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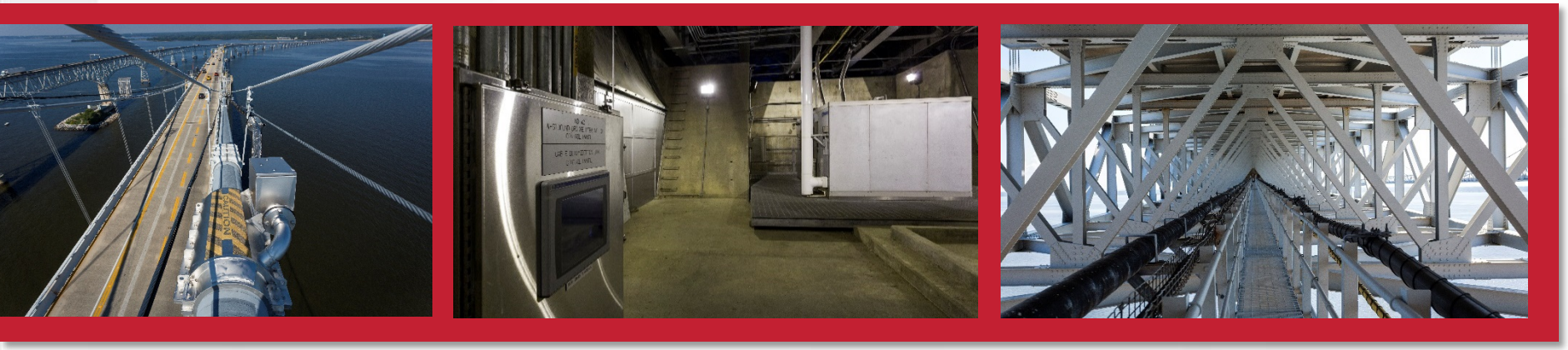
A Practical Design Approach to Main Cable Dehumidification



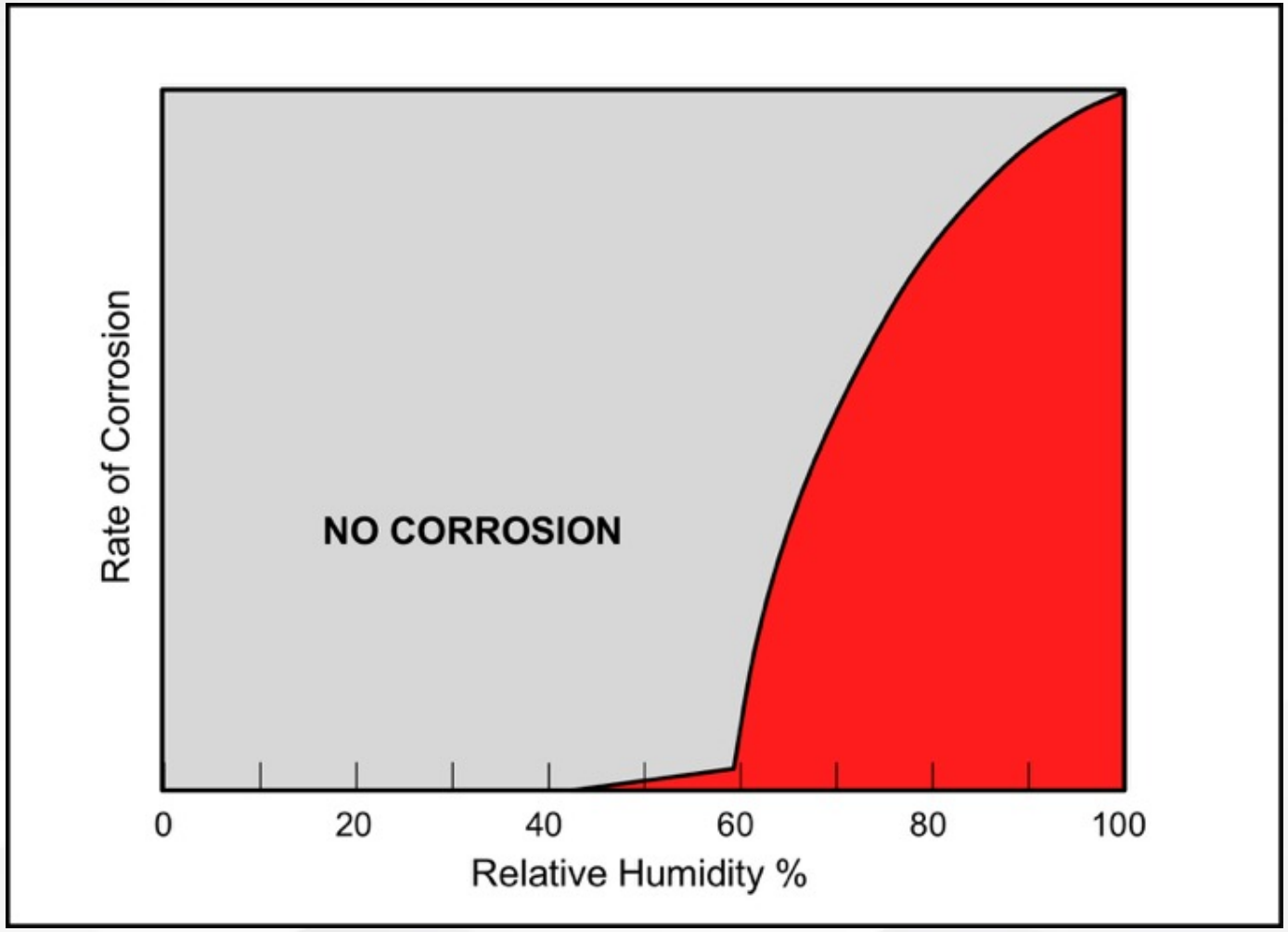
IBTTA Maintenance & Roadway Operations Workshop: June 24-26, 2018

