PERFORMANCE OF UTILITY POWER CONNECTIONS IN A SALINE ENVIRONMENT

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BACKGROUND

- Connector is generally a weak link in the distribution system.
- Some connector designs lack the ability to provide effective long-term performance.
- Corrosion is considered as one of the most significant reliability concern.
- Corrosion is particularly severe in some areas when connections has to be made between dissimilar metals.

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OBJECTIVES

- To conduct a control field study of examining the long-term effect of a worst-case operating environment on the performance of power connection systems.
- To obtain an even more basic appraisal of the chemical severity of the exposure environment.
- Emphasis was placed on the comparative evaluation of compression, bolted and fired wedge connector systems.
- The program was initiated in 1995.

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EXPERIMENTAL

- *Test Site*
  - Battelle Florida Marine Research Facility located in Daytona Beach.
  - The location is characterized by a high salt deposition rate from the Atlantic Ocean and a high humidity in the range of 55-60% annual average.
  - Seasonal temperature vary from approximately 0°C in winter to max. 40°C in summer.

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EXPERIMENTAL

- *Test Samples*
  - Compression, bolted and fired wedge overhead power connectors.
  - Sample size was 50 connectors of each type.
  - AWG 2/0, 19 strand bare AAC aluminum or copper conductors.
  - All connectors supplied with a corrosion inhibitor in place.

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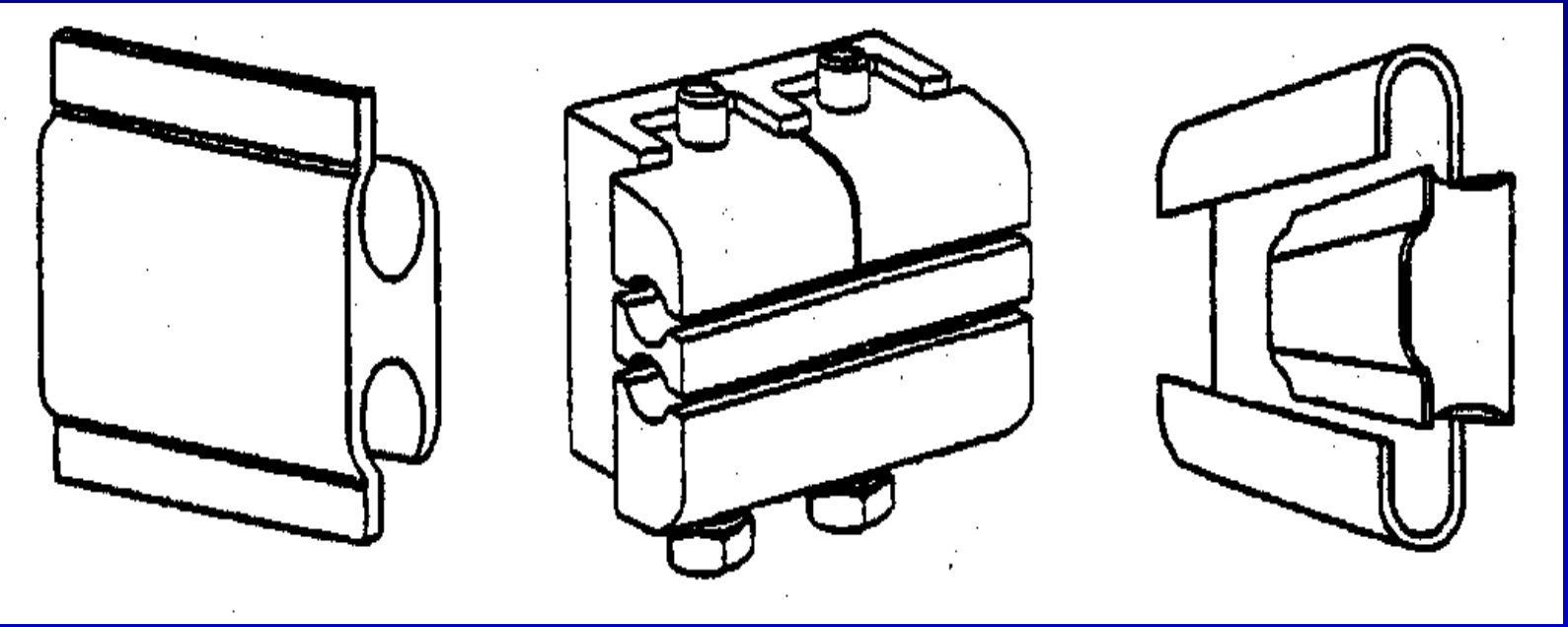
EXPERIMENTAL

Types of overhead power connectors used in this study

COMPRESSION BOLTED FIRED WEDGE



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EXPERIMENTAL

- *Electrical Measurements*
  - Voltage drop was measured periodically using a custom-designed and computer-controlled data acquisition system.
  - The resolution of voltage measurement was 10 μV giving resistance resolution of 2 μΩ.
  - Current of 5 A DC was used throughout the entire exposure test.

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EXPERIMENTAL

- *Installation*
  - Connectors were installed at the site according to the practices recommended by the respective manufactures.
  - Prior to the assembly of each connector, the surfaces of all conductors were wire brushed.
  - Separate brushes were used for the copper and aluminum conductors.
  - After brushing, connections were typically made within 3-5 minutes.

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EXPERIMENTAL

- *Failure Criterion*
  - Connector was deemed to have failed when the resistance between the two corresponding equalizers increased by 1000 μΩ above its initial value.
  - The initial value of each connector was determined as an average resistance measured for the first 100 days of exposure.

