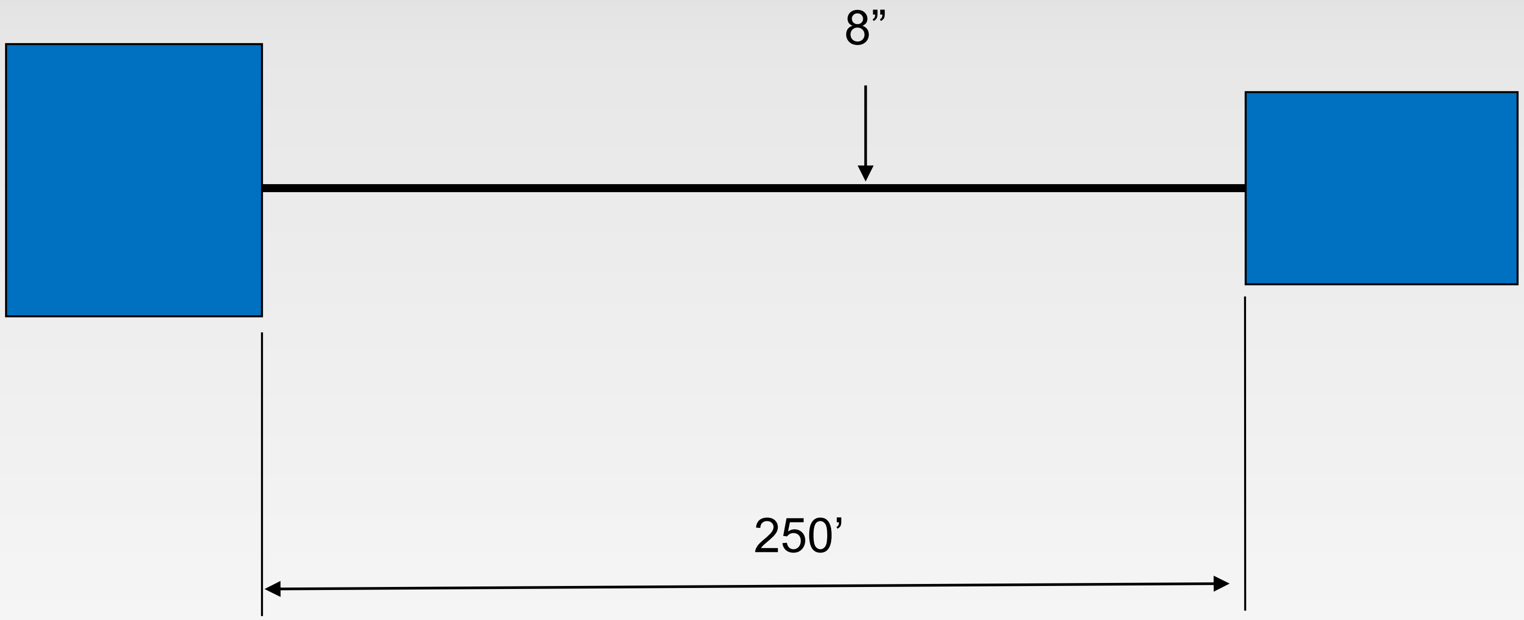
Lets Calculate How Much The Pipe Will Expand

Pipe Material	**Carbon Steel**
Service	**Hot Water**
Design Temperature	**200°F**



Lets Calculate How Much The Pipe Will Expand

Pipe Material	Carbon Steel
Service	Hot Water
Design Temperature	200°F



1.179” X 2.5 = 2.95”

Now You Try!!!

- 4" Carbon Steel Pipe
- Heating hot water 180 F
- 200 feet between anchors

Thermal Expansion between Anchors ____________________

Now You Try!!!

- 4” Carbon Steel Pipe
- Heating hot water 180 F
- 200 feet between anchors

1.016” per/100 ft X 2 = 2.032”

Thermal Expansion between Anchors 2.032”

Now You Try!!!

- 4" Copper pipe
- Heating hot water 180 F
- 200 feet between anchors

Thermal Expansion between Anchors ____________________

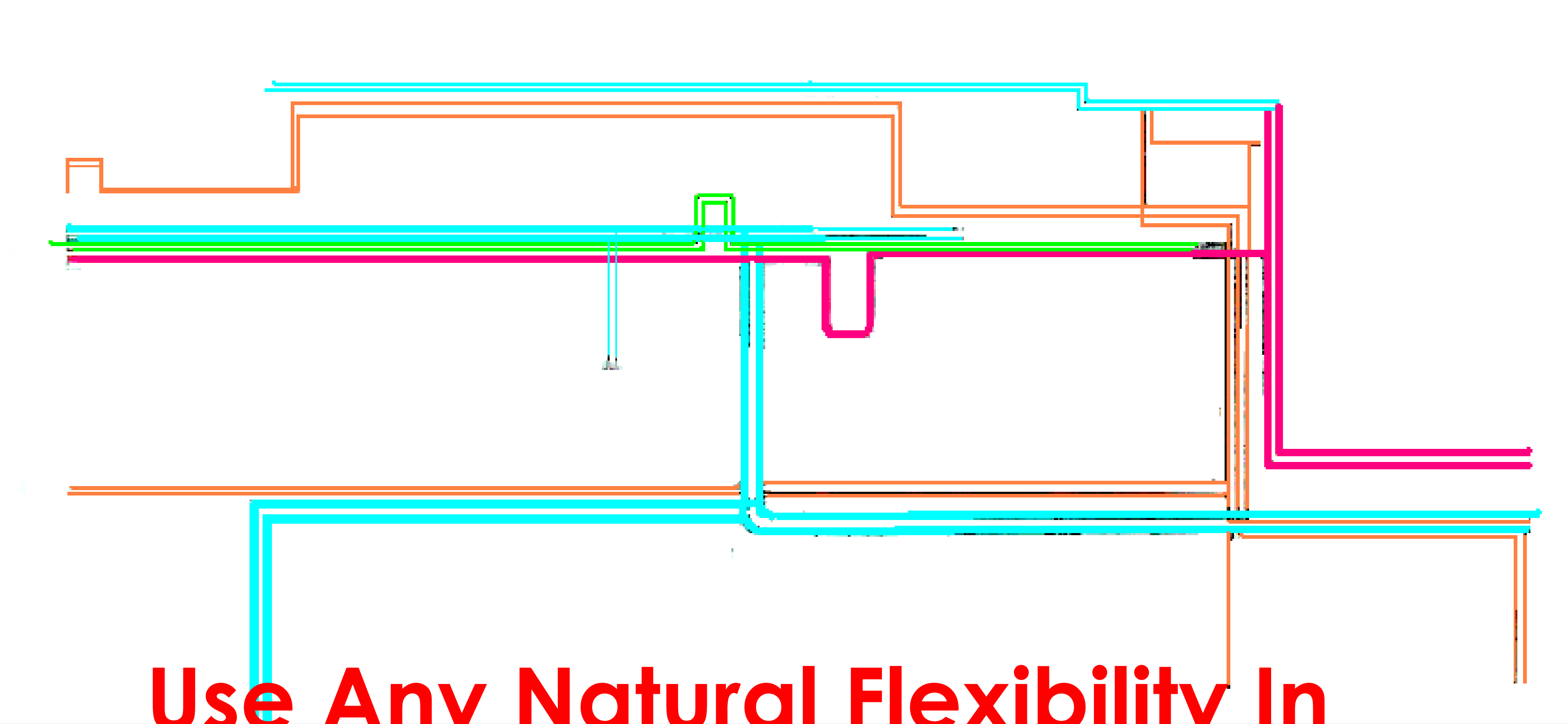
Now You Try!!!

- 4" Copper pipe
- Heating hot water 180 F
- 200 feet between anchors

1.483" per/100 ft X 2 = 2.966"

Thermal Expansion between Anchors 2.966"

So Where Do We Start?

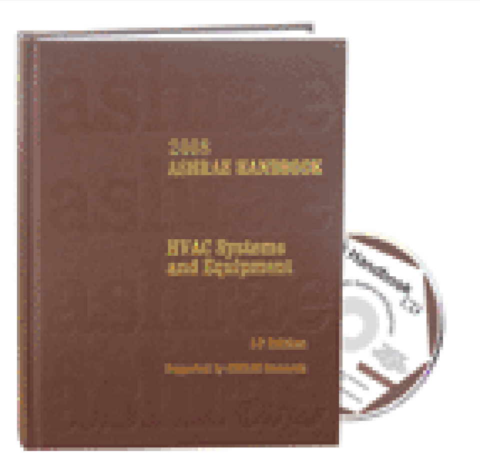


Use Any Natural Flexibility In The piping layout

2020 ASHRAE Handbook

Heating, Ventilating, and Air Conditioning
Systems and Equipment

Chapter 46

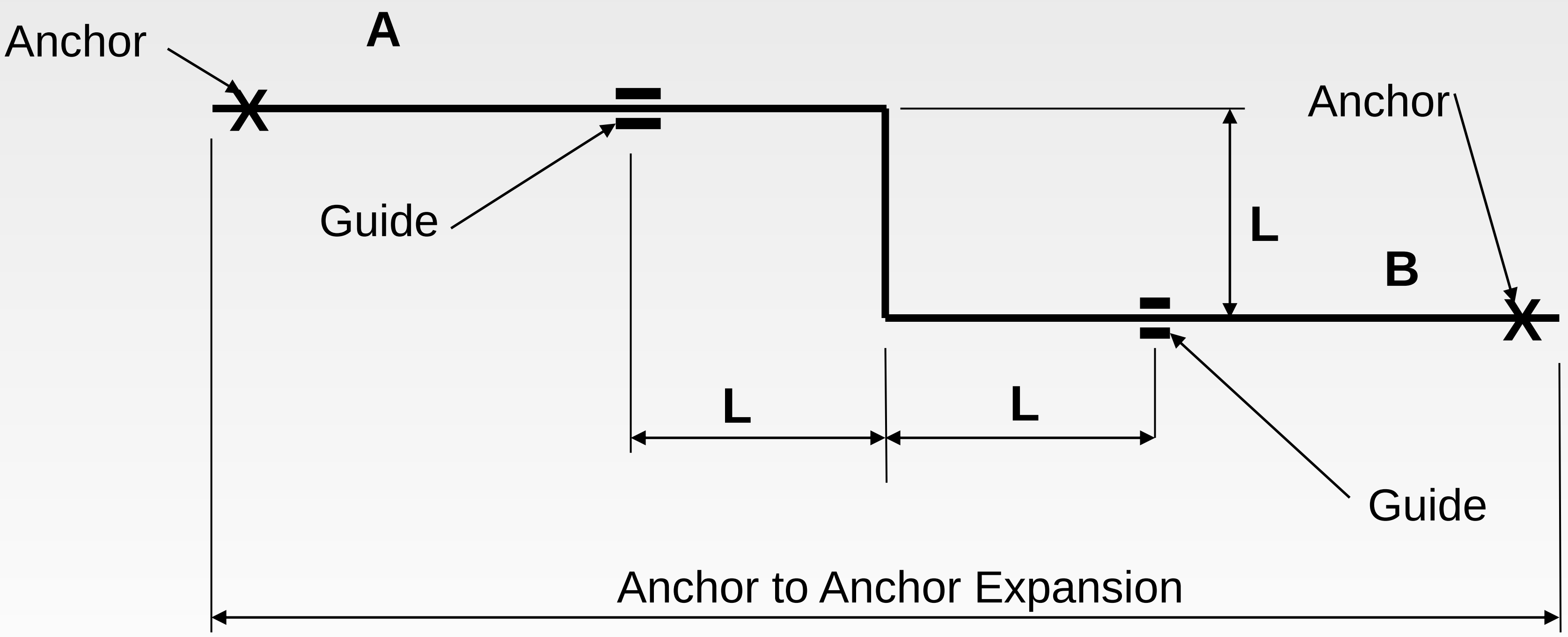


For a Basic Expansion “Z” Bend

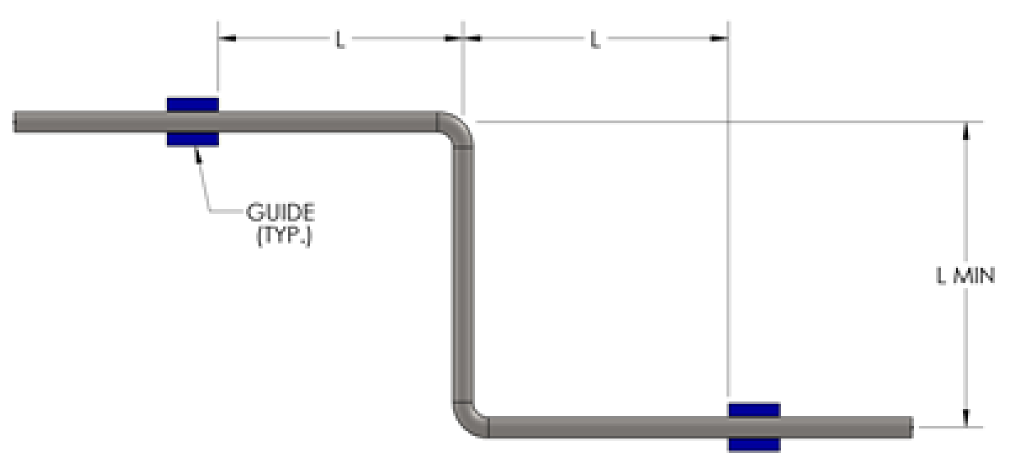
Hard Pipe

$$L = 4\ \sqrt{\Delta D}$$

Where Δ = Thermal expansion of leg AB
D = Pipe Outside Diameter
E = Modulus of Elasticity
S_A = Allowable Stress