Harrisburg, PA

Presented by: Jonathan Morey, PE

What is Main Cable Dehumidification

Corrosion ceases with Relative Humidity below 40%



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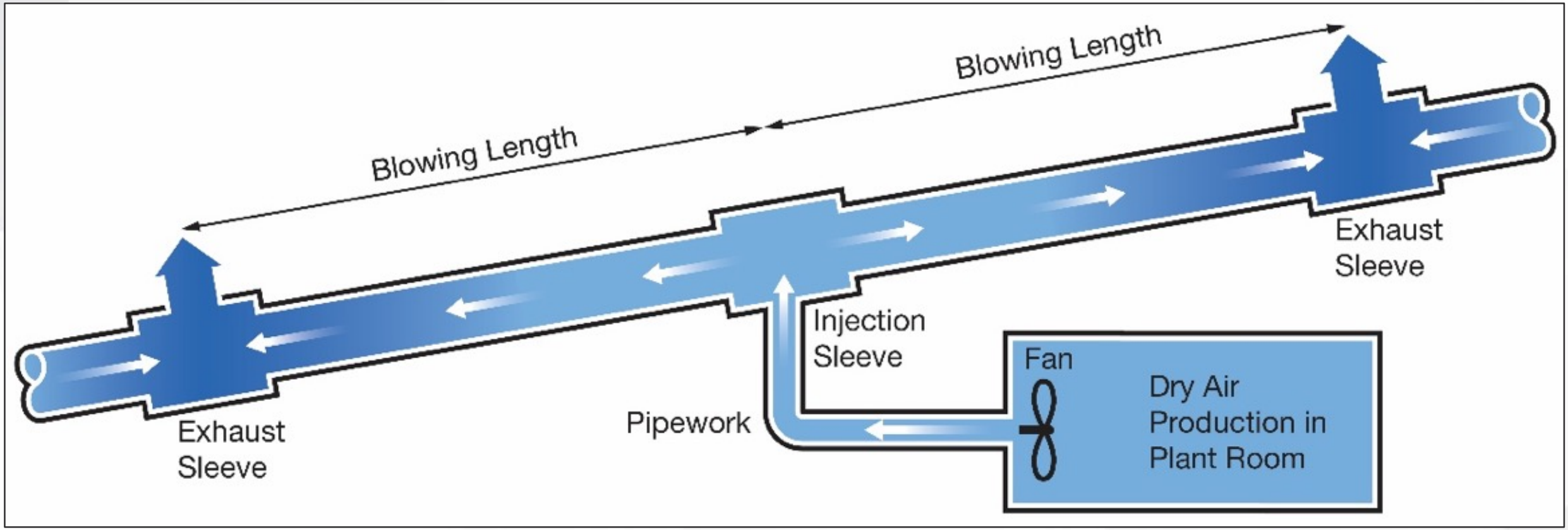
What is Main Cable Dehumidification

