

Component Surface Preparation to Support Nondestructive Examination Activities

2021 TECHNICAL REPORT

Component Surface Preparation to Support Nondestructive Examination Activities

3002019428

Final Report, May 2021

EPRI Project Manager
J. Richardson

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THIS DOCUMENT WAS PREPARED BY THE ORGANIZATION(S) NAMED BELOW AS AN ACCOUNT OF WORK SPONSORED OR COSPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER EPRI, ANY MEMBER OF EPRI, ANY COSPONSOR, THE ORGANIZATION(S) BELOW, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS DOCUMENT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS DOCUMENT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT.

REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY ITS TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE, DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT, RECOMMENDATION, OR FAVORING BY EPRI.

THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

Copyright © 2021 Electric Power Research Institute, Inc. All rights reserved.

ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

Principal Investigator
J. Richardson

This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

Component Surface Preparation to Support Nondestructive Examination Activities. EPRI, Palo Alto, CA: 2021. 3002019428.

ABSTRACT

Most nondestructive examination (NDE) activities require a clean surface. However, surface preparation is probably one of the most subjective and difficult requirements for utility personnel to manage. It is often desirable to remove surface contaminants (such as oxides, rust, corrosion, and coatings) without thermal decomposition (melting) or damage to the structural integrity of the substrate, allowing the component to remain in service. Some NDE techniques, such as electromagnetic acoustic transducer systems and magnetic flux leakage examinations, may only require minimal surface preparation. Other NDE techniques, such as magnetic particle, phased array ultrasonic, and eddy current examination, may require complete removal of mill scale and external oxide scale. When small surface-connected defects are a concern, the selected surface preparation method should not mask surface cracks from detection.

Inadequate surface preparation can lead to suspect inspection results and incomplete exam coverage and can obscure or mask flaws that would be detected with proper preparation. Dry abrasive blasting is typically a first choice; however, for some NDE techniques, manual grinding can be used if the surface is properly cleaned. With manual grinding, it is paramount that the weld, the weld toes, and the base metal on each side of the weld to a distance of three times the wall thickness be ground smooth to bare metal.

This research explored alternatives to dry abrasive blasting and manual grinding, recognizing that the process used needs to produce a smooth finished surface without smearing or clogging surface discontinuities. It included discussions with manufacturers, surface preparation suppliers, and NDE vendors, as well as a brief literature survey to collect background information related to surface preparation technologies for typical power plant applications.

Keywords

CO₂ blasting

Grit blasting

Laser cleaning

Nondestructive evaluation

Surface preparation

Water blasting

Deliverable Number: 3002019428

Product Type: Technical Report

Product Title: Component Surface Preparation to Support Nondestructive Examination Activities

PRIMARY AUDIENCE: Utility plant engineers and maintenance managers

SECONDARY AUDIENCE: Nondestructive evaluation (NDE) support staff and safety personnel

KEY RESEARCH QUESTION

What are the different surface preparation technologies available to support NDE activities, and how effective are they?

RESEARCH OVERVIEW

This research evaluated legacy and emerging surface preparation technologies to support NDE activities through discussions with manufacturers, surface preparation suppliers, and NDE vendors.

KEY FINDINGS

- Dry abrasive blasting provides the best finish for performing subsequent NDE activities.
- Selection of the wrong abrasive size/type will reduce the detection effectiveness of some NDE methods.
- When dry abrasive blasting is undesirable or impractical, the available alternatives include CO₂ blasting, thermal descaling, and manual or tool-based cleaning.
- Some of the emerging surface preparation technologies, such as laser cleaning, bristle blasting, and dry ice blasting, compare unfavorably with the top traditional methods, dry abrasive blasting and manual grinding.
- Appendix B expounds on findings described in Section 4, providing photographic comparison between surface preparation methods.

WHY THIS MATTERS

The quality of each NDE examination performed is highly dependent on proper surface preparation. Poor surface preparation can not only lead to delays in the outage schedule, but also mask detection of flaws or service damage and reduce the sensitivity of the NDE examination method, leading to missed indications and increased risk of forced outages. Further, the need to repeat surface preparation can generate unneeded waste. It is critical that both surface preparation contractors and NDE examiners understand the requirements and details of proper surface preparation.

HOW TO APPLY RESULTS

The results included herein can be used to understand the following:

- Various surface preparation technologies
- The advantages and disadvantages of various common cleaning techniques
- How to apply alternative surface preparation technologies when dry grit blasting is undesirable or inappropriate for surrounding conditions
- Examples of surface preparation requirements for common boiler components

The report provides examples of acceptable and unacceptable surface preparation. These examples should be used to determine if surface preparation is at an acceptable level to accomplish the desired inspection results.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- The learnings from this research should be applicable to most nondestructive activities where fitness for service is important.
- The surface preparation technologies discussed in this report are applicable to other plant components where nondestructive inspections are required.
- New engineers and plant support staff should use the examples provided in the appendix when overseeing outage preparation activities.

EPRI CONTACT: Jay Richardson, Technical Leader, jrichardson@epri.com

PROGRAM: Boiler Life and Availability Improvement, P214

Together...Shaping the Future of Electricity®

Electric Power Research Institute

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA

800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

© 2021 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

CONTENTS

ABSTRACT	V
EXECUTIVE SUMMARY	VII
1 INTRODUCTION	1-1
Pre-Outage Walkdown	1-1
Foreign Material Exclusion	1-2
Personnel Protective Equipment (PPE)	1-3
2 SURFACE PREPARATION TECHNOLOGIES.....	2-1
Abrasive Blasting.....	2-1
Dry Grit Blasting (Sandblasting)	2-3
Wet Abrasive Blast Cleaning	2-5
Vacuum Blasting.....	2-7
Dry Ice Blasting	2-8
Laser Cleaning	2-10
Manual or Tool-Based Cleaning.....	2-12
Grinding/Sanding.....	2-12
Bristle Blasting.....	2-15
Pneumatic Needle Descaling	2-16
Thermal Descaling/Flame Cleaning	2-17
Ultra-High-Pressure Water Blasting	2-18
Surface Preparation Dust Reduction.....	2-19
3 TYPICAL SURFACE PREPARATION REQUIREMENTS	3-1
Considerations for Surface Preparation Prior to NDE	3-1
Surface Contaminant and Scale Removal	3-2
Typical Baseline Surface Preparation Requirements.....	3-4

4 SUMMARY OF SURFACE PREPARATION METHODS	4-1
5 REFERENCES	5-1
A COMPONENT SURFACE PREPARATION ILLUSTRATIONS.....	A-1
B SURFACE PREPARATION METHOD COMPARISON.....	B-1

LIST OF FIGURES

Figure 1-1 (A) Example of inadequate surface preparation around a welded radiographic plug, which led to an unacceptable surface examination. (B) After proper preparation to remove surface oxide/scale, the welded radiographic plug was reexamined, revealing a 170° crack.....	1-2
Figure 1-2 Pre-outage walkdown photo of NDE location	1-2
Figure 2-1 Blasting standards to determine cleanliness	2-1
Figure 2-2 Abrasive blasting process.....	2-2
Figure 2-3 Sampling of popular grit blast media used in power generation	2-3
Figure 2-4 Abrasive grit blasting operational diagram	2-4
Figure 2-5 Sandblasting operational principle.....	2-4
Figure 2-6 Example of dry abrasive blasting (sandblasting)	2-4
Figure 2-7 Wet abrasive blasting diagram	2-6
Figure 2-8 Wet abrasive blasting operational principle	2-6
Figure 2-9 Example of wet abrasive blasting surface after cleaning.....	2-7
Figure 2-10 Examples of vacuum blasting	2-8
Figure 2-11 Illustration of a vacuum blaster	2-8
Figure 2-12 Examples of various dry ice pellets	2-9
Figure 2-13 Example of dry ice (CO ₂) blasting.....	2-9
Figure 2-14 (A) Dry ice blasting of combustion turbine blade; (B) views of cleaned blade and uncleaned blade.....	2-10
Figure 2-15 Comparison of dry ice blast cleaning of fouled and dirty heat recovery steam generator (HRSG) tubes	2-10
Figure 2-16 Illustration of laser ablation process	2-11
Figure 2-17 Example of surface rust removal using an 800-watt pulsed laser cleaning system.....	2-12
Figure 2-18 Improper surface scale removal by power wire brushing	2-12
Figure 2-19 Example of manual surface preparation by coarse grinding (A) and power sanding with 80-to-120-grit abrasive wheels (B)	2-13
Figure 2-20 Improper surface scale removal along weld toes by power grinding.....	2-13
Figure 2-21 Incomplete surface scale removal along a long seam weld by power grinding. This surface condition is unacceptable for most NDE methods.	2-14
Figure 2-22 Incomplete surface scale removal from hanger attachment lugs, which could lead to false/missed indications	2-14

Figure 2-23 (A) Depiction of bristle tips' initial contact with the accelerator bar and subsequent rearward retraction prior to release, (B) micro-indentation caused by bristle tip impact, and (C) bristle brush surface profile	2-15
Figure 2-24 Photographs showing general use of bristle-blasting tool to remove surface scale and coatings	2-16
Figure 2-25 Example of high-temperature scale removal from a seam weld using a pneumatic needle descaler	2-16
Figure 2-26 Example surface peened by excessive pressure during needle descaler operation. This surface will require additional finishing/smoothing with 40-to-120-grit sanding disks.	2-17
Figure 2-27 Example of thermal descaling using an oxy-acetylene rosebud torch.....	2-18
Figure 2-28 Example of thermal descaling using a multiflame block burner.....	2-18
Figure 2-29 Example of UHP blasting.....	2-19
Figure 2-30 Example of insulation abatement/sandblasting enclosure around a hot reheat piping system after blast media removal.....	2-20
Figure 2-31 Example of insulation abatement/sandblasting enclosure built around scaffolding during a high-energy piping inspection	2-20
Figure 3-1 Example of incomplete scale removal along weld toes that could lead to false indications during surface examination	3-3
Figure 3-2 Examples of acceptable and unacceptable surface preparation	3-3
Figure 3-3 Three levels of preparation: surface with all scale removed, surface where mill scale remained and was cleaned by power wire brushing, and thick "original" oxide layer.....	3-4
Figure 3-4 Example surface roughness comparator block. Segment 1 is representative of a near-white metal finish	3-5
Figure 4-1 Example of phased array scan where manual overgrinding created dished areas along the scanning surface, resulting in loss of probe contact.....	4-2
Figure 4-2 Example of phased array scan where remnant surface oxide led to a low-quality signal (A) and signal amplitude was acceptable after surface oxide removal (B)	4-3
Figure A-1 Piping and header circumferential (girth) weld: acceptable grit blast finish (A) and surface preparation area recommendation (B).....	A-1
Figure A-2 Piping and header tee circumferential (girth) weld: acceptable combination grit blast/hand preparation (A) and surface preparation area recommendation (B).....	A-2
Figure A-3 Piping wye block girth weld: unacceptable/incomplete grit blast preparation (A) and surface preparation area recommendation (B).....	A-3
Figure A-4 Piping and header girth weld surface preparation recommendation.....	A-4
Figure A-5 Turbine piping girth weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)	A-5
Figure A-6 Steam line seam-welded pipe spool and seam-welded elbow: acceptable grit blast finish (A) and surface preparation area recommendation (B).....	A-6
Figure A-7 Typical longitudinal seam weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)	A-7

Figure A-8 Header stub tube: acceptable grit blast finish (A) and surface preparation area recommendation (B)	A-8
Figure A-9 Weld-o-let attachment weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)	A-9
Figure A-10 Typical welded lateral surface: acceptable grit blast finish (A) and surface preparation area recommendation (B)	A-10
Figure A-11 Boiler tube weld surface preparation and tube weld scanner; recommended surface preparation area for ultrasonic examination	A-11
Figure A-12 Grit-blasted boiler tube DMW surface preparation; recommended surface preparation area for DMW ultrasonic examination	A-12
Figure A-13 Piping and header girth weld: acceptable manual hand preparation	A-13
Figure A-14 Piping seam weld: acceptable manual hand preparation (A) and unacceptable hand preparation (failed to remove mill scale) (B)	A-13
Figure A-15 Example of a welded attachment showing acceptable manual hand preparation	A-14
Figure B-1 Pipe girth weld: examples of unacceptable and acceptable manual hand preparation	B-1
Figure B-2 Piping seam weld: examples of unacceptable hand preparation that failed to remove surface mill scale (A) and acceptable manual hand preparation finished with 120-grit sanding disk (B)	B-1
Figure B-3 Piping seam weld: examples of unacceptable hand preparation that failed to remove mill scale (A) and acceptable manual hand preparation finished with 120-grit sanding disk (B)	B-2
Figure B-4 Girth weld and seam weld: example of acceptable surface preparation using grit blasting	B-2
Figure B-5 Welded nozzle: Example of acceptable surface preparation using manual power wire brushing	B-3
Figure B-6 Example of unacceptable grit blast distance from weld toes for ultrasonic examination	B-3
Figure B-7 Girth weld: example of incomplete oxide removal from the weld beads	B-4
Figure B-8 Tube DMWs: examples of improper base metal oxide removal by wire brushing (A) and acceptable oxide removal by hand grinding (B)	B-4
Figure B-9 Grit-blasted tube weld: examples of acceptable base metal oxide removal and incomplete base metal oxide removal	B-5

LIST OF TABLES

Table 3-1 Comparison of representative surface roughness values.....	3-5
Table 3-2 Recommended minimum surface preparation dimensions.....	3-6
Table 3-3 Commonly applied NDE methods and recommended surface preparation methods	3-7
Table 4-1 Commonly applied surface preparation methods	4-4

1

INTRODUCTION

An effective in-service inspection process anticipates the occurrence of damage and provides for a cost-effective program to identify this damage early in its development, which allows for budgeted repair or replacement. In any instance where nondestructive examination (NDE) is used to target service damage, it is desirable to perform a high-quality inspection while optimizing inspection efficiency and recognizing the need to return the unit to service. This concept is universally applicable to high-energy piping, tubing, headers, valves, turbines, and various other power and industrial systems and components. Properly inspecting plant piping, boilers, turbines, and various other components for service damage is an integral part of proper asset management.

Planning and execution of NDE inspections includes one seemingly minor activity that can have a very significant impact on the success of these inspections: surface preparation. Most NDE methods require the examination surface and some of the adjacent area to be clean, dry, and free of all dirt, oil, grease, paint, lint, scale, weld spatter, welding flux, and other extraneous material that could obstruct proper application of the method.

The quality of each NDE is highly dependent on proper surface preparation. Inadequate surface preparation can reduce the effectiveness of the NDE method, leading to missed indications, incomplete coverage, and suspect results. It can obscure or mask evidence of flaws or service damage that would be detected with proper preparation, lead to delays in the outage schedule, and increase risk. An example is shown in Figure 1-1. Here the initial surface preparation for a welded radiographic plug was performed with a powered wire wheel brush, which only shined the oxide scale surface rather than removing it. When the NDE examination was performed, the remnant scale obscured the indication formation and detection of the weld crack. Proper surface scale removal was then performed by manual grinding to a 120-grit finish. Reexamination of the radiographic plug after this scale removal revealed a 170° weld toe crack.

The need to perform proper cleaning should be verified with the appropriate NDE personnel before proceeding with surface preparation activities. Each specific NDE method has its own requirements for surface preparation that will be discussed in greater detail in Section 3.

Pre-Outage Walkdown

It is often recommended that a walkdown of the equipment requiring NDE (Figure 1-2) be conducted to identify scaffolding requirements and surrounding limitations that may constrain surface preparation methods. The walkdown can also provide a clear understanding of the work scope, the appropriate surface preparation method for each inspection location, and unforeseen challenges.

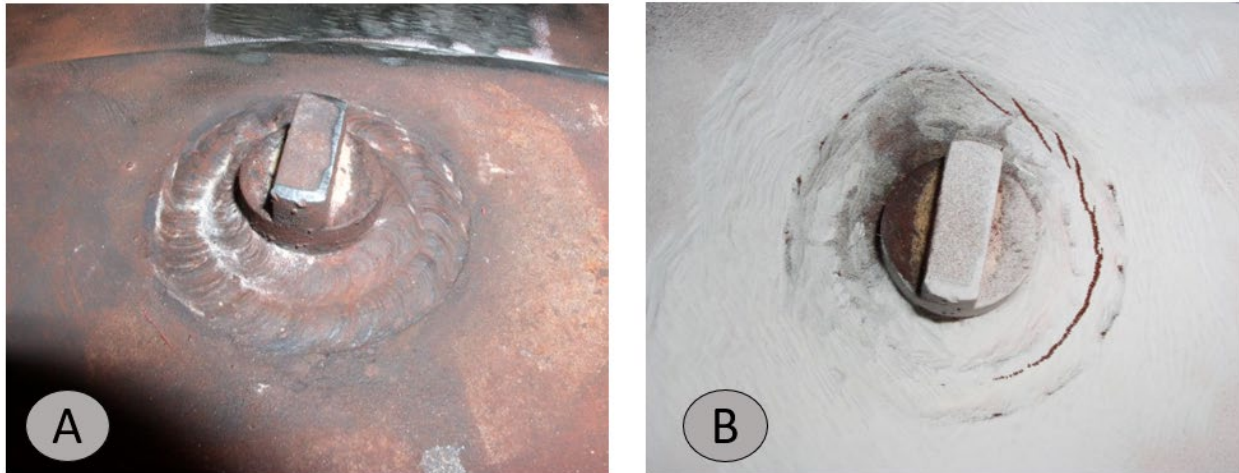


Figure 1-1
(A) Example of inadequate surface preparation around a welded radiographic plug, which led to an unacceptable surface examination. (B) After proper preparation to remove surface oxide/scale, the welded radiographic plug was reexamined, revealing a 170° crack.



