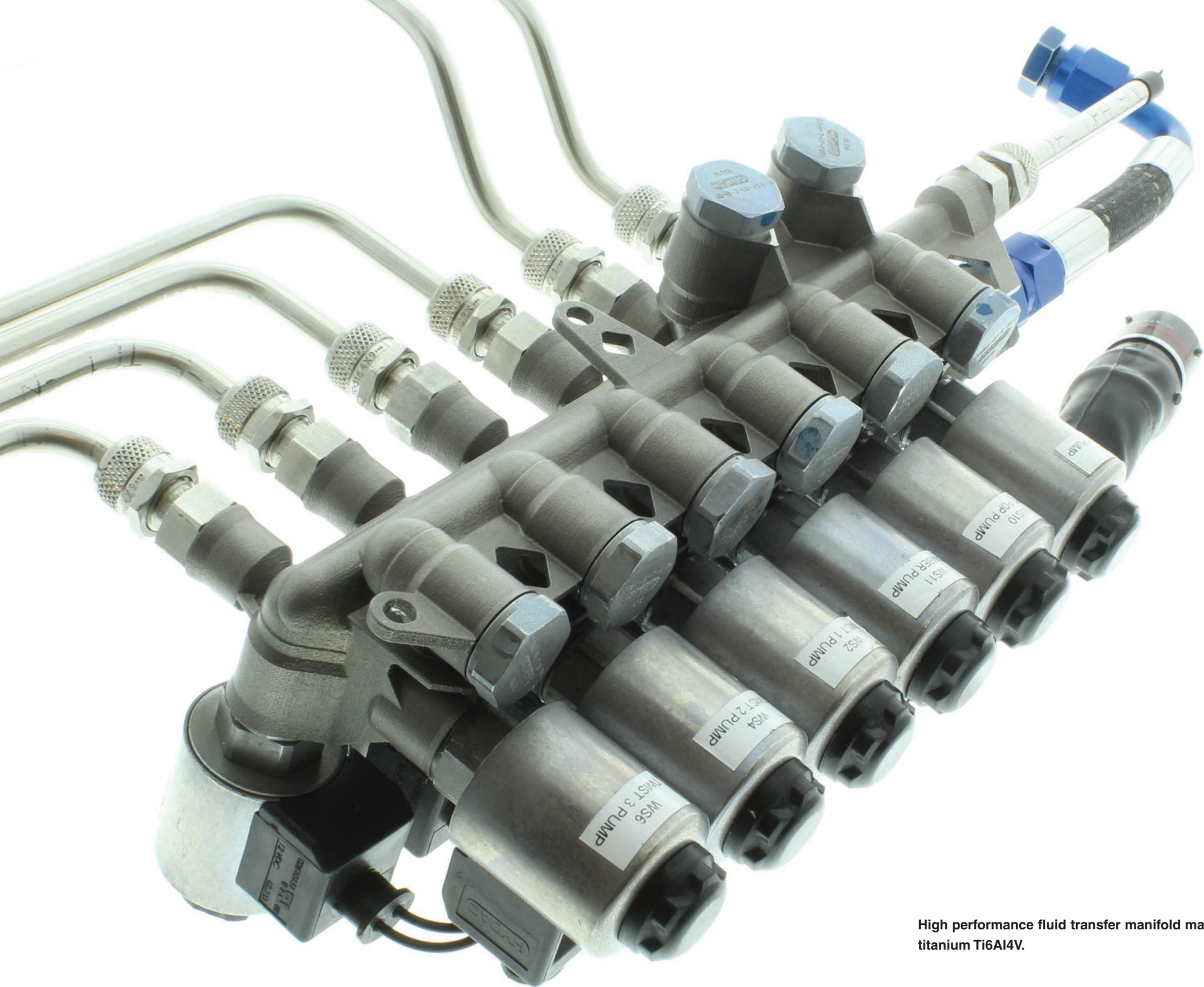


RenAM 500 series additive manufacturing systems





High performance fluid transfer manifold manufactured in titanium Ti6Al4V.

Why metal AM?

Metal additive manufacturing (AM) is helping innovators create new product designs and develop new business opportunities. Deciding if AM has a part to play in your business requires a thorough evaluation of your products, supply chains, operational capability and business needs. For maximum benefit parts need to be designed to exploit the advantages of AM. Some of the areas below are where metal AM is already delivering exceptional value for our customers:

Design freedom

- Produce geometries with hollow and hidden features
- Build complex structures and lattices

Part performance

- Consolidate parts into single objects to improve reliability
- Use conformal channels to improve thermal management

Supply chain

- Geometry-independent raw materials
- Reduce inventory, manufacture on demand

Production flexibility

- Increased customisation possibilities
- Minimum batch size of one

Materials

- Process alloys that are difficult to form
- Waste reduction, as material is only used where it is needed

RenAM 500 series additive manufacturing systems

Metal additive manufacturing (AM) is already transforming the way many products are designed and manufactured, leading to improved in-service performance and new innovations. Broadening the adoption of metal AM depends on increasing processing speed, assuring consistent high product quality and improving process economics. The RenAM 500 series of AM systems is designed to break down the barriers to wider use and enable organisations to create production environments for manufacturing a new generation of high performance components.

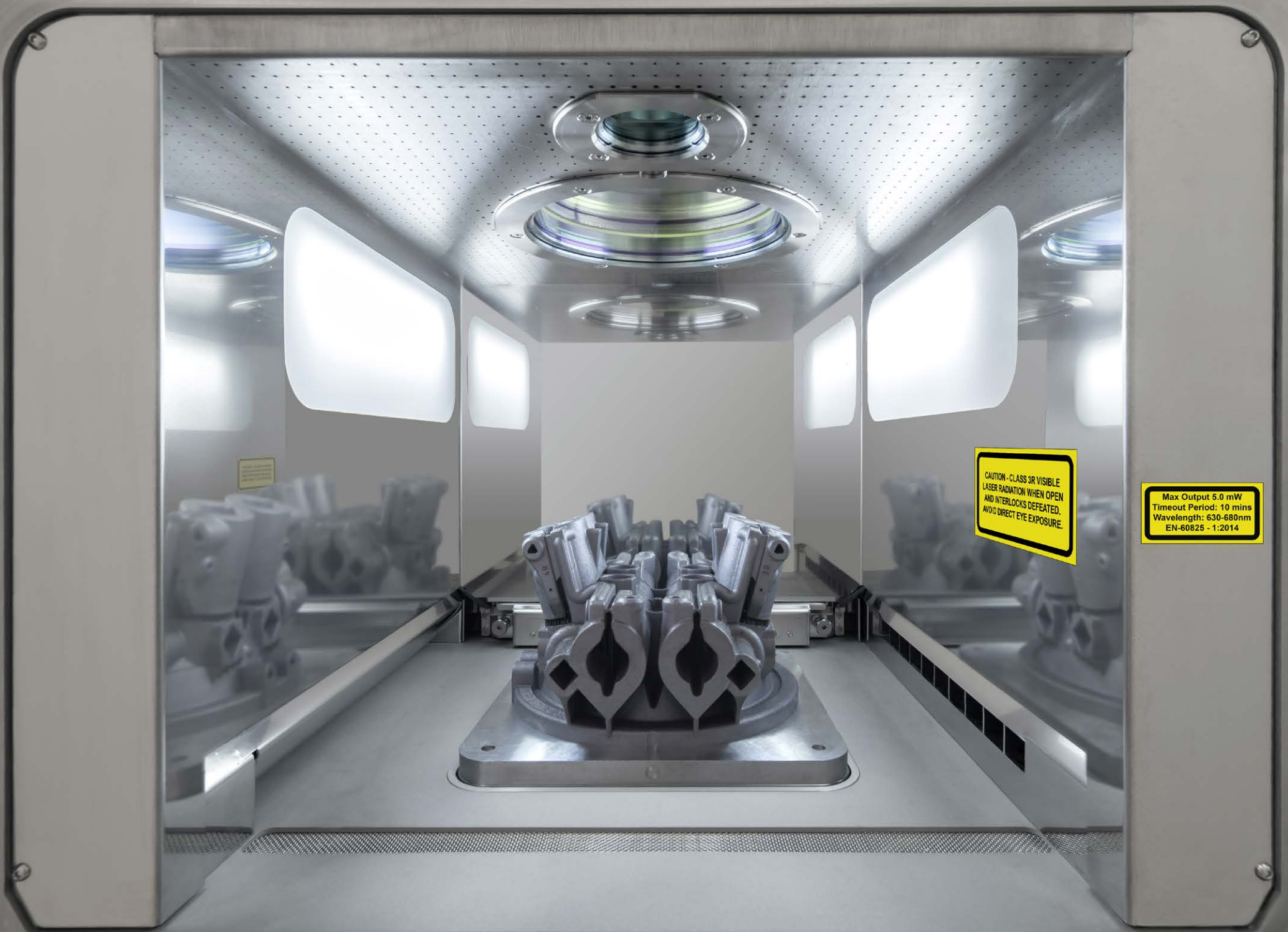
The RenAM 500 series of AM systems can be configured with a choice of one, two, three or four lasers. The RenAM 500Q is configured with four high-power 500 W lasers. Each laser is able to access the entire powder bed surface simultaneously to achieve the most efficient laser assignment, so RenAM 500Q can achieve significantly higher build rates, vastly improving productivity and lowering the cost per part.

