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Sub-One Technology

INNERARMOR: A REVOLUTION IN INTERNAL COATING

InnerArmor®

Sub-One Technology's global headquarters are strategically located in Pleasanton, California, adjacent to "Silicon Valley."

Manufacturing and technology development as well as R&D and testing of coatings are done at the state-of-the-art Pleasanton facility.

Here a Sub-One engineer is using a non-contact temperature gage to monitor a pipe that is being coated inside.

The Sub-One name derives from the scientific description of surface smoothness. A surface with a roughness coefficient lower than 1.0 microinch (or sub-one) is extremely smooth and highly desirable for many processes. Sub-One's unique technology applies advanced coatings that are not only extremely smooth but also provide corrosion and erosion resistance and many other significant benefits.

InnerArmor: from Sub-One Technology

Sub-One Technology has invented a revolutionary coating technology for depositing hard, smooth, pure coatings on the *internal* surfaces of a broad spectrum of products. These products can range from small metal components to long, large-diameter production pipes. Sub-One has also developed families of advanced coatings and specialized systems for applying them.

The company's patented InnerArmor® technology and coatings provide a broad array of new advantages and capabilities: They block corrosion. They minimize friction, wear, abrasion, erosion and fouling. They maximize flow. They reduce materials costs. They lower installation and maintenance costs. They maintain purity of contents. They protect the environment. All of this and more.

InnerArmor applications range across a wide spectrum of industries. For example, virtually any function involving the handling or movement of fluids or gases can benefit. This includes everything from oil and gas to chemical processing, from pulp and paper to food processing, from medical to semiconductor, from public utilities to aerospace.

Advanced coating systems, licensed coating providers worldwide

Sub-One is continually developing and extending its InnerArmor technology, creating innovative new coatings and coating systems. It makes these available through a global network of certified and licensed coating service providers. This network, too, is continually expanding.

InnerArmor: A revolution in internal coating

Many industries make extensive use of pipes, couplers, tanks, valves, cylinders, etc. through which fluids, gases and materials flow. Prior to Sub-One, various techniques attempted to protect, strengthen or enhance the internal-surface performance of such parts, but each method had basic limitations…

For example, parts were sometimes manufactured from special high-grade metals and then machined for extra smoothness, but this was an expensive proposition. And traditional coating methods—electroplating, sprays and others—provided limited effectiveness because they were primarily intended for *external* surfaces, not *internal*. Plus, they were often toxic or environmentally dangerous. InnerArmor technology eliminates all of those problems and produces a hard, smooth, corrosion-and erosion-resistant internal surface on a variety of base materials at substantially reduced cost.

InnerArmor advantages over thermal spray coating

Thermal sprays such as arc, plasma and High Velocity Oxy-Fuel (HVOF) spray deposit melted materials onto a surface. However, these are line-of-sight processes that cannot reach into small, complex or very long cavities, such as pipes. And spray-coated surfaces are rough, increasing friction or requiring additional grinding and polishing. Also, spray coating is often done by hand, making it expensive and difficult to apply evenly. In contrast, InnerArmor coating is fully automated, less expensive, smooth and evenly applied, even in very long cavities.

