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FACULTAD DE INGENIERIA QUIMICA Y METALÚRGICA

ESCUELA ACADÉMICA PROFESIONAL DE INGENIERIA QUIMICA

PROPUESTA DE MEJORA DEL PROCESO DE GRANALLADO PARA CONTROLAR LA RUGOSIDAD Y AUMENTAR EL RENDIMIENTO DE LOS RECUBRIMIENTOS IMPRIMANTES EPOXICOS EN LA EMPRESA HAUG S.A.

TESIS PARA OPTAR EL TITULO DE INGENIERO QUIMICO

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DEDICATORIA

Dedico esta tesis a Dios por permitirme tener la dicha de vivir y poder demostrar al mundo que mi existencia tiene un objetivo, a mis padres por darme la educación la cual me ha llevado a este punto de mi vida, a mis hermanos que siempre son los remos de mi vida y a mis seres queridos que están presente en mis buenos y malos momentos.

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A Dios por darme la vida, y darme la seguridad de que mis seres queridos se encuentran con la fortaleza ante las adversidades.

A mis padres por ser mi razón para seguir luchando día a día.

A mis hermanas y hermanos que son mi ejemplo de vida a seguir.

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RESUMEN

El presente trabajo de investigación se basó en la propuesta de mejora del proceso de granallado para controlar la rugosidad y aumentar el rendimiento de los recubrimientos imprimantes epóxicos en la empresa Haug S.A con la finalidad de reducir costos en la compra de recubrimientos para los proyectos.

En el capítulo I, esta contenido la realidad problemática, motivo por el cual se optó realizar el trabajo de investigación al observar que el proceso de granallado no ha tenido mejoras en su proceso desde que se implementó en el 2015 la cual está teniendo repercusión en la obtención de la rugosidad ya que presenta un exceso de volumen muerto y como consecuencia el rendimiento de recubrimientos imprimantes epóxicos es bajo teniendo como resultado el alto consumo de pintura y los excesivos costos en los proyectos, así mismo se definió el objetivo principal del trabajo de investigación que se centra en la evaluación del proceso de granallado y pintura y sus subprocesos respectivos para proponer las mejoras respectivas , de la misma forma se menciona los objetivos específicos que se toman para este trabajo, a la vez se detalla la justificación del porque se realizó esta investigación y las limitaciones y viabilidad de estudio con la que cuenta.

En el capítulo II contiene los antecedentes de la investigación y el marco teórico donde se adoptaron las principales teorías utilizadas en el presente trabajo de investigación. Se formularon las hipótesis generales y específicas para el inicio de la investigación.

En el capítulo III se definió el diseño metodológico del trabajo de investigación, se determinó el tipo de investigación que se tomó en cuenta, el nivel y enfoque que se da al presente trabajo de investigación. Se limitó la población y muestra que se va a abarco, se describió las técnicas e instrumentos utilizados para la recolección de datos necesarios para haber realizado el trabajo de investigación.

El capítulo IV, se detalla y presenta los resultados obtenidos durante el tiempo que se realizó el trabajo de investigación, mediante cuadros, gráficos y la realización de las interpretaciones de las mismas.

En el capítulo V, se realizaron las discusiones de los resultados obtenidos con las investigaciones consultadas, se determinaron las conclusiones y se dieron las recomendaciones pertinentes.

Las fuentes bibliográficas utilizadas que sirvieron de soporte para la ejecución del trabajo de investigación se detalla en el capítulo VI, finalmente se anexaron las normas, códigos, tablas y hojas técnicas utilizadas para realizar la investigación.

Palabras claves: granallado, recubrimiento epóxico, rugosidad, mezcla operativa, rendimiento del recubrimiento.

ABSTRACT

This research work was based on the proposal to improve the shot blasting process to control roughness and increase the performance of epoxy primer coatings in the company Haug S.A in order to reduce costs in the purchase of coatings for projects.

In Chapter I, the problematic reality is contained, which is why it was decided to carry out the research work when observing that the blasting process has not had improvements in its process since it was implemented in 2015, which is having an impact on the obtaining roughness since it presents an excess of dead volume and as a consequence the performance of epoxy primer coatings is low, resulting in high consumption of paint and excessive costs in the projects, likewise the main objective of the research work was defined which focuses on the evaluation of the blasting and painting process and its respective sub-processes to propose the respective improvements, in the same way the specific objectives that are taken for this work are mentioned, at the same time the justification of why this was carried out is detailed. research and the limitations and feasibility of the study that it has.

Chapter II contains the background of the research and the theoretical framework where the main theories used in this research work were adopted. The general and specific hypotheses were formulated for the beginning of the investigation.

In chapter III, the methodological design of the research work was defined, the type of research that was taken into account, the level and approach given to the present research work was determined. The population was limited and the sample to be covered, the techniques and instruments used to collect the data necessary to have carried out the research work were described.

Chapter IV details and presents the results obtained during the time that the research work was carried out, through tables, graphs and the performance of their interpretations.

In chapter V, the discussion that was generated when the analysis of the results obtained was carried out; The conclusions were determined and the necessary recommendations are given based on the results obtained.

The bibliographic sources that were used and were of support during the realization of the research work are detailed in chapter VI, as a final part data that were relevant in the execution of the work is attached.

Keyword: shot peening, epoxy coating, roughness, operational mix, coating performance.

INTRODUCCION

En el área de granallado y pintura de la empresa Haug S.A. se cuenta con un proceso de granallado semiautomático el cual es muy productivo respecto al área por metro cuadrado granallado diariamente el cual alimenta al proceso de pintura.

Como resultado del granallado se evalúo el parámetro de limpieza superficial y rugosidad la cual debe tener una dimensión mínima de 50 micras para que el recubrimiento a aplicarse se adhiera eficientemente de acuerdo a la hoja técnica del producto Macropoxy 646 la cual fue el recubrimiento de muestra para la investigación realizada, pero la rugosidad obtenida del proceso es de 96.5 micras la cual resulto muy excesiva.

Esta rugosidad que se obtuvo presento una cantidad de volumen muerto excesivo la cual debe ser recubierta por el recubrimiento teniendo como consecuencia un bajo rendimiento de aplicación y a largo plazo un costo de sobreconsumo de recubrimiento para los diversos proyectos de la empresa.

El sistema actual que se ha descrito viene realizándose desde que se implementó el proceso en el 2015 y desde aquel entonces no se ha realizado mejoras continuas en el proceso por lo que resulto necesario evaluar el proceso de granallado y pintura la cual tuvo como fin las propuestas de mejoras descritas que aportaron una reducción en los costos por litros de pintura consumidos el área.

La propuesta de mejora se realizó previa evaluación del proceso de granallado y se determinaron las características operativas de cada subproceso y se identificó en la mezcla operativa que la granalla utilizada es de tipo angular G-25 así como también presencia de tipo esférica S-330 las cuales son excesivas, también se determinó que el porcentaje de tamaños finos

(60%), tamaños medios (30%) y tamaños gruesos (10%) no se encontraron dentro de los parámetros recomendados de operatividad.

Se propuso cambiar el abrasivo a G-40 y se implementó un sistema de limpieza que tenga la finalidad de eliminar la granalla de tamaño fino para controlar la rugosidad obtenida de tal manera que se mantenga constante, como consecuencia la rugosidad a obtener fue de 50 micras y la mezcla operativa de tamaños finos, tamaños medios y tamaños gruesos se encontró dentro de los parámetros de operatividad.

El resultado obtenido a partir de la reducción de la rugosidad y la disminución del volumen muerto fue un consumo de pintura menor a diferencia del proceso que tenía la empresa el cual aumenta el rendimiento de recubrimiento a aplicarse teniendo un menor costo en la compra de recubrimientos en los diferentes proyectos futuros.

CAPITULO I

PLANTEAMIENTO DEL PROBLEMA

1.1. Descripción de la realidad problemática

La empresa Haug S.A. tiene una productividad diaria promedio de 520 m^2 de granallado de acero el carbono el cual se realiza desde el 2015 en cámaras de granallado semi automático y desde ese entonces no se han realizado las mejoras continuas pertinentes que aporten productividad y reduzcan costos en los proyectos llevados a cabo.

Debido a que los controles en el proceso de granallado han sido insuficientes han repercutido en el rendimiento de los diversos recubrimientos industriales que interactúan directamente como capa base con el acero granallado y esto se debe a que el consumo de el recubrimiento se eleva altamente por el exceso de volumen muerto generado por la alta rugosidad como consecuencia de los escasos mantenimientos y mejoras continuas del proceso de granallado.

El proceso de preparación superficial con chorro abrasivo utilizando granalla tiene como resultado la obtención de la rugosidad la cual tiene relación directa con el rendimiento del recubrimiento imprimante epóxico a aplicarse.

La granalla utilizada y su mezcla operativa son los factores más importantes que se controlaron ya que de estas depende para la obtención de una rugosidad específica la cual debe estar regida por el proceso de granallado el cual presento deficiencias en el proceso de eliminación de granalla fina improductiva.

La rugosidad obtenida debe tener la dimensión mínima suficiente para que el recubrimiento se adhiera eficientemente, pero la dimensión máxima para que no se genere un volumen muerto excesivo la cual debe ser cubierta con el recubrimiento epóxicos que se aplican como capa base directa al acero granallado, generando un bajo rendimiento y aumentando los costos por el excesivo volumen muerto.

Los recubrimientos imprimantes epóxicos son recubrimientos que en su formulación tienen resinas epóxicas las cuales son utilizadas masivamente en la mayoría de procesos de inhibición de la corrosión debido a su alto desempeño en la industria: marina, petrolera, agroindustrial y otros, así como también su facilidad de aplicación, generación de buena adherencia con la superficie de acero por enlaces polares y/o químicos y su alto rendimiento el cual está relacionada con su porcentaje de sólidos en volumen.

Por lo tanto, nació la necesidad evaluar el proceso de granallado y a partir de ello implemento una mejora para que sea continuo y sostenible para que la rugosidad obtenida en el proceso no sea excesiva y posteriormente en la aplicación de recubrimientos imprimantes el rendimiento sea mayor.

1.2.Formulación Del Problema

1.2.1. Problema General

¿En qué medida la propuesta de mejora del proceso de granallado para controlar la rugosidad nos ayudó a aumentar el rendimiento de los recubrimientos imprimantes epóxicos?

1.2.2. Problemas Específicos

¿En qué medida al cambiar la granulometría de la granalla utilizada en el proceso de granallado nos ayudó a reducir la rugosidad?

¿En qué medida añadir un sistema de filtros de abrasivos finos reutilizados nos ayudara a obtener una rugosidad constante?

¿En qué medida el reducir la rugosidad del proceso de granallado nos ayudó a reducir los costos de recubrimiento a utilizados en la empresa?

1.3.Objetivos

1.3.1. Objetivo General

Mejorar el proceso de granallado para controlar la rugosidad y aumentar el rendimiento de los recubrimientos imprimantes epóxicos.

1.3.2. Objetivos Específicos

Utilizar una granalla de otra granulometría para reducir la rugosidad obtenida del proceso de granallado.

Utilizar un sistema de filtrado de abrasivos finos reutilizados para obtener una rugosidad constante.

Disminuir la rugosidad del proceso de granallado para reducir los costos de recubrimiento a utilizar en la empresa.

1.4.Justificación De La Investigación

1.4.1. Justificación Técnica

La evaluación técnica de los factores y parámetros a controlar del proceso de chorreado abrasivo con granalla nos permitieron obtener una rugosidad más acorde a los intereses económicos de la empresa para reducir costos en los diferentes proyectos futuros a realizarse.

En el presente trabajo se enfocó en un análisis del proceso de granallado para realizar las mejoras respectivas que tengan impacto en la rugosidad a obtener el cual tuvo mucha implicancia con reducir los consumos de los recubrimientos imprimantes epóxicos para la empresa.

1.4.2. Justificación Económica

La evaluación realizada a raíz del análisis del proceso de chorreado abrasivo con granalla conllevo a encontrar los mejores resultados la cual será presentada a lo largo de la investigación que tuvo un impacto económico sustancial en la reducción de costos de los recubrimientos imprimantes epóxicos a utilizarse en los diferentes proyectos de la empresa.

1.4.3. Justificación Social

Realizar la implementación de un plan de mejora para el proceso de granallado nos permitirá generar utilidades en los diferentes proyectos a aplicar obteniendo el personal obrero y empleados una ganancia extra la cual tendrá impacto para el crecimiento económico de la ciudad local y las inversiones personales las cuales se hacen.

1.5.Delimitación De Estudio

1.5.1. Delimitación Temporal

La evaluación y propuesta de mejora del proceso de granallado para controlar la rugosidad y aumentar el rendimiento de los recubrimientos imprimantes epóxicos, se llevó a cabo en los meses de febrero a diciembre del 2020.

1.5.2. Delimitación Espacial

El presente trabajo se realizó en las instalaciones de la empresa metalmecánica Haug S.A. ubicado en Lurín, distrito de Lima.

1.5.3. Delimitación Académica

El trabajo de investigación cumplió con los requerimientos mínimos de investigación exigidos por la Universidad Nacional José Faustino Sánchez Carrión el cual será sustentado con bibliografías, informes, textos, reportes, libros, normas estandarizadas y estudios referenciales que proporcionan teoría sobre el proceso de preparación superficial con chorro abrasivo de tipo granalla el cual es realizado en muchas metalmecánicas las cuales implementan mejoras para aumentar su rendimiento en la aplicación de recubrimientos industriales.

1.6. Viabilidad De Estudio

1.6.1. Viabilidad de recurso teórico

El tema de investigación: “Propuesta de mejora del proceso de granallado para controlar la rugosidad y aumentar el rendimiento de los recubrimientos imprimantes epóxicos en la empresa Haug S.A.”, cuento con suficiente acceso a información primaria tanto de libros, revistas, códigos, normas, etc.

1.6.2. Viabilidad de recurso humano

El estudio poblacional se realizó a los encargados de apoyar en el proceso de granallado y pintado. El estudio conto con viabilidad de recurso ya que se realizó con el apoyo de los trabajadores del área de granallado y pintura de la empresa Haug S.A.

Si fue viable por medio de recursos monetarios propios, así como también se tuvo apoyo de la empresa Haug S.A. en los recursos de maquinarias y humanos para la investigación realizada.

CAPITULO II

MARCO TEORICO

2.1.Antecedentes De La Investigación

2.1.1. Investigaciones Internacionales

(Blandino J., 2017), tiene como objetivo realizar un análisis de control de calidad en el área de pintura en la cual se realizó desde el ingreso de la materia prima, habilitado, armado y soldado hasta derivarse al área de preparación superficial donde de acuerdo a los parámetros establecidos por el cliente se va a tomar acción del tipo de limpieza, tipo de recubrimiento, espesor, pruebas, ensayos y la tolerancia de todo lo mencionado. De todo el proceso en general se pudo evidenciar que el control de calidad no es el adecuado por lo que se requiere un control exhausto para prevenir errores en el proceso que puedan retardar el producto.

(Belloso W. & Flamenco I. 2014), en la investigación de tesis se describe el diseño y construcción de un sistema de granallado en la cual se evaluaron: presión de salida, distancia de acción y ángulo de proyección, las cuales se controlaron con el fin de tener una productividad optima en el proceso en mención.

2.1.2. Investigaciones Nacionales

(Cárdenas, M. 2014), tiene como objetivo diseñar un sistema de extracción de polvo para una cabina de granallado la cual tiene como finalidad la captación del polvo residual del proceso de chorreado abrasivo en las cabinas de granallado eliminando la falta de visibilidad en la cámara, reduciendo improductividad y eliminando los contaminantes de la superficie removida con el acero proyectado.

(Dávila P., & Calle P., 2018), tiene como objetivo evaluar la adherencia del imprimante IOZ respecto a la rugosidad obtenida con diferentes granulometrías de arena en la cual tuvo como conclusión que la adherencia no es más elevada si la rugosidad también lo es, por consecuente en las probetas obtenida se tuvo que la Probeta A el valor de adherencia el 112.7% de lo indicado en la hoja técnica por lo que es lo recomendable para la durabilidad del sistema de recubrimiento seguir las pautas de acuerdo a la prueba.

(López J. 2018), tiene como objetivo demostrar que la implementación de las herramientas Lean Manufacturing mejoraron la productividad en el área de granallado evaluando el parámetro de su proceso en el mes de diciembre del 2017 y a los 2 meses después se realizó la implementación para demostrar sus hipótesis, el cual tuvo con resultado que el aumento de la eficiencia en 5.61% y la eficacia en un 4.15%.

(Berroa E., 2019), tiene como objetivo aplicar control de calidad en la preparación superficial y aplicación de recubrimiento de un tanque basados en códigos, estándares y normas internacionales. Los resultados obtenidos en el proceso en general fueron aceptables y estuvieron dentro de los parámetros establecidos por el cliente los cuales se registraron en documentación la cual se le entrego al usuario final.

(Mitma D. & Mera G. & Vela A. 2019), tiene como objetivo optimizar el proceso de limpieza superficial metálica mediante chorro abrasivo realizando un previo análisis y estudio en 24 probetas que representan el proceso en el cual se controlaron las variables de: distancia, tiempo y ángulo de proyección. Se tuvo como resultado que el factor distancia es altamente significativo para optimizar el proceso de preparación superficial.

(Saldarriaga J., 2006), tiene como objetivo optimizar el proceso de preparación superficial en el servicio industrial de la marina el cual se realizó implementado el proceso con hidrolavadora a ultra alta presión (UHPW) el cual cumple con los requerimientos mínimos para la limpieza superficial, pero este no genera una rugosidad en el acero ya que no se utiliza abrasivo metálico por lo cual solo se recomienda usar para elementos que ya cuentan con rugosidad previa.

(Cáceres O. & Gámez J., 2019), tiene como objetivo aplicar herramientas de mantenimiento productivo total en el proceso de granallado para el cual se realizó una evaluación previa del proceso teniendo como resultado que la empresa carecía de una deficiente respuesta de mantenimiento, a partir de ello se aplicaron pilares de mantenimiento autónomo y planificado a la maquina granuladora, posteriormente de la implementación de la herramienta se obtuvo que la productividad aumento en 22.86%.

2.2.Bases Teóricas

2.2.1. Introducción General al Granallado

El proceso de granallado es una técnica de tratamiento superficial por impacto con el cual se puede lograr un excelente grado de limpieza y simultáneamente una correcta terminación superficial en una amplia gama de piezas metálicas y no metálicas (CyM Materiales S.A, 2015).

En resumen, se utiliza el granallado para:

Limpieza superficial de piezas de fundición metálicas y no metálicas.

Decapado mecánico/químico para accesorios metálicos.

Shot Peening.

Limpiar y preparar superficies para la aplicación de recubrimientos y revestimientos.

El granallado es la proyección de granalla metálica a mucha velocidad que cuando impacta con la superficie produce una limpieza de la misma (CyM Materiales S.A., 2015)

Debido a la aparición de la turbina centrifuga fue posible realizar de manera automática y producción el granallado centrifugo teniendo como ventaja de ser muy uniforme (CyM Materiales S.A., 2015)

Las características de la superficie a tratar y los requerimientos en términos de calidad tendrán mucha importancia sobre el tiempo de sistema de granallado a utilizar. En ocasiones es necesario utilizar otros métodos para asegurar una adecuada limpieza de la superficie (CyM Materiales S.A., 2015)

El sistema de chorreado abrasivo está compuesto por 6 partes:

1. Sistema de aceleración de abrasivo
2. Sistema de flujo y eliminación de abrasivo residual
3. Sistema de extracción de residuos inoperativos
4. Cabina.
5. Sistema de flujo y soporte
6. Control automático del sistema

2.2.2. Limpieza Superficial Metálica

La limpieza superficial es la remoción de contaminantes visibles y no visibles de la superficie que puedan impedir la adherencia del recubrimiento a aplicar posteriormente. El grado de limpieza a obtener estará de acuerdo a los requerimientos especificados (Mitma, Mera & Vela, 2019).

Tener en cuenta los parámetros siguientes:

a) Proceso de limpieza superficial

La limpieza superficial consiste en la eliminación de los contaminantes visibles y no visibles (Mitma, Mera & Vela, 2019):

1) Contaminantes visibles

Son los contaminantes presentes en la superficie como grasas, pintura vieja, aceite y otros los cuales dificultan la adherencia de los recubrimientos a aplicar (Mitma, Mera & Vela, 2019).

2) Contaminantes no visibles

Son los contaminantes presentes en la superficie como las sales o iones las cuales pueden causar una aceleración de Corrosion (Mitma, Mera & Vela, 2019).

La preparación de superficie metálica implica tres pasos importantes:

1) Pre – limpieza o pre preparación de superficie:

Se procede a inspeccionar los defectos mecánicos del acero los cuales deben ser reparados, así como también contaminantes visibles y no visibles los cuales deben ser retirados (Mitma, Mera & Vela, 2019).

2) Limpieza o preparación de superficie

Se ejecuta el chorreo abrasivo la cual se encarga de remover el óxido, pintura vieja, cascara de laminación para alcanzar la preparación de superficie y obtener la rugosidad requerida (Mitma, Mera & Vela, 2019).

3) Post limpieza o post preparación de superficie

Se procede a eliminar restos de residuos del proceso chorreado abrasivo con aire seco dentro de los cuales se encuentra polvo y granalla fina (Mitma, Mera & Vela, 2019).

b) Calidad de superficie

La superficie preparada debe estar de acuerdo a los requerimientos especificados para obtener un mejor desempeño del recubrimiento. La SSPC (Steel Structures Painting Council) indica cuatro niveles de preparación superficial: Metal blanco, Metal casi blanco, Comercial y brush off (Mitma, Mera & Vela, 2019).

c) Tipos de limpieza

1) Limpieza con solvente

Las limpiezas con solventes utilizados son orgánicos e inorgánicos para retirar contaminantes visibles y no visibles (Mitma, Mera & Vela, 2019).

2) Limpieza manual

La limpieza manual se realiza con herramientas eléctricas o neumáticas, así como también se pueden utilizar herramientas como el cepillo, lija etc. (Mitma, Mera & Vela, 2019).

3) Limpieza con herramientas de poder

La limpieza con herramientas de poder se realizar con herramientas eléctricas o neumáticas y generalmente son utilizadas para ejecutarse en zonas donde otros tipos de preparación no es posible o por temas restrictivos (Mitma, Mera & Vela, 2019).

4) Limpieza con chorro abrasivo

La limpieza con chorro abrasivo se utiliza para remover la cascara de laminación, pintura vieja y oxido la cual es realizada de manera homogénea y muy productiva (Mitma, Mera & Vela, 2019).

d) Grado de corrosión

De acuerdo a la SSPC VIS 1 define cuatro grados de Corrosion (A, B, C y D), conocer el estado inicial de Corrosion es importante para poder identificar el grado de limpieza a alcanzar (Mitma, Mera & Vela, 2019).

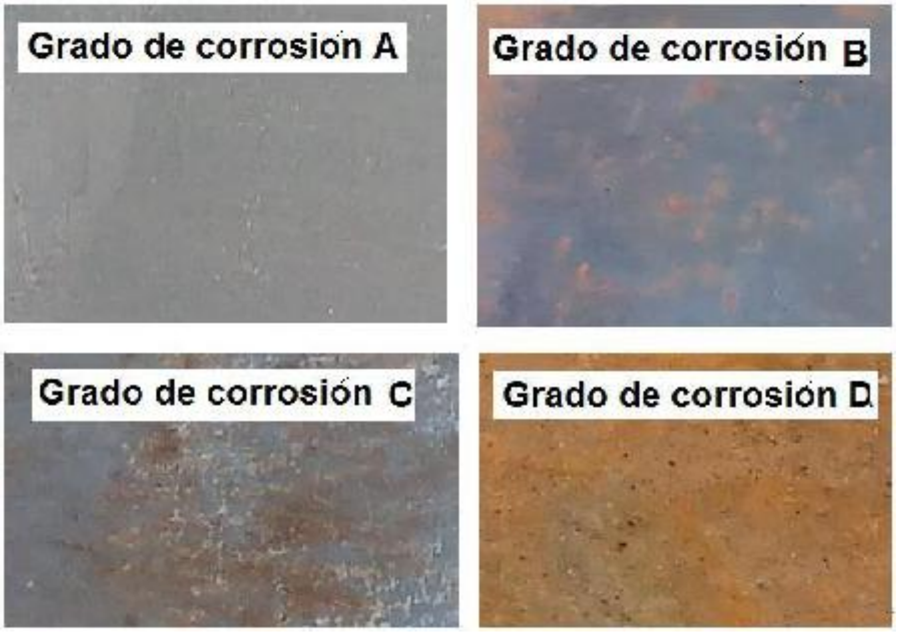


Figura 1. Grados de corrosión de metales. (Mitma D., Mera G. y Vela A., 2019).

e) Rugosidad

La rugosidad obtenida en la limpieza con chorro abrasivo es un factor importante debido a que aportara adherencia mecánica cuando se aplique el recubrimiento (Mitma, Mera & Vela, 2019).

La superficie perfecta es ideal ya que por naturaleza estas son irregulares. Para determinar el patrón de rugosidad se deben medir los parámetros como la distancias de las picos y valles (Rt) conforme al valor medio (Ra) en una determinada medida longitudinal (Rz) (Mitma, Mera & Vela, 2019).

1) Línea Media

La línea media es la recta longitudinal de rugosidad dejando divididos los picos y valles (Mitma, Mera & Vela, 2019).

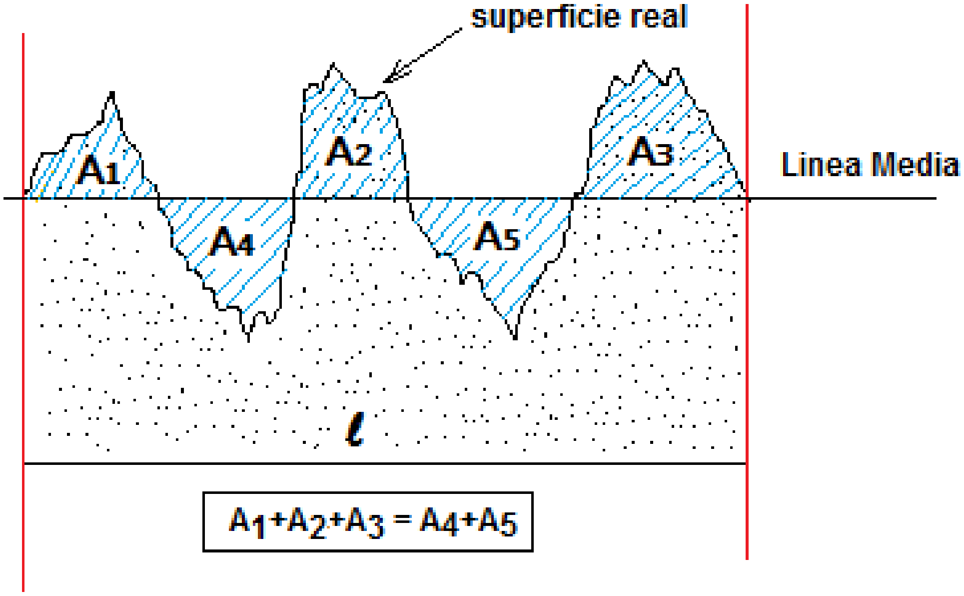
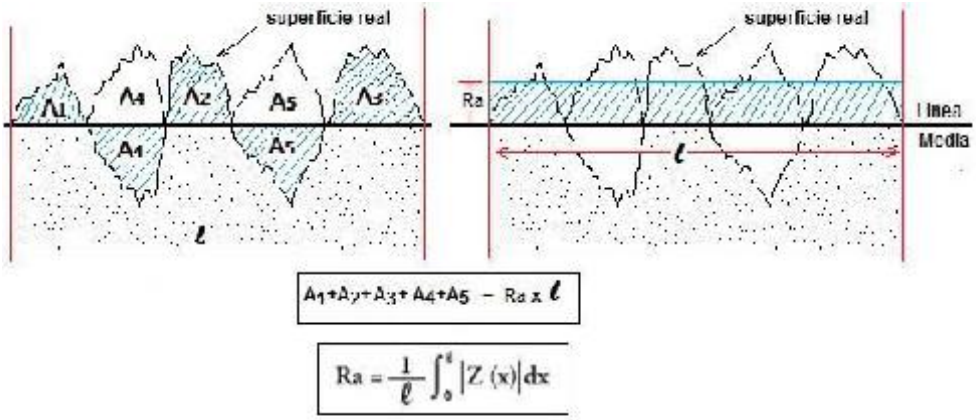


Figura 2. Línea media. (Mitma D., Mera G. y Vela A., 2019).

2) Rugosidad media

La rugosidad media es la suma de los valores absolutos de las áreas entre la línea media y el perímetro del perfil de rugosidad, dividido entre la longitud del tramo donde se realiza la medición (Mitma, Mera & Vela, 2019).



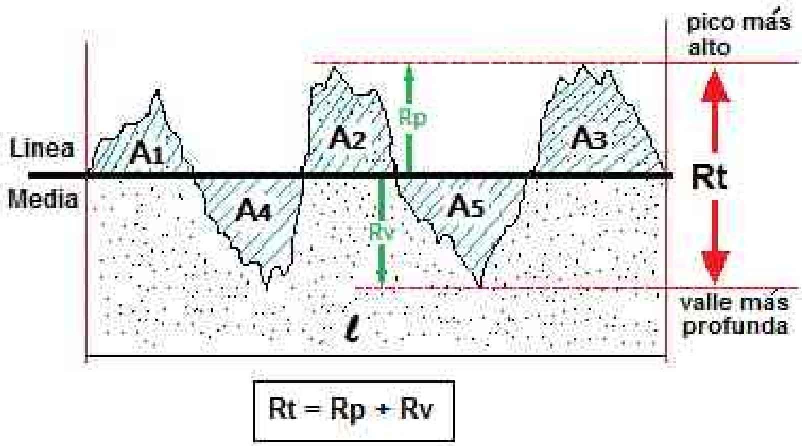
$$A_1+A_2+A_3+A_4+A_5 = Ra \times \ell$$

$$Ra = \frac{1}{\ell}\int_0^{\ell} |Z\,(x)|\,dx$$

Figura 3. Rugosidad media. (Mitma D., Mera G. y Vela A., 2019).

3) Rugosidad total

La rugosidad total o rugosidad máxima es la distancia entre el pico más alto (Rp) y el valle más bajo (Rv) en un área de medición (Mitma, Mera & Vela, 2019).

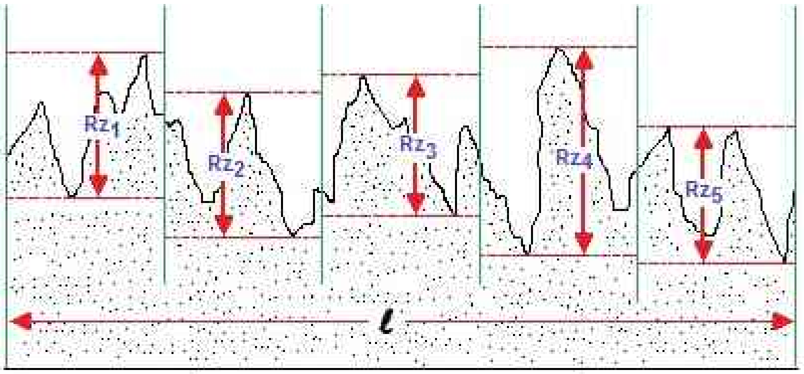


$$Rt = Rp + Rv$$

Figura 4. Rugosidad Total. (Mitma D., Mera G. y Vela A., 2019).

4) Profundidad de rugosidad media

La profundidad de rugosidad media es el promedio de distancias de los picos más altos y valles más bajos (Mitma, Mera & Vela, 2019).



$$Rz = \frac{RZ1 + RZ2 + RZ3 + RZ4 + RZ5}{5}$$

Figura 5. Profundidad de rugosidad media. (Mitma D., Mera G. y Vela A., 2019).

Existen diversos métodos para medir estos parámetros y obtener la rugosidad requerida la cual es muy importante para asegurar la buena adherencia del recubrimiento a aplicar (Mitma, Mera & Vela, 2019).

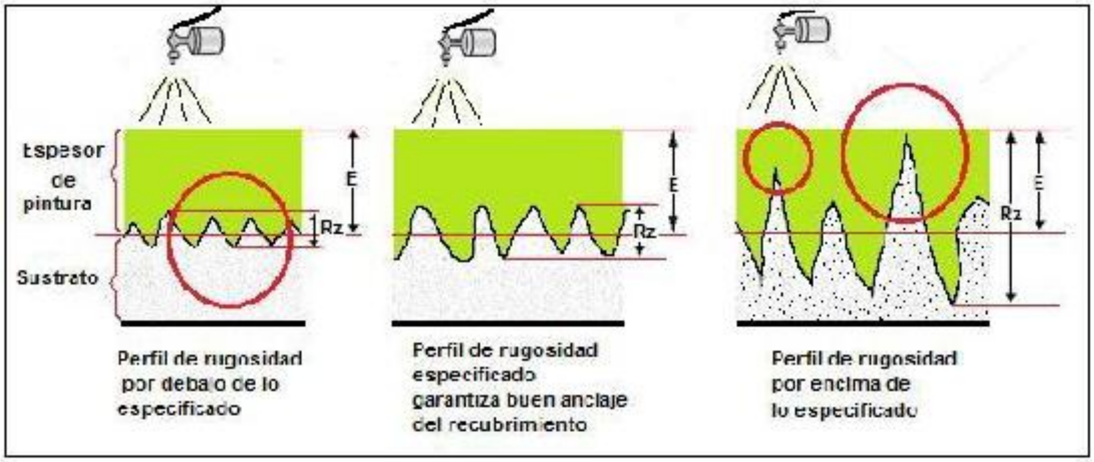


Figura 6. Anclaje de recubrimiento respecto al perfil de rugosidad. (Mitma D., Mera G. y Vela A., 2019).

Si la rugosidad es alta, el recubrimiento no puede cubrir los picos superiores y si la rugosidad es demasiada baja puede haber falta de anclaje y fallas de adherencia (Mitma, Mera & Vela, 2019).

f) Métodos de medición de la rugosidad

La norma ASTM D4417 detalla cuatro métodos de medición de perfil de rugosidad (Mitma, Mera & Vela, 2019).

1) Comparador de superficie: ASTM D4417 Método A

El método A consiste en comparar de manera táctil y visual en comparadores de diferentes medidas las cuales se clasifican en fino, medio y grueso (Mitma, Mera & Vela, 2019).

2) Medidor de profundidad/ASTM D4417 – Método B

El método B consta de un equipo que tiene una base que mide los picos más altos y una sonda que mide los valles más bajos (Mitma, Mera & Vela, 2019).

3) Medidor según cinta réplica/ASTM D4417 – Método C

El método C consiste en colocar una cinta que replica la rugosidad al presionarla sobre la superficie, luego la muestra tomada se mide en un Rugosímetro (Mitma, Mera & Vela, 2019).

4) Rugosímetro mediante palpador/ ASTM D7127

Los rugosimetros palpadores cuentan con una guja que recorre toda la superficie rugosa registrando los picos y valles (Mitma, Mera & Vela, 2019).

De los métodos presentados el más utilizado es el método C con la cinta replica y el micrómetro (Mitma, Mera & Vela, 2019).

Figura 7. Métodos de medición de rugosidad. (Mitma D., Mera G. y Vela A., 2019).

La cinta replica está compuesta por una espuma compresible unida a una tira de apoyo llamado Mylar de 50 micras de espesor, medida la cual debe ser tomada en cuenta en la respectiva medición con el micrómetro (Mitma, Mera & Vela, 2019).

Se coloca la cinta sobre la superficie a evaluar y se rota con un artículo circular para que esta área quede bruñida, quedando posteriormente reflejada la rugosidad (Mitma, Mera & Vela, 2019).

La cinta se retira de la superficie y se mide utilizando un micrómetro, se coloca la cinta entre los yunques de medición y se suelta para tomar la medida, tener en cuenta que, si el equipo se coloca a cero, se debe restar la medida del Mylar (50micras) para obtener el valor real (Mitma, Mera & Vela, 2019).

Figura 8. Cinta replica y medidor de rugosidad. (Mitma D., Mera G. y Vela A., 2019).

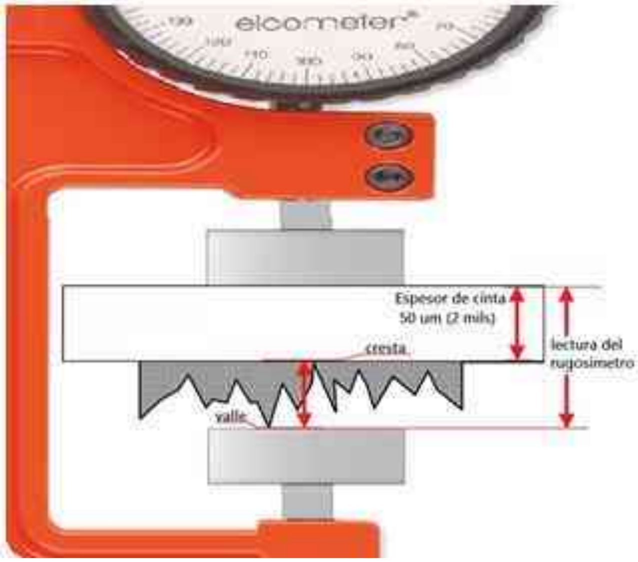


Figura 9. Cinta replica entre yunque de medidor. (Mitma D., Mera G. y Vela A., 2019).

Existen 4 tipos de cintas que se representan en diferentes rangos teniendo: Coarse minus (Menos grueso), Coarse (Grueso), X Coarse (Extra grueso) y X Coarse plus (Extra grueso plus (Mitma, Mera & Vela, 2019).

Figura 10. Diferentes rangos de cinta replica. (Mitma D., Mera G. y Vela A., 2019).

Elegir el tipo correcto de cinta dependerá debe ser importante ya que, si los valles son más profundos que el rango de cinta, esta no copiara la medida requerida (Mitma, Mera & Vela, 2019).

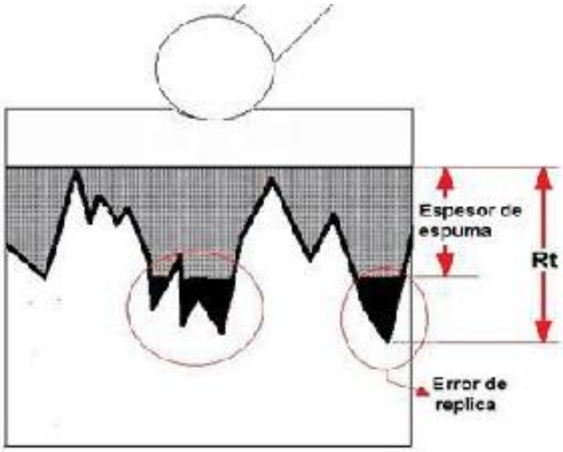


Figura 11. Cinta replica de espesor inadecuado. (Mitma D., Mera G. y Vela A., 2019).

2.2.3. Método chorro abrasivo

A partir de la eyección de aire comprimido por una maquina compresora transporta el abrasivo hasta la boquilla de salida la cual hace que sea expulsado a gran velocidad otorgándole fuerza de abrasión con la que se realiza la limpieza y preparación de superficies (Mitma, Mera & Vela, 2019).

La limpieza con chorro abrasivo es considerada el método más efectivo porque elimina contaminantes visibles y no visibles, así como también genera perfil de rugosidad la cual es necesaria para que el recubrimiento a aplicarse de adhiera correctamente (Nolasco, 2015).

Tipos de chorro abrasivo: Hay de dos tipos:

a) Chorreo abrasivo seco

El chorro abrasivo seco es una técnica la cual consiste en utilizar aire seco combinado con el abrasivo generalmente en un recipiente a presión para que sea proyectado hacia una salida de mangueras (Mitma, Mera & Vela, 2019).

b) Chorreo abrasivo en medio húmedo

El chorro abrasivo húmedo es una técnica que combina el abrasivo con humedad la cual puede ser aire húmedo o agua para que este sea presurizado en una tolva y eyectado hacia la superficie a limpiar (Mitma, Mera & Vela, 2019).

Tabla 1. Perfil de anclaje de abrasivos

	Profile Height				
ABRASIVE	**25 µm 1 mil**	**37 µm 1.5 mil**	**50 µm 2 mil**	**63 µm 2.5 mil**	**75-100 µm 3-4 mil**
Silica Sand	30/60 mesh	16/35 mesh	16/35 mesh	8/35 mesh	8/20 mesh
Steel Grit	G80	G50	G40	G40	G25
Steel Shot	S110	S170	S280	S280	S330
Garnet	80 mesh	36 mesh	36 mesh	16 mesh	16 mesh
Aluminum Oxide	100 grit	50 grit	36 grit	24 grit	16 grit

Fuente: Publicado por SSPC SP COM en noviembre 1 de 2004.

Tipos de abrasivos:

1) Arena Silica

La arena Silica muy económica y eficiente pero no es muy amigable con el medio ambiente por la emisión de polución la cual produce riesgos en la salud (Mitma, Mera & Vela, 2019).

2) Óxido de aluminio

El óxido de aluminio es costoso pero utilizado en preparaciones de superficies especiales como aluminio o aceros inoxidables, además tiene una alta tasa de reutilización y excelente dureza para limpieza (Mitma, Mera & Vela, 2019).

3) Carburo de silicio

El carburo de silicio es el más duro, afilado y costoso en el mercado. Es un abrasivo muy productivo y reutilizable ya que tiene una dureza muy elevada (Mitma, Mera & Vela, 2019).

4) Escoria de cobre

La escoria de cobre es obtenida de residuos de procesos de cobre en hornos metalúrgicos, es muy efectiva ya que es muy tenaz y presenta una alta dureza (Mitma, Mera & Vela, 2019).

2.2.4. Corrosión

La Corrosion es un proceso electroquímico compuesto por 4 elementos: ánodo, cátodo, ruta metálica y electrolito (Guerra, 2014).

La presencia de agentes externos como humedad, sales, contaminación producen una capa de óxido las cuales se muestran algunas reacciones a continuación: (Guerra C., 2014).

Reacciones anódicas:

$Fe \quad Fe^{2+} + 2e$ $\qquad$ $Fe^{+2} \quad Fe^{+3} + e$

Reacción catódica:

$O_2 + 2H_2O + 4e^- \quad 4OH^-$

La reacción general de corrosión podemos expresarla de la siguiente forma:

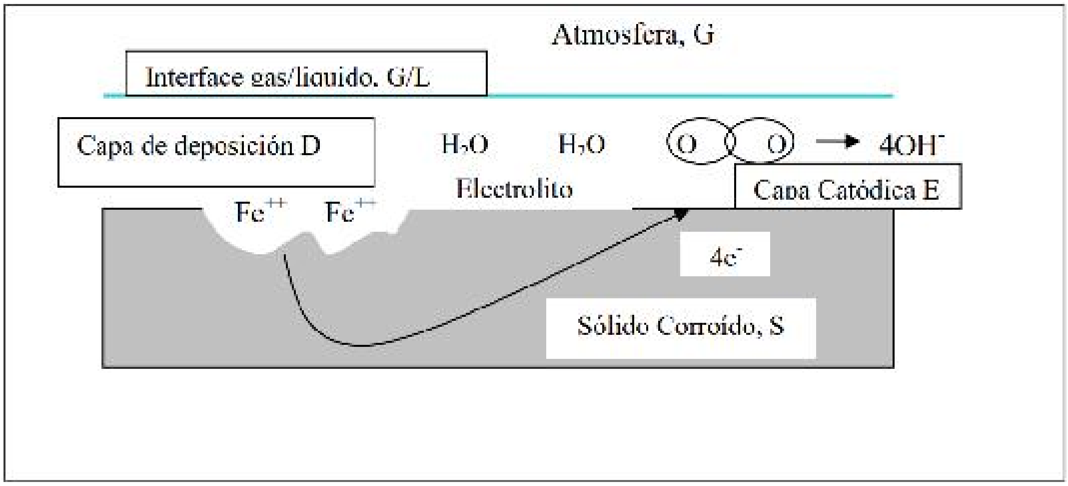


Figura 12. Idealización del proceso de corrosión atmosférico sobre una superficie de acero. (Guerra C., 2014).

En la tabla 2, mostramos la naturaleza de los productos de corrosión encontrados en diferentes metales expuestos a la atmosfera.

Tabla 2. Naturaleza de productos de corrosión atmosférica.

Metal	Especies Comunes	Especies raras
Al	$Al(OH)_3$	$AlOOH$, $Al_x(OH)_y(SO4)_z$
	Al_2O_3, $Al2O_3.3H_2O$	$AlCl(OH)_2.4H_2O$
Fe	Fe_2O_3, $FeOOH$, $FeSO_4.4H_2O$	$Fe_x(OH)_yCl_z$, $FeCO_3$
Cu	Cu_2O, $Cu_4SO_4(OH)_6$	$Cu_2Cl(OH)_3$,
	$Cu_4SO_4(OH)_6.2H_2O$	$Cu_2CO_3(OH)_2$
	$Cu_3SO_4(OH)_4$	$Cu_2NO_3(OH)_3$
Zn	ZnO, $Zn_5(OH)_6(CO_3)_2$	$Zn(OH)_2$, $ZnSO_4$
	$ZnCO_3$	$Zn_5Cl_2(OH)_8.H2O$

Fuente: Roberge P.R.1999.Handbook of Corrosion Engineering.

2.2.4.1.Tipos de corrosión

Corrosión industrial

Los ambientes industriales presentan un ambiente compuesto por sulfatos, estos son absorbidos por el polvo ambiental y con la presencia de humedad forman ácido sulfúrico. El ácido sulfúrico formado toma forma de gotas y cae como lluvia conocido como la lluvia acida (Guerra, 2014).

Corrosión marina

Los ambientes marinos contienen en su ambiente sales provenientes del mar que al combinarse con la humedad son depositadas en las superficies acelerando la Corrosion, el ambiente marino es el más agresivo para el acero (Guerra, 2014).

Corrosión rural

Los ambientes rurales son menos agresivos con las superficies por lo general solo hay lluvia, presencia de humedad y condensación (Guerra, 2014).

Corrosión en interiores

Los ambientes interiores son considerados de muy amigables y por lo general solo hay presencia de humedad la cual es fácil de controlar (Guerra, 2014).

2.2.5. Principios De Pintura

Los recubrimientos tienen un papel importante ya que favorecen a la protección de diversas superficies de la Corrosion de diferentes ambientes y el método más utilizado es el aislamiento por barrera ya que impide la penetración de los agentes externos a el interior de la superficie (Parrilla, 2011).

2.2.5.1.Tipos De Recubrimientos

2.2.5.1.1. Recubrimientos Metálicos

Los recubrimientos metálicos son producidos por procesos de inmersión o electrolisis en mayoría de los casos, así como también por atomización de manera líquida. La mayoría de recubrimientos metálicos son de zinc, plata, cobre y cromo (Parrilla, 2011).

2.2.5.1.2. Recubrimientos Cerámicos

Los recubrimientos cerámicos tienen una alta impermeabilidad y resistencia mecánica por lo que son utilizados en zonas donde hay abrasión latente o hay presencia de agentes ácidos. Estos se pueden aplicar sobre acero y concreto (Parrilla, 2011).

2.2.5.1.3. Recubrimientos Sintéticos

La variedad de productos disponible es muy grande Los recubrimientos sintetizados son utilizados generalmente con refuerzos de fibra y las aplicaciones más vistas son en PVC, poliéster, teflón, etc. (Parrilla, 2011).

2.2.6. Pinturas

Las pinturas son parte de los recubrimientos y tienen una función más decorativa que protectora (Parrilla, 2011).

2.2.6.1. Composición De Las Pinturas

Existe una diversidad de pinturas protectoras cada una tiene propiedades asicas respecto a otro, así como también características como viscosidad, protección ultravioleta, otras secan rápido y otras lento (Parrilla, 2011).

La característica principal que tienen en común los diversos recubrimientos es la capacidad de formar una película protectora la cual es generada por la resina que debe estar en estado líquido al aplicarse en conjunto con su agente de curado por lo que es viable utilizar disolventes para reducir su viscosidad (Parrilla, 2011).

2.2.6.2. Composición De Una Pintura

La composición de la pintura consta de 3 grupos: pigmentos, vehículo y aditivos. Estos componentes aportan en la formación de película (Parrilla, 2011).

Tabla 3. Componentes de la pintura y sus características.

PINTURA	**PIGMENTOS**	COLORANTES
		REFORZANTES
		QUIMICOS
	VEHICULOS	NO VOLATIL
		FORMADORES DE PELICULA
		VOLATIL
		SOLVENTES
	ADITIVOS	PLASTIFICANTES
		SECANTES
		HUMECTANTES
		DISPERSANTES
		TIXOTROIZANTES
		ACELERANTES
		ABRILLANTADORES
		ANTIFUOCULANTES
		ANTINATA
		ANTIESTATICOS
		ANTIOXIDANTES

Fuente: Juan G., 2003.

Resina:

Es el componente principal de los recubrimientos y es la que da las propiedades primarias las cuales pueden ser adherencia, impermeabilidad, protección uv, etc. Existen varios tipos de resinas: (Parrilla, 2011).

- Látex
- Nitrocelulosa
- Alquídicas
- Poliuretanos

Pigmentos:

Es el componente encargado de dar las propiedades secundarias al recubrimiento y son de tipo natural o sintético, se tienen las siguientes propiedades: (Parrilla, 2011).

- Poder cubriente
- Color
- Retención del color
- Tamaño y forma de partícula
- Capacidad de humectación
- Absorción de aceite
- Reactividad química
- Estabilidad a la luz
- Resistencia al calor
- Índice de reflexión

Los pigmentos se segmentan en 2 tipos: pigmentos básicos/colorantes y pigmentos reforzadores. (Parrilla, 2011).

Solventes:

Los solventes se volatilizan y no permanecen en el recubrimiento, es la encargada de hacer que el fluido sea más aplicable, menos viscoso y manejable, son de varios tipos: (Parrilla, 2011).

- Aromáticos

- Agua

- Alcoholes

- Glicoles

- Acetona

Aditivos:

“Son productos químicos que se agregan en pequeña proporción a la pintura, con el objeto de modificar sus propiedades y ajustarla a los requerimientos. Dentro de los aditivos más importantes se encuentran los siguientes” Los aditivos son sustancias químicas que se adicionan a la mezcla para hacer que tenga ciertas propiedades requeridas para su desempeño de los cuales son: plastificantes, secantes, humectantes, dispersantes, Acelerantes, abrillantadores, anti aglomerantes, anti piel, anti estáticos y antioxidantes (Parrilla, 2011):

2.2.6.3.Secados En La Pintura

2.2.6.3.1. Grupo Secamiento Evaporativos

Son recubrimientos que se forman en base a la evaporación del solvente y son no convertibles ósea que no hay procesos químicos involucrados, son de tipo reversibles, que se disuelven fácilmente en presencia de solventes, su proceso de curado depende de la temperatura, sus aplicaciones son: acrílicos, nitro celuloso, caucho Ciclizado, vinílicos, goma laca y bitúmenes brea asfalto (Parrilla, 2011).

