KANTHAL Resistance Heating Alloys – Summary

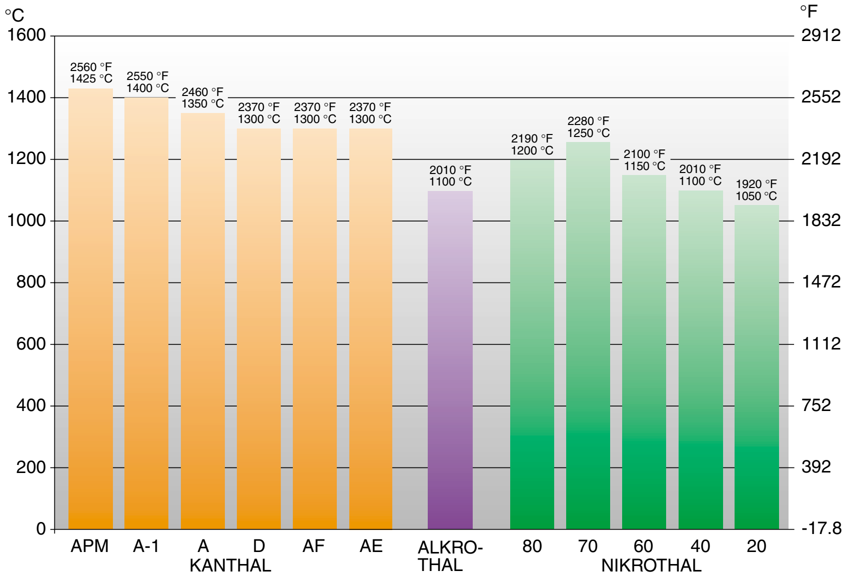

Fig. 1 - Maximum operating temperature per alloy

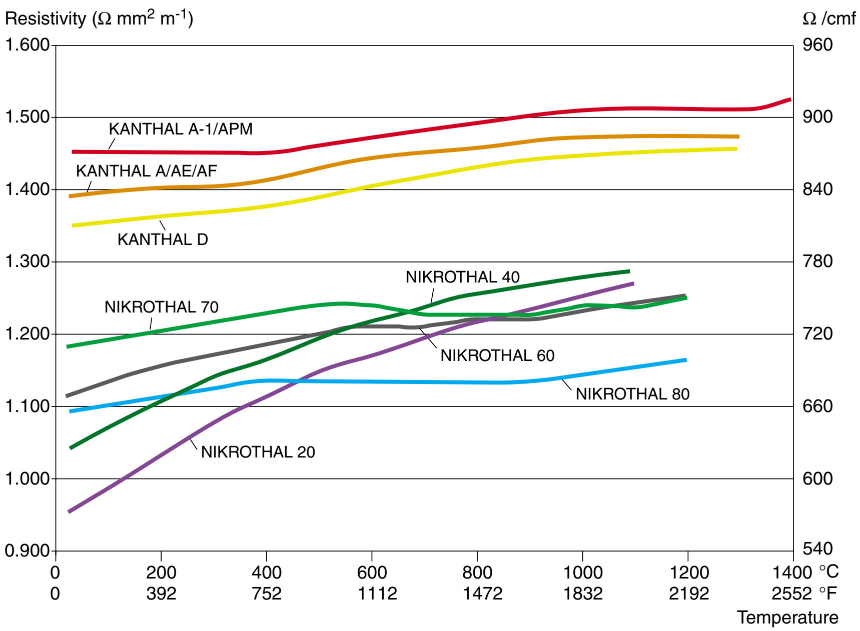

Fig. 2 - Resistivity vs. Temperature.

5. Design Factors

Operating Life

The life of the resistance heating alloy is dependent on a number of factors, among the most important are:
– Temperature
– Temperature cycling
– Contamination
– Alloy composition
– Trace elements and impurities
– Wire diameter
– Surface condition
– Atmosphere
– Mechanical stress
– Method of regulation

Since these are unique for each application it is difficult to give general guidelines of life expectations. Recommendations on some of the important design factors are given below.

Table 1
Relative Durability Values in %, KANTHAL and NIKROTHAL Alloys (ASTM-test wire 0.7 mm *0.028 in)*

	1100 °C *2010 °F*	1200 °C *2190 °F*	1300 °C *2370 °F*
KANTHAL A-1	340	**100**	30
KANTHAL AF	465	120	30
KANTHAL AE	550	120	30
KANTHAL D	250	75	25
NIKROTHAL 80	120	25	-
NIKROTHAL 60	95	25	-
NIKROTHAL 40	40	15	-

Oxidation properties

When heated, resistance-heating alloys form an oxide layer on their surface, which slows down further oxidation of the material. To accomplish this function the oxide layer must be dense and resist the diffusion of gases as well as metal ions. It must also be thin and adhere to the metal under temperature fluctuations.

The protective oxide layer on KANTHAL alloys formed at temperatures above 1000 °C *1830 °F* consists mainly of alumina (Al_2O_3). The colour is light grey, while at lower temperatures (under 1000 °C, *1830 °F*) the oxide colour becomes darker. The alumina layer has excellent electrical insulating properties and good chemical resistance to most compounds.

