SCS®

FABRICATION GUIDELINES

February 2008

PURPOSE OF THIS DOCUMENT

Flat-rolled steel treated with the SCS® process exhibits advantages over traditional surface finishing processes of pickle and oil (P&O), pickle dry, temper pass, cold-rolled, shot blast, and others. For users to capture the maximum SCS benefits in cost, quality and performance, they may, in some situations, wish to alter the settings or the consumables they normally use for particular fabrication processes such as welding, laser cutting, paint pre-treatment, etc.

Extensive testing and 'production shop' use of SCS has established process parameters, consumables and/or procedures for determining settings that work particularly well. The information has been compiled into this single document for the convenience of SCS users. It should be consulted any time:

(1) You wish to ***optimize**** the performance of your SCS-processed steel for a specific fabrication process covered by this document;

(2) SCS-processed steel ***does not perform acceptably**** when using the processing equipment manufacturer's recommended settings.

* *Note: It is recommended that the processing equipment settings be restored to the manufacturer's recommended settings as a starting point for SCS.*

Please note that every fabrication process is somewhat unique and the results obtained following these guidelines will vary. In many cases, you will not need to change process settings or consumables at all when switching between SCS-processed steel and another steel. However, in the event that you do not obtain acceptable performance from your SCS-processed steel, even after following the recommendations in these guidelines, you should contact your SCS supplier for assistance.

SCS users and licensed producers continue to independently test and optimize the performance of SCS-processed steel in fabrication processes. As new findings become available that supplement or improve upon the information in this document, those findings will be incorporated through updates. To make sure you are using the latest revision of this document consult the SCS web site at:

www.scsprocess.com

or contact your SCS supplier.

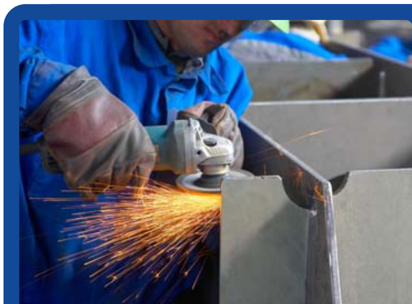
Note: The results contained in this document are true and accurate in describing the outcomes of any tests performed. You may wish to perform your own tests as an adjunct to those described herein. If attempting to replicate test results, be advised that outcomes may vary based upon substrate material properties, test conditions, duration, and sampling and measurement techniques.

INDEX OF SCS FABRICATION GUIDELINES

WELDING

PAINTING & PAINT PRE-TREATMENT

LASER AND PLASMA CUTTING



OTHER FABRICATION PROCESSES

Gas Arc Welding - GMAW and GTAW

Advisory Consultants

Optimum Engineering Solutions, Inc.
Barry Heure,
Chief Welding Engineer & Metallurgist

Illinois Manufacturing Extension Center
Steve Bosworth,
Certified Welding Inspector

OBJECTIVES

- Obtain uniform welds with minimum porosity.
- Minimize weld spatter.
- Use customary, easily obtained consumables.

EVALUATION PROCEDURE

SCS samples of thickness 0.079" and 0.101" were welded using common shielding gasses and filler wire/rod. No surface preparation was performed on the samples. Resulting welds were examined for uniformity, porosity and spatter and recommendations formulated.

RECOMMENDATIONS

GMAW (MIG) - Successful Parameters

- **Filler Wire: 0.035" ER70S-6**
- **Shielding Gas: Argon/ 3-5% Oxygen with flow rate of 25 - 30 CFH**
- **Wire Feed Speed and Voltages:**

400 in./min.	**24 volts**
430 in./min.	**24 volts**
460 in./min.	**25 volts**
500 in./min.	**26 volts**

The 95%Ar/5%O_2 gas achieves spray arc mode, which minimizes spatter and produces a very uniform bead, allowing for a decreased wire feed speed. To avoid porosity from the O_2 in the gas, the filler wire must have oxidizers. ER-70S-6 has high manganese content which serves this purpose.

Parameters To Avoid

- **Shielding Gas: Argon/ 10% CO_2**
  Argon/ 25% CO_2

Use of these shielding gasses resulted in a less stable arc and transfer in globular or short-arc mode. The resulting bead was less uniform with more spatter.

