2022

# HEAT EXCHANGER TUBE MATERIAL RESPONSE TO HIGH PRESSURE WATERJET IMPACT

## AND THE FACTORS AFFECTING THE RISK OF DAMAGE DURING THE CLEANING PROCESS


**Research and Publication:**
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ENGINEERING THE POWER OF WATER

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# INTRODUCTION

- METHODOLOGY
  - Hydroblasting or High Pressure Water-Jetting has become widely accepted to efficiently remove fouling from heat exchanger tubes (**tube-side** & shell-side)
  - Manually-fed, positioned, and manipulated techniques are present, but are succeeded by mechanized (semi-automated) or fully-automated cleaning techniques
- CONCERN
  - Generally, Carbon Steel & Stainless-Steel substrate are reasonably resistant to the velocity of properly applied hydroblasting cleaning techniques, however these materials are not impervious to waterjet damage
  - Equipment constructed of softer metallic materials like brass, nickel, and copper alloys, may raise a greater concern when specified to be serviced via hydroblasting
- MITIGATION
  - ***UNDERSTANDING*** the impact of a high-pressure waterjet conveyed by orifice(s)
  - ***IDENTIFYING POTENTIAL*** for cavitation-erosion to adversely affect substrate beyond foulant removal
  - ***KNOWING*** deployed equipment components & characteristics within the operation

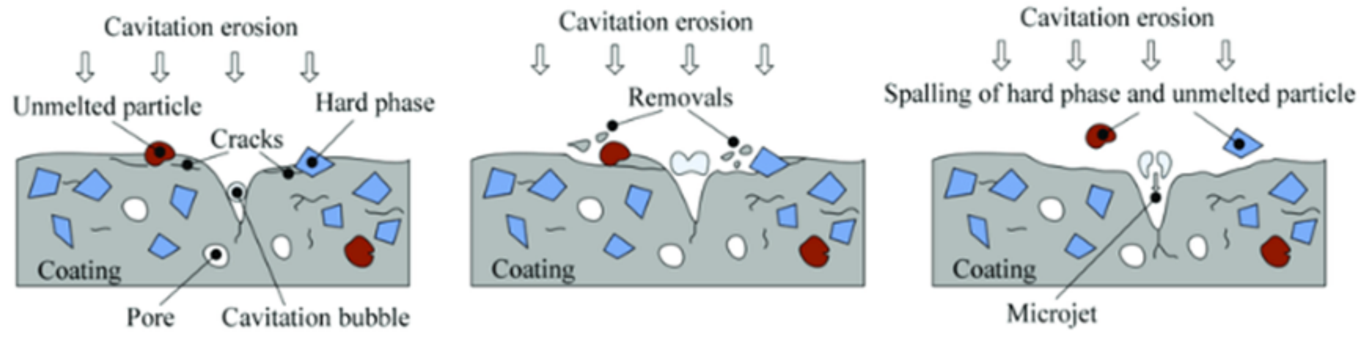
# PURPOSE OF PUBLICATION

**WHY?**

Testing was conducted to aid in the specification of heat exchanger tube cleaning processes involving:

- **Operating Parameters** (Pressure, Volume, Clearance Fit, Rotation, Traverse Rate)
- **Types of Nozzle Assemblies** (Static, Self-Rotary, Powered-Rotary)
- **Personnel Training / Automated Controls** (Operating Procedures, Awareness, Countering Human-Error with programmed points of function)

# WHAT ARE THE RISKS?




Schematic of the cavitation erosion mechanism. Image Source: Effect of Heat Treatment on the Cavitation Erosion Performance of WC–12Co Coatings

## CAVITATION EROSION

- The application of a water-jet upon a metallic surface may remove material through ***cavitation erosion***, but what **determines the risk?**
  - MATERIAL TYPE
  - JET IMPACT
  - JET DWELL-TIME
  - JET ROTATION
  - JET ANGLE
  - JET TRAVERSE / TRANSLATION
  - JET DIAMETER