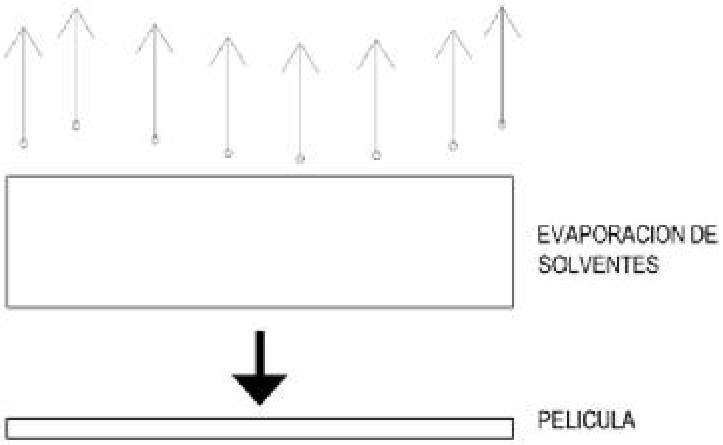


Figura 13. Secado de pintura. (Parrilla P., 2011).

2.2.6.3.2. Grupo Secamiento Evaporativo Más Oxidación

Son recubrimientos que se forman a partir de la absorción de oxígeno. Son recubrimientos de buena adherencia, irreversibles pero sensibles a solventes fuertes por lo tanto tienen una resistencia química pobre (Parrilla, 2011).

- **ÓLEOS:**

Los recubrimientos en base a oleo son de tipo domestico utilizados en baños, cocinas, puertas, casas, ventanas, etc. (Parrilla, 2011).

- **ALQUÍDICOS:**

Los recubrimientos alquídicos son elaborados con resinas Alquídicas que son obtenidas a partir del aceite natural. En la actualidad son los más aplicados con respecto a los oleos de tipo industrial debido a que secan rápidamente, tienen mayor dureza, mejor retención de brillo y son resistentes a la humedad y agua (Parrilla, 2011).

2.2.6.4.Grupo Secamiento Evaporativo Más Reacción Química

Los recubrimientos de este grupo son caracterizan por que presentan reacciones químicas luego de su curado y pueden ser de varios tipos: (Parrilla, 2011):

- **Reacción A Temperatura Ambiente**

Para este tipo, son recubrimientos de 2 componentes que están separados y deben mezclarse para consolidar una sola mezcla. Al mezclarse se inicia la reacción química de tipo irreversible (Parrilla, 2011).

Reacción A Temperatura Alta:

Los recubrimientos de este tipo requieren temperatura para culminar su curado y adquirir todas sus propiedades químicas y mecánicas (Parrilla, 2011).

2.2.7. Pinturas Epóxicas:

Los recubrimientos epóxicos son los más utilizados a nivel industrial por lo general son de 2 componentes que deben mezclarse para tener una mezcla homogénea. Las propiedades a obtener variaran del tipo de resina, agente curante y endurecedores (Parrilla, 2011).

2.2.8. Poliuretanos:

Los recubrimientos cerámicos son de buena resistencia química, así como carácter estético constan de aceite secante e isocianato y otros tienen resinas activas. Los usos de este tipo de recubrimiento son el concreto, pistas de básquet, exteriores de tanques, etc. (Parrilla, 2011).

2.2.9. Calculo Y Consumo De Recubrimiento Utilizado

2.2.9.1. Volumen De Solidos

Un recubrimiento es una mezcla homogénea compuesta por sólidos y líquidos, los sólidos formaran el recubrimiento y los líquidos se volatilizan. La relación de sólido y liquido variara de acuerdo al recubrimiento, pero el valor de volumen de solidos será de suma importancia ya que es la que proporcionara el espesor del recubrimiento (Samaniego, 2000).

Si se tiene un litro de un recubrimiento con un % de sólidos en volumen de 100% y se esparce a 25 micras de espesor, se puede afirmar que ese litro cubre un área de 39.4 m2, y si el recubrimiento fuera de 50% solidos, el rendimiento seria la mitad (Berroa, 2019).

R T: Para el caso descrito, el rendimiento teórico será el área máxima en metros cuadrados que será recubierta con 1 litro de recubrimiento a 25 micras. (Samaniego, 2000).

$$= (\qquad 100\% \qquad 1 \qquad) \ \%$$

$$= (39.37 \, \frac{2}{} \quad 1 \qquad) \ \% \tag{1}$$

Volumen= Área * Espesor de la película

Área = l m * 1 m = 1 m^2

Espesor = 1 milésima de pulgada

Espesor= 0.000254 m Volumen= 1 m^2 * 0.0000254m = 0.0000254 m^3

R T = NV = 1 m^2 / 0.0000254 m3

> 0.0000254 m^3 = 0.0254 l

RT = 1 m2 / 0.0254 l

RT = 39.37 m2/l

R T 100% sólidos = 39.37m2/l a 1 milésima de pulgada EPS

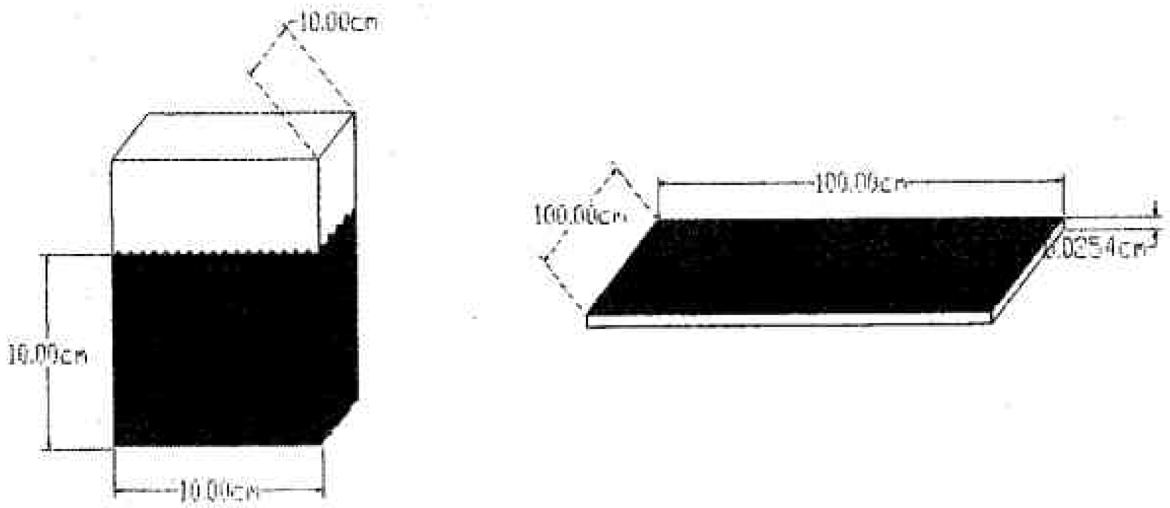


Figura 14. Capa de recubrimiento. (Berroa E., 2019).

2.2.9.2.Espesor De La Película

Los recubrimientos tienen una dimensión la cual se define como el espesor expresado en micras o mils y puede evaluarse cuando el recubrimiento está seco o húmedo (Berroa, 2019)

2.2.9.2.1. Espesor De La Película Húmeda

El espesor de película húmeda es el espesor que debe ser identificado instantáneamente cuando el recubrimiento es aplicado, de esta manera se podrá estimar el espesor de película seca (Berroa, 2019).

Para verificar el espesor de película húmeda se utilizar un equipo llamado medidor de película húmeda o peine metálico el cual se introduce de manera longitudinal en la superficie apenas fue recubierto (Berroa, 2019).

Figura 15. Medidor de película húmeda. (Berroa E., 2019).

2.2.9.2.2. Espesor De La Película Seca

El espesor de película seca es el espesor obtenido cuando el recubrimiento se encuentra seco y libre de solventes (Berro, 2019).

Para evaluar el espesor seco se utilizan equipos magnéticos que detectan la superficie metálica a la cual fue recubierta y diferencia el recubrimiento no conductor (Berroa, 2019).

2.2.9.3. Aumento De La Superficie Y Formación Del Volumen Muerto

Las superficies de acero visualmente son lisas, pero si se identifican con equipos de acercamiento se puede determinar que presentan picos y valles, a esto se le llama rugosidad superficial (Berroa, 2019).

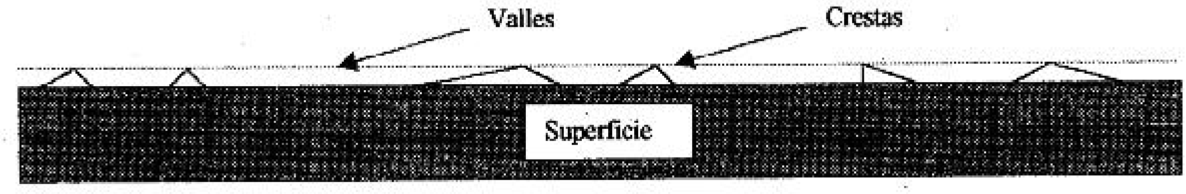


Figura 16. Rugosidad de una superficie. (Berroa E., 2019).

La rugosidad superficial origina el volumen muerto, este volumen muerto es formado por picos y valles. Este volumen muerto es necesario que sea recubierto con el espesor de recubrimiento, pero si el volumen muerto es muy excesivo hará falta más volumen de recubrimiento para cubrir los picos y valles (Berroa, 2019).

Tabla 4. Relación rugosidad - volumen muerto (Pintura húmeda).

RUGOSIDAD EN MICRAS	**AUMENTO DE LA SUPERFICIE EN %**	**"VOLUMEN MUERTO" cm^3/m^2 @ 1 Micra PINTURA HUMEDA**
30	26	25
40	36	31
50	46	38
60	54	45
70	61	51

Fuente: Berroa E., 2019.

La rugosidad será obtenida a partir del sistema de limpieza utilizado teniendo en cuenta: abrasivo utilizado, tipo de material limpiado, presión de salida del abrasivo, grado de oxidación inicial del acero, mezcla operativa actual del abrasivo, ángulo de proyección de la boquilla de salida, etc. (Berroa, 2019).

2.2.9.3.1. Consumo De Recubrimiento Y Volumen Muerto

El consumo para obtener un espesor de película se puede calcular conociendo el volumen de saludos (Berroa, 2019).

(EPS micras) / (Proporción de Sólidos en Volumen%)* (10) = CONSUMO (l / 100 m^2)

La fórmula descrita nos indica que un recubrimiento está compuesto por parte sólida que permanece en el recubrimiento y parte liquida que se volatiliza (Berroa, 2019).

"Por ejemplo, si tenemos una especificación de una película a.; 60. micras de película seca y la proporción de sólidos en volumen es de 0.70 obtenemos" (Berroa E., 2019, p.27).:

(60) / (0.70) * (10) = 8.57. l /100 m^2

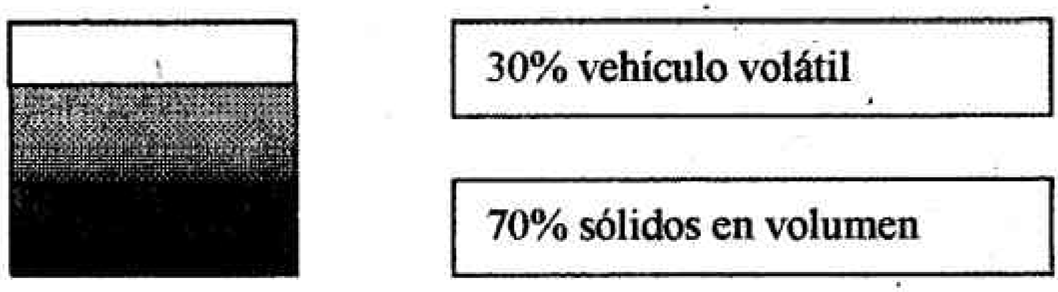


Figura 17. Consumo de recubrimiento. (Berroa E., 2019).

Con lo obtenido se tiene el consumo y el rendimiento de una superficie lisa pero ahora se requiere el recubrimiento extra para rellenar todos los picos y valles para así asegurar un espesor real por lo cual nos basamos en la siguiente tabla (Berro, 2019):

Tabla 5. Relación rugosidad - volumen muerto

RUGOSIDAD EN MICRAS	FACTOR DE VOLUMEN MUERTO (FVM)
15	1
20	2
45	3
60	4
75	5
90	6
105	7

Fuente: Gómez Ramírez. 2008.

Y utilizamos la fórmula:

$$(\quad) = \frac{\qquad}{\% \qquad 2} \tag{2}$$

Si en el caso tuvimos una rugosidad de 20 micras, podríamos decir de acuerdo a la tabla 5 que el consumo extra es:

$$= \quad ^{2} \qquad \frac{}{2} \tag{3}$$

CONSUMO MUERTO= 210.70 = 2.86 l / 100 m^{2}

“Lo cual sumado a lo inicial nos da un consumo de” (Berroa E., 2019, p.28).

CONSUMO TOTAL= CONSUMO TEORICO + CONSUMO MUERTO+ PERDIDAS

CONSUMO TOTAL= 8.57 l / 100 rn^{2} + 2.86 l / 100 rn^{2} + PERDIDAS

CONSUMO TOTAL = 11.43 l / 100rn^{2} + PERDIDAS

RENDIMIENTO= 8.75 rn^{2} / l + PERDIDAS a 60 micras (Berroa E., 2019, p.28).

Para hallar el volumen de recubrimiento requerido para un área específica es:

$$= \frac{\qquad}{\qquad} \frac{2}{\frac{2}{}} \tag{4}$$

Finalmente, para hallar el consumo total sumamos la ecuación 3 y ecuación 4:

$$= \qquad + \tag{5}$$

Lo obtenido fue el rendimiento teórico, ahora hay que considerar las perdidas por el proceso de aplicación de recubrimientos como: salpicaduras, sobras, limpieza, flujo, etc. Lo obtenido se llamará rendimiento practico el cual es (Berroa, 2019):

$$= \frac{(1-\% \qquad)}{\qquad\qquad\qquad\qquad} \frac{2}{\quad} \tag{6}$$

El rendimiento practico es el rendimiento que recubre un área específica con un volumen especifico teniendo en cuenta los factores de perdidas los cuales pueden ser (Berroa, 2019):

Velocidad del viento
Temperatura
Humedad
Geometría del substrato

Tabla 6. Perdidas respecto al tipo de elemento a recubrir.

ELEMENTO	% PERDIDAS
Planchas de acero	35%
Estructuras de acero – vigas H pesada	40%
Estructuras de acero – vigas H mediana	45%
Estructuras de acero – vigas H mediana	45%
Tubería con diámetro mayor a 18"	40%
Tubería con diámetro entre 7" y 18"	45%
Tubería con diámetro menos a 7”	50%

Fuente: Área de granallado y pintura de la empresa Haug S.A.

% SOLIDOS EN VOLUMEN REDUCIDO (%SVr)

% SV: Sólidos en Volumen %R: Valor del 5 al 20% dependiendo del tipo de material y su capacidad de utilización de reductor %SVr: PSV / (%Reductor).

2.3.Definición de Términos Básicos

Corrosión: Deterioro de un material, específicamente el acero, el cual se oxida como consecuencia de un ataque electroquímico con su entorno.

Preparación Superficial: Es una mezcla de operaciones que se realizan previa aplicación de un recubrimiento o revestimiento.

Mezcla Operativa: Es mezcla de abrasivos utilizados en el proceso de granallado.

Granalla: Partículas de acero que se utilizan en el proceso de granallado para realizar una preparación superficial por chorreado abrasivo.

Rugosidad: Irregularidades de una superficie compuesta por picos y valles como consecuencia del chorreado abrasivo.

Volumen muerto: Volumen obtenido por la generación de la rugosidad la cual será cubierta por el recubrimiento a aplicarse.

Recubrimientos epóxicos: Recubrimientos a base de resina epóxica la cual le proporciona propiedades físicas, mecánicas y químicas con la finalidad de proteger el acero e inhibir la Corrosión.

2.4.Formulación De Hipótesis

2.4.1. Hipótesis General

La propuesta de mejora del proceso de granallado para controlar la rugosidad nos permitirá aumentar el rendimiento de los recubrimientos imprimantes epóxicos.

2.4.2. Hipótesis Especificas

Cambiar la granulometría de la granalla utilizada en el proceso de granallado nos ayudara a reducir la rugosidad.

Utilizar un sistema de filtrado de abrasivos finos reutilizados nos ayudara a obtener una rugosidad constante.

Reducir la rugosidad del proceso de granallado nos ayudara a reducir los costos de recubrimiento a utilizar en la empresa.

2.5. Operacionalización de las variables

Propuesta de Mejora del Proceso de Granallado para Controlar la Rugosidad y aumentar el Rendimiento de los Recubrimientos Imprimantes Epóxicos en la Empresa Haug S.A

Tabla 7. Operacionalización de las variables.

Variables	Definición Operacional	Dimensiones	Indicadores	Técnicas e Instrumentos
Rendimiento de los recubrimientos imprimantes epóxicos (V.D.)	Se realizara la aplicación del recubrimiento con los parámetros habituales para obtener la información del proceso actual con la finalidad de argumentar las mejoras a proponer	Tamaño de la muestra	Área (m^2)	Flexómetro
		Cantidad de recubrimiento	Volumen (l)	Verificación de acuerdo a la hoja técnica del producto
		Rendimiento Real	Rendimiento (l/m^2)	Calculo con formulas
		Medición de Espesores de Película Húmeda	Espesor (mils)	Medidor de espesor de película húmeda
		Medición de Espesores de Película Seca	Espesor (mils)	Medidor de espesor de película húmeda
Mejora del proceso de granallado para controlar la rugosidad (V.I.)	Se evaluara el proceso de granallado analizando cada equipo y suministro involucrado así como las variables que repercutan en la obtención y control de la rugosidad	Tamaño de mezcla operativa de abrasivo	Peso (g)	Juego de Tamices para granulometría de la granalla
		Perfil de Anclaje	Rugosidad (micras)	Rugosímetro

Fuente: Elaboración propia.

CAPITULO III

METODOLOGIA

3.1.Diseño Metodológico

La presente investigación se enfocó en la evaluación del proceso de granallado para controlar la rugosidad obtenida con el fin de aumentar el rendimiento de los recubrimientos imprimantes epóxicos, los métodos utilizados son para evaluar el proceso de granallado desde el ingreso de la granalla a las tolvas hasta su objetivo final que es impactar con el acero y los procedimientos y normas utilizados para a partir de ello proponer una mejora para que la rugosidad resultante se encuentre de los parámetros mínimos de calidad y máximos de rendimiento y productividad con el fin de aumentar la eficiencia de los recubrimientos imprimantes epóxicos a aplicar sobre el material granallado. Se tuvo que tomar en cuenta todos los parámetros del proceso del sistema existente con los parámetros del proceso del sistema a proponer con el fin de poder comparar los resultados y a partir de ello realizar las propuestas con datos cuantitativos.

3.1.1. Tipo Experimental

La metodología aplicada fue de tipo experimental ya que se obtuvo información de las actividades realizadas con las constantes y con variables que se midieron en el proceso de experimentación.

3.1.2. Nivel Exploratorio

Se investigó todos y cada uno de los detalles del trabajo realizado, tanto el sistema del proceso, los procedimientos, las normas y los resultados obtenidos. Para esto se indagará cada una de las variables y parámetros para con la que se generaron las hipótesis.

3.1.3. Diseño Descriptivo

Se describió todo el proceso, sub procesos, actividades y tareas con la finalidad de detallar las funciones realizadas en el proceso de granallado hasta la aplicación de los recubrimientos imprimantes epóxicos.

3.1.4. Enfoque Cuantitativo

Se cuantifico la información obtenida de las variables analizadas de los procesos descritos para posteriormente evaluarlas y proponer las mejoras respectivas con la finalidad de obtener los objetivos propuestos.

3.2.Población y Muestra

3.2.1. Población

Es el conjunto de todos los elementos los cuales están en un ámbito espacial de análisis en donde se desarrollada la investigación

Población: Proceso de granallado, 358 g de abrasivo, 414.3 m^2 de planchas de acero A36 y el recubrimiento epóxico Macropoxy 646.

3.2.2. Muestra

Para la presente investigación, el ámbito de recolección de datos será igual a la población, en tal sentido:

Muestra: Proceso de granallado, 358 g de abrasivo, 414.3 m^2 de planchas de acero A36 y el recubrimiento epóxico Macropoxy 646.

3.3.Técnicas e instrumentos de recolección de datos

De acuerdo a los resultados obtenidos de las muestras se elaboró esta tesis el mismo que cumplió con los parámetros estipulados inicialmente con el fin de manipular de manera correcta las variables independientes para su posterior análisis.

3.3.1. Técnicas a emplear

La técnica aplicada fue de tipo descriptiva debido a que la evaluación y mejora se realizó a los involucrados en el proceso.

La técnica que se aplico fue la observación ya que hay constantes que se controlaron.

3.3.2. Descripción de los instrumentos

a) Para la descripción: Se utilizó para expresar el proceso evidenciado con el fin de compararlo con el proceso propuesto.

Consulta técnica a expertos

Revisión del plano de diseño del proceso de granallado

Revisión de Literatura relacionada

Trabajo de campo

Captación de información directa de la fuente

Informes Técnicos

Normas, Códigos, Estándar

Cámara

b) Para la observación: Se utilizó para controlar las constantes utilizando el criterio técnico de acuerdo a las normas, códigos, procedimientos y estándar de referencia.

Reporte de sucesos

Anotaciones

3.4. Técnicas para el procedimiento de la información

Se utilizaron las siguientes técnicas para poder procesar los datos recaudados:

Clasificación: Para realizar el diagnóstico del área de granallado se hizo de acuerdo a la cadena de proceso: Tolvas, Recogedoras, Recolectoras, Filtro de reciclaje, filtro de desecho y posteriormente la aplicación de recubrimiento.

Registro: Los datos obtenidos se reportaron de acuerdo al diagnóstico evidenciado en el proceso.

Tratamiento: Se determinó la autonomía del proceso para realizar la evaluación respecto y el plan de mejora requerido.

Presentación: La información recolectada y digitada para una evaluación técnica y económica expresada en tablas, gráficos y propuestas

El estudio tuvo el siguiente procedimiento:

Recopilación de la información teórica basadas en experiencia

Recopilación del diseño del sistema de granallado

Recopilación de información del proceso a evaluar

Diagnóstico del proceso de granallado

Diagnóstico de la rugosidad obtenida

Diagnóstico del rendimiento de los recubrimientos imprimantes epóxicos

Propuesta de mejora del proceso de granallado

Propuesta de mejora de la rugosidad para controlarla

Análisis de los resultados

Conclusiones y recomendaciones

CAPITULO IV

RESULTADOS

4.1.Información General

El proceso de chorreado abrasivo con granalla que realiza la empresa Haug S.A. denominado actualmente granallado es ejecutado por la eyección de aire comprimido mezclándose con la granalla en una tolva la cual expulsa ambos a una presión determinada por la salida inferior haciendo un recorrido por una manguera y teniendo una salida final la cual es proyectada hacia las estructuras metálicas que se van a preparar y limpiar superficialmente.

La granalla al impactar en el acero negro cae en la parte inferior el cual es recolectado por un barredor hacia la parte central de la cámara, posteriormente la granalla es conducida por el gusano giratorio hacia un elevador de cangilones hasta la parte superior donde se encuentra con una tolva de recepción que dosifica las tolvas de granallado para de esta manera reiniciar y hacer el proceso continuo.

La finalidad de granallar las superficies es generar limpieza y perfil de anclaje al acero con el objetivo de que el recubrimiento a aplicarse tenga una durabilidad y adherencia.

Figura 18. Vista General de la cámara de granallado.

4.2.Evaluación del proceso de granallado y aplicación de recubrimiento

4.2.1. Evaluación del proceso de Granallado

4.2.1.1.Tolva de granallado

La tolva de granallado se encarga de contener la granalla y el aire comprimido para eyectar ambos por la zona inferior cónica atreves de la manguera la cual es manipulada por el usuario granallador.

La tolva se encontraba en estado óptimo con certificación ASME para trabajar a presiones controladas con una capacidad de 2000 kg de granalla

La tolva contaba con una zaranda en la parte superior en donde recibe abrasivo de la tolva superior del ciclo final de circulación.

Figura 19. Tolva de granallado y compresora de aire.

Tabla 8. Diagnóstico de la tolva de granallado.

Diagnostico - Tolva de granallado					
a) Infraestructura	Muy bueno	Bueno	Regular	Malo	Muy malo
			X		
b) Operación	Muy bien	Bien	A veces Falla	Mucha Falla	Falla total
		X			

Fuente: Elaboración propia

En la tabla 01, observamos el diagnóstico de la tolva de granallado, donde se distingue que se encontró en un estado regular observándose que en la manguera de la tolva inferior presentaba fuga por lo que la óptima operatividad del sistema reduce la calidad del producto a trabajar en la empresa.

4.2.1.2.Sistema de recolección y retorno del abrasivo

La granalla impactada en la superficie a limpiar cae en la zona inferior de la cámara donde se encuentran las barredoras debajo del piso de rejillas el cual traslada la granalla hacia el sinfín transversal de noria.

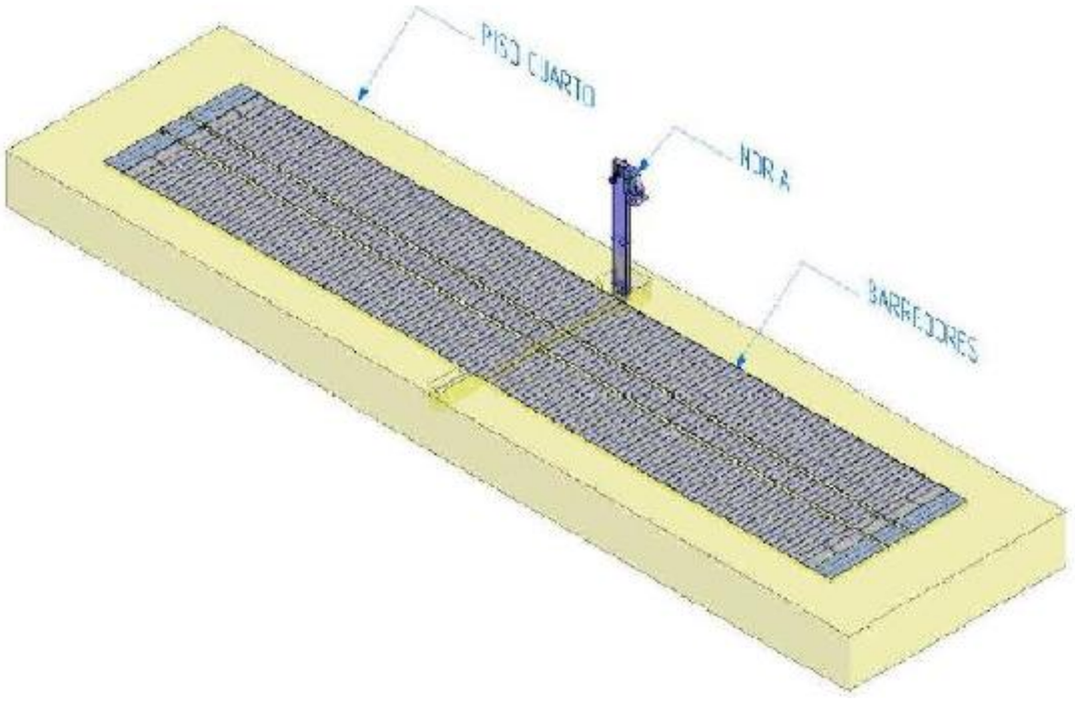


Figura 20. Diseño del piso de la cámara de granallado con las barredoras y noria.

El sistema de recolección automática de la granalla está compuesto por planchas con cuchillas barredoras oscilantes que movilizan la granalla hacia el sinfín transversal.

De acuerdo al diseño de fabricación de CyM Materiales S.A., se obtuvo la información siguiente: compuesto de módulos independientes de 15 m x 8 m de ancho. Se debe de prever un foso que sea de 150 mm por debajo de los rieles

Debajo del piso de rejillas se observan zarandas para recolectar residuos, y contaminantes que pueden obstruir la operatividad del sinfín transversal.

El mantenimiento manual se realiza cada 5 días ya que el sistema de filtro de limpieza automática no se encuentra operativo por lo que los contaminantes como: piedras, plástico, restos de madera, paja, plantas, etc.; se acumulan en la zona central.

Figura 21. Retiro de la granalla manualmente para realizar mantenimiento al recolector central y el sinfín transversal.

Figura 22. Mantenimiento del recolector central y el sinfín transversal.

Tabla 9. Diagnóstico del sistema de recolección y retorno del abrasivo.

Diagnostico - Sistema de recolección y retorno de abrasivo					
a) Infraestructura	Muy bueno	Bueno	Regular	Malo	Muy malo
			X		
b) Operación	Muy bien	Bien	A veces Falla	Mucha Falla	Falla total
		X			

Fuente. Elaboración propia

En la tabla 02, se muestra el diagnóstico del sistema de recolección y retorno del abrasivo, donde se observa que la integridad de la infraestructura se encuentra dentro de lo requerido pero su operatividad tiene muchas fallas por lo que tiene como consecuencia muchas paradas de proceso por mantenimiento.

4.2.1.3.Sistema de circulación

La granalla sube transversalmente por la noria por una cinta de cangilones a la tolva superior para abastecer nuevamente a la tolva de granallado la cual tiene un filtro de zarandas para residuos y contaminantes.

Figura 23. La noria abastece la tolva superior (azul) y esta abastece a la tolva de granallado (amarilla) para continuar con el ciclo del proceso de granallado.

Tabla 10. Diagnóstico del sistema de circulación y limpieza de abrasivo.

Diagnostico - Sistema de circulación y limpieza del abrasivo					
a) Infraestructura	Muy bueno	Bueno	Regular	Malo	Muy malo
				X	
b) Operación	Muy bien	Bien	A veces Falla	Mucha Falla	Falla total
			X		

Fuente. Elaboración propia

En la tabla 03, se muestra el diagnóstico del sistema de circulación y limpieza donde se observa que los cangilones transversales se encuentran en buen estado.

Se observó también que la granalla es llevada hasta la tolva superior y posteriormente cae en la tolva de granalla donde una zaranda filtra la basura, restos de piedras, madera, paja, etc.

4.2.1.4.Sistema colector de polvo

En el proceso de granallado por impacto de abrasivo a las superficies metálicas con presión de aire comprimido tiene como consecuencia que los residuos sólidos como: tierra, cascara de laminación removida, contaminantes no visibles; queden suspendidos en el ambiente

La polución metálica de los residuos resultantes del granallado es captada por un sistema colector de polvo el cual tiene como finalidad purificar el ambiente para que el operario ejecutor de las labores se encuentre con un microclima amigable para su operación.

Figura 24. Recolector de polvo izquierdo y derecho en el interior de la cabina de granallado.

Tabla 11. Diagnóstico del sistema colector de polvo.

Diagnostico - Sistema colector de polvo					
a) Infraestructura	Muy bueno	Bueno	Regular	Malo	Muy malo
		X			
b) Operación	Muy bien	Bien	A veces Falla	Mucha Falla	Falla total
		X			

Fuente. Elaboración propia

En la tabla 04, se muestra el diagnóstico del sistema colector de polvo, donde se observa que su operatividad se encontró optima ya que se encontró en buen estado debido a que tuvo mantenimientos semanales.

4.2.2. Evaluación del proceso de aplicación de recubrimiento

Posteriormente del granallado y evaluar la limpieza y preparación superficial se deriva el material granallado a las cabinas de pintura para su proceso de aplicación de los diversos sistemas de pintura.

El sistema de recubrimiento como muestra fue el Macropoxy 646 como capa imprimante y única.

El recubrimiento imprimante industrial Macropoxy 646 se encontró debidamente almacenado en un ambiente con temperatura controlada

El producto a utilizar estuvo rotulado para su correcta trazabilidad el día de su uso.

Los componentes a utilizar: Macropoxy 646 Parte A, Macropoxy 646 Catalizador y su Diluyente P33, contaban con su fecha de fabricación menor a 1 año, fecha de caducidad dentro de lo permisible y número de lote de acuerdo a los certificados de calidad correspondiente.

La aplicación se realizó con un equipo de aspersión Air less Neumático Marca Graco con una boquilla 0.017” y a una presión variable de 2800 a 3000 psi

Se realizó la agitación de los 2 componentes de manera independiente y posteriormente se procedió a combinar ambos, añadiendo después el 10% del volumen preparado de Diluyente P33.

Se evaluaron los espesores en película húmeda de 7 mils para obtener espesores en seco uniformes.

Figura 25. Aplicación del Macropoxy 646 en las planchas de muestra.

Tabla 12. Información técnica del sistema y el recubrimiento

N° Capa	Producto	Color / RAL	Espesor de Película Húmeda	Espesor de Película Seca	Sólidos en Volumen
1	Macropoxy 646	Gris / 7035	7 mils	5 mils	72%

Fuente: Hoja Técnica del Macropoxy 646 – Anexo 2.

4.3.Registro de información

4.3.1. Información del proceso de granallado

El grado de limpieza y la preparación de la superficie a evaluar es SSPC SP5 sobre 36 planchas de acero al carbono A-36 con un total de 414.3 m^2 las cuales se granallaron dentro de las 8 horas laborales a lo largo de 6 días.

Figura 26. Proceso de granallado de las planchas de acero al carbono A36.

De acuerdo a los suministros de ingreso de granalla utilizada en el proceso se tienen que son de tipo y S-330. Se tomó una muestra de las barredoras con un peso de 358 gr y se realizó el proceso de separación de tamaños con tamices de acuerdo a la norma SAE J444 obteniendo la siguiente mezcla operativa:

Tabla 13. Mezcla operativa de la granalla actual del proceso.

Tamiz mm.	Valor (gr.)	% retenido	Medida
0.6	34	9.5	Gruesos
0.42	116	32.4	Medios
Fondo	208	58.1	Finos
Total	358	100	

Fuente: Elaboración propia.

En la tabla 13 se muestra la composición de la granalla del sistema operativo

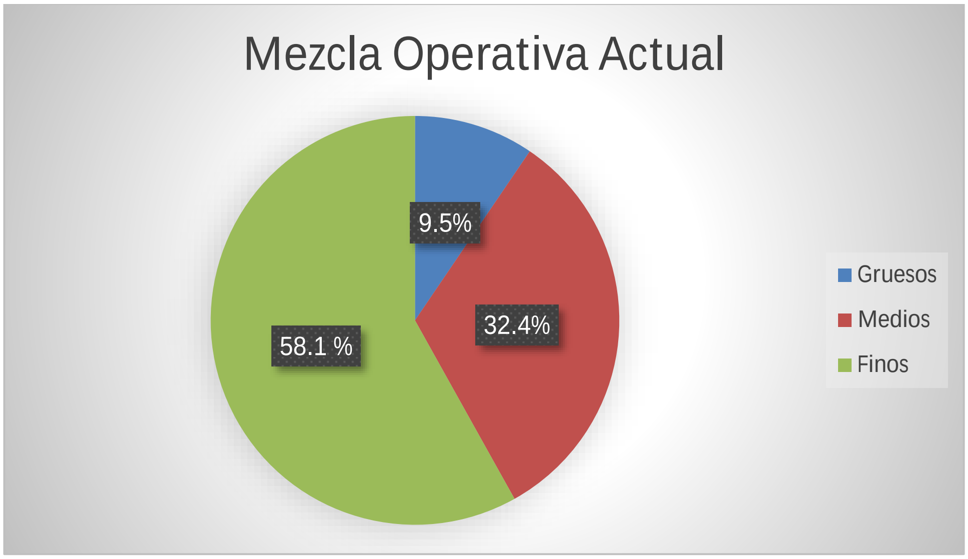


Figura 27. Composición de la mezcla operativa actual de granalla: fina, media y gruesa.

En la figura 27, se muestra el porcentaje de granalla gruesa, mediana y fina que representa a la muestra tamizada de la mezcla operativa obtenida.

Se realizó un acercamiento visual a la mezcla operativa y se verifico que contenía granalla esférica y además contenía granalla angula en mínima proporción.

Figura 28. Acercamiento visual de la muestra de granalla extraída.

Se utilizó un microscopio de acercamiento para visualizar las zonas de granallado y se identificó que la presencia de granalla esférica provoca valles ovalados donde hay exceso de rugosidad.

Figura 29. Acercamiento visual del área granallada donde se evidencia excesiva rugosidad generada por la granalla esférica.

Además, se realizó la medición de la rugosidad en las planchas que salieron del proceso de granallado a lo largo de los días y se obtuvo la información siguiente:

Tabla 14. Rugosidad obtenida del proceso de granallado por cada unidad de la muestra total.

Rugosidad obtenida en las planchas acero al carbono A-36

N°	Descripción	Elemento	Fecha	Área (m2)	Muestra 1 (mils)	Muestra 2 (mils)	Muestra 3 (mils)	Muestra 4 (mils)	Muestra 5 (mils)	Promedio (mils)
1	Muestra 01	Plancha Acero 01	10/02/2020	14.40	3.9	3.9	3.7	3.4	3.7	3.7
2	Muestra 02	Plancha Acero 02		14.40	3.9	3.6	4.1	3.5	3.8	3.8
3	Muestra 03	Plancha Acero 03		14.40	3.5	4.1	3.8	3.5	3.7	3.7
4	Muestra 04	Plancha Acero 04		14.40	3.8	3.6	4.0	4.1	3.7	3.8
5	Muestra 05	Plancha Acero 05		12.00	3.7	3.8	3.9	3.6	3.9	3.8
6	Muestra 06	Plancha Acero 06		14.40	3.4	3.7	3.5	3.5	3.5	3.5
7	Muestra 07	Plancha Acero 07	11/02/2020	14.40	4.0	3.9	3.8	3.5	3.9	3.8
8	Muestra 08	Plancha Acero 08		14.40	4.1	3.8	4.0	3.7	4.0	3.9
9	Muestra 09	Plancha Acero 09		14.40	3.4	3.5	3.5	4.0	3.6	3.6
10	Muestra 10	Plancha Acero 10		12.00	4.0	3.5	3.6	4.0	4.0	3.8
11	Muestra 11	Plancha Acero 11		14.40	3.5	3.8	3.5	4.0	3.9	3.7
12	Muestra 12	Plancha Acero 12		14.40	4.1	4.1	4.0	3.8	3.7	3.9
13	Muestra 13	Plancha Acero 13	12/02/2020	14.40	3.9	3.6	3.5	4.0	4.1	3.8
14	Muestra 14	Plancha Acero 14		14.40	3.5	3.6	4.0	3.7	3.8	3.7
15	Muestra 15	Plancha Acero 15		12.00	3.5	3.9	3.5	3.8	3.5	3.7
16	Muestra 16	Plancha Acero 16		14.40	3.9	4.1	3.6	3.9	3.6	3.8
17	Muestra 17	Plancha Acero 17		14.40	3.6	3.9	3.4	3.8	4.0	3.7
18	Muestra 18	Plancha Acero 18		14.40	3.8	3.7	3.9	4.1	4.0	3.9
19	Muestra 19	Plancha Acero 19	13/02/2020	14.40	3.8	3.7	4.1	3.9	3.5	3.8
20	Muestra 20	Plancha Acero 20		12.00	4.0	3.8	3.7	3.7	4.0	3.8
21	Muestra 21	Plancha Acero 21		8.49	4.1	3.4	3.9	4.0	4.0	3.9
22	Muestra 22	Plancha Acero 22		8.49	3.7	3.7	3.9	4.0	3.8	3.8

23	Muestra 23	Plancha Acero 23		8.49	3.6	3.5	3.4	4.0	4.0	3.7
24	Muestra 24	Plancha Acero 24		8.49	3.4	3.5	3.7	3.9	3.8	3.6
25	Muestra 25	Plancha Acero 25	14/02/2020	8.49	3.4	3.7	3.5	3.5	3.5	3.5
26	Muestra 26	Plancha Acero 26		8.49	3.6	3.9	3.4	3.8	4.0	3.7
27	Muestra 27	Plancha Acero 27		8.49	3.8	3.7	3.9	4.1	4.0	3.9
28	Muestra 28	Plancha Acero 28		8.49	3.8	3.7	4.1	3.9	3.5	3.8
29	Muestra 29	Plancha Acero 29		8.49	4.1	3.8	4.0	3.7	4.0	3.9
30	Muestra 30	Plancha Acero 30		8.49	3.4	3.5	3.5	4.0	3.6	3.6
31	Muestra 31	Plancha Acero 31	15/02/2020	8.49	4.0	3.5	3.6	4.0	4.0	3.8
32	Muestra 32	Plancha Acero 32		8.49	3.9	3.6	4.1	3.5	3.8	3.8
33	Muestra 33	Plancha Acero 33		8.49	3.5	4.1	3.8	3.5	3.7	3.7
34	Muestra 34	Plancha Acero 34		8.49	3.8	3.6	4.0	4.1	3.7	3.8
35	Muestra 35	Plancha Acero 35		8.49	3.4	3.7	3.5	3.5	3.5	3.5
36	Muestra 36	Plancha Acero 36		8.49	3.6	3.9	3.4	3.8	4.0	3.7
								TOTAL	**3.8 mils = 96.5 micras**	

Fuente: Elaboración propia.

En la tabla 14, se muestra que el promedio total de todas las planchas evaluadas con el mismo sistema de operación de granallado es de 96.5 micras o 3.8 mils.

Figura 30. Medición de la rugosidad obtenida.

4.3.2. Información del proceso de aplicación del recubrimiento

La evaluación de los espesores de película seca del producto Macropoxy 646 se realizó bajo la norma SSPC PA2 de referencia y se obtuvieron los resultados siguientes:

Tabla 15. Espesores de película seca obtenidos del proceso de aplicación del recubrimiento Macropoxy 646.

Espesores de película seca obtenidos en las planchas acero al carbono A-36																	
N°	**Descripción**	**Elemento**	**Fecha**	**Área (m2)**	**Spot 1**				**Spot 2**				**Spot 1**				**Promedio (mils)**
					Medida 1 (mils)	**Medida 2 (mils)**	**Medida 3 (mils)**	**Promedio (mils)**	**Medida 1 (mils)**	**Medida 2 (mils)**	**Medida 3 (mils)**	**Promedio (mils)**	**Medida 1 (mils)**	**Medida 2 (mils)**	**Medida 3 (mils)**	**Promedio (mils)**	
1	Muestra 01	Plancha Acero 01	11/02/2020	14.40	5.0	5.1	5.3	5.1	5.2	5.7	5.2	5.3	5.7	5.9	5.8	5.8	5.4
2	Muestra 02	Plancha Acero 02		14.40	5.7	5.4	5.6	5.6	5.7	5.5	4.9	5.4	5.8	5.1	5.4	5.5	5.5
3	Muestra 03	Plancha Acero 03		14.40	4.9	5.4	5.7	5.3	5.7	5.5	5.2	5.5	5.3	5.3	5.0	5.2	5.3
4	Muestra 04	Plancha Acero 04		14.40	5.7	5.3	5.5	5.5	5.5	5.8	4.8	5.4	5.0	5.1	4.9	5.0	5.3
5	Muestra 05	Plancha Acero 05		12.00	5.1	5.3	5.3	5.2	5.6	5.4	4.8	5.3	5.1	5.6	5.4	5.4	5.3
6	Muestra 06	Plancha Acero 06		14.40	4.8	5.0	5.2	5.0	4.8	5.5	5.6	5.3	5.2	5.8	5.8	5.6	5.3
7	Muestra 07	Plancha Acero 07	12/02/2020	14.40	5.9	5.0	5.2	5.4	5.3	5.7	5.4	5.5	5.4	5.6	5.8	5.6	5.5
8	Muestra 08	Plancha Acero 08		14.40	5.3	5.4	5.6	5.4	5.4	5.0	5.1	5.2	5.1	5.2	5.4	5.3	5.3
9	Muestra 09	Plancha Acero 09		14.40	5.2	5.4	4.8	5.1	5.4	5.5	4.9	5.3	5.6	4.8	5.4	5.3	5.2
10	Muestra 10	Plancha Acero 10		12.00	5.7	4.9	5.5	5.4	5.5	4.9	5.5	5.3	5.1	5.4	5.0	5.2	5.3
11	Muestra 11	Plancha Acero 11		14.40	5.7	5.5	5.6	5.6	5.4	5.5	5.3	5.4	5.7	5.5	5.7	5.6	5.5
12	Muestra 12	Plancha Acero 12		14.40	5.4	5.3	5.5	5.4	5.6	5.4	5.0	5.3	5.0	5.7	5.5	5.4	5.4
13	Muestra 13	Plancha Acero 13	13/02/2020	14.40	5.7	5.1	5.8	5.5	5.7	5.4	5.6	5.6	5.0	5.2	5.1	5.1	5.4
14	Muestra 14	Plancha Acero 14		14.40	5.3	5.4	5.7	5.5	5.9	5.0	5.6	5.5	5.3	5.7	4.9	5.3	5.4
15	Muestra 15	Plancha Acero 15		12.00	5.6	5.6	4.9	5.4	5.1	5.2	5.3	5.2	5.0	5.2	5.8	5.3	5.3
16	Muestra 16	Plancha Acero 16		14.40	5.9	5.0	4.8	5.2	5.2	5.1	5.6	5.3	5.3	5.0	5.1	5.1	5.2
17	Muestra 17	Plancha Acero 17		14.40	5.5	5.6	4.9	5.3	5.5	5.4	5.2	5.4	5.7	5.1	5.0	5.3	5.3
18	Muestra 18	Plancha Acero 18		14.40	5.8	5.6	4.8	5.4	5.0	5.2	5.3	5.2	4.9	5.3	4.8	5.0	5.2
19	Muestra 19	Plancha Acero 19	14/02/2020	14.40	4.8	5.0	5.5	5.1	5.4	5.0	5.0	5.1	5.6	4.9	5.5	5.3	5.2
20	Muestra 20	Plancha Acero 20		12.00	5.5	5.0	5.9	5.5	5.1	5.7	5.6	5.5	4.9	5.5	4.9	5.1	5.3

21	Muestra 21	Plancha Acero 21		8.49	5.4	5.0	5.0	5.1	5.6	5.6	4.9	5.4	5.2	5.6	5.8	5.5	5.3
22	Muestra 22	Plancha Acero 22		8.49	5.1	5.1	5.9	5.4	5.4	5.8	4.8	5.3	5.6	5.1	5.2	5.3	5.3
23	Muestra 23	Plancha Acero 23		8.49	5.8	5.3	5.5	5.5	5.5	5.1	5.0	5.2	5.8	5.2	4.9	5.3	5.3
24	Muestra 24	Plancha Acero 24		8.49	5.9	4.8	5.9	5.5	4.9	5.7	5.1	5.2	5.4	4.9	5.5	5.3	5.3
25	Muestra 25	Plancha Acero 25		8.49	5.2	4.9	5.7	5.3	5.2	5.8	5.6	5.5	4.9	5.6	4.9	5.1	5.3
26	Muestra 26	Plancha Acero 26		8.49	5.2	5.8	5.9	5.6	5.4	5.6	5.3	5.4	5.8	5.5	5.6	5.7	5.6
27	Muestra 27	Plancha Acero 27	15/02/2020	8.49	5.0	5.9	5.2	5.3	5.5	4.9	5.3	5.2	5.4	5.6	5.0	5.4	5.3
28	Muestra 28	Plancha Acero 28		8.49	5.5	5.0	5.4	5.3	5.3	5.2	5.3	5.2	5.8	5.6	4.8	5.4	5.3
29	Muestra 29	Plancha Acero 29		8.49	5.1	5.2	5.1	5.1	5.8	5.6	5.6	5.7	5.7	4.9	5.8	5.4	5.4
30	Muestra 30	Plancha Acero 30		8.49	4.9	5.2	5.3	5.1	5.4	5.4	5.4	5.4	5.0	5.1	5.2	5.1	5.2
31	Muestra 31	Plancha Acero 31		8.49	5.1	5.6	5.1	5.2	5.2	5.8	5.1	5.3	5.7	4.9	5.9	5.5	5.4
32	Muestra 32	Plancha Acero 32		8.49	5.5	5.3	5.8	5.5	5.8	4.9	4.9	5.2	5.0	4.9	5.2	5.0	5.3
33	Muestra 33	Plancha Acero 33	16/02/2020	8.49	5.7	5.0	5.7	5.5	5.8	5.2	5.4	5.4	5.6	5.3	5.6	5.5	5.5
34	Muestra 34	Plancha Acero 34		8.49	5.9	5.6	5.8	5.7	4.8	5.8	5.1	5.2	5.2	5.3	5.2	5.2	5.4
35	Muestra 35	Plancha Acero 35		8.49	5.5	5.9	5.5	5.6	4.9	5.2	4.9	5.0	5.3	4.9	4.9	5.0	5.2
36	Muestra 36	Plancha Acero 36		8.49	5.7	5.4	5.7	5.6	4.9	5.0	5.3	5.0	5.5	5.3	5.4	5.4	5.3
																Total	5.3. mils

Fuente: Elaboración propia.

En la tabla 15, se muestran los espesores registrado a todas las planchas pintadas en sus respectivas fechas y se evidencia que mantienen una buena uniformidad con un promedio de espesores en película seca de 5.3 mils o 134.6 micras.

Figura 31. Medición de los espesores de película seca.

El rendimiento del Macropoxy 646 es indirectamente proporcional a las perdidas en la aplicación las cuales son: geometría del elemento a recubrir, velocidad del viento, sistema de circulación en el equipo de aspersión (mangueras, válvulas, etc.), retención en el envase, técnica del operario aplicador, rugosidad, etc.

De acuerdo a la información recopilada hasta el momento se tiene la siguiente tabla:

Tabla 16. Información técnica del proceso de granallado y pintura

Descripción	**Fuente**	**Dato**
Rugosidad	Tabla 14	96.5 micras
Coeficiente de Volumen Muerto	Tabla 4	6.5
% Solidos en volumen	Hoja Tecnica – Anexo 2	72
Espesor de Película Seca	Tabla 15	5 mils
% Perdidas de planchas	Tabla 6	35

Fuente: Elaboración propia.

De acuerdo a la ecuación 1, y a los datos de la tabla 16:

$$= (39.37 \,\frac{{}^{2}}{}\quad 1 \qquad\qquad\qquad\qquad)\ \%$$

El rendimiento teórico es: **28.35 m^2/l**

De acuerdo a la ecuación 6, y los datos de la tabla 16:

$$= \frac{(1 - \% \qquad\qquad)}{}\ \frac{{}^{2}}{}$$

El rendimiento practico es: **3.69 m^2/l**

De acuerdo a la ecuación 2, y los datos de la tabla 16:

$$(\qquad\quad) = \frac{}{\%}\ \frac{}{{}_{2}}$$

El volumen muerto es: **0.0902 l/m^2**

De acuerdo a la información obtenida de la tabla 16 y los resultados del rendimiento teórico, practico y consumo muerto, podemos calcular con la ecuación 4 el volumen de recubrimiento para el área total de muestra el cual es: **414.3 m^2**

$$= \frac{}{}\ \frac{{}^{2}}{\frac{{}^{2}}{}}$$

El volumen de recubrimiento para cubrir 424.3 m^2 a 5 mils de espesor es: **112.27 l.**

Entonces con la ecuación 2, calculamos el consumo muerto para 414.3 m^2:

$$= \qquad {}^{2} \qquad \frac{\quad}{2}$$

El consumo muerto es: **37.37 l.**

Entonces, el consumo total aplicación con la ecuación 5 es:

$$= \qquad +$$

El consumo total respecto al área total de muestra es: **149.63 l.**

4.4.Propuesta al proceso de granallado y aplicación de recubrimiento

Para la tolva de granallado, se propone renovar los accesorios del equipo ya que el abrasivo y el aire comprimido fugaban por las mangueras y accesorios debido al deterioro de los mismos.