InnerArmor advantages over chrome plating

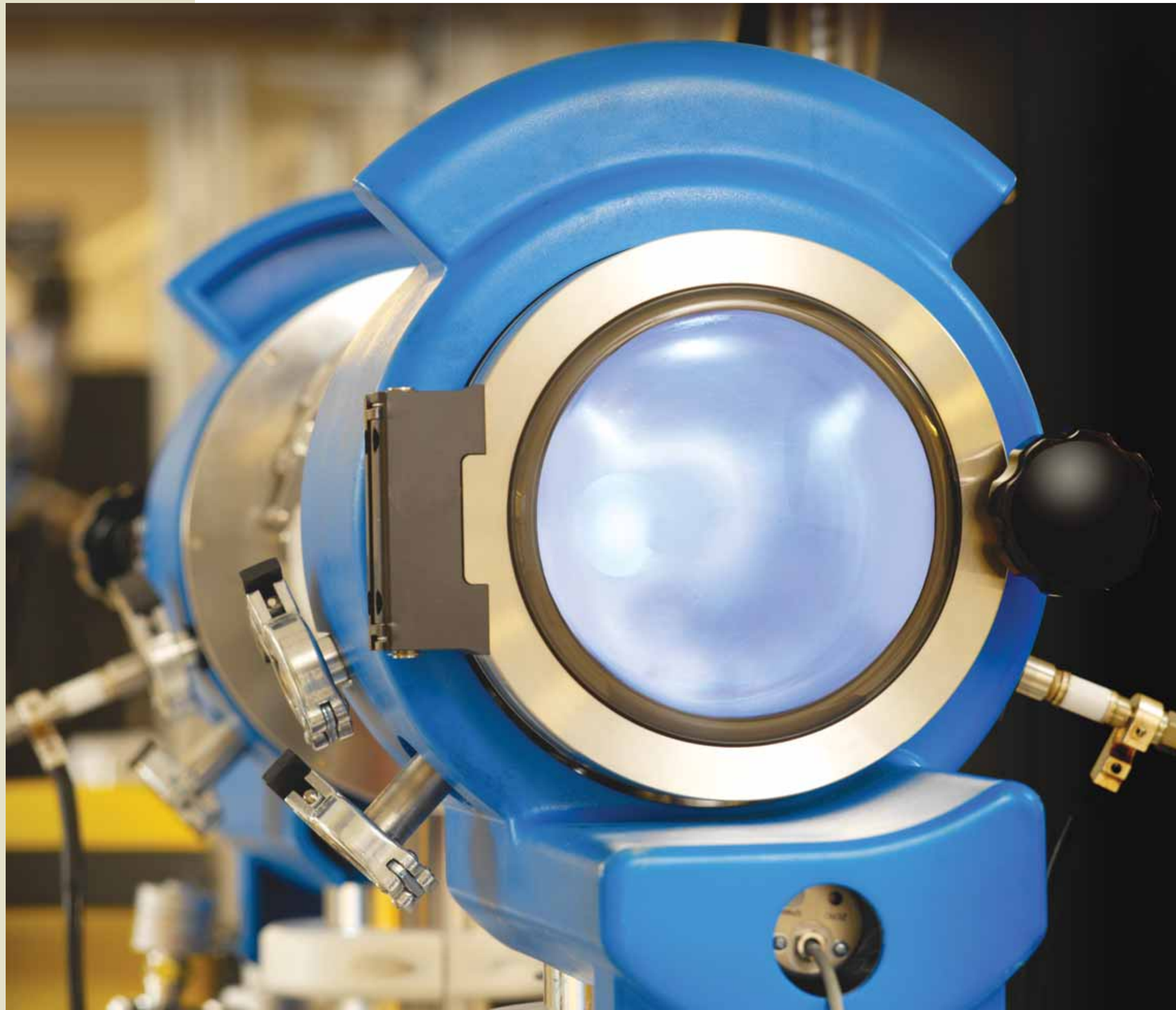
Chrome plating uses harsh, hazardous chemicals that pose health risks and face stiffening government regulations. Also, for aggressive environments, chrome often requires special additional pre-coatings. And imperfect or inadequate surface preparation can cause multiple chrome plating problems, such as microcracking, delamination and substrate corrosion. In comparison, InnerArmor provides superior hardness, wear and corrosion resistance, and it utilizes an environmentally benign process.

InnerArmor advantages over polymer linings

Polymer linings are plastic coatings such as Teflon® that are sprayed or dip-coated onto the product. These coatings provide limited effectiveness against corrosion, are not optimal for wear components and cannot be used in high-temperature environments. InnerArmor prevents corrosion, resists wear and performs at much higher temperatures.

InnerArmor coatings can use multiple layers to achieve finely-tuned performance characteristics. This SEM photo shows four layers.

InnerArmor technology utilizes *Hollow Cathode Plasma Immersion Ion Processing* (HCPIIP) and is the first process capable of reliably applying high-performance coatings onto the *interior* surfaces of parts.



