

FIREARMS SURFACE ENGINEERING GUIDE TO EXCELLENCE SEA HANDBOOK

JANUARY 2022

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FIREARMS SURFACE ENGINEERING GUIDE TO EXCELLENCE

SEA HANDBOOK, JANUARY 2022

This handbook was developed as a resource to help firearms manufacturers better understand the various factors behind a successful partnership with a surface engineering firm.

The content is organized into four main parts:

- 1 - Pretreatment and Manufacturing Considerations**
- 2 - Chemical Finishing of Aluminum Components**
- 3 - Chemical Finishing Options for Ferrous/Steel Components**
- 4 - Production Optimization**

PART 1 - PRETREATMENT AND MANUFACTURING CONSIDERATIONS

PRETREATMENT OVERVIEW - BLASTING

The goal of media blasting is to create a uniform, matte appearance to refract light and aid concealment. Proper blast strategy and execution establishes the foundation for uniform cosmetics; the quality of the blasting is not revealed until later, after the chemical finishing process. Blast defects such as shadowing, streaking, and embedded media often go undetected until additional cost and time are spent in finishing. Fortunately, these defects are avoidable.

BLASTING STRATEGY: OUTSOURCE OR VERTICALLY INTEGRATE?

In today's firearms manufacturing space, it's very common to see both outsourced blasting or vertically integrated blasting. Both have a proper time and place. When choosing a blasting strategy, the first variables to consider are capital, floor space, engineering capability, and ROI.

The most contentious elements are often overlooked manufacturing variables:

Shipping and Handling. Envision a pristine blasted aluminum surface, surely 'Grade A' work. If only bumpy highways and corrugated packaging appreciated the fragility of the blasted surface prior to chemical finishing. Once blasted product arrives to be chemically finished, it must be unpacked and staged. The smallest surface disruption – whether from a table corner, fingernail, or jewelry edge – can result in a blemish that's only revealed in the finishing process. These shipping and handling risks are minimized when both the blasting and chemical processing are performed in the same facility.

Ownership & Blame. When problems arise, especially repeatedly, disputes can erupt between media blasters and chemical finishers: “Who’s fault is it?” The inevitable finger-pointing and “blame game” increases cost and erodes trust for all involved. By consolidating the blast and chemical processing with a single source, these frustrations can be avoided.

Chemical Finishing. The important chemical finishing step and related variables are addressed in Part 2 of this Guide. Please see p. 7.

In summary, if outsourced blasting with chemical finishing is the desired strategy, it’s advantageous to partner with a source that employs automated blasting and performs both blasting and chemical finishing in the same location. If in-house blasting after machining is preferred, choose an automated blast strategy whenever possible. See next section for further information.

BLASTING STRATEGY: MANUAL VS. AUTOMATED

Streaking, shadowing, and embedded media are the most common blast failure modes. All have root causes founded in the variability of the blast process. Specifically, excessive exposure time, fluctuating air pressure (PSI), and inconsistent media characteristics will cause blast-texture variability and consequently rejected parts.

Manual Blasting. Most blasting defects are the result of manual blast application. Manual blast strategies have definite advantages however, including versatility. There is virtually no setup or fixturing required. The operator controls the blast media aim, exposure rate, and media travel; it’s essentially point and shoot. Manual blasting is most appropriate for rapid prototyping, small production runs, and complex geometries not accessible by automation.

Automated Blasting. In contrast, an automated blast strategy controls nearly all variables including angle of attack, targeting envelope, exposure rate, pressure, and media travel. Modern automated blast equipment even measures media degradation over time. Not surprisingly, all of this process control



Inconsistent blasting is a common defect associated with manual blasting. Over-blasting – using too much pressure, not enough travel, and extended dwell time – produced the defect shown above. Prior to hard anodizing the issue was almost undetectable.



Blast shadowing is a common challenge that occurs when features of the component shield or mask blast media access. Inconsistent surface texture results in visual inconsistencies.

requires process development expertise to facilitate proper fixturing and settings. Once automated blast recipes are established, the process is highly repeatable, trainable, and quantifiable.

In today's competitive market for skilled labor, many component manufacturers find manual blast operators to be their most meticulous, high-performing employees. Their attention to detail and personal pride in the product only makes sense. Unfortunately, what many manufacturers fail to identify is the inherent supply risk with such a specialized, operator-driven process. Automated blasting solves much of this with enhanced operational predictability and output reliability.

