11 Materials and material selection

11.1 Materials

The materials which are suitable for pump construction are listed in the following overview 11.2 to 11.8.

The material overview 11.2 for iron and non-ferrous materials is based on the European Standard.

Additionally the superseded comparable national standards DIN and SEW are listed. This is intended to ease the comparison with the old national and the new European standards.

Materials which do not currently have a European standard are listed under the still valid DIN and SEW standards.

Where comparable, the American standards ASTM are also listed. It should be noted however that comparable materials are not similar in all details. Both the chemical analysis and mechanical properties may vary, but generally this should have no importance with respect to their use for pump materials. In borderline cases an exact comparison should be made.

Abbreviations

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
DIN	German Standards Institute
EN	European Standard published by the European Standards Committee CEN
SEW	Steel and Iron Material Publications published by the German Iron & Steel Association
UNS	Unified Numbering System (USA)

Designation

A	Elongation at failure ($L_0 = 5\ d_0$)
KV	Notch impact (ISO-V test) at 20°C, or given temperature
R_m	Tensile strength
$R_{p\,0,2}$	0,2% - Elongation limit at 20°C, for some materials the 0,1% limit or the 1% limit is given

11.2 Material overview - Cast iron and steel

European Standard - EN			German Standard - DIN			USA - Standard	
Material	Short name or description	Standard	Material	Short name or description	Standard	ASTM	UNS
Grey cast iron (flake)							
EN-JL2030	EN-GJL-HB195 [1]	1561	0.6022	GG-190 HB	1691	A 48 30	F 12101
EN-JL1040	EN-GJL-250 [2]	1561	0.6025	GG-25	1691	A 278 30	F 12401
Spheroidal graphite cast iron							
EN-JS1015	EN-GJS-350-22-LT	1563	0.7033	GGG-35.3	1693-1		
EN-JS1020	EN-GJS-400-18	1563	0.7043	GGG-40.3	1693-1	A 395 [2]	
EN-JS1030	EN-GJS-400-15	1563	0.7040	GGG-40	1693-1	A 536 60-40-18 [1]	
Austenitic cast iron							
			0.6656	GGL-NiCuCr 15 6 3	1694	A 436 1b	
			0.7661	GGG-NiCr 20 3	1694	A 439 D-2B	
Abrasion resistant cast iron							
EN-JN2029	EN-GJN-HV 520	12513	0.9620	G-X260 NiCr 4 2	1695	A 532 IB NiCr-LC	
EN-JN2049	EN-GJN-HV 600	12513	0.9630	G-X300 CrNiSi 9 5 2	1695	A 532 ID Ni-Hi-Cr	
High alloy cast iron (silicium)							
			(023 0) [6]	G-X70 Si 15		A 518 1	
			(024 0) [6]	G-X90 SiCr 15 5		A 518 3	
Low temperature cast steel							
1.5422	G18Mo5	10213-3				A 352 LCB	J 03003
1.5638	G9Ni14	10213-3				A 352 LC3	J 31500
Heat resisting cast steel							
1.0619	GP240GH	10213-2	1.0619	GS-C25	17 245	A 216 WCB	J 03002

1) for internal casings, impellers, guide vanes etc. 2) for casings subject to pressure 6) in house material code

Material number	Chemical analysis (Sample from melt analysis) % by weight						Mechanical properties (guide values)				Density ca.
							R_m	$R_{p\,0,2}$	A	KV	
	C	Cr	Ni	Mo	Cu	Other	N/mm²	N/mm²	%	J (t°C)	kg/dm³
Grey cast iron (flake)											
EN-JL2030	3.3					Si 2.0	250 - 350	165-228[3)]	HB30=120-195 [7)]		7.20
EN-JL1040	3.3					Si 2.0	250 - 350	165-228[3)]			7.20
Spheroidal graphite cast iron											
EN-JS1015	min. 3.0					Si max. 2.5	350	220	22	12 (-40°)	7.1
EN-JS1020	min. 3.0					Si max. 2.5	400	250	18	12 (-20°)	7.1
EN-JS1030	3.6					Si 2.2	400	250	15		7.1
Austenitic cast iron											
0.6656	max. 3.0	2.5-3.5	13.5-17.5		5.5-7.5		190				7.4
0.7661	max. 3.0	2.5-3.5	18.0-22.0				390	210	7		7.4
Abrasion resistant cast iron											
EN-JN2029	2.5-3.0	1.5-3.0	3.0-5.5			Si max. 0.8		Vickers-		HV min. 520	7.7
EN-JN2049	2.5-3.5	8-10	4.5-6.5			Si max. 2.5		hardness		HV min. 600	7.7
High alloy cast iron (silicium)											
(023 0) [6)]	0.70				1.0	Si 15.0	120				7.1
(024 0) [6)]	0.90	5.0			1.0	Si 15.0	120				7.1
Low temperature cast steel											
1.5422	0.15-0.20			0.45-0.65			440-790	240	23	27 (-45°)	7.85
1.5638	0.06-0.12		3.0-4.0				500-650	360	20	27 (-90°)	7.85
Heat resisting cast steel											
1.0619	0.18-0.23					Mn 0.5-1.2	420-600	240	22	27 (RT)	7.85

1 N/mm² equals 1 Mpa 3) 0.1% elongation limit 6) in house material code 7) for reference wall thickness from 40 to 80 mm

11.2 Material overview - Cast steel (cont.)

European Standard - EN			German Standard - DIN			USA - Standard	
Material number	Short name or description	Standard	Material number	Short name or description	Standard	ASTM Standard, Grade, Type	UNS
Stainless steel							
Martensitic steel							
1.4008	GX7CrNiMo12-1	5)	1.4008	G-X8 CrNi 13	17 445	A 217, 743 CA 15	J 91150
1.4317	GX4CrNi13-4	"				A 743 CA 6NM	J 91540
Austenitic steel							
1.4308	GX5CrNi19-10	5)	1.4308	G-X6 CrNi 18 9	17 445	A 351,743,744 CF 8	
1.4309	GX2CrNi19-11	"				A 351,743,744 CF 3	J 92900
1.4408	GX5CrNiMo19-11-2	"	1.4408	G-X6 CrNiMo 18 10	17 445	A 351,743,744 CF 8M	J 92900
1.4409	GX2CrNiMo19-11-2	"				A 351,743,744CF 3M	J 92800
1.4552	GX5CrNiNb19-11	"	1.4552	G-X5 CrNiNb 18 9	17 445	A 744 CF 8C	
1.4581	GX5CrNiMoNb19-11-2	"	1.4581	G-X5 CrNiMoNb 18 10	17 445		
Full austenitic steel							
1.4458	GX2NiCrMo28-20-2	5)					
(238 0) 6)	GX4NiCrCuMo30-20-4	"				A 743, 744 CN 7M	
(238 1) 6)	GX1NiCrMoCuN25-20-6	"				A 743, 744 CN 3MN	
(238 2) 6)	GX2CrNiMoN20-18-6	"				A743,744 CK 3MCuN	
Austenitic - ferritic (Duplex) steel							
1.4468	GX2CrNiMoN25-6-3	5)	1.4468	G-X3 CrNiMoN 26 6 3	SEW 410		
1.4469	GX2CrNiMoN26-7-4	"	1.4469	G-X2 CrNiMoN 25 7 4	SEW 410	A 890 5A (CE 3MN)	J 93404
1.4470	GX2CrNiMoN22-5-3	"				A 890 4A (CD 3MN)	J 92205
1.4517	GX2CrNiMoCuN25-6-3-3	"	1.4517	G-X3CrNiMoCuN 26 6 3 3	SEW 410	A 890 1B(CD4MCuN)	

5) Draft DIN 17445 published April 1996, recommendation for EN 6) In house material code

