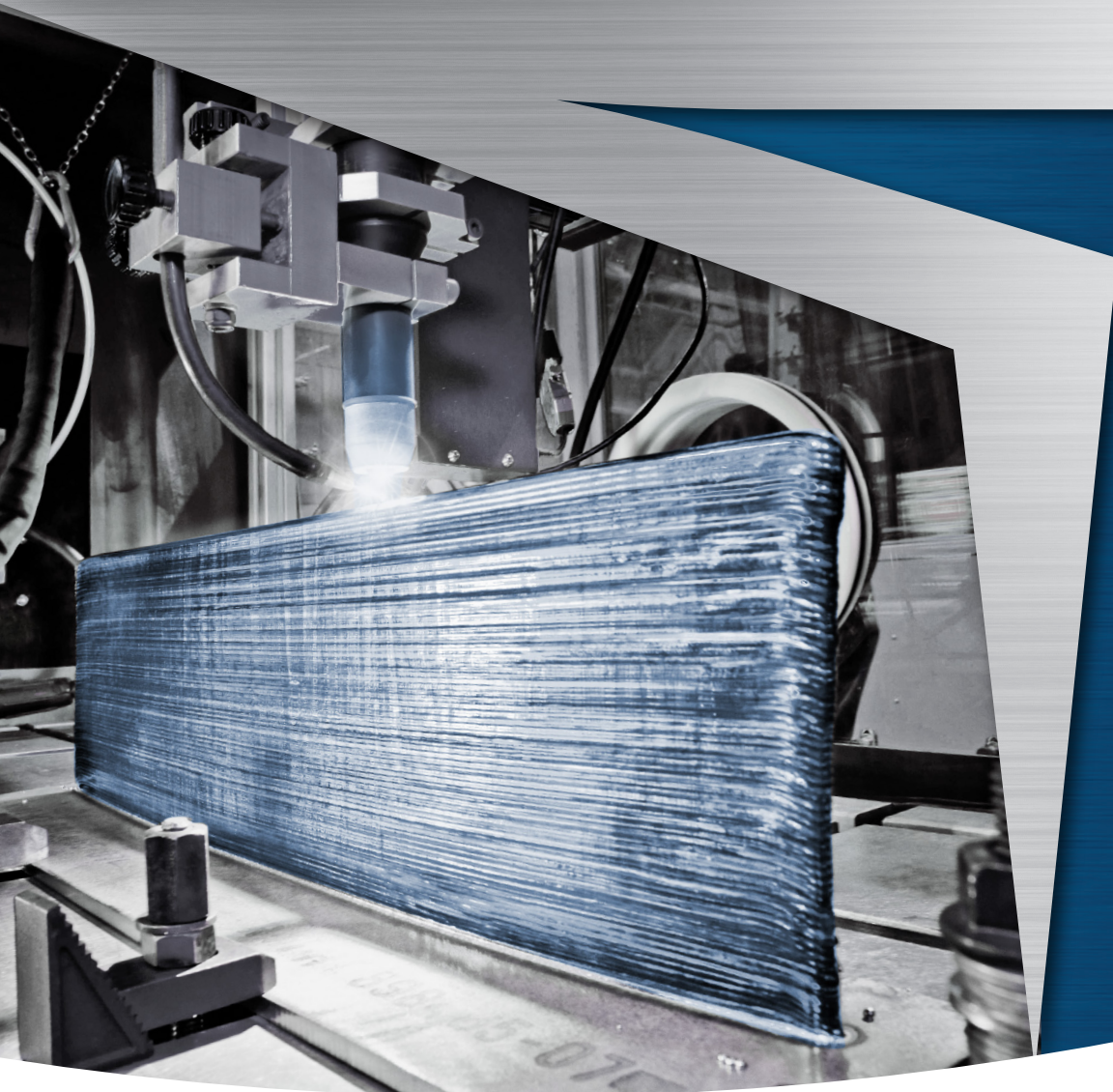


Lasting Connections

# THE FUTURE OF PRODUCTIVITY: WIRE ARC ADDITIVE MANUFACTURING







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## 3D PRINTING WITH THE BEST-IN-CLASS WIRE ALLOYS

**Additive manufacturing – popularly known as 3D printing – is one of the most revolutionary new manufacturing methods of our time.**

Wire Arc Additive Manufacturing is a new disruptive technology that is being enthusiastically adopted at voestalpine Böhler Welding for its leading brand Böhler Welding.