SERVING MANY APPLICATIONS, MANY INDUSTRIES

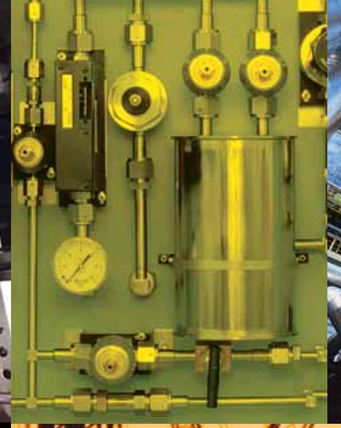
InnerArmor can be applied on a *large scale*, coating the interiors of industrial piping, exhaust systems, chemical delivery systems, gas cylinders, etc. It can also be applied on a *smaller scale*, protecting precision components, couplers, medical devices, etc.

The uses for InnerArmor interior-coating technology are widespread. Virtually any application involving fluids or gases will benefit—from corrosion, wear and erosion resistance, longer service life, improved flow performance, reduced costs and more. Likewise, applications that involve surfaces rubbing together will also benefit, from reduced friction, abrasion and wear. The following are just a few of the industries in which InnerArmor coating technology can bring improved performance and cost savings…

- Oil and Gas
- Chemical Processing
- Industrial and Specialty Gas
- Food Processing
- Geothermal
- Aerospace
- Automotive
- Metals Production
- Semiconductor
- Medical
- Pulp and Paper
- Public Utilities

Enabling new applications

In addition to enhancing existing applications, InnerArmor coating technology offers the possibility of creating new families of products. For example, lower-cost stainless steel pipe can be coated to achieve the inner strength of higher-grade alloys. Perhaps a next-generation gun barrel will be made from carbon fiber with a tantalum metal coating lining the inside diameter. Perhaps future car engine pistons will glide on ultra-frictionless InnerArmor coatings. Perhaps new drug delivery systems will be lined with pure, inert and bio-compatible InnerArmor coatings. The possibilities are virtually limitless.



Virtually any process that involves holding or moving liquids or gases can benefit from InnerArmor coating technology. It virtually eliminates corrosion, wear and erosion, while maximizing flow.

InnerArmor is an *enabling* technology that opens up entirely new applications and manufacturing methods. In essence, it allows lower-cost base materials to be used in place of many premium materials.

UNLIMITED COATING POSSIBILITIES

InnerArmor is flexible technology, offering virtually unlimited possibilities. The coatings can be applied to a wide range of base materials. And the specifications are easily tailored to meet specific application requirements, providing hardness, temperature resistance, wear resistance, corrosion and erosion resistance, whatever is needed…

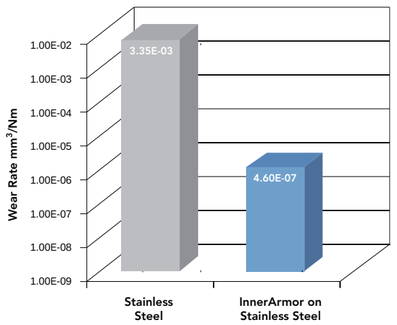
For example, in corrosive or erosive environments, thicker coatings may be preferred. While high-precision, dimension-critical applications may require thinner coatings. Harder coatings can best stand up to high abrasion factors. While softer coatings may be selected when maximum ductility or pliability is needed.

InnerArmor coatings can provide all of the above. Plus, they can combine multiple *layers* to deliver unique finely-tuned performance characteristics.

InnerArmor coatings may be created out of virtually anything that can be ionized. The technology is capable of depositing carbon-based coatings, metals and oxides. And the coatings may be either conductive or non-conductive. Titanium nitride, silicon carbide, silicon oxi-carbide and diamond-like carbon (DLC) films are but a few examples. InnerArmor can also be applied at very high deposition rates, compared to external Plasma CVD methods, lowering processing costs.