Material number	Chemical analysis (Sample from melt analysis) % by weight						Mechanical properties (guide values)				Density ca.
							R_m	$R_{p\,0,2}$	A	KV	
	C	Cr	Ni	Mo	Cu	Other	N/mm²	N/mm²	%	J (t°C)	kg/dm³
Stainless steel											
Martensitic steel											
1.4008	max. 0.10	12.0-13.5	1.0-2.0	0.20-0.50			590	440	15	27 (RT)	7.7
1.4317	max. 0.06	12.0-13.5	3.5-5.0	max. 0.70			760	550	15	50 (RT)	7.7
Austenitic steel											
1.4308	max. 0.07	18.0-20.0	8.0-11.0				440	175-200 [4]	30	60 (RT)	7.88
1.4309	max. 0.030	18.0-20.0	9.0-12.0			Nmax. 0.20	440	185-210 [4]	30	80 (RT)	7.88
1.4408	max. 0.07	18.0-20.0	9.0-12.0	2.0-2.5			440	185-210 [4]	30	60 (RT)	7.9
1.4409	max. 0.03	18.0-20.0	9.0-12.0	2.0-2.5		Nmax. 0.20	440	195-220 [4]	30	80 (RT)	7.9
1.4552	max. 0.07	18.0-20.0	9.0-12.0			Nb 8x%C	440	175-200 [4]	25	40 (RT)	7.88
1.4581	max. 0.07	18.0-20.0	9.0-12.0	2.0-2.5		Nb 8x%C	440	185-210 [4]	25	40 (RT)	7.9
Full austenitic steel											
1.4458	max. 0.03	19.0-22.0	26.0-30.0	2.0-2.5	max. 2.0	Nmax 0.20	430	165-190 [4]	30	60 (RT)	8.0
(238 0) [6]	max. 0.06	19.0-22.0	27.5-30.5	2.0-3.0	3.0-4.0		430	170-195 [4]	35	60 (RT)	8.0
(238 1) [6]	max. 0.02	19.0-21.0	24.0-26.0	6.0-7.0	0.5-1.5	N 0.10-0.25	480	210-235 [4]	30	60 (RT)	8.0
(238 2) [6]	max.0.025	19.5-20.5	17.5-19.5	6.0-7.0	0.5-1.0	N 0.18-0.24	500	260-285 [4]	35	50 (RT)	7.9
Austenitic - ferritic (Duplex) steel											
1.4468	max. 0.03	24.5-26.5	5.5-7.0	2.5-3.5		N 0.12-0.25	650	480	22	50 (RT)	7.7
1.4469	max. 0.03	25.0-27.0	6.0-8.0	3.0-5.0	max. 1.30	N 0.12-0.22	650	480	22	50 (RT)	7.7
1.4470	max. 0.03	21.0-23.0	4.5-6.5	2.5-3.5		N 0.12-0.20	600	420	20	30 (RT)	7.7
1.4517	max. 0.03	24.5-26.5	5.0-7.0	2.5-3.5	2.75-3.5	N 0.12-0.22	650	480	22	50 (RT)	7.7

1 N/mm² equals 1 Mpa 4) 1% elongation limit 6) in house material code

11.2 Material overview - Cast steel (cont.)

European Standard - EN			German Standard - DIN			USA - Standards	
Material number	Short name or description	Standard	Material number	Short name or description	Standard	ASTM Standard, Grade, Type	UNS
Stainless steel for pressure vessels							
Austenitic steel							
1.4308	GX5CrNi19-10	10213-4	1.4308	G-X6 CrNi 18 9	17 445	A 351,743,744 CF 8	
1.4309	GX2CrNi19-11	10213-4				A 351,743,744 CF 3	J 92500
1.4408	GX5CrNiMo19-11-2	10213-4	1.4408	G-X6 CrNiMo 18 10	17 445	A 351,743,744 CF 8M	J 92900
1.4409	GX2CrNiMo19-11-2	10213-4				A 351,743,744 CF 3M	
1.4552	GX5CrNiNb19-11	10213-4	1.4552	G-X5 CrNiNb 18 9	17 445	A 744 CF 8C	
1.4581	GX5CrNiMoNb19-11-2	10213-4	1.4581	G-X5 CrNiMoNb 18 10	17 445		
Full austenitic steel							
1.4458	GX2NiCrMo28-20-2	10213-4				A 351,743,744 CN7M	
Austenitic - ferritic (Duplex) steel							
1.4469	GX2CrNiMoN26-7-4	10213-4	1.4469	G-X2 CrNiMoN 25 7 4	SEW 410	A 890 5A (CE 3MN)	J 93404
1.4470	GX2CrNiMoN22-5-3	10213-4				A 890 4A (CD 3MN)	J 92205
1.4517	GX2CrNiMoCuN25-6-3-3	10213-4	1.4517	G-X3 CrNiMoCuN 26 6 3 3	SEW 410	A 890 1B (CD4MCuN)	
Cast steel for special applications							
			1.4034	G-X46 Cr 13		A 743 CA 40	J 91150
			1.4059	G-X22 CrNi 17	17 445	A 743, 744	J 91803
			1.4138	G-X120 CrMo 29 2	SEW 410	A 743, 744	
			1.4316	G-X2 CrNiSi 18 15			
1.4931	GX23CrMoV12-1	10213-2	1.4391	G-X22 CrMoV 12 1	17 245		
1.7706	G17CrMoV5-10	10213-2	1.7706	GS-17 CrMoV 5 11	17 245		

Material number	Chemical analysis (Sample from melt analysis) % by weight						Mechanical properties (guide values)				Density ca.
	C	Cr	Ni	Mo	Cu	Other	R_m N/mm²	$R_{p\,0,2}$ N/mm²	A %	KV J (t°C)	kg/dm³
Stainless steel for pressure vessels											
Austenitic steel											
1.4308	max. 0.07	18.0-20.0	8.0-11.0				440-640	175,200 [4)]	30	60 (-196°)	7.88
1.4309	max. 0.03	18.0-20.0	9.0-12.0			Nmax. 0.20	440-640	185,210 [4)]	30	70 (-196°)	7.88
1.4408	max. 0.07	18.0-20.0	9.0-12.0	2.0-2.5			440-640	185,210 [4)]	30	60 (-196°)	7.9
1.4409	max. 0.03	18.0-20.0	9.0-12.0	2.0-2.5		Nmax. 0.20	440-640	195,220 [4)]	30	70 (-196°)	7.9
1.4552	max. 0.07	18.0-20.0	9.0-12.0			Nb 8xC	440-640	175,200 [4)]	25	40 (RT)	7.88
1.4581	max. 0.07	18.0-20.0	9.0-12.0	2.0-2.5		Nb 8xC	440-640	185,210 [4)]	25	40 (RT)	7.9
Full austenitic steel											
1.4458	max. 0.03	19.0-22.0	26.0-30.0	2.0-2.5	max. 2.0	Nmax. 0.20	430-630	165,190 [4)]	30	60 (-196°)	8.0
Austenitic - ferritic (Duplex) steel											
1.4469	max. 0.03	25.0-27.0	6.0-8.0	3.0-5.0	max. 1.30	N 0.12-0.22	650-850	480	22	35 (-70°)	7.7
1.4470	max. 0.03	21.0-23.0	4.5-6.5	2.5-3.5		N 0.12-0.20	600-800	420	20	30 (RT)	7.7
1.4517	max. 0.03	24.5-26.5	5.0-7.0	2.5-3.5	2.75-3.5	N 0.12-0.22	650-850	480	22	35 (-70°)	7.7
Cast steel for special applications											
1.4034	0.45	15.0					Rockwell hardness HRC 55				7,7
1.4059	0.20-0.27	16.0-18.0	1.0-2.0				780-980	590	4		7.7
1.4138	0.90-1.30	27.0-29.0		2.0-2.5							7.7
1.4316	max. 0.03	18.0-19.0	14.0-15.0	max. 0.30	max. 0.30	Si 4.3-4.7	540-700	250	30	55 (RT)	7.9
1.4931	0.20-0.26	11.3-12.2	max. 1.0	1.0-1.2		V 0.25-0.35	740-960	550	15	27 (RT)	7.7
1.7706	0.15-0.20	1.2-1.5		0.9-1.1		V 0.25-0.35	590-780	440	15	27 (RT)	7.8

1 N/mm² equals 1 Mpa 4) 1% elongation limit

11.2 Material overview - Steel

European Standard - EN			German Standard - DIN			USA - Standard	
Material number	Short name or description	Standard	Material number	Short name or description	Standard	ASTM Standard, Grade, Type	UNS
Heat treatable steel							
Stainless steel							
1.1191	C45E	10083-1	1.1191	C 45 E (Ck 45)	17 200	A 29, 108 1045	
1.7225	42CrMo4	10083-1	1.7225	42 CrMo 4	17200	A 322 4140	G 41400
Non-alloy quality steel							
1.0501	C35	10083-2	1.0501	C 35	17 200	A 519, 576 1035	G 10350
1.0503	C45	10083-2	1.0503	C 45	17 200	A 576 1045	G 10450
Stainless steel Martensitic steel							
1.4021	X20Cr13	10088-3	1.4021	X20Cr13	17 440	A 276, 473 420	S 42000
1.4112	X90CrMoV18	10088-3	1.4112	X90 CrMoV 18	SEW 400		
1.4122	X39CrMo17-1	10088-3	1.4122	X35 CrMo 17	SEW 400		
1.4313	X3CrNiMo13-4	10088-3	1.4313	X4 CrNi 13 4	SEW 400	A 182 F6NM	
Austenitic steel							
1.4306	X2CrNi19-11	10088-3	1.4306	X2CrNi19-11	17 440	A 276, 403 304L	S 30403
1.4404	X2CrNiMo17-12-2	10088-3	1.4404	X2CrNiMo17-12-2	17 440	A 182, 276, 403 316L	S 31603
1.4541	X6CrNiTi18-10	10088-3	1.4541	X6CrNiTi18-10	17 440	A 182, 276, 403 321	S 32100
1.4571	X6CrNiMoTi17-12-2	10088-3	1.4571	X6CrNiMoTi17-12-2	17 440	A 182, 276, 403 316Ti	
Austenitic-ferritic (Duplex) steel							
1.4462	X2CrNiMoN22-5-3	10088-3	1.4462	X2 CrNiMoN 22 5 3	SEW 400	A 182 F 51 A 276 318 LN	S 31803
1.4507	X2CrNiMoCuN25-6-3	10088-3					

