TECHNICAL BULLETIN

EXPANSION JOINTS
AIR-COOLED CONDENSER

PIPING TECHNOLOGY & PRODUCTS, INC.

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Figure 1
Typical Air-Cooled Condenser

Air-Cooled Condenser Expansion Joints

Modern power plants frequently use air-cooled condensers to return spent steam back into the cycle after it has been used to spin the turbine to generate electricity. This is a critical part of the Rankin cycle, which improves power generation efficiency.

Of greatest concern for the piping designer is the thermal expansion that occurs in the major duct system that feeds the condenser from the turbine.

The first expansion joint is required at the turbine case at the exhaust to the condenser duct. This is frequently a rubber dogbone design. It serves to reduce loads transmitted via differential thermal growth from the expanding ducting and turbine casing. Generally, the restrictions on the turbine case which often must comply with NEMA 23A limits preclude the use of metallic bellows expansion joints.

Rubber dogbone expansion joints are quite simple, but can be very large and require some care in design and fabrication.

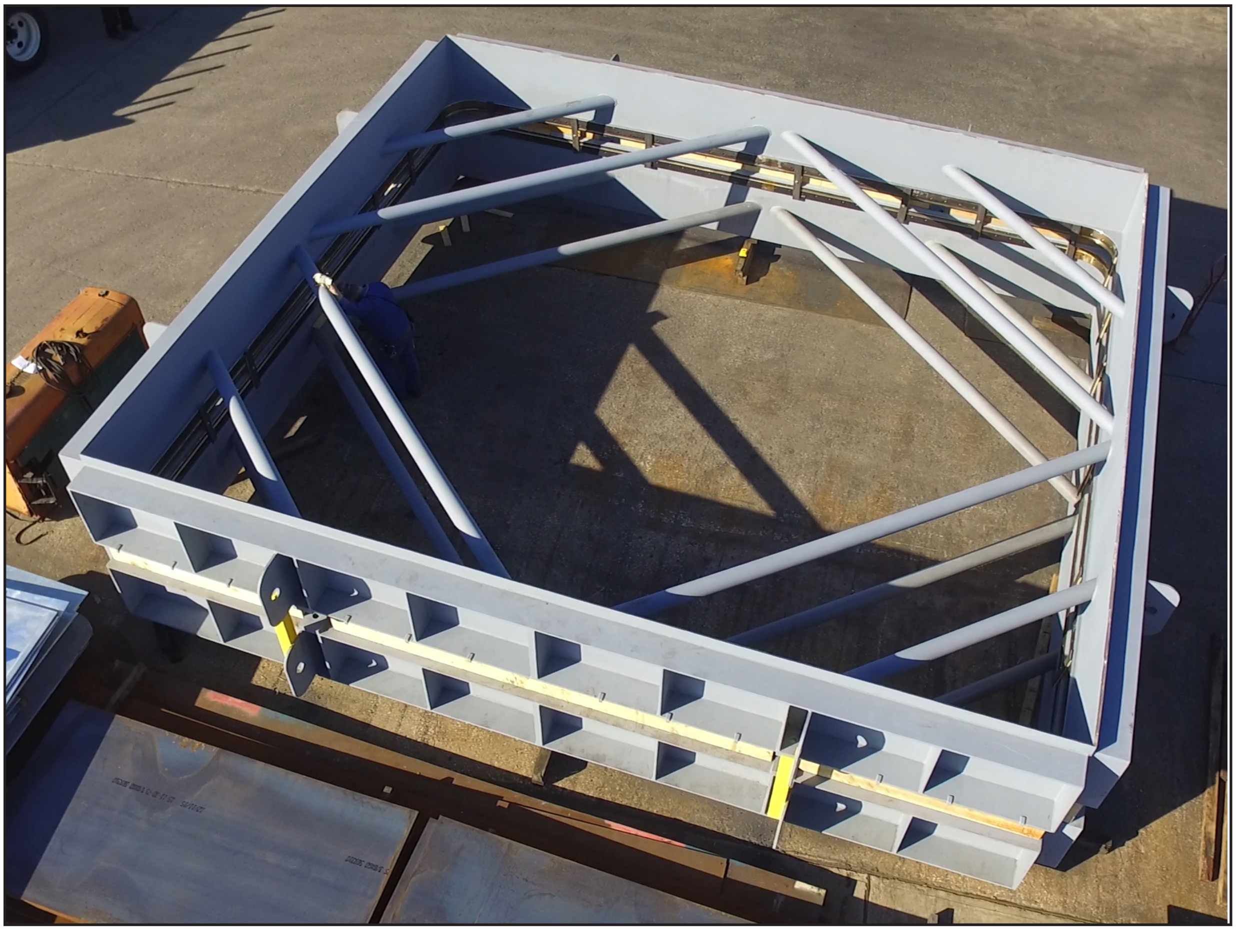
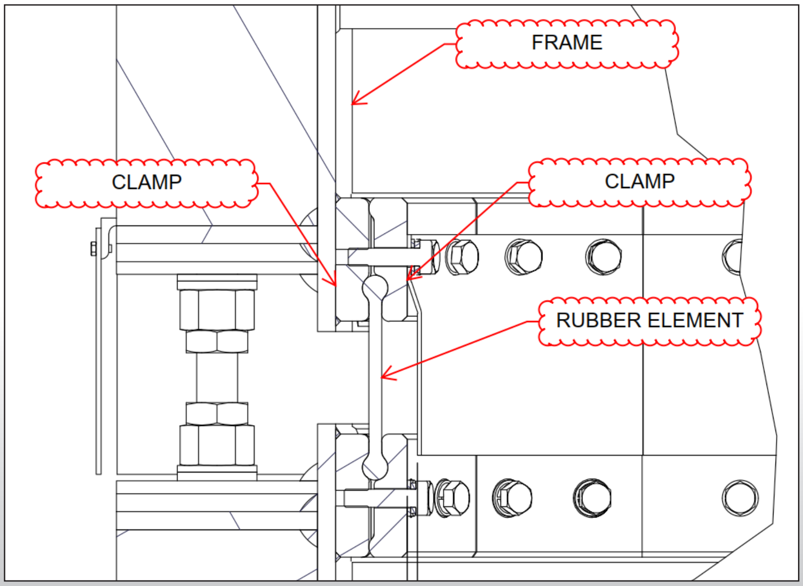