Se propone realizar un cambio en las zarandas que se encuentra debajo de las rejillas del piso de las barredoras ya que no retiene los contaminantes correctamente provocando que el recolector sinfín transversal se atascara de manera continua.

La mezcla operativa de la figura 27 de la granalla es improductiva y trae una inestabilidad en la rugosidad a obtener, de acuerdo a la investigación realizada en campo y a la información técnica obtenida de la empresa CyM Materiales S.A., se propone colocar un filtro de limpieza el cual tiene como finalidad principal retirar la granalla fina para mantener un control de la mezcla operativa y obtener una rugosidad media estable.

1) Mezcla Operativa

La granalla posteriormente de impactar al acero se fractura provocando que su tamaño se reduzca, luego es recirculada por el proceso y otra vez utilizada y reduciéndose por cada uso continuo.

El desgaste por fractura provoca que la granalla alcance una medida por debajo de lo recomendado lo que la hace improductiva y si no es retirada del sistema operativo provoca inestabilidad en la rugosidad a obtener.

Desgaste por fractura

ERVIN AMASTEEL

El impacto repetido provoca fracturas,
la granalla se va redondeado por el impacto continuo.

Figura 32. Reducción de la granalla al fracturarse al impactar. (Blasting Experts Ltda., 2020).

Desgaste de granalla

ERVIN AMASTEEL
The World Standard for Quality

Nueva

Después
de 300 impactos

Figura 33. Acercamiento visual de antes y después del abrasivo desgastado. (Blasting Experts Ltda., 2020).

La mezcla operativa pose tamaños múltiples de granalla que son gruesos, medios y finos. El tamaño mínimo el cual aporta un eficiente trabajo de granallado se llama punto de corte, cualquier tamaño debajo del punto de corte debe ser retirada del sistema de granallado.

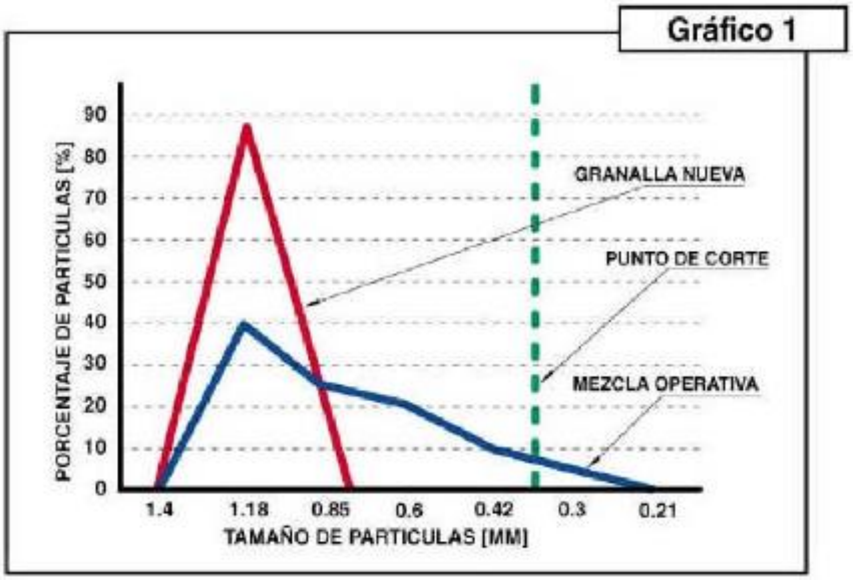


Figura 34. Punto de corte respecto a la mezcla operativa de granalla. (CyM Materiales S.A., 2015).

La empresa CyM Material suministro información técnica para que el proceso de granallado sea eficiente con respecto a la mezcla operativa por lo cual detallo en la figura 34 el punto de corte ideal para que el proceso de la empresa Haug S.A. sea productivo y genere una rugosidad controlada y constante.

La granalla fina debe ser retirada del proceso de granallado por lo cual se propuso añadir un filtro antes de que la granalla llegue a la tolva superior.

2) Tolva Superior

La granalla al llegar al elevador es suministrada de manera esparcida en una caja horizontal de forma que la granalla se desparrame en forma de cortina, para lo cual se propone colocar un flujo de aire que atraviese la cortina de granalla retirando el abrasivo en polvo el cual es arrastrado y retenido por una chapa captadora la cual dirige el abrasivo a una zona adyacente.

Para lograr un correcto funcionamiento del sistema propuesto es primordial que el flujo de aire sea uniforme y que la cortina abarque todo el ancho de la caja horizontal.

a) Regulación de la cortina del abrasivo

Se debe mantener la cortina de abrasivo en todo el ancho horizontal, de tal forma que el flujo de airea retire de la mezcla operativa la granalla fina.

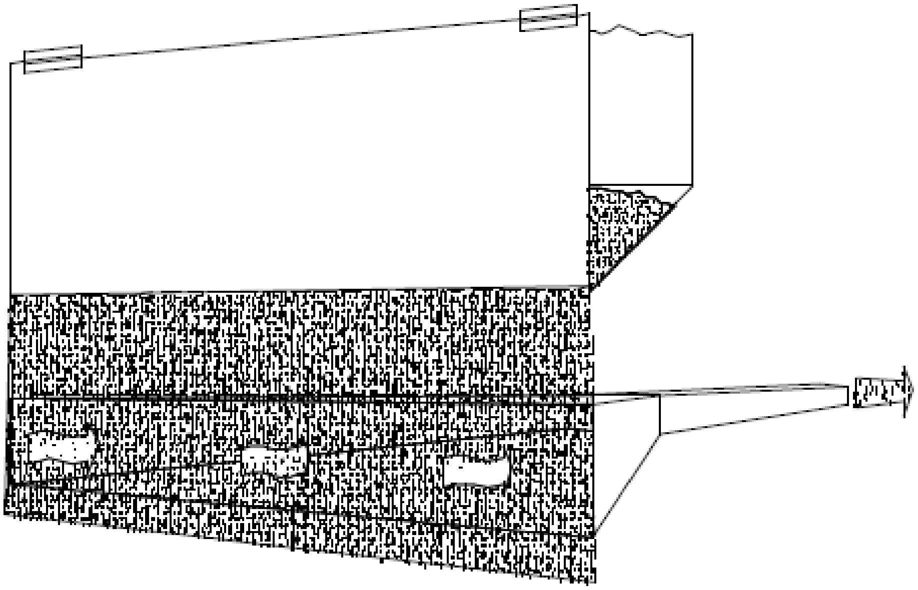


Figura 35. Sistema de filtro con aplicación de aire a la cortina de abrasivo. (CyM Materiales S.A., 2015).

b) Regulación de la limpieza del abrasivo

La finalidad es tener un flujo de aire constante y que la chapa captadora este regulada para retirar de la mezcla operativa la granalla fina.

Se regula la válvula de aire situada en la zona lateral de donde se ubica la cortina de abrasivo.

Si la válvula es demasiado cerrada, no habrá un flujo de aire que retire eficientemente el abrasivo fino, pero si la válvula esta demasiada abierta puede provocar que se extraiga abrasivo bueno hacia la chapa captadora.

Para regularla correctamente debe controlarse continuamente verificando la mezcla operativa, así como también los desechos del aspirador. Si existiese abrasivo bueno en la zona de desechos se deberá cerrar gradualmente la válvula de aire del sistema de limpieza.

Para regular la extracción de contaminantes finos proceder de la siguiente manera:

Verificar que la cortina de granalla cubra todo el ancho de la caja horizontal de abrasivos.

Colocar la chapa regulable o captadora lo más alejada posible de la cortina de granalla.

Abrir en un punto medio la válvula del sistema de limpieza del abrasivo ubicada en el tubo de aspiración.

Verificar en la bajada de granalla de desuso del tipo de polvo que está sacando del sistema.

Alternativa 1: De estar retirando granalla buena del circuito cerrar la válvula de regulación de aire.

Alternativa 2: Si por la granalla en desuso solamente se observan polvos finos verificar en el mix de operación si hay granalla o polvo que tiene que ser sacado del circuito. El sistema se puede regular aumentando el caudal de aire que atraviesa la cortina (abriendo más la válvula del sistema de limpieza de abrasivo y/o acercando la chapa captadora a la cortina de granalla.

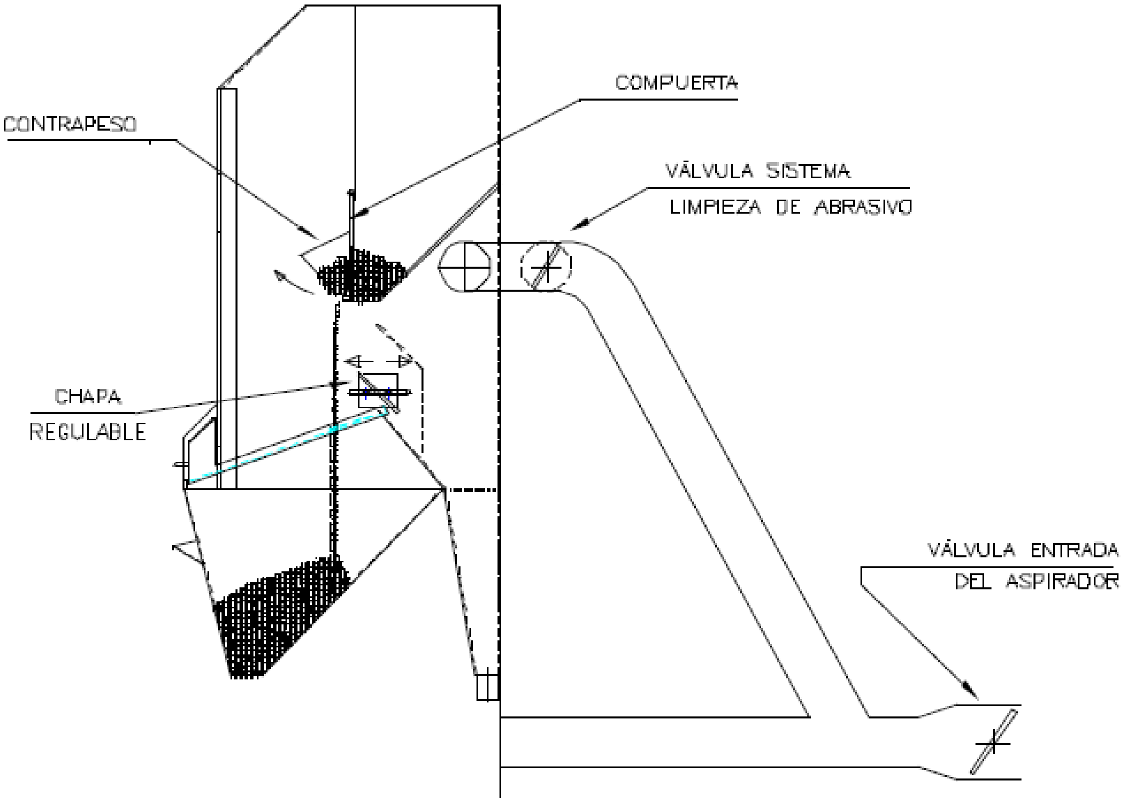


Figura 36. Sistema operativo propuesto. (CyM Materiales S.A., 2015).

Con la propuesta del filtro de partículas finas se podrá obtener una mezcla operativa aceptable la cual es la recomendada para que la rugosidad se encuentre controlada y constante:

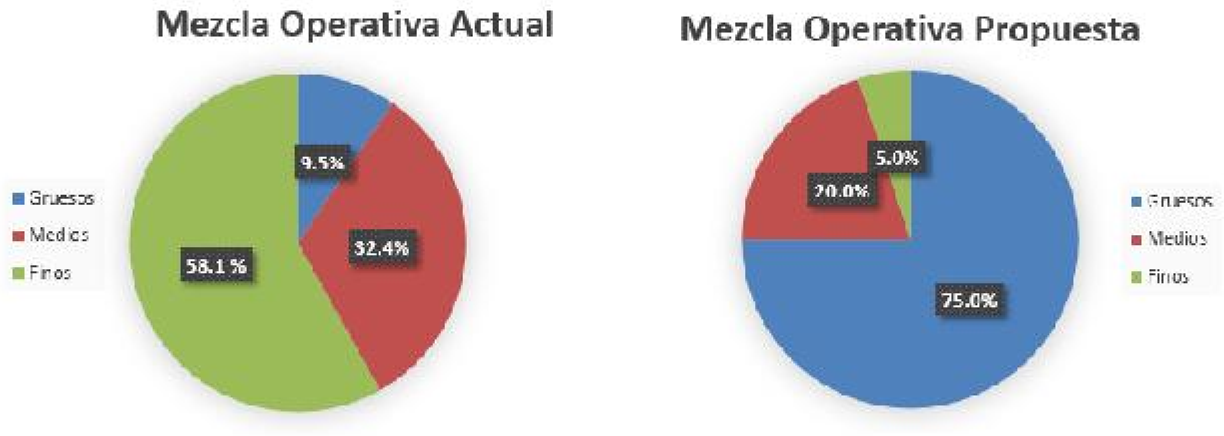


Figura 37. Comparación de la mezcla operativa actual vs la mezcla operativa propuesta.

La rugosidad media obtenida en las muestras tomadas es de 3.8 mils (96.5 micras) provocando una excesiva rugosidad y como consecuencia un volumen muerto el cual el recubrimiento imprimante epóxico debe de cubrir reduciendo el rendimiento del mismo, se propone utilizar solo granalla G-40 de acuerdo a la norma SSPC SP COM indicado en la tabla 1 con la finalidad de obtener una rugosidad menor con el fin de obtener menor volumen muerto para aumentar el rendimiento del recubrimiento epóxico imprimante.

Existe granalla de acero Grit (angular) y Shot (Esférica) de diferentes tamaños de acuerdo a la figura 1 y 2 de la norma SAE J444 del anexo 3 que respecto a la necesidad se utiliza el adecuado para obtener una rugosidad especifica.

Al obtener una rugosidad de 2 mils o 50 micras se obtiene una reducción del consumo con respecto a la rugosidad actual el cual es un valor significativo cuando este se refiere a que será usado en lo largo de los múltiples proyectos de la empresa.

En la siguiente tabla se muestra la cantidad de volumen de recubrimiento que puede ahorrarse a partir de la muestra tomada como referencia:

Tabla 17. Comparación del consumo muerto actual vs el consumo muerto a obtener con las mejoras propuestas.

Área Total de muestra (m2)	Rugosidad actual (micras)	Consumo de Volumen Muerto (litros)	Consumo muerto respecto al área total (litros)	Rugosidad propuesta (micras)	Consumo de Volumen Muerto (litros)	Consumo muerto respecto al área total (litros)	Diferencia de consumo respecto al área total (litros)
414.3	96.5	0.0902	37.37	51	0.0486	20.13	17.23

Fuente: Elaboración propia.

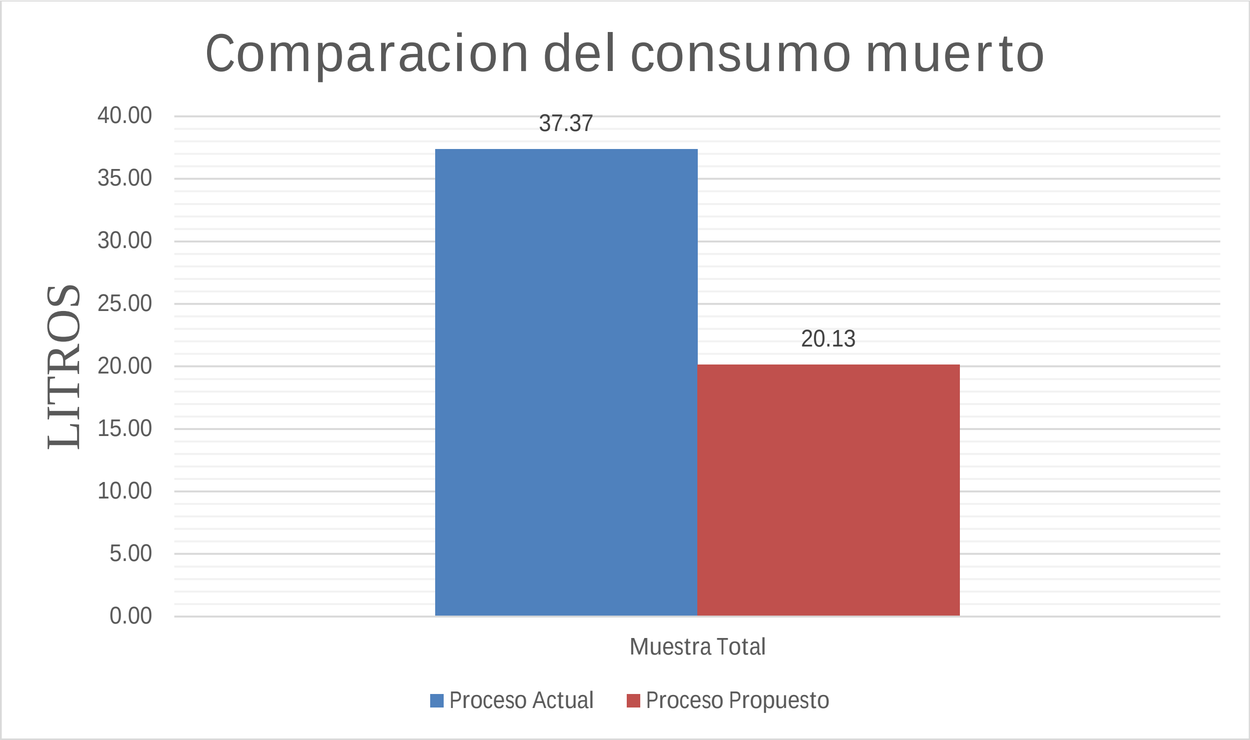


Figura 38. Diferencias en litros del consumo muerto actual vs el consumo muerto propuesto.

Se debe tener en cuenta que el recubrimiento epóxico tomado como referencia en la investigación es el Macropoxy 646 por ser de alta aplicabilidad para los diferentes proyectos y en lo que respecta a la empresa Haug S.A. siempre se realizan cotizaciones con recubrimientos imprimantes epóxicos, a continuación, se muestra una tabla de los diferentes proyectos manejados en los años en los que se ha usado recubrimientos imprimantes epóxicos en los cuales se puede tener un análisis teniendo como referencia la propuesta de mejora.

En consideración del volumen de Macropoxy 646 de la figura 38 el cual sería ahorrado con el sistema operativo propuesto y de acuerdo al costo del producto consultado al área de costos y presupuestos de la empresa Haug S.A.:

Tabla 18. Costo del recubrimiento de muestra en litros, Macropoxy 646.

Volumen de recubrimiento ahorrado (litros)	**US$./Gal**	**US$./l**	**Costo de recubrimiento total US$.**
17.23	30	7.93	136.6

Fuente: Información de la empresa Haug S.A.

La siguiente tabla muestra el área, el tipo de recubrimiento, el volumen de recubrimiento ahorrado y el costo por litros de producto que puede ahorrarse de todos los proyectos más importantes ejecutados en los últimos años.

Tabla 19. Información del consumo muerto y el costo por litro ahorrado en los proyectos más resaltantes en los últimos años.

N°	**Código de proyecto**	**Fecha**	**Recubrimiento imprimante epóxico**	**Área total (m^2)**	**% Solidos en Volumen**	**Consumo Muerto (l/m^2) - Proceso actual**	**Consumo Total por Volumen Muerto (l) - Proceso actual**	**Consumo Muerto (l/m^2) - Proceso propuesto**	**Consumo Total por Volumen Muerto (l) - Proceso propuesto**	**Diferencia de volumen muerto del proceso actual (l) vs. el proceso propuesto (l)**	**Costo de recubrimiento por litro (US$./l)**	**Costo del recubrimiento total (US$.)**
1	2139	22/10/2020	Jet 70 MP	2051	0.72	0.090	185.16	0.05	99.70	85.46	4.86	415.44
2	2136	4/08/2020	Macropoxy 646	6222.5	0.72	0.090	561.75	0.05	302.48	259.27	7.93	2054.99
		4/08/2020	Duraplate UHS TS	6222.5	0.98	0.066	412.72	0.04	222.23	190.48	13.03	2481.08
3	2126	3/01/2020	Jet 85 MP	16276	0.85	0.076	1244.64	0.04	670.19	574.45	5.48	3149.21
		3/01/2020	Jet Pox High Resistant	16276	0.98	0.066	1079.53	0.04	581.29	498.24	13.37	6660.82
4	2109	28/06/2019	Duraplate UHS TS	8523	0.98	0.066	565.30	0.04	304.39	260.91	13.03	3398.35
5	2115	27/06/2019	Macropoxy 851	9131	0.85	0.076	698.25	0.04	375.98	322.27	6.34	2043.46
6	2104	15/12/2018	Macropoxy 851	18517	0.85	0.076	1416.01	0.04	762.46	653.54	6.34	4143.99
		15/12/2018	Duraplate UHS TS	18517	0.98	0.066	1228.17	0.04	661.32	566.85	13.03	7383.24
7	2101	29/10/2018	Macropoxy 646	1045.5	0.72	0.090	94.39	0.05	50.82	43.56	7.93	345.28
		29/10/2018	Duraplate UHS TS	1045.5	0.98	0.066	69.34	0.04	37.34	32.01	13.03	416.87
											Total	**32492.72**

Fuente: Información de la empresa Haug S.A.

2139: Suministro De Tanques Fabricados En Taller - Código - Ampliación De Embalse De Relaves - Quebrada Honda
2136: Suministro Y Fabricación De Estructuras Metálicas De 01 Espesador HRT Ø50.0 m
2126: RFQ: Quellaveco - 402005-Platework - Quellaveco Project - Package ID: 103504
2109: Suministro Y Fabricación Celdas De Flotación TC 300 Bridado – Proyecto Quellaveco
2115: Quellaveco Project Tailing Thickeners
2104: Toromocho Expansión Project - 170 KTDP
2101: Suministro De 04 Tanques De Almacenamiento De Agua

Como se puede apreciar en la tabla 19, la cantidad de área de trabajo por proyectos es altamente considerable.

CAPITULO V

DISCUSIÓN

5.1.Discusión de resultados

Respecto a Dávila y Calle (2018), mencionan que la buena adherencia en las probetas ensayadas no depende de la rugosidad obtenida del proceso de chorro abrasivo por lo tanto esta conclusión aporta de manera positiva ya que al disminuir la rugosidad en la investigación realizada no se va a ver afectada la adherencia del sistema de recubrimiento y más teniendo en cuenta que el recubrimiento imprimante epóxico evaluado detalla en sus hojas técnicas que tiene un desempeño adecuado en 50 micras.

Respecto a Blandino (2017), detallan que realizar un método de gestión de control de calidad para el fortalecimiento del proceso de pintura permitirá generar un producto de mayor calidad resultando ahorro en los gastos de operatividad y por consiguiente mayores utilidades para la misma, esta conclusión de los investigadores apoya la mentalidad de la mejora continua por lo que es una conclusión que aporta en la investigación a tal forma que me motivo emocionalmente para buscar mejoras en el proceso del área de granallado y pintura, y aportar en la obtención de resultados eficaces en la empresa.

Respecto a López (2018), indican que para incrementar la productividad es necesario enfocarse en la mejora del "cuello de botella" el cual ayuda a mejorar la eficiencia y como consecuencia trae ahorro económico por lo que esta conclusión aporta en la investigación ya que se pudo ubicar los puntos donde se puede mejorar el rendimiento del consumo de recubrimientos imprimantes epóxicos los cuales fueron el alto volumen muerto generada por una ineficiente mezcla operativa que a la vez no genera productividad al proceso.

Respecto a Belloso y Flamenco (2004), comprobaron que la distancia de proyección, ángulo de incidencia y presión de granallado son las variables que aportan en la eficiencia de la limpieza y la obtención de la rugosidad, esto aporta en la de tal manera que se tomaron en cuenta para tenerlas como constantes en el proceso de mejora y obtener una eficiencia óptima.

CAPITULO VI

CONCLUSIONES Y RECOMENDACIONES

6.1.Conclusiones

De acuerdo a la investigación realizada se tiene lo siguiente:

Al proponer una mejora en el proceso de granallado la cual consiste en añadir un filtro para la extracción de granalla fina la cual hará que la mezcla operativa se encuentre controlada con la rugosidad requerida y a la vez hará que la rugosidad disminuya, se obtendrá un mayor rendimiento en los recubrimientos imprimantes epóxicos a aplicar.

Al proponer utilizar una granalla de menor granulometría basándonos como referencia en la norma SSPC SP COM la cual nos menciona la rugosidad a obtener con un grano de abrasivo especifico se reducirá el volumen muerto.

Al proponer utilizar un filtro con cortina de aire para que el abrasivo fino fluya por el proceso de recirculación sea extraído y eliminado de la mezcla operativa, hará que la mezcla operativa se mantenga de acuerdo a lo propuesto para que la rugosidad a obtener sea constante

Al proponer un cambio de abrasivos y un filtro de aire que retire el abrasivo fino se obtendrá una rugosidad menor, por lo tanto, el consumo de recubrimientos imprimantes epóxicos será mayor por lo que el costo de los proyectos disminuirá.

6.2.Recomendaciones

Respecto a la investigación realizada sobre la evaluación y propuestas de mejora para disminuir la rugosidad y controlarla con la finalidad de aumentar el rendimiento del recubrimiento teniendo como consecuencia un ahorro en costos en las compras del proyecto, se recomiendan los siguientes puntos:

El sistema de mejora propuesto deberá ser evaluado con la finalidad de detectar puntos donde puede ocurrir fallas, esto con la finalidad de que el mantenimiento de la mejora sea preventivo y sea un proceso beneficioso.

El abrasivo a cambiarse deberá suministrarse de manera paulatina añadiendo 5 kg diarios con la finalidad de no saturar el sistema con granalla nueva y mantener el sistema equilibrado

El filtro a añadirse deberá ser inspeccionado semanalmente hasta hallar rastros de deterioro para evitar paradas de proceso.

La rugosidad obtenida y la mezcla operativa deberá ser evaluados semanalmente con la finalidad de mantener un registro del rendimiento de los recubrimientos imprimantes epóxicos y detectar problemas en la mejora propuesta.

REFERENCIAS

7.1.Fuentes Bibliográficas

Cárdenas, M. (2014). Diseño de un sistema de extracción de polvo para una cabina de granallado semiautomática en la empresa PROMETAL ROCA HERMANOS E.I.R.L. (Tesis de Pregrado). Universidad Nacional Tecnológica del Cono Sur de Lima, Perú.

Dávila P., y Calle P. (2018). Estudio de la variabilidad de la adherencia generada por diferentes granulometrías de área utilizada como abrasivo en la preparación de superficies para un sistema de recubrimiento primer- IOZ. (Tesis de Pregrado). Universidad Nacional de San Agustín de Arequipa, Perú.

Jarrín A. (2012). Estudio de procesos de pintura de alto desempeño y su incidencia en la calidad de los equipos petroleros de superficie de la empresa Saurus Ecuador Cía. Ltda. (Tesis de Pregrado). Universidad Técnica de Ambato, Ecuador.

Blandino J. (2017). Análisis del control de calidad en el área de pintura de la empresa inversiones y negocios de Nicaragua, S.A. (INDENICSA), TIPITAPA, en el periodo de julio a noviembre 2017. (Tesis de Pregrado). Universidad Nacional Autónoma de Nicaragua - Managua, Nicaragua.

López J. (2018). Mejora de la productividad del área de granallado a través de la aplicación de herramientas de Lean Manufacturing en la empresa Transformaciones Metálicas Pro S.A.C. - S.M.P., 2018. (Tesis de Pregrado). Universidad César Vallejo, Perú.

Berroa E. (2019). Aplicación de control de calidad de los requisitos mínimos para el proceso de preparación superficial y recubrimientos en un tanque de clarificación del proyecto Tamboyamo. (Tesis de Pregrado). Universidad Nacional San Agustín de Arequipa, Perú.

Cáceres O. y Gámez J. (2019). Aplicación de la herramienta TPM para mejorar la productividad en el proceso de granallado, empresa JCB Estructuras S, A, C., 2019. (Tesis de Pregrado). Universidad Ricardo Palma, Perú.

Belloso W. y Flamenco I. (2014). Diseño y construcción de un sistema semiautomático de granallado para uso didáctico. (Tesis de Pregrado). Universidad de el Salvador, El Salvador.

Mitma D. y Mera G. & Vela A. (2019). Optimización del proceso de limpieza 8superficial mecánica utilizando escoria de cobre. Método del chorro abrasivo. (Tesis de Pregrado). Universidad Nacional Del Callao, Perú.

Saldarriaga J. (2006). Optimización del proceso de preparación superficie en el servicio industrial de la marina. (Tesis de Pregrado). Universidad de Piura, Perú.

Samaniego V. (2000). Principios y procedimientos para la aplicación de recubrimientos industriales en la construcción. (Tesis de Pregrado). Universidad de Sonora, México.

Parrilla P. (2011). Pinturas y Revestimientos. (Tesis de Pregrado). Universidad San Carlos de Guatemala, Guatemala.

Guerra C. (2014). Estudio de la Corrosión atmosférica sobre dos tipos de acero de bajo carbono en instalaciones industriales petroleras cercanas al mar en el nor este del Perú. (Tesis de Pregrado). Universidad Nacional Mayor de San Marcos, Perú.

Programa de Certificación de Inspectores de Recubrimientos nivel 2 NACE International, 2004.

Programa de Certificación de Inspectores de Recubrimientos nivel 1 NACE International, 2004.

7.2.Fuentes Electrónicas

CyM Materiales S.A. (2015). Introducción general al granallado (IT-001). Recuperado de: http://cym.com.ar/intranet/Introduccion-general-proceso-granallado-cym-shot-blasting.pdf.

CyM Materiales S.A. (2015). Sistema de Limpieza (1-FC). Recuperado de: https://cym.com.ar/faqs/que-es-el-mix-operativo-en-un-proceso-de-granallado/.

CyM Materiales S.A. (2015). Introducción general al granallado. Recuperado de: http://www.metalcym.com.br/intranet/Introduccion-general-proceso-granallado-cym-shot-blasting.pdf

Blasting Experts Ltda. (2020). Seminario especializado sobre granallado y abrasivos (08-2020). Recuperado de: https://blastingexperts.com/Web_final/docs/seminario-especializado-granallado-abrasivos.pdf.

ANEXOS

Anexo 1. Matriz de Consistencia

Anexo 2. Sherwin Williams Hoja – Protective & Marine Coatings - Macropoxy 646

Anexo 3. Society of Automotive Engineers - Specification J444 – Cast Shot and Grit Size Specifications

Anexo 4. Society for Protective Coatings – Surface Preparation Specifications - Surface Preparation Commentary for Steel and Concrete Substrates

Anexo 5. The Society for Protective Coatings Paint Aplication Standard N. º 2

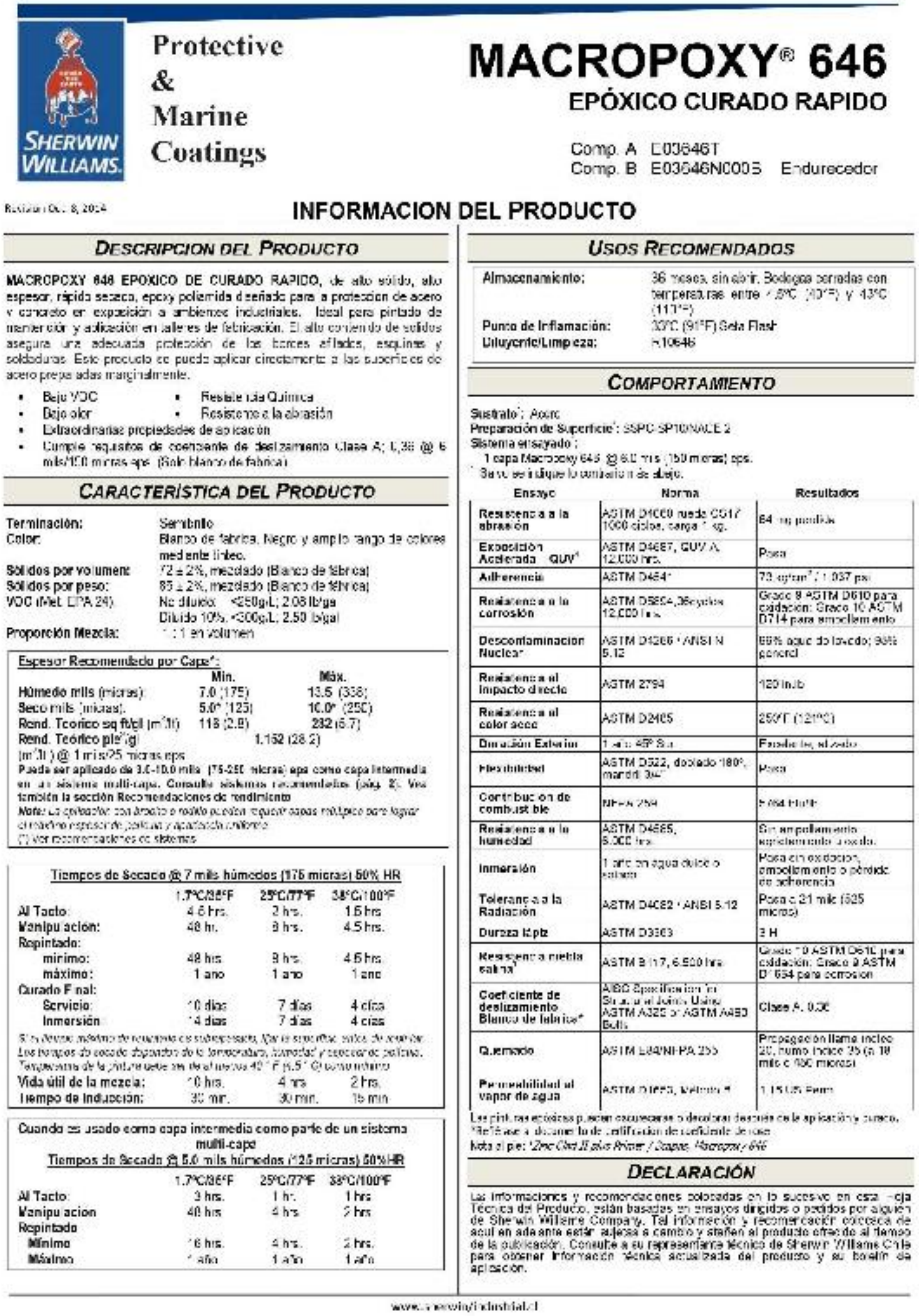
Anexo 6. Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

Anexo 7. Abrasive Standard N°. 2 Cleanliness of Recycled Ferrous Metallic Abrasives

Tabla 20. Matriz de consistencia.

Problema	Objetivos	Hipótesis	Variable	Método
P.G. ¿En qué medida la propuesta de mejora del proceso de granallado para controlar la rugosidad nos ayudara a aumentar el rendimiento de los recubrimientos imprimantes epóxicos?	**O.G.** Proponer una mejora en el proceso de granallado para controlar la rugosidad y aumentar el rendimiento de los recubrimientos imprimantes epóxicos.	**H.G.** La propuesta de mejora del proceso de granallado para controlar la rugosidad nos permitirá aumentar el rendimiento de los recubrimientos imprimantes epóxicos.	Rendimiento de los recubrimientos imprimantes epóxicos **(V.D.)**	Mediante la evaluación técnica del proceso de granallado se identificara las deficiencias con la finalidad de proponer mejoras que aporten resultados a los objetivos propuestos.
P.E.1. ¿En qué medida cambiar la granulometría de la granalla utilizada en el proceso de granallado nos ayudara a reducir la rugosidad?	**O.E.1.** Utilizar una granalla de otra granulometría para reducir la rugosidad obtenida del proceso de granallado.	**H.E.1.** Cambiar la granulometría de la granalla utilizada en el proceso de granallado nos ayudara a reducir la rugosidad.		
P.E.2. ¿En qué medida añadir un sistema de filtros de abrasivos finos reutilizados nos ayudara a obtener una rugosidad constante?	**O.E.2.** Utilizar un sistema de filtrado de abrasivos finos reutilizados para obtener una rugosidad constante.	**H.E.2.** Utilizar un sistema de filtrado de abrasivos finos reutilizados nos ayudara a obtener una rugosidad constante.	Mejora del proceso de granallado para controlar la rugosidad **(V.I.)**	Mediante la evaluación técnica del proceso de aplicación de recubrimiento se obtendrá información con los parámetros del proceso actual con la finalidad de realizar una comparación técnica para la mejora.
P.E.3. ¿En qué medida el reducir la rugosidad del proceso de granallado nos ayudara a reducir los costos de recubrimiento a utilizar en la empresa?	**O.E.3.** Disminuir la rugosidad del proceso de granallado para reducir los costos de recubrimiento a utilizar en la empresa.	**H.E.3.** Reducir la rugosidad del proceso de granallado nos ayudara a reducir los costos de recubrimiento a utilizar en la empresa.		

Fuente: Elaboración propia.



Protective
&
Marine
Coatings

MACROPOXY® 646

EPÓXICO CURADO RAPIDO

Comp. A E03646T
Comp. B E03646N0005 Endurecedor

Revision Oct. 8, 2014

INFORMACION DEL PRODUCTO

DESCRIPCION DEL PRODUCTO

MACROPOXY 646 EPOXICO DE CURADO RAPIDO, de alto sólido, alto espesor, rápido secado, epoxy poliamida diseñado para la protección de acero y concreto en exposición a ambientes industriales. Ideal para pintado de mantención y aplicación en talleres de fabricación. El alto contenido de sólidos asegura una adecuada protección de los bordes afilados, esquinas y soldaduras. Este producto se puede aplicar directamente a las superficies de acero preparadas marginalmente.

- Bajo VOC
- Bajo olor
- Extraordinarias propiedades de aplicación
- Cumple requisitos de coeficiente de deslizamiento Clase A; 0,36 @ 6 mils/150 micras eps. (Solo blanco de fabrica)
- Resiste a la Química
- Resistente a la abrasión

CARACTERÍSTICA DEL PRODUCTO

Terminación:	Semibrillo
Color:	Blanco de fabrica, Negro y amplio rango de colores mediante tinteo.
Sólidos por volumen:	72 ± 2%, mezclado (Blanco de fábrica)
Sólidos por peso:	85 ± 2%, mezclado (Blanco de fábrica)
VOC (Met. EPA 24)	No diluido: <250g/L; 2.08 lb/gal Diluido 10%: <300g/L; 2.50 lb/gal
Proporción Mezcla:	1 : 1 en volumen

Espesor Recomendado por Capa*:

	Min.	Máx.
Húmedo mils (micras):	7.0 (175)	13.5 (338)
Seco mils (micras):	5.0* (125)	10.0* (250)
Rend. Teorico sq ft/gl (m²/lt)	118 (2.9)	232 (5.7)
Rend. Teórico pie²/gl (m²/lt) @ 1 mils/25 micras eps	1.152 (28.2)	

Puede ser aplicado de 3.0-10.0 mils (75-250 micras) eps como capa intermedia en un sistema multi-capa. Consulte sistemas recomendados (pág. 2). Vea también la sección Recomendaciones de rendimiento

Nota: La aplicación con brocha o rodillo pueden requerir capas múltiples para lograr el máximo espesor de película y apariencia uniforme.

(*) Ver recomendaciones de sistemas

Tiempos de Secado @ 7 mils húmedos (175 micras) 50% HR

	1.7°C/35°F	25°C/77°F	38°C/100°F
Al Tacto:	4.5 hrs.	2 hrs.	1.5 hrs
Manipulación:	48 hr.	8 hrs.	4.5 hrs.
Repintado:			
mínimo:	48 hrs.	8 hrs.	4.5 hrs.
máximo:	1 año	1 año	1 año
Curado Final:			
Servicio:	10 días	7 días	4 días
Inmersión:	14 días	7 días	4 días

Si es [illegible] máximo de repintado es sobrepasado, [illegible] la superficie antes de repintar. Los tiempos de secado dependen de la temperatura, humedad y espesor de película. Temperatura de la pintura debe ser de al menos 40 °F (4.5 °C) como mínimo

Vida útil de la mezcla:	10 hrs.	4 hrs.	2 hrs.
Tiempo de Inducción:	30 min.	30 min.	15 min.

Cuando es usado como capa intermedia como parte de un sistema multi-capa

Tiempos de Secado @ 5.0 mils húmedos (125 micras) 50%HR

	1.7°C/35°F	25°C/77°F	38°C/100°F
Al Tacto:	3 hrs.	1 hr.	1 hrs
Manipulación	40 hrs	4 hrs	2 hrs
Repintado			
Mínimo	16 hrs.	4 hrs.	2 hrs.
Máximo	1 año	1 año	1 año

USOS RECOMENDADOS

Almacenamiento:	36 meses, sin abrir. Bodegas cerradas con temperaturas entre 4.5°C (40°F) y 43°C (110°F)
Punto de Inflamación:	33°C (91°F) Seta Flash
Diluyente/Limpieza:	R10646

COMPORTAMIENTO

Sustrato*: Acero
Preparación de Superficie*: SSPC-SP10/NACE 2
Sistema ensayado*:
1 capa Macropoxy 646 @ 6.0 mils (150 micras) eps.
*Salvo se indique lo contrario más abajo.

Ensayo	Norma	Resultados
Resistencia a la abrasión	ASTM D4060 rueda CS17 1000 ciclos, carga 1 kg.	64 mg perdida
Exposición Acelerada QUV¹	ASTM D4587, QUV A, 12.000 hrs.	Pasa
Adherencia	ASTM D4541	72 kg/cm² / 1.037 psi
Resistencia a la corrosión	ASTM D5894, 36 cycles 12.000 hrs.	Grado 8 ASTM D610 para oxidación; Grado 10 ASTM D714 para ampollamiento
Descontaminación Nuclear	ASTM D4256 / ANSI N 5.12	89% agua de lavado; 99% general
Resistencia al impacto directo	ASTM 2794	120 in.lb
Resistencia al calor seco	ASTM D2485	250°F (121°C)
Duración Exterior	1 año 45° Sur	Excelente, al yeso
Flexibilidad	ASTM D522, doblado 180°, mandril 3/4"	Pasa
Contribución de combustible	NFPA 259	5.464 Btu/lb
Resistencia a la humedad	ASTM D4585, 6.000 hrs.	Sin ampollamiento, agrietamiento u oxido.
Inmersión	1 año en agua dulce o salada	Pasa sin oxidacion, ampollamiento o pérdida de adherencia
Tolerancia a la Radiación	ASTM D4082 / ANSI 5.12	Pasa a 21 mils (525 micras)
Dureza lápiz	ASTM D3363	3 H
Resistencia niebla salina¹	ASTM B117, 6.500 hrs.	Grado 10 ASTM D610 para oxidación; Grado 9 ASTM D1654 para corrosion
Coeficiente de deslizamiento Blanco de fabrica*	AISC Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts	Clase A, 0.36
Quemado	ASTM E84/NFPA 255	Propagación llama indice 20, humo indice 35 (a 18 mils o 450 micras)
Permeabilidad al vapor de agua	ASTM D1653, Método B	1.15 US Perm

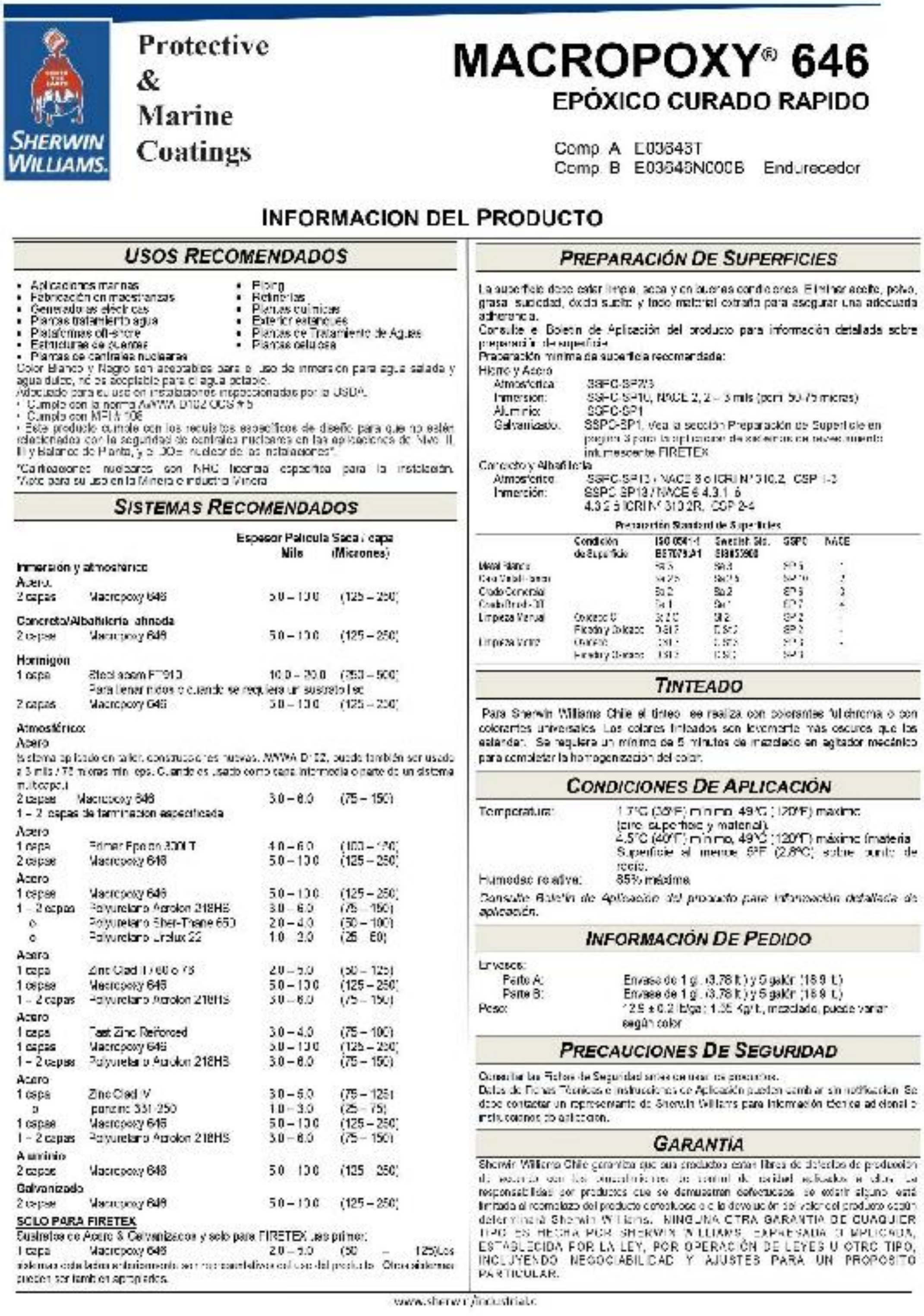
Las pinturas epóxicas pueden oscurecerse o decolorar después de la aplicación y curado.
*Refiérase a documento de certificación de coeficiente de roce.

Nota al pie: *¹Zinc Clad II plus Primer / 2capas Macropoxy 646*

DECLARACIÓN

Las informaciones y recomendaciones colocadas en lo sucesivo en esta Hoja Técnica del Producto, están basadas en ensayos dirigidos o pedidos por alguien de Sherwin Williams Company. Tal información y recomendación colocada de aquí en adelante están sujetas a cambio y atañen al producto ofrecido al tiempo de la publicación. Consulte a su representante técnico de Sherwin Williams Chile para obtener información técnica actualizada del producto y su boletín de aplicación.

www.sherwin/industrial.cl



Sherwin Williams.

Protective
&
Marine
Coatings

MACROPOXY® 646

EPÓXICO CURADO RAPIDO

Comp. A E03643T
Comp. B E03646NC00B Endurecedor

INFORMACION DEL PRODUCTO

USOS RECOMENDADOS

- Aplicaciones marinas
- Fabricación en maestranzas
- Generadoras eléctricas
- Plantas tratamiento agua
- Plataformas off-shore
- Estructuras de puentes
- Plantas de centrales nucleares
- Piping
- Refinerías
- Plantas químicas
- Exterior estanques
- Plantas de Tratamiento de Aguas
- Plantas celulosa

Color Blanco y Negro son aceptables para el uso de inmersion para agua salada y agua dulce, no es aceptable para el agua potable.
Adecuado para su uso en instalaciones inspeccionadas por la USDA.
- Cumple con la norma AWWA D102 OCS # 5
- Cumple con MPI # 108
- Este producto cumple con los requisitos específicos de diseño para que no estén relacionados con la seguridad de centrales nucleares en las aplicaciones de Nivel II, III y Balance de Planta, y el DOE nuclear de las instalaciones*.

*Certificaciones nucleares con NRC licencia específica para la instalación. *Apto para su uso en la Minería e industria Minera

SISTEMAS RECOMENDADOS

		Espesor Película Seca / capa Mils	(Micrones)
Inmersión y atmosférico			
Acero			
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
Concreto/Albañilería alisada			
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
Hormigon			
1 capa	Steel-seam FT910	10.0 – 20.0	(250 – 500)
	Para llenar nidos o cuando se requiera un sustrato liso		
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)

Atmosféricos
Acero
Sistema aplicado en taller, construcciones nuevas. AWWA D102, puede también ser usado a 3 mils / 75 micras min. eps. Cuando es usado como capa intermedia o parte de un sistema multicapa.

2 capas	Macropoxy 646	3.0 – 6.0	(75 – 150)
1 – 2 capas de terminación especificada			
Acero			
1 capa	Primer Epoxico 300 T	4.0 – 6.0	(100 – 150)
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
Acero			
1 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
1 – 2 capas	Polyuretano Acrolon 218HS	3.0 – 6.0	(75 – 150)
o	Polyuretano Sher-Thane 650	2.0 – 4.0	(50 – 100)
o	Polyuretano Urolux 22	1.0 – 2.0	(25 – 50)
Acero			
1 capa	Zinc Clad II / 60 o 75	2.0 – 5.0	(50 – 125)
1 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
1 – 2 capas	Polyuretano Acrolon 218HS	3.0 – 6.0	(75 – 150)
Acero			
1 capa	Fast Zinc Reinforced	3.0 – 4.0	(75 – 100)
1 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
1 – 2 capas	Polyuretano Acrolon 218HS	3.0 – 6.0	(75 – 150)
Acero			
1 capa	Zinc Clad IV	3.0 – 5.0	(75 – 125)
o	Corozinc 331-250	1.0 – 3.0	(25 – 75)
1 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
1 – 2 capas	Polyuretano Acrolon 218HS	3.0 – 6.0	(75 – 150)
Aluminio			
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)
Galvanizado			
2 capas	Macropoxy 646	5.0 – 10.0	(125 – 250)

SOLO PARA FIRETEX
Sustratos de Acero & Galvanizados y solo para FIRETEX los primer:

1 capa	Macropoxy 646	2.0 – 5.0	(50 – 125)

Los sistemas detallados anteriormente son representativos del uso del producto. Otros sistemas pueden ser también apropiados.