Figure 1-2
Pre-outage walkdown photo of NDE location

Foreign Material Exclusion

The potential ingress of foreign material (FM) into systems, equipment, and components is a continuous concern at power plants. This ingress can cause loss of generation, degradation of components and equipment, and long-term increases in operation and maintenance costs. A formal foreign material exclusion (FME) program is key to ensure FM does not enter plant systems or equipment [1].

The surface preparation process can create significant dust and debris. The following elements of a robust FME process should be reviewed and potentially implemented:

- A pre-job brief including discussion of FME should be completed prior to the start of the surface preparation.
- Potential FM entry points should be identified, and FME devices (such as plugs and covers) should be used to protect these openings from FME entry.
- If significant dust/debris will be created during the surface preparation process, a tent or covering for the workspace may be needed to avoid FM entry into equipment or systems in the surrounding area.

Additional guidance on development of an effective FME plan, including self-checking, peer checking, and pre-job and post-job briefs, is available in the EPRI report *Foreign Material Exclusion Guidelines* (1019805) [1].

Personnel Protective Equipment (PPE)

Several of the surface preparation techniques use media, with or without fluids, to dislodge and remove the contaminants. Some of these can create significant dust and debris. Proper PPE should always be worn in a power plant, but additional use may be needed during surface preparation. These additional PPE items could include (but are not limited to):

- Safety goggles (fully enclosed) or face shield
- Additional gloves
- Additional hearing protection
- Face mask or respirator, depending on media and amount of dust

Additional needs for PPE should be discussed during work planning and again during the pre-job brief. These items should be available to the personnel performing and supporting the surface preparation.

2

SURFACE PREPARATION TECHNOLOGIES

The quality of each NDE examination is highly dependent on proper surface preparation. Poor surface preparation can not only reduce the effectiveness of the examination method, but also mask evidence of flaws or service damage, leading to missed indications and increased risk. Poor surface preparation can also lead to delays in the outage schedule.

The material or materials to be cleaned should be considered prior to selection of surface preparation and cleaning methods. Some materials, for example, cannot be exposed to chemicals and must be cleaned using purely mechanical means. Other components must be cleaned using chemicals because of surface finish requirements or dimensional tolerances that cannot be disturbed [2]. Component operating conditions and whether there is heavy, tenacious scale or just general corrosion should be assessed. The selection of surface preparation method should be coordinated amongst personnel knowledgeable in plant operations and maintenance, NDE, and materials to ensure the proper selection is made.

To support NDE activities, the surface should be prepared to a near-white metal finish in accordance with SSPC-SP 5, NACE No. 1, and ISO 8501 Sa 3, standards (essentially an exposed, clean metal surface with no significant surface damage or residual roughness from the surface preparation process). Typical surface cleanliness images from recognized standards are provided in Figure 2-1. When using abrasives for surface preparation, damage to the substrate (metal surface) should be avoided. The resultant surface profile should be equivalent to <1 mil (25.4 μm). A typical paint coating profile is >2.5–5 mil (63.5–127 μm).



Figure 2-1
Blasting standards to determine cleanliness [3]

Abrasive Blasting

Abrasive blasting is a surface finishing process using compressed air or pressurized water to propel a stream of abrasive media through a nozzle against a surface under high pressure to remove surface contaminants and smooth, roughen, or shape a surface (Figure 2-2). This action allows the abrasive particles to quickly remove paint, rust, scale, ash buildup, corrosion, dirt, and discoloration from many different types of surfaces.

Kinetic energy is responsible for most of the work done by blast technologies. Upon impact, kinetic energy is transformed into a removal force generated by the mass and speed of the pellet. A surface contaminant is removed once the removal force exceeds the adhesion force.

Just as there are different types of surfaces to be cleaned, there are many different types of abrasive materials that can be used. These media include aluminum oxide, silicon carbide, coal slag, garnet, glass beads, walnut shells, and corncobs. The three common methods of abrasive blasting are dry abrasive grit blasting (sandblasting), wet abrasive blasting, and vacuum blasting.

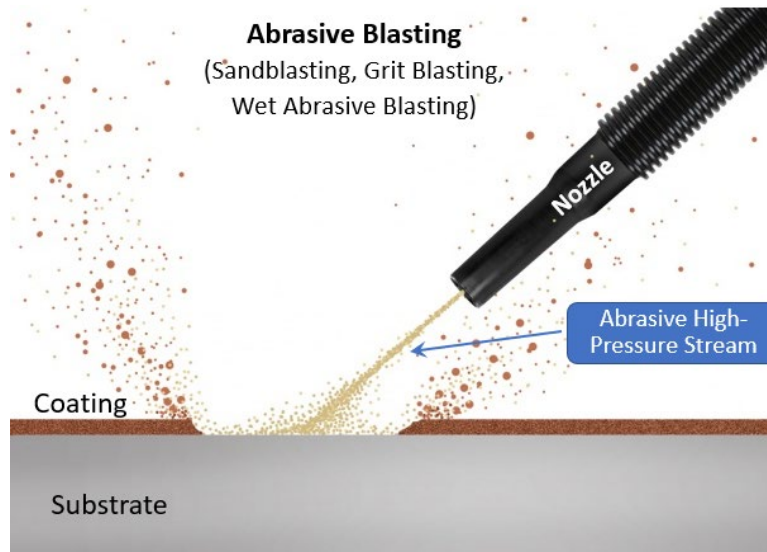


Figure 2-2
Abrasive blasting process

Selection of the blasting media for surface preparation is vital. Different media types have different characteristics and hardness and, if not carefully chosen, can damage the surface. Knowing the surface characteristics and the maximum allowable profile depth for successful NDE methods ensures that discontinuities open to the surface are not obscured, smeared, or clogged by abrasive materials or pinged over. Four properties of abrasives contribute surface roughness (increased profile depth) after preparation: size, shape, hardness, and density.

The shape of the abrasive affects how deeply it cuts into the contaminant and underlying substrate. Shapes are classified according to their angularity. Rounded particles produce a more even, peened surface and are good for breaking away hard, brittle coatings and mill scale. Angular particles cut through soft coatings and rust, cleaning faster and producing sharper anchor patterns.

Harder abrasives cut a deeper profile, removing mill scale, rust, corrosion, and brittle coatings (oxide). Softer abrasives are best for removing dirt, oil, grease, and paint without damaging the underlying substrate.

As an example, a 120-mesh garnet leaves a typical profile of 0.5 mil to 1.5 mil, while a 50/100-mesh crushed glass leaves a typical profile of 0.75 mil to 2.5 mil. A sampling of popular blast media is provided below and in Figure 2-3.



Figure 2-3
Sampling of popular grit blast media used in power generation [4]

- Garnet is a naturally occurring gemstone with excellent naturally abrasive properties. It is a relatively hard, dense material with a semiangular form and is regarded as an expendable single-use abrasive. It also produces low amounts of dust during the blasting operation and is excellent for removing tough coatings, paint, rust, and mill scale from steel.
- Aluminum oxide [5] is a high-grade alumina manufactured from bauxite, silica, coke, and iron. It has exceptional hardness and high recyclability, and it is effective at removing surface debris. It also produces low amounts of dust during the blasting operation and is reusable.
- Walnut shell grit is a hard, fibrous product made from ground or crushed walnut shells. It is extremely durable, angular, and multifaceted, yet is considered a “soft abrasive.”
- Coal slag, a byproduct of coal-burning power plants, is considered a “green” abrasive because it would otherwise be disposed of as waste. It is a relatively cheap, low-dusting abrasive with low free silica. However, it is considered a dirty abrasive and is not widely used in wet abrasive blasting because of the high quantity of “fines” (fine particles), which mud up on the surface. Typical applications include the removal of rust, paint, weathered coatings, and scale from steel

Dry Grit Blasting (Sandblasting)

Dry grit blasting uses compressed air to propel a high-pressure stream of a dry abrasive medium like aluminum oxide or garnet against the surface of the part or component at a high velocity (Figure 2-4). The stream loosens surface contaminants and scale through a chiseling action much like that of an ice pick, but it often takes away part of the substrate as well. This chiseling action and substrate removal are depicted in Figure 2-5. An example of dry grit blasting is provided in Figure 2-6.

Dry grit blasting has been used within the power generation industry for cleaning steam turbine components, high-energy piping welds, headers, boiler tubes, evaporators, and surfaces requiring painting.

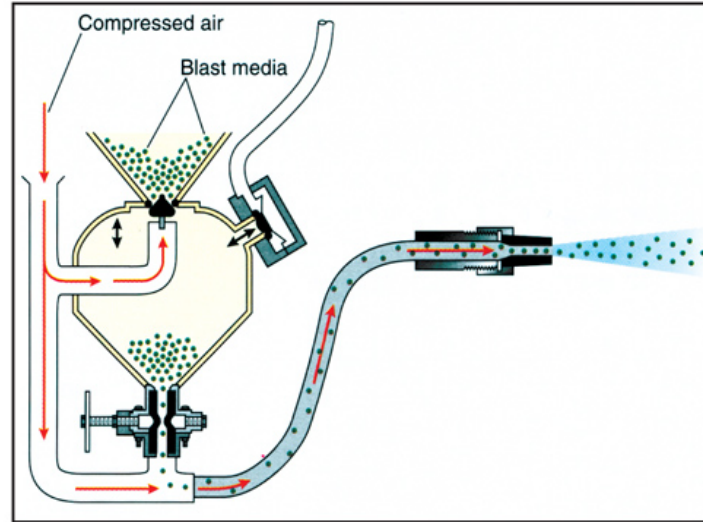


Figure 2-4
Abrasive grit blasting operational diagram [6]

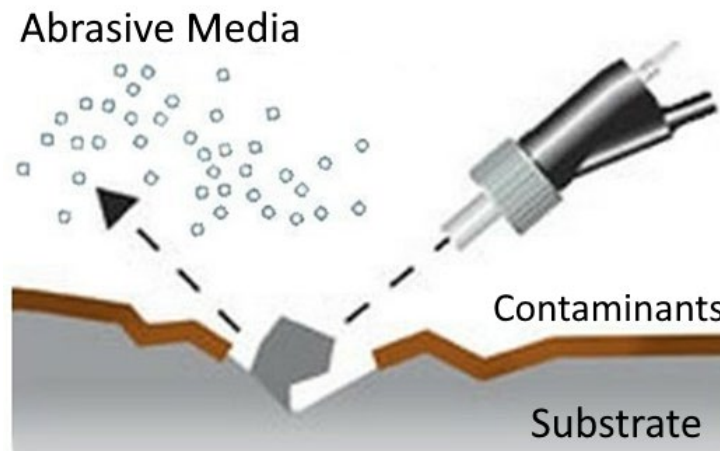


Figure 2-5
Sandblasting operational principle



Figure 2-6
Example of dry abrasive blasting (sandblasting)

Wet Abrasive Blast Cleaning [7, 9]

The introduction of water into an abrasive blast stream contributes to reduction of the dust hazard, particularly when removing water-soluble contaminants and old lead-based paints. Conventional wet abrasive blast cleaning uses the same pressures as conventional dry blasting, and the equipment is similar. The water is usually introduced immediately behind the nozzle (Figure 2-7) so that it is atomized and accelerated through the nozzle orifice along with the air and abrasive. Water can also be introduced in controlled amounts at the base of the blast pot and is then mixed with the air and abrasive as it passes along the blast hose. The water cushions the impact of the wet abrasive on the surface, and removed fine particles are sequestered in water droplets (Figure 2-8). The additional water weighs the particles down, preventing dust.

Wet abrasive blasting is a clean and efficient way to remove paint, mill scale, rust, grease, and other coatings from surfaces. Some wet abrasive processes use inhibitors in the water to prevent rusting of the cleaned surface. It is important to establish whether any remaining traces of such inhibitors will be compatible with the paint coating to be applied subsequently. Where inhibitors are not used, any surface rusting after wet abrasive blasting is usually removed by a final light dry blast cleaning. An example of a welded nozzle that was wet blast cleaned prior to NDE is provided in Figure 2-9.

There are three types of wet abrasive blasting units: slurry, venturi, and vapor abrasive blasters [8].

- Slurry blasters are dry abrasive blasting machines equipped with nozzles for adding water to the blast media prior to their touching the part surface. One style encircles the blast stream with a curtain of water (halo ring) after it leaves the nozzle. A second style uses a water injection nozzle to inject water into the blast stream just before it reaches the blast nozzle.
- In a venturi blaster, water and blast media are combined in the pot. Under influence of the passing pressurized airstream, this combined mixture is sucked out of the pot (the venturi effect). The amount of pressurized air determines the volume of water and blast media in the blast stream.
- Vapor abrasive blasters combine water and abrasive in a pot under water pressure. The resulting moist abrasive is injected into the airstream by hydraulic controls, affording an independent and fine control over the air pressure and the water/abrasive consumption rate. Vapor abrasive blasters can effectively blast at low pressures (30 psi) and at pressures as high as 170 psi, using only the amount of water and media required by the application.

Wet grit/vapor blasting is typically used for cleaning water wall tubes in the boiler, air preheater baskets, the precipitator, evaporators, and other equipment that can get wet during cleaning without being damaged.

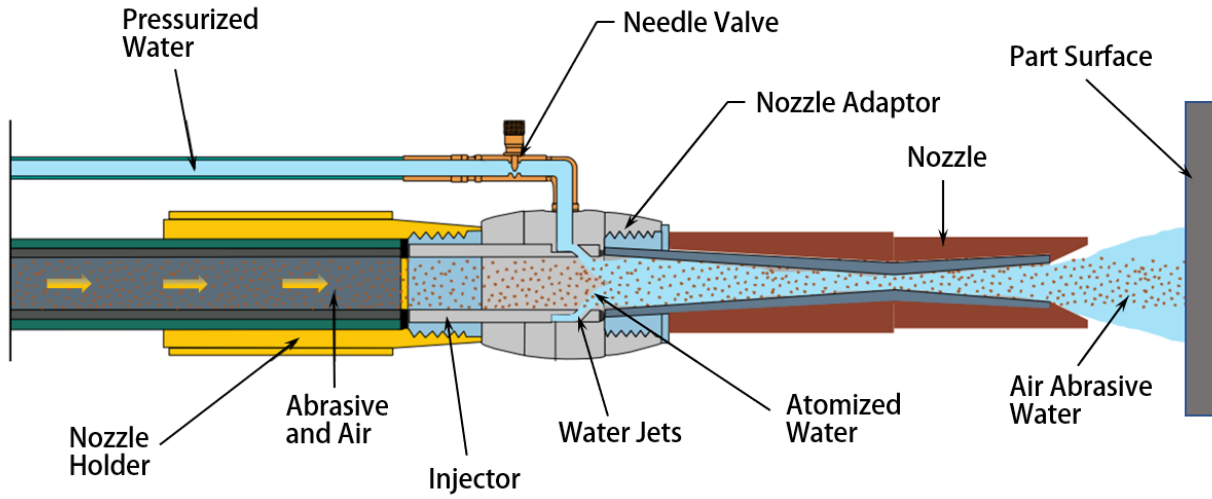


Figure 2-7
Wet abrasive blasting diagram [9]

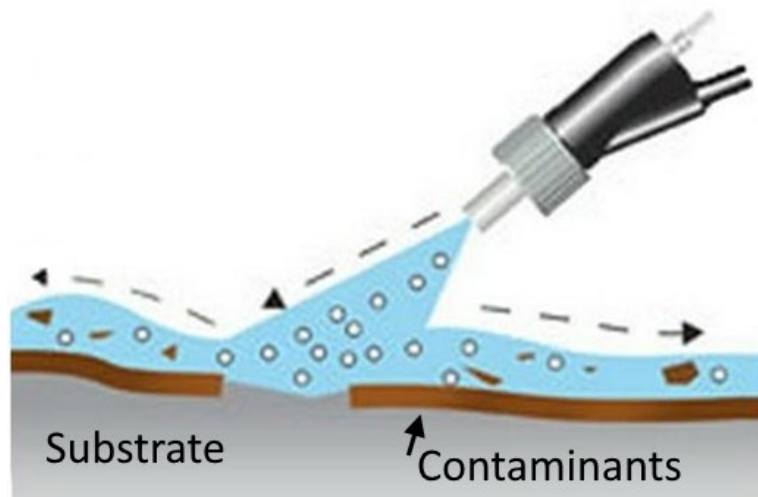


Figure 2-8
Wet abrasive blasting operational principle [8]



Figure 2-9
Example of wet abrasive blasting surface after cleaning

Vacuum Blasting [10]

Vacuum blasting is a dustless solution with no airborne abrasives and can be performed without disruption of adjacent activities or impact to on-site personnel. As in dry abrasive blasting, abrasive material is propelled towards the part by compressed air. A shroud surrounds the blast and suction head (Figure 2-10), and a vacuum line collects the dust, spent abrasives, and removed material to a collection unit. That unit continuously separates dust and loosened particles from the blast media, recycling the blast media back into the pressurized air flow, as shown in Figure 2-11. The dust and loosened particles are collected in a waste bin for disposal. The operator can blast continually without losing visibility of the work area. Production is slower than with open blasting and may be difficult on irregularly shaped surfaces. The amount of debris entering the air and the amount of cleanup are kept to a minimum if the work is done properly (for instance, the shroud is kept against the surface). Because the blast nozzle is always in the same proximity to the surface, a uniform blast is obtained as the operator overlaps strokes, achieving the desired surface cleanliness.