The oxide formed on NIKROTHAL alloys consists mainly of chromium oxide (Cr_2O_3). The colour is dark and the electrical insulating properties inferior to those of alumina.

The oxide layer on NIKROTHAL alloys spalls and evaporates more easily than the tighter oxide layer that is formed on the KANTHAL alloys.

Results of several life tests according to ASTM B 78 (modified) are given in Table 1 for KANTHAL and NIKROTHAL alloys. In the table, the durability of KANTHAL A-1 wire at 1200 °C *2190 °F* is set at 100 %, and the durability of the other alloys is related to that figure.

Corrosion Resistance

Corrosive or potentially corrosive constituents can considerably shorten wire life. Perspiring hands, mounting or supporting materials or contamination can cause corrosion.

Steam
Steam shortens the wire life. This effect is more pronounced on NIKROTHAL alloys than on KANTHAL alloys.

Halogens
Halogens (fluorine, chlorine, bromine and iodine) severely attack all high-temperature alloys at fairly low temperatures.

Sulphur
In sulphurous atmospheres KANTHAL alloys have considerably better durability than nickel-base alloys. KANTHAL is particularly stable in oxidising gases containing sulphur, while reducing gases with a sulphur content diminish its service life. NIKROTHAL alloys are sensitive to sulphur.

Salts and oxides
The salts of alkaline metals, boron compounds, etc. in high concentrations and are harmful to heating alloys.

Metals
Some molten metals, such as zinc, brass, aluminium and copper, react with the resistance alloys. The elements should therefore be protected from splashes of molten metals.

Ceramic support material
Special attention must be paid to the ceramic supports that come in direct contact with the heating wire. Firebricks for wire support should have an alumina content of at least 45 %. In high-temperature applications, the use of sillimanite and high-alumina firebricks is often recommended. The free silica (uncombined quartz) content should be held low. Iron oxide lowers the melting point of the ceramics. Water glass as a binder in cements must be avoided.

Embedding compounds
Most embedding compounds including ceramic fibres are suitable for KANTHAL and NIKROTHAL if composed of alumina, alumina-silicate, magnesia or zirconia.

Maximum Temperature per Wire Size

The table below gives maximum wire temperatures as a function of wire diameter when operating in air.

Table 2
Maximum Permissible Temperature as a Function of Wire Size

	Diameter, mm *(in)*: **0.15-0.4** ***(0.0059-0.0157)*** **°C** ***°F***	**0.41-0.95** ***(0.0061-0.0374)*** **°C** ***°F***	**1.0-3.0** ***(0.039-0.118)*** **°C** ***°F***	**>3.0** ***(>0.118)*** **°C** ***°F***
KANTHAL AF	900-1100	1100-1225	1225-1275	1300
	1650-2010	*2010-2240*	*2240-2330*	*2370*
KANTHAL A	925-1050	1050-1175	1175-1250	1350
	1700-1920	*1920-2150*	*2150-2300*	*2460*
KANTHAL AE	950-1150	1150-1225	1225-1250	1300
	1740-2100	*2100-2240*	*2240-2300*	*2370*
KANTHAL D	925-1025	1025-1100	1100-1200	1300
	1700-1880	*1880-2010*	*2010-2190*	*2370*
NIKROTHAL 80	925-1000	1000-1075	1075-1150	1200
	1700-1830	*1830-1970*	*1970-2100*	*2190*
NIKROTHAL 60	900-950	950-1000	1000-1075	1150
	1650-1740	*1740-1830*	*1830-1970*	*2100*
NIKROTHAL 40	900-950	950-1000	1000-1050	1100
	1650-1740	*1740-1830*	*1830-1920*	*2010*

6. Element types and heating applications

The Embedded Element Type

The wire in the embedded element type is completely surrounded by solid or granular insulating material.

Metal Sheathed Tubular Elements

KANTHAL D is generally the best heating wire for tube temperatures below 700 °C *1290 °F* and NIKROTHAL 80 for temperatures above.

To use KANTHAL instead of NiCr gives the following advantages:

- Lower wire weight by some 20-30 % at the same wire dimension
- More even temperature along the element and lower maximum wire temperature. This means that the element can be charged higher for a short time - important when there is a risk of dry boiling
- Closer tolerances of rating. Rating and temperature remains more constant since the resistivity in hot state does not change as much as for NiCr
- Longer life at high surface loads. The element life is also easier forecasted
- KANTHAL is easier to manufacture when high resistance per length is needed, since a thicker wire can be used
- Less sensitive to corrosion attacks

The Supported Element Type

The wire, normally in spiral form, is situated on the surface, in a groove or a hole of the electrical insulating material.

KANTHAL AE, KANTHAL AF and NIKROTHAL 80 are generally the best materials.
In order to avoid deformations on horizontal coils, the wire temperature should not exceed the values given in Figure 3.

The Suspended Element Type

The wire is suspended freely between insulated points and is exposed to the mechanical stress caused by its own weight, its own spring force and in some cases also from the forces of an external spring.

NIKROTHAL 80, NIKROTHAL 60, KANTHAL D and KANTHAL AF are the best materials.

