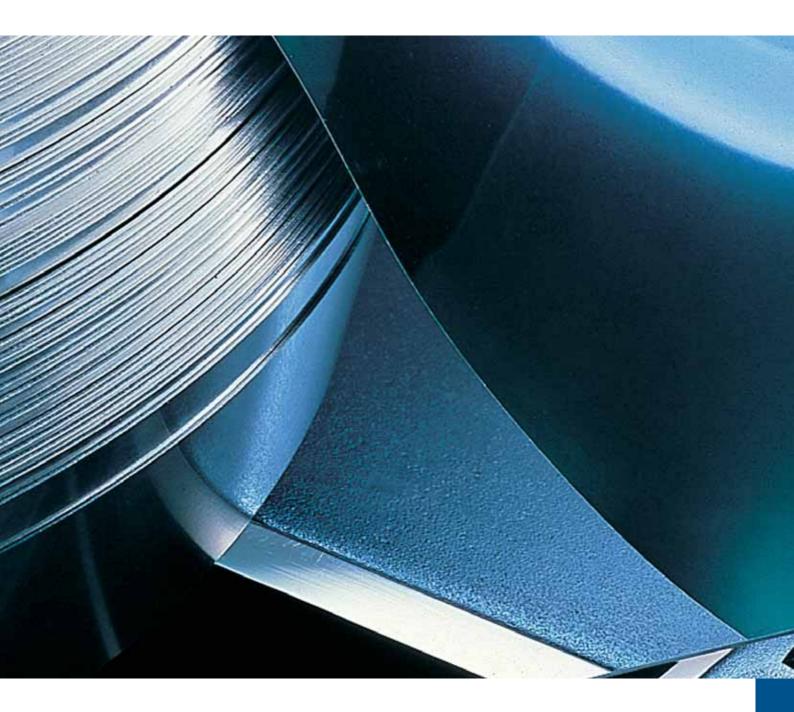
Pernifer and Pernima Alloys.

Alloys with special thermal expansion characteristics.









Pernifer and Pernima Alloys.

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Valle Leise

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 ironnickel 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 magnetovolume 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

 $CTE = [I - I_o] / [I_o \bullet (T - T_o)] = \Delta I / [I_o \bullet \Delta T]$

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 ΔI / 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.

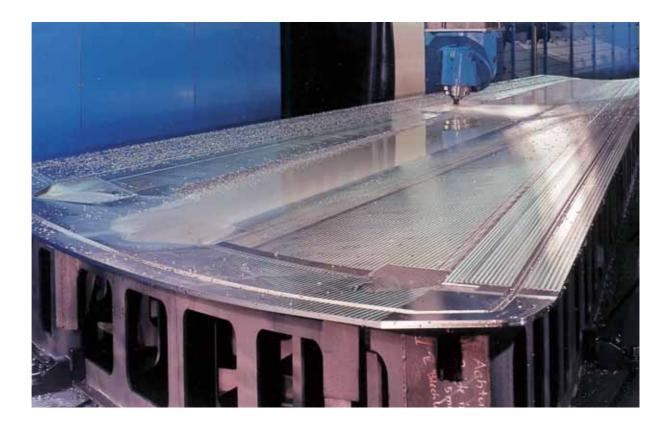








The respective Pernifer alloys are identified by a numbering code which follows the Pernifer designation and which approximately corresponds to the nickel content or significant alloying additions. In the case of Pernima 72 the number indicates the manganese content.



Alloys with very low coefficients of thermal expansion.





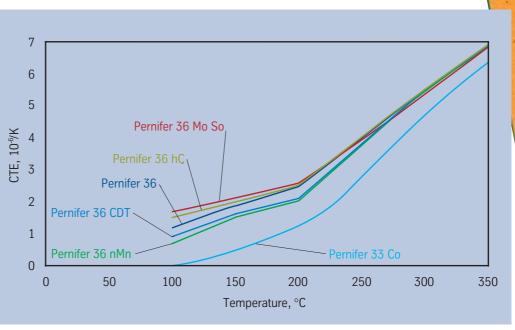


Fig. 1 - Typical graphs of coefficients of thermal expansion (CTE) of iron-nickel alloys with very low coefficients of thermal expansion.

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.



N125

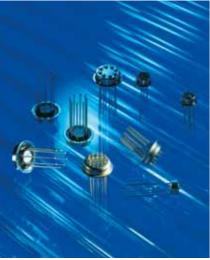
Beside Pernifer 36, alloy modifications were developed with special properties for specific requirements. Pernifer 36 CDT exhibits especially good etching characteristics. The Pernifer 36 nMn modification was developed specially for applications requiring an even lower coefficient of thermal expansion 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 temperaturedependent 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

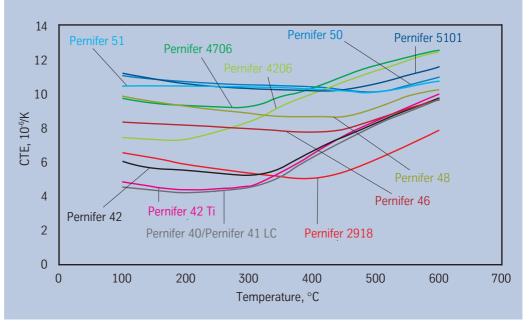
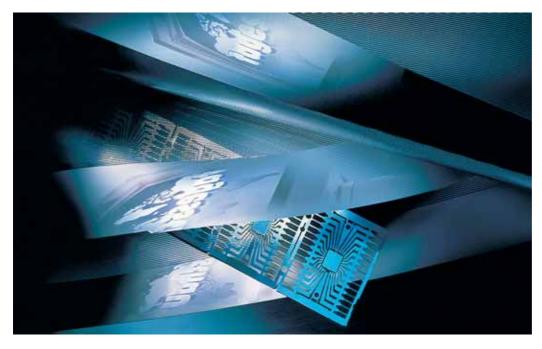


Fig. 2 – Temperature-dependent plots of coefficients of thermal expansion CTE of iron-nickel alloys used as glass sealing materials.



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 CO₂ 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.



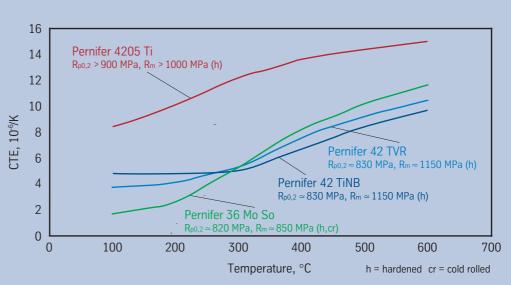


Fig. 3 – Temperature-dependent plots of coefficients of thermal expansion CTE of iron-nickel alloys with special mechanical properties.

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^{i} , 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 largesized 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.

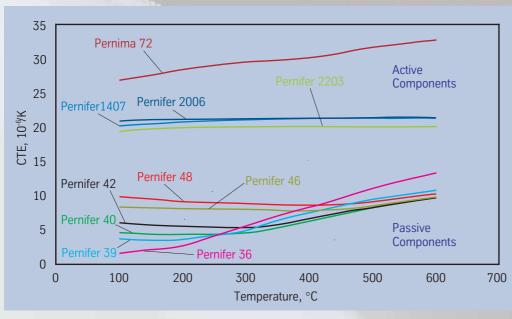


Fig. 4 – Comparison of the coefficients of thermal expansion of iron-nickel alloys as bimetallic components.

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 carboncontaining 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 \leq 5 K/min.

ASTM F 30: Pernifer 40/46/48/50/51Heating in a hydrogen atmosphere for 1 h at 900 °C, followed by cooling down to 200 °C at a rate of \leq 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⁾
> 25.001)	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⁾
> 1.0001)	hr	100 ²⁾	320 ²⁾
1) other sizes subject to	special onguiny		

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)	(³ / ₁₆ - ³ / ₄)	
	Х	Х	not standard
	(8 – 24)	(4 ³ / ₄ - 24)	
Bar, hexagonal (s)	$1^{5}/_{8} - 3^{1}/_{8}$	$^{1}/_{2} - 1^{5}/_{8}$	≤ 2
¹⁾ other sizes and cond	itions subject to spe	cial 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.