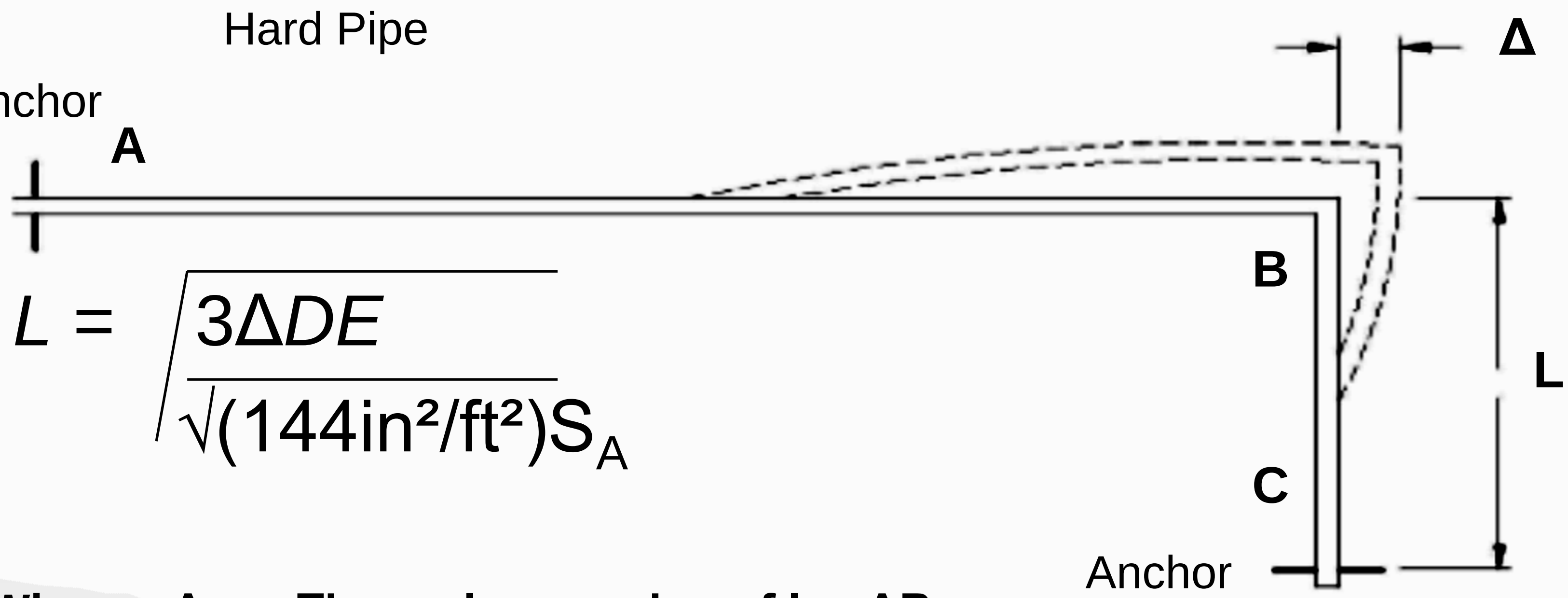


Standard Weight Carbon Steel			Z Bend "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5"	0.84		3.71	5.24	6.42	7.42	8.29	9.08	10.49
0.75"	1.05		4.15	5.86	7.18	8.29	9.27	10.15	11.73
1"	1.315		4.64	6.56	8.04	9.28	10.37	11.37	13.12
1.25"	1.66		5.21	7.37	9.03	10.43	11.65	12.77	14.74
1.5"	1.9		5.58	7.89	9.66	11.15	12.47	13.66	15.78
2"	2.375		6.24	8.82	10.80	12.47	13.94	15.28	17.63
2.5"	2.875		6.86	9.70	11.88	13.72	15.34	16.80	19.40
3"	3.5		7.57	10.71	13.11	15.14	16.93	18.54	21.41
4"	4.5		8.58	12.14	14.87	17.17	19.19	21.03	24.28
5"	5.563		9.54	13.50	16.53	19.09	21.34	23.37	26.99
6"	6.625		10.41	14.73	18.04	20.83	23.29	25.51	29.46
8"	8.625		11.88	16.81	20.58	23.77	26.57	29.11	33.61
10"	10.75		13.27	18.76	22.98	26.53	29.67	32.49	37.52
12"	12.75		14.45	20.43	25.02	28.90	32.34	35.39	40.87



Drawn Copper			Z Bend "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5	0.625		3.01	4.26	5.22	6.03	6.74	7.38	8.52
0.75	0.875		3.57	5.04	6.18	7.13	7.97	8.74	10.08
1	1.125		4.04	5.72	7.00	8.09	9.04	9.90	11.43
1.25	1.375		4.47	6.32	7.74	8.94	9.99	10.95	12.64
1.5	1.625		4.86	6.87	8.42	9.72	10.86	11.90	13.74
2	2.125		5.56	7.86	9.62	11.11	12.42	13.61	15.72
2.5	2.625		6.18	8.73	10.70	12.35	13.81	15.13	17.47
3	3.125		6.74	9.53	11.67	13.48	15.07	16.50	19.06
4	4.125		7.74	10.95	13.41	15.48	17.31	18.96	21.89

For a Basic Expansion Elbow



$$L = \sqrt{\frac{3\Delta D E}{\sqrt{(144 in^2/ft^2)} S_A}}$$

Where Δ = Thermal expansion of leg AB

D **= Pipe Outside Diameter**

E **= Modulus of Elasticity**

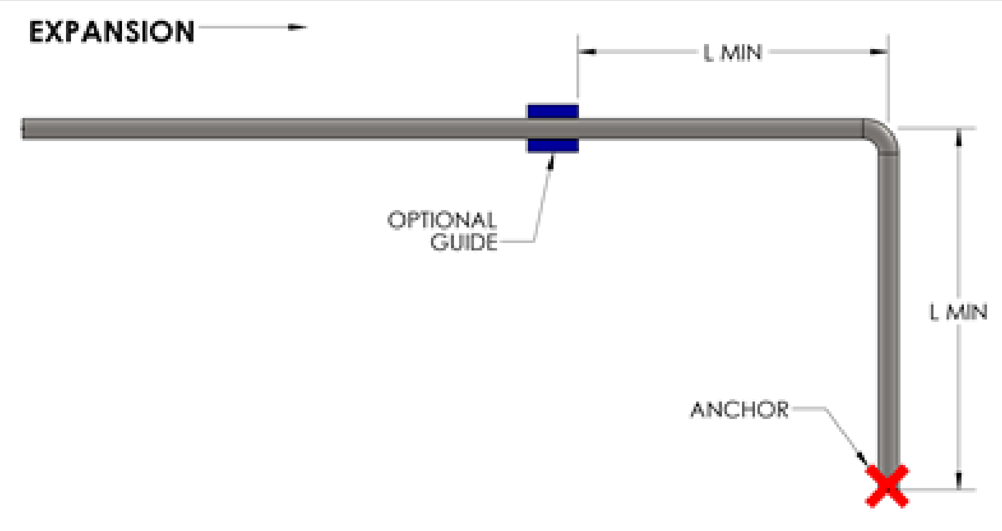
S_A = Allowable Stress

Or this can be simplified to

$$L = 6.225 \sqrt{\Delta D}$$

Standard Weight Carbon Steel			90⁰ Elbow Minimum "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5"	0.84		5.71	8.07	9.88	11.41	12.76	13.97	16.14
0.75"	1.05		6.38	9.02	11.05	12.76	14.26	15.62	18.04
1"	1.315		7.14	10.10	12.36	14.28	15.96	17.49	20.19
1.25"	1.66		8.02	11.34	13.89	16.04	17.93	19.65	22.68
1.5"	1.9		8.58	12.13	14.86	17.16	19.19	21.02	24.27
2"	2.375		9.59	13.57	16.62	19.19	21.45	23.50	27.13
2.5"	2.875		10.55	14.93	18.28	21.11	23.60	25.85	29.85
3"	3.5		11.65	16.47	20.17	23.29	26.04	28.53	32.94
4"	4.5		13.21	18.67	22.87	26.41	29.53	32.35	37.35
5"	5.563		14.68	20.76	25.43	29.36	32.83	35.96	41.53
6"	6.625		16.02	22.66	27.75	32.04	35.83	39.25	45.32
8"	8.625		18.28	25.85	31.66	36.56	40.88	44.78	51.71
10"	10.75		20.41	28.86	35.35	40.82	45.64	49.99	57.73
12"	12.75		22.23	31.43	38.50	44.46	49.76	54.45	62.87

Drawn Copper			90⁰ Elbow Minimum "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5	0.625		4.64	6.56	8.03	9.27	10.37	11.35	13.11
0.75	0.875		5.48	7.76	9.50	10.97	12.26	13.44	15.51
1	1.125		6.22	8.80	10.77	12.44	13.91	15.23	17.59
1.25	1.375		6.88	9.72	11.91	13.75	15.37	16.84	19.45
1.5	1.625		7.47	10.57	12.95	14.95	16.71	18.31	21.14
2	2.125		8.55	12.09	14.80	17.10	19.11	20.94	24.18
2.5	2.625		9.50	13.44	16.45	19.00	21.24	23.27	26.87
3	3.125		10.37	14.66	17.95	20.73	23.18	25.39	29.32
4	4.125		11.91	16.84	20.63	23.82	26.63	29.17	33.68



For a Basic Expansion Loop

Hard Pipe

$$L = 6.225\sqrt{\Delta D}$$

Where Δ = Thermal expansion of run

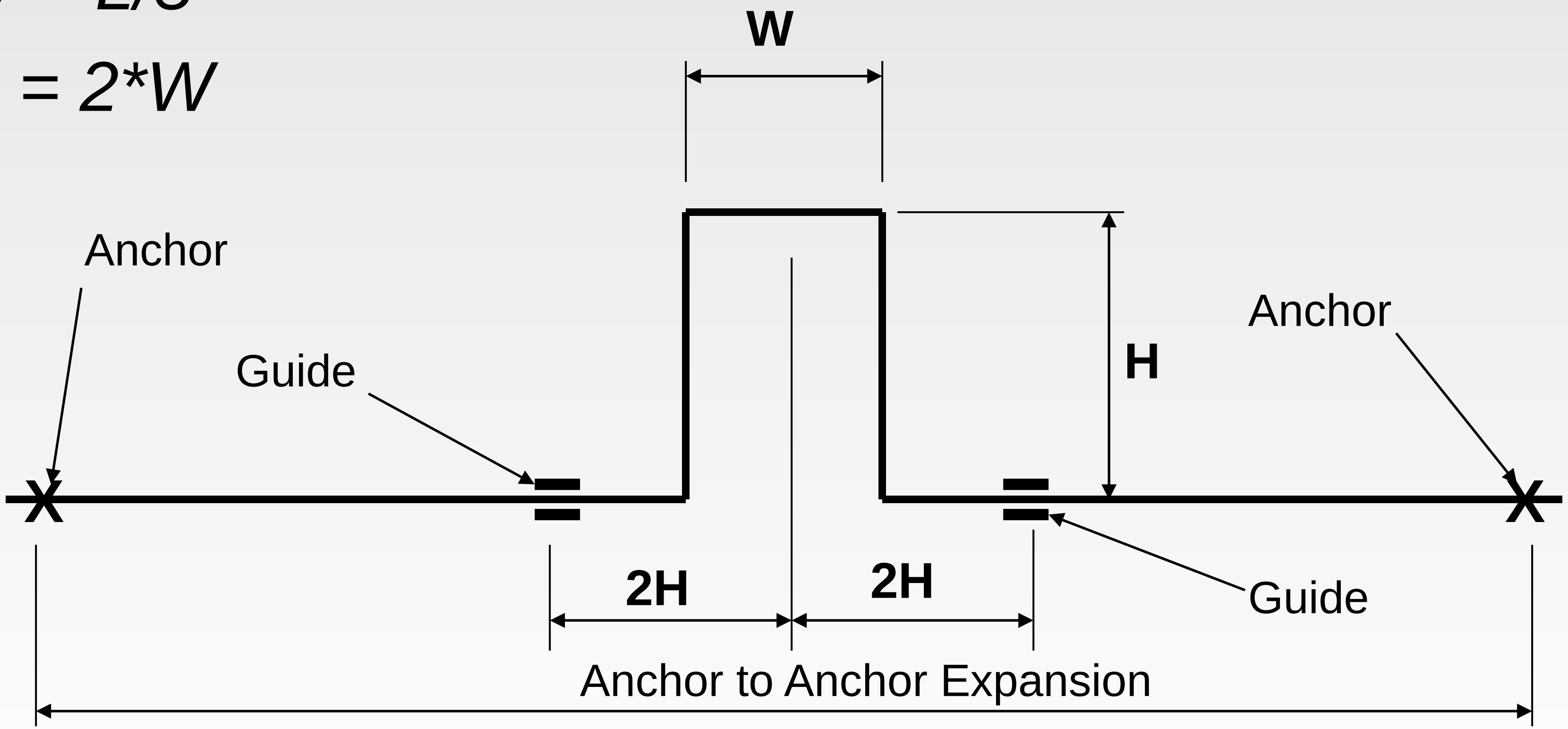
D = Pipe Outside Diameter

E = Modulus of Elasticity

S_A = Allowable Stress

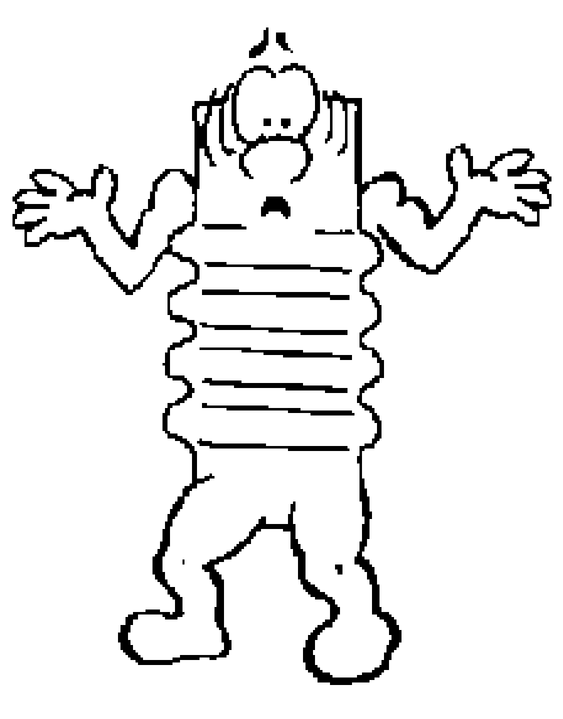
$$W = L/5$$

$$H = 2*W$$



So if we do not have enough natural flexibility

What do we do?