Figure 2
Aerial View of Dogbone Expansion Joint Frame



VIDEO: Fabrication Process from Start to Finish

Special clamps are machined to properly mount the rubber belt. In turn these clamps are welded to the frame and provide the sealing point for the dogbone.

Figure 3
Clamp Details

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Critical analyses are performed on the associated structures to ensure that there is no risk of collapse due full vacuum conditions, which frequently occur.

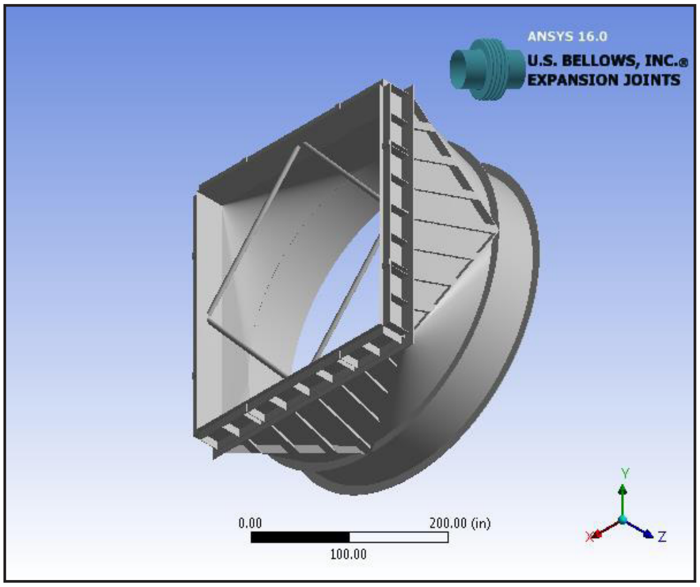


Figure 4
Turbine Exhaust Structure

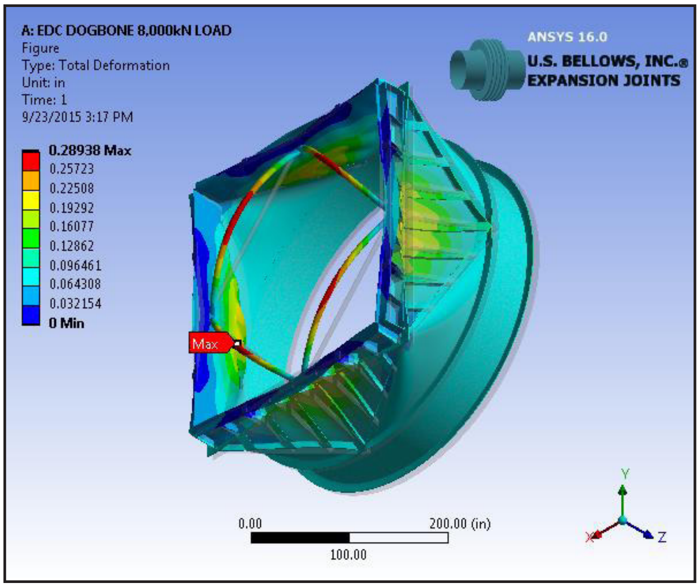


Figure 5
Turbine Exhaust Structure Loading Analysis

Tied Universal Expansion Joints