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EXPERIMENTAL

- *Corrosion Monitoring*
  - The chemical severity of the exposure environment was monitored using Battelle reactivity monitoring coupons.
  - Coupons were specially finished and cleaned pieces of silver, copper, 1010 steel and 7075 and 6061 aluminum.
  - Corrosion rate was determined by measuring the weight gain on a microbalance.

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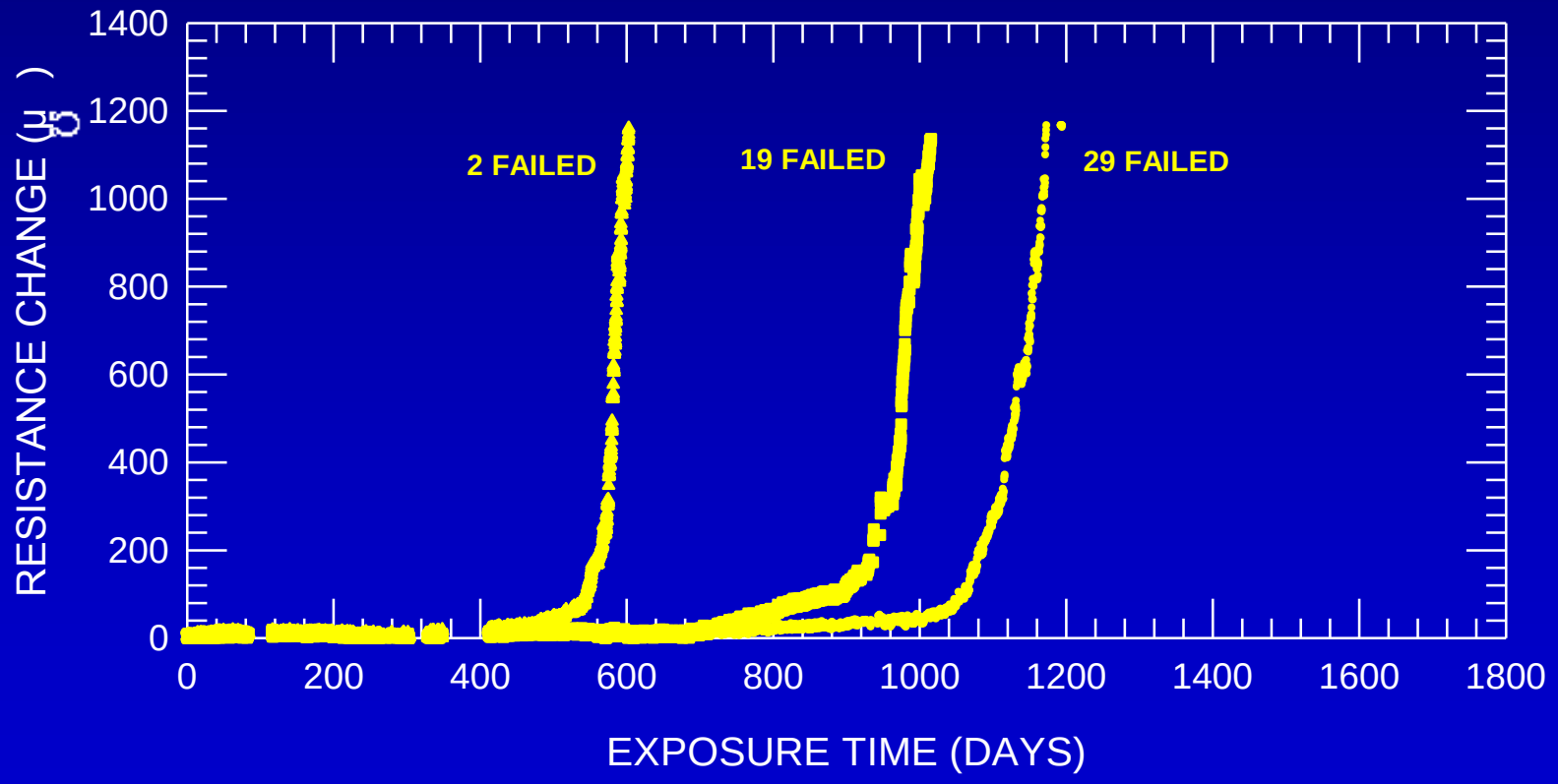
RESULTS