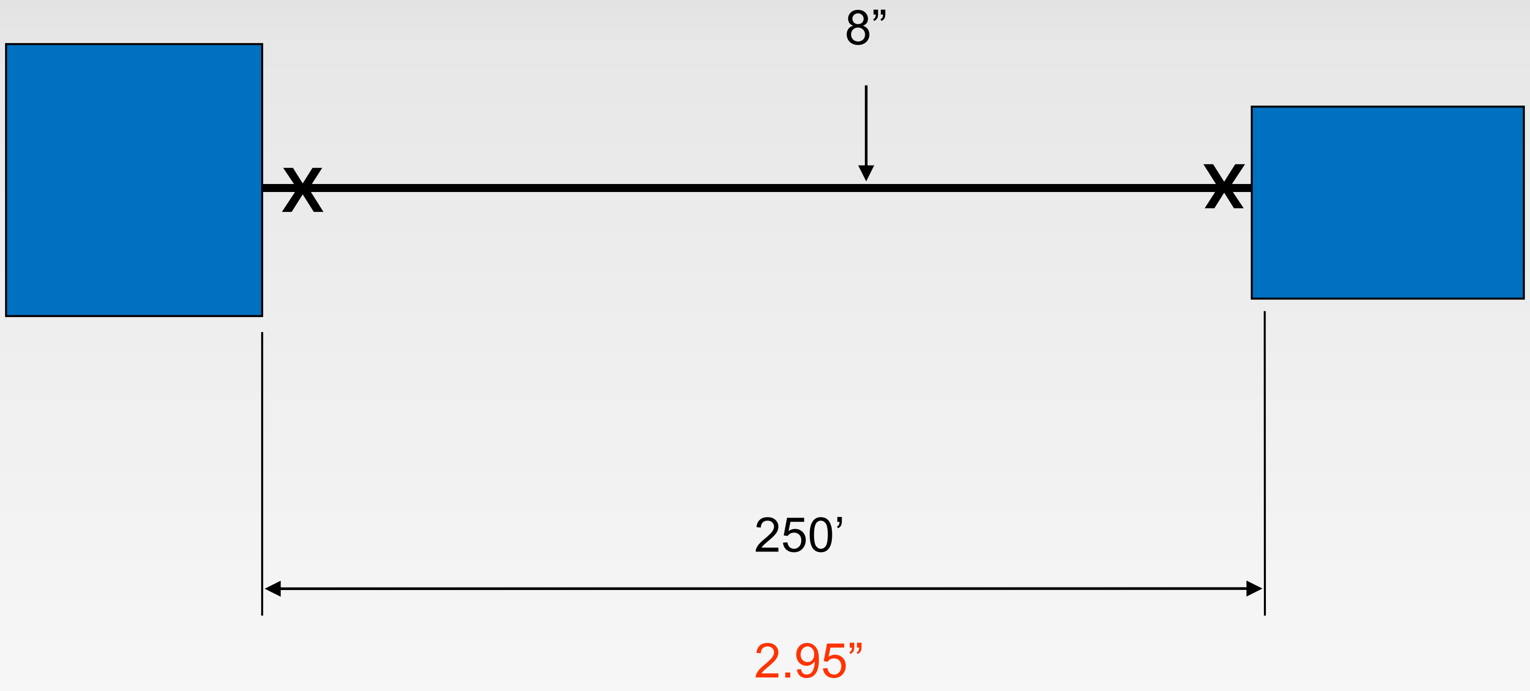
Basic Rules for Placing Expansion Joints

Determine anchor locations. The anchor loads associated with bellows expansion joints often limit the areas where they can be placed

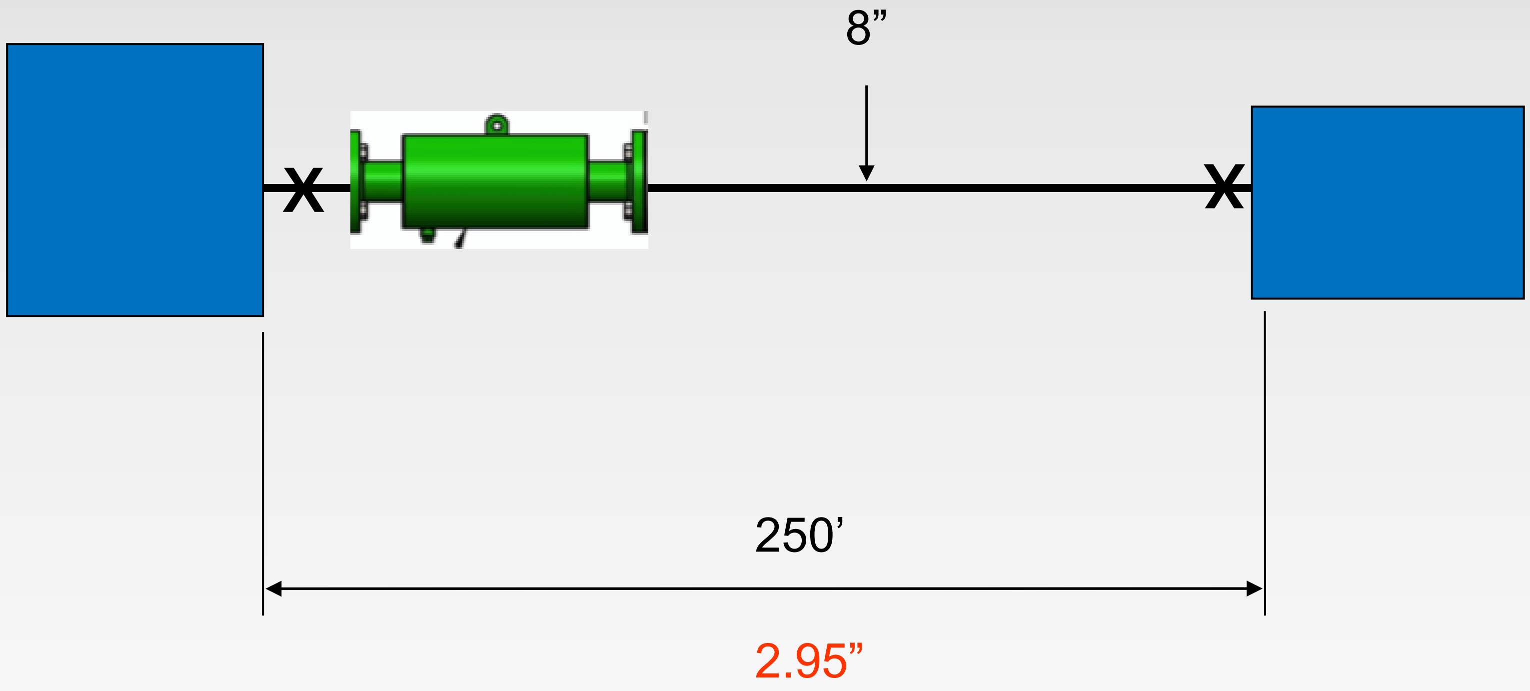
Divide up the piping system into the largest sections that one expansion joint can handle

<u>Only 1 expansion joint between anchors</u>

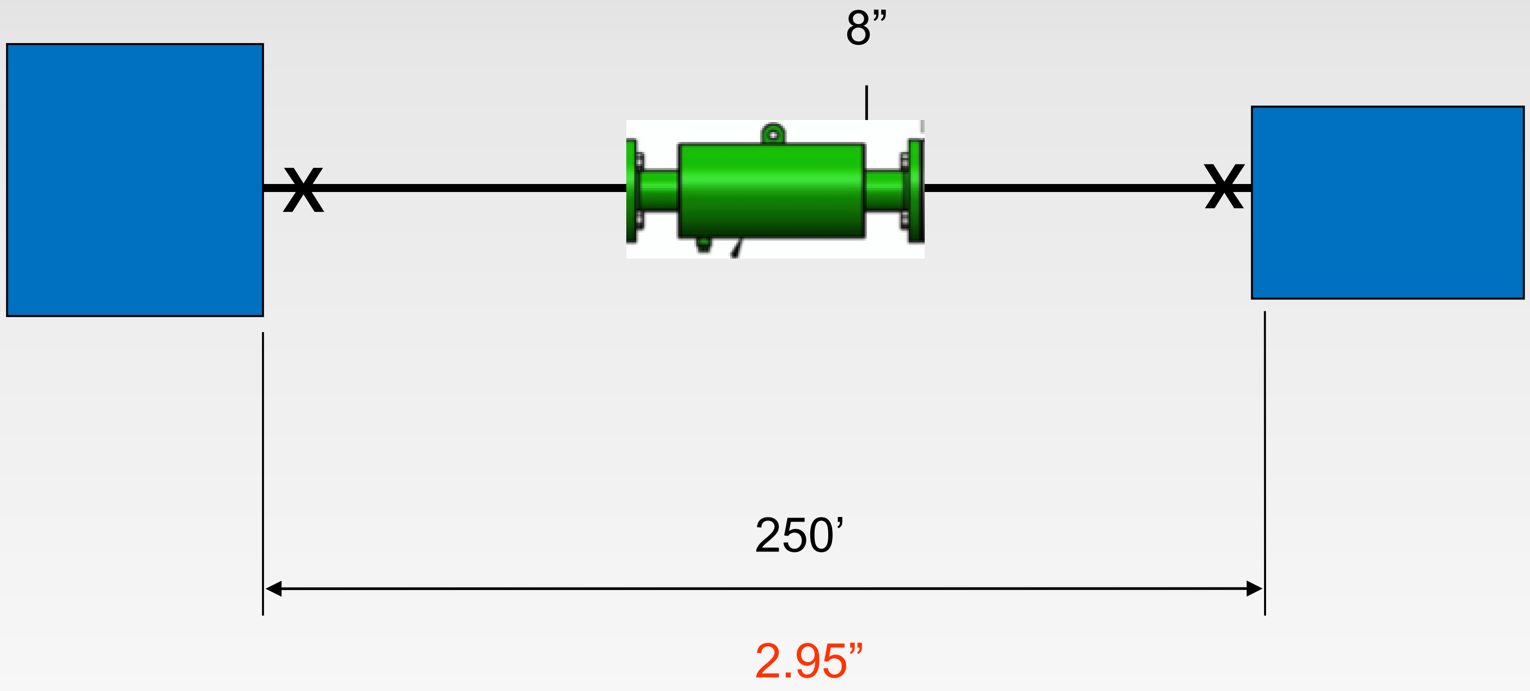
Let’s Place Anchors



Let’s Place Expansion Joints



Let’s Place Expansion Joints



CONCENTRIC PIPE GUIDE SPACING

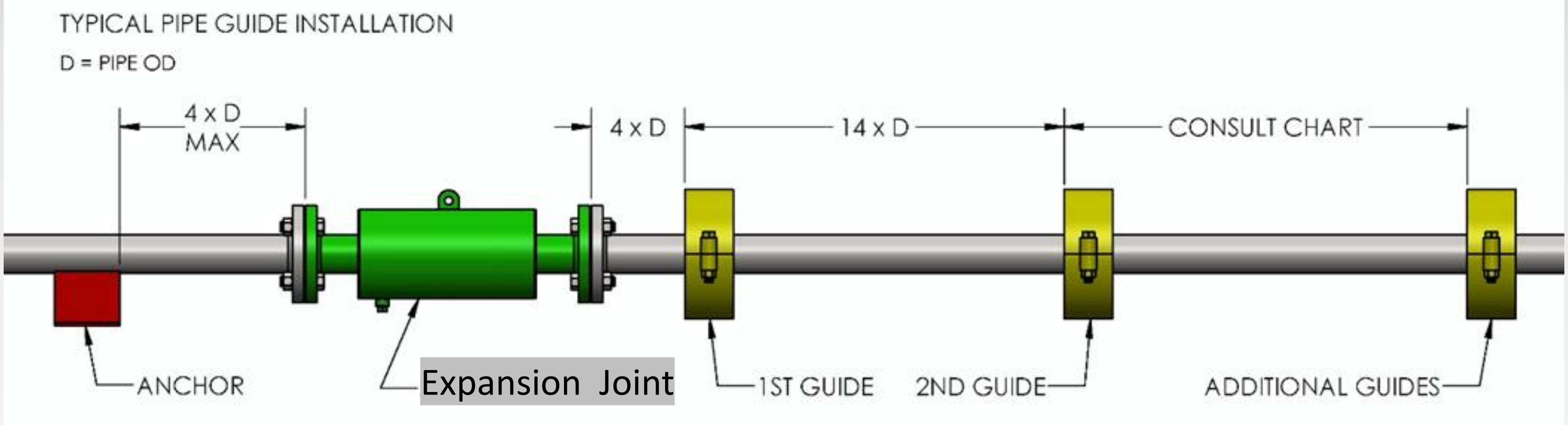
* Data Per Expansion Joint Manufacturers Association

Pipe Size	Maximum Distance To 1st Guide	Approx. Distance Between 1st to 2nd Guide	Approximate Distance Between Additional Pipe Guides (In feet)			
			@ 50 PSI	@ 100 PSI	@ 150 PSI	@ 300 PSI
1"	4"	1'4"	21'	15'	12'	10'
1-1/4"	5"	1'5"	23	17	13	12
1-1/2"	6"	1'9"	28	20	17	13
2"	8"	2'4"	32	23	18	15
2-1/2"	10"	2'11"	35	28	22	20
3"	1'	3'6"	38	28	23	17
3-1/2"	1'2"	4'1"	45	35	27	19
4"	1'4"	4'8"	52	38	31	22
5"	1'8"	5'8"	63	45	38	25
6"	2'	7'	68	48	40	28
8"	2'8"	9'4"	87	62	45	38
10"	3'4"	11'8"	107	75	60	48
12"	4'	14'	118	85	70	50
14"	4'8"	16'4"	122	88	72	55
16"	5'4"	18'8"	137	96	80	60
18"	6'	21'	145	105	85	65
20"	6'8"	23'4"	160	118	90	70
24"	8'	28'	181	125	105	75