Automated Blasting: Fixtured vs Bulk. While automation is generally preferred, it's important to note that the blast strategy differs based on component shape and size. The most agile blasting operations employ automation across multiple blast techniques. Two of the most common automation techniques can be defined either as fixtured single piece or bulk batch process. Both produce a uniform appearance with substantial consistency enhancements vs. manual blast.

Fixtured Single Piece. Larger parts with significant sharp edges, like receivers or Picatinny rails that cannot be blasted in bulk, require a fixtured automated blast strategy. Fixture design, spray nozzle settings, and rotational speed are vital to success when utilizing a fixtured blast strategy.

Bulk Batch. For a bulk blast strategy to be successful, the components should be small enough to properly interface with the media and receive 100% blast coverage. They should also lack any sharp edges that could cause part-to-part damage during blasting. Lastly, proper care to avoid over- or underloading the bulk blast process is critical to avoiding defects such as shielding or part-to-part damage.

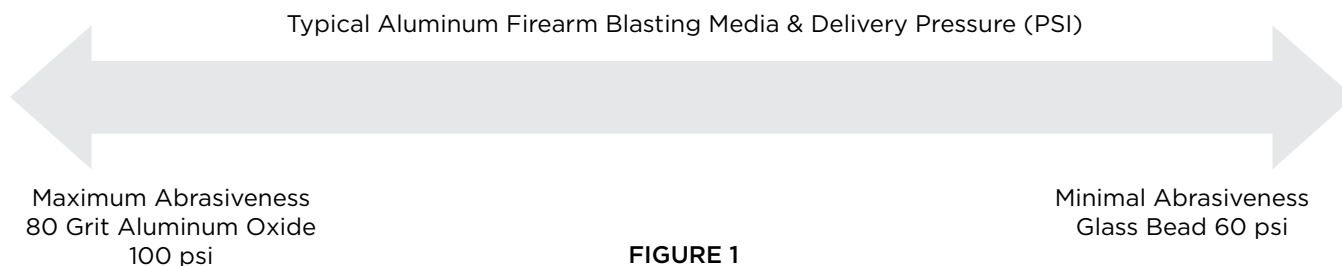


MEDIA SELECTION

The blast process is often described as shot blast, grit blast, or sand blast. While generic descriptions may start the discussion, they're far from a defined recipe for producing best-in-class firearms products.

When selecting the media, it's prudent to start with the obvious variables: media type, shape, and size. There are hundreds of media options ranging from very abrasive to very subtle. Sharper, harder blast media such as aluminum oxide produces a jagged, matte surface finish. In contrast, rounded, softer media behaves more like a 'peen' in producing rounded impacts on the substrate. Be advised that non-standard blast media requirements can add significant cost and

lead time as finishers strive to avoid media changeovers. Figure 1 below shows a continuum of blast variables and their effect on final outcome.



Media Type	Media Life Cycles	% Breakdown
Garnet	3-4 Cycles	25%
Plastic Media	7-9 Cycles	13%
Glass Bead	9-12 Cycles	10%
Silicon Carbide	9-10 Cycles	11%
Aluminum Oxide	10-12 Cycles	9%
Ceramic Media	70-90 Cycles	1.2%
Steel Shot (Grit)	80-100 Cycles	1.0%
Stainless Shot (Grit)	90-180 Cycles	0.7%

PROPER BLAST SPECIFICATIONS

To produce consistent blast results, it's important to control the type, size, shape, and PSI as we've outlined. While specifying stringent input settings seems logical, a more flexible, more objective approach is to specify a quantifiable outcome such as Ra (Roughness Average) surface finish. The Ra surface reading can easily be taken with a profilometer and represents the average distance from peak to valley in a particular

surface when compared to the 'mean' line. In simplest terms, it's the measure of texture created on the substrate. Be sure to consider a +/- 5 point range when using Ra as an acceptance criteria because subtle variables (e.g., substrate hardness) do exist outside the control of an automated blast process.

While Ra surface readings provide a quantifiable measure of texture, other cosmetic elements such as gloss and color depth aren't fully represented by Ra. Chemical finishing plays a vital role in additional appearance refinements. Part 2 of this Guide is devoted to chemical finishing.



FINAL BLAST CONSIDERATIONS

Component Cleanliness. An often overlooked but non-negotiable aspect of blasting is cleanliness. Components must be free of coolants/oils, excessive tumbling residue, and machining or knurling flakes. Surface interference with the blast process will create a masking effect of the blast media, resulting in uneven blasting. Submitting contaminated components to an outsourced blasting partner will most certainly result in added cleaning time and cost.

