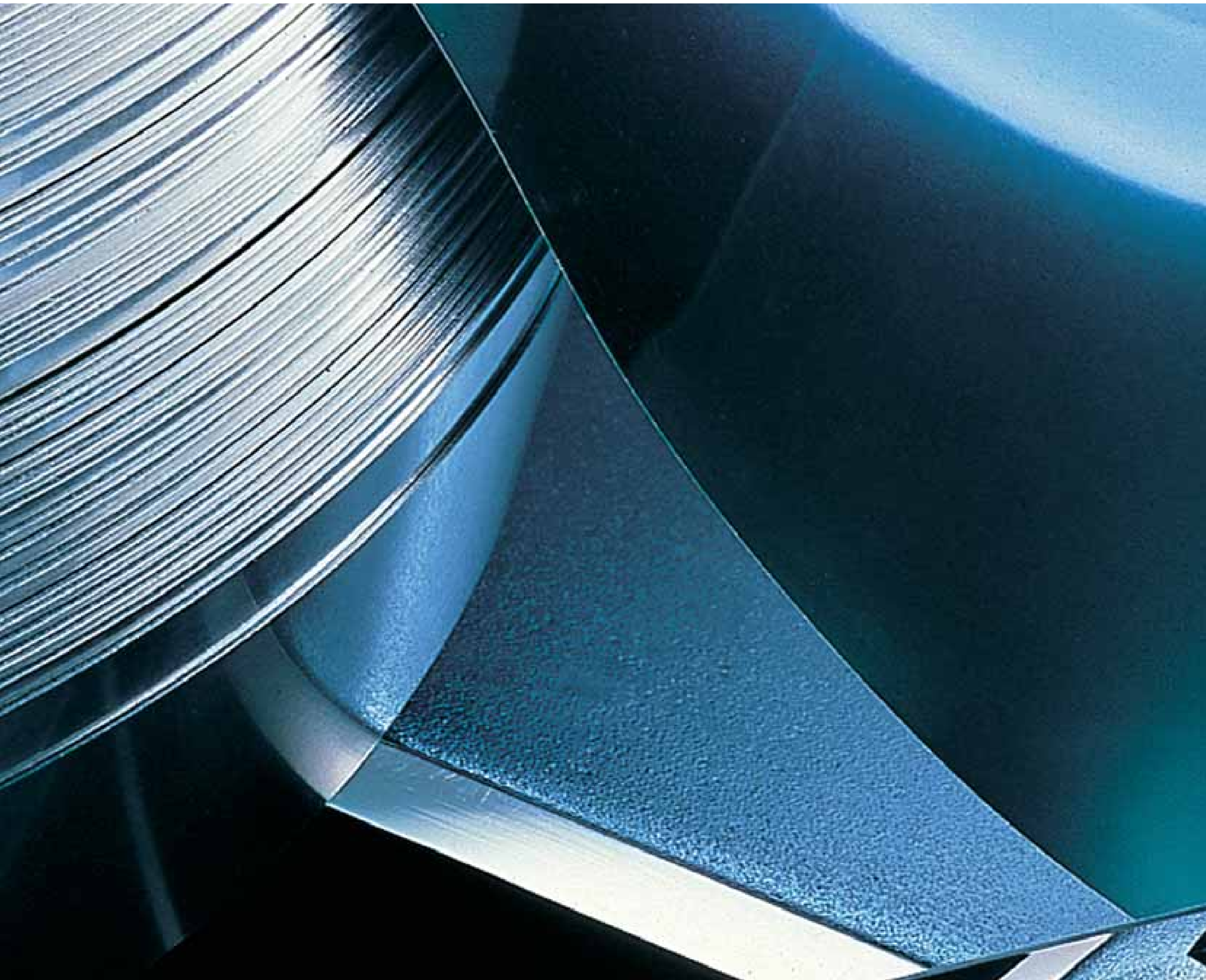
Pernifer and Pernima Alloys.
Alloys with special thermal expansion characteristics.



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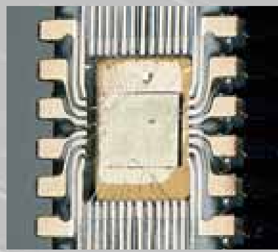
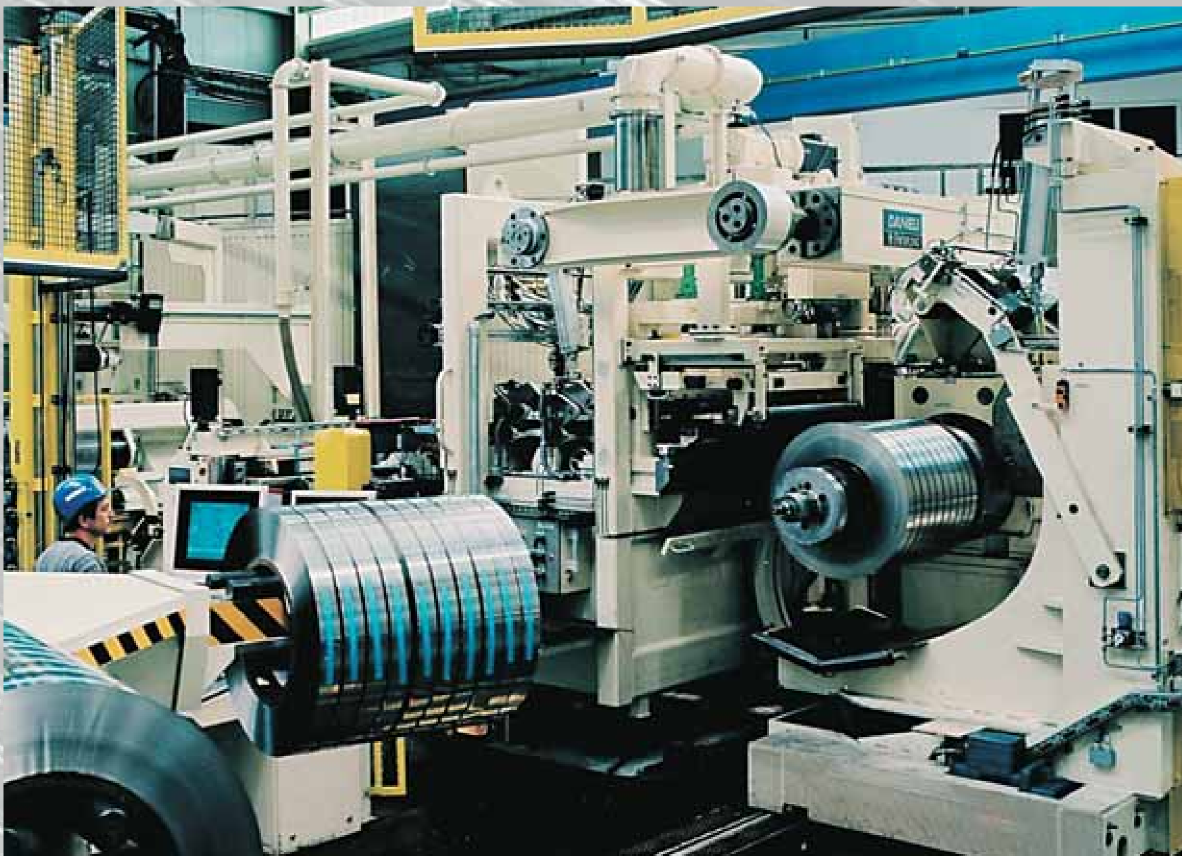




Pernifer and Pernima Alloys.

Pernifer and Pernima Alloys. Materials with special thermal expansion properties.

The physical properties of the iron-nickel alloy group exhibits a number of special effects which are being utilized in many technical applications. The main areas of technical applications essentially involve the thermo-mechanical, electrical and magnetic properties of these alloys. Through addition of further alloying elements, e.g. cobalt, chromium, manganese, titanium, niobium, molybdenum, and copper specific alloys were created which are used as magnetic materials, as well as materials with special expansion characteristics.

The materials with special expansion characteristics can essentially be divided into three alloy groups. These are alloys with lowest coefficients of expansion, alloys with a low coefficient of expansion and alloys with a controlled, high adjusted coefficient of expansion.

Basic physical considerations.

The special expansion characteristics of the iron-nickel alloys are a result of magneto-volume effects. The abnormally low coefficients as well as the abnormally high coefficients of thermal expansion, compared to alloys without magneto-volume effects, can be explained using a model proposed for the magneto-volume effects. The principal basis for the theoretical understanding results from the electron-band structure calculations from which the properties of these alloy systems in the base condition can be derived.

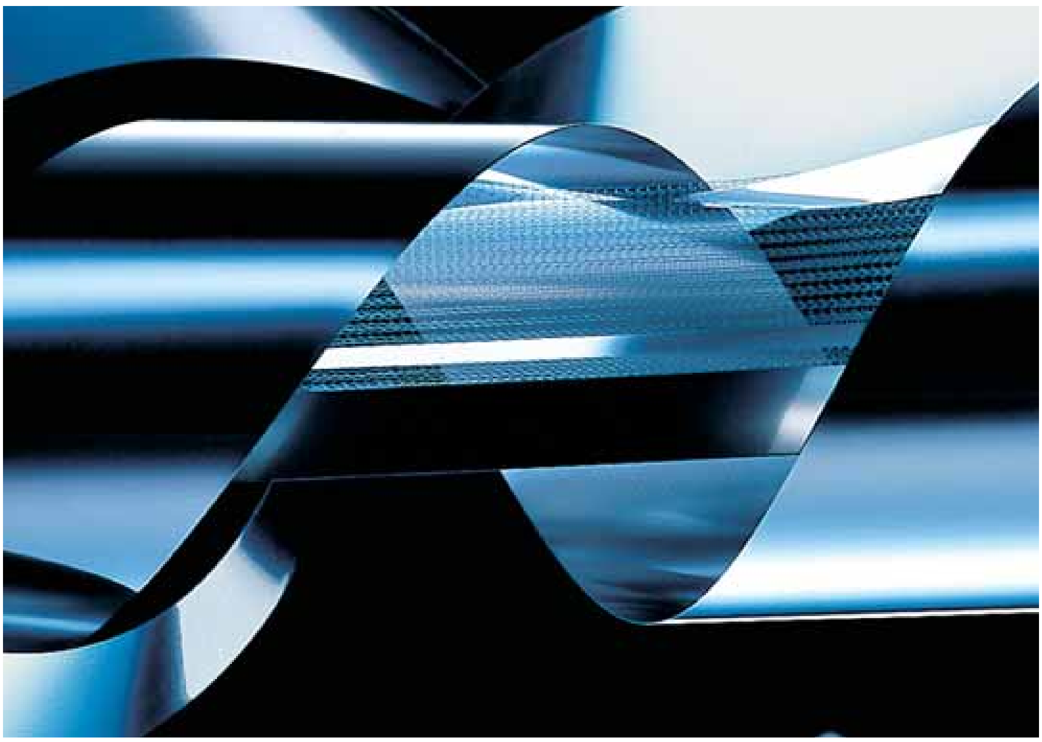
In the case of alloys with abnormally low coefficients of thermal expansion there exists, besides the minimum in the ground state with a big lattice volume and a high magnetic moment known as the "high spin" (HS) condition, a secondary minimum with a smaller volume and a lower magnetic moment known as the "low spin" (LS) condition.

Changes from the HS base condition with a big volume to the LS condition with a small volume which occur with rising temperature compensate the "normal" lattice expansion below the ferromagnetic Curie temperature of the alloy. During such changes the magnetic moment in the HS condition jumps to the magnetic moment in the LS condition. In the case of alloys with abnormally high coefficients of thermal expansion the base condition is the LS condition with a small volume. Excitation to the HS condition with a large volume leads to an abnormally large increase in volume.

