

HP Metal Jet S100 Printing Solution



Reinvent business opportunities with digitally driven metal
3D Printing for mass production





Accelerate innovative designs and products, and efficiently produce high-quality 3D metal parts at scale



Data courtesy of Schneider Electric, Legor, Volkswagen and Domin.

Accelerate innovative designs and products

- Embrace design freedom and achieve:
 - Efficient flow of various mediums (gasses, fluids, heat, etc.) through optimized design profiles that help minimize loss—such as pressure drops and resistance.
 - Improved strength-to-weight ratio for lightweight parts.
 - Simplified manufacturing processes with part consolidation.
 - Innovative, high-quality products—such as industrial filters—with HP’s density control.
- Differentiate your products with mass customization—of consumer goods, auto parts, and medical instruments.
- Accelerate time to market with fast design iterations and digital simulation capability—e.g., sinter simulation; easily and rapidly iterate and adjust part design to help avoid deformation during the sintering process.
- Enhance your printing capabilities with an increased build height up to 170 mm, allowing you to explore new dimensions in product design and innovation by creating larger parts and more parts in a single build.



Efficiently 3D print metal parts at scale



- Achieve industrial Overall Equipment Effectiveness (OEE) with a digital end-to-end solution that delivers:
 - Operational efficiency enabled by device status and KPI monitoring with HP Metal Jet Software Solutions.
 - Maximum system uptime with an industrial-grade printing system designed for 24/7 manufacturing conditions.
 - Comprehensive set of proactive, preventive, and responsive maintenance delivered by HP Metal Jet Solution Services.
- Reduce manual labor and improve operational efficiency with automated features:
 - HP Metal Jet Powder Removal Station automates removal and recovery of loose powder which is 100% reusable¹ while simultaneously performing build unit cleaning.
 - Speed up production and minimize the potential for human error in powder management processes with the HP Metal Jet Powder Management Station, which automatically mixes, sieves, and loads powder to the build unit.
 - HP Metal Jet API enables digital orchestration of the production workflow for routing and monitoring of jobs.
- Help lower costs and reduce time to production from months to days vs. analog methods by eliminating time-consuming tooling and manufacturing processes.
- Achieve cost-effective production at scale by leveraging the economies of scale with Metal Injection Molding (MIM) powders to reduce operational and material costs². Enjoy flexibility and cost efficiency by accessing a range of compatible materials that allow you to select the best options for your specific requirements.

Deliver top quality from a trusted global industry leader

- Rely on 30 years of HP Thermal Inkjet expertise in 2D and 3D printing for industrial production-grade quality.
- Meet demanding industry standards³
 - Enable repeatable parts and reliable process control at speed with up to 4 times nozzle redundancy⁴ from 2 print bars and HP voxel-level 1200 x 1200 dpi 3D printing resolution.
 - Achieve consistent layer quality with a recoating system that delivers precise tolerances.
- Confidently achieve part-specific requirements with HP Process Center and HP Metal Jet materials.
- Experience enhanced capabilities with minimal disruption through seamless integration and in-field upgrades. Stay ahead of the competition with a system designed to accommodate future advancements and upgrades, securing your investment for the long term.



