IPC SERIES 9000

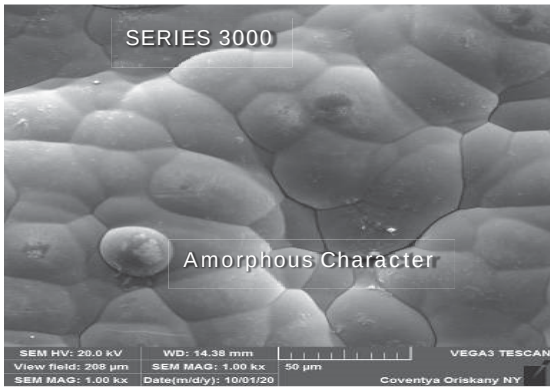
SPECIFICATIONS AND PERFORMANCE DATA

Deposit Properties

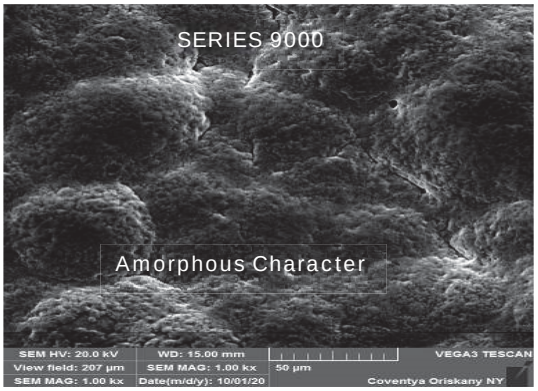
IPC Series 9000 is a thermally treated and diffused nickel-super-alloy deposit with a dramatic improvement in corrosion resistance and exceptional erosion & abrasion properties. A thick, hard, protective, and tenacious oxide film is formed on the surface along with a Ni-Fe alloy layer, pore free and ductile, created at the interface between the coating and the substrate. Due to the solid-state diffusion, the adhesion bond strength of this amalgamated alloy is outstanding and far more reliable than plated coatings alone.

Historically, high phosphorous deposits have provided excellent barrier protection for corrosive environments making it one of the preferred solutions offered for Oil & Gas applications. With the further enhancement using IPC's proprietary heat treatment, we created a metallic alloy with three additional barrier layers of protection to meet highly corrosive and erosive problems often encountered by oilfield equipment such as H_2S, CO_2, O_2, Cl, brine, solids, and high temperature.

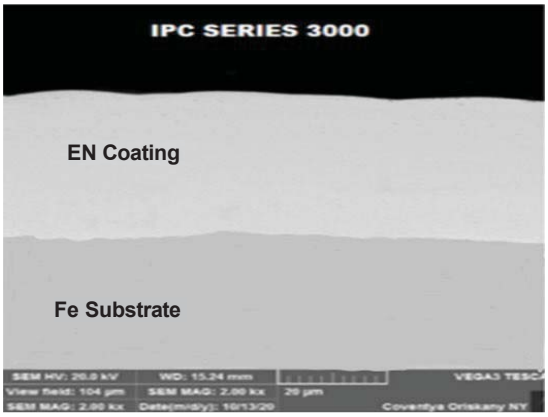
In brackish water markets which have been subjected to severely corrosive & erosive environments including sand, produced water, injection and disposal wells, Brine service, CO_2/H_2S & Acid Gas services, **IPC Series 9000** is the solution. IPC's thermally diffused coating is the preferred choice for applications such as plant maintenance and expansion where there are corrosion and erosion issues, boiler applications with high temperature, chlorides and particulates, downhole fracturing and wear applications and CO_2 injection wells. **IPC Series 9000** helps extend the life of downhole tools, wellheads, valves, pipes/ spools, and tubing/ casing in both plant & field applications in either conventional or thermal environment.



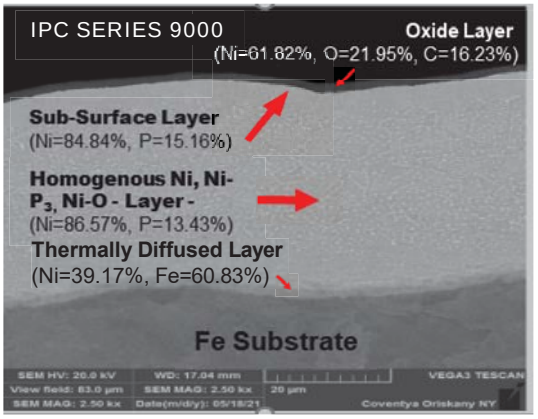
Surface Morphology of Series 3000



Surface Morphology of Series 9000



Cross-section of Series 3000



Cross-section of Series 9000

COATING OPTIONS FOR TUBING

Description	IPC Series 9000	IPC Series 3000	Nylon	PEX	HDPE
Material	Metallic alloy ENC	Metallic alloy ENC	Polymeric Coating	Polymeric Liner	Polymeric Liner
Internal Diameter	Full Bore	Full Bore	Full Bore	Reduced ID	Reduced ID
Coating Thickness	0.0018"-0.0020"	0.0018"-0.0020"	0.012"-0.025"	0.18"-0.271"	0.120"-0.180"
Max Working Temperature	600 ˚C	230 ˚C	107 ˚C	120 ˚C	82 ˚C
Bond/ Adhesion	Thermal Diffusion	Chemical& Mechanical (60,000psi)	Mechanical (~2000 psi)	Mechanical (~2000 psi)	Mechanical (~2000 psi)
Coefficient of Thermal Expansion	12 µm/ m x °C	12 µm/ m x °C	50-80 µm/ m x °C	80-100 µm/ m x °C	60-90 µm/ m x °C
Environment	H_2S, CO_2, H_2, O_2, brine and solid particles	H_2S, CO_2, H_2, O_2, brine	CO_2, brine	H_2S, CO_2	Not recommended for wells with high pressure, high CO_2 & high H_2S
Hardness as Deposited	63-64 HRC	52-53 HRC	60-80 Shore D (soft)	60-80 Shore D (soft)	40 BHN (soft)
Abrasion (TWI)	9-10 mg/1000 cycles	15-18 mg/1000 cycles	85 mg/1000 cycles	N/A	N/A