Material number	Chemical analysis (Sample from melt analysis) % by weight						Mechanical properties (guide values)				Density ca.
	C	Cr	Ni	Mo	Cu	Other	R_m N/mm²	$R_{p\,0,2}$ N/mm²	A %	KV J (t°C)	kg/dm³
Heat treatable steel											
Stainless steel											
1.1191	0.42-0.50	max. 0.40	max. 0.40	max. 0.10			630-780	370	17	25 (RT)	7.85
1.7225	0.38-0.45	0.90-1.20		0.15-0.30			900-1100	650	12	35 (RT)	7.85
Non-alloy quality steel											
1.0501	0.32-0.39						550-700	320	20		7.85
1.0503	0.42-0.50						630-780	370	17		7.85
Stainless steel Martensitic steel											
1.4021	0.16-0.25	12.0-14.0					700-850	500	13	25 (RT)	7.7
1.4112	0.85-0.95	17.0-19.0		0.90-1.30		V 0.07-0.12					7.7
1.4122	0.33-0.45	15.5-17.5	max. 1.0	0.80-1.30			750-950	550	12	14 (RT)	7.7
1.4313	max. 0.05	12.0-14.0	3.5-4.5	0.30-0.70		N 0.020	900-1100	800	12	50 (RT)	7.7
Austenitic steel											
1.4306	max. 0.03	18.0-20.0	10.0-12.0			Nmax. 0.11	460-680	180- 215[4)]	45	100 (RT)	7.9
1.4404	max. 0.03	16.5-18.5	10.0-13.0	2.0-2.5		Nmax. 0.11	500-700	200- 235[4)]	40	100 (RT)	7.98
1.4541	max. 0.08	17.0-19.0	9.0-12.0			Ti 5xC	500-700	190- 225[4)]	40	100 (RT)	7.9
1.4571	max. 0.08	16.5-18.5	10.5-13.5	2.0-2.5		Ti 5xC	500-700	200- 235[4)]	40	100 (RT)	7.98
Austenitic - ferritic (Duplex) steel											
1.4462	max. 0.03	21.0-23.0	4.5-6.5	2.5-3.5		N 0.10-0.22	650-880	450	25	100 (RT)	7.8
1.4507	max. 0.03	24.0-26.0	5.5-7.5	2.7-4.0	1.0-2.5	N 0.15-0.30	700-900	500	25	100 (RT)	7.8

1 N/mm² equals 1 Mpa 4) 1% - elongation limit

11.2 Material overview - Non-ferrous metals

European Standard - EN			German Standard - DIN			USA - Standard	
Material number	Short name or description	Standard	Material number	Short name or description	Standard	ASTM Standard, Grade, Type	UNS
Copper, tin, zinc alloy (cast tin bronze and gunmetal)							
CC480K	CuSn10-Cu	1982	2.1050	G-CuSn10	1705	B 427 C 91600	C 91600
CC491K	CuSn5Zn5Pb5-C	1982	2.1096	G-CuSn5ZnPb	1705	B 584 C 92200	C 92200
Copper, tin, alloy (special brass)							
			2.0550	CuZn40Al 2	17 660		
Copper, aluminium alloy (Aluminium bronze)							
			2.0966	CuAl 10Ni5Fe4	17 665	B 150 C 63000	C 63000
CC333G	CuAl10Fe5Ni5-C	1982	2.0975	G-CuAl 10Ni	1714		
Nickel alloy with molybdenum and chrome							
			2.4610	NiMo16Cr16Ti	17 744	B 574 N 06455	N 06455
			2.4617	NiMo28	17 744	B 335 N 10665	N 10665
			2 4685	G-NiMo 28		A 494 N-12MV	
			2.4686	G-NiMo 17Cr		A 494 CW-12MW	
			2.4819	NiMo16Cr15W	17 744	B 574 N 10276	N 10276
Titanium and Zirconium							
			3.7031	G-Ti 2	17 865	B 367 Gr. C-2	
			3.7255	Ti 3 Pd	17 851/60	B 265 Gr. 7	
			(852 0) [6)]	G-Zr-Nb		B 752 Gr. 705C	
			(853 0) [6)]	Zr-Nb		B 551 R 60705	R 60705

6) In house material code

Material number	Composition, alloy components, permitted levels in brackets % by weight							Mechanical properties			Density
								R_m	$R_{p\,0,2}$	A	ca.
Copper, tin, zinc, alloy (cast tin bronze and gunmetal)								N/mm²	N/mm²	%	kg/dm³
	Cu	Sn	Zn	Pb	Al	Fe	Ni				
CC480K	88.0-90.0	11.0	max. 0.5	max. 1.0	max. 0.01	max. 0.2	max. 2.0	250	130	18	8.7
CC491K	83.0-87.0	4.0-6.0	4.0-6.0	4.0-6.0	max. 0.01	max. 0.3	max. 2.0	200	90	13	8.7
Copper, tin, alloy (special brass)											
2.0550	56.5-59.0	max. 0.5	30.3-40.5	max. 0.8	1.3-2.3	max. 1.0	max. 2.0	510	230	12	8.1
Copper, aluminium alloy (Aluminium bronze)											
2.0966	75.7-85.5				8.5-11.0	2.0-5.0	4.0-6.0	640	270	15	7.5
CC333G	76.0-83.0	max. 0.1	max. 0.50	max. 0.03	8.5-10.5	4.0-5.5	4.0-6.0	600	250	13	7.6
Nickel alloy with molybdenum and chrome											
	Ni	Cr	Mo	W	Fe	Mn	C				
2.4610	56.8-72.0	14.0-18.0	14.0-18.0		max. 3.0	max. 1.0	max. 0.01	700	280	35	8.6
2.4617	64.5-74.0	max. 1.0	26.0-30.0		max. 2.0	max. 1.0	max. 0.01	745	325	40	9.2
2.4685	min. 62.0	max. 1.0	26.0-30.0		max. 7.0	max. 1.0	max. 0.03	530-650	275	15	9.1
2.4686	58.7-72.0	14.0-18.0	14.0-17.0		max. 3.0	max. 1.0	max. 0.02	540	250	12	8.5
2.4819	50.7-63.5	14.5-16.5	15.0-17.0	3.0-4.5	4.0-7.0	max. 1.0	max. 0.015	700	280	35	8.9
Titanium und Zirconium											
	Ti	Pd	Zr + Hf	Hf	Nb	Fe	O				
3.7031	98.8-99.9					max. 0.2		350	280	15	4.5
3.7255	98.7-99.8	0.15-0.25				max. 0.25		460-590	320	18	4.5
(852 0) [6)]			95.6-99.9	max. 4.5	2.0-3.0		max. 0.3	483	345	12	6.5
(853 0) [6)]			95.5-99.9	max. 4.5	2.0-3.0		max. 0.18				