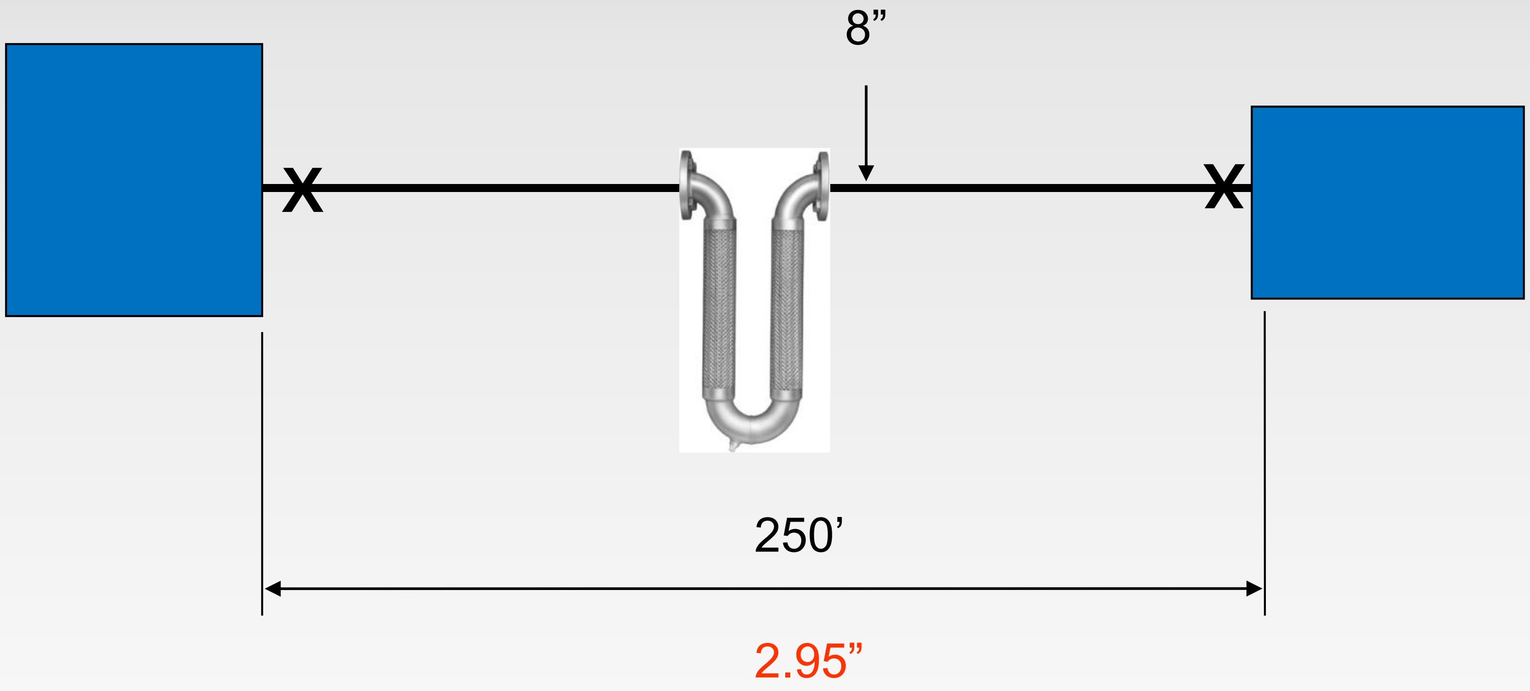
4, 14, 40

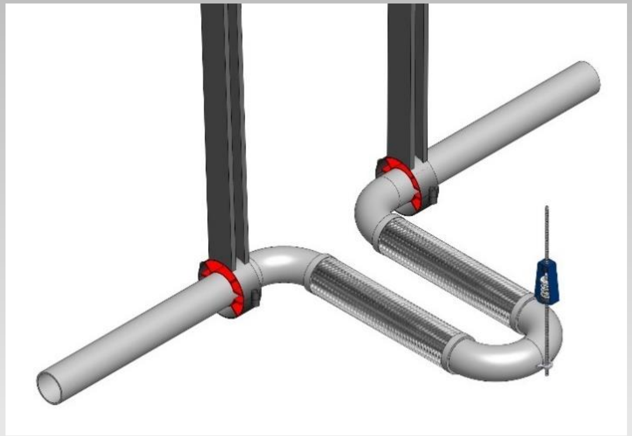
Pipe Diameters

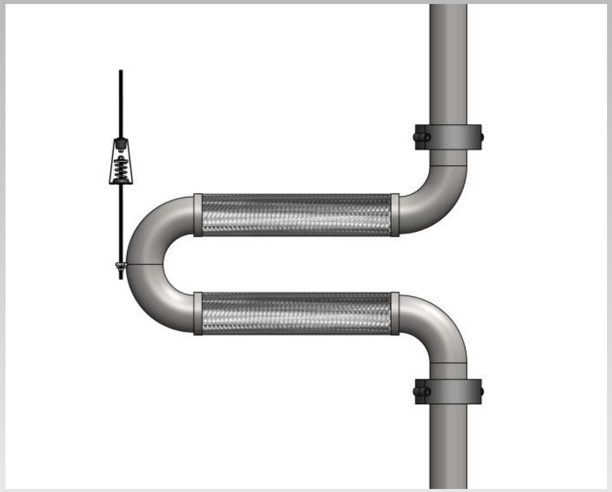
Installation

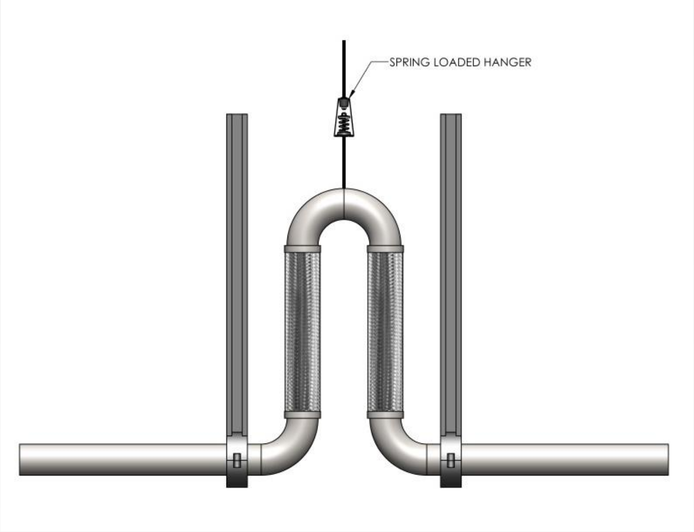


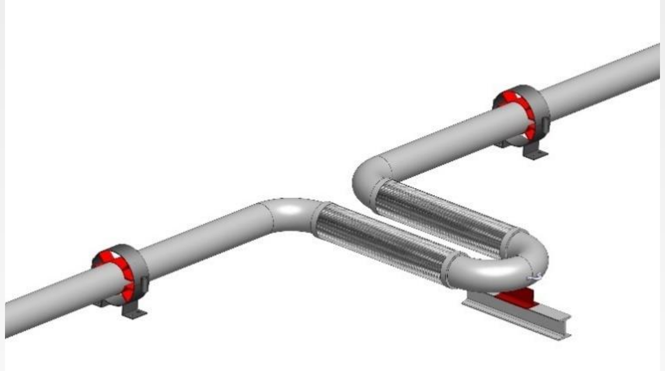
Let’s Place Expansion Joints

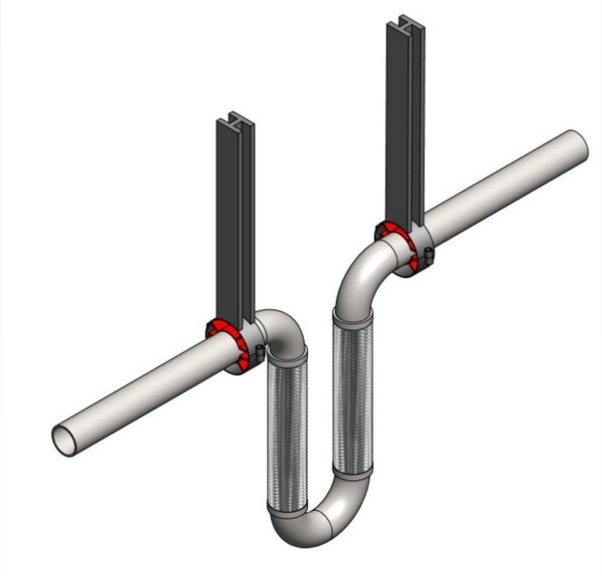




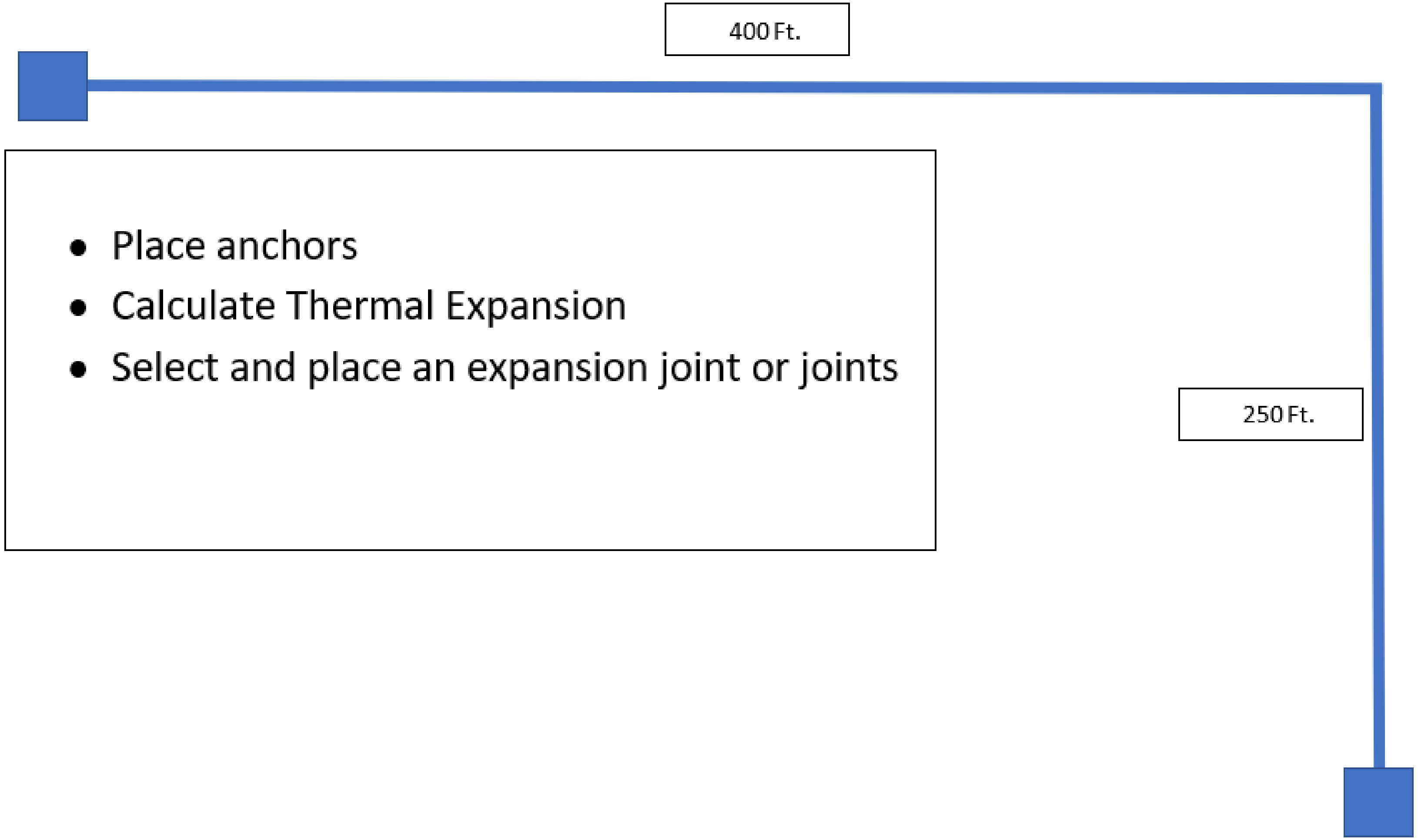



SPRING LOADED HANGER



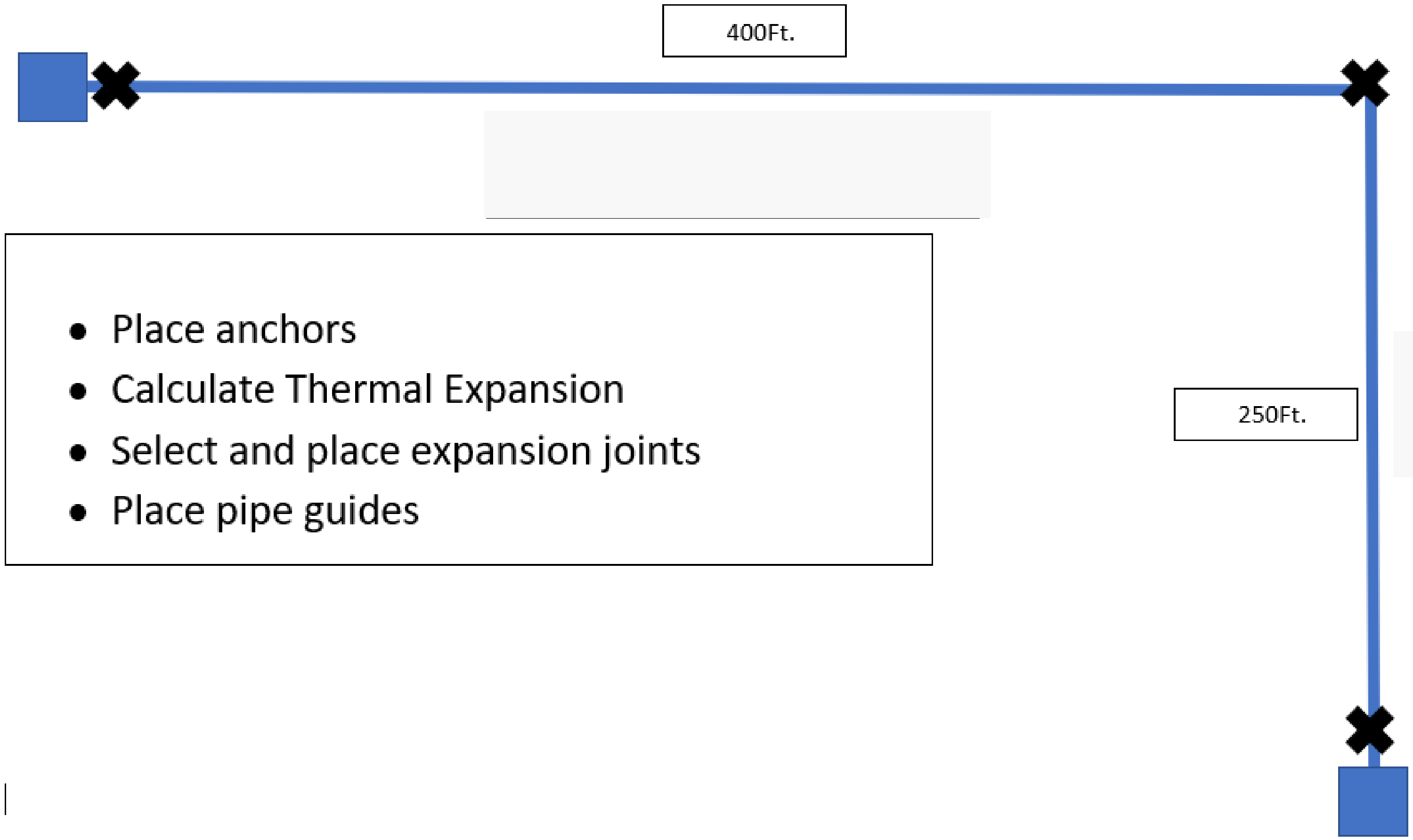


- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs steam



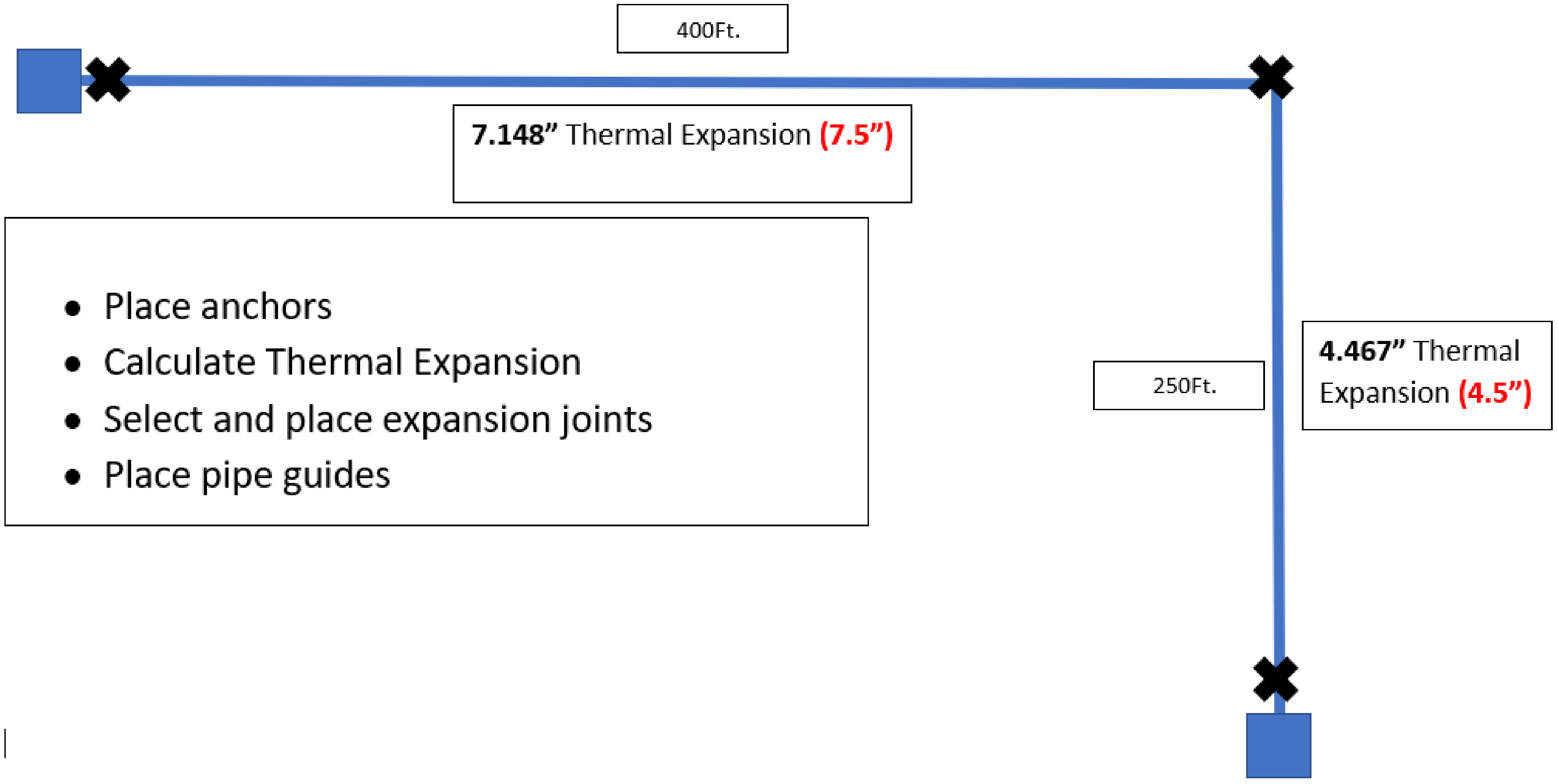