Masking. During media blasting, firearms components with fine threads are commonly masked to prevent thread damage or blast media entrapment in small blind holes. Threaded parts are masked by capping, plugging, or shielding sensitive dimensions from the abrasive blast media.

FINAL PRETREATMENT AND MANUFACTURING CONSIDERATIONS

The pretreatment texturization of the substrate (aluminum or steel) is ultra-critical in achieving uniform, consistent, and desirable firearms aesthetics. Surface texturization is irreversible in subsequent stages in the process; errors are often undetectable until further cost has been added to the parts.

In 99% of the cases, the chemical finishing step is performed by an outside supplier. After investing in the machining, inspection, deburring, and manufacturing of the aluminum or steel substrate, there's the cost and time of the blasting step. Finally, time and money are spent shipping the parts to a chemical metal finisher. Lastly, if the pretreatment blast was done poorly, hidden defects will be revealed in the finishing process. The finisher will inform the customer: "I didn't do anything wrong - and you still owe me money for these parts I treated!"

To avoid these issues, blasting automation and consistent process control are both necessities. This is a key reason why firearms manufacturers appreciate partnering with a full-service, vertically integrated, metal finishing company that offers both blasting and chemical finishing.

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PART 2 – CHEMICAL FINISHING OF ALUMINUM COMPONENTS

SURFACE ENGINEERING SOLUTIONS FOR ALUMINUM COMPONENTS

Anodizing is a controlled reaction that converts an aluminum surface to aluminum oxide. The setting is a hyper-controlled environment where direct electrical current (DC) is passed through the component in a prescribed sulfuric acid electrolyte solution.

Chemistry management, amperage control, tooling design, and equipment capability all play vital roles in producing best-in-class anodize coatings.

The resulting aluminum oxide layer is converted from the base metal in a honeycomb structure, creating a durable layer and providing for excellent colorant options.



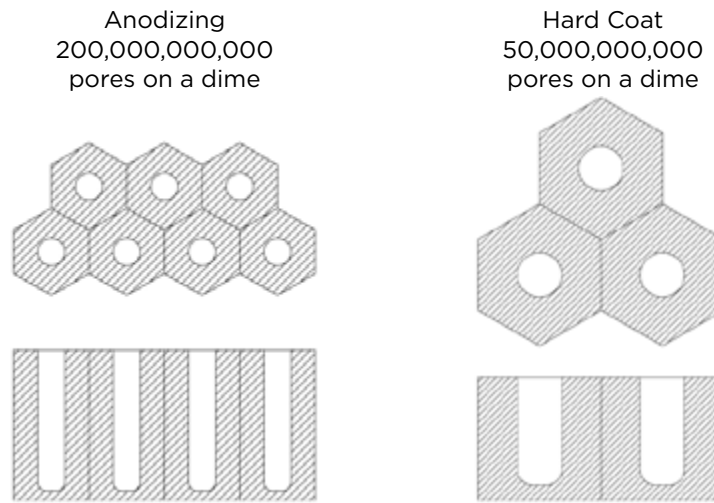
The steps of a traditional Mil-A-8625 anodize process are outlined above. Significant infrastructure, chemistries, and process controls are required to produce best-in-class results.

COMMON ANODIZING PROCESSES FOR FIREARMS

There are two primary anodizing processes specified by firearms manufacturers – Type II and Type III – per Mil-A-8625 specifications. Mil-A-8625 is the foundational spec of firearms anodizing on aluminum substrates. Both Type II and Type III sulfuric acid anodize are rooted in the same foundational process. So what's the difference?

'Type II Anodize'. Type II is often referred to simply as 'anodize' or 'soft anodize'. It's the basic anodize process designed to deliver moderate wear and corrosion protection for aluminum. The relatively thin nature of Type II anodize (.0001-.001") allows for enhanced color aesthetics, thin metal geometries, and ultimately cost savings vs. Type III hardcoat.