In contrast to physical inquiries, in which the difference in the coefficient of thermal expansion between two temperatures is considered, material and customer specifications generally only list the technical or average coefficient of thermal expansion which is defined as

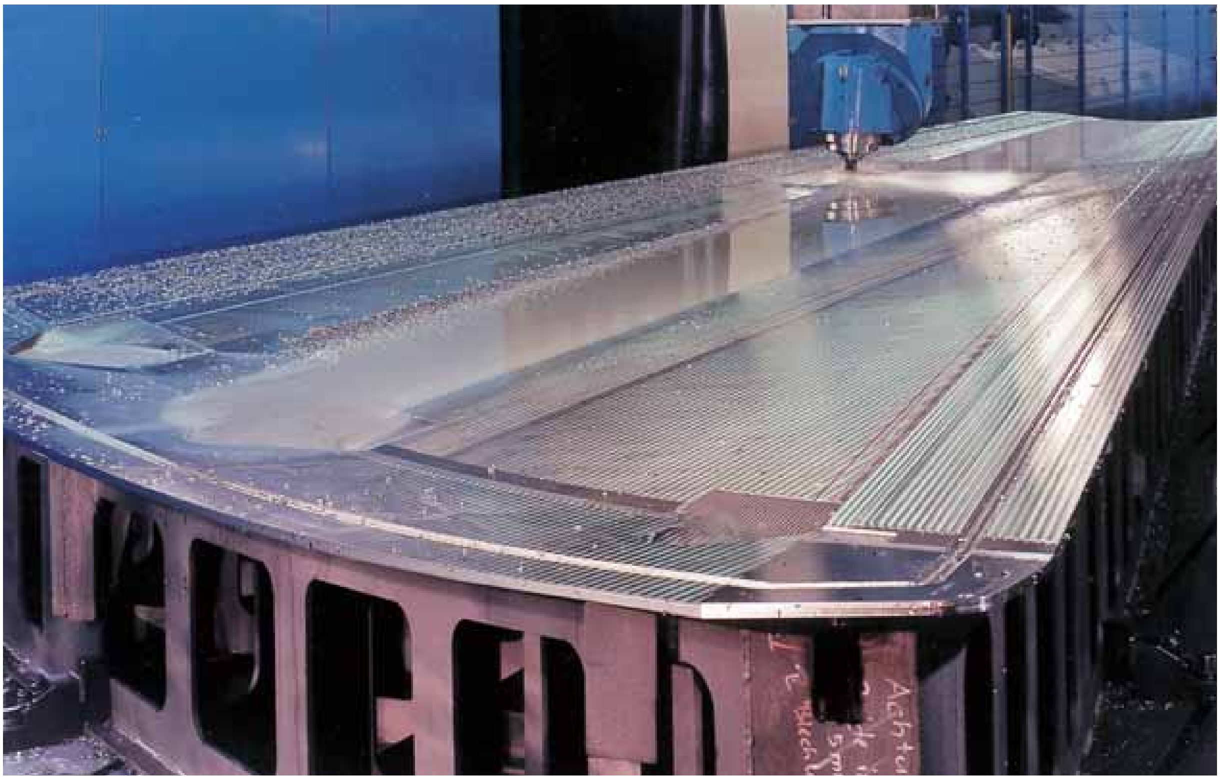
$$CTE = [l - l_0] / [l_0 \bullet (T-T_0)] = \Delta l / [l_0 \bullet \Delta T]$$

The index zero marks the reference point which means the initial values at the start of taking measurements, e.g. at room temperature. This coefficient of thermal expansion yields the secant gradient, if the relative change in length Δl / lo is plotted in relation to the temperature. The value as well as the temperature dependence of the coefficient of thermal expansion CTE and the Curie temperature T_C of ferromagnetic alloys which determines the temperature at the bent along the temperature-dependent thermal expansion plot, can be adjusted to the specified requirements by altering the Ni/Fe ratio and by alloying additions of further elements.

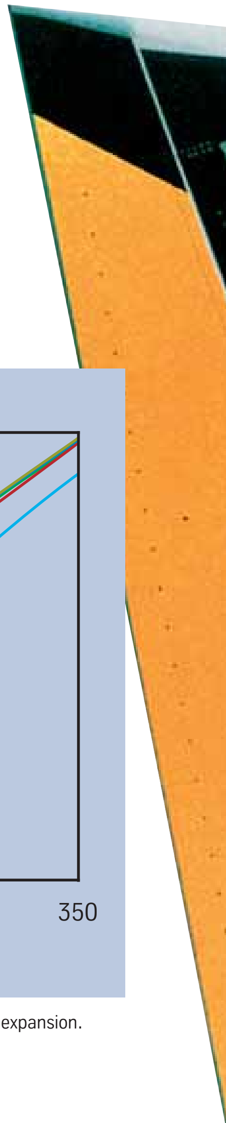


Properties and applications.

The respective Pernifer alloys are identified by a numbering code which follows the Pernifer designation and which approximately corresponds to the nickel content or significant alloying additions. In the case of Pernima 72 the number indicates the manganese content.



Alloys with very low coefficients of thermal expansion.



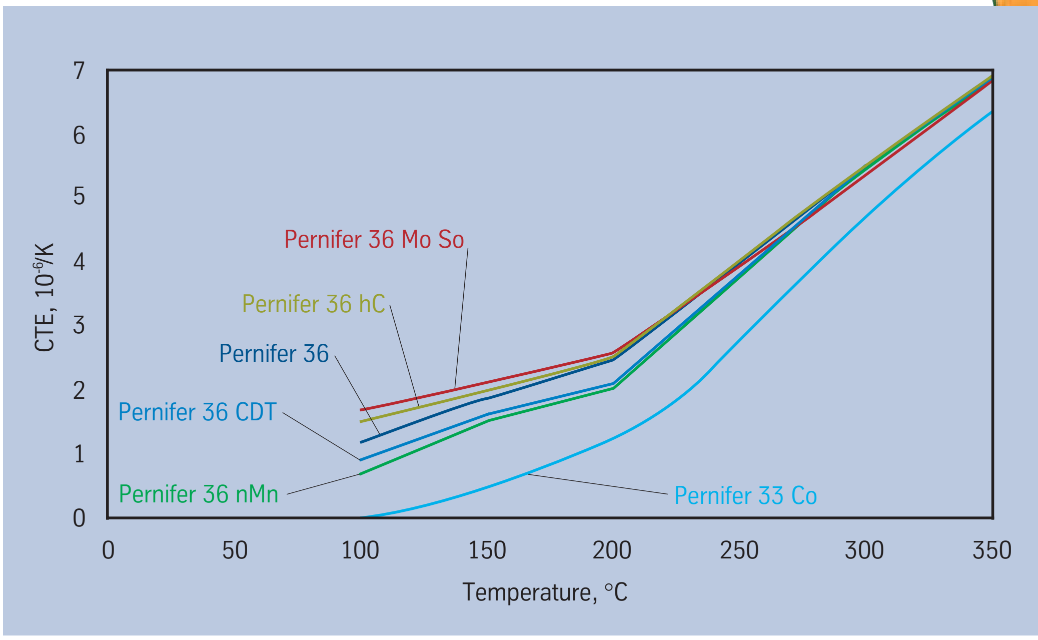


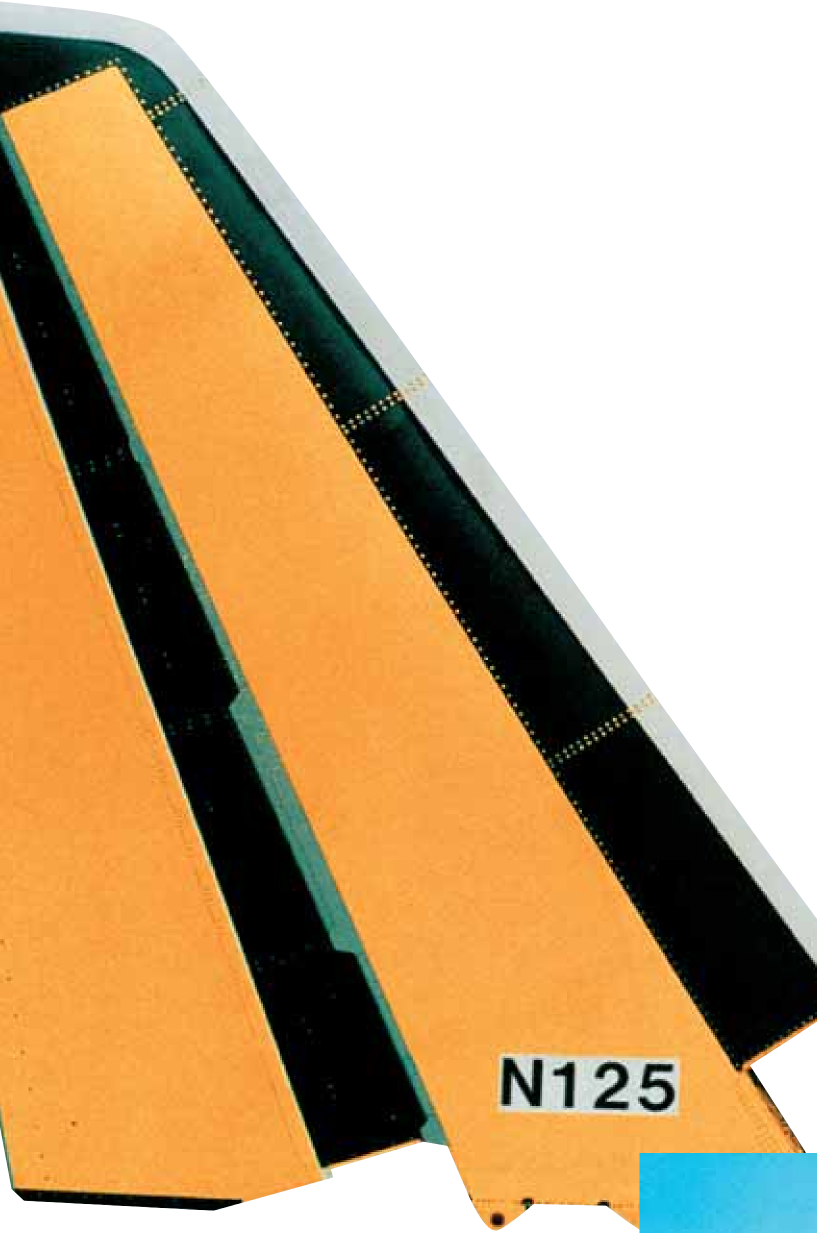
Fig. 1 - Typical graphs of coefficients of thermal expansion (CTE) of iron-nickel alloys with very low coefficients of thermal expansion.

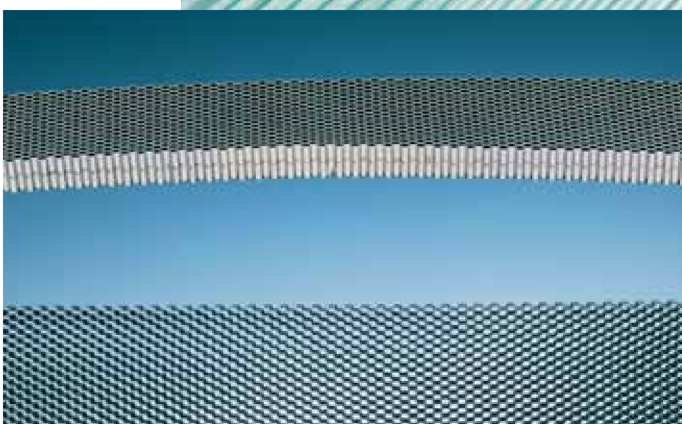
Pernifer 36 is an iron-nickel alloy with approx. 36 % nickel which exhibits an extremely low coefficient of thermal expansion in the temperature range of -250 to +200 °C (-418 to 392 °F). Pernifer 36 and alloy modifications derived from it were developed for applications requiring very low coefficients of thermal expansion.

Typical applications are:

- shadow masks for TV monitors
- frames for shadow masks
- frames in production plants
- passive bimetal component and thermostat bimetals
- measuring and control equipment for temperatures below 200 °C (392 °F), e.g., thermostats and valve controls
- production, storage and transportation of liquefied gases
- molds for the production of carbon fibre reinforced plastic (CFRP) components
- frames for electronic control units in telecommunication, for satellites and space crafts
- mountings for electromagnetic lens systems in laser control devices
- bushings for screw and bolt connections between different metals

Information concerning the chemical composition, as well as mechanical and physical properties for Pernifer 36 and related alloy modifications are listed in the brochure's alloy summary tables following the descriptive introduction. Typical graphs of the coefficients of thermal expansion in relation to temperature are shown in Fig. 1 for Pernifer 36 and its alloy modifications.





Beside Pernifer 36, alloy modifications were developed with special properties for specific requirements. Pernifer 36 CDT exhibits especially good etching characteristics. The Pernifer 36 nMn modification was developed specially for applications requiring an even lower coefficient of thermal expansion than exhibited by Pernifer 36.
If necessary an alloy variation Pernifer 33 Co with a considerable cobalt content of approx. 4 % and a still lower coefficient of thermal expansion can be produced. Alloy Pernifer 36 hC, which has a slightly higher carbon content, exhibits particularly good fabricating characteristics.
Pernifer 36 Mo So shows improved mechanical properties without much higher thermal expansion characteristics compared to the other Pernifer 36 alloy modifications.

