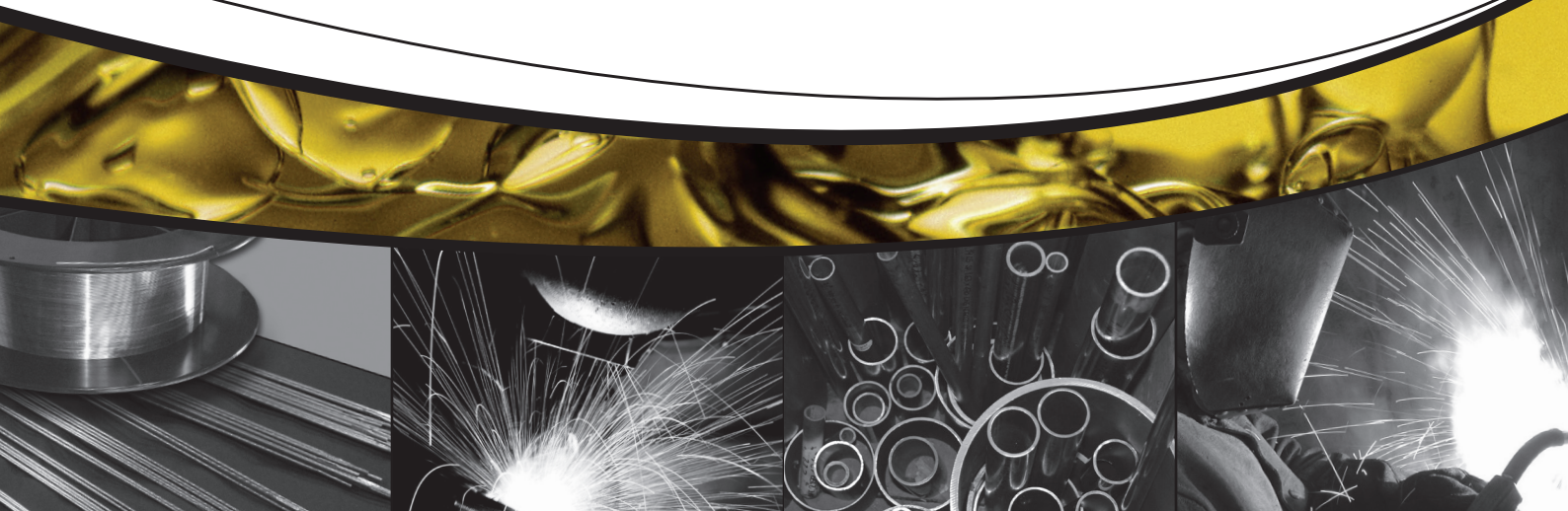




ZERON 100[®] Fabrication

ZERON 100 was the first of the super duplex stainless steels. Its unique chemical composition has been shown to be correctly balanced to offer the best combination of corrosion resistance and strength. The steel is tightly controlled from melting through manufacture to ensure better and consistent performance than the same generic grade.



The Global Leader in Specialty Metals

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ZERON® 100 is a super duplex stainless steel for use in aggressive environments. ZERON 100 offers strength levels exceeding that of standard duplex grades like 2205. ZERON 100 is resistant to corrosion in a wide range of organic and inorganic acids. The copper content gives excellent resistance to corrosion in many non-oxidizing acids. This alloy is also resistant to strong alkalis. ZERON 100 is not recommended for uses which involve extended exposure to temperatures greater than 600°F as this causes a substantial reduction in toughness. ZERON 100 is welded using ZERON 100X filler metal.

