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*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, 1.4401/316, as well as all 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 lower temperatures, but it is less adherent at higher temperatures. At high temperatures this will cause the oxide to spall off, leaving an un-protected surface subject to further oxidation. This process leads to rapid oxidation. Deformation of the material can also occur.
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 the standard stainless steels:

- **Thermodynamic stability**: The $Al_2O_3$ oxide is un-affected 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 will also reduce the tendency to spalling.

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 other iron and nickel base alloys.

This means a large increase of the service life of the protection tubes and therefore a much improved process control and process economy.

The 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 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. | Vertical installation, if not supported |
| Kanthal D | 22 | 4.8 | | Up to 1300 C/2370 F | Ditto |

*Kanthal is a registered trade mark of Kanthal AB.

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

**Kanthal APM** is manufactured using powder metallurgy; This results in a much increased hot strength, as compared to materials manufactured by conventional techniques.
In combination with its excellent oxidation resistance, this makes Kanthal APM quite superior to all other iron- and nickel base alloys in most high temperature applications.

**Kanthal AF** (corresponds to the Fecralloy alloy) is that conventionally manufactured FeCrAl alloy which has the best combination of oxidation resistance at 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.

The alloys Kanthal AF and D are manufactured using a conventional metallurgical technique. While not having the hot strength of the APM-grade, these alloys have an oxidation resistance superior to all other iron- and nickel base alloys in most environments.

Thus, these FeCrAl alloys give large advantages in high temperature processes.

The main advantages of 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 resistance to attack by sulphur compounds.**
- **High resistance 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 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 to 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 material 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.

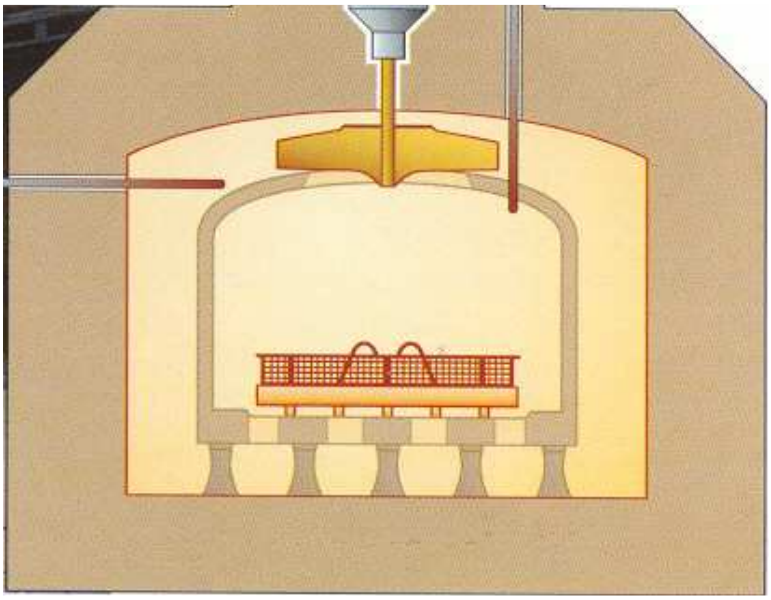
In nitrogen manufactured in a gas plant, there is however enough oxygen to enable the formation of an oxide on the surface of the FeCrAl alloys.

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 grade 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<br>Tp 446 | Kanthal AF | Alloy 600<br>Tp 310 | Kanthal APM | Alloy 800HT<br>253MA<br>Alloy 601 |
| **Oxidation resistance in dry air** | Tp 309, 1050/1922<br>A800HT,1050/1922 | Tp 446, 1100/2012<br>A600, 1100/2012<br>Tp 310, 1100/2012<br>Alkrothal,1100/2012 | 253MA, 1150/2102<br>A601, 1150/2102 | | Kanthal APM,1425/2600<br>Kanthal AF, 1300/2372<br>Kanthal D, 1300/2372 |
| **Oxidation resistance in moist air** | Tp 309, 900/1652<br>A800HT, 900/1652 | Tp 446, 950/1752<br>A600,950/1752<br>Tp 310, 950/1752<br>Alkrothal,950/1752 | 253MA, 1000/1832<br>A601, 1000/1832 | | Kanthal APM,1200/2192<br>Kanthal AF, 1200/2192<br>Kanthal D, 1200/2192 |
| **$N_2$, nitrogen from an oxygen plant** | Tp 446, 650/1202<br>Tp 309, 650/1202 | 253MA, 750/1382<br>Tp 310, 750/1382 | A600, 1000/1832<br>A601,1000/1832<br>A800HT, 900/1652<br>Alkrothal,900/1652 | Kanthal APM,1050/1922<br>Kanthal AF, 1100/2012<br>Kanthal D, 1000/1832<br>Not preoxidized | Kanthal APM,1200/2192<br>Kanthal AF, 1200/2192<br>Kanthal D, 1200/2192<br>Preoxidized |
| **Ar, Argon** | Tp 446, 950/1752<br>A800HT, 950/1752<br>A600, 950/1752<br>Tp 310, 950/1752 | 253MA, 1000/1832<br>A601, 1000/1832 | Alkrothal,1100/2012 | | Kanthal APM,1425/2600<br>Kanthal AF, 1300/2372<br>Kanthal D, 1300/2372 |
| **Exothermic gas: 10 CO, 15$H_2$, 5$CO_2$, 70$N_2$** | Tp 446 | 253MA; 850/1562<br>Tp 310, 850/1562 | A800HT, 950/1752<br>Alkrothal,1000/1832 | A601, 1000/1832<br>A600, 1000/1832 | Kanthal APM,1150/2102<br>Kanthal AF, 1150/2102<br>Kanthal D, 1100/2012 |
| **Endothermic gas; 20 CO, 40 $H_2$, 40 $N_2$** | Tp 446 | 253MA, 700/1292<br>Tp 310, 750/1382 | A601, 900/1652<br>A600, 900/1652<br>A800HT, 800/1472<br>Alkrothal,800/1472 | Kanthal D, 1000/1832 | Kanthal APM,1050/1922<br>Kanthal AF, 1050/1922 |
| **H2, hydrogen, dewpoint<-50** | Tp 446, 900/1652 | 253MA, 1000/1832<br>A800HT, 1000/1832<br>Alkrothal,950/1752 | | | Kanthal APM,1425/2600<br>Kanthal AF, 1400/2552<br>Kanthal D, 1300/2372 |
| **Vacuum, $10^{-3}$ torr** | | | | | Kanthal APM,1150/1922<br>Kanthal AF, 1200/2192<br>Kanthal D, 1100/2012 |
| **Oxidizing $SO_2$, $SO_3$-containing gas*** | | A800HT, 600/1112 | 253MA, 900/1652<br>Tp 446, 950/1742<br>Tp 310, 850/1562<br>Alkrothal,950/1742 | | Kanthal APM,1200/2192<br>Kanthal AF, 1200/2192<br>Kanthal D, 1150/1922 |
| **Reducing sulfur containing gas** | | 253MA, 600/1112<br>A800HT, 600/1112<br>Tp 310, 600/1112 | Tp 446, 700/1292<br>Alkrothal,800/1472 | | Kanthal APM,1025/1877<br>Kanthal AF, 1025/1877<br>Kanthal D, 1000/1832 |
| **Molten metals; Cu**, Zn, Mg** | | 253MA | Tp446 | Kanthal APM, AF | |
| **Cracked ammonia** | | | 253MA,750/1382 | A800HT, 900/1652<br>Kanthal APM,900/1652<br>Kanthal AF,900/1652<br>Kanthal D,900/1652 | A601, 1000/1832<br>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 alloys are rapidly attacked.