When wire feed speed was increased to 600 in./min. excessive spatter resulted, indicative of the wire being overdriven.

Finally, weld smoke was noticeable greater with these shielding gasses.

GTAW (TIG) - Successful Parameters

- **Filler Rod: 1/16" to 1/8" EWTh-2**
- **Shielding Gas: Argon with flow rate of 15 - 25 CFH based upon welding conditions**
- **Amperage: 50-150 based on metal thickness**
- **Voltage: 10-14 based on position/technique**

While MIG welding of carbon steels is preferable to TIG welding, SCS does TIG weld effectively because of its cleanliness. Areas to be welded must be free from moisture, oil and contaminants A filler rod MUST BE USED to avoid weld porosity. A stainless 308 rod will also produce a high quality weld.

Resistance Spot Welding

Advisory Consultants

Welding Engineering Associates, Inc.
Richard Dunbar,
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Unitrol Electronics
Weld Testing Laboratory

OBJECTIVES

- Evaluate SCS suitability for spot welding.
- Evaluate quality of SCS spot welds.
- Establish recommended settings for spot welding SCS.

EVALUATION PROCEDURE

SCS samples of 0.100" thick (12 gauge) of ASME specification SA-414-99 addenda GR-6 pressure vessel quality steel were resistance spot welded, varying selected parameters to evaluate its overall weldability and establish "starting parameters" expected to yield high quality welds. Surface electrical resistivity of SCS samples was measured and compared to hot rolled black (HRB) and hot rolled pickled and oiled (HRPO) material.

RECOMMENDATIONS

Parameter	Description	Starting Point for SCS
Electrode	Varies with specific application	RWMA Class 2 pointed nose electrodes - 5/8" diameter with 3/8" diameter face
Tip Force	Weld force required in psi	2000 psi +/-100 psi
Squeeze Time	The time value for bringing electrodes together capturing parts to be welded with intimate contact prior to electronically energizing the secondary weld current power	Weld machine dependent; open tip spacing varies with welder set up
Preheat	Percent of heat lower than weld heat	5500 amperes +/-200
Preheat Time	Time in cycles (Hz) for preheat	10 Hz
Upslope	Percent of heat lower than the weld percent to ramp of weld heat	Often used with coated materials. Not normally required for SCS or HRPO.
Upslope Time	Time period for ramp up	
Weld (Heat)	In percentage of weld transformer output at a given tap switch position *Note: if constant current feature is available this will be set in desired amperage value.*	12,000 amperes +/-300
Weld Time	Time of weld function	5-10 Hz
Weld Pulsation	Number of pulses	4 pulses (this weld pulse is at the 12,000 amp weld heat setting)
Pulsation Time	Time duration of pulse	10 Hz
Pulsation Cool	Off time between pulses	4 Hz
Downslope	Power ramp down	Often used with coated materials. Not normally required for SCS or HRPO.
Downslope Time	Time period for power ramp down	
Quench Time	Off time used with or in place of squeeze time for permitting the weld to cool prior to post heat	15 Hz
Post Heat	Percent of heat lower than the weld setting for annealing the weld and the heat affected zone	3100 amp +/-200
Post Heat Time	Time period for above sequence	30 Hz
Hold Time	Time applied at end of welding to assure full nugget solidification prior to releasing air pressure tip force and allowing the upper weld electrode to return to its neutral position.	5-10 Hz

Resistance Spot Welding (continued):

ELECTRICAL RESISTIVITY RESULTS

- SCS: 15 - 30 ohms
- HRPO: 15 - 30 ohms
- HRB: 10 - 100 ohms

Advisory Consultants

Welding Engineering Associates, Inc.
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Weld Testing Laboratory

Surface oxides resulting from contaminants (including oil and dirt) are non-conductive and are detrimental to the welding process. In the case of resistance spot welding, it requires additional electrical power to break through these surface contaminants and expel the refuse so as to prevent entrapment within the weld metal nugget.

The electrical resistivity results show that SCS processed material has no more resistance to spot welding than does HRPO and in fact has considerably less resistance than HRB.