- Place anchors
- Calculate Thermal Expansion
- Select and place an expansion joint or joints

- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs steam



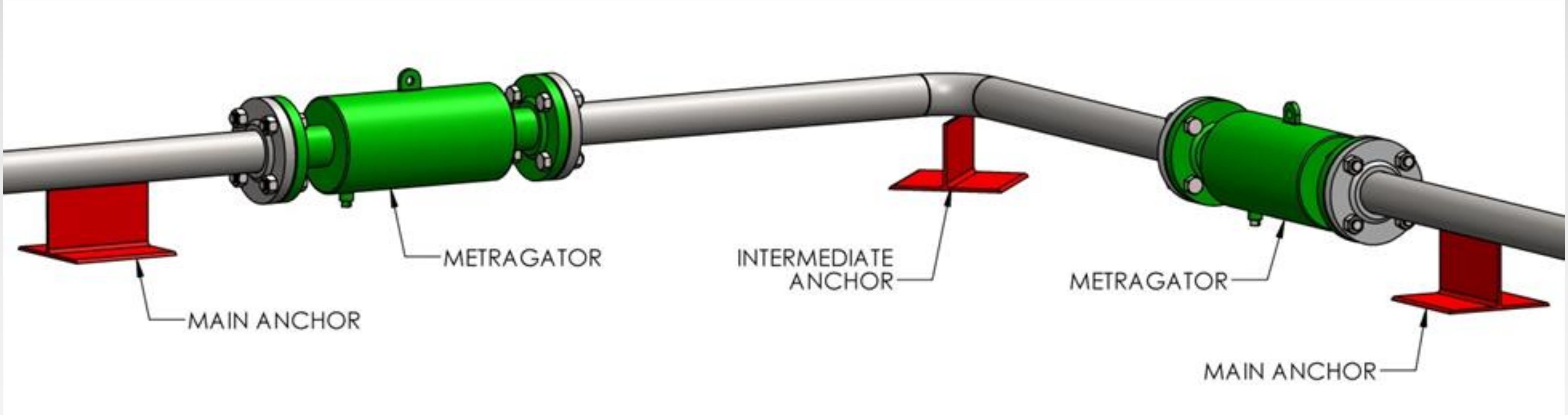
- Place anchors
- Calculate Thermal Expansion
- Select and place expansion joints
- Place pipe guides

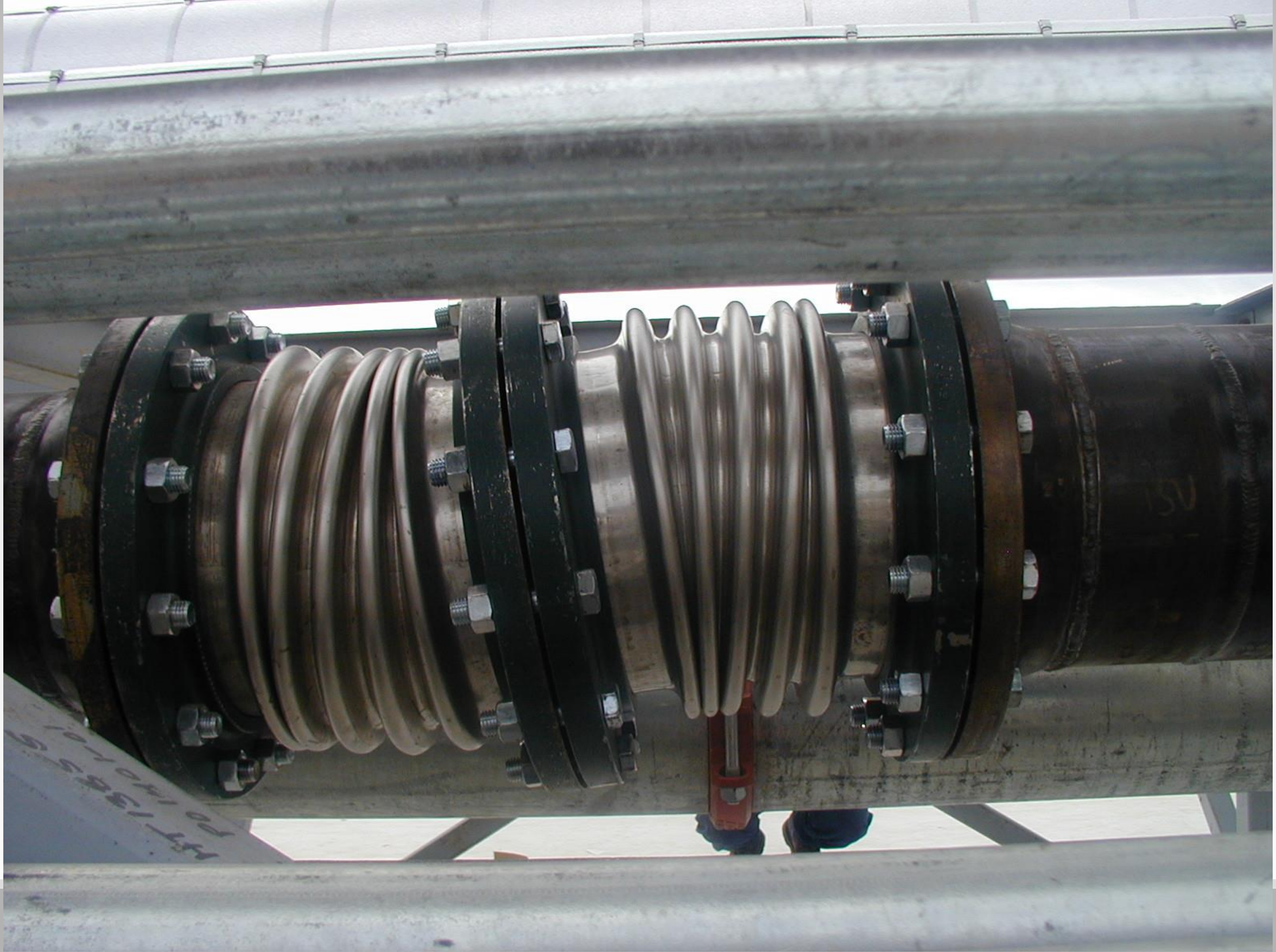
- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs steam



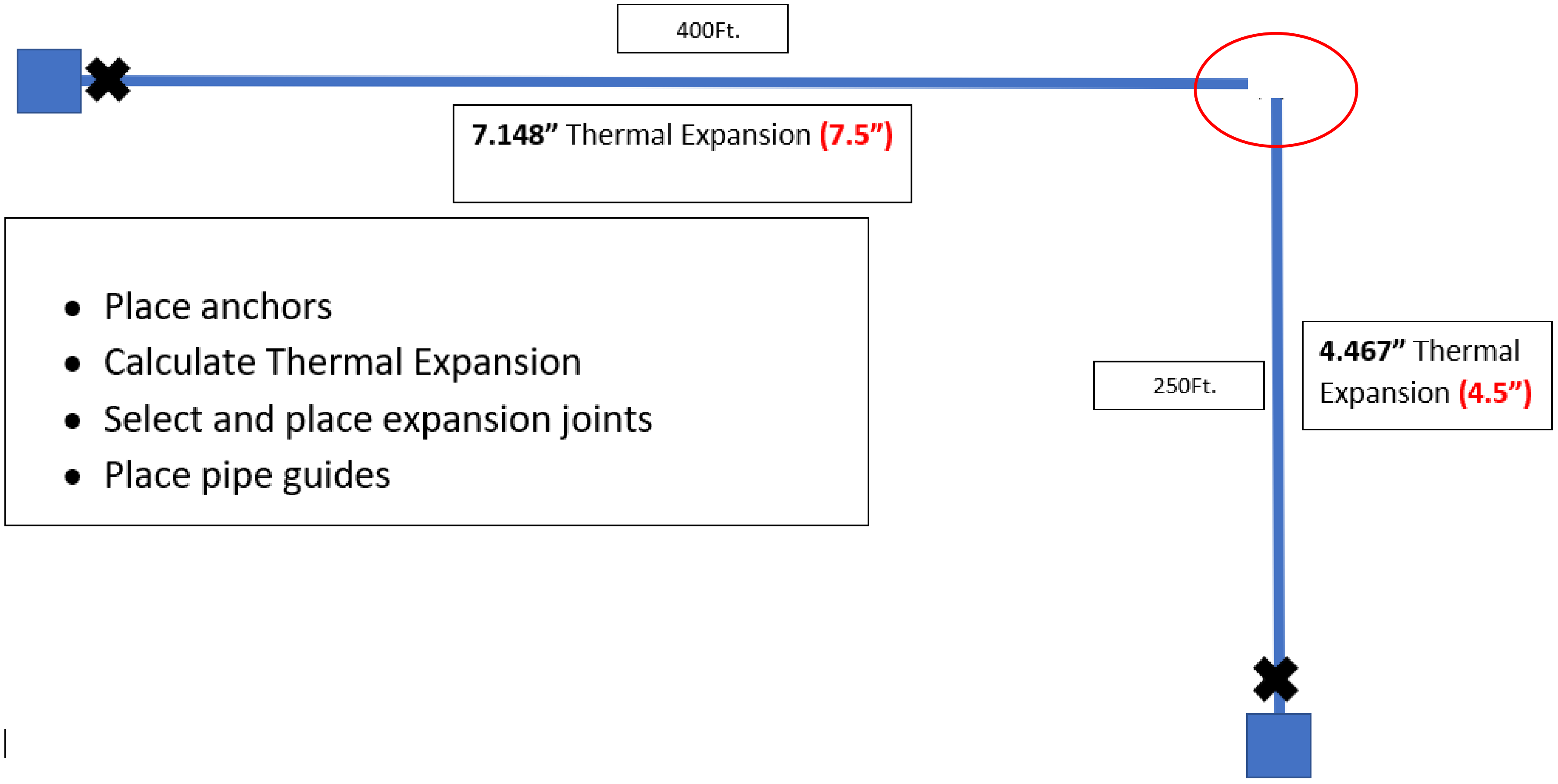
- Place anchors
- Calculate Thermal Expansion
- Select and place expansion joints
- Place pipe guides