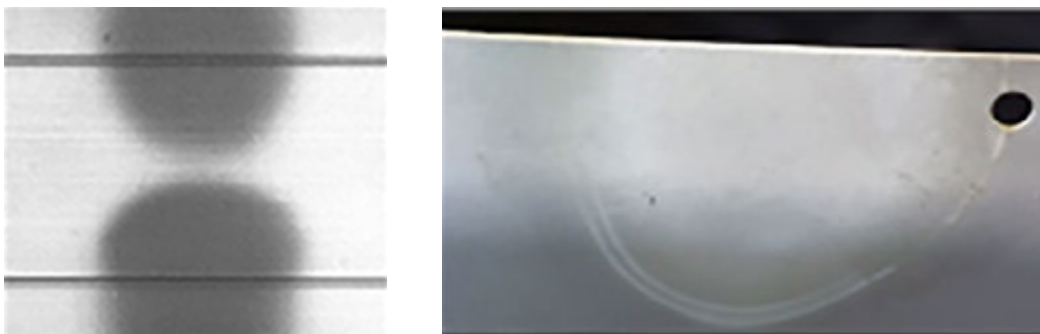
‘Type III Hardcoat’. Type III features greater pore density and thicker pore walls which provide a substantial durability advantage vs. Type II anodize. Mil-A-8625, Type III hardcoat specifies 20-24 amps per square foot of DC density to produce a coating of .0017-.0023” thickness. That’s 2x the current required to produce Type II anodize. Most importantly, the non-conductive nature of anodized coatings creates compounding electrical resistance as coating thickness builds. Electrical resistance creates heat. As a result, Type III hardcoat anodize is traditionally performed using chilled electrolyte solution at 28-32°F. Given these inputs, the cost of Type III hardcoat anodize is approximately 50% more than Type II anodize.



CHOOSING TYPE II OR TYPE III HARDCOAT ANODIZING

As mentioned earlier, Type III hardcoat is nominally 0.002” thick, while Type II is 0.0005” thick. This means Type III hardcoat is approximately 4X the coating thickness of Type II. This explains the longevity and durability enhancement of Type III hardcoat. It also explains why approximately 80 percent of aluminum firearms components are Type III hardcoat anodized black. Other than cost, why wouldn’t all components be Type III hardcoat anodized given its upgraded performance characteristics vs. Type II?

Because there are circumstances where components physically require Type II anodize or where Type III hardcoat is simply overengineering. For example, aluminum fasteners, optic mounts, and small accessories that are not subjected to significant frictional wear or impact do not need Type III. Recall that hardcoat anodize is performed at 20+ amps / square foot and produces .002” thickness. Thin walls (ex: optic tubes) and micro-sized aluminum components have limited surface area to fixture and transfer significant DC current. The result is a high risk of coating burn or material arc – ultimately resulting in scrap.



Thin metal substrates are vulnerable to coating burn and material loss when contact surface area is insufficient to support Type III hardcoat anodize current density.

Common application risk: aluminum magazines, optic extrusions, buffer tubes

It's very common that components with fine threads or limited dimensional tolerance cannot accept hardcoat dimensional buildup. To compensate, masking is sometimes specified, which adds cost, lead time, and risk of process failure. On applications where durability requirements are less, selecting Type II anodizing will avoid the need to mask precision components such as threads.

TWO TYPE IIIS: HARDCOAT VS. 'MODIFIED' HARDCOAT - KNOW THE DIFFERENCE

It's important that firearms manufacturers understand the difference between 'traditional' hardcoat and 'modified' hardcoat anodize. Both are considered Type III anodizing per Mil-A-8625.

'Traditional' Hardcoat. This anodizing process is performed with hyper-chilled electrolyte solution (28-32°F). The hyper-chilled electrolyte allows for maximum efficiency of the anodizing circuit by dissipating heat generated during the process. By controlling temperature, one can more precisely control coating growth and density. The result is maximum wear resistance and durability. With warmer electrolyte temperatures (<38°F), the oxide layer will grow too quickly, creating a deficient, brittle coating with limited durability.

'Modified' Hardcoat. This anodizing process uses additive chemistries within the electrolyte solution chilled to ~55°F. While technically still producing a spec-compliant 'hardcoat', the resulting coating lacks the rugged durability of 'traditional' hardcoat.

PERFORMANCE COMPARISON BETWEEN ALUMINUM ANODIZE PROCESSES

FINISH	Wear (Suga)	Wear (Taber)	Lubricity (C.O.F)	Corrosion (Salt Spray .001")	Thickness Range	Test Panel Material
Type II - Sealed	3.0 mg	23.1 mg	0.347	336-1,000 hrs	0.0001"-0.001"	6061 Aluminum
Type II - No Seal	1.6 mg	3.5 mg	0.282	1,000 hrs	0.0005"-0.003"	6061 Aluminum
Type III - Sealed	2.2 mg	12.1 mg	0.242	2,000 hrs	0.0005"-0.003"	6061 Aluminum
Type III + PTFE	1.6 mg	12.2 mg	0.125	2,000 hrs	0.0005"-0.003"	6061 Aluminum

Suga and Taber wear resistance tests measure material loss post exposure to a controlled abrasive cycle test.