- *Connector Performance*

Compression Connector



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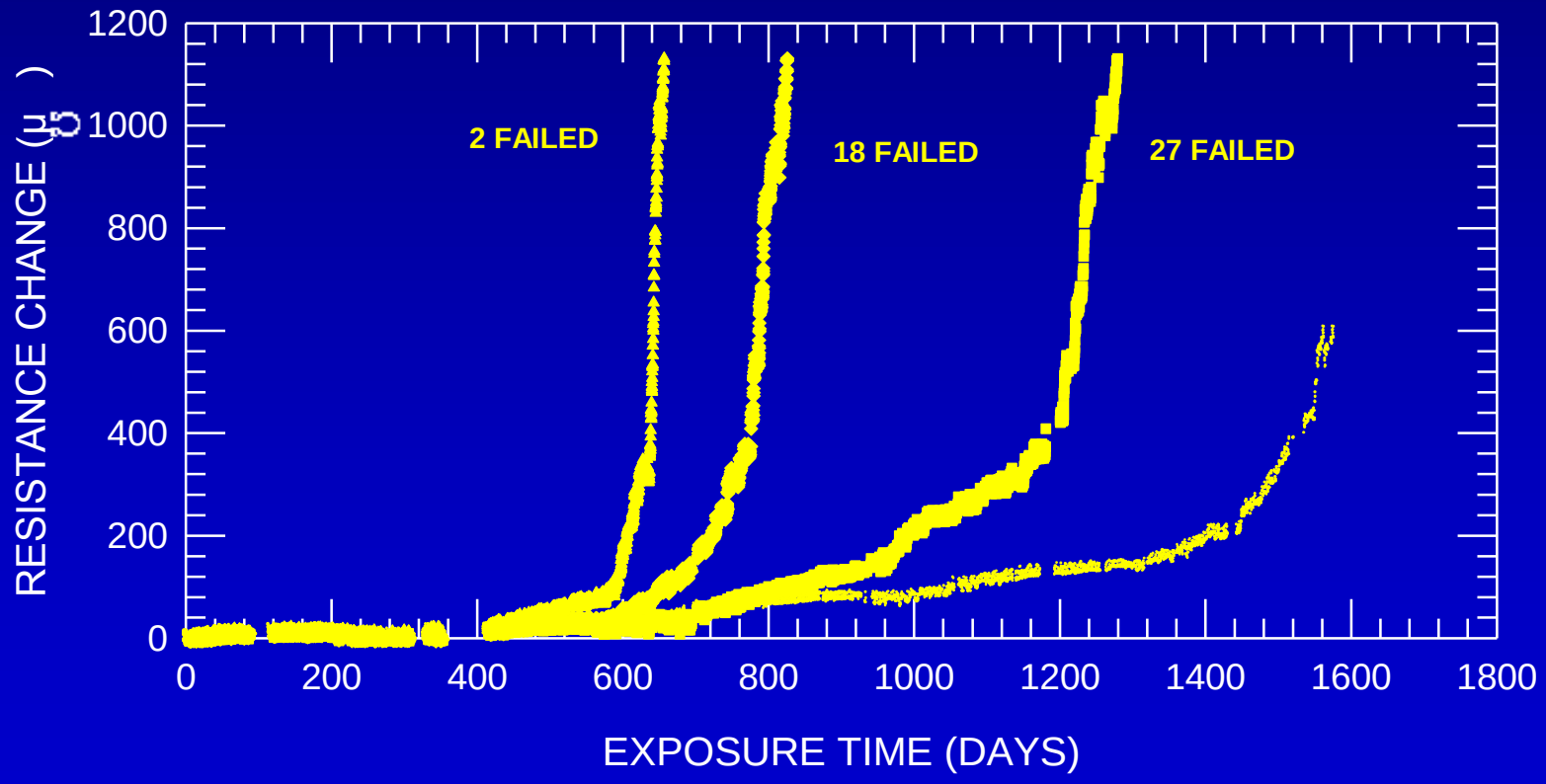
RESULTS

- *Connector Performance*

Bolted Connector



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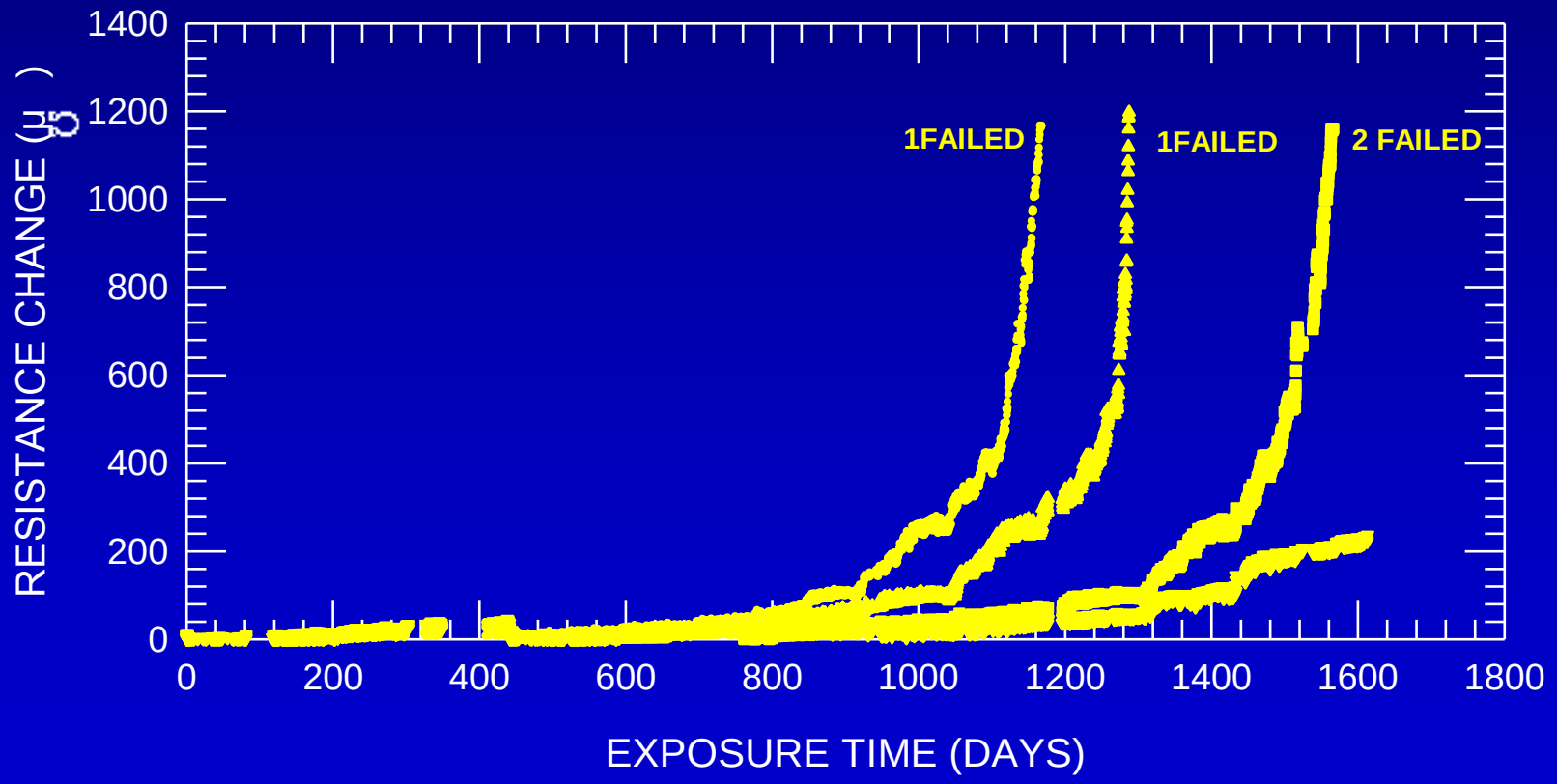
RESULTS