PREPARACIÓN DE SUPERFICIES

La superficie debe estar limpia, seca y en buenas condiciones. Eliminar aceite, polvo, grasa, suciedad, óxido suelto y todo material extraño para asegurar una adecuada adherencia.
Consulte el Boletín de Aplicación del producto para información detallada sobre preparación de superficie.
Preparación mínima de superficie recomendada:
Hierro y Acero
Atmosférica: SSPC-SP2/3
Inmersion: SSPC-SP10, NACE 2, 2 – 3 mils (perfil 50-75 micras)
Aluminio: SSPC-SP1
Galvanizado: SSPC-SP1, vea la sección Preparación de Superficie en página 3 para la aplicación de sistemas de revestimiento intumescente FIRETEX
Concreto y Albañilería
Atmosférico: SSPC-SP13 / NACE 6 o ICRI Nº 310.2, CSP 1-3
Inmersión: SSPC-SP13 / NACE 6 4.3.1 ó 4.3.2 ó ICRI Nº 310.2R, CSP 2-4

Preparación Standard de Superficies

	Condición de Superficie	ISO 8501-1 BS7079:A1	Swedish Std. SIS055900	SSPC	NACE
Metal Blanco		Sa 3	Sa 3	SP 5	1
Casi Metal Blanco		Sa 2.5	Sa 2.5	SP 10	2
Grado Comercial		Sa 2	Sa 2	SP 6	3
Grado Brush-Off		Sa 1	Sa 1	SP 7	4
Limpieza Manual	Oxidado C	C St 2	St 2	SP 2	-
	Picado y Oxidado	D St 2	D St 2	SP 2	-
Limpieza Motriz	Oxidado	C St 3	C St 3	SP 3	-
	Picado y Oxidado	D St 3	D St 3	SP 3	-

TINTEADO

Para Sherwin Williams Chile el tinteo se realiza con colorantes fulchroma o con colorantes universales. Los colores tinteados son levemente más oscuros que los estándar. Se requiere un mínimo de 5 minutos de mezclado en agitador mecánico para completar la homogenización del color.

CONDICIONES DE APLICACIÓN

Temperatura:	1.7ºC (35ºF) mínimo, 49ºC (120ºF) máximo (aire, superficie y material). 4.5ºC (40ºF) mínimo, 49ºC (120ºF) máximo (materia Superficie al menos 5ºF (2.8ºC) sobre punto de rocío.
Humedad relativa:	85% máxima

Consulte Boletín de Aplicación del producto para información detallada de aplicación.

INFORMACIÓN DE PEDIDO

Envases:	
Parte A:	Envase de 1 gl. (3.78 lt.) y 5 galón (18.9 L)
Parte B:	Envase de 1 gl. (3.78 lt.) y 5 galón (18.9 L)
Peso:	12.5 ± 0.2 lb/gal; 1.35 Kg/Lt, mezclado, puede variar según color

PRECAUCIONES DE SEGURIDAD

Consultar las Fichas de Seguridad antes de usar los productos.
Datos de Fichas Técnicas e instrucciones de Aplicación pueden cambiar sin notificación. Se debe contactar un representante de Sherwin Williams para información técnica adicional o instrucciones de aplicación.

GARANTÍA

Sherwin Williams Chile garantiza que sus productos están libres de defectos de producción de acuerdo con los procedimientos de control de calidad aplicados a ellos. La responsabilidad por productos que se demuestren defectuosos, si existir alguno, está limitada al reemplazo del producto defectuoso o a la devolución del valor del producto según determinará Sherwin Williams. NINGUNA OTRA GARANTIA DE CUAQUIER TIPO ES HECHA POR SHERWIN WILLIAMS, EXPRESADA O IMPLICADA, ESTABLECIDA POR LA LEY, POR OPERACIÓN DE LEYES U OTRO TIPO, INCLUYENDO NEGOCIABILIDAD Y AJUSTES PARA UN PROPOSITO PARTICULAR.

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Revisión Oct. 8, 2014

BOLETÍN DE APLICACIÓN

PREPARACIÓN DE SUPERFICIES

La superficie debe estar limpia, seca y firme. Remover todo el aceite, grasa, polvo, óxido suelto, y otras materias extrañas para asegurar una adecuada adherencia.

Hierro y Acero, Servicio Atmosférico: La mínima preparación de superficie es Limpieza con Herramienta Manual SSPC–SP2. Eliminar todo el aceite y grasa de la superficie con Limpieza con Solvente SSPC–SP1. Para mejor comportamiento usar Limpieza con Chorro Comercial según SSPC-SP6 / NACE 3 utilizando abrasivo angular para obtener un óptimo perfil de rugosidad (2 mils / 50 micrones). Aplicar inmediatamente al acero descubierto dentro de 8 horas, o antes que se oxide.

Acero al Carbono, Servicio de Inmersión:

Remover todo aceite y grasa de la superficie mediante limpieza con solventes según SSPC-SP1. Mínima preparación de superficie a metal casi blanco SSPC-SP10 / NACE2 utilizando abrasivo angular para obtener un óptimo perfil de rugosidad (2–3 mils / 50–75 micrones). Remueva toda salpicadura de soldadura, esmerile bordes filos e imprima el mismo día de la limpieza.

Aluminio: Remueva todo aceite, grasa, polvo, óxidos y cualquier otro agente contaminante mediante limpieza con solventes SSPC-SP1.

Acero Galvanizado:

Deje a la intemperie por un mínimo de seis meses antes de pintar. Limpie con solventes según SSPC-SP1. Cuando la exposición a la intemperie no sea posible o la superficie haya sido tratada con cromatos o silicatos primero limpie según SSPC-SP1 y aplique un parche de prueba, permita que la pintura seque al menos por 7 días antes de probar la adherencia. Si la adherencia es pobre ejecute Brush Off SSPC-SP7 para remover los tratamientos. El galvanizado oxidado requiere como mínimo limpieza SSPC-SP2. Pinte el área el mismo día de la limpieza.

En la preparación de sustratos de acero galvanizado para la aplicación de sistemas de revestimiento intumescente FIRETEX, Prepare la superficie según SSPC-SP 16 se debe obtener un perfil de superficie de un mínimo de 1,5 milésimas de pulgada (38 micras). Perfil de la superficie óptima no excederá de 2.0 milésimas de pulgada (50 micras).

Concreto y albañilería.

Para preparación de superficie consulte SSPC SP13/NACE 6, ó ICRI Nº 310.2R, CSP 1–3. La superficie debe estar completamente limpia y seca. El concreto y mortero debe estar curado al menos 28 días a 24ºC (75ºF). Remover todo el mortero suelto y material extraño. La superficie debe estar libre de lechada, polvo, suciedad, agentes de fraguado, membranas húmedas de curado, cemento suelto y endurecedores. Rellenar micro poros, bolsas de aire y otras cavidades con Steel-Seam FT910.

Concreto, Servicio Inmersion.

Para preparación de superficie consulte SSPC-SP13/NACE 6, Sección 4.3.1 ó 4.3.2 ó ICRI Nº 310.2R, CSP 2–4.

Siga los métodos standard indicados cuando corresponda:

ASTM D4258 Práctica Standard para Limpiar Concreto
ASTM D4259 Práctica Standard para Raspar Concreto
ASTM D4260 Práctica Standard para Grabar Concreto
ASTM F1869 Método de Prueba Standard para Medir Proporción de Emisión de Vapor del Concreto
SSPC-SP 13/NACE 6 Preparación de Superficie de Concreto
ICRI Nº 310.2R Preparación de Superficie de Concreto

Superficies Previamente Pintadas:

Si están en condiciones sanas, limpie la superficie de todo material extraño. Los recubrimientos y superficies suaves, duras o brillantes deben ser opacados lijando la superficie. Aplique un área de prueba, permitiendo que la pintura seque una semana antes de probar la adherencia. Si la adherencia es pobre, o si el producto ataca el acabado previo, la eliminación de la capa previa puede ser necesaria. Si la pintura se desprende o esta mal adherida, limpie la superficie hasta el substrato y trate como una nueva superficie.

Preparación Standard de Superficies

	Condición de Superficie	ISO 8501-1 BS7079:A1	Swedish Std. SIS055900	SSPC	NACE
Metal Blanco		Sa 3	Sa 3	SP 5	1
Casi Metal Blanco		Sa 2.5	Sa 2.5	SP 10	2
Chorro Comercial		Sa 2	Sa 2	SP 6	3
Chorro Rápido (Brush Off)		Sa 1	Sa 1	SP 7	4
Limpieza Manual	Oxidado C	St 2 C	St 2	SP 2	-
	Picado y Oxidado	D St 2	D St 2	SP 2	-
Limpieza Motriz	Oxidado	C St 3	C St 3	SP 3	-
	Picado y Oxidado	D St 3	D St 3	SP 3	

CONDICIONES DE LA APLICACIÓN

Temperatura	1.7ºC (35ºF) mínimo, 49ºC (120ºF) máxima (aire, superficie y material).
	4.5ºC (40ºF) mínimo, 49ºC (120ºF) máximo (mezcla)
	Superficie al menos 5ºF (2.8ºC) sobre punto de rocío.
Humedad relativa	85% máxima

Consulte Boletín de Aplicación del producto para información detallada de aplicación.

EQUIPOS DE APLICACIÓN

Lo siguiente es una guía. Pueden necesitarse cambios en presiones y tamaños de boquillas para adecuadas características de aplicación. Siempre limpie el equipo de aplicación antes de utilizar con un diluyente indicado. Cualquier dilución debe ser compatible con las condiciones ambientales y de aplicación existentes.

Diluyente/ Limpieza	Diluyente R10648
Equipo Airless	
Unidad	Bomba 30:1
Presión	2800 – 3000 psi
Manguera	1/4" Diámetro interior
Boquilla	.017" – .023"
Filtro	malla 60
Dilución	La necesaria hasta 10% por volumen
Equipo Convencional	
Pistola	De Vilbiss MBC-510
Boquilla Fluido	E
Boquilla Aire	704
Presión Atomización	60 – 65 psi
Presión Fluido	10 – 20 psi
Dilución	La necesaria hasta 10% por volumen

Requiere el uso de separador de aceite y humedad.

Brocha	
Brocha	Nylon/Poliéster o Cerda Natural
Dilución	No recomendada
Rodillo	
Forro	Tejido 3/8" con centro resistente al solvente
Dilución	no recomendada

Equipo Pluricomponente... Aceptable

Refiérase a boletín técnico de abril 2010, "Guía de aplicación para Macropoxy 646 y Primer Epóxico Repintable utilizando Equipo Plural Componente

Si el equipo de aplicación no es el indicado arriba, un equipo equivalente al indicado puede ser utilizado.

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BOLETÍN DE APLICACIÓN

PROCEDIMIENTO DE APLICACIÓN

La preparación de superficie debe ser efectuada de acuerdo a lo indicado.

Mezclar completamente el contenido de cada componente utilizando agitación mecánica de baja velocidad. Asegúrese de que no queden restos de pigmentos en el fondo del envase. Posteriormente, combine una parte en volumen de componente A con una parte en volumen del componente B. Agitar completamente la mezcla con agitación mecánica. Dejar el material reposar como se indica antes de la aplicación. Revolver nuevamente antes de usar.

Si se va a usar dilución con solvente, agregar sólo después que ambos componentes han sido completamente mezclados, después de la inducción.

Aplicar la pintura al espesor de película y proporción de rendimiento que se indica a continuación:

Espesor Recomendado por Capa*:

	Min.	Máx.
Húmedo mils (micras):	7.0 (175)	13.5 (336)
Seco mils (micras):	5.0* (125)	10.0* (250)
Rend. Teórico sq ft/gl (m²/lt)	116 (2.9)	232 (5.7)
Rend. Teórico pie²/gl	1,152 (28.2)	

(m²/lt) @ 1 mils/25 micras eps

Puede ser aplicado de 3.0-10.0 mils (75-250 micras) eps como capa intermedia en un sistema multi-capa. Consulte sistemas recomendados (pág. 2). Vea también la sección Recomendaciones de rendimiento.

Nota: La aplicación con brocha o rodillo pueden requerir capas múltiples para lograr el máximo espesor de película y apariencia uniforme.

(*) Ver recomendaciones de sistemas

Tiempos de Secado@ 7.0 mils húmedos (175 micras) 50% HR

	1.7°C/35°F	25°C/77°F	38°C/100°F
Al Tacto:	4-5 hrs.	2 hrs.	1.5 hrs
Manipulación:	48 hr.	8 hrs.	4.5 hrs.
Repintado:			
mínimo:	48 hrs.	8 hrs.	4.5 hrs.
máximo:	1 año	1 año	1 año
Curado Final:			
Servicio:	10 días	7 días	4 días
Inmersión:	14 días	7 días	4 días

Si el tiempo máximo de repintado es sobrepasado, lije la superficie antes de repintar. Los tiempos de secado dependen de la temperatura, humedad y espesor de película.

	1.7°C/35°F	25°C/77°F	38°C/100°F
Vida útil de la mezcla:	10 hrs.	4 hrs.	2 hrs.
Tiempo de Inducción:	30 min.	30 min.	15 min.

Cuando es usado como capa intermedia como parte de un sistema multi-capa

Tiempos de Secado @ 5.0 mils húmedos (125 micras) 50%HR

	1.7°C/35°F	25°C/77°F	38°C/100°F
Al Tacto:	3 hrs.	1 hr.	1 hrs.
Manipulación	48 hrs.	4 hrs.	2 hrs.
Repintado			
Mínimo	16 hrs.	4 hrs.	2 hrs.
Máximo	1 año	1 año	1 año

La aplicación de la pintura por encima del máximo o por debajo del mínimo de proporción de esparcimiento recomendado puede afectar negativamente el desempeño de la pintura.

INSTRUCCIONES DE LIMPIEZA

Limpie derrames y salpicaduras inmediatamente con Diluyente R10646. Limpie las herramientas inmediatamente después de usarlas con R10646. Siga las recomendaciones de seguridad del fabricante cuando utilice solventes.

RECOMENDACIONES DE RENDIMIENTO

Pinte con una capa adicional todas las uniones, cordones de soldaduras, bordes, cantos y ángulos agudos para evitar falla prematura en estas áreas.

Cuando use aplicación spray, use un 50% de traslape con cada pasada de pistola para evitar vacíos, áreas sin cubrimiento y poros. Si es necesario, aplique el spray cruzado en ángulo recto.

Los rangos de rendimiento se calculan en base a los sólidos por volumen y no incluyen factor de pérdida de aplicación por rugosidad de la superficie, aspereza, porosidad o irregularidades de la superficie, habilidad y técnica del aplicador, método de aplicación, diversas irregularidades de la superficie, pérdida de material durante mezclado, derrames, dilución excesiva, condiciones climáticas y espesor excesivo de la película.

La dilución excesiva del material puede afectar el espesor de la película, apariencia, adherencia.

No aplicar el material después de la vida útil recomendada.

No mezclar material previamente catalizado con material nuevo.

Para evitar bloqueo del equipo spray, lavar el equipo luego de usarlo o después de una pausa prolongada usando Diluyente R10646.

No se recomienda tintear para servicio de inmersión.

Use solo Mill Blanco y Negro para servicio en inmersión.

La ventilación insuficiente, mezclado incompleto, catalizado incompleto y calentadores externos pueden causar amarillamiento prematuro.

Excesivo cuerpo de la película, pobre ventilación y temperaturas frías pueden causar atrapamiento del solvente y falla prematura de la pintura.

Acelerador de epóxico es aceptable para su uso, ver Hoja Técnica B01755N.

Se recomienda espesores de 2 a 4 mils (50 – 100 micras) para aplicaciones sobre aluminio o galvanizado.

Aceptable su uso para pisos de concreto.

Consulte la hoja de Información del Producto para características y propiedades de desempeño adicionales.

PRECAUCIONES DE SEGURIDAD

Consulte la hoja de seguridad de materiales (MSDS) antes de usar.

Los datos técnicos e instrucciones publicados están sujetos a cambios sin previo aviso.
Contacte su representante Sherwin Williams para datos técnicos e instrucciones adicionales.

DECLARACIÓN

La información y recomendaciones indicadas en esta Hoja de Datos del Producto están basadas en pruebas hechas por o en nombre de Sherwin Williams Company. Tal información y recomendaciones están sujetas a cambios y corresponden al producto ofrecido al momento de la publicación. Consulte a su Representante Sherwin-Williams para obtener información más reciente de Datos del Producto y Boletín de Aplicación.

GARANTÍA

The Sherwin-Williams Company garantiza que nuestros productos están libres de defectos de fabricación conforme a los procedimientos de control de calidad de Sherwin-Williams. La responsabilidad por productos probados como defectuosos, si la hubiera, está limitada al reemplazo del producto defectuoso o al reembolso del precio pagado por el producto defectuoso según lo determine Sherwin Williams. NINGUNA OTRA GARANTÍA DE NINGÚN TIPO OTORGA SHERWIN WILLIAMS EXPRESA O IMPLÍCITA, ESTATUTARIA, POR VIGENCIA DE LEY U OTRA, INCLUYENDO COMERCIABILIDAD Y ADECUACIÓN PARA UN PROPÓSITO PARTICULA.

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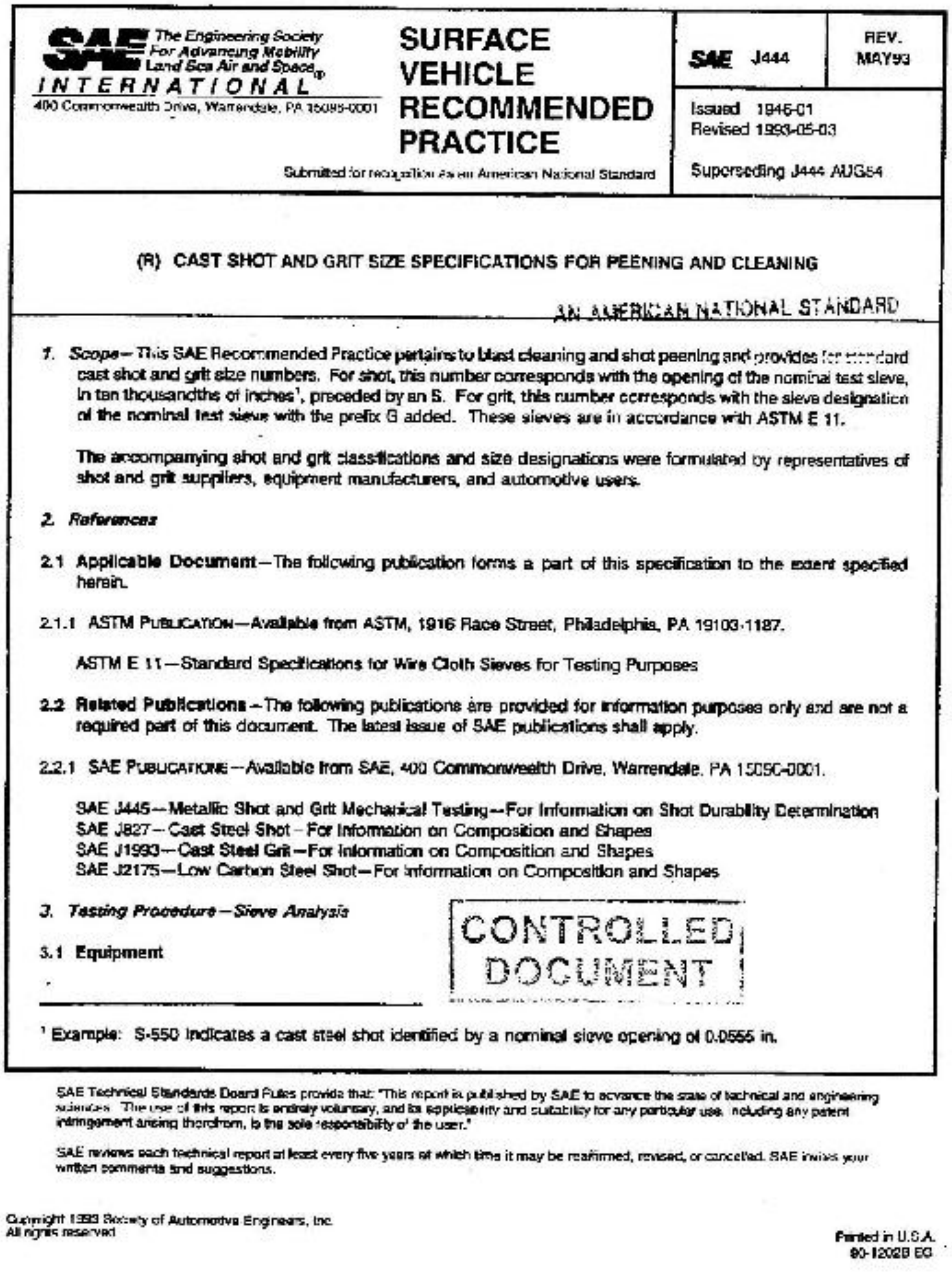

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SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE J444
REV. MAY93

Issued 1946-01
Revised 1993-05-03

Superseding J444 AUG84

(R) CAST SHOT AND GRIT SIZE SPECIFICATIONS FOR PEENING AND CLEANING

AN AMERICAN NATIONAL STANDARD

1. *Scope*—This SAE Recommended Practice pertains to blast cleaning and shot peening and provides for standard cast shot and grit size numbers. For shot, this number corresponds with the opening of the nominal test sieve, in ten thousandths of inches[1], preceded by an S. For grit, this number corresponds with the sieve designation of the nominal test sieve with the prefix G added. These sieves are in accordance with ASTM E 11.

The accompanying shot and grit classifications and size designations were formulated by representatives of shot and grit suppliers, equipment manufacturers, and automotive users.

2. *References*

2.1 **Applicable Document**—The following publication forms a part of this specification to the extent specified herein.

2.1.1 ASTM PUBLICATION—Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 11—Standard Specifications for Wire Cloth Sieves for Testing Purposes

2.2 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document. The latest issue of SAE publications shall apply.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J445—Metallic Shot and Grit Mechanical Testing—For Information on Shot Durability Determination
SAE J827—Cast Steel Shot—For Information on Composition and Shapes
SAE J1993—Cast Steel Grit—For Information on Composition and Shapes
SAE J2175—Low Carbon Steel Shot—For Information on Composition and Shapes

3. *Testing Procedure—Sieve Analysis*

3.1 **Equipment**

CONTROLLED DOCUMENT

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[1] Example: S-550 indicates a cast steel shot identified by a nominal sieve opening of 0.0555 in.

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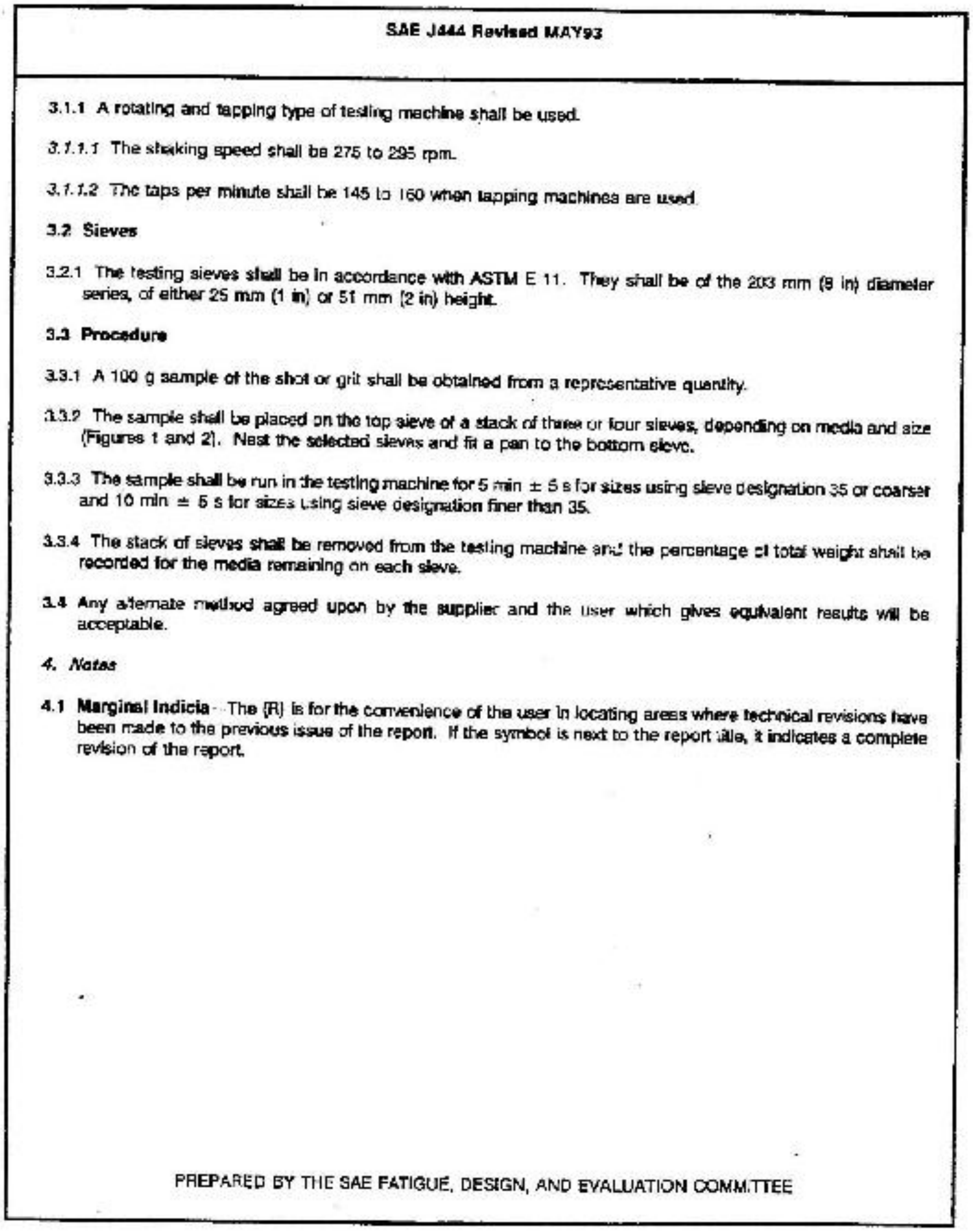
90-12028 EG



3.1.1 A rotating and tapping type of testing machine shall be used.

3.1.1.1 The shaking speed shall be 275 to 295 rpm.

3.1.1.2 The taps per minute shall be 145 to 160 when tapping machines are used.

3.2 Sieves

3.2.1 The testing sieves shall be in accordance with ASTM E 11. They shall be of the 203 mm (8 in) diameter series, of either 25 mm (1 in) or 51 mm (2 in) height.

3.3 Procedure

3.3.1 A 100 g sample of the shot or grit shall be obtained from a representative quantity.

3.3.2 The sample shall be placed on the top sieve of a stack of three or four sieves, depending on media and size (Figures 1 and 2). Nest the selected sieves and fit a pan to the bottom sieve.

3.3.3 The sample shall be run in the testing machine for 5 min ± 5 s for sizes using sieve designation 35 or coarser and 10 min ± 5 s for sizes using sieve designation finer than 35.

3.3.4 The stack of sieves shall be removed from the testing machine and the percentage of total weight shall be recorded for the media remaining on each sieve.

3.4 Any alternate method agreed upon by the supplier and the user which gives equivalent results will be acceptable.

4. Notes

4.1 **Marginal Indicia**—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE FATIGUE, DESIGN, AND EVALUATION COMMITTEE

FIGURE 1—CAST SHOT SPECIFICATIONS FOR SHOT PEENING OR BLAST CLEANING

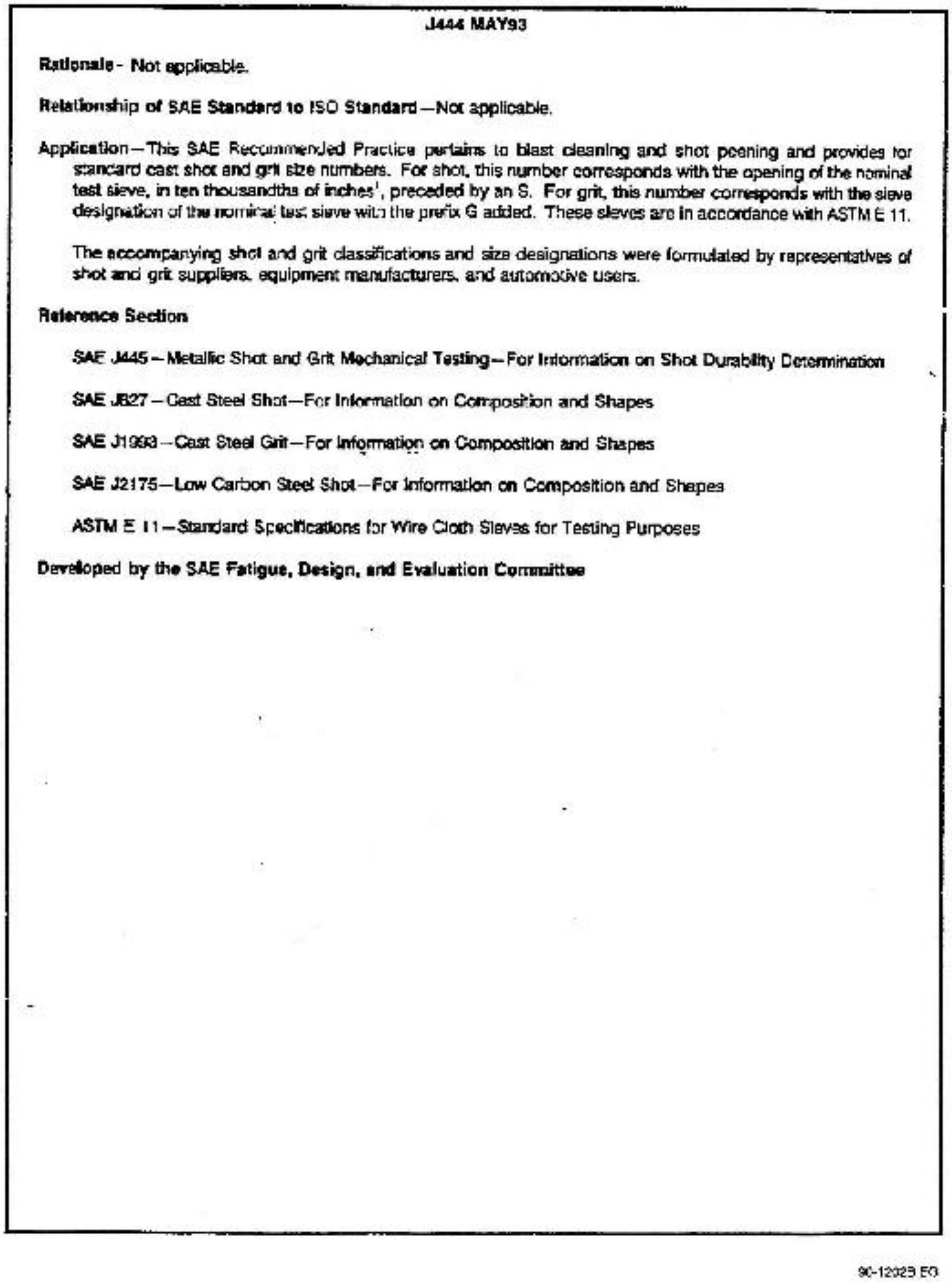
Sieve Opening Standard	Sieve Designation	Nominal Sieve Opening	Test Sieve Opening Size and Designation With Maximum and Minimum Cumulative Percentages Allowed on Corresponding Test Sieves SAE Shot Number													
(mm)[1]		(in)	S1320	S1110	S930	S780	S660	S550	S460	S390	S330	S280	S230	S170	S110	S70
4.75	4	(0.187)	All Pass	—	—	—	—	—	—	—	—	—	—	—	—	—
4.00	5	(0.157)	—	All Pass	—		—	—	—	—	—	—	—	—	—	—
3.35	6	(0.132)	90% min	—	All Pass	—	—	—	—	—	—	—		—	—	—
2.80	7	(0.111)	97% min	90% min	—	All Pass	—	—	—	—	—	—		—	—	—
2.36	8	(0.0937)	—	97% min	90% min	—	All Pass	—	—	—	—	—	—	—	—	—
2.00	10	(0.0787)	—	—	97% min	85% min	—	All Pass	All Pass	—	—	—	—	—	—	
1.70	12	(0.0661)	—	—	—	97% min	85% min	—	5% max	All Pass	—	—	—	—	—	—
1.40	14	(0.0555)	—	—	—	—	97% min	85% min	—	5% max	All Pass	—	—	—	—	—
1.18	16	(0.0469)	—	—	—	—	—	97% min	85% min	—	5% max	All Pass	—	—	—	—
1.00	18	(0.0394)	—	—	—	—	—	—	96% min	85% min	—	5% max	All Pass	—	—	—
0.850	20	(0.0331)	—	—	—	—	—	—	—	96% min	85% min	—	10% max	All Pass	—	—
0.710	25	(0.0278)	—	—	—	—	—	—	—	—	96% min	85% min	—	10% max	—	—
0.600	30	(0.0234)	—	—	—	—	—	—	—	—	—	96% min	85% min	—	All Pass	—
0.500	35	(0.0197)	—	—	—	—	—	—	—	—	—	—	97% min	—	10% max	—
0.425	40	(0.0165)	—	—	—		—	—	—	—	—	—	—	85% min	—	All Pass
0.355	45	(0.0139)	—	—	—	—	—	—	—	—	—	—	—	97% min	—	10% max
0.300	50	(0.0117)	—	—	—	—	—	—	—	—	—	—	—	—	80% min	—
0.180	80	(0.0070)	—	—	—	—	—	—	—	—	—	—	—	—	90% min	80% min
0.125	120	(0.0049)	—	—	—		—	—	—	—	—	—	—	—	—	90% min
0.075	200	(0.0029)	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] Corresponds to ISO Recommendations

FIGURE 2—CAST GRIT SPECIFICATIONS FOR BLAST CLEANING

Sieve Opening Standard	Sieve Designation	Nominal Sieve Opening	Test Sieve Opening Size and Designation With Maximum and Minimum Cumulative Percentages Allowed on Corresponding Test Sieves SAE Grit Number											
(mm[1])		(in)	G10	G12	G14	G16	G18	G25	G40	G50	G80	G120	G200	G325
4.75	4	(0.187)	—	—	—	—	—	—	—	—	—	—	—	—
4.00	5	(0.157)	—	—	—	—	—	—	—	—	—	—	—	—
3.35	6	(0.132)	—	—	—	—	—	—	—	—	—	—	—	—
2.80	7	(0.111)	All Pass	—	—	—	—	—	—	—	—	—	—	—
2.36	8	(0.0937)	—	All Pass	—	—	—	—	—	—	—	—	—	—
2.00	10	(0.0787)	80%	—	All Pass	—	—	—	—	—	—	—	—	—
1.70	12	(0.0661)	90%	80%	—	All Pass	—	—	—	—	—	—	—	—
1.40	14	(0.0555)	—	90%	80%	—	All Pass	—	—	—	—	—	—	—
1.18	16	(0.0469)	—	—	90%	75%	—	All Pass	—	—	—	—	—	—
1.00	18	(0.0394)	—	—	—	85%	75%	—	All Pass	—	—	—	—	—
0.850	20	(0.0331)	—	—	—	—	—	—	—	—	—	—	—	—
0.710	25	(0.0278)	—	—	—	—	85%	70%	—	All Pass	—	—	—	—
0.600	30	(0.0234)	—	—	—	—	—	—	—	—	—	—	—	—
0.500	35	(0.0197)	—	—	—	—	—	—	—	—	—	—	—	—
0.425	40	(0.0165)	—	—	—	—	—	80%	70%	—	All Pass	—	—	—
0.355	45	(0.0138)	—	—	—	—	—	—	—	—	—	—	—	—
0.300	50	(0.0117)	—	—	—	—	—	—	80%	65%	—	All Pass	—	—
0.180	80	(0.0070)	—	—	—	—	—	—	—	75%	65%	—	All Pass	—
0.125	120	(0.0049)	—	—	—	—	—	—	—	—	75%	60%	—	All Pass
0.075	200	(0.0029)	—	—	—	—	—	—	—	—	—	70%	55%	—
0.045	325	(0.0017)	—	—	—	—	—	—	—	—	—	—	65%	20%

[1] Corresponds to ISO Recommendations



Rationale - Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Recommended Practice pertains to blast cleaning and shot peening and provides for standard cast shot and grit size numbers. For shot, this number corresponds with the opening of the nominal test sieve, in ten thousandths of inches[1], preceded by an S. For grit, this number corresponds with the sieve designation of the nominal test sieve with the prefix G added. These sieves are in accordance with ASTM E 11.

The accompanying shot and grit classifications and size designations were formulated by representatives of shot and grit suppliers, equipment manufacturers, and automotive users.

Reference Section

SAE J445—Metallic Shot and Grit Mechanical Testing—For Information on Shot Durability Determination

SAE J827—Cast Steel Shot—For Information on Composition and Shapes

SAE J1993—Cast Steel Grit—For Information on Composition and Shapes

SAE J2175—Low Carbon Steel Shot—For Information on Composition and Shapes

ASTM E 11—Standard Specifications for Wire Cloth Sieves for Testing Purposes

Developed by the SAE Fatigue, Design, and Evaluation Committee

SSPC-SP COM
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SSPC: The Society for Protective Coatings

SURFACE PREPARATION COMMENTARY
for Metal Substrates

1. Introduction

This Surface Preparation Commentary (SP COM) is intended to be an aid for the coating specifier in selecting methods, materials, and standards for specifying the proper surface preparation for steel, and other metals (not including ductile iron pipe). The use of these standards in a coating specification will give direction to the contractor regarding what is required and give direction to the inspector on verifying compliance to the specification.

The SSPC standards, summarized in Table 1A, represent a broad consensus of users, suppliers, and public interest groups. Details of the methods used to verify many of the properties discussed in this SP COM are described in SSPC publication 03-14, "The Inspection of Coatings and Linings, A Handbook of Basic Practice for Inspectors, Owners, and Specifiers, 2nd Ed."

Table 1B includes similar standards published by the International Organization for Standardization (ISO)[1]. It should be noted that that while the ISO and SSPC standards are similar and commonly deemed equivalent, they are not identical. Tables 3A, 3B, and 3C provide a comparison of the ISO and SSPC standards.

2. Contents

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[1] International Organization for Standardization (ISO), Case Postale 56, Geneva CH-1211, Switzerland. In the United States, ISO standards may be obtained from the American National Standards Institute (ANSI) at <http://www.ansi.org>.

8. Summary of SSPC Abrasive Standards

- 8.1 SSPC-AB 1, "Mineral and Slag Abrasives"
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- 8.3 SSPC-AB 3, "Ferrous Metallic Abrasive"
- 8.4 SSPC-AB 4, "Recyclable Encapsulated Abrasives"

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- 12.1 SSPC-VIS 1, "Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning"
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- 12.3 SSPC-VIS 3, "Guide and Reference Photographs for Steel Surfaces Prepared by Hand and Power Tool Cleaning"
- 12.4 SSPC-VIS 4/NACE VIS 7, "Guide and Reference Photographs for Steel Surfaces Prepared by Waterjetting"
- 12.5 SSPC-VIS 5/NACE VIS 9, "Guide and Reference Photographs for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning"
- 12.6 ISO Pictorial Standards
- 12.7 Other Photographic Standards

13. Other SSPC and Joint SSPC/NACE Surface Preparation Guides and Reports

- 13.1 SSPC-TR 1/NACE 6G194, "Joint Technology Report on Thermal Precleaning"
- 13.2 SSPC-TR 2/NACE 6G198, "Joint Technical Report on Wet Abrasive Blast Cleaning"
- 13.3 SSPC-Guide 15, "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates"
- 13.4 SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures"

14. Non-SSPC Cleaning Standards

15. Surface Preparation of Other Metallic Surfaces

- 15.1 SSPC-SP 16, "Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals"
- 15.2 Aluminum
- 15.3 Stainless Steel
- 15.4 Copper Alloys

3. Importance of Surface Preparation

Often, the surface preparation of steel for coating requires a three-step process: 1) initial pre-cleaning to remove deposits of grease, oil, dirt, and other surface contaminants; 2) cleaning with hand/power tools, pressurized water, chemicals, or abrasive blasting; 3) creation or verification of the specified anchor pattern profile. The life of a coating depends as much on the degree and quality of surface preparation as on the selected coating system, because most coating failures can be attributed to inadequate surface preparation or lack of coating adhesion. Surface preparation, therefore, should receive thorough consideration. The primary functions of surface preparation are:

- to remove surface contaminants that can induce premature coating failure
- to provide a clean surface with adequate profile for good coating adhesion

Where conventional abrasive blast cleaning is not allowed or is impractical, alternative abrasives or methods of cleaning the surface must be employed. Chemical stripping will remove coating and is relatively easy to contain. Hence, chemical stripping may be used around sensitive machinery or in densely populated areas. (Refer to SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures."); Alternative abrasives such as sodium bicarbonate (baking soda) or dry ice (CO_2) can sometimes be used in places where conventional abrasives cannot be used. A class of abrasives has been developed that surrounds each abrasive particle with an open-cell sponge matrix. The sponge contains the abrasive and facilitates cleanup and recycling.

When control of dust emissions is critical, wet blast cleaning methods are often employed. Wet blast cleaning methods may involve water alone, abrasive injected into the water stream, water injected into an abrasive air stream, or a water curtain surrounding an air/abrasive stream. Power tools with vacuum shrouds have also been proven effective in controlling dust emissions, particularly in removing lead containing coatings. It is important to note that surface preparation methods used to control dust may not necessarily eliminate any hazards associated with disturbance of hazardous materials such as lead. In applications where the presence of soluble salts on the steel surface creates a serious problem, such as tank linings, it could be beneficial to incorporate water into the cleaning process.

The use of water alone (without abrasive media) at various pressures is a technique for surface preparation that will remove coatings and contaminants without altering the existing surface profile.

TABLE 1A

SUMMARY OF CURRENT SSPC ABRASIVE AND SURFACE PREPARATION STANDARDS

SSPC STANDARD	DESCRIPTION
SSPC-AB 1 Mineral and Slag Abrasives	Definition of requirements for selecting and evaluating mineral and slag abrasives used for blast cleaning
SSPC-AB 2 Cleanliness of Recycled Ferrous Metallic Abrasive	Cleanliness requirements for a recycled work mix and a description of the test procedures.
SSPC-AB 3 Ferrous Metallic Abrasives	Requirements for chemical and physical properties of iron and steel abrasives.
SSPC-AB 4 Recyclable Encapsulated Abrasive Media	Requirements for physical properties and cleanliness of abrasive media encapsulated in a compressible non-uniform cellular matrix
SSPC-PA 17 Conformance to Profile/Surface Roughness/Peak Count Requirements	A procedure suitable for shop or field use for determining compliance with specified profile ranges on a steel substrate
SSPC-SP 1 Solvent Cleaning	Removal of oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam
SSPC-SP 2 Hand Tool Cleaning	Removal of loose rust, loose mill scale, and loose paint to degree specified, by hand chipping, scraping, sanding, and wire brushing
SSPC-SP 3 Power Tool Cleaning	Removal of loose rust, loose mill scale, and loose paint to degree specified, by power tool chipping, descaling, sanding, wire brushing or wire impact tools, and grinding
SSPC-SP 5/NACE No. 1 White Metal Blast Cleaning	Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning by wheel or nozzle (dry or wet) using sand, grit or shot.
SSPC-SP 5 (WAB)/ NACE WAB-1* White Metal Wet Abrasive Blast Cleaning	Same level of cleanliness as SSPC-SP 5/NACE No. 1, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.
SSPC-SP 6/NACE No. 3 Commercial Blast Cleaning	Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning. Staining is permitted on no more than 33% of each 9 in² area
SSPC-SP 6 (WAB)/ NACE WAB-3 Commercial Wet Abrasive Blast Cleaning	Same level of cleanliness as SSPC-SP 6/NACE No. 3, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.
SSPC-SP 7/NACE No. 4 Brush-Off Blast Cleaning	Blast cleaning of all except tightly adhering residues of mill scale, rust, and coatings, while uniformly roughening the surface.
SSPC-SP 7 (WAB)/ NACE WAB-4 Industrial Wet Abrasive Blast Cleaning	Same level of cleanliness as SSPC-SP 7/NACE No. 4, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.
SSPC-SP 8 Pickling	Complete removal of rust and mill scale by acid pickling, duplex pickling, or electrolytic pickling.
SSPC-SP 10/NACE No. 2 Near-White Blast Cleaning	Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning. Staining is permitted on no more than 5% of each 9 in² area of the cleaned surface.
SSPC-SP 10 (WAB)/NACE WAB-2 Near White Metal Wet Abrasive Blast Cleaning	Same level of cleanliness as SSPC-SP 10/NACE No. 2, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.
SSPC-SP 11 Power Tool Cleaning to Bare Metal	Complete removal of all rust, scale, and paint by power tools, with resultant minimum surface profile of 25 µm (1 mil).
SSPC-SP 14/NACE No. 8 Industrial Blast Cleaning	Between SP 7 (brush off) and SP 6 (commercial). The intent is to remove as much coating as possible, but tightly adherent rust, mill scale, and coating can remain on 10 percent of each 9 in² area of the cleaned surface
SSPC-SP 14 (WAB)/NACE WAB-8 Industrial Wet Abrasive Blast Cleaning	Same level of cleanliness as SSPC-SP 14/NACE No. 8, but achieved by wet abrasive blast cleaning. Level of flash rust permissible immediately prior to coating application must be specified.
SSPC-SP 15 Commercial Grade Power Tool Cleaning	Between SP 3 and SP 11. Removes all rust and paint but allows for random staining on up to 33% of each 9 in² area of surface; requires a minimum 25 µm (1 mil) profile.
SSPC-SP 16 Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals	Requirements for removing loose contaminants and coating from coated and uncoated galvanized steel, stainless steels, and non-ferrous metals. Requires a minimum 19 µm (0.75 mil) profile on bare metal substrate

SSPC-SP WJ-1/NACE WJ-1 Waterjet Cleaning of Metals–Clean to Bare Substrate	Cleanest waterjetting level, requires the cleaned metal to be free of all visible oil, grease, dirt, rust and other corrosion products, previous coatings, mill scale, and foreign matter.
SSPC-SP WJ-2/NACE WJ-2 Waterjet Cleaning of Metals–Very Thorough Cleaning	Requires the cleaned metal surface to be free of all visible oil, grease, dirt, rust, and other corrosion products except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter over no more than 5% of each 9 in² area of the cleaned surface.
SSPC-SP WJ-3/NACE WJ-3 Waterjet Cleaning of Metals–Through Cleaning	Requires removal of all visible contaminants as in WJ-2 above. Randomly dispersed staining as described in WJ-2 is limited to no more than 33% of each 9 in² area of the cleaned surface.
SSPC-SP WJ-4/NACE WJ-4 Waterjet Cleaning of Metals–Light Cleaning	Requires removal of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating. Any residual material shall be tightly adhered to the metal substrate.

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TABLE 1B

SUMMARY OF INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) SURFACE PREPARATION STANDARDS

ISO Standard 8501-1	**Description**
Sa 1 Light blast cleaning	Free of oil, grease and dirt and poorly adhering mill scale, rust, paint and foreign matter
Sa 2 Thorough blast cleaning	Free of oil, grease and dirt and most of the mill scale, rust paint and foreign has been removed
Sa 2 ½ Very thorough blast cleaning	Free of oil, grease and dirt and from mill scale, rust and paint. Remaining traces of contamination will only be slight stains
Sa 3 Blast cleaning to visually clean steel	Free of oil, grease, dirt, mill scale, rust, paint and foreign matter. Surface shall have a uniform metallic colour
St 2 Thorough hand and power tool cleaning	Free of oil, grease and dirt and poorly adhering mill scale, rust, paint and foreign matter
St 3 Very thorough hand and power tool cleaning	Same as St 2, but the surface shall be treated much more thoroughly to give a metallic sheen arising from the metallic substrate
ISO Standard 8501-2 Localized Removal of Previous Coatings	**Description**
P Sa 2 Thorough localized blast cleaning	Firmly adhering coatings are intact. Where coatings are removed, surface is free of visible contaminants, loose coating and most mill scale, rust and foreign matter.
P Sa 2 ½ Very thorough localized blast cleaning	Firmly adhering coatings are intact. Exposed substrate is free from visible contaminants and loose coating. Remaining traces of contaminants are visible as slight stains in form of spots or stripes.
P Sa 3 Localized blast cleaning to visually clean steel	Exposed substrate is free of visible contaminants and mill scale, rust, and foreign matter. Surface shall have a uniform metallic color.
P St 2 Thorough localized hand- and power-tool cleaning of previously coated surfaces	Firmly adhering coatings are intact. Exposed substrate is free of loose coating, loose mill scale, loose visible foreign matter
P St 3 Very Thorough localized hand-and power-tool cleaning of previously coated surfaces	Exposed substrate is free of coating, mill scale, foreign matter, and has a uniform metallic sheen
P Ma Localized machine cleaning	Firmly adhering coatings are intact. Exposed substrate is free of visible oil and grease, loose visible loose contaminants, loose coating, mill scale, and rust. Remaining traces of contaminants are visible as slight stains in form of spots or stripes.
ISO Standards 8501-4 Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting	**Description**
Wa 1 Light High Pressure Water Jetting	When viewed without magnification, the surface shall be free from visible oil, grease, loose rust, and foreign matter. Any residual contamination shall be randomly dispersed and firmly adherent.
Wa 2 Thorough High Pressure Water Jetting	When viewed without magnification, the surface shall be free from visible oil, grease and dirt and most of the rust, previous paint, coatings, and foreign matter. Any residual contamination shall be randomly dispersed and can consist of firmly adherent coatings, firmly adherent foreign matter, and stains of previously existent rust.
Wa 2 ½ Very Thorough High Pressure Water Jetting	When viewed without magnification, the surface shall be free from all visible rust, oil, grease, dirt, previous paint coatings and, except for slight traces, all foreign matter. Discoloration of the surface may be present where the original coating was not intact. The grey, brown/black discoloration observed on pitted and corroded steel cannot be removed by further water jetting. Note that this standard does not imply that the cleanliness is limited to Wa 2 ½ but achieving a greater degree of cleanliness may involve disproportionate increase in time.

To gain maximum benefit from a high-performance industrial coating, it is not prudent to cut back on the surface preparation. Surface preparation is important even when a "surface-tolerant" coating is used. When the manufacturer claims a particular coating will "tolerate" a given amount of rust, old coating, or other contamination on the steel surface, it is likely that the coating will perform even better if the surface is prepared to a higher level of cleanliness.

4. Surface Conditions

The initial condition of the surface to be cleaned will determine the amount of work, time, and money required to achieve any particular degree of surface cleanliness. It is more difficult to remove contaminants from rusty steel than from intact mill scale. Therefore, it is necessary to consider the surface condition prior to selecting the method of cleaning.

The initial condition of the steel may determine the choice of abrasive to be used. Steel shot is an economical and effective choice for removing intact mill scale. However, if the steel is rusted and/or pitted, a more angular abrasive such as steel grit or a non-metallic mineral abrasive will more effectively "scour out" the rust.

Although there are almost an infinite number of initial conditions, they can be broadly divided into three categories:

- new construction—steel not previously coated
- maintenance—previously coated steel
- contaminated surfaces—common to both new construction and maintenance.

4.1 NEW CONSTRUCTION: For new construction there are four surface conditions based upon the rust condition classifications. These initial conditions, defined in SSPC visual consensus guides, namely, SSPC-VIS 1, SSPC-VIS 3, and SSPC-VIS 4, are:

- **Condition A:** Steel surface covered completely with adherent mill scale; little or no rust visible
- **Condition B:** Steel surface covered with both mill scale and rust
- **Condition C:** Steel surface completely covered with rust; little or no pitting visible
- **Condition D:** Steel surface completely covered with rust; pitting visible

Conditions A, B, C, and D are also referred to as Rust Grades A, B, C, and D.