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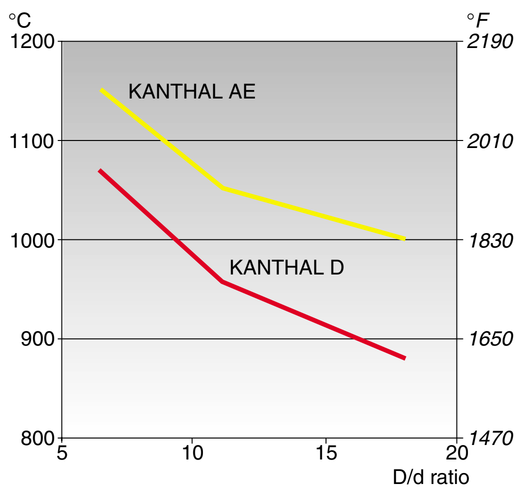

Figure 3. Permissible D/d ratios as a function of wire temperature in supported spiral elements.

KANTHAL D
Wire

Standard stock items	Alloy	Diameter range mm	Resistivity $\Omega mm^2 m^{-1}$	Density gcm^{-3}
■	D	8.0-0.020	1.35	7.25

To obtain resistance at working temperature, multiply by the factor C_t in the following table:

°C	20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300
C_t	1.00	1.00	1.01	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.07	1.07	1.08	1.08

Diameter mm	Resistance at 20 °C Ω/m	cm²/Ω[1] at 20 °C	Weight g/m	Surface area cm²/m	Cross sectional area mm²
8.0	0.0269	9358	364	251	50.3
6.5	0.0407	5019	241	204	33.2
6.0	0.0477	3948	205	188	28.3
5.5	0.0568	3041	172	173	23.8
5.0	0.0688	2285	142	157	19.6
4.75	0.0762	1959	128	149	17.7
4.5	0.0849	1666	115	141	15.9
4.25	0.0952	1403	103	134	14.2
4.06	0.104	1223	93.9	128	12.9
4.0	0.107	1170	91.1	126	12.6
3.75	0.122	964	80.1	118	11.0
3.65	0.129	889	75.9	115	10.5
3.5	0.140	784	69.8	110	9.62
3.25	0.163	627	60.1	102	8.30
3.0	0.191	493	51.2	94.2	7.07
2.95	0.198	469	49.6	92.7	6.8
2.8	0.219	401	44.6	88.0	6.16
2.65	0.245	340	40.0	83.3	5.5
2.5	0.275	286	35.6	78.5	4.91
2.0	0.430	146	22.8	62.8	3.14
1.8	0.531	107	18.4	56.5	2.54
1.7	0.595	89.8	16.5	53.4	2.27
1.6	0.671	74.9	14.6	50.3	2.01
1.5	0.764	61.7	12.8	47.1	1.77
1.4	0.877	50.2	11.2	44.0	1.54
1.3	1.02	40.2	9.62	40.8	1.33
1.2	1.19	31.6	8.20	37.7	1.13
1.1	1.42	24.3	6.89	34.6	0.950

Diameter mm	Resistance at 20 °C Ω/m	cm²/Ω[1] at 20 °C	Weight g/m	Surface area cm²/m	Cross sectional area mm²
1.0	1.72	18.3	5.69	31.4	0.785
0.95	1.90	15.7	5.14	29.8	0.709
0.90	2.12	13.3	4.61	28.3	0.636
0.85	2.38	11.2	4.11	26.7	0.567
0.80	2.69	9.36	3.64	25.1	0.503
0.75	3.06	7.71	3.20	23.6	0.442
0.70	3.51	6.27	2.79	22.0	0.385
0.65	4.07	5.02	2.41	20.4	0.332
0.60	4.77	3.95	2.05	18.8	0.283
0.55	5.68	3.04	1.72	17.3	0.238
0.50	6.88	2.28	1.42	15.7	0.196
0.45	8.49	1.67	1.15	14.1	0.159
0.42	9.74	1.35	1.00	13.2	0.139
0.40	10.7	1.17	0.911	12.6	0.126
0.35	14.0	0.784	0.698	11.0	0.0962
0.32	16.8	0.599	0.583	10.1	0.0804
0.30	19.1	0.493	0.512	9.42	0.0707
0.28	21.9	0.401	0.446	8.80	0.061
0.25	27.5	0.286	0.356	7.85	0.0491
0.22	35.5	0.195	0.276	6.91	0.0380
0.20	43.0	0.146	0.228	6.28	0.0314
0.19	47.6	0.125	0.206	5.97	0.0284
0.18	53.1	0.107	0.184	5.65	0.0254
0.17	59.5	0.0898	0.165	5.34	0.0227
0.16	67.1	0.0749	0.146	5.03	0.0201
0.15	76.4	0.0617	0.128	4.71	0.0177
0.14	87.7	0.0502	0.112	4.40	0.0154
0.13	102	0.0402	0.0962	4.08	0.0133

[1] $cm^2/\Omega = I^2 \cdot C_t/p$ (I = Current, C_t = temperature factor, p = surface load W/cm^2)