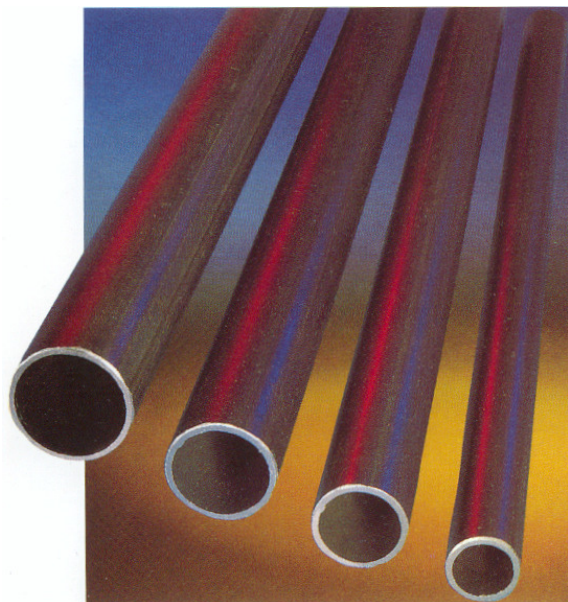


February 2017

Thermal Alloys Engineering

*Protection Tubes in
FeCrAl-Alloys for
High Temperature Service*



*Increased Service Life
Better Process Control
Improved Process Economy*

Thermalloys AB

www.thermalloys.com

Thermalloys' protection tubes for temperatures up to 1425°C/2600°F

Different metallic materials react differently to high temperature environments. Standard stainless steels, such as 1.4301/304, 1.4404/316L, as well as most NiCr and FeNiCr alloyed steels, are protected by a chromium oxide (Cr_2O_3). The protective chromium oxide is formed on the metal surface by a reaction with oxygen present in the environment. The chromium oxide is a good protector of the metal at medium high temperatures, but it is less adherent at higher temperatures. At higher temperatures this will cause the oxide to spall off, leaving an unprotected surface subject to further oxidation. This process leads to rapid oxidation. The temperature at which this deteriorating process starts is referred to as the scaling temperature.

The Thermalloys tubes, on the other hand, are made in FeCrAl alloys, which are protected by an aluminium oxide (Al_2O_3).

The aluminium oxide formed on the surface of the FeCrAl alloys, has the following advantages as compared to the Cr_2O_3 oxide on stainless steels and nickel base alloys:

- **Thermodynamic stability:** The Al_2O_3 oxide is unaffected by most high temperature environments, also at low partial pressures of oxygen.
- **Adhesion to the base metal:** The Al_2O_3 oxide is more tightly bound to the base metal, also during thermal cycling. The addition of yttrium improves the adherence of the aluminum oxide.
- **Low growth rate:** The Al_2O_3 oxide has a much lower growth rate as compared to the Cr_2O_3 oxide. This results in thinner oxides, with less tendency to cracking and spalling off.

Due to the above properties of the Al_2O_3 oxide, the Thermalloys' protection tubes have an oxidation resistance superior to protection tubes made from any other commercially available iron and nickel base alloy.

Thus, the service life of Thermalloys FeCrAl protection tubes is longer as compared to other protection tubes on the market and which results in a much improved process control and process economy.

Thermalloys' protection tubes are manufactured in the following alloys:

Trade name*	% Chromium	% Aluminium	Other additions	Scaling temperature in air at constant temperature	Hot strength
Kanthal APM	22	5.8		Up to 1425 C/2600 F;	High hot strength allows for horizontal installation.
Kanthal APMT	22	5.8	Molybdenum	Up to 1425 C/2600 F;	Even a higher hot strength than Kanthal APM
Kanthal AF	22	5.3	Yttrium	Up to 1300 C/2370 F; The addition of Yttrium makes AF comparable to APM at cyclic/varying temperatures; Yttrium ties the Al-oxide to the surface.	About twice the hot strength of Kanthal A-1, which decreases the risk for sagging of the tube. Vertical installation, if not supported
Kanthal D	22	4.8		Up to 1300 C/2370 F	Low

*Kanthal is a registered trade mark of Kanthal AB.

Protection tubes, tubes for gas analysis, hot gas injection and hot gas sampling

Kanthal APM/Kanthal APMT are manufactured using powder metallurgy; This results in a much increased hot strength/creep strength, as compared to materials manufactured by conventional metallurgical techniques.

In combination with its excellent oxidation resistance, this makes Kanthal APM/APMT superior to most other iron- and nickel base alloys in most high temperature applications.

Kanthal AF (corresponds to the Fecralloy alloy) is the conventionally manufactured FeCrAl alloy which has the best combination of resistance to cyclic oxidation, the highest hot strength, the best formability and weldability. The AF grade has therefore been selected as our standard grade for protection tubes.

