“Effects of Highway Ice-clearing Treatments On Corrosion of Heavy Vehicle Materials”

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Work Is Sponsored By US DOE

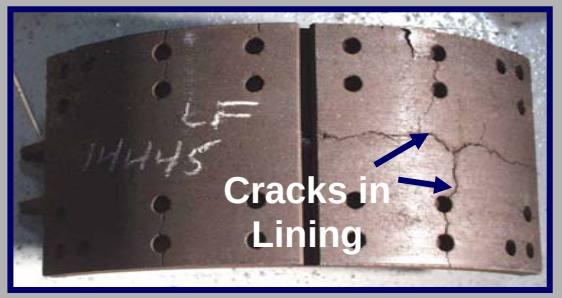
- Office of FreedomCar and Vehicle Technologies
  - High Strength Weight Reduction Materials Program
  - Program Manager---Sid Diamond
- Evaluate the corrosion associated with various ice-clearing chemical systems
- Develop a better understanding of the interaction of these chemicals with heavy vehicle materials
- Model brake failure due to “Rust Jacking”
- Make viable materials recommendations

Approach Being Taken Includes:

- Corrosion Assessment and Evaluation
  - Steering committee
    - Ensure that the work is relevant
  - Heavy truck corrosion assessment & literature search/review
  - $MgCl_2$ usage and characterization
  - Corrosion testing and characterization
    - **<u>Corrosion Field Evaluation</u>**
    - Accelerated corrosion tests

Approach Being Taken Includes:

- Evaluate brake shoe/liner failure
  - Forensic analysis of failed brake assembly
    - Contribution of $MgCl_2$ to reported increased failure
  - Corrosion testing
    - Identify economically viable replacement materials
  - Modeling of brake lining failure
    - Assist in identifying the major failure contributors
      - Materials (table and liner), hole (rivet and unused)
  - Evaluation of change in frictional behavior due to corrosion
    - Do specific corrosion products deteriorate braking performance more than others?



Corrosion Field Evaluation Being Performed In Collaboration With Montana Department of Transportation (2003/2004 Winter)

- Corrosion test panels were placed on select MDT trucks, Utah DOT trucks, and a commercial hauler
- Materials
  - CR 1008 Steel
  - A356 Cast Al, and 5182-O Al
- Exposure
  - Calcium Chloride
    - Both liquid and sand w/pre-wet systems
  - Magnesium Chloride – liquid
  - Sodium Chloride – liquid
  - Mixed chemical exposure

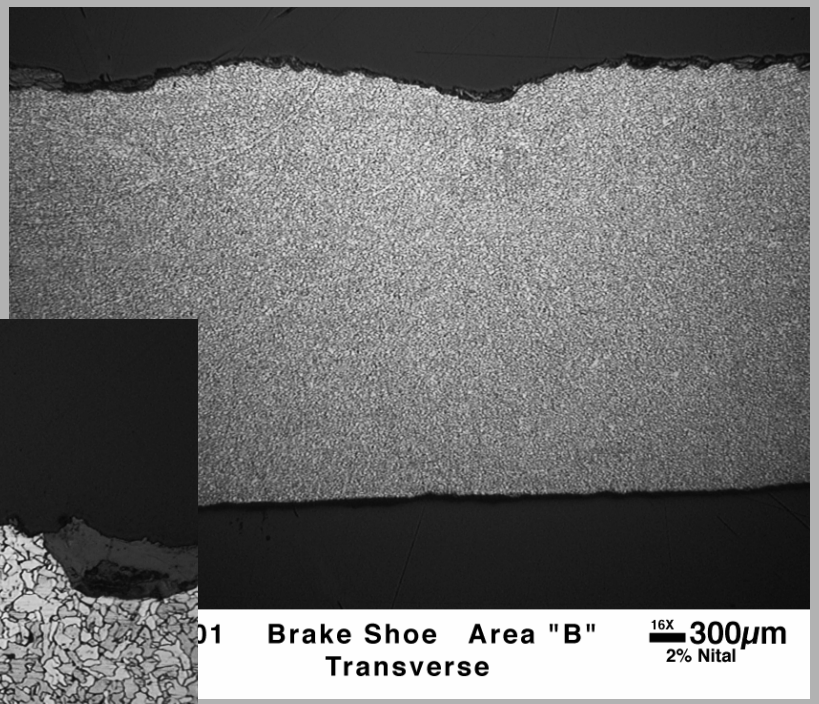
Documentation During Corrosion Field Evaluation Include:

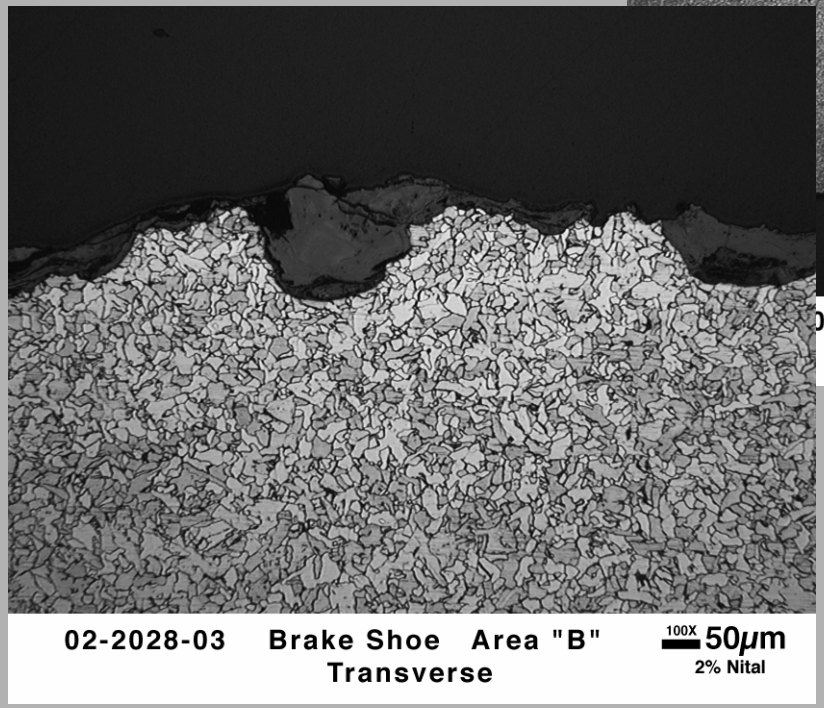
- Number of events (exposure)
- Miles of exposure
- Quantity of chemicals applied
- Weather conditions (average monthly temperature, precipitation, and humidity)
- Truck wash schedules
- Pre- and post-exposure analyses of panels

At the end of the winter season, half of the corrosion test panels will be evaluated, while the remaining panels stay on the trucks through the end of summer

Optical Microscopy of Failed Brake Assembly Revealed Non-uniform Corrosion At The Table/lining Interface