RenAM 500 series models

Choosing your AM system configuration depends on your manufacturing requirements and budget. The RenAM 500 series is available in the following laser configurations:

- Q – Quad 4 × 500 W ytterbium fibre lasers
- T – Triple 3 × 500 W ytterbium fibre lasers
- D – Dual 2 × 500 W ytterbium fibre lasers
- S – Single 1 × 500 W ytterbium fibre laser





CAUTION - CLASS 3R VISIBLE LASER RADIATION WHEN OPEN AND INTERLOCKS DEFEATED. AVOID DIRECT EYE EXPOSURE.

CAUTION - CLASS 3R VISIBLE LASER RADIATION WHEN OPEN AND INTERLOCKS DEFEATED. AVOID DIRECT EYE EXPOSURE.

Max Output 5.0 mW
Timeout Period: 10 mins
Wavelength: 630-680nm
EN-60825 - 1:2014

RenAM 500 series key features

- Intelligent gas flow system
- High precision dynamic optical control
- Controlled powder management
- Integrated process control software
- Connected and intelligent sensing technologies

Options

- LaserVIEW (factory fit only) and MeltVIEW optical process monitoring
- SonicVIEW acoustic monitoring (factory fit only)
- Reduced Build Volume (RBV) for materials experimentation
- High Temperature Build Volume (HTBV) for residual stress management and special materials (factory fit only)

Onsite engineer upgrades

- Additional lasers can be added to S, D and T models on site, providing expandability is specified at initial purchase
- MeltVIEW optical process monitoring
- RBV integration

See pages 28 and 29 for full options list.

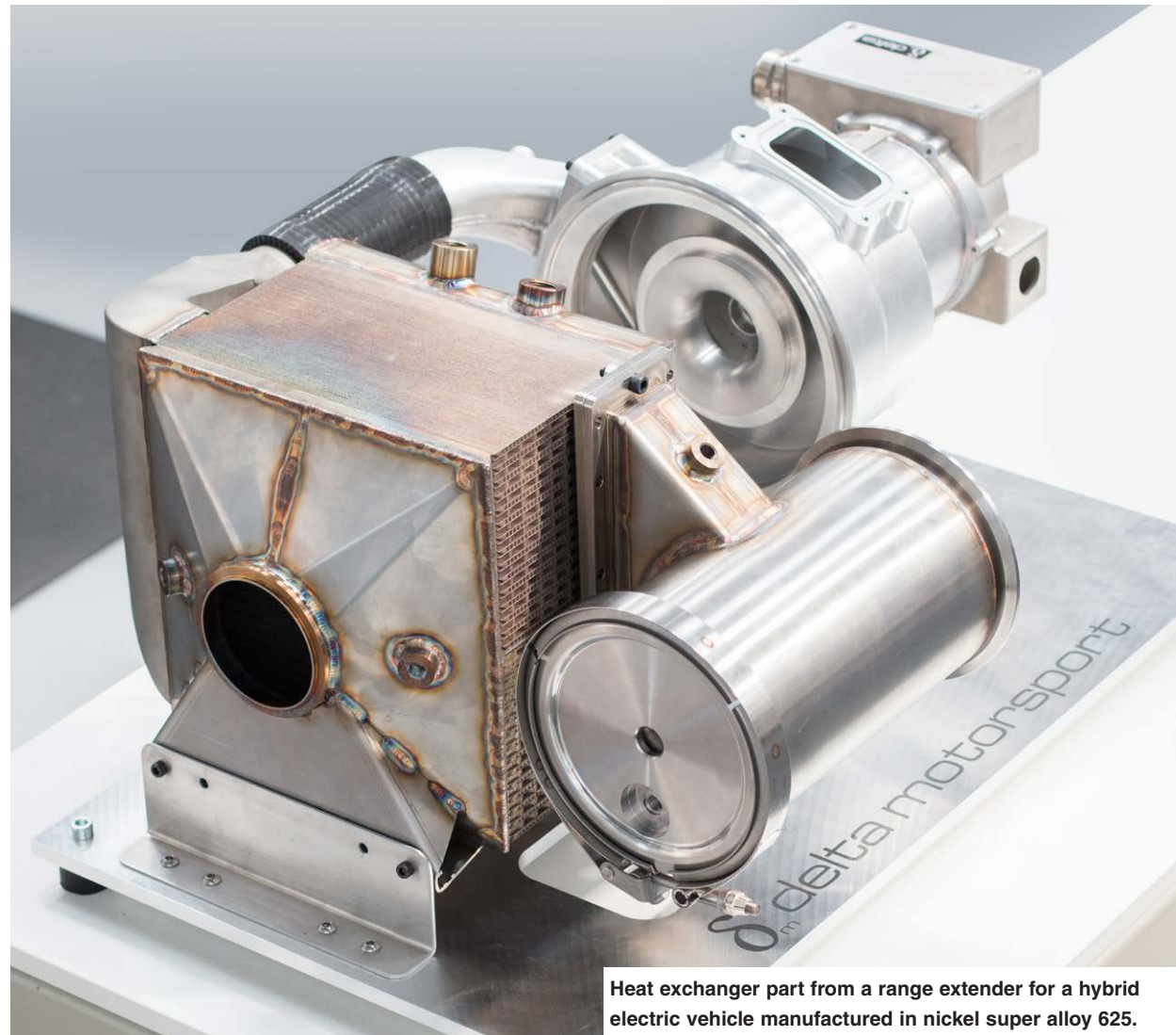


Your process foundation

Renishaw has spent decades engineering products that enable global manufacturers to deliver high-quality, precision components. High-quality manufacturing relies on processes that run under controlled conditions and AM is no exception to this rule.