The next expansion joint is required at spent steam risers to the condenser frame. This is frequently a Tied Universal metal bellows design. It serves to reduce loads transmitted via differential thermal growth from the expanding ducting. Tied Universal expansion joints are relatively simple, but can be very large and also require some care in design and fabrication.

Figure 6
Exhaust Riser Tied Universal Expansion Joints

Several types of structural analyses are performed to ensure conformance with design parameters and special construction loadings that may occur during erection.

VIDEO: Loading of Universal Expansion Joint onto the Truck for Shipment

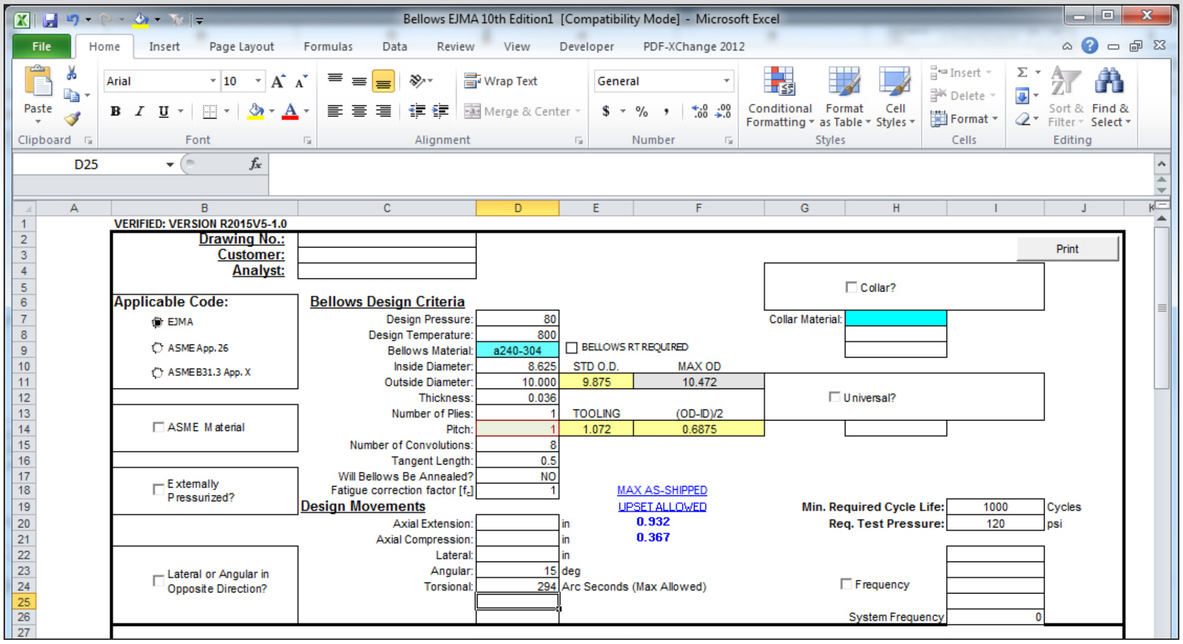
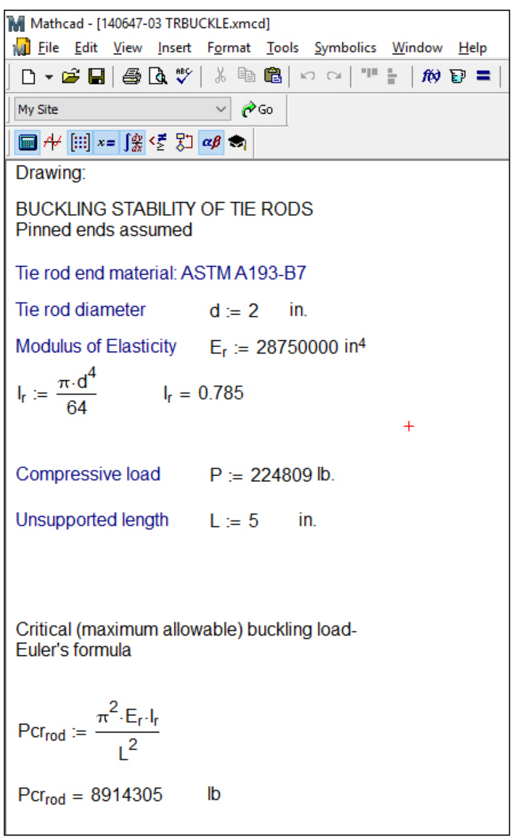


