yesyesyesyesyesPyrometric Conespyroconeyesyes21/02/95

Pyrometric Cones

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PYROMETRIC CONES

Firing instructions provided with ceramic materials, or in ceramics texts and magazine articles, frequently refer to cone numbers rather than temperatures, because the heat treating process involves both time and temperature. Pyrometric cones are special formulations of ceramic material which are designed to mature at different extremes of applied heat, are therefore useful in gauging the progress of a firing. The 'time vs temperature' relationship is reflected in the tables furnished herein. As you can see, a "cone 6" firing can result from a variety of schedules ...

to 2194°F (1201°C) in 20.5 hours,
to 2232°F (1222°C) in 8.27 hours,
to 2291°F (1255°C) in 4.24 hours, ... etc.

When firing with electronic temperature controllers, you must establish the LIMIT setting on the basis of the terminal firing rate (i.e., the rate of temperature change at the end of the firing), using the data presented in this table as a guide.

Example: Firing to cone 6, you intend to approach the limit temperature at a rate of 270°F (150°C) per hour. So you turn to the cone charts, find "Cone Number" 6 in the first column, then move your finger across the page to the "270°F/HR" (or "150°C/HR") column, to find the suggested LIMIT setting ... which is 2232°F (or 1222°C).

This matter of rate vs limit setting naturally applies to the final few hundred degrees of the firing, and you must also consider the nature of the load ... is the rate slow enough to assure a reasonable degree of temperature uniformity throughout just prior to shut-off? On the other hand, if you're firing to a high temperature ... say, over 2100°F ... you might well expect that your kiln will not have enough heating capacity to keep up with the controller's 270°F/Hr ramp, so the "final approach" will occur at some slower, kiln dependent, rate. Experience will help you decide how much to "fudge" on the limit setting to compensate for this "kiln lag".

OVERTIME OR OVER-TEMPERATURE - OVER-FIRED WARE!

This is a simple, but often overlooked point ... its important that you remember it. You can see from the cone charts that firing is a matter of (1) temperature and (2) time. Too much, or not enough, of either ... and the results will be poor; perhaps a complete loss.

Keep this in the back of your mind: if you come up with an over-fired load, it can just as well be the result of too much time, as too much temperature.

ACCURACY - TEMPERATURE STANDARDS

Contrary to popular belief, pyrometric cones are not the last word in temperature-measuring accuracy, and must not be used as standards. As previously mentioned, cones mature as a result of heat treating time and temperature.

For example, a cone rated at 1850F will actually bend a few hundred degrees lower than that point if held at the lower temperature for a sufficiently long period of time.

Pyrometric cones are also subject to other factors which influence their maturity temperature. Besides normal manufacturing tolerances, the mounting method used, the mounting position (angle) and the moisture content of the cone (resulting from relative humidity unless special precautions are taken) all effect the bending point. According to studies done several years ago by the National Bureau of Standards, these factors introduce uncertainties as large as 54°F. The accuracy of any other measuring device should never be judged on the basis of pyrometric cones.

TEMPERATURE EQUIVALENTS FOR ORTON STANDARD PYROMETRIC CONES

(As Determined at the National Bureau of Standards)

CONE NUMBER	LARGE CONES Heating Rate in F/Hr 108F/Hr	270F/Hr	small 540F/Hr	Color	Firing Stage	Customary Firing Application
		302		"black	free water boils out	
		437		heat"	alpha to beta cristobalite inversion	
		1022			alpha to beta quartz inversion	
		1067				
022	1085	1112	1165		dehydration	
021	1116	1137	1189		90% complete	
020	1157	1175	1231			
019	1234	1261	1333	dull		overglaze colors
018	1285	1323	1386	red		enamels and gold
017	1341	1377	1443			ceramic decals
016	1407	1458	1517			
015	1454	1479	1549			glass sagging
014	1533	1540	1596			chrome & red glaze
013	1596	1566	1615			
012	1591	1623	1650	cherry		
011	1627	1641	1680	red	most of	lustre glaze
010	1629	1641	1686		organic matter	
09	1679	1693	1751		now burnt	
08	1733	1751	1801	cherry	away	low firing lead &
07	1783	1803	1846	red to		fritted glazes
06	1816	1830	1873	orange	teracottas	porous biscuit-low
05	1888	1915	1944		mature	fire earthenware
04	1922	1940	2008	orange		
03	1987	2014	2068	changing		
02	2014	2048	2098	to		
01	2043	2079	2152	yellow/	earthenware	industrial earthen
1	2077	2109	2154	orange	matures	ware, bisque and
2	2088	2124	2154			bone china glost
3	2106	2134	2185	yellow/		
4	2134	2167	2208	orange	teracottas	
5	2151	2185	2230	yellow to	melt, increasing	
6	2194	2232	2291	lt. yellow	formation	semi-porcelain
7	2219	2264	2307		of beta type	salt glaze
8	2257	2305	2372	yellow	cristobalite	stoneware
9	2300	2336	2403	with white		bone china bisque
10	2345	2381	2426	tinge		& some porcelain
11	2361	2399	2437	intense		porcelain
12	2383	2419	2471	yellow-		
13		2455		white		
14		2491				
15		2608				