1 N/mm² equals 1 MPa 6) in house material code

11.3 US materials with AISI designation

AISI	Equivalent material		
	Material No.	Short name	Standard
Austenitic steel			
301	1.4310	X10CrNi18-8	EN 10088-3
304	1.4301	X5CrNi18-10	"
304 L	1.4306	X2CrNi19-11	"
304 LN	1.4311	X2CrNiN18-10	"
305	1.4303	X4CrNi18-12	"
308	1.4303	X4CrNi18-12	"
316	1.4401	X5CrNiMo17-12-2	"
"	1.4436	X3CrNiMo17-13-3	"
316 Cb	1.4580	X6CrNiMoNb17-12-2	"
316 L	1.4404	X2CrNiMo17-12-2	"
316 LN	1.4406	X2CrNiMoN17-11-2	"
"	1.4429	X2CrNiMoN17-13-3	"
316 Ti	1.4571	X6CrNiMoTi17-12-2	"
317 L	1.4438	X2CrNiMo18-15-4	"
321	1.4541	X6CrNiTi18-10	"
347	1.4550	X6CrNiNNb18-10	"
Austenitic ferritic steel			
329	1.4460	X3CrNiMoN27-5-2	EN 10088-3
Ferritic and martensitic steel			
403	1.4000	X6Cr13	DIN 17440
405	1.4002	X6CrAl13	"
410	1.4006	X12Cr13	EN 10088-3
420	1.4021	X20Cr13	"
430	1.4016	X6Cr17	DIN 17440
430 F	1.4104	X14CrMoS17	EN 10088-3
430 Ti	1.4510	X3CrTi17	DIN 17440
431	1.4057	X17CrNi16-2	EN 10088-3
440 C	1.4125	X105CrMo17	SEW 400
Heat treatable steel			
C 1035	1.0501	C35	EN 10083-2
C 1045	1.0503	C45	"
4140	1.7225	42CrMo4	EN 10083-1

11.4 US materials according to ASTM standards

ASTM	Comparible standards	
	Standard	Material group
A 29	EN 10083-1	Heat treatable steel
48	EN 1561	Grey cast iron
108	EN 10083-1	Heat treatable steel
182	EN 10088-3	Stainless steel
216	EN 10213-2	Heat resisting steel
217	DIN 17 445	Cast stainless steel, martensitic
276	EN 10088-3	Stainless steel
278	EN 1561	Grey cast iron
322	EN 10083-1	Heat treatable steel
351	EN 10213-4	Cast stainless steel, austenitic
352	EN 10213-3	Low temperature cast steel
395	EN 1563	Spheroidal graphite cast iron
403	EN 10088-3	Stainless steel
436	DIN 1694	Austenitic grey cast iron
439	DIN 1694	Austenitic spheroidal graphite cast iron
473	EN 10088-3	Stainless steel
494	none	Cast nickel alloy with molybdenum and chrome
519	EN 10083-2	Heat treatable steel
532	EN 12513	Abrasion resistant cast irons
536	EN 1563	Spheroidal graphite cast iron
576	EN 10083-1, -2	Heat treatable steel
743	DIN 17 445	Cast stainless steel,
744	DIN 17 445	Cast stainless steel, austenitic
890	SEW 410	Cast stainless steel (Duplex)
B 150	DIN 17 665	Copper, aluminium alloy
265	DIN 17 851 / 60	Titanium alloy sheet and roll
335	DIN 17 744	Nickel alloy with molybdenum
367	DIN 17 865	Cast titanium
427	EN 1982	Copper, tin, zinc alloy
494	see A 494	
574	DIN 17 744	Nickel alloy with molybdenum and chrome
584	EN 1982	Copper,tin,zinc alloy

11.5 Materials by trade name

Trade name	Comparable material		
	Material-number	Short name	Standard
Austenitic cast iron			
Ni-Resist 1b	0.6656 –	GGL-NiCuCr 15 6 3 Type 1b	DIN 1694 ASTM A 436
Ni.Resist D-2B	0.7661 –	GGG-NiCr 20 3 Type D-2B	DIN 1694 ASTM A 439
Abrasion resistant cast iron			
Ni-Hard 2	EN-JN2029 –	EN-GJN-HV520 Class I Type B Ni-Cr-LC	EN12513 ASTM A 532
Ni-Hard 4	EN-JN2049 –	EN-GJN-HV600 Class I Type D Ni-Hi-Cr	DIN 1695 ASTM A 532
Cast stainless steel			
Alloy 20	1.4458 –	GX2NiCrCuMo28-20-2 CN 7M	EN 10213-4 ASTM A 351 A 744
Sterling K 26	see Alloy 20		
Sterling R 48	1.4517 – – –	GX2CrNiMoCuN25-6-3-3 CD 4MCu Grade 1A (ACI CD 4MCu) Grade 1B (ACI CD 4MCuN)	EN 10213-4 ASTM A 351 A 744 ASTM A 890 ASTM A 890
Nickel alloy with molybdenum and chrome			
Hastelloy B-1	2.4685 –	G NiMo28 N 12 MV	EN/DIN none ASTM A 494
Hastelloy B-2	2.4617 –	NiMo28 N 10665	DIN 17 744 ASTM B 335
Hastelloy C-1	2.4686 –	G-NiMo 17Cr CW 12 MW	EN/DIN none ASTM A 494
Hastelloy C-276	2.4819 –	NiMo16Cr15W N 10276	DIN 17 744 ASTM A574
Sterling R 52	see Hastelloy B-1		
Sterling R 53	see Hastelloy C-1		
Sterling R 55	No comparable material Analysis: Ni 58%, Cr 22%, Cu 4%, Si 4% and W 1%		

11.6 Organic materials overview

Abbreviation ISO 1043 ISO 1629	Abbreviation EN 12756 (Mech seals)	Name	Trade name
Elastomers			
CR	N	Chlorobutadiene elastomer old name: Chloroprene rubber	Baypren (Bayer) Neoprene (Du Pont)
EPDM	E	Ethylene propylene rubber	Ketan (DSM) Nordel (Du Pont)
FPM also FCM CFM, FKM	V	Fluorocarbon elastomer	Viton (Du Pont)
NBR HNBR	P X	Acrylonitrile butadiene elastomer old name nitrile rubber Hydrogenated NBR	Perbunan (Bayer) Therban, Zetpol
None	K	Perfluoroelastomer	Kalrez (Du Pont)
Plastics			
Thermoplastic			
PTFE	T	Polytetrafluoroethylene	Teflon (Du Pont)
PE PE - LD PE - HD PE-UHMW		Polyethylene Polyethylene low density ρ = 0.918to 0.95 g/cm³ Polyethylene high density ρ = 0.95 to 0.96 g/cm³ Ultra high molecular PE	 Hostalen (Hoechst) Lupolen (BASF) Hostalen GUR (Hoechst) RCH 1000
PEEK		Polyether-etherketone	Victrex PEEK (ICI)
PFA		Perfluoralkoxyalkane	Hostaflon PFA (Hoechst) Teflon PFA (Du Pont)
PP		Polypropylene	Hostalen PP (Hoechst) Novolen (BASF)
PPS		Polyphenylene-sulphide	Ryton (Phillips)
PVDF		Polyvinylidenefluoride	Diflor 2000 (Hüls) Kynar (Elf)
Thermosetting			
EP		Epoxide resin	Araldit (Ciba Geigy)
VE		Vinyl ester resin	
Natural rubber			
NR		Natural rubber - soft rubber. hot vulcanised rubber with 1.8 to 2.5% sulphur hardness (25 to 100) Shore A - hard rubber. hot vulcanised with 30 to 50% sulphur	 Ebonit

11.6 Organic materials properties

Abbreviation ISO 1043 ISO 1629	Abbreviation EN 12756 (Mech seals)	Usable temperature range Chemical resistance Application
Elastomers		
CR	N	Usable temperature range – 40 to + 100 °C for special compounds: – 55 to + 150 °C Chemically resistant against (e.g.): cold water, seawater, phosphoric acid Not resistant against (e.g.): kerosene, benzene, nitric acid, sulphuric acid, acetic acid Application: O-rings, bellows
EPDM	E	Usable temperature range: – 50 °C to + 120 °C for special hot water compounds: to + 200 °C Chemically resistant against (e.g.): cold water, hot water, seawater, caustic soda, phosphoric acid, hydrochloric acid, acetic acid (10%, <60 °C) Not resistant against (e.g.): petrol and diesel fuel, kerosene, benzene, liquified gases, mineral oil, nitric acid, sulphuric acid Application: O-rings, bellows
FPM	V	Usable temperature range: – 25 °C to + 200 °C for special compounds: – 45 °C to + 260 °C Chemically resistant against (e.g.): effluent (pH>3 <10), cold water, hot water, seawater, petrol and diesel fuel, kerosene, liquified gases, mineral oil, phosphoric acid, sulphuric acid Not resistant against (e.g.): nitric acid, acetic acid, caustic soda, benzene Application: O-rings, bellows
NBR HNBR	P X	Usable temperature range: – 30 to + 100 °C Usable temperature range: – 40 to + 150 °C Chemically resistant against (e.g.): effluent (pH>6<10), cold water, hot water, seawater, petrol and diesel fuel, kerosene, liquified gases, mineral oil, caustic soda (>50%), phosphoric acid (cold concentrated), HNBR is hydrolysis resistant Not resistant against (e.g.): benzene, nitric acid, sulphuic acid, acetic acid Application: O-rings, bellows, membranes
None	K	Usable temperature range: to + 260 °C Chemically resistant as PTFE Elastic properties as FPM