While not having the hot strength of the APM-grade, Kanthal AF has an oxidation resistance superior to all other iron- and nickel base alloys in most environments.

Thus, the use of the FeCrAl alloys in high temperature processes gives large advantages.

The main advantages of the Thermalloys FeCrAl protection tubes as compared to tubes in other alloys are:

- **Resistant to temperatures 150 to 400°C/302 to 752°F higher than other types of metallic protection tubes.**
- **High resistant to attack by sulphur compounds.**
- **High resistant to carburisation.**
- **The high oxidation resistance of the FeCrAl alloys makes it possible to produce tubes with thin walls having long service lives. Thin walls give rapid heat transmission which means faster response to temperature variations.**
- **The aluminium oxide layer on the protection tube has a minimal tendency to spall, which means that contamination of heat treated products is avoided.**
- **No risk of short-circuiting caused by spalled oxide, In contrast to chromium oxide, aluminium oxide is not electrically conductive.**
- **High toughness and ductility compared to ceramic tubes.**



Comments on the table on page 5:

The temperature limits given in the table on page 5, are the so called scaling temperatures, i.e. the temperatures at which the protective oxide starts to crack and as a consequence opens up for oxidation of the metal beneath the oxide.

In cracked ammonia, where oxygen is totally absent, there is an exception with regard to the high oxidation resistance of the FeCrAl alloys; Since a protective aluminium oxide cannot form, nitridation will occur with a certain rate. Nickel base alloys are more suitable in this case.

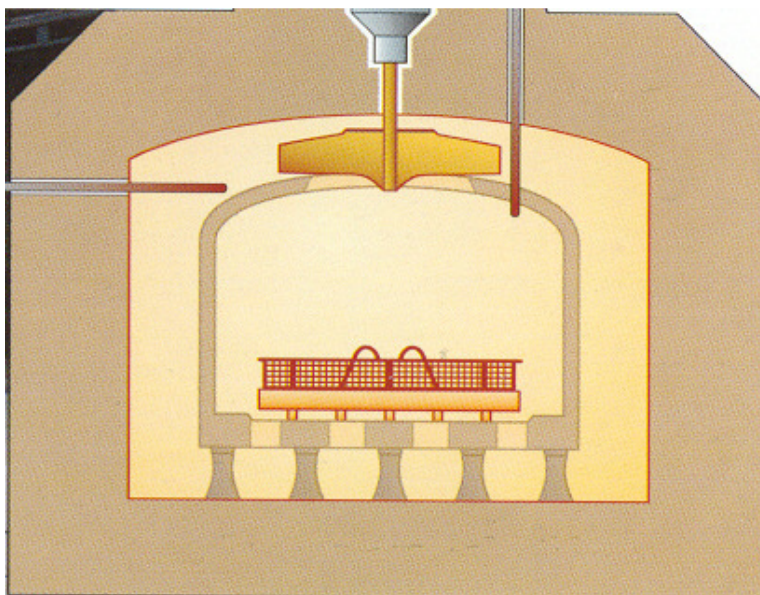
In nitrogen manufactured in a gas plant, there is however enough oxygen to enable the formation of an oxide on the surface of the FeCrAl alloys.

In molten copper, nickel containing alloys dissolve quickly.

Nickel free materials, like the FeCrAl alloys, have a much better resistance in molten copper, molten zinc and molten magnesium.

Horizontal installation of protection tubes in the APM/APMT-grades can be applied.

Protection tubes in the AF grade need support when installed horizontally; Vertical installation is otherwise recommended.



***Properties of Thermalloys' heat resistant alloys; Upper temperature limits
(degrees C/F) for use in different gases and gas mixtures.***