# CONDUCTED TEST PROCEDURES

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## 1. NON-ROTARY

- ***Static Assembly*** applied to X Material
- ***Stand-Off Distance*** comparable to an appropriate Clearance Fit application
- ***Exposure Analysis*** @ 10, 30, and 60 seconds Duration

## 2. ROTARY

- ***Rotary Assembly*** applied to X Material
- ***Radial Rotation*** by itself reduces amount of potential damage to substrate – allows consideration for higher working pressures
- ***Exposure Analysis*** Noting the difference in material removal due to reduced jet dwell-time

## 3. ROTARY + TRAVERSE

- ***Rotary Assembly*** applied to X Material
- ***Linear Traverse*** of the rotating assembly adds another dimension to measure a reduction in potential for substrate damage
- ***Exposure Analysis*** Noting the lack of material removal due to reduced jet dwell-time via rotation compounded with linear traverse

## 4. ADDITIONAL VARIABLES

- ***Varying Stand-Off Distances***
- ***Measuring Material-Removal decreasing potential with steeper attack-angles***
- ***Increasing Flow Rate to adjust jet power comparing exposure durations***

# CONDUCTED TEST EXCERPTS



## MATERIALS USED IN TESTING

| Material | UNS | Form | Other Common Names |
|---|---|---|---|
| Copper-Nickel 90/10 | C70600 | Sheet | Cupro-Nickel |
| 110 Copper | C11000 | Sheet | CDA 110 |
| 101 Copper | C10100 | Tube | C101 |
| 260 Brass | C26000 | Tube | Cartridge Brass |
| 400 Nickel | N04400 | Sheet | Monel 400 |
| 304 Stainless Steel | S30400 | Plate | 304 Stainless Steel |
| 1018 CDF Carbon Steel | G10180 | Plate | 1018 Carbon Steel |
| Titanium Grade 2 | R50400 | Sheet | Titanium Type 2 |

## ORIFICE DIAMETERS & RADIAL CONFIGURATIONS

| Head Name | Orifice Type | Pattern 1 | Orifice Size | Pattern 2 | Orifice Size |
|---|---|---|---|---|---|
| “A” | Drilled | 2 X 90° | .91 mm (.036”) | 2 X 105° | .81 mm (.032”) |
| “D” | Drilled | 2 X 90° | .66 mm (.026”) | 2 X 105° | .66 mm (.026”) |
| “UHP” | Sapphire | 2 X 85° | .25 mm (.010”) | 2 X 110° | .36 mm (.014”) |

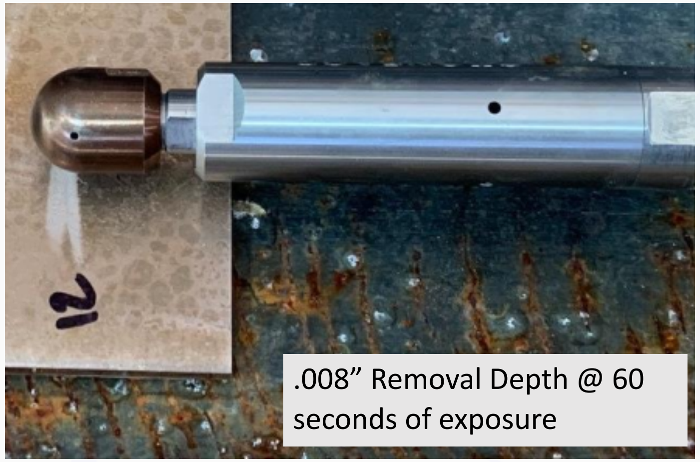
# CONDUCTED TEST EXCERPTS

Material Specifications: Copper Nickel 90/10, 110 Copper

| NOZZLE ASSY. STYLE | IMPACTING ORIFICE(S) DIAMETER | TRAVERSE RATE |
|---|---|---|
| **Static** | .026” (.66MM) | None Applied |
| **ORIFICE LOCATION** | **STAND-OFF DISTANCE** | **SYSTEM OPERATING PRESSURE** |
| Radially @ 90˚ | .189” (4.8MM) | 15,000 PSI (1034 bar, 103 Mpa) |