Scale growth with HP's flexible offering

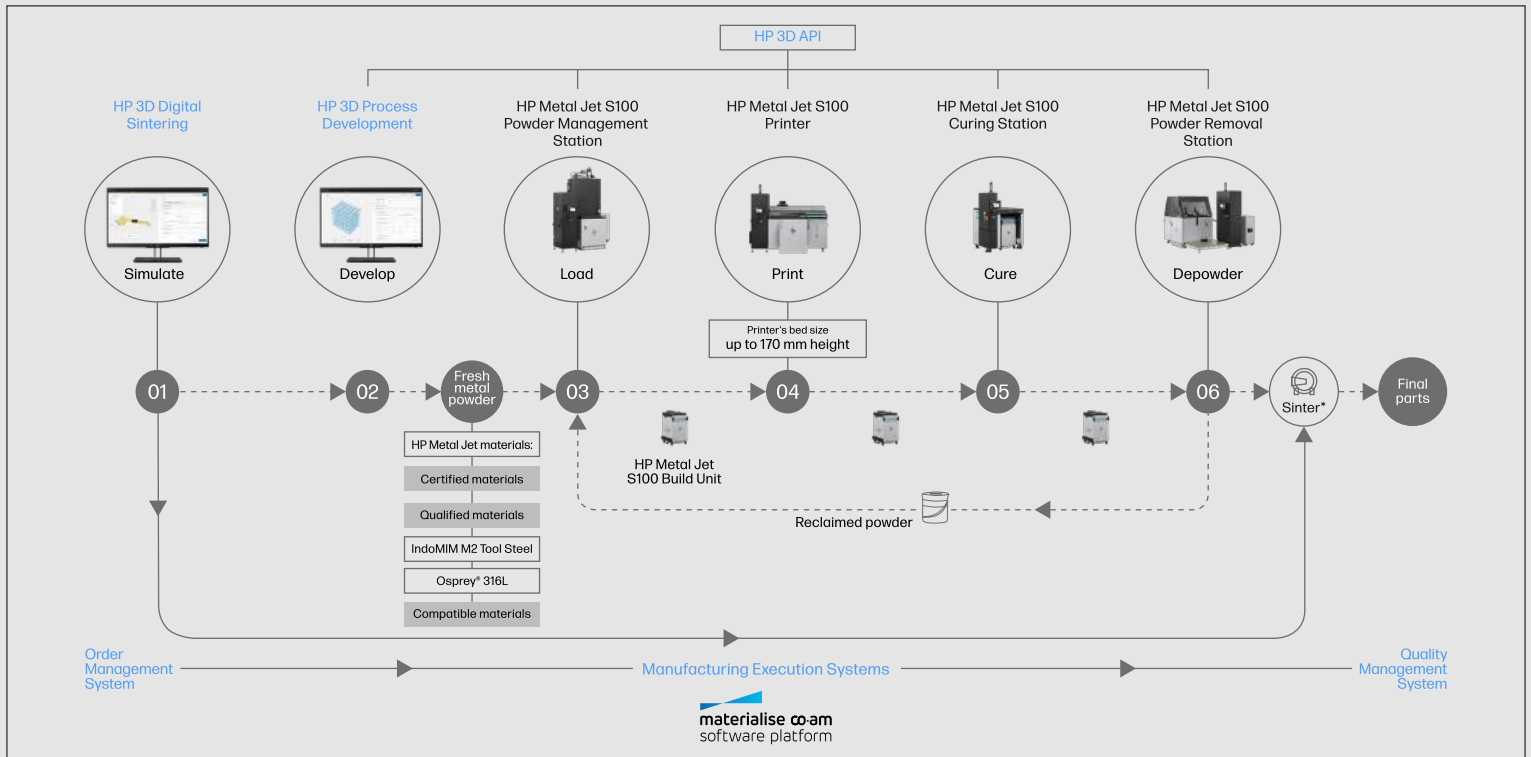
Explore the different ways you can adopt and scale 3D metal printing with the HP Metal Jet S100 Printing Solution.

- Access HP's metal printing technology outright for repeatable results, clean workflows, and industrial production-grade part quality.
- Get bespoke subscription or pay-per-use plans that best fit your business requirements and benefit from a predictable, affordable, and convenient payment model with fixed monthly costs and less upfront investment. These product offerings are customized with your needs in mind and can include a combination of hardware, software, and services.



Streamline your process workflow—from design to final part—with the HP Metal Jet S100 Printing Solution

Produce metal parts at scale that achieve industrial OEE and reduce manual labor with automated systems and features.



- 1 Simulate the impact of sintering on your HP Metal Jet part and 2 access and use a suite of parameter settings to conduct and control process development experiments.
- 3 Before printing, the HP Metal Jet S100 Powder Management Station (Load) automatically blends, sieves, and loads metal powder into the HP Metal Jet S100 Build Unit according to the user-defined print job and customized parameters.
- 4 Once printing (Print) and 5 curing (Cure) are complete, the HP Metal Jet S100 Build Unit is manually inserted into 6 the HP Metal Jet S100 Powder Removal Station (Depowder), which automates the removal and recovery of loose powder for 100% reusability,¹ while simultaneously performing build unit cleaning. For any fine powder remaining on printed parts, the HP Metal Jet S100 Powder Removal Station includes separate vacuum attachments that enable manual removal of the remaining fine powder. All reclaimed powder is pneumatically recovered into the HP Metal Jet S100 Powder Management Station Portable Tank for storage and reintroduced into 3 the HP Metal Jet S100 Powder Management Station.

