MULTIMET® alloy

Principal Features

MULTIMET® alloy (UNS R30155, W73155) is recommended for us in applications involving high stress at temperatures up to 1500°F, and moderate stress up to 2000°F. It has excellent oxidation resistance, good ductility, and is readily fabricated. Its high-temperature properties are inherent and are not dependent upon age-hardening. Production and use of the alloys dates back to the late 1940s.

The alloy has been used in a number of aircraft application including tailpipes and tail cones, afterburner parts, exhaust manifolds, combustion chambers, turbine blades, buckets, and nozzles. It also gives excellent service for high-temperature bolts, and has proven to be an economical material of construction for use in heat-treating equipment where strength at high temperatures is essential.

MULTIMET® alloy has good resistance to corrosion in certain media under both oxidizing and reducing conditions. When solution heat treated, MULTIMET® alloy has about the same resistance to nitric acid as does stainless steel. It has better resistance than stainless steel to weak solutions of hydrochloric acid. It withstands all concentrations of sulfuric acid at room temperature.

MULTIMET® alloy can be machined, forged and cold-formed by conventional methods. The alloy can be welded by various arc and resistance-welding processes.

MULTIMET® alloy is available as sheet, strip, plate, wire, coated electrodes, billet stock and sane and investment castings. It is also available in the form of re-melt stock to a certified chemistry.
Most wrought forms of MULTIMET® alloy are shipped in the solution heat-treated condition to assure optimum properties. Sheet is given a solution heat-treatment of 2150°F, for a time dependent upon section thickness, followed by a rapid air cool or water quench. Bar stock and plate (1/4 in. and heavier) are usually solution heat treated at 2150°F followed by water quench.

MULTIMET® alloy suffered from mediocre oxidation resistance, a tendency for heat affected zone cracking during welding, and a relatively wide scatter band of mechanical properties. MULTIMET® alloy was developed to address these concerns and as an improvement.

Nominal Composition

Weight %	
Iron:	30 Balance
Nickel:	20
Cobalt:	20
Chromium:	21
Molybdenum:	3
Tungsten:	2.5
Carbon:	0.12
Nitrogen:	0.15
Columbium & Tantalum:	1
Silicon:	1 max.
Manganese:	1.5

Hardness

Form	Hardness, HRBW	Typical ASTM Grain Size
Sheet	90	4.5 - 6.5
Plate	92	3 - 6.5
Bar	89	3 - 5

HRBW = Hardness Rockwell “B”, Tungsten Indentor.
All samples tested in solution-annealed condition

Tensile Data

Elevated temperature tensile tests for sheet 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.

Typical Short-Time Tensile Data, Wrought

Form	Condition	Test Temperature		Ultimate Tensile Strength		0.2% Offset Yield Strength		Elongation
		°F	°C	ksi	MPa	psi	MPa	%
Sheet 0.052 in thick	Heat-treated at 2150°F, RAC	RT	RT	116.0	800	57	393	43
		1200	649	73.2	505	-	-	35
		1700	927	19.8	137	-	-	39
		1900	1038	10.0	69	-	-	34
Sheet 0.063 in thick	Heat-treated at 2150°F, RAC	RT	RT	118.1	814	58	400	49
		800	427	98.0	676	42	292	54
		1000	538	93.9	647	40	274	54
		1200	649	73.5	507	38	259	28
		1400	760	58.4	403	36	247	12
		1600	871	38.8	268	30	207	15
		1800	982	24.7	170	17	117	51
		2000	1093	13.0	90	8	58	38
		2100	1149	6.9	48	4	30	36
		2200	1204	4.8	33	3	21	29
		2300	1260	3.4	23	-	-	19
		2350	1288	2.6	18	-	-	7
Plate 1/2 in thick	Heat-treated at 2165°F, WQ	-108	-78	137.7	949	74	513	63
		-320	-196	190.2	1311	-	-	53
Forging, 21 in diameter x 3 1/4 in thick	Stress-relieved 2 h at 1200°F, AC	RT	RT	117.6	811	72	493	30
		1200	649	83.0	572	49	338	25
Forged Bar 1-2 in thick	Heat-treated at 2165°F, WQ	RT	RT	111.0	765	56	384	55*
Hot-Rolled Bar 1/2-2 in diameter	Heat-treated at 2165°F, WQ	RT	RT	111.3	767	54	372	57*
Hot-Rolled Bar 0.242 in diameter, Cold-Reduced	Heat-treated at 2150°F, RAC	RT	RT	115.8	798	-	-	50
	reduced 5%	RT	RT	115.0	793	77	527	40
	reduced 10%	RT	RT	124.0	855	103	709	35
	reduced 15%	RT	RT	135.2	932	123	845	24
	reduced 20%	RT	RT	147.5	1017	136	935	20
	reduced 25%	RT	RT	153.0	1055	143	986	15
	reduced 30%	RT	RT	159.5	1100	153	1051	12
	reduced 35%	RT	RT	174.5	1203	168	1160	10
	reduced 40%	RT	RT	178.5	1231	176	1214	10