Spot welding SCS-processed steel requires regular cleaning of the electrodes, but oxide pick-up when spot welding SCS is considerably less than HRB or HRPO (without cleaning, the SCS surface oxide will accumulate on the electrode faces causing misshaped weld nuggets). Electrode life when welding SCS is equivalent to life when welding HRPO.

General Rules for Making Good Spot Welds

1. Too short squeeze time can result in metal expulsion, overheating electrodes, bad welds, marked work.
2. Too long weld time will shorten electrodes life, cause excessive indentation at surfaces and cause internal cracks in the weld nugget.
3. A peel destructive test on test strips of the same material and combination is recommended.
4. Too short weld time will result in low weld strength, in proportion with weld heat.
5. Too short hold time can result in surface expulsion, electrodes sticking, and internal cracks in the weld nugget.
6. Weld pressure too low can result in expulsion of metal, electrode sticking, short electrode life, and possible internal cracks in the weld nugget.
7. Weld pressure too high can result in variable weld strength, excessive weld current requirements, mushrooming of electrodes, and excessive indentation.
8. With all other settings correct, adjust weld current to meet weld quality standards using recommended starting points.
9. Electrode contact face too small will result in too small a spot, excessive electrode mushrooming, and excessive indentation. Too large an electrode contact area will result in too large a weld (assuming current is set accordingly). Use RWMA charts for electrode manufacturer recommendations.
10. Electrodes misaligned/mis-matched will result in expulsion, and displaced weld nugget and excessive electrode wear.
11. Insufficient cooling will result in mushrooming and short electrode life. Adequate water cooling of the welding system is crucial.

"Rinse Only" Painting Preparation

Advisory Consultant

PPG Industries
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Pre-Treatment & Specialty Products

OBJECTIVES

- Evaluate SCS paint performance (corrosion resistance) using only a rinse pre-treatment without phosphate wash.
- Establish recommended rinse pre-treatment parameters.

BACKGROUND

Significant laboratory testing (salt spray exposure) and practical experience has shown that SCS-processed steel has the capability to meet/exceed specifications for corrosion resistance using a "rinse-only" treatment prior to painting. The reasons are:

(1) The SCS process imparts rust-inhibiting properties to hot-rolled black carbon steel, and;

(2) The SCS process leaves it with a clean surface which promotes good paint adherence.

These attributes allow SCS-processed hot rolled to withstand 300 hour continuous salt spray exposure with a creep rating of 10 (see test results on the following page).

The implication is that conversion coating pre-treatments, such as iron phosphating, are generally not necessary prior to painting SCS material; however, an iron phosphate stage is still advisable for parts that will be subject to severe weathering or exposure cycles when placed in service. SCS samples with an iron phosphate pretreatment have been shown to withstand salt pray test exposures of 500 hours with only 3 mm of creep.

RECOMMENDATIONS

Two-Stage Rinse	One-Stage Rinse
Using conventional spray or immersion pretreatment equipment: **1. The first rinse should contain a low-foaming surfactant at a concentration of one gallon of surfactant per 1000 gallons tank volume (0.1% solution) in a recirculating stage.** **2. Follow with a clean, overflowing water rinse.**	If conventional spray or immersion pretreatment equipment is NOT available, use a high-pressure rinse or rinse with brushes using: **a low-foaming surfactant at a concentration of one gallon of surfactant per 1000 gallons volume (0.1% solution).**

On very clean SCS, it may be feasible to perform only step #1, with a surfactant at a lower concentration: ***1 quart per 1000 gallons*** *(0.04% solution). This ensures the surface is clean from dirt and oils gathered during handling, and gives it a low surface tension so that the paint will 'wet out' evenly over the SCS material during the paint curing operation.*

THE IMPORTANCE OF PAINT QUALITY

These recommendations apply where the paint system will employ a high-quality paint offering reliable corrosion resistance. Examples are 2-part epoxy, 2-part urethane, or powder paint. Lower-performing paints, such as spray alkyds (commonly known as bake enamels) do not offer corrosion protection adequate for this preparation.

Paint systems are variable and it is strongly recommended that you perform tests to ascertain the corrosion resistance your paint system is capable of providing when using these "rinse-only" preparations with SCS material.

SCS Corrosion Resistance - Post Paint #5

OBJECTIVES

- Determine performance in salt spray tests of painted SCS samples pretreated with a single stage water rinse.
- Assess feasibility of reducing or eliminating iron phosphate wash stage for select applications.