Strip¹⁾

Conditions:

cold rolled, thermally treated and pickled or bright annealed²⁾

Thickness mm	Width ³⁾ mm		Coil mm	I.D.	
$0.02 - \le 0.10$	$4 - 200^{4}$	300	400		
> 0.10 - ≤ 0.20	4 - 3504)	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 $- \le 3.0^{2}$ $- \le 3.5^{2}$	25 – 700		400	500	600

inches	inches		inch	es	
$0.0008 - \le 0.004$	0.16 - 84	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
$> 0.080 - \le 0.120^{20} - \le 0.140^{20}$	1.0 -28		16	20	24

 $^{\rm i)}$ Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in.) $^{\rm 2)}$ 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 therm	al 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 t	hermal 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 therr	nal 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 **Designations and standards** D Werkstoff-No. Designation DIN, [DIN EN] SEW F AFNOR UK BS designation USA UNS designation ASTM SAE AMS Chemical composition % Nickel Chromium Iron Carbon Manganese Silicon Copper Molybdenum Cobalt Aluminium Titanium Niobium Others Mechanical properties at RT 0.2% yield strength, $R_{\text{p0.2}}$ N/mm²/ks Tensile strength, $R_{\scriptscriptstyle m}$ N/mm²/ks Elongation, A₅₀ % Hardness ΗV Physical properties at RT Density g/cm³ Thermal conductivity W/m·K Modulus of elasticity kN/mm² Deflection temperature °C Electrical resistivity μΩ·cm Specific heat J/kg ⋅ K Coefficient of thermal expansion between 20 °C [or 30 °C] and T 10⁻⁶/H -196 °C -163 °C -100 °C 50 °C 100 °C 150 °C 200 °C 300 °C 400 °C 500 °C 600 °C Coefficient of thermal expansion between 77 °F (25 °C) and T 10-6/°I 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication °C Melting temperature Max. operating temperature °C Workability Weldability Filler metal Material description Typical applications

		Pernifer 36 36		
		1.3912		
		Ni 36		
(17745)		17745		
(17743)		385		
		Fe-Ni 36		
		FE-INI 30		
_		-		
			/), K93601 (low expansion alloy)	, K93603 (low expansio
		B 388, B 753 (T-36), F 1	684	
		I-23011 (Class 7)		
		DIN 17745		ASTM B 753 (T-36
		DIN 17745		ASTM B 755 (1-50
32.0 - 34.0		35.0 - 37.0		36.0 nominal
-		≤ 0.2		≤ 0.25
Balance		Balance		Balance
≤ 0.01		≤ 0.05		≤ 0.15
≤ 0.05		≤ 0.50		≤ 0.60
≤ 0.04		≤ 0.30		≤ 0.40
_		-		-
_		_		_
		_		≤ 0.50
≤ 4.0 -		_		≤ 0.50 _
		-		-
		-		-
		-		-
soft annealed	E00% and formed	soft annealed	E00/ erthformert	at 100.00%
deep drawing quality	50% cold formed	deep drawing quality	50% cold formed	at -196 °C*)
≥ 275 / ≥ 39.9	≥ 610 / ≥ 88.5	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0	640 / 92.8 typical
≥ 450 / ≥ 65.3	≥ 640 / ≥ 92.8	≥ 440 / ≥ 63.8	≥ 630 / ≥ 91.4	940 / 136.3 typical
≥ 30	≥ 5	≥ 30	≥ 5	45 typica
140	200	130	200	-
-				
8.2		8.1		
12		12.8		
144		143		
220		230		
80		76		
515		515	-	
515 Values are applicable	to the soft annealed	515	DIN 17745	ASTM F 1684
515	to the soft annealed	515 Values are applicable to the	DIN 17745 ne soft annealed condition only	ASTM F 1684
515 Values are applicable	to the soft annealed	515 Values are applicable to the 1.0 typical $/ \le 2.0$		ASTM F 1684
515 Values are applicable	to the soft annealed	515 Values are applicable to th 1.0 typical / \leq 2.0 1.0 typical / \leq 1.8		ASTM F 1684
515 /alues are applicable	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8		ASTM F 1684
515 /alues are applicable condition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6		ASTM F 1684
515 /alues are applicable condition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8		ASTM F 1684
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6	ne soft annealed condition only	ASTM F 1684
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6	ne soft annealed condition only	
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4	ne soft annealed condition only	
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5	ne soft annealed condition only	
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2	ne soft annealed condition only	
15 alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0	ne soft annealed condition only	
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2	ne soft annealed condition only	[1.2 - 2.7] average
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	[1.2 - 2.7] average
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	[1.2 - 2.7] average
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified
15 alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified
15 'alues are applicable ondition only	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
515 /alues are applicable condition only < 0.5	to the soft annealed	515 Values are applicable to th 1.0 typical / \leq 2.0 1.0 typical / \leq 1.8 1.0 typical / \leq 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
15 alues are applicable ondition only 0.5 0.5	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th $^{\sim}$ 1430	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
alt5 (alues are applicable ondition only = 0.5 = 1430	to the soft annealed	515 Values are applicable to th 1.0 typical / \leq 2.0 1.0 typical / \leq 1.8 1.0 typical / \leq 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
 515 <i>a</i>lues are applicable condition only c 0.5 c 1430 c 600 	to the soft annealed	515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th $^{\sim}$ 1430	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
15 (alues are applicable ondition only : 0.5 : 1430 : 600 pood	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to tt \approx 1430 \approx 600	ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
15 alues are applicable ondition only 0.5 0.5 1430 600 jood atisfactory	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to tt \approx 1430 \approx 600 good	ne soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
515 /alues are applicable	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to tt \approx 1430 \approx 600 good	ne soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
 515 /alues are applicable condition only 	to the soft annealed	515 Values are applicable to tt 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to tt \approx 1430 \approx 600 good	ne soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only	 [1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical
15 alues are applicable ondition only 0.5 0.5 1430 600 ood atisfactory natching		515 Values are applicable to th 1.0 typical / \leq 2.0 1.0 typical / \leq 1.8 1.0 typical / \leq 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th \approx 1430 \approx 600 good good matching: Pernifer S 643 Extremely low thermal ex	e soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only ne soft annealed condition only 6 (1.3912) pansion up to 200 °C.	[1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical 3.7 - 4.4 typical
15 alues are applicable ondition only 0.5 0.5 1430 600 ood atisfactory atching		515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th \approx 1430 \approx 600 good good The coefficient of thermal ex	e soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only 6 (1.3912)	[1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical 3.7 - 4.4 typical
5 lues are applicable ndition only D.5 D.5 Land Land Goo od Lisfactory atching tremely low therma		515 Values are applicable to th 1.0 typical / \leq 2.0 1.0 typical / \leq 1.8 1.0 typical / \leq 1.8 1.0 typical / \leq 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th \approx 1430 \approx 600 good good Extremely low thermal ext	e soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only ne soft annealed condition only 6 (1.3912) pansion up to 200 °C.	[1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical 3.7 - 4.4 typical
5 lues are applicable ndition only 0.5 1430 600 od tisfactory atching tremely low therma		515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th \approx 1430 \approx 600 good good The coefficient of thermal ex	e soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only ne soft annealed condition only 6 (1.3912) pansion up to 200 °C.	[1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical 3.7 - 4.4 typical
15 Ilues are applicable ndition only 0.5 0.5 1430 600 bod tisfactory atching tremely low therma		515 Values are applicable to th 1.0 typical / ≤ 2.0 1.0 typical / ≤ 1.8 1.0 typical / ≤ 1.8 0.6 0.6 - 1.4 2.2 5.5 8.2 10.0 11.3 Values are applicable to th \approx 1430 \approx 600 good good The coefficient of thermal ex	e soft annealed condition only 1.2 - 1.8 specified ne soft annealed condition only ne soft annealed condition only 6 (1.3912) pansion up to 200 °C. I expansion can be adjusted by of	[1.2 - 2.7] average ASTM B 753 (T-36) 0.5 - 1.1 typical 0.8 - 1.4 specified 2.0 - 2.7 typical 3.7 - 4.4 typical

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 Carbon	Balance		Balance ≤ 0.03		-	
Manganese	≤ 0.3		≤ 0.05 ≤ 0.4		-	
Silicon	≤ 0.02		≤ 0.4 ≤ 0.2		-	
Copper	-		-		-	
Molybdenum	_		_		1	
Cobalt	-		-		1	
Aluminium	-		-		1	
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	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0			_	
Tensile strength, R_m N/mm ² /ksi	≥ 2707≥ 33.1 ≥ 4407≥ 63.8	≥ 630 / ≥ 91.4	≥ 280 / ≥ 40.6 ≥ 460 / ≥ 66.7	≥ 620 / ≥ 89.9 ≥ 650 / ≥ 94.3	-	
Elongation, A_{50} %	≥ 30	≥ 5	≥ 30	≥ 5	-	
Hardness HV	130	200	140	210	-	
	100	200	140	210		
Physical properties at RT						
Density g/cm ³	8.1		8.1			
Thermal conductivity W/m·K	12.8		12.8			
Modulus of elasticity kN/mm ²	143		143		_	
Deflection temperature °C	230		230		_	
Electrical resistivity $\mu \Omega \cdot cm$	76		76		_	
Specific heat J/kg·K	515 Values are applicable	in the oaft ennealed	515	a the seft ennealed	-	
Coefficient of thermal expansion between 20 °C [or 30 °C] and T $10^{\rm \circ}/K$	condition only	to the solt annealed	Values are applicable t condition only	o the solt annealed		
-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 Coefficient of thermal expansion	11.3		11.3		_	
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		1	
Workability	good		good		1	
Weldability	good		good]	
Filler metal	matching: Pernifer S	6436 (1.3912)	matching: Pernifer S	6436 (1.3912)]	
Material description						
	Extremely low therma	expansion up to	Modified version with	low thermal		
	200 °C. Modified vers	sion with improved	expansion up to 200			
	etching characteristic		workability.			
Typical applications						
	Shaddow masks.		Sheet fabrication.			

