IPC SERIES 3000™

ENC – Electroless Nickel Coating

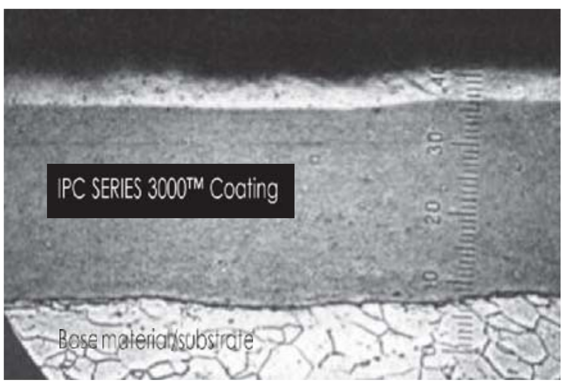
- A high phosphorus nickel alloy coating.
- Imparts superior corrosion resistance and added wear resistance to the base material being coated.
- A grain free amorphous structure with excellent barrier corrosion protection.
- Morphology like that of a metallic glass coating.
- The absence of a well-defined crystal structure eliminates the possibility of intergranular corrosion, inherent in many crystalline coatings.

Specific Advantages:

- Excellent mechanical strength.
- Excellent corrosion and chemical resistance.
- Competes with exotic alloys at a fraction of the cost.
- Protection for severe corrosion attack including CO_2, H_2S and high temperature combinations.
- NSF-61 Food Grade Coating.
- Phenomenal adhesion from mechanical and chemical bonding.

Deposit Alloy Composition:

Nickel metal content (wt.%)	87.5% - 89.5%
Phosphorus content (wt.%)	10.5% - 12.0%
Other elements (wt.%)	0.01% - 0.10%



Notice the *IPC SERIES 3000™* coating exhibits no grain structure as opposed to the base material.
The *IPC SERIES 3000™* structure is an amorphous structure which results in an excellent barrier protective coating.

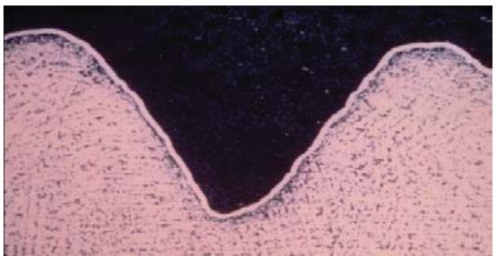
Successful Applications:

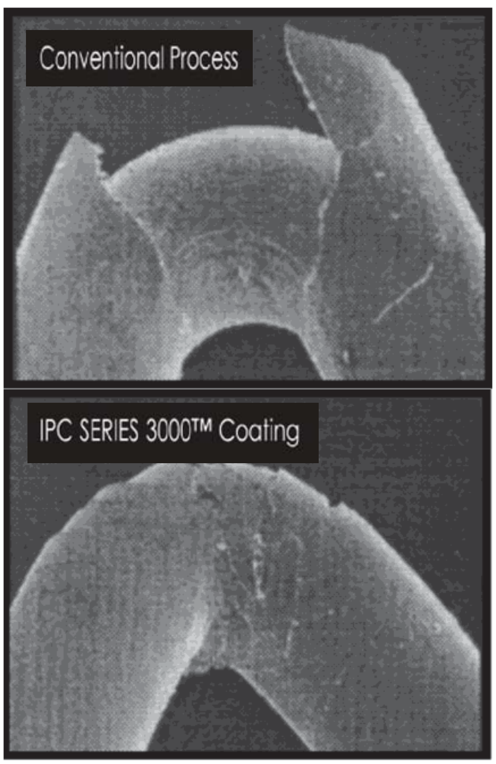
IPC's thin film coatings have been successfully applied to the wetted parts of a wide array of oilfield components which are subject to severely corrosive environments. Components such as valves, fittings, pipe spools, down hole completion tools, etc., are examples of what we can do.

IPC has proven coatings for severe service conditions for various applications (injection wells, brine service, CO_2/H_2S service), in the most corrosive fields in Western Canada - Judy Creek, Brintnell, Pelican Lake, Redwater, the Bakken Play, the Cardium Play, Horn River, Provost, Winter, and Zama.

Uniformity:

IPC SERIES 3000™ coating is an excellent choice for applications requiring a thickness above .001” (25µm). Exhibits excellent deposit uniformity. Below is a photomicrograph of *IPC SERIES 3000™* coated threads. Notice the complete uniformity of the coating even in the recesses.





IPC SERIES 3000™ shows excellent ductility over conventional mid-phosphorus OEM applied coatings.

Corrosion Resistance:

IPC SERIES 3000™ coating is a true barrier protective coating. It is not a sacrificial coating like zinc plating but rather provides an excellent barrier between corrosive environments and the substrate. The amorphous nature of the *IPC SERIES 3000™* coating is advantageous in enabling the coating to withstand very severe corrosive environments where typically only exotic alloys have been used. The amorphous structure does not have any grain boundaries where corrosion sites can be initiated. Additionally, *IPC SERIES 3000™* is passivated by many Oil and Gas environments which have shown to increase the corrosion resistance of *IPC SERIES 3000™* significantly.