APPLICABLE STANDARDS

ASTM B117-02
Practice for Operating Salt Spray Apparatus

ASTM D1654-92
Evaluation of Painted Specimens Subjected to Corrosive Environments

ASTM D3359
Measuring Adhesion by Tape Test

Testing Lab is A2LA Accredited

TEST PROCEDURE

Four (4) flat panels of hot-rolled were put through the SCS process. The panels were given a single-stage pretreatment consisting of a high pressure water rinse, then powder coat painted. The paint was a TGIC Polyester - a good quality, common paint system - applied to between 2 and 3 mils thickness.

After the paint had cured, samples were scribed with a thin 'razor' cut all the way through to the SCS surface. All samples were were placed in a salt spray fog chamber exposed to 5% NaCl mist operating between 93 and 95 ^{o}F. Samples were inspected at specified intervals to measure creep.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 06C-0044
Report dated January 6, 2006

The scribe marks through the paint expose the metal surface directly to the salt spray. This induces rusting and causes the paint to "creep" away from either side of the scribe mark under continued exposure. Creepage is measured as:

10 = 0 inch	6 = 1/16th to 1/8th inch
9 = 0 to 1/64th inch	5 = 1/8th to 3/16th inch
8 = 1/64th to 1/32nd inch	4 = 3/16th to 1/4th inch
7 = 1/32nd to 1/16th inch	3 = 1/4th to 3/8th inch

TEST RESULTS

Sample Number	Creepage from Scribe at increasing exposure					Results of Tape Pull Test conducted only at 384 hours exposure
	48 hrs	96 hrs	168 hrs	288 hrs	384 hrs	
1	10	10	10	10	3	removal of paint beyond scribe
2	10	10	10	10	3	removal of paint beyond scribe
3	10	10	10	10	3	removal of paint beyond scribe
4	10	10	10	10	4	removal of paint beyond scribe

CONCLUSIONS

All four samples maintained excellent corrosion resistance through the 288 hour inspection. Afterwards, corrosion set set in and accelerated to failure level over the next 100 hours.

In the prior Test #4, all SCS samples passed a 500 hour, 3mm creep test with a very lean two stage paint pretreatment consisting of iron phosphate and rinse. In Test #5 SCS samples passed 300 hours without the iron phosphate wash - the pretreatment consisted of just a rinse. To achieve comparable results, other material types must undergo various paint pretreatment stages such as cleaning and phosphating. In Test #5 SCS passed this tough corrosion test level while applying only a one stage water rinse pretreatment followed by a very common polyester paint..

SCS Laser Cutting Optimization

OBJECTIVES

- Validate faster laser cutting speeds for SCS.
- Establish procedure for optimizing laser speed with acceptable cut quality for SCS.
- Document 'Best Practices' and assist gas considerations.

Optimization Test Locations

Trumpf, Inc. North America
Farmington, CT Laser Center

Bystronic North America
Hauppage, NY Laser Laboratory

BACKGROUND

Tests of laser cutting SCS-processed steel have demonstrated higher cutting speeds than hot rolled black or HRPO of comparable thickness and hardness. These tests, conducted at both fabrication production shops and at development laboratories of laser cutting machine manufacturers (OEMs), have shown that "tuning" laser machine parameters is the key to achieving increases in cutting speeds for SCS-processed steel with no sacrifice of quality.

The wide variety of industrial laser machine designs, resonators, power levels, assist gasses, etc. makes impractical the development of a single set of parameters for setting up the laser machine to achieve maximum speed at acceptable cut quality. However, tests conducted have established a general set of "best practices" and a procedure that experienced laser technicians can follow to "tune" their particular laser cutting machines to achieve optimum performance when cutting SCS-processed steel. Those best practices and instructions are described below, along with comparative benchmarks of cutting speed from tests conducted at laser equipment OEM labs.