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

# Tubes and tube products

Tubes in 6 meters 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.

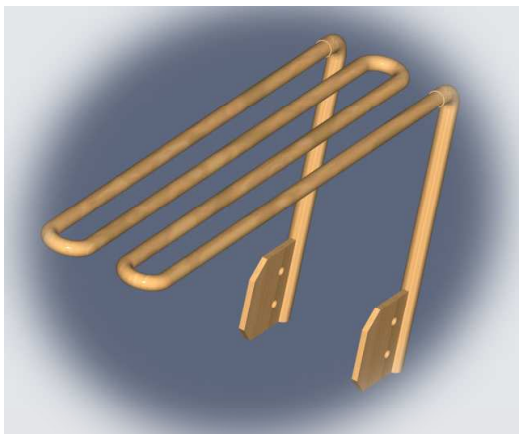
This means that we can make quick deliveries, less than 2 weeks, and even quicker upon customer requests.

We can supply tubes in any of the following conditions:

- As straight tubes with open ends, in 6 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.

Straight tubes with open ends or with one end closed

Protection tubes with welded endcaps



Example of a heating element made from high temperature tubes

Protection tubes with threads, the other end closed

# *Stock list, Thermalloys*

The delivery time for the material below is less than 2 week's ex-works for tubes with endcaps and threads.
The tubes are seam welded, unless otherwise stated.
Even shorter delivery times for tubes with open ends.

| Steel grade | Dimension, mm (ODxWT) | Dimension, inch (ODxWT) | Threads, inch | Comment |
|---|---|---|---|---|
| **Kanthal D** | 6,0x0,4 | 0,24x0,016 | BSP: ½“ | Welded tubes |
| **Kanthal AF** | 12,7x0,8 | 0,50x0,031 | BSP: ½“, ¼“<br>NPT: ½“ | Welded tubes |
| **Kanthal AF** | 15,0x1,3 | 0,59x0,051 | BSP: ¼“, ½“, ¾“, 5/8“<br>NPT: ½“, ¾“ | Welded tubes |
| **Kanthal AF** | 19,1x1,3 | 0,75x0,051 | BSP: ½“, ¾“, 1“<br>NPT: ½“, ¾“ | Welded tubes |
| **Kanthal AF** | 22,0x1,3 | 0,87x0,051 | BSP: ½“, ¾“, 1“<br>NPT: ½“, ¾“, 1“ | Welded tubes |
| **Kanthal APM** | 25,4x1,65 | 1,00x0,065 | BSP: ¾”, 1”<br>NPT: ¾“, 1“ | Seamless tubes |
| **Kanthal APM** | 26,67x2,87 | 1,05x0,113 | BSP: ¾”<br>NPT: ¾“ | Seamless tubes |
| **Kanthal APM** | 33,4x3,38 | 1,31x0,133 | BSP: 1”<br>NPT: 1“ | Seamless tubes |
| **Kanthal APM** | 40,0x3,0 | 1,57x0,118 | BSP: 1 ¼”<br>NPT: 1 ¼” | Seamless tubes |
| **Kanthal APM** | 60,33x3,91 | 2,38x0,154 | Threads are made upon customer request | Seamless tubes |

We carry NPT and BSP external threads in AISI 316L in our standard stock and we can manufacture custom made threads in other grades and thread types upon request.

Always ask us for a quotation, if you have a request for grades and dimensions, not included in the above list.

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

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