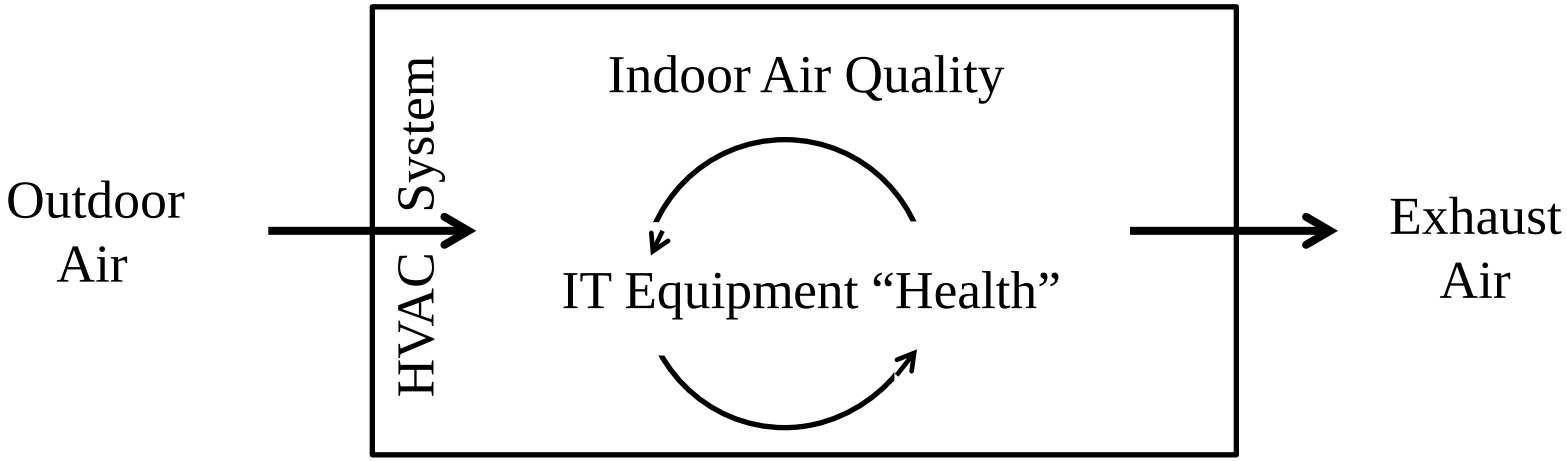
Corrosion Risks in the Data Center

Utah Data Center Consortium (UDCC)



Dan Donahoe (1000 kilometers)
Amanda Smith (University of Utah)

July 16, 2014

Background: Technology Changes

- The evolution of the electronics “shelter” has long followed the evolution of electronic hardware.
  - Our focus is on the impact of selected hardware changes in today’s data center.
- Industry drive to standardization
  - Book title best explains: Rod Canion, Open: How Compaq Ended IBM’s PC Domination and Helped Invent Modern Computing, 2013.
  - ASHRAE TC 9.9’s Guidelines
- Changes in data center architecture
  - Drive to lower operating cost
    - Economizers introduce outside air
  - Increasing power density
- Changes in data center IT equipment
  - Surface finish changes due to European RoHS
- Commoditization of IT equipment (viz., consolidation)

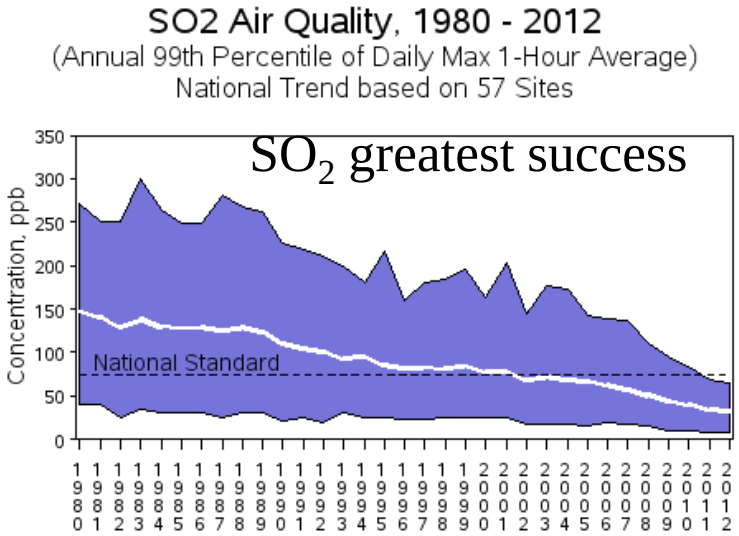
The Clean Air Act 1963 (42 Code §7401)