Further details concerning Pernifer 36 are contained in the ThyssenKrupp VDM material data sheet no. 7001.

Pernifer glass sealing alloys.

The value of the coefficient of thermal expansion (CTE) below the Curie temperature T_c, the position of the Curie temperature as well as the temperature-dependent drift of the coefficient of thermal expansion can be adjusted to the thermal expansion characteristics of different types of glasses and ceramics through the iron-nickel ratio of the alloy and by alloying additions. A further important condition to utilize alloys as glass sealing alloys is attainment of a hermetic seal between the surface of the metal and that of the glass or ceramic respectively, a characteristic which results from the surface oxide on the metal getting readily "wetted" or chemically bonded to certain glasses. This process takes place at high temperatures around 800 °C, at which the oxide layer on the surface of the metal is partially dissolved and forms a boundary layer with elements of the material component to which the metal is to be sealed. This boundary layer exhibits good adhesive properties which result in the hermetic seal required.

Important applications for sound and hermetic seals between metal and glass / ceramic components are encountered in the electrical and electronic industry. Examples are light and flash bulbs, transmitter and X-ray tubes, reed relays, transistors and integrated circuits. For these seals various types of glasses and alloys were developed and adjusted in the process to each other.

Chemical composition details as well as typical mechanical and physical properties for the glass sealing alloys Pernifer 2918, Pernifer 40, Pernifer 41 LC, Pernifer 42, Pernifer 4206, Pernifer 46, Pernifer 4706, Pernifer 48, Pernifer 50, Pernifer 51, and Pernifer 5101 are listed in the summary tables following the descriptive section of this brochure. The corresponding temperature-dependent behaviour of their coefficients of thermal expansion (CTE) are shown in Fig. 2.

Changes in the properties, if required, can be effected by adjustments to the chemical composition.

The greatest demand for materials certainly appears to arise from the semiconductor field. The alloys Pernifer 2918, Pernifer 40, Pernifer 41 LC, Pernifer 42, and Pernifer 42 Ti are used in the form of system supports for integrated circuits (lead frames), transistor base caps as well as connections to current carrying wires. In many cases the alloys are required to exhibit uniform

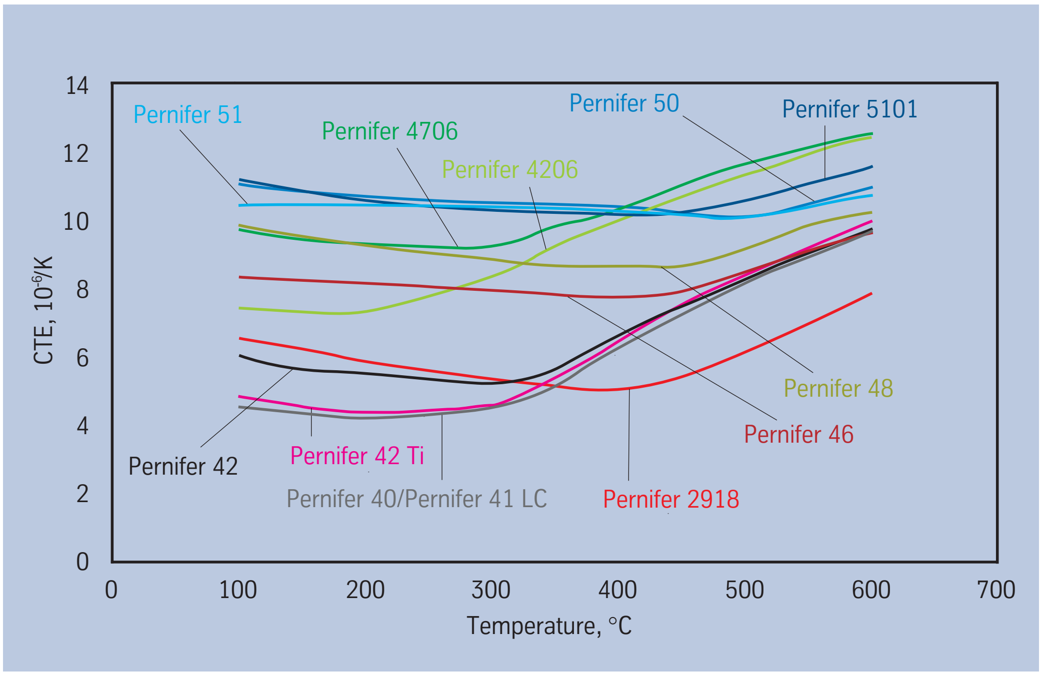
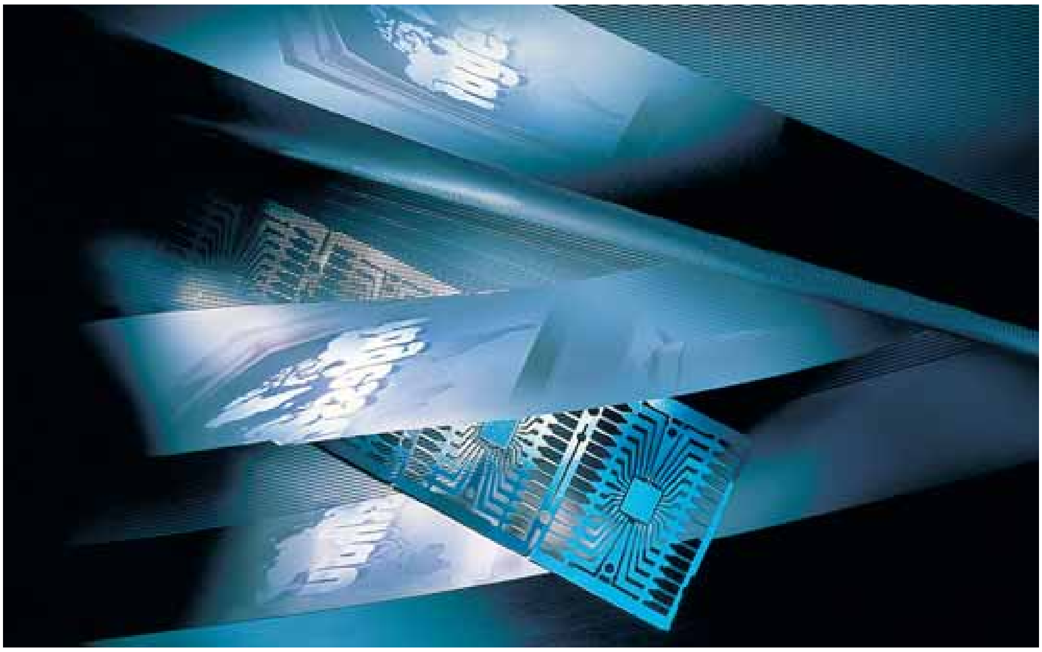


Fig. 2 – Temperature-dependent plots of coefficients of thermal expansion CTE of iron-nickel alloys used as glass sealing materials.



etching characteristics or must be such that they can readily be stamped.

The coefficients of thermal expansion of these five alloys are situated closely together, however, the cobalt content in Pernifer 2918 has resulted in an increase in the Curie temperature of about 100 °C which allows for a combination with hard glasses. The coefficient of thermal expansion of hard glasses amounts to only half of that of soft glasses. The technical significance of the addition of cobalt is also shown by the fact that with optimal composition the best agreement in the linear expansion behaviour of both members of the connection can be attained. This is a condition for a lasting, vacuum-tight glass seal.

The chemical composition of alloy Pernifer 2918 MS has been chosen in such a way that the phase transition from an austenitic to a martensitic structure does not occur during cooling down to -80 °C (-112 °F). Such a transition would result in an abrupt increase in volume which can cause the destruction of the glass seal. For special requirements material with a martensite-free structure down to -196 °C (-321 °F) can be supplied.

Another example for the beneficial effect of a third alloying component is illustrated by chromium in the alloys Pernifer 4206 and Pernifer 4706. The addition of approximately 6 % chromium at the expense of iron increases the value of the coefficient of thermal expansion and changes the shape of the expansion curve in such a way that it can be made to closely resemble that of soft glasses. The small chromium addition of 1 % to Pernifer 5101 has hardly any effect on the expansion characteristics of the alloy, however, it does improve the adhesion between the glass and the metal.

Initial permeability, μ_4	≥ 6 000
Maximum permeability, μ_{max}	≥ 60 000
Saturation induction, Bs	1.5 T
Coercivity, Hc	≤ 8 A/m

Table 1 – Typical magnetic properties (static values) of Pernifer 46, Pernifer 48, Pernifer 50, and Pernifer 51.

The special soft magnetic properties of Pernifer alloys also lead to interesting applications. Examples for this are Pernifer 50 and Pernifer 51 which fulfil an additional function as magnetic end contacts in Reed relays. In this application the requirements on the materials involve not only thermal expansion behaviour. Unevenness and contamination of the surface of the material as well as efflorescence of the trace elements Si, Al, Mg, and Mn present a risk to the quality of the electric contact. Furthermore during decarburization of the edges carbon can cause the formation of tiny CO_2 bubbles in the contact zone between the glass and the metal. Thus absolute cleanliness as well as uniform mechanical and physical properties of the alloy are essential for a long service life of these contact switches.

Pernifer alloys with special mechanical and physical properties.

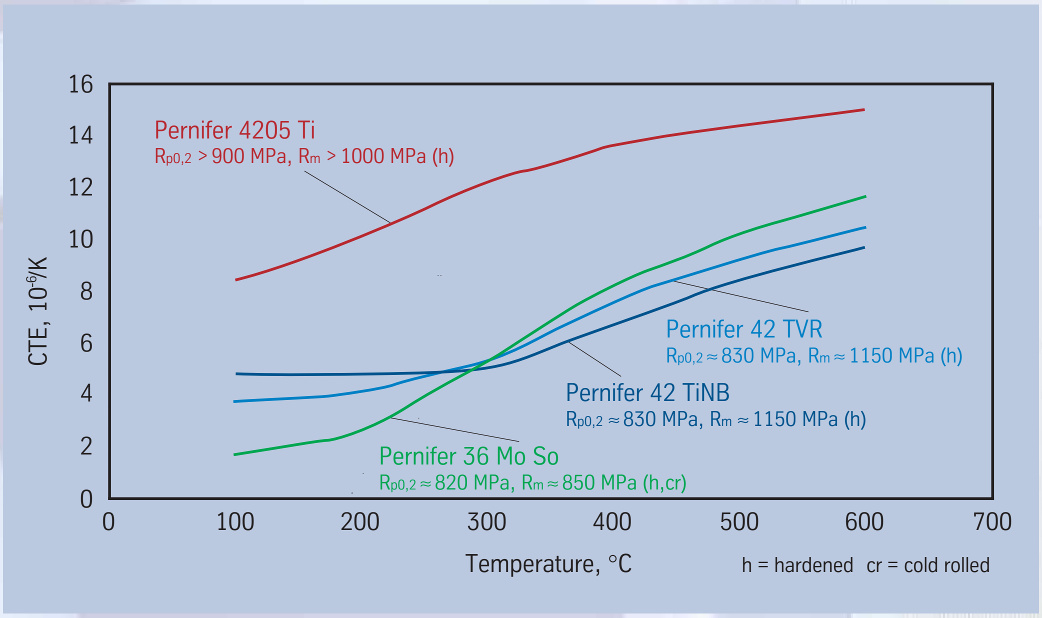


Fig. 3 – Temperature-dependent plots of coefficients of thermal expansion CTE of iron-nickel alloys with special mechanical properties.

In addition in the following tables the special materials Pernifer 36 Mo So, Pernifer 42 TVR, Pernifer 42 TiNb, and Pernifer 4205 Ti are listed. The temperature-dependent changes of their coefficients of thermal expansion (CTE) are shown in Fig. 3.

Compared to Pernifer 36, Pernifer 36 Mo So is an alloy with higher mechanical strength and a lower coefficient of thermal expansion up to approximately 300 °C (570 °F). Precipitated carbides in this case are the cause for the improved mechanical properties. Pernifer 36 Mo So wire is being used for power transmission lines.

Pernifer 42 TVR and Pernifer 42 TiNb, alloys which are hardened through precipitation of γ', were developed for applications requiring high mechanical properties and at the same time meeting specially required temperature-dependent expansion characteristics. Pernifer 42 TVR is used for high temperature, high strength frames for pre-stressed shadow masks in large-sized monitors.