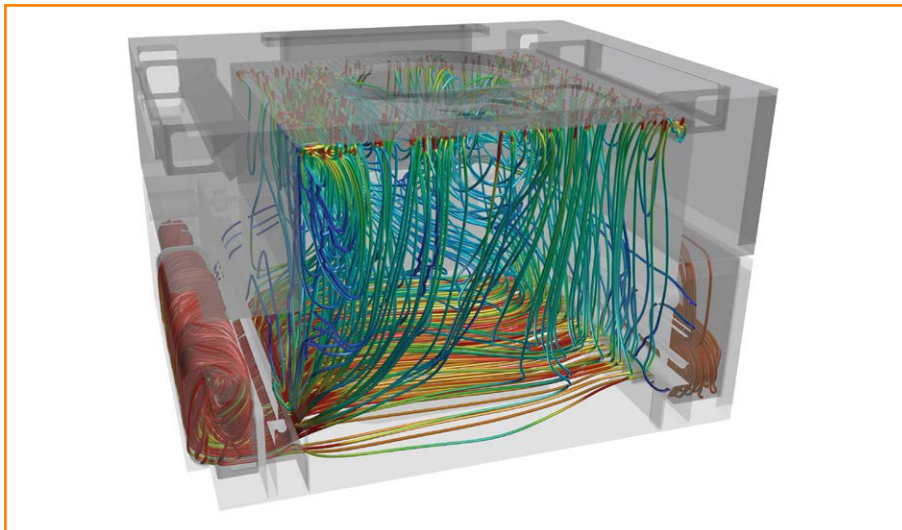
Our investment in compact multi-laser AM systems positions Renishaw as a technology leader, but high-quality productive AM requires much more than precision guided optical systems. To deliver high-quality parts for the most demanding applications demands a stable processing environment and depends on multiple sub-systems working efficiently and harmoniously.

Fundamentally metal AM is a welding process and must take place under tightly controlled inert conditions that protect the process, efficiently remove process emissions and ensure uniform volumetric performance over the entire build.



Heat exchanger part from a range extender for a hybrid electric vehicle manufactured in nickel super alloy 625.

Intelligent gas flow system



Vacuum build chamber preparation and superior sealing

All RenAM 500 series AM systems feature a patented vacuum build preparation system to rapidly reduce the oxygen level, before re-pressurising the system with inert processing gas, creating class-leading processing conditions.

A robust process chamber prevents process gas pressure loss, leading to unmatched low process gas consumption. This economic use of process gas helps maintain uniform processing conditions and reduces waste and cost of ownership.

Intelligent gas flow control

Managing the emissions from four lasers requires superior gas management to ensure that the optical window remains clean for the entire build and that spatter particles do not obstruct the transmission of laser energy.

Intelligent gas flow efficiently removes process emissions in a stream of inert argon gas leaving a clean build chamber – ensuring consistent high-quality processing, improving safety and minimising turn-around time.

The build chamber is designed to be free of obstructions and enables a high volume and flow of gas across the powder bed from right to left. This combined with a cascading flow of gas from the perforations in the top of the chamber provide uniform processing conditions over the entire working area. Results on page 18, 19 and 20 directly demonstrate the effectiveness of the gas management system.

Intercooler

With up to 2 kW of laser power available, heat management becomes more important. The intercooler reduces and stabilises the temperature of the argon gas stream by cooling the recirculating gas. Precise thermal control contributes to a stable atmosphere and uniform processing conditions that lead to better and more consistent metallurgy.



Dual SafeChange™ filters for longer builds

All RenAM 500 series AM systems feature a dual patented SafeChange™ filter system to capture the very smallest process emissions in an inert argon gas atmosphere. At the start of a build the two new filters are pre-conditioned in the argon gas flow to prepare for the build process.

During the build, a sensor monitors the pressure differential across the filter and automatically diverts the argon gas flow to the clean filter when needed. The used filter is then replaced and automatically prepared without interrupting the build process.



High precision dynamic optical control

High performance laser guiding technology

To deliver accuracy at the powder bed takes expert optical and control engineering, something Renishaw has spent years perfecting for products like our REVO® 5-axis measurement system for co-ordinate measuring machines. A critical component in the RenAM 500 series is the new innovative multi-laser optical system which has been designed, developed and manufactured in-house.

Each ytterbium fibre laser enters the optical system and is guided by a pair of mirrors driven by precision galvanometers which rotate to steer the laser beam across the build plate. The optical system focuses the laser dynamically, continually adjusting its focal length to maintain a consistent spot size as the beam angles change.



Renishaw patented galvanometer housing

Achieving and maintaining a precise relationship between each laser requires an integrated approach. Whilst other multi-laser AM systems combine separate optical systems, the RenAM 500 series is different. Renishaw uses a single water cooled additively manufactured galvanometer (galvo) mounting to ensure tight thermal control and unmatched precision.

Using AM to produce the galvo mount component is a key enabler, and has allowed Renishaw to achieve tighter packaging of the guiding mirrors and the incorporation of internal conformal cooling channels to maintain precise thermal stability. This has led to a class-leading compact high performance multi-laser system.





High precision z-axis

The z-axis is equipped with a Renishaw RESOLUTE™ optical encoder with a 1 nm resolution for high-accuracy positional sensing. Maintaining a precise relationship between the optical system and the working plane as the machine indexes through each layer is vital to ensure precise beam-to-beam interaction is maintained.



Kinematic recoater with flexible blade

A kinematic recoater mounting for rapid and precise recoater changes reduces operator error and improves turn-around time. Fitted with Renishaw's flexible recoater blade, the recoater can be removed without special tools and refitted to a precise and repeatable location to maintain a precise relationship between the working plane and the optical system. A flexible blade offers an excellent compromise, and allows both solid and lattice geometries to be built.

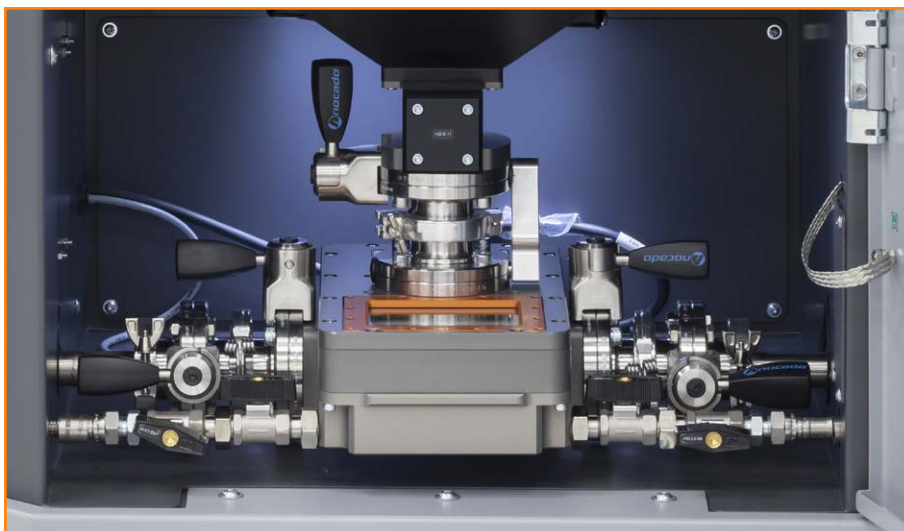
Controlled powder management



Cyclone pre-filter separator

The use of multiple lasers increases the rate at which process emissions are generated.

The RenAM 500 series multi-laser systems feature high volume intelligent gas flow control to remove process emissions safely and efficiently. To allow high volumes of gas at a high velocity to be used, a pre-filter cyclone separator captures larger process emissions from the gas stream before they reach the SafeChange™ filters. This extends the life of the filters and allows surplus powder to be recovered. The larger sized particles are collected directly from the cyclone in a separate flask. These can be re-processed and classified for re-use if required.



