PIPING SOLUTIONS Engineering & Field Services	PATHWAY ENGINEERING BULLETIN	DRAWING NO. LNG DOCK LINE DESIGN	REV 0	SHEET **1** OF 3
CUSTOMER MDP-97	BY DLE	QUOTE/JOB/NO N/A		DATE 6/22/12

LNG DOCK LINE DESIGN

LNG and cryogenic gas loading docks offer a unique challenge in piping design as in most cases the loading station is located a considerable distance from the shore. For example, a mile long loading dock with stainless steel pipe at -300°F will shrink by 192”. This shrinking must be accommodated and is the subject of this bulletin.

There are four basic ways of design for the shrinkage as follows:

PIPE LOOPS – The traditional approach for dealing with thermal growth / shrinkage is the pipe loop. It is a tried and true method, which most designers are comfortable with. However in the case of a loading dock, the pipe loops must either extend vertically or horizontally away from the dock requiring special supports or additional pier caissons. The loops will also increase the pressure drop across the line requiring larger pumps and in some cases restricting the off loading rate for a ship. For these reasons, it is common to investigate alternative solutions.

EXTERNALLY PRESSURIZED EXPANSION JOINTS (X-Press) – An unrestrained, externally pressurized expansion joint(s) can be used in very long runs and can absorb up to 16” of stroke or in some cases more of thermal movement. They will also reduce valuable dock space by allowing a straight run of pipe, reduce pumping costs and allowing high velocities in the line for quick off loading. As such, they are an attractive and economical alternative to pipe loops.

However, these joints have two drawbacks, which can be substantial. The primary drawback is that they do not restrain pressure thrust. Pressure thrust is the longitudinal end load that develops as the result of pressure in the line.

The end thrust is equal to the pipe area times the line pressure. In the case of a 30” diameter line operating at 275 psig it equals 241,485 lbs. The second drawback is that an unrestrained expansion joint will cause the pipeline to become slightly compressive and must be guided accordingly.

INLINE PRESSURE BALANCED EXPANSION JOINT (X-Press II) – It is possible to design an expansion joint to take large amounts of axial movement and still restrain pressure thrust. The joint accomplishes this by creating a balancing bellows cavity, which is sized to be equal and opposite to the line pressure thrust. Thus, they allow for a straight dock line, absorption of large amounts of thermal movement and do not require special anchors and/or guides. The only problem with the X-Press II is that they are complex units requiring special care to insulation details and tend to be expensive.

SPECIAL DESIGN CONSIDERATION for X-Press expansion joints. As discussed earlier, there are two special design considerations for the X-Press style expansion joint, main anchors and guiding which will be the focus of this bulletin.

The guiding requirements for an unrestrained expansion joint are discussed in depth in the Expansion Joint Manufacturer’s Association Standards (EJMA) section 2.10.2 and summarized here. The standards require that the line be guided at $4 \cdot D_p$, $14 \cdot D_p$ and L_{max} per figure 1. The formulas for this figure are contained on sheet 3 of 3.

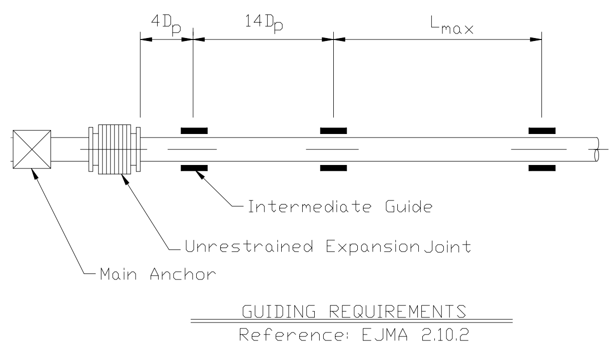

Figure 1

The X-Press expansion joint, see figure 2, has a number of unique features which make it especially suited to absorb large axial movements, consult our catalog for a discussion of these features. For the purposes of this bulletin, the guide rings are worth pointing out as they will allow the first guide requirement ($4 \cdot D_p$) of the EJMA requirements to be eliminated.