Pernifer 42 TiNb exhibits a higher Curie temperature due to the alloying addition of cobalt. This alloy can be used for high temperature, high strength engine components with inherently only low thermal expansion requirements.

The special characteristic of Pernifer 4205 Ti is its temperature-independent modulus of elasticity. Due to its temperature-constant spring properties it is used in the production of scales, mechanical filters, and membranes.

Pernifer and Pernima alloys with very high coefficients of thermal expansion.

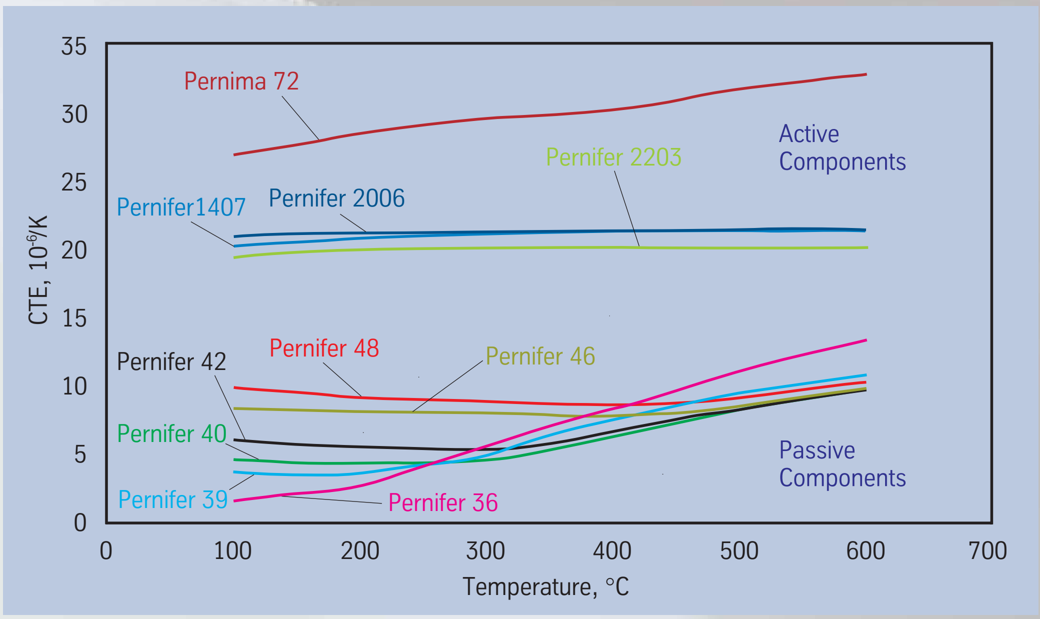


Fig. 4 – Comparison of the coefficients of thermal expansion of iron-nickel alloys as bimetallic components.

The alloys Pernifer 1407, Pernifer 2002, Pernifer 2006, Pernifer 2003, Pernifer 2508, and Pernima 72 are characterized especially by their high coefficients of thermal expansion. For this reason they are used in bimetal combinations as the active alloy component. The values of the coefficients of thermal expansion for these Pernifer alloys between 20 and 100 °C lie approx. between 18 and 21 x 10^{-6}/K. Pernima 72 alloy, with values of the order of 27 to 28 x 10^{-6}/K, shows even higher coefficient of thermal expansion values within this temperature range.

Besides Pernifer 36 the Pernifer alloys 39, 40, 42, 46 and 48 are also used for passive components. By joining passive and active alloy components (as listed on pages 27 - 29) through welding or roll cladding various bimetals with any desired thermal bending characteristics can be obtained.

Chemical compositions as well as typical values for mechanical and physical properties are listed in the following alloy tables. The coefficients of thermal expansion in relation to temperature are shown in Fig. 4.

Heat treatment and Corrosion resistance.

Heat treatment

Prior to any thermal operation the material must be carefully degreased, as any residual greasy surface contaminants will evaporate and will result especially during the glass / ceramic metal sealing operation in the formation of small blisters at the metal – glass / ceramic interface.This is most effectively done by a cleansing thermal treatment in a humid hydrogen atmosphere at 800 – 1000 °C for 10 minutes. Such a treatment is particularly important in the case of carbon-containing alloys and where surfaces are contaminated. After such a treatment the alloy is in the soft condition.

For dilatometer samples prior to measuring their expansion characteristics there exist various thermal treatment requirements. The Stahl-Eisen-Werkstoffblatt (Steel-Iron-Material Data Sheet) SEW 385 only states the thermal cleansing treatment mentioned above. According to ASTM, however, alloy-specific treatments are specified as follows:

ASTM F 15: Pernifer 2918
Heating in a hydrogen atmosphere for 1 h at 900 °C, followed by 15 min. at 1100 °C and cooling down to 200 °C in the hydrogen atmosphere at a rate of ≤ 5 K/min.

ASTM F 30: Pernifer 40 / 46 / 48 / 50 / 51
Heating in a hydrogen atmosphere for 1 h at 900 °C, followed by cooling down to 200 °C at a rate of ≤ 5 K/min.

Corrosion resistance

At 20 °C Pernifer alloys are essentially corrosion resistant in atmospheres which are not too moist. However, under unfavourable conditions, if they are exposed for long periods of time to moist or even salty atmospheres, such as encountered in marine environments, these alloys are not corrosion resistant.

Product availability.

Availability
Pernifer and Pernima alloys are available in the following standard product forms:

Sheet & plate
(for cut-to-length availability, refer to strip)

Conditions:
hot or cold rolled (hr, cr),
thermally treated and pickled

Thickness mm	hr / cr	Width[1] mm	Length[1] mm
1.10 – < 1.50	cr	2000	8000
1.50 – < 3.00	cr	2500	8000
3.00 – < 7.50	cr / hr	2500	8000
7.50 – ≤ 25.00	hr	2500	8000[2]
> 25.00[1]	hr	2500[2]	8000[2]

inches		inches	inches
0.043 – < 0.060	cr	80	320
0.060 – < 0.120	cr	100	320
0.120 – < 0.300	cr / hr	100	320
0.300 – ≤ 1.000	hr	100	320[2]
> 1.000[1]	hr	100[2]	320[2]

[1] other sizes subject to special enquiry
[2] depending on piece weight

Discs and rings
Conditions:
Available up to a maximum piece weight of 6 t for discs and 3 t for rings in accordance to drawings and technical feasability.

Rod & bar and billet
Conditions:
forged, rolled, drawn, thermally treated, pickled, machined, peeled or ground

Product	Forged[1] mm	Rolled[1] mm	Drawn[1] mm
Rod (o. d.)	≤ 600	8 – 100	12 – 65
Bar, square (a)	40 – 600	15 – 280	not standard
Bar, flat (a x b)	(40 – 80) x (200 – 600)	(5 – 20) x (120 – 600)	not standard
Bar, hexagonal (s)	40 – 80	13 – 41	≤ 50

	inches	inches	inches
Rod (o. d.)	≤ 24	5/16 – 4	1/2 – 2 1/2
Bar, square (a)	1 5/8 – 24	10/16 – 11	not standard
Bar, flat (a x b)	(1 5/8 – 3 1/8) x (8 – 24)	(3/16 – 3/4) x (4 3/4 – 24)	not standard
Bar, hexagonal (s)	1 5/8 – 3 1/8	1/2 – 1 5/8	≤ 2

[1] other sizes and conditions subject to special enquiry

Forgings
Shapes other than discs, rings, rod and bar are subject to special enquiry. Flanges and hollow shafts may be available up to a piece weight of 5 t.

Strip[1]
Conditions:
cold rolled, thermally treated and pickled or bright annealed[2]

Thickness mm	Width[3] mm	Coil I. D. mm			
0.02 – ≤ 0.10	4 – 200[4]	300	400		
> 0.10 – ≤ 0.20	4 – 350[4]	300	400	500	
> 0.20 – ≤ 0.25	4 – 700		400	500	600
> 0.25 – ≤ 0.60	6 – 700		400	500	600
> 0.60 – ≤ 1.0	8 – 700		400	500	600
> 1.0 – ≤ 2.0	15 – 700		400	500	600
> 2.0 – ≤ 3.0[2] – ≤ 3.5[2]	25 – 700		400	500	600

inches	inches	inches			
0.0008 – ≤ 0.004	0.16 – 8[4]	12	16		
> 0.004 – ≤ 0.008	0.16 – 14[4]	12	16	20	
> 0.008 – ≤ 0.010	0.16 – 28		16	20	24
> 0.010 – ≤ 0.024	0.20 – 28		16	20	24
> 0.024 – ≤ 0.040	0.32 – 28		16	20	24
> 0.040 – ≤ 0.080	0.60 – 28		16	20	24
> 0.080 – ≤ 0.120[2] – ≤ 0.140[2]	1.0 – 28		16	20	24

[1] Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in.)
[2] Maximum thickness: bright annealed - 3 mm (0.120 in.)
cold rolled only - 3.5 mm (0.140 in.)
[3] Wider widths subject to special enquiry
[4] Wider widths up to 730 mm (29 in.) subject to special enquiry

Wire
Conditions:
bright drawn, 1/4 hard to hard,
bright annealed

Dimensions:
0.1 – 12.0 mm (0.004 – 0.47 in.) diameter,
in coils, pay-off packs, on spools and spiders

Welding filler metals
Suitable welding rods, wire, strip electrodes and electrode core wire are available in standard sizes.

Seamless tube and pipe
Using ThyssenKrupp VDM cast materials seamless tubes and pipes are produced and available from DMV STAINLESS Deutschland GmbH, Wiesenstr. 36, D-45473 Mülheim/Ruhr, (Tel.: +49 208 458-2611; Fax: +49 208 458-2641; Email: salesgermany@dmv-stainless.com).

Welded tube and pipe
Welded tubes and pipes are obtainable from qualified manufacturers using ThyssenKrupp VDM semi-fabricated products.

Notes on how to use the alloy tables.

The following tables have been compiled to assist in selecting the most suitable material for applications where special thermal expansion properties are required.

Specifications and designations
The materials are available in conformity with the standards indicated. Standards in round brackets indicate that the standard is only valid in part or the ThyssenKrupp VDM data deviate from those specified in the standard. When placing an order, standards (DIN, ASTM, etc.) stipulated by the customer will form the basis of the contract following approvel by ThyssenKrupp VDM.

Chemical composition
When an element is reported as the "balance" of a composition, this only means that this element predominates; other elements may also be present in minimal amounts.

Mechanical properties
The stated mechanical properties are typical values for the stated condition, except those reported as minimum or maximum.

Alloy availability.

ThyssenKrupp VDM designation	Alloy	Material No.	UNS designation	Page
Expansion special alloys with very low coefficients of thermal expansion				
Pernifer 33 Co	–	–	–	16
Pernifer 36	36	1.3912	K93600, K93601, K93603	16
Pernifer 36 CDT	–	1.3912	–	17
Pernifer 36 hC	–	1.3912	–	17
Pernifer 36 Mo So	–	1.3912	–	18
Pernifer 36 nMn	–	1.3912	–	18
Expansion special alloys with low, adjusted coefficients of thermal expansion				
Pernifer 39	–	1.3913	–	19
Pernifer 40	42	1.3917	K94000, K94100	19
Pernifer 41 LC	–	1.3917	–	20
Pernifer 42	–	1.3917	K94101, K94200	20
Pernifer 42 Ti	–	(1.3917)	–	21
Pernifer 42 TiNb	–	1.3936	–	21
Pernifer 42 TVR	–	(1.3917)	–	22
Pernifer 46	46	1.3920	K94600	22
Pernifer 48	48	1.3922	K94800	23
Pernifer 50	52	2.4478	N14052	23
Pernifer 51	51	2.4475	–	24
Pernifer 2918	–	1.3981	K94610	24
Pernifer 4205 Ti	–	–	N09902	25
Pernifer 4206	–	1.3946	K94760	25
Pernifer 4706	–	2.4486	–	26
Pernifer 5101	–	2.4480	–	26
Expansion special alloys with very high coefficients of thermal expansion				
Pernifer 1407	–	1.3930	–	27
Pernifer 2002	–	1.3933	–	27
Pernifer 2006	–	1.3932	–	28
Pernifer 2203	–	1.3942	–	28
Pernifer 2508	–	1.3902	–	29
Pernima 72	–	(2.6305)	M27200	29

