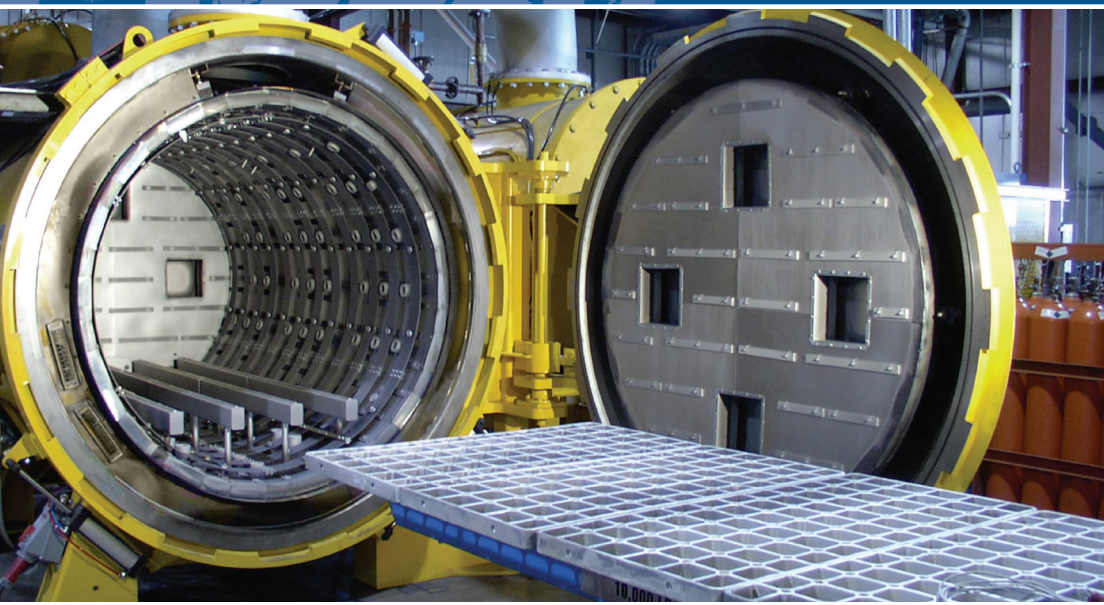
NUMBER 1 | VACUUM FURNACE REFERENCE SERIES

Critical Melting Points and Reference Data for Vacuum Heat Treating



SOLAR

SOLAR ATMOSPHERES INC.

Critical Melting Points and Reference Data for Vacuum Heat Treating

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SOLAR ATMOSPHERES

Acknowledgments

This work is an update of the original reference compilation by Charles F. Burns, Jr., Copyright 1997. The current booklet contains revisions to the original work as well as numerous additions. This booklet should serve as a handy reference for people that work in the metals industry.

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Limitations

This data is for reference only. Solar Atmospheres Inc. will not assume liability for accuracy.

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DEFINITIONS

ALLOY
[MET] Any of a large number of substances having metallic properties consisting of two or more elements; at least one component must be a metal.

EUTECTIC ALLOY
[Met] A material, predominantly one of a specific microstructure, made up of two or more phases formed simultaneously during solidification of two or more elements. A eutectic alloy melts to become a free running liquid at a single temperature, which is lower than the melting point of any of its components.

EMISSIVITY
The ratio defined by the radiation emitted by a surface to the radiation emitted by a blackbody at the same temperature.

MELTING OF PURE SUBSTANCES
[Chem] The temperature, at given pressure, upon which a chemically pure substance changes from a solid state to a liquid state.

MELTING POINT OF MIXTURES OR ALLOYS
[MET] Unlike pure metals, many alloys do not have a single melting point. Instead, they have a melting range in which the material is a mixture of solid and liquid phases during the melting process. The temperature at which melting begins is called the solidus, and that at which melting is complete is called the liquidus. Special alloys can be designed with a single melting point, however, and these are called eutectic mixtures.

VAPOR PRESSURE
The vapor pressure of a substance (liquid or solid) is the equilibrium pressure of a vapor above the substance; in other words the vapor (formed from evaporation or sublimation) above the substance when in a closed container.

When working in vacuum one must recognize that even if the work is not at the boiling point for the substance there is always vapor forming above the surface and excessive heating of a substance under vacuum has the possibility of evaporating the substance. For example at 760 Torr and 50 °C, if water is heated for an extended period in an open container the water will eventually evaporate. Therefore care must be used when heating under vacuum at high temperatures if one is at or near the known vapor pressure of a substance.

SUBLIMATION
A phase change process in which a material passes from a solid state to a gaseous state without becoming a liquid.

MELTING POINTS OF THE ELEMENTS (atmospheric pressure), (s) = sublimes			
ELEMENT	**SYMBOL**	**MELTING POINT (°F)**	**MELTING POINT (°C)**
Aluminum	Al	**1220**	660
Antimony	Sb	**1168**	631
Arsenic	As	**1135 (s)**	613 (s)
Barium	Ba	**1341**	727
Beryllium	Be	**2348.6**	1287
Bismuth	Bi	**520**	271.3
Boron	B	**3767**	2075
Cadmium	Cd	**610**	321
Calcium	Ca	**1544**	840
Carbon	C	**6588 (s)**	3642 (s)
Cerium	Ce	**1468**	798
Cesium	Cs	**83.4**	28.4
Chromium	Cr	**3465**	1907
Cobalt	Co	**2723**	1495
Copper	Cu	**1981**	1083
Columbium (Niobium)	Cb	**4491**	2477
Dysprosium	Dy	**2574**	1412
Erbium	Er	**2784**	1529
Europium	Eu	**1512**	822
Gallium	Ga	**86**	30
Germanium	Ge	**1719**	937
Gold	Au	**1947**	1064
Hafnium	Hf	**4051**	2233
Indium	In	**314**	157
Iodine	I	**237**	114
Iridium	Ir	**4435**	2446
Iron	Fe	**2795**	1535
Lanthanum	La	**1684**	918
Lead	Pb	**622**	328
Lithium	Li	**358**	181
Magnesium	Mg	**1202**	650
Manganese	Mn	**2275**	1246
Mercury	Hg	**-37.97**	-38.87
Molybdenum	Mo	**4748**	2620

MELTING POINTS OF THE ELEMENTS (atmospheric pressure), (s) = sublimes			
ELEMENT	**SYMBOL**	**MELTING POINT (°F)**	**MELTING POINT (°C)**
Neodymium	Nd	**1870**	1021
Nickel	Ni	**2647**	1453
Niobium (Columbium)	Nb	**4491**	2477
Osmium	Os	**5491**	3033
Palladium	Pd	**2826**	1552
Phosphorus	P	**111**	44
Platinum	Pt	**3214**	1768
Potassium	K	**147**	64
Praseodymium	Pr	**1708**	931
Rhenium	Re	**5756**	3180
Rhodium	Rh	**3567**	1964
Rubidium	Rb	**102**	39
Ruthenium	Ru	**4233**	2334
Scandium	Sc	**2802**	1539
Selenium	Se	**422**	217
Silicon	Si	**2570**	1410
Silver	Ag	**1764**	962
Sodium	Na	**208**	98
Strontium	Sr	**1431**	777
Sulfur	S	**239**	115
Tantalum	Ta	**5425**	2996
Tellurium	Te	**842**	450
Thallium	Tl	**579**	304
Thorium	Th	**3182**	1750
Tin	Sn	**450**	232
Titanium	Ti	**3034**	1668
Tungsten	W	**6192**	3422
Uranium	U	**2070**	1132
Vanadium	V	**3434**	1890
Yttrium	Y	**2773**	1523
Zinc	Zn	**788**	420
Zirconium	Zr	**3366**	1852

MELTING POINTS Stainless Steels		
ALLOY	**MELTING RANGE °F**	**MELTING RANGE °C**
301 S/S	**2550-2590**	1400-1420
302 S/S	**2550-2590**	1400-1420
302B S/S	**2500-2550**	1370-1400
303 S/S	**2550-2590**	1400-1420
304 S/S	**2550-2650**	1400-1455
305 S/S	**2550-2650**	1400-1455
308 S/S	**2550-2650**	1400-1455
309 S/S	**2550-2650**	1400-1455
310 S/S	**2550-2650**	1400-1455
314 S/S	**2412-2530**	1322-1388
316 S/S	**2500-2550**	1370-1400
317 S/S	**2500-2550**	1370-1400
321 S/S	**2550-2600**	1400-1425
330 S/S	**2550-2600**	1400-1425
347 S/S	**2550-2600**	1400-1425
384 S/S	**2550-2650**	1400-1455
403 S/S	**2700-2790**	1480-1530
405 S/S	**2700-2790**	1480-1530
409 S/S	**2600-2750**	1425-1510
410 S/S	**2700-2790**	1480-1530
416 S/S	**2700-2790**	1480-1530
420 S/S	**2650-2750**	1455-1510
430 S/S	**2650-2750**	1455-1510
430F S/S	**2550-2650**	1400-1455
431 S/S	**2600-2700**	1476-1482
440A S/S	**2500-2750**	1370-1510
440B S/S	**2500-2750**	1370-1510
440C S/S	**2500-2750**	1370-1510
442,443,446 S/S	**2600-2750**	1425-1510
501 S/S	**2700-2800**	1480-1540
502 S/S	**2700-2800**	1480-1540