It not only allows almost lossless processing of high-value material but also results in high-strength components with a flexibility that would not be conceivable using conventional methods. Up to now, manufacturing methods such as casting/milling and forging have been used for production of large components.

Material is removed from a casting or blank and creates scrap. The specialists at Böhler Welding are researching special materials for the optimized production of highest quality solid and seamless cored wires with excellent surface finishing and properties required for a stable 3D printing processes.

Contact us personally and experience a new dimension in manufacturing.

**Dr. Martin Peruzzi**  
CTO, voestalpine Böhler Welding

# PIONEERING EXPERTISE

As a pioneer in innovative welding consumables, Böhler Welding offers a unique product portfolio for joint welding worldwide. More than 2000 products are adapted continuously to the current industry specifications and customer requirements, certified by well-respected institutes and thus approved for the most demanding welding applications. As a reliable partner for customers, “lasting connections” are the brand’s philosophy in terms of both welding and people.

As long ago as 1927 Böhler Welding developed the “Seelendraht” (“soul wire”) the predecessor of the modern-day flux cored wire. The company has been leading ever since, as current innovations, like the laser-sealed flux cored wires or the leadership in Wire Arc Additive Manufacturing, proves. Customers can rely on a outstanding product portfolio for all demanding welding tasks.

## A revolutionary technology shapes the future of our life

Wire Arc Additive Manufacturing enables fast and highly efficient production processes replacing conventional technologies as casting and forging. The machining effort like milling and drilling is reduced to a minimum due to a near-net-shape using Wire Arc Additive Manufacturing. Lead times can be reduced dramatically by high utilization of the wire consumables and by simplification of the production process in general.

Especially as the Wire Arc Additive Manufacturing is based on the well-known technology of joining and cladding materials with a wide range of commercially available wire consumables from unalloyed, mid- and high alloyed steels. But also nickel- and cobalt base alloys can be used and combined, if metallurgical reasonable, to gradient structured parts.

Given the typical layer thickness applied, Wire Arc Additive Manufacturing is – compared to powder-based Additive Manufacturing – more suitable to generate low to medium complexity and up to large scale preform components.

Due to a wide range of parameter settings it is possible to reach high deposition rates with rates up to 5 kg/h, so that the production of large scale parts is feasible within reasonable time frames. Depending on the material alloy group, heat treatments and post-machining is usually required to give the components the final properties.

### Key Benefits for Wire Arc Additive Manufacturing

- » Wide range of deposition rates (low to high)
- » Near-Net shape and therefore reduced material loss
- » Conventional machining time reduced to minimum
- » Reduced lead times
- » Good structural integrity
- » Low to medium complexity components

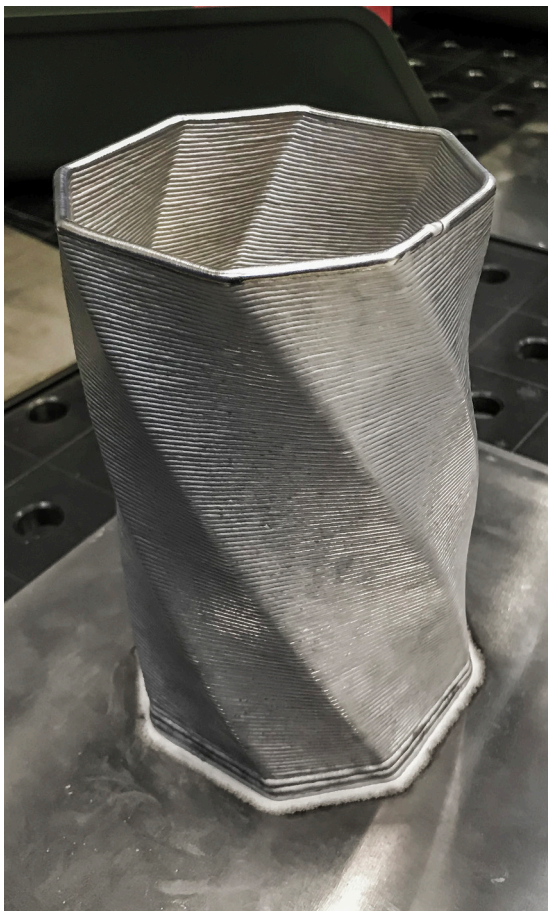
### For Demanding Industries, e.g.