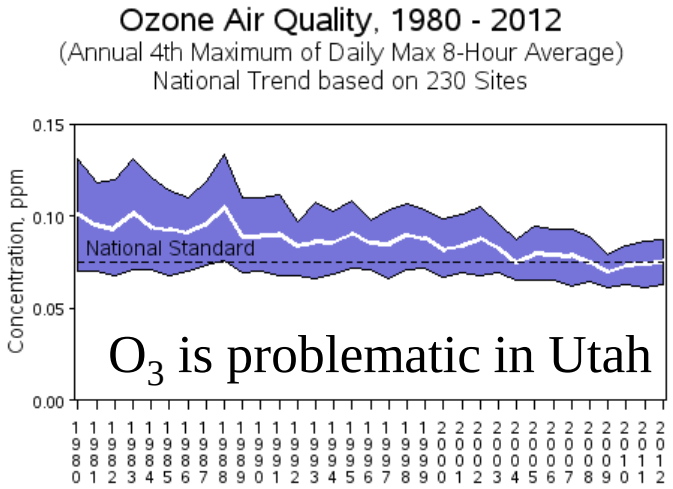
The Congress finds—
(1) that the predominant part of the Nation's population is located in its rapidly expanding metropolitan and other urban areas, which generally cross the boundary lines of local jurisdictions and often extend into two or more States;
(2) that the growth in the amount and complexity of air pollution brought about by urbanization, industrial development, and the increasing use of motor vehicles, has resulted in mounting dangers to the ***public health and welfare****, including injury to agricultural crops and livestock,* ***damage to and the deterioration of property****, and hazards to air and ground transportation;*