Expansion special alloys with very low coefficients of thermal expansion

Alloy	nKrupp VDM Trac	lemark		Pernifer 36 Mo So	
	tions and standa	ards	- i		
D W	/erkstoff-No.			1.3912	
D	esignation			Ni 36	
D	IN, [DIN EN]			(17745)	
S	EW				
	FNOR			-	
	S designation			_	
	NS designation				
	STM AE AMS				
	al composition %		- i		
Nickel	•			35.0 - 37.0	
Chromiu	ım		- +	≤ 0.02	
Iron				Balance	-
Carbon				≤ 0.1	
Mangan	ese			≤ 0.2	
Silicon				≤ 0.2	
Copper				-	
Molybde	enum			≤ 0.6	_
Cobalt Aluminii	Im		4	_	_
Titaniun				_	_
Niobium	-		- +		_
Others			- +		-
				soft annealed	T
Mechar	ical properties a	t R I		deep drawing quality	4
0.2% yi	eld strength, $R_{p0.2}$	N/mm² / ksi		≥ 280 / ≥ 40.6	
Tensile	strength, R _m	N/mm² / ksi		≥ 450 / ≥ 65.3	Ī
Elongati	on, A ₅₀	%		≥ 30	I
Hardnes	S	HV		140	
Physica	I properties at R	г			
Density		g/cm ³	- 1	8.1	-
	conductivity	W/m·K	- +	12	-
	s of elasticity	kN/mm ²		144	
Deflectio	on temperature	°C		210	-
Electrica	al resistivity	μΩ·cm		80	
Specific	heat	J/kg·K		515	_
	ent of thermal exp n 20 °C [or 30 °C]			Values are applicable condition only	tc
-163 °C					
-100 °C					
50 °C					
100 °C				1.8	
150 °C					
200 °C				2.6	
300 °C 400 °C				5.3 8.2	
400 C				0.2 10.2	
600 °C				11.6	
Coefficie	ent of thermal exp			11.0	
	n 77 °F (25 °C) and	d T 10 ⁻⁶ /°F			
	(93 °C) (149 °C)				
	(149°C) (260 °C)				
	(200°C) (371°C)				
Fabrica			- i		
Melting	temperature	°C	-	≈ 1430	1
-	erating temperatu			≈ 600	
Workabi				good	-
Weldabi			-	good	
Filler me			-	matching: Pernifer S	6
	l description		- i		ĵ
Tracerra				Modified version with I	0
				up to 200 °C, but with strength.	n
Typical	applications				Ī
.,	applications				-
.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	applications			Shaddow masks and masks.	fı

6 Mo So		Pernifer 36 nMn		
		1.3912		
		Ni 36		
		17745		
		-		
		-		
		35.0 - 37.0		
		_		
		Balance		
		≤ 0.01		
		≤ 0.01 ≤ 0.05		
		≤ 0.03 ≤ 0.04		
		-		
		_		
		-		
		-		
		-		
		-		
		-		
ed	5000	soft annealed	500	
ig quality	50% cold formed	deep drawing quality	50% cold formed	
0.6	≥ 820 / ≥ 118.9	≥ 270 / ≥ 39.1	≥ 600 / ≥ 87.0	
5.3	≥ 850 / ≥ 123.3	≥ 440 / ≥ 63.8	≥ 630 / ≥ 91.4	
	≥ 5	≥ 30	≥ 5	
	260	130	200	
	l	-	I	
		8.1		
		12.8		
		143		
		230		
		76		
		515		
			to the oaft opposided	
ipplicable (ily	to the soft annealed	Values are applicable t condition only	to the solt annealed	
iiy		oonakion only		
		< 0.8		
		< 0.0		
		2.0		
		2.0		
		5.5		
		8.2		
		10.0		
		11.3		
		≈ 1430		
		≈ 600		
		good		
		good		
Pernifer S	6436 (1.3912)	matching: Pernifer S	6436 (1.3912)	
	,/	,	,/	
sion with lo	ow thermal expansion higher mechanical	Modified version with e		
, out with	nigher mechanical	expansion up to 200 °	С.	
asks and	frames for shaddow	Shaddow masks.		
2 3.10		0		
		L		

Expansion special alloys with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy	Pernifer 39
Designations and standards	
D Werkstoff-No.	1.3913
Designation	Ni 38
DIN, [DIN EN]	17745
SEW	-
F AFNOR UK BS designation	-
USA UNS designation	
ASTM	B 753 (T-3
SAE AMS	
Chemical composition %	DIN 17745
Nickel	37.0 - 40.
Chromium	
Iron	Balance
Carbon	≤ 0.05
Manganese	≤ 0.60
Silicon	≤ 0.30
Copper	
Molybdenum Cobalt	-
Aluminium	_
Titanium	-
Niobium	-
Others	-
Mechanical properties at RT	soft anneale
	deep drawir
0.2% yield strength, R _{p0.2} N/mm ² / ksi Tensile strength, R _m N/mm ² / ksi	≥ 240 / ≥ 3
Tensile strength, R_m N/mm²/ksiElongation, A_{50} %	≥ 490 / ≥ 7 ≥ 30
Hardness HV	130
	150
Physical properties at RT	
Density g/cm ³	8.2
Thermal conductivity W/m·K Modulus of elasticity kN/mm ²	-
Deflection temperature °C	300
Electrical resistivity $\mu\Omega \cdot cm$	71
Specific heat J/kg·K	-
Coefficient of thermal expansion	Values are a
between 20 °C [or 30 °C] and T 10 ⁻⁶ /K	condition or
50 ℃ 100 ℃	3.6
150 °C	3.0 - 3.8 s
200 °C	3.5
300 °C	4.7
400 °C	7.4
450 °C	
500 °C	9.3
550 °C 600 °C	10.6
Coefficient of thermal expansion	Values are a
between 77 °F (25 °C) and T 10 ⁻⁶ /°F	condition of
200 °F (93 °C)	
300 °F (149 °C)	
500 °F (260 °C)	
700 °F (371 °C)	
Fabrication	
Melting temperature °C	≈ 1430
Max. operating temperature °C	
Workability	good
Weldability	satisfactory
Filler metal	matching
Material description	
	Low therma
Typical applications	
	Passive the
	Shaddow n
	1 1

Pernifer 39		Pernifer 40 42	
1.3913		1.3917	_
Ni 38		Ni 42	
17745		17745	
-		(385)	
-		-	
_		_	
		K94000, K94100	
B 753 (T-39)		B 388, B 753 (T-40), I-23011 (Class 5)	F 3(
DIN 17745	ASTM B 753 (T-39)		AS
37.0 - 40.0	39.0 nominal	40.0 - 41.0	4(
_	≤ 0.50	≤ 0.25	_4(≤ (
Balance	Balance	Balance	Ba
≤ 0.05	≤ 0.15		-
≤ 0.05 ≤ 0.60		≤ 0.02	≤ (
	≤ 0.60	≤ 0.7	≤ (
≤ 0.30	≤ 0.40	≤ 0.15	≤ (
	-	-	-
-	-	-	-
-	≤ 0.50	-	≤ (
-	-		-
	-	-	-
	-	-	-
	-	-	-
soft annealed		soft annealed	
deep drawing quality	50% cold formed	deep drawing quality	50
≥ 240 / ≥ 34.8	≥ 720 / ≥ 104.4	≥ 240 / ≥ 34.8	≥ (
≥ 490 / ≥ 71.1	≥ 740 / ≥ 107.3	≥ 490 / ≥ 71.1	≥ 1
≥ 30	≥ 5	≥ 30	≥
130	230	130	
	200	100	<u> </u>
8.2		8.2	
_		15	
_		148	
300		345	
71		66	
-		500	
Values are applicable condition only	to the soft annealed	Values are applicable t condition only	o the
3.6		4.5	
	DIN 17745	4.2	
3.0 - 3.8 specified in	DIN 17745	4.2	
3.5			L F A
4.7		4.0 - 5.8 spec. in DIN 17745 6.2	[4.
7.4		0.2	10
9.3		8.1	[6.
10.6		9.6	
Values are applicable		Values are applicable t	o the I AS
condition only	ASTM B 753 (T-39)	condition only	
	2.3 - 3.4 typical		3.6
	2.5 - 3.6 specified		4.0
	2.7 - 3.6 typical		4.0
	5.0 - 5.9 typical		5.4
≈ 1/30		~ 1440	
≈ 1430		≈ 1440	
anad			
good		good	
satisfactory		satisfactory	
matching		matching	
Low thermal expansi	on up to 250 °C	Low thormal exponsion	n
	on up to 200 °C.	Low thermal expansion	ni u
Passive thermostat b Shaddow masks.	imetal component.	Glass seals especially	
Shauuuw masks.		and for metal to ceran tions. Integrated circuit	
		X-ray tubes. Passive t	
		component. Leadfram	

component. Leadframes

)		
40), I	F 30 (alloy 42)	
)		
	ASTM B 753 (T-40)	
	40.0 nominal	
	≤ 0.50	
	Balance	
	≤ 0.15	
	≤ 0.60	
	≤ 0.40 -	
	_ ≤ 0.50	
	<u> </u>	
	-	
	_	
	_	
ality	50% cold formed	
	≥ 620 / ≥ 89.9	
	≥ 700 / ≥ 101.5	
	≥ 5	
	210	
able to	the soft annealed	
	ASTM F 30	
10045	[4.0.4.7]	
1//45	[4.0-4.7] specified	
	[6.7-7.4] specified	
	[0.7 7.4] specified	
able to	o the soft annealed	
	ASTM B 753 (T-40)	
	3.6 typical	
	4.0 ± 8% specified	
	4.0 typical	
	5.4 typical	
	700.00	
ansio	n up to 300 °C.	
cially	with soft glasses	
ceram	ic sealing applica-	
circuit	t (IC) low housings. nermostat bimetal	
	es (blanking quality).	