AC- Air Cooled
RAC- Rapid Air-Cooled
WQ-Water Quenched
*Elongation in 1 in.
RT = Room Temperature

Impact Strength

Test Temperature		Charpy Impact Strength	
°F	°C	ft-lb	J
1500	816	69	94
RT	RT	113	153
-20	-29	105	142
-108	-78	86	117
-216	-138	66	89
-321	-196	56	76

All samples were in solution annealed condition.
RT= Room Temperature

Creep and Stress-Rupture Data

MULTIMET® Sheet, Solution Annealed

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in					
			10 Hours		100 Hours		1,000 Hours	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa
1200	649	0.5	42	290	33	228	25	172
		1	48	331	37	255	29	200
		R	58	400	48	331	40	276
1300	704	0.5	30	207	23	159	17.5	121
		1	36	248	27.5	190	21	145
		R	46	317	37.5	259	29	200
1400	760	0.5	21.5	148	15.5	107	11	76
		1	26	179	19	131	14	97
		R	36	248	26	179	19	131
1500	816	0.5	15.5	107	11.5	79	8.0	55
		1	18.5	128	13.5	93	9.5	66
		R	26	179	18.5	128	13	90
1600	871	0.5	12.0	83	7.8	54	4.9	34
		1	13.2	91	9.2	63	6.0	41
		R	18.5	128	12	83	7.6	52
1700	927	0.5	7.5	52	4.8	33	2.8	19
		1	9.0	62	5.8	40	3.4	23
		R	12	83	7.8	54	4.7	32
1800	982	0.5	5.0	34	2.5	17	1.3	8.6
		1	5.8	40	3.1	21	1.6	11
		R	8.5	59	4.6	32	2.6	18

Thermal Stability

Room Temperature Tensile Properties after 1200°F (650°C) /16,000 hours

Alloy	Form	Ultimate Tensile Strength		Yield Strength		Elongation
		ksi	MPa	ksi	MPa	%
MULTIMET®	**Sheet, 0.125 in**	**138.2**	**953**	**69.0**	**476**	**19.4**
556®	Plate, 0.5 in	129.9	896	64.2	443	29.6

Oxidation Resistance

MULTIMET® exhibits acceptable oxidation resistance up to around 1800°F. However, due to concerns with oxidation resistance, MULTIMET® has been generally replaced by 556® alloy, which has comparable creep-rupture strength but superior oxidation resistance, particularly at temperatures greater than 1800°F.

Short-Term Static Oxidation

Comparative Oxidation Resistance in Flowing Air, 1008 Hours

Alloy	1800°F (980°C)				2000°F (1095°C)			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	µm	mils	µm	mils	µm	mils	µm
MULTIMET®	**0.4**	**10**	**1.3**	**33**	**8.9**	**226**	**14.3**	**363**
556®	0.4	10	2.3	58	1.5	38	6.9	175