- » Mechanical Engineering & Machinery
- » Oil & Gas Upstream and Offshore
- » Chemical Industry
- » Power generation
- » Aerospace

# BEST QUALITY WIRE ALLOYS FOR A REVOLUTIONARY TECHNOLOGY

**With the manufacturing of wires which are tailor-made to its specific purpose, voestalpine Böhler Welding is creating the basis for innovative Wire Arc Additive Manufacturing. The metallurgical and application know-how of its materials specialists makes the company a central element in this technological revolution.**

Wire alloys are the material basis for the revolutionary game-changing process. They may be made from low- and medium alloyed steel, aluminum, nickel, or titanium alloys. The wire alloys used determine the properties of the final printed component. Their production is therefore the focus of increasing attention – especially that of the materials and process specialists at voestalpine Böhler Welding. For example, application of wire alloys in Wire Arc Additive Manufacturing requires constant chemical composition within well-defined tolerances and excellent surfaces enabling good feeding properties.



## Quality manufactured in Europe

With its production facilities for solid wire in Hamm, Germany, and for seamless cored wires in Kapfenberg, Austria, and Cittadella, Italy the company is equipped with the latest state-of-the-art and future manufacturing technologies for the production of wire alloys for additive manufacturing. Well-equipped laboratories allow in-house analysis and characterization of new developed products and ensure the best in class quality.

## Cooperation for material and technology research

Together with its industrial and scientific partners, voestalpine Böhler Welding has initiated R&D programs to explore the application behavior of wire consumables in Wire Arc Additive Manufacturing. Results will allow to further optimize the wire consumables and to develop alloy compositions for the next generation 3D printing applications.



# PRODUCT PORTFOLIO

Product Name	C	Si	Mn	Cr	Mo	Ni	R <sub>p0.2</sub>	R <sub>m</sub>	A <sub>5</sub>	
3Dprint AM 35	0.1	0.3	1.05	–	–	–	> 355 MPa	470-630 MPa	> 22 %	Low alloyed steel
3Dprint AM 46	0.1	1	1.7	–	–	–	> 460 MPa	560-720 MPa	> 22 %	Low alloyed steel
3Dprint AM 50	0.1	0.65	1.4	–	–	1.35	> 500 MPa	560-720 MPa	> 18 %	Low alloyed steel
3Dprint AM 62	0.1	0.65	1.6	–	0.4	1.1	> 620 MPa	700-890 MPa	> 18 %	Medium alloyed steel
3Dprint AM 70	0.08	0.6	1.7	0.2	0.5	1.5	> 690 MPa	770-940 MPa	> 17 %	Medium alloyed steel
3Dprint AM 80 HD	0.09	0.4	1.7	0.35	0.6	2	820 MPa	920 MPa	20 %	Medium alloyed steel (typical mech. Properties after post heat treatment)
3Dprint AM P22	0.08	0.5	1	2.5	1	–	> 310 MPa	515-690 MPa	> 18 %	Medium alloyed steel (mech. Properties after post heat treatment)

Chemical composition in wt.-%

Product Name	C	Si	Mn	Cr	Mo	Ni	N	
3Dprint AM 2209	0.025	0.5	1.6	23	3	9	0.14	Duplex steel (no heat treatment)
3Dprint AM 2205	0.025	0.5	1.5	22	3	5	0.15	Duplex steel (with solution annealing heat treatment)

Chemical composition in wt.-%

Product Name	C	Si	Mn	Cr	Mo	Ni	Cu	Nb	
3Dprint AM 304L	0.02	0.5	1.7	20	–	10	–	–	Standard low carbon austenitic stainless steel
3Dprint AM 316L	0.02	0.5	1.7	18.5	2.6	12.3	–	–	Standard low carbon austenitic stainless steel with Molybdenum
3Dprint AM 17-4 PH	0.02	0.4	0.5	16.5	–	4.5	3.3	0.25	Martensitic precipitation-hardening stainless steel
3Dprint AM 15-5 PH	0.02	0.5	0.5	14.8	–	4.5	3.3	0.28	Martensitic precipitation-hardening stainless steel – free of ferrite (aerospace grade)
3Dprint AM 410 NiMo	0.01	0.65	0.7	13	0.5	4.7	–	–	Martensitic stainless steel
3Dprint AM 430	0.07	0.8	0.7	18	–	–	–	–	Ferritic stainless steel