Expansion special alloys

with very low coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 33 Co		Pernifer 36 36		
Designations and standards					
D Werkstoff-No. Designation DIN, [DIN EN] SEW	 (17745) 		1.3912 Ni 36 17745 385		
F AFNOR	–		Fe-Ni 36		
UK BS designation	–		–		
USA UNS designation ASTM SAE AMS			K93600 (thermostat alloy), K93601 (low expansion alloy), K93603 (low expansion alloy) B 388, B 753 (T-36), F 1684 I-23011 (Class 7)		
Chemical composition %			**DIN 17745**		**ASTM B 753 (T-36)**
Nickel	32.0 - 34.0		35.0 - 37.0		36.0 nominal
Chromium	–		≤ 0.2		≤ 0.25
Iron	Balance		Balance		Balance
Carbon	≤ 0.01		≤ 0.05		≤ 0.15
Manganese	≤ 0.05		≤ 0.50		≤ 0.60
Silicon	≤ 0.04		≤ 0.30		≤ 0.40
Copper	–		–		–
Molybdenum	–		–		–
Cobalt	≤ 4.0		–		≤ 0.50
Aluminium	–		–		–
Titanium	–		–		–
Niobium	–		–		–
Others	–		–		–
Mechanical properties at RT	soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	at -196 °C*)
0.2% yield strength, $R_{p0.2}$ N/mm²/ksi	≥ 275 / ≥ 39.9	≥ 610 / ≥ 88.5	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0	640 / 92.8 typical
Tensile strength, R_m N/mm²/ksi	≥ 450 / ≥ 65.3	≥ 640 / ≥ 92.8	≥ 440 / ≥ 63.8	≥ 630 / ≥ 91.4	940 / 136.3 typical
Elongation, A_{50} %	≥ 30	≥ 5	≥ 30	≥ 5	45 typical
Hardness HV	140	200	130	200	–
Physical properties at RT					
Density g/cm³	8.2		8.1		
Thermal conductivity W/m·K	12		12.8		
Modulus of elasticity kN/mm²	144		143		
Deflection temperature °C	220		230		
Electrical resistivity μΩ·cm	80		76		
Specific heat J/kg·K	515		515		
Coefficient of thermal expansion between 20 °C [or 30 °C] and T 10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	**DIN 17745**	**ASTM F 1684**
-196 °C			1.0 typical / ≤ 2.0		
-163 °C			1.0 typical / ≤ 1.8		
-100 °C			1.0 typical / ≤ 1.8		
50 °C			0.6		
100 °C	< 0.5		0.6 - 1.4	1.2 - 1.8 specified	
150 °C					[1.2 - 2.7] average
200 °C			2.2		
300 °C			5.5		
400 °C			8.2		
500 °C			10.0		
600 °C			11.3		
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F			Values are applicable to the soft annealed condition only		**ASTM B 753 (T-36)**
200 °F (93 °C)					0.5 - 1.1 typical
300 °F (149 °C)					0.8 - 1.4 specified
500 °F (260 °C)					2.0 - 2.7 typical
700 °F (371 °C)					3.7 - 4.4 typical
Fabrication					
Melting temperature °C	≈ 1430		≈ 1430		
Max. operating temperature °C	≈ 600		≈ 600		
Workability	good		good		
Weldability	satisfactory		good		
Filler metal	matching		matching: Pernifer S 6436 (1.3912)		
Material description					
	Extremely low thermal expansion up to 200 °C.		Extremely low thermal expansion up to 200 °C. The coefficient of thermal expansion can be adjusted by changes in analysis as well as in the production route.		
Typical applications					
	Shaddow masks.		Passive thermostat bimetal component. Molds. *) Condition: cold formed and soft annealed.		

Expansion special alloys

with very low coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 36 CDT		Pernifer 36 hC		
Designations and standards						
D Werkstoff-No.		1.3912		1.3912		
Designation		Ni 36		Ni 36		
DIN, [DIN EN]		17745		17745		
SEW						
F AFNOR		–		–		
UK BS designation		–		–		
USA UNS designation						
ASTM						
SAE AMS						
Chemical composition %						
Nickel		35.0 - 37.0		35.0 - 37.0		
Chromium		–		≤ 0.1		
Iron		Balance		Balance		
Carbon				≤ 0.03		
Manganese		≤ 0.3		≤ 0.4		
Silicon		≤ 0.02		≤ 0.2		
Copper		–		–		
Molybdenum		–		–		
Cobalt		–		–		
Aluminium		–		–		
Titanium		–		–		
Niobium		–		–		
Others		–		–		
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	
0.2% yield strength, $R_{p0.2}$	N/mm²/ksi	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0	≥ 280 / ≥ 40.6	≥ 620 / ≥ 89.9	
Tensile strength, R_m	N/mm²/ksi	≥ 440 / ≥ 63.8	≥ 630 / ≥ 91.4	≥ 460 / ≥ 66.7	≥ 650 / ≥ 94.3	
Elongation, A_{50}	%	≥ 30	≥ 5	≥ 30	≥ 5	
Hardness	HV	130	200	140	210	
Physical properties at RT						
Density	g/cm³	8.1		8.1		
Thermal conductivity	W/m·K	12.8		12.8		
Modulus of elasticity	kN/mm²	143		143		
Deflection temperature	°C	230		230		
Electrical resistivity	µΩ·cm	76		76		
Specific heat	J/kg·K	515		515		
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only		
-196 °C						
-163 °C						
-100 °C						
50 °C						
100 °C		< 1.1		1.2 - 1.8		
150 °C						
200 °C		2.1		2.2 - 2.8		
300 °C		5.5		5.5		
400 °C		8.2		8.2		
500 °C		10.0		10.0		
600 °C		11.3		11.3		
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F					
200 °F (93 °C)						
300 °F (149 °C)						
500 °F (260 °C)						
700 °F (371 °C)						
Fabrication						
Melting temperature	°C	≈ 1430		≈ 1430		
Max. operating temperature	°C	≈ 600		≈ 600		
Workability		good		good		
Weldability		good		good		
Filler metal		matching: Pernifer S 6436 (1.3912)		matching: Pernifer S 6436 (1.3912)		
Material description						
		Extremely low thermal expansion up to 200 °C. Modified version with improved etching characteristics.		Modified version with low thermal expansion up to 200 °C and improved workability.		
Typical applications						
		Shaddow masks.		Sheet fabrication.		

Expansion special alloys

with very low coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		**Pernifer 36 Mo So**		**Pernifer 36 nMn**		
Designations and standards						
D Werkstoff-No.		1.3912		1.3912		
Designation		Ni 36		Ni 36		
DIN, [DIN EN]		(17745)		17745		
SEW						
F AFNOR		–		–		
UK BS designation		–		–		
USA UNS designation						
ASTM						
SAE AMS						
Chemical composition %						
Nickel		35.0 - 37.0		35.0 - 37.0		
Chromium		≤ 0.02		–		
Iron		Balance		Balance		
Carbon		≤ 0.1		≤ 0.01		
Manganese		≤ 0.2		≤ 0.05		
Silicon		≤ 0.2		≤ 0.04		
Copper		–		–		
Molybdenum		≤ 0.6		–		
Cobalt		–		–		
Aluminium		–		–		
Titanium		–		–		
Niobium		≤ 0.1		–		
Others		–		–		
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	
0.2% yield strength, $R_{p0.2}$	N/mm^2 / ksi	≥ 280 / ≥ 40.6	≥ 820 / ≥ 118.9	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0	
Tensile strength, R_m	N/mm^2 / ksi	≥ 450 / ≥ 65.3	≥ 850 / ≥ 123.3	≥ 440 / ≥ 63.8	≥ 630 / ≥ 91.4	
Elongation, A_{50}	%	≥ 30	≥ 5	≥ 30	≥ 5	
Hardness	HV	140	260	130	200	
Physical properties at RT						
Density	g/cm^3	8.1		8.1		
Thermal conductivity	W/m·K	12		12.8		
Modulus of elasticity	kN/mm^2	144		143		
Deflection temperature	°C	210		230		
Electrical resistivity	µΩ·cm	80		76		
Specific heat	J/kg·K	515		515		
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only		
-196 °C						
-163 °C						
-100 °C						
50 °C						
100 °C		1.8		< 0.8		
150 °C						
200 °C		2.6		2.0		
300 °C		5.3		5.5		
400 °C		8.2		8.2		
500 °C		10.2		10.0		
600 °C		11.6		11.3		
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F					
200 °F (93 °C)						
300 °F (149 °C)						
500 °F (260 °C)						
700 °F (371 °C)						
Fabrication						
Melting temperature	°C	≈ 1430		≈ 1430		
Max. operating temperature	°C	≈ 600		≈ 600		
Workability		good		good		
Weldability		good		good		
Filler metal		matching: Pernifer S 6436 (1.3912)		matching: Pernifer S 6436 (1.3912)		
Material description						
		Modified version with low thermal expansion up to 200 °C, but with higher mechanical strength.		Modified version with even lower thermal expansion up to 200 °C.		
Typical applications						
		Shaddow masks and frames for shaddow masks.		Shaddow masks.		

ThyssenKrupp VDM Trademark Alloy		Pernifer 39		Pernifer 40 42	
Designations and standards					
D	Werkstoff-No.	1.3913		1.3917	
	Designation	Ni 38		Ni 42	
	DIN, [DIN EN]	17745		17745	
	SEW	–		(385)	
F	AFNOR	–		–	
UK	BS designation	–		–	
USA	UNS designation			K94000, K94100	
	ASTM	B 753 (T-39)		B 388, B 753 (T-40), F 30 (alloy 42)	
	SAE AMS			I-23011 (Class 5)	
Chemical composition %		DIN 17745	ASTM B 753 (T-39)		ASTM B 753 (T-40)
Nickel		37.0 - 40.0	39.0 nominal	40.0 - 41.0	40.0 nominal
Chromium		–	≤ 0.50	≤ 0.25	≤ 0.50
Iron		Balance	Balance	Balance	Balance
Carbon		≤ 0.05	≤ 0.15	≤ 0.02	≤ 0.15
Manganese		≤ 0.60	≤ 0.60	≤ 0.7	≤ 0.60
Silicon		≤ 0.30	≤ 0.40	≤ 0.15	≤ 0.40
Copper		–	–	–	–
Molybdenum		–	–	–	–
Cobalt		–	≤ 0.50	–	≤ 0.50
Aluminium		–	–	–	–
Titanium		–	–	–	–
Niobium		–	–	–	–
Others		–	–	–	–
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed
0.2% yield strength, $R_{p0.2}$	N/mm^2 / ksi	≥ 240 / ≥ 34.8	≥ 720 / ≥ 104.4	≥ 240 / ≥ 34.8	≥ 620 / ≥ 89.9
Tensile strength, R_m	N/mm^2 / ksi	≥ 490 / ≥ 71.1	≥ 740 / ≥ 107.3	≥ 490 / ≥ 71.1	≥ 700 / ≥ 101.5
Elongation, A_{50}	%	≥ 30	≥ 5	≥ 30	≥ 5
Hardness	HV	130	230	130	210
Physical properties at RT					
Density	g/cm^3	8.2		8.2	
Thermal conductivity	W/m·K	–		15	
Modulus of elasticity	kN/mm^2	–		148	
Deflection temperature	°C	300		345	
Electrical resistivity	µΩ·cm	71		66	
Specific heat	J/kg·K	–		500	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	ASTM F 30
50 °C					
100 °C		3.6		4.5	
150 °C		3.0 - 3.8 specified in DIN 17745		4.2	
200 °C		3.5		4.2	
300 °C		4.7		4.0 - 5.8 spec. in DIN 17745	[4.0 - 4.7] specified
400 °C		7.4		6.2	
450 °C					[6.7 - 7.4] specified
500 °C		9.3		8.1	
550 °C					
600 °C		10.6		9.6	
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F	Values are applicable to the soft annealed condition only	ASTM B 753 (T-39)	Values are applicable to the soft annealed condition only	ASTM B 753 (T-40)
200 °F (93 °C)			2.3 - 3.4 typical		3.6 typical
300 °F (149 °C)			2.5 - 3.6 specified		4.0 ± 8% specified
500 °F (260 °C)			2.7 - 3.6 typical		4.0 typical
700 °F (371 °C)			5.0 - 5.9 typical		5.4 typical
Fabrication					
Melting temperature	°C	≈ 1430		≈ 1440	
Max. operating temperature	°C				
Workability		good		good	
Weldability		satisfactory		satisfactory	
Filler metal		matching		matching	
Material description					
		Low thermal expansion up to 250 °C.		Low thermal expansion up to 300 °C.	
Typical applications					
		Passive thermostat bimetal component. Shaddow masks.		Glass seals especially with soft glasses and for metal to ceramic sealing applica-tions. Integrated circuit (IC) low housings. X-ray tubes. Passive thermostat bimetal component. Leadframes (blanking quality).	

