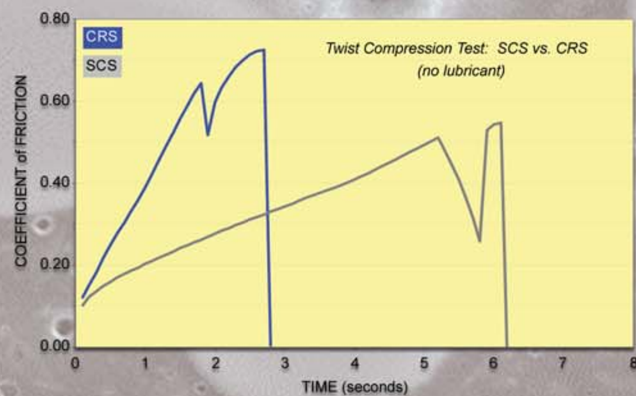
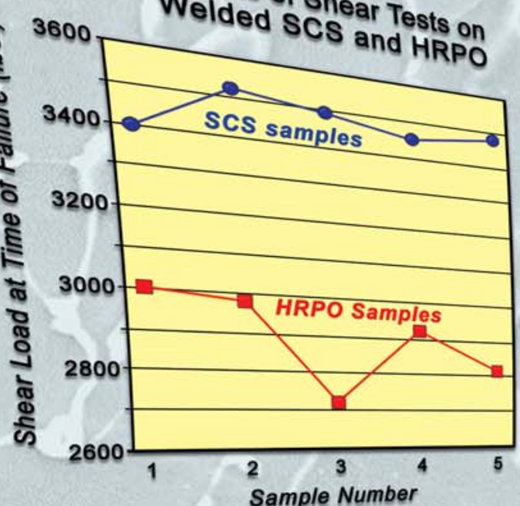
SCS SUMMARY OF METALLURGICAL TESTS



ASTM INTERNATIONAL

Figure 1: Results of Shear Tests on Welded SCS and HRPO



Revision 4 - 2/25/2007

PURPOSE OF THIS DOCUMENT

Flat-rolled steel treated with the SCS® process exhibits several advantages over traditional finishing processes of pickle and oil (P&O), pickle dry, temper pass, cold-rolled, shot blast, and others. For users to capture the SCS benefits in cost, quality and performance, SCS must be shown to be interchangeable with these other finished steels when fabricating, painting or applying value-added processes like galvanizing.

Extensive testing of SCS samples has been conducted to establish its metallurgical and mechanical properties and to benchmark its performance in manufacturing processes. The results of these tests are important to users and potential producers of SCS, as they:

(1) validate its conformance to accepted material/process specifications,
(2) testify to its performance in common manufacturing processes,
(3) demonstrate interchangeability with other common flat rolled steel finishing processes.

We realize it is time-consuming to examine the numerous pertinent test reports, therefore, we created this document to compile the test results in a single place and consistent format.

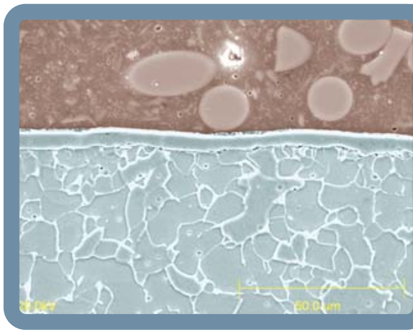
New SCS users and licensed producers will continue to independently test SCS in order to prove that it satisfies additional manufacturing criteria. TMW will compile these test results as they become available, and disseminate them as updates to this document. TMW will also provide the full report for any of the tests that are summarized here, should you require more in-depth information.

To request additional copies of this document or the complete report for any of the tests described on the following pages, please contact us at:

The Material Works, Ltd.
101 South Main Street
Red Bud, Illinois 62278
Tel: 618-282-4200
Fax: 618-282-4201
email: info@thematwks.com

Note: The results described in this document are true and accurate in describing the outcomes of the tests performed. Test results and, in some cases, the conclusions drawn from those results will vary based upon substrate material properties, test conditions, duration, and sampling and measurement techniques. Use of SCS in conditions and processes that differ from test conditions described herein is not supported by the results and conclusions of this document. You may wish to perform your own tests as an adjunct to these results and The Material Works will be pleased to provide you with information to assist in your testing program and analysis of results.

INDEX OF SCS METALLURGICAL TESTS



Metallurgical/Mechanical Properties

Painting Properties

Fabricating Properties

SCS vs. Temper Pass Metallurgy Comparisons

OBJECTIVES

- To characterize the metallurgical/mechanical properties of Hot Roll low carbon steel affected by the SCS process.
- Compare the SCS-treated steel to comparable Hot Roll after temper pass processing.

APPLICABLE STANDARDS

ASTM E 112-96
Determination of average grain size

ASTM A370-97a
Procedures for mechanical testing of steel

ASTM E 18-02
Test Methods for Rockwell hardness.

