HAYNES® 25 alloy

Principle Features

Excellent High-Temperature Strength and Good Oxidation Resistance
HAYNES® 25 alloy (UNS R30605) is a cobalt-nickel- chromium-tungsten alloy that combines excellent high-temperature strength with good resistance to oxidizing environments up to 1800°F (980°C) for prolonged exposures, and excellent resistance to sulfidation. It can be fabricated and formed by conventional techniques, and has been used for cast components. Other attractive features include excellent resistance to metal galling.

Applications
HAYNES® 25 alloy combines properties which make it suitable for a number of component applications in the aerospace industry, including parts in established military and commercial gas turbine engines. In modern engines, it has largely been replaced by newer materials such as HAYNES® 188 alloy, and, most recently, 230® alloy, which possess improved properties. Another area of significant usage for 25 alloy is as a bearing material, for both balls and races.

Nominal Composition

	Weight %
Cobalt:	51 Balance
Nickel:	10
Iron:	3 max.
Chromium:	20
Molybdenum:	1 max.
Tungsten:	15
Manganese:	1.5
Silicon:	0.4 max.
Carbon:	0.1

Creep and Stress Rupture Strength

HAYNES® 25 alloy is a solid-solution-strengthened material which possesses excellent high-temperature strength. It is particularly effective for very long-term applications at temperatures of 1200 to 1800°F (650 to 980°C). It is stronger than nickel-base solid-solution-strengthened alloys, and is the strongest of the cobalt-base materials which still have good fabrication characteristics.

Solution-Annealed Sheet*

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in					
			10 h		100 h		1,000 h	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	0.5	62	427	47.5	328	33.5**	231**
		1	71	490	54	372	39.0**	269**
		R	82	565	69	476	57	393
1300	704	0.5	43	296	30.0**	207**	21.0**	145**
		1	49.5	341	35	241	23.2**	160**
		R	64	441	50	345	38	262
1400	760	0.5	28	193	19.5	134	14.8**	102**
		1	32	221	21.5	148	16.2**	112**
		R	47.0**	324**	36	248	26	179
1500	816	0.5	18.5	128	14	97	10.2**	70**
		1	20.2	139	15.5	107	12.3**	85**
		R	34.0**	234**	24.7	170	18.1	125
1600	871	0.5	13.7	94	9.9	68	6.9**	48**
		1	15.2	105	12	83	8.9**	61**
		R	24.0**	165**	17.5	121	12	83
1700	927	0.5	9.7	67	6.8	47	4.5**	31**
		1	12	83	8.8	61	5.6	39
		R	17.3**	119**	11.8	81	7.2	50

*Based upon limited data
**Significant extrapolation
R= Rupture

Creep and Stress Rupture Strength Continued

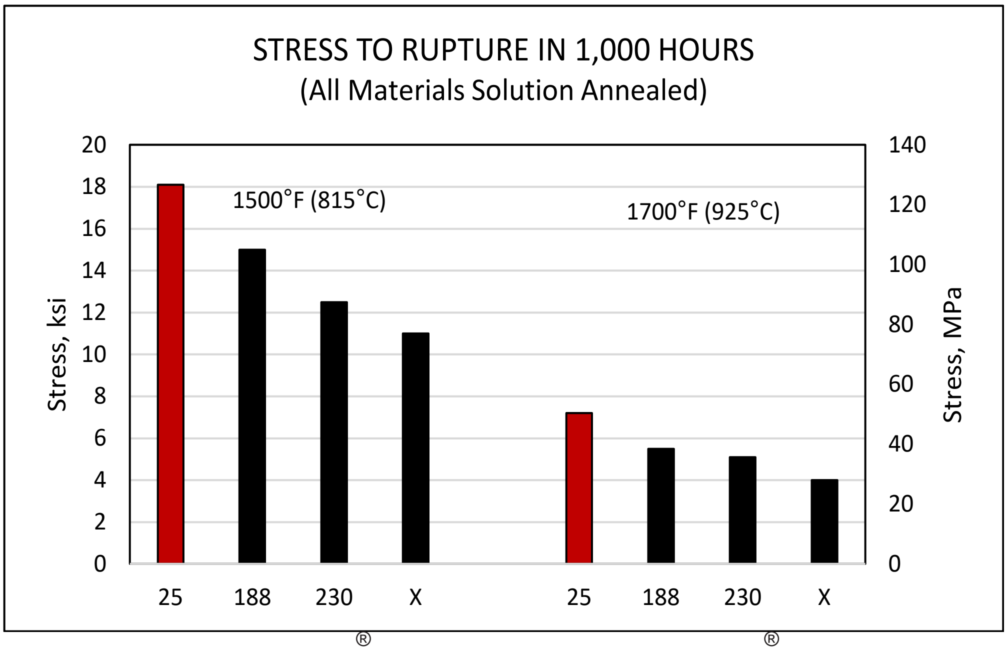
Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:					
			10 h		100 h		1,000 h	
°F	°C	%	ksi	Mpa	ksi	Mpa	ksi	Mpa
1800	982	0.5	6.8	47	4.5	31	2.6	18
		1	8.8	61	5.6	39	3	21
		R	11.8**	81**	7.2	50	4	28
2000	1093	0.5	2.8	19	1.3	9	-	-
		1	3.3	23	1.4	9.7	-	-
		R	4.5	31	2	14	-	-