Piping Solutions Group:
P.O. Box 10
Pine Valley, Ca. 91962
(619) 473-8248

Senior Operations LLC, Pathway Div:
2400 Longhorn Industrial Dr
New Braunfals, Texas 37830
(830) 629-8080

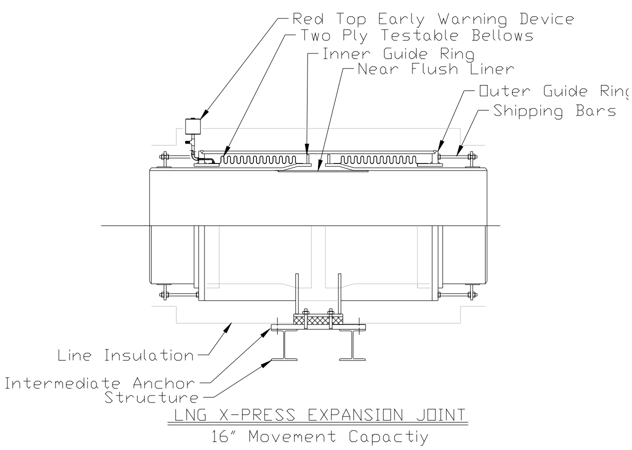

Figure 2

If we were to take a 30"diameter line with 0.375" thick wall of stainless steel material operating at -300°F, the resulting coefficient of growth would be -3.63 in/100ft. Utilizing a 16" stroke X-Press would yield a maximum line length of 440 ft. The maximum support spacing for this size pipe would be 35 ft. Figure 3 below depicts what the resulting line support, guide and anchor requirements would be.

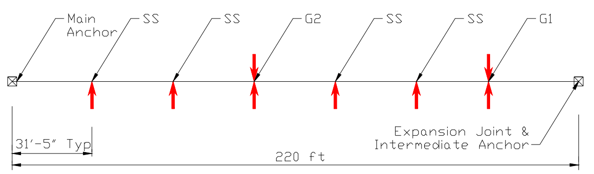

Figure 3

Where:
Main Anchor would be a main thrust anchor as discussed below, SS would be a sliding support and G1 & G2 are planar guides.

MAIN THRUST ANCHORS absorb the axial pressure thrust generated by an unrestrained expansion joint. Due to the special considerations surrounding LNG lines, great care must be taken to eliminate or significantly reduce the amount of conductive heat that an anchor can generate. In the industry, there are two basic types of thrust anchors, inline and elbow dummy leg. The calculation of the intermediate and main thrust anchor loads are contained by sheet 3 of this bulletin.

INLINE ANCHOR – The inline anchor is similar to the traditional pipe clamp anchor that most designers are accustom to using, see figure 4. The primary difference is the use of high-density polyurethane insulation between the line pipe and the exterior pipe clamp. The insulation is intended to reduce the heat transfer from the clamp to the line. The insulation is bonded to the pipe and frictional forces prevent the line from shifting. One vendor uses interlock lug plates separate by structural insulating form in extreme cases. This style of anchor is commonly used for intermediate anchors and occasionally used for main thrust anchors. If used as a main anchor, it would have to be custom engineered and manufactured for the very high pressure thrust loads.

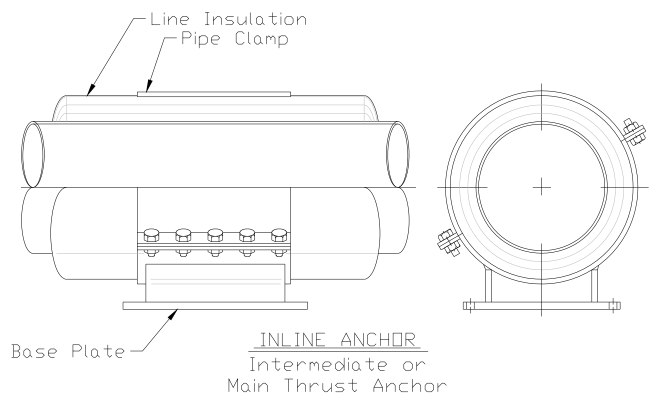

Figure 4

ELBOW DUMMY LEG ANCHORS are more commonly used and are commercially available, see figure 5. This style of anchor has a capacity as much as a half million pounds and is readily available from most cold support manufacturers or Pathway can supply the anchor with the expansion joint order. They are similar to a standard dummy leg support except a layer of polyurethane has been placed between the line and he anchor point to reduce heat transfer.