- Corrosion typical of carbon steel in occluded chloride environment

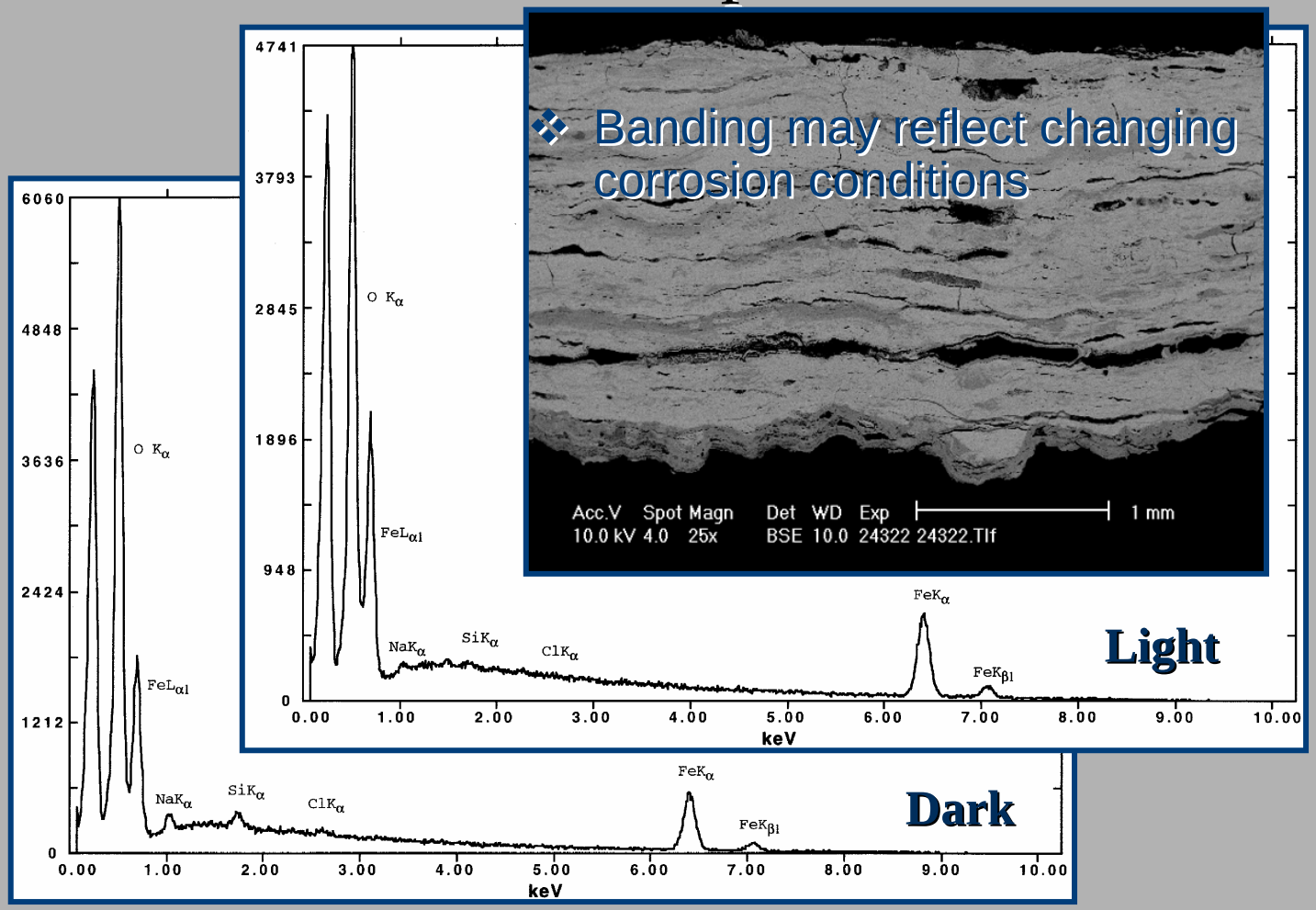




Optical Microscopy Revealed Little, If Any, Uniform