HP Digital Production Suite—delivering the science and power of HP Metal Jet technology

HP Digital Production Suite provides the control and analytics required to scale additive manufacturing for a complete supply chain solution.

Design

Development

Production



Design

Development

Production

HP 3D Digital Sintering



AI enhanced sintering prediction for HP Metal Jet printed parts with near zero mesh repair and the power to handle high model complexity.

HP 3D Process Development



Expand HP Metal Jet applications with access to a full suite of process parameter settings. Experiment and create processes designed to scale. Maintain a library with your testing procedures and control process development across a distributed supply chain.

Design

Development

Production

HP 3D Build Manager



Quickly and easily prepare your jobs for printing with all the elements you need.

HP 3D Command Center



Client/server application for system setup, registration, device monitoring, and connectivity management.

HP 3D Center



Cloud-based dashboard delivers timely and historical data for greater productivity and efficiency.

Integration with industry-leading software partners



Explore new application designs with HP Metal Jet stainless steel materials

Expanded HP Metal Jet materials portfolio

Discover the three HP Metal Jet materials' categories available for the HP Metal Jet S100 Printing Solution, providing a balance between fully tested parameters, qualified performance, and system compatibility for even greater versatility and value.

HP Metal Jet Certified materials

Exclusively available from HP, these materials have successfully passed HP's rigorous certification procedures, ensuring optimal performance across various printers and powder batches. Guaranteed reliability and consistency, these materials can only be purchased through HP, providing dependable performance for your HP Metal Jet Printing Solution.



Data courtesy of Legor

HP Metal Jet SS 316L

This material is a non-magnetic austenite stainless steel used in applications requiring extremely high corrosion resistance, excellent elongation, ductility, and strength at elevated temperatures. The high alloy and low carbon content makes it a great fit for automotive, aerospace, medical, jewelry, and oil/chemical industries.

HP Metal Jet SS 17-4PH

This material is a martensite precipitation hardening stainless steel used in applications that require a combination of high strength and mechanical properties with good corrosion and wear resistance. Properties can be tailored through heat treatment, making this versatile material valuable for a wide use of applications in the medical, aerospace, marine, food processing, and automotive industries.



Data courtesy of Lumenium

HP Metal Jet Qualified materials

Sourced from HP-approved suppliers, these materials have undergone an HP-defined qualification process. Reliable performance and availability, offering a balance of value, quality, and accessibility, these materials are readily available for purchase from trusted HP suppliers.



Data courtesy of IndoMIM

IndoMIM M2 Tool Steel

IndoMIM M2 Tool Steel is a high-speed tool steel material optimized for printing with the HP Metal Jet S100 Printing Solution. It offers a well-balanced combination of toughness, hardness at elevated temperatures, and abrasion resistance, making it ideal for creating complex, high-strength mold inserts, dies, and cutting tools. This material is particularly suited for applications in the injection molding, cutting, and die industries due to its superior ability to maintain hardness and wear resistance. Sourced from IndoMIM, an HP-approved supplier, the M2 Tool Steel material has undergone an HP-defined qualification process, ensuring reliable performance. Offering a balance of value, quality, and accessibility, this material is readily available for purchase from IndoMIM, your trusted HP-approved supplier.

Osprey® 316L

Osprey® 316L is a material optimized for printing in HP Metal Jet S100 systems. Osprey® 316L has good corrosion resistance and a high creep strength at elevated temperatures. The low carbon content and excellent processability makes it a good fit for a wide range of applications in the medical, automotive, metallic filters, and general industrial markets. Sourced from Sandvik, an HP-approved supplier, Osprey® 316L material has undergone an HP-defined qualification process, ensuring reliable performance. Offering a balance of value, quality, and accessibility, this material is readily available for purchase from Sandvik, your trusted HP-approved supplier.



HP Metal Jet Compatible materials

Tested on the HP Metal Jet S100 Printing Solution by select suppliers, these materials meet HP's compatibility and performance criteria. Versatile and valuable, these materials empower users to explore diverse applications while maintaining the high standards synonymous with the HP Metal Jet Printing Solution.