Vacuum blasters are typically used around critical equipment when dust and abrasive contamination needs to be avoided.



Figure 2-10
Examples of vacuum blasting [11]

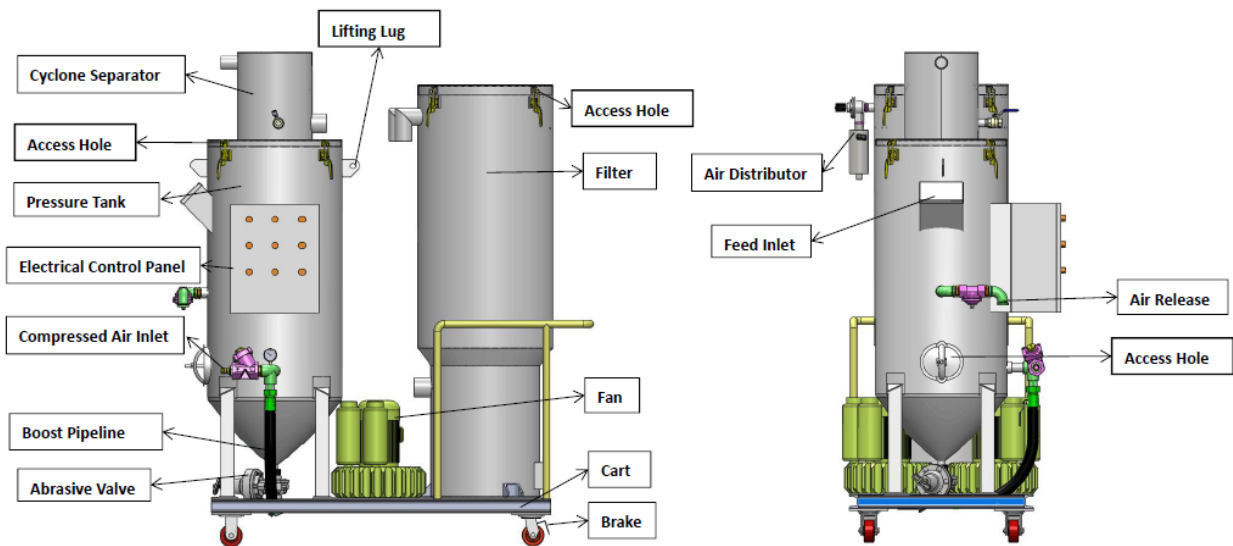


Figure 2-11
Illustration of a vacuum blaster

Dry Ice Blasting [12]

Dry ice (CO_2) blasting is a nonabrasive, nonconductive form of blast cleaning utilizing dry compressed air or nitrogen gas to propel dry ice pellets at extremely high velocity (up to 305 m/s [1000 ft/s]) against the surface to be cleaned. The dry ice pellets (Figure 2-12) sublime immediately after surface impact (changing from solid directly into CO_2 gas, as illustrated in Figure 2-13). The instantaneous change from the solid to the vapor state increases its volume 750-fold. This micro-explosion of the pellets causes microscopic shockwaves, allowing the loosened contaminants to be carried away by the flow of the compressed air, leaving no solid residue after blasting [13]. Dry ice blasting might better be compared to a spatula, as it lifts away contaminants with little or no substrate damage.



Figure 2-12
Examples of various dry ice pellets

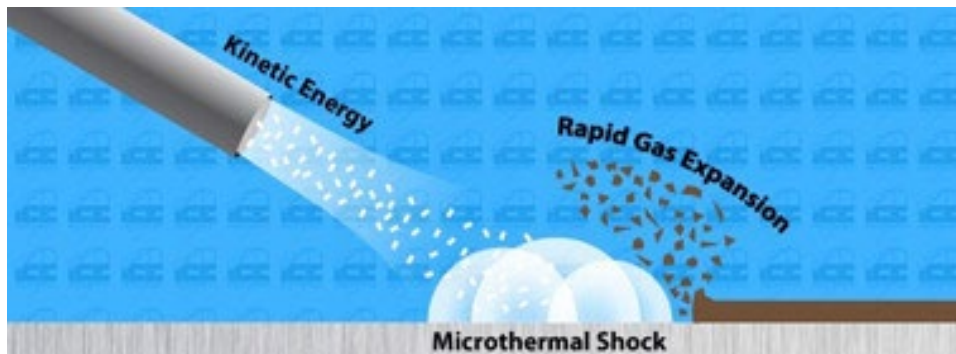


Figure 2-13
Example of dry ice (CO₂) blasting

Kinetic energy working in combination with this molecular expansion makes CO₂ blasting effective. Thermal differentials assist in breaking the contaminants' bond with the surface and aid their removal. As the propelled dry ice pellets impact the surface, a slight temperature differential is established between the surface and the contaminate. Each surface will accept the BTUs of the dry ice at a specific rate. The thermal differential between the surface and the contaminate will initiate or assist in the removal process. CO₂ blasting does not remove mill scale, rust, or oxide without damaging the substrate. To limit damage to the substrate, these items would need to be removed by a secondary process.

CO₂ blasting works best at removing loose surface contamination on hard, nonporous surfaces. CO₂ blasting does not accumulate contaminants in the waste stream, is nonabrasive, and will not damage critical electronics, electrical equipment, or plant structures. CO₂ blast cleaning has a slower production rate than other abrasive blast processes, partly because of its nonabrasive properties. However, in most cases, the overall CO₂ cleaning process is much faster than conventional cleaning methods using abrasives. This is primarily because very little cleanup time is required, as there is no chemical or secondary waste to be removed and processed. There is also very little, if any, drying time. For these reasons, CO₂ blast cleaning is quicker and very competitive in cost when all factors are considered. Examples of dry ice blast cleaning are provided in Figure 2-14 and Figure 2-15.

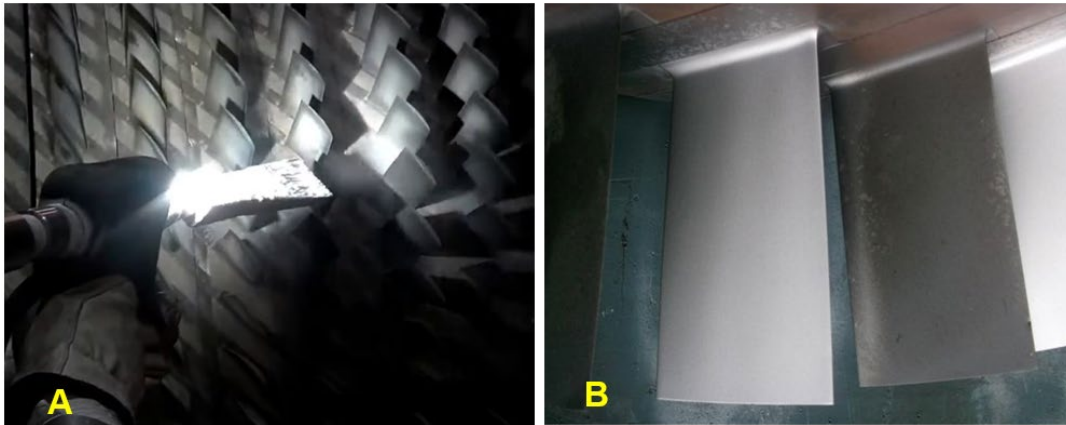


Figure 2-14
(A) Dry ice blasting of combustion turbine blade; (B) views of cleaned blade (left) and uncleaned blade (right)

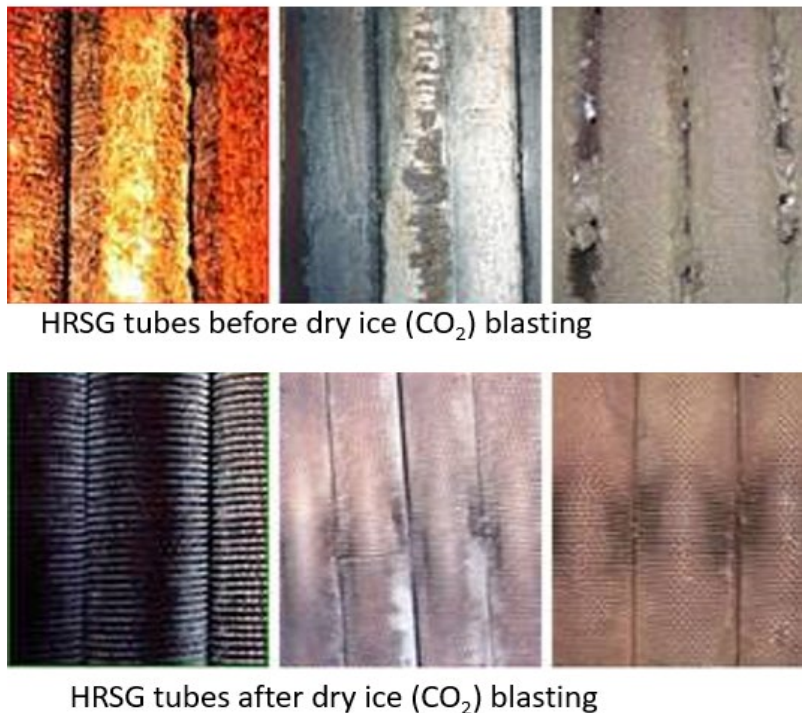


Figure 2-15
Comparison of dry ice blast cleaning of fouled and dirty heat recovery steam generator (HRSG) tubes

Laser Cleaning [14, 15]

Laser cleaning, or laser ablation, is a process whereby a surface is bombarded with focused light energy in short pulses (typically 50 watts or greater). The laser pulse excitation (on/off action) disrupts the contaminant layer by rapidly heating the targeted material to temperatures much higher than that of the substrate surface. The difference in heat escalates rapidly; this makes the contaminant layers highly unstable, causing them to vaporize and ultimately dislodge from the substrate surface (Figure 2-16).

All materials have different ablation thresholds due to their different properties and molecular bonds. Ablation thresholds have been measured for a variety of metals; they range from 0.1 to 10 J/cm² and are influenced by the laser beam wavelength and pulse duration [16]. The ablation rate, or amount of material being removed, is proportional to the logarithm of a laser's power. The efficiency of the laser beam absorption depends on the material reflectivity, the quality of the surface, and the properties of the contaminant on the surface. To successfully remove a layer of material from a substrate, the transferred energy from the laser beam must be above the ablation threshold of the material to be removed.

Using a pulsed fiber laser, the power, wavelength, pulse energy, and pulse length are adjusted to control the amount of material removed by a single laser pulse. To increase the rate of ablation, the pulse energy is increased. To increase penetration depth, a longer pulse is used, but increasing pulse length may require increasing pulse energy to ablate the material. Both the thickness of the layer and its physical (absorption) properties have an influence on the speed of cleaning or, more precisely, on the surface cleaning rate.

The ablation depth can be controlled within 5–10 μm, making laser cleaning equally suitable for rapid and deep rust removal without damaging the substrate. In general, the removal of layers with a thickness of more than 0.5 mm is uneconomical, and aggressive laser cleaning can result in substrate damage (due to overexposure to the laser beam). An example of rust removal with laser cleaning is shown in Figure 2-17.

While laser cleaning has some uses within the power generation industry, the typical application is for the removal of paint, coatings, grease, and rust using 200-watt units. Newer laser cleaning designs will also remove thin layers of mill scale and oxide without damaging the base metal substrate.

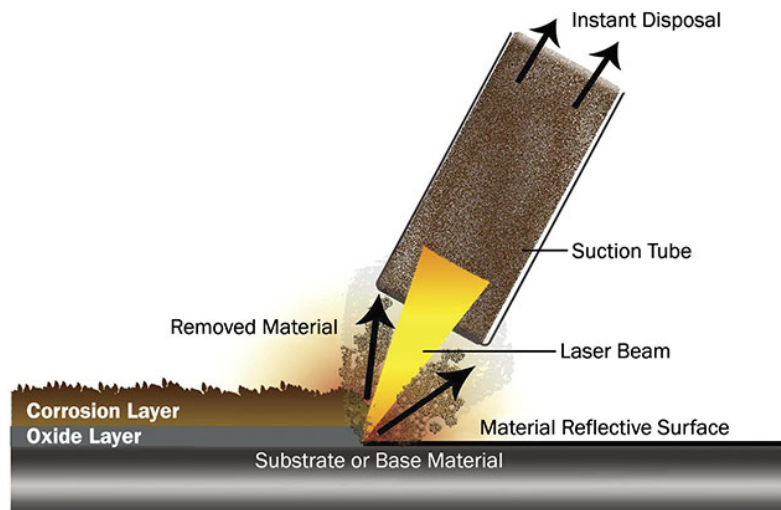


Figure 2-16
Illustration of laser ablation process [16]

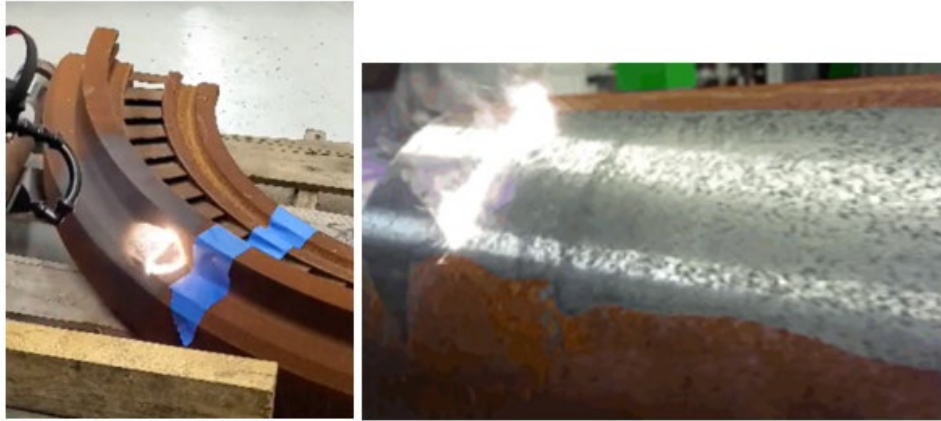


Figure 2-17
Example of surface rust removal using an 800-watt pulsed laser cleaning system

Manual or Tool-Based Cleaning

Grinding/Sanding

Power wire brushing is suitable for removing surface rust and light coatings. It is not suitable for the removal of scale, ash deposits, or grease. When grease is present, wire brushing tends to smear it across the surface, requiring supplemental chemical cleaning. Power wire brushing the component surface and welds can remove loose material but will not adequately remove tightly adhered coatings or oxide layers. It also has difficulty removing scale between the weld toes on rough multipass welds, as illustrated in Figure 2-18.



Figure 2-18
Improper surface scale removal by power wire brushing

Manual surface preparation is an acceptable method when abrasive blasting is too costly or impractical. It can be performed on large or small welds and components. When performing manual surface preparation, it is preferred to remove coatings or oxide layers using grinding stones as a first pass, and to follow up with a second pass using an abrasive wheel with a grit size ranging from 80 to 120 [17] (Figure 2-19). The manual surface preparation process is labor

intensive, time consuming, and dusty, making it an expensive cleaning option when compared to some grit-blasting processes. In addition, the resulting finish provides lower-quality inspection results, particularly for the detection of surface cracking by wet fluorescent magnetic particle testing (WFMT). Remnant scale and uneven grinding can also interfere with WFMT and ultrasonic examinations (UT) (Figure 2-20 and Figure 2-21). Manual grinding preparation may also be impractical for branch connections, hanger attachments, and tube-to-header welds due to limited access from adjacent connections (Figure 2-22).

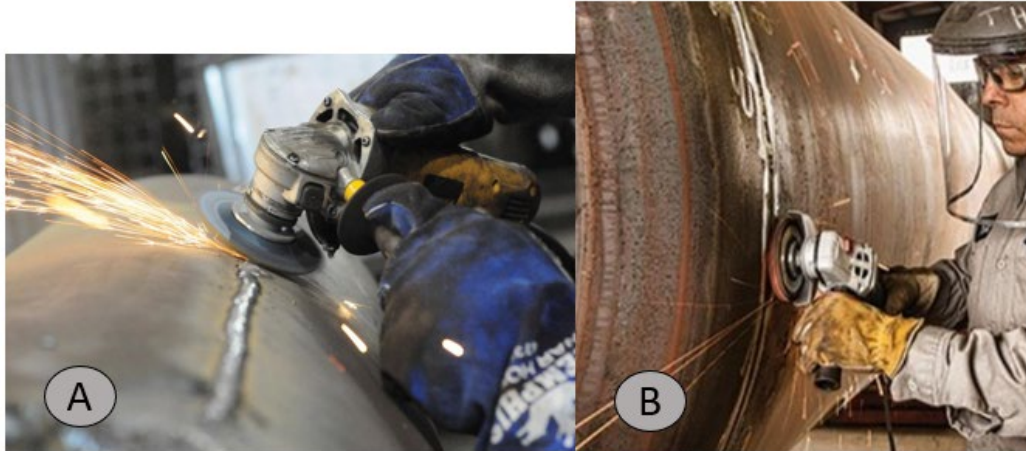


Figure 2-19
Example of manual surface preparation by coarse grinding (A) and power sanding with 80-to-120-grit abrasive wheels (B)

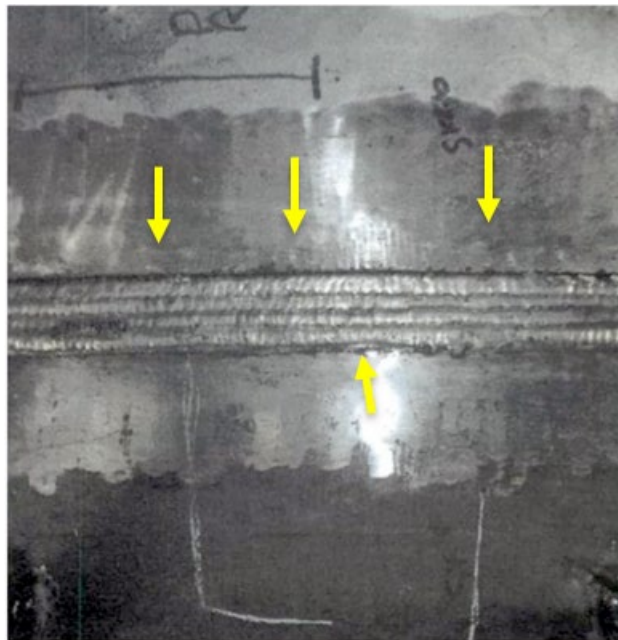


Figure 2-20
Improper surface scale removal along weld toes by power grinding



Figure 2-21
Incomplete surface scale removal along a long seam weld by power grinding. This surface condition is unacceptable for most NDE methods.