Dry Air injected into a cable drives water towards exhaust points



What is Main Cable Dehumidification

Over-Wrapping Existing Cables

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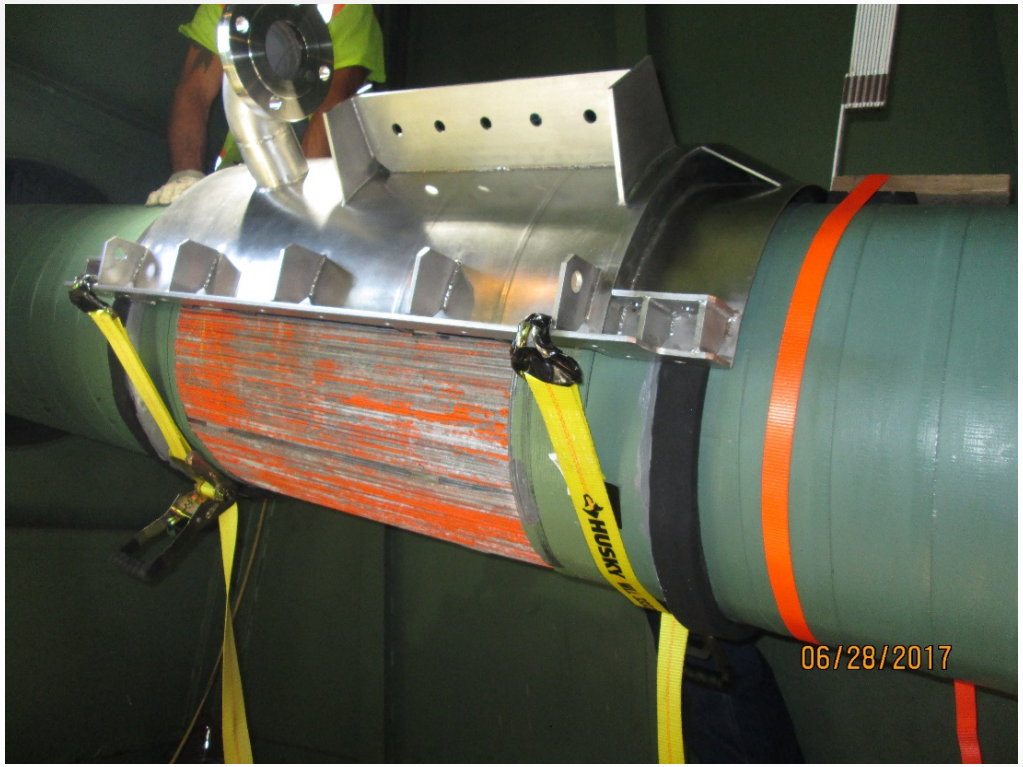
What is Main Cable Dehumidification

Sleeve Installation



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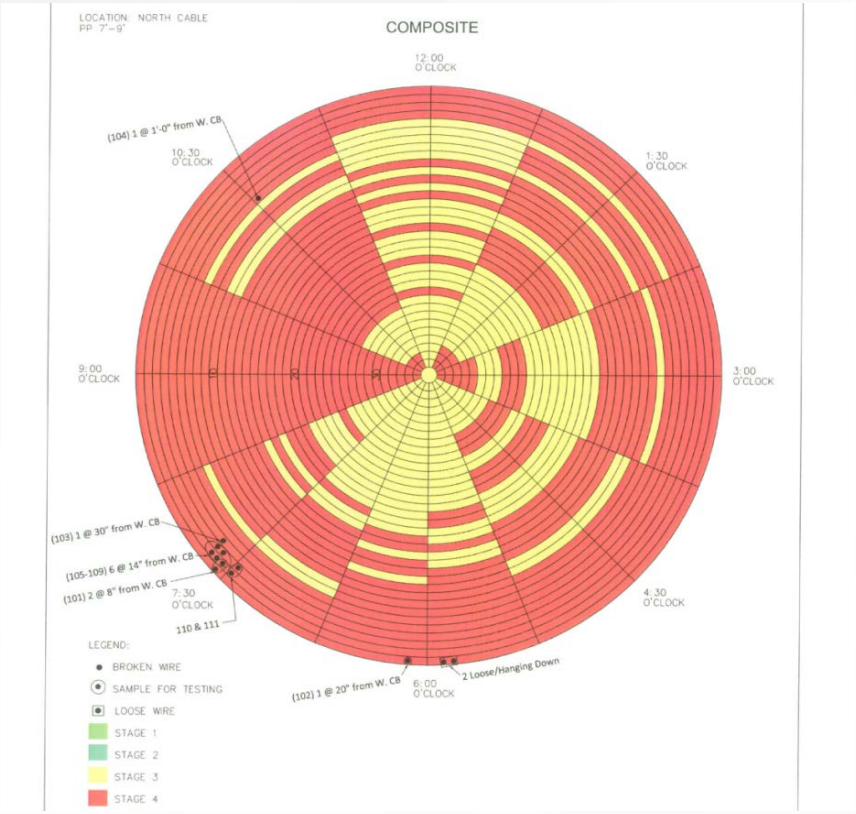
Suspension Bridge Main Cable Preservation