← **Public focus is on health**

← **We'll focus on electronics (IT) "health"**

Good National Air Quality Trends

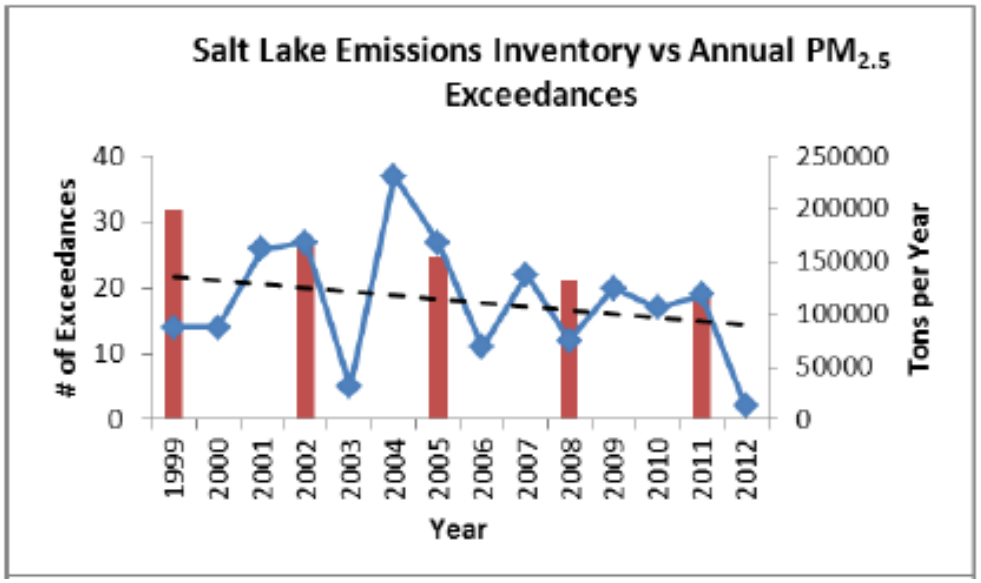


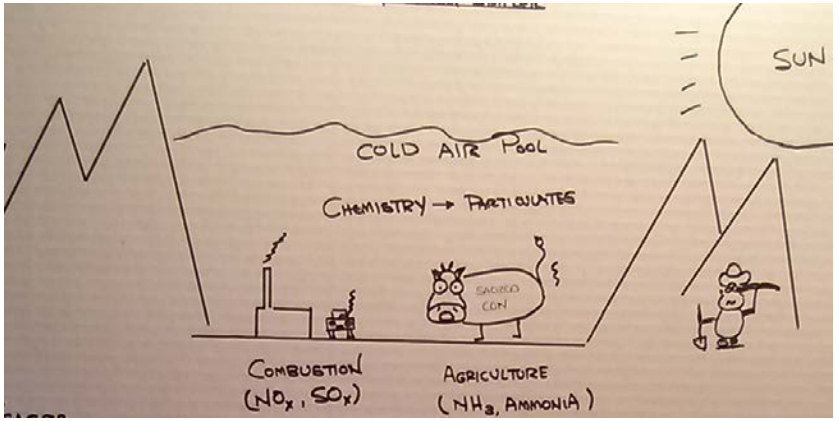


- Air pollution consists of many gaseous species and suspended particulates in atmospheric air, know as an aerosols.
- Particulates originate from crustal dust, sea salt, biosphere and industry (primary particulates) and from reactions in the atmosphere (secondary particulates).
- Atmospheric chemistry is complex and full of surprises!