Properties/ Ranking	Less good	Good	Very good	Better	Best
Hot strength, T>600C/1112F	Kanthal D Tp 446	Kanthal AF	Alloy 600 Tp 310	Kanthal APM	Kanthal APMT Alloy 800HT 253MA Alloy 601
Oxidation resistance in dry air	Tp 309, 1050/1922 A800HT,1050/1922	Tp 446, 1100/2012 A600, 1100/2012 Tp 310, 1100/2012 Alkrothal,1100/2012	253MA, 1150/2102 A601, 1150/2102		Kanthal APM/APMT , 1425/2600 Kanthal AF, 1300/2372 Kanthal D, 1300/2372
Oxidation resistance in moist air	Tp 309, 900/1652 A800HT, 900/1652	Tp 446, 950/1752 A600,950/1752 Tp 310, 950/1752 Alkrothal,950/1752	253MA, 1000/1832 A601, 1000/1832		Kanthal APM/APMT , 1200/2192 Kanthal AF, 1200/2192 Kanthal D, 1200/2192
N₂, nitrogen from an oxygen plant	Tp 446, 650/1202 Tp 309, 650/1202	253MA, 750/1382 Tp 310, 750/1382	A600, 1000/1832 A601,1000/1832 A800HT, 900/1652 Alkrothal,900/1652	Kanthal APM,1050/1922 Kanthal AF, 1100/2012 Kanthal D, 1000/1832 Not preoxidized	Kanthal APM/APMT , 1200/2192 Kanthal AF, 1200/2192 Kanthal D, 1200/2192 Preoxidized
Ar, Argon	Tp 446, 950/1752 A800HT, 950/1752 A600, 950/1752 Tp 310, 950/1752	253MA, 1000/1832 A601, 1000/1832	Alkrothal,1100/2012		Kanthal APM/APMT, 1425/2600 Kanthal AF, 1300/2372 Kanthal D, 1300/2372
Exothermic gas: 10 CO, 15H₂, 5CO₂, 70N₂	Tp 446	253MA; 850/1562 Tp 310, 850/1562	A800HT, 950/1752 Alkrothal,1000/1832	A601, 1000/1832 A600, 1000/1832	Kanthal APM/APMT, 1150/2102 Kanthal AF, 1150/2102 Kanthal D, 1100/2012
Endothermic gas; 20 CO, 40 H₂, 40 N₂	Tp 446	253MA, 700/1292 Tp 310, 750/1382	A601, 900/1652 A600, 900/1652 A800HT, 800/1472 Alkrothal,800/1472	Kanthal D, 1000/1832	Kanthal APM/APMT, 1050/1922 Kanthal AF, 1050/1922
H₂, hydrogen, dewpoint<-50	Tp 446, 900/1652	253MA, 1000/1832 A800HT, 1000/1832 Alkrothal,950/1752			Kanthal APM/APMT, 1425/2600 Kanthal AF, 1400/2552 Kanthal D, 1300/2372
Vacuum, 10⁻³ torr					Kanthal APM/APMT, 1150/1922 Kanthal AF, 1200/2192 Kanthal D, 1100/2012
Oxidizing SO₂, SO₃-containing gas*		A800HT, 600/1112	253MA, 900/1652 Tp 446, 950/1742 Tp 310, 850/1562 Alkrothal,950/1742		Kanthal APM/APMT ,1200/2192 Kanthal A1, 1200/2192 Kanthal AF, 1200/2192 Kanthal D, 1150/1922
Reducing sulfur containing gas		253MA, 600/1112 A800HT, 600/1112 Tp 310, 600/1112	Tp 446, 700/1292 Alkrothal,800/1472		Kanthal APM/APMT, 1025/1877 Kanthal AF, 1025/1877 Kanthal D, 1000/1832
Molten metals; Cu**, Zn, Mg		253MA	Tp446	Kanthal APM, APMT,AF	
Cracked ammonia			253MA,750/1382	A800HT, 900/1652 Kanthal APM/APMT, 900/1652 Kanthal AF,900/1652 Kanthal D,900/1652	A601, 1000/1832 A600, 1000/1832

KANTHAL is a registered trademark of Kanthal AB

253MA is a registered trademark of Outokumpu

* Under deposits, conditions may be reducing

** Nickel containing high temperature alloys are rapidly attacked.

Since a number of process parameters affects the materials behavior, the information given above is only to be considered as guidelines, not as guaranteed values.

Tubes and tube products

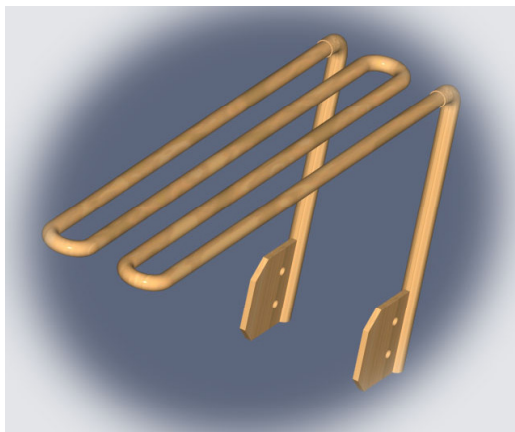
Tubes in 5900 mm lengths are stocked in our inventory, with exception for the tubes in size 6 x 0.4 mm, where the length is 5800 mm.

We also stock end caps and threads in different sizes, see table on page 7.