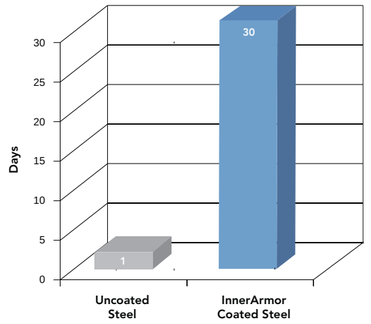
InnerArmor—Reducing Wear

Wear Rate with 25N load, non-lubricated



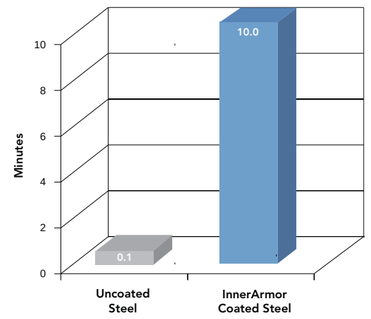
InnerArmor—Blocking Corrosion

InnerArmor Withstands the Maximum 30 Days Of NACE-standard TM185 Sour Autoclave Test With No Attack or Undercut of Coating



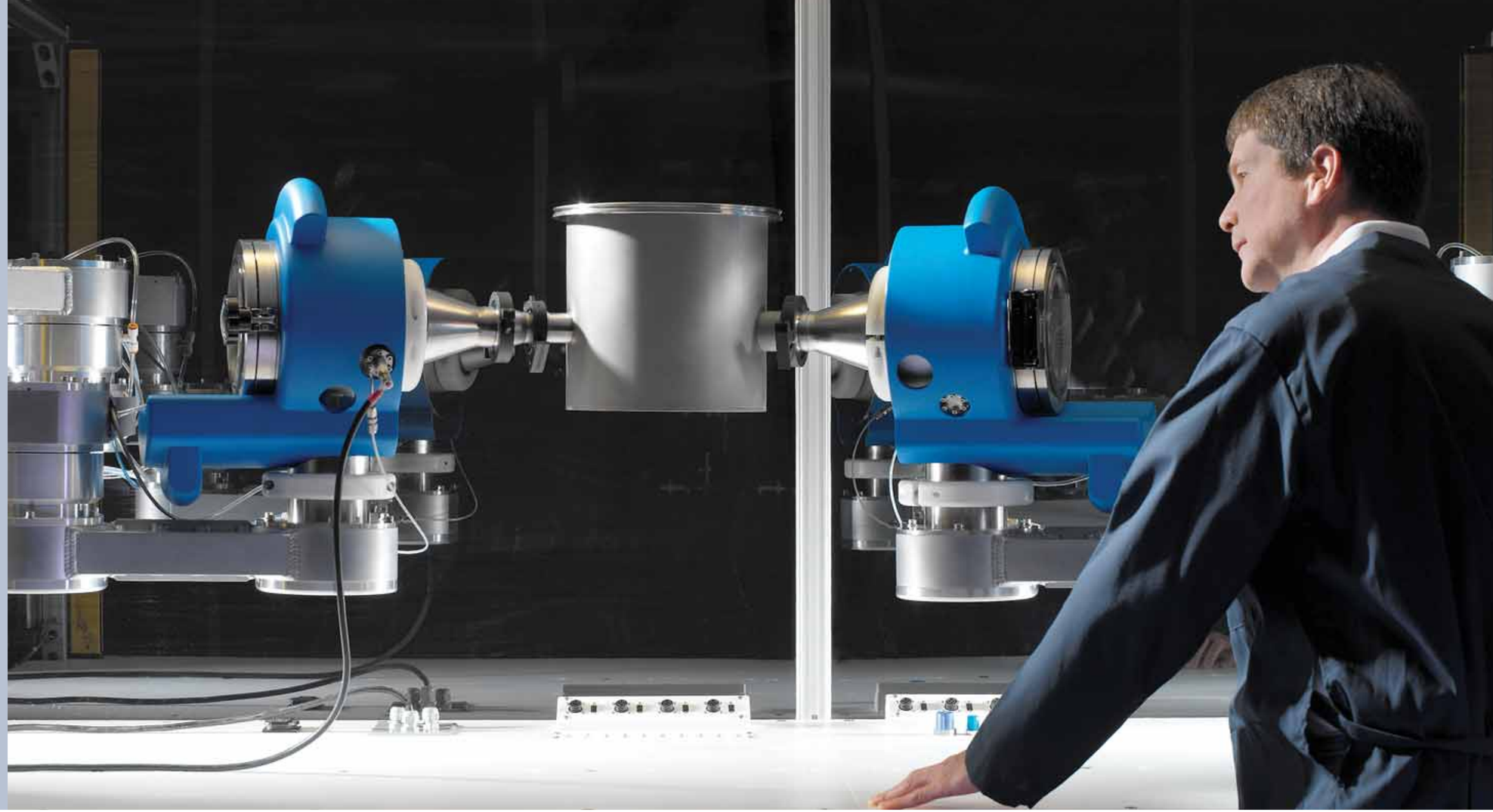
InnerArmor—Resisting Erosion

InnerArmor Withstands the Maximum 10 Minutes of ASTM-standard G76 Abrasive Air Jet Test With No Surface Damage



The comparisons above are but a few examples of the dramatic performance improvements that InnerArmor coatings can provide.

InnerArmor technology can coat the internal surfaces of a broad range of products, from long industrial pipe to small components with complex shapes.



InnerArmor provides excellent internal-coating adhesion and conformality, even on challenging subjects such as threads, bellows, bottles, flexible substrates, etc.

POWERFUL TECHNOLOGY, POWERFUL CAPABILITIES

The unique qualities of InnerArmor technology enable it to coat the internal surfaces of a very broad spectrum of products in a wide range of shapes and sizes… Such as long industrial pipes and other large tubular products. Or small components with complex internal configurations that would otherwise be difficult to coat.

Essentially, Sub-One's film deposition systems introduce a gas-phase chemical precursor and create a *hollow-cathode plasma* within the part to be coated. Using this same fundamental technology and simply changing the chemistries, a range of films can be deposited. And this enables a broad selection of coating performance characteristics.