Expansion special alloys

with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 41 LC		Pernifer 42	
Designations and standards				
D Werkstoff-No.	1.3917		1.3917	
Designation	Ni 42		Ni 42	
DIN, [DIN EN]	17745		17745	
SEW	(385)		385	
F AFNOR			Fe-Ni 42	
UK BS designation			–	
USA UNS designation			K94101 (Dumet), K94200	
ASTM			B 388, B 753 (T-42), F 29 (Dumet)	
SAE AMS			7734, I-23011 (Class 5)	
Chemical composition %				**ASTM B 753 (T-42)**
Nickel	40.0 - 42.0		41.0 - 43.0	42.0 nominal
Chromium	–		–	≤ 0.50
Iron	Balance		Balance	Balance
Carbon	≤ 0.005		≤ 0.02	≤ 0.15
Manganese	≤ 0.60		≤ 0.70	≤ 0.60
Silicon	≤ 0.15		≤ 0.20	≤ 0.40
Copper	–		–	–
Molybdenum	–		–	–
Cobalt	–		–	≤ 0.50
Aluminium	–		–	–
Titanium	–		–	–
Niobium	–		–	–
Others	–		–	–
Mechanical properties at RT	soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed
0.2% yield strength, $R_{p0.2}$ N/mm²/ksi	≥ 240 / ≥ 34.8	≥ 620 / ≥ 89.9	≥ 240 / ≥ 34.8	≥ 650 / ≥ 94.3
Tensile strength, R_m N/mm²/ksi	≥ 490 / ≥ 71.1	≥ 700 / ≥ 101.5	≥ 490 / ≥ 71.1	≥ 710 / ≥ 103.0
Elongation, A_{50} %	≥ 30	≥ 5	≥ 30	≥ 5
Hardness HV	130	210	130	210
Physical properties at RT				
Density g/cm³	8.2		8.2	
Thermal conductivity W/m·K	15		15	
Modulus of elasticity kN/mm²	148		148	
Deflection temperature °C	345		345	
Electrical resistivity μΩ·cm	66		66	
Specific heat J/kg·K	500		500	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T 10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	**ASTM F 29**
50 °C				
100 °C	4.5		6.0	
150 °C	4.2			
200 °C	4.2		5.5	
300 °C	4.0 - 5.8 specified in DIN 17745		4.0-5.8 specified in DIN 17745	
400 °C	6.2		6.6	[6.3 - 7.2] average
450 °C				
500 °C	8.1		8.3	
550 °C				
600 °C	9.6		9.7	
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F			Values are applicable to the soft annealed condition only	**ASTM B 753 (T-42)**
200 °F (93 °C)				5.6 typical
300 °F (149 °C)				5.4 ± 8% specified
500 °F (260 °C)				5.2 typical
700 °F (371 °C)				5.4 typical
Fabrication				
Melting temperature °C	≈ 1430		≈ 1440	
Max. operating temperature °C				
Workability	good		good	
Weldability	satisfactory		satisfactory	
Filler metal	matching		matching	
Material description				
	Low thermal expansion up to 300 °C.		Low thermal expansion up to 300 °C.	
Typical applications				
	Leadframes (etching grade).		Glass seals especially with soft glasses and for metal to ceramic sealing applications. Integrated circuit (IC) low housings. Shape-etched components. Transistor caps. Core wire for 'Dumet' wire. Passive thermostat bimetal component.	

ThyssenKrupp VDM Trademark Alloy	Pernifer 42 Ti	Pernifer 42 TiNb	
Designations and standards			
D Werkstoff-No.	(1.3917)	1.3936	
Designation	(Ni 42)	X2 NiCoTiNb 42-3-2	
DIN, [DIN EN]	(17745)	–	
SEW	(385)	–	
F AFNOR	–	–	
UK BS designation	–	–	
USA UNS designation			
ASTM			
SAE AMS			
Chemical composition %			
Nickel	40.0 - 41.5	42.0 - 43.5	
Chromium	–	–	
Iron	Balance	Balance	
Carbon	≤ 0.025	≤ 0.02	
Manganese	≤ 1.0	≤ 0.2	
Silicon	≤ 0.2	≤ 0.15	
Copper	–	–	
Molybdenum	–	–	
Cobalt	–	≤ 2.3	
Aluminium	–	–	
Titanium	0.10 - 0.30	≤ 2.0	
Niobium	–	≤ 0.6	
Others	–	–	
Mechanical properties at RT	soft annealed deep drawing quality		
0.2% yield strength, $R_{p0.2}$ N/mm² / ksi	≥ 250 / ≥ 36.3		
Tensile strength, R_m N/mm² / ksi	≥ 490 / ≥ 71.1		
Elongation, A_{50} %	≥ 40		
Hardness HV	150		
Physical properties at RT			
Density g/cm³	8.2	8.1	
Thermal conductivity W/m·K	15	–	
Modulus of elasticity kN/mm²	150	–	
Deflection temperature °C	330	310	
Electrical resistivity µΩ·cm	66	–	
Specific heat J/kg·K	500	–	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T 10^{-6}/K	Values are applicable to the soft annealed condition only	Values are applicable to the soft annealed condition only	
50 °C			
100 °C	4.6	4.8	
150 °C			
200 °C	4.4	4.8	
300 °C	4.5	5.0	
400 °C	6.3	6.7	
450 °C			
500 °C	8.0	8.4	
550 °C			
600 °C	9.6	9.7	
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F			
200 °F (93 °C)			
300 °F (149 °C)			
500 °F (260 °C)			
700 °F (371 °C)			
Fabrication			
Melting temperature °C	≈ 1450	1430 (liquidus)	
Max. operating temperature °C		–	
Workability	good	good	
Weldability	satisfactory	satisfactory	
Filler metal	matching	matching	
Material description			
	Low thermal expansion up to 300 °C.	High mechanical strength with low thermal expansion.	
Typical applications			
	Deep-drawn transistor caps.	Components with low thermal expansion exposed to higher temperatures.	

Expansion special alloys
with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 42 TVR		Pernifer 46 46	
Designations and standards					
D Werkstoff-No.		(1.3917)		1.3920	
Designation		(Ni 42)		NiCr 42-6	
DIN, [DIN EN]		–		17745	
SEW		–		385	
F AFNOR		–		–	
UK BS designation		–		–	
USA UNS designation				K94600	
ASTM				F 30 (alloy 46)	
SAE AMS				I-23011 (Class 4)	
Chemical composition %					
Nickel		41.0 - 43.0		45.0 - 46.5	
Chromium		–		–	
Iron		Balance		Balance	
Carbon		≤ 0.02		≤ 0.10	
Manganese		≤ 0.1		≤ 0.80	
Silicon		≤ 0.1		≤ 0.50	
Copper		–		–	
Molybdenum		–		–	
Cobalt		–		–	
Aluminium		–		–	
Titanium		≤ 2.4		–	
Niobium		≤ 0.4		–	
Others		–		–	
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed
0.2% yield strength, $R_{p0.2}$	N/mm² / ksi	≥ 340 / ≥ 49.3	≥ 830 / ≥ 120.4	≥ 250 / ≥ 36.3	≥ 770 / ≥ 111.7
Tensile strength, R_m	N/mm² / ksi	≥ 660 / ≥ 95.7	≥ 1150 / ≥ 166.8	≥ 510 / ≥ 74.0	≥ 780 / ≥ 113.1
Elongation, A_{50}	%	≥ 34	≥ 14	≥ 30	≥ 3
Hardness	HV	160	340	135	240
Physical properties at RT					
Density	g/cm³	8.1		8.2	
Thermal conductivity	W/m·K	–		15	
Modulus of elasticity	kN/mm²	–		152	
Deflection temperature	°C	270		460	
Electrical resistivity	µΩ·cm	–		60	
Specific heat	J/kg·K	–		500	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	**ASTM F 30**
50 °C					
100 °C		3.7		8.4	
150 °C					
200 °C		4.1		8.0	
300 °C		5.3		7.1 - 8.4 spec. in DIN 17745	[7.5] typical
350 °C					[7.1 - 7.8] specified
400 °C		7.6		7.4	[7.5] typical
425 °C					
450 °C					
500 °C		9.2		8.4	[8.2 - 8.9] specified
550 °C					
600 °C		10.4		9.6	[9.8] typical
700 °C					[10.7] typical
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F				
200 °F (93 °C)					
300 °F (149 °C)					
Fabrication					
Melting temperature	°C	1450 (liquidus)		≈ 1440	
Max. operating temperature	°C	–			
Workability		good		good	
Weldability		satisfactory		satisfactory	
Filler metal		matching		matching	
Material description					
		High mechanical strength with low thermal expansion.		Low thermal expansion up to 450 °C.	
Typical applications					
		TV frames.		Glass seals especially with soft glasses and for metal to ceramic sealing applications.	

Expansion special alloys
with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 48 48		Pernifer 50 52	
Designations and standards					
D Werkstoff-No.		1.3922		2.4478	
Designation		Ni 48		NiFe 47	
DIN, [DIN EN]		17745		17745	
SEW		385		385	
F AFNOR		Fe-Ni 48		Fe-Ni 50.5	
UK BS designation		–		–	
USA UNS designation		K94800		N14052	
ASTM		F 30 (alloy 48)		F 30 (alloy 52)	
SAE AMS		I-23011 (Class 3)		I-23011 (Class 2)	
Chemical composition %				**DIN 17745**	
Nickel		46.0 - 49.0		50.0 - 51.0	
Chromium		–		≤ 0.25	
Iron		Balance		Balance	
Carbon		≤ 0.05		≤ 0.01	
Manganese		≤ 0.50		≤ 0.5	
Silicon		≤ 0.30		≤ 0.1	
Copper		–		–	
Molybdenum		–		–	
Cobalt		–		–	
Aluminium		≤ 0.10		≤ 0.10	
Titanium		–		–	
Niobium		–		–	
Others		–		–	
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed
0.2% yield strength, $R_{p0.2}$	N/mm² / ksi	≥ 280 / ≥ 40.6	≥ 700 / ≥ 101.5	≥ 240 / ≥ 34.8	≥ 810 / ≥ 117.5
Tensile strength, R_m	N/mm² / ksi	≥ 530 / ≥ 76.9	≥ 750 / ≥ 108.8	≥ 540 / ≥ 78.3	≥ 820 / ≥ 118.9
Elongation, A_{50}	%	≥ 30	≥ 4	≥ 30	≥ 3
Hardness	HV	125	220	135	250
Physical properties at RT					
Density	g/cm³	8.3		8.3	
Thermal conductivity	W/m · K	15.9		16.8	
Modulus of elasticity	kN/mm²	164		160	
Deflection temperature	°C	465		520	
Electrical resistivity	µΩ · cm	50		44	
Specific heat	J/kg · K	500		500	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only	**ASTM F 30**	Values are applicable to the soft annealed condition only	**ASTM F 30**
50 °C					
100 °C		9.8	[9.2] typical	11.0	[10.2] typical
150 °C					
200 °C		9.2	[9.0] typical	11.6	[10.1] typical
300 °C		8.8	[8.8] typical	10.4	[10.1] typical
350 °C					
400 °C		8.3 - 8.9 spec. in DIN 17745	[8.2 - 9.2] specified	9.7-10.5 spec. in DIN 17745	[9.9] typical
425 °C					
450 °C					[9.7 - 10.2] specified
500 °C		9.1	[9.4] typical	10.0	[9.9] typical
550 °C			[9.6 - 10.3] specified		[10.0 - 10.5] specified
600 °C		10.2	[10.4] typical	10.9	[10.8] typical
700 °C			[11.3] typical		[11.7] typical
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F				
200 °F (93 °C)					
300 °F (149 °C)					
Fabrication					
Melting temperature	°C	≈ 1440		≈ 1445	
Max. operating temperature	°C				
Workability		good		good	
Weldability		satisfactory		satisfactory	
Filler metal		matching		matching	
Material description					
		Low thermal expansion up to 450 °C.		Constant thermal expansion up to 500 °C.	
Typical applications					
		Glass seals especially with soft glasses and for metal to ceramic sealing applications.		Glass seals especially with soft and lead glasses and for metal to ceramic sealing applications. Reed relays.	

