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Hyspan

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Fax Number: (815) 439-6010

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Attn: Marty Tellalian

Reference: P.O. 930212-0016, S.O. 53353

Attached are bellows design calculations performed in accordance with the EJMA Sixth Edition Standards. It can be noted that the spring rates and cycle life vary somewhat from those produced to the Fifth Edition Standards, as previously submitted. The new calculations produce what we believe to be a more accurate profile of bellows performance.

Best regards,

Jim Johnson
Project Manager

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TECHNICAL SERVICES CO.
TIME 3:08pm



Design Calculations

DRAWING: OPERATING

Reference: Standards of the Expansion Joint Manufacturers Association Sixth Edition

DESIGN PARAMETERS

TEMPERATURE	: 100°F	BELLOWS MATERIAL	: A240-T304	BAND MATERIAL	: N/A
PRESSURE	: 14.7 psig	BELLOWS MODULUS	: 28123462	SAND MODULUS	: N/A
INSIDE DIA.	: 48.750 IN.	OUTSIDE DIA.	: 55.000 IN.	CON. HGT., w	: 3.020
NO. OF PLIES	: 1	BELLOWS THK.	: 0.105 IN.	BAND THK.	: N/A
NO. OF CONS	: 6	PITCH, q	: 2.500 IN/CONS.	MAX OPE. PITCH, q _o	: 2.925
TANGENT LENGTH, L _t	: 6.000 IN	TUBE LENGTH	: 60 IN.		

CONSTANTS

 $D_m = D_b + w + nt = 51.875 \text{ IN}$
 $q/(2.2\sqrt{(d_p t_p)}) = 0.49$
 $C_p = 0.70$
 $C_e = 1.60$
 $\text{EFF. AREA} = 2113.5 \text{ IN}^2$
 $t_p = t\sqrt{(D_b/D_m)} = 0.1018$
 $q/2w = 0.41$
 $C_f = 1.56$
 $K = 1.000$
 ANNEALED - NO

DESIGN MOVEMENTS

EQUIVALENT MOVEMENT, e = 0.496

EXTENSION	: 1.210 IN	$e_{xe} = 0.202$
COMPRESSION	: 0.430 IN	$e_{xc} = 0.072$
LATERAL	: 0.125 IN	$e_y = 0.200$
ANGULAR	: 0.300°	$e_\theta = 0.023$

PRESSURE STRESSES

 $S1 = P(D_b + nt)^2 E_b k / [2nt E_b L_t (D_b + nt) + t_c k E_c L_c D_c] = 14.7(48.75 + 1(0.105))^2 (6.00)(281)(1.00) / [2(1(0.105)(281)(6.00)(48.75 + 1(0.105)) + (0.000)(1.00)(0)(5.25)(49.0))] = 3420 \text{ psi}$
 $S2 = [(P D_m) / (2nt_p)] [1 / (0.571 + 2w/q_o)] = [(14.7(51.875)) / (2(1)(0.1018))] [1 / (0.571 + 2(3.020) / 2.925)] = 1421 \text{ psi}$
 $S3 = [Pw] / (2nt_p) = [14.7(3.020)] / (2(1)(0.1018)) = 218 \text{ psi}$
 $S4 = [P / (2n)] (w / t_p)^2 C_p = [14.7 / (2(1))] (3.020 / 0.1018)^2 (0.70) = 4544 \text{ psi}$

DEFLECTION STRESSES

 $S5 = (E_b t_p^2 e) / (2w^3 C_f) = (281230000(0.1018)^2(0.496)) / (2(3.020)^3(1.56)) = 1691 \text{ psi}$
 $S6 = (5E_b t_p e) / (3w^2 C_f) = (5(281230000)(0.1018)(0.496)) / (3(3.020)^2(1.56)) = 162718 \text{ psi}$

FATIGUE LIFE

 $\text{PER EJMA} = [c / (S_f C_f b)]^n = [1860000 / (167742(1) - 54000)]^{3.400} = 13372 \text{ CYCLES}$

SPRING RATES

 $f_w = 1.7(D_m E_b t_p^3 n) / (w^3 C_f) = 1.7[(51.875)(28123462)(0.1018)^3(1)] / (3.020^3(1.56)) = 60861$
 $\text{AXIAL S/R} = f_w / N = 60861 / 6 = 10144 \text{ LB/IN.}$
 $\text{LATERAL S/R} = 1.5\{(f_w D_m^2) / (N L_b (L_b + x))\} = 1.5\{(60861(51.875)^2) / (6(15.000)(15.000 + (-0.430)))\} = 187347 \text{ LB/IN.}$
 $\text{ANGULAR S/R} = 0.0022 f_w D_m^2 / N = 0.0022(60861)(51.875)^2 / 6 = 59687 \text{ IN-LB/DEG.}$

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Design Calculations

DRAWING: CONDITION #1, 70 DEG. F.