Chemical composition in wt.-%

Product Name	C	Si	Cr	Mo	Nb	Fe	Ni	W	Al	Ti	
3Dprint AM 625	< 0.03	< 0.25	22	9	3.6	0.5	bal.	–	–	–	Nickel base alloy with chromium, molybdenum and niobium
3Dprint AM 718	0.03	< 0.1	17.5	3	5	bal.	53	–	0.5	1	Precipitation hardening nickel base alloy

Chemical composition in wt.-%

Product Name	Mg	Ni	Fe	C	N	O	H	V	Zr	Mn	Al	Cu	Ti	
3Dprint AM Al 2219	< 0.02	–	–	–	–	–	–	–	0.18	0.35	bal.	6.3	0.14	Aluminium alloy
3Dprint AM Cu 6328	–	4.5	3.5	–	–	–	–	–	–	1	9	bal.	–	Copper-Aluminium alloy
3Dprint AM Ti-5	–	–	< 0.15	< 0.05	< 0.03	0.18	< 0.01	4	–	–	6	–	bal.	High strenght titanium alloy

Chemical composition in wt.-%



## WHAT MAKES BÖHLER WELDING 3DPRINT WIRES DIFFERENT?

**Wires are specifically designed and manufactured for wire arc additive manufacturing, meaning that every production step is fine tuned to bring wire feedability and arc stability at its best:**

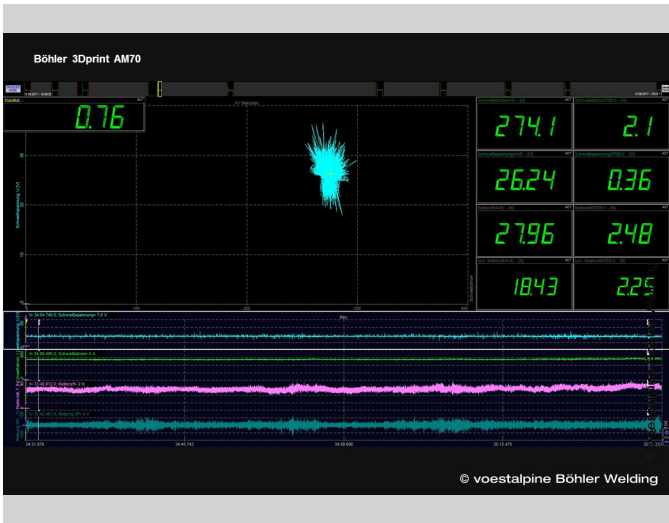
- » Drawing process is more accurate providing the best surface finishing.
- » Feedability is enhanced also thanks to specific coating.
- » Wires wounding of spools and drums is controlled within restricted tolerances.
- » Endurance testing protocols with the related acceptance criteria have been settled in order to prove a high level of arc stability and feedability measuring in real-time all the electrical parameters involved and the wire resistance at the wire feeder.



## 3Dprint wires chemical analysis is fine-tuned for Wire Arc Additive Manufacturing

About metallurgical aspects, productivity leads to the use of high heat input and low cooling rate due to the subsequent layers deposition technique, hence physical and mechanical properties of the deposit has to be soundness also in such conditions; additionally it has to be tolerant to take multiple hardening/tempering cycles by multiple layers and afford heat treatment when and if necessary.

Wire chemistry is also influencing the arc stability, the molten material fluidity as well as the silicate islands formation over the bead, which might be detrimental for the deposition of the subsequent layer. Level of impurities and Silicon is of course very important to keep this issue under control.



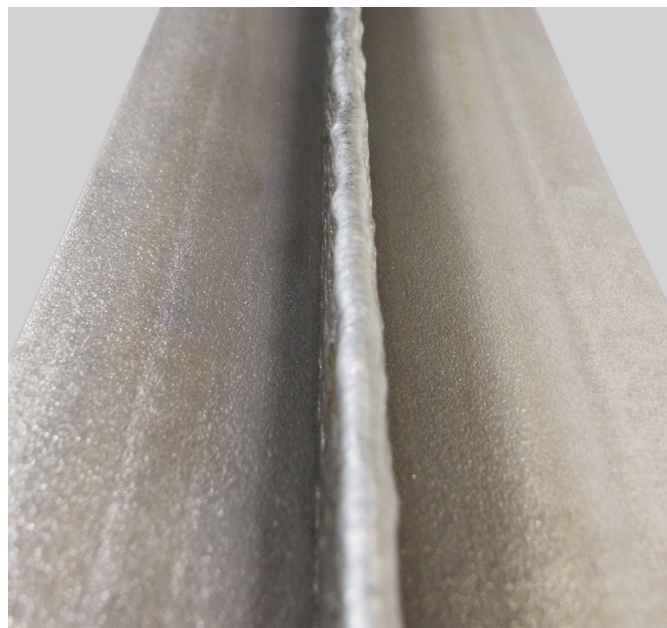
U[V]/I[A] integral plot over time (blue star in the middle) of stable process which shows only minor deviations