Best Practices for Preparing Industrial Lasers for Speed Optimization

1. Maintain the laser resonator as per the manufacturer's specifications.
2. Mode is controlled by resonator and optics. Use a qualified laser technician who can perform 'Mode Shot' for maximum performance.
3. Pierce Methods:
   a. Continuous Wave.
   b. Pulse allows operator to select or modify parameters.
   c. Controlled Pulse monitors cut, completes pierce, starts travel.
4. Steel Chemistry Specification:
   a. Carbon - .08% or less is optimum.
   b. Silicon - less is better.
5. Lens sizes for cutting hot rolled steel products on newer 4kw lasers:**
   a. 5.0 mm lens for material 1/8" and thinner.
   b. 7.5 mm lens for material thicker than 1/8".
6. Assist Gas Considerations:

Nitrogen	Oxygen	Shop Air
a. Will not cut material thicker than 12 ga. (4kw laser) to 11 ga (6kw laser).	*a. Oxide on edges of cut has to be removed prior to painting.*	*a. Leaves very hard oxide layer on cut edge; however, this has good paint adhesion and does not need to be removed.*
b. Will cut faster than Oxygen.	*b. For material 0.125" thick or less, expect a light finger dross on the bottom side of cut.*	*b. Large volume and high pressure required make it impractical for material thicker than 14 ga.*
c. Cuts will have slightly rougher edge.	*c. Requires lower pressure to operate.*	*c. Requires very clean, very dry air.*
d. No oxidation of cut edge. Edges can be painted w/o additional preparation.		
e. More costly to operate because more gas is used.		

7. Nozzle size selection depends on assist gas. Nozzle sizes below are for newer 4kw lasers:**
   a. For Nitrogen, use 0.8 to 1.0 mm nozzle for material 16 ga. to 12 ga. thick.
   b. For Oxygen, nozzle size should increase from 0.8 mm for 16 ga., to 1.0 mm for 1/8", to 1.2 mm for 1/2" material.
   c. For Shop Air, use 2.3 mm nozzle up to 14 ga.

** Optimum lens and nozzle size depend on laser power and design. Use your laser manufacturer's recommended settings for hot rolled steel as a starting point if they are notably different from the values listed here.

SCS Laser Cutting Optimization (continued):

SCS Laser Cutting Speed Optimization Procedure

1. Start with laser settings that have given the best performance for cutting similar material. If unclear what these settings should be, use the laser OEM's recommended settings as follows:
   - *- for material thickness 0.250" or less, use settings for cold rolled steel (CRS).*
   - *- for material thickness greater than 0.250", use settings for HRPO.*
2. Increase speed until cut quality decreases. Experience shows increasing speed in increments of 250 mm/min (10 in./min.) is an efficient way to reach this peak speed.
3. Adjust focus (up or down) to improve cut quality.
4. Adjust assist gas pressure (up or down) to improve cut quality.
5. Adjust power (typically increase, but may decrease) to improve cut quality.
6. Decrease frequency to improve cut quality.
7. If cut quality is now acceptable, ***go to Step 2 and repeat,*** or . . .
8. If speed appears to be maximized with acceptable cut quality, ***switch to next larger nozzle, go to Step 2 and repeat.***

COMPARATIVE BENCHMARKS

Bystronics, a leading manufacturer of laser cutting systems, ran SCS Laser Speed Optimization Tests to compare against their benchmark top speeds for cutting P&O in their Hauppage, New York laser lab. The table below presents the Bystronics P&O benchmark top speeds and the optimized SCS laser cutting speeds. Note that the assist gas for all cases was oxygen.

Sheet Thickness	Focal Length	Assist Gas Pressure	Laser Power	Nozzle Type	Optimized Nozzle Size - P&O	Maximum Cutting Speed - P&O	Optimized Nozzle Size - SCS	Maximum Cutting Speed - SCS
0.071”	5.0	60 psi	1400 watts	standard	1.0 mm	5600 mm/min	1.0 mm	6800 mm/min
0.071”	5.0	60 psi	1400 watts	standard	1.0 mm	5600 mm/min	1.2 mm	7000 mm/min
0.071”	5.0	45 psi	1400 watts	standard	1.0 mm	5600 mm/min	1.5 mm	7000 mm/min
0.125”	5.0	60 psi	1450 watts	standard	1.0 mm	3800 mm/min	1.2 mm	5000 mm/min
0.250”	7.5	7 psi	3500 watts	standard	1.2 mm	3100 mm/min	1.5 mm	3100 mm/min
0.250”	7.5	7 psi	3500 watts	NK[1]	1.2 mm	3100 mm/min	1.2 mm	3300 mm/min
0.250”	7.5	7 psi	3500 watts	NK[1]	1.2 mm	3100 mm/min	1.0 mm	3400 mm/min
0.250”	7.5	7 psi	3500 watts	NK[1]	1.2 mm	3100 mm/min	1.0 mm	3300 mm/min