Reference: Standards of the Expansion Joint Manufacturers Association Sixth Edition

DESIGN PARAMETERS

TEMPERATURE	: 70°F	BELLOWS MATERIAL	: A240-T304	BAND MATERIAL	: N/A
PRESSURE	: 14.7 psig	BELLOWS MODULUS	: 28300000	BAND MODULUS	: N/A
INSIDE DIA.	: 48.750 IN.	OUTSIDE DIA.	: 55.000 IN.	CON. HGT., w	: 3.020
NO. OF PLYS	: 1	BELLOWS THK.	: 0.105 IN.	BAND THK.	: N/A
NO. OF CONS	: 6	PITCH, q	: 2.500 IN/CONS.	MAX OPE. PITCH, q _o	: 2.515
TANGENT LENGTH, L _t	: 6.000 IN	TUBE LENGTH	: 60 IN.		

CONSTANTS

$$D_m = D_b + w + nt = 51.675 \text{ IN} \quad q/(2.2\sqrt{(d_p t_p)}) = 0.49 \quad C_p = 0.70 \quad C_d = 1.60 \quad \text{EFF. AREA} = 2113.5 \text{ IN}^2$$

$$t_p = t\sqrt{(D_p/D_m)} = 0.1018 \quad q/2w = 0.41 \quad C_f = 1.56 \quad K = 1.000 \quad \text{ANNEALED - NO}$$

DESIGN MOVEMENTS

$$\text{EQUIVALENT MOVEMENT, } e = 0.558$$

EXTENSION	: 0.000 IN	e _{xe}	= 0.000
COMPRESSION	: 3.260 IN	e _{xc}	= 0.543
LATERAL	: 0.000 IN	e _y	= 0.000
ANGULAR	: 0.200°	e _θ	= 0.015

PRESSURE STRESSES

$$S1 = P(D_b + nt)^2 L_t E_b k / [2(nt E_b L_t (D_b + nt) + t_c k E_c L_c D_c)] = 14.7(48.75 + 1(0.105))^2(6.00)(283)(1.00) / [2(1(0.105)(283)(6.00)(48.75 + 1(0.105)) + (0.000)(1.00)(0)(5.36)(49.0))] = 3420 \text{ psi}$$

$$S2 = (P D_m) / (2n t_p) [1 / (0.571 + 2w/q_o)] = [(14.7)(51.675) / (2(1)(0.1018))] [1 / (0.571 + 2(3.020) / 2.515)] = 1260 \text{ psi}$$

$$S3 = (Pw) / (2n t_p) = [14.7(3.020)] / [2(1)(0.1018)] = 218 \text{ psi}$$

$$S4 = [P / (2n)] (w/t_p)^2 C_p = [14.7 / (2(1))] (3.020 / 0.1018)^2 0.70 = 4544 \text{ psi}$$

DEFLECTION STRESSES

$$S5 = (E_b t_p^2 e) / (2w^2 C_d) = (28300000)(0.1018)^2(0.558) / (2(3.020)^2(1.56)) = 1903 \text{ psi}$$

$$S6 = (5E_b t_p e) / (3w^2 C_d) = (5(28300000)(0.1018)(0.558)) / (3(3.020)^2(1.60)) = 183057 \text{ psi}$$

FATIGUE LIFE

$$\text{PER EJMA} = [c / (S_f C_f b)]^2 = [1860000 / (186293(1-54000))]^{3.400} = 7603 \text{ CYCLES}$$

SPRING RATES

$$f_{su} = 1.7[(D_m E_b t_p^3 n) / (w^3 C_d)] = 1.7[(51.675)(28300000)(0.1018)^3(1)] / (3.020^3(1.56)) = 61211$$

$$\text{AXIAL S/R} = f_{su} / N = 61211 / 6 = 10202 \text{ LB/IN.}$$

$$\text{LATERAL S/R} = 1.5[(f_{su} D_m^2) / (N L_b (L_b + x))] = 1.5[(61211)(51.675)^2] / (6(15.000)(15.000 + (-3.260))) = 233843 \text{ LB/IN.}$$

$$\text{ANGULAR S/R} = 0.0022 f_{su} D_m^2 / N = 0.0022(61211)(51.675)^2 / 6 = 60030 \text{ IN-LB/DEG.}$$