Expansion special alloys with low, adjusted coefficients of thermal expansion

Alloy	senKrupp VDM	Tradem	ark
Desig	nations and st	andards	;
D	Werkstoff-No.		
	Designation		
	DIN, [DIN EN]		
F	SEW AFNOR		
UK	BS designation		
-	UNS designation		
	ASTM		
	SAE AMS		
Chen	nical composition	on %	
Nicke			
Chror	nium		
Iron Carbo	n		
	anese		
Silico			
Сорр	er		
	denum		
Coba			
Alum	-		
Titani Niobi		_	
Other	·		
	anical properti	es at RT	
			/mm² / ksi
	yield strength, I le strength, R _m	p0.2	/mm² / ksi /mm² / ksi
	ation, A_{50}	%	
Hardr		H	
	ical properties		
Densi	-		/cm ³
	nal conductivity lus of elasticity		//m·K N/mm²
	tus of elasticity		
	ical resistivity	-	Ω·cm
	fic heat		/kg·K
Coeff	cient of thermal		-
	en 20 °C [or 30	°C] and	T 10 ⁻⁶ /K
50 100			
100			
200			
300			
400			
450			
500			
550			
600		ovpanci	00
betwe	cient of thermal en 77 °F (25 °C) and T	on 10 ⁻⁶ /°F
	°F (93 °C)		
300	°F (149 °C)		
	°F (260 °C)		
700	°F (371 °C)		
_	cation		
Fabri	a tomporaturo		°C
Meltir	ig temperature	erature	°C
Meltir Max.	operating tempe		
Meltir Max. Worka	operating temperating temperating temperating temperating temperature and the second sec		
Meltir Max. Worka Welda	operating tempe ability ability		
Meltir Max. Worka Welda Filler	operating tempe ability ability metal		
Meltir Max. Worka Welda Filler	operating tempe ability ability		
Meltir Max. Worka Welda Filler Mate	operating temperating temperating temperating temperating ability metal rial description		
Meltir Max. Worka Welda Filler Mate	operating tempe ability ability metal		
Meltir Max. Worka Welda Filler Mate	operating temperating temperating temperating temperating ability metal rial description		
Meltir Max. Worka Welda Filler Mate	operating temperating temperating temperating temperating ability metal rial description		
Meltir Max. Worka Welda Filler Mate	operating temperating temperating temperating temperating ability metal rial description		

D			
Pernifer 41 LC		Pernifer 42	
1.3917		1.3917	
Ni 42		Ni 42	
17745		17745	
(385)		385 Eo Ni 42	
		Fe-Ni 42	
		K94101 (Dumet), K94 B 388, B 753 (T-42), 7734, I-23011 (Class	F 29 (Dumet)
		7754, I-25011 (Class	o) ASTM B753 (T-42)
40.0 - 42.0		41.0 - 43.0	42.0 nominal
-		-	≤ 0.50
Balance		Balance	Balance
≤ 0.005		≤ 0.02	≤ 0.15
≤ 0.60 ≤ 0.15		≤ 0.70	≤ 0.60
≤ 0.15		≤ 0.20	≤ 0.40
_		_	_
_		_	≤ 0.50
-		-	-
		_	-
_			-
-		-	-
soft annealed	50% cold formed	soft annealed	50% cold formed
deep drawing quality		deep drawing quality	50% cold formed
≥ 240 / ≥ 34.8	≥ 620 / ≥ 89.9	≥ 240 / ≥ 34.8	≥ 650 / ≥ 94.3
≥ 490 / ≥ 71.1 ≥ 30	≥ 700 / ≥ 101.5 ≥ 5	≥ 490 / ≥ 71.1	≥ 710 / ≥ 103.0
		≥ 30	≥ 5
130	210	130	210
8.2		8.2	
15		15	
148		148	
345		345	
66		66	
500		500	
Values are applicable t condition only	o the soft annealed	Values are applicable t condition only	o the soft annealed
condition only		condition only	A01111 20
4.5		6.0	
4.2			
4.2		5.5	
4.0 - 5.8 specified in	DIN 17745	4.0-5.8 specified in DIN 17745	
6.2		6.6	[6.3 - 7.2] average
8.1		8.3	
0.1		0.0	
9.6		9.7	
		Values are applicable t	o the soft annealed
		condition only	ASTM B 753 (T-42)
			5.6 typical
			5.4 ± 8% specified
			5.2 typical
			5.4 typical
≈ 1430		≈ 1440	
		1	
good		good	
satisfactory		satisfactory	
matching		matching	
Low thermal expansion	on up to 300 °C	Low thermal expansion	n up to 300 °C
Leadframes (etching	grade).	Glass seals especially	
		and for metal to ceran tions. Integrated circuit	t (IC) low housings
		Shape-etched compo	nents. Transistor
		caps. Core wire for 'D Passive thermostat bi	umet wire. metal component

		_

Expansion special alloys with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trademark	Pernifer 42 Ti	Pernifer 42 TiNb	
Alloy			
Designations and standards	(4.2012)	1 7070	
D Werkstoff-No.	(1.3917) (N: 42)	1.3936 X2 NiCoTiNb 42 3 2	
Designation DIN, [DIN EN]	(Ni 42) (17745)	X2 NiCoTiNb 42-3-2	
SEW	(385)	_	
F AFNOR	(585)	_	
UK BS designation	_	_	
USA UNS designation			
ASTM			
SAE AMS			
Chemical composition %			
Nickel	40.0 - 41.5	42.0 - 43.5	
Chromium	-	-	
Iron Carbon	Balance	Balance	
Manganese	≤ 0.025 ≤ 1.0	≤ 0.02	
Silicon	≤ 1.0 ≤ 0.2	≤ 0.2 ≤ 0.15	
Copper	-	<u> </u>	
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/mm ² /ksi	≥ 250 / ≥ 36.3		
Tensile strength, R _m N/mm ² /ksi	≥ 490 / ≥ 71.1		
Elongation, A ₅₀ %	≥ 40		
Hardness HV	150		
Physical properties at RT			
Density g/cm ³	0.2	8.1	
Density g/cm ³ Thermal conductivity W/m·K	8.2	-	
Modulus of elasticity kN/mm ²	15	_	
Deflection temperature °C	330	310	
Electrical resistivity $\mu \Omega \cdot cm$	66	-	
Specific heat J/kg·K	500	_	
Coefficient of thermal expansion	Values are applicable to the soft annealed	Values are applicable to the soft annealed	
between 20 °C [or 30 °C] and T $~10^{\text{-6}}\text{/K}$	condition only	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	8.0	8.4	
500 °C 550 °C	0.0	0.4	
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	- 14JU		
Workability	good	 good	
Weldability	satisfactory	satisfactory	
Filler metal	matching	matching	
	matering	matering	
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