[1] *special Bystronics tip - it has slits around the OD of the nozzle which puts a gas shield around the cut to keep contaminants out.*

SCS Laser Cutting Optimization (continued):

COMPARATIVE BENCHMARKS (continued)

Trumpf, a leading manufacturer of laser cutting systems, ran SCS Laser Speed Optimization Tests to compare SCS with hot rolled black (HRB), cold rolled (CRS) and P&O (HRPO) sheets. The tests, run at Trumpf's Farmington, CT laser lab, also included additional trials run only on SCS to examine sensitivities to different assist gases. The tables below presents the various trial results.

Cutting Speed vs. Thickness for HRB, CRS and SCS

Sheet Thickness	Assist Gas	Laser Power	Maximum Cutting Speed - HRB	Maximum Cutting Speed - CRS	Maximum Cutting Speed - SCS
4 gauge	Oxygen	4000 watts	60 in/min	65 in/min	70 in/min
7 gauge	Oxygen	4000 watts	85 in/min	110 in/min	100 in/min
10 gauge	Oxygen	4000 watts	150 in/min	160 in/min	200 in/min
12 gauge	Oxygen	4000 watts	170 in/min	205 in/min	200 in/min
14 gauge	Oxygen	4000 watts	220 in/min	250 in/min	320 in/min
14 gauge	Oxygen	6000 watts	-	-	450 in/min
14 gauge	Nitrogen	6000 watts	-	-	600 in/min

Cutting Speed Response to Assist Gas for SCS (4000 watt laser)

Sheet Thickness	Assist Gas	Assist Gas Pressure	Nozzle Diameter	Maximum Cutting Speed - SCS
14 gauge	Oxygen	1.0 X	1.0 mm	190 in/min
14 gauge	Nitrogen	1.5 X	0.8 mm	240 in/min
14 gauge	Shop Air	3.5 X	2.3 mm	350 in/min

Cutting Speed Comparison: SCS and HRPO (4000 watt laser)

Sheet Thickness	Assist Gas	Maximum Cutting Speed - HRPO	Maximum Cutting Speed - SCS
0.125 in.	Oxygen	165 in/min	180 in/min
0.125 in.	Nitrogen	165 in/min	180 in/min
0.125 in.	Oxygen	110 in/min	125 in/min

SCS Grinding Guidelines

BACKGROUND

If You Use HRPO: SCS's smooth, dry finish and thin layer of scale presents a surface that may require some adjustments to your grinding. If grinding SCS accelerates pad wear or seems more difficult, please follow the recommendations below. Fabricators that have followed these recommendations have received equivalent or improved performance when grinding their HRPO; switching back and forth between different grinding procedures is not necessary.

If You Use Hot Rolled Black: Changes to your grinding practices are likely not required when using SCS; however, you may enjoy improved performance by following these recommendations

Recommendations for Light Grinding: Weld Spatter, Small Surface Imperfections, Light Scratches

- Use 3M Scotch Brite Clean and Strip Cup Wheel – or equivalent
- 4" Grinder with 5/8-11 threaded stud: – Cup Wheel 3M part # 34-7017-9867-9
- 6" Grinder with 5/8-11 threaded stud: use Adapter – 3M part # 051144-88769
  Cup Wheel – 3M part # 38-9018-4694-9
- 6" Grinder Recommendation – Ingersoll-Rand model #88V60S106 pneumatic 90 deg rotary grinder
  or equivalent 6000 rpm grinder

Recommendations for Heavy Grinding: Deep Scratches That Require Feathering, Weld Plugs

- Use 40 grit Abrasive Flap Disc
- 7" Grinder with 5/8"-11 threaded stud – flap disc is 3M part # 051111-01199
- 7" Grinder Recommendation – Milwaukee model #6088-20 or equivalent 7000 rpm grinder