- *Connector Performance*

Fired Wedge Connector



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RESULTS

- ***Connector Performance***

  Cumulative failures over the entire exposure period

TIME TO FAILURE	FIRED WEDGE CONNECTOR	BOLTED CONNECTOR	COMPRESSION CONNECTOR
300 DAYS	0	0	0
600 DAYS	0	2	2
900 DAYS	1	18	19
1200 DAYS	1	27	29
1600 DAYS	2	-	-
TOTAL FAILED	*4*	*47*	*50*

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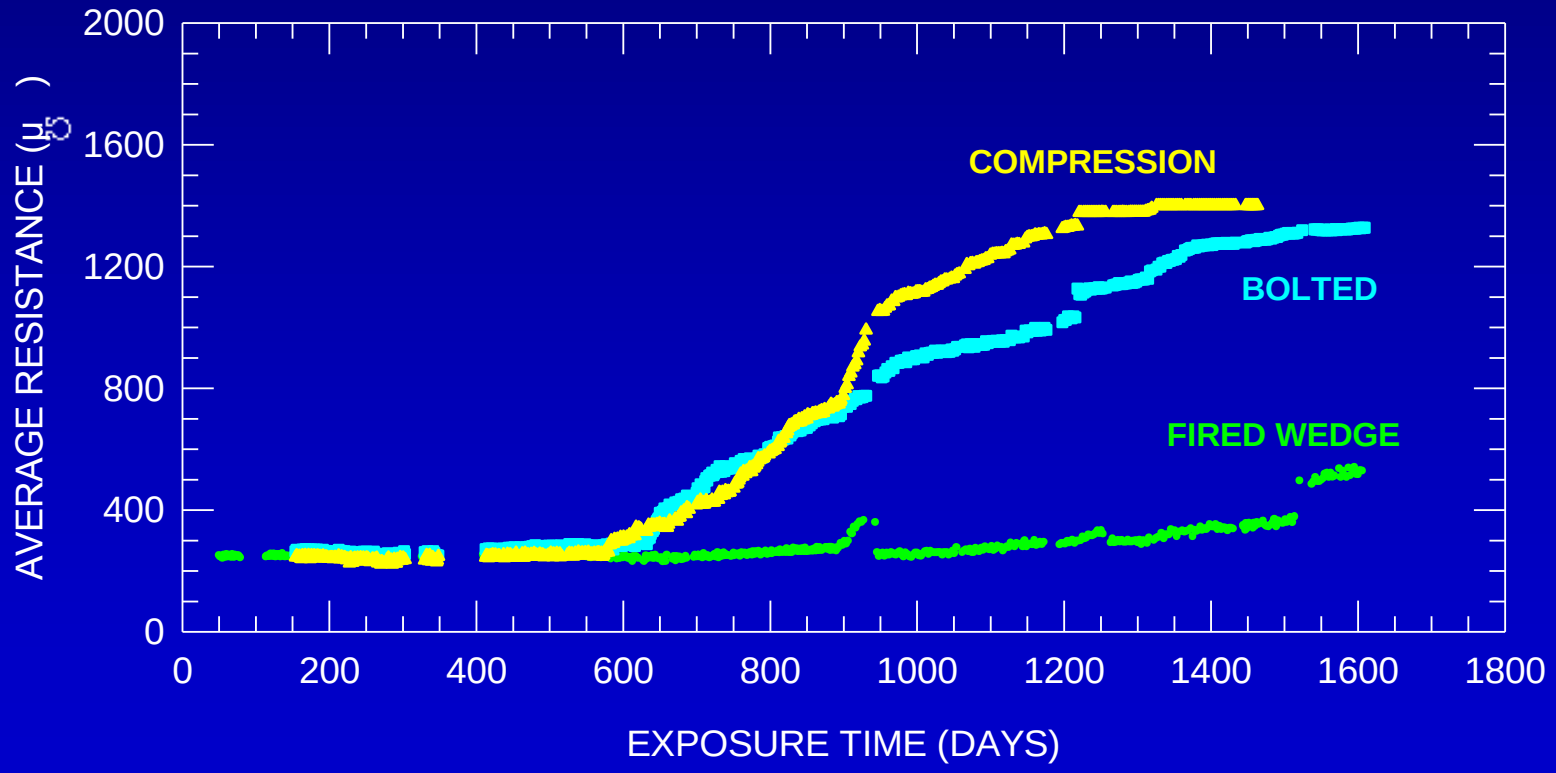
RESULTS