**Corrosion testing per ASTM B117

ENGINEERED ANODIZE TOOLING

Anodize tooling or ‘fixturing’ is crucial for achieving maximum quality and efficiency. Every anodized part will have fixture marks given the electrical nature of the process. Proper tooling design determines the cosmetic concealment of these marks while maximizing load size.

Additionally, chemical immersion processes like anodizing potentially have hidden pitfalls surrounding solution flow and entrapment. It’s essential that the exfiltration of process solution from the load be proper and complete at the conclusion of each process step. Solution entrapment in cavities and blind holes can contaminate the process line. This is the leading cause of cosmetic defects during anodizing.

TOOLING FIXTURES: ALUMINUM VS. TITANIUM

Both aluminum and titanium tooling strategies are common in anodizing. Cost and volume often determine which strategy to employ. Aluminum is consumable, meaning it anodizes during each process cycle and subsequently must be stripped with each use. As a result, clip tension and integrity degrade with each cycle until replacement is required. For this reason, aluminum tooling is typically geared towards low-/mid-volume, quick-turn flexibility. Aluminum’s malleability makes it a versatile tooling option without the upfront setup cost of titanium.

Conversely, titanium tooling is much more durable and rigid in its design. Titanium fixtures are intended to be a permanent tooling solution for repeatable volume programs. Titanium tooling fixtures that support anodizing and hardcoat anodizing of firearms components can range in cost from \$5,000 to \$30,000+. When properly maintained, titanium tooling life cycles often survive the life of the programs.

Lastly, many AR firearms components are standardized in shape & size (receivers, buffer tubes, charging handles, rails). A skilled and scalable firearms surface finisher should employ a standardized tooling strategy, able to readily accept such common components. This helps expedite supplier selection and process setup.

PRE-TREATMENT CLEANING

Following blast, components will exhibit a fine layer of blast media dust and aluminum particulate. Proper cleaning, etching, and rinsing prior to anodize is required to avoid subsequent defects. Using a series of industrial grade soaps and de-oxidizers ensures a clean, reactive surface of aluminum is ready for conversion to aluminum oxide.

POWER SOURCE CONTROLS: RECTIFIERS

During anodizing, a rectifier is the power source, converting current from AC to DC. The prescribed and controlled DC current application is fundamental to producing successful results each and every cycle. Today’s production anodize suppliers employ both manual and automated rectifier controls.

Programmable rectifiers, similar to CNC-controlled machinery, follow an automated amperage process. This ensures a particular anodizing recipe is run the same way every cycle, providing a very consistent, predictable aluminum oxide layer.

Additionally, programmable rectifiers continuously measure process parameters such as tank temperature, amperage, conductivity, and cycle times.

Many job shop metal finishers continue to employ manual rectifiers for the cost savings and flexibility they provide. Manual rectifiers require skilled operators to adjust settings throughout the duration of prescribed cycle times. As a consequence of human variability, dimensional control and coating density experience much higher variation than when automated approaches are used.

DYE & SEAL

Once anodizing is complete, component parts are almost always dyed – usually black. It's worth noting that not all black dyes are created equal. Anodizers have 50+ black dyes to choose from ranging in quality, cost, and lightfast durability. Dye maintenance is ultra-critical to avoid off-color hues from tainting finished product. The most precise anodize suppliers will manage their dye formulation using photonics equipment to ensure objective consistency and utmost quality.

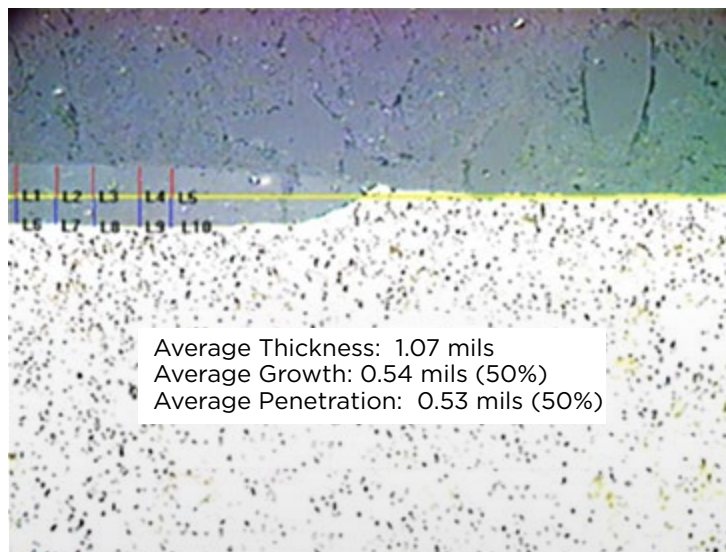
Immediately following dye introduction, product is sequenced through final rinsing and sealing. All dyed anodized product must be sealed to ensure dye retention and stain protection. While sealing does slightly soften anodize coatings, it's important to note that an ambient or 'cold seal' is preferable for preserving maximum wear resistance and coating integrity.