MELTING POINTS Corrosion-Resistant Steel Castings		
ALLOY	**MELTING POINT °F**	**MELTING POINT °C**
CA-15	**2750**	1510
CA-40	**2750**	1510
CB-30	**2725**	1496
CC-50	**2725**	1496
CE-30	**2650**	1454
CF-8	**2600**	1427
CF-20	**2575**	1413
CF-8M	**2550**	1399
CF-12M	**2550**	1399
CF-8C	**2600**	1427
CF-16F	**2550**	1399
CH-20	**2600**	1427
CK-20	**2600**	1427
CN-7M	**2650**	1454

MELTING POINTS Heat-Resistant Alloy Castings		
ALLOY	**MELTING POINT °F**	**MELTING POINT °C**
HA	**2750**	1510
HC	**2725**	1496
HD	**2700**	1482
HE	**2650**	1454
HF	**2550**	1399
HH	**2500**	1371
HI	**2550**	1399
HK	**2550**	1399
HL	**2600**	1427
HN	**2500**	1371
HP	**2450**	1343
HT	**2450**	1343
HU	**2450**	1343

MELTING POINTS Heat-Resistant Alloy Castings		
ALLOY	**MELTING POINT °F**	**MELTING POINT °C**
HA	**2750**	1510
HC	**2725**	1496
HD	**2700**	1482
HE	**2650**	1454
HF	**2550**	1399
HH	**2500**	1371
HI	**2550**	1399
HK	**2550**	1399
HL	**2600**	1427
HN	**2500**	1371
HW	**2350**	1288
HX	**2350**	1288

MELTING POINTS Aluminum Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
EC	**1215**	657
1060	**1195-1215**	646-657
1100	**1190-1215**	643-657
2011	**1005-1190**	541-643
2014	**945-1180**	507-637
2024	**935-1180**	507-638
2218	**940-1175**	504-635
3003	**1190-1210**	643-654
4032	**990-1060**	532-571
5005	**1170-1210**	632-654
5050	**1155-1205**	624-652
5052	**1125-1200**	607-649
5056	**1055-1180**	568-638
5083	**1095-1180**	591-638
5086	**1085-1185**	585-641
5154	**1100-1190**	545-643

MELTING POINTS Aluminum Alloys		
ALLOY	**MELTING RANGE °F**	**MELTING RANGE °C**
5357	**1210**	654
5456	**1055-1180**	568-638
6061	**1080-1205**	582-652
6063	**1140-1210**	616-654
6101	**1150-1210**	621-654
6151	**1090-1200**	588-649
7075	**890-1175**	477-635
7079	**1180**	637
7178	**890-1165**	477-629

MELTING POINTS Aluminum Casting Alloys		
ALLOY	**MELTING RANGE °F**	**MELTING RANGE °C**
201.0	**1060-1200**	570-650
206.0	**1060-1200**	570-650
A206.0	**1060-1200**	570-650
208.0	**970-1170**	520-630
222.0	**970-1160**	520-625
224.0	**1020-1190**	550-645
238.0	**950-1110**	510-600
240.0	**960-1120**	515-605
242.0	**990-1180**	530-635
295.0	**970-1190**	520-645
296.0	**970-1170**	520-630
308.0	**970-1140**	520-615
319.0	**970-1120**	520-605
324.0	**1010-1120**	545-605
332.0	**970-1080**	520-580
333.0	**970-1090**	520-585
336.0	**1000-1060**	540-570
354.0	**1000-1110**	540-600
355.0	**1020-1150**	550-620
C355.0	**1020-1150**	550-620
356.0	**1040-1140**	560-615

MELTING POINTS Aluminum Casting Alloys		
ALLOY	**MELTING RANGE °F**	**MELTING RANGE °C**
A356.0	**1040-1130**	560-610
357.0	**1040-1140**	560-615
A357.0	**1030-1130**	555-610
358.0	**1040-1110**	560-600
359.0	**1050-1110**	565-600
360.0	**1060-1090**	570-590
A360.0	**1060-1090**	570-590
364.0	**1040-1110**	560-600
380.0	**970-1090**	520-590
A380.0	**970-1090**	520-590
384.0	**900-1080**	480-580
390.0	**950-1200**	510-650
392.0	**1020-1240**	550-670
413.0	**1070-1090**	575-585
A413.0	**1070-1090**	575-585
443.0	**1070-1170**	575-630
A444.0	**1070-1170**	575-630
511.0	**1090-1180**	590-640
512.0	**1090-1170**	590-630
513.0	**1080-1180**	580-640
514.0	**1110-1180**	600-640
518.0	**1000-1150**	540-620
520.0	**840-1110**	450-600
535.0	**1020-1170**	550-630
A535.0	**1020-1150**	550-620
B535.0	**1020-1170**	550-630
705.0	**1110-1180**	600-640
707.0	**1090-1170**	585-630
710.0	**1110-1200**	600-650
711.0	**1110-1190**	600-645
712.0	**1110-1180**	600-640
713.0	**1100-1170**	595-630
850.0	**440-1200**	225-650
851.0	**450-1170**	230-630
852.0	**410-1180**	210-635

MELTING POINTS/RANGES Copper Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
C10200 (Oxygen Free)	**1950-1980**	1065-1083
C11000 (Copper ETP)	**1950-1980**	1065-1083
C12000 (Copper DLP)	**1981**	1083
C12200 (Copper DHP)	**1981**	1083
C14500 (Free Machining [Te])	**1924-1967**	1051-1075
C17000 (Beryllium Copper)	**1590-1800**	805-980
C21000 (Gilding)	**1920-1950**	1050-1066
C22000 (Commercial Bronze [90% Cu])	**1870-1910**	1020-1043
C22600 (Jewelry Bronze [87.5% Cu])	**1840-1890**	1005-1035
C23000 (Red Brass [85% Cu])	**1810-1880**	990-1027
C24000 (Low Brass [80% Cu])	**1770-1830**	965-1000
C26000 (Cartridge Brass [70% Cu])	**1680-1750**	915-954
C27000 (Yellow Brass [65% Cu])	**1660-1710**	905-932
C280000 (Muntz Metal [60% Cu])	**1650-1660**	900-904
C31400 (Leaded Commercial Bronze)	**1850-1900**	1010-1038
C33000 Low Leaded Brass [0.5% Pb])	**1660-1720**	905-938
C34000 (Medium Leaded Brass [1% Pb])	**1630-1700**	885-927
C35300 (High Leaded Brass [1.6% Pb])	**1650-1710**	900-932
C34200 (High Leaded Brass [2% Pb])	**1630-1670**	885-910
C35600 (Extra High Leaded Brass [2.5% Pb])	**1630-1660**	885-904
C36000 (Free Cutting Brass)	**1630-1650**	885-900
C36500 (Leaded Muntz Metal)	**1630-1650**	885-900
C37700 (Forging Brass)	**1620-1640**	880-893
C38500 (Architectural Bronze)	**1610-1630**	875-888
C44400 (Inhibited Admiralty)	**1650-1720**	900-938
C46400 (Naval Brass)	**1630-1650**	885-900
C50500 (Phosphor Bronze [1.25% Sn])	**1890-1970**	1035-1077
C51000 (Phosphor Bronze [5% Sn])	**1790-1940**	975-1060
C52100 (Phosphor Bronze [8% Sn])	**1620-1880**	880-1027
C52400 (Phosphor Bronze [10% Sn])	**1550-1830**	845-1000
C54400 (Free Cutting Phosphor Bronze)	**1710-1830**	930-1000
C60600 (Aluminum Bronze [5% Al])	**1920-1950**	1050-1065

MELTING POINTS/RANGES Copper Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
C61000 (Aluminum Bronze [7% Al])	**1900-1910**	1040-1045
C62300 (Aluminum Bronze [11% Al])	**1880-1900**	1025-1040
C63200 (Aluminum Bronze [9% Al])	**1900-1910**	1040-1045
C64200 (Aluminum Silicon Bronze)	**1800-1840**	985-1004
C65500 (High Silicon Bronze [3% Si])	**1780-1880**	970-1027
Low Silicon Bronze (1.5% Si)	**1890-1940**	1030-1060
C67500 (Manganese Bronze)	**1630-1690**	888-920
C70600 (Cupro-Nickel [10% Ni])	**2010-2100**	1100-1149
C71500 (Cupro-Nickel [30% Ni])	**2140-2260**	1170-1238
C75200 (Nickel-Silver [65% Cu])	**2030**	1110
C75700 (Nickel-Silver [65% Cu- 12% Ni])	**1900**	1038
C77000 (Nickel-Silver [55% Cu])	**1930**	1054