4.2 MAINTENANCE: The SSPC documents containing the consensus reference photographs also define conditions E, F, G, and H for previously coated surfaces.

- **Condition E:** Paint applied over a blast-cleaned surface, paint mostly intact.
- **Condition F:** Zinc-rich paint applied over blast-cleaned steel, paint mostly intact.
- **Condition G:** Painting system applied over mill scale bearing steel; system thoroughly weathered, thoroughly blistered, or thoroughly stained.
- **Condition H:** Degraded painting system applied over steel; system thoroughly weathered, thoroughly blistered, or thoroughly stained.

In maintenance repainting, the degree of surface preparation required depends on the new coating system and on the extent of degradation of the surface to be coated. The amount of rusting on a surface is based on the numerical scale of 0 to 10 given in SSPC VIS 2 (ASTM D610),[21] "Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces," where a rating of 10 indicates no rust and a rating of 0 indicates more than 50% rusting. SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems," suggests the minimum surface preparation needed for each degree of rusting.

In estimating rust percentages, photographs and schematic diagrams of the type shown in SSPC-VIS 2 can serve as practical aids. The Guide to SSPC-VIS 2 shows black and white schematics of actual rust patterns that serve as guides for judging the percentage of surface covered by rust (after removal of stains) or rust blisters. SSPC-VIS 2 shows three different configurations of rusting – general, pinpoint, and spot rust.

Comments on surface preparation for maintenance repainting are also given in SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems." This guide includes a description of accepted practices for retaining old, sound coating, removing unsound coating, feathering, and spot cleaning.

4.3 SURFACE CONTAMINANTS: Typical contaminants that should be removed during surface preparation are rust, corrosion products, mill scale, grease, oil, dirt, dust, moisture, soluble salts containing anions, such as chlorides, sulfates (if present in detrimental quantities), paint chalk, and loose, cracked, or peeling coating.

4.3.1 Rust, Stratified Rust, Pack Rust, and Rust Scale: Rust consists primarily of iron oxides, the corrosion products of steel. Whether loose or relatively tightly adherent, rust must be removed for satisfactory coating performance. Rust is not a good base for applying coatings because it expands and becomes porous. So-called "over-rust primers" (also referred to as "rust converters") do not perform as well as conventional coatings applied over clean steel, and the effectiveness of rust converters is unproven.

Stratified rust, pack rust, or rust scale occur when the iron oxides form in a definite shape rather than in grains or powder. Pack rust typically forms between mating surfaces (e.g., in crevice areas), whereas rust scale and stratified rust form on the surface of the steel (e.g., on steel plates, webs and flanges). Stratified rust, pack rust, and rust scale can be dislodged from the surface in pieces or layers as large as several inches (centimeters) across. Some of this rust can adhere so tightly to the base metal that a power wire brush will not remove it. Even though it is considered "tightly adherent" because it cannot be lifted with a dull putty knife, it provides a very poor surface to paint over. Eventually the rust will loosen and dislodge from the surface leaving large areas unprotected.

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[21] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

Stratified rust, pack rust, and rust scale must be removed with impact tools such as chipping hammers, scabblers, needle guns, and rotary impact flap assemblies. High- and ultrahigh-pressure waterjetting also can be used to remove pack rust; then the crevices must be blown out by compressed air or dried to remove the water.

Ideally, these types of rust should be removed even when the lowest levels of hand and power tool cleaning, SSPC-SP 2 and SSPC-SP 3, are specified. However, a judgment must be made on each job as to whether the cost and effort required to remove the stratified rust, pack rust, and rust scale can be justified by the expected increase in the life of the coating system. Where these forms of rust are a problem, the contracting parties should come to an agreement on the extent of removal at the outset of the job.

4.3.2 Mill Scale: Mill scale is a bluish, somewhat shiny oxide residue that forms on steel surfaces during hot rolling. Although initially tightly adherent, it eventually cracks, pops, and disbonds. Unless completely removed before coating, mill scale will eventually cause the coatings to crack and expose the underlying steel. Steel is anodic to mill scale and so corrodes more rapidly in this combination of "dissimilar metals."

Mill scale varies in its effects upon the performance of coatings. Tightly adhered or intact mill scale may not need to be removed for mild atmospheric service. If, however, the steel surface will be coated with primers with low wetting properties or exposed to severe environments, such as chemical exposures or immersion in fresh or salt water, then removal of mill scale by blast cleaning or power tool cleaning is necessary. Note that the effort required to remove all tightly adherent mill scale usually results in a surface that has less staining than the maximum 33% permitted by SP 6 or SP 15, but may have more staining than the maximum 5% permitted by SP 10.

4.3.3 Grease and Oil: Even thin films of grease and oil, which may not be visible to the unaided eye and therefore are not required to be removed by SSPC-SP 1, can prevent tight bonding of high-performance coatings. Oil paints and a few specific epoxy coatings may be tolerant of thin oil films. Visible deposits of grease and oil must be removed by solvent cleaning, SSPC-SP 1, prior to mechanical cleaning (e.g., power tool or abrasive blast cleaning). If this precleaning is not done, power tool or abrasive blast cleaning may spread the grease or oil over the surface without removing it. Other methods of precleaning include hot water (typically under pressure) with emulsifier or grease cutting chemicals. High- and ultrahigh-pressure waterjetting may also be capable of removing grease and oil. Most air driven power tools require a daily lubrication by the addition of oil in the air stream. This oil can be transmitted to the surface being cleaned. Although not visible, the specifier may require its removal by solvent cleaning prior to the application of the coating system. ASTM F22, "Standard Test Method for Hydrophobic Surface Films by the Water Break Test," can be used to determine the presence of non-visible oil on the surface. Ultraviolet ("black") light can also be used to detect films of hydrocarbons on the surface. Appropriate eye protection should be worn when using ultraviolet light to inspect surfaces.

4.3.4 Dirt and Dust: Dirt and dust can also prevent tight bonding of coatings, and should be removed completely. ISO 8502-3, "Preparation of steel substrates before application of paints and related products–Tests for the assessment of surface cleanliness–Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)" provides a method of determining the amount of dust on a surface prior to coating.

4.3.5 Moisture: Steel surfaces must be dry before cleaning and coating. Moisture may either produce new rust before coating is applied or accelerate underfilm corrosion after coating is applied. Water can also prevent an organic coating from properly "wetting out" (penetrating into the surface profile) on metal surfaces, and may disrupt the curing of the coating. Specialty coatings designed for application over damp or submerged surfaces or even underwater, are exceptions to this common rule.

4.3.6 Soluble Salts: Steel surfaces are exposed to water-soluble salt deposition from many sources, including contact with contaminated water or cargo, or exposure in industrial or marine environments. If the salts remain on the surface after cleaning, they can attract moisture that can permeate the coating and may result in formation of blisters (osmotic blistering) as the water vapor finds its way to the salt crystals. Salts, particularly chlorides, may also accelerate the corrosion reaction and the formation of underfilm corrosion. Methods for measuring the amount of salt on the surface are described in SSPC-Guide 15, "Field Methods for Retrieval and Analysis of Soluble Salts on Steel and Other Nonporous Substrates." In some circumstances it is desirable to remove soluble salts by power washing or other methods prior to power tool or abrasive blast cleaning. In other circumstances, salt removal is more efficient after initial power tool or abrasive blast cleaning has been performed.

No industry standards currently exist for the maximum level of salts permitted on a steel surface prior to coating application. The results of tests to determine salt levels are affected by the condition of the substrate, the service environment for the coating, and the specific test method and test location selected. Individual coatings have different tolerance levels for various contaminants. The specifier should consult with a protective coating specialist and the manufacturer of the coating to be applied.

4.3.7 Paint Chalk: The sun's ultraviolet light causes all organic coatings in exterior exposures to chalk to some extent. Chalk is the residue left after deterioration of the coating's surface organic binder. All loose chalk must be removed prior to recoating in order to avoid intercoat adhesion problems. It is often specified that, before topcoating, old coating must have a rating of no less than 8 in accordance with ASTM D4214, "Test Method for Evaluating Degree of Chalking of Exterior Paint Films."

4.3.8 Deteriorated Coating: All loose coating that can be removed with a dull putty knife or coating that fails to meet pre-established adhesion values must be removed before performing maintenance coating. Prior to removal, the coating should be tested for the presence of lead or other toxic materials. If toxic materials are found, special precautions must be taken to protect workers, others in the area, and the environment.

4.4 SURFACE DEFECTS: Coatings tend to draw thin and pull away from sharp edges and projections, leaving little or no coating to protect the underlying steel, thereby increasing the potential for premature coating failure. This results in poor coating film quality. Other features of steel that are difficult to properly cover and protect include crevices, weld porosity, laminations, etc. These considerations are discussed below. The high cost to remedy these surface imperfections requires weighing the benefits of remedial methods, such as edge rounding or grinding, versus a potential coating failure.

Poorly adhering contaminants, such as weld slag residues, loose weld spatter, and some minor surface laminations, may be removed by abrasive blast cleaning. Other surface defects, such as steel laminations, weld porosities, or deep corrosion pits, may not be evident until after abrasive blast cleaning is completed. Therefore, the timing of such surface repair work may occur before, during, or after preliminary surface preparation operations have begun.

4.4.1 **Welds and Weld Spatter:** Weld spatter should be removed prior to blast cleaning. Most weld spatter, except that which is very tightly adherent, can be readily removed using a chipping hammer, spud bar, or scraper. Tightly adhering weld spatter may require removal by grinding. Weld spatter that is not removed will result in a lower coating film thickness (as on sharp edges) and may disbond from the base metal, resulting in adhesion failure. Welds can also have sharp projections that may penetrate through the wet coating film. NACE SP0178, "Standard Recommended Practice, Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to Be Lined for Immersion Service," provides details on grinding welds.

4.4.2 Weld Porosity: Although it may be outside the scope of surface preparation for coating application, areas of porosity might warrant further investigation. Unacceptable porosity is defined in the American Welding Society standard AWS D1.1, "Structural Welding Code." Acceptable weld profiles, arc strikes, and weld cleaning are also addressed in Section 3 of AWS D1.1.

4.4.3 Sharp Edges: Sharp edges, such as those normally occurring on rolled structural members or plates, as well as those resulting from flame cutting, welding, grinding, etc., and especially shearing, have an influence on coating performance and may need to be removed (e.g., grinding, mechanical sanding, filing). During removal operations, care should be taken use proper grinding techniques to prevent the formation of new sharp edges. SSPC PA Guide 11, "Guide to Methods for Protection of Edges, Crevices, and Irregular Steel Surfaces," provides additional information to assist specifiers in determining how to treat edges. Some high solids coatings often requiring plural component spray, have edge-retentive properties that may lessen the effect of sharp edges.

4.4.4 Crevices: Areas of poor design for corrosion protection, such as tack or spot welded connections, back-to-back angles, crevices, etc., may require special attention. When possible, such deficiencies should be corrected by structural or design modification. When this is not possible, filling or special surface preparation and coating procedures may be needed.

4.4.5 Laminations, Slivers: Rolling discontinuities (laps) may have sharp protruding edges and deep penetrating crevices. It is beneficial to remove such defects prior to coating. Various methods can be used to eliminate minor slivers (e.g. scraping and grinding), and filling may be necessary. Filling of indentations may also be necessary.

4.4.6 Pits: Deep corrosion pits, gouges, clamp marks, or other surface discontinuities may require grinding prior to coating. The surface may also require filling with weld material.

4.5 POST-CLEANING SURFACE CONDITIONS (RUST BLOOM, RUST-BACK, FLASH RUST)

It is important that the surface conditions do not change between the time of inspection for the specified visual cleanliness preparation level and the time immediately prior to coating application.

Section 4.3.1 describes forms of rust that are pre-existing on steel. Rust Bloom, Rust-Back, and Flash Rust are forms of rust that might develop between the time that the inspection is completed after surface preparation is accomplished and the time that coating is applied. Rust-back is general atmospheric rust contaminated with chemicals from the environment in which the metal has been exposed. In contrast, flash rust formed while preparing surfaces by waterjetting using potable water, consists of pure iron oxide, which is actually a component of some coatings. The coatings industry treats Rust-Back and Flash Rust differently. Coatings are not normally applied over rust back. Under some circumstances, however, coatings MAY be applied over light levels of flash rust if recommended by the coating manufacturer and allowed by the contract specification.

4.5.1 Rust Bloom: Rust Bloom is defined by NACE/ASTM G193-12D, "Standard Terminology and Acronyms Relating to Corrosion,"[14] as discoloration indicating the beginning of rusting. This is new rust. Rust bloom is usually visible as somewhat uniform rust spread evenly over a large section of the surface. This condition can occur on both wet or dry blast cleaned steel and can take days to develop. Both flash rust and rust-back could look like rust bloom. In a case where carbon steel is cleaned by wet methods and then left for longer periods

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[14] NACE/ASTM G193-12D, "Standard Terminology and Acronyms Relating to Corrosion," NACE International, 1565 Park Ten Place, Houston, TX 77084, phone 1-281-228-6200.

of time before coating is applied, the new rust bloom could consist of a mixture of flash rust and rust back. In this case, the party doing the work (coating contractor) should consult with the owner to inquire whether this rust bloom should be coated, or remediated before coating is applied.

4.5.2 Rust-Back (dry blast methods or atmospheric rusting): Rust-back (re-rusting) is rusting that occurs when freshly cleaned steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere. It is the term used when steel cleaned by dry abrasive blast cleaning or power tool cleaning, for example, begins to rust after the steel surface has completely dried, and there is no visible moisture or condensation on the substrate. Rust-back is different from Flash Rust. New rust that is very localized and dark, almost black, is caused by microscopic salt crystals on the surface or in the crevices, pits, and craters. Very dark, localized, splotchy rust spots that appear to be isolated in localized areas usually indicate that spots of non-visible salt contaminants are left in pits, under metal lips, or in crevices. These non-visible salt contaminants, depending on their levels, may be found to be detrimental to coating performance.

The time interval between blast cleaning and rust-back will vary greatly (from minutes to weeks) from one environment to another. Residual chemical contamination on the surface can cause the steel to rust-back quickly. Because of this factor, timeliness of inspection is of great importance. Inspection must be coordinated with the contractor's schedule of operation to avoid delays in production. Acceptance of the prepared surface must be made prior to application of the prime coat, because the degree of surface preparation cannot be readily verified after coating. Coating immediately after blast cleaning before the rust-back occurs will trap any remaining contamination between the coating and the substrate. Even though the steel "looked" clean when it was coated, it is better to first remove the contamination that caused the rapid rust-back to acceptable levels before coating.

Rust-back is addressed in the SSPC surface preparation standards in the non-mandatory notes. Re-rusting of dry abrasive blasted steel, as there is little moisture present in the preparation process, can be a sign that non-visual salt contaminants have been left on the steel, which is generally not acceptable to the coatings manufacturers.

Under normal mild atmospheric conditions it is best to coat a blast-cleaned surface within 24 hours after blast cleaning. Under no circumstances should the steel be permitted to rust-back before coating, regardless of the time elapsed. If visible rust develops prior to coating, surfaces must be re-cleaned to meet contract cleaning requirements (e.g., SSPC-SP 10). It is incumbent upon the contractor to verify (using recognized quality control tests) and to document the quality of the cleaned surface before proceeding with application of the primer.

Moisture condenses on any surface that is colder than the dew point of the surrounding air. It is therefore recommended that final dry blast cleaning should not be conducted when the steel surface is less than 3 C° (5 F°) above the dew point. Sometimes, dehumidification is used to control the humidity during surface preparation to prevent formation of rust bloom, rust-back or flash rust. This is commonly referred to as "holding the blast." SSPC-TR 3/NACE 6A192, "Dehumidification and Temperature Control During Surface Preparation, Application and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces," contains additional information on the use of dehumidification.

After blast cleaning, even when dehumidification is used to "hold the blast," unacceptable levels of invisible soluble salt contamination may exist on the blast-cleaned steel, especially if such contaminants were not removed to acceptable levels before blasting. Physical evidence of such contamination can be masked by the dehumidification process because visual evidence of the soluble salts doesn't manifest itself due to the low humidity. Testing for such contamination may be prudent after blast cleaning even though the steel surface is visibly clean. Excessive weathering or exposure of bare steel to water soluble contaminants such as chlorides and sulfates prior to blast cleaning should be avoided since pitting of the steel may increase cleaning costs and makes removal of contaminants difficult. After blast cleaning, even slight residues of water-soluble contaminants such as chlorides, sulfates, or other electrolytes on the steel surface may adversely affect coating performance if left on surface above acceptable levels and, for some coatings, result in premature coating failure.

Residual chemical contamination on the surface can cause the steel to rust back quickly. Coating immediately after blast cleaning before the rust-back occurs will trap the contamination between the coating and the substrate. Even though the steel "looked" clean when it was coated, it is better to first remove the contamination that caused the rapid rust-back before coating.

4.5.3 Flash Rust (Wet Methods): Flash rust is an oxidation product that forms as a wetted carbon steel substrate dries. This is different from rust back. Flash rust may appear as rust spots on the surface of newly cleaned steel during the drying phase. Flash rust is an additional consideration when a carbon steel substrate is subjected to waterjet or wet abrasive blast cleaning. Gray or brown black discoloration remaining in the pits of waterjet cleaned carbon steel is not the same as flash rust. The four SSPC/NACE Joint Standards for Water Cleaning of Metals (WJ-1, WJ-2, WJ-3 and WJ-4) contain descriptions of three levels of flash rusting: Light, Moderate, and Heavy, as well as sample specification language that an owner could use to specify the maximum level of flash rust permitted on a steel substrate immediately prior to coating application. These same levels are also described in the five SSPC/NACE joint standards for wet abrasive blast cleaning (see discussion in Section 9.3).

Steel that is cleaned with water can rust rapidly. The rate of re-rusting will depend on the purity of the water, the amount of oxygen dissolved in the water, the amount and type of ions (chloride, sulfate, etc.) left on the surface, the temperature, and the drying time. The major factor is the length of time for drying. The amount of flash rust can be significantly reduced by drying the cleaned surface with forced air, squeegeeing water from the surface, or using a vacuum shroud on the cleaning head that does not allow the water to remain on the surface. The use of low-conductivity water with the removal of most salts will reduce the amount of flash rust. Soluble salt removers and/or inhibitors are generally not added when doing high-pressure or ultra-high pressure waterjet cleaning. However, during the cleaning process, they can be added to a secondary pressure washer to reduce the potential of flash rusting if soluble salts are considered to be a problem (see Section 8.3).

The terms "flash rust" and "rust bloom" are often used interchangeably. However, not all rust bloom is flash rust. The distinguishing feature of flash rust is that it occurs within minutes of cleaning while the water is drying and will quickly change the initial appearance of the surface. It is not the rust itself, but the source of the re-rusting that is of concern, as inert iron oxides (rust) are used as pigments. A light, easily removed rust bloom is considered inert and a sign of general steel oxidation. Coating manufacturers have concerns about performance when their coatings are applied over loose dust or loose rust. The level of flash rust that can be tolerated in a given environment is normally contained in the coating manufacturer's product data sheets, but must be approved by the facility owner. Flash rusting is not addressed in the dry abrasive blast cleaning standards. Flash rusting by water is addressed in SSPC-VIS 4/ NACE VIS 7, "Guide and Consensus Reference Photographs for Steel Surfaces Prepared by Waterjetting." The consensus reference photographs depict steel with light, medium, or heavy flash rusting prior to re-coating. Depending on the particular coating and exposure environment, the coating manufacturer may allow flash rusting at one of these levels. The SSPC report, "Maintenance Coating of Weathering Steel," found that coatings can perform quite well over a blasted surface that has a uniform rust bloom.

The National Shipbuilding Research Panel has also prepared an illustrated set of photographs "Recommended Guidelines for Evaluating Flash Rust," which is available from SSPC. This guide contains a field method for evaluating the amount of flash rust removed from a surface by brushing a white cloth wrapped around a paintbrush across the surface. The amount and color of the rust on the cloth determines the level of flash rust.

5. Tools for Specifying Surface Preparation

5.1 WRITTEN STANDARDS: The SSPC surface preparation standards are numbered according to the chronological order in which they were issued, not according to the degree of of cleaning thoroughness each represents. For example, after SSPC-SP 5, "White Metal Blast Cleaning" and SSPC-SP 6, "Commercial Blast Cleaning" were issued, a need arose for a standard between these two. Hence, the standard for Near-White Blast Cleaning was developed, but the next available number was SSPC-SP 10. Similarly, despite the numbering, SSPC-SP 14, "Industrial Blast Cleaning," is a degree of cleaning between SSPC-SP 7 "Brush-Off Blast Cleaning" and SSPC-SP 6. Most recently, SSPC-SP 15, "Commercial Grade Power Tool Cleaning" falls between SSPC-SP 3, Power Tool Cleaning" and SSPC-SP 11, "Power Tool Cleaning to Bare Metal." Table 2 lists the SSPC surface preparation standards in order of thoroughness of cleaning.

5.2 REFERENCE PHOTOGRAPHS: SSPC has developed four sets of reference photographs through a consensus process to illustrate levels of cleanliness of coated and uncoated steel substrates prepared using different cleaning methods. It is recommended that reference photographs be used to supplement the cleaning criteria of the written standard. However, it is important to remember that in case of a dispute, the written requirements of the standard take precedence. Reference photographs give only an approximation of the final surface condition, because they are based on one

TABLE 2

RELATIVE RANKING OF SSPC SURFACE PREPARATION STANDARDS FOR STEEL BASED ON THOROUGHNESS OF CLEANING[1]

Most Thorough Cleaning	Dry Abrasive Blast[2]	Wet Abrasive Blast	Hand and Power Tool	Waterjetting
↑	SSPC-SP 5	SSPC-SP 5 (WAB)/ NACE WAB-1		SSPC-SP WJ-1/ NACE WJ-1
	SSPC-SP 10	SSPC-SP 10 (WAB)/ NACE WAB-2	SSPC-SP 11	SSPC-SP WJ-2/ NACE WJ-2
	SSPC-SP 6	SSPC-SP 6 (WAB)/ NACE WAB-3		SSPC-SP WJ-3/ NACE WJ-3
	SSPC-SP 14	SSPC-SP 14 (WAB)/ NACE WAB-8	SSPC-SP 15	
	SSPC-SP 7	SSPC-SP 7 (WAB)/ NACE WAB-4		SSPC-SP WJ-4/ NACE WJ-4
			SSPC-SP 3	
			SSPC-SP 2	

[1] This ranking is not meant to imply that different methods of cleaning at the same level are equivalent. For example, SP 10 is not the same as SP 11, nor are either of these the same as WJ-2. If SP 10 is desired, but abrasive blast cleaning is not possible, then the closest alternatives would be SP 11 or WJ-2.

[2] SSPC-SP 1, "Solvent Cleaning," to remove oil, visible oil and grease is a prerequisite to all abrasive blast and hand and power tool cleaning standards.

specific set of steel conditions and cleaning operations. These conditions will not be identical to the conditions faced on other projects; however, the reference photographs are a valuable aid in establishing the general appearance described by the surface preparation standards and are especially useful in depicting the relative differences between the various levels of cleanliness.

SSPC has consensus reference photographs for degrees of blast cleaning (SSPC-VIS 1); for the amount of rust on a coated surface (SSPC-VIS 2); for hand and power tool cleaning (SSPC-VIS 3); for waterjetting (SSPC-VIS 4); and for wet abrasive blast cleaning (SSPC-VIS 5). Some SSPC consensus reference photographs are jointly issued with NACE International (SSPC VIS 4 and VIS 5) or ASTM International (SSPC-VIS 2). Other associations, such as ISO, as well as individual companies, have reference photographs.

Tables 3A, 3B, and 3C provide the correlation between the SSPC, joint SSPC/NACE, and ISO reference photographs for power and hand-cleaned steel, blast cleaned steel, and waterjet cleaned steel.

5.3 JOB REFERENCE STANDARDS (JRS): Determining the degree of cleaning required to comply with some standards is often very difficult. Prepared steel will often appear different from the photographic standards due to metallurgy of the steel, variations in initial surface conditions, abrasives being used, profile required, angle and amount of light, etc. An alternative to the use of photographs as visual aids is to prepare a sample area (sometimes called a "Job Reference Standard" or "JRS") that shows the standard of cleanliness for a particular job. The sample area should be representative of the surface to be cleaned, and may be a separate specimen or a designated flat portion of the actual surface. After the contracting parties agree on the cleanliness desired, the surface is protected and retained for comparison through the duration of the project.

It is emphasized that this practice establishes a standard of cleanliness, but not a production rate. As long as the cleaned surface is as clean as the JRS, the actual production rate of cleaning is not in question. The JRS is of value in resolving differences of opinion as to whether or not the surface had been properly cleaned.

6. Summary of SSPC Surface Preparation Standards for Metals

6.1 SSPC-SP 1, "SOLVENT CLEANING:" This solvent cleaning standard includes simple organic solvent wiping, immersion in solvent, solvent spray, vapor degreasing, alkaline cleaning, emulsion cleaning, and steam cleaning. The 2015 revision of SSPC-SP 1 defines "solvent" as "any liquid or vapor, permitted by the owner of the item being cleaned and used in compliance with all health, safety and environmental regulations applicable at the job site, that will dissolve or emulsify visible deposits of contaminants on the surface." Examples of solvents include water, emulsion or alkaline cleaners, and hydrocarbons." In SP-1, the term "visible" means detectable with normal or corrected normal vision without the use of additional equipment.

Solvent cleaning is used primarily to remove visible oil, grease, dirt, soil, drawing compounds, and other similar organic compounds. Detergent/water cleaning is a very gentle method of solvent cleaning. Aqueous solutions of household detergents may be effective in the removal of light deposits of grease and oil. They seldom have adverse effects on substrates.

Alkaline cleaning compounds are available in a wide range of compositions. It is important that residues of alkaline compounds do not remain on the surface after cleaning. The cleaned surface may be tested with litmus paper or universal indicating paper to see that it is neutral or at least no more alkaline than the rinse water that is used.

Though not specifically mentioned in SP 1, pressure washing with emulsifier or detergents, high and ultra-high pressure waterjet cleaning are methods frequently used to remove oil and grease. These methods may also reduce levels of soluble salts on the surface.

Many solvents are hazardous and care must be taken when using them. Special safety precautions must be followed with regard to ventilation, smoking, static electricity, respirators, eye protection, and skin contact. Used solvents should always be recycled or disposed of according to applicable environmental regulations. Consult an industrial hygienist or certified safety professional before specifying a solvent.

The SSPC SP-1 standard requires visual verification of the removal of contaminants. Supplementary tests for verification of removal of contaminants, the areas subject to testing, and the acceptance criteria should be included in the project specification.

The SSPC surface preparation standards require the removal of visible deposits of oil and grease using solvent cleaning prior to performing mechanical cleaning, and again following mechanical cleaning and prior to coating application. Normally, a dust-free surface is not required prior to mechanical surface preparation, since the mechanical preparation itself will create dust. After performing blast cleaning, visible deposits of oil, grease, and other soluble contaminants are to be removed from the surface in accordance with SSPC-SP 1. The surface must also be free of visible dust and dirt immediately prior to coating application.

6.2 SSPC-SP 2, "HAND TOOL CLEANING:" Hand tool cleaning is a method of surface preparation often used for normal atmospheric exposures, for interiors, and for maintenance coating when using coatings with good wetting ability. Hand cleaning will remove loose rust, loose coating, and loose mill scale but will not remove all residue of rust or intact mill scale. For cleaning small, limited areas prior to maintenance priming, hand cleaning will usually suffice.

Care in hand tool cleaning is also especially important if the prime coat is to be applied by spray, because a sprayed coating may bridge gaps and crevices, whereas brushing works the coating into these areas.

The hand tool cleaning standard requires that visible deposits of and grease, along with any other visible contaminants, first be removed as specified in SSPC-SP 1, "Solvent Cleaning." On welded work, particular care should be

TABLE 3A

COMPARISON OF SSPC AND ISO SURFACE PREPARATION STANDARDS FOR POWER- AND HAND-TOOL CLEANED STEEL

Surface Preparation Standard		Initial Condition of Steel		Reference Photographs	
SSPC	**ISO**	**Rust Condition**	**Description**	**SSPC-VIS 3**[1]	**ISO 8501-1**[2]
SP 11 Power Tool Cleaning to Bare Metal		A	intact mill scale	A SP 11	*
		B	partially rusted mill scale	B SP 11	*
		C	100% rusted, no pits	C SP 11	*
		D	rusted and pitted	D SP 11	*
		E	paint mostly intact	E SP 11, E SP 11/R	*
		F	zinc-rich paint	F SP 11, F SP 11/R	*
		G	deteriorated paint over mill scale	G SP 11	*
SP 15 Commercial Grade Power Tool Cleaning		A	intact mill scale	*	*
		B	partially rusted mill scale	B SP 15	*
		C	100% rusted, no pits	C SP 15	*
		D	rusted and pitted	D SP 15	*
		E	paint mostly intact	E SP 15	*
		F	zinc-rich paint	F SP 15	*
		G	deteriorated paint over mill scale	G SP 15	*
SP 3 Power Tool Cleaning	St 2 St 3	A	intact mill scale	A SP 3/PWB, A SP 3/SD	*
		B	partially rusted mill scale	B SP 3/PWB, B SP 3/SD	B St 3
		C	100% rusted, no pits	C SP 3/PWB, C SP 3/SD	C St 3
		D	rusted and pitted	D SP 3/PWB, D SP 3/SD	D St 3
		E	paint mostly intact	E SP 3/PWB, E SP 3/SD	*
		F	zinc rich paint	F SP 3/PWB, F SP 3/SD	*
		G	deteriorated paint over mill scale	G SP 3/PWB, G SP 3/SD	*
SP 2 Hand Tool Cleaning	St 2 St 3	A	intact mill scale	A SP 2	*
		B	partially rusted mill scale	B SP 2	B St 2
		C	100% rusted, no pits	C SP 2	C St 2
		D	rusted and pitted	D SP 2	D St 2
		E	paint mostly intact	E SP 2	*
		F	zinc-rich paint	F SP 2	*
		G	deteriorated paint over mill scale	G SP 2	*

* no photograph

[1] SSPC-VIS 3 contains photographs for SP 11, SP 15, SP 3, and SP 2.

[2] The United Kingdom Standard BS 7079 Part A1 is equivalent to ISO 8501-1 and depicts the degrees of cleanliness of unpainted steel. BS 7079 Part A2 is equivalent to ISO 8501-2 and depicts the same degrees of cleanliness of previously painted steel.

TABLE 3B
COMPARISON OF SSPC AND ISO SURFACE PREPARATION STANDARDS FOR BLAST-CLEANED STEEL

Surface Preparation Standard		Initial Condition of Steel		Reference Photographs		
SSPC/NACE	**ISO[1]**	**Rust Condition**	**Description**	**SSPC-VIS 1/ SSPC VIS 5[2]**		**ISO 8501-1**
SP 5/ NACE No. 1, White Metal Blast Cleaning	Sa 3	A	intact mill scale	A SP 5, A SP 5-N1[3] A SP 5-N2 A SP 5-N3	A SP 5-M1[3] A SP 5-M2 A SP 5-M3	A Sa 3
		B	partially rusted mill scale	B SP 5		B Sa 3
		C	100% rusted, no pits	C SP 5		C Sa 3
		D	rusted and pitted	D SP 5		D Sa 3
		G	deteriorated paint over mill scale	G, SP 5 G, SP 5 G, SP 5 G, SP 5 P G, SP 5 H, G, SP 5 L G, SP 5 D	G, SP 5 P G, SP 5 H G, SP 5 L G, SP 5 D	*
SP 10/ NACE No. 2, Near-White Blast Cleaning	Sa 2-1/2	A	intact mill scale	A SP 10		A Sa 2-1/2
		B	partially rusted mill scale	B SP 10		B Sa 2-1/2
		C	100% rusted, no pits	C SP 6 C WAB 5[2]		C Sa 2-1/2
		D	rusted and pitted	D SP 6 D WAB 5[2]		D Sa 2-1/2
		G	deteriorated paint over mill scale	G, SP 6 G, SP 6 G, SP 6		*
SP 6/ NACE No. 3, Commercial Blast Cleaning	There is no comparable written ISO definition for SP 6, however, the ISO photographs C Sa 2 and D Sa 2 are consistent with the written definition of the commercial blast cleaning cleanliness level contained in SSPC-SP 6.	A	intact mill scale	*		*
		B	partially rusted mill scale	B SP 6		See Note 4
		C	100% rusted, no pits	C SP 6		C Sa 2
		D	rusted and pitted	D SP 6		D Sa 2
		G	deteriorated paint over mill scale	G, SP 14 G, SP 14 G, SP 14		*
SP 14/ NACE No. 8, Industrial Blast Cleaning	Sa 2	A	intact mill scale	*		*
		B	partially rusted mill scale	B SP 14		B Sa 2[4]
		C	100% rusted, no pits	C SP 14		*
		D	rusted and pitted	D SP 14		*
		G	deteriorated paint over mill scale	G, SP 14 G, SP 14 G, SP 14		*
SP 7/NACE No. 4, Brush-Off Blast Cleaning	Sa 1	A	intact mill scale	*		*
		B	partially rusted mill scale	B SP 7		B Sa 1
		C	100% rusted, no pits	C SP 7		C Sa 1
		D	rusted and pitted	D SP 7		D Sa 1
		G	deteriorated paint over mill scale	G, SP 7 G, SP 7 G, SP 7		*

* = No photograph.

[1] ISO standards Sa 3, Sa 2 1/2, Sa 2, Sa 1, St 2 and St 3 approximate the corresponding SSPC written standards.

[2] SSPC-VIS 1 contains photographs for SP 5, SP 6, SP 7, SP 10, and SP 14. SSPC-VIS 5 photographs of wet abrasive blast cleaning are indicated by WAB.

[3] Alternate non metallic abrasives: A SP 5-N1, A SP 5-N2, A SP 5-N3.
Alternate metallic abrasives: A SP 5-M1, A SP 5-M2, A SP 5-M3.

[4] ISO photograph illustrating B Sa 2 shows dark areas that could be interpreted as mill scale and, therefore, represents SSPC-SP 14 and does not represent SSPC-SP 6.

TABLE 3C
COMPARISON OF SSPC AND ISO SURFACE PREPARATION STANDARDS FOR WATERJET-CLEANED STEEL

Surface Preparation Standard		Initial Condition of Steel		Reference Photographs	
SSPC/ NACE	**ISO**	**Rust Condition**	**Description**	**SSPC-VIS 1/ SSPC VIS 4**	**ISO 8501 4**
WJ-1 Clean to Bare Substrate	Wa 3	C	100% rusted, no pits	C WJ-1	
		D	rusted and pitted	D WJ-1	
		E	Light-colored paint over blast-cleaned steel, mostly intact	E WJ-1	This standard does not imply that the cleanliness is limited to Wa 2-1/2 but achieving a greater degree of cleanliness may involve disproportionate increase in time.
		F	Zinc-rich paint over blast-cleaned steel; paint mostly intact	F WJ-1	
		G	Multi-coat non-brittle paint system over mill scale-bearing steel	G WJ-1	
		H	Deteriorated brittle multicoat painting system	H WJ-1	
WJ-2 Very Thorough Cleaning	Wa 2-1/2	C	100% rusted, no pits	C WJ-2 C WJ-2 L C WJ-2 M C WJ-2 H	DC C Wa 2-1/2
		D	rusted and pitted	D WJ-2 D WJ-2 L D WJ-2 M D WJ-2 H	
		E	Light-colored paint over blast-cleaned steel, mostly intact	E WJ-2	DF 1 Wa 2-1/2 DC B Wa 2-1/2*
		F	Zinc-rich paint over blast-cleaned steel; paint mostly intact	F WJ-2	DF Z Wa 2-1/2
		G	Multi-coat non-brittle paint system over mill scale-bearing steel	G WJ-2*	DC A Wa2-1/2*
		H	Deteriorated brittle multicoat painting system	H WJ-2	
WJ-3 Thorough Cleaning	Wa 2	C	100% rusted, no pits	C WJ-3 C WJ-3-L C WJ-3 M C WJ-3 H	DC C Wa 2
		D	100% rusted and pitted	D WJ-3 D WJ-3 L D WJ-3 M D WJ-3 H	Condition D Stee Wa 2 L M H
		E	Light-colored paint over blast-cleaned steel, mostly intact	E WJ-3	DF I Wa 2 DC B Wa 2
		F	Zinc-rich paint over blast-cleaned steel; paint mostly intact	F WJ-3	DF Z Wa 2
		G	Multi-coat non-brittle paint system over mill scale-bearing steel	G WJ-3	*DC A Wa 2
		H	Deteriorated brittle multicoat painting system	H WJ-3*	
WJ-4 Light Cleaning	Wa 1	C	100% rusted, no pits	C WJ-4	DC C Wa1
		D	rusted and pitted	D WJ-4	*
		E	Light-colored paint over blast-cleaned steel, mostly intact	E WJ-4	DF I Wa 1 DC B Wa 1*
		F	Zinc-rich paint over blast-cleaned steel; paint mostly intact	F WJ-4*	DF Z Wa 1*
		G	Multi-coat non-brittle paint system over mill scale-bearing steel	G WJ-4	DC A Wa 1
		H	Deteriorated brittle multicoat painting system	H WJ-4	

* = no photograph

taken to remove as much welding flux, slag, and fume deposit as is possible since these are notorious in promoting coating failure on welded joints. All loose matter should be removed from the surface prior to coating. Blowing off with clean, dry, oil-free compressed air, brushing, or vacuum cleaning are satisfactory removal methods. See Section 5.3 for establishing a Job Reference Standard.

6.2.1 Loose Rust, Mill Scale, and Coating: Determiningf the degree of cleaning required to comply with SSPC-SP 2 is often very difficult. The problem is in establishing whether a residue is "adherent" or "loose." Residue that cannot be removed by lifting with a dull putty knife is considered to be "adherent." Tightly adherent rust scale is discussed in Section 4.3.1.

One possible solution is for the contracting parties to establish a standard cleaning procedure in which the type of tool, force, speed, etc., is stipulated.

Another possibility is for the contracting parties to agree on a JRS that shows the standard of cleanliness for a particular job. The sample area should be representative of the surface to be cleaned, and may be a separate specimen or a designated flat portion of the actual surface. After the contracting parties agree on the cleanliness desired, the surface is protected and retained for comparison.

6.3 SSPC-SP 3, "POWER TOOL CLEANING:" Similar to hand tool cleaning, power tool cleaning removes loose rust, loose mill scale, and loose coating. Intact materials may remain. Power tools use electrical and pneumatic equipment to provide faster cleaning. They include sanders, wire brushes or wheels, chipping hammers, scalers, rotating flaps (rotopeen), needle guns, hammer assemblies, and right angle or disk grinders. Some have high efficiency particulate air (HEPA) vacuum lines attached to reduce air pollution and collect debris produced in the cleaning operation. Power tools clean by impact, abrasion, or both. Cleaning of metal surfaces is less expensive using power tools than using hand tools. Less particulate contamination results from power tool cleaning than from abrasive blast cleaning. Thus, power tools are frequently used for spot cleaning of damaged coatings, where contamination of adjacent areas by abrasive is unacceptable, and when a surface-tolerant coating, such as oil-based paint, is to be used.

The power tool cleaning standard requires that oil and grease, along with any visible salts, first be removed as specified in SSPC-SP 1, "Solvent Cleaning." On welded work, particular care should be taken to remove as much welding flux, slag, and fume deposit as is possible since these are notorious in promoting coating failure on welded joints. All loose matter should be removed from the surface prior to coatinging. Blowing off with clean, dry, oil-free compressed air, brushing, or vacuum cleaning are satisfactory methods.

When using power tools, care must be exercised to prevent excessive roughening of the surface. Ridges and burrs can contribute to coating failure because the sharp edges may not be protected by adequate thickness of coating. Excessive power wire brushing can also be detrimental to the performance of the coating, since the surface (particularly mill scale) is easily burnished to a smooth, slick finish to which coating will not adhere.

Some of the air-driven power tools require daily lubrication with a light oil that may be sprayed out in the air discharge in the form of a very fine mist. This oil will settle on the surface and, although it is not normally visible, it can degrade the adhesion of the coating. It should be removed by solvent wiping prior to the application of the coating.

6.3.1 Loose Rust, Mill Scale, and Coating: Determining the degree of cleaning required to comply with this standard is often very difficult. The problem is in establishing whether a residue is "adherent" or "loose." The standard considers the residue adherent if it cannot be lifted with a dull putty knife, a somewhat subjective criteria. Tightly adherent rust scale is discussed in Section 4.3.1.

One possible solution is for the contracting parties to agree on a standard cleaning procedure in which the type of tool, force, speed, etc., are all stipulated. Another possibility is for the contracting parties to agree on a sample area or JRS that shows the standard of cleanliness for a particular job. See Section 5.3 for establishing a JRS.

6.4 SSPC-SP 4, "FLAME CLEANING OF NEW STEEL:" This standard was discontinued in 1982.

6.5 SSPC-SP 5/NACE No. 1, "WHITE METAL BLAST CLEANING:" White metal blast cleaning is generally used for exposures in very corrosive atmospheres and for immersion service where the highest degree of cleaning is required and a high surface preparation cost is warranted.

Blast cleaning to white metal will result in high performance of the coating systems due to the complete removal of all rust, mill scale, and foreign matter or visible contaminants from the surface. In ordinary atmospheres and general use, white metal is seldom warranted.

The use of this grade of blast cleaning without rust-back is particularly difficult in the environments where it is most needed as a preparation for coating; for example, in humid chemical environments. White metal blast cleaning should be conducted at a time when no contamination or rusting can occur, and when prompt coating is possible. A good rule is that no more surface should be prepared for coating than can be coated the same day unless the environment is enclosed and controlled continuously by dehumidification.

6.6 SSPC-SP 5 (WAB)/NACE WAB-1, "WHITE METAL WET ABRASIVE BLAST CLEANING:" This is one of five standards issued in 2016 for surface preparation of steel by blast cleaning using a combination of water and abrasive media (WAB cleaning). The definition of the cleaned surface immediately prior to coating application is identical to the SSPC-SP 5/NACE No.1 definition for dry abrasive blast cleaning. Like the dry abrasive blast cleaning standards, the WAB standards contain requirements for methods and materials for achieving the defined level of surface cleanliness. However, when using wet methods of surface preparation, the specifier must also consider specifying the maximum level of flash rust that may remain on the surface immediately prior to coating application. The WAB standards contain definitions for three levels of flash rust, based on the degree to which it obscures the steel substrate and the ease with which it can be removed from the surface using adhesive tape or a white cloth. Nonmandatory appendices describe procedures for both tests. If no level of permissible flash rust is specified, no flash rust is permitted).

6.7 SSPC-SP 6/NACE No. 3, "COMMERCIAL BLAST CLEANING:" Commercial blast cleaning should be employed for all general purposes where a high, but not perfect, degree of blast cleaning is required. It will remove all rust, all mill scale, and all other detrimental matter from the surface, but will permit a great deal of staining from rust, mill scale, or previously applied coating to remain. The surface will not necessarily be uniform in color, nor will all surfaces be uniformly clean. The advantage of Commercial Blast Cleaning lies in the lower cost for providing a degree of surface preparation that should be suitable for the majority of cases where blast cleaning is believed to be necessary. However, if it is possible that Commercial Blast Cleaning will result in a surface unsatisfactory for the service, SSPC-SP 10 (near-white metal) or SSPC-SP 5 (white metal) should be specified.

When a project specification includes maintenance coating, with the intent that some of the existing coating be permitted to remain (e.g. because it is thin, well adherent, and compatible with the new coating system), the contract documents should stipulate the extent of the surface to be cleaned in accordance with this standard. SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel" and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems" address additional maintenance coating procedures.

6.8 SSPC-SP 6 (WAB)/NACE WAB-3, "COMMERCIAL WET ABRASIVE BLAST (WAB) CLEANING:" This is one of five standards issued in 2016 for surface preparation of steel by blast cleaning using a combination of water and abrasive media. The definition of the cleaned surface immediately prior to coating application is identical to the SSPC-SP 6/NACE No.3 definition for dry abrasive blast cleaning. Like the dry abrasive blast cleaning standards, the WAB standards contain requirements for methods and materials for achieving the defined level of surface cleanliness. However, when using wet methods of surface preparation, the specifier must also consider specifying the maximum level of flash rust that may remain on the surface immediately prior to coating application. The WAB standards contain definitions for three levels of flash rust, based on the degree to which flash rust obscures the steel substrate and the ease with which the rust can be removed from the surface using adhesive tape or a white cloth. Nonmandatory appendices describe procedures for both tests. If no level of permissible flash rust is specified, no flash rust is permitted.

6.9 SSPC-SP 7/NACE No. 4, "BRUSH-OFF BLAST CLEANING:" Brush-off blast cleaning should be employed when the environmental exposure conditions are mild enough to permit tightly adhering mill scale, tightly adhering coating (if the surface was previously coated), and tightly adhering rust to remain on the surface. The resulting surface should be free of all loose mill scale, loose coating, and loose rust. The small amount of rust remaining should be an integral part of the surface. The surface should be sufficiently abraded to provide a good anchor for coating. The low cost of this method may result in economical protection in mild environments.

It is not intended that brush-off blast cleaning be used in very severe service environments. Brush-off blast cleaning is generally intended to supplant power tool cleaning where facilities are available for blast cleaning. With this method of surface preparation, as with any other, it is understood that the rate of cleaning will vary from one part of the structure to another depending upon the initial condition of the surface. Because of the high rate of cleaning, the cost is low relative to the higher grades of blast cleaning. Coatings that are used should have a fair degree of wetting because of the material that is allowed to remain on the surface.

If brush-off blast cleaning is specified in a maintenance coating project, the existing adherent coating should be compatible with the new coating system. If a substantial amount of the existing coating will be removed during brush-off blast cleaning, a higher level of cleaning should be specified, e.g. SSPC-SP 14 (industrial) or SSPC-SP 6 (commercial). SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel" and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems" cover additional maintenance coating procedures.

When the project requirement or coating product data sheet requires "sweep blasting" to roughen the surface of an existing intact coating in preparation for overcoating, the SSPC-SP 16 standard is more appropriate than SSPC-SP 7.

6.10 SSPC-SP 7 (WAB)/NACE WAB-4, BRUSH-OFF WET ABRASIVE BLAST CLEANING: This is one of five standards issued in 2016 for surface preparation of steel by blast cleaning using a combination of water and abrasive media. The definition of the cleaned surface immediately prior to coating application is identical to the SSPC-SP 7/NACE No. 4 definition for dry abrasive blast cleaning. Like the dry abrasive blast cleaning standards, the WAB standards contain requirements for methods and materials for achieving the defined level of surface cleanliness. However, when using wet methods of surface preparation, the specifier must also consider specifying the maximum level of flash rust that may remain on the surface immediately prior to coating application. The WAB standards contain definitions for three levels of flash rust, based on the degree to which flash rust obscures the steel substrate and the ease with which the rust can be removed from the surface using adhesive tape or a white cloth. Nonmandatory appendices describe procedures for both tests. If no level of permissible flash rust is specified, no flash rust is permitted.

6.11 SSPC-SP 8, "PICKLING:" Pickling is considered a desirable method of removing rust and mill scale from structural shapes, beams, and plates when the cost of such removal is felt to be justified. Properly accomplished, pickling produces a surface that will promote long coating life with most coatings, but it is most commonly associated with hot-dipped galvanizing.

Where production is sufficiently high to keep the equipment in use, pickling results in low-cost shop preparation. It is impractical for field use.

Facilities are extremely limited for pickling of large fabricated members or large structural beams. However, there are a number of facilities for large steel plates and structural members that are not exceedingly long. Small-scale pickling facilities are widely available.

Both hydrochloric and sulfuric acid can be used for pickling. Hydrochloric acid dissolves scale faster than does sulfuric acid, but hydrochloric acid is seldom heated to induce greater action because of the large amount of toxic hydrogen chloride fumes emitted. Any acid used should contain an appropriate inhibitor to control the chemical action. Considerable use is made of the duplex type of pickling where sulfuric acid is used to remove the rust and scale and phosphoric acid is used for a fine phosphate treatment. Special precautions, including fresh water rinsing, are necessary to remove residues of unreacted sulfuric or hydrochloric acid.

Design of fabricated steel may require special consideration to eliminate pockets or crevices that trap acid during pickling. This may be avoided by pickling in phosphoric acid. Pickled steel, like blast cleaned steel, should be coated as soon as possible after cleaning. A more detailed discussion of pickling is available in SSPC Vol. 1: Good Painting Practice of the SSPC Painting Manual.

6.12 SSPC-SP 9, "WEATHERING FOLLOWED BY BLAST CLEANING:" This standard was discontinued in 1971. Weathering prior to blast cleaning has been found to be a very harmful practice, especially in corrosive environments, since deleterious surface impurities are much more difficult to remove after weathering away of mill scale.

6.13 SSPC-SP 10/NACE No. 2, "NEAR-WHITE METAL BLAST CLEANING:" In many exposures involving a combination of high humidity, chemical atmosphere, marine, or other corrosive environments, the use of SSPC-SP 5 "White Metal Blast Cleaning" was found to be overly expensive due to the disproportionately large amount of work required to remove the last vestiges of streaks and shadows. There are many applications in which these traces can be tolerated without appreciable loss in coating life. The near-white blast-cleaning standard was developed to fill the need for a grade of cleaning beyond that of SSPC-SP 6 but less than that of SSPC-SP 5.

Near-white blast cleaning can be employed for all general purposes where a high degree of surface cleanliness is required. It will remove all rust, mill scale, and other detrimental matter from the surface but streaks and stains are permitted to remain. The surface will not necessarily be completely uniform in color, nor will all surfaces be uniformly clean. However, it is explicit in this standard that shadows, streaks, or discolorations, if any, be slight and be distributed uniformly over the surface—not concentrated in spots or areas.

The advantage of near-white blast cleaning lies in the lower cost for surface preparation that is satisfactory for all but the most severe service conditions. Depending upon the initial condition of the new or previously painted steel, it has been variously estimated that near-white blast cleaning can be carried out at a cost of 10 to 35% less than that of SSPC-SP 5. These numbers are estimates only and will not hold true in all cases.

The verbal description calling for at least 95% of the surface being equivalent to SSPC-SP 5 is based upon a large number of visual observations and a limited number of light reflectivity measurements. It is hoped that the amount of surface impurity can be quantified by specific measurement technique, but efforts to date have been unsuccessful except in a laboratory. It is believed, however, that a visual estimate of the amount of residuals can be agreed upon between owner and contractor.

When a project specification includes maintenance painting, if it is intended that some of the existing coating be permitted to remain (e.g., because it is thin, well adherent, and compatible with the new coating system), the contract documents should stipulate the extent of the surface to be cleaned in accordance with this standard. SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel" and SSPC-PA Guide 4, "Guide to Maintenance Repainting with Oil Base or Alkyd Painting Systems" cover additional maintenance painting procedures.

Performing this grade of blast cleaning without rust-back forming is particularly difficult in the environments where it is most needed as a preparation for painting; for example, in humid chemical environments (see Rust-Back, Section 4.5.2).