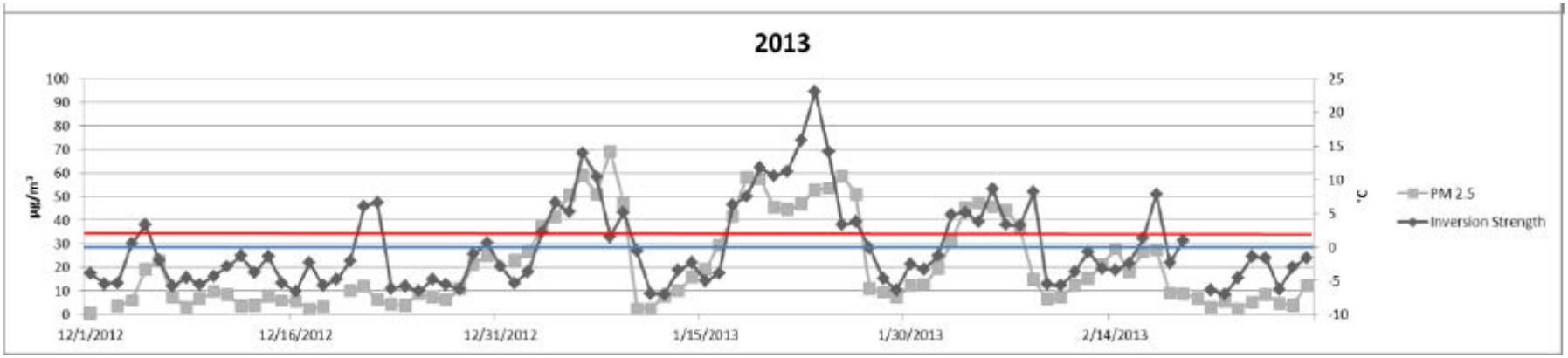
http://www.epa.gov/airtrends/

Salt Lake Inversions - Particulate



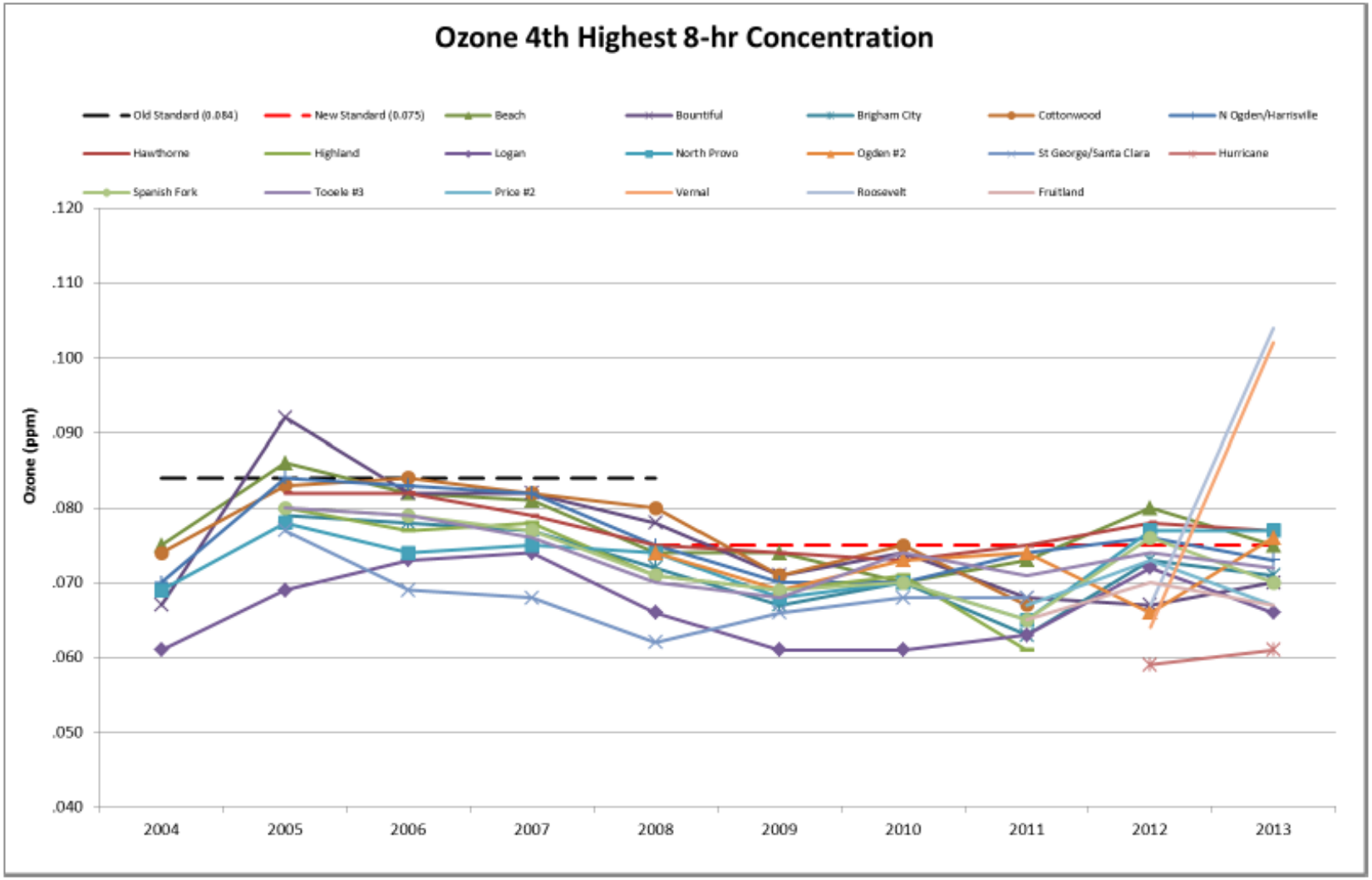


Cartoon - Secondary Particulates due to winter inversions & sources



PM2.5 State Implementation Plan Weight-Of-Evidence to the Model Attainment Test, Utah Division of Air Quality, 01 October 2013, p 9 and 22; PM 2.5 data from Hawthorne monitoring station.