Corrosion At The Free Table Surface

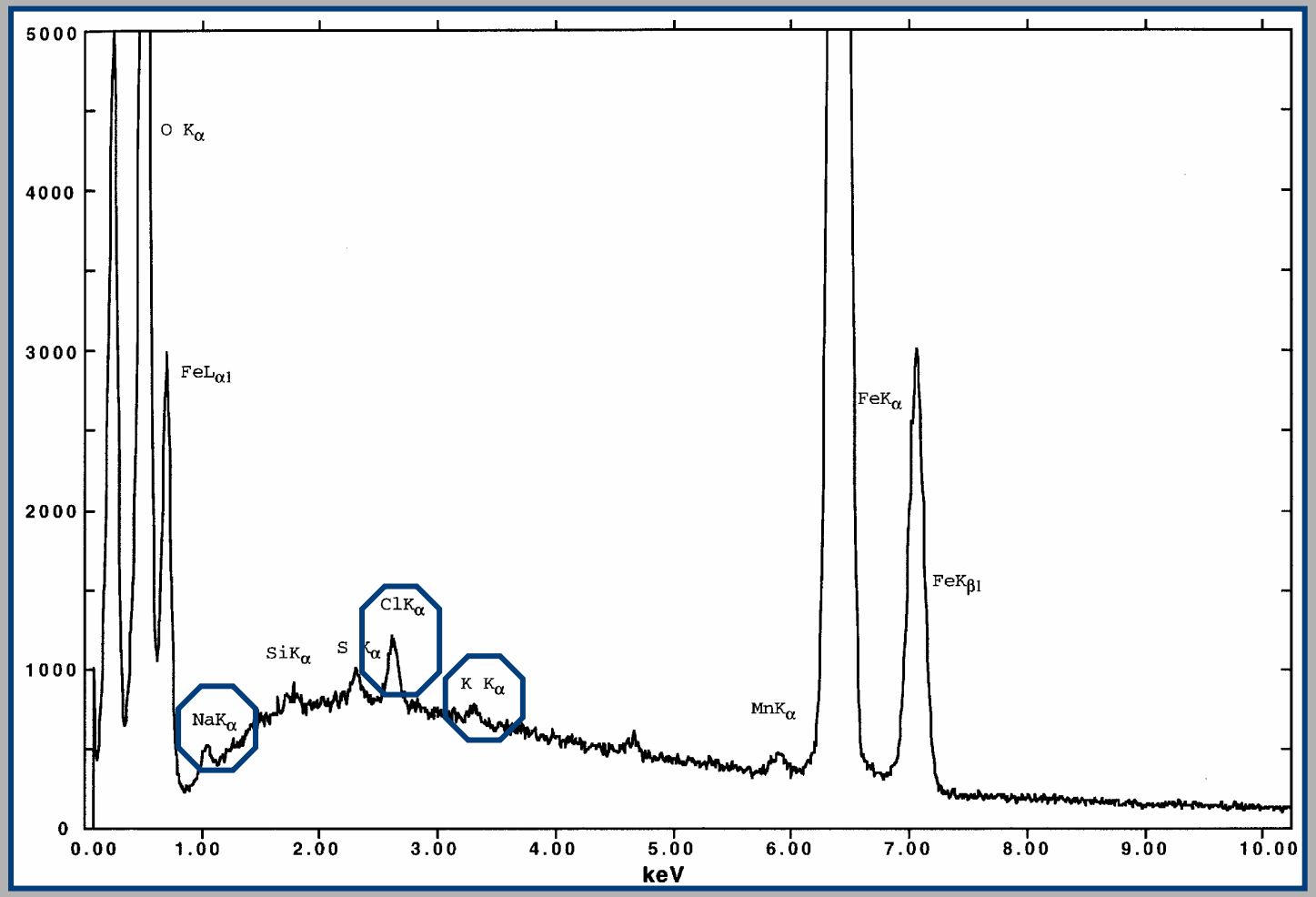
- Relatively smooth surface
- Shoulder on the rivet hole is clearly delineated