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Design Calculations

DRAWING: CONDITION #1

Reference: Standards of the Expansion Joint Manufacturers Association Sixth Edition

DESIGN PARAMETERS

TEMPERATURE	: 302°F	BELLOWS MATERIAL	: A240-T304	BAND MATERIAL	: N/A
PRESSURE	: 14.7 psig	BELLOWS MODULUS	: 26990000	BAND MODULUS	: N/A
INSIDE DIA.	: 49.750 IN.	OUTSIDE DIA.	: 55.000 IN.	CON. HGT., w	: 3.020
NO. OF PLIES	: 1	BELLOWS THK.	: 0.105 IN.	BAND THK.	: N/A
NO. OF CONS	: 6	PITCH, a	: 2.500 IN/CONS.	MAX OPE. PITCH, a ₀	: 2.515
TANGENT LENGTH, L _t	: 6.000 IN	TUBE LENGTH	: 60 IN.		

CONSTANTS

$$D_m = D_b + w + nt = 51.875 \text{ IN} \quad q/(2.2\sqrt{(d_p t_p)}) = 0.49 \quad C_p = 0.70 \quad C_d = 1.60 \quad \text{EFF. AREA} = 2113.5 \text{ IN}^2$$

$$t_p = t\sqrt{(D_b/D_m)} = 0.1018 \quad q/2w = 0.41 \quad C_1 = 1.56 \quad K = 1.000 \quad \text{ANNEALED - NO}$$

DESIGN MOVEMENTS

EXTENSION	: 0.000 IN	e _{xe}	= 0.000
COMPRESSION	: 3.260 IN	e _{xc}	= 0.543
LATERAL	: 0.000 IN	e _y	= 0.000
ANGULAR	: 0.200°	e _θ	= 0.015

EQUIVALENT MOVEMENT, e = 0.553

PRESSURE STRESSES

$$S1 = P(D_b + nt)^2 L_t E_b / [2nt E_b L_t (D_b + nt) + t_p K E_c L_c D_c] = 14.7(49.75 + 1(0.105))^2(6.00)(270)(1.00) / [2(1(0.105)(270)(6.00)(49.75 + 1(0.105)) + (0.000)(1.00)(0)(5.58)(49.0))] = 3420 \text{ psi}$$

$$S2 = ((P D_m) / (2 n t_p)) [1 / (0.571 + 2w/a_0)] = [(14.7(51.875)) / (2(1)(0.1018))] [1 / (0.571 + 2(3.020) / 2.515)] = 1260 \text{ psi}$$

$$S3 = (Pw) / (2 n t_p) = [14.7(3.020)] / (2(1)(0.1018)) = 218 \text{ psi}$$

$$S4 = [P / (2n)] (w / t_p)^2 C_p = [14.7 / (2(1))] (3.020 / 0.1018)^2 0.70 = 4544 \text{ psi}$$

DEFLECTION STRESSES

$$S5 = (E_b t_p^2 e) / (2w^2 C_d) = (26930000(0.1018)^2(0.553)) / (2(3.020)^2(1.56)) = 1903 \text{ psi}$$

$$S6 = (5E_b t_p e) / (3w^2 C_d) = (5(26930000)(0.1018)(0.553)) / (3(3.020)^2(1.60)) = 183057 \text{ psi}$$

FATIGUE LIFE

$$\text{PER EJMA} = [c / (S_1 C_1 - b)]^2 = [1860000 / (183293(1) - 54000)]^{3.400} = 7603 \text{ CYCLES}$$

SPRING RATES

$$f_{w'} = 1.7[(D_m E_b t_p^3 n) / (w^3 C_d)] = 1.7[(51.875(26990000)(0.1018)^3(1)) / (3.020^3(1.561))] = 58377$$

$$\text{AXIAL S/R} = f_{w'} / N = 58377 / 6 = 9730 \text{ LB/IN.}$$

$$\text{LATERAL S/R} = 1.5[(f_{w'} D_m^2) / (N L_b (L_b + x))] = 1.5[(58377(51.875)^2) / (6(15.000)(15.000 + (-3.260)))] = 223019 \text{ LB/IN.}$$

$$\text{ANGULAR S/R} = 0.0022 f_{w'} D_m^2 / N = 0.0022(58377)(51.875)^2 / 6 = 57251 \text{ IN-LB/DEG.}$$