TEST PROCEDURE

Five (5) flat rolled low carbon steel material samples were prepared and examined:

A. Hot Roll prior to stretching and brushing
B. Stretched Hot Roll
C. Stretched and Brushed (SCS) Hot Roll
D. Hot Roll prior to temper passing
E. Temper passed Hot Roll

Cross sections from the samples were prepared for micro-examination in accordance with ASTM E3-01. Cross sections were examined in etched and unetched conditions. Surface finish testing was conducted on the top surface of the samples using a Mitutoyo Surftest 201 profilometer.

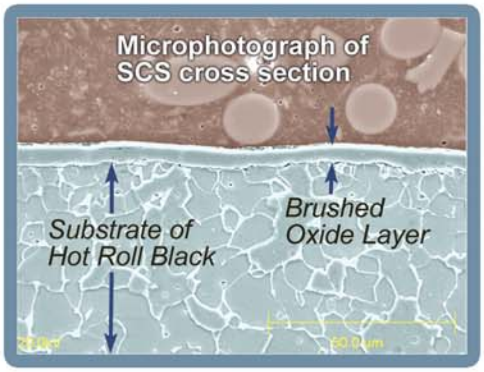
Sample dimensions were taken to determine the amount of thinning and elongation resulting from the stretching and temper pass processes. Yield strength and hardness were measured for all samples.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 03M0281
Reports dated 4/11, 4/15/2003

TEST RESULTS

SAMPLE	Average Grain Size	Avg. Surface Roughness	Hardness No's (HRB)	Yield Strength	Width (inches)	Thickness Reading 1	Thickness Reading 2
A - Hot Roll (HR)	10	40.5 µinches	73, 73, 73	46,000 psi	0.4960	0.0985	0.0985
B - HR Stretched	10	43.5 µinches	77, 76, 76	47,400 psi	0.5000	0.0984	0.0985
C - SCS	10	24.6 µinches	76, 77, 78	47,000 psi	0.5000	0.0984	0.0984
D - HR pre-TP	10	37.5 µinches	75.5, 75, 77	49,100 psi	0.5000	0.1334	0.1335
E - Temper Pass	10	30.5 µinches	76, 77.5, 78	48,500 psi	0.5050	0.1269	0.1271



CONCLUSIONS

1. The SCS Brushing process (Sample C) results in a much smother surface (Regular Bright Finish).
2. The Stretching process reduces thickness by 0.0001" (Sample B) whereas temper passing reduces thickness almost 5% (Sample E).
3. The SCS process (stretching/brushing) has no significant affect on Elongation, Hardness, Grain Size and Yield Strength.

SCS Effects on Mechanical Properties

TEST SPONSOR
Heidtman Steel Products, Toldeo, Ohio
www.heidtman.com

APPLICABLE STANDARDS
ASTM A370
Procedures for mechanical testing of steel

OBJECTIVES

- To measure the changes in mechanical properties induced in Hot Roll flat rolled steel by SCS stretching and brushing.
- Determine the consistency and predictability of changes, if any, caused by SCS stretching and brushing processes.

TESTING LAB

Veltec Laboratories
Taylor, Michigan
A2LA Certificate 0248-01

TEST PROCEDURE

Four (4) coils of Hot Rolled Black low carbon steel comprised the sample base. Part of each coil was stretcher-leveled only (not brushed) and part was stretcher-leveled and brushed. The balance of each coil was kept in its original 'as-rolled' state. Samples were prepared from each of these three groups for all four coils, making 12 samples in all.

Each sample was tested for yield and tensile strength, hardness, elongation and N-value in the transverse, diagonal and longitudinal directions. *(Note that results presented below are for longitudinal measurements).*

TEST RESULTS

SAMPLE	Tensile Strength	Yield Strength	Hardness (Avg. HRB)	Elongation (% over 2")	N-Value
Coil 1 - Hot Roll (HR)	54,679 psi	39,905 psi	64	37.79	0.207
- Stretched	55,509 psi	37,544 psi	64	39.70	0.201
- Stretched + Brushed	55,310 psi	38,405 psi	64	36.99	0.205
Coil 2 - Hot Roll (HR)	66,649 psi	48,424 psi	76	31.33	0.185
- Stretched	67,183 psi	51,438 psi	74	33.19	0.179
- Stretched + Brushed	68,414 psi	51,764 psi	76	31.51	0.180
Coil 3 - Hot Roll (HR)	75,153 psi	67,534 psi	86	28.47	0.145
- Stretched	76,608 psi	70,320 psi	87	28.09	0.134
- Stretched + Brushed	76,973 psi	68,948 psi	88	23.92	0.134
Coil 4 - Hot Roll (HR)	60,352 psi	44,713 psi	71	25.02	0.142
- Stretched	60,399 psi	47,634 psi	73	25.55	0.135
- Stretched + Brushed	61,762 psi	47,915 psi	69	25.36	0.137

CONCLUSIONS

The SCS Stretching process produces very minor mechanical property changes, evidenced by the changes in yield and tensile strength and N-value. Hardness and elongation are not affected. Changes are predictable and within the variation as might be observed within a single coil. Brushing has virtually no effect on mechanical properties.