Figure 2-22
Incomplete surface scale removal from hanger attachment lugs, which could lead to false/missed indications

Bristle Blasting [18, 19]

Bristle blasting is based upon synchronized/repeated impact of bristle tips on the component surface. The process removes corrosion and leaves a multitude of impact craters similar to those formed during grit blasting. Bristle blasting uses a specially designed handheld power tool with a belt containing sparsely populated wire bristle tips that are bent forward against the rotation direction. During belt rotation, the wire bristles are temporarily halted by an accelerator bar, storing additional (potential) energy, then released. This action increases kinetic energy, accelerating the bristles prior to impact with the surface (Figure 2-23). The multitude of bristle impacts mechanically peens the surface, removing corrosion, coatings, scale, temper colors, and other oxidation from the component surface.

During use, the face of the bristle tool is oriented perpendicular to the surface and the bristle tips are brought into direct contact using minimal applied force. The rotating tool is gradually moved along the transverse direction (either left or right), removing scale, corrosion, and coatings (Figure 2-24). Tool force and feed rate are determined by direct experimentation on the surface coating requiring removal.



Figure 2-23

(A) Depiction of bristle tips' initial contact with the accelerator bar and subsequent rearward retraction prior to release, **(B)** micro-indentation caused by bristle tip impact, and **(C)** bristle brush surface profile



Figure 2-24
Photographs showing general use of bristle-blasting tool to remove surface scale and coatings

Pneumatic Needle Descaling

A needle descaler has several fine chisels known as needles. When activated, compressed air forces a piston forwards and backwards, reciprocating the steel needles at speeds up to around 4000 times per minute to chip away at scale, paint, and contaminants (Figure 2-25). Incorrect use can cause peening that will seal or obscure discontinuities that are open to the surface, making them undetectable by most NDE surface methods (Figure 2-26). When this occurs, the use of the needle descaler should be followed by finishing the surface with 80-to-120-grit sanding disks to remove smeared metal and smooth the pin indentions.

Manual needle descaling is typically used to remove thick layers of oxide scale from girth and seam welds selected for NDE examination.



Figure 2-25
Example of high-temperature scale removal from a seam weld using a pneumatic needle descaler



Figure 2-26
Example surface peened by excessive pressure during needle descaler operation. This surface will require additional finishing/smoothing with 40-to-120-grit sanding disks.

Thermal Descaling/Flame Cleaning

Thermal descaling works by differential expansion of the scale and the steel substrate. An acetylene flame is used to heat the outer thick thermal scale layer, dislodging (hot popping) it from the steel substrate, as shown in Figure 2-27. The oxy-acetylene torch is positioned approximately 2 to 4 inches from the surface at an angle of 30° to 50°. This angle keeps the releasing scale from popping into the torch and extinguishing the flame. The torch is slowly moved back and forth across a small area, creating a difference in thermal expansion between the scale and the underlying base metal. Use of thermal crayons is recommended to avoid overheating the substrate. When the scale starts to release (pop), the speed of the torch movement should be increased to avoid heating the steel base metal. If the scale and the base metal are heated at the same time, the scale will not release. If the oxide scale is too thin, thermal descaling may not be able to create a wide enough temperature differential to release the oxide from the steel substrate.

In lieu of an oxy-acetylene rosebud torch, a multiflame block burner may be used. The block burner contains several closely spaced nozzles designed to produce a row of small flames covering a larger area (Figure 2-28).

Thermal descaling is an efficient method for removal of thick oxide scale and can be used when high-pressure blasting (dry or wet) is unsuitable due to FME or environmental control issues. It can remove thick layers of oxide scale from girth and seam welds selected for NDE examination. After scale removal, finishing/smoothing of the surface with a power wire brush or 40-to-120-grit sanding disks may be required.



Figure 2-27
Example of thermal descaling using an oxy-acetylene rosebud torch

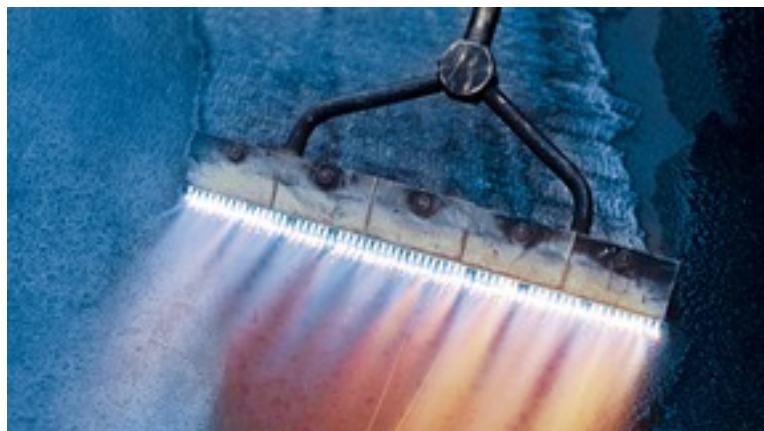


Figure 2-28
Example of thermal descaling using a multiflame block burner [20]

Ultra-High-Pressure Water Blasting

Ultra-high-pressure (UHP) water blasting is defined by the Society for Protective Coatings (SSPC) as blasting with water pressure greater than 25,000 psi (1400 bar) to remove a coating or contaminant from a substrate (Figure 2-29). UHP blasting has the advantage of not generating spent abrasive and thereby avoiding the cost of disposing of that abrasive. Also, at the higher pressures, lower volumes of water are used, resulting in lower disposal costs than traditional water blasting methods [21].

While these high pressures can be effective for cleaning, they are also dangerous, produce high noise levels, and require specialized hearing protection. UHP systems use an engine-driven pump to force water through a small-bore nozzle mounted on the end of a jetting lance/gun. The resulting high-pressure, high-velocity water jet impacts the component surface, breaking up surface deposits. If a small amount of abrasive grit is injected into the stream, it can induce a rough surface profile or cut into the component surface. The steel becomes very clean. Without the addition of abrasives, UHP blasting will not remove mill scale and therefore cannot be used for new steel.



Figure 2-29
Example of UHP blasting

Surface Preparation Dust Reduction

A blasting enclosure may be constructed around the component to contain dust and blast media. This enclosure will help prevent FM from getting into components and systems adjacent to the working area. The enclosure may be constructed from plastic sheeting or mastic to which adhesive is applied, and it will contain exhaust fans for reducing dust within the enclosure. Sometimes the enclosure will be constructed during the insulation removal phase and reused during blasting. An enclosure works well in containing dry blast media but becomes messy when wet blasting is performed. Two typical enclosures constructed for surface preparation of high-energy steam lines are shown in Figure 2-30 and Figure 2-31.



Figure 2-30
Example of insulation abatement/sandblasting enclosure around a hot reheat piping system after blast media removal



Figure 2-31
Example of insulation abatement/sandblasting enclosure built around scaffolding during a high-energy piping inspection

3

TYPICAL SURFACE PREPARATION REQUIREMENTS

Most NDE techniques, including liquid penetrant testing (PT), magnetic particle testing (MT), and UT, require that the examination surface be free of contaminants that may interfere with their application. This requires removal of surface rust, corrosion, grease, coatings, scale, weld splatter, and other items that may mask defects. Surface contaminants can restrict the movement of magnetic particles or block liquid penetrant from entering flaws. Thick oxide scale can greatly reduce the amount of ultrasonic energy entering a component, affecting sensitivity.

However, there are some exceptions to the need for surface preparation. Examination of boiler tubes (particularly in gas-fired units) by electromagnetic acoustic transducer or focused-beam UT and internal inspection of heat exchanger tubing by eddy current testing (ET) can be performed with no surface preparation unless deposits and debris accumulation are excessive. Magnetic flux leakage inspections and even some general UT techniques can be performed with little to no surface preparation, depending on the as-found component surface condition, the criticality of the inspection, and other factors [2].

Considerations for Surface Preparation Prior to NDE

The need to perform any cleaning operation and the selection of the proper operation should be verified with the appropriate NDE personnel before proceeding. The effect of surface preparation methods on the subsequent NDE must be considered; arbitrary use of these methods can severely limit NDE effectiveness. It is therefore important to coordinate surface preparation activities with cognizant NDE personnel and materials specialists to ensure that the selected cleaning methods are compatible with the materials and NDE methods. Planning and coordination are critical to minimizing the cost and time involved in surface preparation, as well as the impact on parallel plant projects being performed during the outage.

Four main things should be considered when selecting appropriate surface preparation methods:

- The materials involved
- The contaminant/coating to be removed
- Subsequent NDE methods to be applied
- Impact on surrounding work

Other considerations include local, state, or federal regulations that dictate cleaning techniques and govern the resulting airborne contamination, specifically for confined spaces. Grit blasting of tubes, welds, or other connections inside the boiler is a good example of a regulated technique that requires specific monitoring during and after use.

Surface Contaminant and Scale Removal

The most popular surface preparation method is dry grit blasting (sandblasting). Large areas can be cleaned quickly and, with proper air pressure and media density, with minimal damage to the substrate surface. In the past, blast cleaning was performed with silica sand (the term “sandblasting” originates from those days). The dust generated from silica sand is hazardous; when inhaled, it can cause respiratory problems, silicosis, and sometimes death. Silicosis is one of the world's oldest known occupational diseases. Most countries have established laws that prohibit the use of sand as a blast medium. Alternative abrasives (containing less than 1% crystalline silica) have been developed that are less toxic and environmentally safe. Aluminum oxide is the most widely used because of its cost advantage, longevity, and hardness.

When selecting the abrasives for surface preparation, damage to the substrate (metal surface) should be avoided. As a general rule, the finest abrasive capable of performing the surface preparation should be selected, to limit damage to the surface. If the blast medium is too aggressive, the grit particles deform the steel surface into valleys, push up peaks (similar to the texture of sandpaper), and remove some of the substrate material. This can lead to indications being pinged closed and to false indications or excessive wear on ultrasonic wedges.

For smaller inspection areas, local wire brushing, needle gunning, or light grinding followed by finish sanding to 120 grit is preferred because of portability. There is a possibility that some small, shallow cracks will be peened over with these techniques. Prudence is recommended for soft or thin materials to ensure that small cracks do not go undetected. Weld toes must be as clean as possible without gouging into the pipe wall. Overgrinding the weld toes can leave dished-out areas that can create coupling issues when performing UT for volumetric service damage.

Since most service damage in welds occurs between weld passes, within the heat-affected zones (just below the weld toes), or at the weld toes, removing all oxide and nonmetallic material along the weld toes is essential. Complete removal of oxide and scale in the weld toe valley is perhaps the most common requirement that leads to delays, as incomplete removal leaves a thin line of oxide in and along the weld toes, the exact location where service-induced cracking is most likely (Figure 3-1). Welds prepared in this manner cannot be properly inspected with visual testing, MT, or PT methods.

Manual surface preparation can severely limit certain surface inspections, particularly PT and, to a lesser degree, MT and ET. Photographic examples of acceptable and unacceptable surface preparation are provided in Figure 3-2.



Figure 3-1
Example of incomplete scale removal along weld toes that could lead to false indications during surface examination



Figure 3-2
Examples of acceptable and unacceptable surface preparation

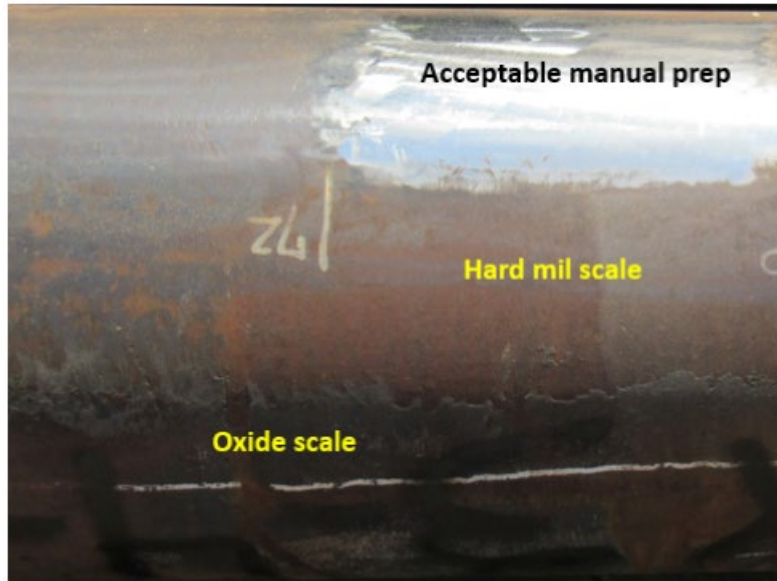


Figure 3-3
Three levels of preparation: surface with all scale removed (top), surface where mill scale remained and was cleaned by power wire brushing (middle), and thick “original” oxide layer (bottom)

Typical Baseline Surface Preparation Requirements

As previously mentioned, dry grit blasting is the preferred method for coated or oxidized components. The surface should be prepared to a near-white metal finish in accordance with SSPC-SP 5, NACE No. 1, and ISO 8501 Sa 3 standards (essentially an exposed, clean metal surface with no significant damage or residual roughness from the surface preparation process). Some typical abrasives that will produce a near-white finish are Starblast™ XL and garnet 100–120 mix.

The prepared surface is defined as smooth, with a surface profile equivalent to <1 mil (25.4 μm). One way to compare surface finishes is to look at surface roughness. In essence, a smaller number for roughness means a smoother surface. There are several parameters for surface roughness. Usually, surface roughness is displayed in micrometers. Table 3-1 shows a comparison of the most common surface roughness values.

A blast surface comparator block can be used in determining the residual surface roughness after cleaning. A typical comparator has four segments representing grades of surface roughness and can be used for either visual or tactile comparison. An example of a four-segment grit-blasted roughness block is shown in Figure 3-4.

Table 3-1
Comparison of representative surface roughness values

Grit Number Equivalent	Roughness Values, Mean (RA)		Roughness, ISO Grade Number
	Micrometers (µm)	Microinches (µin.)	
40	12.5	500	N10
60	6.3	250	N9
–	3.2	125	N8
80	1.8	71	–
–	1.6	63	N7
120	1.32	52	–
150	1.06	42	–
–	0.8	32	N6
180	0.76	30	–



Figure 3-4
Example surface roughness comparator block. Segment 1 (upper left quadrant) is representative of a near-white metal finish (SSPC-SP 5, NACE No. 1).

Recommended surface preparation dimensions for the most common components are provided in Table 3-2. When performing volumetric inspections such as UT, additional area adjacent to welds should be cleaned, allowing for smooth transducer travel. Please note that the recommended surface preparation dimensions are associated with the component thickness/diameter and weld cap width. Thicker components will require wider surface preparation regions. Dimensions are based on standard angle-beam UT methods. Examples of representative component surface preparation areas are provided in Appendix A. These examples should provide guidance when marking components for cleaning.

Table 3-2
Recommended minimum surface preparation dimensions

Weld Type	Recommended Surface Preparation Area Dimension
Circumferential Weld	Weld + 4X Wall Thickness, Centered on Weld
Saddle Weld	2 Inches on Pipe Side + Weld + 3X Wall Thickness
Tee Circumferential Weld	Weld + 2.5X Wall Thickness (Pipe Side) 1X Wall Thickness (Tee Side)
Wye Block Circumferential Weld	Weld + 2.5X Wall Thickness (Pipe Side) 1X Wall Thickness (Tee Side)
Turbine Connection Circumferential Weld	Weld + 2.5X Wall Thickness (Pipe Side) 1.5X Wall Thickness (Turbine Shell Side)
Large Pipe-to-Fitting Weld	2 Inches on Fitting Side + Weld + 2.5X Wall Thickness Pipe Side
Welded Lateral	Weld + 1.5 Inch on Each Side of Weld (Surface Inspection) Weld + 1X Wall Thickness on Each Side of Weld (Ultrasonic Inspection)
Attachment (Fillet) Weld	Weld + 1.5 Inch on Each Side of Weld
Tube Socket Weld	1 Inch on Header + Weld + 4 Inches on Tube Surface
Boiler Tube Weld	Weld + 1.5X Tube Diameter on Each Side of Weld
Boiler Tube Dissimilar Metal Weld (DMW)	Weld + 2X Tube Diameter on Low Alloy or Ferritic Tube
Longitudinal Seam Weld	Weld + 3X Wall Thickness on Each Side of Weld

Note: In all locations where insulation is removed to access the inspection area, 8-inch clearance from insulation to surface preparation area boundary is typically required.