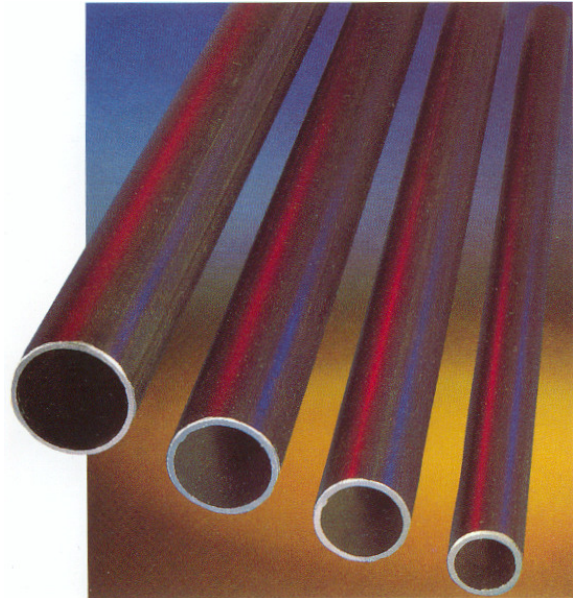
This means that we can make quick deliveries, less than 2 weeks, and even quicker upon customer requests.

We can supply tubes in any of the following conditions:

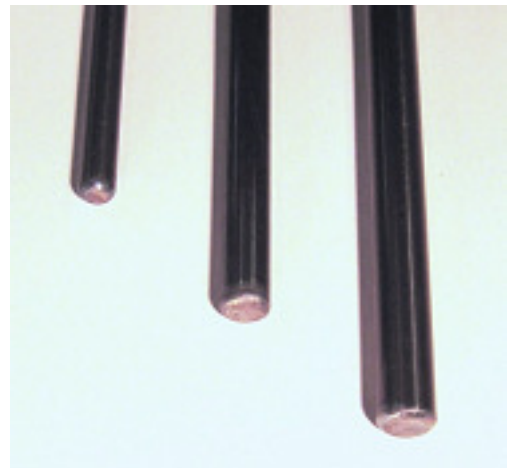
- As straight tubes with open ends, in 5,9 m lengths or cut to a shorter length; Suitable end caps can also be delivered.
- As tubes cut to fix lengths, with an end cap welded to one end, the other end open.
- As tubes cut to fixed lengths, with an end cap welded to one end and a suitable thread in the other end.; For thin walled tubes, a stainless thread is welded on to the tube, for thick walled tubes, the end of the tube itself can be threaded.
- In any of the executions above, but with flanges welded on to the tubes.
- As bent tubes for specific applications, e.g. as heating elements or for cooling purposes.
- As heating elements manufactured by strip+tubes+bar material, for the heating of various products.



Example of a heating element made from high temperature tubes



Straight tubes with open ends or with one end closed



Protection tubes with welded endcaps



Protection tubes with threads, the other end closed

Stock list, Thermalloys' tubes in FeCrAl alloys

The tubes are either longitudinally welded or seamless.

The delivery time for the material below is most often less than 2 week's ex-works for plain tubes and for tubes with endcaps and threads.

Steel grade	Size, mm (ODxWT)	Size, inch (ODxWT)	Threads, inch	Comment
Kanthal D	6,0x0,4	0,24x0,016	BSP: 1/2"	Welded tubes
Kanthal AF	6,5x0,8	0,26x0,032	BSP: 1/2"	Welded tubes
Kanthal AF	15,0x1,3	0,59x0,05	BSP: 1/4", 1/2", 3/4", 5/8" NPT: 1/2", 3/4"	Welded tubes
Kanthal AF	19,1x1,3	0,75x0,05	BSP: 1/2", 3/4", 1" NPT: 1/2", 3/4"	Welded tubes
Kanthal AF	22,0x1,3	0,87x0,05	BSP: 1/2", 3/4", 1" NPT: 1/2", 3/4", 1"	Welded tubes
Kanthal AF	22,0x2,0	0,87x0,08	BSP: 1/2", 3/4", 1" NPT: 1/2", 3/4", 1"	Welded tubes
Kanthal APM	25,4x1,65	1,00x0,065	BSP: 3/4", 1" NPT: 3/4", 1"	Seamless tubes
Kanthal APM Kanthal APMT	26,67x2,87	1,05x0,113	BSP: 3/4" NPT: 3/4"	Seamless tubes
Kanthal APM Kanthal APMT	33,4x3,38	1,31x0,133	BSP: 1" NPT: 1"	Seamless tubes
Kanthal APM Kanthal APMT	40,0x3,0	1,57x0,118	BSP: 1 1/4" NPT: 1 1/4"	Seamless tubes
Kanthal APM Kanthal APMT	60,33x3,91	2,38x0,154	Threads are made upon customer request	Seamless tubes

We carry NPT and BSP threads in AISI 316L in stock and can manufacture special threads in other grades and thread types, if required.

If you have the need for other high temperature alloys or other tube sizes, not included in the above list, please contact us. We will probably be able to supply such tubes to you.

The Kanthal AF, D, APM and APMT are also available as plate, strip, bar and wire.

You are most welcome to contact us for further information, for technical assistance, for a quotation or an order.

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