	enKrupp VDM T	rademark
Alloy Design	ations and sta	ndards
-	Werkstoff-No.	
	Designation	
[DIN, [DIN EN]	
	SEW	
	AFNOR BS designation	
	JNS designation	1
	ASTM	
Ś	SAE AMS	
Chemi	cal compositio	n %
Nickel		
Chrom	ium	
Iron		
Carbor Manga		
Silicon	nese	
Copper	r	
Molybo		
Cobalt		
Alumin Titaniu	-	
Niobiur		
Others		
	nical properties	s at RT
	rield strength, R _r strength, R _m	N/mm ² /ksi N/mm ² /ksi
	tion, A ₅₀	%
Hardne		HV
Physic	al properties at	RT
-		g/cm ³
Density		q/ull
Therma	al conductivity	•
	al conductivity us of elasticity	W/m·K kN/mm ²
Modulu		W/m·K kN/mm ²
Modulu Deflect Electric	us of elasticity ion temperature cal resistivity	W/m·K kN/mm² °C μΩ·cm
Modulu Deflect Electric Specifi	us of elasticity ion temperature cal resistivity c heat	W/m·K kN/mm² °C μΩ·cm J/kg·K
Modulu Deflect Electric Specific	us of elasticity ion temperature cal resistivity c heat ient of thermal e	W/m·K kN/mm² °C μΩ·cm J/kg·K
Modulu Deflect Electric Specific	us of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 °	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 °	us of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific Detwee 50 ° 100 ° 150 ° 200 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflectric Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 350 ° 400 ° 425 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 300 ° 400 ° 425 ° 450 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modult Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 350 ° 400 ° 425 ° 450 ° 500 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 300 ° 400 ° 425 ° 450 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modult Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 350 ° 400 ° 425 ° 450 ° 500 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K kN/mm ² c μΩ · cm J/kg · K expansion
Modult Deflect Electric Specific betwee 50 ° 150 ° 200 ° 300 ° 350 ° 400 ° 425 ° 450 ° 550 ° 600 ° 700 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² °C μΩ · cm J/kg · K expansion C] and T 10 [*] /ł
Modulu Deflect Electric Specifi Dooffic betwee 50 ° 100 ° 200 ° 300 ° 300 ° 300 ° 400 ° 400 ° 400 ° 400 ° 500 ° 500 ° 600 ° 700 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² °C μΩ · cm J/kg · K expansion C] and T 10 [*] /ł
Modulu Deflect Electric Specifi Coeffic betwee 50 ° 100 ° 200 ° 300 ° 350 ° 400 ° 450 ° 500 ° 500 ° 600 ° 700 ° Coeffic betwee 200 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² °C μΩ · cm J/kg · K expansion C] and T 10 [*] /ł
Modulu Deflect Electric Specifi Coeffic betwee 50 ° 100 ° 200 ° 300 ° 400 ° 400 ° 400 ° 500 ° 500 ° 500 ° 500 ° 600 ° 700 ° Coeffic betwee 200 ° 300 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² °C μΩ · cm J/kg · K expansion C] and T 10 [*] /ł
Modulu Deflect Electric Specifi Coeffic betwee 50 ° 150 ° 200 ° 300 ° 350 ° 400 ° 500 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabricz:	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specifi Coeffic betwee 50° 150° 200° 300° 350° 400° 500° 500° 500° 600° 700° Coeffic betwee 200° 300°	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specifi Coeffic betwee 50° 150° 200° 300° 350° 400° 500° 500° 500° 600° 700° Coeffic betwee 200° 300° 450° 600° 700° Coeffic betwee 200° 300° Fabricz Melting	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 350 ° 400 ° 425 ° 450 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabrics Max. o Workat	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 300 ° 400 ° 425 ° 450 ° 550 ° 600 ° 550 ° 600 ° 700 ° 200 ° 300 ° 550 ° 600 ° 700 ° 700 ° 550 °	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 400 ° 425 ° 400 ° 425 ° 400 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabrica Melting Max. o Workat Filler m	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 °C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 400 ° 425 ° 400 ° 425 ° 400 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabrica Melting Max. o Workat Filler m	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 ° C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 400 ° 425 ° 400 ° 425 ° 400 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabrica Melting Max. o Workat Filler m	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 °C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specific betwee 50 ° 100 ° 150 ° 200 ° 300 ° 400 ° 425 ° 400 ° 425 ° 400 ° 550 ° 550 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabrica Melting Max. o Workat Filler m Materia	is of elasticity ion temperature cal resistivity c heat ient of thermal e en 20 °C [or 30 °C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k
Modulu Deflect Electric Specifi Coeffic betwee 50 ° 100 ° 200 ° 350 ° 425 ° 400 ° 425 ° 450 ° 550 ° 550 ° 600 ° 700 ° Coeffic betwee 200 ° 300 ° Fabric: Melting Max. o Workat Weldat Filler n Materi:	is of elasticity ion temperature c heat ient of thermal e en 20 °C [or 30 °C C C C C C C C C C C C C C C C C C C	W/m · K KN/mm ² C μΩ · cm J/kg · K expansion (C] and T 10 ⁻⁶ /k expansion and T 10 ⁻⁶ /k

Pernifer 42 TVR		Pernifer 46	
		46	
(1.3917)		1.3920	
(Ni 42)		NiCr 42-6	
_		17745	
-		385	
		_	
		– K94600	
		F 30 (alloy 46)	
		I-23011 (Class 4)	
41.0 - 43.0		45.0 - 46.5	
-		_	
Balance		Balance	
≤ 0.02		≤ 0.10 ≤ 0.80	
≤ 0.1 ≤ 0.1		≤ 0.80 ≤ 0.50	
-		-	
-		_	
-		-	
-		-	
≤ 2.4 ≤ 0.4		_	
		_	
soft annealed		_ soft annealed	
deep drawing quality	50% cold formed	deep drawing quality	50% cold formed
≥ 340 / ≥ 49.3	≥ 830 / ≥ 120.4	≥ 250 / ≥ 36.3	≥ 770 / ≥ 111.7
≥ 660 / ≥ 95.7	≥ 1150 / ≥ 166.8	≥ 510 / ≥ 74.0	≥ 780 / ≥ 113.1
≥ 34	≥ 14	≥ 30	≥ 3
160	340	135	240
8.1		8.2	
-		15	
-		152	
270		460 60	
_		500	
Values are applicable t	o the soft annealed	Values are applicable to	the soft annealed
condition only		condition only	ASTM F 30
3.7		8.4	
5.7		0.4	
4.1		8.0	
5.3		7.1 - 8.4 spec. in DIN 17745	[7.5] typical
			[7.1 - 7.8] specified
7.6		7.4	[7.5] typical
9.2		8.4	[8.2 - 8.9] specified
10.4		9.6	[9.8] typical
			[10.7] typical
1450 (liquidus)		≈ 1440	
-			
good		good	
satisfactory		satisfactory	
matching		matching	
High mechanical stren	gth with low thermal	Low thermal expansio	n up to 450 °C.
expansion.			
TV frames.		Glass seals especially w for metal to ceramic sea	ith soft glasses and
		for metal to ceramic sea	ing applications.

Expansion special alloys with low, adjusted coefficients of thermal expansion

Thys	senKrupp VDM Tra	demark
Alloy	nations and stand	larde
	-	
D	Werkstoff-No.	
	Designation	
	DIN, [DIN EN]	
F	SEW	
	AFNOR RS designation	
UK USA	BS designation UNS designation	
USA	ASTM	
	SAE AMS	
Chen	nical composition	0/0
Nicke		
Chror		
Iron		
Carbo	n	
	anese	
Silico		
Copp		
	denum	
Coba		
Alumi		
Titani	-	
Niobi	-	
Other		
	anical properties a	at PT
	yield strength, R _{p0.2}	N/mm ² /ksi
	le strength, R _m	N/mm ² / ksi
	ation, A_{50}	%
Hardr	iess	HV
Phys	ical properties at F	रा
Densi		g/cm ³
	nal conductivity	W/m·K
	lus of elasticity	kN/mm ²
	ction temperature	<u> </u>
	ical resistivity	μΩ·cm
- · · ·	fic heat	J/kg·K
	icient of thermal exp een 20 °C [or 30 °C]	
50		
100		
150		
200		
300		
350		
400		
425		
450		
500		
550	°C	
600		
700		
Coeff	°C	
Coeff betwe	°C icient of thermal exp een 77 °F (25 °C) ar	
Coeff betwe 200	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C)	
Coeffi betwee 200 300	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C)	
Coeffi betwee 200 300	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C)	
Coeffi betwee 200 300 Fabri	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C)	
Coeffi betwe 200 300 Fabri Meltir	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation	nd T 10 ⁻⁶ /°F
Coeffi betwe 200 300 Fabri Meltir	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation ng temperature operating temperatu	nd T 10 ⁻⁶ /°F
Coeff betwe 200 300 Fabri Meltir Max.	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation ng temperature operating temperatura ability	nd T 10 ⁻⁶ /°F
Coeffi betwe 200 300 Fabri Meltir Max. Worka	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation Ing temperature operating temperature ability ability	nd T 10 ⁻⁶ /°F
Coeffi betwe 200 300 Fabri Meltir Max. Worka Worka Filler	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation ng temperature operating temperature ability ability metal	nd T 10 ⁻⁶ /°F
Coeffi betwe 200 300 Fabri Meltir Max. Worka Worka Filler	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation Ing temperature operating temperature ability ability	nd T 10 ⁻⁶ /°F
Coeffi betwe 200 300 Fabri Meltir Max. Worka Worka Filler	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation ng temperature operating temperature ability ability metal	nd T 10 ⁻⁶ /°F
Coeffi betwee 200 300 Fabri Meltir Max. Worka Worka Filler Mate	°C icient of thermal exp een 77 °F (25 °C) ar °F (93 °C) °F (149 °C) cation ng temperature operating temperature ability ability metal	nd T 10 ⁻⁶ /°F