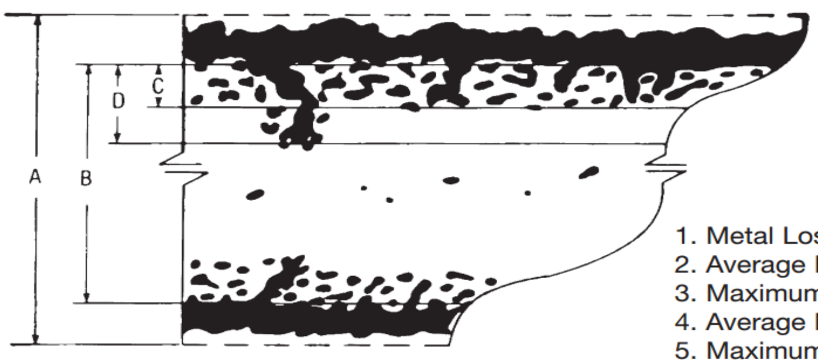
Flowing air at a velocity of 7.0 ft/min (213.4 cm/min) past the samples. Samples cycled to room temperature once per week.

Dynamic Oxidation Burner Rig

Alloy	1600°F (870°C), 1000 h, 30-min cycles				1600°F (870°C), 2000 h, 30-min cycles			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	µm	mils	µm	mils	µm	mils	µm
MULTIMET®	**1.3**	**33**	**2.2**	**56**	**2.7**	**69**	**4.9**	**124**
556®	1.4	36	3.1	79	1.5	38	3.9	99

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 fan-cooled to near ambient temperature and then reinserted into the flame tunnel.

Metallographic Technique used for Evaluating Environmental Tests



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

Hot Corrosion Resistance

Hot Corrosion Burner Rig

Hot Corrosion Resistance at 1650°F (900°C)

Alloy	5 ppm Salt, 200 Hours				50 ppm Salt, 200 Hours				5 ppm Salt, 1000 Hours			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
MULTIMET®	**1.8**	**46**	**3.7**	**94**	**1.8**	**46**	**4.2**	**107**	**1.8**	**46**	**5.4**	**137**
556®	0.9	23	2.7	69	1.1	28	2.6	66	1.6	41	5.9	150

Hot corrosion tests were conducted in a low velocity burner rig burning No. 2 Fuel oil with 0.4 percent sulfur. The air:fuel ratio was 30:1. Artificial sea water was injected at a rate equivalent to the salt concentration noted in the table. Tests were run for 1000 hours, with samples cycled out of the gas stream once an hour and cooled to near ambient temperature. Gas velocity was 13 ft./ sec. (4 m/s).

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.296 lb/in³	RT	8.20 g/cm³
Melting Range	2350-2470°F		1288-1354°C	
Thermal Conductivity	400°F	101 Btu-in/ft²-hr-°F	200°C	14.6 W/m-°C
	600°F	112 Btu-in/ft²-hr-°F	300°C	15.9 W/m-°C
	800°F	122 Btu-in/ft²-hr-°F	400°C	17.3 W/m-°C
	1000°F	133 Btu-in/ft²-hr-°F	500°C	18.6 W/m-°C
	1200°F	143 Btu-in/ft²-hr-°F	600°C	20.0 W/m-°C
Mean Coefficient of Thermal Expansion	70-300°F	8.2 µin/in.-°F	20-100°C	14.1 µm/m-°C
	70-400°F	8.5 µin/in.-°F	20-200°C	15.2 µm/m-°C
	70-500°F	8.5 µin/in.-°F	20-300°C	15.3 µm/m-°C
	70-600°F	8.5 µin/in.-°F	20-400°C	15.6 µm/m-°C
	70-800°F	8.7 µin/in.-°F	20-500°C	16.0 µm/m-°C
	70-1000°F	9.1 µin/in.-°F	20-600°C	16.7 µm/m-°C
	70-1200°F	9.4 µin/in.-°F	20-700°C	17.2 µm/m-°C
	70-1400°F	9.8 µin/in.-°F	20-800°C	17.5 µm/m-°C
	70-1600°F	9.9 µin/in.-°F	20-900°C	17.8 µm/m-°C
	70-1800°F	10.1 µin/in.-°F	20-1000°C	18.1 µm/m-°C
	70-2000°F	10.3 µin/in.-°F	20-1100°C	18.4 µm/m-°C
Electrical Resistivity	400°F	40.1 µohm-in	200°C	101.7 µohm-cm
	800°F	43.4 µohm-in	400°C	109.5 µohm-cm
	1000°F	44.6 µohm-in	600°C	115.0 µohm-cm
	1200°F	45.7 µohm-in	700°C	117.0 µohm-cm
	1400°F	46.5 µohm-in	800°C	119.0 µohm-cm
	1600°F	47.4 µohm-in	900°C	121.0 µohm-cm
	1800°F	48.2 µohm-in	1000°C	122.7 µohm-cm
Specific Heat (Calculated)	70-212°F	0.104 Btu/lb.-°F	22-100°C	0.104J/kg-°C
Poisson's Ratio	-108°F	0.319	-78°C	0.319
	RT	0.298	RT	0.298
	800°F	0.315	426°C	0.315
	1200°F	0.325	650°C	0.325
	1500°F	0.339	816°C	0.339
Emissivity (Oxidized)	2000°F	0.88	1090°C	0.88