Test Corrosion Rate, µm/year								
Salt Content of Solutions, % TDS	Series A CO_2 Tests		Series B H_2S Tests		Series C Mixed CO_2/H_2S Tests		Series D $CO_2 + H_2S$ Tests	
	CS	Series 3000	CS	Series 3000	CS	Series 3000	CS	Series 3000
Nil	180	5	260	Nil	190	Nil	150	Nil
0.5	190	5	130	Nil	230	Nil	350	Nil
3.5	290	5	250	Nil	490	Nil	390	Nil
10	350	8	230	Nil	750	Nil	510	Nil

ASTM B-117 Test Data:

IPC SERIES 3000™ plated in accordance with the ASTM B-117 for corrosion resistance, meets or exceeds the 1000-hour requirement at .001” without the presence of red rust.

Porosity Test:

IPC SERIES 3000™ meets the requirements of ASTM B 733 section 9.6.1 for pinhole porosity via immersion in a Ferroxyl solution.

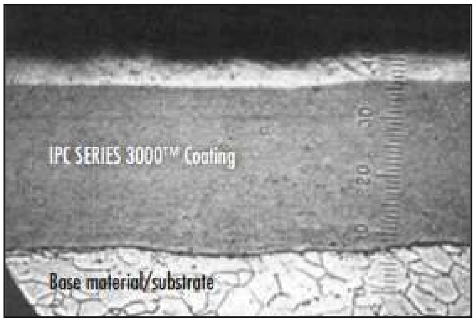
IPC SERIES 3000

Stats

SPECIFICATIONS AND PERFORMANCE DATA

Deposit Properties

Nickel metal content (wt%) ..... 87.5% - 89.5%
Phosphorus content (wt%) ...... 10.5% - 12.0%
Other elements (wt%) .... 0.01% - 0.10%



Structure..Amorphous
Density .... 7.8 ± 0.2 g/cm³
Melting Point......................................880 – 900ºC
Hardness (as plated) ....450 – 580 HK_{100}
Wear Resistance, wt. loss mg/1000 cycles, CS-10 1kg load
(As plated).. 15 – 20 mg
(HT: 1hr, 288ºC) .... 10 – 15 mg
(HT: 1hr, 400ºC) ....6 mg
(HT: 1hr, 600ºC) ....4 mg
Chromium.. 2 mg

Intrinsic Stress...................................Compressive
Internal Stress ....< 7MPa
Elongation ....1.0% - 1.5%
Bond Strength ....370 – 470 MPa
Co-eff of Thermal Expans... 13 – 14.5 $x10^{-6}$/deg

Mating surface................Coefficient of Friction
Series 3000 to Steel (Un-Lubricated)................0.38
(Lubricated).......................0.20
Series 3000 to Series 3000
(Un-lubricated).................0.45
(Lubricated.......................0.25
Steel to Steel (Un-Lubricated)............galling
(Lubricated).......................0.20

Electrical Resistivity................................0.90 µΩm
Modulus of Elasticity .... 1.7 – 2.0 $x10^{-5}$ N/mm²
Thermal Conductivity, cal/cm/sec/°C 0.0105-0.0135
Coercivity Oe.. 0
Magnetism ....Non-magnetic

Specifications and Compliances

Meets or exceeds the requirements of:
RoHS – Reduction of Hazardous Substances
WEEE – Waste Electronic Equipment
ELV – End of Live Vehicle
NACE Standard TM-01-69
NACE MR0175/ISO 15156
ASTM Standard G31
ASTM B-117
ASTM B-733
MIL-C 26074
AMS 2404
AMS 2405
AMS 26074E

Corrosion of Series 3000 in Oilfield Brine at 95ºC* (200ºF)

Test	Corrosion Rate, µm/year							
Salt Content % TDS	Series A CO_2 Test		Series B H_2S Test		Series C CO_2 Mixed CO_2/H_2S Tests		Series D $CO_2 + H_2S$ Tests	
	CS	Series 3000	CS	Series 3000	CS	Series 3000	CS	Series 3000
0	180	5	260	Nil	260	Nil	190	Nil
0.5	190	5	130	Nil	130	Nil	230	Nil
3.5	290	5	250	Nil	250	Nil	490	Nil
10	350	8	230	Nil	230	Nil	750	Nil

** Tested in duplicate for 72 hrs for carbon steel (CS) and 168 hr for Series 3000 with volume: area ratio of 20 mL/cm².*