ZERON 100X grade welding consumable is overalloyed with nickel and is intended for joints that are to be put into service in the as-welded condition. ER 2594 (AWS A5.9), E 2594-15 (AWS A5.4)

Autogenous welding of square close butt preparations can only be used under specific circumstances and its use needs to be considered on a case by case basis. Advice on specific situations can be supplied on request. ASME Section IX F Numbers, ZERON 100X wire (F #6), ZERON 100X electrodes (F #5)

Specifications

UNS: S32760 **W. Nr./EN:** 1.4501 **EN:** 10028-7, 10088-2, 10088-3, 10272, 10216-5, 10217-7
ASTM: A 182 (Grade F55), A 240, A 276, A 314, A 473, A 479, A 789, A 790, A 815, A 890, A 928, A 988, A 995
ASME: B16.5, B16.34, B16.47, B31.3, Section VIII Division 1 Case 2244-2, 2245-1, Section III Division 1 Case N-564-2, SA-240, SA-182 (Grade F55), SA-479, SA-815, SA-789, SA-790 **NACE:** ISO 15156 / MRO175 Part 3 **API:** 5LC **BSI:** PD 5500 - Enquiry Case 5500/87 **AWS:** 5.9 **AWS CLASSIFICATION:** ER2594

Chemical Composition, %

	Ni	Cr	Mo	Mn	Cu	Si	C	N	S	P	W	Fe
MIN	6.0	24.0	3.0	—	0.5	—	—	0.2	—	—	0.5	—
MAX	8.0	26.0	4.0	1.0	1.0	1.0	0.03	0.3	0.01	0.03	1.0	balance

Features

- Guaranteed corrosion performance ($PRE_N = \%Cr + 3.3\%Mo + 16\%N \geq 40$)
- Provides excellent resistance to chloride pitting and crevice corrosion
- Excellent resistance to sulfuric acid
- Excellent resistance to stress corrosion cracking in both chloride and sour environments
- High resistance to erosion corrosion and corrosion fatigue
- Excellent mechanical properties and good weldability

Applications

- Subsea manifolds and pipe work
- Umbilical tubing
- Slickline
- Flue gas desulfurization equipment
- Reverse osmosis desalination equipment
- Sulfuric acid plants
- Marine fasteners

Successful Welding Tips

Successful welding begins with implementing good practices. The main points to be remembered are:

- Use good stainless steel fabrication practice
- Use a consistent joint fit up as detailed in the qualified WPS
- Control the backing gas composition and flow rate
- Choose the correct arc energy relative to the joint thickness
- Control the arc energy during production welding of the qualified WPS
- Ensure consistent and maximum filler wire additions are made
- Monitor / control the interpass temperatures and ensure that the maximum temperature quoted in qualified WPS is not exceeded
- Utilize stringer bead techniques with minimal weaving (maximum 3x wire diameter)

Welding Equipment

There are no specific welding equipment requirements associated with ZERON 100 over and above good stainless steel welding practice.

As with sophisticated stainless steel welding, slope in/out facilitates together with pre and post gas purge are important requirements for GTAW welding. Equipment with pulsed arc capabilities is considered beneficial for GTAW and GMAW welding of ZERON 100 due to optimal control of arc energy.

Welding Consumables

Handling and Storage

Welding consumables for ZERON 100 should be handled and stored in accordance with the manufacturer's recommendations. In general, the consumables should be stored in an "electrode store" held at approximately 50°F above ambient temperature and with a relative humidity below 60%. Opened packs of electrodes and flux should be baked in accordance with the manufacturer's recommendations.

Preheat

Welding Procedure

Preheat is normally not required. It should only be applied where material is not dry or is below 41°F prior to welding. Also in highly restrained heavy constructions or in particularly thick fabrications, preheating up to 212°F has been shown to be beneficial. Oxyfuel or carburizing flames should not impinge directly onto the material. Hot spots should be avoided.

Welding Procedure Specs

Welding Procedure

ASME Section IX assigns ZERON 100 (UNS S32760) to P #10H, group 1.

Joint Preparation Welding Procedure

Welding bevels should be prepared by cold methods. Where plasma cutting is used, the process should be under water and at least 0.04" of material should be ground off to remove the heat affected zone. The recommended root gaps, root faces and joint angle are based on the need to:

- Maximize production
- Minimize parent metal dilution in the root
- Control the heat input

For this reason, control of the root gap is considered an important factor. Compound bevels must be balanced to ensure access while minimizing joint volume.