Formability

Form	Condition	Typical Erichsen Cup Depth
-	-	mm
Sheet 0.025-0.050 in.	Heat-Treated at 2150°F RAC	10.0-11.5

RAC- Rapid Air-Cooled
WQ-Water-Quenched

Aged and Cold-reduced Hardness Data

Form	Condition		Test Temperature		Typical Hardness	
-	°F	°C	°F	°C	Rockwell	Brinell
Hot-Rolled Bar	Heat-Treated at 2165°F WQ	Heat-Treated at 1185°C WQ	RT	RT	91 HRBW	190
	Aged 20 min at:	Aged 20 min at:	-	-	-	-
	752°F	400°C	752°F	400°C	-	138*
	932°F	500°C	932°F	500°C	-	130*
	1112°F	600°C	1112°F	600°C	-	130*
	1292°F	700°C	1292°F	700°C	-	120*
	1472°F	800°C	1472°F	800°C	-	105*
	1652°F	900°C	1652°F	900°C	-	60*
	752°F	400°C	RT	RT	-	190†
	932°F	500°C	RT	RT	-	192†
	1112°F	600°C	RT	RT	-	187†
	1292°F	700°C	RT	RT	-	192†
	1472°F	800°C	RT	RT	-	192†
	1652°F	900°C	RT	RT	-	218†
Hot-Rolled Bar, Cold-Reduced from Initial Diameter of 0.242 in	As-Heat-Treated at 2150°F RAC	RT	RT	RT	92 HRBW	-
	reduced 5%	RT	RT	RT	92 HRBW	-
	reduced 10%	RT	RT	RT	19 HRC	-
	reduced 15%	RT	RT	RT	25 HRC	-
	reduced 20%	RT	RT	RT	30 HRC	-
	reduced 25%	RT	RT	RT	34 HRC	-
	reduced 30%	RT	RT	RT	37 HRC	-
	reduced 35%	RT	RT	RT	40 HRC	-
	reduced 40%	RT	RT	RT	40 HRC	

*Special Brinell hot hardness tests were made using a 2000 kg. load and 10mm tungsten carbide ball. Both the ball and specimen were help at temperature for 20 minutes before testing.
**Maximum
†Special Brinell hardness measured at room temperature using a 2000 kg. load and 10mm tungsten carbide ball.
RT=Room Temperature.
HRBW = Hardness Rockwell “B”, Tungsten Indentor. HRC = Hardness Rockwell “C”.

Welding

MULTIMET® alloy is readily welded by Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW), Shielded Metal Arc Welding (SMAW), and resistance welding techniques. Submerged Arc Welding (SAW) 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 welding surface and adjacent regions should be thoroughly cleaned with an appropriate solvent prior to any welding operation. All greases, oils, cutting oils, crayon marks, machining solutions, corrosion products, paint, scale, dye penetrant solutions, and other foreign matter should be completely removed. It is preferable, but not necessary, that the alloy be in the solution annealed condition when welded.