Utah Ozone – Changing Chemistry



Seth Arens and Kiera Harper, 2012 UTAH OZONE STUDY, January 2013

Problematic Outdoor Air Pollutants

Secondary Particulates (acid and base yields a salt):

$$NH_4NO_{3(s\ or\ aq)} \leftrightarrow HNO_{3(g)} + NH_{3(g)}$$

Ammonium nitrate Nitric acid Ammonia

$$NH_4Cl_{(s\ or\ aq)} \leftrightarrow HCl_{(g)} + NH_{3(g)}$$

Ammonium chloride Hydrochloric acid Ammonia

$$NH_4SO_{4(s\ or\ aq)} \leftrightarrow HNO_{3(g)} + NH_{3(g)}$$

Ammonium sulfate Sulfuric acid Ammonia

Ozone cycle is complex, maximum daytime methane oxidation (but many other reaction pathways yield ozone):

$$CH_{4(g)} + 6O_{2(g)} + 4h\nu \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + 4O_{3(g)}$$

Möller p 478

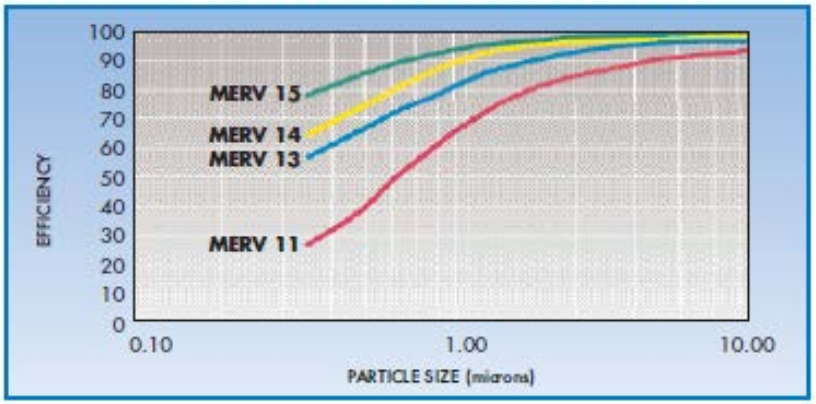
Deliquescence Point

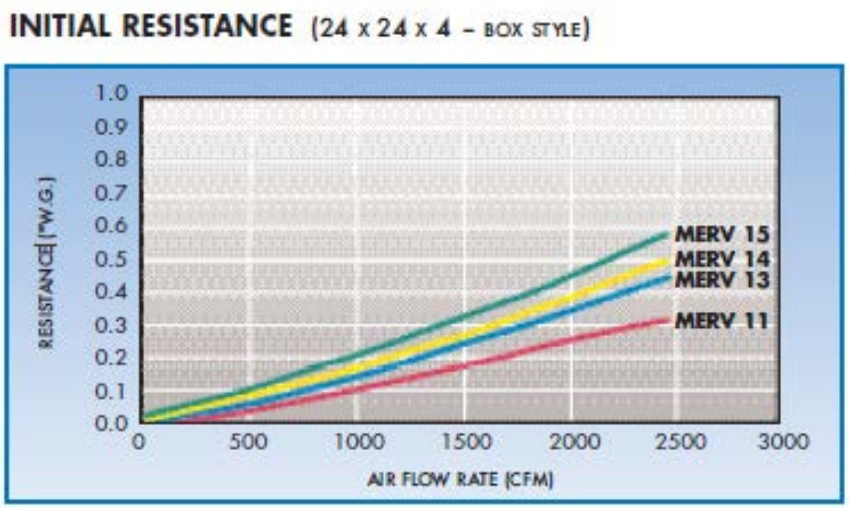
Particulate Name	Chemical	~Deliquesence Point	~Dissociation
Ammonium Nitrate	NH_4NO_3	62%	32 °C
Ammonium Chloride	NH_4Cl	78%	10 °C
Ammonium Sulfate	$(NH_4)_2SO_4$	80%	> 50 °C

- Moisture plays a dominant role in atmospheric thermodynamics and can constitute up to 5.6 % of the atmosphere (by volume)
  - The dry atmosphere's major constituents are 78% oxygen, 21 % nitrogen, 1% argon, 0.04% CO_2 (by volume = mole fraction)
  - At the deliquescence point, a particle's surface becomes wetted and dissolves into solution
- Ammonium nitrate is semi-volatile (dissociates into gas, as shown previously)
- Values shown are approximate (~)

Filter Basics

- Filter particulate efficiencies defined by ASHRAE Standard 52.2
- [Minimum Efficiency Reporting Value] MERV 11 or 13 recommended for air side economizer equipped data centers
- "Air horsepower" is power cost through filter
  - Dimensional analysis: $\Delta P * Q = (Pa)(m^3/s) = W$
- Gas phase filters are added as required