Joint Cleanliness Welding Procedure

Joint faces and pipe/vessel surfaces 2" either side of joint seam should be cleaned and degreased using a suitable solvent and a lint free cloth. Abrasive cleaning is rarely necessary. Should mechanical cleaning be necessary, light grinding or grit (alumina) blasting may be used.

Joint Fill-up Welding Procedure

Line up clamps can be used to assist joint fit up. The clamp may be either internal or external. Excessive mismatch of abutting joint edges "Hi-Lo" should be avoided in order to ensure a satisfactory final root underbead profile and weld quality. Counterboring of tubular components can be carried out to achieve the required fit up alignment. Care must be taken to avoid reducing the wall thickness excessively and to taper in the counterbore in accordance with the specification.

Joint fit up, and plate pre-setting, must be related to the normal distortion control techniques including balanced welding and back step welding.

Arc Energy Welding Procedure

Arc energy is the common parameter controlled during the welding process. However, when welding duplex/super duplex it is the cooling rate which controls the microstructure and so the arc energy should be controlled in conjunction with the joint thickness.

It is more effective in the control of optimum arc energy to maintain faster welding travel speeds and associated higher welding currents rather than lower welding current and slower travel speeds.

To ensure a consistent arc energy, weaving of the weld bead should be kept to a minimum with a maximum of 3x filler wire diameter.

Interpass Temperatures Welding Procedure

The interpass temperature, together with welding arc energy, is important in optimizing the cooling rate of a joint. Excessively high interpass temperature or arc energy may impair the corrosion resistance and impact toughness of the joint. The interpass temperature and welding arc energy must always be balanced in order to optimize the properties of the joint. If, for example, the arc energy cannot be maintained in the appropriate range, it would be necessary to reduce the interpass temperature. The maximum interpass temperature should be consistent with appropriate WPS and certainly less than 300°F.

The interpass temperature is measured immediately prior to any welding directly at the points where a weld run is to commence and where it is supposed to terminate. A contact thermocouple should be used. The weld zone must be below the interpass temperature before restarting welding. The interpass temperature must be measured at each break in welding and not just when starting a new pass.

Shielding & Backing Gases
Welding Procedure

When welding ZERON 100, it is recommended that commercial purity argon is used to displace the air behind the joint. The oxygen content of the resulting argon/air mixture must be monitored and controlled to ensure that sufficient nitrogen is retained in the backing gas "mixture" in order to inhibit loss of nitrogen from the weld pool. In practice the oxygen level of this mixture should be controlled at approximately 0.5% oxygen, monitored at the start of the welding sequence. In this way, a positive partial pressure of nitrogen is maintained behind the joint thus preventing nitrogen loss from the root bead, while the oxidation produced remains acceptable. Passes subsequent to the root pass can be made with minimum oxygen contents.

An alternative method of maintaining the nitrogen content of the root is to use argon + 2% nitrogen as the shielding gas. This is only necessary on the root pass and pure argon may be used for the fill passes. Argon or argon + 2% nitrogen may be used as the backing gas.

Parent Metal	Filler Material	Gas Shield	ASTM G48 (Method A) Test Temperature, °F				
			86	95	104	113	122
25% Cr Super Duplex (S32760)	ZERON 100X	Pure Ar					
25% Cr Super Duplex (S32760)	ZERON 100X	Ar + 2% N ₂					

The backing gas composition should be monitored at the joint line using a portable oxygen monitor immediately prior to starting or re-starting welding in order that consistency can be maintained. Adhesive tape low in sulfur and chloride is used around the open joint seam, and the tape should be removed progressively during the welding sequence.

Care should be taken to regulate the flow rate of the back purge gas to prevent gas turbulence and possible air entrainment through the open weld seam. The flow rate of the backing gas is typically 20-30 ft³/hr although it is necessary to reduce flow rate at the tie-in location to avoid the risk of expulsion of molten metal and root underbead concavity.

