

## Thermal Expansion

A simple way to calculate the thermal expansion of a fixture is to use the chart below. Pick the alloy, read down the column to the operating temperature and read the number, which is how much (in inches) each foot of metal will expand. (Multiply by 83.33 to get how many millimeters each meter of metal will expand) Remember that thermal expansion occurs in all three dimensions. It is really a volume expansion, not just an expansion in one direction. So while the fixture is increasing in length, it is also increasing in width and height. A hole, incidentally, will expand at the same rate as the piece of solid metal which would just fill that hole.

Example: An RA330 D-muffle 36 inches wide and 20 feet long operates at 1800F. How far will the free end expand? Looking down the RA330 column we find a total expansion of 0.208 inches/foot at 1800F (982C). Multiply this figure by the length of the muffle,  $0.208 \text{ in/ft} \times 20 \text{ ft} = 4.16 \text{ inches}$  total expansion. How wide will it be in the hottest zone?  $36 \text{ inches} + 0.208 \text{ in/ft} \times 3 \text{ ft} = 36.624 \text{ inches}$ .

## Thermal Expansion, continued

Temperature Range												
F	SA-387	RA446	RA321	RA309	RA 253 MA	RA85H	RA310	RA 353 MA	RA330	RA333	RA601	RA600
70-200	0.0104	0.00874	0.0145	0.0137	0.0141	0.0144	0.0131	0.0134	0.0129	0.0109	0.0119	0.0115
-400	0.0281	0.0225	0.0372	0.0356	0.0370	0.0372	0.0348	0.0345	0.0341	--	0.0317	0.0305
-600	0.0471	--	0.0604	0.0591	0.0610	0.0604	0.0569	0.0566	0.0566	--	0.0516	0.0502
-800	--	0.0526	0.0876	--	0.0859	0.0850	0.0806	0.0796	0.0797	--	0.0727	0.0710
-1000	0.870	0.0681	0.115	0.108	0.111	0.110	0.106	0.104	0.104	0.0960	0.0949	0.0937
-1200	--	0.0854	0.144	--	0.137	0.137	0.133	0.129	--	0.122	0.120	0.117
-1400	--	0.102	0.174	--	0.164	0.164	0.160	0.154	--	0.148	0.147	0.142
-1600	--	0.123	0.204	0.185	0.193	0.191	0.186	0.181	0.180	0.173	0.175	0.167
-1800	--	0.139	0.237	--	0.224	0.222	0.214	0.209	0.208	0.201	0.204	0.193
-2000	--	--	--	--	--	--	0.245	--	--	--	0.236	--

The more general way to calculate thermal expansion is to use the mean coefficients of thermal expansion, such as those given on the next page. Multiply the length in inches, times the difference between room temperature and operating temperature, times the expansion coefficient. Note that these coefficients are all multiplied by  $10^{-6}$ , which is the same as dividing by one million. For that 20 ft long RA330 muffle operating 1800F(982C) this is:

$$20 \text{ ft} \times 12 \text{ inches/foot} \times (1800-70\text{F}) \times 10.0 \times 10^{-6} = 240 \text{ inch} \times 1730\text{F} \times 10 \times 10^{-6} = 4.152 \text{ inches.}$$

To convert these numbers to the metric system, multiply by 83.33 to get millimeters expansion per meter of length.

**MEAN COEFFICIENTS OF THERMAL EXPANSION**

ALLOY	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
304	9.6	--	--	--	9.9	--	--	--	10.2	--	10.4	--	--	--	--	--	--	--	--
316	8.9	--	--	--	9.0	--	--	--	9.7	--	10.3	--	--	11.1	--	--	--	--	--
2205	7.2	7.3	7.5	7.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RA321	9.3	--	9.4	--	9.5	--	10.0	--	10.3	10.5	10.6	--	10.9	--	11.1	--	11.4	--	--
RA309	8.8	8.9	9.0	9.2	9.3	9.4	--	--	9.7	--	--	--	--	10.0	10.1	--	--	--	--
RA310	8.4	8.6	8.8	--	8.95	--	9.2	--	9.5	--	9.8	--	10.05	--	10.15	--	10.3	--	10.6
SA-387	6.7	--	7.1	--	7.4	--	--	--	7.8	--	--	--	--	--	--	--	--	--	--
RA 253 MA <sup>®</sup>	9.06	--	9.34	--	9.59	--	9.81	--	9.97	--	10.14	--	10.3	--	10.5	--	10.8	--	--
410	5.5	--	--	--	--	--	--	--	--	--	6.5	--	--	--	--	--	--	--	--
RA85H <sup>®</sup>	9.2	--	9.4	--	9.5	--	9.7	--	9.9	--	10.1	--	10.3	--	10.4	--	10.7	--	--
RA330 <sup>®</sup>	8.3	8.4	8.6	8.7	8.9	9.0	--	9.2	9.3	9.4	9.6	--	--	9.7	9.8	9.9	10.0	--	--
HR-120 <sup>™</sup>	7.95	--	8.29	--	8.56	--	8.80	--	8.98	--	9.24	--	9.52	--	9.72	--	9.87	--	--
RA 353 MA <sup>®</sup>	8.48	--	8.68	--	8.88	--	9.07	--	9.27	--	9.46	--	9.66	--	9.86	--	10.05	--	--
RA800AT	7.9	--	8.8	--	9.0	--	9.2	--	9.4	--	9.6	--	9.9	--	10.2	--	--	--	--
RA446 <sup>®</sup>	5.6	--	5.7	5.8	--	5.9	6.0	--	6.1	--	6.3	--	6.4	--	6.7	6.9	7.3	--	--
RA600	7.4	--	7.7	--	7.9	--	8.1	--	8.4	--	8.6	--	8.9	--	9.1	--	9.3	--	--
RA601	7.6	--	8.01	--	8.11	--	8.3	--	8.5	--	8.87	--	9.19	--	9.51	--	9.82	--	10.18
RA333 <sup>®</sup>	7.0	--	--	8.0	--	--	--	--	8.6	--	9.0	--	9.3	9.3	9.4	9.5	9.7	--	--
HH	--	--	--	--	--	--	--	--	9.5	--	9.7	--	9.9	--	10.2	--	10.5	--	10.7
HK	--	--	--	--	--	--	--	--	9.4	--	9.6	--	9.8	--	10.0	--	10.2	--	10.4
HT	7.9	--	8.14	--	8.37	--	8.61	--	8.85	--	9.09	--	9.33	--	9.56	--	9.8	--	10.04
HP	--	--	--	--	--	--	--	--	9.2	--	9.5	--	9.8	--	10.0	--	10.3	--	10.6
E-BRITE <sup>®</sup>	5.17	5.3	5.44	5.56	5.67	--	--	--	--	6.09	6.22	6.4	6.57	6.72	6.85	6.88	7.1	--	--
825	7.8	--	8.3	--	8.5	--	8.7	--	8.8	--	9.1	--	9.5	--	9.7	--	--	--	--
20Cb-3 <sup>®</sup>	8.2	8.3	8.4	--	8.65	--	--	8.9	8.95	--	9.15	--	9.3	9.4	9.5	--	--	--	--
AL-6XN <sup>®</sup>	7.9	8.3	8.37	8.42	8.6	8.7	8.8	8.85	8.96	--	9.3	--	--	--	--	--	--	--	--
TiGr 2	4.8	--	--	--	5.1	--	--	--	5.4	--	5.6	--	--	--	--	--	--	--	--

NOTE: All coefficients are reported as inch/inch °F x 10<sup>-6</sup>, room temp to indicated temp. Multiply by 1.8 for metric units.