Two intrinsic advantages of InnerArmor coatings are their exceptionally strong surface adhesion and tight conformality. This provides excellent coating even on challenging surfaces like machine threads.

EXTENDING SERVICE LIFE, REDUCING COSTS

InnerArmor coatings are able to give longer life by virtue of their fundamental chemical and physical characteristics. An intrinsic chemical inertness allows these films to shield inner surfaces from chemical attacks of many kinds. And exceptional hardness provides unprecedented protection against erosion, abrasion and wear.

In addition, InnerArmor's uniquely low surface energy and coefficient of friction improve flow dynamics. This helps maintain line pressure and reduces the amount of energy needed to move product—which further reduces cost.

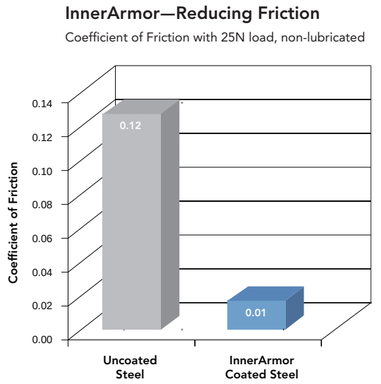
Fewer problems, greater profitability

Because InnerArmor-coated parts last longer, fewer replacement parts are needed. And less standby capacity is required. As a result, uptime is increased and productivity maximized—for a considerable net gain in profitability.

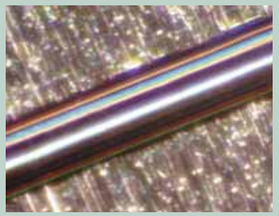
Enabling materials-cost reductions

Because of Sub-One's technology, many parts that previously required expensive metal alloys can now use less expensive base materials—simply coating the inner surfaces with InnerArmor. Equal or better performance can be achieved, but with significant net savings.

The bottom line: InnerArmor coatings produce unique and substantial cost savings on many fronts, both short- and longer-term.



Use of InnerArmor-coated piping can result in fewer failures and less-frequent replacements.



Applying known pressure in a linear reciprocating motion, a groove is worn into a sample to measure a film's wear resistance and coefficient of friction.