MELTING POINTS Copper Casting Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Chrome Copper (1% Cr)	**1970-1990**	1075-1085
Tin Bronze, Alloy 1A	**1570-1830**	834-1000
Tin Bronze, Alloy 1B	**1570-1830**	834-1000
Tin Bronze, Alloy SAE 65	**1832**	1000
Navy M Bronze, Alloy 2A	**1520-1810**	825-990
Leaded Tin Bronze, Alloy 2B	**1570-1830**	854-1000
Leaded Tin Bronze, Alloy 2C	**1550-1800**	845-980
High Leaded Tin Bronze, Alloy 3A	**1400-1710**	762-930
High Leaded Tin Bronze, Alloy 3B	**1570-1790**	855-975
High Leaded Tin Bronze, Alloy 3C	**1570-1830**	855-1000
High Leaded Tin Bronze, Alloy 3D	**1570-1730**	855-945
High Leaded Tin Bronze, Alloy 3E	**1650-1700**	900-925
Leaded Red Brass, Alloy 4A	**1570-1850**	855-1010
Leaded Red Brass, Alloy 4B	**1550-1840**	845-1005
Leaded Semi Red Brass, Alloy 5A	**1540-1840**	840-1005
Leaded Semi Red Brass, Alloy 5B	**1530-1750**	832-955
Leaded Yellow Brass, Alloy 6A	**1700-1720**	925-940

MELTING POINTS Copper Casting Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Leaded Yellow Brass, Alloy 6B	**1700-1720**	925-940
Manganese Bronze (59% Cu)	**1675**	913
Manganese Bronze (57.5% Cu)	**1616**	880
Manganese Bronze (64% Cu)	**1700**	937
Manganese Bronze (110,000 psi)	**1693**	923
Aluminum Bronze, Alloy 9A	**1900-1910**	1040-1045
Aluminum Bronze, Alloy 9B	**1900-1910**	1040-1045
Aluminum Bronze, Alloy 9C	**1880-1900**	1027-1040
Aluminum Bronze, Alloy 9D	**1900-1930**	1038-1055
Nickel Silver (12% Ni)	**Max: 1900**	Max: 1040
Nickel Silver (15% Ni)	**1850-1970**	1010-1075
Nickel Silver (18% Ni)	**Max: 1930**	Max: 1055
Nickel Silver (25% Ni)	**2300**	1260
Low-Silicon Bronze (1% Si)	**1890-1940**	1030-1060
High-Silicon Bronze (3% Si)	**1780-1880**	700-875
Silicon Brass	**1510-1680**	821-917

MELTING POINTS Magnesium Alloys/Casting Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
AM100A	**1101**	594
AZ63A	**1130**	610
AZ81A	**1132**	611
AZ91A, B & C Alloys	**1105**	596
AZ92A	**1100**	593
HK31A	**1090-1200**	590-650
HZ32A	**1020-1200**	550-650
ZH42	**1180**	638
ZH62A	**968-1170**	520-630
ZK51A	**1020-1180**	550-640
ZE41A	**977-1190**	525-645
EZ33A	**1010-1190**	545-645
EZ30A	**1184**	640
EZ41A	**1193**	645

MELTING POINTS Magnesium Alloys/Wrought Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
MIA	**1200**	649
AZ31B	**1120-1170**	605-632
PE	**990-1170**	532-632
AZ61A	**785-1150**	418-620
AZ80A	**801-1130**	421-610
ZK60A	**964-1170**	518-635
ZE10A	**1195**	646
HM21A	**1120-1200**	605-650
HM31A	**900-1200**	482-650

MELTING POINTS Nickel Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
“A” Nickel	**2642**	1450
“D” Nickel	**2600**	1427
Duranickel	**2550-2620**	1400-1440
Cast Nickel	**2450**	1343
Monel	**2370**	1299
“K” Monel	**2400-2460**	1315-1349
Monel (Cast)	**2450**	1343
“H” Monel (Cast)	**2315**	1268
“S” Monel (Cast)	**2300**	1260
Inconel	**2470-2580**	1354-1413
Inconel (Cast)	**2500**	1371
Ni-O-Nel	**1340-1390**	727-754
Hastelloy Alloy “B”	**2375-2495**	1302-1368
Hastelloy Alloy “C”	**2417-2498**	1325-1370
Hastelloy Alloy “D”	**2050**	1121
Hastelloy Alloy “F”	**2350**	1288
Hastelloy Alloy “N”	**2370-2550**	1300-1400
Hastelloy Alloy “W”	**2400**	1316
Hastelloy Alloy “X”	**2300-2470**	1260-1355

MELTING POINTS/RANGES Superalloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Inconel Alloy 600	**2470-2575**	1354-1413
Inconel Alloy 601	**2480-2571**	1360-1411
Inconel Alloy 601GC	**2374-2494**	1301-1368
Inconel Alloy 603XL	**2516-2552**	1380-1400
Inconel Alloy 617	**2430-2510**	1332-1380
Inconel Alloy 625	**2350-2460**	1290-1350
Inconel Alloy 625LCF	**2350-2460**	1290-1350
Inconel Alloy 686	**2440-2516**	1338-1380
Inconel Alloy 690	**2450-2510**	1343-1377
Inconel Alloy 693	**2403-2493**	1317-1367
Inconel Alloy 706	**2434-2499**	1334-1371
Inconel Alloy 718	**2300-2437**	1260-1336
Inconel Alloy 718SPF	**2300-2437**	1260-1336
Inconel Alloy 725	**2320-2449**	1271-1343
Inconel Alloy 740	**2350-2484**	1288-1362
Inconel Alloy X-750	**2540-2600**	1393-1427
Inconel Alloy 751	**2540-2600**	1393-1427
Inconel Alloy MA754	**2550**	1400
Inconel Alloy MA758	**2507**	1375
Inconel Alloy 783	**2437-2565**	1336-1407
Inconel Alloy 230	**2480-2570**	1360-1410
Inconel Alloy C-276	**2415-2500**	1325-1370
Inconel Alloy G-3	**2300-2450**	1260-1343
Inconel Alloy HX	**2300-2470**	1260-1355
Inconel Alloy 22	**2464-2529**	1351-1387
Incoloy Alloy 800	**2475-2525**	1357-1385
Incoloy Alloy 800H/800HT	**2475-2525**	1357-1385
Incoloy Alloy 803	**2490-2555**	1365-1400
Incoloy Alloy 825	**2500-2550**	1370-1400
Incoloy Alloy 864	**2467-2539**	1353-1393

MELTING POINTS/RANGES Superalloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Incoloy Alloy 890	**2388-2522**	1309-1383
Incoloy Alloy 903	**2405-2539**	1318-1393
Incoloy Alloy 907	**2440-2550**	1335-1400
Incoloy Alloy 908	**2482-2571**	1361-1410
Incoloy Alloy 925	**2392-2490**	1311-1366
Incoloy Alloy MA956	**2700**	1482
Incoloy Alloy DS	**2426-2552**	1330-1400
Incoloy Alloy 330	**2520-2590**	1380-1420
Incoloy Alloy 25-6MO	**2410-2550**	1320-1400
Incoloy Alloy A-286	**2500-2600**	1370-1430
Brightray Alloy B	**2550-2590**	1400-1420
Brightray Alloy C	**2520-2550**	1380-1400
Brightray Alloy F	**2430-2550**	1330-1400
Brightray Alloy S	**2550-2590**	1400-1420
Brightray Alloy 35	**2440-2520**	1340-1380
Nimonic Alloy 75	**2450-2520**	1340-1380
Nimonic Alloy 80A	**2410-2490**	1320-1365
Nimonic Alloy 81	**2381-2507**	1305-1375
Nimonic Alloy 90	**2390-2500**	1310-1370
Nimonic Alloy 91	**2372-2462**	1300-1350
Nimonic Alloy 105	**2354-2453**	1290-1345
Nimonic Alloy 115	**2300-2399**	1260-1315
Nimonic Alloy 263	**2372-2471**	1300-1355
Nimonic Alloy 901	**2336-2453**	1280-1345
Nimonic Alloy PE11	**2340-2460**	1280-1350
Nimonic Alloy PE16	**2390-2471**	1310-1355
Nimonic Alloy PK33	**2372-2453**	1300-1345
Udimet Alloy 188	**2375-2425**	1300-1330
Udimet Alloy L-605	**2426-2570**	1330-1410

MELTING POINTS/RANGES Superalloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Udimet Alloy 520	**2300-2560**	1260-1405
Udimet Alloy 720	**2180-2440**	1194-1338
Udimet Alloy D-979	**2225-2530**	1220-1390
Udimet Alloy R41	**2250-2535**	1232-1391
Udimet Alloy 250	**2600-2650**	1427-1454
Udimet Alloy 300	**2600-2650**	1427-1454
Nilo Alloy 36	**2605**	1430
Nilo Alloy 42	**2615**	1435
Nilo Alloy 48	**2640**	1450
Nilo Alloy K	**2640**	1450