SCS vs. P&O Surface Roughness Comparison

ROUGHNESS MEASUREMENT

A Profilometer measures distance between peaks and valleys on the sample surface. The quantified Ra value is the average of several measurements taken over the sample. Reference Ra values for cold rolled steel are:

SURFACE FINISH	Ra VALUES
Commercial Bright	10 - 20
Regular Bright	15 - 25
Light Matte	25 - 45
Regular Matte	40 - 60
Heavy Matte	50 - 90

OBJECTIVES

To analyze and compare the surfaces of pickled HR Black low carbon steel and HR Black low carbon steel after stretcher leveling and single-pass or double-pass SCS brushing.

TESTING LAB

Met Services, Inc.
Stan Bevans
Consulting Metallurgical Engineer

TEST PROCEDURE

Steel sheets were sheared and reference samples having no further surface preparation were grouped (Bare). Next, a group of samples were given a primer coat of Valspar Grey Metal Spray (Primer). Of this group, a sub-group was then given a paint coat of Valspar Gloss Black Spray (Primer + Paint).

Profilometer readings were made in both longitudinal and transverse directions over the surface of the samples from the three groups.

TEST RESULTS

	SURFACE ROUGHNESS (Ra)		
SAMPLE GROUP	Pickled** HR	1-Pass SCS	2-Pass SCS
Bare (no paint)	48	39	44
Primer	52	41	43
Primer + Paint	54	44	42

*** pickling liquor was 30% hydrochloric acid + 70 % water*

CONCLUSIONS

1. Stretched, brushed material has a surface roughness comparable to cold roll regular matte finish.
2. Pickled material has a slightly rougher surface finish, believed to be the result of the pickling agent removing all the scale, leaving a clean but slightly coarse surface.
3. The SCS brushing process does not completely remove the scale jacket. Loose scale is completely removed and fleck scale is partially removed. The thin, tight adhering layer of scale, next to the steel surface, remains mostly intact. It is thin and relatively smooth
4. The remaining scale layer required no surface prep prior to primer coat and paint coat.
5. Painting characteristics of the surfaces of pickled and brushed material are almost indistinguishable.

SCS Corrosion Resistance - Post Paint #1

OBJECTIVES

- Conduct preliminary assessments of SCS paint adherence and corrosion resistance properties to obtain benchmarks.
- Encompass both straight and formed (corner) parts using conventional liquid spray and powder coat paints.

TEST SPONSORS

Midwest Metal Coatings - St. Louis, MO
The Material Works, Ltd.

PAINT TEST FACILITIES

Certified by the American Architectural Manufacturers Association

TEST PROCEDURE

Two sets of samples were prepared. Set 1 consisted of straight, flat parts receiving no pre-treatment. They were spray painted with a thin (0.7 - 0.8 mil) inexpensive purlin paint. These parts were not scribed.

Set 2 consisted of both straight and formed parts. They received a lean 2 stage pre-treatment (cleaning and iron phosphate bath) and a standard 2.4 mil powder coat with no rust inhibitor. Set 2 parts were not scribed.

All parts were subjected to a 5% salt fog for 1000 hours at 95 °F, with examinations made at 200 hour intervals.

TESTING LAB

Valspar Corporation
Coil Coating Division
Kankakee, Illinois

TEST RESULTS

Set/ Sample #	Paint DFT[1] Avg. (mil)	Initial 60° M Gloss[2]	Sample Shape	Paint Integrity Observations				
				200 hrs	400 hrs	600 hrs	800 hrs	1000 hrs
Set 1 Avg.	0.75 spray	NA	Flat	no blisters	no blisters	#8 blisters	#6 blisters	#6 blisters
Set 2:								
KPT1076-1,2	2.4 powder	94	Flat	no blisters	no blisters	no blisters	no blisters	no blisters
KPT1076-3	2.4 powder	74	Bent[3]	no blisters	no blisters	no blisters	no blisters	no blisters
KPT1076-4,5	2.4 powder	94	Bent[3]	no blisters	no blisters	no blisters	no blisters	no blisters
KPT1076-6	2.4 powder	23	Bent[3]	no blisters	no blisters	no blisters	no blisters	loss of gloss
KPT1076-7	2.4 powder	76	Bent[3]	no blisters	no blisters	no blisters	no blisters	no blisters

[1] *Dry Film Thickness, plus painting method (liquid spray or powder) shown.*
[2] *Measure of Paint Gloss based on reflectivity of light placed at a 60° angle to surface.*
[3] *Panels are pressbrake bent 90° in the center.*

CONCLUSIONS

1. SCS Set 1 parts with inexpensive, thin coat purlin paint and no pre-treatment experienced no loss of adhesion and developed two blisters at 600 hours. Standard requirement is no blisters before 144 hours. Valspar stated the SCS parts after 1000 hours looked better than most P&O parts with pre-treatment look after the normal 144 hours.
2. All SCS Set 2 parts - flat and bent - with paint pre-treatment and 2.4 mils powder coat were resistant to blisters through the entire 1000 hours and experienced no loss of adhesion. Some loss of gloss was seen at 1000 hours on one side of the lowest gloss sample.

SCS Corrosion Resistance - Post Paint #2

OBJECTIVES

- Determine how SCS samples perform in salt spray creep tests where rust is induced by scribing through the paint.
- Compare the SCS results to P&O samples prepared in the same manner and tested side-by-side with the SCS.

