CARPENTER ADDITIVE®

DATASHEET

PowderRange 15-5PH

Applicable specifications: AMS5659

Associated specifications: UNS S15500, ASTM A564/A564M, AMS7021

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Chromium**	14.00–15.50 %	**Nickel**	3.50–5.50 %
Copper	2.50–4.50 %	**Manganese**	1.00 %	**Silicon**	1.00 %
Molybdenum	0.50 %	**Niobium**	5x C to 0.45 %	**Nitrogen**	0.10 %
Carbon	0.070 %	**Oxygen**	0.030 %	**Phosphorus**	0.030 %
Sulfur	0.015 %				

Description

PowderRange 15-5PH stainless steel is a martensitic precipitation/age-hardening stainless-steel similar to 17-4PH offering higher strength and hardness, along with excellent corrosion resistance, up to 600°F (316°C). It has good fabricating characteristics and can be age-hardened using a single-step, low temperature treatment that can be chosen to achieve specific strength and toughness combinations. Due to this balanced combination of performance and ease of use in AM, 15-5PH stainless steel has been used for a wide variety of additive manufacturing applications, including rapid tooling, functional components in nearly every market, and prototyping.

Key Properties:

- Good strength, toughness, hardness, and ductility
- Good corrosion resistance

Markets:

- Aerospace
- Food processing
- Petrochemical
- Medical

Applications:

- Surgical instruments and tools
- Valves and fittings
- Pumps and impellers
- Tooling
- Manifolds
- Industrial and chemical processing equipment

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Powder properties

PART NUMBER	PowderRange 155 F
APPLICATION	L-PBF[1]
MAXIMUM PARTICLE SIZE	Max 1 wt% > 53 µm[2]
MINIMUM PARTICLE SIZE	Max 10 vol% < 15 µm[3]
LSD PERCENTILE	D10, D50, D90[3], reported
ATOMIZATION	Nitrogen Gas Atomized
APPARENT DENSITY (G/CM³)	Measured according to ASTM B212[4] and reported
HALL FLOW (S/50G)	Measured according to ASTM B213[5] and reported

[1] ASTM/ISO 52900: Laser—Powder Bed Fusion (L-PBF), Electron-Beam Powder Bed Fusion (EB-PBF), Directed Energy Deposition (DED)
[2] ASTM B214 Standard Test Method for Sieve Analysis for Metal Powders
[3] ASTM B822 Standard Test Method for Particle Size Distribution of Metal Powders and Related Compounds by Light Scattering
[4] ASTM B212 Standard Test Method for Apparent Density of Free-Flowing Metal Powders Using the Hall Flowmeter Funnel
[5] ASTM B213 Standard Test Method for Flow Rate of Metal Powders Using the Hall Flowmeter Funnel
Testing of powder will fulfill certification requirements to Nadcap Materials Testing and ISO/IEC 17025 Chemical, per relevant ASTM procedures

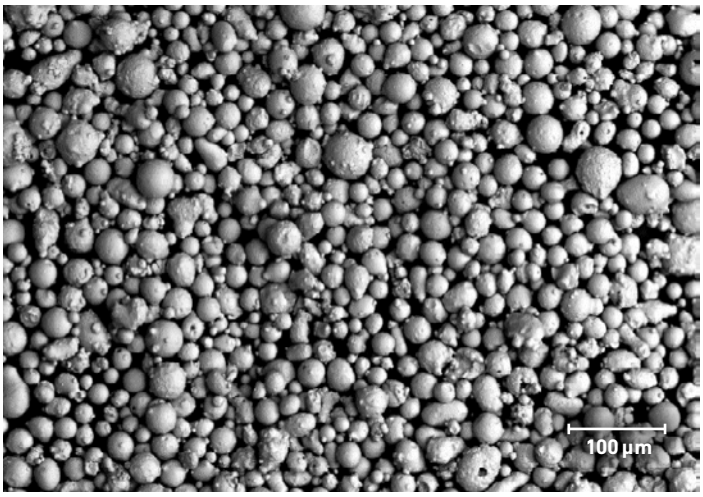

FIGURE 1—SEM IMAGE OF TYPICAL PowderRange 15-5PH POWDER

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Additive manufacturing process guidance