COATING CAPABILITIES

IPC Series 9000 is an exceptional coating for downhole tubing. It is Full Bore, provides both corrosion and wear protection, it has the best coating to metal bond when compared to organic coatings, and it has similar coefficient of thermal expansion as regular steel so in higher temperature applications, coating delamination, peeling, and cracking are less common when compared to polymer coatings and liners (see chart to the right for a product comparisons overview). At Integrated Protective Coatings Inc., we are capable of handling casing and tubing lengths in Range 1, 2, and 3 and custom lengths up to 50 ft.

Integrated Protective Coatings 500 Streambank Avenue / Sherwood Park, AB T8H 1N1 https://www.ipccoatings.com/

CONTACT US
1-800-856-4959

Performance Testing

CORROSION EVALUATION

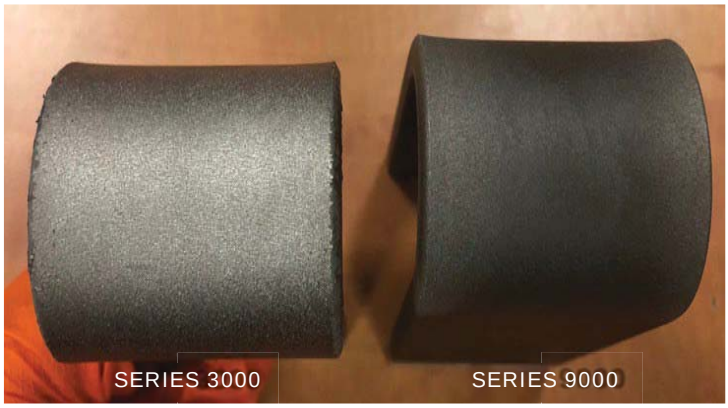
ASTM G-123 (Acidified NaCl Boiling -Brine)

1018 Mat, Not coated	56.90 pits
1018 Mat, As plated	15.05 mpy
1018 Mat, Heat treated at 400°C	23.62 mpy
1018 Mat, Heat treated at 600°C	6.71 mpy
4130 Mat, Heat treated at 600°C	5.87 mpy

1) This test method is performed in 25 % (by mass) sodium chloride acidified to pH 1.5 with phosphoric acid.
2) An immersion test in 30% nitric acid for 30 sec. at 25-35°C showed no deposit discoloration to the unaided eye.
3) ASTM B117 salt fog test found no corrosion after 1500 hours in the chamber

DEPOSIT ADHESION – BEND TEST (ASTM B571)

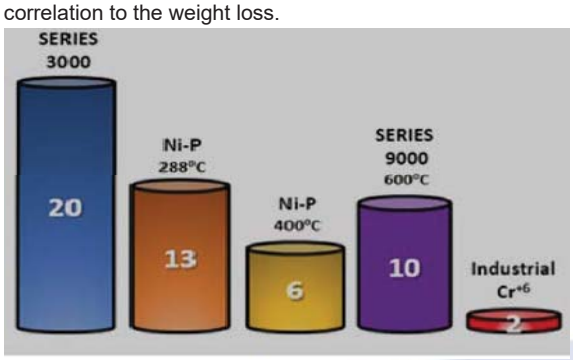
One of the major advantages of the **IPC Series 9000** over conventional high phosphorus EN deposits is the ability to pass severe corrosion exposure even after deformation. Amazingly, when we evaluated a deposit thermal processed at 600°C, which had been bent severely around a mandrel with deformation down to the diffusion layer, the Ni-Fe layer was still capable of exceeding the ASTM B-117 NSS test for more than 500 hrs. Typically this type of exposure would render the deposit compromised and not suitable for corrosive service in the past.



Adhesion Test (Bend Test)

TABER ABRADER WEAR TEST (ASTM D4060)

With regard to wear test data as it relates to the Taber Wear Index (TWI), in general, deposits that are more nodular and less planar result in less weight loss. In the case of electroless nickel high phosphorus, we find deposits which contain clusters of nickel phosphide like **IPC Series 9000** to outperform deposits without the formation, with an 50% drop in weight loss per 1000 cycles. This is also evident in the data exhibited below where we see that the temperature increase affects hardness and that has a direct correlation to the weight loss.



***Taber Wear Index** = weight loss in mg/1000 cycles CS-10 wheel, 1 kg load.*

Deposit Passivity

The presence of the tenacious Ni-O layer directly correlates to higher deposit passivity and resistance to strong Oxidizers like Nitric Acid. The **IPC Series 9000** deposit has the ability to meet very stringent and corrosive performance requirements. During the diffusion process, the phosphorus is expelled towards the surface of the coating and excluded from the diffusion layer, while nickel dissolves into the iron substrate to render the Ni-Fe alpha phase. This is able to occur since Ni and Fe are very similar size structures with atomic radii of 1.24 Å vs. 1.28 Å respectively, resulting in a highly adhesive austenitic alloy layer with excellent synergy.

Successful Applications

Sand Protection in a plant expansion

Successful after 24 stages frac, 600 tons of sand at 6.5 m^3/min comparing to other surface treatment technologies.

WAG Injection (Water Alternating Gas Injection) – using CO_2 as an Enhanced Oil Recovery Method.

IPC™
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www.ipccoatings.com Sherwood Park TF 800 856 4959