- *Connector Performance*

Variations of average connector resistance with exposure time



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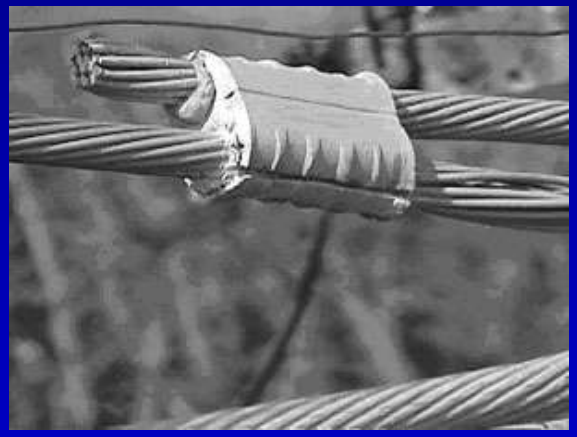
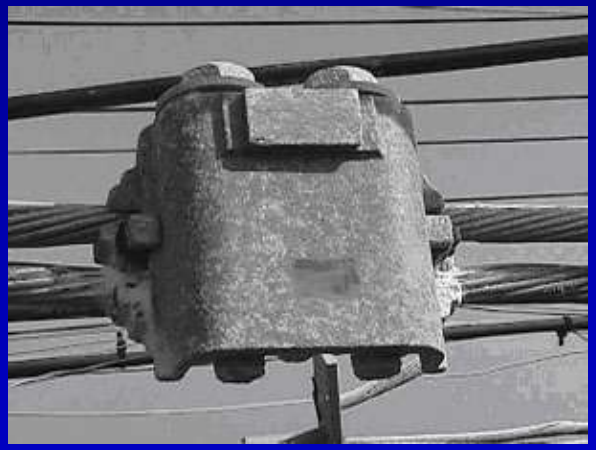
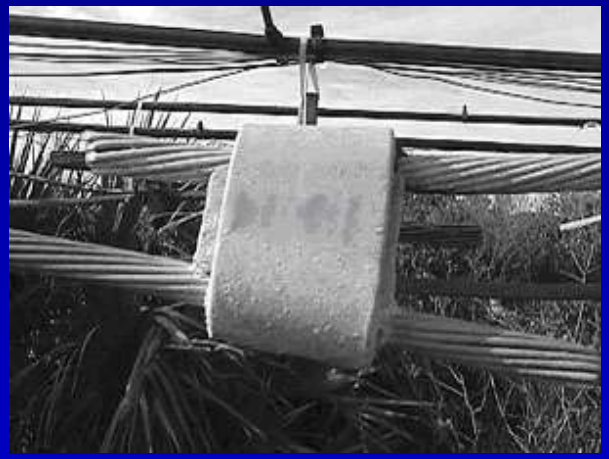
RESULTS

- *Connector Performance*

Compression Connector *Bolted Connector* *Fired Wedge Connector*







Photos of compression, bolted and fired wedge connectors after 3 years of exposure at the test site

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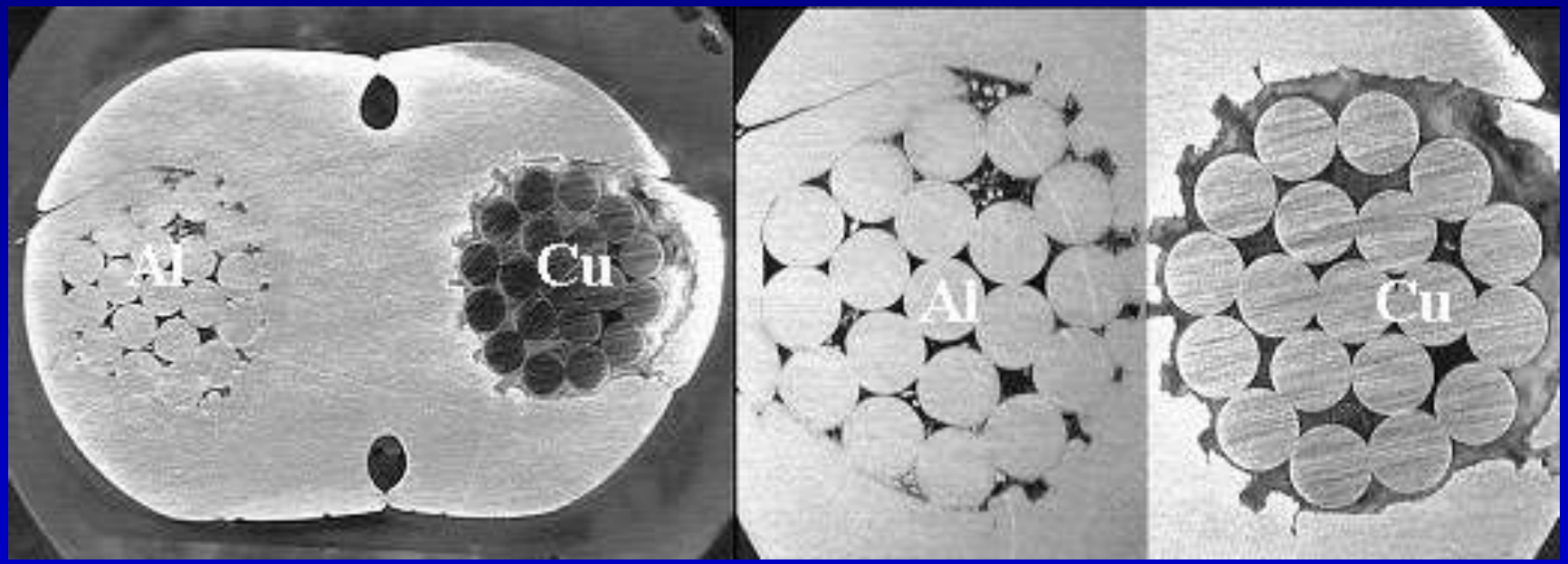
RESULTS