Fossil power generation plants are complex systems of piping, boiler tubing, headers, steam turbines, and support components working together to transfer heat energy from combustion into the kinetic energy of pressurized steam. Service duty conditions range from 250°F (121°C) and 250 psi to over 1050°F (566°C) and 3600 psi for main steam piping. Applying the appropriate NDE methods to each of the components for detection of damage mechanisms is the key to maintaining safe continued plant operation.

In critical high-energy and supporting piping systems and boilers, locations that require NDE inspection are normally associated with circumferential butt welds (girth welds), longitudinal seam welds, saddle welds, and attachment (fillet) welds. In boilers, NDE inspection is also required for boiler tube butt welds, tube DMWs, tube piping bends, and header stub attachment welds. Commonly used NDE methods for these locations are listed in Table 3-3, along with the recommended accompanying surface preparation methods.

**Table 3-3
Commonly applied NDE methods and recommended surface preparation methods**

NDE Method	NDE Method Description	Recommended Surface Preparation Method
Visual Inspection (VT)	Surface inspections involving the entire weld region for open or near-surface flaws	Dry grit blasting Vacuum blasting Dry ice/CO ₂ blasting Manual grinding/finish sanding Thermal descaling
Magnetic Particle Testing (MT)		
Liquid Dye Penetrant Testing (PT)		
Linear Phased Array Ultrasonic Testing (LPA-UT)	Volumetric inspections involving the entire weld region	Dry grit blasting Vacuum blasting Wet abrasive blasting Manual grinding/finish sanding Thermal descaling Pneumatic needle descaling (localized areas)
Time-of-Flight Diffraction Ultrasonic Testing (TOFD)		
Electromagnetic Acoustic Transducer (EMAT)	Volumetric inspection involving the entire weld region or component for wall loss	Removal of surface oxide scale not required
Radiography Testing (RT)	Volumetric inspection involving the entire weld region or component for wall loss	Manual grinding/finish sanding
Balanced Field Electromagnetic Technique (BFET)	Detection of surface and subsurface cracks in base metal, welds, and DMWs	Removal of loose surface contaminants and heavy ash Dry grit blasting
Low-Frequency Electromagnetic Technique (LFET)		
Metallographic Replications (Reps)	Surface inspections	Manual grinding/finish sanding of localized area
Positive Material Identification (PMI)		
Hardness Testing (HT)		
Ultrasonic Thickness Testing (UTT)	Testing of wall thickness	Dry grit blasting Wet blasting Pneumatic needle descaling Manual grinding/finish sanding

4

SUMMARY OF SURFACE PREPARATION METHODS

As discussed in the prior sections, there are several surface preparation technologies that can be used to remove dirt, oil, grease, rust, and paint/coatings and to create a suitable substrate surface profile. Items to consider when selecting the appropriate surface preparation method include:

- Contaminant to be removed
- Degree of cleanliness required
- Substrate to be cleaned
- Purpose of cleaning
- Follow-up processing/NDE methods
- Influence on other local work areas
- Environmental restrictions/effects
- Size and geometry of component/area requiring cleaning

When surface preparation is performed to support subsequent NDE examinations, the weld and adjacent base metal should be prepared to a smooth, near-white metal finish in accordance with Table 3-2 above. If the NDE examinations are targeting surface-connected, near-surface, or volumetric damage, the preparation method needs to be capable of removing all areas of mill scale and oxide scale in the examination region.

Some of the surface preparation methods discussed in Section 2 cannot be controlled to provide the level of detail required by most NDE methods. Laser cleaning and dry ice blasting, for example, can remove rust and most surface contaminants, but not mill scale or tightly adhered oxide scale.

After evaluating all the surface preparation methods listed in this report, we conclude that the preferred surface preparation method to support NDE activities is dry abrasive grit blasting. Dry blasting is the most desirable because it produces a consistent surface finish and is able to clean bead-to-bead interfaces and weld toes. When dry grit blasting is impractical, thermal descaling or manual tool-based cleaning may be acceptable alternatives.

When properly performed, thermal descaling should remove most, if not all, external surface oxide along longitudinal seam welds and some shop girth welds. Final surface finishing by power wire brush or 80-to-120-grit sanding disks may be needed. Thermal descaling is not recommended on multipass field welds with rough weld beads where oxide may remain entrapped at the weld toes.

Manual grinding can lead to suspect inspection results if not properly performed. Surface abrasions induced by nonuniform grinding can lead to transducer bridging and signal dropouts, as shown in Figure 4-1. The final examination surface should be finished with 80-to-120-grit abrasive wheels to remove small localized areas of remnant scale and create a smooth surface.

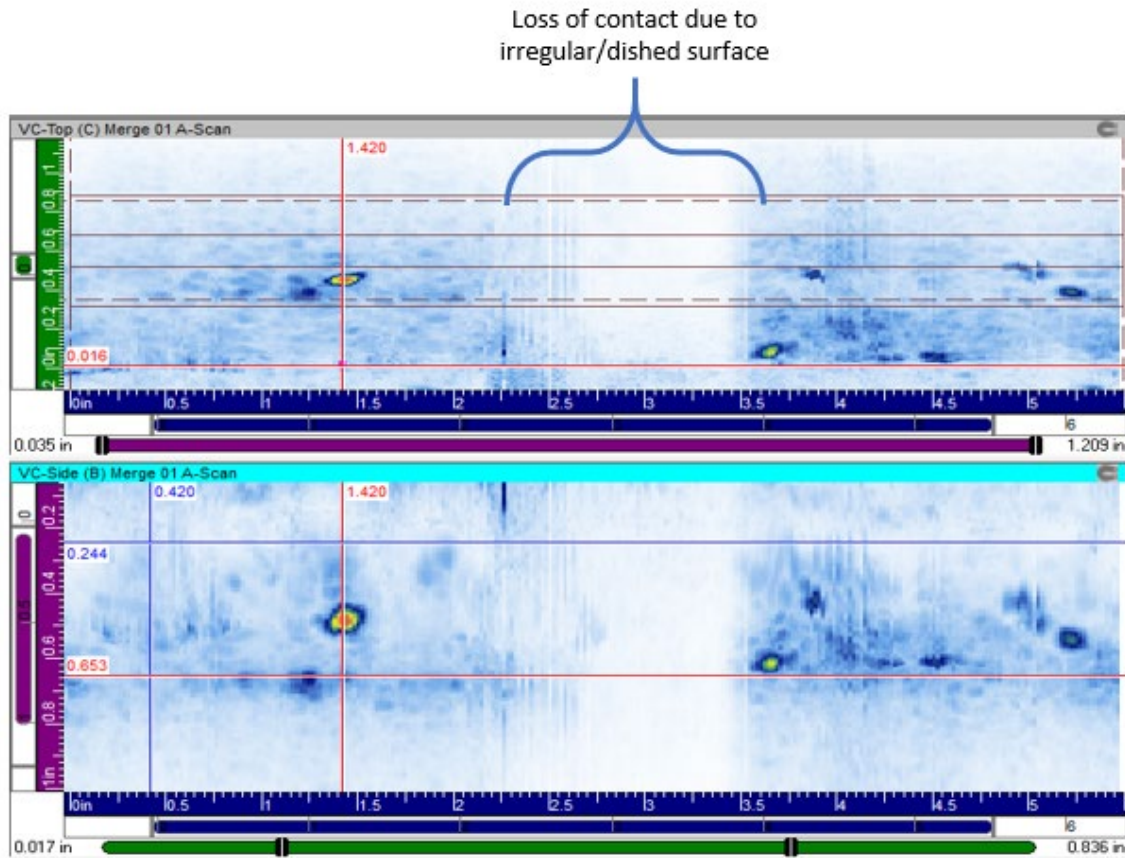


Figure 4-1
Example of phased array scan where manual overgrinding created dished areas along the scanning surface, resulting in loss of probe contact

If a component has been previously cleaned by grit blasting to remove all mill scale in the NDE area, CO₂ (dry ice) blasting may be an attractive option during subsequent outage inspections. CO₂ cleaning uses conventional blasting technology combined with dry ice pellets as the medium. The cleaning process is nonabrasive and environmentally friendly, and the CO₂ pellets evaporate during it, producing minimal secondary waste.

Vapor or wet blasting may be an attractive alternative to dry grit blasting when the components' surroundings allow for a wet environment. The key to vapor/wet blasting is that the abrasive is drained with water, giving a better finish due to the flushing action of the water. No media are put into the components, nor is dust generated as a result of media removal, as it is with dry blasting. The surface cleaning rate of wet/vapor blasting is 15% to 20% slower compared to dry blasting, but the final media cleanup is faster.

When ultrasonic examinations are performed, a high surface roughness can reduce the energy transmitted to the sample, therefore reducing the amplitude of the received signal. Remnant surface oxide can have the same effect. When the transducer passes over areas of surface scale, a decrease in sound energy transited into the component is visible in encoded scans, as illustrated in Figure 4-2.

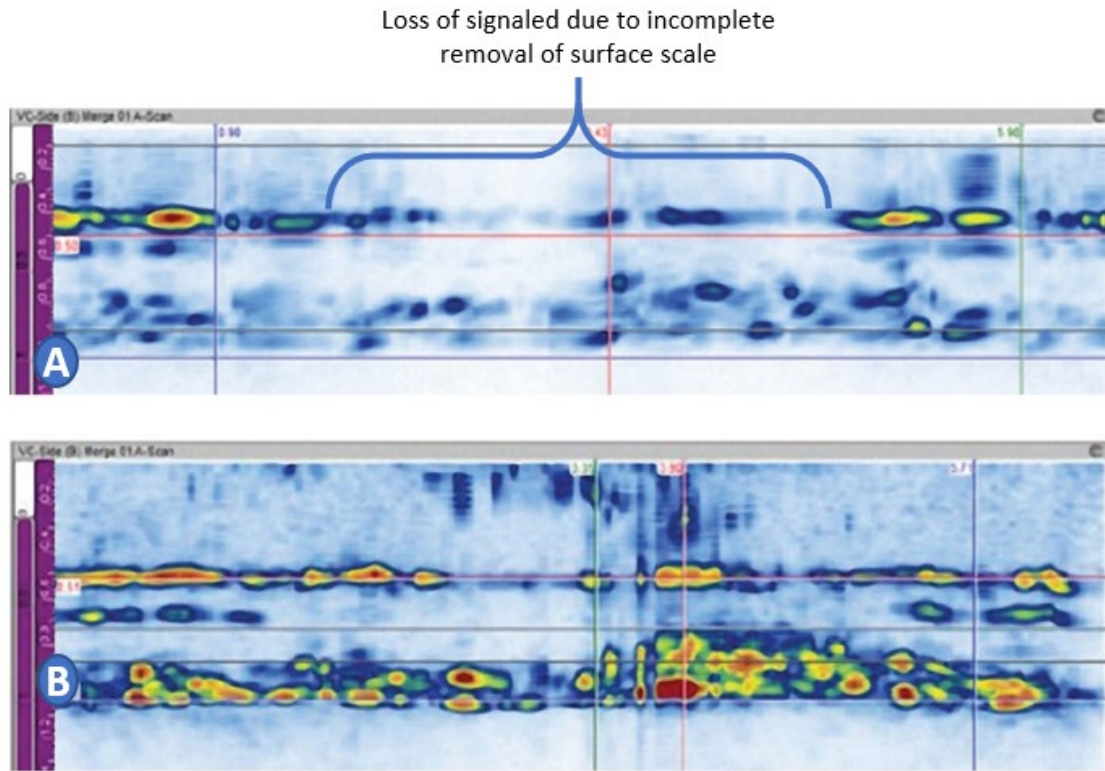


Figure 4-2
Example of phased array scan where remnant surface oxide led to a low-quality signal (A)
and signal amplitude was acceptable after surface oxide removal (B)

Bristle blasting was introduced in 2008, and its popularity as an alternative to grit blasting has started to increase. The process is eco-friendly and does not use hazardous materials or generate hazardous waste, thereby providing a “green” approach to surface preparation. At this time EPRI has not evaluated the bristle blaster for surface preparation to support NDE inspections.

Table 4-1 compares all the surface preparation technologies reviewed and provides advantages, disadvantages, and typical power plant applications for each process.

Table 4-1
Commonly applied surface preparation methods

Surface Preparation Method	Advantages	Disadvantages	Typical Applications
Dry Grit Blasting (Sandblasting)	Efficient at stripping away old coatings, mill scale, oxide scale, corrosion, and other contaminants from metal surfaces Cost effective Versatile	Health hazard Very abrasive (may damage substrate) Waste disposal of media Messy; requires cleanup time May require abatement/tent to contain dust	Surface preparation of weld and adjacent base metal to support NDE activities
Wet Abrasive Blasting	Reduced dust creation Surface wash during blasting process Media impregnation into substrate is not possible Deeply cleans irregular surfaces Can remove old coatings, oxide scale, slag, and loose mill scale	More expensive; can lead to flash rust unless rust inhibitor is added to water stream; blast media containment can be challenging High water consumption Heavier waste that is difficult to remove Higher cost Slower than grit blasting when containment of removed contaminants is required Will not remove tightly adhered scale)	Surface preparation of weld and adjacent base metal to support NDE activities (Boiler tubes, waterwall tubes, ash removal Not intended for turbine components
Vacuum Blasting	Dust free; zero dust contamination on the job site	Slower than dry abrasive blasting; requires more compressed air than standard abrasive blasting	Surface preparation of weld and adjacent base metal to support NDE activities Typically used on smaller/localized areas Used when blasting around open pumps, valves, and turbines

Table 4-1 (continued)
Commonly applied surface preparation methods

Surface Preparation Method	Advantages	Disadvantages	Typical Applications
CO ₂ /Dry Ice Blasting	No secondary waste cleanup Environmentally friendly Lower health hazard Removes contaminants including rust, grease, oil, and loose/flaking oxide scale	Expensive Only removes paint and coatings where the bond with the substrate is broken Removal of mill scale or tight oxide scale may require the addition of abrasive	HRSG fined tubes Fly ash-coated boiler tubes Electrical equipment Turbines, rotors
Laser Cleaning	High-speed noncontact cleaning Environmentally friendly Can remove rust, paint, oil, and grease Minimal cleanup	Will not remove tight mill scale or oxide scale May damage base metal Not portable Expensive	Surface rust removal Paint, grease, oil removal
Ultra-High-Pressure Water Blasting	No abrasive consumption Cleanest surface	No profile roughening High water consumption Lower cleaning rates Will not remove oxide scale without damaging base metal	Tank liners Precipitators Air preheater Paint and coating removal Fly ash-coated boiler tubes
Manual or Tool-Based Cleaning			
Power Grinding Power Sanding	Applicable to tight, hard-to-reach areas Can be performed where abrasive blasting is not feasible or permissible	Scale removal from weld toes difficult Time consuming Results in irregular surface May require removal of excessive material to smooth the surface Could leave fine lines along surface, leading to false indications, if not finished properly	Girth welds and seam welds where abrasive blasting is undesirable or interferes with adjacent activities Preparation of boiler tubes/welds, stub welds, attachment welds, etc.