11.6 Organic materials properties (cont)

Abbreviation ISO 1043 / ISO 1629	Abbreviation EN 12756 (Mech seals)	Usable temperature range / Chemical resistance / Application
Thermoplastic		
PTFE	T	Usable temperature range: – 200 to + 260 °C Chemically resistant against practically all chemicals and water Application: pure PTFE:- for corrosion resistant coating
	M_1	- for encapsulation of O-rings
	M_2	FPM, double PTFE encapsulation EPDM, double PTFE encapsulation
		PTFE, glass fibre reinforced and PTFE, carbon fibre reinforced:
	Y1 / Y2	- for pump impellers - for shaped seals and bellows
Thermoplastic		
PE PE-LD PE-HD		Usable temperature range: – 50 to + 80 °C – 50 to + 90 °C Chemically resistant against (e.g.): alkali, salt solutions, inorganic acids (reducing and weakly oxidising), organic acids, esters, ketones Not resistant against (e.g.): aliphatic and aromatic hydrocarbons and chlorinated hydrocarbons Application: pump casings and impellers for plastic pumps
PE-UHMW		Usable temperature range: – 30 to + 80 °C Chemically resistant against strongly abrasive and corrosive liquids Application: pump casings and impellers for plastic pumps
PEEK		Usable temperature range: – 40 to + 160 °C Chemically resistant against (e.g.): nearly all inorganic and organic chemicals Not resistant against (e.g.): hydrochloric acid, fuming nitric acid, concentrated sulphuric acid Application: nearly always reinforced, e.g. carbon fibre reinforced PEEK-CF30 for impellers of side channel pumps
PFA		Usable temperature range: – 100 to + 180 °C Chemical resistance as PTFE Application: corrosion resistant coatings and linings

11.6 Organic materials properties (cont)

Abbreviation ISO 1043 ISO 1629		Usable temperature range Chemical resistance Application
PP		Usable temperature range: 0 to + 90 °C Chemically resistant against e.g.: aqueous solutions of inorganic salts, weak inorganic acids and alkalis Not resistant against (e.g.): strongly oxidising acids, aliphatic and aromatic hydrocarbons and halogenated hydrocarbons Application: pump casings and impellers for plastic pumps
PPS		Usable temperature range: – 40 to + 200 °C Chemically resistant against (e.g.): concentrated caustic soda, concentrated hydrochloric and sulphuric acid, dilute nitric acid and solvents, to + 180°C Not resistant against (e.g.): concentrated nitric acid Application: nearly always glass fibre reinforced, e.g. PPS-GF40 parts for plastic pumps
PVDF		Usable temperature range: – 20 to + 120 °C Chemically resistant against (e.g.): dissolved salts, alkalis, acids, aliphatic and aromatic hydrocarbons and chlorinated hydrocarbons Not resistant against (e.g.): oleum, high temperature ketones, esters, organic amines Application: pump casings and impellers for plastic pumps
Thermosetting		
EP		Usable temperature range: + 10 to + 80 °C Chemically resistant against (e.g.): dilute acids and alkalis, chlorinated hydrocarbons, toluene Not resistant against (e.g.): concentrated acids and alkali, ammonia, esters, ketones, acetone Application: parts for plastic pumps
VE		Usable temperature range: – 40 to + 120 °C Chemically resistant against (e.g.): dilute acids and alkalis and bleaches Not resistant against (e.g.): concentrated acids and alkalis, hydrofluoric acid, chromic acid, ammonia, solvents Application: glass fibre reinforced, parts for plastic pumps

11.6 Organic materials properties (cont)

Abbreviation ISO 1043 ISO 1629		Usable temperature range Chemical resistance Application
Natural rubber		
NR		Usable temperature range: soft rubber: – 40 to + 65 °C hard rubber: – 40 to + 80 °C Chemically resistant against (e.g.): acids, alkali, hot water Not resistant against (e.g.): fuels, mineral oils, solvents Application: soft rubber: (Shore hardness 40 to 60) wear resistant coating and lining of solids pumps Conditional on: solids are not sharp edged and particle size < 6,4 mm maximum tip speed 27 m/s hard rubber: corrosion resistant coating and lining of pumps and pump parts

11.7 Fibre reinforced materials

Fibre reinforcement improves the mechanical and thermal properties of plastics. With PTFE for example, it will prevent plastic cold forming (pre-forming) under the influence of load at room temperature.

The common reinforcing materials are carbon, glass and synthetic fibres.

Fibre reinforced plastics are designated according to DIN 7728 Pt 2 according to the type of fibre, as follows:

Abbreviation	Material
CFK	Carbon fibre reinforced plastic
GFK	Glass fibre reinforced plastic
SFK	Synthetic fibre reinforced plastic

The material can be defined in more detail according to DIN 7728 Pt 1 by including in the abbreviation, the proportion of reinforcing material

Example:

PTFE-GF 30 → PTFE with 30% glass fibre reinforcement
PPS-GF 40 → Polyphenylene sulphide with 40% glass fibre reinforcement

11.8 Ceramic materials

Material	Composition	Application
Silica ceramic materials		
Porcelain	Al_2O_3 30 to 35% SiO_2 rest	chemically resistant pump parts (not suitable for hydrofluoric acid)
Glass Borax aluminium glass	SiO_2 65.3% Al_2O_3 3.5% B_2O_3 15.0% BaO. ZnO rest	alkali free instrument glass for chemically resistant pump housings (not suitable for hydrofluoric acid)
Oxide ceramic materials		
Aluminium oxide (corundum) Al_2O_3 type Al_2O_3-SiO_2 type Zirconium dioxide	 Al_2O_3 99.7% Al_2O_3 96 to 97.5% ZrO_2 > 90% Y_2O_3. MgO rest	chemically resistant pump parts, mechanical seal faces for pressures <25 bar (not suitable for hydrofluoric acid) Mechanical seal code: V Chemically resistant shroud material for magnetic coupling pumps
None-oxide ceramic materials		
Carbon resin impregnated e.g. with phenolic resin metal impregnated e.g. with antimony	C > 99.7%	Bearing sleeves, mechanical seal faces good chemical resistance, installation limit 150 °C, pressure to 25 bar Mechanical seal code: B Chemical resistance not as good as resin impregnated, but suitable for higher temperatures Mechanical seal code: A
Silicon carbide S-SiC, sintered (pressure free) SiSiC, sintered (reaction)	 SiC > 98% SiC > 90% + Si	Bearing sleeves and journalss, lubricated by pumped liquid, mechanical seal faces Mechanical seal code: Q

11.9 Material selection

After the mechanical properties, the corrosion resistance of the material to the pumped liquid is the determining criterion in the selection.

The following table gives guidelines to the groups of materials which have proven suitable in practice. It must be remembered however that the corrosion resistance and hence the material selection can be greatly affected by the temperature, concentration, impurity content, abrasive solids and the flow velocity and distribution of the liquid.

11.9.1 Tips for notes 1) to 8) and material selection table

1. Pressure retaining pump parts made of grey cast iron (flake) are not permitted in chemical plants for handling dangerous media.
2. Spheroidal graphite cast iron may only be used in quality EN-GJS-400-18 (previous designation GGG 40.3) with a maximum perlite content 5%.
3. Material groups in brackets, e.g. (D) have restricted application.
4. There is pitting danger with this aqueous solution. Preference should be given to materials with high molybdenum content in material groups H and K.
5. In the presence of water, hydrochloric acid (HCl) will form with the danger of pitting, crevice and stress corrosion.
6. If material group D is selected, then only spheroidal graphite cast iron is suitable.
7. The data is only valid for pure phosphoric acid produced by the dry thermal process. For acid produced by wet process, a full analysis of the acid must be made for material selection.
8. When pumping nitric acid, molybdenum free materials with high silicon content have an advantage (material number 1.4306 and 1.4361).

Fp = Flow or melting point at standard pressure 101,325 Pa.

Bp = Boiling point at standard pressure 101,325 Pa. For other reference pressures, the figure is given as /hPa.

Warning! ***General Danger Note*** **Warning!**

Some of the liquids in the material tables are extremely corrosive, poisonous, on inhalation and skin contact irritant, flammable, environmentally dangerous and carcinogenic. If not handled correctly they may also cause considerable damage to the pump and plant. Furthermore there are health and injury dangers to persons and possible loss of life.