MELTING POINTS Tin Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Hard Tin (pure tin)	**450**	232
Antimonial Tin Solder	**453-464**	234-240
Tin-Silver Solder	**430-473**	221-245
Soft Solder (70% Sn)	**361-378**	183-192
Soft Solder (63% Sn)	**361**	183
Soft Solder (50% Sn)	**361-421**	183-216
Tin Babbitt Alloy 1	**433-700**	223-371
Tin Babbitt Alloy 2	**466-669**	241-354
Tin Babbitt Alloy 3	**464-792**	240-422
Tin Babbitt Alloy 4	**363-583**	184-306
Tin Babbitt Alloy 5	**358-565**	181-296
Tin Die Casting Alloy	**700**	371
White Metal	**475**	246
Pewter	**471-563**	244-295

MELTING POINTS Zinc Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Pure Zinc	**787**	419.6
AG40A	**718-729**	381-387
AC41A	**716-727**	380-386
Zinc-Base Slush-Casting Alloy (4.75% Al)	**716-734**	380-390
Zinc-Base Slush-Casting Alloy (5.5% Al)	**716-743**	380-395
Commercial Rolled Zinc (0.08% Pb)	**786**	419
Commercial Rolled Zinc (0.06% Pb)	**786**	419
Commercial Rolled Zinc (0.3% Pb)	**786**	419
Copper Hardened Rolled Zinc	**786-792**	419-422
Rolled Zinc Alloy (1% Cu)	**786-792**	419-422
Zn-Cu-Ti	**786-792**	419-422

MELTING POINTS Precious Metal Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Silver	**1760**	962
70% Gold – 30% Platinum	**2240-2640**	1228-1450
60% Pd – 40% Cu	**2180-2240**	1196-1224

MELTING POINTS Ni-Cr-Mo-Cu Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
Illium “B”	**------**	------
Illium “G”	**2300-2440**	1260-1338
Illium “R”	**2500**	1371

MELTING POINTS Electrical Resistance Alloys		
ALLOY	**MELTING POINT °F**	**MELTING POINT °C**
80 Ni -20 Cr	**2550**	1400
60 Ni -24 Fe-16 Cr	**2530**	1390
35 Ni-45 Fe-20 Cr	**2530**	1390
Constantan	**2230**	1220

MELTING POINTS Titanium Alloys		
ALLOY	**MELTING POINT/RANGE °F**	**MELTING POINT/RANGE °C**
99.2%	**3135**	1724
99.0%	**3020**	1660
Ti- 6 Al - 4V	**2920-3020**	1604-1660
Ti – 5 Al - 2.5 Sn	**Max: 2890**	Max: 1590
Ti – 2 Fe – 2 Cr - 2Mo	**3010**	1654
Ti – 8 Mn	**2370-2970**	1300-1635
Ti – 4 Al -4 Mn	**2820**	1549

MELTING POINTS Eutectics		
ALLOY (Element-Wt. %)	**MELTING POINT °F**	**MELTING POINT °C**
Aluminum-Gold (Au-96)	**968**	520
Aluminum-Beryllium (Be-0.8)	**1191**	644
Aluminum-Copper (Cu-33)	**1019**	548
Aluminum-Iron (Fe-98)	**1211**	655
Aluminum-Lithium (Li-93)	**351**	177
Aluminum-Magnesium (Mg-66)	**819**	437
Aluminum-Nickel (Ni-5.7)	**1182**	639
Aluminum-Silicon (Si-12.6)	**1071**	577
Aluminum-Zinc (Zn-94)	**718**	381
Aluminum-Zirconium (Zr-57)	**2732**	1500
Beryllium-Chromium (Cr-13)	**2232**	122
Beryllium-Copper (Cu-94.7)	**1576**	858
Beryllium (Fe-22.6)	**2219**	1215
Beryllium-Nickel (Ni-95)	**2102**	1150
Beryllium-Silicon (Si-64)	**1994**	1090
Carbon-Iron (Fe-22.6)	**2107**	1153
Carbon-Molybdenum	**4001**	2205
Carbon-Nickel (C-2.5)	**2421**	1327
Chromium-Carbon (C-3.6)	**2793**	1534
Chromium-Cobalt (Co-59)	**2489**	1365
Chromium- Molybdenum (Mo-21)	**3308**	1820
Chromium-Nickel (Ni-46)	**2453**	1345
Chromium-Tantalum (Ta-34)	**3200**	1760
Chromium-Titanium (Ti-53)	**2570**	1410
Chromium-Zirconium (Zr-86)	**2430**	1332
Cobalt-Carbon (C-2.6)	**2498**	1320
Cobalt-Molybdenum (Mo-39)	**2435**	1335
Cobalt-Tantalum (Ta-21)	**2336**	1280
Cobalt-Tin (Sn-34)	**2034**	1112
Cobalt-Titanium (Ti-73)	**1868**	1020
Cobalt-Vanadium (V-38)	**2278**	1248
Cobalt-Tungsten (W-45)	**2680**	1471
Copper-Magnesium(Mg-66)	**909**	487

MELTING POINTS Eutectics		
ALLOY (Element-Wt. %)	**MELTING POINT °F**	**MELTING POINT °C**
Copper-Silicon	**1476**	802
Copper-Titanium (Ti-12)	**1607**	875
Iron-Carbon (C-4.2)	**2107**	1153
Iron-Molybdenum (Mo-37)	**2640**	1449
Iron-Niobium (Nb-19)	**2503**	1373
Iron-Silicon (Si-20 &Si-53)	**2197**	1203
Iron-Tin (Sn-49)	**2066**	1130
Iron-Tantalum(Ta-20))	**2606**	1430
Iron-Titanium (Ti-67)	**1985**	1085
Magnesium-Nickel (Mg-24)	**946**	508
Magnesium-Silicon (Si-1.34)	**1180**	638
Magnesium-Tin (Sn-98)	**399**	204
Magnesium-Zinc (Zn-53)	**644**	340
Manganese-Titanium (Ti-59)	**2156**	1180
Molybdenum-Nickel (56-Mo)	**2388**	1309
Molybdenum-Silicon (Si-94)	**2577**	1414
Nickel-Carbon (C-0.6)	**2421**	1327
Nickel-Niobium (Nb-23)	**2347**	1286
Nickel-Silicon (Si-29)	**1767**	964
Nickel-Tantalum (Ta-63)	**2462**	1350
Nickel-Tin (Sn-33)	**2066**	1130
Nickel-Titanium ((Ti-73)	**1728**	942
Nickel-Vanadium (V-47)	**2196**	1202
Silicon-Tantalum (Ta-5)	**2543**	1395
Silicon-Zinc (Zn-99.98)	**787**	419
Silver-Aluminum (Al-26.5)	**1053**	567
Silver-Beryllium (Be-0.03)	**1616**	880
Silver-Calcium (Ca-60)	**878**	470
Silver-Copper (Cu-28)	**1434**	779
Silver-Magnesium (Mg-51.4)	**882**	472
Silver-Tin(Sn-96.5)	**430**	221
Tantalum-Carbon (C-2)	**5149**	2843
Tungsten-Carbon (W-1.3)	**4919**	2715

ONSET TEMPERATURE FOR ADVERSE REACTIONS BETWEEN GRAPHITE OR OXIDES AND FURNACE COMPONENTS		
Surface to Surface Contact	**Temperature °F**	**Temperature °C**
Al_2O_3-C	**<2912**	<1600
Al_2O_3-Mo	**3452**	1900
Al_2O_3-Ta	**3452**	1900
Al_2O_3-W	**3452**	1900
BeO-C	**4172**	2300
BeO-Mo	**3452**	1900
BeO-MgO	**3272**	1800
BeO-W	**3632**	2000
C-Mo	**2192**	1200*
C-Ta	**1832**	1000*
C-W	**2730**	1499*
BeO-ZrO_2	**3452**	1900
MgO-C	**3272**	1800
MgO-Mo	**2912**	1600
MgO-Ta	**3272**	1800
MgO-W	**3632**	2000**
MgO-ZrO_2	**3632**	2000
ZrO_2-C	**2912**	1600
ZrO_2-Mo	**3992**	2200
ZrO_2-W	**2912**	1600

- *Strong Carbide Formation at higher temperatures.
- ** Strong Magnesia evaporation

