A Boiler Jacket for WW&F Locomotive No. 9
Final Report

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Introduction

"It needs paint!"
The toddler exclaimed almost eight years ago when he saw the unfinished and uncovered boiler for WW&F Forney Locomotive No. 9 in our restoration shop. "Yes, it does," replied our CMO – and thus the hunt for a suitable covering for the locomotive began.

As part of the operational restoration of No. 9, it was decided to fabricate a new boiler jacket in the style of Russia Iron using commercially available materials and modern techniques. The goal was to create a jacket that matched the one that No. 9 carried during its service life. While badly deteriorated, enough of the jacket remained to possibly match the reproduction to the original.

In short, we obtained a near perfect match to the original. However, we discovered that what we had replicated was not "Russia Iron." Instead, it appears to be a closer match to ARMCO's "Ingot Iron Polished" sheets, which are an improved version of early planished iron sheets.

It's In the Details

Throughout No. 9's restoration we were impressed by the level of craftsmanship that went into its construction, including the locomotive's decoration. For example, the smokebox diameter was offset so that the jacket and smokebox would be flush which created clean lines. While this level of decoration was common practice on steam locomotives produced during the mid-19th century, it had fallen out of favor by the time locomotive No. 9 was built in 1891. The attention given to decoration by the original builders inspired us to pay similar attention to decoration during the restoration process.

The first detail we attended to was the creation of boiler jacket standoffs, to give the jacket sheets a firm backing. Originally, this backing was provided by stiff magnesia-asbestos fiber board insulation. We would be using soft ceramic fiber insulation, requiring the standoffs backing up the jacket sheets at each joint. In deciding where to locate these standoffs, we decided to replicate the size of the original jacket sheets. While the original jacket was deteriorated beyond the point of reuse, we learned that the original jacket was made up of unusually sized 28" by 60" sheets rather than the 4' by 8' foot sheets available today.

More research taught us that the 28" by 60" sheet size we observed in the original jacket was actually a standard supplied size for planished iron from both Russia and the United States. Further inspection of the original sheets led us to seek out locations where the original finish might be preserved. Under layers of built up grease and oil we discovered some small portions of the original finish. This original finish was clearly some form of planished iron. At this point in the process we strongly suspected it was Russia Iron, so we set out to replicate its production using commercially available materials and techniques.

Russia Iron

"Russia Iron" is a trade name for a particular treatment of wrought iron sheet. It is so branded because it originated in the Ural Mountains of Russia. The basic manufacturing process involved stacking more than 100 iron sheets together, interspersed with wood charcoal, heating to forge temperature, and hammering the stack with a steam hammer. The stacks were then broken apart, the sheets inspected, and the process repeated until the desired results were achieved (high polish, consistent finish.) There is some debate about the exact specifics of the process and what transformations were actually happening to the surface of the metal; however, the general consensus is that the polished surface had a black-oxidized surface, similar to gun bluing. The color hues would vary between source mines, generally ranging from dark to light grey in neutral light. The high polish would further skew the color hue by reflecting the color of whatever was around (blue sky for example.)

"Russia Iron" provided a rust resistant locomotive boiler jacket prior to the advent of paint enamels that could withstand the high temperatures of this job. The highest grade, which was exceptional in color and finish, was used for locomotive boiler jackets and engine cylinder lagging. Lower grades were used for other products which required similar rust resistance such as stove pipe and roofing. In later years the trade name "Russia Iron" was used commonly for many products, both imported and domestic, bearing the characteristics of the original.

High trade tariffs caused a great effort in this country to develop a comparable domestic version. Several American versions were successful, including "American Iron" and "Wood's Iron." Most of the American versions were squeezed between rollers at high pressure, before being hammered; this created a surface with even greater reflectivity and smoothness.

The Process, Modernized

Our research into how to reproduce the material began with the efforts of Chris DeWitt, of the Nevada State Railroad Museum, and Dan Markoff, owner of the 1875 3-foot gauge Baldwin "Eureka." About 20 years ago, these gentlemen produced reproduction Russia Iron boiler jackets for the Eureka, and the "Inyo," a locomotive at Chris's museum. Their approach was to adopt "gun bluing" as the principal chemical process to reproduce the essential functional element, as well as the look, of Russia Iron. Their results were outstanding and are well documented. However, rather than attempt to duplicate these efforts (which are dangerous, costly, and time-consuming) we set out to get equivalent results using commercially available processes.