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Design Calculations

DRAWING: CONDITION #2

Reference: Standards of the Expansion Joint Manufacturers Association Sixth Edition

DESIGN PARAMETERS

TEMPERATURE	: 328°F	BELLOWS MATERIAL	: A240-T304	BAND MATERIAL	: N/A
PRESSURE	: 14.7 psig	BELLOWS MODULUS	: 26610000	BAND MODULUS	: N/A
INSIDE DIA.	: 48.750 IN.	OUTSIDE DIA.	: 55.000 IN.	CON. HGT., w	: 3.020
NO. OF PLYS	: 1	BELLOWS THK.	: 0.105 IN.	SAND THK.	: N/A
NO. OF CONS	: 6	PITCH, q	: 2.500 IN/CONS.	MAX OPE. PITCH, q _o	: 2.515
TANGENT LENGTH, L _t	: 6.000 IN	TUBE LENGTH	: 60 IN.		

CONSTANTS

$D_m = D_b + w + nt = 51.875$ IN $q/(2.2\sqrt{(d_p t_p)}) = 0.49$ $C_p = 0.70$ $C_d = 1.60$ EFF. AREA = 2113.5 IN²
 $t_p = t\sqrt{(D_b/D_m)} = 0.1018$ $q/2w = 0.41$ $C_1 = 1.56$ $K = 1.000$ ANNEALED - NO

DESIGN MOVEMENTS

EQUIVALENT MOVEMENT, e = 0.642

EXTENSION	: 0.000 IN	e _{xe}	= 0.000
COMPRESSION	: 3.760 IN	e _{xc}	= 0.627
LATERAL	: 0.000 IN	e _y	= 0.000
ANGULAR	: 0.200°	e _θ	= 0.015

PRESSURE STRESSES

$S1 = P(D_b + nt)^2 L_t E_b k / [2nt E_b L_t (D_b + nt) + t_c k E_c L_c D_c] = 14,7(48.75 + 1(0.105))^2(6.00)(266)(1.00) / [2(10.105)(266)(6.00)(48.75 + 1(0.105)) + (0.000)(1.00)(0)(5.25)(48.0)] = 3420$ psi
 $S2 = [(PD_m) / (2nt_p)] [1 / (0.571 + 2w/q_o)] = [(14.7(51.875)) / (2(1)(0.1018))] [1 / (0.571 + 2(3.020) / 2.515)] = 1260$ psi
 $S3 = [Pw] / [2nt_p] = [14.7(3.020)] / [2(1)(0.1018)] = 218$ psi
 $S4 = [P / (2n)] (w/t_p)^2 C_p = [14.7 / (2)(1)] (3.020 / 0.1018)^2 0.70 = 4544$ psi

DEFLECTION STRESSES

$S5 = (E_b t_p^2 e) / (2w^2 C_1) = (26300000(0.1018)^2(0.642)) / (2(3.020)^2(1.56)) = 2189$ psi
 $S6 = (5E_b t_p e) / (3w^2 C_d) = (5(26300000)(0.1018)(0.642)) / (3(3.020)^2(1.60)) = 210614$ psi

FATIGUE LIFE

PER EJMA = $[c / (S_1 C_1 - b)]^a = [1860000 / (216137(1) - 54000)]^{3.400} = 4006$ CYCLES

SPRING RATES

$f_{us} = 1.7[(D_m E_b t_p^3 n) / (w^3 C_1)] = 1.7[(51.875(26610000)(0.1018)^3(1)) / (3.020^3(1.561))] = 57988$
 AXIAL S/R = $f_{us} / N = 57988 / 6 = 9665$ LB/IN.
 LATERAL S/R = $1.5[(f_{us} D_m^2) / (NL_b(L_b + x))] = 1.5[(57988(51.875)^2) / (6(15.000)(15.000 + (-3.760)))] = 231386$ LB/IN.
 ANGULAR S/R = $0.0022 f_{us} D_m^2 / N = 0.0022(57988)(51.875)^2 / 6 = 56869$ IN-LB/DEG.

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