MELTING POINTS OF CERTAIN SIMPLE AND COMPLEX REFRACTORY OXIDES			
Compound	**Chemical Formula**	**Melting Point**	
		°F	**°C**
Alumina	Al_2O_3	**3762**	2072
Aluminum Silicate (mullite)	$3Al_2O_3{\cdot}2SiO_2$	**3326**	1830*
Aluminum Titanate	Al2O3·TiO2	**3371**	1855
Aluminum Titanate	Al2O3·2TiO2	**3443**	1895
Barium Aluminate	BaO·Al2O3	**3632**	2000
Barium Aluminate	BaO 6Al2O3	**3380**	1860
Barium Orthosilicate	BaO·SiO2	**3191**	1755
Barium Zirconate	BaO·ZrO2	**4892**	2700
Berylium Oxide	BeO	**4649**	2565
Chromic Oxide	Cr_2O_3	**4109**	2265
Iron (II) Oxide	FeO	**2510**	1377
Iron (III) Oxide	Fe_2O_3	**2851**	1566
Iron (IV) Oxide	Fe_3O_4	**2901**	1594
Magnesium Aluminate	$MgO{\cdot}Al_2O_3$	**3875**	2135
Magnesium Ferrite	$MgO{\cdot}Fe_2O_3$	**3200**	1760
Magnesium Oxide	MgO	**5156**	2852
Manganese Oxide	Mn_3O_4	**2849**	1565
Niobium Pentoxide	Nb_2O_5	**2716**	1491
Nickel Oxide	NiO	**3603**	1984
Silicon Dioxide	SiO_2	**3133**	1723
Tantalum Pentoxide	Ta_2O_5	**3402**	1872
Titanium Dioxide	TiO_2	**3344**	1840
Vanadium Oxide	V_2O_3	**3578**	1970
Zinc Aluminate	$ZnO{\cdot}Al_2O_3$	**3542**	1950
Zinc Oxide	ZnO	**3576**	1969
Zirconium Oxide	ZrO_2	**4825**	2663
Zirconium Oxide (stabilized)	ZrO_2 (stabilized)	**4500**	2482
Zinc Zirconium Silicate	$ZnO{\cdot}ZrO_2{\cdot}SiO_2$	**3772**	2078
Tungsten Oxide	WO_3	**2683**	1473

BLACK BODY RADIATION

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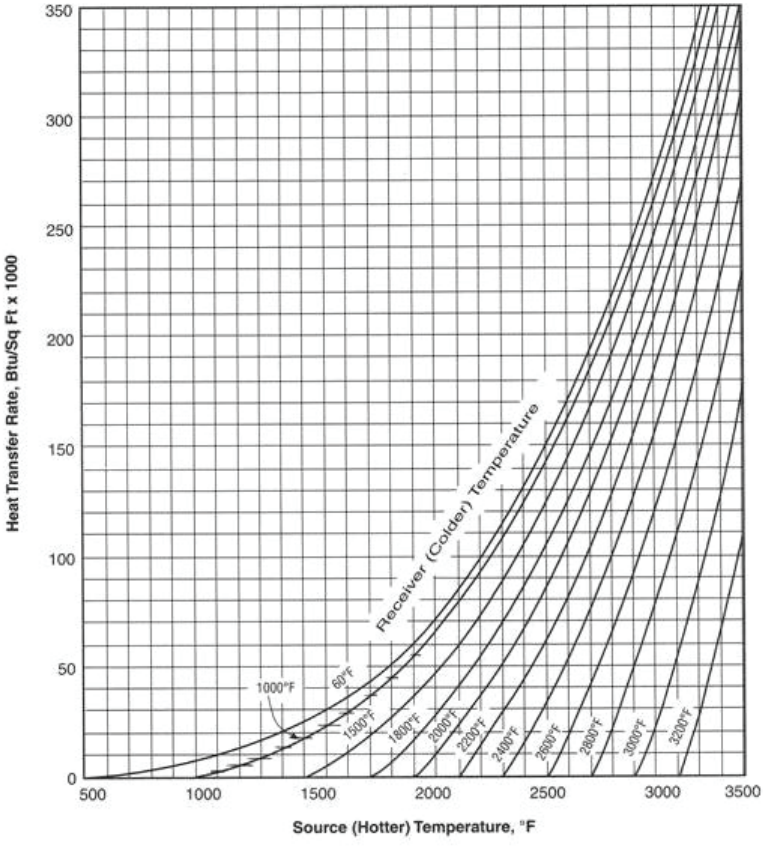


These curves are plotted from the relationship

$$Q = \frac{AK\left(T_1^4 - T_2^4\right)}{\frac{1}{P_1} + \frac{1}{P_2} - 1}$$

where P_1 & P_2 equal 1, that is, the heat source and receiver both have emissivities of 1.0, and they are arranged so there is no barrier to heat transfer between them.

EMISSIVITY OF COMMON MATERIALS			
MATERIAL	**TEMPERATURE °F**	**TEMPERATURE °C**	**EMISSIVITY NUMBER**
Blackbody	**75**	24	1.0
Black Paint, CuO	**75**	24	0.96
Carbon, Lamp Black	**75**	24	0.96
Soot , acetylene	**75**	24	0.97
Cement	**32-392**	0-200	0.96
White ceramic, Al2O3	**75**	24	0.90
Carbon, unoxidized	**75**	24	0.81
Water	**100**	38	0.67

EMMISSIVITY OF SELECT METALS			
MATERIAL	**TEMPERATURE °F**	**TEMPERATURE °C**	**EMISSIVITY NUMBER**
Aluminum unoxidized	**75**	24	0.02
Aluminum oxidized	**390**	199	0.11
Aluminum heavily oxidized	**200**	93	0.20
Brass unoxidized	**77**	25	0.035
Brass oxidized	**392**	200	0.61
Bronze polished	**122**	50	0.10
Chromium unoxidized	**212**	100	0.08
Chromium oxidized	**600**	316	0.08
Copper cuprous oxide	**100**	38	0.87
Copper heavily oxidized, black	**100**	38	0.78
Copper polished	**100**	38	0.03
Copper Dow Metal	**100**	38	0.15
GOLD polished or unoxidized	**212**	100	0.02
Iconel X	**75**	24	0.19
Iconel B	**75**	24	0.21
Iron cast unoxidized	**392**	200	0.21
Iron cast oxidized	**392**	200	0.64
Iron cast heavily oxidized	**100**	38	0.95
Iron unoxidized	**212**	100	0.05
Iron oxidized	**212**	100	0.74
Iron heavily oxidized (rust)	**77**	25	0.65
Iron (Wrought)	**77**	25	0.94
Lead oxidized	**100**	38	0.43
Magnesium	**100**	38	0.07

EMMISSIVITY OF SELECT METALS			
MATERIAL	**TEMPERATURE °F**	**TEMPERATURE °C**	**EMISSIVITY NUMBER**
Mercury	**77**	25	0.10
Molybdenum	**100**	38	0.06
Molybdenum	**2000**	1093	0.18
Monel Ni-Cu	**392**	200	0.41
Monel Ni-Cu, oxidized	**77**	25	0.43
Nickel unoxidized	**77**	25	0.05
Nickel oxidized	**100**	38	0.31
Niobium unoxidized	**1500-2000**	816-1093	0.19-0.24
Niobium oxidized	**1500**	816	0.73
Nichrome wire unoxidized	**122**	50	0.65
Nichrome wire oxidized	**122**	50	0.95
Nickel unoxidized	**77-932**	25-500	0.045-0.0.12
Nickel oxidized	**392**	200	0.37
Platinum	**100**	38	0.05
Platinum Black	**100**	38	0.93
Silver polished	**100**	38	0.01
Steel unoxidized	**212**	100	0.08
Steel oxidized	**77**	25	0.80
Steel type 301 polished	**75**	24	0.27
Steel type 303 oxidized	**600**	316	0.74
Steel type 316	**75**	24	0.28
Tantalum unoxidized	**2732**	1500	0.21
Tin unoxidized	**77**	25	0.04
Titanium C110M	**300**	149	0.08
Tungsten unoxidized	**77**	25	0.02
Zinc Bright galvanized	**100**	38	0.23
Zinc unoxidized	**500**	260	0.05
Zinc oxidized	**500**	260	0.11