*Based upon limited data
**Significant extrapolation
R= Rupture

Solution-Annealed Bar*

Temperature		Approximate Initial Stress to Produce Rupture in					
		10 h		100 h		1,000 h	
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa
1350	732	42.5	293	36.5	252	30.3	209
1400	760	39.2	270	31.5	217	24.1	166
1500	816	30.0	207	22.0	152	17.0	117
1600	871	23.0	159	16.5	114	12.0	83
1700	927	17.0	117	12.0	83	8.4	58
1800	982	11.5	79	7.5	52	5.0	34

Comparative Rupture Strength, Sheet



Tensile Properties

Solution Heat-Treated Sheet*

Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	69	476	144.5	996	54.7
1000	538	38.8	268	119	820	63.4
1200	649	37.2	256	119.3	823	54.2
1400	760	35.5	245	82.5	569	33.9
1600	871	33.5	231	46.3	319	97.8
1800	982	18.6	128	25.8	178	94.1
2000	1093	9.0	62	13.3	92	63.0

*Limited Data

Solution Heat-Treated Plate

Test Temperature		0.2% Offset Yield Strngth		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	68.7	474	145.1	1000	58.8
1000	538	38.4	265	122.1	842	71
1200	649	33.4	230	123.5	852	64.3
1400	760	34.4	237	86	593	45.7
1600	871	32	221	48.3	333	104.7
1800	982	18.7	129	27.3	188	113.7
2000	1093	9.3	64	14.5	100	97.5

Hot-Rolled and 2250°F (1230°C) Solution-Annealed Bar*

Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	73	505	147	1015	60
1000	538	43	295	113	780	63
1200	649	43	295	105	725	49
1400	760	41	285	90	620	29
1600	871	34	235	54	370	29
1800	982	19	130	28	195	41

*Limited Data

RT- Room Temperature

*Elevated temperature tensile tests for bar were performed with a strain rate that is no longer standard. These results were from tests with a strain rate of 0.005 in./in./minute through yield and a crosshead speed of 0.5 in./minute for every inch of reduced test section from yield through failure. The current standard is to use a strain rate of 0.005 in./in./minute though yield and a crosshead speed of 0.05 in./minute for every inch of reduced test section from yield through failure.

Hardness and Grain Size

Form	Hardness, HRB	Typical ASTM Grain Size
Sheet	97	3.5 - 5.5
Plate	99	3.5 - 5
Bar	98	3.5 - 5

All samples tested in solution-annealed condition

Cold-Worked Properties

HAYNES® 25 alloy has excellent strength and hardness characteristics in the cold-worked condition. These high property levels are also evident at elevated temperature, making 25 alloy quite suitable for applications such as ball bearings and bearing races. A modest additional increase in hardness and strength can be achieved through aging of the cold-worked material.

Typical Tensile Properties, Cold-Worked Sheet*

Cold Reduction	Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
-	°F	°C	ksi	MPa	ksi	MPa	%
10	70	20	105	725	155	1070	41
	100	540	78	540	114	785	48
	1200	650	80	550	115	795	37
	1400	760	67	460	87	600	8
	1600	870	47	325	62	425	13
	1800	980	27	185	39	270	15
15	70	20	124	855	166	1145	30
	1000	540	107	740	134	925	29
	1200	650	111	765	129	890	15
	1400	760	86	595	104	715	5
	1600	870	52	360	70	485	9
	1800	980	30	205	40	275	5
20	70	20	141	970	183	1260	19
	1000	540	133	915	156	1075	18
	1200	650	120	825	137	945	2
	1400	760	96	660	107	740	3
	1800	980	30	205	41	285	4

*Limited data for cold-rolled 0.050-inch (1.3 mm) thick sheet

Cold-Worked Properties Continued

Typical Tensile Properties, Cold-Worked and Aged Sheet*

Condition	Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
-	°F	°C	ksi	MPa	ksi	MPa	%
15% CW + Age A	70	20	136	940	168	1160	31
	1200	650	104	715	128	885	23
20% CW + Age A	70	20	152	1050	181	1250	17
	1000	540	129	890	151	1040	19
	1200	650	128	885	144	995	8
	1400	760	97	670	108	745	2
	1600	870	59	405	74	510	6
	1800	980	33	230	43	295	5
20% CW + Age B	70	20	162	1115	191	1315	16
	600	315	132	910	165	1140	28
	1000	540	124	855	149	1025	23
	1200	650	119	820	140	965	13
	1400	760	92	635	116	800	7
	1600	870	50	345	71	490	9
	1800	980	31	215	42	290	12