Table 4-1 (continued)
Commonly applied surface preparation methods

Surface Preparation Method	Advantages	Disadvantages	Typical Applications
Manual or Tool-Based Cleaning (continued)			
Pneumatic Needle Descaling	Can be performed where abrasive blasting is not feasible or permissible	Leaves impact impressions that require additional finishing by sanding wheels to remove smeared material Scale removal from weld toes difficult	Girth welds and seam welds where abrasive blasting is undesirable or interferes with adjacent activities Small areas of ash buildup on tubes
Thermal Descaling/Flame Cleaning	Applicable to smooth seam welds and girth welds Can be performed where abrasive blasting is not feasible or permissible	Care required not to overheat base metal/substrate during process Scale removal from field welds may be difficult Requires additional finishing by sanding wheels to remove patches of missed scale/oxide Labor intensive	Girth welds and seam welds where abrasive blasting is undesirable or interferes with adjacent activities

5

REFERENCES

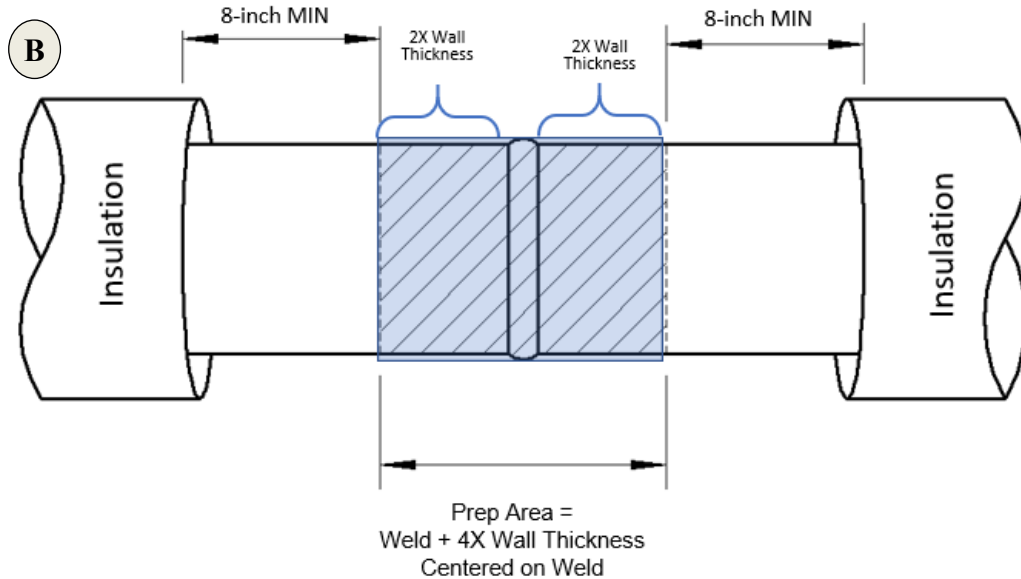
1. *Generation Maintenance Applications Center: Foreign Material Exclusion Guidelines*. EPRI, Palo Alto, CA: 2010. 1019805.
2. *Guidelines for the Nondestructive Evaluation of Boiler Components*. EPRI, Palo Alto, CA: 2015. 3002005941.
3. SSPC-SP 5/NACE No. 1 (2007), White Metal Blast Cleaning. Society for Protective Coatings, Pittsburgh, PA, and National Association of Corrosion Engineers, Houston, TX.
4. Graco Abrasive Blasting, “How to Choose the Right Blast Abrasive Media,” 2021. [Choosing the Right Blast Media for Abrasive Blasting \(graco.com\)](#).
5. KUE Group, “What Is Grit Blasting?” 2021. <https://www.kuegroup.com/grit-blasting/>.
6. M. C. Finishing.com, “Blasting Technical Information,” January 2021. [Blasting Technical Knowledge](#).
7. William A. Heitbrink, “Field Tests of a Water Induction Nozzle as a Dust Control for Abrasive Blasting,” Center to Protect Workers’ Rights, January 2007. <https://www.cpw.com/wp-content/uploads/publications/Heitbrink.pdf>.
8. Graco Abrasive Blasting, “Evaluation of Wet Abrasive Blasting Methods,” 2021. [Advantages & Disadvantages of Different Wet Abrasive Blasting Methods \(graco.com\)](#).
9. Thomas P. Enger, “Surface Preparation by Wet Abrasive Blast Cleaning,” PaintSquare Educational Webinar, 2017. [Surface Preparation by Wet Abrasive Blast Cleaning: PaintSquare Archived Webinars](#).
10. “High Productivity Vacuum Blasting System.” LTC Teletrak-HCET Final Report, DE-AR26-98FT40367, 2001.
11. VariBlast.com, “Case Studies,” December 2020. [Case Studies | Variblast](#).
12. *CO₂ Blast Cleaning Process*. EPRI, Palo Alto, CA: 2002. 1006617.
13. Tex Blast Sandblasting, “CO₂ Blasting,” 2021. [CO₂ | Tex Blast Sandblasting](#).
14. K. L. Mittal, *Developments in Surface Contamination and Cleaning: Applications of Cleaning Techniques*, Volume 11. Netherlands, Elsevier Science, 2018.
15. Laser Photonics, “How Laser Cleaning Systems Work,” 2021. <https://www.laserphotonics.com/laser-cleaning-introductory>
16. Wayne Tupuola, Laser Photonics, “Laser Cleaning Techniques in Industrial Applications,” 2020. [Laser Cleaning Techniques in Industrial Applications | Features | Feb 2020 | Photonics Spectra](#).

References

17. B. Ruchte, S. Gressler, and C. McDonald, “Surface Preparation a Pivotal Step in the Inspection Process,” *Structural Integrity News and Views* 47. Charlotte, NC, 2021.
18. MontiPower manufacturer website, 2021. <https://montipower.com/10-powers/>.
19. Robert Stango, Raymond Fournelle, Jorge Martinez, and Piyush Khullar, “Surface Preparation of Ship-Construction Steel/(ABS-A) Via Bristle Blasting Process.” *NACE - International Corrosion Conference Series* (2010).
20. Linde, “Flame Cleaning,” 2021. https://www.linde-gas.se/en/processes_ren/welding_related_processes/flame_cleaning/.
21. Journal of Protective Coatings & Linings, *Ultra-High-Pressure Waterjetting eBook*. PaintSquare, Pittsburgh, PA, 2012.

A

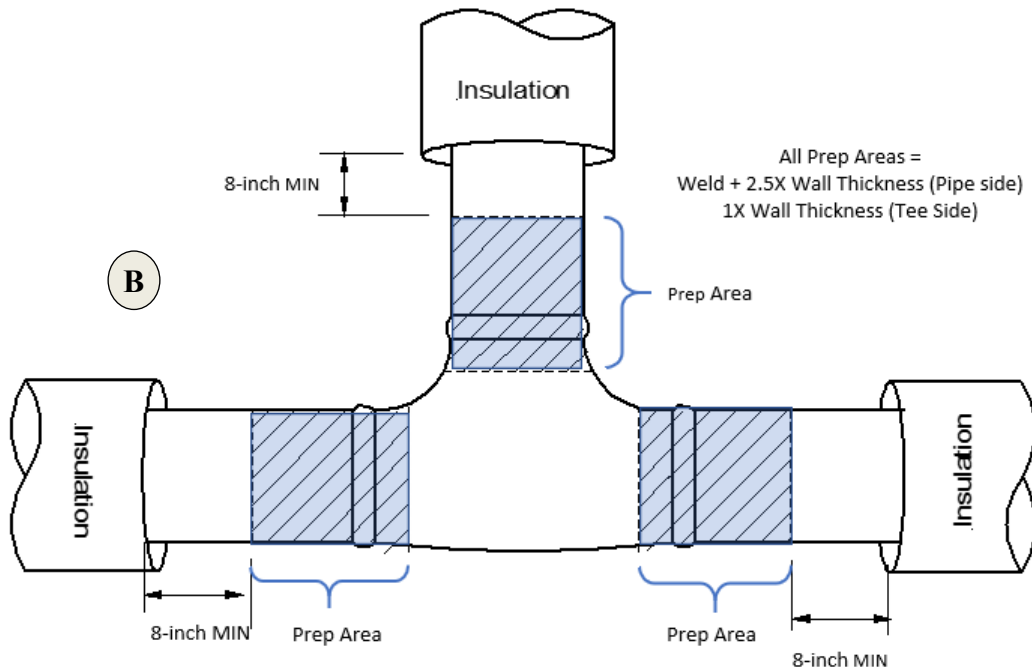
COMPONENT SURFACE PREPARATION ILLUSTRATIONS



Note:

- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

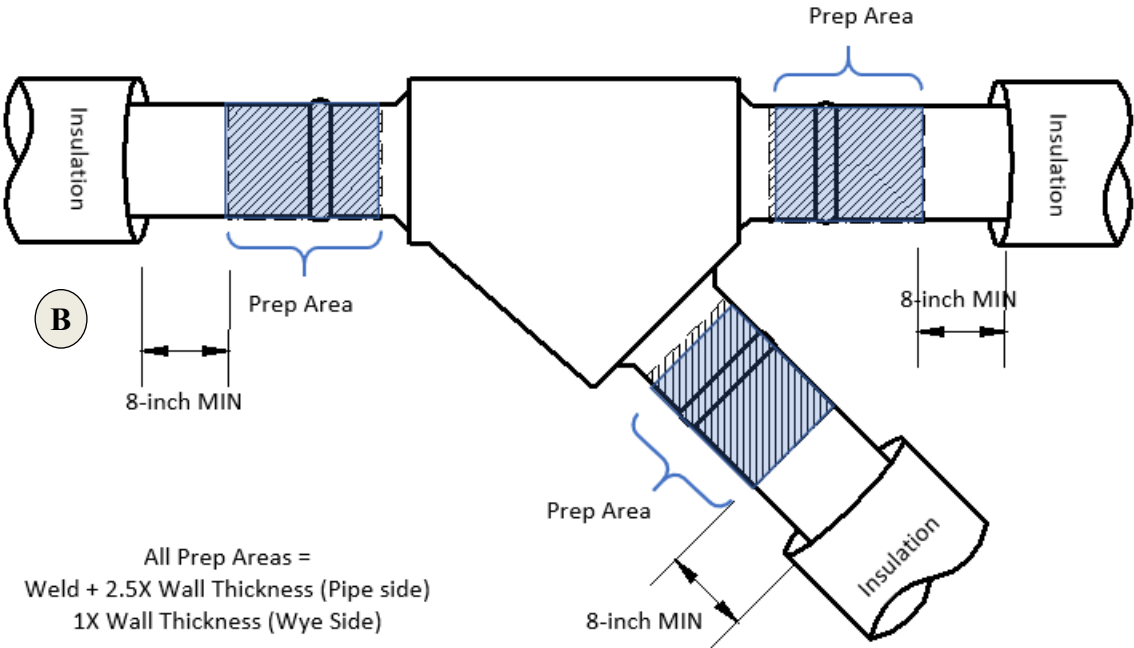
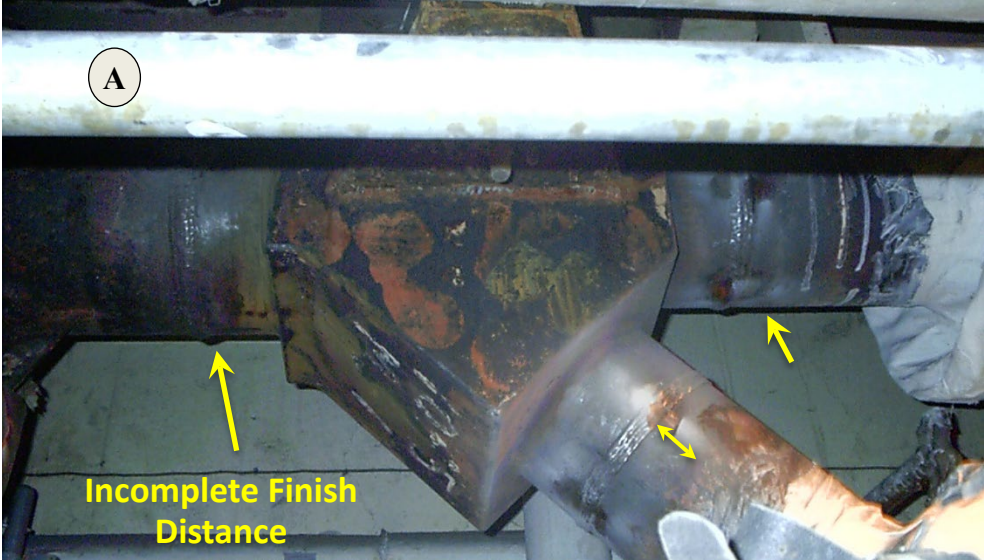
Figure A-1
Piping and header circumferential (girth) weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)



Note:

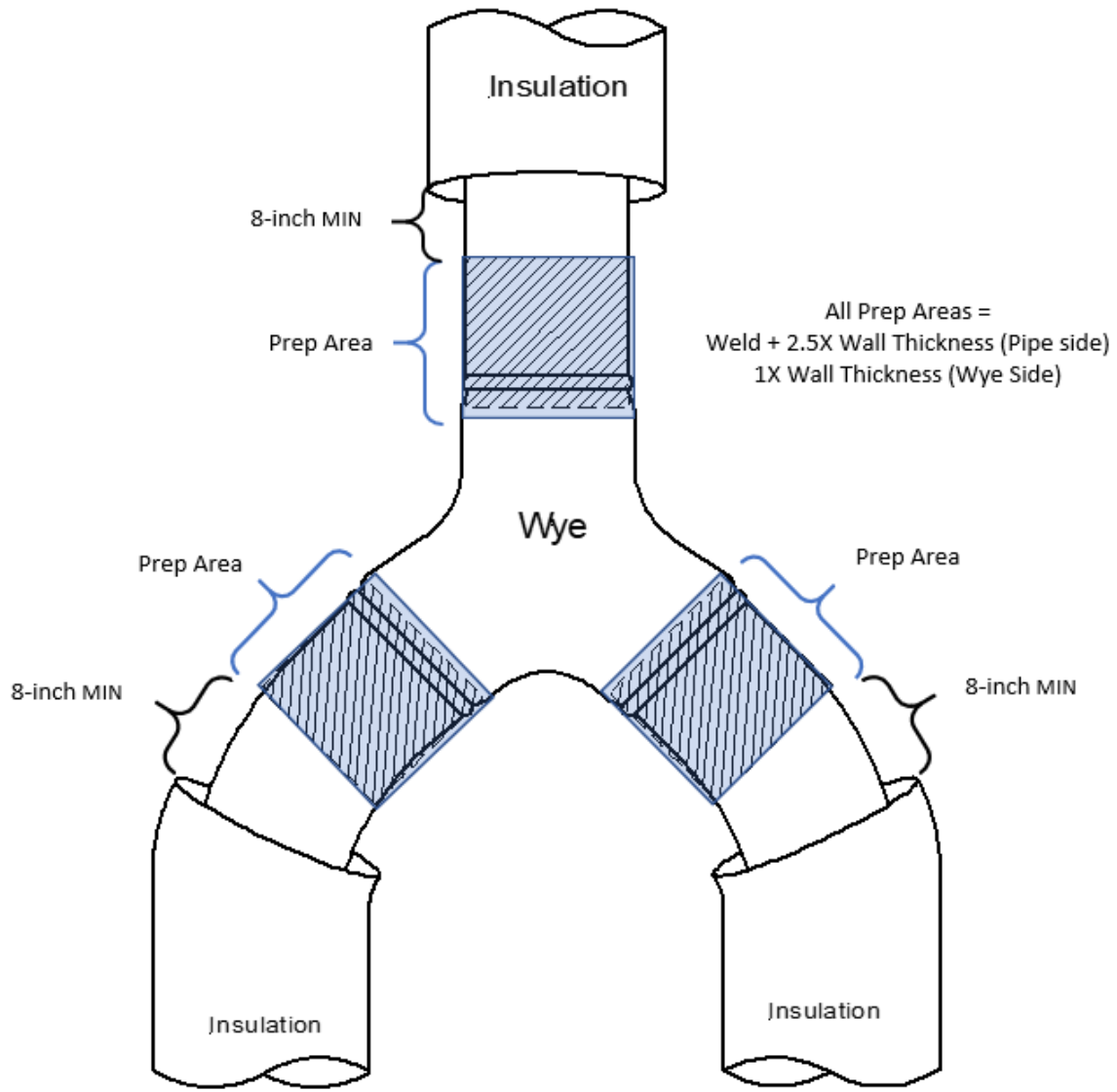
- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

Figure A-2
Piping and header tee circumferential (girth) weld: acceptable combination grit blast/hand preparation (A) and surface preparation area recommendation (B)



- Note:
- Preferred cleaning method is by Grit Blasting
 - Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

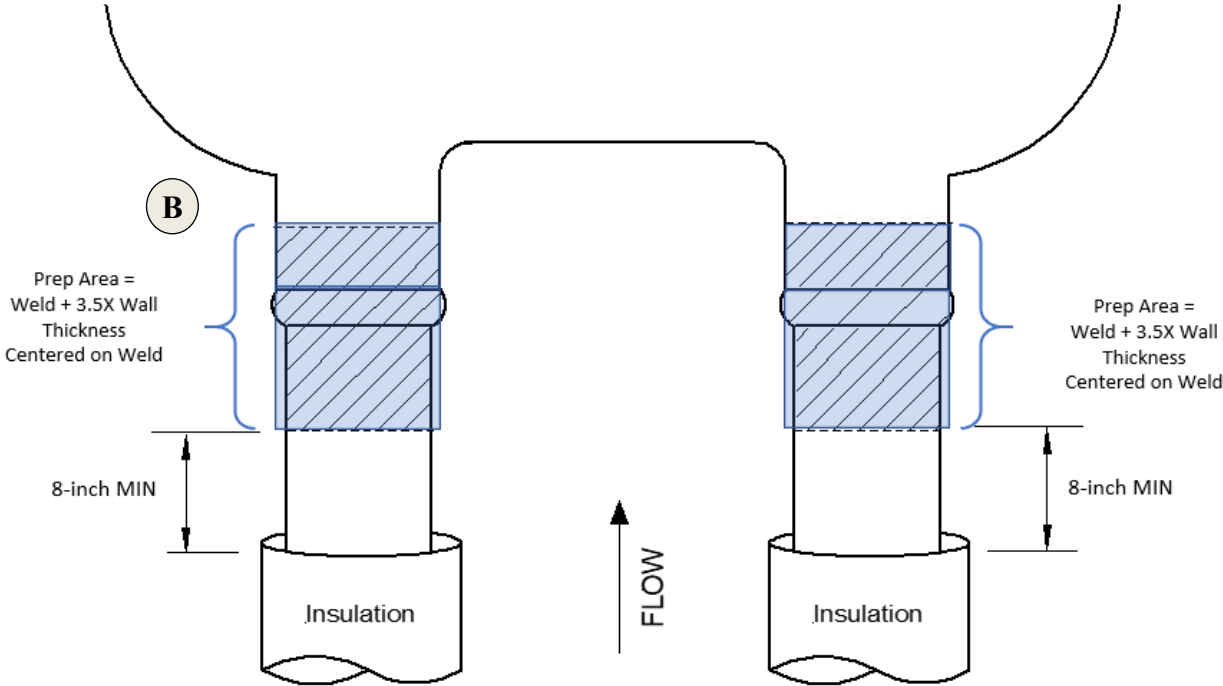
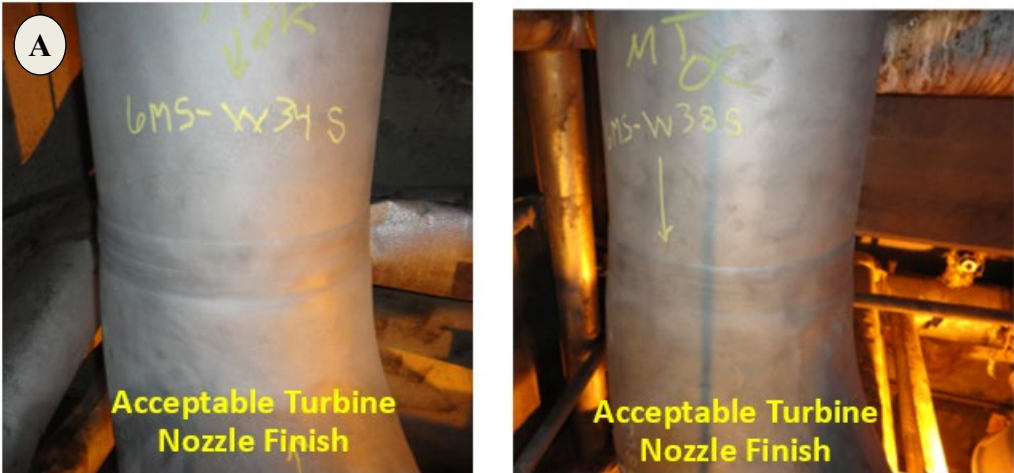
Figure A-3
Piping wye block girth weld: unacceptable/incomplete grit blast preparation (A) and surface preparation area recommendation (B)