TECHNOLOGY'S ANSWER TO CORROSION

The cost of corrosion—just in U.S. industrial piping—totals more than $8 billion annually! In attempting to combat the problem, approximately 10% of all new U.S. steel pipe is treated to resist corrosion. For the same reason, expensive corrosion-resistant alloy and specialty pipes are also being used. Now, InnerArmor provides a more cost-efficient, more *effective* solution—literally a high-performance barrier against corrosion.

Unique coating qualities

Unlike other coatings, InnerArmor coatings are custom-tailored to be *inert* to the application environment, whether that is salt water, acid or another corrosive chemistry. InnerArmor coatings are also uniquely *amorphous.* Like glass, they have no crystalline grain structure. And *no porosity.* Also like glass, they provide smooth, uniform coverage, even across very long lengths. So pin-holes or "holidays" are eliminated.

That's not all. InnerArmor also adheres exceptionally well to metals. And it is extremely hard. Plus, it can be applied in layers to be very thick—with multiple layers providing multiple barriers against corrosive agents. Finally, InnerArmor's low coefficient of friction enhances flow dynamics and strongly discourages sludge build-up.

The net result: InnerArmor provides an unprecedented level of protection not only against corrosion but also against erosion, abrasion, wear, scaling and fouling.

Above: An InnerArmor-coated pipe interior versus non-coated pipe. Billions of feet of piping are replaced each year because of failure or preventive maintenance. By pre-coating with InnerArmor, users can get much longer service life and fewer failures, while dramatically reducing their service and replacement costs.

InnerArmor coatings have passed many standard corrosion tests, including 1000+ hour salt spray (ASTM B117), and sweet and sour autoclave tests (NACE TM0815).

Corrosion breaks down metal surfaces by an electrochemical process in which metal ions react with water, acids or other chemicals in the environment.

Holiday-free InnerArmor DLC coatings provide excellent corrosion protection due to their chemical inertness, high density and low porosity.

Reducing friction, enhancing flow, combating corrosion, erosion and more, InnerArmor finds many applications in the Oil and Gas industry.

Many older coating methods involve toxic materials and discharges. By contrast, InnerArmor technology is chemically benign and environmentally friendly.

REDUCING FRICTION, MAXIMIZING FLOW

In many industries the loss of line pressure over time is accepted as an unavoidable problem and part of the cost of doing business. Often, this loss results from the inherent roughness of older internal coatings—such as metal cladding and thermally-sprayed metal films—or from corrosion and sludge build-up. But a solution is now provided—by the unique surface qualities of InnerArmor coatings…

First, InnerArmor coatings are extremely hard. Second, they have an exceptionally low coefficient of friction. Third, they are hydrophobic—they repel water. Which means that liquids slide quickly across an InnerArmor-coated surface. The net result is that InnerArmor improves flow dynamics and reduces line-pressure loss. It means that smaller diameter pipe—which costs less—can be used to move the same amount of fluid.

In addition, in applications involving reciprocating action—such as pistons moving inside of cylinders—carbon-based InnerArmor films actually create a graphitic interface layer, which produces a self-lubricating effect! The coating reduces the coefficient of friction to levels as low as 0.01, and wear factors to as low as $10^{-7}mm^3/(Nm)$.

By reducing friction, InnerArmor can improve efficiency and performance in a multitude of applications such as down-hole components, automotive engines, chemical production processes, pulp and paper manufacturing and more.

PROOF OF PERFORMANCE

Before becoming qualified, each InnerArmor coating is subjected to rigorous testing in Sub-One laboratories. This means in-depth measurement of coating thickness, hardness, modulus, toughness, adhesion, wear, coefficient of friction, strain, corrosion, abrasion and erosion resistance and more. To do that, Sub-One laboratories are equipped with state-of-the-art test equipment, and coating properties are measured following ASTM specifications whenever possible.

To determine thickness, a ball of known diameter is used to wear through the coating and thickness is computed by geometry. Sub-One uses a micro-indenter to measure hardness and modulus by driving a diamond tip into the coating at a set force.