Pernifer 48		Pernifer 50
48		52
1.3922		2.4478
Ni 48		NiFe 47
17745		17745
385		385
Fe-Ni 48		Fe-Ni 50.5
-		-
K94800		N14052
F 30 (alloy 48)		F 30 (alloy 52)
I-23011 (Class 3)		I-23011 (Class 2)
		DIN 17745
46.0 - 49.0		50.0 - 51.0
-		≤ 0.25
Balance		Balance
≤ 0.05		≤ 0.01
≤ 0.50		≤ 0.5
≤ 0.30		≤ 0.1
_		-
_		-
_		-
≤ 0.10		≤ 0.10
-		-
_		-
-		-
soft annealed	FO () and a lab for some of	soft annealed
deep drawing quality	50% cold formed	deep drawing quality
≥ 280 / ≥ 40.6	≥ 700 / ≥ 101.5	≥ 240 / ≥ 34.8
≥ 530 / ≥ 76.9	≥ 750 / ≥ 108.8	≥ 540 / ≥ 78.3
≥ 30	≥ 4	≥ 30
125	220	135
0.7		0.7
8.3 15.9		8.3 16.8
164		16.0
465		520
50		44
500		500
Values are applicable to	the soft annealed	Values are applicable t
condition only	ASTM F 30	condition only
		,
9.8	[9.2] typical	11.0
9.2	[9.0] typical	11.6
8.8	[8.8] typical	10.4
8.3 - 8.9 spec. in DIN 17745	[8.2 - 9.2] specified	9.7-10.5 spec. in DIN 17745
	reim eiml eheeninge	9.7-10.3 spec. III DIN 17743
	[]	9.7-10.5 spec. III DIN 17745
	[] -p	3.7-10.3 spec. in Div 17743
9.1	[9.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified	
9.1	[9.4] typical [9.6-10.3] specified [10.4] typical	
-	[9.4] typical [9.6-10.3] specified	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
-	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0
10.2	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0 10.9
10.2 ≈ 1440	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0 10.9
10.2 ≈ 1440 good	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0 10.9 ≈ 1445 good
10.2 ≈ 1440	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0 10.9 ≈ 1445
10.2 ≈ 1440 good satisfactory	[9.4] typical [9.6-10.3] specified [10.4] typical	10.0 10.9 ≈ 1445 good satisfactory
10.2 ≈ 1440 good satisfactory matching	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical	10.0 10.9 ≈ 1445 good satisfactory matching
10.2 ≈ 1440 good satisfactory	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical	10.0 10.9 ≈ 1445 good satisfactory
10.2 ≈ 1440 good satisfactory matching	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical	10.0 10.9 ≈ 1445 good satisfactory matching
10.2 ≈ 1440 good satisfactory matching	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical	10.0 10.9 ≈ 1445 good satisfactory matching
10.2 ≈ 1440 good satisfactory matching Low thermal expansio Glass seals especially w	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical n up to 450 °C.	10.0 10.9 ≈ 1445 good satisfactory matching Constant thermal expansion Glass seals especially
10.2 ≈ 1440 good satisfactory matching Low thermal expansio	[9.4] typical [9.6-10.3] specified [10.4] typical [11.3] typical n up to 450 °C.	10.0 10.9 ≈ 1445 good satisfactory matching Constant thermal expansion

Pernifer 50 52	
52	
0.4450	
2.4478	
NiFe 47	
17745	
385	
Fe-Ni 50.5	
_	-
N14052	
F 30 (alloy 52)	
I-23011 (Class 2)	
DIN 17745	
50.0 - 51.0	
≤ 0.25	
Balance	
≤ 0.01	
≤ 0.5	
≤ 0.1	
-	
-	
-	
≤ 0.10	
-	
-	
-	
soft annealed deep drawing quality	50% cold formed
≥ 240 / ≥ 34.8	≥ 810 / ≥ 117.5
≥ 540 / ≥ 78.3	≥ 820 / ≥ 118.9
≥ 30	≥ 3
135	250
100	200
0.7	
8.3	
16.8	
160	
520	
44	
500	
	the coff oppooled
Values are applicable to	ASTM F 30
condition only	ASTHE SU
11.0	[10.2] typical
	1
11.6	[10.1] typical
10.4	[10.1] typical
0.710 5	[0, 0] h/=:==1
9.7-10.5 spec. in DIN 17745	[a.a] typical
	[9.7-10.2] specified
10.0	[9.9] typical
	[10.0-10.5] specified
10.9	[10.8] typical
	[11.7] typical
~ 1445	
≈ 1445	
good	
satisfactory	
matching	
Constant thermal expa	nsion up to 500 °C
constant thermal expa	naion up to 300 °C.
Class or -l	with a feature of the state
Glass seals especially glasses and for metal	to ceramic soaling
applications. Reed rela	ays.

Expansion special alloys with low, adjusted coefficients of thermal expansion

ThyssenKrupp VDM Trad Alloy	emark
Designations and standa	rds
D Werkstoff-No.	
Designation	
DIN, [DIN EN]	
SEW	
F AFNOR	
UK BS designation USA UNS designation	
ASTM	
SAE AMS	
Chemical composition %	
Nickel	
Chromium	
Iron	
Carbon	
Manganese Silicon	
Copper	
Molybdenum	
Cobalt	
Aluminium	
Titanium	
Niobium	
Others	
Mechanical properties at	RT
0.2% yield strength, R _{p0.2}	N/mm ² / ksi
Tensile strength, R _m	N/mm ² / ksi
Elongation, A ₅₀	%
Hardness	HV
Physical properties at RT	
Density	g/cm ³
Thermal conductivity	W/m⋅K
Modulus of elasticity	kN/mm ²
Deflection temperature	°C
Electrical resistivity Specific heat	µΩ · cm J/kg · K
Coefficient of thermal expa	
between 20 °C [or 30 °C] a	
50 °C	
100 °C	
150 °C	
200 °C 300 °C	
400 °C	
450 °C	
500 °C	
500 °C 550 °C 600 °C	
500 ℃ 550 ℃ 600 ℃ 700 ℃	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C)	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C)	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C)	
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C)	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperatur	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability Weldability	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expa between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperatur Workability Weldability	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability Weldability Filler metal	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability Weldability Filler metal Material description	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability Weldability Filler metal	°C
500 °C 550 °C 600 °C 700 °C Coefficient of thermal expandence between 77 °F (25 °C) and 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature Max. operating temperature Workability Weldability Filler metal Material description	°C

Pernifer 51 51		Pernifer 2918	
2.4475		1.3981	
NiFe 46		NiCo 29 18	
17745		17745	
385		385	
Fe-Ni 51.5		-	
_		-	
-		K94610	
F 30 (alloy 51)		F 15	(0) 1)
-		7726 - 7728, I-23011	(Class 1)
510 520		28.0 - 30.0	
51.0 - 52.0		≤ 0.10	
Balance		Balance	
≤ 0.01		≤ 0.05	
≤ 0.1		≤ 0.50	
≤ 0.1		≤ 0.30	
_		-	
-		-	
-		16.0 - 18.0	
-		-	
-		-	
-		-	
-		-	
soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed
≥ 240 / ≥ 34.8	≥ 810 / ≥ 117.5	≥ 380 / ≥ 55.1	≥ 660 / ≥ 95.7
		≥ 440 / ≥ 63.8	≥ 720 / ≥ 104.4
≥ 540 / ≥ 78.3 ≥ 30	≥ 820 / ≥ 118.9 ≥ 3		
135	250	≥ 25 150	≥ 5 220
155	250	150	220
8.3		8.2	
16.8		17.5	
155		160	
520		425	
44		49	
500		500	
Values are applicable	to the soft annealed	Values are applicable to	
condition only	ASTM F 30	condition only	ASTM F 15
10.5	[10.2] typical	6.3	[5.8] typical
10.0	[10.2] ()picui		[oro] () prodi
10.4	[10.1] typical	5.8	[5.4] typical
10.3	[10.2] typical	5.3	[5.1] typical
9.8-10.6 spec. in DIN 17745		4.6-5.6 spec. in DIN 17745	[4.6-5.2] specified
	[9.9-10.5] specified		[5.1-5.5] specified
10.0	[10.1] typical	6.1	[6.1] typical
	[10.0-10.7] specified		[6.8] typical
10.7	[11.0] typical	7.8	[7.5] typical
	[11.9] typical		
≈ 1445		≈ 1450	
		≈ 700	
good		good	
satisfactory		satisfactory	
matching		matching	
Constant thermal exp	ansion up to 500 °C	Very low thermal expa	uncion un to 450 °C
20and arennal exp	up to 000 0.	A martensite-free stru	cture is attainable
		down to -196 °C (-320	
Glass seals especiall	y with soft and lead	Glass seals especially	with hard glasses
glasses and for meta	I to ceramic sealing	and for metal to ceram	ic sealing applica-
applications. Reed re	lays.	tions. X-ray tubes. Sha nents. Mountings.	pe-etcned compo-

Expansion special alloys with low, adjusted coefficients of thermal expansion

	senKrupp VDM Tra	demark
Alloy	unotions and sta	larda
Desig	mations and stand	lafus
U	Designation	
	DIN, [DIN EN]	
	SEW	
F	AFNOR	
	BS designation	
USA	UNS designation	
	ASTM SAE AMS	
Chem	nical composition of	0/0
Nicke		
Chror	nium	
Iron		
Carbo		
	anese	
Silico		
Copp		
Coba	odenum	
Alumi		
Titani	-	
Niobi		
Other	S	
Mech	anical properties a	at RT
0.2%	yield strength, R _{p0.2}	N/mm ² / ksi
	le strength, R _m	N/mm ² / ksi
	ation, A ₅₀	%
Hardr	ness	HV
Physi	ical properties at F	RT
Densi	ty nal conductivity	g/cm³ W/m·K
	lus of elasticity	kN/mm ²
	ction temperature	°C
	ical resistivity	μΩ·cm
	fic heat	J/kg·K
betwee 50 100 200 300 350 400 425 450 550 600 700 Coeffi betwee 200 300	°C °C °C °C °C °C °C °C °C °C °C °C °C	and T 10 ⁻⁶ /K
	°F (371 °C)	
		00
	ng temperature	°C ure °C
Max. Worka	operating temperat	
Worka		
Filler		
mate	rial description	
Туріс	al applications	