Built-in sieve and powder recirculation system

The built-in sieve and powder recirculation system ensures all powder handling is automated and under a safe argon gas atmosphere. Unused powder passes through the on-board sieve and any oversize particles are collected and removed from the machine via a metal flask. Sieve meshes to suit different materials are available.

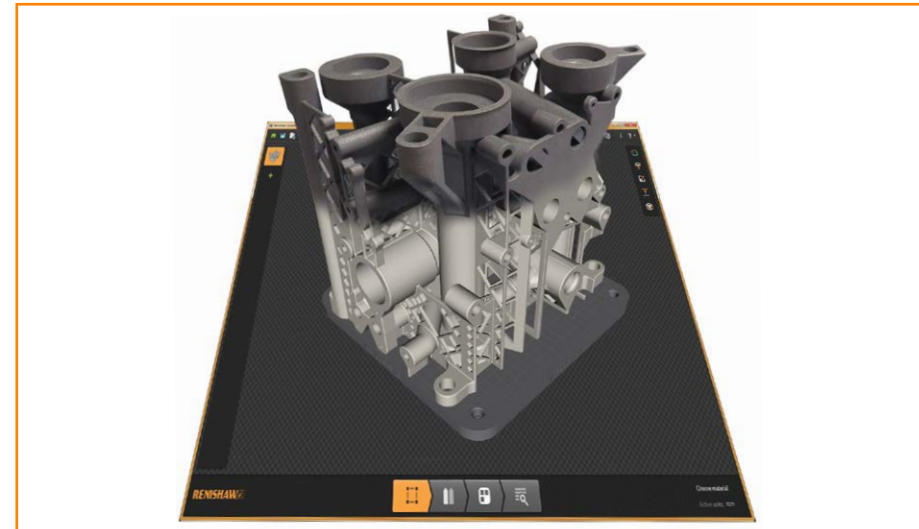
Options for external powder handling are available, should working methods require it.

Integrated process control software

QuantAM build preparation software

QuantAM is a dedicated file preparation software tool for Renishaw additive manufacturing (AM) systems. With an intuitive workflow and easy navigation QuantAM accepts CAD exports in the form of STL data and allows you to prepare your model for the AM process.

QuantAM is designed specifically for Renishaw AM platforms, allowing tighter integration into the machine control software and the ability to accurately and rapidly review all build files for Renishaw AM systems, including files from third party software packages. QuantAM can also be used as a tool to guide your Design for Additive Manufacturing (DfAM) process, helping you unlock the benefits of additive manufacturing.

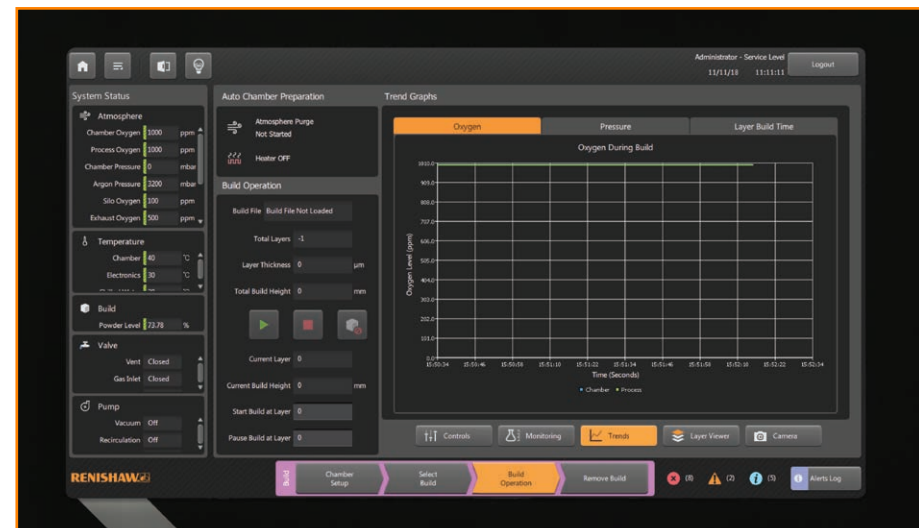


Features

RenAMP operating software

At the heart of the RenAM 500 series is the RenAMP operating software. RenAMP controls all aspects of how the AM system operates, from the laser firing sequence, to the oxygen levels in the build chamber. RenAMP has been designed and built in-house as a modular platform to enable easy updates when new features become available.

RenAMP's graphic rich user interface is operated from an industrial grade 480 mm (19 in) touch screen and features user configurable access controls and password protection.



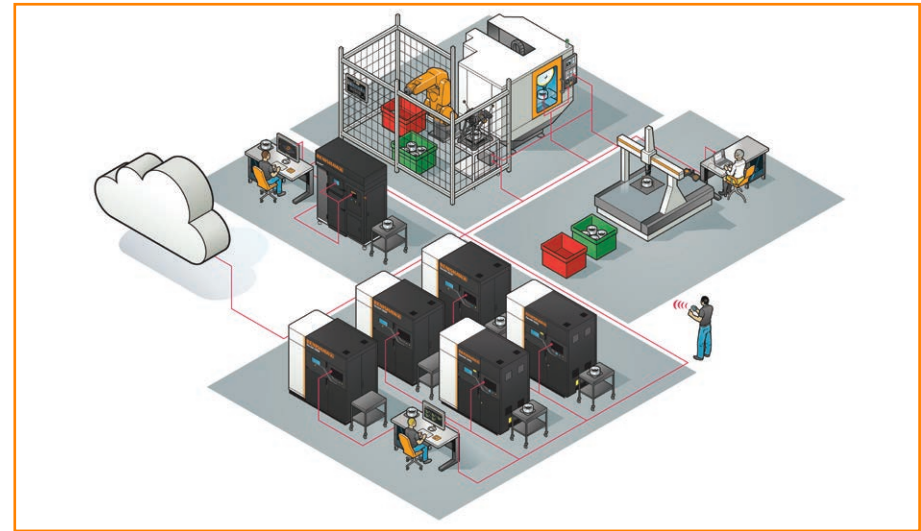
Connected and intelligent sensing technologies

Smart manufacturing with Industry 4.0 technologies

Intelligent manufacturing processes are critical to companies that want to exploit the full benefits of Industry 4.0. Smart factory concepts require connected systems, that are easy to use and generate data sets immediately.

Renishaw additive manufacturing systems support a digital workflow from inventory and part design to traceable high-quality functional components. Embedding AM into smart factories requires an integrated data driven approach that connects manufacturing systems and processes together to deliver exceptional value.

Renishaw InfiniAM Central and Spectral software allows users to capture view and manage key process performance data.

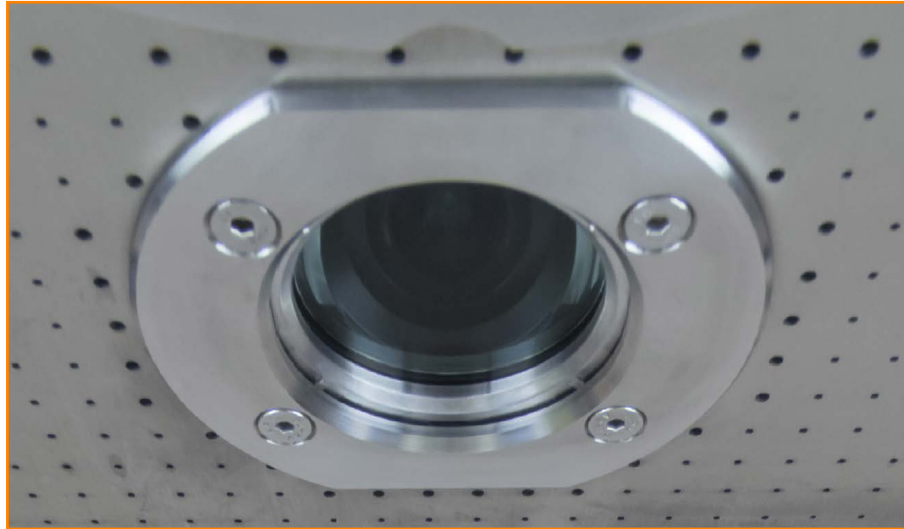


InfiniAM Central software

InfiniAM Central is Renishaw's AM workflow planning and process monitoring software solution. It enables live process monitoring and build data recording for your Renishaw AM systems.