Root Pass
Welding Procedure

The GTAW process is normally specified to enhance control of root bead quality. While fabricator choice and the practices used in a particular shop are very important, it is generally found that:

- 1/16" or 5/64" diameter filler wire is often used for material up to 0.16" thick.
- 3/32" or 1/8" diameter filler wire is generally used for other material thicknesses.
- Keyhole rooting practice is considered to be a preferred technique to obtain the optimum properties within the arc energy restraints in the root pass.

Welder preference can be considered but it should be recognized that it is beneficial to deposit larger bead thicknesses within the arc energy restrictions.

Welding arc energy (heat input) must be controlled to avoid adversely slow weld cooling rates developing during welding cycles.

Arc Energy Equations

*Arc Energy	
$\frac{\text{Amps} \times \text{Volts} \times 60}{\text{Travel Speed (in/min)} \times 1000} \text{ kJ/in}$	(or) $\frac{\text{Amps} \times \text{Volts} \times \text{Arc time(s)}}{\text{Run Out Length (in)} \times 1000} \text{ kJ/in}$

Root Arc Energy and Layer Thickness

It should be considered that one important variable that is not commonly controlled during manual GTAW welding is filler metal addition. The typical root pass thickness indicated in the table below is based on:

- Welding into the controlled root gaps specified in the diagrams on the following page.
- Addition of maximum & consistent levels of filler metal into the weld pool to promote optimum cooling rates.

An excessively thick root pass is generally associated with too high an arc energy, whereas too thin a root pass is likely to result in burn through by the second pass. Root beads that are either too thick or too thin do, of course, result in practical welding problems and are likely to result in poor penetration bead profile.

Wall Thickness, in	0.113	0.28	0.70
Arc Energy, kJ/in	10-15	20-30	38-46
Typical Pass Thickness, in	0.08	0.12-0.14	0.12-0.14

The root pass thicknesses shown are typical for the thickness being welded at the appropriate arc energy.

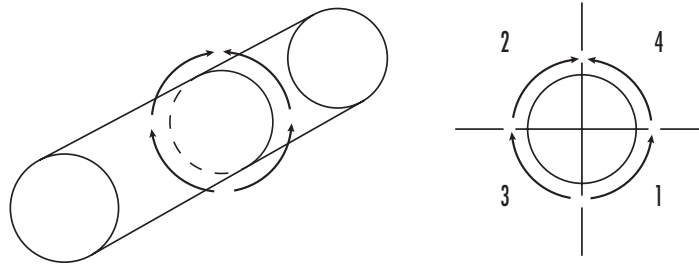
It may be considered advisable to deposit weld beads as a series of balanced segments, for example such as shown in the Balanced Joint Sequences, as this offers the advantage of:

- Controlling joint gap closure
- Reducing overall joint distortion
- Maximizing production while maintaining interpass temperature requirements.

Balanced Joint Sequences

The stop and start regions of all weld beads should be taper ground to facilitate smooth tie in. In GTAW welding industrial grade argon (99.995%) is recommended as shielding gas at typical flow rates of 17-25 ft³/hr.

Nozzles incorporating a gas lens ensure good gas coverage and effective weld protection with the avoidance of gas turbulence where extended tungsten electrode stick out is being applied. Slope down techniques at the termination of a weld to control phase balance should be used.



Second Layer 'Cold Pass'

The root weld bead upper surface should, if necessary, be dressed smooth and stainless steel wire brushed. However, grinding is rarely required.

As a general guide the second "cold" pass is deposited at a lower arc energy than that of the root pass. GTAW welding is normally used. Interpass temperature control as detailed previously must be maintained. It may be necessary to manipulate the weld pool in order to ensure that the pool is "washed in". This can be achieved by "flicking" the weld pool up onto the side wall. Weaving must be minimized. Single bead or split layer welding techniques can be used within arc energy and joint configuration requirements.

A single bead "cold pass" is preferred. The Variations in Welding section on the following page illustrates the effect of different root pass and 2nd "cold" pass arc energy combinations.