Figure 7
Bellows Design Calculation



Internal pressure calculations are performed for the bellows elements, shell, and the hardware attached to the expansion joint.

Figure 8
Tie Rod Calculations

Additionally, finite element models must be created and analyzed to ensure that the shell does not excessively distort during internal pressure and vacuum loading conditions.

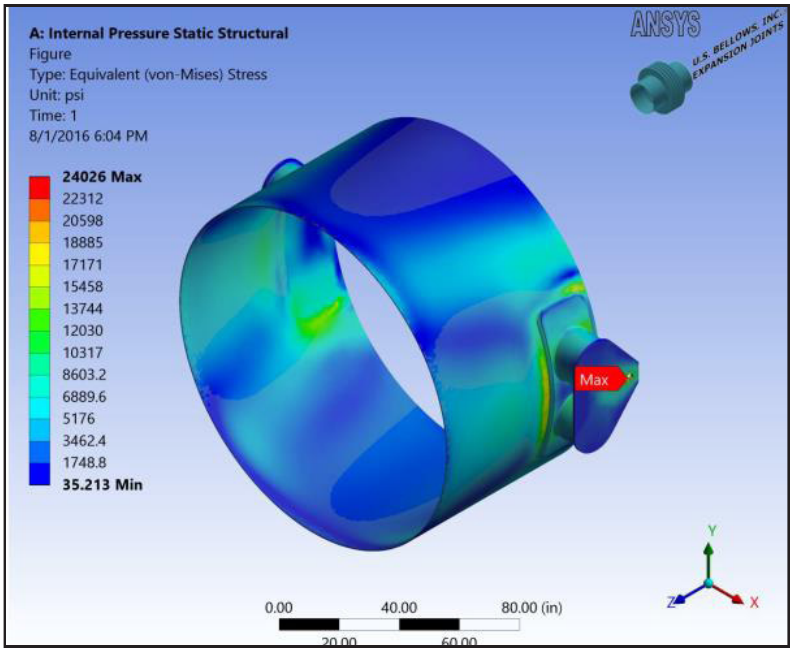


Figure 9
Shell / Hardware Interaction Under Load

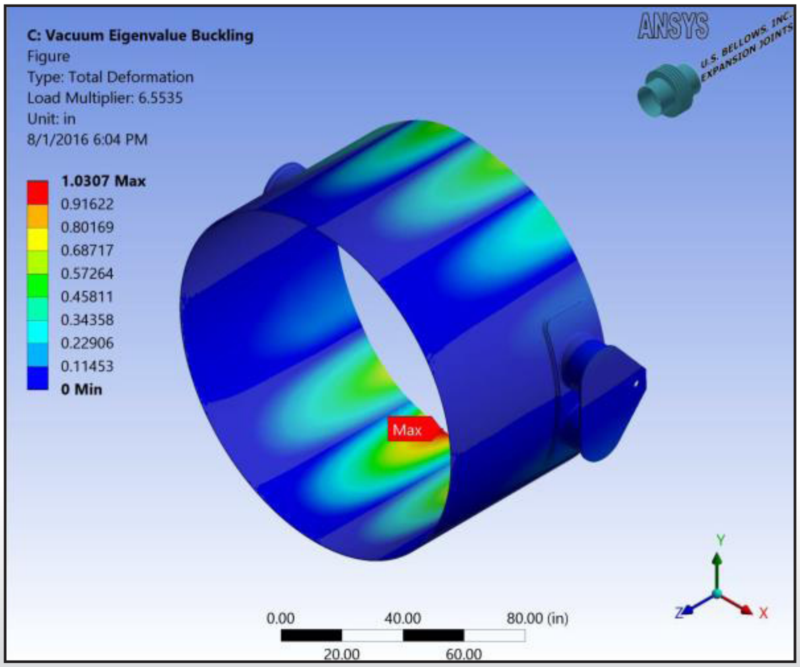


Figure 10
Shell / Hardware Buckling During Vacuum Loading

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Special erection considerations must be studied to ensure that the structure as defined by the customer is suitable to withstand lifting loading during installation.

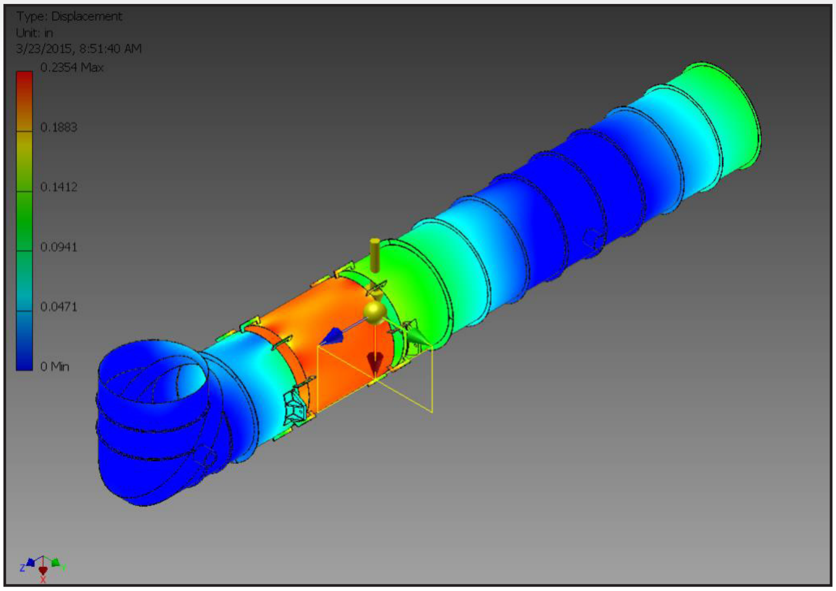

Figure 11
Structural Loading During Installation

Figure 12
Actual Structual Loading During Installation

As power plants have grown in generating capacity, so too have the sizes of the ducting that must service them. The units pictured above will be welded together in the field to form a tied universal expansion joint assembly.

VIDEO: Transportation from PT&P's Manufacturing Facility

Figure 13
178" Diameter Tied Universal Expansion Joints On-Site

Figure 14
On-Site Assembly

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The final expansion joint is required at spent steam lines which run perpendicular to the risers. This is frequently a Single Hinge or Single Gimbal metal bellows design. It serves to reduce loads created when the tied universal joint causes foreshortening in the duct system. Hinge expansion joints are moderately complex, but when dealing with a very large size require some care in design and fabrication.