Note:

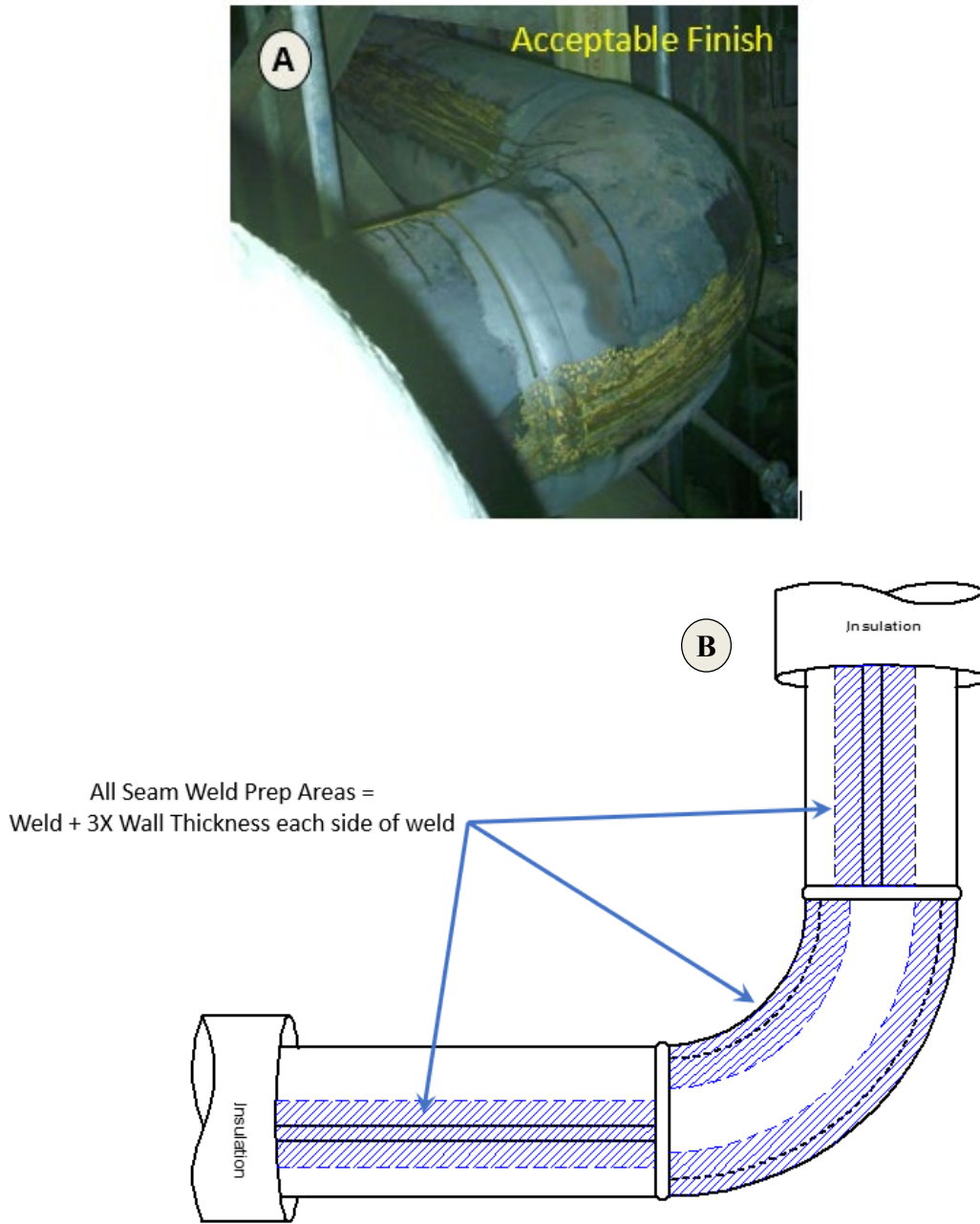
- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

Figure A-4
Piping and header girth weld surface preparation recommendation



- Note:
- Preferred cleaning method is by Grit Blasting
 - Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

Figure A-5
Turbine piping girth weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)



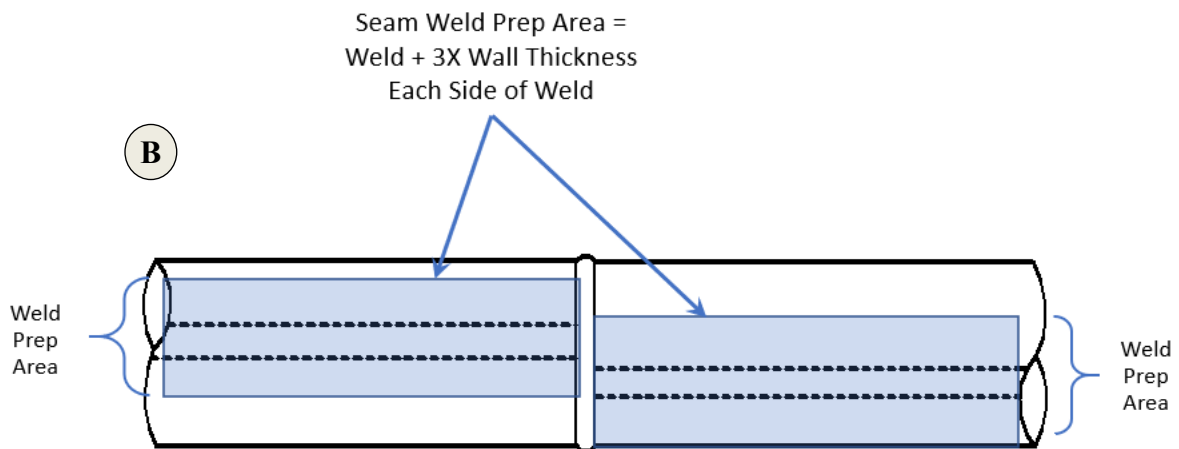
Note:

- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned include weld and 3X wall thickness each side of weld to a White Metal (SSPC-SP 5) finish

Alternate surface prep when Grit Blasting Unavailable

- Clean same amount of area using Flame Descaling or Pneumatic Needle Descaler
- Prep with 120-grit to smooth finish

Figure A-6
Steam line seam-welded pipe spool and seam-welded elbow: acceptable grit blast finish (A) and surface preparation area recommendation (B)



Note:

- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned include weld and 3X wall thickness each side of weld to a White Metal (SSPC-SP 5) finish

Alternate surface prep when Grit Blasting Unavailable

- Clean same amount of area using Flame Descaling or Pneumatic Needle Descaler
- Prep with 120-grit to smooth finish

Figure A-7
Typical longitudinal seam weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)

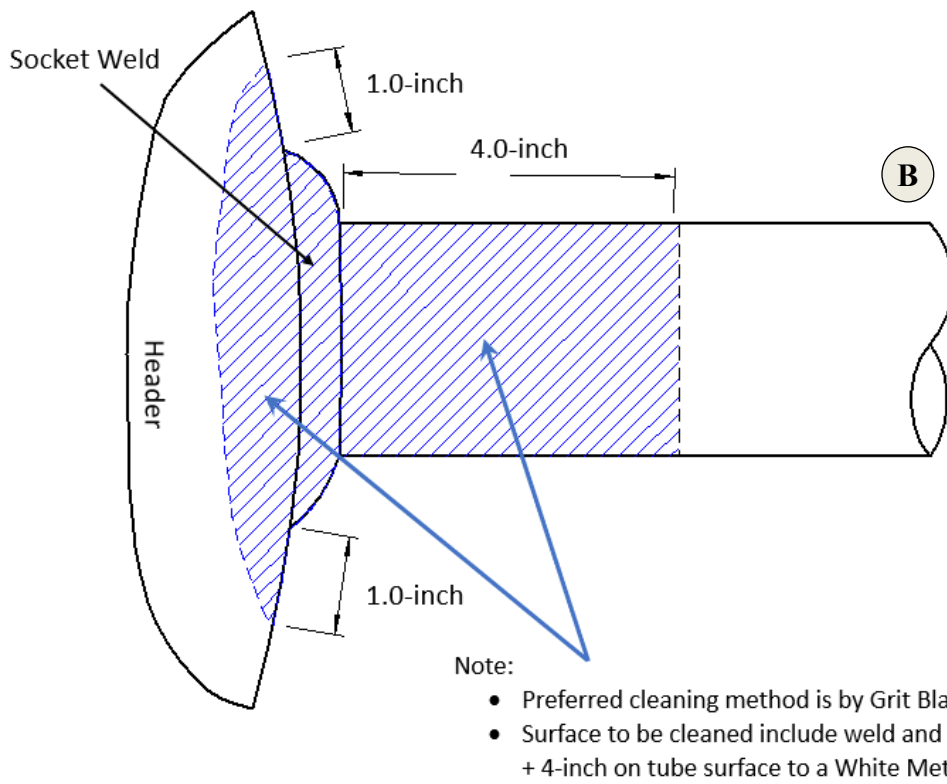
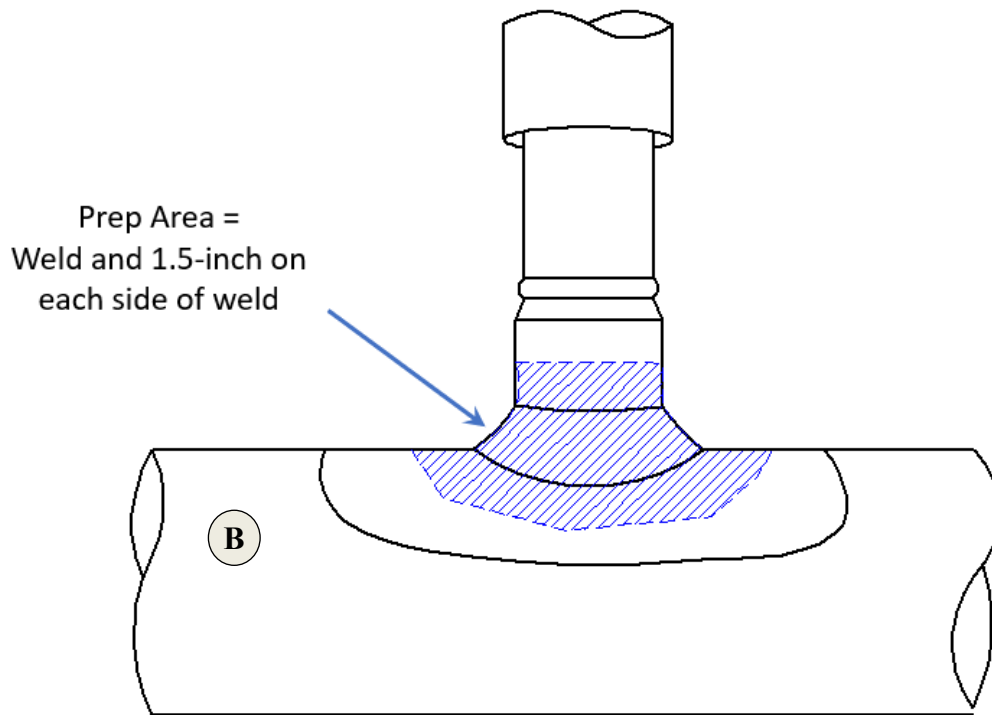


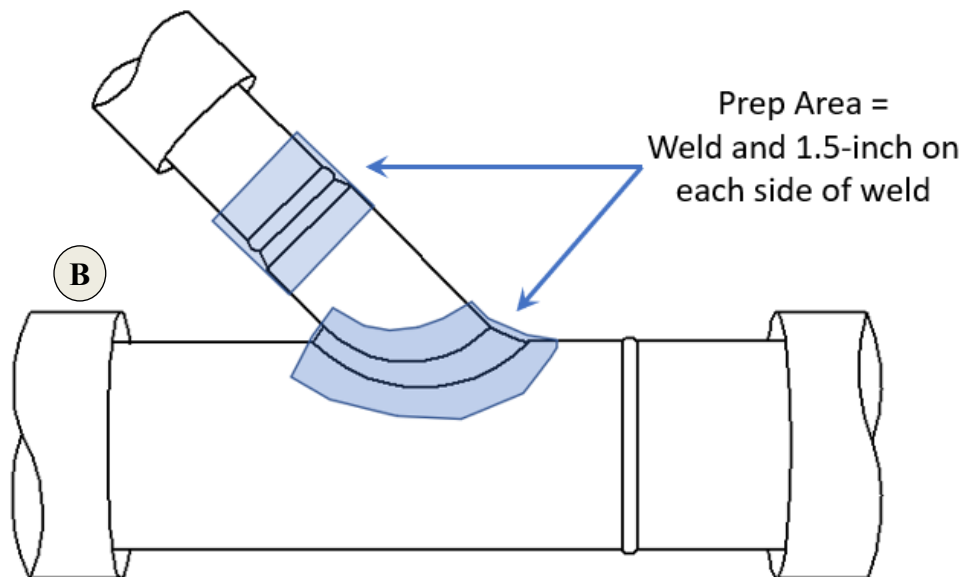
Figure A-8
Header stub tube: acceptable grit blast finish (A) and surface preparation area recommendation (B)



Note:

- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned include weld and 1.5-inch on each side of weld, clean to a White Metal (SSPC-SP 5) finish

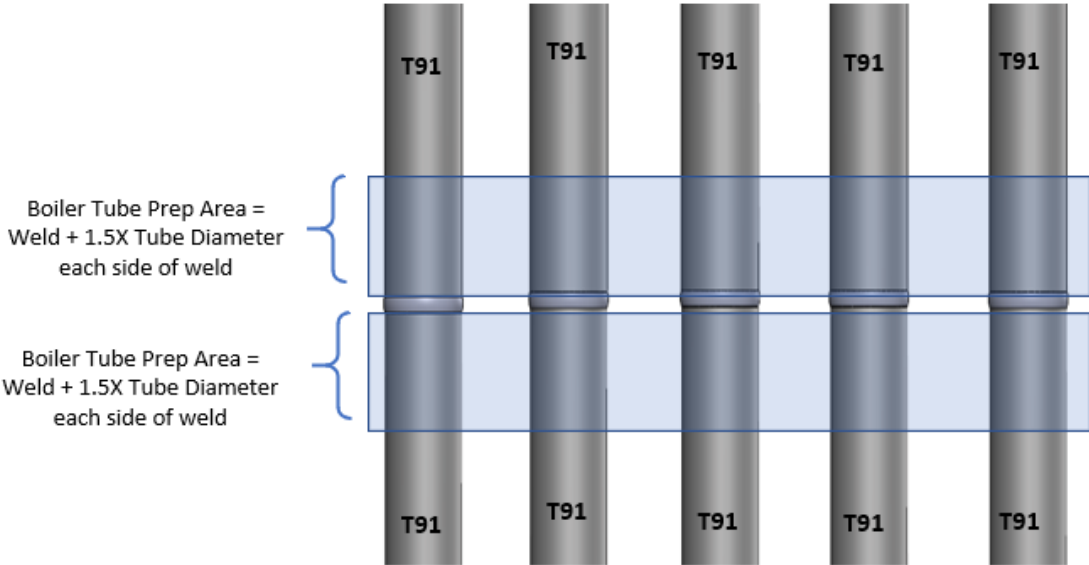
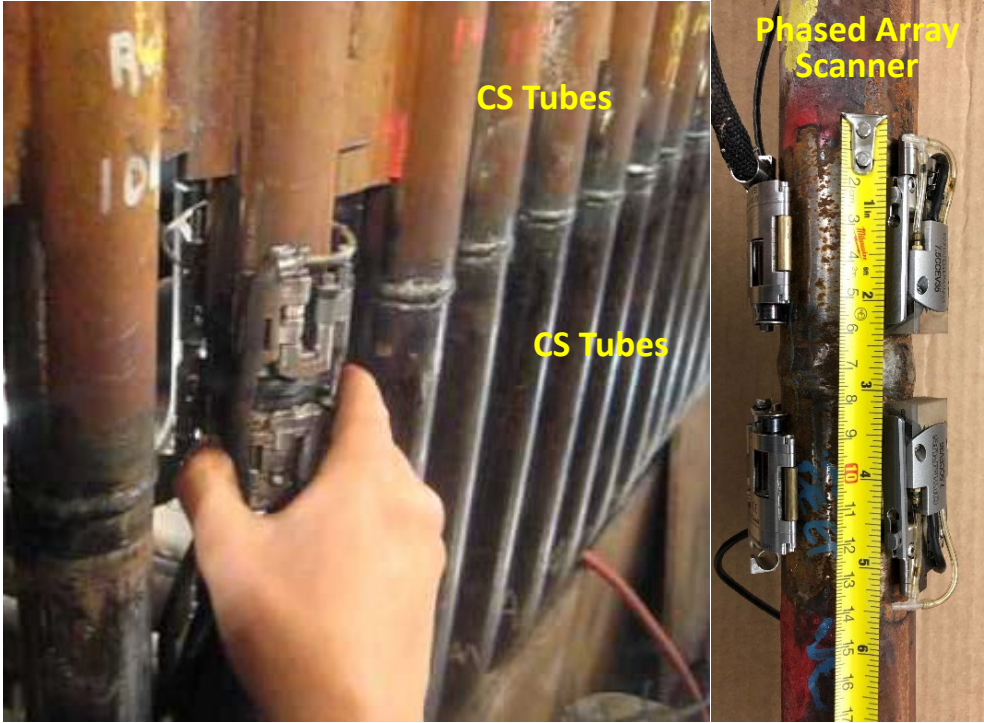
Figure A-9
Weld-o-let attachment weld: acceptable grit blast finish (A) and surface preparation area recommendation (B)