APPLICABLE STANDARDS

ASTM B117-97
Practice for Operating Salt Spray Apparatus

ASTM D1193
Standard Specification for Reagent Water

Testing Lab is A2LA Accredited

TEST PROCEDURE

Four (4) flat-rolled steel parts were prepared. All were 8"x6" and pressbrake bent in the center. All were powder coat painted and scribed through the paint in the same locations. Sample differences are:

S1 *is SCS (stretched and brushed) that received only solvent pre-treatment prior to painting.*

S5 *is identical SCS and received standard paint pre-treatment, including phosphate wash.*

P1 *is P&O material of the same base steel specs as the SCS. It received only solvent pre-treatment.*

P5 *is identical P&O material and received standard paint pre-treatment, including phosphate wash.*

All four samples were placed in the same salt spray fog chamber having a 5% salt solution and operating between 93 and 95 °F. Samples were exposed for 250 hours without interruptions.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 03C-0158
Report dated March 10, 2003

TEST RESULTS

Hours of Exposure	SAMPLE	Rust Creepage		
		MAX	MIN	AVG
192	S1	10	10	10
	S5	10	10	10
	P1	10	10	10
	P5	10	10	10
216	S1	9	10	9
	S5	9	10	9
	P1	9	10	9
	P5	9	10	9
250	S1	8	10	9
	S5	8	10	9
	P1	7	10	9
	P5	9	10	9

No paint blisters were observed on any samples

Interpretation of Results

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. Blistering of the paint in this area indicates reduced adherence and less corrosion protection. Creepage is measured as:

10 = 0 inches of creep
9 = between 0 and 1/64th inches of creep
8 = between 1/64th and 1/32nd inches of creep
7 = between 1/32nd and 1/16th inches of creep

CONCLUSIONS

1. This more sever (but limited duration) test of resistance to corrosion with different paint preparations shows SCS and P&O parts to be comparable in performance.
2. While SCS samples showed slightly less creep at test conclusion, differences are not statistically significant.
3. Complete absence of blisters on any samples indicates no apparent problems with paint adherence that would lead to accelerated corrosion.

SCS Corrosion Resistance - Post Paint #3

APPLICABLE STANDARDS

ASTM B117
Practice for Operating Salt Spray Apparatus

GM 9540 Cycle B
Test Procedure for Cyclic Corrosion

ASTM 4465P
Practice for Conducting Humidity Exposures

OBJECTIVES

- Conduct more comprehensive testing on painted SCS corrosion resistance properties using scribed samples.
- Establish performance benchmarks against the lab's control standard 1010 unpolished ACT Cold Rolled steel samples to determine SCS compatibility with PPG customers' requirements and specifications.

TESTING LAB

PPG Technical Services
Industrial Pretreatment and Specialty
Euclid, Ohio

TEST PROCEDURE

Four (4) sets of flat-rolled steel parts were prepared. Two sets of Hot Rolled panels underwent the SCS process and two were 1010 unpolished ACT Cold Rolled Steel (CRS). All were prepared/painted as:

1AT1 *is SCS receiving a high alkaline cleaning, iron phosphate, and powder coat paint.*

2BT1 *is identical SCS receiving a high alkaline cleaning, iron phosphate, and electrocoat paint.*

1AP1 *is CRS receiving a high alkaline cleaning, iron phosphate, and powder coat paint.*

2BP1 *is identical CRS receiving a high alkaline cleaning, iron phosphate, and electrocoat paint.*

Samples were subjected to 500 hour salt spray (fog) test, 40 count cycle testing and 500 hour humidity test. Scribe loss (creepage) was recorded and surface appearance inspected for discoloration, rust and paint loss.

TEST RESULTS

PAINT	SAMPLE	Average Scribe Loss: 500 hour Salt Spray	Average Scribe Loss: 40 Cycles Cyclic Test	500 Hour Humidity Test
powder coat	SCS - 1AT1	3.5/32ND inch	7.9 mm	no discoloration, red rust or paint loss observed
	CRS - 1AP1	3.0 - 3.5/32ND inch	8.2 mm	no discoloration, red rust or paint loss observed
electro-coat	SCS - 2BT1	2.0 - 3.0/32ND inch	5.5 mm	no discoloration, red rust or paint loss observed
	CRS - 2BP1	2.0 - 3.0/32ND inch	7.4 mm	no discoloration, red rust or paint loss observed

CONCLUSIONS

PPG's report summary stated, *"The SCS substrate had comparable results to lab control ACT CRS panels . . . Based upon the data, PPG customers with this type of process should not encounter any compatibility problems with using the SCS substrate."*

SCS Corrosion Resistance - Post Paint #4

OBJECTIVES

- Determine comparative performance in salt spray tests of SCS produced from hot roll sourced from different mills and processed using both types of SCS brush.
- Assess fitness of lean, 2-stage paint prep. for SCS.