ASTM/ISO 52900: LASER-POWDER BED FUSION (L-PBF)	
Laser-Powder Bed Fusion (L-PBF) As-built	PowderRange 15-5PH is compatible with all commercially available L-PBF equipment. To achieve mean, as-built density >99.9%, 20 to 60 µm layer thicknesses and Specific Energy ≥ 50 J/mm^3 is recommended.
Stress relief	Stress relieve at 1250°F (677°C) for 1 hour per inch of thickness (minimum 2 hours) up to 4 hours.
Homogenization (Hom)	Carpenter Additive recommends a homogenization treatment at 2000°F (1093°C) for 1 hour followed by an air cool to minimize anisotropy. If performing a HIP step, a separate homogenization treatment is not required.
Hot Isostatic Press (HIP/Sol/H900)	We recommend HIP as standard practice for microstructure homogenization, removal of residual spatter-induced voids, trapped gas porosity in powder and keyhole porosity, as well as to heal any shrinkage-induced micro-cracks in the material. **To achieve up to full density (100%):** Process components under argon at not less than 14.5 ksi (100 MPa) at a temperature of approximately 2087°F (1141°C); hold at the selected temperature for approximately 240 min then cool under inert atmosphere to below 800°F (427°C). Follow with Solution Anneal and Age treatment as described below.
Solution Anneal and Age Condition (Hom/Sol/H900)	After either homogenization or HIP'ing, Solution Anneal at 1900°F (1038°C) per ASTM A564/A564M for 0.5 hours, cool to below 90°F (32°C) to achieve complete transformation to martensite. Sections under 3in. (76mm) can be quenched in a suitable liquid quenchant (e.g. water or oil) and sections over 3in. (76mm) should be rapidly air cooled. It is recommended not use this Solution Annealed condition, without age hardening, for the final product due to susceptibility to stress-corrosion cracking. After Solution Anneal, age material as desired per ASTM A564/A564M, e.g. 900°F (482°C) for 1 hour and air cool.
Machinability	PowderRange 15-5PH is readily machined in both the solution-treated and various age-hardened conditions. In the solution-treated condition, it machines similarly to stainless steel types 302 and 304. When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

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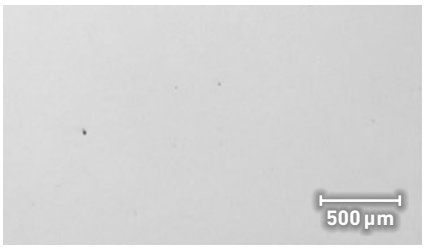
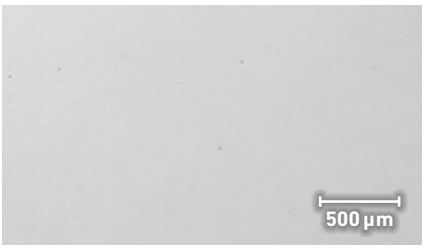
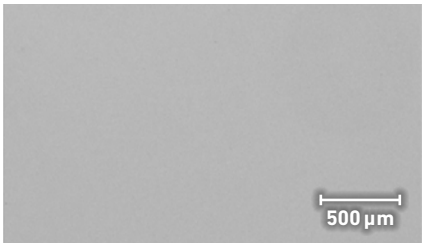
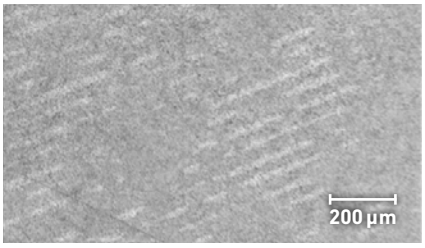
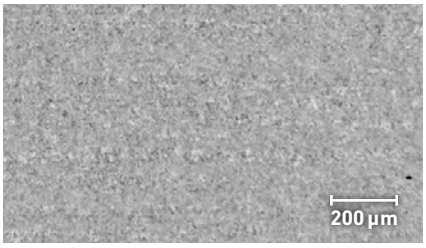
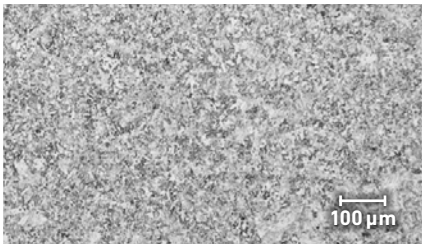
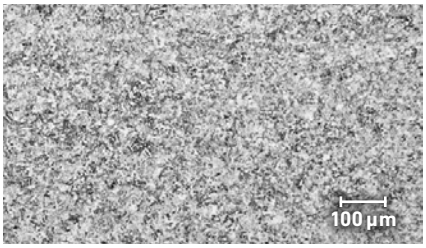
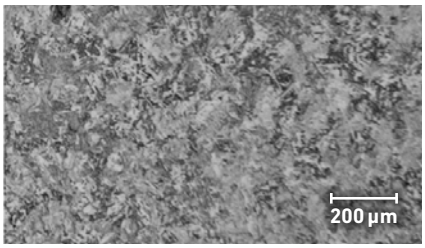
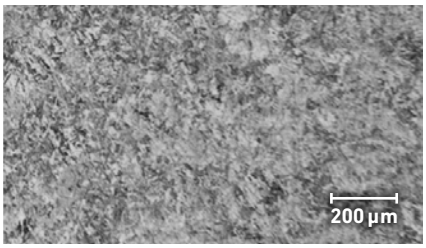
TYPICAL MICROSTRUCTURES