- *Connector Performance*
  Compression Connector



Cross section of failed compression connector with close-up view of Al and Cu conductor-connector interface regions affected by corrosion

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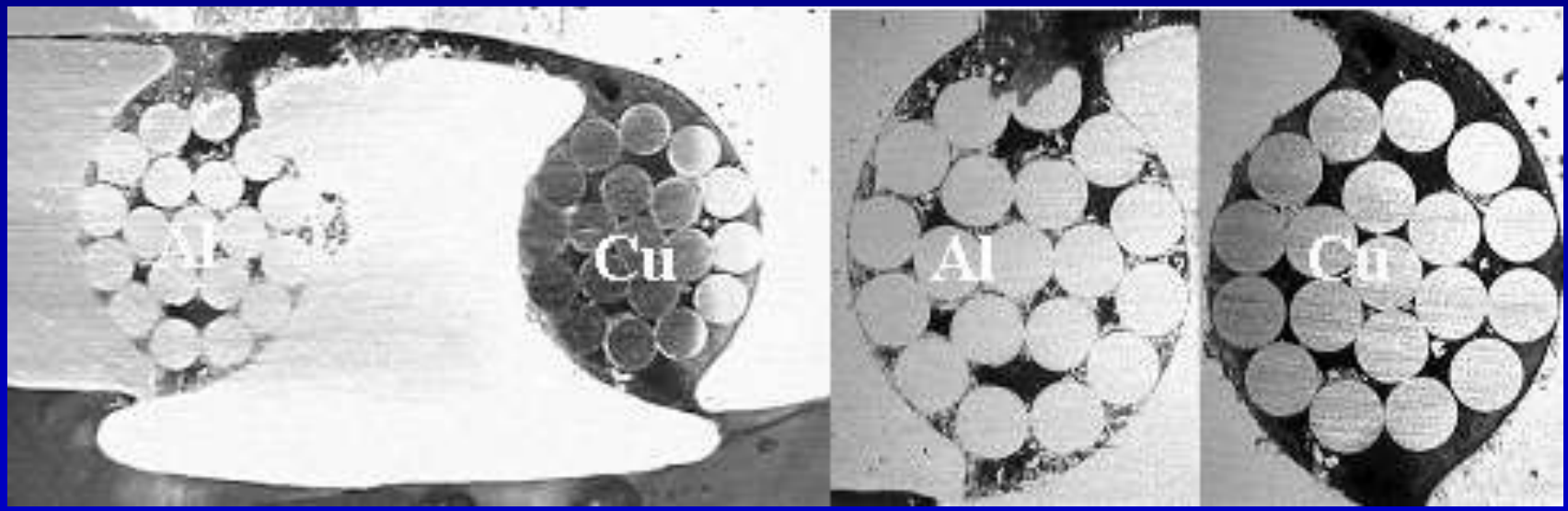
RESULTS

- *Connector Performance*

  Bolted Connector



Cross section of failed bolted connector with close-up view of Al and Cu conductor-connector interface regions affected by corrosion

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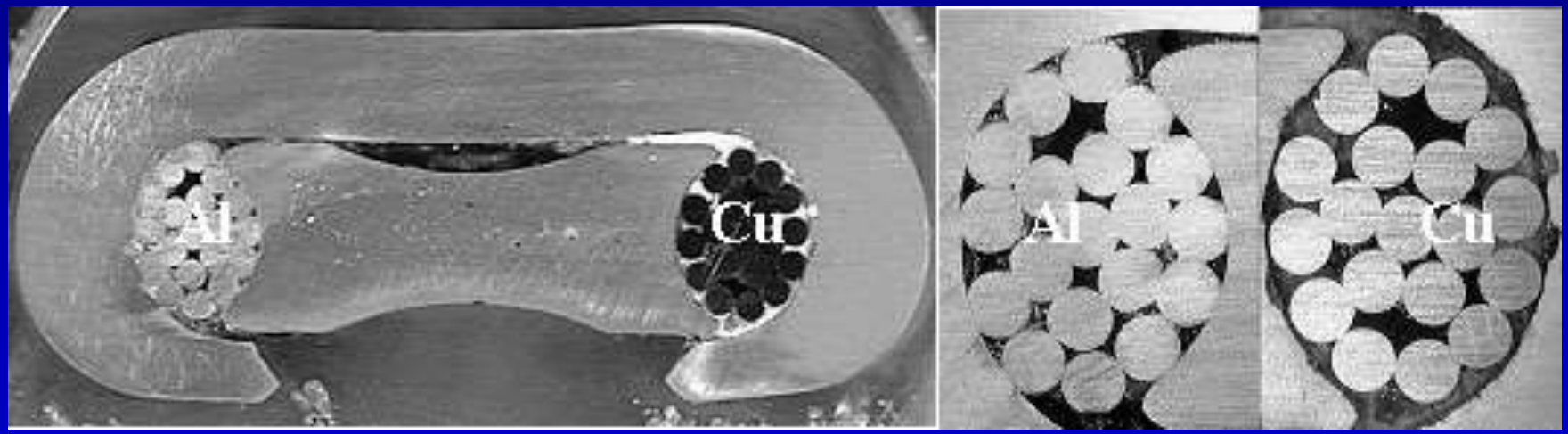
RESULTS