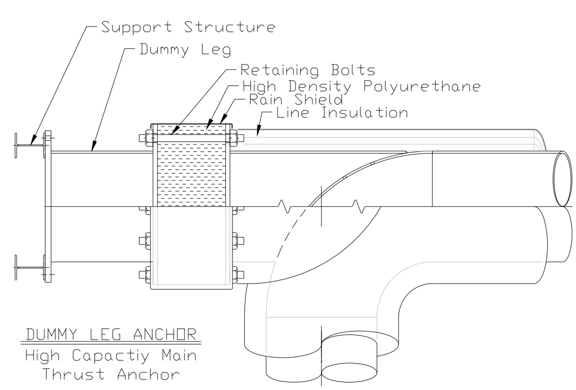

Figure 5

Piping Solutions Group:
P.O. Box 10
Pine Valley, Ca. 91962
(619) 473-8248

Senior Operations LLC, Pathway Div:
2400 Longhorn Industrial Dr
New Braunfals, Texas 37830
(830) 629-8080

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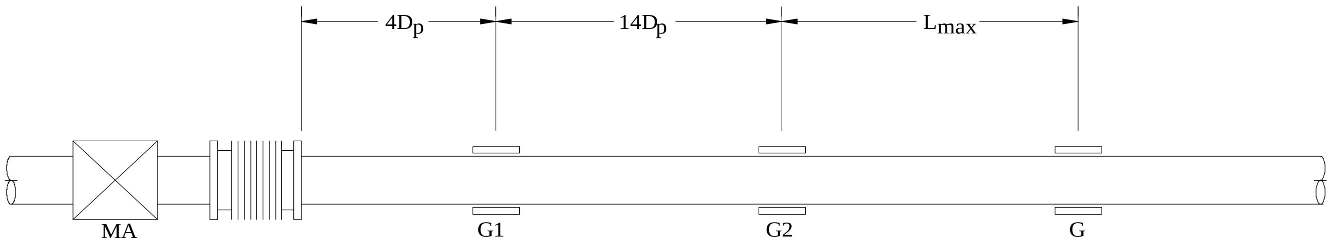

INPUT

P	Line design pressure	= Per design specification	275	psi
O_{dp}	Pipe outside diameter	= Per design specification	30	sq in
t_p	Pipe wall thickness	= Per design specification	0.375	sq in
E_p	Pipe modulus of elasticiy at temperature	= Per design specification	3.02E+07	sq in
A_e	Bellows effective area	= Per attached BDA	878.127	sq in
F_{m1}	Force to compress / extend the expansion joint to the right of intermediate anchor	= Per attached BDA	14,825	lbs
F_{m2}	Force to compress / extend the expansion joint to the left of intermediate anchor	= Per attached BDA	14,825	lbs

CALCULATIONS

I_{dp}	Pipe inside diameter	$= OD_p - 2 \times t_p$	29.25	lbs
A_{dp}	Pipe inside area	$= OD_p^2 \times \pi / 4$	707	s.i.
F_{g1}	Frictional force due to guides on the right	= 0	0	lbs
F_{g2}	Frictional force due to guides on the left	= 0	0	lbs
F_{ia1}	Inermediate anchor design load, operating	$= F_{m1} + F_{g1} + F_{m2} + F_{g2}$	44,475	lbs
F_{ia2}	Inermediate anchor design load, start up	$=$ Larger of $\text{abs}(F_{m1} + F_{g1})$ or $\text{abs}(F_{m2} + F_{g2})$	29,650	lbs
F_{ia}	Inermediate anchor design load	$=$ Larger of F_{ia1} or F_{ia2}	44,475	lbs
F_s	Static thrust due to internal pressure	$= A_e \times P$	241,485	lbs
F_{ma}	Main anchor design force	$= F_s + F_{ia}$	285,960	lbs
I_p	Moment of Inertia of pipe	$= (OD_p^4 - ID_p^4) \times \pi / 64$	3,829	in
L_{max}	Maximum intermediate guide spacing	$= 0.131 \times [\, E_p \times I_p / (P \times A_e + \text{Max}(F_{m1} \text{ or } F_{m2})\,)\,]$ ^0.5	88	ft