To measure adhesion strength, a diamond stylus is repeatedly drawn across the coating surface at a fixed rate and under progressive loading, until the critical load first delaminates the coating. A linear reciprocating tribometer is used to measure wear resistance and coefficient of friction.

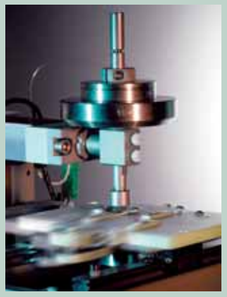
Two methods measure the porosity and corrosion resistance of coatings: an electrical test for pinholes and the application of strong acids.

To test erosion, Sub-One has constructed a special test apparatus (with ASTM specifications) that can control sand flow rate, velocity and impact angle.

All of this and more is done to verify that each InnerArmor coating does the job it was designed for.

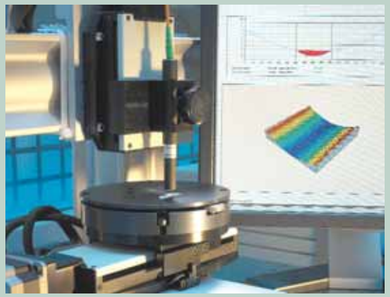
A micro-scratch test machine applies increasing force to a coating until it starts to delaminate from the substrate. The higher the force needed, the better the adhesion quality.

Below: An atomic force microscope image of coating test scratches.



A linear reciprocating tribometer wears a track across a sample, yielding precisely calibrated friction and wear measurements.

A CaloTest system uses liquid diamond abrasive on a rotating ball of known diameter to wear through the coating being studied. The precise coating thickness is then determined by geometry.



This instrument is an optical profilometer. The screen shows a section of coated pipe that has gone through a tribometer wear test and the wear track volume is being measured.

ADVANCING THE TECHNOLOGY

The goal of Sub-One Technology is quite simply to improve the end users' operating performance while reducing their costs…

To continue to create the most advanced, highest performance technology, Sub-One maintains a vigorous program of research and development, both on its coatings and coating systems, at the Sub-One laboratories in Pleasanton, California—and also through joint research programs with leading universities.

