Analysis of stress on steel after cleaning with 36-40K psi waterjetting. Work was performed for [redacted] so they could evaluate steel surface. The UHP WJ equipment was intensifier system.

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GENERAL INFORMATION

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WORK PERFORMED

Different surface cleaning techniques were used to prepare test samples for examination. These were evaluated to determine the effect each technique has on a "cleaned" surface.

The evaluation consisted of three phases. The prepared samples were examined visually and then using a stereographic microscope. Metallographic specimens were prepared for microscopic study of surface edge sections. Computations were performed to determine weight-loss per unit area for each of the samples after cleaning.

RESULTS

Sample Description

The principle test samples were 12 by 8 inch sections of plate. Two common steel designations were represented, ASTM A-516 Gr 70 and ASTM A-36. The sample materials had average Brinell hardness numbers of 139HB and 101HB respectively.

The plate samples were from new, but "weathered", material. That is, the surface deposits were a combination of mill scale with a moderate amount of rust. Sample labels and brief descriptions of the cleaning method used are tabulated in the following. Data sheets generated as the samples were prepared and any associated material safety data sheets are attached to the report.

No.	Material	Cleaning Method
2	A516 Gr70	[A/A] Compressed air with abrasive
3	A516 Gr70	[H2O] Pressurized, inhibited water
4	A516 Gr70	[W/A] Pressurized, inhibited water with abrasive
5	A516 Gr70	[M/A] Mechanical "flapper-wheel"
7	A36	[A/A] Compressed air with abrasive
8	A36	[H2O] Pressurized, inhibited water
9	A36	[W/A] Pressurized, inhibited water with abrasive
10	A36	[M/A] Mechanical "flapper-wheel"
11	A36	[W/A] Pressurized, inhibited water

Four additional samples were prepared from a welded flange spool piece. These were for comparison with material which had been in actual service prior to cleaning. The spool piece was quarter-sectioned, with the resulting samples described as follows:

ID	Cleaning Method
P1	[NC] (Not Cleaned)
P2	[H2O] Pressurized, inhibited water
P3	[H2O] Pressurized, inhibited water
P4	[W/A] Pressurized, inhibited water with abrasive

Macro Analysis

Each of the cleaning techniques successfully removed the rust deposits from the surface. Abrasive particles, however, were necessary to remove mill scale. Observations regarding each of the samples are provided in the following.

#02 [A/A] Particles in the air stream had worn the surface. Some of these were embedded in the metal. Small ring-like spots of mill scale were still present.

#03 [H2O] Splotches of thin, adherent mill scale remained. No gross mechanical disturbance of the metal was noted.

#04 [W/A] Results like those for Sample #02. This is an aggressive technique. It left distinct streaks on the cleaned surface.

#05 [M/A] Spots of mill scale remained. The finish was uneven with burnished regions.

#07 [A/A] Similar to the results for Sample #02; however, the softer A36 metal was abraded more heavily.

#08 [H2O] Similar results to those for Sample #03 with a greater amount of mill scale remaining.

#09 [W/A] Very nearly identical to the results noted for Sample #04.

#10 [M/A] Considerable mechanical smoothing of the metal. Much of the mill scale remained.

#11 [H2O] Results much like those for Sample #03 with a roughly equivalent amount of mill scale remaining.

P2/P3 [H2O] Metal left clean and undisturbed. Some light residue in the deepest recesses.

P4 [W/A] Thoroughly cleaned, but somewhat abraded.

Micro Analysis

Specimens representing typical surface conditions were machined from each plate sample. These were metallographically prepared for examination of the metal surface in cross section. Descriptions of the surface features are provided in the following.

A516Gr70 The bulk microstructure was considered typical for a carbon steel plate. The material was in the as-rolled condition with an ASTM Grain Size No. of 8 or smaller. The surface had mill scale and rust deposits ranging from 2 to 10 mils in thickness.

A36 The plate had a bulk microstructure characteristic of a plain carbon steel in the as-rolled condition. An ASTM Grain Size No. of 6 or smaller was estimated. The mill scale and rust deposits were from 3 to 15 mils thick.

#02 [A/A] Metal grain flow and "folding-over" of surface irregularities. Abrasive particles and debris were embedded in the metal.

#03 [H2O] The surface microstructure was undisturbed. Some small patches of mill scale were present.

#04 [W/A] More severe surface grain distortion and erosion of the metal than for #02; other features very similar.

#05 [M/A] The surface was abraded to a smooth finish with some smearing. A few regions of deposits remained.

#07 [A/A] Similar to the results for #02; however, the softer metal experienced more extensive distortion.

#08 [H2O] Exhibited a generally clean surface, free of any grain flow or distortion. Some mill scale remained.

#09 [W/A] Results much as depicted for #04. The softer metal, however, was effected more aggressively.

#10 [M/A] Surface features were smeared over and smoothed. Pieces of remaining scale had edges polished away such that they blended with the metal surface.

#11 [H2O] Results were comparable to those for #08. Many of the fine irregularities were still present. Slightly more mill scale remained.

Figures 1 through 24 illustrate the test samples after cleaning and the features discussed in the macro and micro analyses.

Weight Loss per Unit Area

The test plates were measured and weighed prior to cleaning. A weight measurement after cleaning was also recorded. From this data, values for deposit/metal-loss-per-unit-area-cleaned were computed. The results are tabulated in the following using units of ounces per square foot (oz/ft^2) and milligrams per square millimeter (mg/mm^2).

Material	No.	(oz/ft^2)	(mg/mm^2)	Method
A516Gr70	2	0.52	0.16	air w/abrasive
A516Gr70	3	0.42	0.13	pressurized water (Method 1)
A516Gr70	4	1.6	0.48	pressurized water w/abrasive
A516Gr70	5	0.74	0.23	"flapper-wheel"
A36	7	0.69	0.23	air w/abrasive
A36	8	0.48	0.14	pressurized water (Method 1)
A36	9	1.5	0.45	pressurized water w/abrasive
A36	10	0.42	0.13	"flapper-wheel"
A36	11	0.42	0.13	pressurized water (Method 2)

CONCLUSIONS

The following comments are the Author's opinions based upon the results of this evaluation:

1. Pressurized water effectively removed rust and other corrosion products from metal surfaces. This was done with minimal disturbance of microstructural features.

2. Methods using abrasive particles were necessary for the removal of adherent mill scale. Those techniques cause severe distortion of the metal surface.

3. The pressurized water method was considered the best preparatory cleaning for non-destructive inspection. It offered a more "authentic" representation of the surface than the other methods evaluated.

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