- ***Connector Performance***

  Fired Wedge Connector



Cross section of failed fired wedge connector with close-up view of Al and Cu conductor-connector interface regions affected by corrosion

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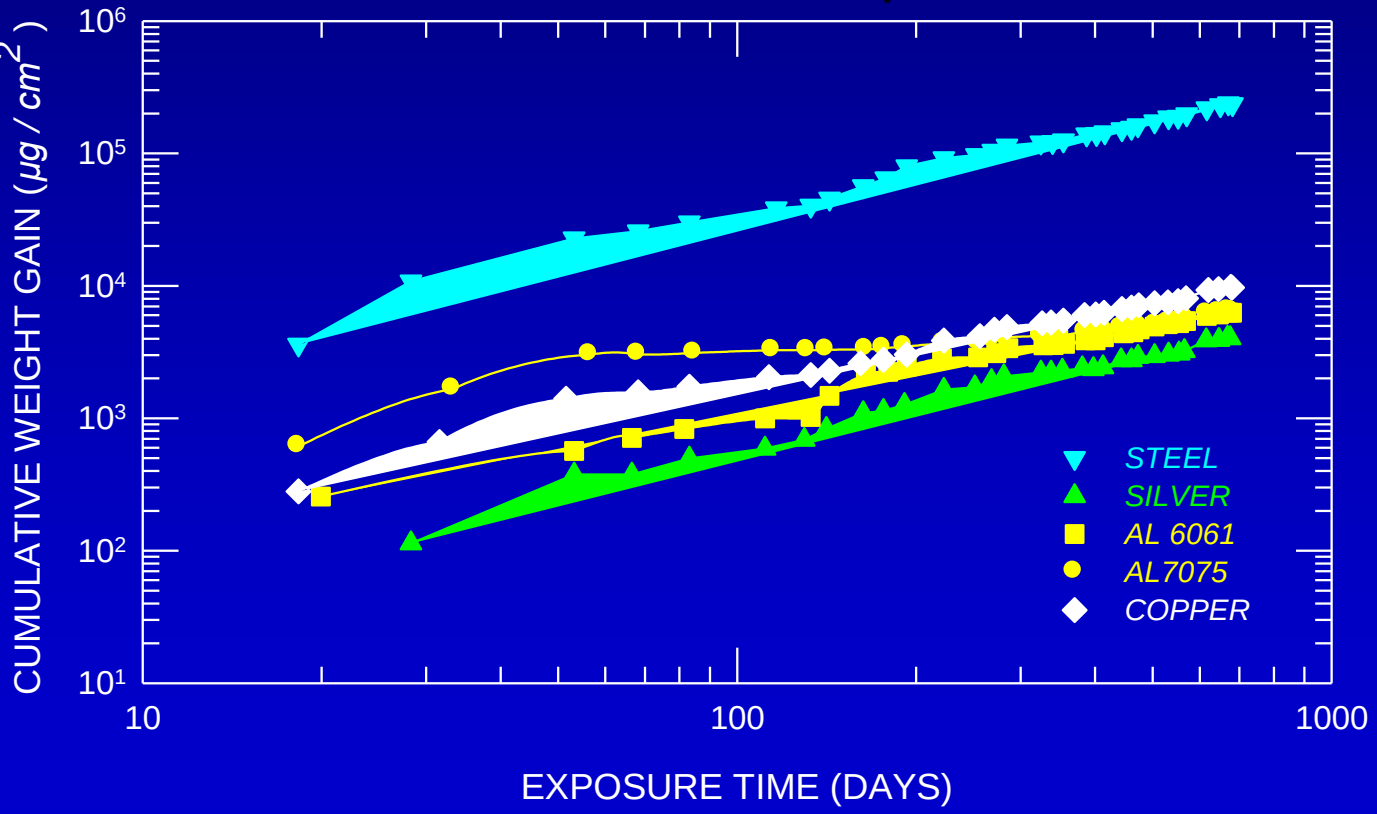
RESULTS

- *Connector Performance*

Corrosion rates of different metals at exposure site



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DISCUSSION

- The results show that there is a considerable difference in the performance of the three connector populations used.
- Difference is manifested not only by the number of failed connectors but also by the onsets of connector failure.
- First failures occurred in compression and bolted connectors after 600 days and after 1000 days in fired wedge connectors.
- By the end of field exposure test all of the compression connectors failed, only three from bolted survived whereas only four fired wedge connectors failed.

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DISCUSSION

- *Plausible Failure Mechanisms*
  - Loss of mechanical contact force due to metal loss at the contact interfaces.
  - Compression and bolted connectors are prone to this degradation since their design does not provide an elastic-energy storing capability.
  - The spring action of the C-member design of fired wedge connector maintains not only steady contact load but also uniform stress distribution and large metal-to-metal contact

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DISCUSSION

- ***Plausible Failure Mechanisms***
  - **Growth and accumulation of corrosion products in the interspaces between conductor and connector can provoke separation of conductor from the connector.**
  - **Compression connectors are particularly prone to this type of degradation due to the action of mechanical forces generated by the build-up of corrosion products, that pry open the connector.**
  - **Bolted and fired wedge connectors showed no such susceptibility to deformation by the corrosion product build-up.**

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DISCUSSION

- *Plausible Failure Mechanisms*
  - Differential thermal expansion between copper and aluminum caused by seasonal temperature variations.
  - Differential thermal expansion results in large lateral movement of the contact interface (fretting).
  - Direct result of fretting is rupture of metallic conducting bridges, significant loss of contact area and formation of an insulated layer of debris at the contact interface.