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

Sixteen (16) flat panels of hot-rolled were put through SCS process using either the (**B**) bristle brush type or the (**3M**) Scotchbrite brush type. The panels were given a lean, 2-stage pretreatment, then powder coat painted and scribed through the paint in the same location on each panel. The steel was sourced from:

G - Gallatin Steel **US** - US Steel **N** - Nucor

All samples were exposed to 5% salt spray fog operating between 93 and 95 ^{o}F. One side of each panel was directly exposed for 504 hours, then the panel "flipped" and the reverse side exposed for 504 hours. Total salt fog exposure was 1008 hours.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 05C-0764
Report dated October 28, 2005

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 inches of creep
9 = between 0 and 1/64th inches of creep
8 = between 1/64th and 1/32nd inches of creep
7 = between 1/32nd and 1/16th inches of creep
6 = between 1/16th and 1/8th inches of creep

TEST RESULTS

Sample Group	Creepage from Scribe at increasing exposure: 48 hrs	144 hrs	288 hrs	384 hrs	504 hrs	Results of Tape Pull Test (conducted only at 504 hours exposure)
"G-B" (3 panels)	10	8	8	7	6[1]	removal of paint beyond scribe
"G-3M" (1 panel)	10	8	8	7	6	removal of paint beyond scribe
"US-B" (3 panels)	10	8	8	7	6[2]	removal of paint beyond scribe
"US-3M" (3 panels)	10	8	8	7	6[1]	removal of paint beyond scribe
"N-B" (3 panels)	10	8	8	7	6	removal of paint beyond scribe
"N-3M" (3 panels)	10	8	8	7	6	removal of paint beyond scribe

[1] One of the six panels recorded a "7" creepage
[2] Two of the six panels recorded a "7" creepage

CONCLUSIONS

No differences in corrosion resistance observed among different sources of hot-rolled steel, nor were there differences based on which brush style was used in the SCS processing. Lean 2-stage paint prep. afforded very good adherence based on creepage in normal, expected range.

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 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 Corrosion Resistance - Pre-Paint

OBJECTIVES

- Determine how SCS samples that are pre-painted, then formed, perform on a standard 144 hour salt spray test.
- Compare the SCS results to pre-painted P&O samples, formed after painting, and tested with the SCS parts.

APPLICABLE STANDARDS

ASTM B117-97
Practice for Operating Salt Spray Apparatus
ASTM D1193
Standard Specification for Reagent Water

Testing Lab is A2LA Accredited

TEST PROCEDURE

Eight (8) flat-rolled steel parts were prepared - four were SCS and four were Hot Rolled P&O material. All parts were pre-painted, then bent 90° in the center.

All four samples were placed in the same salt spray fog chamber having a 5% salt solution and operating between 93 and 95° F. Samples were exposed for 144 hours without interruptions.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 02M-0404
Report dated June 17, 2002

IMPORTANT NOTE: Paint thickness for the P&O parts averaged 41% greater than for the SCS parts. Resistance to corrosion is directly proportional to paint coat thickness.

TEST RESULTS

Hours of Exposure	SAMPLE	RESULTS *
24	SCS 1,3,4	no corrosion/blisters
	SCS 2	20% corrosion
	P&O 5,6,7,8	no corrosion/blisters
48	SCS 1,3,4	no corrosion/blisters
	SCS 2	20% corrosion
	P&O 5,6,7	no corrosion/blisters
	P&O 8	10% corrosion
72	SCS 1,2,3	10%, 20%, 5% corrosion
	SCS 4	no corrosion/blisters
	P&O 5,6	no corrosion/blisters
	P&O 7,8	5%, 30% corrosion

Hours of Exposure	SAMPLE	RESULTS *
96	SCS 1,2,3	10%, 40%, 5% corrosion
	SCS 2	no corrosion/blisters
	P&O 5,7,8	5%, 20%, 70% corrosion
	P&O 6	no corrosion/blisters
120	SCS 1,2,3	10%, 50%, 5% corrosion
	SCS 4	no corrosion/blisters
	P&O 5,6,7,8	5%,1%,20%,75% corrosion
144	SCS 1,2,3	10%, 50%, 5% corrosion
	SCS 4	no corrosion/blisters
	P&O 5,6,7,8	5%,1%,20%,75% corrosion

** all corrosion occurs on O.D. Bend side of sample*

CONCLUSIONS

1. All corrosion occurred on the OD of the bend where the pre-paint coating is stretched and thinned by forming. This is normal and expected. While red corrosion developed, no blisters were observed on any sample parts.
2. The SCS parts developed corrosion more rapidly than the P&O parts, owing to their notably thinner paint coat.
3. Despite the differences in paint thickness, corrosion of the SCS group and P&O group plateaued by 144 hours at roughly comparable levels. Normalizing for paint thickness suggests better corrosion resistance for the SCS parts.

Discoloration Test on Rusted HRS After SCS

OBJECTIVES

- Determine if contour lines ("stains") that remain on SCS sheets of previously rusted material present any problems with paint coverage.
- Examine the previously-rusted locations to determine if the contour lines are visible after a typical primer and painting.

TEST PROCEDURE

The test was conducted at the TMW toll processing facility in Red Bud, IL, following the standards used by Maytag and Square D.

A Hot Roll low carbon steel sheet with heavy surface rust was brushed with the SCS Brush Cleaner. A noticeable contour stain remained in the location where the rust had been, although the area had an otherwise smooth, cold rolled surface appearance.