CONDITION	TRANSVERSE (X-Y PLANE)	LONGITUDINAL (Y-Z PLANE)	NOTES
As-built			Mean densities greater than 99.9%
HIP/Sol/ H900			Up to 100% density
As-built, etched[6]			Typical pre-solutionized PowderRange 15-5PH microstructure, consisting of martensite with minimal carbide precipitates
Hom/Sol/ H900, etched[6]			Average grain size ASTM 7-8[7] Typical PowderRange 15-5PH aged martensitic microstructure
HIP/Sol/ H900, etched[6]			Average grain size ASTM 7-8[7] Typical PowderRange 15-5PH aged martensitic microstructure

[6] Etched with Ralph's etchant
[7] ASTM E112 Standard Test Method for Determining Average Grain Size

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Typical achievable mechanical properties

ROOM TEMPERATURE MECHANICAL PROPERTIES[8]

FORM	ORIENTATION	0.2% YIELD STRENGTH $\sigma_{0.2\%}$		ULTIMATE TENSILE STRENGTH σ_{UTS}		ELONGATION IN 4D	REDUCTION OF AREA	IMPACT ENERGY		HARDNESS
		ksi	MPa	ksi	MPa	%	%	FT-LBS	J	HRC
As-built	X and Y	149	1027	186	1282	21.7	68.1	111	150.5	37.5
	Z	137	945	186	1282	18.2	69.8	108	146.4	
Sol/H900	X and Y	188	1296	210	1448	13.9	44.0	4.8	6.5	46
	Z	190	1310	211	1455	12.1	38.0	4.2	5.7	
HIP/Sol/H900	X and Y	181	1248	205	1413	13.5	46.3	11.6	15.7	42
	Z	186	1282	208	1434	14.4	52.0	12.5	16.9	
ASTM Spec.[9]	—	170	1170	190	1310	10	35	—	—	40

[8] Average of a minimum of 5 samples taken from across the extents of a build plate in each orientation and for each heat treatment. Testing performed in accordance with ASTM E8/E8M-16a (tensile), ASTM E23-18 (impact energy), and ASTM E18-19 (hardness). Additional data may be available through a wide range of consortia and other collaborations. Please contact Carpenter Additive for additional information.

[9] ASTM A564A564M-13 XM-12 H900 Mechanical Test Requirements after Age Hardening Heat Treatment

Corrosion resistance

IMPORTANT NOTE:
The following 4-level rating scale (Excellent, Good, Moderate, Restricted) is intended for comparative purposes only and is derived from experiences with wrought product. Additive manufactured material may perform differently; corrosion testing is recommended. Factors that affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish, and dissimilar metal contact.

Nitric Acid	Good	**Sulfuric Acid**	Restricted
Phosphoric Acid	Restricted	**Acetic Acid**	Moderate
Sea Water	Restricted	**Salt Spray (NaCl)**	Good
Humidity	Excellent	**Sour Oil/Gas**	Restricted
Sodium Hydroxide	Moderate		

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Similar materials

COMPANY	ALTERNATIVE TITLE
Other Generic Names	1.4540, 15-5PH
Concept Laser	—
EOS	PH1
DMG Mori (Realizer)	—
Renishaw	—
SLM Solutions	1.4545 (15-5PH)

For additional information, please contact your nearest sales office:
info@carpenteradditive.com | 610 208 2000

The mechanical and physical properties of any additively manufactured material are strongly dependent on the processing conditions used to produce the final part. Significantly differing properties can be obtained by utilizing different equipment, different process parameters, different build rates and different geometries. The properties listed are intended as a guide only and should not be used as design data.

The information and data presented herein are typical or average values and are not a guarantee of maximum or minimum values. Applications specifically suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his/her own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes. There is no representation that the recipient of this literature will receive updated editions as they become available.

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