Filler Metal Selection

MULTIMET® filler wire (AMS 5794) is recommended for joining MULTIMET® alloy by Gas Tungsten Arc or Gas Metal Arc welding. Coated electrodes of MULTIMET® alloy (AMS 5795) are also available for Shielded Metal Arc welding. For dissimilar metal joining of MULTIMET® alloy to nickel-, cobalt-, or iron- base materials, MULTIMET® filler wire, HAYNES® 556® alloy (AWS A5.9 ER3556, AMS 5831), HASTELLOY® S alloy (AMS 5838) or HASTELLOY® W alloy (AMS 5786, 5787) welding products may all be considered, depending upon the particular case. Please see our "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 MULTIMET® alloy. For further information, please consult the "Welding and Fabrication" brochure.

Nominal Welding Parameters

Details for GTAW, GMAW and SMAW welding are given in the Welding and Fabrication brochure. Nominal welding parameters are provided as a guide for performing typical operations and are based upon welding conditions used in our laboratories.

Welded Tensile Data

Welding Method and Material	Condition	Test Temperature		Ultimate Tensile Strength		Yield Strength		Elongation
		°F	°C	ksi	MPa	ksi	MPa	%
SMAW, Sheet, 0.125 in	As-Welded	RT	RT	116.0	800	60.9	420	27
SMAW, Plate, 0.375 in		RT	RT	105.1	725	65.6	452	28
SMAW, Plate, 0.500 in		RT	RT	102.6	707	49.8	343	44
GTAW, Sheet, 0.125 in	As-Welded	RT	RT	108.2	746	60.5	417	22
GTAW, Plate, 0.250 in		RT	RT	111.4	768	65.0	448	21
GTAW, Plate, 0.375 in		RT	RT	105.9	730	60.4	416	19

RT= Room Temperature

Heat Treatment and Fabrication

Forging

Ingots should be hot-forged, using an initial maximum of 2200°F. If the ingots are heated to higher temperatures, they will rupture at the surfaces and become badly oxidized. The minimum temperature at which MULTIMET® alloy should be forged is 1700°F. Forging at a lower temperature might have an adverse effect on the high-temperature strength of the alloy, especially if it is to be used at temperatures of 1300°F and above. The ingots should be thoroughly soaked at about 2200°F, after which forging can be conducted at a relatively fast rate. MULTIMET® alloy does not rupture easily and, in most cases, it is not necessary to use light hammer blows to break up the ingot structure. When reheating is necessary, the forging should be permitted to soak thoroughly to make sure that it reaches the proper temperature.

Forming

Cold-worked is the preferred method for such operation as spinning, drawing, and dishing. As the alloy work-hardens to a considerable extent, solution heat-treating between various stages of forming may be required to soften the material and restore the ductility lost in the cold-working operations.

Heat-Treatment

Optimum properties can be developed in MULTIMET® alloy sheet by a solution heat-treatment at 2150°F for a time depending on the section thickness. This is followed by either a rapid air-cool or a water-quench. Bar stock and plate (1/4 in. and heavier) are generally solution heat-treated at 2150°F and then water-quenched. Most wrought products are shipped in the solution heat-treated condition.

Stress-relieving the metal after hot-working is advisable to eliminate internal stress. Heavy or intricate forging may warp during machining unless stresses are remove. The recommended stress-relieving procedure is to heat the alloy two to four hours at temperatures corresponding to the maximum service temperature to be encountered. The heat-treatment brings about a mild precipitation hardening effect simultaneously with the removal stresses.

Bars and forgings that have been solution heat-treated may be aged at 1500°F for four hours followed by an air-cool. This increases the Brinell hardness to a range of 192 to 241. Since bar in the aged condition is difficult to straighten and form, it is recommended that the bar be purchased in the solution heat-treated condition and then aged after final fabrication.

Specifications

MULTIMET® alloy (R30155, W73155)	
Sheet, Plate & Strip	AMS 5532
Billet, Rod & Bar	AMS 5769
Coated Electrodes	AMS 5795 SFA 5.4/ A 5.4 (E3155)
Bare Welding Rods & Wire	AMS 5794
Seamless Pipe & Tube	-
Welded Pipe & Tube	-
Fittings	-
Forgings	AMS 5768 B 639
DIN	-
Others	-