Guides Not Shown for Clarity





- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs steam



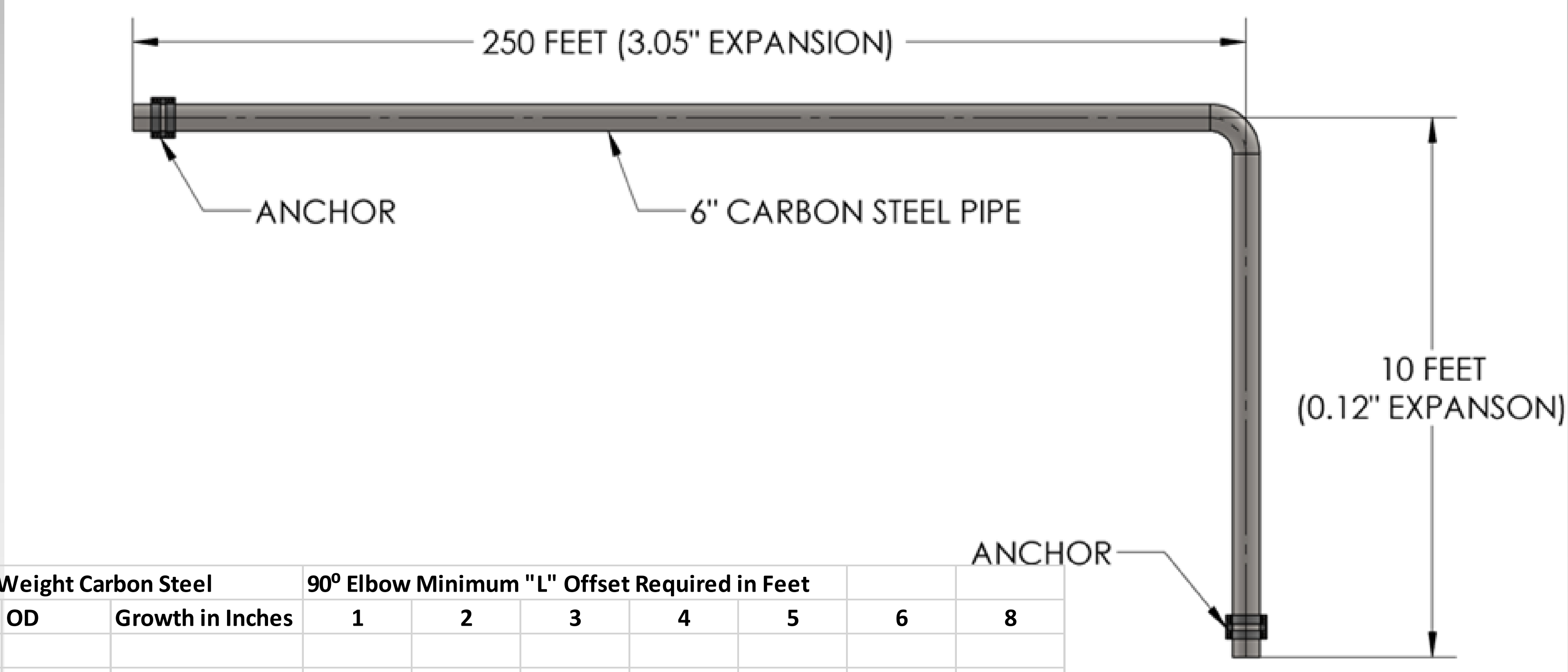
- Place anchors
- Calculate Thermal Expansion
- Select and place expansion joints
- Place pipe guides

The Dog Leg

<u>Note: For Dog Legs, each section of hose must be sized for the full amount of movement</u>

That will look like this

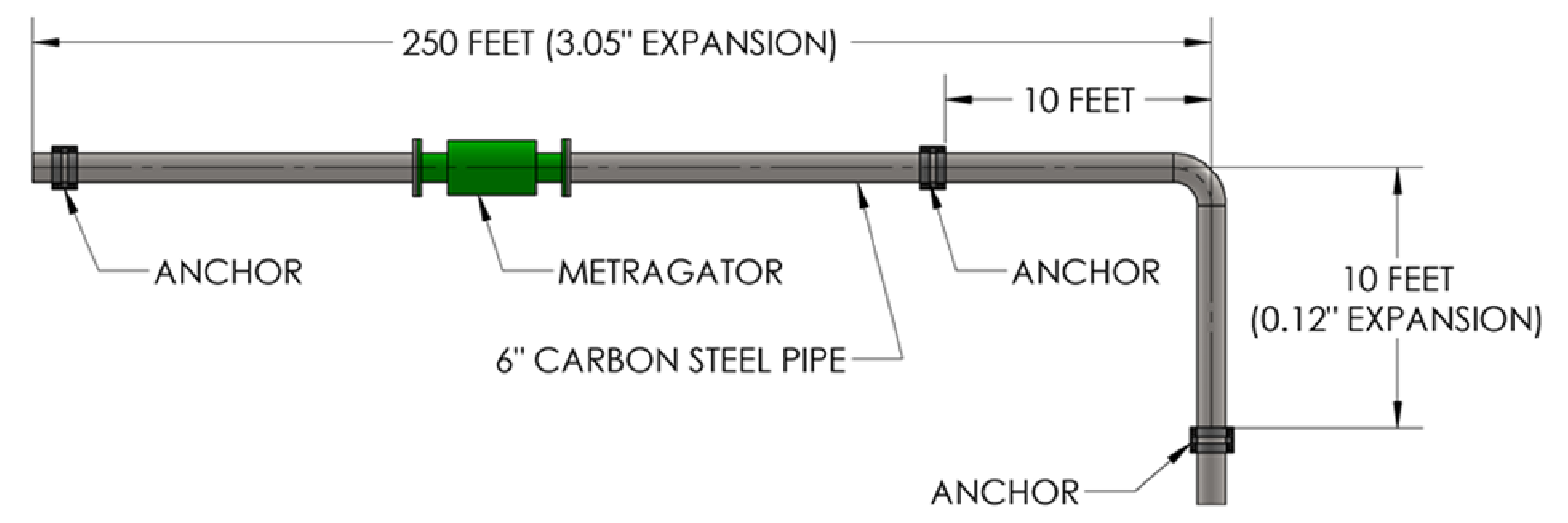
Lets Check for Natural Flexibility



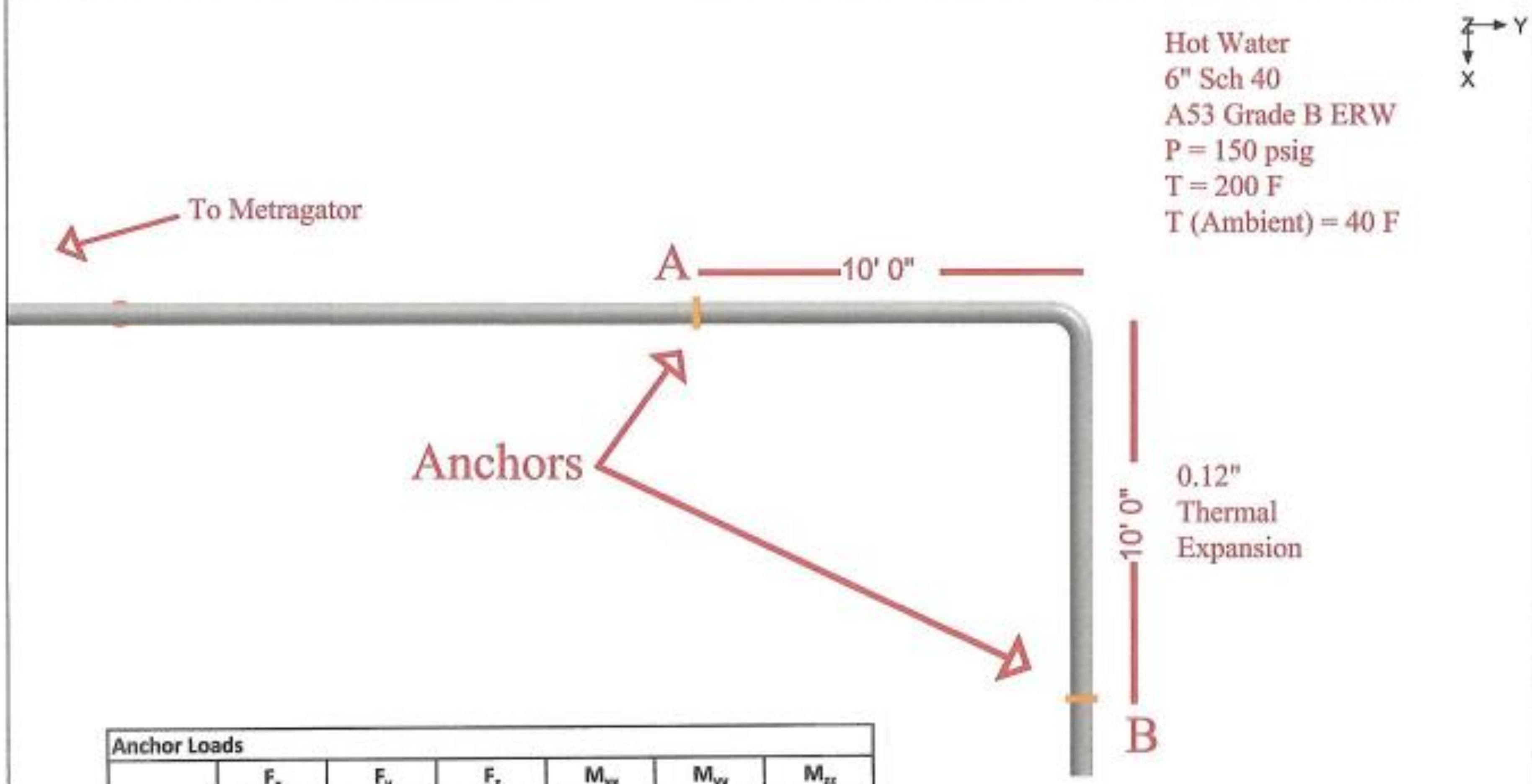
Standard Weight Carbon Steel			90^0 Elbow Minimum "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5"	0.84		5.71	8.07	9.88	11.41	12.76	13.97	16.14
0.75"	1.05		6.38	9.02	11.05	12.76	14.26	15.62	18.04
1"	1.315		7.14	10.10	12.36	14.28	15.96	17.49	20.19
1.25"	1.66		8.02	11.34	13.89	16.04	17.93	19.65	22.68
1.5"	1.9		8.58	12.13	14.86	17.16	19.19	21.02	24.27
2"	2.375		9.59	13.57	16.62	19.19	21.45	23.50	27.13
2.5"	2.875		10.55	14.93	18.28	21.11	23.60	25.85	29.85
3"	3.5		11.65	16.47	20.17	23.29	26.04	28.53	32.94
4"	4.5		13.21	18.67	22.87	26.41	29.53	32.35	37.35
5"	5.563		14.68	20.76	25.43	29.36	32.83	35.96	41.53
6"	6.625		16.02	22.66	27.75	32.04	35.83	39.25	45.32
8"	8.625		18.28	25.85	31.66	36.56	40.88	44.78	51.71
10"	10.75		20.41	28.86	35.35	40.82	45.64	49.99	57.73
12"	12.75		22.23	31.43	38.50	44.46	49.76	54.45	62.87

Table 3. expansion Offset Required, found on page 3

Guides Not Shown for Clarity

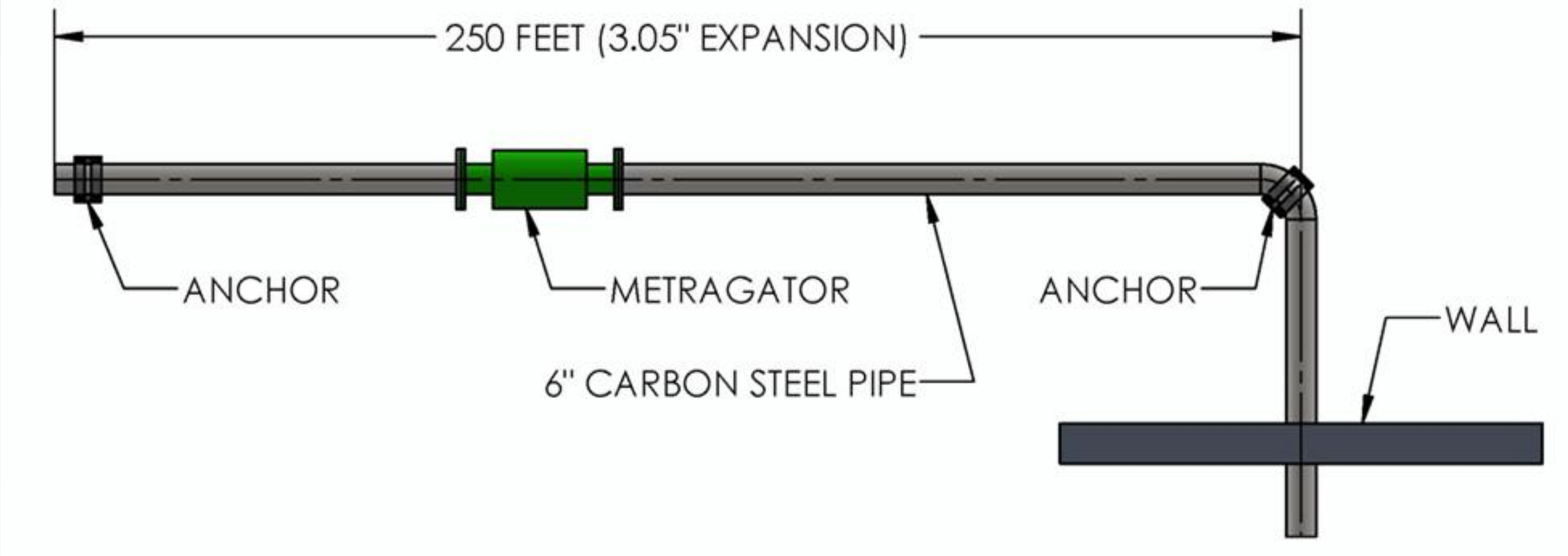


6 in Metragator Sample



Anchor Loads						
	F_x	F_y	F_z	M_{xx}	M_{yy}	M_{zz}
Node	lbs	lbs	lbs	ft. lbs	ft. lbs	ft. lbs
A	-477	10409	-546	-753	-179	2880
B	477	477	-373	-179	-1280	-2880