Pernifer 4205 Ti	,	Pernifer 4206		
		1.3946		
– (NiCr 42-5-2)		NiCr 42-6		
-		17745		
-		385		
_		Fe-Ni 42 Cr 6		
- N00002		– K94760		
N09902		F 31		
5221, 5223, 5225		I-23011 (Class 6)		
		DIN 17745		
42.0 - 43.5		41.0 - 43.0		
5.0 - 5.8		5.0 - 6.0		
Balance		Balance		
≤ 0.05		≤ 0.07		
≤ 0.6		≤ 0.50 ≤ 0.30		
<u>≤ 1.0</u>		-		
_		-		
-		16.0 - 18.0		
≤ 0.8		≤ 0.20		
2.0 - 3.0		_		
_		_		
soft annealed		soft annealed		
deep drawing quality	50% cold formed	deep drawing quality	50% cold formed	
≥ 340 / ≥ 49.3	≥ 900 / ≥ 130.5	≥ 240 / ≥ 34.8	≥ 720 / ≥ 104.4	
≥ 440 / ≥ 63.8 ≥ 25	≥ 1000 / ≥ 145.0 ≥ 5	≥ 440 / ≥ 63.8 ≥ 30	≥ 750 / ≥ 108.8 ≥ 3	
170	240	140	280	
0.0		0.2		
8.2 11.8		8.2 12.5		
-		159		
_		295		
100		95		
– Values are applicable t	a the coft appealed	500 Values are applicable to	a the coft appealed	
condition only	o the solt annealed	condition only	ASTM F 31	
8.4 [8.2]		7.4		
10.1 [10.1]		7.3		
12.2 [12.2]		8.3	[7.9] typical	
			[8.5 - 9.2] specifie	
13.6 [13.6]		9.6-10.4 spec. in DIN 17745		
14.4 [14.4]		[10.6]	[9.7-10.4] specifie	
14.4 [14.4]		11.3	[11.2] typical	
		-	1 1 7 1	
15.0 [15.1]		12.4	[12.1] typical	
			[13.0] typical	
1440		≈ 1440		
good		good		
satisfactory		satisfactory		
matching		matching		
Temperature-constant :	spring characteristics.	Thermal expansion adjust	ted to the type of glass	
Alloy with relative const				
Weighing machine co Mechanical filters.	mponents.	Glass seals especially w for metal to ceramic sea		
		TV-tube glass seals. Fla		

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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			
JK BS designation	Fe-INI 47 Cr b					
JSA UNS designation	-					
ASTM	-		-			
SAE AMS	-		-			
SAE AMS	-		-			
Chemical composition %						
Nickel	40.0 40.0		510 520			
Chromium	46.0 - 48.0		51.0 - 52.0			
ron	5.5 - 6.5		1.0 - 1.3			
Carbon	Balance		Balance			
Manganese	≤ 0.02		≤ 0.01			
Silicon	≤ 0.3		≤ 0.6			
	≤ 0.30		≤ 0.15			
Copper	-		_			
1olybdenum Sobalt	-		-			
Cobalt	-		-			
Aluminium	-		-			
Fitanium	-		-			
Niobium	-		-			
Others	-		-			
Mechanical properties at RT	soft annealed deep drawing quality	50% cold formed	soft annealed deep drawing quality	50% cold formed		
) 2% yield strength P N/mm ² /kei	≥ 200 / ≥ 29.0	≥ 930 / ≥ 134.9	$\geq 250 / \geq 36.3$	≥ 790 / ≥ 114.6		
0.2% yield strength, $R_{p0.2}$ N/mm ² /ksi Tensile strength, R_m N/mm ² /ksi						
	≥ 500 / ≥ 72.5	≥ 950 / ≥ 137.8	≥ 550 / ≥ 79.8	≥ 800 / ≥ 116.0		
Elongation, A ₅₀ %	≥ 35	≥ 3	≥ 30	≥ 3		
lardness HV	120	280	135	250		
hysical properties at RT						
Density g/cm ³	8.1		8.3			
Thermal conductivity W/m·K	14		17			
Modulus of elasticity kN/mm ²	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 condition only	to the soft annealed	Values are applicable t condition only	to the soft annealed		
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 ir	ו DIN 17745		
425 °C						
450 °C						
430 ℃ 500 °C	11.6		10.5			
550 °C	11.0		10.0			
550°C 600 °C	12.5		10.5			
700 °C	12.5		10.5			
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)						
abrication						
1elting temperature °C	≈ 1450		≈ 1440			
fax. operating temperature °C	1400		- 1440			
	good		good			
Vorkability Valdability	good		good			
Veldability	satisfactory		satisfactory			
iller metal	matching		matching			
Aterial description						
Typical applications	Thermal expansion adjus	ted to the type of glass.	Constant thermal expa	insion up to 450 °C.		
Joined applications						
	Glass seals especially glasses and for metal	with soft and lead	Glass seals especially overvoltage protection			

Expansion special alloys with very high coefficients of thermal expansion

ThyssenKrupp VDM Trademark Alloy **Designations and standards** D Werkstoff-No. Designation DIN, [DIN EN] SEW F AFNOR IJΚ BS designation USA UNS designation ASTM SAE AMS Chemical composition % Nickel Chromium Iron Carbon Manganese Silicon Copper Molybdenum Cobalt Aluminium Titanium Niobium Others Mechanical properties at RT 0.2% yield strength, $R_{\scriptscriptstyle p0.2}$ N/mm² / ksi Tensile strength, R_m N/mm²/ksi Elongation, A₅₀ % Hardness ΗV Physical properties at RT Density g/cm³ Thermal conductivity W/m·K Modulus of elasticity kN/mm² Deflection temperature °C $\mu\Omega\cdot cm$ Electrical resistivity Specific heat J/kg ⋅ K Coefficient of thermal expansion between 20 °C and T 10-6/K 50 °C 100 °C 150 °C 200 °C 300 °C 400 °C 450 °C 500 °C 550 °C 600 °C Coefficient of thermal expansion 10⁻⁶/°F between 77 °F (25 °C) and T 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication Melting temperature °C Max. operating temperature °C Workability Weldability Filler metal Material description **Typical applications**

Pernifer 1407 Pei 1.3 1.3930 Ni№ X60 NiMn 14-7 (Thermobimetalle: 1715-1) _ 385 -В7 SEW 385 12.5 - 14.5 19 2 Bal Balance 0.55 - 0.65 0 ≤ 1. 6.0 - 7.0 ≤ 0 ≤ 1.0 --sof dee soft annealed deep drawing quality 50% cold formed $\geq 230 \: / \geq 33.4$ $\geq 1150 \ / \geq 166.8$ ≥ 590 / ≥ 85.6 ≥ 1200 / ≥ 174.0 ≥ 30 > 5 130 300 8.0 1 13 196 A deflection temperature does not exist for this alloy. 78 73 Val Values are applicable to the soft annealed cor condition only 20 19.4 20. 20.3 20 20.8 20 21.1 Val cor ≈ 1420 146 Hig High thermal expansion. Active thermostat bimetal component. Act Thermostat bimetal designations in

DIN 1715-1: TB 1170 and TB 1577.

	•	
nifer 2002		
933		
1n 20		
'53 (T-19)		
	ASTM B 753 (T-19)	
.5 - 21.5	19.0 nominal	
.0 - 3.0	2.0 nominal	
ance .50 - 0.65	Balance 0.5 nominal	
.50	1.0 nominal	
.30	≤ 0.40	
	-	
	_	
	-	
	-	
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t annealed p drawing quality		
3.0		
-		
3		
ues are applicable t	beleanne tha soft annealed	
idition only	o the solit annealed	
5		
-		
7 8		
8		
0		
ues are applicable to Idition only	ASTM B 753 (T-19)	
,	20.0 typical	
	$19.4 \pm 4\%$ specified	
	20.2 typical	
	20.2 typical	
60 (liquidus)		
h thermal expansion	on.	
ive thermostat bim	etal component	
	- in componenti	