*Limited data for cold-rolled 0.050-inch (1.3 mm) thick sheet.
Age A = 700°F (370°C)/1 hour
Age B = 1100°F (595°C)/2 hours

Typical Hardness at 70°F (20°C), Cold-Worked and Aged Sheet*

Cold-Work	Hardness Rockwell C, After Indicated Level of Cold Work and Subsequent Aging Treatment		
	-	900°F (480°C)	1100°F (595°C)
%	None	5 h	5 h
None	24	25	25
5	31	33	31
10	37	39	39
15	40	44	43
20	44	44	47

*Limited data for cold-rolled 0.070-inch (1.8 mm) thick sheet.

Impact Strength

Impact Strength Properties, Plate

Test Temperature		Typical Charpy V-Notch Impact Resistance	
°F	°C	ft.-lbs.	J
-321	-196	109	148
-216	-138	134	182
-108	-78	156	212
-20	-29	179	243
RT	RT	193	262
500	260	219	297
1000	540	201	273
1200	650	170	230
1400	760	143	194
1600	870	120	163
1800	980	106	144

Thermal Stability

When exposed for prolonged periods at intermediate temperatures, HAYNES® 25 alloy exhibits a loss of room temperature ductility in much the same fashion as some other solid-solution-strengthened superalloys,such as HASTELLOY® X alloy or alloy 625. This behavior occurs as a consequence of the precipitation of deleterious phases. In the case of a 25 alloy, the phase in question is Co_2W laves phase. HAYNES® 188 alloy is significantly better in this regard than 25 alloy; however, for applications where thermal stability is important, 230® alloy is an even better selection.

Room-Temperature Properties of Sheet After Thermal Exposure*

Exposure Temperature		Exposure Time	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	h	ksi	MPa	ksi	MPa	%
None		0	66.8	460	135	930	48.7
1200	650	500	70.3	485	123.6	850	39.2
		1000	92.3	635	140	965	24.8
		2500	95.1	655	130.7	900	12
1400	760	100	68.9	475	115.3	795	18.1
1600	870	100	72.1	495	113.6	785	9.1
		500	77.3	535	126.1	870	3.5
		1000	81.7	565	142	980	5

*Composite of multiple sheet lot tests

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.327 lb/in^3	RT	9.07 g/cm^3
Melting Range	2425-2570°F	-	1330-1410°C	-
Electrical Resistivity	RT	34.9 µohm-in	RT	88.6 µohm-cm
	200°F	35.9 µohm-in	100°C	91.8 µohm-cm
	400°F	37.6 µohm-in	200°C	95.6 µohm-cm
	600°F	38.5 µohm-in	300 °C	97.6 µohm-cm
	800°F	39.1 µohm-in	400 °C	98.5 µohm-cm
	1000°F	40.4 µohm-in	500 °C	100.8 µohm-cm
	1200°F	41.8 µohm-in	600 °C	104.3 µohm-cm
	1400°F	42.3 µohm-in	700 °C	106.6 µohm-cm
	1600°F	40.6 µohm-in	800 °C	107.8 µohm-cm
	1800°F	37.7 µohm-in	900 °C	101.1 µohm-cm
	-	-	1000 °C	95.0 µohm-cm
Thermal Diffusivity	70°F	4.4 x 10^{-3} in^2/sec	RT	28.3 x 10^{-3}cm^2/sec
	125°F	4.6 x 10^{-3} in^2/sec	100°C	30.1 x 10^{-3}cm^2/sec
	200°F	4.8 x 10^{-3} in^2/sec	200°C	32.7 x 10^{-3}cm^2/sec
	400°F	5.5 x 10^{-3} in^2/sec	300°C	35.6 x 10^{-3}cm^2/sec
	600°F	6.0 x 10^{-3} in^2/sec	400°C	41.2 x 10^{-3}cm^2/sec
	800°F	6.5 x 10^{-3} in^2/sec	500°C	43.5 x 10^{-3}cm^2/sec
	1000°F	6.9 x 10^{-3} in^2/sec	600°C	45.5 x 10^{-3}cm^2/sec
	1200°F	7.3 x 10^{-3} in^2/sec	700°C	47.6 x 10^{-3}cm^2/sec
	1400°F	7.6 x 10^{-3} in^2/sec	800°C	49.6 x 10^{-3}cm^2/sec
	1600°F	7.7 x 10^{-3} in^2/sec	900°C	48.7 x 10^{-3}cm^2/sec
	1800°F	7.9 x 10^{-3} in^2/sec	1000°C	51.6 x 10^{-3}cm^2/sec
	2000°F	8.3 x 10^{-3} in^2/sec	-	-
Thermal Conductivity	70°F	72 Btu-in/ft^2-h-°F	25°C	10.5 W/m-°C
	125°F	77 Btu-in/ft^2-h-°F	100°C	12.0 W/m-°C
	200°F	83 Btu-in/ft^2-h-°F	200°C	14.0 W/m-°C
	400°F	99 Btu-in/ft^2-h-°F	300°C	15.9 W/m-°C
	600°F	114 Btu-in/ft^2-h-°F	400°C	17.7 W/m-°C
	800°F	127 Btu-in/ft^2-h-°F	500°C	19.5 W/m-°C
	1000°F	140 Btu-in/ft^2-h-°F	600°C	21.2 W/m-°C
	1200°F	152 Btu-in/ft^2-h-°F	700°C	22.9 W/m-°C
	1400°F	165 Btu-in/ft^2-h-°F	800°C	24.5 W/m-°C
	1600°F	178 Btu-in/ft^2-h-°F	900°C	26.0 W/m-°C
	1800°F	191 Btu-in/ft^2-h-°F	1000°C	27.5 W/m-°C
	2000°F	201 Btu-in/ft^2-h-°F	-	-