- GKN Free Sintering Low Alloy Steel (Binder AM)
- GKN 17-4PH - 1.4542 (Binder AM)
- GKN Nickel Free Stainless Steel (Binder AM)
- GKN 316L - 1.4404 (Binder AM)
- GKN M2 Tool Steel - High Speed Steel (Binder AM)

Enhance your journey to scale production with HP Digital Production Services

HP Digital Production Services provide your business with a comprehensive suite of onboarding, maintenance, and professional services to help you achieve the most value with HP Metal Jet technology.



HP Metal Jet Onboarding Services

Launch and scale your HP Metal Jet S100 Printing Solution with installation and training onboarding services designed to quickly and efficiently get your team, equipment, and site up and running.

HP Metal Jet Maintenance Services

Maximize your Overall Equipment Effectiveness (OEE) with proactive, preventive, and responsive HP Metal Jet Maintenance Services tailored to your operational needs.



HP Metal Jet Professional Services

Optimize and accelerate your application designs as well as process and new material development efforts with HP Metal Jet Professional Services customized to help you achieve your desired part quality and production outcomes.

HP Metal Jet Production Service

Experience HP Metal Jet quality and streamline your metal parts orders. Simply submit your contact information and an HP Metal Jet expert will tailor solutions to your needs providing a design compatibility check. Should the design meet compatibility criteria, HP will support you during the whole part qualification and production process ensuring timely delivery to your doorstep⁵



Data courtesy of GKN

Achieve final part properties with post-processing: sintering and finishing



Data courtesy of Legor



Data courtesy of Legor

HP supports your entire workflow, from initial idea to final part—even going beyond the HP Metal Jet Printing process—to cover your entire ecosystem, including sintering and surface finishing assistance if required.⁶

When it comes to sintering, HP Metal Jet Professional Services can provide assistance with sintering operation requirements. Specific sintering profiles have been developed for each qualified material that meet industry standards.³ Additionally, assistance can be provided to develop new profiles for other specific materials.

After printing and sintering, if additional finishing is required, HP's engineering team can provide services that help you achieve your final desired part properties using alternative processes (such as machining, polishing, coating, and hot isostatic pressing).

Leverage Binder Jetting technology and HP's expertise in additive manufacturing

AM advantages over traditional metal manufacturing	Binder Jetting 3D printing advantages over other 3D printing processes	HP Metal Jet technology advantages
<p>Enables innovative new designs for:</p> <ul style="list-style-type: none"> ● Lightweight or consolidated parts ● Performance improvements ● Customization <p>Improves customer economics:</p> <ul style="list-style-type: none"> ● Reducing manufacturing process steps ● Reducing manual labor 	<p>Offers higher productivity:</p> <ul style="list-style-type: none"> ● Processing layer by layer versus point process ● Isotropic properties for better surface finishing (i.e., requiring less post-processing) ● No support removal required <p>Uses metal powders from established global powder suppliers, which are less expensive than laser-based 3D printing powders.</p>	<p>Printhead advantage:</p> <ul style="list-style-type: none"> ● HP Thermal Inkjet technology drives economics ● Higher resolution drives part quality (including surface finish and accuracy) <p>HP Metal Jet binding agent advantage:</p> <ul style="list-style-type: none"> ● Leverages IP from HP Latex ● Uses a minimum of binder, allowing for thicker and larger mass parts than metal injection molding (MIM).

Benefit from 80 years of HP heritage

HP has an 80-year history of innovation, including 30 years of HP Thermal Inkjet expertise in 2D and 3D printing. As a result, HP Metal Jet is the latest technology, designed specifically for industrial production-grade quality of 3D metal parts, building further on this strong heritage.

HP Thermal Inkjet (TIJ) printheads and nozzle arrangement contribute to part quality and cost reduction

HP Metal Jet printers employ multiple printbars for high productivity and nozzle redundancy. The printhead is a complex, integrated system that controls how and where to apply fluids. It allows HP Metal Jet to accurately apply the binder to produce stronger parts with outstanding definition. Each printhead produces a 108-mm (4.25-inch) print swath with two independent columns of 5,280 nozzles that are spaced 1200/inch in each column. There are two independent supply ports for HP Metal Jet binding agent and two built-in pressure regulators.