Backscattered Electron Image Revealed Light (Fe_3O_4) and Dark (Fe_2O_3) Gray Regions of Different Compositions



- Increased O/Fe ratio for dark regions

Sodium And Potassium (But No Magnesium and Calcium) Were Detected In The Scales



Overall Chemical Analyses Showed

- Chlorides of sodium and potassium identified in the scale
- No evidence for the chlorides of calcium and magnesium
  - Less soluble in water than the identified chlorides of sodium and potassium
  - Vehicle may have not been used in states that use calcium and magnesium
  - Possible that the corrosion products that form in the presence of calcium and magnesium are more friable and were readily lost once the lining was removed from the brake table
  - Possible use of potassium acetate

However, Magnesium And Calcium Chlorides And Acetates Could Affect Corrosion Of Brake System

- Increased corrosion rate due to increase in the corrosion potential
  - Change in corrosion potential due to a small change in salt composition and/or concentration, with or without a slight change in pH
- Increased corrosion due increased “time of wetness”
  - Chlorides of magnesium and calcium, and the acetates of calcium, magnesium, and potassium are hygroscopic
    - Chlorides of sodium and potassium are not hygroscopic

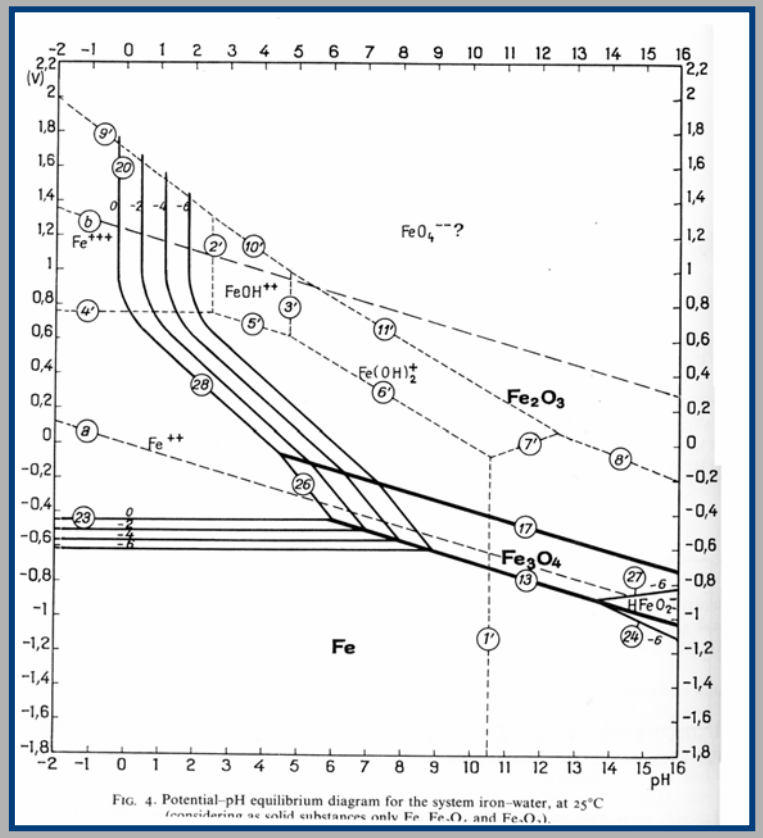


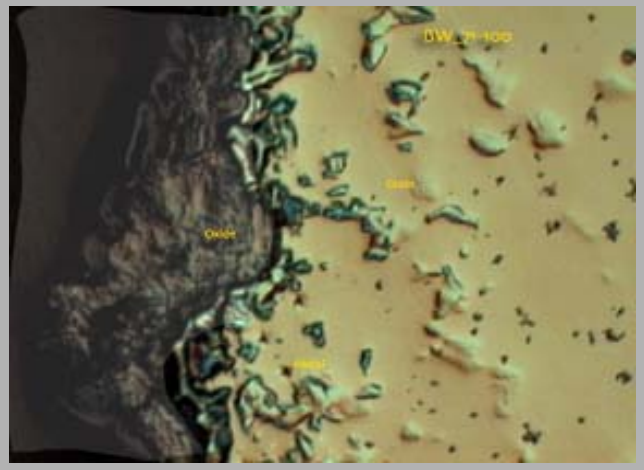
FIG. 4. Potential–pH equilibrium diagram for the system iron–water, at 25°C (considering as solid substances only Fe, Fe_3O_4 and Fe_2O_3).

Reference: Marcel Pourbaix, “Atlas of Electrochemical Equilibria in Aqueous Solutions,” NACE International, Houston, Texas, 1974

Factors Affecting Stresses In Brake Assembly Include:

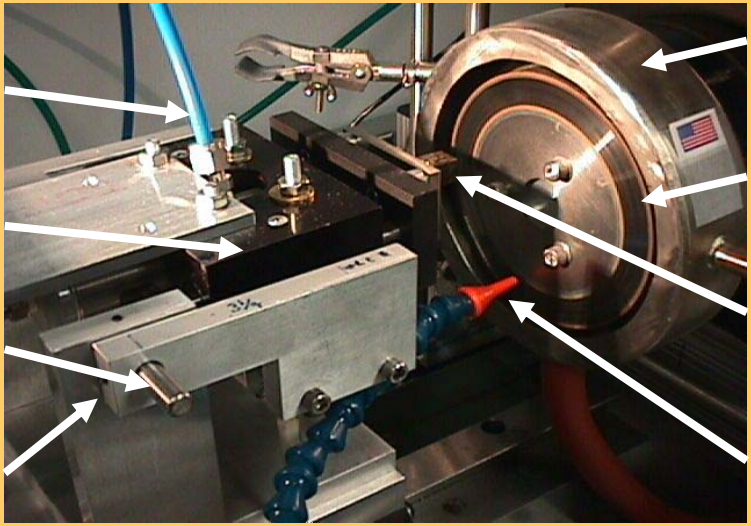
- Growth of corrosion product at the brake pad/brake shoe interface
- Thermoelastic and mechanical properties of pads, brake shoe table and corrosion products
- Transients associated with daily changes in temperature and application of brakes

The finite element stress analysis method is being used to evaluate the stresses in the brake assembly



Subscale Brake Tests were Conducted on Intentionally-Rusted Cast Iron Discs

- ORNL's research-scale, disc-type brake lining tester was used
- A commercial drum brake lining material and gray cast iron were used as the test materials
- Cast iron rusted in either sodium or magnesium chloride solution (spray)



Results Of Brake Test Against Drum Liner Armada AR4 at 6 m/s Sliding Speed Showed

- ***Discs rusted in the two types of solutions had a reduction in friction coefficient by about 33%***
  - **Friction results were compared with un-rusted cast iron discs**

As-rusted in $MgCl_2$

After friction testing

In Summary, the US DOE Program Plans To:

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- Make via materials recommendations