6.14 SSPC-SP 10 (WAB)/NACE WAB 2, "NEAR WHITE METAL WET ABRASIVE BLAST CLEANING:" This is one of five standards issued in 2015 for surface preparation of steel by blast cleaning using a combination of water and abrasive media. The definition of the cleaned surface immediately prior to coating application is identical to the SSPC-SP 10/NACE No. 2 definition for dry near-white metal blast cleaning. Like the dry abrasive blast cleaning standards, the WAB standards contain requirements for methods and materials for achieving the defined level of surface cleanliness. However, when using wet methods of surface preparation, the specifier must also consider specifying the maximum level of flash rust that may remain on the surface immediately prior to coating application. The WAB standards contain definitions for three levels of flash rust, based on the degree to which flash rust obscures the steel substrate and the ease with which the rust can be removed from the surface using adhesive tape or a white cloth. Nonmandatory appendices describe procedures for both tests. If no level of permissible flash rust is specified, no flash rust is permitted.

6.15 SSPC-SP 11, "POWER TOOL CLEANING TO BARE METAL:" Power tool cleaning to remove tightly adherent material produces a surface that is visibly free from all rust, mill scale, and old coatings, and that has a surface profile of at least 25µm (1 mil). SSPC-SP 11 is the highest level of power tool cleaning. It produces a greater degree of cleaning than SSPC-SP 3 (which does not remove tightly adherent material) and SSPC-SP 15, "Commercial Grade Power Tool Cleaning," which allows substantial staining. SSPC-SP 11 may be considered for coatings requiring a bare metal substrate.

The surfaces prepared according to this standard are not to be compared to surfaces cleaned by abrasive blasting. Although this method produces surfaces that resemble near-white or commercial blast, they are not necessarily equivalent to those surfaces produced by abrasive blast cleaning as called for in SSPC SP 10 (near white) or SP 6 (commercial) due to characteristics of the profile.

The SSPC-SP 11 standard gives the specifier an opportunity to select a method of cleaning suitable for certain coatings in areas where wet or dry abrasive blasting or waterjetting is prohibited or not feasible. Examples of other circumstances where this standard may be applied are:

- touch-up of welded or damaged areas of erection assemblies
- reducing volume of hazardous waste produced by abrasive blasting
- cleaning around sensitive equipment or machinery

6.15.1 Power Tools and Cleaning Media: A power tool cleaning system consists of a surface cleaning medium for abrading the surface and a powered tool for driving that medium. The standard distinguishes between media that clean the surface and those that produce a profile. Similarly, power tools are classified as surface cleaning type or profile producing type.

Surface cleaning power tools are those that drive two main classes of surface cleaning media: 1) non-woven abrasive wheels and discs; and 2) coated abrasive discs, flap wheels, bands, or other coated abrasive devices.

Profile-producing power tools are classified as grinding tools (using media containing bonded adhesive grains to cut through corroded surfaces and include, but are not limited to, discs or wheels) and impact tools (using media that repeatedly collide with the target surface and include, but are not limited to, various rotary and reciprocating devices). In instances where a profile already exists, such as on previously painted surfaces, only surface cleaning power tools and media may be required, if the appropriate degree of cleanliness is created without reducing the profile to less than 25 micrometers (1 mil). Where an existing profile is reduced to less than 25 micrometers (1 mil) in the process of cleaning, surface profiling power tools are required to restore the appropriate profile.

Where there is no existing profile, both cleanliness and profile must be produced as specified. This may require using both kinds of tools and media, although in some cases a surface profiling tool/medium may adequately clean the surface without requiring a separate cleaning operation. It should be noted that misuse of power tools on metals can produce a burnished rather than a textured surface that compromises coating adhesion.

Cleaning of metal surfaces is usually faster and less expensive using abrasive blasting than using power tools, without considering the cost of mobilization and containment for the control of dust and debris. However, power tools are used frequently for spot cleaning of damaged coatings where contamination of adjacent areas by abrasive is unacceptable. Less particulate contamination of the environment occurs with power tools than from abrasive blasting.

6.15.2 Power Tools With Vacuum Shrouds: Special power tools may also have high-efficiency particulate air (HEPA) vacuum lines attached to reduce air pollution and to contain the debris generated at the point source during coating removal. The vacuum shroud surrounds only the tool itself, providing a localized containment of the debris at the point of generation.

The method of operation of vacuum shrouded tools is similar to that of non-vacuum shrouded tools. This is difficult when cleaning irregular surfaces. As a result, special custom shrouds can be fitted onto the ends of the tools. Some tools however, are not amenable to shrouds, and therefore the collection of debris is not as efficient. A surface can be cleaned to comply with SSPC-SP 3, "Power Tool Cleaning," SSPC-SP 15 "Commercial Grade Power Tool Cleaning," or SSPC-SP 11, using these vacuum shrouded tools.

6.16 SSPC-SP 12/NACE No. 5, "SURFACE PREPARATION AND CLEANING OF METALS BY WATERJETTING PRIOR TO COATING:" This standard has been discontinued. See Sections 6.17, 6.18, 6.19 and 6.20.

6.17 SSPC-SP 14/NACE No. 8, "INDUSTRIAL BLAST CLEANING:" Industrial blast cleaning is used when the objective is to remove most of the coating, mill scale, and rust, but the extra effort required to remove every trace of these materials is determined to be unwarranted. Industrial blast cleaning provides a greater degree of cleaning than SSPC-SP 7 but less than SSPC-SP 6.

The difference between industrial blast cleaning and brush-off blast cleaning is that the objective of brush-off blast cleaning is to allow as much of an existing coating to remain as possible, while the objective of industrial blast cleaning is to remove most of the coating. Industrial blast cleaning allows defined mill scale, coating, and rust to remain on less than 10% of the surface and allows defined stains to remain on all surfaces. Commercial blast cleaning provides a higher level of cleaning, and the surface is free of mill scale, rust, and coatings, allowing only random staining to remain on no more than 33% of each 9 in² (60 cm²) increment of the surface.

6.18 SSPC-SP 14 (WAB)/NACE WAB-8, "INDUSTRIAL WET ABRASIVE BLAST CLEANING:" This is one of five standards issued in 2016 for surface preparation of steel by blast cleaning using a combination of water and abrasive media. The definition of the cleaned surface immediately prior to coating application is identical to the SSPC-SP 14/NACE No.8 definition for dry industrial blast cleaning. Like the dry abrasive blast cleaning standards, the WAB standards contain requirements for methods and materials for achieving the defined level of surface cleanliness. However, when using wet methods of surface preparation, the specifier must also consider specifying the maximum level of flash rust that may remain on the surface immediately prior to coating application. The WAB standards contain definitions for three levels of flash rust, based on the degree to which flash rust obscures the steel substrate and the ease with which the rust can be removed from the surface using adhesive tape or a white cloth. Nonmandatory appendices describe procedures for both tests. If no level of permissible flash rust is specified, no flash rust is permitted.

6.19 SSPC-SP 15, "COMMERCIAL GRADE POWER TOOL CLEANING:" A surface cleaned with power tools to commercial grade is visibly free from all rust, mill scale, and old coating, and it has a surface profile of at least 25 µm (1 mil). SSPC-SP 15 provides a higher level of cleanliness than SSPC-SP 3, "Power Tool Cleaning" in that all paint, rust, and mill scale are removed. SSPC-SP 15 provides a lesser level than SSPC-SP 11, "Power Tool Cleaning to Bare Metal" because staining is permitted on 33% of the surface. Both SSPC-SP 15 and SSPC-SP 11 require a minimum 25-µm (1-mil) profile.

The surfaces prepared according to this standard are not to be compared to surfaces cleaned by abrasive blasting. Although this method produces surfaces that resemble commercial blast cleaned surfaces, they are not necessarily equivalent to those surfaces produced by abrasive blast cleaning to SP 6. After power tool cleaning to SP 15, slight residues of rust and paint may remain in the bottoms of pits if the original surface is pitted. Commercial blast cleaning (SP 6) allows only staining of the surface and does not permit residue to remain in pit bottoms.

SSPC-SP 15 helps to bridge the gap between the marginal surface preparation described in SP 3, "Power Tool Cleaning" and the more thorough cleaning described in SP 11, "Power Tool Cleaning to Bare Metal." It gives the specifier an opportunity to select a method of cleaning suitable for certain coatings in areas where the added expense of going to SP 11 is not justified by an anticipated increase in coating life. Examples of circumstances where this standard may be applied are:

- touch-up of welded or damaged areas of erection assemblies
- reducing volume of hazardous waste produced by abrasive blasting
- cleaning around sensitive equipment or machinery
- cleaning where abrasive blasting is not permitted

6.20 SSPC-SP 16, "BRUSH-OFF BLAST CLEANING OF COATED AND UNCOATED GALVANIZED STEEL, STAINLESS STEELS, AND NON-FERROUS METALS:" See Section 15.

6.21 SSPC-SP WJ-1/NACE WJ-1, "Clean to Bare Substrate:" This standard requires the removal of all visible oil, grease, dirt, rust, mill scale, paint and any other foreign matter. The surface is described as having a matte (dull mottled) finish. Within the hierarchy of degrees of surface cleanliness achieved by waterjet cleaning this standard is intended to be similar to the cleanliness level of SSPC-SP 5/NACE No. 1, except that stains are permitted to remain on the surface and no profile is achieved. The revealed profile is that which was under the coating or rust that has been removed.

6.22 SSPC-SP WJ-2/NACE WJ-2, "Very Thorough Cleaning:" WJ-2 requires the removal of all visible oil, grease dirt, rust and other corrosion products except for randomly dispersed stains of rust and other corrosion products. The staining or tightly adherent matter shall be limited to no more than 5% of each unit area. Within the hierarchy of degrees of surface cleanliness achieved by waterjet cleaning this standard is intended to be similar to the cleanliness level of SSPC-SP 6/NACE No. 2, except that tightly adherent material rather than only stains are permitted to remain on the surface and no profile is achieved. The revealed profile is that which was under the coating or rust that has been removed.

6.23 SSPC-SP WJ-3/NACE WJ-3 "Thorough Cleaning:" A metal surface after Thorough Cleaning, when viewed without magnification, shall have a matte (dull, mottled) finish and shall be free of all visible oil, grease, dirt, rust, and other corrosion products except for randomly dispersed stains of rust and other corrosion products, tightly adherent thin coatings, and other tightly adherent foreign matter. The staining or tightly adherent matter shall be limited to no more than 33% of each unit area of surface and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter. The revealed profile is that which was under the coating or rust that has been removed.

6.24 SSPC-SP WJ-4/NACE WJ-4 "Light Cleaning:" A metal surface after Light Cleaning, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating. Any residual material shall be tightly adhered to the metal substrate and may consist of randomly dispersed stains of rust and other corrosion products or previously applied coating, tightly adherent thin coatings, and other tightly adherent foreign matter.

7. Selection of Abrasives, Blast Cleaning Parameters, and Equipment

The selection of the size and type of abrasive that will most effectively and economically produce the desired surface finish is not an exact science because of the many variables involved. These variables include the following at a minimum:

- The nature of the steel being cleaned, i.e., the hardness and the degree of rusting which may have developed prior to blast cleaning
- The basic purpose for blast cleaning, which may include either new construction or maintenance and repair programs.

TABLE 4
APPROXIMATE PROFILE HEIGHT OF BLASTED STEEL USING DIFFERENT SIZED NON-METALLIC ABRASIVES*

Abrasive	Profile Height				
	25 µm 1 mil	38 µm 1.5 mil	50 µm 2 mil	63 µm 2.5 mil	75-100 µm 3-4 mils
Silica Sand	30/60 mesh	16/35 mesh	16/35 mesh	8/35 mesh	8/20 mesh
Steel Grit	G 80	G 50	G 40	G 40	G 25
Steel Shot	S 110	S 170	S 280	S 280	S 330
Garnet	80/100 mesh	30/100 mesh	30/60 mesh	20/60 mesh	20/40 mesh
Aluminum Oxide	100 grit	50 grit	36 grit	24 grit	16 grit

* These profile heights are typical if the nozzle pressure is between 620 and 700 kPa (90 and 100 psi)

- The type of surface finish desired, i.e., degree of cleanliness and height of profile required to meet the specification or requirement of the paint to be applied. See SSPC report, "Surface Profile for Anti Corrosion Paints," (SSPC 74-01)
- The type of blast cleaning systems which may be employed, e.g., centrifugal wheel or air blast recirculating abrasive systems, or open nozzle air blasting with expendable abrasives.

In general, select the smallest size abrasive that will produce the desired cleaning results. Usually this will give the fastest, most economical cleaning operation.

Non-traditional blast cleaning media may be expendable or recyclable. Such materials include sponge, dry ice, sodium bicarbonate and ice crystals. All require specialized equipment and may or may not create a surface profile.

General information concerning the chemical and physical properties of cast steel shot and grit and the physical properties of various non-metallic abrasives along with information on their usage, are presented in the following sections.

7.1 ABRASIVE CHARACTERISTICS: Selecting the appropriate type of abrasive for the job is important because the type of abrasive can have a significant influence on the appearance of the blast cleaned surface, productivity, and subsequent cleanup. Abrasives vary in hardness, particle size distribution, shape, bulk density, friability, waste generation, and recyclability. The following is a discussion of these characteristics and how they influence abrasive performance. Some physical data on non-metallic abrasives are given in Table 4.

7.1.1 Hardness: Metallic abrasive hardness is measured on the Rockwell C scale while non metallic abrasive hardness is measured on the Mohs scale. Hardness is important because the harder an abrasive, the deeper the profile it is likely to generate.

7.1.2 Size: Specifications may include abrasive sieve size designations because particle size plays a major role in productivity and in the subsequent profile generated. The role of abrasive size will be discussed in more detail in Section 7.3.1.

7.1.3 Shape: Abrasive particles range from spherical to sharply angular. Spherical to rounded particles clean by impact, producing a peened surface. Angular to irregularly shaped particles clean by scouring or cutting, producing an etched surface.

7.1.4 Bulk Density: The bulk density of an abrasive is a measure of an abrasive's weight per unit volume and is usually expressed in kilograms per cubic meter or pounds per cubic foot. For example, the bulk density of sand is approximately 1.6 MT/m³ (100 lb/ft³) whereas for steel grit abrasives, it is typically 4 MT/m³ (250 lb/ft³). Bulk density is important when lifting abrasive filled bulk containers. Using the bulk density values for sand and steel shown above, a 2.8 m³ (100 ft³) container filled with sand weighs 4500 kg (5 tons) and the same container filled with steel grit weighs 11,000 kg (12.5 tons).

7.1.5 Friability/Waste Generation: Abrasive friability is a measure of an abrasive's resistance to breakdown on impact. The more friable the abrasive, the greater the tendency for the abrasive to breakdown on impact, thereby generating more waste and dust.

7.1.6 Recyclability: Recyclability is a property of an abrasive that allows it to be reused many times without excessive breakdown. In order to meet the strict cleanliness requirements for recycling, the abrasive must also be able to withstand the rigorous cleaning process for removal of contaminants from the abrasive mix. Most mineral and byproduct abrasives can be recycled 1 to 3 times, but they have difficulty meeting the strict cleanliness requirements for recycling. Metallic abrasives, on the other hand, show the lowest friability; generate the least amount of waste; can be recycled many times, and meet the strict cleanliness requirements for recycling. Usually, the greater the hardness of a metallic abrasive, the more quickly it breaks down and the fewer times it can be recycled.

7.2 SURFACE PROFILE CONSIDERATIONS: Surface profile is a measure of surface roughness resulting from abrasive blast cleaning. The height of the profile produced on the surface is measured from the bottoms of the lowest valleys to the tops of the highest peaks.

The thickness and generic type of paint to be applied determines the allowable minimum and maximum profile height. The abrasive size is then chosen to achieve that profile. SSPC-AB 1, "Mineral and Slag Abrasives" defines five abrasive grades yielding profile heights from 13 to 150 micrometers (0.5 to 7.0 mils).

7.2.1 Profile Height: SSPC studies have shown that metallic abrasives larger than those which will pass through a 16 mesh sieve (ASTM E11) may produce a profile that is too deep to be adequately covered with a single coat of primer. Accordingly, it is recommended that the use of larger abrasives be avoided whenever possible. However, when heavy mill scale or rust is present, abrasives of a larger size may be needed. In these cases, two coats of primer may be required instead of the usual single coat. Alternatively, if the nozzle pressure is increased, a smaller size abrasive may remove heavy paint or scale more effectively than a larger abrasive at the lower pressure. Higher nozzle pressures may still produce larger profiles.

Table 4 gives the range of maximum and average maximum profile heights to be expected under normal good operating conditions (wheel and nozzle). At nozzle pressures in excess of 750 kPa (110 psi), the profile may be significantly higher.

Profile comparators are available to aid in estimating the average maximum profile of surfaces blasted with sand, steel grit, and steel shot. Surface profile can also be measured by use of replica tape. Methods for measuring profile are described in ASTM D4417, "Test Method for Field Measurement of Surface Profile of Blast Cleaned Steel" and in ASTM D7127, "Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument."

When the abrasive media impacts the surface it creates a surface profile. It is this profile (or "anchor pattern") that is necessary for most coating systems to adhere to the substrate. The depth of the profile is controlled by the following parameters:

- **Abrasive Size:** The larger the abrasive, the larger the profile.
- **Abrasive Type/Shape:** Angular abrasives create a deeper profile than round abrasives of the same size.
- **Hardness:** The harder the abrasive, the deeper the profile.
- **Abrasive Metering:** Amount of abrasive flowing through the air stream; optimum flow will provide consistent profile.
- **Blast Nozzle Air Pressure:** The higher the nozzle pressure, the deeper the profile.
- **Type of Blast Nozzle:** A venturi nozzle generates a deeper profile than a straight-bore nozzle with an opening of the same diameter.
- **Distance of Blast Nozzle to Surface:** The closer to the work, the deeper profile.
- **Angle of Blast Nozzle to Surface:** The more oblique the angle of abrasive impact on the abrasive, the lower the profile.
- **Substrate hardness and initial condition**

Altering any of these parameters during the blasting operation could affect profile and surface cleanliness. To avoid undesirable changes in profile and surface cleanliness, blasting trials are recommended before changing any of the parameters noted above.

A small abrasive can produce larger profiles by increasing the wheel speed or the nozzle pressure. If a small abrasive is used, there will be more impacts per pound of abrasive than if a larger abrasive is used. The abrasive must be large enough to remove the rust and mill scale present. The rule of thumb is to use the smallest abrasive that will do the job.

7.2.2 Profile Texture (Roughness): A 2 mil profile produced by a round abrasive (steel shot) will have a different texture than a 2-mil profile produced by an angular abrasive (steel grit). Similarly, a surface blasted with a small abrasive at a high pressure may have the same profile height as a surface blasted with a large abrasive at a lower pressure, but the small abrasive will produce more peaks. Coating systems may have measurably different performance characteristics over these two types of surface. For example, the angular profile produced by grit is required for metalizing (see SSPC-CS 23.00/AWS C2.23/NACE No. 12).

Shot produces a surface composed of rounded craters. Grit produces a more irregular surface with many smaller peaks between adjacent large peaks. It is only the tallest peaks and lowest valleys that determine the profile height. Non-metallic abrasives create profiles with the maximum amount of roughness.

The surface roughness can be measured quantitatively with a stylus instrument as described in ASTM D7127. This is a device that drags a needle across about an inch (2.5 cm) of the surface and electronically computes the distance between the highest peak and the lowest valley, the number of peaks, and the average peak height. Laser versions are also available.

With a rough profile (higher peaks and deeper valleys) more metal/paint interface is available for bonding. However, if the valleys are too deep and narrow, the coating may not be able to penetrate to the bottom of the valleys, thereby leaving a void at the bottom of the pits. Rough surfaces can be advantageous if the coating is able to completely wet the surface.

SSPC-PA 17, "Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements" contains requirements for taking profile measurements to determine whether project requirements have been met. As with SSPC-PA 2, individual gage readings in several locations are averaged. The reported surface profile is the average of the location averages. The procedure also contains requirements for additional measurements to determine the extent of noncompliant areas.

7.2.3 Peak Count Density: ASTM D7127 defines peak count (P_c) as "the number of peak/valley pairs, per unit of length, extending outside a 'deadband' centered on the mean line.[95] In less technical terms, the number of peaks per linear centimeter recorded as a stylus moves across a fixed length of the blast cleaned surface. Research has shown that peak density can affect coating performance providing a greater surface area for mechanical adhesion of the coating. Peak count can be affected by abrasive hardness, density, size, and the velocity of the abrasive as it strikes the surface.[96]

7.3 PARAMETERS THAT AFFECT PRODUCTIVITY: Factors such as initial steel condition, specified degree of cleaning, and accessibility are job specific. Eleven controllable parameters that affect the productivity of abrasive blast cleaning are described below.

7.3.1 Particle Size: Decreasing abrasive particle size can dramatically increase cleaning rate. Increasing abrasive particle size may be necessary to remove heavy coatings and scale. The general rule is to use the smallest size abrasive that will do the job.

7.3.2 Hardness: Typically, the harder the abrasive, the better it will perform. However, very hard abrasives shatter on impact expending most of their energy in particle breakdown and dust generation. As with selecting abrasive size, the general rule is to select the minimum abrasive hardness that will effectively do the job.

7.3.3 Shape: Rounded particles are most effective in removing brittle coatings such as mill scale, whereas angular or irregular shaped particles are more effective in removing softer coatings such as rust and paint.

7.3.4 Specific Gravity: The higher the specific gravity, the more energy a given abrasive particle size will impart to the surface on impact, thereby increasing productivity. Generally, a higher specific gravity implies a higher bulk density.

7.3.5 Nozzle Pressure: The higher the nozzle pressure, the more productive the blast operation. For example, for each 7 kPa (1 psi) increase there is a 1.5% increase in productivity. Most equipment for dry abrasive blasting has a practical upper limit of 1000 kPa (150 psi). However the most common range of pressure is from 90 to 110 psi. Higher pressures will take a physical toll on the blaster and may end up reducing productivity. See Section 7.5.3 for more information on blasting at pressures above 110 psi.

7.3.6 Nozzle Type: It is important to choose the right nozzle for the job. For example, straight bore nozzles create a tight blast pattern that is best suited for blast cleaning small areas such as hand rails, weld seams, etc. Venturi-bore nozzles create a wide blast pattern and are best suited for large area blast cleaning. Venturi bore nozzles increase nozzle velocity by as much as 100% and therefore are 35% more efficient when compared to straight bore nozzles of the same diameter.

7.3.7 Nozzle to Surface Distance: For optimum cleaning rate, the nozzle-to-surface distance should be about 46 cm (18 in). However, this distance can vary depending on the type of surface contamination being removed, nozzle pressure, and abrasive and nozzle type.

7.3.8 Nozzle Travel Speed: Dwell time required to achieve a given degree of cleanliness is dependent upon the initial surface condition (hardness/thickness of coating, amount of rust scale, etc.).

7.3.9 Impact Angle: An 80-to-90 degree angle is best suited for removing mill scale or heavy rust and for cleaning pitted areas; a 45-to-60 degree angle is best for peeling heavy layers of paint or rust; a 60-to-70-degree angle is recommended for general cleaning. Operator technique in controlling the motion of the nozzle determines the impact angle at any instant.

7.3.10 Abrasive Metering: Each abrasive type has a different optimum flow rate through the metering valve. Before starting any blast cleaning job, it is important to conduct a test blast with the metering valve set at lean, moderate, and high abrasive flow rates to find the optimum flow for the given abrasive.

7.3.11 Abrasive Cleanliness: A clean, dry, dust-free abrasive is essential for optimum productivity. Check the abrasive before starting a job and regularly thereafter for foreign matter, moisture, and dust.

7.3.12 Embedment: Some abrasive products, particularly non-metallics, tend to embed in the blast-cleaned surface. Conduct a test blast with the abrasive and evaluate the blast-cleaned surface to be sure the amount of embedment does not exceed the job specification requirements.

7.4 ABRASIVE TYPES: Abrasives can be divided into two major categories: metallic, generally ferrous, abrasives and non-metallic abrasives. The non-metallic abrasives can be further subdivided into naturally occurring, by-product, or manufactured abrasives.

7.4.1 Metallic Abrasives: Steel shot consists of nearly spherical particles of steel obtained by granulating a molten stream of metal with water, air, etc. Steel shot will generally conform to SSPC-AB 3 "Ferrous Metallic Abrasive" in terms of hardness, chemical composition, size, and microstructure.

Cast steel grit consists of angular particles produced by crushing steel shot (SAE J827). Steel grit is available in a wide range of hardness, from 30 to 65 on the Rockwell C scale (R_c) produced by varying the tempering time cycles to which the grit is subjected. Generally, three hardness ranges are most commonly produced: 40 to 50 R_c, 55 to 60 R_c, and 60 to 65 R_c. The first two hardness ranges are used for structural steel.

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[95] ASTM D7127 Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument. ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[96] "Peak Performance from Abrasives," Hugh J. Roper, Raymond E.F. Weaver, and Joseph H. Brandon, *Journal of Protective Coatings and Linings*, vol. 22, no. 6, June 2005.

and the latter is used primarily for selective application where deep, consistent, sharp etched finishes are required, or where moderate etches on extremely hard surfaces are needed.

In addition to steel shot and grit, iron grit may also conform to SSPC-AB 3. Iron abrasive is characterized by high carbon content and hardness typically over 55 R_c. The particle shape requirements for iron grit are less stringent than those for steel grit.

Iron abrasive cannot be recycled as many times as steel abrasive, but it can be recycled many more times than non-metallic abrasives. Iron abrasive is also less costly to purchase than steel abrasive. In situations where full recovery is not possible, such as a bridge containment, iron abrasive has an economic advantage over steel abrasive. Steel abrasive is more cost effective in centrifugal wheel machines in a shop.

Metallic shot will produce a peened surface texture, whereas grit produces more of an etched surface texture. The etch becomes more pronounced with increasing abrasive hardness.

Typical applications of various steel abrasives, referring to rust condition classifications described in Section 4.1, are:

- **Shot:** Commonly used on new steel (rust conditions A and B) to remove mill scale with centrifugal wheel machines.
- **Grit (40-50 R_c):** Most effective on rust conditions C and D, but also commonly used for rust conditions A and B.
- **Shot/Grit Mixture (Shot 40-50 R_c/Grit 55-60 R_c):** Used on new steel to remove both mill scale and rust. Shot/grit mixes demand careful attention and close control of abrasive additions to maintain the shot/grit ratio.

7.4.2 Non-Metallic Abrasives: Non-metallic abrasives can be categorized as naturally occurring, by-product, or manufactured. Naturally occurring abrasives include silica sand, olivine sands, staurolite and other minerals, flint, garnet, zirconium, and novaculite. By-product abrasives include those from smelters (nickel or copper slag) and utility generators (coal or boiler slag) and those from agricultural products (walnut shells, peach shells, or corncobs). Manufactured abrasives include silicon carbide, aluminum oxide, and glass beads.

Commonly used non-metallic abrasives for surface preparation of steel to be painted include silica sand, coal and smelter slags, staurolite, olivine, and garnet. Some countries have banned the use of abrasives with a high free-silica content because of possible health hazards. The U.S. Navy specification MIL-A-22262, "Abrasive Blasting Media, Ship Hull Blast Cleaning" allows the maximum crystalline silica content of the abrasive to be 1.0% by weight. This level of silica corresponds to a Class A abrasive as described in SSPC-AB 1, "Mineral and Slag Abrasives."

7.5 BLAST EQUIPMENT: For the most economical production, the appropriate blast cleaning equipment must be used.

7.5.1 Conventional Blasting: Air abrasive blasting equipment has five basic components: air compressor, air hose, blasting machine (blast pot), blast hose, and nozzle. The compressor must be large enough to supply the volume of air needed at the correct pressure. This depends on factors such as nozzle size, number of nozzles, and length and size of air hose. Nozzles are available in several lengths, designs, sizes of openings, and lining materials. Nozzle lengths of 13 to 20 cm (5 to 8 inches) are generally used for removing tightly adhering rust and scale. Shorter nozzles 8 cm (3 in) or less are more appropriate for use behind beams and in other areas difficult to access using full range of motion.

Where shop cleaning of steel is possible, centrifugal wheel blasting units using recyclable steel abrasive are the most economical.

7.5.2 Vacuum Blasting: Vacuum blast cleaning is less productive than conventional blast cleaning and therefore is typically used for small localized areas. Vacuum blast cleaning can achieve the highest levels of surface preparation while minimizing worker exposure to emissions of dust and debris. The tools must be properly operated and fitted with the appropriate shroud in order to maintain the seal between the blast nozzle and the substrate. Compressed air is used to propel abrasive particles against the surface to be cleaned. The blast nozzle is fitted into a localized containment assembly (surrounding the nozzle only) that is equipped with a vacuum. Dust, abrasive, and old paint are sent to a recycler. The cleaned abrasive is returned for re-use. Aluminum oxide or metallic abrasives such as iron or steel grit or steel shot are commonly used.

7.5.3 Abrasive Blast Cleaning Above 760 kPa (110 psi): Over the last several years many blast cleaning operators have been developing techniques that will allow them to blast clean at nozzle pressures greater than 760 kPa (110 psi). The primary driving force has been dramatic increases in productivity. For every 7 kPa (1 psi) increase in nozzle pressure there is a 1.5% increase in productivity. For example, going from 690 to 760 kPa (100 to 110 psi) is a 10% increase in nozzle pressure but a 15% increase in productivity. Going from 690 to 860 kPa (100 to 125 psi) results in a 38% increase in productivity.

Another important advantage of higher nozzle pressures is the ability to use finer abrasives to achieve a given profile. Using finer abrasives means more abrasive impacts per unit time, which translates into faster cleaning and higher productivity. Steel or iron abrasives are recommended for high-pressure blasting because they do not break down at these elevated pressures. When using non-metallic abrasives at elevated pressures, much of the energy imparted to the abrasive particles is dissipated in the pulverizing of the abrasive particles, thus reducing cleaning efficiency and dramatically increasing dust levels.

7.5.4 Centrifugal Blast Cleaning: A blast cleaning process (usually enclosed) that uses rotating, motor-driven, bladed wheels to hurl abrasive (usually steel shot, steel grit, or a shot/grit mixture) at the surface being cleaned. The abrasive

TABLE 5
PHYSICAL DATA ON NON-METALLIC ABRASIVES

Naturally Occurring Abrasives	Hardness (Mohs)	Shape	Specific Gravity	Bulk Density		Color	Free Silica (wt %)	Degree of Dusting	Reuse
				lb/ft³	kg/m³				
Silica Sand	5	Rounded	2 to 3	100	1600	White	90+	High	Poor
Heavy Mineral Sand	5 to 7	Rounded	3 to 4	25	2000	Variable	<5	Medium	Good
Flint	6.5 to 7	Angular	2 to 3	80	1300	Light Gray	90+	Medium	Good
Garnet	8.5	Angular /Blocky	4	145	2300	Pink/Brown	Nil	Low	Good
Zircon	7.5	Cubic	4	185	3000	White	Nil	Low	Good
Kasarda	3.5	Angular	2.6	90	1400	White	Nil	Medium	Poor
Novaculite	4	Angular	2.5	100	1600	White	90+	Low	Good
				By Product Abrasives					
Boiler Slag	7	Angular	2.8	85	1400	Black	Nil	High	Poor
Copper Slag	8	Angular	3.3	110	1800	Black	Nil	Medium	Fair
Nickel Slag	8	Angular	2.7	85	1400	Green	Nil	High	Poor
Walnut Shells	3	Cubic	1.3	45	720	Brown	Nil	Low	Poor
Peach Shells	3	Cubic	1.3	45	720	Brown	Nil	Low	Poor
Corn Cobs	4.5	Cubic	1.3	30	480	Tan	Nil	Low	Good
				Manufactured Abrasives					
Silicon Carbide	9	Angular	3.2	105	1700	Black	Nil	Low	Good
Aluminum Oxide	8	Blocky /Angular	4.0	120	1900	Brown White	Nil	Low	Good
Glass Beads	5.5	Spherical	2.5	100	1600	Clear	67	Low	Good
Crushed Glass	6 to 8	Irregular	2.5	68 to 81	1000-1500	Gray	67	Low	Poor
Sodium Bi-carbonate	2.5	Powder	2.2	60	960	White	Nil	None	Poor
Sponge	0.018	Granular	0.29-1.45	5 to 25	80 to 400	Various	Nil	Low	Good
Plastic Beads	3.5	Blocky		55	300	Various	Nil	Low	Fair
Dry Ice	Nil	Cylinder	92.4	50	800	White	Nil	Low	Poor

material is fed to the center of the wheel and then onto blades that radiate from the hub. Centrifugal force produced by the turning wheel accelerates the abrasive to the ends of the blades from which it is thrown against the surface.

8. Summary of SSPC Abrasive Standards

8.1 SSPC-AB 1, "MINERAL AND SLAG ABRASIVES:" This standard defines the requirements for selecting and evaluating non-metallic mineral and slag abrasives used for blast cleaning steel and other surfaces for painting. The standard defines two types: 1) natural mineral abrasives, including sand, flint, garnet, staurolite, and olivine; and 2) by-product abrasives, such coal, copper and nickel slags, or manufactured media such as aluminum oxide. The abrasives covered by the standard are primarily intended for one-time use without recycling.

The abrasives are also classified based on the crystalline silica content and the profile produced by the abrasive. The surface profile is determined by a blasting test conducted on 60 cm x 60 cm (2 ft by 2 ft) steel plates. In order to meet SSPC-AB 1, a non-metallic abrasive must also meet minimum requirements for specific gravity, hardness, weight change on ignition, water-soluble contaminants, moisture content, and

TABLE 6
SSPC DEFINITIONS OF WATER CLEANING AND WATERJETTING

Low-Pressure Water Cleaning (LP WC)	Less than 34 MPa (less than 5,000 psi)
High-Pressure Water Cleaning (HP WC)	34 to 70 MPa (5,000 to 10,000 psi)
High-Pressure Waterjetting (HP WJ)	70 to 210 MPa (10,000 to 30,000 psi)
Ultrahigh-Pressure Waterjetting (UHP WJ)	Over 210 MPa (over 30,000 psi)

oil content. For a given abrasive type, the surface profile is determined by the size and shape of the abrasive particles. The abrasive supplier is required to furnish a representative sieve analysis of the abrasive used in the profile determination. This sieve analysis is used to determine the typical particle size distribution for subsequent delivery of the abrasive. Additional information on physical properties of non-metallic abrasives is given in Table 5.

8.2 SSPC-AB 2, "CLEANLINESS OF RECYCLED FERROUS METALLIC ABRASIVES:" This standard gives the cleanliness requirements for recycled work mix ferrous metallic abrasives. The limits and test methods are given for non-abrasive residue, lead content, water-soluble contaminants, and oil content.

8.3 SSPC-AB 3, "FERROUS METALLIC ABRASIVE:" This standard defines the physical and chemical requirements for steel and iron abrasives. Abrasive size is determined by sieve analysis. Abrasive shape, divided into shot or grit, is determined by the percentage of round and elongated particles in a sample. The minimum specific gravity is 7.0 for steel abrasive and 6.8 for iron abrasive. A specified percent of the abrasive must be retained on the appropriate take-out screen after 100 cycles in a durability test. Properties include requirements for carbon, manganese, and phosphorous content as well as conductivity and cleanliness.

8.4 SSPC-AB 4, "RECYCLABLE ENCAPSULATED ABRASIVES:" This standard provides performance and acceptance criteria for recyclable encapsulated abrasives (cutting media surrounded by sponge). In addition to containing requirements for new media, AB 4 contains requirements for reused media, limiting conductivity and oil contamination, as well as ensuring the classifier is functioning effectively.

9. Wet Abrasive Blast and Waterjet Cleaning Methods

Methods of coating removal that involve water may or may not include abrasive. Several wet abrasive blast methods are described in SSPC-TR 2/NACE 6G198, "SSPC/NACE Joint Technical Report, Wet Abrasive Blast Cleaning." The joint consensus reference photographs are contained in SSPC VIS 4/NACE VIS 7, "Guide and Consensus reference Photographs for Steel Surfaces Prepared by Waterjetting." SSPC and NACE restrict the terms "blast" or "blasting" to refer to processes that involve abrasives. If no abrasives are present, the preferred terms are cleaning or jetting.

In the past, the term "water blasting" has generically referred to the use of 34 to 170 MPa (5,000 to 25,000 psi) water for cleaning where abrasives may or may not be added. In SSPC terminology, the term "water blasting" indicates that an abrasive has been added to the water stream. It is not used as a defined term in either wet abrasive blast or waterjet cleaning documents. Other common terms used for waterjet cleaning are: "water jetting," "water blast cleaning," "hydrojetting," "aquajetting," "hydroblasting," "aquablasting," "and cleaning by directing a jet of pressurized water onto the surface to be cleaned.". "Waterjetting" has been replaced by "Waterjet Cleaning" in NACE and SSPC documents; ISO continues to use "Water Jetting."

The definitions of low, high, and ultra-high pressure and the use of "cleaning" instead of "jetting" are based on the nozzle pressure and are related to the water velocity. Pressures below 34 MPa (5,000 psi) are defined as low; pressures above 34 MPa (5,000 psi) are defined as high pressure. The term "jetting" is used when the velocity of the water exceeds 335 meters per second (m/s) [(1100 feet per second (ft/s)]. That condition occurs around 70 MPa (10,000 psi). The reader is cautioned that different sectors may use the terms "low, medium, or high" at other levels or velocities. For example ASTM E1575 "Standard Practice for Pressure Water Cleaning and Cutting" uses the term "high" for anything above 6.9 MPa (1000 psi). See Table 6.

9.1 WATER CLEANING AND WATERJET CLEANING (WITHOUT ABRASIVE): Waterjet cleaning is used for maintenance or rehabilitation when the substrate has been previously profiled and coatings, or the surface, are rusted. It reveals the substrate under the coating. Unlike abrasive blast cleaning, a new profile is not produced. Waterjet cleaning is used on many ferrous and non-ferrous metals. Contaminants can be removed from a surface with water at pressures from 0.1 to over 300 MPa (15 psi to 45,000 psi). Water cleaning in its most general sense is simply removal of surface contaminants such as dirt, soil, and salts from a surface with liquid water.

9.1.1 Degrees of Cleaning: Four SSPC/NACE Joint Surface Preparation Standards for Waterjet Cleaning of Metals define four degrees of visual cleaning (WJ-1, WJ-2, WJ-3 and WJ-4) based on the amount of VISIBLE contaminants remaining on the surface. The waterjetting standards do not relate water pressure nor volume to the degree of visual cleaning.

The assessment process is 1) assess the surface, often when it is still wet, for the degree of cleanliness, then 2) assess the amount of flash rust prior to paint application.

The appearance of a surface cleaned by water can differ from that of a surface cleaned by abrasive blasting. If the coating to be removed is intact, the resultant surface will look like the original blasted surface, but darker and dull. If the coating is breached or there is rust to be removed, the surface can be mottled or very non-uniform. Every defect is revealed. The surface can show variation in texture, shade, color, tone, pitting, or flaking.

The gray to brown-black discoloration remaining on corroded and pitted carbon steel that cannot be removed by further waterjet cleaning is allowed. This discoloration is generally found under corroded area, or might be present over large substrate areas where the coating is still intact but has been exposed to salt water long enough for the water to permeate the coating and cause corrosion under the coating.

Because water cleaning and waterjetting are used in maintenance cleaning, not on new steel, the coating manufacturer should be contacted for details of coating performance over residual paint, rust, and mill scale.

Water alone, under various pressures, can be used to remove coating materials, water-soluble surface contaminants, rust, cement spatter, and surface grease and oil. It cannot efficiently remove light mill scale or tightly adherent magnetite within a visible, economic time frame. The contractor should test an area if mill scale is thought to be present under the existing coatings. Waterjet cleaning is effective in removing abrasion resistant coatings, rubber, elastomeric coatings, tape wrap, and fiberglass coatings. Caution should be exercised if there are electrical lines or insulation in the vicinity of the activity to avoid getting water under insulation or cutting live electrical circuits.

9.1.2 Non-visible Contaminants: Water cleaning and waterjetting can remove soluble salts. Salts can adversely affect coating performance by causing underfilm corrosion or osmotic blistering. Some claim it may be useful to add a salt remover or rinse aid to achieve the desired cleanliness. It is necessary to rinse from the surface any product used in cleaning to achieve the desired level of cleanliness. In all cases, it is recommended that surfaces be tested for non-visible contaminants after washing and prior to coating to ensure compliance with recommended guidelines or specified limits.

9.1.3 Profile: Because waterjetting does not provide the anchor pattern needed for coating adhesion, water cleaning or waterjetting is used primarily for recoating or relining projects where there is an adequate preexisting profile. Waterjet cleaning reveals the profile that is under the paint or rust layer.

9.1.4 Precleaning: Typically, high-pressure or ultra-high pressure waterjet cleaning is sufficient to remove oil and grease at the same time it is being used to clean the surface for recoating. Power washing with water only might not remove oil and grease. It is also not recommended to attempt to remove a heavy layer of soft float coat or greasy material with water. Scraping the thick grease/oily layer, or using an emulsifier with water would be a more efficient pre-cleaning choice.

9.1.5 Water Consumption: Low-pressure water cleaning (LP WC) is often called pressure washing or power washing. Pressure washing of an existing coating is done to remove salts and surface contaminants (chalk, dirt, etc.) prior to "cleaning" the surface for painting. Cleaning steel for coatings can be achieved with water pressures as great as 300 MPa (45,000 psi) or above and water volumes of only 6 to 55 liters (1.5 to 15 gallons) per minute. While pressures up to 700 MPa (100,000) psi are used commercially under controlled situations an upper limit of 340 MPa (50,000 psi) is typically being used in field cleaning equipment designed for the coatings industry. Caution

TABLE 7
TYPICAL PRESSURIZED WATER SYSTEMS

Pressure at Nozzle	**68 MPa (10,000 psig)**	**140 MPa (20,000 psig)**	**270 MPa (40,000 psig)**
Number of Tips	2	2	5
Diameter	1.02 mm (0.040 in.)	0.686 mm (0.027 in.)	0.28 mm (0.011 in.)
Flow	12.96L/min (3.42 gpm)	8.33 L/min (2.2 gpm)	1.96 L/min (0.517 gpm)
Cross-Sectional Area	0.811 mm² (0.0013 in.²)	0.369 mm² (0.0006 in.²)	0.0613 mm² (0.0001 in.²)
Jet Velocity	363 m/s (1,190 ft/s)	522 m/s (1,700 ft/s)	738 m/s (2,400 ft/s)
Impact Force (per tip)	8.1 kg (17.8 lb)	7.3 kg (16.7 lb)	2.4 kg (5.3 lb)
Jet Energy	142 kJ (134 BTU)	189 kJ (179 BTU)	96 kJ (91 BTU)
Energy Intensity (energy/ cross-sectional area)	175 kJ/mm² (107,000BTU/in.²)	512 kJ/mm² (314,000 BTU/in.²)	1,450 kJ/mm² (887,000BTU/in.²)

must be maintained with water cleaning or waterjetting to avoid injuries to personnel and structures. Table 7 shows that there is less water consumption at higher pressures, since reducing the diameter of the orifice increases the water pressure.

9.1.6 Equipment: Vacuum shrouds, remote controls, filtration, and collection, in both manual and non-manual systems, are available. The water stream can be combined with a vacuum system to remove the water from the surface immediately, thereby preventing flash rust. After filtration the water is then recycled. If effluent jetting water is captured for reuse in the jetting method, caution should be used to avoid introducing any contaminants back onto the cleaned substrate. Dust emissions are low because the particulates are wetted and do not disperse in the atmosphere. The environmental risk is low as long as the water is properly contained or collected. The rate of coating removal can approach or exceed that of dry abrasive blasting depending on the coating system and the complexity of the structure and project.

9.1.7 Flash Rust: Levels of flash rusting are defined in SSPC-VIS 4/NACE VIS 7, "Guide and Consensus Reference Photographs for Steel Surfaces Prepared by Waterjetting." Flash rust and rust bloom are evaluated separately from visual cleanliness prior to recoating. If the surface is cleaned by waterjetting, uniform rust bloom may not be a problem provided the desired non visible cleanliness is achieved and verified by testing. Section 4.5 provides a more thorough discussion of flash rusting and rust bloom.

Flash rust should be mitigated in accordance with the requirements of the procurement documents. It is common practice to remove heavy flash rust by low-pressure water cleaning (LP WC), high-pressure water cleaning (HP WC), or dry abrasive sweep blasting.

The predominant factor in controlling flash rust is to control the time of wetness.

9.1.8 Surface Preparation Water: Water used in surface preparation should not contain grit or sediments that could clog the orifice. It should also be of sufficient purity and quality that it will not prevent the surface being cleaned from achieving the specified degree of surface cleanliness or non-visible contaminant criteria. Typically potable water is used. UHP WJ equipment may contain a pre-filter to remove solids and a low-pressure pump to ensure an adequate water supply to the UHP pump.

9.1.9 Factors in Determining Production Rates: Factors that control the rate and degree of coating removal are: pressure (velocity), flow rate (volume), transverse rate (or dwell time), stand-off distance, and choice of nozzle and number of orifices, as well as rotating versus stationary nozzles, coherent flow or interrupted, pulsed flows.

As a general rule, production and ease of removal of the total paint system increase as the waterjetting pressure increases.

Cleanup time to remove waste material should be considered when determining the overall production rate.

There are two thoughts on increasing production rates during the removal of materials by pressurized water. First, determine the threshold pressure at which the material will be removed. The user can then either increase the flow to achieve adequate production rates or increase the pressure by a factor no greater than three over the threshold pressure. These two methods do not necessarily yield the same result.

Characteristics of typical pressurized water systems are included in Table 7.

In field terms, the 68-MPa (10,000-psig) jets might not significantly erode the coatings. Therefore, they are typically used for partial removal or for cleaning loose detrital material. The 140-MPa (20,000-psig) jets erode the coatings fairly rapidly and are typically used for partial removal. The 270 MPa (40,000-psig) jets erode and destroy coatings very fast and are typically used when most or all of the coating is to be removed (WJ-1 or WJ-2).

Operators or users who make the decisions concerning water cleaning or waterjetting pressure must decide between:

(a) HP WC (the water's flow rate is the predominant energy characteristic);

(b) HP WJ (pressure [i.e., the velocity of the water] and flow rate are equally important); or

(c) UHP WJ (the pressure [i.e., the velocity of the water] is the dominant energy characteristic)

9.2 WET ABRASIVE BLAST CLEANING: Wet abrasive blast (WAB) cleaning is performed using a mixture of water, air, and abrasives. The abrasive media will create a surface profile on the substrate. The water wets the abrasive and helps to substantially reduce dispersion of fine particulates (dust) created by the breakup of the abrasives, surface corrosion products, and existing coatings. In some of the WAB cleaning systems, the water stream is sufficient to reduce or completely remove water-soluble surface contaminants.

Other generic terms used to describe specific WAB cleaning systems are: "water shroud," "wet-head blasting," "water-enclosed abrasive blasting," "wet blasting," "low-volume water/abrasive blasting," "slurry blasting," "abrasive waterjetting" (AWJ), or "abrasive injected waterjetting/blasting" (AIWJ or AIWB).

WAB cleaning is a process using a mixture of water and abrasive that can produce various levels of surface cleanliness and surface profile (roughness) similar to those obtained with dry abrasive blast (DAB) cleaning. It can be used for new built and for maintenance. WAB cleaning may be specified when dust suppression is desired, and may also be a means for reducing soluble salt contamination. The WAB cleanliness level specified should be the same as the corresponding degree of cleaning specified if DAB cleaning were the process being used. In some of the systems, water aids in the removal of visible and non-visible material.

Each configuration can remove both visible and non-visible contaminants from the surface. Variations in cleaning efficiency exist with each of the referenced WAB configurations. The efficiency and degree to which each configuration cleans the subject surface is dependent on many factors including, but not limited to, the knowledge and expertise of the operator.

WAB cleaning systems are classified as (1) modifications of dry abrasive blast systems to introduce water and (2) modifications of water blast systems to introduce abrasive. WAB cleaning systems are also classified as (1) systems where the abrasive and water are mixed near the nozzle; and (2) systems in which the abrasive and water mix is transported through a hose. A conventional dry abrasive blast-cleaning nozzle with a water curtain around the perimeter may also be used to perform WAB cleaning.

The system processes thus range from mostly abrasive with a small amount of water to mostly water with a small amount of abrasive.

In March 2016, SSPC and NACE released five standards for wet abrasive blast cleaning. These standards are:

- SSPC-SP 7 (WAB)/NACE WAB-4, Brush-Off Wet Abrasive Blast Cleaning
- SSPC-SP 14 (WAB)/NACE WAB-8, Industrial Wet Abrasive Blast Cleaning
- SSPC-SP 6 (WAB) /NACE WAB-3, Commercial Wet Abrasive Blast Cleaning
- SSPC-SP 10 (WAB) /NACE WAB-2, Near-White Wet Abrasive Blast Cleaning
- SSPC-SP 5 (WAB) /NACE WAB-1, White Metal Wet Abrasive Blast Cleaning

These standards combine elements of the existing standards for dry abrasive blast cleaning with elements of the 2012 SSPC/NACE waterjet cleaning standards. As indicated by the SSPC alphanumeric designations and titles, the definitions of cleanliness for the steel surface immediately following wet abrasive blast cleaning are identical to the definitions in the five dry abrasive blast cleaning standards. However, because water is used to convey the abrasive onto the surface, a layer of flash rust will form on the cleaned steel as the water evaporates. Due to the varied tolerance of coatings for the presence of flash rust on the surface, it is important that the contractor know the maximum permissible level of flash rust that may be present on the steel immediately prior to the application of the protective coating, and how to assess how much flash rust has developed. The wet abrasive blast cleaning standards define four levels of flash rust: no flash rust, light flash rust; medium flash rust; and heavy flash rust. These definitions are based on the extent to which the flash rust obscures the underlying steel substrate, the ease with which it can be removed by wiping with a cloth, and the amount of material that appears on the cloth after the surface is wiped.

As with the waterjetting standards and the dry abrasive blast cleaning standards, the wet abrasive blast cleaning standards also include information on materials and methods used to perform the cleaning process. For example, the water used must be free of contaminants that would affect the cleanliness of the prepared surface, as well as the functioning of the pumps or other equipment. If the project specification includes specific requirements for non-visible contaminants, the water used for wet abrasive blast cleaning must be free of impurities that could prevent the surface from meeting those requirements.

9.2.1 Visual Appearance: The assessment process is (1) to assess the surface, often when it is still wet, for the degree of cleanliness; (2) to assess the amount of flash rust present immediately prior to paint application.

The visual appearance of wet abrasive blasted surfaces is not necessarily the same as the visual appearance of dry abrasive blasted surfaces. Inspectors should exercise care and judgment. SSPC-VIS 5/NACE VIS 9, "Guide and Consensus Reference Photographs for Steel Surfaces Prepared by Wet Abrasive Blast Cleaning" contains reference photographs of WAB-cleaned surfaces. Acceptable variations in appearance that do not affect surface cleanliness include variations caused by type of steel, original surface condition, thickness of the steel, weld metal, mill or fabrication marks, heat treating, heat affected zones, blasting abrasives, and differences due to blasting technique.

Surfaces cleaned by wet abrasive blasting typically appear darker and duller in appearance than surfaces cleaned with the same abrasive in dry abrasive blasting. Wide variations in appearance can be observed among abrasives within a given generic class. See SSPC-VIS 1 for illustrative photographs for dry blasting.