RT- Room Temperature

Physical Properties Continued

Physical Property	British Units		Metric Units	
Specific Heat	70°F	0.096 Btu/lb.-°F	25°C	403 J/kg-°C
	125 °F	0.098 Btu/lb.-°F	100 °C	424 J/kg-°C
	200 °F	0.101 Btu/lb.-°F	200 °C	445 J/kg-°C
	400 °F	0.106 Btu/lb.-°F	300 °C	455 J/kg-°C
	600°F	0.111 Btu/lb.-°F	400 °C	462 J/kg-°C
	800 °F	0.116 Btu/lb.-°F	500 °C	495 J/kg-°C
	1000 °F	0.119 Btu/lb.-°F	600 °C	508 J/kg-°C
	1200 °F	0.123 Btu/lb.-°F	700 °C	582 J/kg-°C
	1400 °F	0.128 Btu/lb.-°F	800 °C	592 J/kg-°C
	1600 °F	0.137 Btu/lb.-°F	900 °C	596 J/kg-°C
	1800 °F	0.143 Btu/lb.-°F	1000 °C	598 J/kg-°C
	2000 °F	0.142 Btu/lb.-°F	-	-
Mean Coefficient of Thermal Expansion	70 - 200 °F	7.1 µin/in.-°F	25 - 100 °C	12.8 µm/m-°C
	70 - 400 °F	7.3 µin/in.-°F	25 - 200 °C	13.1 µm/m-°C
	70 - 600 °F	7.5 µin/in.-°F	25 - 300 °C	13.3 µm/m-°C
	70 - 800 °F	7.7 µin/in.-°F	25 - 400 °C	13.7 µm/m-°C
	70 - 1000 °F	7.9 µin/in.-°F	25 - 500 °C	14.0 µm/m-°C
	70 - 1200 °F	8.2 µin/in.-°F	25 - 600 °C	14.6 µm/m-°C
	70 - 1400 °F	8.6 µin/in.-°F	25 - 700 °C	15.1 µm/m-°C
	70 - 1600 °F	8.9 µin/in.-°F	25 - 800 °C	15.8 µm/m-°C
	70 - 1800 °F	9.2 µin/in.-°F	25 - 900 °C	16.2 µm/m-°C
	70 - 2000 °F	9.5 µin/in.-°F	25 - 1000 °C	16.7 µm/m-°C
Dynamic Modulus of Elasticity	RT	32.6×10^6 psi	RT	225 GPa
	200°F	32.3×10^6 psi	100°C	222 GPa
	400°F	31.0×10^6 psi	200°C	214 GPa
	600°F	29.4×10^6 psi	300°C	204 GPa
	800°F	28.3×10^6 psi	400°C	197 GPa
	1000°F	26.9×10^6 psi	500°C	188 GPa
	1200°F	25.8×10^6 psi	600°C	181 GPa
	1400°F	24.3×10^6 psi	700°C	174 GPa
	1600°F	22.8×10^6 psi	800°C	163 GPa
	1800°F	21.4×10^6 psi	900°C	154 GPa
	-	-	1000°C	146 GPa

RT- Room Temperature

Wear Resistance

HAYNES 25 alloy exhibits excellent resistance to metal galling and cavitation. Metal-to-Metal Galling results shown below were generated for standard matching material room-temperature pin on disc tests. Wear depths are given as a function of applied load. Cavitation tests were performed in accordance with ASTM G 32 water at 16°C, with a frequency of 20 kHz and an amplitude of 0.05 mm. The results of the wear tests indicate that 25 alloy is superior in galling and cavitation resistance to many materials, and is surpassed only by ULTIMET® alloy and HAYNES 6B alloy. Both of these materials were specifically designed to have excellent wear resistance.

