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POWER SYSTEMS, INC.

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ELECTRO MOTIVE

NEW 144-AUTO FERRIES PROJECT
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4-DOC-004 Rev. -
(Formerly Calculation P-0291-04)

WSF Contract 00-6679

ENGINEERING CALCULATION

REDUCTION GEAR THERMAL GROWTH

Performed by: The Falk Corporation

Date: March 30, 2006

Reviewed/Approved by:

Christopher K Lane, PE — 3/30/06 Date

October 11, 2005

Washington State Ferries New 130-Auto Ferry Program

PROPULSION SYSTEM CONTRACT No. 00-6679

REDUCTION GEAR DATA SHEET

REDUCTION GEAR THERMAL GROWTH CALCULATION

The below outlined thermal growth calculations have been based on the following assumptions.

1. Reduction Gear Operating Temperature = 140 Degrees Fahrenheit. (Based on past reduction gear operational data)

2. Ambient Temperature during Alignment Verification = 70 Degrees Fahrenheit.

LOCATION	THERMAL GROWTH
Low Speed Output Shaft to Housing Mounting Foot	.006 Inches (Upward)
High Speed Input Shaft to Housing Mounting Foot	.026 Inches (Upward)

Thermal growth calculations are based on the following formula :

$\Delta L = L \times \Delta T \times C_{TE}$

Where :

L = Length under consideration
ΔL = Change in Length or Thermal Expansion
ΔT = Change in Temperature (Operating Temp – Alignment Temp)
C_{TE} = Thermal Expansion Coefficient

Based on the above formula :

1. Thermal Growth – Low Speed Output Shaft to Housing Mounting Foot

L = 14.00 Inches
ΔT = (140 F – 70 F) = 70 Degrees F
C_{TE} = 6.5×10^{-6}/Degrees F

ΔL = (14.00 Inches) x (70 Degrees F) x (6.5×10^{-6}/Degrees F) = **.006 Inches (Upward)**

2. Thermal Growth – High Speed Input Shaft to Housing Mounting Foot

L = 58.00 Inches
ΔT = (140 F – 70 F) = 70 Degrees F
C_{TE} = 6.5×10^{-6}/Degrees F

ΔL = (58.00 Inches) x (70 Degrees F) x (6.5×10^{-6}/Degrees F) = **.026 Inches (Upward)**

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This sheet added to Falk
Calculation by Valley PSI.

Mechanical Design and Systems Handbook

Second Edition

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Table 14.5 Physical Properties of Metallic Elements*

Element	Symbol	Melting point, °F	Boiling point, °F	Specific heat,[a] cal/g/°C	Thermal conductivity,[a] Btu/hr/sq ft/°F/ft	Density,[a] g/cm³	Modulus of elasticity in tension, million psi	Coefficient of linear thermal expansion,[a] μ in./in./°F	Electrical resistivity, microhm-cm	Crystal structure
Aluminum	Al	1220	4442	0.215	128.	2.70	9	13.1	2.65	f.c.c.
Antimony	Sb	1167	2516	0.049	10.8	6.62	11.3	4.7	39	Rhomb.
Arsenic	As	1503 (28 atm)	1135[b]	0.082	.....	5.72	.....	2.6	33.3	Rhomb.
Barium	Ba	1317	2980	0.068	.....	3.5	.....	.....	.....	b.c.c.
Beryllium	Be	2332	5020	0.45	84.4	1.85	42	6.4	4	h.c.p.
Bismuth	Bi	520	2840	0.020	4.8	9.80	4.6	7.4	107	Rhomb.
Boron	B	3690	.....	0.309	.....	2.34	.....	4.6	10^{11}	Orthorhomb.
Cadmium	Cd	610	1409	0.055	53.	8.65	8	16.55	6.83	h.c.p.
Calcium	Ca	1540	2625	0.149	72.3	1.55	3.5	12.4	3.91	f.c.c.
Carbon (graphite)	C	6740[b]	8730	0.165	13.8	2.25	0.7	0.3 to 2.4	1375	Hexag.
Cerium	Ce	1479	6280	0.045	6.6	6.77	6	4.4	75	f.c.c.
Cesium	Cs	84	1273	0.048	.....	1.90	.....	54	20	b.c.c.
Chromium	Cr	3407	4829	0.11	40.3	7.19	36	3.4	12.9	b.c.c.
Cobalt	Co	2723	5250	0.099	41.5	8.85	30	7.66	6.24	h.c.p.
Columbium	Cb	4474	8901	0.065	31.5	8.57	.....	4.06	12.5	b.c.c.
Copper	Cu	1981	4703	0.092	226.	8.96	16	9.2	1.67	f.c.c.
Gallium	Ga	86	4059	0.079	19.4	5.91	.....	10	17.4	Orthorhomb.
Germanium[c]	Ge	1719	5125	0.073	33.7	5.32	.....	[illegible]	[illegible] × 10^6	Diam. cubic
Gold	Au	1954	5380	0.031	171.	19.32	11.6	7.9	2.35	f.c.c.
Indium	[illegible]	[illegible]	3632	0.057	13.8	7.31	1.57	18	8.37	f.c.tetr.
Iridium	[illegible]	[illegible]	[illegible]	0.031	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Iron	Fe	2798	5430	0.11	43.3	7.87	28.5	6.53	9.71	b.c.c.
[illegible]	[illegible]	[illegible]	6280	0.048	8.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lead	Pb	621	3137	0.031	20.	11.36	2	[illegible]	20.6	f.c.c.
Lithium	Li	357	2426	0.79	41.	0.534	.....	[illegible]	8.55	b.c.c.
Magnesium	Mg	1202	2025	0.245	88.5	1.74	6.35	[illegible]	4.45	h.c.p.
Manganese	Mn	2273	3900	0.115	.....	7.43	23	12.22	185	Complex cubic
Mercury	Hg	−37	675	0.033	4.7	13.55	.....	.....	98.4	Rhomb.

Confirming coefficient use by Falk.