Table 11.01 Compilation of materials in groups for the selection table 11.9

Material group	Material	Standard
D	Grey cast iron (flake) 1)	EN 1561 DIN 1691 ASTM A48 and 278
	Spheroidal graphite or nodular cast iron (ductile iron) 2)	EN 1563 DIN 1693 ASTM A395 and 536
	Cast steel	EN 10213-2 DIN 17 245 ASTM A216
H	Austenitic stainless steel with molybdenum	EN 10213-4 DIN 17 445, E DIN 17445 ASTM A351, 743 and 744
K	Full austenitic stainless steel (Alloy 20 type)	EN 10213-4 E DIN 17445 ASTM A743 and 744
L	Austenitic ferritic stainless steels, Duplex	EN 10213-4 E DIN 17445 and SEW 410 ASTM A890
M	Nickel alloy with molybdenum (Hastelloy B type)	EN none DIN 17 744 ASTM A494 and B335
N	Nickel alloy with molybdenum and chrome (Hastelloy C type)	EN none DIN 17 744 ASTM B574
T	Titanium and titanium alloys	EN none DIN 17851,17860 und17865 ASTM B265 and B367
U	Zirconium and zirconium alloys	EN and DIN none ASTM B551 and B752
W	High alloy cast iron (cast silicium)	EN and DIN none ASTM A518
Z	Hard rubber coating	none

1) and 2) see previous page

11.9 Materials of Construction For Pumping Various Liquids

Liquid	Conditions of liquid *w* %	*t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
A							
Acetaldehyde	to 100	20	CH_3CHO	HKL MN TU		– 123.5	20.5
Acetic Acid	< 5	20	CH_3COOH	(D) HKL MN TU			
	to 70	to boiling		HKL MN TU			
Acetic Acid Glacial	100	to 100		HKL MN TU		16.7	118
	100	boiling		MN TU		16.7	118
Acetic Anhydride		20	$(CH_3CO)_2O$	HKL MN TU		– 74.2	138.9
Acetone	to 100	40	CH_3COCH_3	D HKL MN TU		– 95	56.3
Acetyl Chloride		20	CH_3COCl	HKL MN U	5)	– 112	51
Allyl Alcohol	to 100	20	$CH_2{=}CHCH_2OH$	D HKL MN TU		– 129	97
Allyl Chloride		20	$CH_2{=}CHCH_2Cl$	KL MN TU	5)	– 136.4	45.7
Alum	sat'd	to 90	$KAl(SO_4)_2 \cdot 12\ H_2O$	(H)KL MN			
Aluminium Chloride	25	20	$AlCl_3$	KL M U	4)		
	40	20		M U	4)		
Aluminium Nitrate	30	20	$Al(NO_3)_3 \cdot 9\ H_2O$	HKL MN T			
Aluminium Sulphate	sat'd	20 to 60	$Al_2(SO_4)_3$	HKL MN TU			
	10	to boiling		KL TU			
	sat'd	to boiling		KL			

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Ammonia		20	NH_3	D HKL MN U		– 77.7	– 33.4
Ammonia, Aqueous Sol.	10	20	NH_4OH	D HKL MN TU			
	30	20		D HKL MN TU			
Ammonium Acetate	10	90	$NH_4(C_2H_3O_2)$	HKL M			
Ammonium Bicarbonate	20	20	NH_4HCO_3	D HKL			
Ammonium Difluoride	sat'd	20	NH_4HF_2	KL	4)		
Ammonium Bromide	5	50	NH_4Br	HKL MN U Z	4)		
Ammonium Carbonate	20	20	$(NH_4)_2CO_3$	HKL			
Ammonium Chloride	sat'd	50	NH_4Cl	HKL MN TU	4)		
	sat'd	to boiling		KL MN TU	4)		
Ammonium Nitrate	all	to boiling	NH_4NO_3	HKL MN TU			
Ammonium Sulphate	10	80	$(NH_4)_2SO_4$	HKL MN TU			
	40	80		KL MN TU			
Aniline		to 100	$C_6H_5NH_2$	HKL N TU		– 6.2	184.4
Anisole		20	$C_6H_5OCH_3$	D HKL MN TU		– 37.2	153.8
Arsenic Acid	to 70	65	$H_3AsO_4 \cdot ½ H_2O$	KL MN U			
B							
Barium Chloride	cold sat'd	20	$BaCl_2$	HKL MN TU	4)		
	cold sat'd	100		KL MN TU	4)		

Liquid	Conditions of liquid *w* %	*t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Barium Hydroxide	all	20	$Ba(OH)_2$	D HKL MN TU			
Barium Nitrate	all	to boiling	$Ba(NO_3)_2$	HKL MN TU			
Benzaldehyde		20	C_6H_5CHO	HKL MN U		– 56	178.9
Benzene		20	C_6H_6	D HKL MN TU		5.5	80.2
Benzoic Acid	1	to boiling	C_6H_5COOH	HKL MN TU			
Benzyl Alcohol		20	$C_6H_5CH_2OH$	HKL MN U		– 15.3	205.4
Benzyl Chloride		20	$C_6H_5CH_2Cl$	HKL MN	5)	– 39.2	179.4
Borax	sat'd	to boiling	$Na_2B_4O_7 \cdot 10\ H_2O$	HKL MN TU			
Boric Acid	4	to boiling	H_3BO_3	(H)KL MN TU			
Bromine	dry	20	Br	MN U		– 8.3	58.8
Butadiene (1,3-B.)		20	$CH_2=CHCH=CH_2$	HKL M		– 108.9	– 4.5
Butanol (n-B.)		20	C_4H_9OH	(D) HKL MN TU		– 89.3	117.8
Butanone		20	$CH_3CH_2COCH_3$	HKL MN TU		– 86.7	79.7
Butene (1-B.)		20	$C_2H_5CH=CH_2$	HKL MN TU		– 185.4	– 6.3
Butyl Acetate (n-B.)		20	$CH_3COOC_4H_9$	(D) HKL MN TU		– 76.8	126.5
Butylene Glycol	to 100	40	$HO(CH_2)_4OH$	(D) HKL MN TU		19	235
Butyric Acid	100	100		KL N TU			
Butyric Acid (n-B.)	100	20	$CH_3(CH_2)_2COOH$	HKL MN TU		– 5.3	163.3

Liquid	Conditions of liquid *w* % *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
C						
Cadmium Chloride	all 20	$CdCl_2$	HKL MN	4)		
Calcium Bisulphite	25 20	$Ca(HSO_3)_2$	HKL N TU			
	25 boiling		KL TU			
Calcium Chloride	all 20	$CaCl_2$	D HKL MN TU Z	4)		
	all boiling		KL N TU			
Calcium Hydroxide	0.15 20	$Ca(OH)_2$	D HKL MN T			
	15 20		D HKL MN T			
	30 100		N T			
Calcium Hypochlorite	to 3 30	$Ca(ClO)_2$	HKL N TU Z	4)		
	25 60		N TU Z	4)		
Calcium Nitrate	all 20	$Ca(NO_3)_2$	(H)KL MN T			
Carbolic Acid	10% H_2O to 90		HKL U			
Carbon Disulphide	20	CS_2	D HKL MN TU		– 111.9	46.3
Carbon Tetrachloride	dry 20	CCl_4	D HKL	5)	– 23.2	76.6
	wet 20		L N TU	4)		
Carbonic Acid	20	H_2CO_3	(D) HKL MN TU			
Caustic Soda	*see Sodium Hydroxide*					
Chlorobenzene (Mono-C.)	20	C_6H_5Cl	(D) HKL MN TU	5)	– 45.6	131.8

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Chloric Acid	20	18	$HClO_3$	N			
Chlorine	dry	20	Cl_2	(D) HKL		– 101	– 34.5
	wet	20		KL N T Z	5)		
Chlorine Water	1 g/l Cl_2	20	$Cl_2 + H_2O$	HKL N Z	4)		
	sat'd	20		N Z			
Chloroacetic Acid (Mono-C.)	50	20	$CH_2ClCOOH$	MN TU W			
	50	90		MN TU (W)			
Chloroform		to 50	$CHCl_3$	(D) HKL MN TU	5)	– 63.5	61.3
Chlorosulphuric Acid	100	20	HSO_3Cl	H MN T	5)	– 80	152
	10	20		MN T	4)		
Chrome Alum	sat'd	to 55	$KCr(SO_4)_2 \cdot 12\ H_2O$	(H)KL W			
	sat'd	90		KL W			
Chromic Acid	10	to boiling	H_2CrO_4	K TU W			
	30	100		TU W			
	47	60		N W			
	75	20		K N			
	75	93		(N)			
	with SO_3	20		K W			
Citric Acid	1	20	$C_6H_8O_7$	HKL MN TU			