Welding

Argon back purging of single sided welds should be maintained throughout the welding of pipe and plate with weld deposit thicknesses up to 0.5", to avoid progressive root underbead oxidation through reheating. The back purging of double sided welds can be stopped earlier. Balanced weld sequences should be maintained for the initial 0.2" of joint thickness. Control of interpass temperature and arc energy should be maintained throughout the welding of the whole joint.

Variations in Welding GTAW root & second pass; Cold Pass Technique

Root Pass:	GOOD	GOOD
BAD: arc energy too high		
2nd Run:	BAD: arc energy too high	GOOD
GOOD		
Overall Results:	BAD: reheated root poor corrosion resistance	GOOD: optimum corrosion resistance
BAD: overheated root poor corrosion resistance		

Manual Welding

The joints detailed below are for single sided manual welding with the GTAW or GMAW-STT process in the root. Other joints, for example two sided, are similar to those applied in general stainless steel practice.

Single Bevel

Manual Welding

Wall Thickness (t), in	0.08-0.12	>0.16	
Included Angle (a), °	70-90	70-80	
Root Gap (g), in	0.08-0.12	0.08-0.12	
Root Face (f), in	0.02-0.06	0.02-0.06	

Compound Bevel

Manual Welding

Wall Thickness (t), in	0.8	
Included Angle (a), °	70-80	
Included Angle (B), °	15-20	
Root Gap (g), in	0.08-0.12	
Root Face (f), in	0.02-0.06	

"J" Preparation

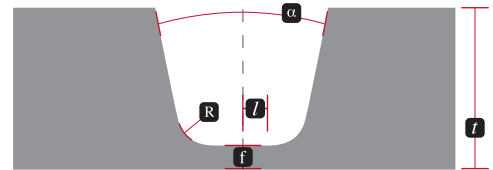
Manual Welding

Wall Thickness (t), in	0.8	
Included Angle (a), °	15-30	
Radius (R), in	0.16-0.24	
Root Gap (g), in	0.08-0.12	
Root Face (f), in	0.02-0.06	

Automated Welding

For automated GTAW welding a closed butt (zero root gap) may be used. The joint is designed to maximise the filler addition to the root bead and to achieve adequate root bead thickness. Care must be taken to ensure that there is sufficient filler metal addition.

Included Angle (α), °	20-25
Radius (R), in	0.12
Land (l), in	0.04
Face (f), in	0.06



SMAW

Shielded Metal Arc Welding

ZERON 100 requires correct electrode handling procedures, in particular, protection against moisture pick-up. Electrodes should be used directly from unopened containers, vacuum pack containers or from a 300°F minimum temperature storage oven.

Electrodes should be issued and stored on the job in heated quivers in quantities suitable for 4 to 5 hours production or consumed within 8 to 10 hours of removal from vacuum packaging. In all cases the manufacturers' recommendations for the particular type of flux coating should be followed.

Welding techniques are based on electrode manipulation avoiding distinct weaving and associated high arc energy. Arc strikes should be avoided. Electrodes should be operated within the amperage range recommended by the manufacturers.

Electrode Diameter, in	Current Range, DC + (A)
0.10	50-65
1/8	70-90
5/32	100-140

GMAW

Gas Metal Arc Welding

Both 0.039" and 0.047" diameter wires are available for welding. Multipass weld layers employing minimum weave and controlled arc energy are advocated for joint filling. Argon/helium (CO₂) gas mixtures have been successfully used for welding.

100% Ar OR Ar + 35% He + 2% Co₂

Position	Wire Diameter, in	Current, Amp	Arc Voltage, Volt	Travel Speed, in/min	Arc Energy, kJ/in	Gas Flow, ft ³ /hr
1G	0.047	220-240	30-32	10-16	25-38	42
5G/6G	0.039	80-95	30-32	8-12	15-20	42

Welding practice should aim to combine the productivity benefits of the process with maintenance of arc energy control.