## Summarized benefits of Böhler Welding 3Dprint wires

Metallurgical benefits	Process benefits	
» Made for low cooling rates and high heat input	» High process stability for Robotic MIG or other mechanised processes	
» Accepts multiple hardening/tempering cycles by multiple layers	» Drum and spool weights can widely be adopted to the weight of parts	
» Optimised for post print heat treatment	» Extended quality control to ensure consistent arc and feeding behavior	
» Tailor-made metallurgy for complex materials	» Optimised surface technology for long arc cycles, Liners stay clean, contact tips last longer	

# EXCELLENT PROPERTIES OF THE PRINTED METAL

A fine-tuned printing process together with the described benefits lead structures made with Böhler Welding 3Dprint wires to meet demanding industries requirements.



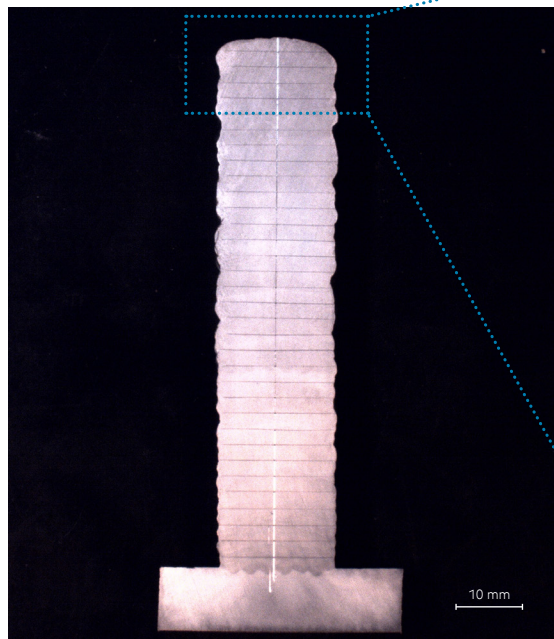
Wall made with wire 3Dprint AM 80HD for properties characterization

## PRINTED METAL CHARACTERIZATION

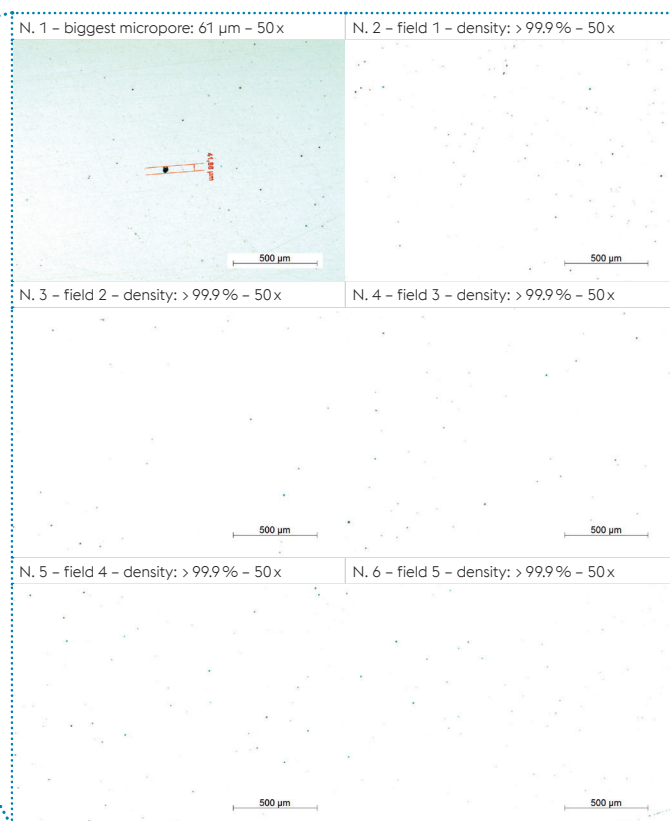
As far as materials properties are concerned, voestalpine Böhler Welding is deeply involved in testing wires in wire arc additive manufacturing conditions, remarking analogies and differences with the conventional technologies as well as the welding conditions.