VAPOR PRESSURE OF THE ELEMENTS (s-sublime)								
Element	10^{-4} Torr		10^{-3} Torr		10^{-2} Torr		10^{-1} Torr	
	°C	°F	°C	°F	°C	°F	°C	°F
Aluminum	808	**1486**	889	**1632**	996	**1825**	1123	**2053**
Beryllium	1029	**1884**	1130	**2066**	1246	**2275**	1395	**2543**
Boron	1140	**2084**	1239	**2262**	1355	**2471**	1489	**2712**
Cadmium	180	**356**	220	**428**	264	**507**	321	**610**
Calcium	463	**865**	528	**982**	605	**1121**	700	**1292**
Carbon	2290	**4150**	2471	**4480**	2681	**4858**	2926	**5299**
Cerium	1091	**1996**	1190	**2174**	1305	**2381**	1439	**2622**
Cesium	74	**165**	110	**230**	153	**307**	207	**405**
Chromium	992	**1818**	1090	**1994**	1205	**2201**	1342	**2448**
Cobalt	1362	**2484**	1494	**2721**	1649	**3000**	1833	**3331**
Copper	1035	**1895**	1141	**2086**	1273	**2323**	1432	**2610**
Gallium	859	**1578**	965	**1769**	1093	**1999**	1248	**2278**
Germanium	996	**1825**	1112	**2034**	1251	**2284**	1421	**2590**
Gold	1190	**2174**	1316	**2401**	1465	**2669**	1646	**2995**
Iron	1195	**2183**	1310	**2390**	1447	**2637**	1602	**2916**
Lead	548	**1018**	620	**1148**	718	**1324**	832	**1508**
Magnesium	331	**628**	380	**716**	443	**829**	515	**959**
Manganese	791	**1456**	878	**1612**	980	**1796**	1020	**1868**
Mercury			18	**64**	48	**118**	82	**180**
Molybdenum	2098	**3809**	2295	**4163**	2533	**4591**	2880	**5216**
Neodymium			1192	**2177**	1342	**2448**	1537	**2799**
Nickel	1257	**2295**	1371	**2500**	1510	**2750**	1679	**3054**
Niobium	2355	**4271**	2539	**4602**				
Palladium	1271	**2320**	1405	**2561**	1566	**2851**	1759	**3198**
Phosphorus			160	**320**	190	**374**	225	**437**
Platinum	1744	**3171**	1904	**3459**	2090	**3794**	2293	**4150**
Potassium	123	**253**	161	**322**	207	**405**	265	**509**
Rhenium			2790	**5054**	3060	**5540**	3400	**6152**
Rhodium	1815	**3299**	1971	**3580**	2149	**3900**	2358	**4274**
Selenium			200	**392**	235	**455**	280	**536**
Silicon	1116	**2041**	1223	**2233**	1343	**2449**	1485	**2705**
Silver	848	**1558**	920	**1688**	1047	**1917**	1184	**2163**
Sodium	195	**383**	238	**460**	291	**556**	356	**673**
Sulfur			66	**151**	97	**207**	135	**275**
Tantalum	2599	**4710**	2820	**5108**	3074	**5565**	3370	**6098**
Tin	922	**1692**	1042		1189		1373	
Titanium	1250		1384	**2523**	1546	**2815**	1742	**3168**
Tungsten	2767		3016	**5461**	3309	**5988**		
Uranium	1585		1730	**3146**	1898	**3448**	2098	**3808**
Vanadium	1586		1725	**3137**	1888	**3430**	2079	**3774**
Yttrium	1362	**2484**	1494	**2721**	1650	**3000**	1833	**3331**
Zinc	248	**478**	292	**558**	343	**649**	405	**761**
Zirconium	1660	**3020**	1816	**3301**	2001	**3634**	2212	**4014**

VAPOR PRESSURE OF THE ELEMENTS (s-sublimes)								
Element	1.0 Torr		10^{1} Torr		10^{2} Torr		760 Torr	
	°C	°F	°C	°F	°C	°F	°C	°F
Aluminum	1279	**2334**	1487	**2709**	1749	**3180**	2467	**4473**
Beryllium	1567	**2853**	1787	**3249**	2097	**3087**	2507	**4545**
Boron	1648	**2998**	3030	**5486**	3460	**6260**	2527(s)	**4581(s)**
Cadmium	394	**741**	484	**903**	611	**1132**	765	**1409**
Calcium	817	**1503**	983	**1801**	1207	**2205**	1487	**2709**
Carbon	3214	**5817**	3946	**7135**	4373	**7903**	4827	**8721**
Cerium							3426	**6199**
Cesium			373	**703**	513	**955**	690	**1274**
Chromium	1504	**2739**					2222	**4031**
Cobalt	2056	**3732**	2380	**4316**	2720	**4928**	3097	**5607**
Copper	1628	**2962**	1879	**3414**	2207	**4005**	2595	**4703**
Gallium	1443	**2629**	1541	**2806**	1784	**3243**	2427	**4400**
Germanium	1635	**2975**	1880	**3416**	2210	**4010**	2707	**4905**
Gold	1867	**3393**	2154	**3909**	2521	**4570**	2966	**5371**
Iron	1783	**3241**	2039	**3702**	2360	**4280**	2727	**4941**
Lead	975	**1787**	1167	**2133**	1417	**2583**	1737	**3159**
Magnesium	605	**1121**	702	**1296**	909	**1668**	1126	**2059**
Manganese	1251	**2284**	1505	**2741**	1792	**3257**	2097	**3807**
Mercury	126	**259**	184	**363**	216	**421**	361	**682**
Molybdenum	3102	**5616**	3535	**6395**	4109	**7428**	4804	**8679**
Neodymium	1775	**3227**	2095	**3803**	2530	**4586**	3090	**5594**
Nickel	1884	**3423**	2007	**3645**	2364	**4287**	2837	**5139**
Niobium							4742	**8568**
Palladium	2000	**3632**	2280	**4136**	2780	**5036**	3167	**5732**
Phosphorus	265	**509**	310	**590**	370	**698**	431,	**808**
Platinum	2582	**4680**	3146	**5695**	3714	**6717**	3827	**6921**
Potassium	338	**640**	443	**829**	581	**1078**	779	**1434**
Rhenium	3810	**6890**					5630	**10166**
Rhodium	2607	**4725**	2880	**5216**	3392	**6138**	3877	**7011**
Selenium	350	**662**	430	**806**	550	**1022**	685	**1265**
Silicon	1670	**3038**	1888	**3430**	2083	**3781**	2477	**4491**
Silver	1353	**2467**	1575	**2867**	1865	**3389**	2212	**4013**
Sodium	437	**819**	548	**1018**	696	**1285**	914	**1677**
Sulfur	183	**361**	246	**475**	333	**631**	444	**831**
Tantalum	3740	**6764**					6027	**10881**
Tin	1609		1703		1968		2727	
Titanium	1965	**3569**	2180	**3956**	2480	**4496**	3127	**5661**
Tungsten							5927	**10701**
Uranium	2338	**4240**					3527	**6381**
Vanadium	2207	**4005**	2570	**4665**	2950	**5342**	3380	**6116**
Yttrium							3338	**6040**
Zinc	487	**907**	593	**1099**	736	**1357**	907	**1665**
Zirconium	2459	**4458**					3577	**6471**

Vapor Pressures of Certain Metal Oxides

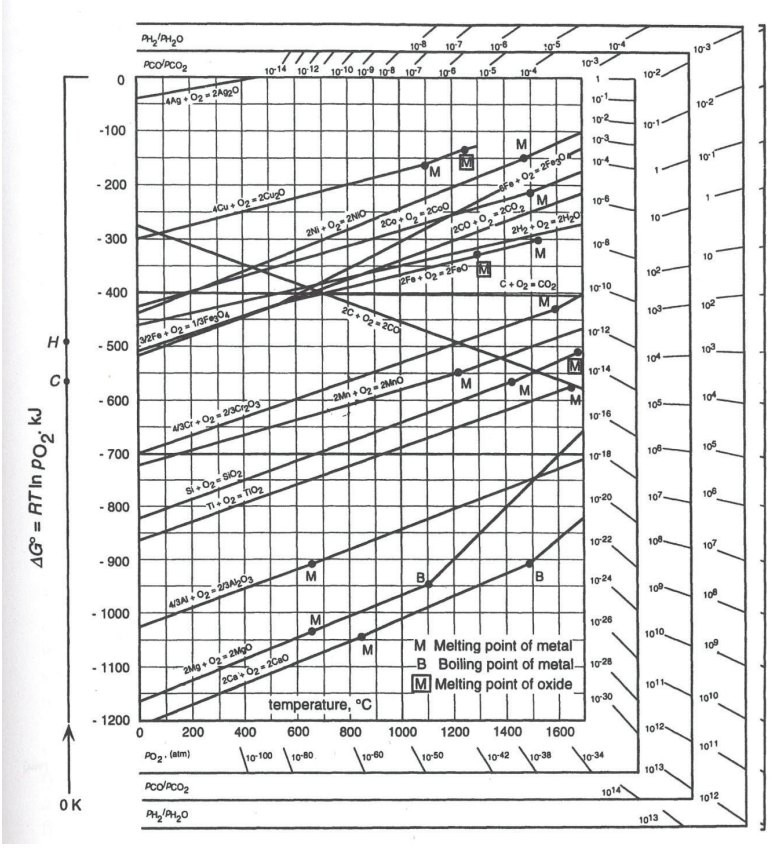
Compound	Formula	10^{-5} Torr (0.01 micron)		10^{-4} Torr (0.1 microns)		10^{-3} Torr (1.0 micron)		10^{-2} Torr (10 microns)		10^{-1} Torr (100 microns)		760 Torr 760,000 microns	
		°C	**°F**	°C	**°F**	°C	**°F**	°C	**°F**	°C	**°F**	°C	**°F**
Aluminum Oxide	Al_2O_3			1880	**3390**	1980	**3570**	2105	**3790**	2265	**4080**	3545	**6330**
Barium Oxide	BaO			1266	**2310**	1382	**2520**	1516	**2760**			1999	**3630**
Beryllium Oxide	BeO	1754	**3190**	1893	**3440**	2049	**3720**	2227	**4040**	2421	**4390**	4132	**7470**
Calcium Oxide	CaO	1543	**2810**	1666	**3030**	1810	**3290**	1982	**3600**	2182	**3960**	2849	**5160**
Chromic Oxide	Cr_2O_3	1320	**2410**	1425	**2600**	1555	**2830**	1695	**3080**	1875	**3380**	3030	**5440**
Iron (III) Oxide	Fe_2O_3								**1880**				
Magnesium Oxide	MgO	1388	**2530**	1510	**2750**	1632	**2970**	1788	**3250**	1954	**3550**	3599	**6510**
Molybdenum Trioxide	MoO_3					593	**1100**	627	**1160**	699	**1290**	793	**1460**
Potassium Oxide	K_2O	438	**820**	499	**930**	577	**1070**	643	**1190**	743	**1370**	1466	**2670**
Silicon Dioxide	SiO_2	1366	**2490**	1482	**2700**	1604	**2920**	1738	**3160**	1893	**3440**	2232	**4050**
Sodium Oxide	Na_2O	554	**1031**	627	**1160**	704	**1300**	799	**1470**	916	**1680**	1277	**2330**
Titanium Oxide	TiO_2	1577	**2870**	1704	**3100**								
Zirconium Oxide	ZrO_2	1877	**3410**	2049	**3720**	2177	**3950**	2399	**4350**	2577	**4670**	4299	**7770**