TEMPERATURE EQUIVALENTS FOR ORTON STANDARD PYROMETRIC CONES

(As Determined at the National Bureau of Standards)

CONE NUMBER	LARGE CONES Heating Rate in C/Hr 60C/Hr	150C/Hr	small 300C/Hr	Color	Firing Stage	Customary Firing Application
		150		"black	free water boils out	
		225		heat"	alpha to beta cristobalite inversion	

		550			alpha to beta quartz inversion	
		575				
022	585	600	630		dehydration	
021	602	614	643		90% complete	
020	625	635	666			
019	668	683	723	dull		overglaze colors
018	696	717	752	red		enamels and gold
017	727	747	784			ceramic decals
016	764	792	825			
015	790	804	843			glass sagging
014	834	838	870			chrome & red glaze
013	869	852	880			
012	866	884	900	cherry		
011	886	894	915	red	most of	lustre glaze
010	887	894	919		organic matter	
09	915	923	955		now burnt	
08	945	955	983	cherry	away	low firing lead &
07	973	984	1008	red to		fritted glazes
06	991	999	1023	orange	teracottas	porous biscuit-low
05	1031	1046	1062		mature	fire earthenware
04	1050	1060	1098	orange		
03	1086	1101	1131	changing		
02	1101	1120	1148	to		
01	1117	1137	1178	yellow/	earthenware	industrial earthen
1	1136	1154	1179	orange	matures	ware, bisque and
2	1142	1162	1179			bone china glost
3	1152	1168	1196	yellow/		
4	1168	1186	1209	orange	teracottas	
5	1177	1196	1221	yellow to	melt, increasing	
6	1201	1222	1255	lt yellow	formation	semi-porcelain
7	1215	1240	1264		of beta type	salt glaze
8	1236	1263	1300	yellow	cristobalite	stoneware
9	1260	1280	1317	with white		bone china bisque
10	1285	1305	1330	tinge		& some porcelain
11	1294	1315	1336	intense		porcelain
12	1306	1326	1355	yellow-		
13		1346		white		
14		1366				
15		1431				

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Firing, refers to the heat-treating process used in ceramic work to convert soft clay shapes to a hardened glass-like form, or to process glazes which are used to provide the desired surface texture or color. This usually involves heating the piece up to a temperature somewhere within the range of 1500°F to 2500°F over a specified period of time.

The concept of monitoring the process of heat-treating ceramics by using small specially-formulated cone-shaped clay pieces, originated in Germany. Known abroad as Seger Temperature Cones (named for their developer), and also sometimes referred to as the sentinel pyrometer outside of the U.S., these devices have not changed much over several decades of use. Cones are actually shaped in the form of triangular pyramids (about 3-inches high), and are composed of metallic and mineral substances which fuse at certain temperatures. They are made in a series, each successive cone having a fusing temperture that differs slightly from the one above or below it in the scale; that is, if the series were placed in a furnace and the temperature gradually raised, one cone after another would melt as its melting point was reached.
These cones are usually used in threes to determine the minimum and maximum exposure for a given firing process, the lower cone giving warning that process is about to approach completion, the middle cone being watched as the indicator of the desired firing results, and the upper cone guarding the process from over-firing.

The firing process for ceramics is usually a simple matter of increasing the temperature at a given rate to a specified maximum value, known as the Limit Temperature, then simply turning the kiln off, allowing it to cool on its own.

Ceramic kilns (pronounced kills - the n is silent), are special purpose gas or electric furnaces specially designed for firing ceramics.   Kilns range in size from, small enough to contain only a tea cup, to large enough to accomodate a train car.

The Edward Orton Jr Ceramics Foundation has always been the recognized authority on,and premere producer of, pyrometric cones in the United States, and sponsors continuing research and development activities in this field. If you would like to know more about Orton Cones, write them at 6991 Old 3C Highway, Westerville, OH 43081 Phone: (614) 895-2663 FAX: 895-5610.

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