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
	10	20		HKL MN TU			
	10	100		HKL MN TU			
	30	20		HKL MN TU			
	30	50		KL MN TU			
	50	20		HKL MN TU			
	50	boiling		K MN U			
Copper Chloride	20	20	$CuCl_2$	N T Z	4)		
	20	80		T Z	4)		
Copper Sulphate	sat'd	to boiling	$CuSO_4$	(H)KL N TU			
Cresol (m-C.)		> 40	$CH_3C_6H_4OH$	(D) HKL MN TU		12.3	202.3
Cumene		20	$C_6H_5CH(CH_3)_2$	HKL MN TU		– 99.5	159.3
Cyclohexane		20	C_6H_{12}	D HKL MN TU		6.6	80.8
Cyclohexanol		50	$C_6H_{11}OH$	(D) HKL MN TU		24.9	161.2
Cyclohexanone		20	$C_6H_{10}O$	(D) HKL MN TU		– 30	155.7
D E							
Dibutyl Ether		20	$(C_4H_9)_2O$	D HKL MN TU		– 95	141
Diethyl Ether		20	$(C_2H_5)_2O$	(D) HKL MN TU		– 116.3	34.6
Diethylene Glycol	to 100	20	$C_4H_{10}O_3$	(D) HKL MN TU		– 8	245

Liquid	Conditions of liquid *w* %	*t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Dioxane (1.4-D.)	to 100	30	$C_4H_8O_2$	D HKL MN TU		11.1	101.4
Ethanol	to 100	to boiling	C_2H_5OH	(D) HKL MN TU		– 114.1	78.4
Ethyl Acetate		20	$CH_3COOC_2H_5$	HKL MN TU		– 83.6	77.2
Ethyl Chloride		20	CH_3CH_2Cl	HKL MN TU	5)	– 136.4	12.3
Ethyl Formate		20	$HCOOC_2H_5$	(D) HKL MN TU		– 79.4	54.3
Ethylbenzene		20	$C_6H_5C_2H_5$	D HKL MN TU		– 95	136.2
Ethylene Chlorhydrin		20	$ClCH_2CH_2OH$	HKL MN TU	5)	– 70	129.5
Ethylene Dichloride		to boiling	CH_2ClCH_2Cl	HKL MN TU	5)	–35.7	83.5
Ethylene Glycol	bis 100	20	CH_2OHCH_2OH	(D) HKL MN TU		– 13	197.3
F G							
Fatty Acids	*see Oleic Acid and Stearic Acid*						
Fatty Alcohols	Octadecanol		$C_{18}H_{37}OH$	HKL MN TU		58	$210/_{20}$
Ferric Chloride	15	25	$FeCl_3$	N T Z	4)		
	45	25		N T Z	4)		
Ferric Sulphate	30	20	$Fe_2(SO_4)_3$	HKL N TU			
Ferrous Chloride	all	40	$FeCl_2$	(K)(L) MN TU Z	4)		
Ferrous Nitrate	all	to boiling	$Fe(NO_3)_2 \cdot 6\ H_2O$	HKL N T			
Ferrous Sulphate	10	20	$FeSO_4$	(H)KL MN TU			
Formaldehyde	40	to boiling	CH_2O	HKL MN TU	4)		

Liquid	Conditions of liquid *w* % *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Formamide	to 100 20	CH_3NO	(D) HKL MN TU		2.5	210.5
Formic Acid	100 20	HCOOH	HKL MN TU		8.4	100.7
	50 70		(K)L N U			
	100 90		K(L) U		8.4	100.7
Furfural	20	$C_5H_4O_2$	(D) (H)KL MN TU		– 36.5	161.8
Gallic Acid	hot sat'd to boiling	$C_6H_2(OH)_3COOH$	HK N			
Glaubers Salt	*see Sodium Sulphate*					
Glycerol	to 100 30	$C_3H_5(OH)_3$	(D) HKL MN TU		17.9	289.9
H						
Hexane	20	C_6H_{14}	(D) HKL MN TU		– 95.4	68.8
Hydrobromic Acid	50 20	HBr	M Z	4)		
Hydrochloric Acid	0.5 20	HCl	K MN TU Z	4)		100
	0.5 80		MN TU Z	4)		100
	5 20		K MN TU W Z	4)		101
	5 80		M TU W Z	4)		101
	10 20		MN TU W Z	4)		103
	10 80		M U W Z	4)		103
	20 20		MN TU W Z	4)		108
	20 80		M U W Z	4)		108

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
	30	20		MN U W Z	4)		90
	30	80		M U Z	4)		90
	37	20		M U Z	4)		60
	37	boiling		M U Z	4)		60
Hydrocyanic Acid	dil.	20	HCN	(D) HKL MN TU			
Hydrofluoric Acid	< 40	20	HF	MN Z			
	> 60	20		(D) M			
Hydrofluorosilicic Acid	sat'd	20	H_2SiF_6	(H)KL N			
Hydrogen Peroxide	30	20	H_2O_2	HKL MN TU			
L M							
Lactic Acid	< 5	to 100	$CH_3CH(OH)COOH$	KL N TU W			
	25	20		HKL MN TU W			
	50	20		HKL N TU W			
	50	80		HKL N TU W			
	80	20		HKL MN TU W			
	80	120		KL T			
	100	25		HKL MN TU W		18	$119/_{16}$
Lead Acetate	20	to boiling	$Pb(C_2H_3O_2)_2 \cdot 3\ H_2O$	HKL MN TU			
Lithium Bromide	sat'd	20	LiBr	HKL N	4)		

Liquid	Conditions of liquid *w* % *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Lithium Chloride	10 to 80	LiCl	KL MN TU	4)		
Magnesium Chloride	all 20	$MgCl_2$	HKL MN TU W	4)		
	< 5 to boiling		KL MN TU W	4)		
	> 5 to boiling		KL N TU W	4)		
Magnesium Sulphate	sat'd to boiling	$MgSO_4$	(H)KL TU			
Maleic Acid	50 20	HOOCCH=CHCOOH	HKL MN TU			
Manganese Chloride	20 to 100	$MnCl_2$	K N TU W Z	4)		
Manganese Sulphate	30 20	$MnSO_4$	(D) HKL MN TU			
Mercuric Chloride	0.1 20	$HgCl_2$	HKL N TU	4)		
	0.7 20		KL N TU			
Mercuric Nitrate	5 20	$Hg_2(NO_3)_2 \cdot 2\ H_2O$	HKL N			
Methanol	bis 100 to 80	CH_3OH	(D) HKL MN TU		– 97.7	64.7
Methyl Acetate	25	CH_3COOCH_3	HKL MN		– 98.2	57
Methylene Chloride	20	CH_2Cl_2	(D) HKL MN T	5)	– 96	39.9
Methylpentanone	20	$CH_3COCH_2CH(CH_3)_2$	HKL MN TU		– 80	114.5
Mine Water	*see Chapter 10 „Water" Table 10.07*					
Mixed Acids						
50% H_2SO_4 + 50% HNO_3	50		HK N T			85
	85		K			85

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
75% H_2SO_4 + 25% HNO_3		50		(D) K N W			105
		90		K W			105
20% H_2SO_4 + 15% HNO_3		50		HK			110
		80		K			110
70% H_2SO_4 + 10% HNO_3		50		(D) HK W			113
		90		K W			113
30% H_2SO_4 + 5% HNO_3		90		HK			110
		110		HK			110
15% H_2SO_4 + 5% HNO_3		100		K			107
2% H_2SO_4 + 1% HNO_3		100		HK			100
N O							
Nickel Chloride	to 30	20	$NiCl_2$	KL MN TU Z	4)		
Nickel Nitrate	to 10	20	$Ni(NO_3)_2 \cdot 6\ H_2O$	HKL TU			
Nickel Sulphate	all	20	$NiSO_4$	HKL N TU			
Nitric Acid 8)	10	20	HNO_3	1.4309 N TU		– 12	100
	10	60		1.4309 N TU		– 12	100
	37	20		1.4309 N TU		– 35	111
	37	boiling		1.4361 U W		– 35	111