Richardson-Ellingham Diagram

The Richardson-Ellingham Diagram is a graphical representation of the standard Gibbs free energy changes for chemical reactions. It can be used to determine necessary furnace conditions for prevention of unwanted oxidation of metals or the reduction of metal oxides.

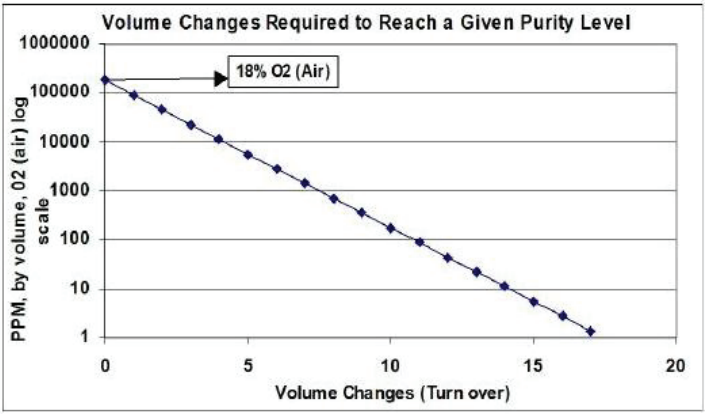
The main uses of this diagram are:

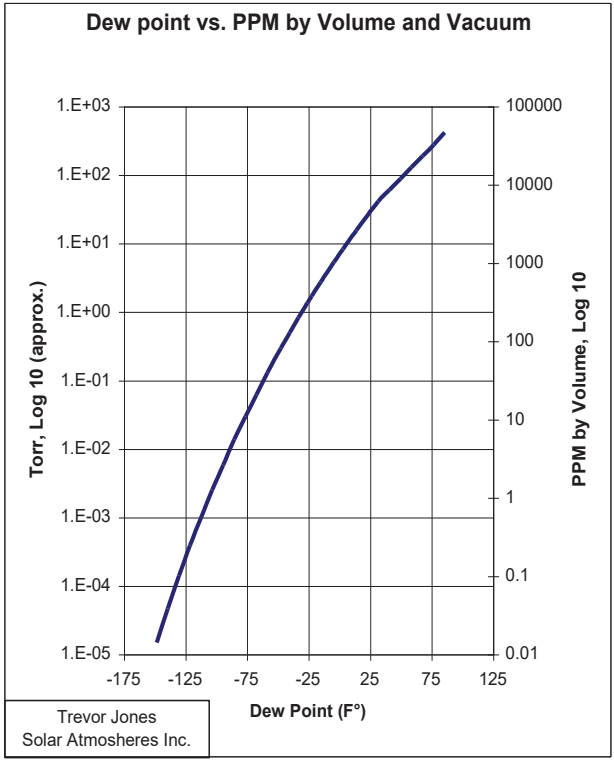
1. Determine the partial pressure of oxygen that is in equilibrium with the metal oxide for a given temperature;
2. Calculate the CO/CO_2 ratio required to reduce an oxide at a given temperature.
3. Determine the ease of oxidation for a given temperature and dew point.
4. Predict the temperatures at which a metal is stable and the temperature that it will readily oxidize.



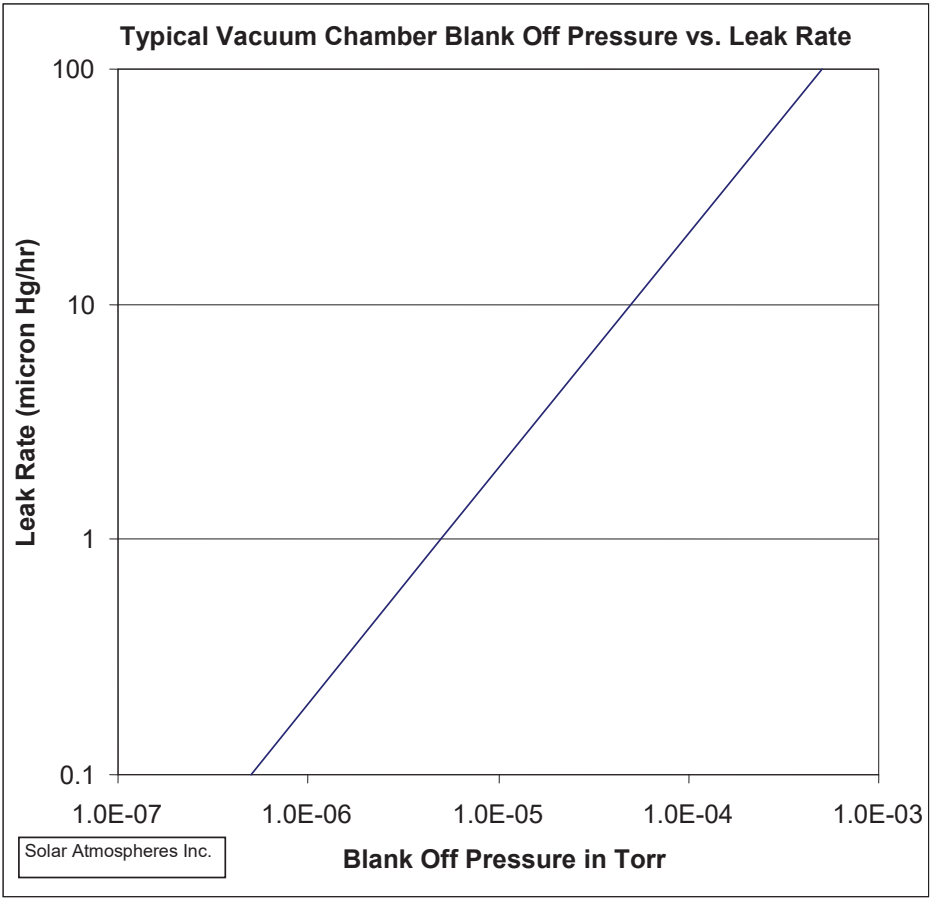
Gaskell, David R. *Introduction of the Thermodynamics of Materials, 4th Edition*. New York: Taylor & Francis, 2003

Gas Purge Chart





Vacuum Furnace Blank Off Pressure vs. Leak Rate



Common English to Metric Conversions

Conversion Factors for Common Units of Length
1 inch = 2.54 centimeters (cm) = 25.4 millimeters (mm)
1 foot = 0.305 meters
1 centimeter = 0.394 inches
1 meter = 39.37 inches = 3.28 feet = 1.094 yards

Conversion Factors for Common Units of Area
1 square inch = 6.45 square centimeters
1 square foot = 0.093 square meter = 930 square centimeters
1 square centimeter = 0.155 square inches
1 square meter = 10.764 square feet= 1550 square inches

Common Conversion Factors for Units of Volume (Solid and Liquid)
1 cubic inch = 16.4 cubic centimeters (cc)
1 cubic inches = 16.4 milliliters (ml)
1 cubic foot = 0.0283 cubic meters
1 cubic foot = 7.48 U.S. gallons
1 U.S. gallon = 3.78 liters
1 cubic foot= 28.3 liters (L)
1 cubic centimeter (cc) = 0.061 cubic inches
1 milliliters (ml) = 0.061 cubic inches
1 cubic meter = 35.314 cubic feet
1liter = 35.314 cubic feet

Common Conversion Factors for Units of Mass (Weight)
1 pound (avoirdupois) lb. = 453.6 gram
1 ounce = 0.0625 lb. = 28.35 grams
1 gram = 0.0022 pounds = 0.0353 ounces

Common Pressure Conversion Factors

Multiply by ↓ to calculate→	Atmosphere (Atm)	Torr	Pascal	Bar	Micron	Psia (lb/in^2)
Atm	1	760	$1.01325X10^5$	1.01325	$7.6X10^5$	14.696
Torr	$1.316X10^{-3}$	1	133.322	$1.3332X10^{-3}$	1000	$1.9337X10^{-2}$
Pascal	$9.8692X10^{-6}$	$7.5006X10^{-3}$	1	$1X10^{-5}$	7.5006	$1.4504X10^{-4}$
Bar	$9.8692X10^{-1}$	750.06	$1X10^5$	1	$7.5006X10^5$	14.504
Microns	$1.31579X10^{-6}$	$1X10^{-3}$	$1.3332X10^{-1}$	1.3332X10-6	1	$1.9337X10^{-5}$
Psia Lb/In^2	$6.8046X10^{-2}$	51.7151	6894.757	$6.8946X10^{-2}$	51715.1	1

To convert from one pressure unit to another use the left column to locate the old unit and multiply by the conversion factor to obtain the value in the new pressure unit.

