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Outline:

- Historical Timeline
  - Emphasis on Processes/Early to Present
- Notable Corrosion Incidents
- Challenges of Today and the Future
Historical Timeline

- Pulp & Paper Industry Changes Due To:
  - Expansion of the Industry and Greater Demand for Paper
  - Changes in both Process and Equipment
Early Paper Machine Production

- 1915 to 1940, Machine Production More than Doubled
- Number of Machines Stayed Nearly the Same

Corrosion & Control 1900 -1930

- 1920 - The industry was more focused on meeting production demands than on controlling corrosion
Processes/Equipment 1900-1930

- Acid Sulfite Cooking Predominant
- Some Kraft Production

Available Materials of Construction 1915

- Gray Cast Iron
- Wrought (Rolled & Forged) Carbon Steel
- Brass, Bronze & Babbitt
- Aluminum
- Nickel Electroplating
- Monel
- Rubber
- Wood
- Tile, Grout
Methods of Joining 1915

- Castings Predominant
- Forgings
- Bolting & Screws
- Rivets
- Welding Carbon Steel
- Brazing Copper Alloys

Digester Manufacture 1930
Additional Materials Available 1930

- Austenitic Stainless Steels 18/8
- Duplex Stainless Steel, Type 329
- Ni-Resist Castings (20% Nickel)

Methods of Joining 1930

- Welding of Carbon Steel
  - Oxyacetylene, Covered Electrode Arc Welding
  - No Welding Yet for Stainless Steel
Ni-Resist Applications 1930

Ni-Resist Applications 1930
Ni-Resist Applications 1930

Corrosion & Control 1930

- Awareness of Corrosion Impact on Production and Safety
- Kraft Digester Failure, Berlin, N.H 1930
Historical Timeline
1931-1945

Processes/Equipment
1931 - 1945

- Tomlinson Recovery Boiler Invented, Early 1930s
- Continuous Cooking Invented
(2) Processes / Equipment 1931-1945

- Increasing Paper Machine Speed – Better Dewatering

![Graph showing Paper Machine Speed from 1900 to 1950](image)

(3) Processes / Equipment 1940

- Batch Digesters Fabricated by Welding
- First ASME Code Dryers About 1940
Metal Joining
1940 - 1945

- Welding Stainless Steel in 1945
  - GTAW, GMAW Developed

- Carbon Steel Welding
  - SMAW, SAW, Oxyacetylene

Historical Timeline
1946 - 1960

![Graph showing historical timeline from 1940 to 1960 with data on consumption and production of paper and paperboard products in the United States from 1900 to 1970. The graph highlights the period 1946 to 1960.]
Processes/Equipment 1946 - 1960

- Hydrosulfite Brightening Introduced
  - Promotes Thiosulfate
  - Increases Whitewater Corrosivity

Processes/Equipment 1950s

- First Continuous Digesters Built in North America
- First High Pressure (1200 psi) Recovery Boilers
- Paper Machine
  - Type 304 SS Standard for Wet-end
  - Suction Rolls CA-15 and CF3M SS Replacing Bronze for Wider Machines
Processes / Equipment 1950s & Later

- Wastewater Recycling Begins
- Buildup Ions in System
- Higher Temperatures (More Corrosive)

Corrosion & Control 1950s

- Digester Wall Thinning –
  - The Most Important Corrosion Problem of the 1950s
  - TAPPI Digester Corrosion Monograph and Reports
- Mueller Research - Liquor Corrosivity
- 309 Weld O/L Testing

- Many Continuous Digester Built
  - (~ 100 Kamyr Units 1965-1970)
- Many High Pressure Recovery Boilers
  - Up to 1500 psi (Average 1000 psi)
- Paper Machines Bigger and Faster
  - First 390” Machines in 1971
  - DSS Suction Rolls