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
	53	20		1.4309 N TU		– 24	118
	53	boiling		1.4361 U W		– 24	118
	68	20		1.4361 N TU		– 34	121.5
	68	boiling		1.4361 TU W		– 34	121.5
	99	20		1.4361 TU W		– 43	88
	99	boiling		1.4361 T W		– 43	88
Nitrobenzene		20	$C_6H_5NO_2$	D HKL MN T		5.7	210.9
Oleic Acid		150	$C_{18}H_{34}O_2$	HKL MN		13.2	$260/_{53}$
		180		KL MN		13.2	$260/_{53}$
		300		K N		13.2	$260/_{53}$
Oleum	11% free SO_3	20	$H_2SO_4 + SO_3$	(D) HKL MN	6)		167
	11% free SO_3	100		KL MN			167
Oleum	60% free SO_3	20		HKL			66
	60% free SO_3	60		KL			66
Oxalic Acid	5	20	HOOC-COOH	HKL MN TU			
	5	100		HKL MN U			
	10	20		HKL MN TU			
	10	100		HKL N U			
	25	to 100		HKL N U			

Liquid	Conditions of liquid *w* % *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
	50 to 100		KL N			
P						
Phenol	dry 45	C_6H_5OH	D HKL MN U		40.9	181.9
	dry 100		HKL MN U		40.9	181.9
Phosphoric Acid 7)	< 10 20	H_3PO_4	HKL MN TU			
	10 100		HKL MN U			102
	50 70		HKL MN U			112
	50 110		KL MN U			112
	75 20		HKL MN U			135
	75 80		HKL MN			135
	75 135		L			135
	85 20		HKL MN			154
	85 90		HKL			154
Phthalic Acid	7 85	$C_6H_4(COOH)_2$	KL TU			
Phthalic Anhydride	180	$C_6H_4(CO)_2O$	HKL MN		131	285
Potassium Bromide	sat'd 20	KBr	HKL MN TU	4)		
Potassium Carbonate	20 to 80	K_2CO_3	(D) HKL MN TU			
Potassium Chlorate	sat'd 20	$KClO_3$	(D) HKL N TU	4)		
Potassium Chloride	all to 80	KCl	(H)KL MN TU Z	4)		

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Potassium Cyanide	sat'd	20	KCN	(D) HKL MN			
Potassium Dichromate	sat'd	20	$K_2Cr_2O_7$	D HKL N TU			
Potassium Ferricyanide	10	to 80	$K_3[Fe(CN)_6]$	HKL MN TU			
Potassium Ferrocyanide	10	to 80	$K_4[Fe(CN)_6] \cdot 3\ H_2O$	(H)KL MN U			
Potassium Hydroxide	to 50	to 80	KOH	(D) (H)KL U			
Potassium Hypochlorite	13% free Cl_2	20	KClO	N T Z	4)		
Potassium Iodide	10	20	KI	(H)KL MN TU Z	4)		
Potassium Nitrate	sat'd	20	KNO_3	HKL N T			
Potassium Permanganate	sat'd	to boiling	$KMnO_4$	(D) HKL			
Potassium Sulphate	sat'd	20	K_2SO_4	HKL MN TU			
Propionic Acid	to 100	20	CH_3CH_2COOH	HKL T		– 20.7	140.9
Pyridine	to 100	20	C_5H_5N	D HKL MN TU		– 41.7	115.4
S							
Silver Nitrate	all	20	$AgNO_3$	HKL N TU			
Soda Ash	*see Sodium Carbonate*						
Sodium Bicarbonate	to 8	to boiling	$NaHCO_3$	(D) HKL MN TU			
Sodium Bisulphate	15	35	$NaHSO_4 \cdot H_2O$	KL MN TU			
Sodium Bisulphite	38	to boiling	$NaHSO_3$	HKL N T			
Sodium Bromide	all	20	NaBr	(D) (H)KL MN TU	4)		

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Sodium Carbonate	all	20	Na_2CO_3	(D) HKL MN TU			
Sodium Chlorate	all	20	$NaClO_3$	(H)KL MN TU W	4)		
Sodium Chloride	< 3	20	NaCl	(D) HKL MN TU	4)		
	> 3 to 26	20		HKL MN TU	4)		
	> 3 to 28	120		KL MN TU	4)		
Sodium Chlorite	30	20	$NaClO_2$	KL N T W	4)		
	+ 2% NaOH	60		(H)KL N T W	4)		
Sodium Cyanide	sat'd	20	NaCN	(H)KL N T			
Sodium Dichromate	all	20	$Na_2Cr_2O_7$	D HKL N U			
Sodium Hydroxide	20	20	NaOH	D HKL MN TU			
	50	50		(D) HKL MN TU			
	50	90		KL MN TU			
Sodium Hypochlorite	20 g/l Cl_2	40	NaOCl	(H)(K) N T W Z	4)		
	120 g/l Cl_2	20		T W Z	4)		
Sodium Nitrate	sat'd	to boiling	$NaNO_3$	(D) HKL N TU			
Sodium Phosphates							
monobasic	to 10	25	$NaH_2PO_4 \cdot H_2O$	HKL N			
dibasic	to 6	20	$Na_2HPO_4 \cdot 2\ H_2O$	(D) HKL MN TU			
tribasic	to 10	to 100	$Na_3PO_4 \cdot 12\ H_2O$	(D) HKL MN TU			

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Sodium Silicates	all	20	$Na_2O \cdot x\ SiO_2$	(D) HKL MN TU			
Sodium Sulphate	cold sat'd	20	$Na_2SO_4 \cdot 10\ H_2O$	HKL MN TU			
	cold sat'd	100		HKL MN TU			
Sodium Sulphide	20	20	Na_2S	HK M TU			
	20	boiling		K M TU			
Sodium Sulphite	2	20	Na_2SO_3	HK MN TU			
	+ free SO_2	20		KL MN TU			
Sodium Thiosulphate	30	to 80	$Na_2S_2O_3$	HKL MN TU			
Stannic Chloride	24	20	$SnCl_4$	N TU W Z			
Stannous Chloride	sat'd	50	$SnCl_2$	HL N TU W Z	4)		
	sat'd	boiling		N TU W	4)		
Stearic Acid		150	$C_{18}H_{36}O_2$	HKL MN		70	$184/_2$
		250		K N		70	$184/_2$
Sulphur monochloride		20	S_2Cl_2	(D) HKL N T	5)	– 76	138.1
Sulphuric Acid	5	20	H_2SO_4	HKL MN TU			101
	5	100		K MN TU W			101
	10	20		HKL MN TU W			102
Sulphuric Acid	10	100	H_2SO_4	TU			102
	20	20		KL MN TU W			104

Liquid	Conditions of liquid *w* %	 *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
	20	100		U			104
	50	20		KL MN TU W			122
	50	120		M U			122
	70	20		KL MN TU W			164
	70	80		M U W			164
	70	160		U W			164
	85	20		(D) HKL MN T W			230
	85	50		MN W			230
	85	80		M W			230
	85	150		W			230
	98	20		D HKL MN T W		10	327
	98	50		HKL MN W		10	327
	98	80		MN W		10	327
	98	150		W		10	327
Sulphurous Acid		20	H_2SO_3	KL MN TU			
T							
Tetrachloroethen		20	C_2Cl_4	(D) HKL MN TU		– 22.2	121.2
Tetrahydrofuran	to 100	20	C_4H_8O	HKL MN TU		– 108.5	65.5
Titanium Tetrachloride		20	$TiCl_4$	N TU		– 24.3	136.5

Liquid	Conditions of liquid *w* % *t* °C	Formula	Material selection 3)	Refer to	Fp °C	Bp °C
Toluene	20	$C_6H_5CH_3$	(D) HKL N T		– 95.2	110.7
Trichloroethene	20	$CHCl=CCl_2$	D HKL	5)	– 86.5	87.3
	80		HKL MN TU	5)	– 86.5	87.3
Tricresyl Phosphate	pure 80	$(C_6H_4CH_3)_3PO_4$	HKL N T		– 25	410
Triethylamine	to 100 20	$(C_2H_5)_3N$	HKL		– 114.8	89.6
U V W						
Urea	all 25	CH_4N_2O	(D) (H)KL TU			
Vinyl Acetate	20	$CH_3COOCH=CH_2$	HKL N		– 100	72
Vinyl Chloride	20	$CH_2=CHCl$	(D) HKL N T		– 153.8	– 13.4
Water	*see Chapter 10 "Water" Table 10.07*					
X Z						
Xylene (m-X.)	20	$C_6H_4(CH_3)_2$	D HKL N T		– 47.9	139.2
Zinc Chloride	sat'd 20	$ZnCl_2$	HKL MN TU W Z	4)		
	sat'd 45		K MN TU W Z	4)		
	sat'd boiling		K U W			
Zinc Sulphate	30 20	$ZnSO_4$	HKL N T			