HP Metal Jet printers address a 1200 x 1200 dpi grid with a layer typically between 35 and 140 microns thick. HP Metal Jet's high voxel resolution produces fine details and precision definition of edges and surfaces both inside and outside the part. Defects are suppressed with 4-times nozzle redundancy.⁴

HP Metal Jet binding agent—key enabler for higher quality and productivity

HP Metal Jet binding agent is formulated with a polymer that binds the metal particles together wherever HP Metal Jet binding agent is printed. This binding agent produces thicker-walled parts more quickly than metal injection molding (MIM). Even better, no wax debinding is required with this process, which can save up to 20 workflow hours compared to traditional MIM.⁷

Technical specifications

HP Metal Jet S100 Printing Solution

Printer Performance	Technology	HP Metal Jet technology
	Build platform volume	430 x 309 x 200 mm
	Effective build volume ^g	430 x 309 x 170 mm
	Building speed	1990 cc/hr ^g
	Layer thickness	35 - 140 um
	Job processing resolution (x,y)	1200 dpi
	Printer resolution (x,y)	1200 dpi
	Printhead system	2 print bars/ 6 HP Thermal Inkjet printheads (63,360 nozzles)/ Automatic nozzle health detector and nozzle replacement
	Print redundancy	4-times nozzle redundancy at 1200 dpi resolution ^g
Printer dimensions (w x d x h)	Printer	2937 x 1409 x 2478 mm
	Shipping	3330 x 1500 x 2340 mm
	Operating area	4775 x 3850 x 2500 mm
Build unit dimensions (w x d x h) *Including cover	Physical	657 x 872 x 1170*
	Shipping	780 x 1000 x 1410 mm
Curing station dimensions (w x d x h) **Including front panel	Physical	1350 x 1486** x 2250 mm
	Shipping	1560 x 1770 x 2150 mm
	Operating area	3150 x 3775 x 2500 mm
Weight	Printer	851 kg
	Build unit	261 kg
	Curing station	400 kg
Network	Gigabit Ethernet (10/100/1000Base-T), supporting the following standards: TCP/IP, DHCP (IPv4 only), TLS/SSL	
Processor and memory	Processor	HP Metal Jet S100 Printer: Intel® Xeon® W-2255 3.7GHz 10C 165W HP Metal Jet S100 Curing Station: Intel® Celeron® J3455 1.5 GHz Quad-Core
	Memory	HP Metal Jet S100 Printer: 128 GB DDR4 HP Metal Jet S100 Curing Station: 4G DDR3L memory
	Hard disk	HP Metal Jet S100 Printer: 1 TB PCIe NVMe TLC SSD HP Metal Jet S100 Curing Station: SSD 240 GB
	Industrial safety PLC	HP Metal Jet S100 Printer and HP Multi Jet S100 Curing Station: Siemens SIMATIC ET 200SP, CPU 1512SP F-1 PN 300 KB/1 MB 3 Ports SIMATIC S7 MEMORY CARD 24 MB

Software	HP Metal Jet Software Solutions	HP 3D Digital Sintering
		HP 3D Process Development
	Compatible software	HP 3D Build Manager
		HP 3D Command Center
HP 3D Center		
Power	Consumption	Autodesk Fusion 360
		Autodesk Netfabb Premium and Ultimate
	Requirements	Materialise HP Plugin
		Simufact Additive by Hexagon/MSC
Supported file formats	Altair® Inspire™ Print 3D	
Supported file formats	STL, 3MF	
Power	Consumption	HP Metal Jet S100 Printer: 8 kW HP Metal Jet S100 Curing Station: 3 kW
	Requirements	HP Metal Jet S100 Printer: 3phase, 3W + N + PE, 220-240 / 380-415 Vac, 30 A max., 50/60 Hz, 8 kW; or 3phase, 3W + PE, 200-240 Vac, 48 A max., 50/60 Hz, 8 kW HP Metal Jet S100 Curing Station: 3phase, 3W + N + PE, 220-240 / 380-415 Vac, 16 A max., 50/60 Hz, 3 kW; or 3phase, 3W + PE, 200-240 Vac, 28 A max., 50/60 Hz, 3 kW
Certifications and statement	Safety	EU: Machinery Directive compliant, EN 60204-1, EN 12100-1, EN 13849-1, EN 13849-2, EN 1127-1 US/Canada: UL 2011, CSA C22.2 No.14-18
	Electromagnetic	Compliant with Class A requirements, including USA (FCC rules), Canada (ICES), EU (EMC Directive)
	Environmental statement	REACH
Warranty & Service Coverage included	One-year limited hardware warranty	