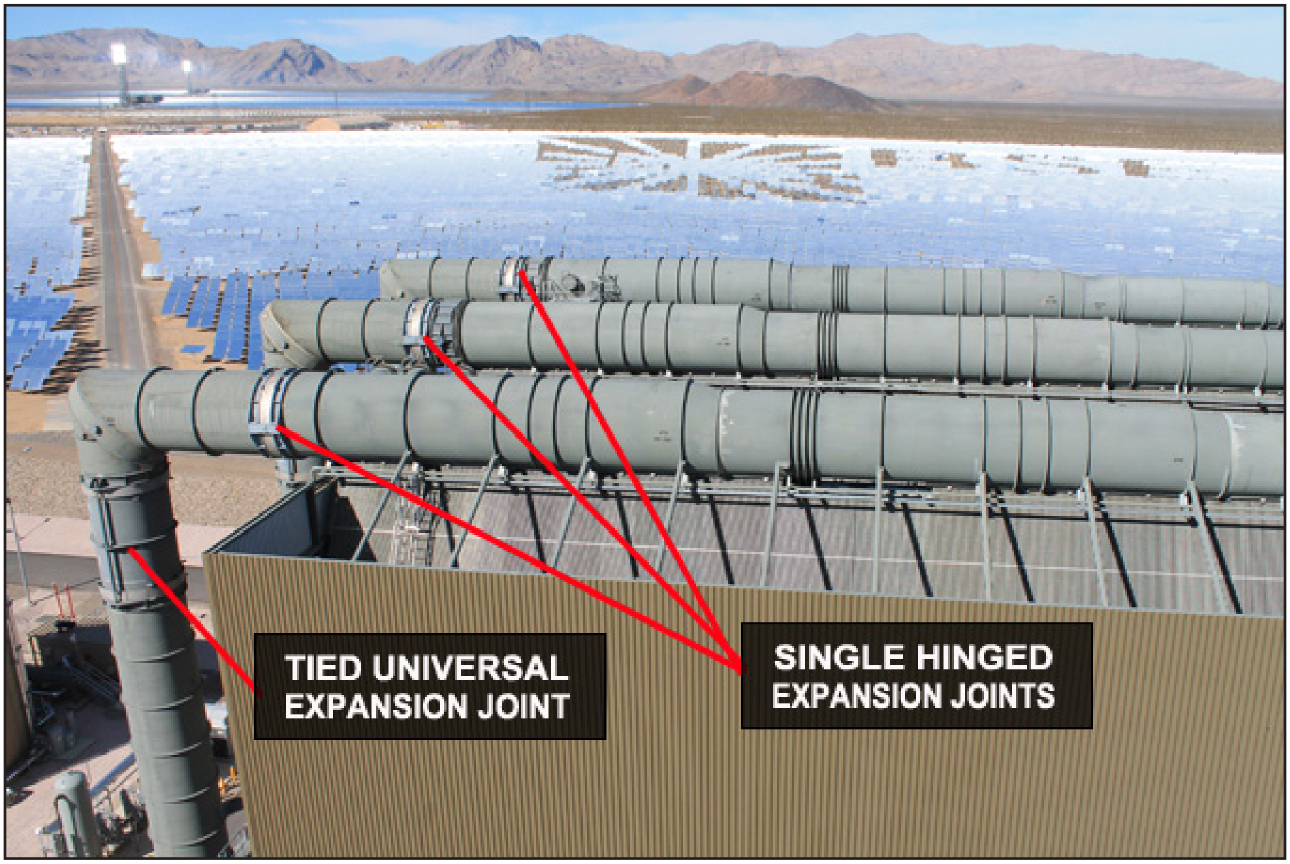
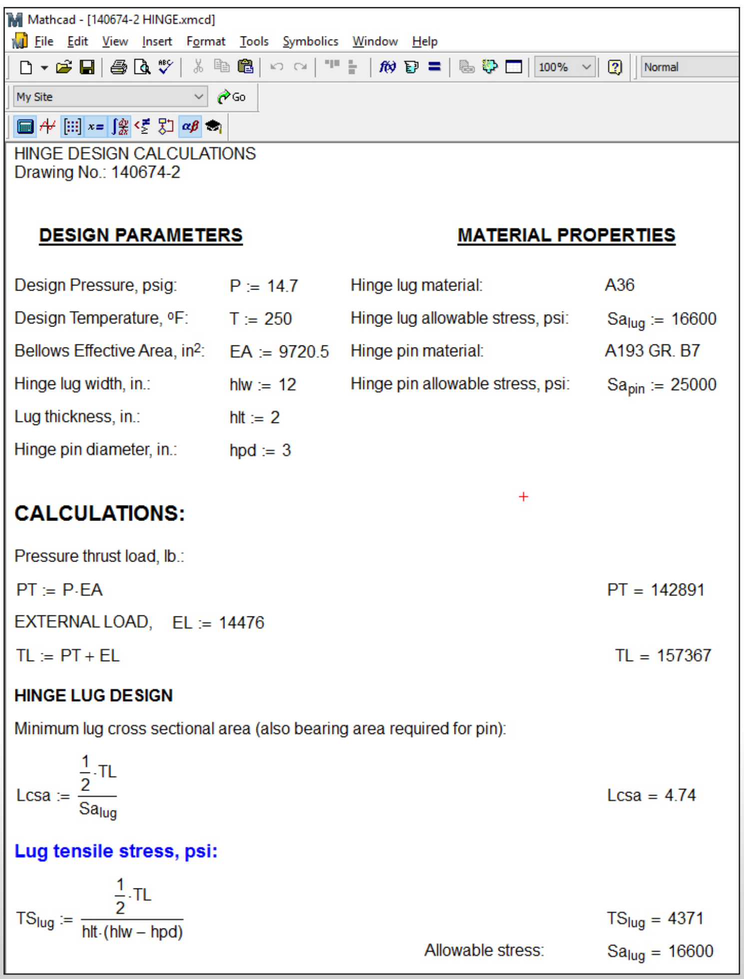