When the surface is still damp or wet, it will appear darker and defects and variations in shading are magnified. As the surface dries, streaks will form, which are not necessarily depicted in small unit size photographs, but which can be clearly seen on larger areas. The effects of streaking and flash rust are referenced in SSPC-VIS 5 and SSPC-VIS 4.

Flash Rust and Rust-Back: WAB systems can develop both flash rust and rust back. The type and the quantity of rust depend greatly on the amount of abrasive and water in the cleaning stream (see Section 4.5)

Flash Rust: Steel surfaces prepared by WAB cleaning can develop flash rust within minutes after the cleaning is completed. The project specification often contains requirements for the permissible level of flash rust prior to coating application.

Flash rust shall be mitigated in accordance with the requirements of the procurement documents. It is common practice to remove heavy flash rust by low-pressure water cleaning (LP WC), high-pressure water cleaning (HP WC), or dry abrasive sweep blasting.

The key to the amount of flash rust that forms on a surface is the length of time the surface remains wet and the quality of the water being used. Wetted abrasive should be removed from the substrate after blasting. This is frequently accomplished using low-pressure water cleaning (LPWC).

Rust-Back: WAB cleaning systems can also develop Rust Back. If Rust back occurs after the cleaned surface has dried and before paint application, it should be handled in the same manner as dry abrasive cleaning. If rust-back is a concern, an inhibitor can be added to the water. Sometimes a soluble salt remover is also added to the water. The coating manufacturer should confirm that the use of additives in the water will not affect coating performance.

9.2.2 Air/Water/Abrasive Blasting: Air/water/abrasive blasting is a cleaning method in which water is injected into the air/abrasive stream generated by conventional air-pressurized abrasive blasting equipment, or in which the premixed abrasive/water combination is forced into the blast air stream generated by a conventional air compressor. Other generic terms to describe specific air/water/abrasive blast cleaning methods are water shroud blasting, wet-head blasting, wet blasting, low volume water abrasive blasting, water induction nozzle (WIN), and slurry blasting.

The equipment used for this type of wet abrasive blasting generally consists of conventional dry abrasive blasting equipment supplemented with modules to inject water into the abrasive stream, or specialized equipment that creates an abrasive/water slurry that is forced into the compressed blast air stream. Several methods exist for introducing water into the air stream. With radial water injectors (water rings), water-induced nozzles, and coaxial water injectors, water is injected near the blast nozzle.

9.3 CORROSION INHIBITORS AND SALT REMOVERS: To some extent, the surface preparation industry does not always distinguish clearly between rust inhibitors and salt removers. If salts are removed, the corrosion rate is reduced because the strength of the electrolyte in the corrosion cell is decreased. An inhibitor generally retards the reaction of oxygen or oxidizing agents with iron. Inhibitors and/or soluble salt removers can be added to the pressurized cleaning water or to a rinse water to temporarily prevent rust formation.

The formation of visible rust can be temporarily delayed by adding corrosion inhibitors or other additives to the SP water or applying them to the surface immediately after WAB cleaning. The coatings manufacturer should be consulted to ensure that the proposed inhibitor or additive will not interfere with the performance of the coating system. Environmental and health concerns have prompted changes in the chemistry of rust inhibitors. Their chemical components include polyphosphates, volatile amines, benzoates, nitrites, surface tension reducers, organic acids, chelating agents, and other proprietary compounds. These can also be included in the formulation of water-borne paints to reduce rust bloom. Additives containing soluble salts or film formers, while providing short-term protection, can adversely affect the long-term performance of the coating system.

Chemical rinse aids range from very acidic to neutral to basic. The product literature normally focuses on the perceived benefits of the materials, and not on the chemistry. The safety data sheet will generally list the pH.

If an additive is used in the water, it is imperative that the coating manufacturer be queried about the compatibility of the coating with the water additive, such as an inhibitor or soluble salt remover. Some coatings manufacturers will accept the compatibility process in ASTM D5367, "Practice for Evaluating Coatings Applied over Surfaces Treated with Inhibitors Used to Prevent Flash Rusting of Steel When Water or Water/Abrasive Blasted." Other coatings manufacturers prefer their own in house test methods. At the present time many coatings manufacturers prefer placing their coatings over a clean, light flash rust whose origin is not in question rather than adding the uncertainty of an inhibitor, chemical rinse aid, or soluble salt remover.

10. Other Cleaning Methods

10.1 CHEMICAL STRIPPING: Paint strippers are frequently used to remove paint from industrial structures. Alkaline strippers are more effective in removing oil-based paints, and solvent strippers are more effective in removing latex paints. It may be necessary to use both types to strip alternating layers of oil and latex coatings from a surface. Strippers usually contain a thickener to provide more contact time for solvent or chemical attack on the paint. Some are covered with a sheet of plastic to increase the contact time. Chemical stripping is one method of removing old, lead-containing paint.

An alkaline-(caustic) based or solvent-based chemical stripper is applied to the surface using trowels, brushes, rollers, or spray. After the specified dwell time, the stripper is removed with scrapers, although water cleaning or ice blasting can be used. Mill scale and rust are not removed, and a profile is not generated, but an existing profile can be restored.

Another class of chemical strippers is selective adhesion release agents (SARA) based on alcohol hydroxycarboxylic acid peroxide (AHP). These are slow acting but are environmentally friendly. A permeable cloth can be placed on the ground at the base of the structure to collect the paint debris, while the stripper can be absorbed into the ground. SARA strippers do not work well on highly cross-linked Novolac epoxies, rigid urethanes, and vinyl esters, but they are useful in removing alkyds, latexes, polyurethanes, epoxy esters, and amine and polyamide epoxies.

The specific type of stripper must be selected based upon the generic type of the existing coating system as well as health, safety, and environmental concerns. Some of the strippers require a minimum four hours set time while others may require two full days. In addition, many of the solvent strippers involve chemical reactions that generate heat. This heat must be contained in order for the chemical reaction to continue, which may require covers if ambient temperatures are too low. Many paint strippers are available for the complete immersion of painted surfaces, but these are generally specialty items.

Once the strippers have performed the desired softening of the existing coating system, they are frequently removed by a scraper. Water cleaning or ice blasting methods increase the volume of waste due to the addition of the water. Even for the removal of non-lead containing coatings, the resulting waste stream may be classified as hazardous due to either the caustic or the solvent component. Information on chemical stripping can be found in the technology update SSPC-TU 6, "Chemical Stripping of Organic Coatings from Steel Structures."

10.2 SODIUM BICARBONATE (BAKING SODA) BLAST CLEANING: This low-dusting method of blast cleaning uses a slurry of water and sodium bicarbonate, a water soluble non-reactive salt, to remove paint from a surface. The portable unit can be wheeled from one location to another. Once in place, the system requires a source of compressed air (typically 600-700 kPa [85-100 psi] at the nozzle), clean water, and drainage. In most cases, special ventilation or dust collection is unnecessary. The operator can vary the angle of attack, standoff, and dwell time to strip the paint layer by layer or all at once.

This blast medium is a formulation of sodium bicarbonate and is free from silica dusts and toxic fumes. The medium is claimed to be effective in:

- removing surface rust from screws and other metal parts without embedding itself into the material being stripped
- removing coatings down to the metal or one layer at a time
- controlling layer removal, allowing for an extra measure of safety when used on galvanized or other specially protected metals
- removing grease, oil, paint, and dirt from flat or contoured surfaces, cooling towers, motor parts, and hard-to-reach equipment parts

This system was developed for removal of aircraft coatings and similar materials from surfaces that do not require "profiling." It also reduces dusting.

For blasting alone, productivity depends on the coating being removed and the degree of cleaning. Removal rates can be as high as 11 m^2/h (120 ft^2/h) for thin deteriorated films. Removal of deteriorated thicker films may be much slower, on the order of 2 to 5 m^2/h (20 to 50 ft^2/h). Intact films may not be dislodged using sodium bicarbonate blasting.

10.3 PLIANT MEDIA BLASTING (SPONGE JETTING): Another low dusting method of cleaning, sponge jetting, involves the use of specialized blasting equipment that propels a manufactured urethane sponge against the surface to be cleaned. The sponge particles are approximately 3 to 6 mm (1/8 to 1/4 inch) in diameter and are available in a mild grade for degreasing and aggressive grades for paint or mill scale removal. The aggressive grades have the sponge formed around an abrasive. Abrasives include staurolite, garnet, and steel grit. SSPC-AB 4, "Recyclable Encapsulated Abrasive Media," contains requirements for recycling this material.

The productivity is lower than traditional abrasive blast cleaning (30-50% of the productivity), but typically will be higher than power tool cleaning to bare metal and vacuum blast cleaning. White metal quality of preparation is possible and a surface profile of approximately 50 micrometers (2 mils) can be achieved. The dust generated is low because the cells of the sponge help to suppress the dust, and the paint tends to be dislodged in larger chips rather than being pulverized, as is the case with traditional abrasive blast cleaning.

10.4 CARBON DIOXIDE (DRY ICE) BLASTING: In this dust free method, liquid carbon dioxide is formed into pellets of dry ice using specialized equipment. The CO_2 pellets are approximately the size of rice. The pellets are conveyed through a blast hose using compressed air in a manner similar to open abrasive blast cleaning. The pellets exit through a specialized nozzle assembly.

An advantage of CO_2 blasting is a reduction in the volume of debris created as the abrasive sublimes upon use. As a result, the waste involves only the paint being removed. Carbon dioxide is also non-conductive and will not create a spark, and therefore can be considered for use in areas where any sparking is unacceptable.

Disadvantages are that the abrasive does not appear to be hard enough to productively remove heavy coatings, rust, or mill scale. More than just stains of old primer will remain on the surface. Tight coatings are difficult to remove without frosting the surface. The equipment is also expensive.

10.5 ELECTROCHEMICAL STRIPPING: By applying cathodic current to a painted metal substrate, electrochemical stripping disbonds the coating. The benign electrolyte is contained in a liquid-absorbent material to which a counter electrode is attached. This combination, often used with a liner, is applied with magnets to the painted steel surface. If the paint is intact it must be scored to initiate current flow. After electrochemical treatment for 0.5 to 2 hours at 8 to 10 volts, the pads are removed and paint fragments are recovered. No particles become airborne, making this method attractive for lead paint removal.

Banks of conducting pads may cover an area up to 14 m^2 (150 ft^2) and can be run simultaneously. This method was developed particularly for application on highway structures to remove lead-based alkyd coatings, but it may be employed for paint removal on other objects.

10.6 LASER STRIPPING: Removal of coatings by pulse-by-pulse laser has continued to develop as a niche market in conservation and preservation. Corrosion products, paint, and radionuclides can be removed. The advantages include portability for small spaces, the use of vacuum to remove all airborne particles, capability to perform layer-by-layer removal, and safe use on many types of substrates. The beam is very focused so that small areas can be cleaned without ancillary damage. However, the focused beam also means that laser stripping is best for small areas.

11. Film Thickness

It is essential that ample coating be applied after blast cleaning to adequately cover and protect the peaks of the surface profile. The method of measuring dry film thickness (DFT) described in SSPC-PA 2, "Procedure for Determining Conformance to Dry Coating Thickness Requirements," takes into account the effect of surface profile so that the measured DFT is approximately the thickness of the coating over the peaks. Thus, the depth of the surface profile should be considered in determining the amount of coating to be applied. For example, if a 50-micrometer (2 mil) DFT is desired, it will require a larger volume of paint to fill the valleys in a 75-micrometer (3 mil) profile than to fill the valleys in a 25-micrometer (1 mil) profile and still have 50 micrometers (2 mils) over the peaks. Because of the existence of rogue peaks, a greater coating thickness may need to be specified when coating deeper profiles.

12. Consensus Reference Photographs

SSPC has developed four sets of reference photographs to supplement its written surface preparation standards, and one set of reference photographs to illustrate various percentages of rust on a painted steel surface. The written standards are the primary means to determine conformance with cleaning requirements, but use of the reference photographs may be specified to assist in determining compliance with the written standard.

12.1 SSPC-VIS 1, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY DRY ABRASIVE BLAST CLEANING:" SSPC VIS 1 contains consensus reference photographs of specimens showing seven initial conditions of uncleaned rusted steel that are progressively cleaned by dry abrasive blast cleaning to illustrate SSPC SP 5, 6, 7, 10 and 14. The appendix of SSPC VIS 1 includes supplementary photographs illustrating steel surfaces cleaned to SSPC-SP 5 (white metal blast cleaning) using various non-metallic and metallic abrasives to show the effect that the type of abrasive media may have on the appearance of a cleaned surface. Additional photographs show the effect of profile height, viewing angle, and diffusion of light.

12.2 SSPC-VIS 2, "STANDARD METHOD OF EVALUATING DEGREE OF RUSTING ON PAINTED STEEL SURFACES:" This standard defines a nine-level rust grade scale which ranges from 10 (up to 0.01% of a given area is rusted) to 0 (the entire area is rusted). Twenty-seven color photographs illustrate each of nine rust grades in the scale (rust grade 0 is not illustrated) in three categories of rust distribution over the surface.

The photographs were subjected to computer analysis to ensure they accurately illustrate the percentage of rust defined in the written standard. For each color photograph, there is a corresponding black and white image showing only the rusted area, to illustrate the effect that rust staining may have on interpretation of the percentage of rust. The written description and the black and white images are identical in content to ASTM D610.

12.3 SSPC-VIS 3, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY HAND AND POWER TOOL CLEANING:" SSPC-VIS 3 contains consensus reference photographs of specimens showing seven initial conditions of uncleaned rusted steel that are progressively cleaned to each of the four levels of hand and power tool cleaning (SSPC-SP 2, 3, 11, and 15). The tools used to clean these surfaces include hand and power wire brushes, sanding discs, and non-woven abrasive discs. Needle guns or rotary flap peen assemblies were used to create the profile in the surfaces cleaned to SSPC-SP 11 and SP 15.

12.4 SSPC-VIS 4/NACE VIS 7, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WATERJETTING:" SSPC-VIS 4 provides consensus reference photographs for six initial rust conditions (pre-blast conditions) and four degrees of cleaning by waterjetting. End conditions corresponding to SSPC-SP WJ-1, WJ-2, WJ-3, and WJ-4 are illustrated using two initial unpainted conditions and four painted conditions. Three levels of flash rusting after cleaning are depicted for two initial rust conditions cleaned to two degrees of waterjetting cleanliness (WJ-2 and WJ-3). SSPC-VIS 4, which contains the color photographs, is a separate publication (SSPC #01-05).

12.5 SSPC-VIS 5/NACE VIS 9, "GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WET ABRASIVE BLAST CLEANING:" SSPC-VIS 5 contains consensus reference photographs of steel specimens in two initial rust conditions (C and D) that have been cleaned to two degrees of wet abrasive blast cleaning (SSPC-SP 6 and SP 10). Three levels of flash rusting after cleaning are depicted for the two initial rust conditions. A revision of this guide is beginning in 2016 to better illustrate the new joint standards for wet abrasive blast cleaning.

12.6 ISO PICTORIAL STANDARDS: The International Organization for Standardization (ISO) in conjunction with Swedish Standards Institution (SIS) has issued a booklet of reference photographs (ISO 8501-1:2007/SIS SS 05 59 00) depicting the appearance of surfaces prepared by hand and power tool cleaning, abrasive blast cleaning (four degrees) and flame cleaning. The methods of cleaning are depicted over various rust grades of unpainted steel. ISO 8501-2 depicts a similar set of surfaces where the substrate was previously painted steel.

12.7 OTHER PHOTOGRAPHIC STANDARDS: The Production Technical Society (Japan) has printed color illustrations of wash primed and zinc-rich primed steel before and after weathering and re-cleaning. The photographs of the Shipbuilding Association of Japan illustrate the appearance of painted, unpainted, welded, and flame-cut steel before and after various degrees of damage or weathering.

British standard BS 7079 Part A1 is equivalent to ISO 8501-1 (unpainted steel) and BS 7079 Part A2 is equivalent to ISO 8501-2 (previously painted steel).

13. Other SSPC and Joint SSPC/NACE Surface Preparation Guides and Reports

13.1 SSPC-TR 1/NACE 6G194, "JOINT TECHNOLOGY REPORT ON THERMAL PRECLEANING:" Thermal precleaning is used in conjunction with other surface preparation methods, such as abrasive blast cleaning, to remove soluble salts from the pits of heavily corroded steel. The oil and gas industry as well as the rail car industry use thermal precleaning extensively. This report describes the parameters used for dry heat and wet heat. It also lists methods for verifying the surface cleanliness.

13.2 SSPC-TR 2/NACE 6G198, "JOINT TECHNICAL REPORT ON WET ABRASIVE BLAST CLEANING:" This document covers procedures, equipment, and materials involved in a variety of air/water/abrasive, water/abrasive, and water-pressurized abrasive blast cleaning systems. Various types of wet blast systems are described and compared. SSPC-TR 2 discusses selection of abrasives, water delivery systems, inhibitors, and equipment operation and maintenance (see Section 9.2.)

13.3 SSPC-TECHNOLOGY GUIDE 15 "FIELD METHODS FOR EXTRACTION AND ANALYSIS OF SOLUBLE SALTS ON STEEL AND OTHER NONPOROUS SUBSTRATES" (2013): This guide describes the most commonly used field methods for the extraction and analysis of soluble salts on steel and other nonporous substrates. It includes fully automated conductivity measurement techniques, multi-step conductivity measurement techniques, and multi-step field methods measuring specific ions.

Laboratory reference methods are included for situations where more complete salt extractions are desired through rigorous laboratory retrieval and analysis protocols. Laboratory methods include boiling and sonic bath extractions, titration for chloride, ion chromatography, and ion selective electrode.

SSPC Technology Guide 15 gives detailed procedures for obtaining a liquid sample and for analyzing it to determine the level of soluble salt. The 1994 and 2002 versions of SSPC-SP 12 defined three levels of soluble salt contamination or non-visible surface cleanliness. These levels have been discontinued in the 2012 WJ standards. However, contractors might see the salt levels referenced in procurement documents. SSPC has established no levels for permissible salt concentrations on substrates. Individual companies and organizations, as well as the coatings manufacturers, have issued levels suitable for different exposure conditions.

13.4 SSPC-TU 6, "CHEMICAL STRIPPING OF ORGANIC COATINGS FROM STEEL STRUCTURES:" This document defines chemical strippers and discusses their use for removing conventional organic coatings from steel structures. Chemical stripping involves application of a chemical to existing paint, allowing it to dwell for a period of time to attack the organic binder, removing bulk paint/stripper residues, and properly cleaning the steel substrate prior to repainting. This technology update describes methods used to identify the type of stripper that will work most effectively, and typical application and removal options. It also presents containment and disposal options for stripper wastes. Chemical stripping is also discussed in SSPC: Vol. 1 Good Painting Practice of the SSPC Painting Manual.

14. Non-SSPC Cleaning Standards

NSRP "RECOMMENDED GUIDELINES FOR EVALUATING FLASH RUST:" This guide was developed by the National Shipbuilding Research Program (NSRP) Surface Preparation and Coatings Panel, NSRP SP-03. It is distributed by SSPC. Several SSPC members and major shipyards in the U.S. provided input for development of the guide. It was reviewed by U.S. Navy inspectors before its publication. The Guide describes a method of wiping the flash rust with a cloth over a brush and has been instrumental in reducing on-site discussion about moderate and heavy flash rust levels.

Timing of Inspection: Flash rust may completely change the appearance of a waterjetted surface from the time immediately after waterjetting is completed to the time of surface evaluation prior to coating. The speed at which flash rust develops is dependent on a number of variables, including the time of wetness, temperature and humidity near the cleaned surface. Regardless of the level of flash rust allowed, all surfaces should conform to the specified degree of cleanliness (WJ-1, WJ-2, WJ-3, or WJ-4) ***before*** flash rust develops. When large areas are cleaned by waterjetting, flash rusting might occur, obscuring the level of visual cleanliness before an inspection can be conducted. Establishing the required visual cleanliness by cleaning and drying a small representative area prior to production may help, provided that rest of the job is cleaned to the same manner.

OTHER STANDARDS: The recommendations, standards, and guides of a number of other associations reference the SSPC surface preparation standards, including: American Association of State Highway and Transportation Officials (AASHTO); American Institute of Steel Construction (AISC); American Iron and Steel Institute (AISI); American Petroleum Institute (API); American Railway Bridge and Building Association (ARBBA); American Water Works Association (AWWA); Canadian Institute of Steel Construction (CISC); Painting and Decorating Contractors of America (PDCA); Steel Plate Fabricators Association (SPFA); and the Texas Structural Steel Institute (TSSI). They are also used by many state highway departments and other federal, state, and local agencies.

Governmental agencies have been active in preparing good surface preparation specifications, but most of these deal with thin metal and do not particularly apply to structures. The U.S Army Corps of Engineers Civil Works Division has issued CW-09940, "Guide Specifications for Painting Hydraulic Structures and Appurtenant Works." This specification covers the cleaning and treating of structural steel as well as the application of paint and the paints to be used. It makes use of the SSPC surface preparation standards.

Federal Specification TT-C-490, "Chemical Conversion Coatings and Pretreatments for Ferrous Surfaces (Base for Organic Coatings)" covers various types of surface preparation and pretreatments.

For internal use, the U.S. Department of the Navy, Naval Sea Systems Command, has prepared Chapter 631, "Preservation of Ships in Service (Surface Preparation and Painting), NAVSEA-S9086-VD-STM-000C/H-631," which includes surface preparation standards in addition to painting specifications and paint systems. Detailed specifications for pickling are included. Navy Standard Item 009 032 covers the cleaning and painting requirements for surface ships, and is usually updated every year.

The International Organization for Standardization (ISO) has included written definitions and photographs depicting the appearance of uncoated steel surfaces cleaned by flame cleaning (ISO 8501-1:2007, reviewed and confirmed 2011). This book also includes photographs for uncoated steel surfaces cleaned by hand and power tools and by abrasive blasting. A parallel standard ISO 8501-2:1994 depicts degrees of cleaning over previously painted surfaces.

The British Standards Institution standard BS 7079:Parts A1 and A2, "Preparation of Steel Substrates Before Application of Paints and Related Products" is essentially equivalent to ISO 8501-1 and ISO 8501-2.

15. Surface Preparation of Other Metallic Surfaces

15.1 SSPC-SP 16, "Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-ferrous Metals:" This standard covers surface preparation of coated or uncoated metal surfaces, other than carbon steel, prior to the application of a protective coating system. Surface preparation using this standard uniformly roughens and cleans the bare substrate and roughens the surface of intact coatings on these metals prior to coating application. Substrates that may be prepared by this method include, but are not limited to, galvanized surfaces, stainless steel, copper, aluminum, and brass. For the purpose of this standard, the zinc metal layer of hot-dip galvanized steel is considered to be the substrate, rather than the underlying steel. This standard is not to be used for cleaning coated or uncoated carbon steel substrates.

SSPC-SP 16 is similar to SSPC-SP 7 in that it is used to remove loose visible contaminants and loose coating from the substrate. Unlike SSPC-SP 7, SP 16 requires the exposed metal to have a minimum 19-µm (0.75 mil) profile and tightly adherent intact coatings to be roughened and cleaned as required by the product data sheet for the coating to be applied.

15.2 ALUMINUM: Because aluminum is soft and chemically reactive, special precautions must be exercised when preparing an aluminum surface for painting. Chipping hammers and scrapers tend to gouge the soft aluminum. Wire brushes work well on aluminum, but they must have stainless steel bristles, not carbon steel or copper. Abrasive mats, paper, and cloths can be used to remove corrosion products or to feather the edges of intact paint. However, these materials should not be used on any other type of surface to prevent cross contamination of the aluminum. Aluminum wool may also be used for cleaning.

Abrasive blast cleaning can be performed on aluminum if the abrasive and blasting pressures are chosen correctly. The most common situations are 80-grit aluminum oxide (alumina, corundum, or emery) or garnet at 410 - 480 kPa (60 - 70 psi). Ferrous abrasives should never be used. Alternative media for cleaning aluminum include pliant media (sponges), plastic pellets, agricultural abrasives (corn cobs, walnut shells, peach pits), glass beads, sodium bicarbonate (baking soda), and carbon dioxide (dry ice). Chemical stripping has been used on aluminum in situations where blasting is not feasible. Care must be exercised to use a stripper that does not attack the aluminum.

Waterjetting provides another option for cleaning aluminum. Usually, if a profile is desired and an existing profile does not exist, abrasive might be added to the water for a uniform profile. Because aluminum is a soft metal, high and ultra-high pressure waterjetting, typically controlled by automation for consistency, can impart a profile without an abrasive, although it will look different from a profile created using abrasives.

15.3 STAINLESS STEEL: As with aluminum, care must be taken to avoid contaminating the stainless steel with carbon steel or iron. Hence, common steel shot and grit as well as most slag abrasives are not used to blast stainless steel. A hard non-metallic abrasive such as aluminum oxide or garnet is commonly used. Because stainless steel is hard, reducing the blast pressure is not necessary. Waterjet cleaning is used if a profile already exists.

The most common painting problem associated with stainless steel is lack of adhesion. Some attribute this to the protective oxide film that forms on the surface. A blast profile increases the effective surface area to promote chemical bonding. An acid-etching vinyl butyral wash primer, SSPC-Paint 27, is sometimes used to promote adhesion.

15.4 COPPER ALLOYS: Most copper, bronze, or copper alloy substrates come in the form of pipes, valves, pumps, strainers, heat exchangers, and statues. As with all metallic surfaces, solvent cleaning is the first step in surface preparation. Usually, the only method specified for these alloys is hand or power tool sanding using abrasive cloths, belts, or pads. Ultra-high pressure waterjet cleaning is used in conservation of copper, bronze, and softer alloy structures. Laser removal is becoming more accepted by conservation and preservation professionals.

Editorial Revision March 15, 2017: *Table 3B revised to indicate that the written text of ISO 8501-1 Cleanliness Level Sa 2 is comparable to SSPC-SP 14 (both standards permit small amounts of tightly adherent material to remain on the substrate after cleaning); however the ISO photographs C Sa 2 and D Sa 2 are consistent with the written definition of the commercial blast cleaning cleanliness level contained in SSPC-SP 6 (which permits only staining to remain on the substrate after cleaning). ISO photograph D Sa 2 shows dark areas that could be interpreted as mill scale, and, therefore, represents SSPC-SP 14 and does not represent SSPC-SP 6. A footnote to Table 3B referring to printings of ISO 8501-1 between 1978 and 1989 and to BS 7079 has been removed.*

SSPC: The Society for Protective Coatings
Paint Application Standard No. 2

Procedure for Determining Conformance to Dry Coating Thickness Requirements

1. SCOPE

1.1 This standard describes a procedure for determining shop or field conformance to a specified coating dry film thickness (DFT) range on ferrous and non-ferrous metal substrates using two types of nondestructive coating thickness gages (Type 1, magnetic pull-off; and Type 2, electronic) described in ASTM D7091.[1]

1.2 This standard defines a procedure to determine whether coatings conform to the minimum and the maximum thickness specified. See Note 12.1 for an example of a possible modification when measuring dry film thickness on overcoated surfaces.

1.3 This document contains the following non-mandatory appendices:

Appendix 1 - Numerical Example of Average Thickness Measurement and Illustration of the Procedure for Determining the Magnitude of a Nonconforming Area
Appendix 2 - Methods for Measuring Dry Film Thickness on Steel Beams (Girders)
Appendix 3 - Methods for Measuring Dry Film Thickness for a Laydown of Beams, Structural Steel, and Miscellaneous Parts after Shop Coating
Appendix 4 - Method for Measuring Dry Film Thickness on Coated Steel Test Panels
Appendix 5 - Method for Measuring Dry Film Thickness of Thin Coatings on Coated Steel Test Panels that Have Been Abrasive Blast Cleaned
Appendix 6 – Method for Measuring the Dry Film Thickness of Coatings on Edges
Appendix 7 – Method for Measuring Dry Film Thickness on Coated Steel Pipe Exterior
Appendix 8 – Examples of the Adjustment of Type 2 Gages Using Shims
Appendix 9 – Precaution Regarding Use of the Standard for Coating Failure Investigations
Appendix 10 – Procedure for Obtaining a Greater Population of Thickness Measurements Using Type 2 Gage Continuous Read/Scanning Probe Technology

1.5 **Units of Measure:** This standard makes use of both the ASTM SI 10, "American National Standard for Metric Practice" International System Units (SI) and U.S. Customary units. The measurements are not exact equivalents; therefore, each system must be used independently of the other.

2. REFERENCED STANDARDS

2.1 The latest issue, revision, or amendment of the referenced standards in effect on the date of invitation to bid shall govern unless otherwise specified. Standards marked with an asterisk (*) are referenced only in the Notes, which are not requirements of this standard.

2.2 If there is a conflict between the requirements of any of the cited reference standards and this standard, the requirements of this standard shall prevail.

2.3 ASTM International

ASTM D7091	Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

2.4 SSPC: The Society for Protective Coatings

***PA Guide 11**	Protecting Edges, Crevices, and Irregular Steel Surfaces by Stripe Coating

3. DEFINITIONS

3.1 **Gage Reading:** A single instrument reading.

3.2 **Spot Measurement:** The average of three, or at least three gage readings made within a 4-cm (approximately [~]1.5-in) diameter circle.

Discussion: Acquisition of more than three gage readings within a spot is permitted. Any unusually high or low gage readings that are not repeated consistently are discarded. The average of the acceptable gage readings is the spot measurement.

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[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. For referenced ASTM standards, visit the ASTM website, www.astm.org. For Annual Book of ASTM Standards volume information, or to review the scope of an ASTM standard refer to the standard's Document Summary page on the ASTM website.

3.3 Area Measurement: The average of five spot measurements obtained over each 10 m² (~100 ft²) area of coated surface, or portion thereof.

3.4 Certified Standards: Coated or plated metal plates (containing an uncoated plate for zero reference) with assigned values traceable to a national metrology institution. Also, uncoated shims of flat plastic sheet with assigned values traceable to a national metrology institution.

4. DESCRIPTION OF GAGES

4.1 Gage Types: The gage type is determined by the operating principle employed in measuring the thickness and is not determined by the mode of data readout, i.e. digital or analog.

4.2 Type 1 – Magnetic Pull-Off Gages: For magnetic pull-off gages, a permanent magnet is brought into direct contact with the coated surface. The force necessary to pull the magnet from the surface is measured and interpreted as the coating thickness value on an analog dial (scale) on the gage. Less force is required to remove the magnet from a thick coating. The gage scale is non-linear.

4.3 Type 2 – Electronic Gages: An electronic gage uses electronic circuitry to convert a reference signal into coating thickness.

5. CALIBRATION, VERIFICATION OF ACCURACY AND ADJUSTMENT

5.1 Three operational steps are necessary to ensure accurate coating thickness measurement: calibration, verification of accuracy and adjustment. These steps shall be completed before taking coating thickness measurements to determine conformance to a specified coating thickness range. Verification of accuracy shall be performed using certified standards. Type 2 gage adjustment to compensate for characteristics including (but not limited to) substrate metallurgy, geometry, thickness/thinness and roughness shall be performed using certified shims. The measured shims commonly supplied with Type 2 gages are also acceptable for gage adjustment.

5.2 Gages shall be calibrated by the equipment manufacturer, their authorized agent or an accredited calibration laboratory. A test certificate or other documentation showing traceability to a national metrology institution is required. There is no standard time interval for re-calibration, nor is one absolutely required. Calibration intervals are usually established based upon experience and the work environment, or when specified. A one year calibration interval is a typical starting point suggested by gage manufacturers.

5.3 To guard against measuring with an inaccurate gage, gage accuracy shall be verified at a minimum of the beginning and end of each work shift according to the procedures described in ASTM D 7091 or the gage manufacturer's instructions. The user is advised to verify gage accuracy during measurement acquisition (e.g., hourly) when a large number of measurements are being obtained. If the gage is dropped or suspected of giving erroneous readings during the work shift, its accuracy shall be rechecked.

5.4 Record the serial number of the gage, the reference standard used, the stated thickness of the reference standard as well as the measured thickness value obtained, and the method used to verify gage accuracy. If the same gage, reference standard, and method of verification are used throughout a job, they need to be recorded only once. The stated value of the standard and the measured value must be recorded each time accuracy is verified.

5.5 If the gage fails the post measurement accuracy verification check, all measurements acquired since the last accuracy verification check are suspect. In the event of physical damage, wear, or high usage, or after an established calibration interval, the gage shall be rechecked for accuracy of measurement. If the gage is not measuring accurately, it shall not be used until it is repaired and/or recalibrated (usually by the gage manufacturer).

5.6 A Type 1 gage that does not meet the manufacturer's stated accuracy (when verified on certified standards) cannot be adjusted to correct for the out-of-tolerance condition and shall not be used until it is repaired and/or re-calibrated (typically by the gage manufacturer). Any manual adjustment of these gages will limit the DFT range for which the gage will provide accurate readings; therefore, adjustment of the gage is not permitted. Furthermore, the application of a single "correction value" representing the full range of the gage to compensate for a gage that is not measuring accurately is not appropriate, since the gage scale is non-linear.

6. MEASUREMENT PROCEDURE – TYPE 1 GAGES

6.1 Verify Type 1 gage accuracy using certified coated metal plates having at least one thickness value within the expected range of use. Unless explicitly approved by the gage manufacturer, certified shims of plastic or of non-magnetic metals that are acceptable for verifying the accuracy of Type 2 (electronic) gages shall not be used for verifying the accuracy of Type 1 gages.

6.2 In order to compensate for any effect of the substrate itself and surface roughness, obtain one reading from the bare prepared substrate at each of a minimum of ten (10) arbitrarily spaced locations and calculate the average value. This value represents the effect of the substrate/surface roughness on a coating thickness gage. This average value is the base metal reading (BMR).

6.3 Measure the DFT of the coating at the number of spots specified in Section 8.

6.4 Subtract the BMR from the gage reading to obtain the thickness of the coating.

7. MEASUREMENT PROCEDURE – TYPE 2 GAGES

7.1 The manufacturers of Type 2 (electronic) gages prescribe different methods of adjustment to measure dry film thickness over roughened surfaces. Adjust the gage according to the manufacturer's instructions using one of the methods described in ASTM D 7091 or Appendix 8 of this standard.

7.2 Measure the DFT of the coating at the number of spots specified in Section 5.

8. REQUIRED NUMBER OF MEASUREMENTS FOR CONFORMANCE TO A THICKNESS SPECIFICATION

8.1 **Number of Measurements:** Repeated gage readings, even at points close together, often differ due to small surface irregularities of the coating and the substrate. Therefore, a minimum of three (3) gage readings shall be made for each spot measurement of the coating. For each new gage reading, move the probe to a new location within the 4-cm (approximately [~]1.5-in) diameter circle defining the spot. Discard any unusually high or low gage readings that are not repeated consistently. The average of the acceptable gage readings is the spot measurement.

8.2 Unless otherwise specified in the procurement documents (project specification), an area measurement is obtained by taking five (5) separate spot measurements (average of the gage readings described in Section 8.1) randomly spaced throughout each 10-m^2 (~100 ft^2) area to be measured and representative of the coated surface. The five spot measurements shall be made for each 10-m^2 (~100 ft^2) area as follows:

8.2.1 For areas of coating not exceeding 30 m^2 (~300 ft^2) arbitrarily select and measure each 10-m^2 (~100 ft^2) area.

8.2.2 For areas of coating greater than 30 m^2 (~300 ft^2) and not exceeding 100 m^2 (~1,000 ft^2), arbitrarily select and measure three 10-m^2 (~100 ft^2) areas.

8.2.3 For areas of coating exceeding 100 m^2 (~1,000 ft^2), arbitrarily select and measure the first 100 m^2 (~1,000 ft^2) as stated in Section 8.2.2. For each additional 100 m^2 (~1,000 ft^2) coated area (or increment thereof), arbitrarily select and measure one additional 10 m^2 (~100 ft^2) area.

8.3 **Nonconforming Areas:** If the coating thickness for any 10-m^2 (~100 ft^2) area is not in compliance with the contract documents, the procedure described here shall be followed to assess the magnitude of the nonconforming thickness.

8.3.1 Determine the spot DFT at 1.5-meter (5-foot) intervals in eight equally spaced directions radiating outward from the nonconforming 10-m^2 (100-ft^2) area.

If there is no place to measure in a given direction, then no measurement in that direction is necessary. Acquire spot measurements in each direction (up to the maximum surface area coated during the work shift) until two consecutive conforming spot measurements are acquired in that direction or until no additional measurements are possible. Acceptable spot measurements are defined by the minimum and maximum values in the contract documents. No allowance is made for variant spot measurements, as is the practice when determining the area DFT. An illustration of this procedure is shown in Figure A1.2.

8.3.1.1 On complex structures or in other cases where making spot measurements at 1.5-meter (5-foot) intervals is not practical, spot measurements shall be performed on repeating structural units or elements of structural units. This method shall be used when the largest dimension of the unit is less than 3 meters (~10 feet). Make spot measurements on repeating structural units or elements of structural units until two consecutive units in each direction are conforming or until there are no more units to test.

8.3.2 Non-compliant areas shall be demarcated using removable chalk or other specified marking material and documented. All of the area within 1.5 meters (5 feet) of any non-compliant spot measurement shall be designated as non-compliant. For a given measurement direction or unit measurement, any compliant area or unit preceding a non-compliant area or unit shall be designated as suspect and as such is subject to re-inspection after corrective measures are performed (see Note 12.2).

8.3.3 Appendices 2 through 7 and Appendix 10 provide specifiers with optional alternatives for defining the area size as well as the number and frequency of spot measurements to include in project specifications as appropriate for the size and shape of the item or structure to be coated.

9. CONFORMANCE TO SPECIFIED THICKNESS

9.1 A minimum and a maximum thickness are normally specified for each layer of coating. If a single thickness value is specified and the coating manufacturer does not provide a recommended range of thickness, then the minimum and maximum thickness for each coating layer shall be ± 20% of the stated value.

9.2 Table 1 provides five thickness restriction levels. Level 1 is the most restrictive and does not allow for any deviation of spot or area measurements from the specified minimum and maximum thickness, while Level 5 is the least restrictive. Depending on the coating type and the prevailing service environment, the specifier selects the dry film thickness restriction level for a given project. If no restriction level is specified, then Level 3 is the default. It is possible to specify a maximum thickness threshold for Level 5 Spot or Area measurements for some generic product types and service environments.

TABLE 1
COATING THICKNESS RESTRICTION LEVELS

Thickness	Gage Reading	Spot Measurement	Area Measurement
Level 1			
Minimum	Unrestricted	As specified	As specified
Maximum	Unrestricted	As specified	As specified
Level 2			
Minimum	Unrestricted	As specified	As specified
Maximum	Unrestricted	120% of maximum	As specified
Level 3 (default)			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	120% of maximum	As specified
Level 4			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	150% of maximum	As specified
Level 5			
Minimum	Unrestricted	80% of minimum	As specified
Maximum	Unrestricted	Unrestricted	Unrestricted

9.3 For the purpose of final acceptance of the total dry film thickness, the cumulative thickness of all coating layers shall be no less than the cumulative minimum specified thickness and no greater than the cumulative maximum specified thickness.

10. Report

The following items shall be reported:

10.1 The type of instrument used, including manufacturer, model number, serial number and date of calibration.

10.2 The type of certified standard used to verify gage accuracy, including manufacturer, model number, serial number and thickness value(s).

10.3 The thickness of the measured shim(s) used to adjust a Type 2 gage.

10.4 The average BMR (if appropriate).

10.5 The spot and area measurements.

10.6 The gage operator and date of measurement acquisition.

11. Disclaimer

11.1 While every precaution is taken to ensure that all information furnished in SSPC standards and specifications is as accurate, complete, and useful as possible, SSPC cannot assume responsibility nor incur any obligation resulting from the use of any materials, coatings or methods specified therein, or of the specification or standard itself.

11.2 This standard does not attempt to address problems concerning safety associated with its use. The user of this standard, as well as the user of all products or practices described herein, is responsible for instituting appropriate health and safety practices and for ensuring compliance with all governmental regulations.

12. Notes

Notes are not requirements of this standard.

12.1 Overcoating: Maintenance painting often involves application of a new coating over an existing coating system. It can be very difficult to accurately measure the DFT of this newly applied coating using non-destructive methods. First, access to the profile is not available, compromising the accuracy of the BMR or the adjustment of a Type 2 gage. Second, unevenness in the DFT of the existing coating necessitates careful mapping of the "before and after" DFT readings. This unevenness also adds to the statistical variation in trying to establish a base DFT reading to be subtracted from the final DFT.

A paint inspection gage (sometimes called a Tooke or PIG gage) will give accurate DFT measurements, but it requires that an incision be made through the coating (overcoat only or total system), so each measurement site will require repair.

A practical approach to monitoring DFT (when overcoating) is to compute the DFT using wet film thickness (WFT) readings, the percent volume solids of the coating being applied, and any thinner addition as shown here.

$$\text{DFT} = \text{Measured WFT} \times \%\ \text{Volume Solids},$$

or

$$\text{DFT} = \text{Measured WFT} \times \%\ \text{volume solids} \div (100\% + \%\ \text{thinner added})$$

If the DFT of the existing coating is not too uneven or eroded, the average DFT of the existing coating can be measured per this standard to establish a base DFT. This base DFT can then be subtracted from the total DFT to isolate the thickness of the overcoat(s).

12.2 Correcting for Low or High Thickness: The specifier should specifically state the methodology to correct the applied and cured film for low or high thickness. If this information is not contained in the specification, then the coating manufacturer's instructions should be followed.

APPENDIX 1 – NUMERICAL EXAMPLE OF AVERAGE THICKNESS MEASUREMENT AND ILLUSTRATION OF THE PROCEDURE FOR DETERMINING THE MAGNITUDE OF A NONCONFORMING AREA

Appendix 1 is not a mandatory part of this standard.

Considering Metric Measurements:

The following numerical example is presented as an illustration of Section 8. The example is based on a Level 3 Restriction (default).

Suppose the coated area is 30 m² in area. Divide the area into three equal parts, each being about 10 m².

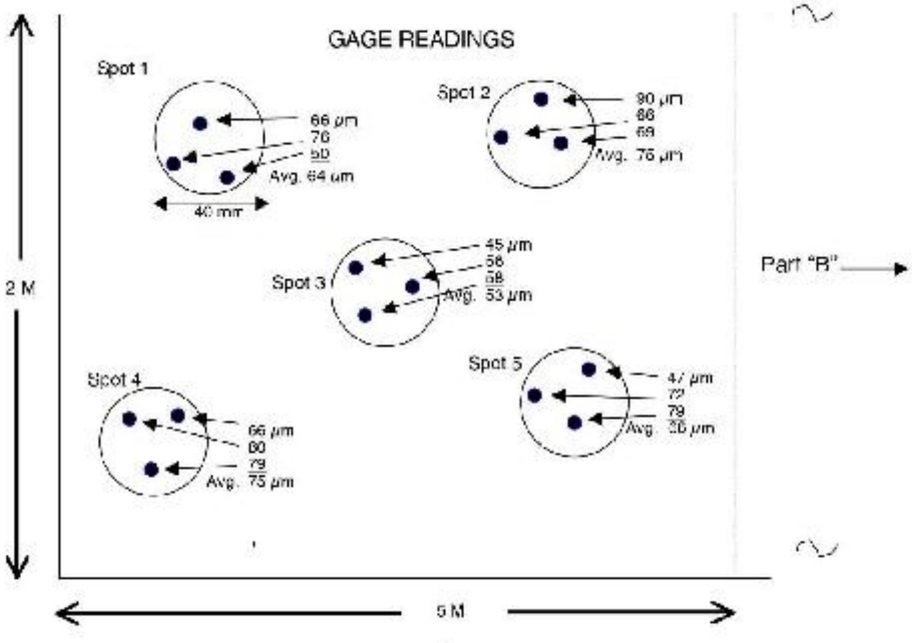
Part A - 10 m²
Part B - 10 m²
Part C - 10 m²

First, measure the coating thickness on Part A. This involves at least 15 gage readings with a Type 1 or Type 2 device (see Figure A1.1). Assume the specification calls for 64 μm minimum thickness. The coating thickness for area A is then the average of the five spot measurements made on area A, namely 67 μm.

Spot 1	64 μm
Spot 2	75
Spot 3	53
Spot 4	75
Spot 5	68
Average	67 μm

The average, 67 μm, exceeds the specified minimum of 64 μm and thus satisfies the specification. Next, determine if the lowest spot measurement, 53 μm, is within 80% of the specified minimum thickness (based on Coating Thickness Restriction Level 3, or the default). Eighty percent of 64 μm is 51 μm (0.80 x 64 = 51). Although a measurement of 53 μm is below the specified minimum, it is still within 80% of it, so the specification is satisfied. There are individual gage readings of 47 μm at Spot 5 and 45 μm at Spot 3, both of which are clearly less than 51 μm. This is allowed because only the average

Figure A1 (Metric). Part "A" of Structure
(area is 10 m²)



of the three readings (i.e., the spot measurement) must be greater than or equal to 51 µm.

Since the structure used in this example is approximately 30 m², the procedure used to measure the film thickness of part A must be applied to both part B and part C. The measured thickness of part B must exceed the 64 µm specified minimum, as must the thickness of part C.

To monitor the thickness of this entire 30-m² structure, at least 45 individual gage readings must be taken, from which 15 spot measurements are calculated. The five spot measurements from each 10-m² part of the structure are used to calculate the thickness of that part.

Considering the U.S. Customary Measurements

Suppose the coated area is 300 ft² in area. Divide the area into three equal parts, each being about 100 ft².

Part A - 100 ft²
Part B - 100 ft²
Part C - 100 ft²

First, measure the coating thickness on Part A. This involves at least 15 gage readings with a Type 1 or Type 2 device (see Figure A1.1). Assume the specification calls for 2.5 mils minimum thickness. The coating thickness for area A is then the average of the five spot measurements made on area A, namely 2.6 mils.

Spot 1	2.5 mils
Spot 2	2.9 mils
Spot 3	2.1 mils
Spot 4	2.9 mils
Spot 5	2.6 mils
Average	2.6 mils

The average, 2.6 mils, exceeds the specified minimum of 2.5 mils and thus satisfies the specification. Next, determine if the lowest spot measurement, 2.1 mils, is within 80% of the specified minimum thickness (based on Coating Thickness Restriction Level 3, or the default). Eighty percent of 2.5 mils is 2.0 mils (0.80 x 2.5 = 2.0). Although 2.1 mils is below the specified minimum, it is still within 80 percent of it, so the specification is satisfied. There are individual gage readings of 1.5 mils at Spot 3 and 1.8 mils at Spot 5, both of which are clearly less than 2.0 mils. This is allowed because only the average of the three readings (i.e. the spot measurement) must be greater than or equal to 2.0 mils.

Figure A1 (U.S Custom Units). Part "A" of Structure (area is 100 ft²)

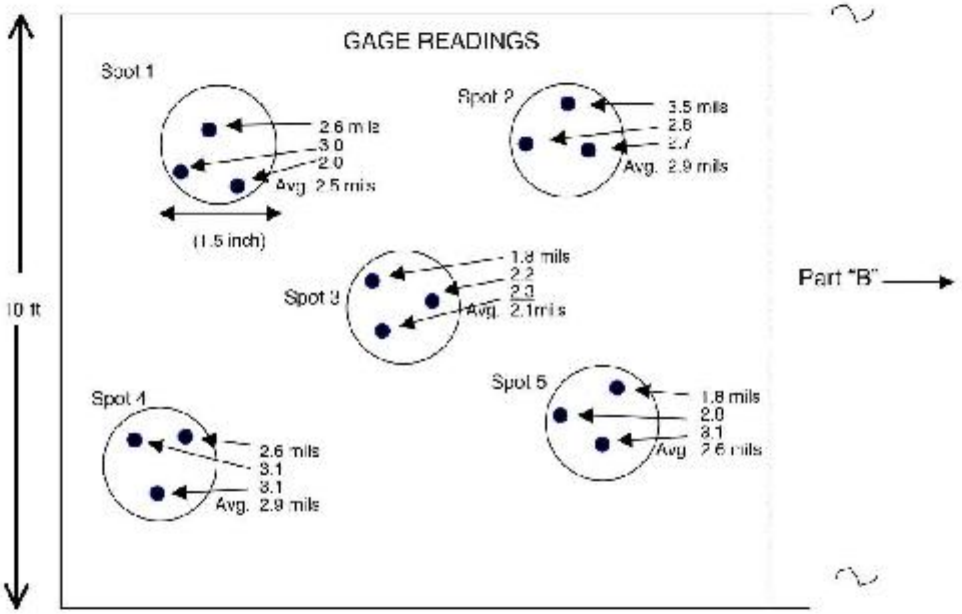


FIGURE A1.2
DETERMINING EXTENT OF NONCONFORMING AREAS

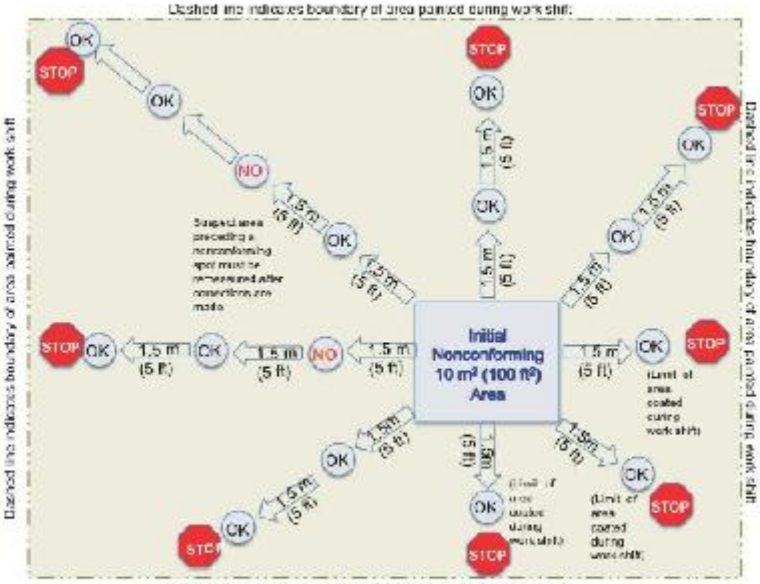


Figure A1.2 illustrates the procedure described in Section 8.3 of this standard for determining the magnitude of the nonconforming thickness.

APPENDIX 2 – METHODS FOR MEASURING DRY FILM THICKNESS ON STEEL BEAMS (GIRDERS)

Appendix 2 is not a mandatory part of this standard, but it provides two sample protocols for measuring DFT on beams and girders.

A2.1 A challenge for the painter in coating steel beams or girders is providing the same uniform thickness over high and low vertical surfaces as over horizontal surfaces. On a beam, there are proportionately more edges that tend to have low dry film thickness (DFT) and inside corners that tend to have high DFT compared to the center of the flat surfaces. Each painter usually develops a pattern of work for a specific task. Hence, the DFT on the underside of the top flange, for example, may be consistently on the high side or the low side of the target DFT. This type of error is easy to detect and correct. Random errors pose a more difficult problem. Gross errors where the paint is obviously too thin or too thick must be corrected and are beyond the scope of this standard.