In contrast, a 'hot seal' such as nickel acetate will substantially degrade the coating's hardness and subsequent wear resistance. Surfactants found in nickel acetate seal formulas may also interfere with adhesion of topical coatings such as dry film lubricant, CeraKote, or paint. Firearms manufacturers should proactively consult their anodize supplier to confirm the preferred and proper sealing strategy.

ANODIZE THICKNESS – DIMENSIONAL IMPACT

It's important to know that – unlike metal plating – the dimensional buildup from the anodize process is not 100%. For example, the coating produced in the Type III hardcoat anodize process has a 50% penetration factor and a 50% growth factor. This means that if the nominal thickness is .002", then .001" will be penetration into the base metal while .001" grows outward as added dimension. By comparison, Type II anodize carries a 70% penetration to 30% dimensional growth ratio. To avoid fit issues, this must be considered in the dimensional design prior to anodize.

MIL-A-8625 recommends – but does not require – a two thousandths (.002") nominal anodize coating thickness. In reality, the firearms manufacturer can determine the preferred thickness and still comply with Mil-A-8625. While .002" nominal hardcoat thickness produces maximum wear and durability, many firearms manufacturers default to .002" thickness without realizing the consequences: increased cost, greater risk, and additional run time. Lastly, increased hardcoat thickness of .002" typically eliminates all salvageability options in the event of first cycle defect.



Anodize thickness penetration vs. growth is illustrated in the photo above for a .001" nominal hardcoat profile. Note the 50% penetration to 50% growth ratio of the coating profile.

The yellow line represents a proximity trace of the substrate's surface while the gray matter is the base substrate.

FINAL ANODIZING CONSIDERATIONS

Anodize coatings are the best option for enhancing longevity and functionality of aluminum firearms componentry. Unlike plating or painting, the anodize process has inherent complexity and variability given its reliance on the base aluminum substrate. For best-in-class results, a production anodize strategy should focus on consolidated, scalable source(s) with the ability to service all platform components. This drives maximum consistency in both appearance and performance.

To view videos with more information, [click here](#).

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PART 3 – SURFACE ENGINEERING SOLUTIONS FOR FERROUS/STEEL COMPONENTS

Chemical finishing options for ferrous or steel-based substrates are vast when compared to the narrow, anodize-centric options for aluminum componentry. When design engineering a finishing strategy for steel components, first consider each component's location and function.

For example, exterior components such as frames, receivers, or barrels require corrosion and abrasion protection in addition to concealment. Interior bolt carrier group (BCG) components should be engineered with finishes that drive performance and dependability.

SURFACE ENGINEERING SOLUTIONS FOR EXTERIOR STEEL COMPONENTS

Black Oxide. Commonly referred to as 'bluing' in the firearms industry, black oxide is a cost-effective black coating for ferrous parts. A more matte finish is achieved by incorporating pre-treatment blast prior to black oxide (See Part 1). Note that the depth of black produced will vary based on substrate and heat treatment prior to the black oxide process.

The high-temperature (285°F) process oxidizes the surface of the steel via electrochemical reaction, transforming the surface iron to magnetite. The resulting finish provides moderate abrasion resistance without altering the substrate's dimensions. Post-process oil application is essential to prevent rust, as salt spray testing results for black oxide are generally >100 hours per ASTM B117 standard. (See Chart, p. 9)



Black oxide or 'bluing' is commonly used in ferrous substrate components such as fasteners, brackets, and even frames or receivers.

Manganese Phosphate. Sometimes referred to as Parkerizing or 'mag phos', this steel substrate conversion coating requires component immersion in phosphoric acid solution. Incorporating media blasting prior to manganese phosphate produces a matte charcoal black finish appearance with less color depth than black oxide. Manganese phosphate parts are self-lubricating; the phosphate coating's porous nature allows topical oil application to reside long after surface drying. Manganese phosphate's durability is measured by coating weight. Most commonly, MIL-STD-171 requires a minimum weight of 16 grams per square meter. Traditionally, 'mag phos' yields superior corrosion protection vs. black oxide; its self-lubricating properties provide modest surface protection against abrasion or traffic marks.