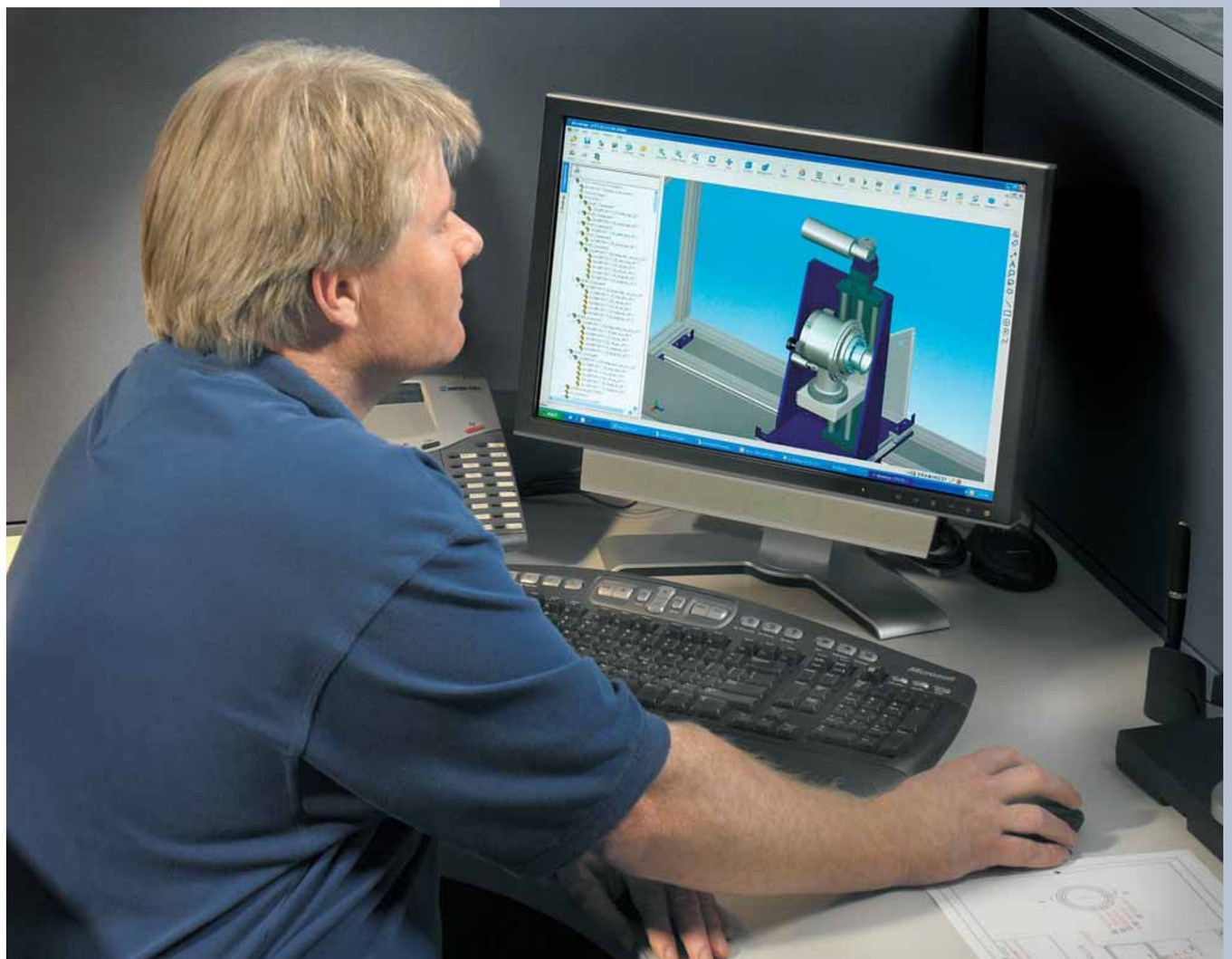
The research is focused on deepening our core knowledge. InnerArmor processes are scaled and modeled to extend the company's understanding of this powerful technology—with a view toward expanding its capabilities and applications.

At the Pleasanton research center, the work is focused primarily on customer-specific applications and new coating development. A vital part of that effort is listening to customers, understanding their requests and anticipating their future needs. Strategically located next to Silicon Valley, Sub-One's Pleasanton center is able to draw from some of the finest minds in technology.

In addition to the Pleasanton facility, Sub-One also maintains offices in Texas and Europe to work directly with end users and develop the technology for specific applications. All three facilities coordinate closely—to stay on the leading edge and to constantly deliver the most advanced internal coatings and coating systems to the world.

InnerArmor technology is covered by numerous patents and additional patents are in progress.

Sub-One systems are designed, manufactured and performance-tested in the company's spacious, state-of-the-art Pleasanton facility. A test lab is immediately adjacent to the manufacturing floor.



Computer aided design assists Sub-One engineers in developing next-generation coating systems that maximize performance and flexibility while enhancing user-friendliness.

New ways to improve coating performance are constantly being tested and evaluated. That includes hardware and software design as well as coating innovation.

InnerArmor coating services worldwide

For end users and for Sub-One's global network of licensed coating providers, the company provides a complete, integrated solution. Sub-One works directly with Fortune 500-level end users to qualify InnerArmor coatings and processes for their specific parts. Once approved, these recipes go into Sub-One's master database and are instantly available online to every authorized InnerArmor coating provider around the globe…

Whenever a coating provider at a different location has a need for a specific part, he simply enters the part number and his InnerArmor system downloads the recipe. He copies the process exactly, simply by telling the machine to proceed. For end users, it ensures copy-exact parts anywhere in the world. For network coating suppliers it automates professional performance—with Sub-One providing state-of-the-art InnerArmor systems, coating technology and global database as well as ongoing service and upgrades.

If you are a professional coating provider you may want to contact us to see if you qualify to cover a region of the InnerArmor network. If you are an end user, we invite you to tour our Pleasanton headquarters and see the future of internal-coating technology unfolding, firsthand…

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