Used with permission – Filtration Group, Joliet, IL

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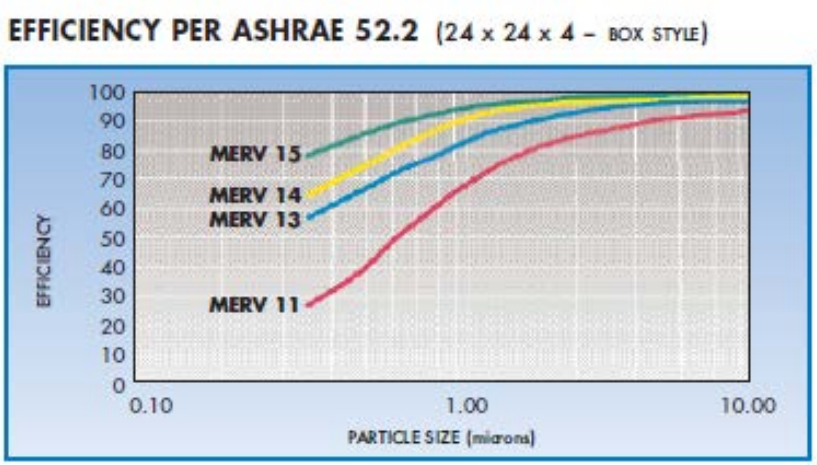