Alloy	Galling - Degree of Damage for Various Applied Loads					
	3,000 lbs. (1,365 kg)		6,000 lbs. (2,725 kg)		9,000 lbs. (4,090 kg)	
-	mils	µm	mils	µm	mils	µm
6B	0.02	0.6	0.03	0.7	0.02	0.5
ULTIMET®	0.11	2.9	0.11	2.7	0.08	2
25	**0.23**	**5.9**	**0.17**	**4.2**	**0.17**	**4.2**
188	1.54	39.2	3.83	97.3	3.65	92.6
HR-160®	1.73	43.9	4.33	109.9	3.81	96.8
214®	2.32	59	3.96	100.5	5.55	141
556®	3.72	94.4	5.02	127.6	5.48	139.3
230®	4.44	112.7	7.71	195.8	8.48	215.5
HR-120®	6.15	156.2	7.05	179	10.01	254.2

Alloy	Cavitation - Mean Depth of Erosion							
	24 h		48 h		72 h		96 h	
	mils	µm	mils	µm	mils	µm	mils	µm
ULTIMET®	0.3	6.8	0.9	22.9	1.6	40.2	2.3	57.4
6B	0.3	7.7	0.9	22.3	1.4	34.8	1.9	48
25	**1**	**24.4**	**2.1**	**53.6**	**3.4**	**85.6**	**4.5**	**115.1**
625	3.1	80	7	176.6	10.2	259.2	Not tested	Not Tested
556®	3.3	83.8	6.9	175.8	9.6	244.3	11.4	289.8
230®	3.8	97.6>	7.5	190.1	9.9	251.8	11.9	301.7

Tested in accordance with ASTM G 32 water at 16ºC, with a frequenct of 20 kHz and an amplitude of 0.05 mm

High-Temperature Hardness

The following are results from standard vacuum furnace hot hardness tests. Values are given in originally measured DPH (Vickers) units and conversions to Rockwell C/B scale.

	Vickers Diamond Pyramid Hardness (Rockwell C/B Hardness)									
	70°F (20°C)		800°F (425°C)		1000°F (540°C)		1200°F (650°C)		1400°F (760°C)	
Solution Treated	251	22 HRC	171	87 HRC	160	83 HRB	150	80 HRB	134	74 HRB
15% Cold Work	348	35 HRC	254	23 HRC	234	97 HRB	218	95 HRB	-	-
20% Cold Work	401	41 HRC	318	32 HRC	284	27 HRC	268	25 HRC	-	-
25% Cold Work	482	48 HRC	318	32 HRC	200	30 HRC	286	28 HRC	-	-

HRB = Hardness Rockwell “B”.
HRC = Hardness Rockwell “C”.

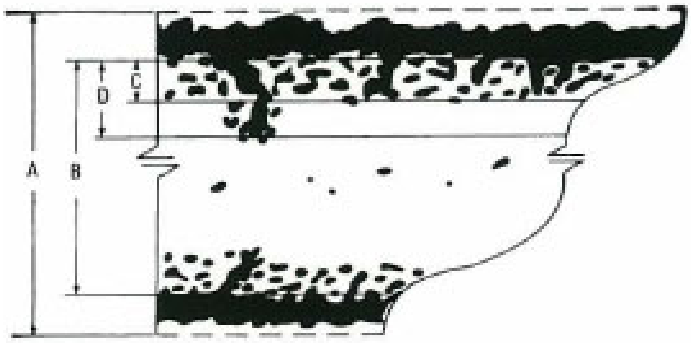
Aqueous Corrosion Resistance

Alloy	Average Corrosion Rate, per year					
	1% HCl (Boiling)		10% H_2SO_4 (Boiling)		65% HNO_3 (Boiling)	
-	mils	mm	mils	mm	mils	mm
ULTIMET®	<1	<0.03	99	2.51	6	0.15
C-22®	3	0.08	12	0.3	134	3.4
25	**226**	**5.74**	**131**	**3.33**	**31**	**0.79**
Type 316L	524	13.31	1868	47.45	9	0.23

HAYNES® 25 alloy was not designed for resistance to corrosive aqueous media. Representative average corrosion data are given for comparison. For applications requiring corrosion resistance in aqueous environments, ULTIMET® alloy and HASTELLOY® corrosion-resistant alloys should be considered.