Technical specifications

HP Metal Jet S100 Powder Management Station

Performance	Technology	HP Metal Jet technology
	Mixer capacity	78 liters (max weight: 350 kg)
	Speed range	14.3 rpm to 27.6 rpm
	Sieving technology	90 µm replaceable mesh with Ultrasonic Technology and external port for vacuum cleaning
	Material transport speed ¹⁰	2.5 l/min (based on HP Metal Jet SS 316L material and bulk density, measured with HP Metal Jet S100 Powder Management Station Vacuum Pump)
Dimensions (w x d x h)	Station	System: 2040 x 2105 x 3170 mm
	Operating area	System: 4100 x 3500 x 3170 mm
Weight	System	1348 kg
Network	Gigabit Ethernet (10/100/1000Base-T), supporting the following standards: TCP/IP, DHCP (IPv4 only), TLS/SSL	
Processor and memory	Processor	Intel® Celeron® J3455 1.5 GHz Quad-Core
	Memory	4G DDR3L memory
	Industrial PLC	Siemens SIMATIC ET 200SP Open Controller, CPU 1515SP PC2 F (Windows 10)
Power	Consumption	Basic 4 kW (with Vacuum Pump 7 kW)
	Requirements	3phase, 3W + PE, 380-415 Volts (line-to-line) (±10%) 3phase, 3W + PE, 480 Volts (line-to-line) (±10%) Maximum load current (per phase) 16 Amperes 50/60Hz
Certifications and statement	Safety	CE compliant according to Machinery Directive 2006/42/EC: EN 60204-1, EN 12100, EN 13849-1, EN 13849-2, EN 1127-1
		US/Canada: UL 2011, CSA C22.2 No.14-18
	Electromagnetic	Compliant with Class A requirements, including USA (FCC rules), Canada (ICES), EU (EMC Directive)
Environmental statement	REACH	
Warranty & Service Coverage included	One-year limited hardware warranty	

HP Metal Jet S100 Powder Removal Station

Performance	Technology	HP Metal Jet technology
	Automatic coarse depowder	Powder recovery with vibration control
Build unit cleaning	Build unit cleaning	Enclosed material recovery from build unit with optional manual vacuum cleaning
	Dimensions (w x d x h)	Station System: 1680 x 1640 x 2200 mm
Operating area	Operating area	System: 4600 x 3500 x 2615 mm
	Weight	System 1086 kg
Network	Gigabit Ethernet (10/100/1000Base-T), supporting the following standards: TCP/IP, DHCP (IPv4 only), TLS/SSL	
Processor and memory	Processor	Intel® Celeron® J3455 1.5 GHz Quad-Core
	Memory	4G DDR3L memory
	Industrial PLC	Siemens SIMATIC ET 200SP Open Controller, CPU 1515SP PC2 F (Windows 10)
Power	Consumption	Basic 1 kW (with vacuum pump 4 kW)
	Requirements	3phase, 3W + PE, 380-415 Volts (line-to-line) (±10%) 3phase, 3W + PE, 480 Volts (line-to-line) (±10%) Maximum load current (per phase) 7 Amperes 50/60Hz
Certifications and statement	Safety	EU: Machinery Directive compliant, EN 60204-1, EN 12100-1, EN 13849-1, EN 13849-2, EN 1127-1
		US / Canada: UL 2011, CSA C22.2 No.14-18
	Electromagnetic	Compliant with Class A requirements, including USA (FCC rules), Canada (ICES), EU (RED Directive)
Environmental statement	REACH	
Warranty & Service Coverage included	One-year limited hardware warranty	

Ordering information

Printer system

	50V69C	HP Metal Jet S100 Printer
	50V67C	HP Metal Jet S100 Build Unit
	6N9K6A	HP Metal Jet Build Unit Curing Station Cover
	50V68B	HP Metal Jet S100 Curing Station
	7D7W5A	HP Metal Jet S100 Printer Printhead Alignment Tool