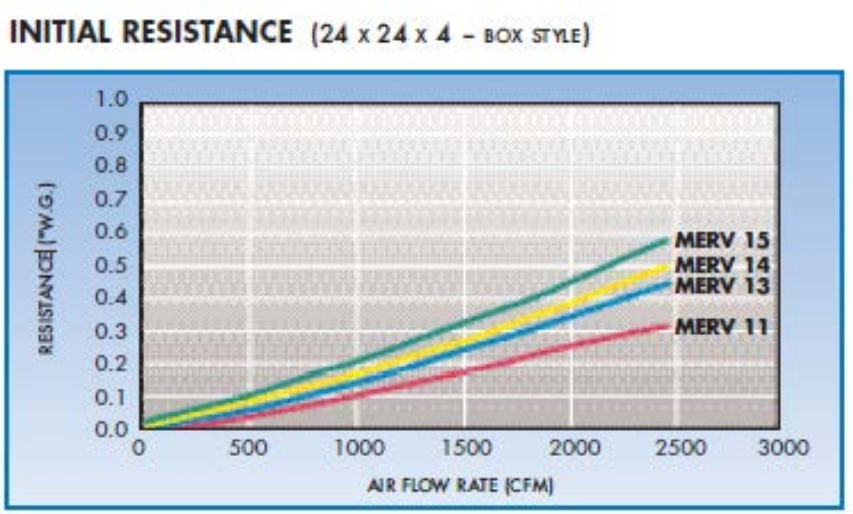

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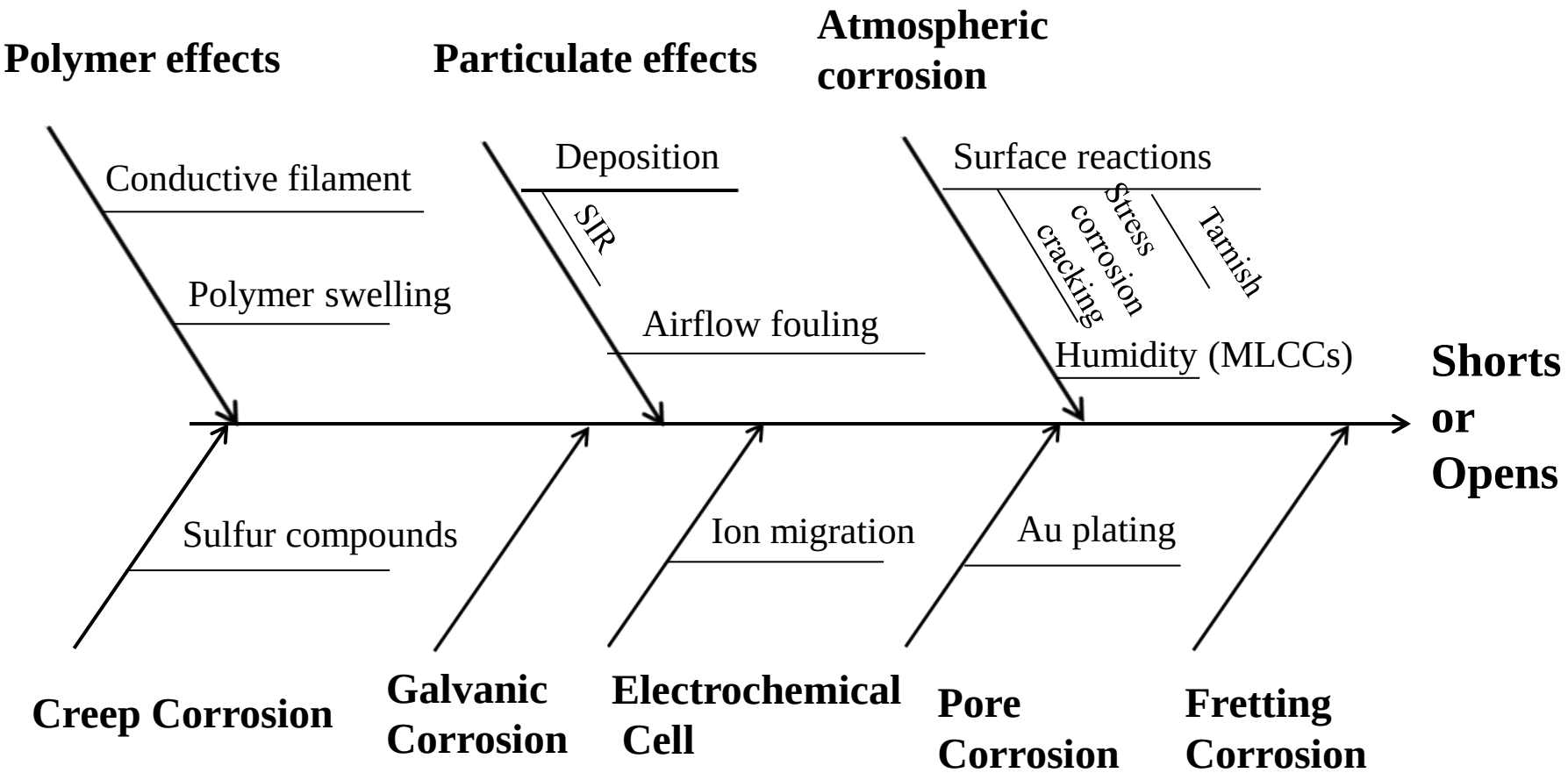
All the Action Is at the Interface

- Surfaces (metal oxides) collect moisture in a set of layers called "monolayers" (Leygraf, C. and Graedel, T., Atmospheric Corrosion, 2000, pp 9-24)
  - A hydroxyl (OH) layer forms quickly upon exposure to the atmosphere
  - Layers of water stack up, depending upon relative humidity. The number of layers ~2 to ~10.
- Water in these monolayers acts as a solvent for gaseous and particulate in the atmosphere
  - Ions thus formed chemical interact with the surface
  - Corrosion can begin within minutes and continue for decades
  - Dust particles on surfaces greatly exacerbate (Bo Song's dissertation)

Fishbone Diagram



Alternatives for Corrosion Mitigation

- Electronic original equipment (IT) manufacturers rely upon industry design standards, standard tests, internal product qualification testing, analysis of field returns and upon shared knowledge published at industry conferences preventing corrosion issues in their products.
  - The Mixed Flowing Gas (MFG) test exposes samples to temperature, relative humidity, H_2S, Cl_2, NO_2 to promote corrosion.
- The data center environmental specifications have been established by ASHRAE guidelines
  - In situ coupons for reactive monitoring of corrosion limits recommended (ISA-71.04-2013)
  - ISO 14644-1 class 8 cleanroom standards
    - MERV 11/13 inlet air filters

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