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DISCUSSION

- *Economical Consequences*
  - The result of this study show that exposure to a harsh environment resulted in sharp increase in the connector resistance.
  - Increase in contact resistance affects not only connector performance but creates serious economical consequence on the network as a whole.

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DISCUSSION

- *Economical Consequences*

  Calculation of cost of energy loss due to increase in connector resistance

  $C = (\Delta R/\Delta t) * I^2 * f * t^2 * (8760/2000)*G$

  $\Delta R/\Delta t$ – increase in resistance per year ($x10^{-6}$)

  I – operating current=400A f – load factor (40%)

  t – time (years) G – generation cost/kWh = $ 0.05

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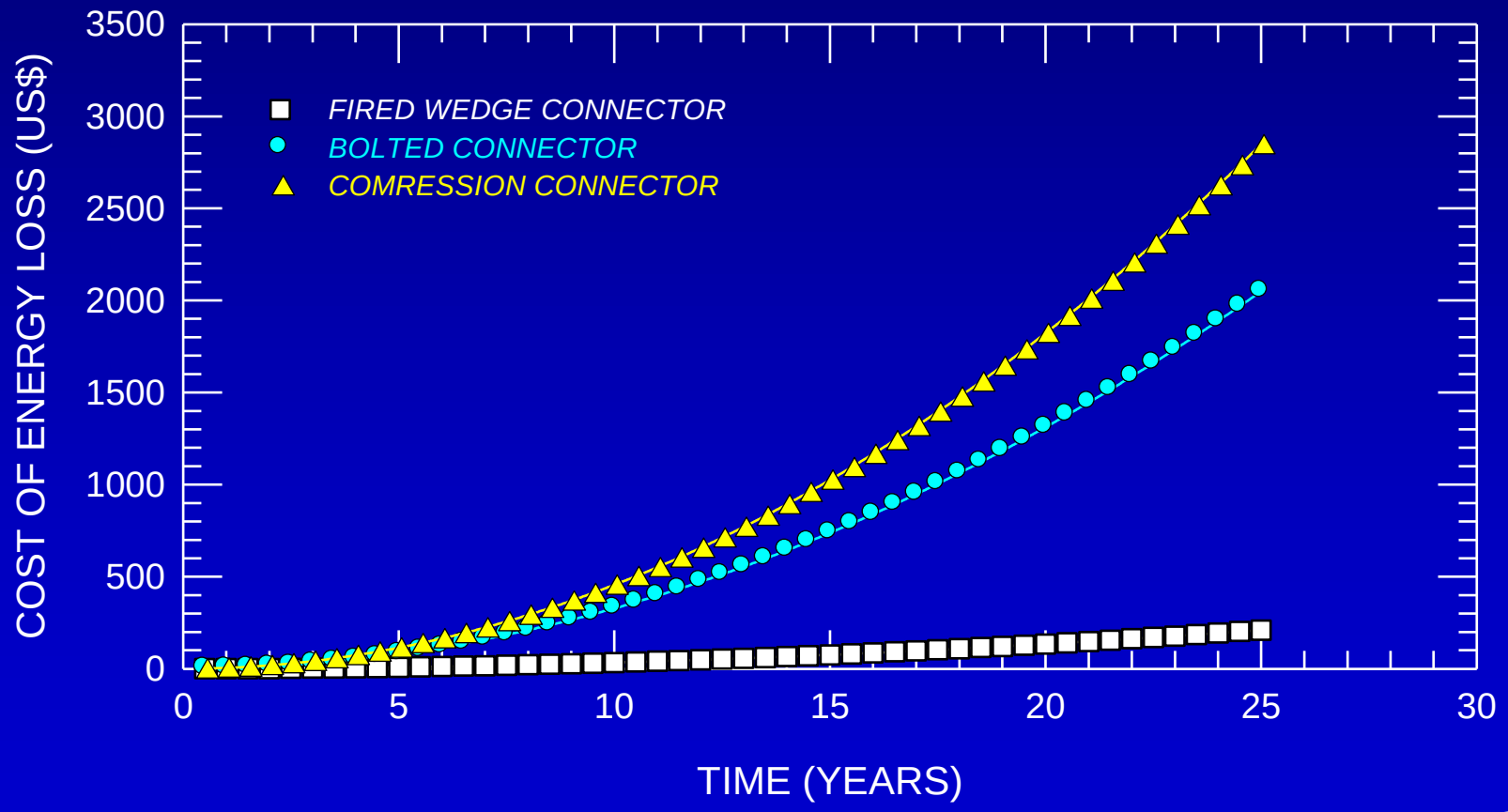
DISCUSSION

- ***Economical Consequences***



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CONCLUSIONS

- Differences in design, installation procedure and inhibitors exert major effect on the connector performance in a saline environment.
- Galvanic corrosion was the main cause for the connector failure.
- Build-up of corrosion products at the conductor-connector interface was the major factor controlling connector life.
- Connector life is largely determined by the connector design and the loss of mechanical contact load.

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CONCLUSIONS

- Ever increasing load on the network will accelerate connector degradation and accentuate the importance of connector design in mitigating deleterious effects resulting from increasing connector temperature.
- The superior performance of fired-wedge connector is due to the “spring action” of the connector C-member.
- The C-member design resists loss of contact load, maintains uniform stress distribution over contact interface and assures large metal-to-metal contact area.

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