Two light coats of grey primer were applied to the sheet. One coat was applied 'east-west' and the other coat applied 'north-south'. Then two light coats of a top color were applied and the sheet left to dry.

TEST RESULTS

1. During application of both primer and top coat no problems with paint coverage were observed in the stained area.
2. Both immediately after painting and after a thorough dry, the sheet was visually inspected for irregularities in coverage or discoloration in the area of the stain. None were observed.

CONCLUSIONS

The discoloration that remains after surface rust removal through SCS brushing appears to have no adverse effects on paint coverage or appearance.

A CURE FOR SURFACE RUST

Hot Rolled with surface rust has undergone the SCS brushing process with the result that all rust is removed and does not later reappear. Very light contour lines (a "stain") discolor the surface area where the rust had previously been (see photos below).

The brushed surface is completely smooth and serviceable; however, it's necessary to determine if the stain affects the painting performance of a previously rusted surface.

SCS Corrosion Resistance - Humidity

OBJECTIVES

- Determine comparative corrosion resistance of samples of SCS, P&O produced through continuous in-line pickling, and P&O produced through a batch pickling process, when exposed to a persistent high humidity environment.

APPLICABLE STANDARDS

ASTM D 2247-02
Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity

ASTM D 1193-99E
Standard Specification for Reagent Water

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 07C-0024
Report dated January 25, 2007

TEST PROCEDURE

Three sets of three flat panels each were placed in a high humidity cabinet - constant temperature 100°F and 98% relative humidity. Samples were removed at regular intervals and visually inspected for evidence of corrosion (rust). Corrosion levels were characterized and panels returned to the cabinet for further exposure.The sets of panels were marked as follows:

SCS - SCS-processed hot rolled with no coating.

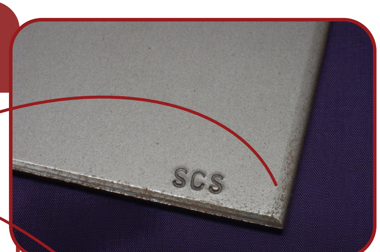
P&O - hot rolled which underwent a continuous in-line pickling and had oil applied to prevent oxidation. The oil coating remained on throughout the humidity exposure testing.

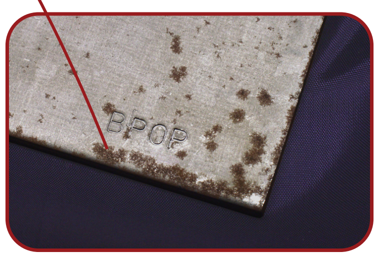
BP&O - hot rolled which underwent an immersion (batch) pickling and had oil applied to prevent oxidation. The oil coating remained on throughout the humidity exposure testing.

TEST RESULTS

Sample Group	Observation of corrosion at increasing exposure					
	48 hrs	96 hrs	144 hrs	312 hrs	384 hrs[1]	504 hrs[1]
"SCS" (3 panels)	none	none	none	none	none	red corrosion
"P&O" (3 panels)	none	none	none	slight red corrosion	red corrosion	--
"BP&O" (3 panels)	none	none	none	slight red corrosion	red corrosion	--

[1] Sample testing concluded when distinct corrosion observed





CONCLUSIONS

The test provides a relative indication of "shelf life" of the three different steel sample sets, inasmuch as it simulates storage in a high humidity environment. Even though the two P&O samples were placed in the test chamber with their protective oil coatings intact, moisture penetration eventually caused surface oxidation by 300 hours exposure. The SCS samples did not show corrosion until 504 hours exposure, and then only edges where the sample had been sheared. It is suspected that the shearing pressure dislodged protective SCS brushed scale layer enough to allow moisture penetration in only these areas.

Punch Tooling Wear - SCS vs. P&O

OBJECTIVES

Determine the effect, if any, of the stretching process and the SCS surface oxide layer on punch tool wear.

TEST PROCEDURE

Two Hot Rolled blanks of .083" x 30" x 60" size were selected - one P&O and the other SCS. Each in turn was loaded on TMW's high speed hydraulic turret punch press.

A brand new OEM punch tool was loaded with each sheet and 10,000 holes punched. The two punches were presented to the OEM tooling engineer for inspection and judgement of wear.

RESULTS AND CONCLUSIONS

The OEM tooling engineer felt the punch used on the SCS blank showed less wear than the punch used on the P&O blank (both punch tools are shown at left next to a new punch). **The conclusion is the thin SCS oxide layer has no adverse impact on punch tool life.**

Laser Cutting Double-Stacked SCS Blanks

OBJECTIVES

Through multiple trials, determine the practicality of laser cutting two stacked sheets of SCS material.

TEST PROCEDURE

Several sheets of Hot Roll that had undergone SCS processing (stretching and brushing) were provided to Precision Laser Manufacturing (PLM) of East Peoria, IL. PLM tested their theory that due to SCS' extreme flatness and clean, oil-free surface, it may be possible to laser through two SCS sheets at once and have the blanks fall out cleanly (not stick in the cut opening of the blank).