Figure 15
Single Hinged and Tied Universal Expansion Joints
Installed at a Solar Power Plant

The bellows element is analyzed the same way as the tied universal except that the motion is angular instead of lateral. Hardware / Shell interaction under loading will be a duplication of those for the tied universal except for the hinge arms and the pins, which are subject to classical design analysis.

Figure 16
Single Hinged Expansion Joints



HINGE DESIGN CALCULATIONS
Drawing No.: 140674-2

DESIGN PARAMETERS

Design Pressure, psig:	$P := 14.7$
Design Temperature, ºF:	$T := 250$
Bellows Effective Area, in^2:	$EA := 9720.5$
Hinge lug width, in.:	$hlw := 12$
Lug thickness, in.:	$hlt := 2$
Hinge pin diameter, in.:	$hpd := 3$

MATERIAL PROPERTIES

Hinge lug material:	A36
Hinge lug allowable stress, psi:	$Sa_{lug} := 16600$
Hinge pin material:	A193 GR. B7
Hinge pin allowable stress, psi:	$Sa_{pin} := 25000$

CALCULATIONS:

Pressure thrust load, lb.:

$PT := P \cdot EA$ $\qquad PT = 142891$

EXTERNAL LOAD, $EL := 14476$

$TL := PT + EL$ $\qquad TL = 157367$

HINGE LUG DESIGN

Minimum lug cross sectional area (also bearing area required for pin):

$$Lcsa := \frac{\frac{1}{2} \cdot TL}{Sa_{lug}} \qquad Lcsa = 4.74$$

Lug tensile stress, psi:

$$TS_{lug} := \frac{\frac{1}{2} \cdot TL}{hlt \cdot (hlw - hpd)} \qquad TS_{lug} = 4371$$