Powder Processing system

Powder Management Station	50P69B	HP Metal Jet S100 Powder Management Station
	6W7L5A	HP Metal Jet S100 Powder Management Station Changeover Kit
	72R36A	HP Metal Jet S100 Powder Management Station Vacuum Pump Cables
Powder Removal Station	227Z8C	HP Metal Jet S100 Powder Removal Station
	6W7L2A	HP Metal Jet S100 Powder Removal Station Starter Kit
	6W7L1A	HP Metal Jet S100 Powder Removal Station Storage Drum 85L
	5R8W3A	HP Metal Jet S100 Powder Removal Station Platform
	6W7L4A	HP Metal Jet S100 Powder Removal Station Changeover Kit
	72R37A	HP Metal Jet S100 Powder Removal Station Vacuum Pump Cables
Powder Management and Removal Stations	6L053A	HP Metal Jet S100 Powder Management and Removal Station Vacuum Pump
HP Metal Jet stainless steel materials	V1R43A	HP Metal Jet SS 316L, 20 kg
	V1R44A	HP Metal Jet SS 17-4PH, 15 kg

HP Metal Jet process consumables	6C2Y3A	HP 3DM200 Printhead
	V1Q93A	HP 3DM100 Cleaning Roll
	91Q03A	HP 3DM250 Build Unit Filter Sheets
	6C2Y4A	HP 3DM200 Binding Agent 5L
HP Metal Jet Installation and Onboarding Services	HP Metal Jet Installation Services (HP Metal Jet Operator Training and Certification included)	
	HP Metal Jet Onboarding Services	
HP Metal Jet Maintenance Services	HP Metal Jet Maintenance Service Models	
	HP Metal Jet Recertification Service	
	HP Metal Jet Uptime Kits	
	HP Metal Jet Train-to-Maintain Training	
HP Metal Jet Professional Services	HP Metal Jet Material Changeover Service	
	HP Metal Jet Application Development Services	
	HP Metal Jet Process Engineering Consultation Service	
HP Metal Jet Production Service ⁵	HP Metal Jet Materials Development Service	
	HP Metal Jet Production Service ⁵	

For more information, please visit: hp.com/go/3Dmetals

Connect with an HP Metal Jet expert or sign up for the latest news about HP Metal Jet Printing: hp.com/go/3DmetalsContactus

1. Powder removal involves a mix of automated and manual processes, where trace amounts of loose powder may be lost.
2. Osprey® 316L metal powder is used in a variety of powder metal processes (such as MIM, AM, PM, Micro-MIM, etc.) enabling economies of scale in pricing as compared to the metal powders that are specifically designed for laser powder bed fusion and typically available at much higher price points.
3. Meets ASTM and MPIF standards for stainless steel.
4. To achieve 4 times nozzle redundancy, nozzles are aligned so that four nozzles print the same 1/1200-inch dot row in the powder bed. This means up to four different nozzles can print HP Metal Jet binding agent in the same 1200 dpi grid point, helping to suppress defects. For more information, see hp.com/metaljet-whitepaper.
5. HP provides design compatibility check for HP Metal Jet printing. Manufacturing of sample parts, qualification process, and production of bulk order can be driven either directly from HP or from an HP-approved Manufacturing Partner.
6. Additional fee may be required for sintering and finishing support services.
7. Compared to metal injection molding, a time-consuming debinding process is unnecessary with HP Metal Jet technology, taking up to 20 hours out of the workflow.
8. Meets MPIF standards for stainless steel with HP Metal Jet SS 316L and HP Metal Jet SS 17-4PH materials.
9. In the case of a layer thickness of 50 microns, actual build speed is affected by build depth, materials, and processing parameter settings.
10. Material transport speed: considers transport from the HP Metal Jet S100 Powder Management Station Portable Tank to the HP Metal Jet S100 Powder Management Station using the HP Metal Jet S100 Powder Management and Removal Station Vacuum Pump.
11. Build unit loading speed considers material discharge from the HP Metal Jet S100 Powder Management Station to HP Metal Jet S100 Build Unit, including sieving and compaction.

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