Oxidation Resistance

HAYNES® 25 alloy exhibits good resistance to both air and combustion gas oxidizing environments, and can be used for long-term continuous exposure at temperatures up to 1800°F (980°C). For exposures of short duration, 25 alloy can be used at higher temperatures. Applications for which oxidation resistance is a serious consideration normally call for newer, more capable materials such as 230® alloy or HAYNES® 188 alloy. This is particularly important at temperatures above 1800°F (980°C).



1. Metal Loss = (A - B)/2
2. Average Internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A - B)/2) + C
5. Maximum Metal Affected = ((A - B)/2) + D

Comparative Burner Rig Oxidation Resistance 1000 Hour Exposure at 1800°F (980°C)

Alloy	Metal Loss		Average Metal Affected		Maximum Metal Affected	
	mils	µm	mils	µm	mils	µm
188	1.1	28	3.2	81	3.9	99
230®	2.8	71	5.6	142	6.4	163
617	2.4	61	5.7	145	6.9	175
625	3.7	94	6	152	6.6	168
X	4.3	109	7.3	185	8	203
25	**7.8**	**198**	**9.8**	**249**	**10.3**	**262**
310SS	16	406	18.3	465	19.5	495
800H	22.9	582	Internal oxidation through thickness			

Oxidation Resistance Continued

Oxidation Test Parameters

Burner rig oxidation tests were conducted by exposing samples 3/8 in. x 2.5 in. x thickness (9 mm x 64 mm x thickness), in a rotating holder, to products of combustion of No. 2 fuel oil burned at a ratio of air to fuel of about 50:1. (Gas velocity was about 0.3 mach). Samples were automatically removed from the gas stream every 30 minutes and fancooled to near ambient temperature and then reinserted into the flame tunnel.

Comparative Oxidation Resistance in Flowing Air*

Alloy	1800°F (980°C)				2000°F (1095°C)				2100°F (1150°C)			
	Average Metal Affected**		Average Metal Loss		Average Metal Affected**		Average Metal Loss		Average Metal Affected**		Average Metal Loss	
-	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
188	1.1	28	0.1	3	3.7	94	0.5	13	10.7	272	8.6	218
230®	1.5	38	0.2	5	3.3	84	0.5	13	4.4	112	1.2	30
25	**2**	**51**	**0.3**	**8**	**10.2**	**259**	**9.2**	**234**	**10.7**	**272**	**8.2**	**208**
X	1.5	38	0.2	5	4.4	112	1.3	33	6.1	115	3.6	91
625	1.9	48	0.4	10	7.8	198	3.5	89	20.2	513	18.3	465
617	2	51	0.3	8	3.8	97	0.6	15	5.2	132	1	25
800HT	4.1	104	0.5	13	11.6	295	7.6	193	15	381	11	279

* Flowing air at a velocity of 7.0 ft./min. (213.4 cm/min.) past the samples. Samples cycled to room temperature once-a-week.

** Metal Loss + Average Internal Penetration.

Comparative Burner Rig Oxidation Resistance at 2000°F (1095°C) for 500 Hours

Alloy	Average Metal Loss per Side		Maximum Metal Affected	
-	mils	µm	mils	µm
214®	1.2	30.5	1.8	45.7
230®	7.1	180.3	11.8	299.7
188	10.9	276.9	14.1	358.1
X	11.6	294.6	15.1	383.5
25	**> 25***	**>635***	**-**	**-**