### Material Integrity

In this regard, microporosity assessment demonstrates that wire arc additive manufacturing using 3Dprint wires can provide an integrity level often comparable to forging and better than casting.



Determination of density by micrographic examination (estimation of porosity) on a 24 mm printed metal wall of 3Dprint AM46 wire. The analysis showed a material integrity above 99.9 %. Biggest micropore: 42 µm





## Testing of printed metal in Wire Arc Additive Manufacturing Conditions

voestalpine Böhler Welding is investigating specific geometry walls and blocks to reproduce the typical cooling rates of Wire Arc Additive Manufacturing, extracting specimen for tensile, impact energy, bending and any other relevant test depending upon the specific alloy.

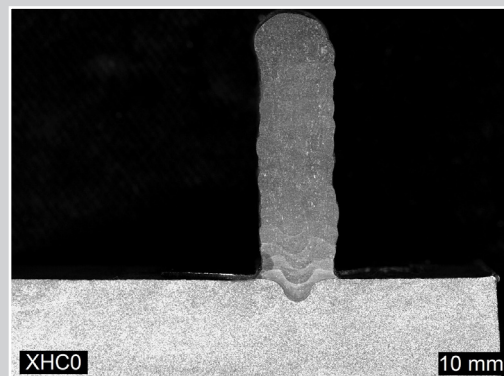
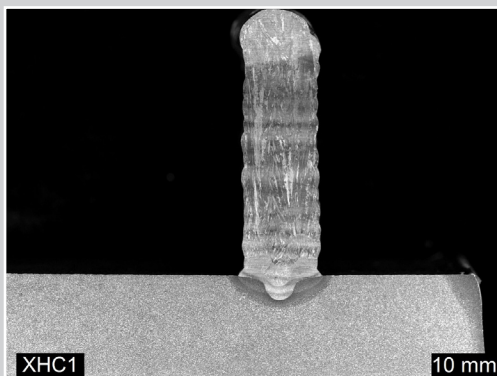


Printed coupon and destructive tests on precipitation hardening martensitic stainless steel 3Dprint AM 17-4 PH deposit

## PRINTING OF CHALLENGING MATERIALS

Böhler 3Dprint product portfolio includes a wide range of high technology sophisticated alloys. An adequate knowledge of these materials behavior when printing is a precondition to achieve high level results.

voestalpine Böhler Welding makes available wire arc additive manufacturing experts and application engineers to support customers whenever it is needed.



Macro of precipitation hardening martensitic stainless steel 3Dprint AM 17-4 PH deposit as printed and after heat treatment





# JOIN! voestalpine Böhler Welding

With over 100 years of experience, voestalpine Böhler Welding is the global top address for the daily challenges in the areas of joint welding, repair, hardfacing and cladding as well as brazing. Customer proximity is guaranteed by more than 40 subsidiaries in 25 countries, with the support of 2,200 employees, and through more than 1,000 distribution partners worldwide. With individual consultation by our application technicians and welding engineers, we make sure that our customers master the most demanding welding challenges. voestalpine Böhler Welding offers three specialized and dedicated brands to cater our customers' and partners' requirements.



**Lasting Connections** – As a pioneer in innovative welding consumables, Böhler Welding offers a unique product portfolio for joint welding worldwide. More than 2000 products are adapted continuously to the current industry specifications and customer requirements, certified by well-respected institutes and thus approved for the most demanding welding applications. As a reliable partner for customers, “lasting connections” are the brand's philosophy in terms of both welding and people.



**Tailor-Made Protectivity™** – UTP Maintenance ensures an optimum combination of protection and productivity with innovative and tailor-made solutions. Everything revolves around the customer and their individual requirements. That is expressed in the central performance promise: Tailor-Made Protectivity™.



**In-Depth Know-How** – As a leading brand of soldering and brazing consumables, Fontargen Brazing offers proven solutions based on 50 years of industrial experience, tried and tested processes and methods. This In-Depth Know-How has made Fontargen Brazing an internationally preferred partner for every soldering and brazing task.

The Management System of voestalpine Böhler Welding Group GmbH, Peter-Mueller-Strasse 14-14a, 40469 Duesseldorf, Germany has been approved by Lloyd's Register Quality Assurance to: ISO 9001:2015, ISO 14001:2015, OHSAS 18001:2007, applicable to: Development, Manufacturing and Supply of Welding and Brazing Consumables. More information: [www.voestalpine.com/welding](http://www.voestalpine.com/welding)