Build data forms an essential part of a quality management system to ensure consistent and repeatable AM production. InfiniAM Central enables real-time insight into your live AM builds and access to analyse historic builds. System sensor and build information is displayed in graphic form to enable intuitive in-depth analysis.





Build chamber camera

A process monitoring build chamber camera enables visual monitoring and recording pre and post layer. Images can be downloaded from the machine for sequential viewing via image viewing software. For maximum benefit, camera images can be imported into InfiAM Spectral and viewed in combination with other process sensor data, either as a 2D image or 3D render.



InfiAM Spectral software

InfiAM Spectral is designed to operate with Renishaw's LaserVIEW, MeltVIEW and SonicVIEW hardware. It provides feedback on laser energy input, optical and acoustic emissions from the AM build process, and is licensed on a subscription basis. Raw sensor data is captured alongside high-accuracy galvanometer actual position data and streamed directly to a layer-specific data file. Volumes of data can be viewed offline almost immediately using the viewing tools in InfiAM Spectral software.

MeltVIEW monitors the optical emissions from the AM process across a wide spectral range within the visible and infrared (IR) fields.

LaserVIEW measures the energy contained in every laser pulse during a build.

SonicVIEW monitors acoustic emissions from the build, and displays a graphical representation of magnitude and location.

RenAM 500 series metallurgical performance

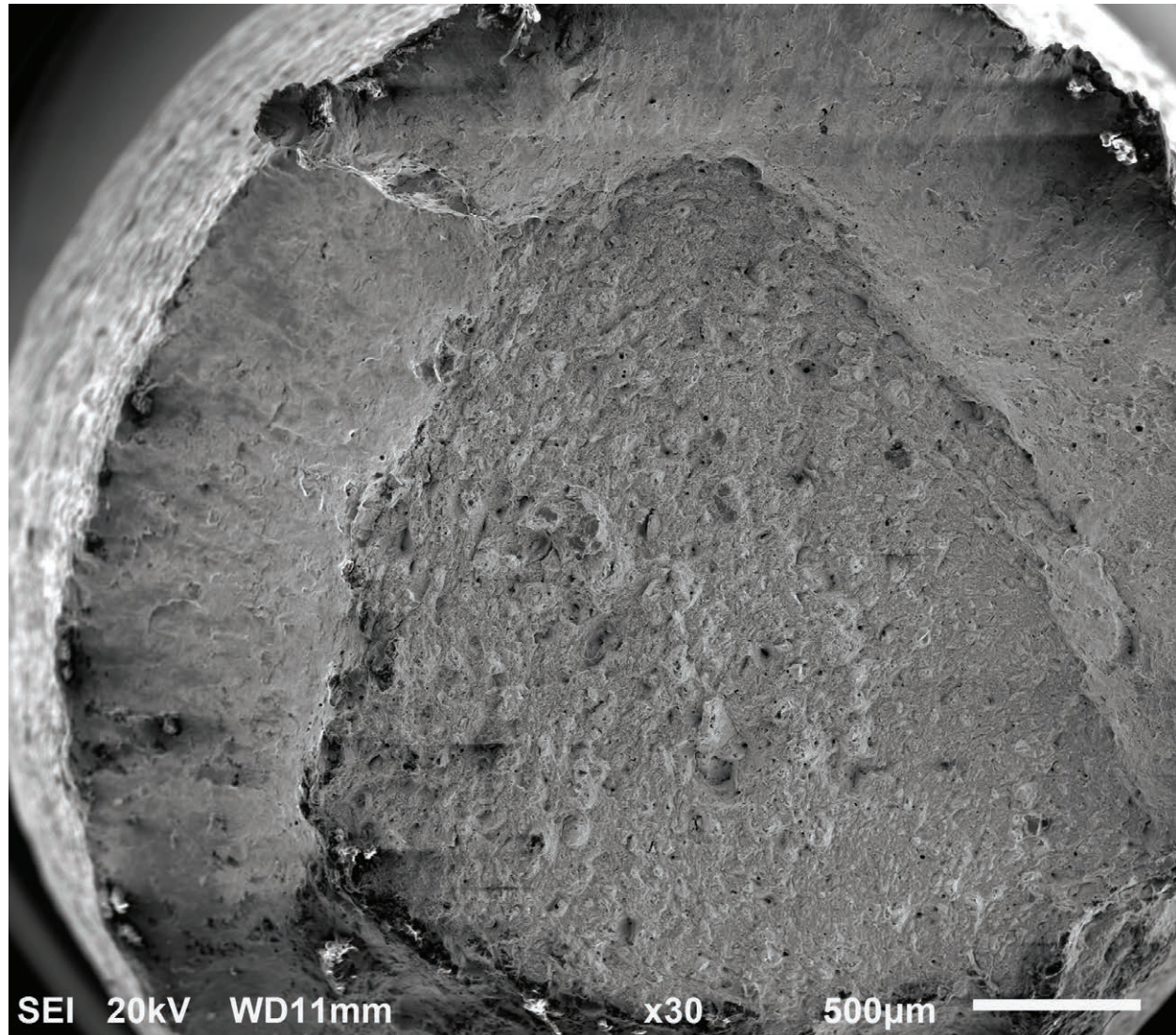
Component quality

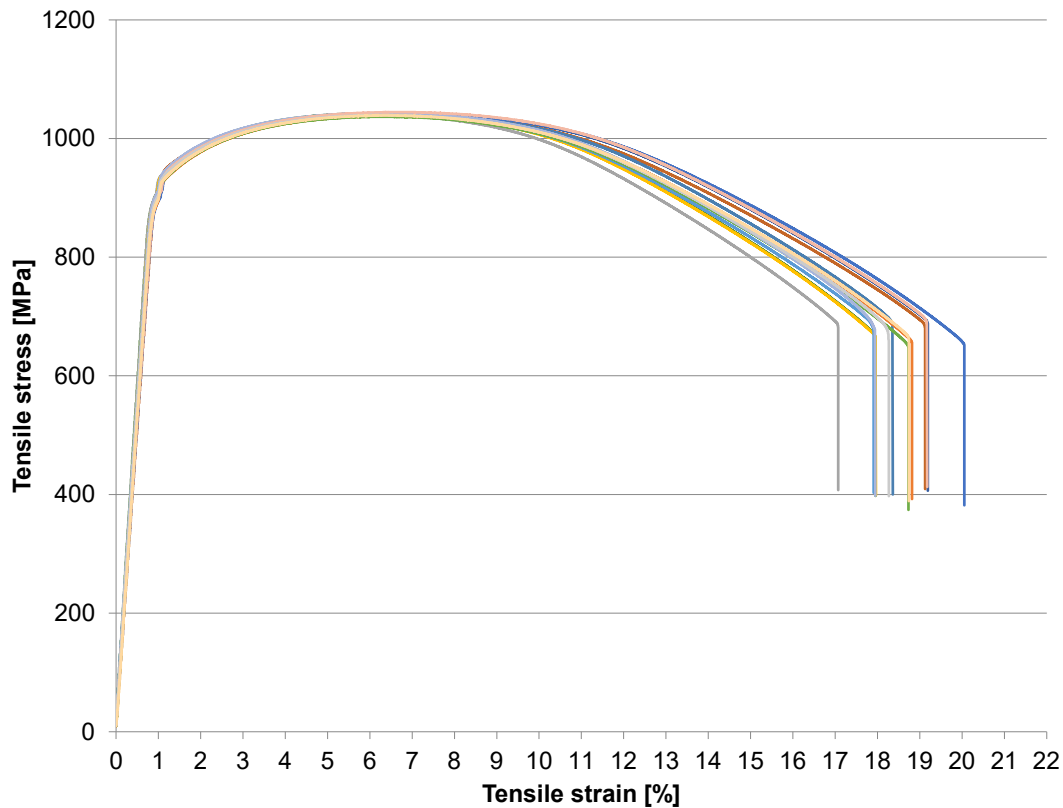
The strength and ductility of an AM component is driven by its chemistry, density and micro-structure. These characteristics are of particular importance in applications where strong fatigue performance is required. Here we need parts that are free from impurities and defects so that we attain the full potential performance of the alloy.