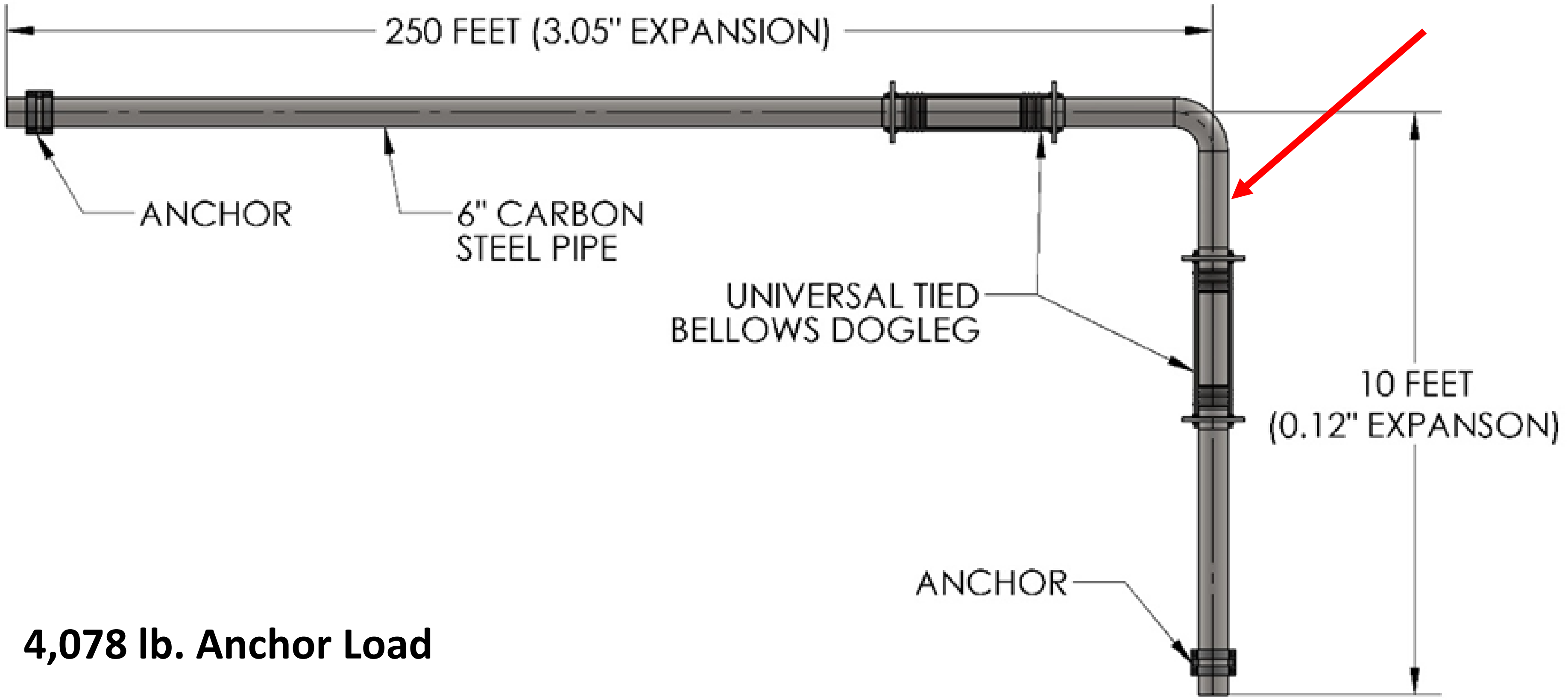
Guides Not Shown for Clarity



AT 150 PSI – Anchor Load of 12,272.75 lbs.

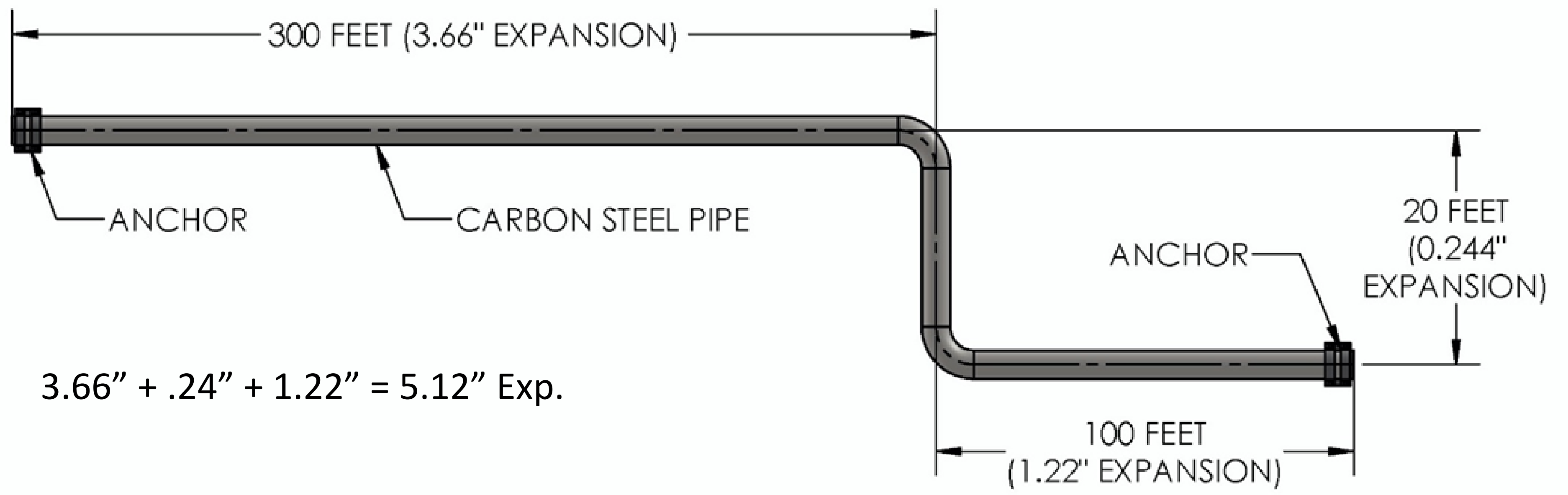
Always Will Have Lower Anchor Load

Another Option



4,078 lb. Anchor Load

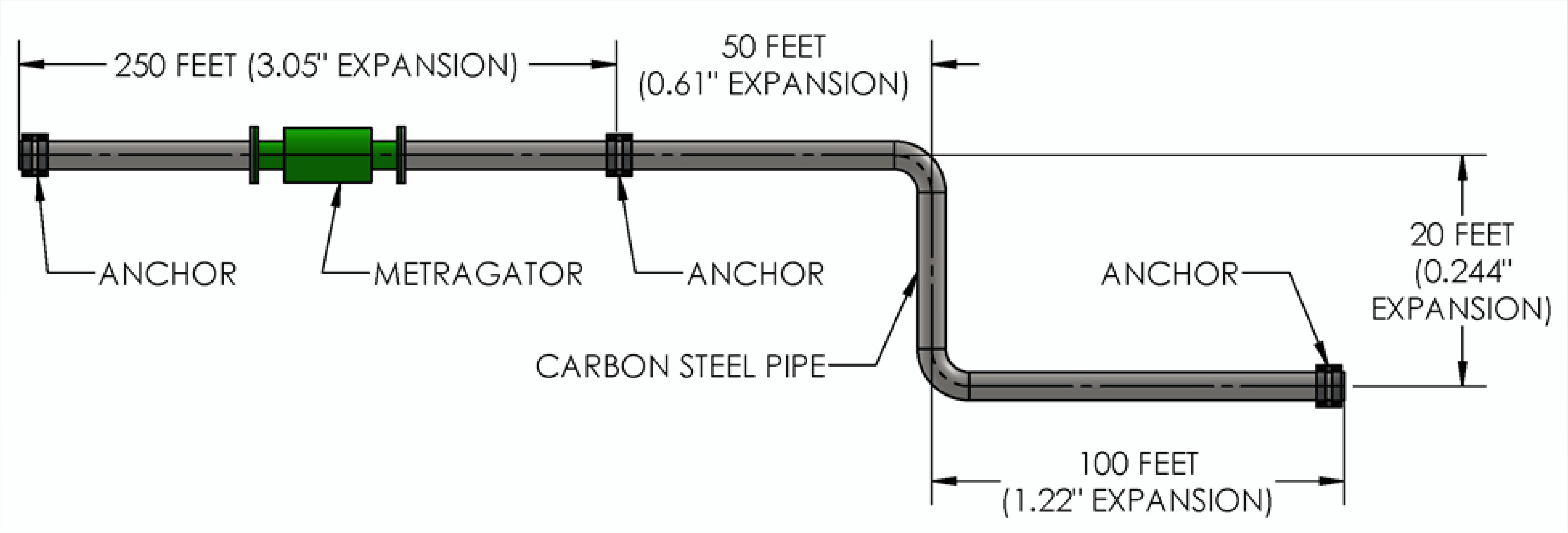
Z - Bend Example

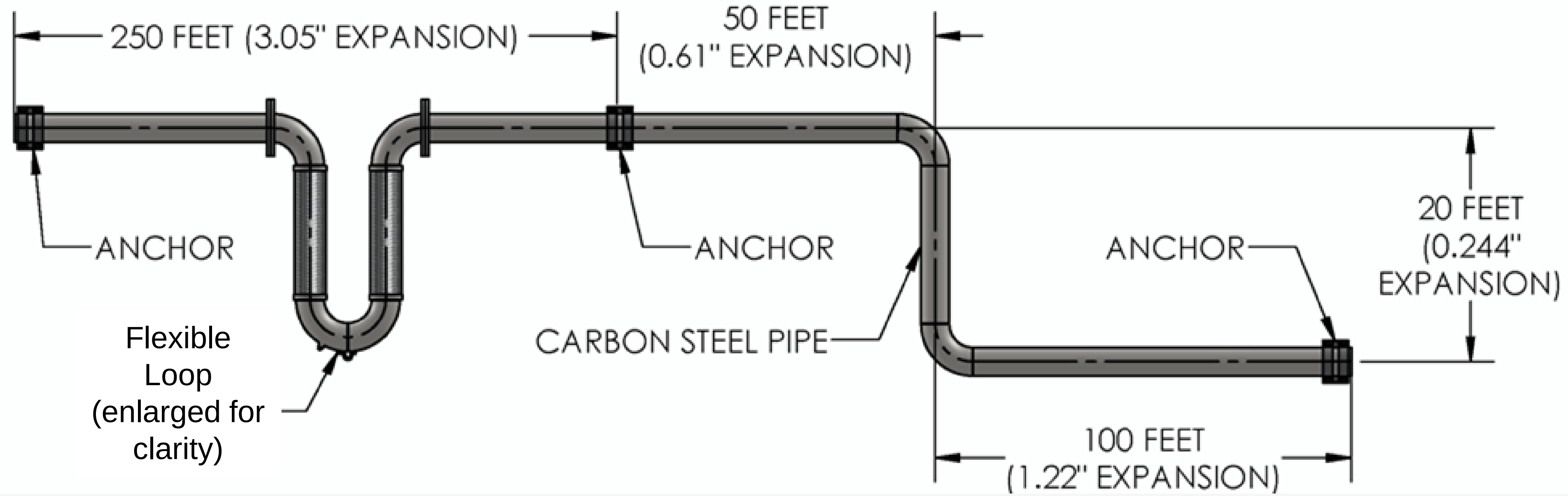


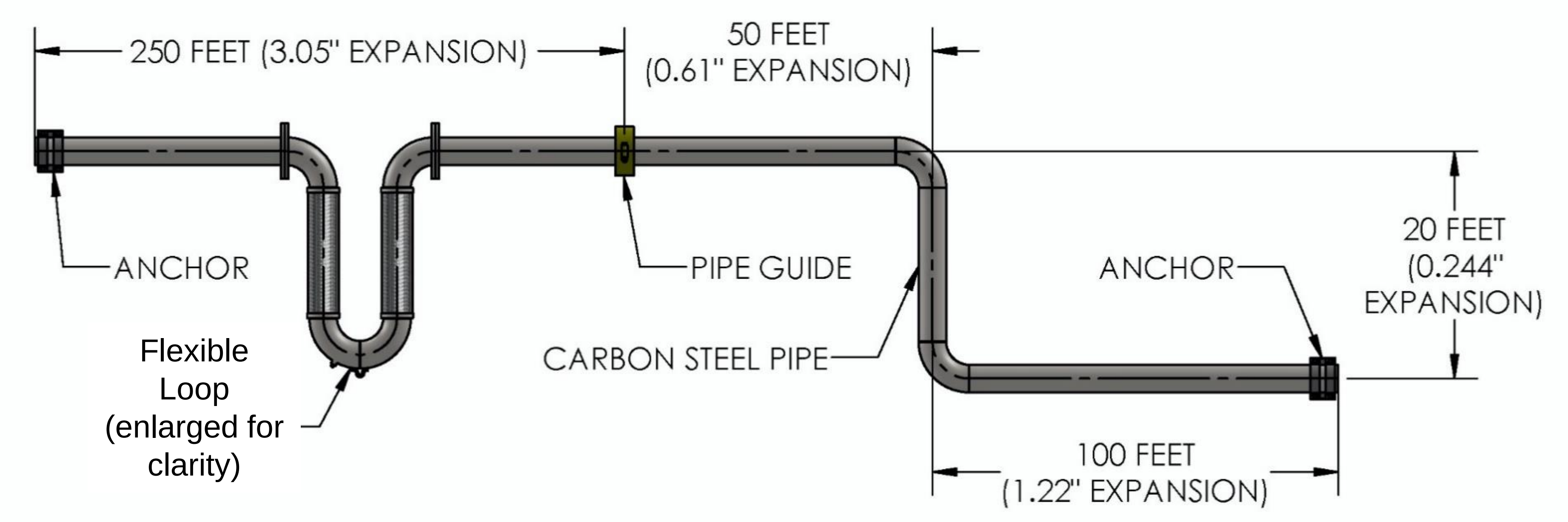
Standard Weight Carbon Steel			Z Bend "L" Offset Required in Feet						
Size	OD	Growth in Inches	1	2	3	4	5	6	8
0.5"	0.84		3.71	5.24	6.42	7.42	8.29	9.08	10.49
0.75"	1.05		4.15	5.86	7.18	8.29	9.27	10.15	11.73
1"	1.315		4.64	6.56	8.04	9.28	10.37	11.37	13.12
1.25"	1.66		5.21	7.37	9.03	10.43	11.65	12.77	14.74
1.5"	1.9		5.58	7.89	9.66	11.15	12.47	13.66	15.78
2"	2.375		6.24	8.82	10.80	12.47	13.94	15.28	17.63
2.5"	2.875		6.86	9.70	11.88	13.72	15.34	16.80	19.40
3"	3.5		7.57	10.71	13.11	15.14	16.93	18.54	21.41
4"	4.5		8.58	12.14	14.87	17.17	19.19	21.03	24.28
5"	5.563		9.54	13.50	16.53	19.09	21.34	23.37	26.99
6"	6.625		10.41	14.73	18.04	20.83	23.29	25.51	29.46
8"	8.625		11.88	16.81	20.58	23.77	26.57	29.11	33.61
10"	10.75		13.27	18.76	22.98	26.53	29.67	32.49	37.52
12"	12.75		14.45	20.43	25.02	28.90	32.34	35.39	40.87