Expansion special alloys
with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 51 51		Pernifer 2918		
Designations and standards					
D Werkstoff-No.	2.4475		1.3981		
Designation	NiFe 46		NiCo 29 18		
DIN, [DIN EN]	17745		17745		
SEW	385		385		
F AFNOR	Fe-Ni 51.5		–		
UK BS designation	–		–		
USA UNS designation	–		K94610		
ASTM	F 30 (alloy 51)		F 15		
SAE AMS	–		7726 - 7728, I-23011 (Class 1)		
Chemical composition %					
Nickel	51.0 - 52.0		28.0 - 30.0		
Chromium	–		≤ 0.10		
Iron	Balance		Balance		
Carbon	≤ 0.01		≤ 0.05		
Manganese	≤ 0.1		≤ 0.50		
Silicon	≤ 0.1		≤ 0.30		
Copper	–		–		
Molybdenum	–		–		
Cobalt	–		16.0 - 18.0		
Aluminium	–		–		
Titanium	–		–		
Niobium	–		–		
Others	–		–		
Mechanical properties at RT	soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	
0.2% yield strength, $R_{p0.2}$ N/mm²/ksi	≥ 240 / ≥ 34.8	≥ 810 / ≥ 117.5	≥ 380 / ≥ 55.1	≥ 660 / ≥ 95.7	
Tensile strength, R_m N/mm²/ksi	≥ 540 / ≥ 78.3	≥ 820 / ≥ 118.9	≥ 440 / ≥ 63.8	≥ 720 / ≥ 104.4	
Elongation, A_{50} %	≥ 30	≥ 3	≥ 25	≥ 5	
Hardness HV	135	250	150	220	
Physical properties at RT					
Density g/cm³	8.3		8.2		
Thermal conductivity W/m·K	16.8		17.5		
Modulus of elasticity kN/mm²	155		160		
Deflection temperature °C	520		425		
Electrical resistivity µΩ·cm	44		49		
Specific heat J/kg·K	500		500		
Coefficient of thermal expansion between 20 °C [or 30 °C] and T 10^{-6}/K	Values are applicable to the soft annealed condition only	**ASTM F 30**	Values are applicable to the soft annealed condition only	**ASTM F 15**	
50 °C					
100 °C	10.5	[10.2] typical	6.3	[5.8] typical	
150 °C					
200 °C	10.4	[10.1] typical	5.8	[5.4] typical	
300 °C	10.3	[10.2] typical	5.3	[5.1] typical	
400 °C	9.8-10.6 spec. in DIN 17745	[10.2] typical	4.6-5.6 spec. in DIN 17745	[4.6-5.2] specified	
450 °C		[9.9-10.5] specified		[5.1-5.5] specified	
500 °C	10.0	[10.1] typical	6.1	[6.1] typical	
550 °C		[10.0-10.7] specified		[6.8] typical	
600 °C	10.7	[11.0] typical	7.8	[7.5] typical	
700 °C		[11.9] typical			
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F					
200 °F (93 °C)					
300 °F (149 °C)					
500 °F (260 °C)					
700 °F (371 °C)					
Fabrication					
Melting temperature °C	≈ 1445		≈ 1450		
Max. operating temperature °C			≈ 700		
Workability	good		good		
Weldability	satisfactory		satisfactory		
Filler metal	matching		matching		
Material description					
	Constant thermal expansion up to 500 °C.		Very low thermal expansion up to 450 °C. A martensite-free structure is attainable down to -196 °C (-320 °F).		
Typical applications					
	Glass seals especially with soft and lead glasses and for metal to ceramic sealing applications. Reed relays.		Glass seals especially with hard glasses and for metal to ceramic sealing applications. X-ray tubes. Shape-etched components. Mountings.		

Expansion special alloys
with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 4205 Ti		Pernifer 4206		
Designations and standards						
D Werkstoff-No.		–		1.3946		
Designation		(NiCr 42-5-2)		NiCr 42-6		
DIN, [DIN EN]		–		17745		
SEW		–		385		
F AFNOR		–		Fe-Ni 42 Cr 6		
UK BS designation		–		–		
USA UNS designation		N09902		K94760		
ASTM				F 31		
SAE AMS		5221, 5223, 5225		I-23011 (Class 6)		
Chemical composition %				**DIN 17745**		
Nickel		42.0 - 43.5		41.0 - 43.0		
Chromium		5.0 - 5.8		5.0 - 6.0		
Iron		Balance		Balance		
Carbon		≤ 0.05		≤ 0.07		
Manganese		≤ 0.6		≤ 0.50		
Silicon		≤ 1.0		≤ 0.30		
Copper		–		–		
Molybdenum		–		–		
Cobalt		–		16.0 - 18.0		
Aluminium		≤ 0.8		≤ 0.20		
Titanium		2.0 - 3.0		–		
Niobium		–		–		
Others		–		–		
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	
0.2% yield strength, $R_{p0.2}$	N/mm² / ksi	≥ 340 / ≥ 49.3	≥ 900 / ≥ 130.5	≥ 240 / ≥ 34.8	≥ 720 / ≥ 104.4	
Tensile strength, R_m	N/mm² / ksi	≥ 440 / ≥ 63.8	≥ 1000 / ≥ 145.0	≥ 440 / ≥ 63.8	≥ 750 / ≥ 108.8	
Elongation, A_{50}	%	≥ 25	≥ 5	≥ 30	≥ 3	
Hardness	HV	170	240	140	280	
Physical properties at RT						
Density	g/cm³	8.2		8.2		
Thermal conductivity	W/m · K	11.8		12.5		
Modulus of elasticity	kN/mm²	–		159		
Deflection temperature	°C	–		295		
Electrical resistivity	μΩ · cm	100		95		
Specific heat	J/kg · K	–		500		
Coefficient of thermal expansion between 20 °C [or 30 °C] and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	**ASTM F 31**	
50 °C						
100 °C		8.4 [8.2]		7.4		
150 °C						
200 °C		10.1 [10.1]		7.3		
300 °C		12.2 [12.2]		8.3	[7.9] typical	
350 °C					[8.5 - 9.2] specified	
400 °C		13.6 [13.6]		9.6-10.4 spec. in DIN 17745	[9.8] typical	
425 °C					[9.7-10.4] specified	
450 °C		14.4 [14.4]		[10.6]		
500 °C				11.3	[11.2] typical	
550 °C						
600 °C		15.0 [15.1]		12.4	[12.1] typical	
700 °C					[13.0] typical	
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F					
200 °F (93 °C)						
300 °F (149 °C)						
500 °F (260 °C)						
700 °F (371 °C)						
Fabrication						
Melting temperature	°C	1440		≈ 1440		
Max. operating temperature	°C					
Workability		good		good		
Weldability		satisfactory		satisfactory		
Filler metal		matching		matching		
Material description						
		Temperature-constant spring characteristics. Alloy with relative constant E-modulus.		Thermal expansion adjusted to the type of glass.		
Typical applications						
		Weighing machine components. Mechanical filters.		Glass seals especially with soft glasses and for metal to ceramic sealing applications. TV-tube glass seals. Flash bulbs.		

Expansion special alloys
with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 4706	Pernifer 5101
Designations and standards		
D Werkstoff-No.	2.4486	2.4480
Designation	NiFe 47 Cr 6	NiFe 48 Cr
DIN, [DIN EN]	17745	17745
SEW	385	385
F AFNOR	Fe-Ni 47 Cr 6	Fe-Ni 50 Cr 1
UK BS designation	–	–
USA UNS designation	–	–
ASTM	–	–
SAE AMS	–	–
Chemical composition %		
Nickel	46.0 - 48.0	51.0 - 52.0
Chromium	5.5 - 6.5	1.0 - 1.3
Iron	Balance	Balance
Carbon	≤ 0.02	≤ 0.01
Manganese	≤ 0.3	≤ 0.6
Silicon	≤ 0.30	≤ 0.15
Copper	–	–
Molybdenum	–	–
Cobalt	–	–
Aluminium	–	–
Titanium	–	–
Niobium	–	–
Others	–	–

Mechanical properties at RT	Pernifer 4706 soft annealed deep drawing quality	Pernifer 4706 50% cold formed	Pernifer 5101 soft annealed deep drawing quality	Pernifer 5101 50% cold formed
0.2% yield strength, $R_{p0.2}$ N/mm² / ksi	≥ 200 / ≥ 29.0	≥ 930 / ≥ 134.9	≥ 250 / ≥ 36.3	≥ 790 / ≥ 114.6
Tensile strength, R_m N/mm² / ksi	≥ 500 / ≥ 72.5	≥ 950 / ≥ 137.8	≥ 550 / ≥ 79.8	≥ 800 / ≥ 116.0
Elongation, A_{50} %	≥ 35	≥ 3	≥ 30	≥ 3
Hardness HV	120	280	135	250

Physical properties at RT	Pernifer 4706	Pernifer 5101
Density g/cm³	8.1	8.3
Thermal conductivity W/m · K	14	17
Modulus of elasticity kN/mm²	170	157
Deflection temperature °C	330	490
Electrical resistivity μΩ · cm	92	43
Specific heat J/kg · K	500	500
Coefficient of thermal expansion between 20 °C and T 10^{-6}/K	Values are applicable to the soft annealed condition only	Values are applicable to the soft annealed condition only
50 °C		
100 °C	9.7	11.1
150 °C		
200 °C	9.3	10.5
300 °C	9.2	10.3
350 °C		
400 °C	10.0 - 10.8 specified in DIN 17745	9.9 - 10.7 specified in DIN 17745
425 °C		
450 °C		
500 °C	11.6	10.5
550 °C		
600 °C	12.5	10.5
700 °C		
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F		
200 °F (93 °C)		
300 °F (149 °C)		
500 °F (260 °C)		
700 °F (371 °C)		
Fabrication		
Melting temperature °C	≈ 1450	≈ 1440
Max. operating temperature °C		
Workability	good	good
Weldability	satisfactory	satisfactory
Filler metal	matching	matching
Material description		
	Thermal expansion adjusted to the type of glass.	Constant thermal expansion up to 450 °C.
Typical applications		
	Glass seals especially with soft and lead glasses and for metal to ceramic sealing applications. Welding filler metal.	Glass seals especially with soft glasses for overvoltage protection.

Expansion special alloys
with very high coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 1407		Pernifer 2002	
Designations and standards					
D Werkstoff-No.		1.3930		1.3933	
Designation		X60 NiMn 14-7		NiMn 20	
DIN, [DIN EN]		(Thermobimetalle: 1715-1)		–	
SEW		385		–	
F AFNOR		–		–	
UK BS designation		–		–	
USA UNS designation					
ASTM				B 753 (T-19)	
SAE AMS					
Chemical composition %		**SEW 385**			**ASTM B 753 (T-19)**
Nickel		12.5 - 14.5		19.5 - 21.5	19.0 nominal
Chromium		–		2.0 - 3.0	2.0 nominal
Iron		Balance		Balance	Balance
Carbon		0.55 - 0.65		0.50 - 0.65	0.5 nominal
Manganese		6.0 - 7.0		≤ 1.50	1.0 nominal
Silicon		≤ 1.0		≤ 0.30	≤ 0.40
Copper		–		–	–
Molybdenum		–		–	–
Cobalt		–		–	–
Aluminium		–		–	–
Titanium		–		–	–
Niobium		–		–	–
Others		–		–	–
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	
0.2% yield strength, $R_{p0.2}$	N/mm² / ksi	≥ 230 / ≥ 33.4	≥ 1150 / ≥ 166.8		
Tensile strength, R_m	N/mm² / ksi	≥ 590 / ≥ 85.6	≥ 1200 / ≥ 174.0		
Elongation, A_{50}	%	≥ 30	≥ 5		
Hardness	HV	130	300		
Physical properties at RT					
Density	g/cm³	8.0		8.0	
Thermal conductivity	W/m · K	13		–	
Modulus of elasticity	kN/mm²	196		–	
Deflection temperature	°C	A deflection temperature does not exist for this alloy.		–	
Electrical resistivity	µΩ · cm	73		78	
Specific heat	J/kg · K	–		–	
Coefficient of thermal expansion between 20 °C and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	
50 °C					
100 °C		19.4		20.5	
150 °C					
200 °C		20.3		20.7	
300 °C		20.8		20.8	
400 °C		21.1		20.8	
450 °C					
500 °C					
550 °C					
600 °C					
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F			Values are applicable to the soft annealed condition only	**ASTM B 753 (T-19)**
200 °F (93 °C)					20.0 typical
300 °F (149 °C)					19.4 ± 4% specified
500 °F (260 °C)					20.2 typical
700 °F (371 °C)					20.2 typical
Fabrication					
Melting temperature	°C	≈ 1420		1460 (liquidus)	
Max. operating temperature	°C				
Workability					
Weldability					
Filler metal					
Material description					
		High thermal expansion.		High thermal expansion.	
Typical applications					
		Active thermostat bimetal component. Thermostat bimetal designations in DIN 1715-1: TB 1170 and TB 1577.		Active thermostat bimetal component.	