The intelligent gas flow design, and precise optical and mechanical control of the RenAM 500 series enables components to be produced with minimal pores and defects, typically >99.9% dense. Process emissions from melt pools are quickly removed from the build chamber, ensuring stable processing conditions and melting behaviour. Real-time process monitoring capability provides traceability of the processing performance.

The inert processing environment is also important. Low levels of oxygen and moisture inside the build chamber contribute to components with fewer chemical impurities, which benefit the ductility of the metal.

Elongation at break in 'as built' and heat treated conditions, in a range of materials, is both high and consistent. This offers users the power to govern the mechanical performance of the final part using advanced heat treatment processes.





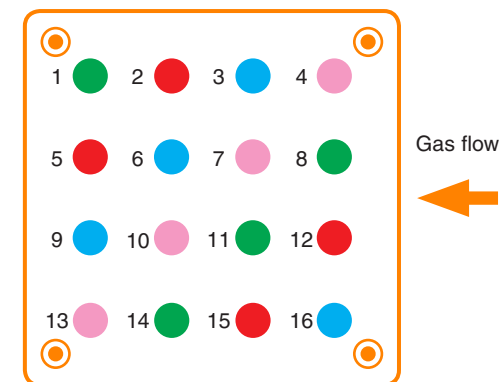
- Sample 1
- Sample 2
- Sample 3
- Sample 4
- Sample 5
- Sample 6
- Sample 7
- Sample 8
- Sample 9
- Sample 10
- Sample 11
- Sample 12
- Sample 13
- Sample 14
- Sample 15
- Sample 16

Tensile test data for titanium cylinders

Stress-strain curves from tensile testing of multiple Ti6Al4V vertical test specimens following heat treatment in a vacuum furnace. Titanium 64 is an alloy that typically exhibits a high Ultimate Tensile Strength (UTS) with relatively low ductility. The graph demonstrates consistent processing across the entire working area in line with standard industry performance values.

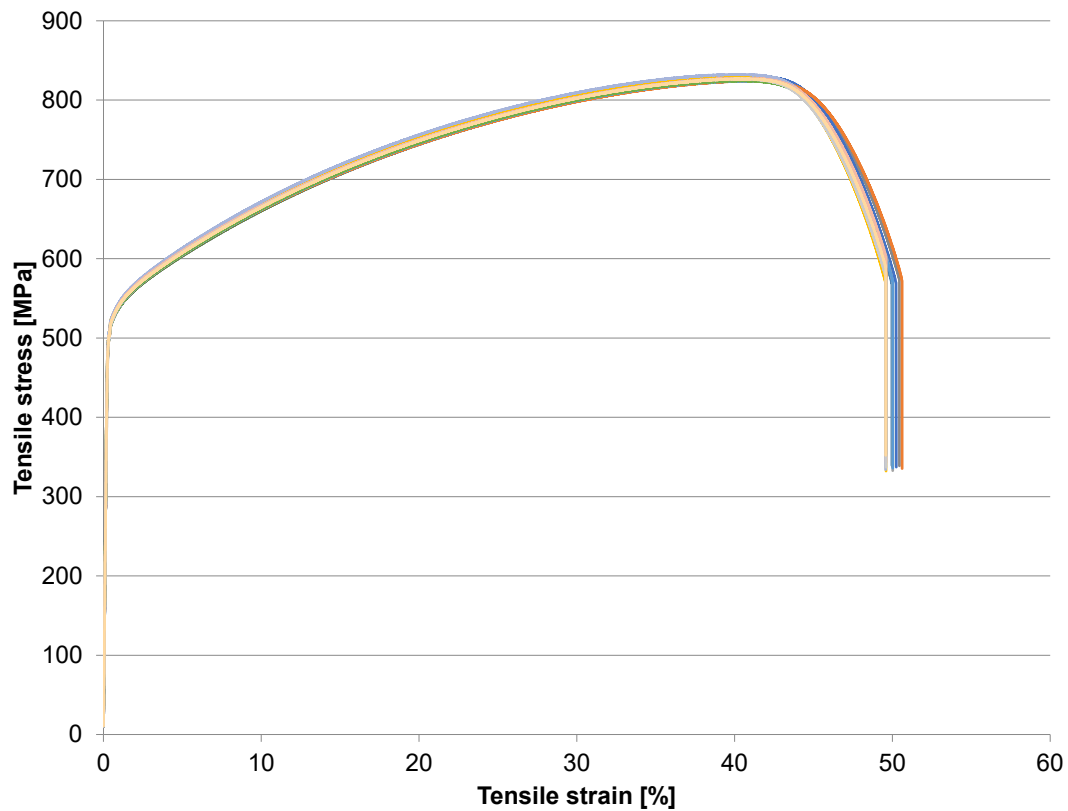
- Test in accordance with: ISO 6892-1: 2009
- Test specimen machined to 6 mm diameter cylinder over the gauge length
- Build: 30 µm layers

Concurrent processing of test specimens on build plate, processed in columns using four lasers from left to right.



- Laser 1
- Laser 2
- Laser 3
- Laser 4

Metallurgical performance



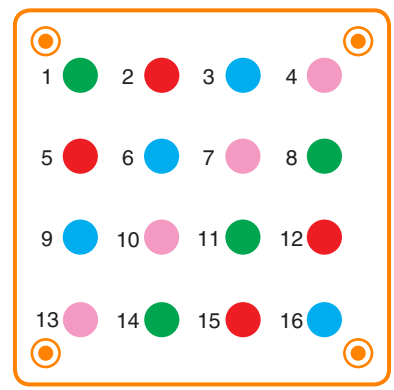
- Sample 1
- Sample 2
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- Sample 4
- Sample 5
- Sample 6
- Sample 7
- Sample 8
- Sample 9
- Sample 10
- Sample 11
- Sample 12
- Sample 13
- Sample 14
- Sample 15
- Sample 16

Tensile test data for nickel super alloy 625 cylinders

Stress-strain curves from tensile testing of multiple nickel super alloy 625 vertical test specimens following heat treatment. This ductile material exhibits elongation to failure of nearly 50%, with a low level of variation.

- Test in accordance with: ISO 6892-1: 2009
- Test specimen machined to 6 mm diameter cylinder over the gauge length
- Build: 30 μ m layers

Concurrent processing of test specimens on build plate, processed in columns using four lasers from left to right.



- Laser 1
- Laser 2
- Laser 3
- Laser 4



RENISHAW TP20
MADE IN UK
SRB828

RENISHAW

Explore the possibilities with advanced additive manufacturing

Through AM, our customers can create parts that deliver enhanced performance and explore new business opportunities – limited only by their imagination.