Expansion special alloys with very high coefficients of thermal expansion

ThyssenKrupp VDM Trade Alloy	emark	Pernifer 2006		Pernifer 2203	
Designations and standar	rds				
D Werkstoff-No.		1.3932		1.3942	
Designation		NiMn 20-6		X15 NiCr 22-3	
DIN, [DIN EN]		(Thermobimetalle: 17	15-1)	-	
SEW		(385)	15-1)	385	
F AFNOR		-		-	
UK BS designation		_		_	
USA UNS designation		-		-	
ASTM				B 753 (T-22)	
SAE AMS				D 733 (1-22)	
SAE AMS					
Chemical composition %					ASTM B 753 (T-22)
Nickel		20.0 - 21.0		21.0 27.0	22.0 nominal
Chromium				21.0 - 23.0 2.5 - 3.5	22.0 nominal 3.0 nominal
Iron					Balance
Carbon		Balance ≤ 0.10		Balance ≤ 0.20	0.12 nominal
Manganese		5.5 - 7.0		≤ 0.20 ≤ 0.50	≤ 0.60
Silicon					
Copper		≤ 0.30 -		≤ 0.50 -	≤ 0.30 -
Molybdenum		_		_	_
Cobalt				_	_
Aluminium		≤ 0.30 			
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	≥ 170 / ≥ 24.7		≥ 200 / ≥ 29.0	≥ 800 / ≥ 116.0
Tensile strength, R _m	N/mm ² /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					
	g/cm ³	8.1		0.0	
Density Thermal conductivity	g/cm ^o W/m·K	13		8.2	
Thermal conductivity	W/m·K kN/mm ²	196			
Modulus of elasticity			oc not ovict for this allow	186	and water to the second to the
Deflection temperature	<u> </u>	A deflection temperature de	Des HULEXISCIUF UNS AllOY.	A deflection temperature d	ues not exist for this alloy.
Electrical resistivity	μΩ·cm	/8		77	
Specific heat	J/kg·K		o the coft or readed	-	
Coefficient of thermal expanded between 20 °C and T 10 ⁻⁶		Values are applicable t condition only	o the soft annealed	Values are applicable condition only	to the soft annealed
50 °C				contaction only	
100 °C		20.1		19.3	
150 °C				10.0	
200 °C		20.6		19.8	
300 °C		20.9		19.8	
400 °C		21.0		19.9	
400 °C		21.0		19.9	
450°C 500°C		21.1		19.9	
550 °C		L		13.3	
550 °C 600 °C		21.2		10.0	
	ncion	21.2		19.9	to the coft operated
Coefficient of thermal expanded between 77 °F (25 °C) and	nsion T 10 ⁻⁶ /°F			Values are applicable condition only	to the soft annealed ASTM B 753 (T-22)
200 °F (93 °C)	. 10/1			contaction only	19.3 typical
300 °F (149 °C)					19.35±4.5% specified
500 °F (260 °C)					19.55±4.5% specified 19.6 typical
500 °F (260 °C) 700 °F (371 °C)					19.6 typical 19.6 typical
Fabrication					
Melting temperature	°C	≈ 1440		≈ 1460	
Max. operating temperature		-			
Workability					
Weldability					
Filler metal					
Material description					
		High thermal expansi	on.	High thermal expansi	ion.
				g internal expanse	
Turning any light					
Typical applications					
		Active thermostat bin	netal component.	Active thermostat bin	netal component.
		L		L	

Expansion special alloys with very high coefficients of thermal expansion

ThyssenKrupp VDM Trademark Pernifer 2 Alloy **Designations and standards** 1.3902 D Werkstoff-No. Designation X15 NiCr DIN, [DIN EN] SEW F AFNOR BS designation UK USA UNS designation B 753 (T-ASTM SAE AMS **Chemical composition %** Nickel 24.5 - 25 Chromium 8.2 -Iron Balance Carbon ≤ 0.03 Manganese ≤ 0.9 Silicon ≤ 0.5 Copper Molybdenum Cobalt Aluminium Titanium Niobium Others soft annea Mechanical properties at RT deep draw 0.2% yield strength, $R_{\scriptscriptstyle p0.2}$ N/mm² / ksi ≥ 250 / ≥ Tensile strength, R_m N/mm²/ksi \geq 550 / \geq Elongation, A₅₀ % ≥ 30 ΗV ≥ 135 Hardness Physical properties at RT g/cm³ Density Thermal conductivity W/m·K Modulus of elasticity kN/mm² °C Deflection temperature μΩ·cm 86 Electrical resistivity Specific heat J/kg ⋅ K Coefficient of thermal expansion Values are between 20 °C and T 10-6/K condition 50 °C 100 °C 18.9 150 °C 200 °C 18.9 300 °C 19.0 400 °C 19.1 450 °C 500 °C 550 °C 600 °C Coefficient of thermal expansion Values are between 77 °F (25 °C) and T 10⁻⁶/°F condition 200 °F (93 °C) 300 °F (149 °C) 500 °F (260 °C) 700 °F (371 °C) Fabrication °C 1430 (liqu Melting temperature Max. operating temperature °C Workability Weldability Filler metal Material description High therr **Typical applications** Active the

	0		
2508		Pernima 72	
		0.0705)	
~~ 7		2.6305)	
22-3		MnCuNi	
		(Thermobimetalle:	1715-1)
		-	
		_	
		-	
25)		M27200	0)
25)		(B 388), B 753 (T-1	10)
	ASTM B 753 (T-25)		ASTM B 753 (T-10)
5.5	25.0 nominal	9.0 - 11.0	10.0 nominal
8.8	8.0 nominal	-	≤ 0.25
	Balance	≤ 0.2	≤ 1.0
	≤ 0.15	≤ 0.10	≤ 0.1
	≤ 1.0	Balance	72.0 nominal
	≤ 1.0	≤ 0.2	≤ 0.25
	-	17.0 - 19.0	18.0 nominal
	-	_	-
	-	-	-
	-	-	-
	_	_	_
	_	_	_
	-	-	-
aled /ing quality	50% cold formed	soft annealed deep drawing quality	1
		deep drawing quality	1
36.3	≥ 790 / ≥ 114.6		
79.8	≥ 800 / ≥ 116.0		
	≥ 3		
	≥ 250	≥ 130	
		7.2	
		8.5	
		0.0	
		-	
		176	
		-	
	to the soft annealed		e to the soft annealed
only		condition only	
		20.0	
		26.8	
		28.4	
		29.5	
		30.1	
		31.7	
		32.7	
	to the soft annealed		e to the soft annealed
only	ASTM B 753 (T-25)	condition only	ASTM B 753 (T-10)
	17.6 typical		27.2 typical
	$17.6 \pm 4\%$ specified		27.7 ±4% specified
	18.0 typical		28.1 typical
	18.2 typical		29.9 typical
uidus)		≈ 1120	
_			
mal expansi	on.	Very high thermal e	expansion.
rmostat bin	netal component.	Active thermostat b Thermostat bimetal	imetal component. I designation in DIN
		1715-1: TB 20110.	

1	51011	20
1		
		_

Conversion factors.

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

To convert from	to	multiply by	
Mass: SI unit – kg			
kg	pound (Ib avoirdupois)	2.2046	
lb (avoirdupois)	kg	4.536 x 10 ⁻¹	
ton (short, 2000 lbs)	kg	9.07185 x 10 ²	
kg	ton (short)	1.102 x 10 ⁻³	
lbs/in. coil width	kg/mm coil width	1.78549 x 10 ⁻²	
kg/mm coil width	lbs/in. coil width	5.6007 x 10	
Length: SI unit – meter (m) = 100 cm			
m	inches (in.)	3.937 x 10	
m	feet (ft)	3.281	
mm	in.	3.937 x 10 ⁻²	
mm	mils	3.937 x 10	
mils	mm	2.54 x 10 ⁻²	
mils	μm	25.4	
in.	mm	25.4	
ft	m	0.305	
		0.000	
Density: kg/m ³ = g/cm ³ x 10 ⁻³			
g/cm ³	lb/in. ³	3.613 x 10 ⁻²	
kg/m³	lb/in. ³	3.613 x 10⁻⁵	
lb/in. ³	g/cm ³	2.77 x 10	
lb/in. ³	kg/m ³	2.77 x 10 ⁴	
Specific heat: $kJ / kg \cdot K = J \times 10^3 / k$	kg ∙ K; cal. / g ∙ K = Btu / Ib ∙ °F		
calorie (cal.)	joule (J)	4.187	
joule	Btu (British thermal units)	9.486 x 10 ⁻⁴	
Btu	J	1.055056 x 10 ³	
cal. / g • K	kJ / kg • K	4.187	
Thermal conductivity: watt (W) / m •	К		
Btu • in. / ft² • h • °F	W / m • K	1.4422 x 10 ⁻¹	
W/m•K	Btu • in. / ft ² • h • °F	6.9339	
Electrical resistivity: μohm (Ω) • cm			
Ω • circ mil / ft	μΩ•cm	1.662426 x 10 ⁻¹	
$\mu \Omega \cdot cm$	$\Omega \cdot \operatorname{circ} \operatorname{mil} / \operatorname{ft}$	6.015305	
Coefficient of thermal expansion: µr		0.010000	
um/m • K	µin./in. • °F	0.5555	
µin./in. • °F	μm/m • K	1.8	
	tance and stress: N/mm ² ; pound-force (lbf)/in. ² (ps		
ksi (= psi x 10 ³)	N/mm ²	6.8964	
N/mm ²	psi	1.45003 x 10 ²	
Magnetic conversion factors:	par	1.45000 X 10	
-	Weber (Wb)/m ² = Tesla (T)	10-4	
Gauss (G) Oersted (Oe)	Ampere (A)/m	7.9577 x 10	
A/m	Oe		
A/m A/m	A/cm	1.2566 x 10 ⁻² 10 ⁻²	
A/m G/Oe	A/cm Wb/A • m	1.2566 × 10 ⁻⁶	
Wb/A • m	G/Oe	7.9577 x 10 ⁵	
	G/08	1.33/1 X 10	
Temperature: SI unit - Kelvin (K)			
Temperature: SI unit - Kelvin (K) K to degrees Celcius (°C): subtract 275	3		
K to degrees Celcius (°C): subtract 27	v by 9/5 and add 32		

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

Imprint.

Pernifer and Pernima alloys

Alloys with special thermal expansion characteristics.

Publisher:

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