Expansion special alloys

with very high coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 2006		Pernifer 2203		
Designations and standards					
D Werkstoff-No.	1.3932		1.3942		
Designation	NiMn 20-6		X15 NiCr 22-3		
DIN, [DIN EN]	(Thermobimetalle: 1715-1)		–		
SEW	(385)		385		
F AFNOR	–		–		
UK BS designation	–		–		
USA UNS designation					
ASTM			B 753 (T-22)		
SAE AMS					
Chemical composition %				**ASTM B 753 (T-22)**	
Nickel	20.0 - 21.0		21.0 - 23.0	22.0 nominal	
Chromium	–		2.5 - 3.5	3.0 nominal	
Iron	Balance		Balance	Balance	
Carbon	≤ 0.10		≤ 0.20	0.12 nominal	
Manganese	5.5 - 7.0		≤ 0.50	≤ 0.60	
Silicon	≤ 0.30		≤ 0.50	≤ 0.30	
Copper	–		–	–	
Molybdenum	–		–	–	
Cobalt	≤ 0.30		–	–	
Aluminium	–		–	–	
Titanium	–		–	–	
Niobium	–		–	–	
Others	–		–	–	
Mechanical properties at RT	soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed	
0.2% yield strength, $R_{p0.2}$ N/mm² / ksi	≥ 170 / ≥ 24.7		≥ 200 / ≥ 29.0	≥ 800 / ≥ 116.0	
Tensile strength, R_m N/mm² / ksi	≥ 500 / ≥ 72.5		≥ 500 / ≥ 72.5	≥ 850 / ≥ 123.3	
Elongation, A_{50} %	≥ 30		≥ 35	≥ 5	
Hardness HV	≥ 130		≥ 120	≥ 250	
Physical properties at RT					
Density g/cm³	8.1		8.2		
Thermal conductivity W/m·K	13		17		
Modulus of elasticity kN/mm²	196		186		
Deflection temperature °C	A deflection temperature does not exist for this alloy.		A deflection temperature does not exist for this alloy.		
Electrical resistivity µΩ·cm	78		77		
Specific heat J/kg·K	–		–		
Coefficient of thermal expansion between 20 °C and T 10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only		
50 °C					
100 °C	20.1		19.3		
150 °C					
200 °C	20.6		19.8		
300 °C	20.9		19.9		
400 °C	21.0		19.9		
450 °C					
500 °C	21.1		19.9		
550 °C					
600 °C	21.2		19.9		
Coefficient of thermal expansion between 77 °F (25 °C) and T 10^{-6}/°F			Values are applicable to the soft annealed condition only	**ASTM B 753 (T-22)**	
200 °F (93 °C)				19.3 typical	
300 °F (149 °C)				19.35±4.5% specified	
500 °F (260 °C)				19.6 typical	
700 °F (371 °C)				19.6 typical	
Fabrication					
Melting temperature °C	≈ 1440		≈ 1460		
Max. operating temperature °C					
Workability					
Weldability					
Filler metal					
Material description					
	High thermal expansion.		High thermal expansion.		
Typical applications					
	Active thermostat bimetal component.		Active thermostat bimetal component.		

Expansion special alloys
with very high coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy		Pernifer 2508		Pernima 72	
Designations and standards					
D Werkstoff-No.		1.3902		2.6305)	
Designation		X15 NiCr 22-3		MnCuNi	
DIN, [DIN EN]		–		(Thermobimetalle: 1715-1)	
SEW		–		–	
F AFNOR		–		–	
UK BS designation		–		–	
USA UNS designation				M27200	
ASTM		B 753 (T-25)		(B 388), B 753 (T-10)	
SAE AMS					
Chemical composition %			**ASTM B 753 (T-25)**		**ASTM B 753 (T-10)**
Nickel		24.5 - 25.5	25.0 nominal	9.0 - 11.0	10.0 nominal
Chromium		8.2 - 8.8	8.0 nominal	–	≤ 0.25
Iron		Balance	Balance	≤ 0.2	≤ 1.0
Carbon		≤ 0.03	≤ 0.15	≤ 0.10	≤ 0.1
Manganese		≤ 0.9	≤ 1.0	Balance	72.0 nominal
Silicon		≤ 0.5	≤ 1.0	≤ 0.2	≤ 0.25
Copper		–	–	17.0 - 19.0	18.0 nominal
Molybdenum		–	–	–	–
Cobalt		–	–	–	–
Aluminium		–	–	–	–
Titanium		–	–	–	–
Niobium		–	–	–	–
Others		–	–	–	–
Mechanical properties at RT		soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	
0.2% yield strength, $R_{p0.2}$	N/mm² / ksi	≥ 250 / ≥ 36.3	≥ 790 / ≥ 114.6		
Tensile strength, R_m	N/mm² / ksi	≥ 550 / ≥ 79.8	≥ 800 / ≥ 116.0		
Elongation, A_{50}	%	≥ 30	≥ 3		
Hardness	HV	≥ 135	≥ 250	≥ 130	
Physical properties at RT					
Density	g/cm³	–		7.2	
Thermal conductivity	W/m·K	–		8.5	
Modulus of elasticity	kN/mm²	–		–	
Deflection temperature	°C	–		–	
Electrical resistivity	μΩ·cm	86		176	
Specific heat	J/kg·K	–		–	
Coefficient of thermal expansion between 20 °C and T	10^{-6}/K	Values are applicable to the soft annealed condition only		Values are applicable to the soft annealed condition only	
50 °C					
100 °C		18.9		26.8	
150 °C					
200 °C		18.9		28.4	
300 °C		19.0		29.5	
400 °C		19.1		30.1	
450 °C					
500 °C				31.7	
550 °C					
600 °C				32.7	
Coefficient of thermal expansion between 77 °F (25 °C) and T	10^{-6}/°F	Values are applicable to the soft annealed condition only	**ASTM B 753 (T-25)**	Values are applicable to the soft annealed condition only	**ASTM B 753 (T-10)**
200 °F (93 °C)			17.6 typical		27.2 typical
300 °F (149 °C)			17.6 ± 4% specified		27.7 ± 4% specified
500 °F (260 °C)			18.0 typical		28.1 typical
700 °F (371 °C)			18.2 typical		29.9 typical
Fabrication					
Melting temperature	°C	1430 (liquidus)		≈ 1120	
Max. operating temperature	°C				
Workability					
Weldability					
Filler metal					
Material description					
(Material description)		High thermal expansion.		Very high thermal expansion.	
Typical applications					
(Typical applications)		Active thermostat bimetal component.		Active thermostat bimetal component. Thermostat bimetal designation in DIN 1715-1: TB 20110.	

Conversion factors.
International System of Units (SI)*
Customary U. S./English Units

To convert from	to	multiply by
Mass: SI unit – kg		
kg	pound (lb avoirdupois)	2.2046
lb (avoirdupois)	kg	4.536×10^{-1}
ton (short, 2000 lbs)	kg	9.07185×10^{2}
kg	ton (short)	1.102×10^{-3}
lbs/in. coil width	kg/mm coil width	1.78549×10^{-2}
kg/mm coil width	lbs/in. coil width	5.6007 x 10
Length: SI unit – meter (m) = 100 cm = 1000 mm		
m	inches (in.)	3.937 x 10
m	feet (ft)	3.281
mm	in.	3.937×10^{-2}
mm	mils	3.937 x 10
mils	mm	2.54×10^{-2}
mils	µm	25.4
in.	mm	25.4
ft	m	0.305
Density: $kg/m^3 = g/cm^3 \times 10^{-3}$		
g/cm^3	$lb/in.^3$	3.613×10^{-2}
kg/m^3	$lb/in.^3$	3.613×10^{-5}
$lb/in.^3$	g/cm^3	2.77 x 10
$lb/in.^3$	kg/m^3	2.77×10^{4}
Specific heat: kJ / kg • K = J x 10^3 / kg • K; cal. / g • K = Btu / lb • °F		
calorie (cal.)	joule (J)	4.187
joule	Btu (British thermal units)	9.486×10^{-4}
Btu	J	1.055056×10^{3}
cal. / g • K	kJ / kg • K	4.187
Thermal conductivity: watt (W) / m • K		
Btu • in. / ft^2 • h • °F	W / m • K	1.4422×10^{-1}
W / m • K	Btu • in. / ft^2 • h • °F	6.9339
Electrical resistivity: µohm (Ω) • cm		
Ω • circ mil / ft	µ Ω • cm	1.662426×10^{-1}
µ Ω • cm	Ω • circ mil / ft	6.015305
Coefficient of thermal expansion: µm/m • K		
µm/m • K	µin./in. • °F	0.5555
µin./in. • °F	µm/m • K	1.8
Mechanical properties: Units of resistance and stress: N/mm^2; pound-force (lbf)/$in.^2$ (psi)		
ksi (= psi x 10^3)	N/mm^2	6.8964
N/mm^2	psi	1.45003×10^{2}
Magnetic conversion factors:		
Gauss (G)	Weber (Wb)/m^2 = Tesla (T)	10^{-4}
Oersted (Oe)	Ampere (A)/m	7.9577 x 10
A/m	Oe	1.2566×10^{-2}
A/m	A/cm	10^{-2}
G/Oe	Wb/A • m	1.2566×10^{-6}
Wb/A • m	G/Oe	7.9577×10^{5}
Temperature: SI unit - Kelvin (K)		
K to degrees Celcius (°C): subtract 273		
°C to degrees Fahrenheit (°F): multiply by 9/5 and add 32		
°F to °C: subtract 32 and multiply by 5/9		

Selected conversion factors applicable to Material Data Sheets and technical publications.
* SI = Systeme International d'Unités

Comparison according to Material Numbers.

Material No.	ThyssenKrupp VDM designation	Alloy	UNS designation	Page
1.3902	Pernifer 2508	–	–	29
1.3912	Pernifer 36	36	K93600, K93601, K93603	16
1.3912	Pernifer 36 CDT	–	–	17
1.3912	Pernifer 36 hC	–	–	17
1.3912	Pernifer 36 Mo So	–	–	18
1.3912	Pernifer 36 nMn	–	–	18
1.3913	Pernifer 39	–	–	19
1.3917	Pernifer 40	42	K94000, K94100	19
1.3917	Pernifer 41 LC	–	–	20
1.3917	Pernifer 42	–	K94101, K94200	20
(1.3917)	Pernifer 42 Ti	–	–	21
(1.3917)	Pernifer 42 TVR	–	–	22
1.3920	Pernifer 46	46	K94600	22
1.3922	Pernifer 48	48	K94800	23
1.3930	Pernifer 1407	–	–	27
1.3932	Pernifer 2006	–	–	28
1.3933	Pernifer 2002	–	–	27
1.3936	Pernifer 42 TiNb	–	–	21
1.3942	Pernifer 2203	–	–	28
1.3946	Pernifer 4206	–	K94760	25
1.3981	Pernifer 2918	–	K94610	24
2.4475	Pernifer 51	51	–	24
2.4478	Pernifer 50	52	N14052	23
2.4480	Pernifer 5101	–	–	26
2.4486	Pernifer 4706	–	–	26
(2.6305)	Pernima 72	–	M27200	29

Comparison according to UNS designations.

UNS designation	ThyssenKrupp VDM designation	Alloy	Material No.	Page
K93600, K93601, K93603	Pernifer 36	36	1.3912	16
K94000, K94100	Pernifer 40	42	1.3917	19
K94101, K94200	Pernifer 42	–	1.3917	20
K94600	Pernifer 46	46	1.3920	22
K94610	Pernifer 2918	–	1.3981	24
K94760	Pernifer 4206	–	1.3946	25
K94800	Pernifer 48	48	1.3922	23
M27200	Pernima 72	–	(2.6305)	29
N09902	Pernifer 4205 Ti	–	–	25
N14052	Pernifer 50	52	2.4478	23

Photo credits.

P. 5 Machining of a mold for the production of a carbon fibre reinforced plastic (CFRP) aircraft rudder component.
Courtesy of Airbus Deutschland

P. 7 Quality check of the surface of a mold for the production of a carbon fibre reinforced plastic (CFRP) aircraft rudder component.
Courtesy of Airbus Deutschland

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Alloys with special thermal expansion characteristics.

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