Table 4. Expansion Offset Required for "Z" Bend found on page 9

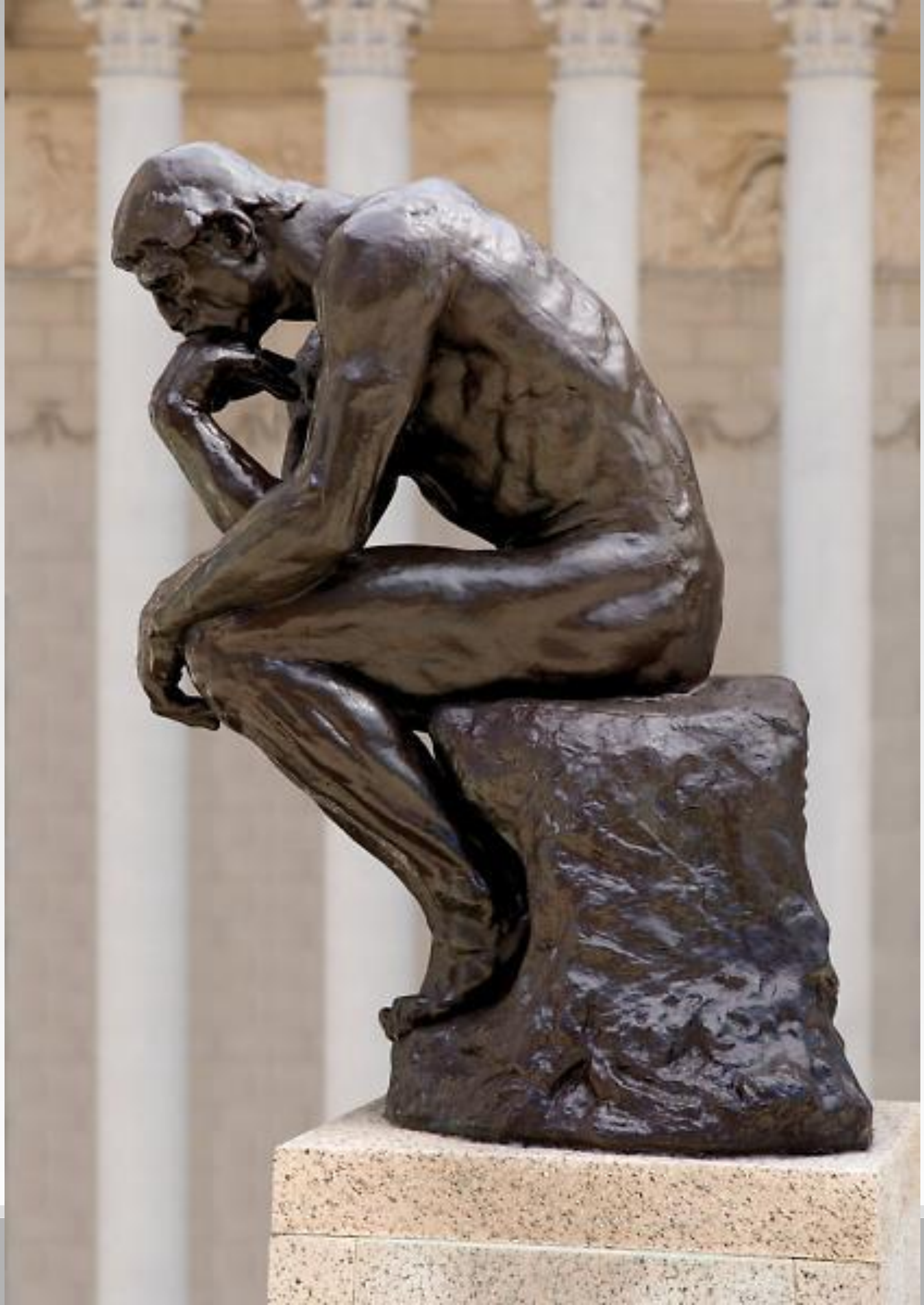
Guides Not Shown for Clarity




250 FEET (3.05" EXPANSION)
50 FEET
(0.61" EXPANSION)
ANCHOR
ANCHOR
ANCHOR
20 FEET
(0.244"
EXPANSION)
CARBON STEEL PIPE
Flexible
Loop
(enlarged for
clarity)
100 FEET
(1.22" EXPANSION)


250 FEET (3.05" EXPANSION)
50 FEET
(0.61" EXPANSION)
ANCHOR
PIPE GUIDE
ANCHOR
20 FEET
(0.244"
EXPANSION)
CARBON STEEL PIPE
Flexible
Loop
(enlarged for
clarity)
100 FEET
(1.22" EXPANSION)

Things to think about.



Is it chilled water?

Ambient Temperature

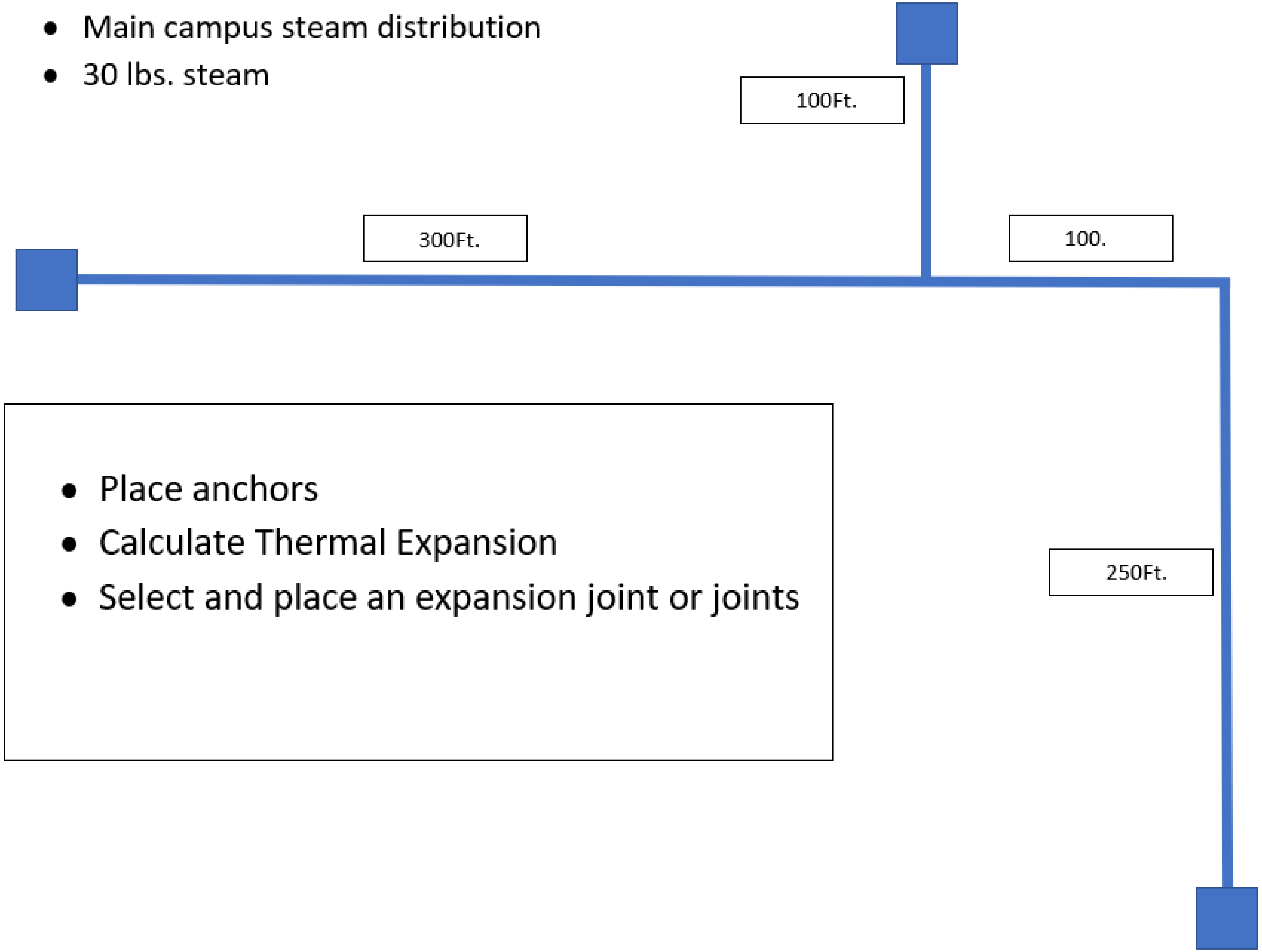
PRV

Testing

Questions?

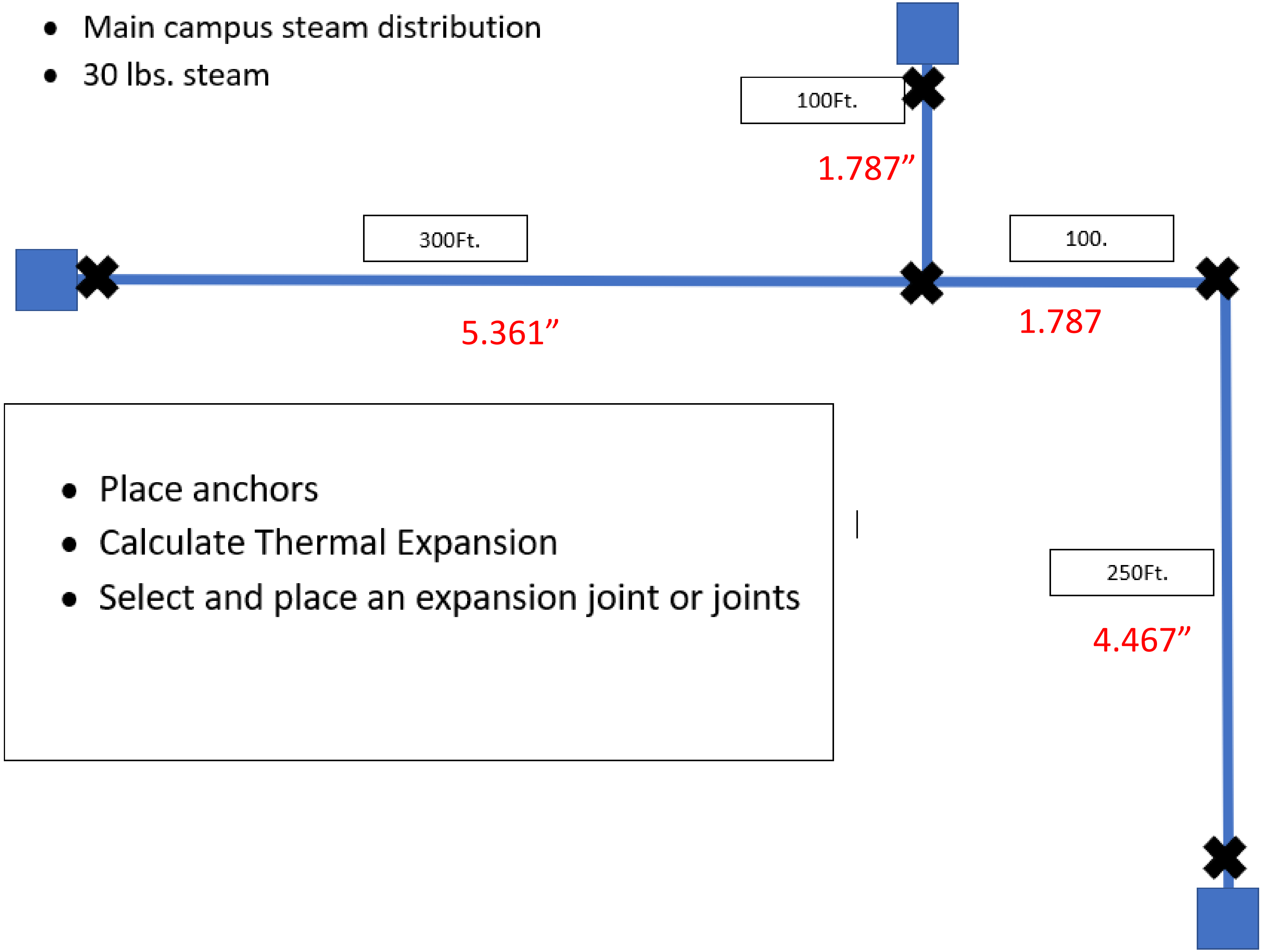
Dan Holbach – DanH@Metraflex.com

- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs. steam



- Place anchors
- Calculate Thermal Expansion
- Select and place an expansion joint or joints

- 6” Carbon Steel Pipe
- Main campus steam distribution
- 30 lbs. steam



- Place anchors
- Calculate Thermal Expansion
- Select and place an expansion joint or joints

Questions?

Dan Holbach – DanH@Metraflex.com