Black Electroless Nickel. This plating option is a coating technology rapidly gaining popularity in the firearms market, both for its cosmetic appeal and functional performance characteristics. Electroless nickel traditionally had been a reflective metallic product until very recently when chemical providers infused pigment to produce a uniform black appearance. All the benefits of the electroless plating process are retained including hardness (55+Rc), corrosion protection (500Hrs), and minimal variation of the coating profile.

Cerakote™. A thin-film ceramic paint making tremendous strides in the marketplace due to its flexibility and consistent color, Cerakote's primary application is exterior-facing componentry where cosmetics are critical. For corrosion and wear performance, Cerakote performs quite well on steel substrates, especially when combined as a duplex system over phosphate or 'Parkerized' finishes. The underlying phosphate conversion coating acts as a recipient primer to promote adhesion while preventing filiform corrosion in the event of a surface-level breach of a stand-alone Cerakote™ finish.

The cosmetic appeal of Cerakote™ and other organic paint systems has allowed for significant customization in the civilian firearms market. This trend is expected to continue, along with age-old challenges of corrosion and wear. The best strategy when incorporating topical coatings and paints is using a conversion coating such as phosphate or hardcoat anodize (aluminum) as an underlying performance enhancer.

SURFACE ENGINEERING SOLUTIONS FOR CRITICAL INTERIOR COMPONENTS (BCG)

While firearms cosmetics are critical, the BCG 'engine' of any best-in-class firearm must function without fail in all conditions. The dependability of any firing mechanism is heavily reliant upon the components' engineered coating strategy.

Tribology is the harmonized benefit of lubricity and wear protection of interfacing components. When considering coating strategies for critical BCG components, lubricity and wear are top of mind. The challenge is that lubricious coatings often rely on softer constituents to achieve low coefficient of friction, which in turn reduces wear resistance and longevity.

FINISH	Hardness	Wear	(C.O.F)	Lubricity	Salt Spray Rating	Cost Rating
Hard Chrome*	70 Rc	9	0.19	7	4	7
PTFE Nickel*	50 Rc	6	0.10	9	8	7
Nickel Boron	68 Rc	8	0.13	8	7	8
Nitride	55 Rc	7	0.25	5	6	5
Phosphate	25 Rc	5	0.30	4	5	5
PVD/DLC	70 Rc	9	0.12	8	7	8

*Processes offered at Pioneer Metal Finishing

Functional Hard Chrome. This plating option has long been a preferred coating strategy for bolts, carriers, pins, and barrel lining. The 70Rc+ hardness of chrome, coupled with its natural lubricity, makes it the reliable, preferred choice of firearms component engineers. Additionally, hard chrome will not stain/tarnish like nitride or nickel boron coatings in a BCG application. Chemical process controls and tooling design are paramount in producing precision hard chrome plating solutions.

PTFE Electroless Nickel. This is a preferred coating strategy for hammers, triggers, and supporting components due to its balanced hardness and lubricity attributes. Pioneer Metal Finishing's branded PTFE co-deposit electroless nickel product is called NorLube™. PTFE electroless nickel provides a smoother trigger transition vs. a more wear-centric, harder coating like nickel boron. Ease of cleaning and tarnish prevention are also its favorable attributes vs. harder coatings like nickel boron.

Electroless Nickel Boron. Arriving on the firearms component scene in the late 1990s, electroless nickel boron is a direct competitor to hard chrome given its ease of application and availability. It delivers enhanced hardness and wear longevity vs. PTFE nickel but falls short in lubricity. Nickel boron will stain/tarnish and provide a more rigid trigger feel due to the coating's hardness.

Nitriding [or Melonite/Salt Bath Nitride (SBN)]. This heat-treating process case-hardens the component surface by infusing nitrogen into the substrate. The resulting surface is smooth and extremely hard, providing enhanced wear-resistance and moderate corrosion protection. Lubricity lags considerably behind chrome and nickel-based coatings. Given nitrided BCG components do not require chrome lining of the gas key or bolt carrier's inner areas, manufacturing costs are reduced. The deep black appearance conceals any staining or tarnish during use. Importantly, however, nitriding is not a mil-spec coating for defense-specific applications.

Manganese Phosphate. This option has a mil-spec heritage and traditional approach to BCG components. As previously reviewed, mag phos will produce a charcoal black porous conversion coating that lends itself well to lubrication. The black appearance will not stain or tarnish. Given its similar appearance to black hardcoat anodize, mag phos is often preferred when cosmetic uniformity across the entire AR platform is desired.