Corrosion Resistance of Series 3000 in Produced Water Environments

Field	Chlorides, mg/L	Sodium, mg/L	H_2S,mg/L	pH	Loss µm/yr
T102 Regen	18,900	12,000	ND	7.90	5 - 7
Deionized Water	1,000	Trace	ND	6.3 - 9.0	1.5
Foster Creek - 1	1,970	1,600	ND	8.48	< 2.5
Foster Creek - 2	3,120	2,090	ND	8.56	< 2.5
Swan Hills	1,800	2,070	ND	7.50	> 5
East Hayter	43,000	25,600	ND	7.50	< 2.5
Sierra Ekwan	10,997	7,670	ND	8.24	< 2.5
Horn River	12,677	7,425	ND	7.05	< 2.5
Nexen Court	8,532	5,683	Trace	8.00	< 2.5
Pelican Lake	12,309	7.810	ND	8.0	< 2.5
Viking-Kinsella	44,981	22,856	ND	6.70	< 2.5
Oasis Rebne	162,000	52,700	ND	6.91	< 2.5
Christina Lake	1,970	1,600	ND	8.42	< 2.5

Comparison of the Corrosion rates of Series 3000 vs. Materials in Chemical Process Environments

Corrosion Rates (µm/year), 60 days exposure at 40ºC ± 2ºC				
Corrodent	Nickel 200	Series 3000	Mild Steel	AISI 316 SS
Thionyl chloride (FP)	7	2.5	200	5.1
Orthochlorobenzyl chloride (Crude)	12.7	7.1	n/a	25
Orthochlorobenzyl chloride (FP)	12.7	9.4	n/a	2.5
Phosphoric acid 75% (FP)	10	19.3	1270	2.5
Phosphorous oxychloride (FP)	10	2.5	100	18.8
Benzotrichloride (FP)	5.1	6.1	9	5.1
Benzoyl chloride (FP)	5.1	0.5	8.6	5.1
Sea Water	30	1.5	125	75
Sulfuryl Chloride	7.5	1.8	200	n/a

(FP) – Final Product
n/a – no data available, product polymerizes when exposed to mild steel

Effect of Heat Treatment on the Corrosion of Series 3000 Deposit

	Deposit Hardness (HK_{100})	CO_2 Saturated Brine	Corrosion Rate, µm/yr Saturated Brine	10% Foil	HCL Coupon
As Deposited	480	5	Nil	15	16
190ºC for 90 min	500	9	Nil	21	14
290ºC for 10 hrs.	970	34	Nil	1400	7200
340ºC for 4 hrs.	970	22	Nil	860	3000
400ºC for 1 hr.	1050	33	4000	1000	2500

Performance Testing

ASTM B 499 - Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

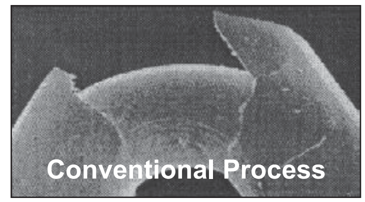
ASTM B 571- Practice for Qualitative Adhesion Testing of Metallic Coatings

D 2670 Test Method for Measuring Wear Properties of Fluid Lubricants (Falex Pin and Vee Block Method)

Porosity - The coatings shall be essentially pore free when tested according to Ferroxyl test

Micro hardness - The micro hardness of the coating can be measured by Test Method B 578 using Knoop indenter and is reported in Knoop Hardness Number (HK_{100}).

Bond Strength – Although the Series 3000 is a hard coating the elongation of the deposit is typically 1 - 2.5%. Recent advancements in the Series 3000 coating have been used effectively to enhance the performance and ductility of the plated film. Furthermore, this coating offers excellent bond strength in the range of 370 – 470 MPa on AISI 4340 steel, and exhibits a greater ability to be twisted and manipulated further than conventional deposits



Effect of pH on Corrosion Resistance of Series 3000 in DI Water*

Solution pH	Corrosion Rate, μm/year
1.5	21
2.0	20
3.0	15
4.0	2
5.1	1.5
6.3	1.3
7.0	1.5
8.1	1.0
9.0	1.5
10.0	0.8
11.0	0
12.0	0

DI Water containing 1000 mg/L HCl was neutralized with NaOH to the desired pH, held at ambient temperature, and tested in duplicate for 1850 hr with a volume : area ratio of 60 mL/cm^2.

Effect of Temperature on Corrosion in Brine*

Temperature °C	Corrosion Rate, μm/year	
	SaturatedCO_2	Saturated H_2S
95	5	Nil
120	36	Nil
150	30	Nil
180	20	Nil

**Tested in duplicate for 24 hours with a volume : area ratio of 50 mL/cm2. The 3.5% brine was saturated with CO_2 or $H2_S$*

Effect of H_2S Concentration on Corrosion of Series 3000 in CO_2 saturated 3.5% brine at 95°C

H_2S Concentration, mg/L	Corrosion Rate, μm/year
4 ppm	Nil
8 ppm	Nil
16 ppm	Nil
24 ppm	Nil
32 ppm	Nil
48 ppm	Nil
63 ppm	Nil
80 ppm	Nil
160 ppm	Nil

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