The first goal was to find a supplier of iron sheets. Our theory was that the chemical difference between steel and iron may affect the hue and durability of the finished boiler jacket. Because of the unique nature of our restoration and approach, we secured a Heritage Grant from the National Railway Historical Society to assist with the costs of materials and labor. We located a supplier in the UK, Don Barker, known by his web site: www.pureiron.com. Eight iron sheets were purchased and shipped to our museum shops for under $3000. (See cost breakdown, below.)

Meanwhile, one of our volunteers used thin plastic sheets to create templates for the boiler jacket. This allowed us to ensure that the final jacket could be cut prior to fitting, and match exactly. These sheets were then removed and converted into CAD files; this permitted the iron to be cut on a computer-controlled water-jet cutting machine by a local firm.

Next, in order to achieve the "mirror-like" quality described in the literature describing Russia Iron (and its domestically-produced counterparts), we attempted to mechanically polish the material prior to chemical treatment. This was intended to be done rather inexpensively using a floor polisher and volunteer labor. When that failed, other techniques were attempted – without any satisfactory results. Having exhausted all other options, we finally contracted a local company, New England Castings of Standish Maine (www.newenglandcastings.com), to complete the polishing. While this greatly exceeded the intended budget, we were ultimately very pleased with the resulting mirror finish.

With the polishing complete, the sheets were transported to Cleveland, Ohio.

The key to replicating the jacket is the black oxide treatment offered by Cleveland Black Oxide (www.clevelandblackoxide.com.) The black oxide process is a chemical conversion coating. This means that the black oxide is not deposited on the surface of the substrate like nickel or zinc electroplating. Instead, the black oxide coating is produced by a chemical reaction between the iron on the surface of the ferrous metal and the oxidizing salts present in the black oxide solution. These oxidizing salts include penetrates, catalysts, activators and proprietary additives which all take part in the chemical reaction. The result of this chemical reaction is the formation of black iron oxide, magnetite (Fe_3O_4), on the surface of the metal being coated.

While this process has been around for many years, no other provider has previously had the capability to treat large metal sheets required for a locomotive boiler jacket. Moreover, no one to our knowledge had ever tried the black oxide treatment with iron rather than steel.

The process of treating the sheets only took a few hours and our intrepid transporter was quickly on the road again, returning to the museum with the results. Upon arrival, the sheets were coated with temporary plastic adhesive covering – so not to damage them during final installation, fitting of appliances, paint, etc.

Once the jacket was installed and locomotive assembly complete, the plastic adhesive covering was removed just prior to the first steam-up. For the first time in over 80 years, locomotive No. 9 gleamed in a reflective boiler jacket nearly identical to the one it wore when it was constructed.

Cost Breakdown (for materials and related expenses only)

Item	Budgeted	Actual Cost
Iron Sheets	$2500.00	$2193.20
Shipping/Tariffs/Fees (from UK)	$800.00	$832.76
Plastic Sheets for Template	$350.00	$350.00
Jacket Offset Standoffs	$300.00	$300.00
Polishing, In-house* (unsuccessful)	$250.00	$1041.08
Polishing, Outsourced	$0.00	$4500.00
Cutting of Sheets to Shape*	$0.00	$1200.00
Application of Black Oxide	$1000.00	$1100.00
Transportation (to/from Ohio)	$450.00	$450.00
TOTAL:	**$5650.00**	**$13,767.04**

**Originally intended to be done in-house using volunteer labor.*

First Conclusion: Iron vs. Steel
At the onset of this effort we asked Cleveland Black Oxide to apply their process on two samples: polished cold rolled steel obtained locally, and a sample of similarly polished English pure iron. The goal was to determine if the added expense of using pure iron would be worth it in the end result.

While subtle, the iron sample came back with a more vibrant, shifting color hue (based on angle of entrance light) bringing us closer to reproducing the original jacket. We were also curious how the formation of rust would be abated by the use of pure iron rather than steel. After a year in our locomotive shop, the oxidized steel sample had developed several small spots of rust, while the oxidized iron sample was free of rust.

Second Conclusion: Russia vs. America Iron
We understood the bulk of the surviving Portland Company records to exist at the Maine Historical Society, Portland, Maine; these records did not include material order lists. Shortly after we received our finished jacket panels, we discovered another library, the Baker Library at Harvard Business School, has the Portland Company material order records. While the specification sheet for Locomotive No. 9 (Portland Company 622) has been lost, the material order records for the locomotives constructed immediately prior and following (which were essentially the same as our No. 9) were consulted.

