Corrosion Testing and Flue Gas Desulfurization (FGD)

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INTRODUCTION

Flue Gas Desulfurisation

Air pollution control systems to remove oxides of sulphur from the effluent created by burning high-sulphur coal for electric power generation. Such systems are required for prevention of acid rain and to maintain reasonable health standards.
INTRODUCTION

Flue Gas Desulfurisation

Wet lime / limestone FGD systems operate under very corrosive conditions ... acidic chloride media at elevated temperatures and low pH. Thus, corrosion-resistant nickel-base alloys are often used in the construction of FGD system components. Construction techniques and material and welding product selection are critical for a serviceable, reliable FGD system.
CORROSIVE CONDITIONS IN THE WET LIMESTONE FGD SYSTEM

CORROSIVE CONDITIONS
- MILD
- MODERATE
- AGGRESSIVE
Premature Failure of FGD Absorber Vessel due to Localised Corrosion
CREVICE “UNDER DEPOSIT” CORROSION
Duplex Steel FGD Absorber Vessel Experience

In the USA from 2000 to 2006, 84 FGD absorber vessels were fabricated from grade 2205 duplex stainless steel plate. All failed in less than 2 years due to localized corrosion. In most cases, the attack was due to crevice attack under a mineral deposit that built up on the vessel wall.
While the general corrosion rate of the material was low, failure was due perforation from localised attack. The stainless steel simply did not offer adequate corrosion resistance for the environment.
FGD CONSTRUCTION SCENARIOS

- Solid Alloy Plate – GMAW/P; SMAW
- Alloy Clad Steel Plate – GMAW/P; SMAW
- Alloy Sheet ("Wallpaper") Cladding – GMAW/P; GTAW
SOLID ALLOY PLATE FGD CHIMNEY FLUES
EXPANSION JOINTS

Expansion Joints Fabricated from Solid Alloy Plate
Solid Alloy Plate Chimney Flue Construction
ALLOY CLAD STEEL PLATE FGD CHIMNEY FLUE
“WALLPAPER” LINED FGD DUCT
“WALLPAPER” LINED FGD ABSORBER VESSEL
“WALLPAPER” REPAIR OF FGD DAMPER BLADE
WALLPAPER CLADDING TECHNIQUES
FGD Alloy Selection

➤ Mild Conditions: **FeNiCrMo Super-Austenitic Stainless Steels**
  - INCOLOY alloys 25-6MO, 25-6HN & 27-7MO

➤ Severe Conditions: **NiCrMoW Corrosion-Resistant Alloys**
  - INCONEL alloys C-276, 22 & 686
### Chemical Composition of Some FGD Construction Materials

<table>
<thead>
<tr>
<th></th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Fe</th>
<th>W</th>
<th>Others</th>
</tr>
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<tbody>
<tr>
<td>316 L</td>
<td>12</td>
<td>17</td>
<td>2.2</td>
<td>68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-6MO</td>
<td>25</td>
<td>20</td>
<td>6.5</td>
<td>47</td>
<td></td>
<td>Cu 0.9, N 0.25</td>
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<tr>
<td>625</td>
<td>61</td>
<td>21</td>
<td>9</td>
<td>2.5</td>
<td></td>
<td>Nb 3.6</td>
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<tr>
<td>22</td>
<td>59</td>
<td>22</td>
<td>14.2</td>
<td>2.3</td>
<td>3.2</td>
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<tr>
<td>C-276</td>
<td>57</td>
<td>16</td>
<td>16</td>
<td>5.5</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>686</td>
<td>58</td>
<td>21</td>
<td>16.3</td>
<td>1</td>
<td>3.8</td>
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</table>
Proper alloy selection is critical. Four materials ... INCONEL alloys 686, 22 and C-276 and a super-austenitic stainless steel, INCOLOY alloy 25-6MO were exposed for 6 months in a FGD outlet duct. Alloy 686 was not attacked. Alloys C-276 and 22 exhibited slight initiation of localized corrosion. The stainless steel sample was completely corroded away.
Corrosion of Stainless Steels and Alloys in a Simulated FGD Solution at 70°C (158°F)
DON’T BE MISLED BY TEST RESULTS: G28

The ASTM G28 corrosion tests are designed to verify that alloy and stainless steel products have been properly heat treated (e.g., heating temperature and cooling rate. They are very effective in this role. However, some have tried to use a material’s corrosion rate in the G28 tests to judge relative corrosion resistance. This is a misapplication of the test.
# ASTM G28, METHOD A CORROSION TEST RATES

<table>
<thead>
<tr>
<th>Material</th>
<th>Corrosion Rate (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-276</td>
<td>6.4</td>
</tr>
<tr>
<td>686</td>
<td>1.8</td>
</tr>
<tr>
<td>622</td>
<td>1.0</td>
</tr>
<tr>
<td>316L</td>
<td>0.50</td>
</tr>
<tr>
<td>25-6MO</td>
<td>0.45</td>
</tr>
<tr>
<td>625</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**Note: Corrosion rates are mm/year**
DON’T BE MISLED BY TEST RESULTS: G48

The ASTM G48 tests for localized corrosion are better used to compare FGD alloys than the G28 tests. However, the G48 tests also have shortcomings for this purpose. The test medium for the G48 tests is a 6% ferric chloride (FeCl₃) solution. Ferric chloride is a highly oxidising salt whereas FGD media are normally more reducing.
Thus, the G48 test results will normally make higher chromium alloys appear more resistant than they actually are in FGD service. Examples are alloys 22 and C-276. In the ASTM G48, Method D test, alloy 22 with 22% chromium exhibits a critical crevice temperature (CCT) of 70°C while alloy C-276 with only 16% chromium exhibits a value of only 50°C. However, it is well known that these alloys exhibit similar performance in FGD service.
NiCrMo ALLOY STABILITY

NiCrMo corrosion-resistant alloys must have a balanced composition and proper heat treatment to exhibit optimum performance and corrosion resistance. Due to the complexity of these alloys, they can precipitate secondary phases (e.g., mu and sigma) which can severely compromise their mechanical properties, corrosion resistance and fabricability. Thus, it is suggested that users refrain from specifying non-standard composition limits in attempts to alter the properties of these materials.
Due to the high melting points of molybdenum and tungsten, welds containing these elements can suffer from the effects of elemental segregation during solidification. This can result in some areas of the weld offering less corrosion resistance than others. This effect can be offset by the use of overmatching composition welding consumables.
OVERMATCHING WELDING PRODUCTS

Preferential Attack of Matching Composition Weld in Alloy C-276 FGD Outlet Duct
INCO-WELD filler metal 686CPT replacement weld after 6 months service. Base metal corrosion continues but the weld attack has stopped.
IRON DILUTION OF WELDS

When joining alloy clad steel plate or wallpaper cladding over a steel substrate, it must be considered that iron will be melted into the weld deposit. This will dilute the alloy composition of the weld and can reduce its corrosion resistance. This is just another reason to use overmatching composition welding consumables.
SUCCESSFUL FGD DESIGN & FABRICATION

Successful FGD Design & Fabrication Requires:

1. A Full Understanding of the Corrosive Conditions & the Requirements of Service
2. Proper Alloy Selection for the Specific Environment
3. Proper Welding Product & Process Selection
4. A Reliable Construction Scenario for the Application
5. Proper & Adequate Quality Control & Inspection
6. Control of the Operating Conditions during Service
7. Avoid Crevice Conditions due to Mineral Deposits
CLEAN AIR AND CLEAN SKIES
Thank You