Physical Vapor Deposition (PVD). This process is sometimes referred to as DLC or 'diamond-like-coating'. It's an advanced technology delivering engineered hardness, lubricity, and corrosion-protection attributes. PVD coatings address all the performance and process-capability gaps of previously cited coatings. Proper application techniques for firearms components are still under development, striving to ensure consistent coverage and performance. The limited availability of these coatings and technical challenges related to PVD application on complex internal geometries prevents full utilization and cost effectiveness.

COATING APPEARANCES



BCG Finish Appearance

Hard
Chrome

Titanium
Nitride

PVD/DLC
Black

Nickel
Boron

Nitride
Black

PTFE
Nickel

Phosphate
Black



PART 4 – PRODUCTION OPTIMIZATION

PRODUCTION FIXTURING/TOOLING

The coating processes for ferrous substrates outlined above are heavily reliant upon expert tooling and fixture engineering with the exception of the electroless nickel-based processes. The primary reason for this is the electrolytic reliance of the coating process contrasting with the precision-machined nature of bolts, carriers, receivers, etc.

For example, when plating hard chrome one can expect a 40% thickness variation in a single part when applying thicknesses .001” or greater. Recessed areas exhibit low thickness buildup as opposed to convex, exterior geometries receiving the highest thickness.

To combat this, the best coating applicators will have developed solutions incorporating strategically placed cathodes, contact points, and process-current stabilizers.

FFL LICENSE COMPLIANCE AND SUPPLY RISK CONSIDERATIONS

All firearms component manufacturers and OEMs are keenly aware of security protocols mandated by the ATF with respect to serialized components. Efficient means of serial verification and control can be considered price of market entry.

Increasingly today, the challenge of labor scarcity for manufacturers is worth noting. This risk is magnified in labor-centric processes such as surface finishing and coating. Combined with ATF and ITAR restrictions, the risk of supply disruption is heightened without personnel and physical process redundancy. Multi-site supply chain partners help mitigate indirect risk attributable to single-site mechanical infrastructure, labor, and environmental controls.

CONCLUSION: FIREARMS SURFACE ENGINEERING GUIDE TO EXCELLENCE

Surface engineering for firearms manufacturing continues to advance in technology and capabilities every year, spurred on by developments at firearms manufacturers and overall industry innovation. Additionally, exciting advances are certainly on the horizon as the pace of progress accelerates.

As addressed in this white paper, the most successful outcome for firearms excellence relies on a partnership between the firearms manufacturer and surface engineering firms. From pretreatment considerations through various chemical finishing options, tooling selection, and legal requirements, world-class products will only result from collaboratively considering all variables in a proactive, team approach.

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ABOUT PIONEER METAL FINISHING

Headquartered in Green Bay, WI, Pioneer Metal Finishing provides specialized outsourced metal surface engineering services to customers across a range of industries including automotive, defense, aerospace, medical, and consumer goods.

For over 75 years, Pioneer has served its customers with comprehensive processes including anodizing, plating, powder coating, heat treating, and adhesive & coating applications.

With approximately one million square feet of manufacturing space in nine locations across WI, MN, IN, MI, UT, CA, OR, and Mexico, Pioneer offers robust manufacturing scalability and business continuity services. This provides organizations with enterprise-wide management of product development, manufacturing controls, quality, and logistics together in a complete and seamless surface engineering solution. All Pioneer facilities are ISO 9001 certified with select facilities also having AS 9100 and NADCAP certification.

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The data contained herein are intended as reference only. Please contact Pioneer Metal Finishing for assistance.

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Mission-Critical, Scalable Solutions.

The Pioneer Difference.



REDUCED
SUPPLY
CHAIN RISK



SCALABLE
PRODUCTION



HARSH
ENVIRONMENT
APPLICATIONS



FUNCTIONAL
PERFORMANCE
SOLUTIONS



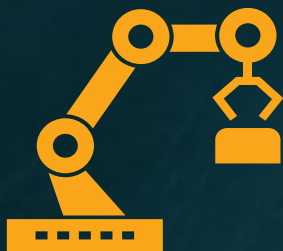
CONSOLIDATED
SUPPLY CHAIN
MANAGEMENT



11
NORTH
AMERICAN
LOCATIONS

75 YEARS
OF MISSION-CRITICAL
SURFACE ENGINEERING

1,000+
EMPLOYEES



600
MILLION PARTS
PROCESSED
ANNUALLY

DEDICATED
ENGINEERING
AND QUALITY GROUP



800,000
SQUARE FEET OF MANUFACTURING

SOLVING THE WORLD'S TOUGHEST SURFACE ENGINEERING
PROBLEMS WITH CONFIDENCE, CLARITY AND QUALITY.



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