The material lists for those locomotives specified "A. R. Iron" (American Rolled Iron) to be used as the boiler jacket. Moreover, by 1888 the domestic production of planished iron sheets, such as Wood's Iron, had virtually replaced Russia Iron on the domestic market (see Gordon, p 195); this predates No. 9's construction in 1891. Therefore, it is quite likely that WW&F locomotive No. 9 was not constructed with a Russia Iron jacket, but rather with a planished iron jacket of American origin.

Third Conclusion: Bluish Grey vs. Bluish Black
All of the various manufacturing methods resulted in iron jackets of high reflectivity; it is generally accepted that this reflectivity had the greatest effect on the perceived color hue of the material.

When the first pictures of the replica boiler jacket appeared on the Internet, some were quick to observe that the color did not appear, to their eyes, to match their perception of Russia Iron. While our stated goal was to use modern methods and techniques to recreate that material, it became apparent that we had matched the original jacket quite well, but possibly not Russia Iron. In fact to our eye, our results appear to match the Ingot Iron Locomotive Jacket produced by ARMCO in the early part of the 20th century, which in ARMCO's advertising photography in 1930 appeared to be a highly reflective, near black finish.

These various details caused us to study and reach a hypothesis on why the various period products carried different subtle color hues. We theorize that the earliest versions, including Russia Iron, Woods Iron and A.R. Iron, involved an incomplete surface transformation to black oxide. This would allow small amounts of un-converted iron on the surface to be seen blended with the converted iron (black iron oxide.) This results from the primitive methods used which were aimed at particular color results rather than a complete chemical conversion of the surface. Continuing with this logic, we theorize that by the time ARMCO was producing their polished, black-oxide converted jacket material, they fully understood the conversion process and the merits of a complete conversion. Our black oxide treatment was done

commercially, in a manner which caused a complete chemical conversion of the iron sheet surfaces. For this reason, it is black, and very similar to ARMCO's product of the 1930s.

Black oxide is a magnetite coating, which by its nature affects nature of the color spectrum - reflecting differently depending on the angle of the entrance light. This causes any surface with a black oxide coating, whether partially or fully converted, to appear to have a bluish hue from some entrance light angles. Thus, an iron sheet with partial surface conversion to black oxide will appear bluish-grey in color, while an iron sheet with complete surface conversion to black oxide will appear bluish-black in color. Because of their reflectivity, both versions' color hues will vary greatly with the surrounding colors being reflected.

Some confirmation of this theory came from Chris Dewitt of the Nevada State Railroad Museum; he stated that he carefully timed the gun-bluing treatment of his jacket material in order to achieve the desired color hue. A full conversion of the surface to black oxide would negate the need for careful timing, as the chemical reaction ceases once full conversion has been achieved. It appears that by limiting the time in solution, a partial conversion, and subsequent lighter color hue, can be achieved.

Final Conclusion: Our Reproduction Process in the Spectrum of Reproduction Efforts

We are quite pleased with the final results. Our processing technique resulted in highly-reflective, deep bluish-black finish. The color hue varies with the angle of the entrance light, and is often silky smooth in appearance. We have found that the type of oil we wipe the jacket with to protect it affects these qualities greatly. We believe we have accurately reproduced the appearance of "ARMCO Ingot Iron Polished." The spectrum of reproduction efforts range from blue-paint finishes to using surviving original material. Our effort is a little off our target of American Rolled Iron. However, under most lighting conditions, one can't differentiate between the surviving pieces of original A.R. Iron finish and our reproduction. The reproduction's greatest attribute is certainly its reflectivity.

The restoration is complete and No. 9 will make its revenue debut in March 2016 with a photo charter, followed by many special events throughout the year. The public will be able to observe first hand a sight that is all too rare – a locomotive operating while gleaming in the sunlight, with its jacket material shining in a way that no paint or enamel could ever replicate. And we hope the "it needs paint" toddler, now several years older and wiser, will visit us again and appreciate that difference.

References:

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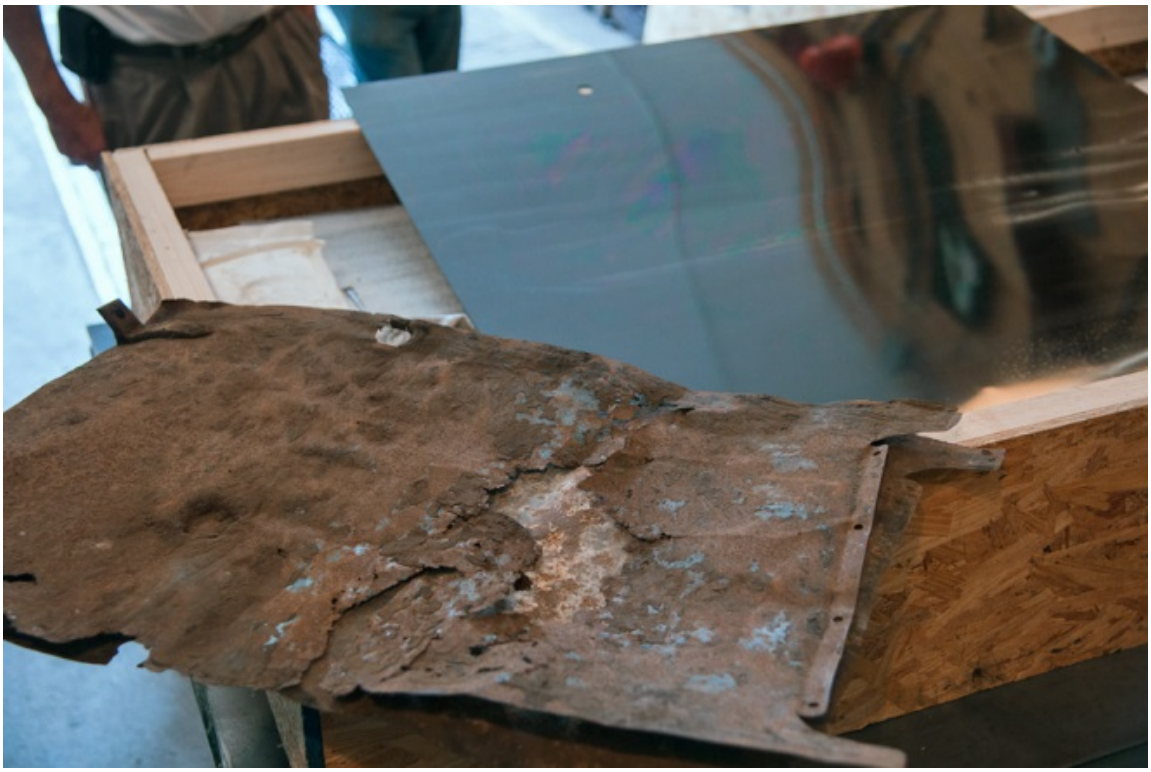
Top: Samples of the black oxide treatment were produced on both iron (left) and steel (right) sheets. The original jacket is in the center, and matches closely the iron.

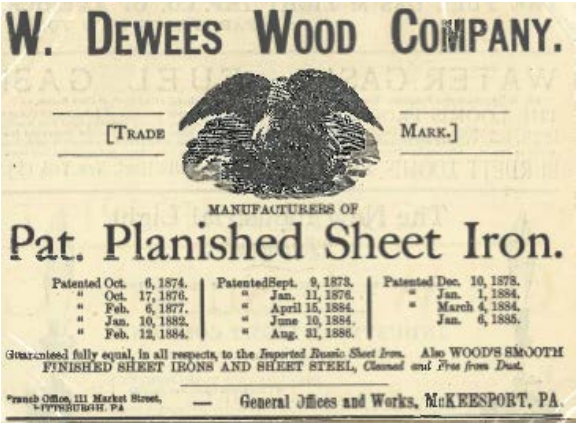
Bottom: The iron sample is placed against the boiler (and offsets) for inspection.



Above: A finished iron sheet following the black oxide treatment. In the foreground is a surviving piece of the original jacket. The portions of the original finish nearly match the reproduction.

Left: The finished reproduction jacket (boiler band) exhibits its various hues and reflective properties prior to installation.

Below: An advertisement for Wood Company Planished Sheet Iron. Note the graphic of the American eagle clawing into a Russian bear.



W. DEWEES WOOD COMPANY.

[TRADE MARK.]

MANUFACTURERS OF

Pat. Planished Sheet Iron.

Patented Oct. 6, 1874.	PatentedSept. 9, 1873.	Patented Dec. 10, 1873.
" Oct. 17, 1876.	" Jan. 11, 1876.	" Jan. 1, 1884.
" Feb. 6, 1877.	" April 15, 1884.	" March 4, 1884.
" Jan. 10, 1882.	" June 10, 1884.	Jan. 6, 1885.
" Feb. 12, 1884.	" Aug. 31, 1886.	

Guaranteed fully equal, in all respects, to the *Imported Russia Sheet Iron.* Also WOOD'S SMOOTH FINISHED SHEET IRONS AND SHEET STEEL, *Cleaned and Free from Dust.*

Branch Office, 111 Market Street, PITTSBURGH, PA. — General Offices and Works, McKEESPORT, PA.

Top: CMO Jason Lamontagne installs the first portion of the jacket prior to the cab's installation. Its reflective qualities are readily apparent.