Example:
To convert Atmospheres to Bar

1 Atm =1.01325 Bar
1 Pascal = $9.8692X10^{-6}$ Atm

Equivalence Table for Pressure/Vacuum Measurements

(Relating Furnace Vacuum Gauge Readings (Inches Hg) to Absolute Pressure Values)

Micron Hg	Millibar (mbar)	Torr (mmHg)	***Inches Hg* Vacuum Gauge***	Inches Hg Absolute	Psia ($lb/in.^2$ absolute)	Atm
760,000	1013	760	***0.0***	29.92	14.7	1.000
750,000	1000	750	***0.42***	29.5	14.5	0.987
735,000	981	735.6	***1.02***	28.9	14.2	0.968
700,000	934	700	***2.32***	27.6	13.5	0.921
600,000	800	600	***6.32***	23.6	11.6	0.789
500,000	667	500	***10.22***	19.7	9.7	0.658
400,000	533	400	***14.22***	15.7	7.7	0.526
380,000	507	380	***14.92***	15.0	7.3	0.500
300,000	400	300	***18.12***	11.8	5.8	0.395
200,000	267	200	***22.07***	7.85	3.9	0.264
100,000	133.3	100	***25.98***	3.94	1.93	0.132
90,000	120	90	***26.38***	3.54	1.74	0.118
80,000	106.8	80	***26.77***	3.15	1.55	0.105
70,000	93.4	70	***27.16***	2.76	1.35	0.0921
60,000	80	60	***27.56***	2.36	1.16	0.0789
51,700	68.8	51.7	***27.89***	2.03	1.00	0.068
50,000	66.7	50	***27.95***	1.97	0.97	0.0658
40,000	53.3	40	***28.35***	1.57	0.77	0.0526
30,000	40.0	30	***28.74***	1.18	0.58	0.0395
25,400	33.8	25.4	***28.92***	1.00	0.4912	0.034
20,000	26.7	20	***29.14***	0.785	0.39	0.0264
10,000	13.33	10	***29.53***	0.394	0.193	0.0132
7,600	10.13	7.6	***29.62***	0.299	0.147	0.01
1,000	1.33	1	***29.88***	0.03937	0.01934	0.00132
750	1.00	0.75	***29.89***	0.0295	0.0145	0.000987
100	0.133	0.1	***29.916***	0.00394	0.00193	0.000132
10	0.0133	0.01	***29.9196***	0.000394	0.000193	0.0000132
1	0.00133	0.001	***29.91996***	0.0000394	0.0000193	0.0000013
0.1	0.000133	0.0001	***29.919996***	0.0000039	0.0000019	0.0000001

EQUIVALENCE TABLE
FURNACE VACUUM GAUGE READINGS (PSIG OR PSI)
TO ABSOLUTE PRESSURE VALUES

Bar	Torr	**Psig** ***(Furnace gauge)***	Psia (lb/in^2 absolute)	Atm
1.01325	760.0	**0**	14.7	1.00
1.082515	811.8	**1**	15.7	1.0682
1.358315	1018.7	**5**	19.7	1.3404
1.703065	1277.4	**10**	24.7	1.6806
2.047815	1535.8	**15**	29.7	2.0208
2.392565	1794.3	**20**	34.7	2.36098
3.082065	2311.4	**30**	44.7	3.04139
3.771565	2828.5	**40**	54.7	3.72179
4.461065	3345.6	**50**	64.7	4.40219
5.150565	3862.7	**60**	74.7	5.08259
5.840065	4379.8	**70**	84.7	5.76299
6.529565	4896.9	**80**	94.7	6.44339
7.219065	5414.0	**90**	104.7	7.12379
7.908565	5931.1	**100**	114.7	7.80419
14.80357	11102.1	**200**	214.7	14.6082
18.25207	13690.2	**250**	264.7	18.0102
21.69857	16273.1	**300**	314.7	21.4122
28.59357	21444.1	**400**	414.7	28.2162
35.48857	26615.1	**500**	514.7	35.0202
42.38357	31786.1	**600**	614.7	41.8242
49.27857	36957.1	**700**	714.7	48.6282
56.17357	42128.1	**800**	814.7	55.4322
63.06857	47299.1	**900**	914.7	62.2362
69.96357	52470.1	**1000**	1014.7	69.0402
104.4386	78325.1	**1500**	1514.7	103.0602
173.3886	130052.9	**2500**	2514.7	171.1206
207.8636	155910.2	**3000**	3014.7	205.1447
242.3386	181769.9	**3500**	3514.7	239.1688

TEMPERATURE CONVERSION
FAHRENHEIT TO CELSIUS OR KELVIN

°F	°C	K	°F	°C	K	°F	°C	K
-40	-40	233.2	**550**	287.8	560.9	**1700**	926.7	1199.8
-32	-35.6	237.6	**600**	315.6	588.7	**1750**	954.4	1227.6
-20	-28.9	244.3	**650**	343.3	616.5	**1800**	982.2	1255.4
-10	-23.3	249.8	**700**	371.1	644.3	**1850**	1010.0	1283.2
0	-17.8	255.4	**750**	398.9	672.0	**1900**	1037.8	1310.9
5	-15	258.2	**800**	426.7	699.8	**1950**	1065.6	1338.7
10	-12.2	260.9	**850**	454.4	727.6	**2000**	1093.3	1366.5
20	-6.7	266.5	**900**	482.2	755.4	**2050**	1121.1	1394.3
32	0	273.2	**950**	510.0	783.2	**2100**	1148.9	1422.0
40	4.4	277.6	**1000**	537.8	810.9	**2150**	1176.7	1449.8
50	10	283.2	**1050**	565.6	838.7	**2200**	1204.4	1477.6
70	21.1	294.3	**1100**	593.3	866.5	**2250**	1232.2	1505.4
90	32.2	305.4	**1150**	621.1	894.3	**2300**	1260.0	1533.2
100	37.8	310.9	**1200**	648.9	922.0	**2350**	1287.8	1560.9
120	48.9	322.0	**1250**	676.7	949.8	**2400**	1315.6	1588.7
150	65.6	338.7	**1300**	704.4	977.6	**2450**	1343.3	1616.5
212	100	373.2	**1350**	732.2	1005.4	**2500**	1371.1	1644.3
250	121.1	394.3	**1400**	760.0	1033.2	**2550**	1398.9	1672.0
300	148.9	422.0	**1450**	787.8	1060.9	**2600**	1426.7	1699.8
350	176.7	449.8	**1500**	815.6	1088.7	**2650**	1454.4	1727.6
400	204.4	477.6	**1550**	843.3	1116.5	**2700**	1482.2	1755.4
450	232.2	505.4	**1600**	871.1	1144.3	**2750**	1510.0	1783.2
500	260	533.2	**1650**	898.9	1172.0	**2800**	1537.8	1810.9

Formulas:

°C = (°F - 32)/1.8 **K = (°F + 459.67)/1.8** **°F = (1.8*K) - 459.67**

°F = (1.8 *°C) + 32 **°C = K - 273** **K= °C + 273**

POWDERED METALS U.S. MESH TO MICRON CONVERSION CHART				
U.S. Mesh	Microns	Millimeters	Inches	Appearance
5	400	4.0	0.1570	
10	2000	2.0	0.0787	
20	841	0.841	0.0331	
28	700	0.700	0.028	Beach Sand
35	500	0.500	0.0197	
40	400	0.400	0.0165	
50	297	0.297	0.0117	
60	250	0.250	0.0098	Fine Sand
70	210	0.210	0.0083	
80	177	0.177	0.0070	
100	149	0.149	0.0059	
120	125	0.125	0.0049	
140	105	0.105	0.0041	
200	74	0.074	0.0029	Cement
325	44	0.044	0.0017	Silt
400	37	0.037	0.0015	Plant pollen

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