Unlock the benefits

Achieving significant productivity gains from a proportionally low increase in investment, without compromising quality, is a goal for all competitive manufacturers. Bringing more parts within reach of AM technology requires both improvements in processing speed, and increased process stability to maintain consistent high-quality metallurgy.

The RenAM 500 series makes this possible, firstly by applying multi-laser technology efficiently across the working area and secondly by ensuring a high integrity stable processing environment to lock in predictable performance, build after build.

Advanced sensors provide process feedback and build a comprehensive digital record of processing conditions that empower manufacturers to deliver high performance AM in the most demanding applications.

How we do it . . .

The patented Renishaw galvanometer mounting block (galvo), shown on the facing page, is the housing that contains the eight motorised guiding mirrors in the RenAM 500Q system. The 'quad galvo' is a prime example of how AM can bring advanced performance to a conventional design problem. Packaging eight motorised guiding mirrors into a space that would normally house only two in a single laser AM system, requires design freedoms unmatched by conventional forming technologies, including conformal cooling, thermal asymmetry and the ability to put material only where necessary.

Using AM to change the rules in the design of the RenAM 500Q optical system has unlocked performance capabilities that cannot be bought off the shelf. Achieving best in class performance is a result of decades of metrology, production engineering and motion control knowledge, brought together in our own designed and built optical system.

Explore how Renishaw metal AM can help you solve your manufacturing and design challenges.

Quad laser **RenAM 500Q**
builds eight galvanometer
 housings in one week

Triple laser **RenAM 500T**
builds six galvanometer
 housings in one week

Dual laser **RenAM 500D**
builds four galvanometer
 housings in one week

Single laser **RenAM 500S**
builds two galvanometer
 housings in one week



Explore the possibilities . . .

System overview

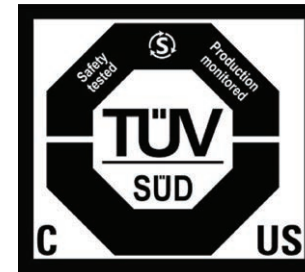
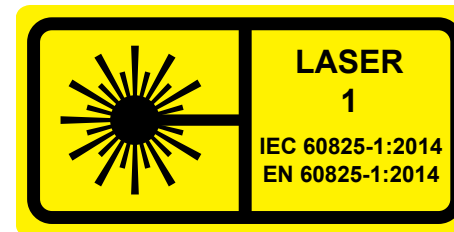


Safety classification marks and compliance

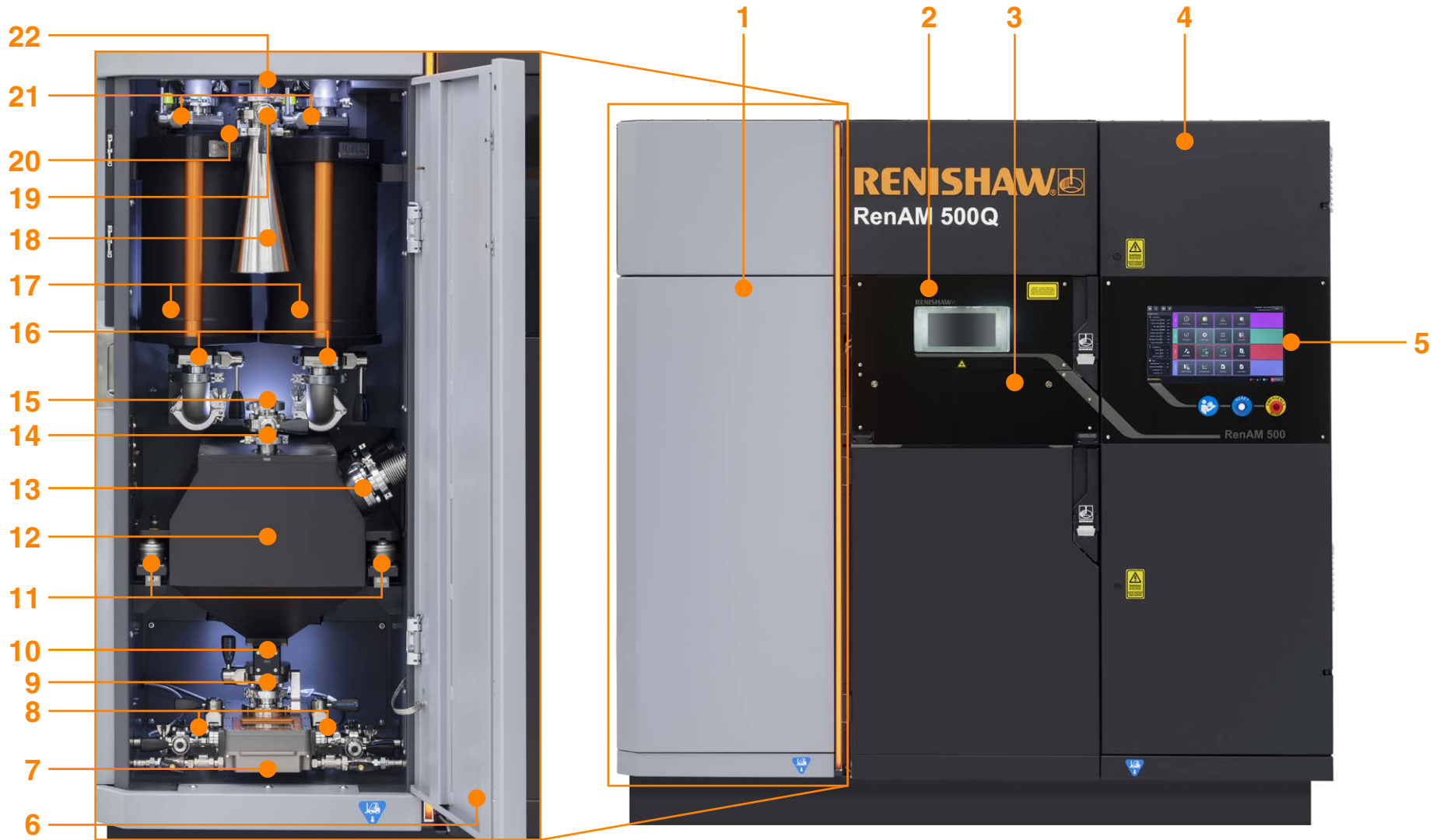
The RenAM 500 series of AM systems contains Class 4 lasers. The design of the system, control measures and interlocks in place give the system an overall laser classification of a Class 1 laser product.

This means the Maximum Permissible Exposure (MPE) cannot be exceeded when viewing the process laser with the naked eye or with the aid of typical magnifying optics.

The RenAM 500 series of AM systems have been independently assessed by the TÜV SÜD organisation against all the applicable international standards and are approved for sale in North America, and are CE marked for sale in Europe.