GTAW

Gas Tungsten Arc Welding

For small diameter tubes and pipes TIG is often used for filling the joint, but TIG process can also be used for filling thicker wall pipes. The TIG process has the advantage of producing high quality weld metal and there is no slag to be removed. The productivity of the TIG process can be improved by using 1/8" diameter wire.

Commercial purity Argon (99.995%) should be used as the shielding gas or possibly Argon-Helium mixtures if preferred; gases containing hydrogen should not be used. As mentioned earlier, for root runs in ZERON 100 corrosion performance can be improved by using an Argon shielding gas containing 2% Nitrogen.

Run	Process	Consumable	Diameter, in	Current, Amp	Voltage, Volt	Travel Speed, in/min	Current, Polarity	Heat Input, kJ/in
1	TIG	ZERON 100 X	3/32	80-100	~12	~50	DC-	~1.2
2	TIG	ZERON 100 X	3/32	90-130	~12	~125	DC-	~0.8
Fill	TIG	ZERON 100 X	1/8	200-225	~12	100-175	DC-	~1.5

SAW

Submerged Arc Welding

Combines fast deposition of high quality weld metal with mechanized process productivity, is a very viable alternative for joint filling with:

- Material thickness in excess of 0.6" - 0.8"
- Pipe or vessel diameters in excess of 6"
- Circumferential or longitudinal seams can be welded in the downhand (ASME: 1G) position.

The welding procedure with ZERON 100 is similar to that with standard austenitic stainless steels (316/316L etc) although in order to maintain requisite arc energy/weld cooling rate control, use of smaller diameter wires (e.g. $\frac{3}{32}$ ") and modest welding parameters is recommended. The comparatively fast travel speed and low arc energy conditions facilitate the benefits of continuous (e.g. full circumferential) welding and a reduced level of interruptions associated with interpass temperature control.

Control of weld bead shape is very important. The depth to width ratio must be less than 1.0, which requires careful control of arc voltage, to avoid risk of centerline solidification cracking. Avoid too thick a bead per layer. The process is normally introduced to fill out joints following deposition of 0.3"-0.4" of GTAW and SMAW root weld layers. An interpass temperature of 300°F maximum throughout the joint is recommended.

The flux used must be maintained in a reliable dry condition i.e., either directly from new, unopened bags/drums or storage ovens operating at 480°F. Unfused flux recovered from the weld should be sieved and rebaked before further use.

With the agglomerated fluxes involved, repeated recycling will lead to excessive build-up of fines and a shift in flux grain size balance, ultimately causing a deterioration in operating characteristics. To counter this effect, recycled flux should be diluted with new unused flux in a 1:1 ratio.

The recommended 1.0-1.2" deep flux pile is intended to prevent arc flaring through the flux cover, leading to loss of arc/weld pool stability, possible entrapment of air into the arc cavity, potential risk of weld surface "gas flats" and, at worst, internal porosity. Above 1.2", flux pile depth will tend to inhibit release of gases generated during welding.

With regard to electrode extensions, "stick-out" of less than $\frac{3}{4}$ ", will cause resistive heating effects and metal droplet detachment may become unstable, resulting in weld bead wander "slalom effect".

Wire Diameter, in	Welding Current DC+, Amp	Arc Voltage, Volt	Travel Speed, in/min	Arc Energy, kJ/in	Electrode Extension, in	Flux Height, in
$\frac{3}{32}$	280-350	28-30	18-20	23-30	0.75-1.0	1.0-1.2

Tack Welding

Bridge tacks or spacer "bullet" blocks are recommended to maintain the root gap and joint alignment. Plate joints must be pre-set as normal to counteract distortion. All spacer blocks are to be stainless steel and they should be tacked at a controlled heat input in accordance with the WPS.

Where tack welds are intended to form an integral part of the weld root bead, the root tack welds should be deposited in accordance with the approved WPS and the ends should be taper ground to ensure fusion with subsequent weld runs. Back purging should be employed when GTAW is used to deposit integral tacks.