- CA-15 and CF8 Suction Roll Failures, Late 1960s
- DSS Suction Rolls – First of a long string of new suction roll alloys
  - Sandusky Alloy 63
  - DSS-69
  - A-70
  - VKA-171
  - 3RE60
  - Etcetera, Etcetera, Etcetera...
Corrosion & Control 1961 – 1980

Recovery Boilers
- 99 Recovery Boiler Explosions between 1960 and 1980
- Lower Furnace Corrosion Carbon Steel
  - Thermal Metal Spray by CE
  - Pin Studs by B&W
- First Composite Tubes Installed 1971 in Scandinavia

Bleach Plant System Closures
- Temperature increases
- Oxidant (Chlorine & Chlorine Dioxide) Carryover
  - Type 316 & 317 SS Unsatisfactory
  - 6% Molybdenum SS Introduced, Late 1970s
  - FRP Materials Introduced
- First Electrochemical Protection Bleach Washer in 1978 (90 installations by 1986)
Historical Timeline

1981 – 2000


- Bleach Plants
  - Reversion to Chlorine-Free and Near-Neutral ClO\textsubscript{2} Substitution Bleaching, 1990s
  - Higher Bleaching Temperatures
  - Use of 6% Mo SS Standard for ClO\textsubscript{2}

- Recovery Boilers
  - Composite Tubes – Boiler Pressure >900 psi
  - Begin High Solids Liquor Mid-1980s
    - Corrosion higher in lower furnace


Black Liquor Dry Solids

Virgin dry solids, %

Source: Wikipedia.org, Recovery Boiler

11/12/2014
Recovery Boiler Problems:
- 1981, First Reports of Near-Drum Corrosion of Generating Tubes
- 1983, First Balding of Composite Tubes at Air Ports
- 1983, DA Explosion & Cracking
- 1984, First Composite Tube Cracking
- 1987, First Waterside Stress-Assisted Corrosion (SAC)

Batch Digesters
- First DSS in North America, Fort Frances, Ontario, 1997
Historical Timeline

2001 – Present

Process Changes
2001 – Present

- Not Many Process Changes Affecting Corrosion Since 2001
Corrosion & Control 2001 - Present

- DSS for Reduced Life-Cycle Costs
  - Tanks, Clarifiers, Digesters

Corrosion & Control 2001 - Present

- Composite Tubes Alloys 825 & 625
  - Replacing 304 Composite
- Risk-Based Assessments
  - Risk-Based Inspections for Equipment and Adoption of API 579-1/ASME FFS-1
  - Risk-Based Inspections Not Widely Practiced
Future Challenges

- Corrosion Education
  - How to Best Transfer Corrosion Knowledge?
### “The Rise and Fall of Corrosion Engineering in the Pulp & Paper Industry”

W.B.A. Sharp, 2009

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#### 2000s – Decline of Corrosion Groups

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<th>P&amp;P Companies</th>
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Future Challenges

- Corrosion Education
- Maintain the momentum and the business mechanisms for continuing research in critical corrosion areas.

Future Challenges –

- Waterside SAC in Boilers
Future Challenges –

- Waterside SAC in Boilers
- Flow-Induced Corrosion

Future Challenges –

- Waterside SAC in Boilers
- Flow-Assisted Corrosion
- Future Mill Processes
  - BL Gasification
  - Others?
Future Challenges –

- Waterside SAC in Boilers
- Flow-Assisted Corrosion
- Future Mill Processes
  - BL Gasification
  - Biomass Thermochemical Liquefaction
- Risk-Based Inspections – ASME FFS-1

Conclusions

- Lessons from History:
  - Process Changes = Corrosion Dilemmas
- New Developments & Research To Meet Corrosion Challenges
Conclusions

- Lessons from History:
  - Process Changes = Corrosion Dilemmas
  - New Developments & Research To Meet Corrosion Challenges
  - Most Process Changes 1960s – 1990s

Conclusions

- Challenges:
  - Recognize Potential for New Process Changes Affecting Corrosion
  - Means of Transferring Corrosion Knowledge, in Time of Fewer Corrosion Specialists