The number of spot measurements in these protocols may far exceed the "5 spot measurement per 10 m^2 (100 ft^2)" required in the standard. The full DFT determination, described in Section A2.2, provides a very thorough inspection of the beam. The sample DFT determination, described in Section A3.4, allows for fewer spot measurements. The user does not have to require a full DFT determination for every beam in the structure. For example, the requirement may be for a full DFT determination on one beam out of ten, or a sample DFT determination on one beam out of five, or a combination of full and sample DFT determinations. Note that for existing structures, the top side of the top flange (Surface 1) may not be accessible for measuring coating thickness.

A beam has twelve different surfaces as shown in Figure A2 (page 8). Any one of these surfaces may have a DFT outside the specified range, and hence, shall be measured. If the thickness of the flange is less than 25 mm (1 in), the contracting parties may choose not to measure the DFT on the toe, i.e., surfaces 2, 6, 8, and 12 of Figure A2. As an informal initial survey, the inspector may want to check for uniformity of DFT across each surface. Is the DFT of the flange near the fillet the same as near the toe? Is the DFT uniform across the web? The inspector must be sure to use a gage that is not susceptible to edge effects. Follow the gage manufacturer's instructions when measuring the edges.

A2.2 Full DFT Determination of a Beam: Divide the beam or girder into five equal sections along its length. Identify

FIGURE A2
THE SURFACES OF A STEEL BEAM
(36 in [91 cm] in height)

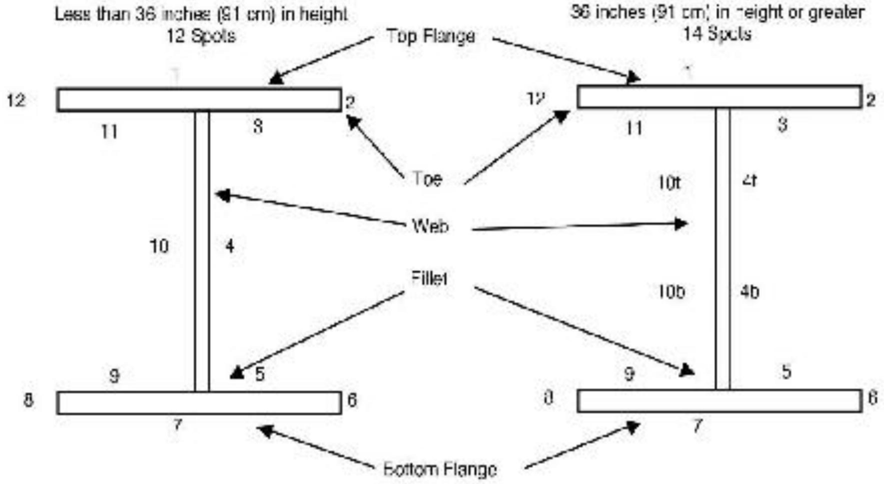


TABLE A2.1
DATASHEET FOR RECORDING SPOT MEASUREMENTS AND AVERAGE DFT VALUES FOR THE 12 SURFACES OF A BEAM OR GIRDER

Spot Measurements of DFT on Beam # _______________

Surface	Section 1	Section 2	Section 3	Section 4	Section 5	Average
1						
2						
3						
4[1]						
4t[2]						
4b[2]						
5						
6						
7						
8						
9						
10[1]						
10t[2]						
10b[2]						
11						
12						

[1] Rows 4 and 10 apply to beams with a web height <36 inches (~1 meter)

[2] Rows 4T/4B and 10T/10B apply to beams with a web height ≥36 inches (~1 meter)

TABLE A2.2 – NUMBER OF SPOT MEASUREMENTS NEEDED ON EACH SURFACE OF A BEAM FOR A FULL OR A SAMPLE DFT DETERMINATION

	Number of Spot Measurements per Surface	
Length of Beam	**Full DFT Determination***	**Sample DFT Determination**
less than 20 ft (6 m)	5	2
from 20 to 60 ft (6 to 18 m)	5	3
over 60 ft (18 m)	5	NA

* For beams 36 inches (91 cm) or more, the top half and the bottom half of the web are treated as separate surfaces in a full DFT determination.

the 12 surfaces of the beam as shown in Figure A2 for each section. For tall beams, where the height of the beam is 91 cm (36 in) or more, divide the web in half along the length of the beam. For the full DFT determination, each half of the web is considered a separate surface. Take one spot measurement (as defined in Section 8.1) on surface 1 in each of the five sections. The location of the surface 1 measurement within a section is arbitrarily chosen by the inspector in each of the five sections. The average of these five spot measurements is the DFT of surface 1. Repeat for the other 11 surfaces (7 surfaces if the toe is not measured; 14 surfaces for tall beams). The data can be reported in a format shown in Table A2.1.

A2.3 If Coating Thickness Restriction Level 3 is invoked by the specification (or if no Restriction Level is invoked by the specification), then no single spot measurement can be less than 80% of the specified minimum DFT, and no single spot measurement can be more than 120% of the specified maximum DFT. The average value for each surface must conform to the specified DFT. (There will be only eight average values if the DFT of the toe is not measured; there may be as many as 14 average values for beams with height greater than 36 in).

A2.4 SAMPLE DFT DETERMINATION OF A BEAM: In lieu of a full DFT determination of each beam, the job specification may require only a sample DFT determination for selected beams less than 18 m (60 ft) long. For a sample DFT determination, the web of beams greater than 0.9 m (36 in) in height is not split.

A2.4.1 Beams less than 6 m (20 ft) in length: For beams less than 6 m (20 ft) in length, take two spot measurements, randomly distributed, on each of the 12 surfaces (8 surfaces if the toe is not measured) of the beam as defined in Figure A2. Each spot measurement must conform to the specified DFT.

A2.4.2 Beams 6 m (20 ft) up to 18 m (60 ft) in length: For beams 6 m (20 ft) up to 18 m (60 ft) in length, take three spot measurements, randomly distributed, on each of the 12 surfaces (8 surfaces if the toe is not measured) of the beam as defined in Figure A2. Each spot measurement must conform to the specified DFT.

A2.5 NON-CONFORMANCE: If any spot measurement falls outside the specified range, additional measurements may be made to define the non-conforming area.

A2.6 RESTRICTED ACCESS: If the beam is situated such that one or more of the surfaces are not accessible, take measurements on each accessible surface in accordance with Section A2.2 or Section A2.4 through A2.4.2, as specified.

A2.7 ATTACHMENTS: Stiffeners and other attachments to a beam should be arbitrarily measured.

APPENDIX 3 – METHODS FOR MEASURING DRY FILM THICKNESS FOR A LAYDOWN OF BEAMS, STRUCTURAL STEEL, AND MISCELLANEOUS PARTS AFTER SHOP COATING

Appendix 3 is not a mandatory part of this standard, but it provides two sample protocols for measuring DFT for a laydown.

A3.1 GENERAL: A "laydown" is a group of steel members laid down to be painted in one shift by one painter. For inspection of a laydown, first make a visual survey to detect areas with obvious defects, such as poor coverage, and correct as necessary. As an informal initial survey, the inspector may want to check for uniformity of DFT across each surface.

A3.2 FULL DFT DETERMINATION

A3.2.1 Beam (Girder): Follow the procedure described in Section A2.2.

A3.2.2 Miscellaneous Parts: Take one spot measurement (as defined in Section 8.1) on each surface of the part. If the part has fewer than five surfaces, take multiple spot measurements on the larger surfaces to bring the total to five. If the total area of the part is over 10 m² (100 ft²), take 5 spot measurements randomly distributed over the part for each 10 m² (100 ft²) or fraction thereof.

A3.3 If Coating Thickness Restriction Level 3 is invoked by the specification (or if no Restriction Level is invoked by the specification), then no single spot measurement can be less than 80% of the specified minimum DFT, and no single spot measurement can be more than 120% of the specified maximum DFT. The average value of the spot measurements on each surface must conform to the specified DFT. If there is only a single spot measurement on a surface, it must conform to the specified DFT.

A3.4 SAMPLE DFT DETERMINATION: In lieu of a full DFT determination of each painted piece as described in Section A2.2, the job specification may require only a sample DFT determination for selected pieces.

A3.4.1 Beams less than 6 m (20 ft) in length: Follow the procedure described in Section A2.4.1.

A3.4.2 Beams greater than 6 m (20 ft) up to 18 m (60 ft) in length: Follow the procedure described in Section A2.4.2.

A3.4.3 Miscellaneous parts: For a miscellaneous part, take three spot measurements, randomly distributed on the part. Each spot measurement must conform to the specified DFT.

A3.5 NON-CONFORMANCE: If any spot measurement falls outside the specified range, additional measurements may be made to define the non-conforming area.

A3.6 RESTRICTED ACCESS: If a beam or miscellaneous part is situated such that one or more of the surfaces are not accessible, take measurements on each accessible surface in accordance with Section A2.2 or Section A3.4, as specified.

A3.7 NUMBER OF BEAMS OR PARTS TO MEASURE: In a laydown, the number of beams or parts to receive a full DFT determination and the number to have a sample DFT determination can be specified. For example, do a full DFT determination on a piece painted near the beginning of the shift, near the middle of the shift, and near the end of the shift in accordance with Section A3.2, and perform a sample DFT determination on every third piece in accordance with Section A3.4.

A3.8 ATTACHMENTS: Stiffeners and other attachments to a beam shall be arbitrarily measured.

APPENDIX 4 – METHOD FOR MEASURING DRY FILM THICKNESS ON COATED STEEL TEST PANELS

Appendix 4 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT on coated steel test panels.

A4.1 PANEL SIZE: The test panel shall have a minimum area of 116 cm² (18 in²) and a maximum area of 930 cm² (144 in²); e.g., minimum 7.5 x 15 cm (3 x 6 in) and maximum 30 x 30 cm (12 x 12 in).

A4.2 PROCEDURE: Use a Type 2 electronic gage. Take two spot measurements from the top third, the middle third, and the bottom third of the test panel. Readings shall be taken at least 12 mm (0.5 in) from any edge and 25 mm (1 in) from any other spot measurements. Discard any unusually high or low gage reading that cannot be repeated consistently. The DFT of the test panel is the average of the six acceptable spot measurements.

A4.3 MINIMUM THICKNESS: The average of the acceptable spot measurements shall be no less than the specified minimum thickness. No single spot measurement shall be less than 80% of the specified minimum.

A4.4 MAXIMUM THICKNESS: The average of the acceptable spot measurements shall be no more than the specified maximum thickness. No single spot measurement shall be more than 120% of the specified maximum.

A4.5 REJECTION: If a spot measurement is less than 80% of the specified minimum DFT or exceeds 120% of the specified maximum DFT, additional measurements may be made to reevaluate the DFT on the area of the test panel near the low or high spot measurement. If the additional measurements indicate the DFT in the disputed area of the panel to be below the minimum or above the maximum allowable DFT, the panel shall be rejected.

APPENDIX 5 – METHOD FOR MEASURING DRY FILM THICKNESS OF THIN COATINGS ON COATED STEEL TEST PANELS THAT HAVE BEEN ABRASIVE BLAST CLEANED

Appendix 5 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT of thin coatings on coated steel test panels that had been abrasive blast cleaned.

A5.1 For the purposes of this standard, a coating is defined as thin if the dry film thickness (DFT) is on the order of 25 micrometers (1 mil) or less. Because the DFT is the same order as the statistical fluctuations of a DFT gage on bare blast cleaned steel, many gage readings must be taken to get a meaningful average.

A5.2 PANEL SIZE: The test panel shall have a minimum area of 116 cm² (18 in²) and a maximum area of 930 cm² (144 in²); e.g., minimum 7.5 x 15 cm (3 x 6 in) and maximum 30 x 30 cm (12 x 12 in).

A5.3 PROCEDURE: Use a properly adjusted Type 2 electronic gage. Take ten gage readings randomly distributed in the top third of the panel. Compute the mean (average) and standard deviation of these ten readings. Similarly, take ten readings from the middle third and ten readings from the bottom third of the test panel and compute their means and standard deviations. Readings shall be taken at least 12 mm (0.5 in) from any other gage reading. Discard any unusually high or low gage reading, i.e., a reading that is more than three standard deviations from the mean. The DFT of the test panel is the average of the three means.

A5.4 MINIMUM THICKNESS: The average of the means shall be no less than the specified minimum thickness. No single mean shall be less than 80% of the specified minimum.

A5.5 MAXIMUM THICKNESS: The average of the means shall be no more than the specified maximum thickness. No single mean shall be more than 120% of the specified maximum.

APPENDIX 6 – METHOD FOR MEASURING THE DRY FILM THICKNESS OF COATINGS ON EDGES WITH TYPE 2 GAGES

Appendix 6 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT of coatings on edges.

A6.1 Type 2 gage manufacturers offer a variety of probe configurations, some of which are less affected by proximity to edges and are designed to better measure the thickness of coatings on edges. The user should consult the gage manufacturer's instructions before measuring coating thickness on edges. SSPC-PA Guide 11 describes the use of coatings with edge retention properties and references a method (MIL-PRF-23236D, Coating Systems for Ship Structures) for assessing edge retention properties of coatings.

A6.2 Prior to measurement of coating on edges, the gage and probe should be verified for accuracy by placing a thin, flexible shim onto the prepared, uncoated edge. Adjustments to the gage may or may not be required. This procedure also verifies that the probe configuration will accommodate the edge configuration prior to coating thickness data acquisition.

A6.3 Obtain a minimum of three gage readings within 4 linear cm (~1.5 linear in) of coated edge. The average of the gage readings is considered a spot measurement. The number of spot measurements along the edge will vary depending on the total length of the coated edge.

APPENDIX 7 – METHOD FOR MEASURING DRY FILM THICKNESS ON COATED STEEL PIPE EXTERIOR

Appendix 7 is not a mandatory part of this standard, but it provides a sample protocol for measuring DFT of the exterior of coated pipe.

A7.1 Pipe sections that are loaded onto a cart or rack are considered a complete unit, as opposed to a single joint of pipe. The total number of spot and area measurements is based on the total square footage of pipe on the cart or rack. The square footage can be calculated using the formula here:

Circumference of pipe = pi (π) x diameter
Area = (length of each pipe x circumference) x no. of pipe sections on cart or rack

Example (U.S. Units):

- 10 pieces of 48-in long x 9-in diameter pipe = 4 ft x (3.14 x 0.75 ft) = 9.4 ft^2 area per pipe section.
- 9.4 ft^2 per pipe section x 10 pipe sections = 94 ft^2 total coated area

Since the total area is less than 100 ft^2, 5 spots (each spot is a minimum of 3 gage readings) are measured according to Section 8.2.1 of SSPC-PA 2.

A7.2 Pipe DFT Frequency Factors: Some carts may contain multiple small pipe sections, resulting in a total coated surface area in excess of 100 ft^2. In such cases, the specifier may require additional spot measurements due to a large number of items on the cart. Using Section 8.2.1 of this standard, five readings are required for the first 100 ft^2 of coated pipe. In addition, the Owner/Contractor may specify one of the Pipe DFT Frequency Factors shown here. Based on the example in Section A7.1, if "Pipe DFT Frequency Factor 4" was invoked, 20 spot measurements would be acquired (5 spots [for the first 100 ft^2] x 4 frequency factor). In such a case more of the items on the cart are measured, giving a better sampling to determine compliance.

Example (U.S. Units) if total coated area exceeds 100 ft^2 and Frequency Factor 2 is invoked:

- Total coated square footage on a cart = 175 ft^2
- Section 8.2.1 of SSPC-PA 2 requires 2 sets of 5 spot measurements (5 spots on each of two 100-square foot areas) = 10 spot measurements.

Pipe DFT Frequency Factor of 2 x 10 spots = 20 spot measurements

A7.2.1 Pipe DFT Frequency Factor 2 = (length of each pipe x circumference) x no. of pipe sections on cart or rack = (number of spot measurements) x 2

A7.2.2 Pipe DFT Frequency Factor 3 = (length of each pipe x circumference) x no. of pipe sections on cart or rack = (number of spot measurements) x 3

A7.2.3 Pipe DFT Frequency Factor 4 = (length of each pipe x circumference) x no. of pipe sections on cart or rack = (number of spot measurements) x 4

TABLE A7
NUMBER AND LOCATIONS OF SPOT MEASUREMENTS – PIPE SPOOLS

Pipe Diameter	Circumferential Spot Measurements	Interval Spacing
Up to 12 in (30 cm)	4 evenly spaced	10 feet (3 meters) apart
14 to 24 inches (36-60 cm)	6 evenly spaced	10 feet (3 meters) apart
Greater than 24 inches (60 cm)	8 evenly spaced	10 feet (3 meters) apart

A7.2.4 Pipe DFT Frequency Factor 5 = (length of each pipe x circumference) x no. of pipe sections on cart or rack = (number of spot measurements) x 5

A7.2.5 Pipe DFT Frequency Factor 6 = (length of each pipe x circumference) x no. of pipe sections on cart or rack = (number of spot measurements) x 6

A7.3 Measurements on Individual Pipe Spools: Pipe spools that are not loaded onto a rack or cart are measured individually. The number and locations of spot measurements are based on Table A7. Three sets of 4 circumferential spot measurements should be obtained on pipe spools less than 3 meters (10 feet) in length.

A7.4 A challenge for the painter in coating fabricated pipe spools is providing a uniform thickness throughout the entire surface. On a fabricated pipe spool, there are potentially valves, flanges, and elbows that tend to have low or high DFT compared to the straight run section. Painters may develop a pattern of work for a specific task. Hence, the DFT on the flange and valves may be consistently on the high side or the low side of the target DFT. This type of error is easy to detect and correct. Random errors pose a more difficult problem. Gross errors where the paint is obviously too thin or too thick must be corrected and are beyond the scope of this standard.

The number of spot measurements in this protocol may far exceed the "5 spot measurements per 10 m² (100 ft²)" required in the standard. The full DFT determination, described in Table A7, provides a very thorough inspection of a joint of pipe. The DFT determination, described in Section A7.1, may allow for fewer spot measurements. The user does not have to require a full DFT determination for every joint of pipe. For example, the requirement may be for a full DFT determination on one pipe out of ten, or a sample DFT determination on one pipe out of five, or a combination of full and sample DFT determinations.

APPENDIX 8 – EXAMPLES OF THE ADJUSTMENT OF TYPE 2 GAGES USING SHIMS

Appendix 8 does not form a mandatory part of this standard, but it provides examples of how to adjust Type 2 gages using certified shims or measured shims on roughened (e.g., abrasive blast cleaned) surfaces.

This example describes a method of adjustment to improve the effectiveness of a Type 2 (electronic) gage on a blast cleaned or otherwise roughened surface. Blast cleaning is used throughout this example, but these methods are applicable to other types of surface preparation. A less uniform surface, such as partially rusted hand tool cleaned steel, may require more gage readings to achieve a satisfactory level of statistical significance. Since gage operation differs among manufacturers, follow the manufacturer's instructions for adjustment of a particular gage.

A Type 2 gage needs to be adjusted to account for the profile of the substrate in order to read the coating thickness directly. Type 2 gages equipped with double pole probes may provide greater measuring precision on rough surfaces compared to single pole probes.

A portion of the substrate, after blast cleaning but prior to coating, can be used to adjust the gage. Alternatively, an uncoated test panel, blast cleaned at the time the structure was blast cleaned and having a profile representative of the structure can be used to adjust the gage provided the test panel is of material with similar magnetic properties and geometry as the substrate to be measured. If this is not available then a correction value can be applied to a smooth surface adjustment as described in A8.3.

Three adjustment techniques can be used depending on the capability and features of the gage to be used for the inspection. Note that due to the statistical variation produced by a roughened surface, individual readings taken using these three methods may not perfectly agree.

The first two examples describe adjustment and verification to one or more shims. When shims are used, resultant gage measurements are less accurate and must be recalculated. For example, if the accuracy of a properly calibrated gage is ± 2% and the thickness of a shim is accurate to within ± 3%, the combined tolerance of the gage and the shim will be ± 4% as given by the sum of squares formula:

$$\sqrt{2^2 + 3^2} = 3.6055 \approx 4\%$$

For the gage to be in agreement with the shim, the average thickness measured by the gage must be within ±4%

TABLE A8
TYPICAL GAGE CORRECTION VALUES USING ISO 8503 PROFILE GRADES
(SOURCE: ISO 19840)[1]

ISO 8503 Profile Grade	Correction Value (mil)	Correction Value (µm)
Fine	0.4	10
Medium	1.0	25
Coarse	1.6	40

[1] International Organization for Standardization (ISO), Case Postale 56, Geneva CH-1211, Switzerland. ISO standards are available online from the American National Standards Institute (ANSI), 1819 L Street, NW, Suite 600, Washington, DC 20036 or at <http://www.ansi.org>

of the shim's thickness. If the average thickness measured on a 250-micrometer (µm) (10-mil) shim is between 240 µm (9.6 mils) and 260 µm (10.4 mils), the gage is properly adjusted. The minimum of 240 is 250 minus 4% of 250 (9.6 is 10 minus 4% of 10); the maximum of 260 is 250 plus 4% of 250 (10.4 is 10 plus 4% of 10). [4% of 250 is 10; 4% of 10 is 0.4.]

A8.1 SINGLE-POINT ADJUSTMENT: This example uses a single shim value at or close to the thickness to be measured. The thickness range over which this adjustment achieves the required accuracy will vary with gage design.

Assuming that the coating thickness to be measured is 100 µm (4.0 mil), then a shim of approximately 100 µm (4.0 mil) or slightly greater should be used to adjust the gage. The shim is placed on an area of the substrate that has been blast cleaned to the required standards, or on a blasted test coupon with a similar surface profile.

The average of 10 readings on the shim is sufficient to allow for the statistical variation in the blast profile.

A8.2 TWO-POINT ADJUSTMENT: This example uses two shim values, one above and one below the expected film thickness to be measured. It should be noted that not all film thickness gages can be adjusted in this manner.

Assuming that the coating thickness to be measured is 100 µm (4.0 mil), then shims of 250 µm (10.0 mil) and 50 µm (2.0 mil) are appropriate for setting the upper and lower values on the scale of the gage.

As protective coatings are normally applied to blast cleaned metal surfaces, a statistical approach is required to obtain a typical value for the adjustment. Ten readings on a shim are sufficient to establish a reliable average value for that shim on the roughened surface. Following the manufacturer's instructions, the gage is adjusted so that the actual shim thickness is then used to set the gage.

This procedure should be repeated for both the upper and lower shim values.

The average of 10 readings on an intermediate shim, approximately 100 µm (4.0 mil) thick in the case described here, will confirm that the gage has been adjusted correctly. It is acceptable for the average reading to be within ± 4% of the shim thickness.

This method ensures that the gage reads the thickness of the coating over the peaks of the profile.

A8.3 SMOOTH SURFACE ADJUSTMENT: If access to the bare blast cleaned substrate is not available because the coating already covers it, a smooth surface can be used to adjust the gage. Adjust the gage on a smooth surface according to the manufacturer's instructions. Alternatively, it may be possible to adjust some Type 2 gages through the coating already applied to an abrasive blast cleaned substrate (may be necessary if no uncoated substrate exists). This procedure should be performed according to the manufacturer's instructions.

Readings taken on the blast-cleaned substrate will be higher than the true value by an amount dependant on the surface profile and the gage probe design. For most applications, a correction value of 25 µm (1.0 mil) is generally applicable. Note that this value is not related to the actual surface profile measurement. This correction value must be subtracted from each gage reading to correct for the effect of the profile. The resulting corrected reading represents the thickness of the coating over the peak.

For fine profiles, the correction value may be as low as 10 µm (0.4 mil) but for coarse profiles it could be as high as 40 µm (1.6 mil). Table A8 gives approximate correction values to be used when a blast-cleaned surface is not available to adjust the gage.

The use of coated standards to adjust gages means that a correction value must be applied to readings as the coated standards make use of smooth substrate surfaces.

APPENDIX 9 – PRECAUTION REGARDING USE OF THE STANDARD FOR COATING FAILURE INVESTIGATIONS

During a coating failure investigation, coating thickness measurements are not typically acquired as described in Sections 8.2.1 through 8.2.3, but rather from failing and non-failing areas based on observed patterns of failure and other observations made during the site investigation. Acquiring measurements in 100 ft^2 areas across the structure during a coating failure investigation may be of lesser value and may be cost-prohibitive. Accordingly, ASTM D7091 may be a more appropriate reference standard for this application.

APPENDIX 10 – PROCEDURE FOR OBTAINING A GREATER POPULATION OF THICKNESS MEASUREMENTS USING TYPE 2 GAGE CONTINUOUS READ/SCANNING PROBE TECHNOLOGY

Appendix 10 is not a mandatory part of this standard, but it provides a protocol for measuring the dry film thickness (DFT) of coatings with Type 2 (electronic) gages utilizing scanning technology. Statistical analysis of data suggests that greater precision of DFT measurements can be achieved by obtaining a greater population of measurements over a larger area using the scanning method over the traditional "place and remove probe" frequency described in Section 8 of this standard. Also, scanning technology enables an operator to collect a greater number of DFT measurements in a shorter time frame than the traditional method described in Section 8. Due to the increased number of measurements being collected, better indication of the sample mean can be obtained through increased precision.

A10.1 DEFINITIONS

A10.1.1 Scanning Batch Measurement: The mean of no less than 12 DFT readings and up to 24 readings, without lifting the probe from the coated surface, using an "infinity symbol motion" ∞ [vertical or horizontal orientation] obtained within a 645 cm^2 (~100 in^2) segment of the coated area.

A10.1.2 Scanning Area Measurement: The sample mean of five scanning batch measurements obtained over each 10 m^2 (~100 ft^2) area of coated surface, or portion thereof.

A10.2 PROCEDURE

A10.2.1 The procedures for gage calibration, verification of accuracy, and adjustment described in Section 5 of this standard shall be completed prior to acquisition of coating thickness readings described in this Appendix.

A10.2.2 Obtain Scanning Batch Measurement: Using a Type 2 gage set to the continuous read mode, traverse the probe across the surface of a coating in an "infinity symbol motion" (∞), within a 645 cm² (~100 in²) segment at the rate necessary to acquire a minimum of 12 readings and a maximum of 24 readings before lifting the probe. While more than 24 readings may be acquired during the scan, research has indicated that there is little improvement to the statistical validity of the data set with additional readings beyond 24. Any unusually high or low gage readings in a scan batch that are not repeated consistently (outliers) may be discarded. Record the mean of the acceptable scanning gage readings (Scanning Batch Measurement), as well as highest and lowest readings (after discarding outliers, if applicable) as shown in the Sample Table A10.1, below. The standard deviation may also be reported if required.

A10.2.3 Obtain Scanning Area Measurements: Repeat the procedure described in A10.2.2 in four additional 645 cm² (~100 in²) segments (total of five segments) over each 10 m² (~100 ft²) area of coated surface, or portion thereof (see Figure A10). The Coating Thickness Restriction Table (Table 1) in Section 9 of this Standard is used to verify conformance to the coating thickness specified in the contract documents. The "Spot Measurement" column in Section 9, Table 1 shall be referenced for the Scanned Batch Measurements.

A10.2.4 Calculate the Scanning Area Measurement: Calculate the total mean of the five scanning batch measurements obtained over each 10 m² (~100 ft²) area of coated surface, or portion thereof and record the information as shown in the Sample Table A10.2, below. The Coating Thickness Restriction Table (Table 1) in Section 9 of this Standard is used to verify conformance to the coating thickness specified in the contract documents. The "Area Measurement" column in Section 9, Table 1 shall be referenced for the Scanned Area Measurements.

SAMPLE TABLE A10.1

Scanned Batch Measurement Segment	Mean	Standard Deviation[1]	Highest Reading[2]	Lowest Reading[2]
1				
2				
3				
4				
5				

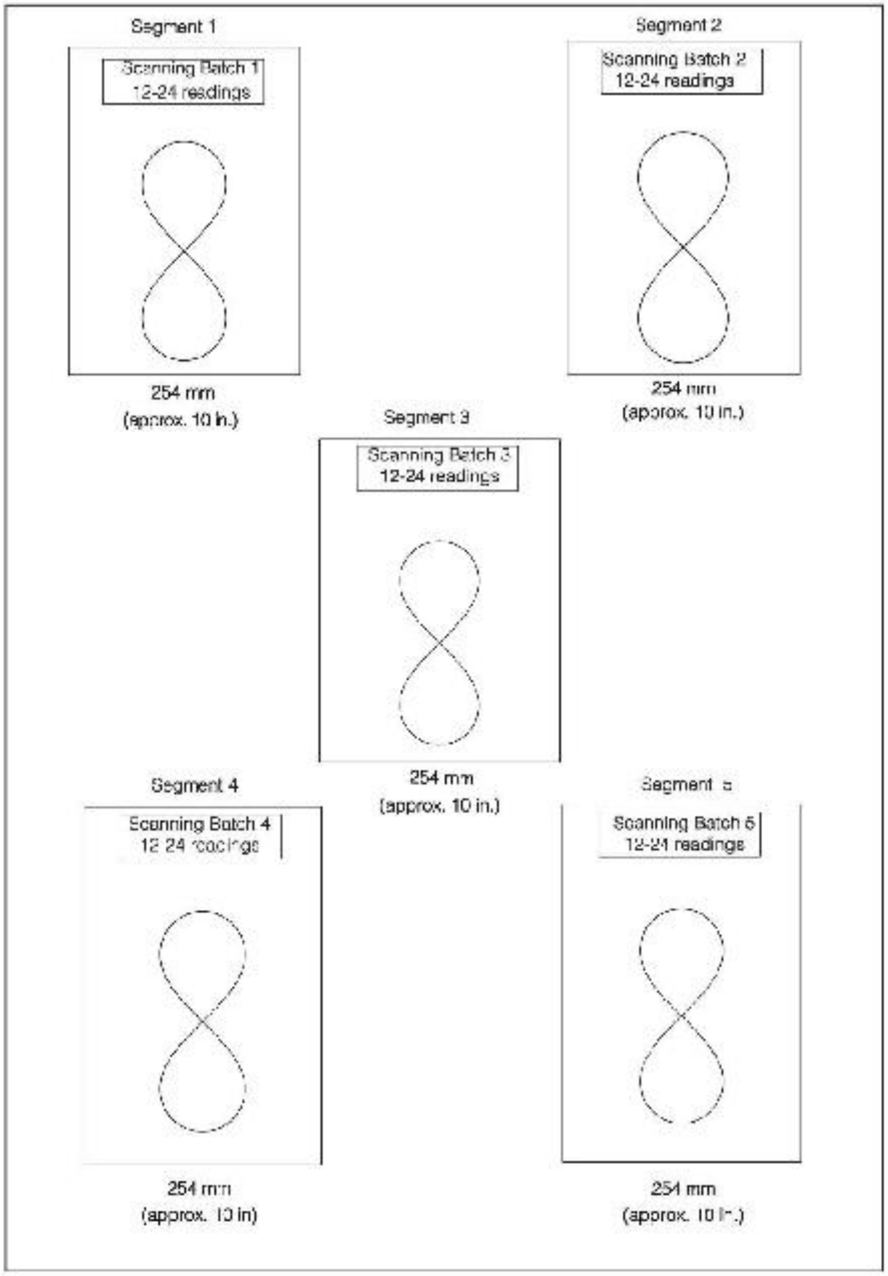
[1] Optional.
[2] After discarding outliers, if applicable.

SAMPLE TABLE A10.2

Scanned Area Measurement Location	Mean	Standard Deviation[1]	Highest Reading[2]	Lowest Reading[2]

[1] Optional.
[2] After discarding outliers, if applicable.

FIGURE A10
SCANNING AREA MEASUREMENT



Editorial Revisions since January 26, 2015: *The revisions listed below are editorial clarifications or corrections of obvious errors identified since the date of the last technical revision of the standard dated January 26, 2015, and the previous editorial revision of March 15, 2017.*

(1) *Section 1.5 (September 14, 2018): Removed following text: "This standard is not intended to be used for measurement of thermal spray coatings. The thickness measurement procedures for thermal spray coatings applied over steel substrates are described in SSPC-CS 23.00/AWS C2.23M/NACE No. 12." (Use of SSPC-PA 2 is required in the September 2016 revision of SSPC-CS 23.00/AWS C2.23M/NACE No. 12.) Added text: "Units of Measure: This standard makes use of both the ASTM SI 10, "American National Standard for Metric Practice" International System Units (SI) and U.S. Customary units. The measurements are not exact equivalents; therefore, each system must be used independently of the other." (Added text clarifies that the user should not attempt to convert values from one system to the other.)*

(2) *Appendix A (September 14, 2018). Divided Appendix A into two sections, one using S.I. units, the other using U.S. Custom units.*

(3) *Section 5.7, (March 15, 2017): Reorganized sentence 1 for clarity. Replaced the word "measurements" with "gage readings," as this sentence refers to multiple gage readings. Formerly read: "In order to compensate for any effect of the substrate itself and surface roughness, obtain measurements from the bare, prepared substrate at a minimum of ten (10) locations (arbitrarily spaced) and calculate the average value."*

(4) *Appendix A7 (March 15, 2017): Sequential numbering corrected. Text unchanged.*

(5) *Section 1.1 (October 1, 2018): Removed Section 1.2 and revised Scope to conform to description of gages in revised ASTM D7091.*

(6) *Section 1.4 (October 1, 2018): Added Appendix A10 to list of appendices.*

(7) *Section 2.3 (October 1, 2018): Deleted parenthetical statement that ASTM D7091 is a mandatory document required to use SSPC-PA 2.*

(8) *Section 5.1 (October 1, 2018): Revised first sentence to remove reference to ASTM D7091.*

(9) *Section 5.3 (October 1, 2018): Revised first sentence to allow use of gage manufacturer's instructions as an alternative to use of ASTM D7091 for verification of gage accuracy.*

(10) *Added Appendix A10 (November 1, 2018) to address use of continuous read/scanning probe technology for obtaining a greater population of measurements over a larger area.*

Designation: D 4417 – 93 (Reapproved 1999)

Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel[1]

This standard is issued under the fixed designation D 4417; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the description of techniques for measuring the profile of abrasive blast cleaned surfaces in the laboratory, field, or in the fabricating shop. There are additional techniques suitable for laboratory use not covered by these test methods.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Test Method

2.1 The methods are:

2.1.1 *Method A*—The blasted surface is visually compared to standards prepared with various surface profile depths and the range determined.

2.1.2 *Method B*—The depth of profile is measured using a fine pointed probe at a number of locations and the arithmetic mean determined.

2.1.3 *Method C*—A composite plastic tape is impressed into the blast cleaned surface forming a reverse image of the profile, and the maximum peak to valley distance measured with a micrometer.

3. Significance and Use

3.1 The height of surface profile has been shown to be a factor in the performance of various coatings applied to steel. For this reason, surface profile should be measured prior to coating application to ensure that it meets that specified. The instruments described are readily portable and sufficiently sturdy for use in the field.

NOTE 1—Optical microscope methods serve as a referee method for surface profile measurement. Profile depth designations are based on the concept of mean maximum profile ($\bar{h}$ max); this value is determined by averaging a given number (usually 20) of the highest peak to lowest valley measurements made in the field of view of a standard measuring microscope. This is done because of evidence that coatings performance in any one small area is primarily influenced by the highest surface features in that area and not by the average roughness.[2]

4. Apparatus

4.1 *Method A*—A profile comparator consisting of a number of areas (each approximately one square inch in size), usually side by side, with a different profile or anchor pattern depth. Each area is marked giving the nominal profile depth in mils or micrometres. Typical comparator surfaces are prepared with steel shot, steel grit, or sand or other nonmetallic abrasive, since the appearance of the profile created by these abrasives may differ. The comparator areas are used with or without magnification of 5 to 10 power.

4.2 *Method B*—A dial gage[3] depth micrometer fitted with a pointed probe. The probe is machined at a 60° angle with a nominal radius of 50 µm. The base of the instrument rests on the tops of the peaks of the surface profile while the spring loaded tip projects into the valleys.

4.3 *Method C*—A special tape[4] containing a compressible foam attached to a noncompressible uniform plastic film. A burnishing tool is used to impress the foam face of the tape into the surface to create a reverse replica of the profile that is measured using a spring-loaded micrometer.

5. Test Specimens

5.1 Use any metal surface that, after blast cleaning, is free of

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[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.46 on Industrial Protective Painting.

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[2] John D. Keane, Joseph A. Bruno, Jr., Raymond E. F. Weaver, "Surface Profile for Anti-Corrosion Paints," Oct. 25, 1976, Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

[3] The sole source of supply of surface depth micrometers known to the committee at this time is the surface profile gage, Model 123, Elcometer Instruments, Ltd., Edge Lane, Droylsden, Manchester M35 6UR, United Kingdom, England. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[4] The sole source of supply of suitable replica tape, Press-O-Film, known to the committee at this time is Testex, 8 Fox Lane, Newark, DE 19711. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

loose surface interference material, dirt, dust, and abrasive residue.

6. Procedure

6.1 *Method A:*

6.1.1 Select the comparator standard appropriate for the abrasive used for blast cleaning.

6.1.2 Place the comparator standard directly on the surface to be measured and compare the roughness of the prepared surface with the roughness on the comparator segments. This can be done with the unaided eye, under 5 to 10 power magnification, or by touch. When using magnification, the magnifier should be brought into intimate contact with the standard, and the depth of focus must be sufficient for the standard and surface to be in focus simultaneously.

6.1.3 Select the comparator segment that most closely approximates the roughness of the surface being evaluated or, if necessary, the two segments to which it is intermediate.

6.1.4 Evaluate the roughness at a sufficient number of locations to characterize the surface as specified or agreed upon between the interested parties. Report the range of results from all locations as the surface profile.

6.2 *Method B:*

6.2.1 Prior to use set the gage to zero by placing it on a piece of plate float glass. Hold the gage by its base and press firmly against the glass. Adjust the instrument to zero.

6.2.2 To take readings, hold the gage firmly against the prepared substrate. Do not drag the instrument across the surface between readings, or the spring-loaded tip may become rounded leading to false readings.

6.2.3 Measure the profile at a sufficient number of locations to characterize the surface, as specified or agreed upon between the interested parties. At each location make ten readings and determine the mean. Then determine the mean for all the locations and report it as the profile of the surface.

6.3 *Method C:*

6.3.1 Select the correct tape range for the profile to be measured: coarse, 0 to 50 µm (0 to 2 mils) and extra coarse, 40 to 115 µm (1.5 to 4.5 mils).

6.3.2 Remove the wax paper backing and place the tape on the prepared surface with the foam side down, that is, put the dull side down.

6.3.3 Hold the tape firmly on the surface and rub the circular cut-out portion (approximately 6.5 mm (¼ in.) diameter) with the burnishing tool until a uniform gray color appears.

6.3.4 Remove the tape and place it between the anvils of a spring-loaded micrometer. Measure the thickness of the tape (compressed foam and non-compressible plastic film combined). Subtract the thickness of the noncompressible plastic film to obtain the surface profile.

6.3.5 Measure the profile at a sufficient number of locations to characterize the surface, as specified or agreed upon between the interested parties. At each location make three readings and determine the mean. Then determine the mean for all the locations and report it as the profile of the surface.

7. Report

7.1 Report the range and the appropriate average (mean or mode) of the determinations, the number of locations measured, and the approximate total area covered.

8. Precision and Bias

8.1 *Test Method A:*

8.1.1 *Applicability*—Based on measurements of profiles on surfaces of 8 steel panels, each blast cleaned with 1 of 8 different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 37 µm (1.5 mils) to 135 µm (5.4 mils), the correlation coefficient for Test Method A was found to be 0.75 and the coefficient of determination was found to be 0.54.

8.1.2 *Precision*—In an interlaboratory study of Test Method A in which 2 operators each running 2 tests on separate days in each of 6 laboratories tested 8 surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 20 % with 141 df and the interlaboratory coefficient was found to be 19 % with 40 df, after rejecting 3 results for one time because the range between repeats differed significantly from all other ranges. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

8.1.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 56 %.

8.1.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 54 %.

8.2 *Test Method B:*

8.2.1 *Applicability*—Based on measurements of profiles on surfaces of 8 steel panels, each blast cleaned with 1 of 8 different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 1.5 mils (37 µm) to 5.4 mils (135 µm), the correlation coefficient for Test Method B was found to be 0.99 and the coefficient of determination was found to be 0.93.

8.2.2 *Precision*—In an interlaboratory study of Test Method B in which 2 operators, each running 2 tests on separate days, in each of 5 laboratories tested 8 surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 19 % with 113 df and the interlaboratory coefficient was found to be 28 % with 32 df, after rejecting 3 results for one time because the range between repeats differed significantly from all other ranges. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

8.2.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 54 %.

8.2.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 79 %.

8.3 *Method C (X-Coarse Tape):*

8.3.1 *Applicability*—Based on measurements of profiles on surfaces of 8 steel panels, each blast cleaned with 1 of 8 different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 37 µm (1.5 mils) to 135 µm (5.4 mils), the correlation coefficient for Test

Method C (X-Coarse Tape) was found to be 0.96 and the coefficient of determination was found to be 0.93.

8.3.2 *Precision*—In an interlaboratory study of Test Method C (X-Coarse Tape) in which 2 operators each running 2 tests on separate days in each of 6 laboratories tested 8 surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 9 % with 120 df and the interlaboratory coefficient 13 % with 32 df. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

8.3.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 25 %.

8.3.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 37 %.

8.4 *Test Method C (Coarse Tape)*:

8.4.1 *Applicability*—Based on measurements of profiles on surfaces of 6 steel panels, each blast cleaned with 1 of 6 different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 37 µm (1.5 mils) to 57 µm (2.3 mils), the correlation coefficient for Test Method C (Coarse Tape) was found to be 0.48 and the coefficient of determination was found to be 0.23.

8.4.2 *Precision*—In an interlaboratory study of Test Method C (Coarse Tape) in which 2 operators each running 2 tests on separate days in each of 6 laboratories tested 6 surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 11 % with 90 df and the interlaboratory coefficient 11 % with 24 df. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

8.4.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 30 %.

8.4.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 28 %.

8.5 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in these test methods for measuring surface profile, bias cannot be determined.

NOTE 3—The test methods measure different values and the qualitative rating on which the applicability was determined also measures a different value. The mode is determined with the comparator of Test Method A. The height of a single valley below a plane at the level of the highest surrounding peaks is measured with the fine pointed probe of Test Method B. The distance from the bottoms of many of the deepest valleys to the tops of the highest peaks (maximum profiles) are measured with the composite plastic of Test Method C. The height of a single peak above an adjacent valley below is measured with a microscope for the qualitative rating that is compared with each of the methods in correlation calculations. Because the results for the microscope and for the fine pointed probe are measurements to an individual valley, the readings range over much broader limits than the results of the tape or the comparator.

9. Keywords

9.1 abrasive; abrasive blast cleaning; anchor pattern; surface profile; surface roughness

SSPC-AB 2
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SSPC: The Society for Protective Coatings

ABRASIVE STANDARD NO. 2

Cleanliness of Recycled Ferrous Metallic Abrasives

1. Scope

1.1 This standard contains requirements for the cleanliness of recycled ferrous metallic blast cleaning abrasives (the "work mix") used for the removal of coatings, paints, scale, rust and other foreign matter from steel or other surfaces. Laboratory and field testing procedures to determine conformance to the requirements of the standard are also included.

2. Description

2.1 FERROUS METALLIC ABRASIVES: Ferrous metallic abrasives are used for blast cleaning steel and other surfaces in field and shop locations. The inherent value of ferrous metallic abrasives is their ability to be recycled many times. The recycled abrasive must be cleaned to remove abrasive fines and debris, including paint, rust, mill scale, and other contaminants generated during the blast cleaning of steel or other surfaces.

2.2 RECYCLED ABRASIVE WORK MIX: The work mix develops during blast cleaning and recycling and is composed of new media and, recycled clean media that meets the requirements of Sections 4.1 through 4.6 of this standard. The new abrasive being added may consist of shot, grit, or a mix of shot and grit.

3. Referenced Standards

3.1 The latest issue, revision, or amendment of the referenced standards in effect on the date of invitation to bid shall govern, unless otherwise specified.

3.1.1 If there is a conflict between the requirements of any of the cited referenced standards and this standard, the requirements of this standard shall prevail.

3.2 SSPC: THE SOCIETY FOR PROTECTIVE COATINGS STANDARD

PA 17	Procedure for Determining Conformance to Steel Profile/Surface Roughness/ Peak Count Requirements

3.3 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS:[1]

D3335	Test Method for Low Concentrations of Lead, Cadmium and Cobalt in Paint by Atomic Absorption Spectroscopy
D4940	Test Method for Conductimetric Analysis of Water Soluble Ionic Contaminants of Blasting Abrasives
D7393	Standard Practice for Indicating Oil in Abrasives

4. Requirements for Recycled Work Mix Abrasives

4.1 Unless otherwise specified, the recycled work mix shall meet the requirements of Sections 4.2 through 4.6 prior to first use at each jobsite. The work mix shall meet the requirements of Sections 4.4, 4.5, and 4.6 when tested thereafter at 12 hour intervals or once per work shift, whichever is shorter. Nonconforming work mix shall not be used, shall be removed from equipment and shall be disposed of in accordance with federal, state, and local regulations and project specification requirements (see Notes 6.1, 6.2 and 6.3).

4.2 The abrasive material as supplied shall comply with all applicable Federal, state/provincial and local regulations. Material Safety Data Sheets shall be furnished for all abrasive materials supplied (see Note 6.4).

4.3 LEAD CONTENT: The maximum lead content of the work mix shall be 0.1% by weight (1000 parts per million [ppm]). Collect a single random sample of approximately 115 grams [g] (1/4 pound [lb]) of the work mix for testing according to requirements of ASTM D3335.

4.4 WATER-SOLUBLE CONTAMINANTS: A single random sample of approximately 300 milliliters (10 fluid ounces) of cleaned work mix shall be tested for conductivity in accordance with ASTM D4940. The conductivity of the abrasive work mix shall not exceed 1000 micromhos/cm (1 mho = 1 siemen). The test shall be performed once every 12 hours or once every work shift, whichever period is shorter (see Notes 6.2 and 6.3).

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[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

4.5 OIL CONTENT: A single random sample of the abrasive work mix shall be tested in accordance with ASTM D7393. There shall be no evidence of oil in the water used for the test, either on the surface or as an emulsion. The test results shall be reported; however since the test is being performed on a recycled work mix, reporting the abrasive manufacturer and batch/lot number, and size designation as required by ASTM D7393 is not a requirement of SSPC-AB 2.

4.6 PARTICLE SIZE DISTRIBUTION: The particle size distribution of the clean work mix shall be capable of achieving and maintaining the profile within the specified range as determined by the procedure in SSPC-PA 17. (See Note 6.5 and subsections and Appendix A for examples of specification language for optional tests that may be used to assess the particle size distribution and determine the amount of nonabrasive residue.) New shot, grit, or a mix of shot and grit shall be added periodically to the work mix to maintain the specified profile range.

5. Disclaimer

5.1 This is a consensus standard developed by SSPC: The Society for Protective Coatings. While every precaution is taken to ensure that all information furnished in SSPC standards is as accurate, complete and useful as possible, SSPC cannot assume responsibility nor incur any obligation resulting from the use of any materials or methods specified therein, or of the standard itself.

5.2 This standard does not attempt to address problems concerning safety and health associated with its use. The user of this standard, as well as the user of all products or practices described herein, is responsible for instituting appropriate health and safety practices and for ensuring compliance with all governmental regulations.

6. Notes

Notes are not requirements of this standard.

6.1 Spent abrasives may contain hazardous paint and other foreign matter. Disposal, storage, and handling of spent abrasives shall be performed in compliance with all applicable Federal, state/provincial, and local regulations and project requirements.

6.2 If non-compliant work mix is detected during continuous recycling, blasting and handling equipment should be checked for residual contamination after removal of the contaminated media. Following cleaning, new compliant media should be fed through the equipment and again tested for compliance with requirements of SSPC-AB 2 before production work resumes.

6.3 The limitation for abrasive conductivity is based on pressure immersion testing and accelerated outdoor exposure tests performed by SSPC.[5]

6.4 Special precautions may be needed to avoid exceeding permissible exposure limits (PELs) when removing hazardous materials. Conform to all safety and regulatory requirements based on the applicable federal, state and local requirements.

6.5 Examples of Specification Language: The examples in Notes 6.5.1 and 6.5.2 may be used if the test for non-abrasive residue or the preparation of a test area is desired. Italicized language between square brackets provides options for the specifier.

6.5.1 The cleaned work mix shall meet the requirements of SSPC-AB 2, including testing for non-abrasive residue in accordance with the procedure described in the Appendix to SSPC-AB 2 [prior to first use/at other specified frequency].

6.5.2 The cleaned work mix shall meet the requirements of SSPC-AB 2. Within 15 minutes after the start of surface preparation [daily/other specified frequency] a test area measuring at minimum 61 x 61 centimeters (2 x 2 feet) shall be prepared and shall meet specified requirements for [surface cleanliness/surface dust/surface profile range]. The test area shall be accepted by the [facility owner's representative] prior to continuation of production.

Appendix: Procedure for Determining Amount of Non-Abrasive Residue in Work Mix (nonmandatory unless specified by procurement documents)

This procedure requires

- Two empty plastic or paper cups capable of holding 100-gram "grab" samples
- A scale accurate to 0.10 gram (0.0035 oz.) with a "tare" function.
- A sheathed magnet (a magnet enclosed by a plastic sheath, see Figure A1).

Step 1: Label one cup A and the other B. Tare the weight of Cup A. If the scale does not have a "tare" function, weigh and record the weight of Cup A, the weight of Cup A is subtracted from the measured weight in Step 8 before determining if the requirements of the standard have been met.

Step 2: Using Cup A, obtain a "grab" sample taken at random from the cleaned work mix. The sample weight shall be approximately 100 g (3.5 oz.). Weigh the sample on the scale. Subtract the weight of the cup if the scale does not have a "tare" function. Record the weight of the sample to the nearest 0.1g.

Step 3: Spread the material over a clean surface of approximately 0.1 square meter [m²] (1 square foot [ft²]).

Step 4: Place the sheathed magnet in contact with the spread "grab" sample from Cup A. The magnet must remain in contact with the bottom of the interior surface of the plastic sheath. Note: Care must be taken not to pick up too much

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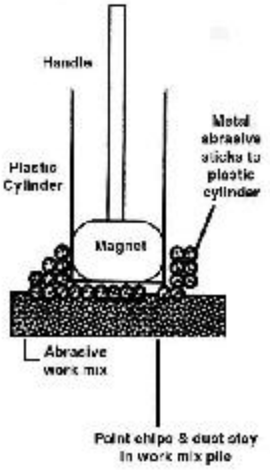
[5] SSPC Report 91-07, Effect of Surface Contaminants on Coating Life (June 1991)

magnetic material at one time to avoid trapping non-magnetic particles among the magnetic particles.

Figure A1
Separating Metallic Abrasive from the Work Mix Using a Sheathed Magnet



Step 5: While keeping the magnet in contact with the interior surface of the plastic sheath, move the sheathed magnet over Cup B. Deposit the collected material into Cup B by raising the magnet from the bottom of the plastic sheath.

Step 6: Return the sheathed magnet to the screened portion of the abrasive and repeat Steps 4 through 6 until no more magnetic material is retrieved from the spread "grab" sample.

Step 7: Return the non-magnetic material from the "grab" sample into Cup A. Weigh Cup A and compare the tared weight of the non-magnetic material to the tared weight of the "grab" sample recorded in Step 2. If the weight of the non-magnetic material in Cup A is greater than 1 percent of the weight of the initial sample, the work mix shall be recleaned.

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