Allowable stress: $Sa_{lug} = 16600$

Figure 17
Classic Hinge Hardware Calculation

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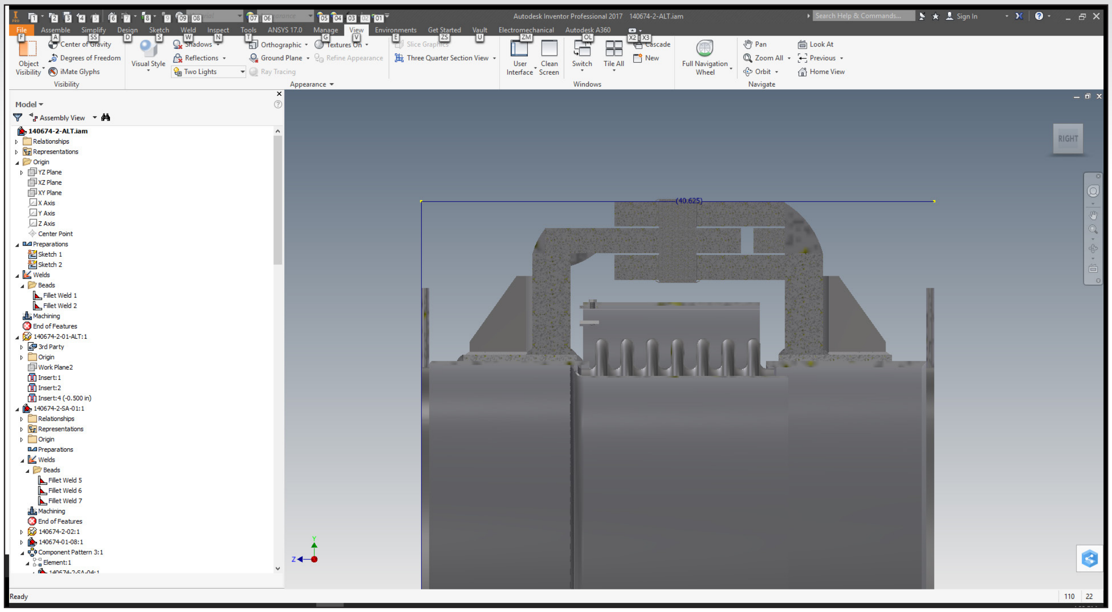

Figure 18
Single Hinge Structure Detail

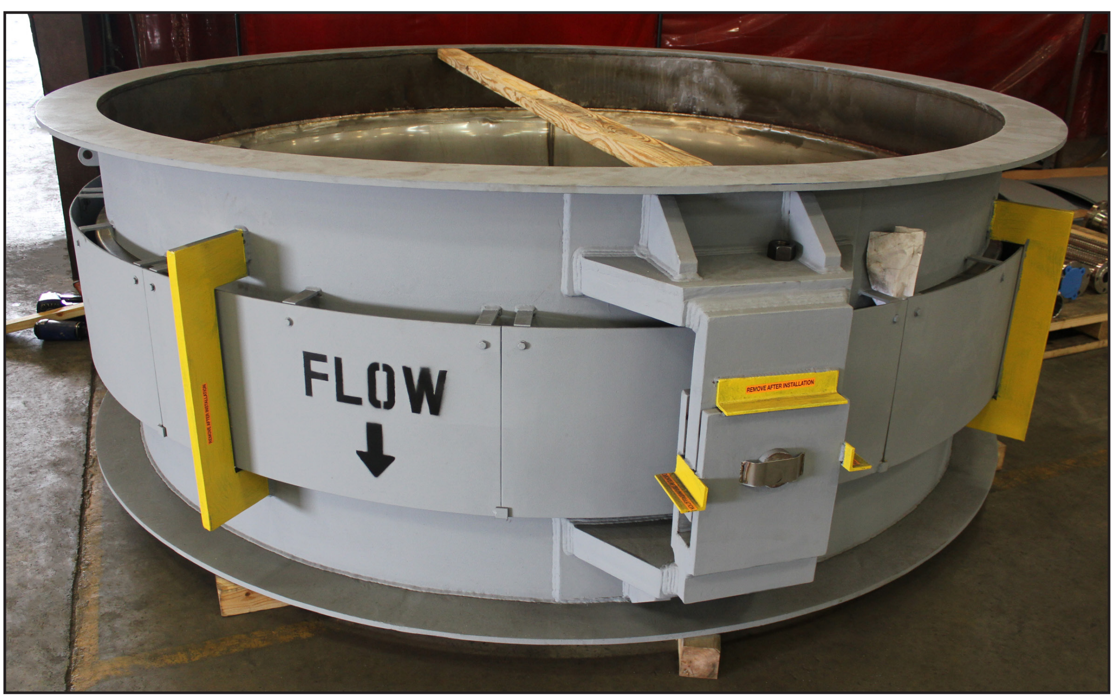

Figure 19
Single Hinged Expansion Joint Assembly

Figure 20
Single Hinged Expansion Joints

Figure 21
Tied Universal Expansion Joint