Note:

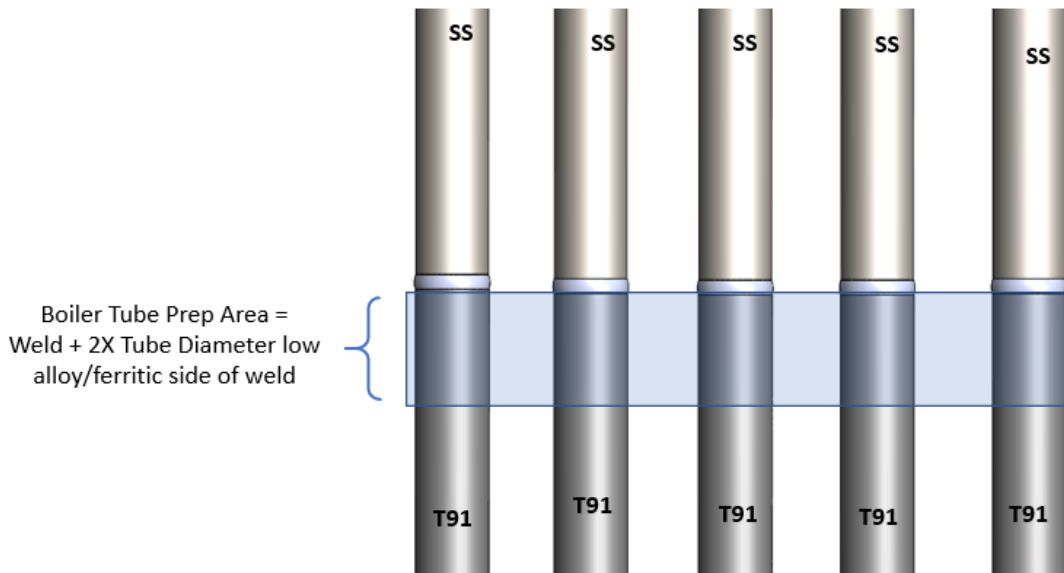
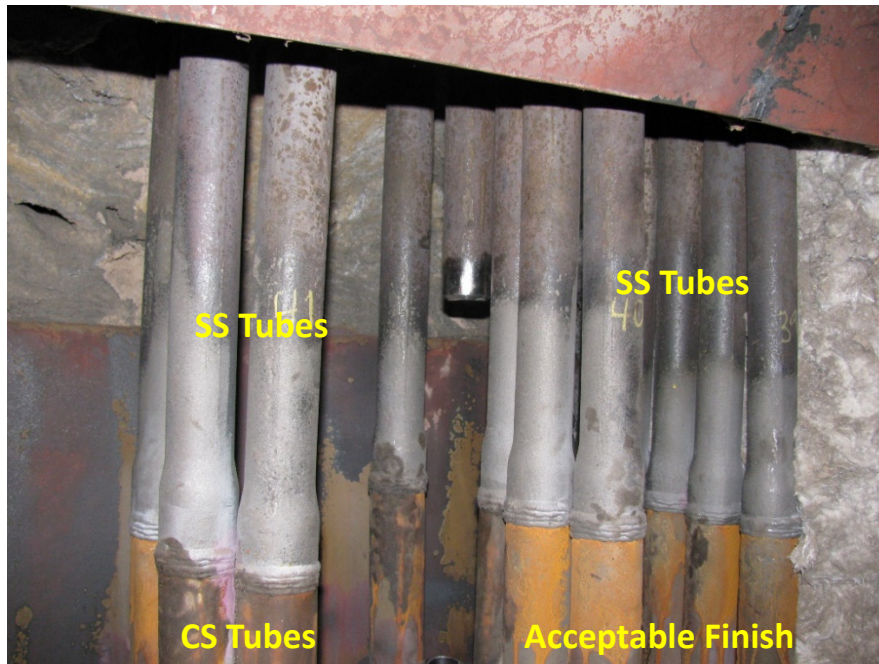
- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned include weld and 1.5-inch on each side of weld, clean to a White Metal (SSPC-SP 5) finish

Figure A-10
Typical welded lateral surface: acceptable grit blast finish (A) and surface preparation area recommendation (B)



- Note:
- Preferred cleaning method is by Grit Blasting
 - Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

Figure A-11
Boiler tube weld surface preparation and tube weld scanner (top); recommended surface preparation area for ultrasonic examination (bottom)



Note:

- Preferred cleaning method is by Grit Blasting
- Surface to be cleaned 360° to a White Metal (SSPC-SP 5) finish

Figure A-12
Grit-blasted boiler tube DMW surface preparation (top); recommended surface preparation area for DMW ultrasonic examination (bottom)

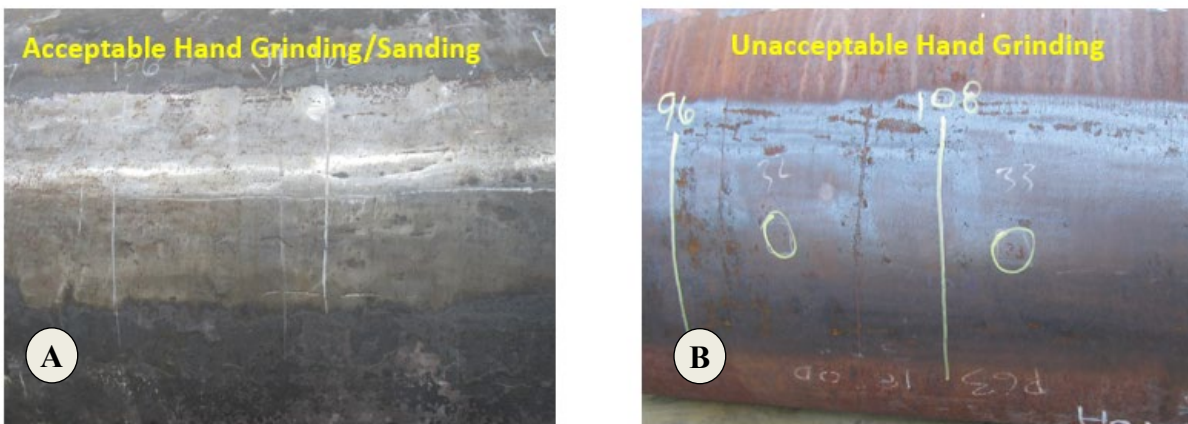


Note:

- Grind to bare metal with stone/rock
- Prep with 120-grit to smooth finish by removing stone chatter marks
- Weld toes must be as clean as possible without gouging into the pipe wall

Figure A-13

Piping and header girth weld: acceptable manual hand preparation



Note:

- Grind to bare metal with stone/rock
- Prep with 120-grit to smooth finish by removing stone chatter marks
- Weld toes must be as clean as possible without gouging into the pipe wall

Figure A-14

Piping seam weld: acceptable manual hand preparation (A) and unacceptable hand preparation (failed to remove mill scale) (B)



Note:

- Grind to bare metal with stone/rock
- Prep with 120-grit to smooth finish by removing stone chatter marks
- Weld toes must be as clean as possible without gouging into the pipe wall

Figure A-15
Example of a welded attachment showing acceptable manual hand preparation

B

SURFACE PREPARATION METHOD COMPARISON

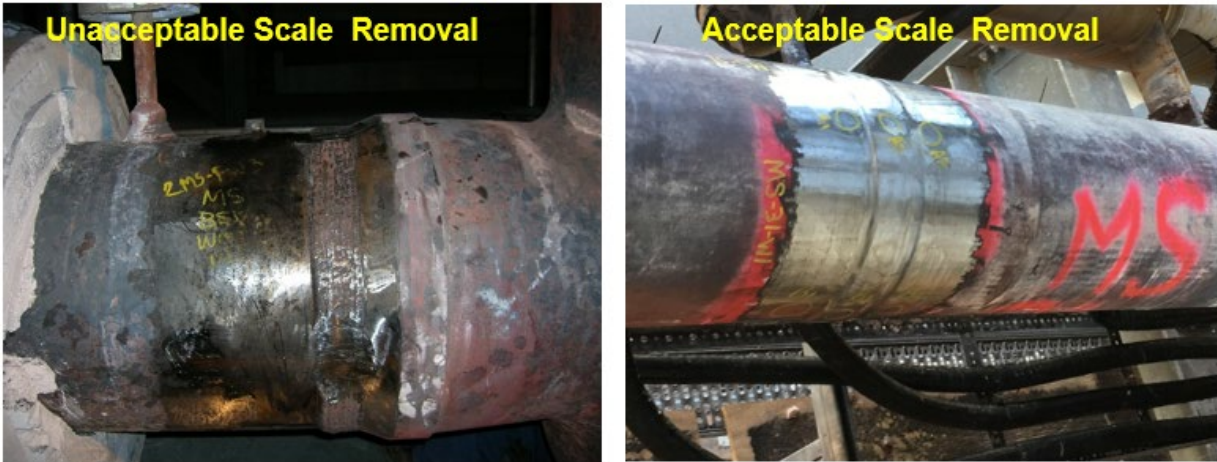
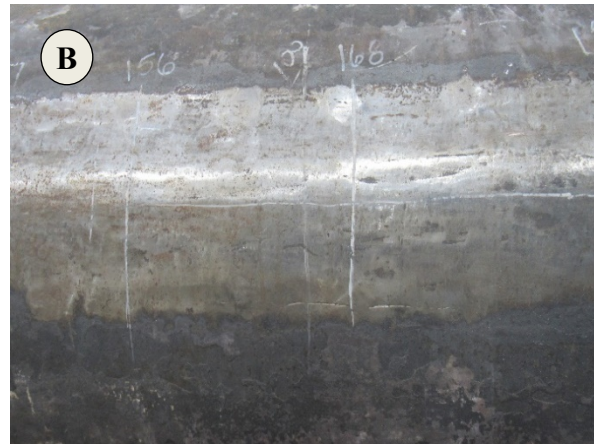


Figure B-1
Pipe girth weld: examples of unacceptable (left) and acceptable (right) manual hand preparation



Bad manual grinding/sanding preparation; mill scale left on surface



Good manual grinding/final sanding preparation; mill scale layer removed

Figure B-2
Piping seam weld: examples of unacceptable hand preparation that failed to remove surface mill scale (A) and acceptable manual hand preparation finished with 120-grit sanding disk (B)



Bad manual grinding preparation; areas of scale left, and MT examination detected no indications



Good manual grinding/final sanding preparation; MT examination detected short weld toe indications

Figure B-3

Piping seam weld: examples of unacceptable hand preparation that failed to remove mill scale (A) and acceptable manual hand preparation finished with 120-grit sanding disk (B)



Figure B-4

Girth weld and seam weld: example of acceptable surface preparation using grit blasting



Figure B-5
Welded nozzle: Example of acceptable surface preparation using manual power wire brushing

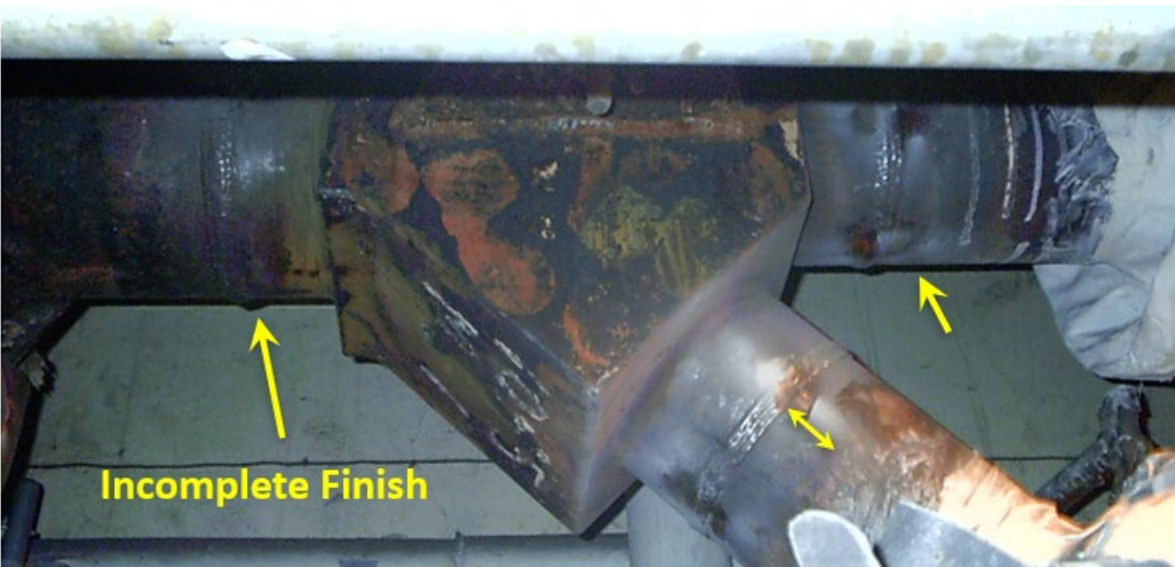


Figure B-6
Example of unacceptable grit blast distance from weld toes for ultrasonic examination



Figure B-7
Girth weld: example of incomplete oxide removal from the weld beads

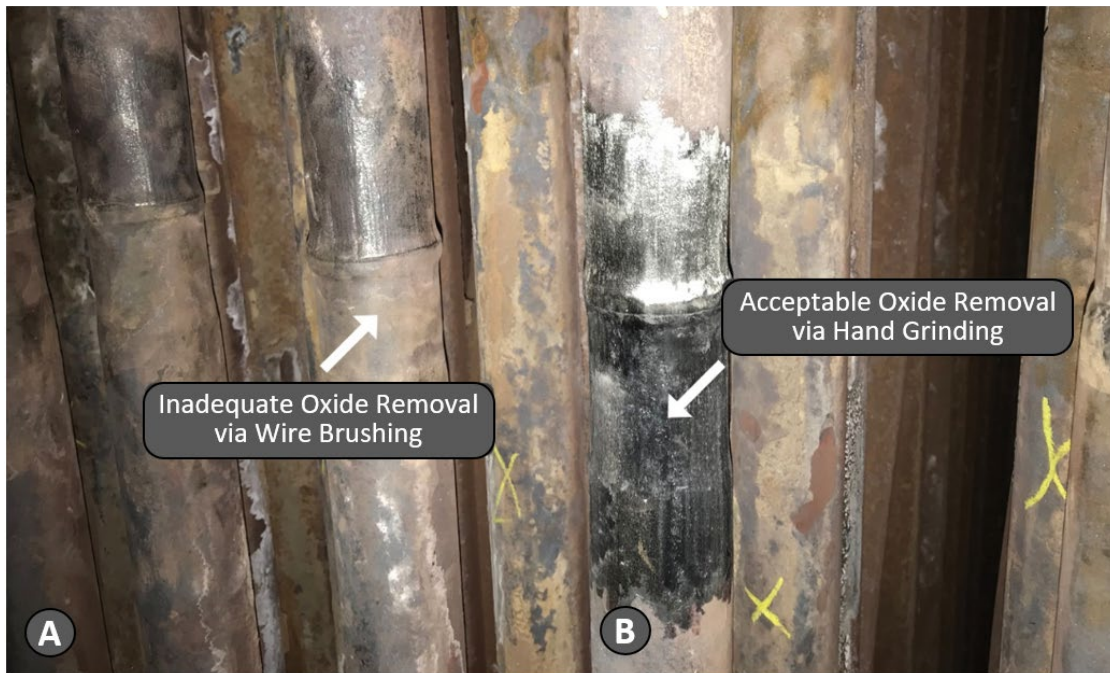


Figure B-8
Tube DMWs: examples of improper base metal oxide removal by wire brushing (A) and acceptable oxide removal by hand grinding (B)



Figure B-9
Grit-blasted tube weld: examples of acceptable base metal oxide removal (left) and incomplete base metal oxide removal (right)



Export Control Restrictions

Access to and use of this EPRI product is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or U.S. permanent resident is permitted access under applicable U.S. and foreign export laws and regulations.

In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI product, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case by case basis an informal assessment of the applicable U.S. export classification for specific EPRI products, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes.

Your obligations regarding U.S. export control requirements apply during and after you and your company's engagement with EPRI. To be clear, the obligations continue after your retirement or other departure from your company, and include any knowledge retained after gaining access to EPRI products.

You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of this EPRI product hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI members represent 90% of the electricity generated and delivered in the United States with international participation extending to nearly 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; Dallas, Texas; Lenox, Mass.; and Washington, D.C.

Together...Shaping the Future of Electricity

Program:

Boiler Life and Availability Improvement

© 2021 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

3002019428