Bottom: December 5, 2015. With its jacket shining in the afternoon sun, locomotive No. 9 moves under its own power for the first time in over 80 years while Jason Lamontagne and other volunteers look on.

1930 ARMCO advertisement from *Locomotive Cyclopedia*. 9th ed.

ARMCO Ingot Iron for Locomotive Jackets

Several grades of ARMCO Ingot Iron locomotive jacket sheets have been widely used for many years. Today, thirty-four Class 1 railroads in the United States have accepted this durable pure iron as standard specification.

ARMCO Ingot Iron Polished: This is a smooth, highly polished sheet, free from buckles, and exceptionally uniform in its deep blue coloring. Soft and ductile, it may be subjected to severe bending and forming without injuring the tight oxide coating. This particular grade is popular for passenger locomotives that haul the "crack" trains because of its attractive finish and close resemblance to the old Russian Planished Iron.

ARMCO Ingot Iron Grade A: This sheet is characterized by a very fine surface. It is usually specified when lacquers are to be used in finishing; or when a higher finish is desired, as for passenger locomotives.

ARMCO Ingot Iron Grade B: Here is a sheet which possesses a dense and velvety surface. It is especially suitable as a base for the heavier paints now widely employed in finishing certain types of locomotive jackets.

Fig. 586—The Jacket on This Locomotive Is Polished ARMCO Ingot Iron. The Trim Attractive Appearance and the Evidence of Careful Construction and Fitting Should Be Observed

Nine points of excellence: ARMCO Ingot Iron Locomotive Jacket Sheets have nine distinct advantages over ordinary materials used for this purpose:

1. Long resistance to corrosion.
2. Easy working qualities which reduce time and labor costs in the shops.
3. Uniform pure iron analysis.
4. Produces sound, dense, smooth welds.
5. Holds paint and other finishes.
6. Enhances beauty of locomotive.
7. May be used through more shoppings.
8. Insures low cost per year of service.
9. Standard sizes available from stock.

Standard Sizes: On roads using ARMCO Ingot Iron for locomotive jackets it is possible to hold storehouse stocks to a minimum and yet avoid causing any shop delays. The American Rolling Mill Company not only produces a quality product but also sees to it that this product is always available. The following

Fig. 587—This Modern Locomotive Is Covered with an ARMCO Ingot Iron Polished Jacket Chosen for Fine Surface, Ductility, Rust Resistance, and Assurance of Long-Time, Low-Cost Service

standard sizes are kept in stock, ready for immediate shipment:

Polished ARMCO Ingot Iron Locomotive Jacket

20 gage	30 in. by 120 in.
22 gage	28 in. by 60 in.
22 gage	28 in. by 84 in.
22 gage	30 in. by 72 in.
22 gage	30 in. by 84 in.
22 gage	30 in. by 96 in.
22 gage	30 in. by 120 in.

Grade A—ARMCO Ingot Iron Locomotive Jackets

18 gage	36 in. by 96 in.
18 gage	48 in. by 120 in.

Grade B—ARMCO Ingot Iron Locomotive Jackets

18 gage	36 in. by 96 in.
18 gage	48 in. by 120 in.
20 gage	30 in. by 60 in.
20 gage	30 in. by 72 in.
20 gage	30 in. by 84 in.
20 gage	30 in. by 96 in.
20 gage	36 in. by 84 in.
20 gage	42 in. by 96 in.
22 gage	30 in. by 60 in.
22 gage	30 in. by 72 in.
22 gage	30 in. by 84 in.
22 gage	30 in. by 96 in.
22 gage	36 in. by 72 in.
22 gage	36 in. by 84 in.
22 gage	42 in. by 84 in.

A consistently uniform iron: Time has shown that ARMCO Ingot Iron is a consistently pure and uniform iron. Sheet after sheet, shipment after shipment, year in and year out, it measures up to a predetermined high standard of chemical and metallurgical uniformity. Hence, ARMCO Ingot Iron can be depended on to perform consistently, whether in fabrication of the jacket, or in actual performance of the jacket when it goes into service on the locomotive.

ARMCO Ingot Iron resists rust: ARMCO Ingot Iron is a highly refined, pure iron, made especially to resist rust and corrosion. It contains fewer of the foreign substances that accelerate rust and corrosion than any other ferrous metals made in commercial quantities. This durable iron possesses the longest record of actual service of any low-cost, rust-resisting sheets and plates.

For other products and branch offices, see classified and alphabetical indexes.

THE AMERICAN ROLLING MILL COMPANY, MIDDLETOWN, OHIO