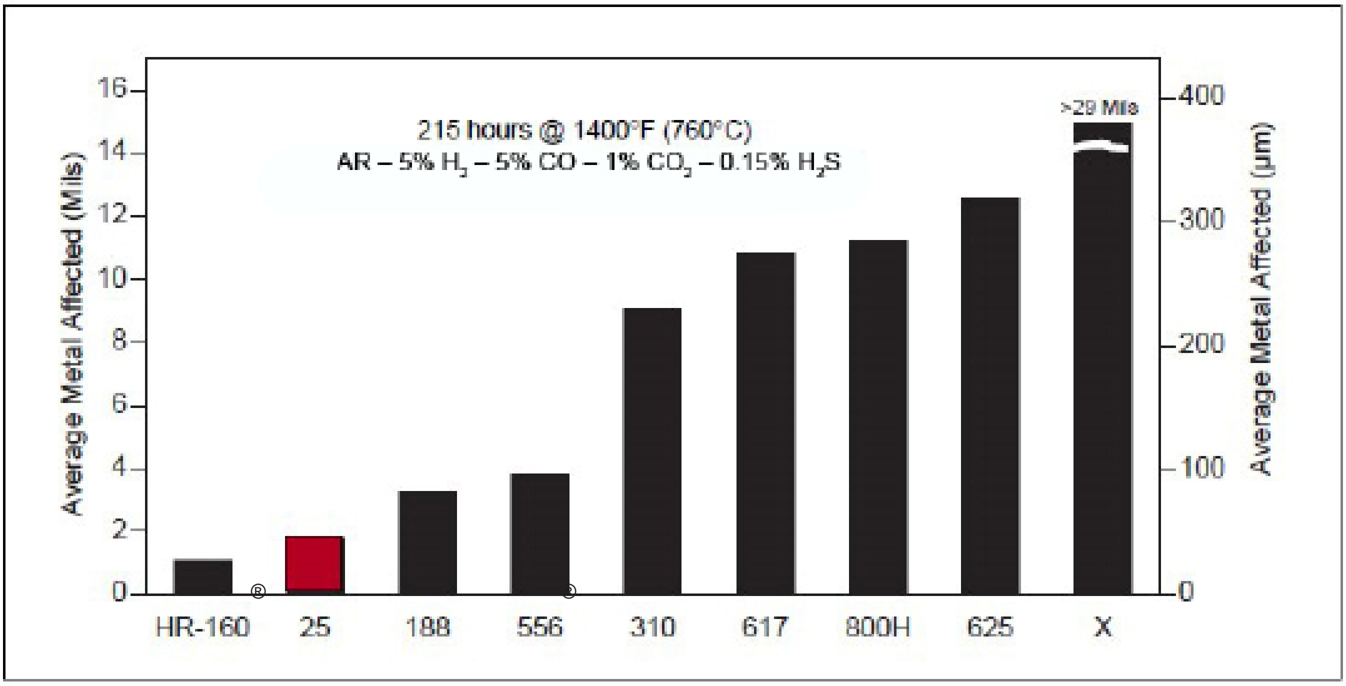
*> 25 mils (635 µm) in 165 hours

Sulfidation Resistance

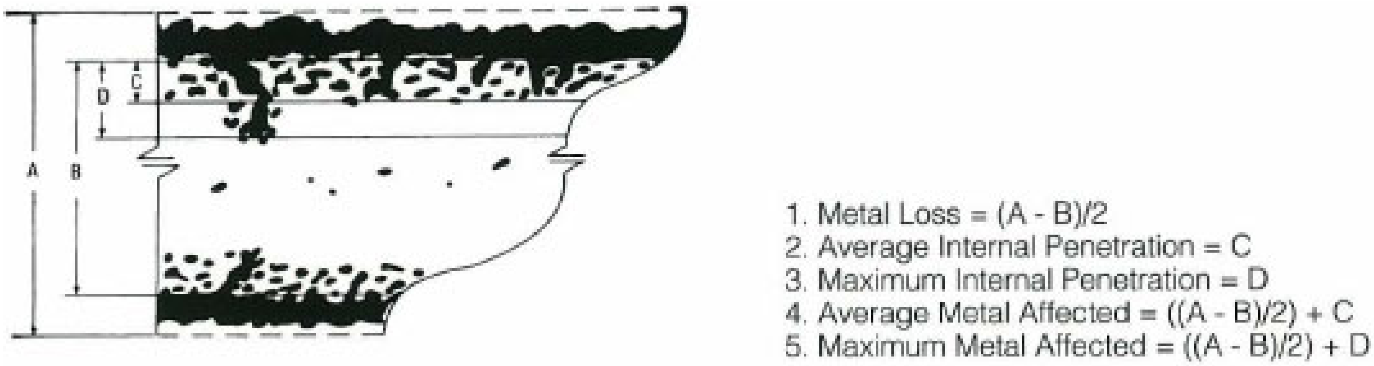
Sulfidation Resistance at 1400°F (760°C)

HAYNES® 25 alloy has very good resistance to gaseous sulfidation environments encountered in various industrial applications. Tests were conducted at 1400°F (760°C) in a gas mixture consisting of 5 percent H_2, 5 percent CO, 1 percent CO_2, 0.15 percent H_2S and 0.1 percent H_2O, balance Ar. Coupons were exposed for 215 hours. This is a severe test, with equilibrium sulfur partial pressure of 10-6 to 10-7 and oxygen partial pressures less than that needed to produce protective chromium oxide scales.

Sulfidation Resistance Continued



Schematic Representation of Metallographic Technique Used for Evaluating Environmental Tests



Fabrication

HAYNES® 25 alloy has good forming and welding characteristics. It may be forged or otherwise hot-worked, providing that it is held at 2200°F (1205°C) for a time sufficient to bring the entire piece to temperature. The alloy has good ductility, and thus also may be formed by cold working. The alloy does work-harden very rapidly, however, so frequent intermediate annealing treatments will be needed for complex component forming operations. All hot- or cold-worked parts should be annealed and rapidly cooled in order to restore the best balance of properties. The alloy can be welded by both manual and automatic welding methods, including gas tungsten arc (GTAW), gas metal arc (GMAW), shielded metal arc, electron beam and resistance welding. It exhibits good restraint welding characteristics.