The tack welds should be balanced around the joint in order to maintain the root gap and joint alignment.



1. Root Tack



3. Bullet Tack



2. Bridge Tack



4. Bullet Tack

Repair welding

ZERON 100 has excellent welding properties and consequently gives a low repair rate even when extensive NDE is applied on completed welds. If repairs are required then it is easier and preferable to cut out and completely reweld all small diameter thin wall welds (Typically <4" diameter and <1/8" wall thickness) rather than repair. When repairs are required on larger diameter, thicker welds then these should be carried out in accordance with a qualified weld repair procedure. It is essential on repair welds that the procedures are designed to prevent excessive heating of the previous weld zone especially where a thin ligament remains after any cut out.

Dissimilar Welding

Each dissimilar combination has to be assessed on its own merit but some general recommendations can be made for a number of commonly encountered combinations.

	ZERON 100	2205	Nickel Alloys	Austenitic Stainless Steel	Mild and Low Steel
ZERON 100	ZERON 100X	2209 ¹	686 CPT	309Mo ¹	309L, 309Mo ¹

¹ - If there are only a limited number of dissimilar joints the ZERON 100X consumables could be used to simplify the weld procedures and consumable control.

Post Weld Cleaning

Care should be taken to ensure that all flux or light spatter is removed from the weld zone. Careful light grinding may be used in conjunction with wire brushing. Avoid the use of power wire brushes at the corrosion side so as not to smear the weld zone, which has been shown to reduce corrosion resistance

Pickling

Pickling of the local weld area has been found to significantly improve corrosion resistance of the weld zone. Specific pickling pastes are available for super duplex stainless steels and give excellent improvements in properties when used in line with the manufacturer's recommendations.