PLM lasered several parts in the stacked sheet configuration to determine practices and part types that worked well and those that presented

RESULTS AND CONCLUSIONS

PLM successfully lasered several "two-at-a-time" parts from stacked SCS sheets. Example parts are shown at left. Parts dropped out with no problems as long as they were not extremely small. Cutting near the periphery of the blank, then moving inward, helps by facilitating heat dissipation in the blank.

SCS Laser Speed Optimization Tests

OBJECTIVES

- Determine sensitivities of laser settings when cutting SCS.
- Optimize settings for max. speed with good cut quality.
- Compare max. SCS cut speeds to max. P&O benchmarks.

TEST PROCEDURE

A Bystronic Laser Cutting reference machine (maintained in accordance with manufacturer's recommendations and fully calibrated) was used to cut several sheets of stretcher-leveled SCS. For a given thickness of SCS material:

(1) A reference part was cut from the sheet at increasingly higher laser speeds until either the laser would not fully cut through the sheet or cut quality became unacceptable. Max speed recorded.
(2) Changed nozzle size by a fixed anount (for sheets thicker than 0.1875", decreased nozzle by 0.2mm, while for sheets less than 0.1875" increased nozzle size by 0.5 mm). Held all other parameters unchanged.
(3) Repeated step (1) and recorded new max. speed. Repeated step (2) + (1) until no further speed improvement.
(4) Stacked two sheets of SCS together. Attempted to cut at the set of "optimized" parameters found for single sheet of thickness equal to the combined stacked sheets. If failure to cut through or poor quality, slow laser.
(5) Recorded speed of complete, acceptable cut. Repeated steps (2) + (1) until no further speed improvements.

TEST RESULTS

Sheet[1] 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
2 x 0.125"	7.5"	9 psi	3500 watts	standard	1.2 mm	not capable	1.2 mm	2500 mm/min
2 x 0.125"	7.5"	9 psi	3500 watts	standard	1.2 mm	not capable	1.5 mm	3000 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[2]	1.2 mm	3100 mm/min	1.2 mm	3300 mm/min
0.250"	7.5"	7 psi	3500 watts	NK[2]	1.2 mm	3100 mm/min	1.0 mm	3400 mm/min
0.250"	7.5"	7 psi	3500 watts	NK[2]	1.2 mm	3100 mm/min	1.0 mm	3300 mm/min

[1] Single sheets, except "2 x" denotes two stacked sheets. [2] Special Bystronic nozzle type

CONCLUSIONS

NOTE: The optimized P&O speeds and nozzles sizes are established Bystronic benchmarks. They were not determined from "side-by-side" tests done with the SCS tests.

1. Lasering stretcher-leveled SCS yields speed increases of 20% to 30% over typical P&O material in lighter gauges (< 0.125"), all laser settings being equal except nozzle diameter.
2. As material thickness increases, the SCS speed increase over P&O diminishes (10% at 0.250").
3. Lasering two stacked sheets of stretcher-leveled SCS is possible at speeds up to 60% of single SCS or 80% of single P&O sheets. Lasering stacked P&O sheets has not been done successfully.

TESTING FACILITY

Bystronic Inc. Laser Center
Hauppauge, New York

Weld Strength Tests - SCS vs. P&O

OBJECTIVES

- Determine if the fusion in the weld nugget of welded SCS is comparable to P&O material.
- Determine the relative strength of welded SCS vs. welded P&O through controlled shear tests.

TESTING LAB

St. Louis Testing Laboratories, Inc.
Lab No. 03P-1385
Report dated May 27, 2003

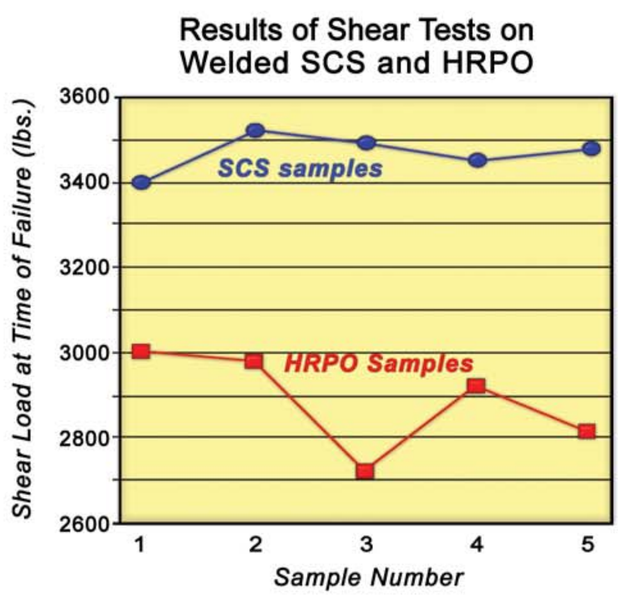
TEST PROCEDURE

Five (5) sets each of SCS and P&O samples were prepared for spot welding. Samples consisted of two heavy gauge Hot Rolled panels 1.5 inches wide by 14 inches long. The parts were overlapped by 2 inches and spot welded at the midpoint of the overlap, making a 26 inch long welded part. Welding conditions for all samples were the same (heat cycle time, hold cycle time and squeeze cycle time) and peak current applied was 72% of maximum.