Fabrication Continued

Heat Treatment

HAYNES® 25 alloy is furnished in the solution heat-treated condition, unless otherwise specified. The alloy is normally final solution heat-treated at 2150 to 2250°F (1175 to 1230°C) for a time commensurated with section thickness and rapidly cooled or water-quenched for optimal properties. Because annealing at temperatures less than the solution heat-treating temperature will produce some carbide precipitation in 25 alloy, which may affect the alloy's properties, annealing during fabrication may be performed at lower temperatures, but a final, subsequent solution heat treatment is needed to produce optimum properties and structure.

Machining

For information on Machining, please refer to the machining section of Welding and Fabrication.

Effect of Cold Reduction Upon Room-Temperature Properties*

Cold Reduction	Subsequent Anneal	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation	HRC
%		ksi	MPa	ksi	MPa	%	-
0	None	68.4	470	144	995	58.5	24
10		123.6	850	181.9	1255	37.1	36
15		148.5	1025	178.2	1230	27.7	40
20		150.9	1040	193.5	1335	18.2	42
25		183.9	1270	232.5	1605	14.6	44
10	1950°F (1065°C) for 5 min.	97.9	675	163	1125	39.3	32
15		91.2	630	167.1	1150	43.8	30
20		96.5	665	170.7	1175	40.8	32
25		88.9	615	169.5	1170	44.3	32
10	2050°F (1120°C) for 5 min.	74	510	156.6	1080	53.4	27
15		78.6	540	161.2	1110	51.9	28
20		82	565	164.8	1135	47.6	31
25		82.9	570	165.6	1140	48	30
10	2150°F (1117°C) for 5 min.	66.9	460	148.1	1020	62.6	21
15		73.6	505	156.1	1075	55.4	26
20		72.1	495	154	1060	59.3	26
25		68.5	470	149.3	1030	61.7	25

*Based upon cold reductions taken upon 0.110-inch (2.8 mm) thick sheet.
Duplicate tests.
HRC = Hardness Rockwell "C".

Welding

HAYNES® 25 alloy is readily welded by Gas Tungsten Arc (GTAW), Gas Metal Arc (GMAW), Shielded Metal Arc (SMAW), electron bean welding, and resistance welding techniques. Its welding characteristics are similar to those of HAYNES® 188 alloy. Submerged Arc welding is not recommended, as this process is characterized by high heat input to the base metal and slow cooling of the weld. These factors can increase weld restraint and promote cracking.

Base Metal Preparation

The joint surface and adjacent area should be thoroughly cleaned before welding. All grease, oil, crayon marks, sulfur compounds, and other foreign matter should be removed. Contact with copper or copper-bearing materials in the joint area should be avoided. It is preferable, but not necessary, that the alloy be in the solution-annealed condition when welded.

Filler Metal Selection

Matching composition filler metal is recommended for joining alloy 25. For shielded metal arc welding, HAYNES® 25 alloy electrodes (AMS 5797) are suggested. For dissimilar joining of 25 alloy to nickel-, cobalt-, or iron- base materials, 25 alloy itself (AMS 5796), 230-W® filler wire (AMS 5839), HAYNES® 556® alloy (AMS 5831), HASTELLOY® S alloy (AMS 5838), or HASTELLOY® W alloy (AMS 5786) welding products are suggested, depending upon the particular case. Please see the “Welding and Fabrication” brochure or the Haynes Welding SmartGuide for more information.

Preheating, Interpass Temperatures, and Post-Weld Heat Treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat treatment is not generally required for 25 alloy. For further information, please consult the “Welding and Fabrication” brochure.

Welded Tensile - Room Temperature

Form	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
	ksi	MPa	ksi	MPa	%
Sheet	69	476	144.5	996	54.7
Plate	68.7	474	145.1	1000	58.8
Welded Transverse, GTAW	72.4	499	134.2	925	36.5
All Weld Metal, SMAW	88.6	611	141	972	31.5

Specifications

Specifications

HAYNES® 25 alloy (UNS R30605)	
Sheet, Plate & Strip	AMS 5537
Billet, Rod & Bar	AMS 5759 MIL-C-24252D
Coated Electrodes	AMS 5797
Bare Welding Rods & Wire	AMS 5796
Seamless Pipe & Tube	-
Welded Pipe & Tube	-
Fittings	-
Forgings	AMS 5759
DIN	-
Others	-

Codes

HAYNES® 25 alloy (R30605)	
MMPDS	6.4.1

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