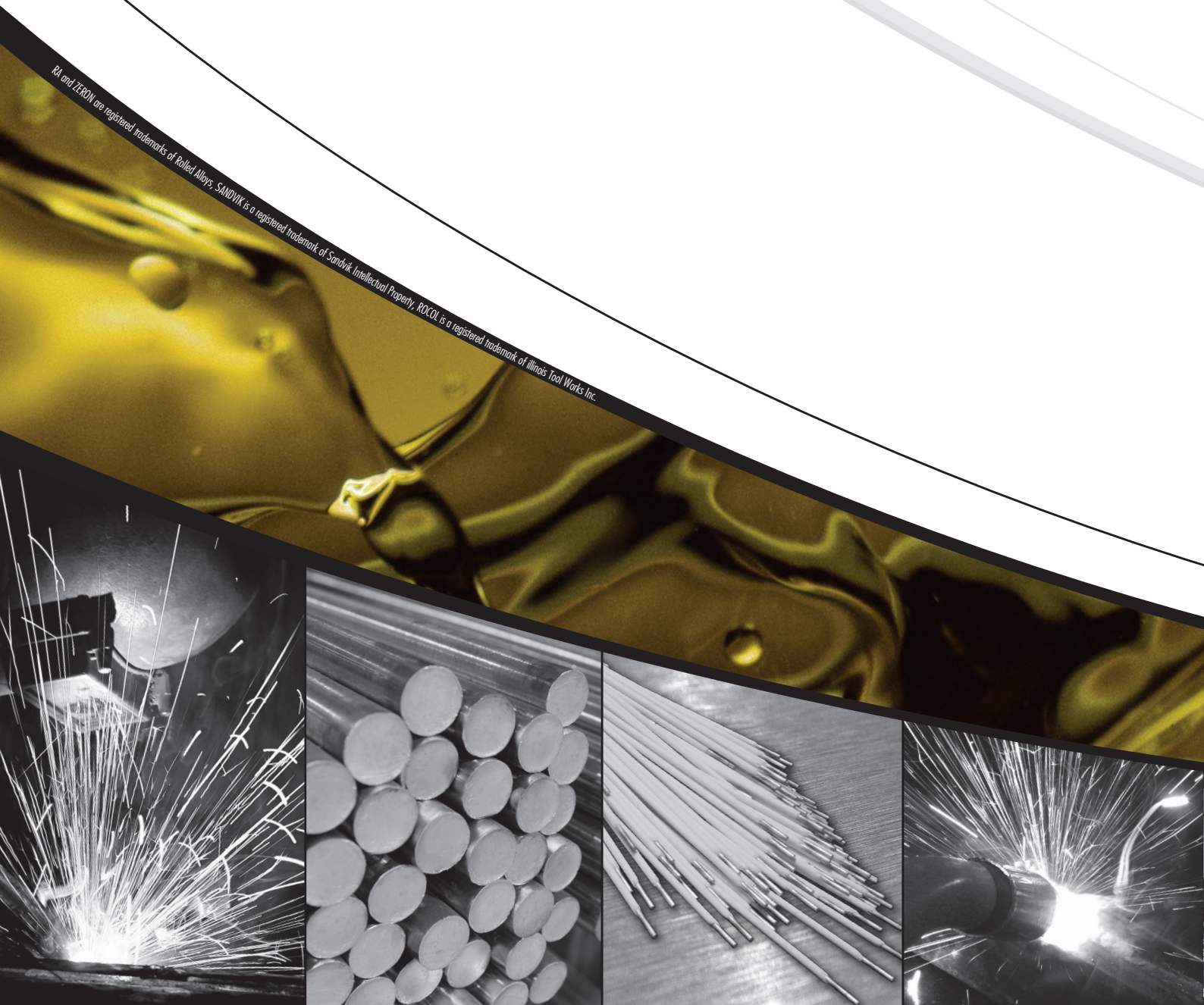
Machining

Operation	Cutting Speed, ft/min	Feed Rate	Depth of Cut, in	Tool Details	Coolant/Lubricant	Comments
Turning (Rough)	98.4-213.2	0.0138-0.0236 in/rev	0.118-0.197	Carbide grade ISO P45 SANDVIK® GC 2035 MR Geometry	Flood	SANDVIK CT 525 may also be used on bright bar or finishing: MR or QM Geometry
Turning (Finish)	278.9-295.3	0.00787-0.01574 in/rev	0.0197	Carbide Grade ISO P45 P25 SANDVIK GC 2035 or CT 525 MR or QM geometry	Flood	SANDVIK CT 525 may also be used on bright bar or finishing: MR or QM Geometry
Milling (Rough)	52.5-164.0	0.00787-0.01574 in/rev	0.236	ISO Grade P45 SANDVIK GC 235 or 4040 245 45° Approach	ROCOL® RTD metal working compound/liquid	SANDVIK T-Max 45° cutters have given superior tool life and performance
Face Milling (Finish)	229.7	min 0.059 in per tooth	0.00984	ISO Grade P45 SANDVIK GC 235 or 4040	ROCOL RTD metal working compound/liquid	SANDVIK Modumills 45° and 75° may be used
H.S.S. Drilling	16.4-29.5	approx 2/3 of rate used for standard sustenitic S.S	—	H.S. steel Point angle: 118° Chisel angle: 120°	ROCOL RTD metal working compound/liquid	SANDVIK U drills have proven very successful
SECO Drilling	196.8-328.1	0.00118-0.00472 in/rev	—	—	—	—
Tapping (Small Sizes)	—	—	—	H.S. steel straight flute hand taps	—	—
Tapping (Large Sizes)	—	—	—	—	ROCOL RTD metal working compound/liquid	Most successful but expensive are "Innespan" Machine Taps (typically 32 rpm for 2" Tap). Less preferred but cheaper choice: standard spiral flute taps.

NOTE (1) The above machining details are guidelines based on Rolled Alloys' experience and are intended only as a starting point. The precise details for any particular application will depend upon other factors such as component geometry and machine tool capacity and rigidity. NOTE (2) Where tight tolerances are required on the final product, it is suggested to make two passes as minimum, ie rough machine to approx. 2mm envelope on final size, stabilise for at least 12 hours at room temperature and then final machine to size.



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