Shear testing of welded samples was set up by placing each sample in a conventional tensile test machine, where each sample was vertically strained until failure. Applied shear force at failure was recorded, along with the location of failure.

TEST RESULTS

SAMPLE	Shear Load at Failure	Failure Location
SCS 1	3400 lbs.	Base Material
SCS 2	3520 lbs.	Base Material
SCS 3	3490 lbs.	Base Material
SCS 4	3450 lbs.	Base Material
SCS 5	3480 lbs.	Base Material
P&O 1	3000 lbs.	Weld Nugget
P&O 2	2980 lbs.	Weld Nugget
P&O 3	2720 lbs.	Weld Nugget
P&O 4	2920 lbs.	Weld Nugget
P&O 5	2810 lbs.	Weld Nugget



CONCLUSIONS

1. The SCS samples had an average failure shear load of 3468 lbs., roughly 20% above the P&O average. All SCS failures occurred in the base material, whereas all P&O failures occur at the weld.
2. Shear test results indicate that weld integrity and fusion to base material is higher for SCS than P&O Hot Rolled.

SCS Formability and Lubricant Tests

OBJECTIVES

- Assess the friction levels and formability (metal flow characteristics) of lubricated and bare SCS for aggressive applications like deep draw.
- Compare the SCS results to standard Cold Rolled Steel.

TEST PROCEDURE

Tests were conducted in two areas on the SCS and CRS samples:

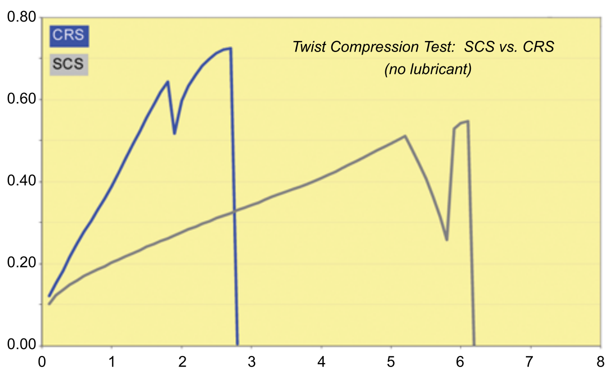
(1) Friction levels were evaluated using a Twist Compression Tester (TCT).

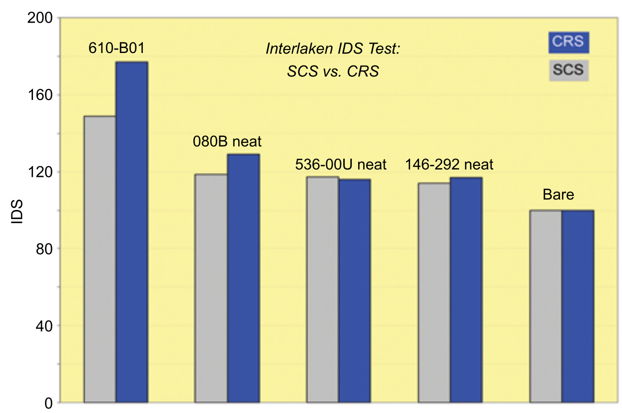
A TCT apparatus brings an annular D2 tool into contact with the stationary sheet metal sample surface (lubricated or bare) under pressure. The tool is rotated, the resulting torque is measured and the coefficient of friction vs. time is calculated.

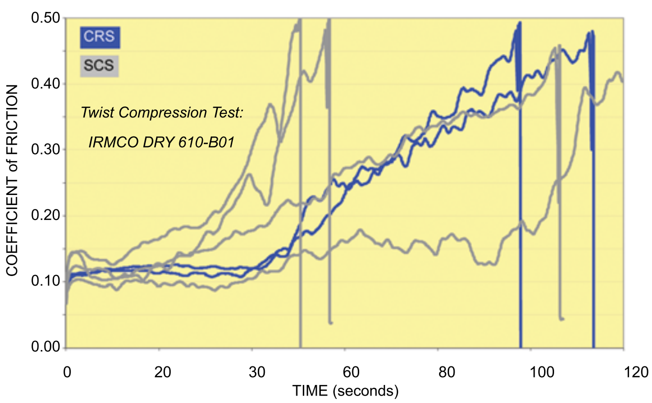
(2) Formability was evaluated using the Interlaken Formability Tester, as a comparative method to evaluate sheet metal formability and forming lubricants.

An Interlaken Formability test uses a hydraulic punch to deform a sample strip against a forming die until fracture. Samples are scribed in two places, so strain can be calculated from the change in distance between the scribe marks. Test are conducted bare and lubricated to assess differences between metals and lubricants separately.

TEST RESULTS







CONCLUSIONS

1. TCT results without lubricant (top left) showed SCS to have a peak coefficient of friction (COF) 25% below CRS. With lubricants, (left) results were more varied, but SCS and CRS performed comparably overall.
2. SCS and CRS samples were similar in terms of how lubricants enhanced their formability in the Interlaken formability tests.
3. Formability and tool wear in aggressive forming applications can be notably improved using an engineered lubricant such as IRMCO Dry (610-B01).

TESTING LAB

Greenleaf Technologies Laboratory Services
Evanston, Illinois