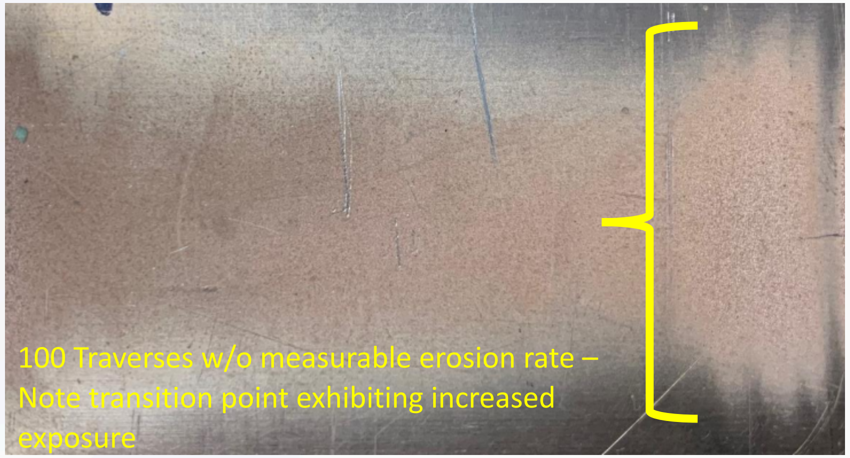
.028” Removal Depth @ 60 seconds of exposure

| NOZZLE ASSY. STYLE | IMPACTING ORIFICE(S) DIAMETER | ASSEMBLY TRAVERSE RATE |
|---|---|---|
| **Self-Rotary** | .026” (.66MM) | None Applied |
| **ORIFICE LOCATION** | **STAND-OFF DISTANCE** | **SYSTEM OPERATING PRESSURE** |
| Radially @ 90˚, Radially @ 105˚ | .189” (4.8MM) | 15,000 PSI (1034 bar, 103 Mpa) |



.008” Removal Depth @ 60 seconds of exposure

| NOZZLE ASSY. STYLE | IMPACTING ORIFICE(S) DIAMETER | ASSEMBLY TRAVERSE RATE |
|---|---|---|
| **Self-Rotary** | .026” (.66MM) | **1.97”/ Sec (50MM / Sec)** |
| **ORIFICE LOCATION** | **STAND-OFF DISTANCE** | **SYSTEM OPERATING PRESSURE** |
| Radially @ 90˚, Radially @ 105˚ | .189” (4.8MM) | 15,000 PSI (1034 bar, 103 Mpa) |



100 Traverses w/o measurable erosion rate – Note transition point exhibiting increased exposure

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# CONDUCTED TEST EXCERPTS

*Unique and Insightful* Test Results


Tl The E The Result of 50 Passes with Rotating Head at 228 MPa (33,000 psi) in 1018 CDF Plate
Figure 16.

- ➢ Too Close? Too Far Away?
- ➢ How steep of an angle creates excessive stand-off for effectivity?
- ➢ At what point is my mitigation tactic STRONGER than the substrate?

# KEY CONCLUSIONS GATHERED

✓ **"KEEP IT MOVING!"**

*Potential for substrate damage post-foulant removal / penetrated-foulant is lessened by keeping jets **ROTATING and TRAVERSING***

✓ **IMPLEMENT CONTROLS!**

*Whether limiting system pressure based on job-scope & material identification or utilizing practices & sensors that inhibit inadvertent jet-contact – **PLAN THE APPROACH***

✓ **JET FOR SUCCESS!**

*Considering appropriate flow by sizing orifices correctly, positioning jets where you need them to work, and clearance-fitting for the most effective stand-off will keep your time spent in each tube to a minimum – saving water and reducing **YOUR EXPOSURE DURATION FOR RISK***

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# THANK YOU!