The anatomy of a RenAM 500 series AM system



Key

1	SafeChange™ filter cabinet	2	Top door
3	Glovebox lockable door (gloves behind door)	4	Front right-hand electrical cabinet door
5	Operator touch screen control panel	6	Powder fill and SafeChange™ filter left-hand door open
7	Ultrasonic sieve system	8	Powder system isolation valves
9	Load hopper and powder metering screw feeder isolation valves	10	Powder metering screw feeder
11	Load hopper level load cells	12	Load hopper
13	Powder return pipe	14	Load hopper filling point isolation valve
15	Load hopper filling point	16	SafeChange™ filter lower isolation valves
17	SafeChange™ filter no. 1 (left-hand) and no. 2 (right-hand)	18	Oversized particle collection flask
19	Oversized particle collection point isolation valve	20	SafeChange™ filter status indicator
21	SafeChange™ filter upper isolation valves	22	Oversized particle collection point

Standard, optional and required equipment

Standard, optional and required equipment	RenAM 500 series model			
	Q – quad	T – triple	D – dual	S – single
Four × 500 W ytterbium lasers	•	n/a	n/a	n/a
Three × 500 W ytterbium lasers	n/a	•	n/a	n/a
Two × 500 W ytterbium lasers	n/a	n/a	•	n/a
One × 500 W ytterbium laser	n/a	n/a	n/a	•
Upgrade to four × 500 W ytterbium lasers	n/a	U	U	U
Upgrade to three × 500 W ytterbium lasers	n/a	n/a	U	U
Upgrade to two × 500 W ytterbium lasers	n/a	n/a	n/a	U
Kinematic recoater with flexible blade	•	•	•	•
Additional kinematic recoater to reduce build turn-around time	O	O	O	O
Dual SafeChange™ filters	•	•	•	•
Additional SafeChange™ filter to reduce build turn-around times	O	O	O	O
Cyclone pre-filter separator	•	•	•	•
Intelligent gas flow control with intercooler	•	•	•	•
High precision Z-axis with Renishaw RESOLUTE™ encoder	•	•	•	•
Built-in sieve and powder recirculation system	•	•	•	•
Renishaw designed and manufactured galvanometer housing	•	•	•	•
High performance laser guiding technology	•	•	•	•
Touch screen control panel	•	•	•	•

• – standard equipment F – factory option O – optional equipment U – upgrade R – required equipment n/a – not available

Standard, optional and required equipment	RenAM 500 series model			
	Q – quad	T – triple	D – dual	S – single
RenAMP operating software	•	•	•	•
Chiller	•	•	•	•
ATEX vacuum cleaner	R	R	R	R
Renishaw equipment lift	O	O	O	O
Renishaw powder silo trolley	O	O	O	O
Furnace	O	O	O	O
Bead blaster and extractor	O	O	O	O
High Temperature Build Volume (HTBV)	F	F	F	F
Reduced Build Volume (RBV) (compatible with HTBV equipped systems with heater off)	O	O	O	O
Interfaces for Smart manufacturing with Industry 4.0 technology	•	•	•	•
InfiniAM Central software	O	O	O	O
InfiniAM Spectral software	O	O	O	O
Build chamber camera	•	•	•	•
LaserVIEW sensing hardware	F	F	F	F
MeltVIEW sensing hardware	U	U	U	U
SonicVIEW sensing hardware	F	F	F	F
QuantAM build preparation software	O	O	O	O

Options

Renishaw strongly recommends you purchase the ATEX vacuum cleaner to ensure standards of safety and AM system integrity are maintained.

Your AM journey

Renishaw works extensively with a large number of organisations across a range of different industries to help them understand how AM technology can bring improvements to their products and manufacturing processes.

If you are investing in your first AM system, exploring AM in our global network of Solutions Centres or would like to upgrade to the latest technology, Renishaw can support you. We have developed all elements of our own manufacturing processes, including AM, enabling us to provide excellent technical service and support.

Talk to Renishaw to find out more about AM systems and services for your industry. View feature articles, white papers, presentations, videos and more.

Visit: www.renishaw.com/amguide

Ownership options

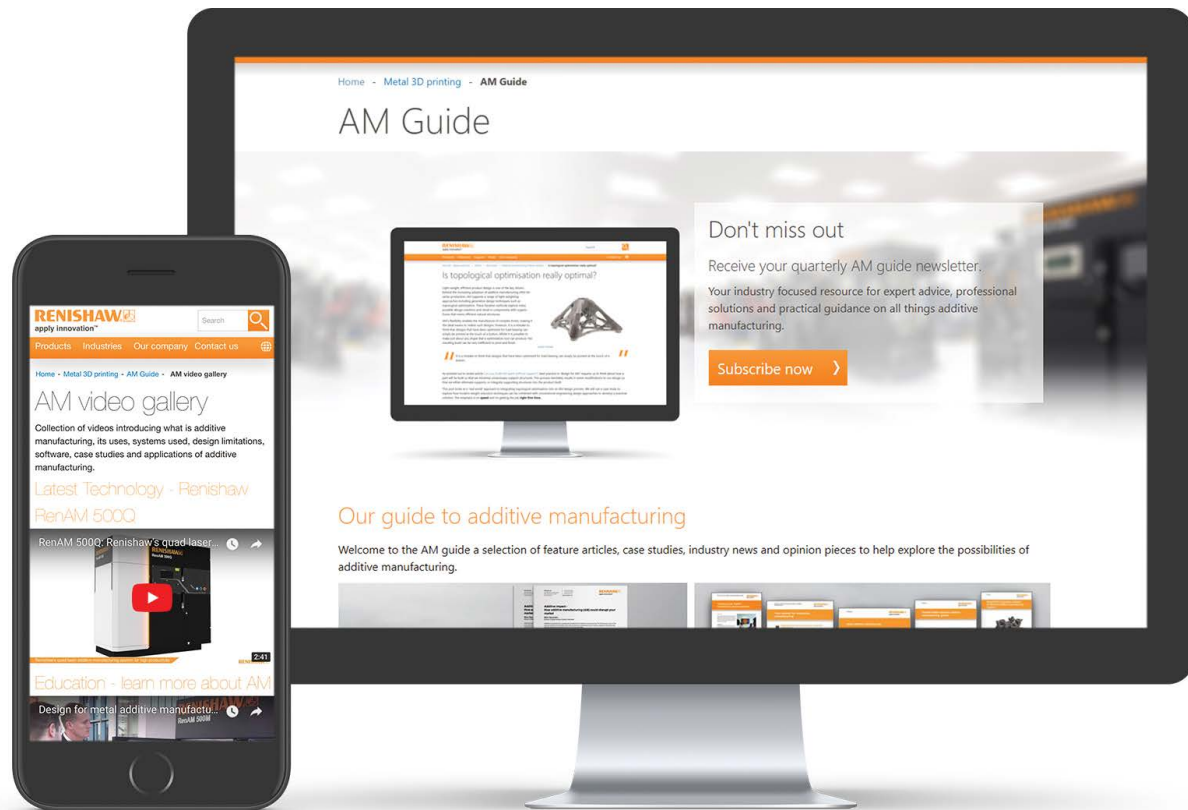
Whether you are considering outright purchase, operating lease or hire purchase, Renishaw can support the option that works best for your business. Renishaw offers a range of flexible financing to give you low initial capital costs and fixed monthly payments over the lifecycle of your AM systems.

Our asset finance agreements are managed in-house and enable us to offer competitive rates with simple pricing structures. Contact your local sales representative to arrange for your asset finance illustration (territory specific restrictions may apply).

Visit: www.renishaw.com/assetfinance

Contact your local Renishaw office, we have over 70 offices in 35 countries around the globe.

Visit: www.renishaw.com/contact



Maintaining your AM capability



Renishaw offers a range of comprehensive service and support packages including:

System installation

Renishaw can install, commission and work with you to carry-out sign-off builds, to ensure your AM system is operating correctly in your AM facility.

Support agreements

We offer costed maintenance plans to ensure your AM system is kept in the best possible condition throughout its life.

Corrective maintenance

Should your system become damaged, for whatever reason, our aim is to repair it swiftly for you.

System parts

We stock a vast range of spare parts and can make recommendations on which critical spares for you to keep in stock to maximise the running time of your AM system.

System and software upgrades

Innovation is in our DNA and we are always developing and improving our systems and software. Stay in contact with your account manager to keep up-to-date with the latest upgrades available for your AM system, system software and software tools.

Relocation of systems

If your AM system needs to be relocated Renishaw is happy to assist and advise before and after the relocation.

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