

Oxidation Resistance of HAYNES® High-Temperature Alloys

OXIDATION IN COMBUSTION GASES

The following results were generated for standard burner rig high-velocity dynamic oxidation tests. Exposures were 1000 hours at 1800°F (980°C) and 500 hours at 2000°F (1095°C). Samples were exposed in a rotating carousel to products of combustion of a mixture of No.1 and No.2 fuel oil burned at an air:fuel ratio of about 50:1. Gas velocity was 0.3 Mach. Samples were automatically removed from the gas stream every 30 minutes, and fan cooled to under 500°F (260°C). Following exposure, samples were evaluated metallographically to determine the extent of metal loss, or thinning, and the average depth of internal penetration. Average metal affected is the sum of these two quantities.

Material	1800°F (980°C)/1000 Hours				2000°F (1095°C)/500 Hours			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	µm	mils	µm	mils	µm	mils	µm
HAYNES 214™ alloy	0.4	10	1.0	25	0.5	13	1.2	30
HAYNES 230™ alloy	0.8	20	2.8	71	2.2	56	5.2	132
HAYNES alloy 188	1.1	28	3.5	89	7.5	191	9.8	249
HAYNES 556™ alloy	1.7	43	4.9	124	8.7	221	10.8	274
HAYNES HR-160™ alloy	-	-	-	-	4.6	117	11.2	284
HASTELLOY® alloy X	2.7	69	5.6	142	9.0	229	12.9	328
HASTELLOY alloy S	3.1	79	5.9	150	11.8	300	13.7	348
Alloy 625	4.9	124	7.1	180	>31.0	>787	>31.0	>787
HAYNES alloy 25	6.2	157	8.3	211	>25.0 ^a	>635 ^a	>25.0 ^a	>635 ^a
Alloy 617	2.7	69	9.8	249	12.4	315	>24.0 ^b	>610 ^b
RA330® alloy	7.8	198	11.8	300	10.9	277	12.9	328
MULTIMET® alloy	11.8	300	14.4	366	49.1 ^c	1247 ^c	53.8 ^c	1367 ^c
Alloy 600	12.3 ^d	312 ^d	14.4 ^d	366 ^d	17.2	437	19.5	495
Alloy 800H	12.3	312	14.5	368	30.5 ^e	775 ^e	33.4 ^e	848 ^e
Type 310 stainless	13.7	348	16.2	411	21.2	538	23.7	602
Alloy 601	3.0	76	18.8	478	10.7	272	>24.0 ^b	>610 ^b
Type 304/316 stainless	-	-	>>23.0 ^f	>>584 ^f	-	-	>>23.0 ^f	>>584 ^f

^a Consumed in 165 hours. ^b Internal penetration through entire thickness. ^c Extrapolated from 225 hours.

^d Extrapolated from 917 hours. ^e Extrapolated from 400 hours. ^f Consumed in 65 hours.

OXIDATION IN FLOWING AIR

The following results were generated for 1008 hour exposures to gently flowing air in a tube furnace. Samples were cycled to room temperature once-a-week. Following exposure, samples were evaluated metallographically to determine the extent of metal loss, or thinning, and the average depth of internal penetration. Average metal affected is the sum of these two quantities.

Material	Average Metal Affected**							
	1800°F (980°C)		2000°F (1095°C)		2100°F (1150°C)		2200°F (1205°C)	
	mils	µm	mils	µm	mils	µm	mils	µm
HAYNES 214 alloy	0.2	5	0.1	3	0.3	8	0.7	18
HAYNES 230 alloy	0.7	18	1.3	33	3.4	86	7.9	201
HASTELLOY alloy S	0.5	13	1.3	33	1.7	43	>31.7	>805
HAYNES alloy 188	0.6	15	1.3	33	8.0	203	>21.7	>551
Alloy 600	0.9	23	1.6	41	2.9	74	8.4	213
Alloy 617	1.3	33	1.8	46	3.4	86	12.5	318
Type 310 stainless	1.1	28	2.3	58	4.4	112	10.3	262
HAYNES 556 alloy	1.1	28	2.6	66	11.6	295	>150.0	>3810
Alloy 601	1.3	33	2.6	66	5.3	135	7.5*	191*
HASTELLOY alloy X	0.9	23	2.7	69	5.8	147	>35.4	>899
HAYNES alloy 150	1.0	25	3.8	97	>26.8	>681	>46.1	>1171
Alloy 625	0.7	18	4.8	122	18.2	462	>47.6	>1209
RA330 alloy	4.3	109	6.7	170	8.7	221	-	-
Alloy 800H	1.8	46	7.4	188	8.9	226	13.6	345
HAYNES HR-120 alloy	3.7	94	7.7	196	16.3	414	25.3	643
253MA® alloy	2.9	74	8.2	208	16.4	417	29.2	742
HAYNES alloy 25	0.7	18	10.2	259	19.2	488	>37.9	>963
HAYNES HR-160 alloy	5.9	150	10.3	262	13.0	330	24.2	615
MULTIMET alloy	1.3	33	11.6	295	>47.2	>1199	>146.4	>3719
800HT® alloy	3.8	97	12.0	305	18.8	478	>58.0	>1473
Type 446 stainless	2.3	58	14.5	368	>21.7	>551	>23.3	>592
Type 304 stainless	8.1	206	>27.1	>688	>23.6	>599	>68.0	>1727
Type 316 stainless	14.3	363	>68.4	>1737	>105.0	>2667	>140.4	>3566

* Large internal voids not included.

** All figures shown as greater than stated value represent extrapolation of tests for which samples were consumed in less than 1008 hours.

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