Cable Condition: Main Cable Inspection & Strength Evaluation



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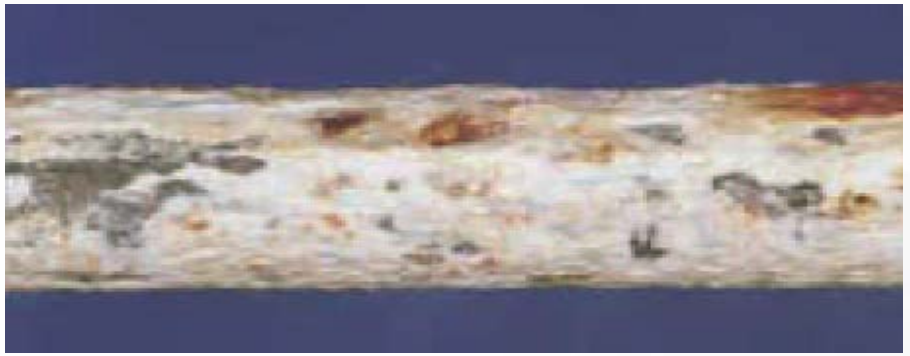
Suspension Bridge Main Cable Preservation

NCHRP Examples of Deterioration

STAGE 1



STAGE 3

STAGE 2

STAGE 4

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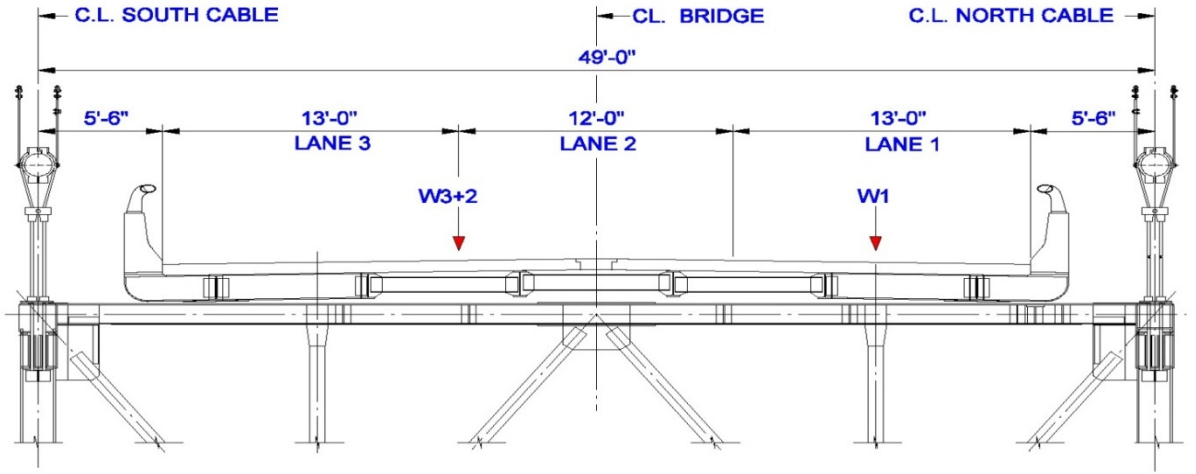
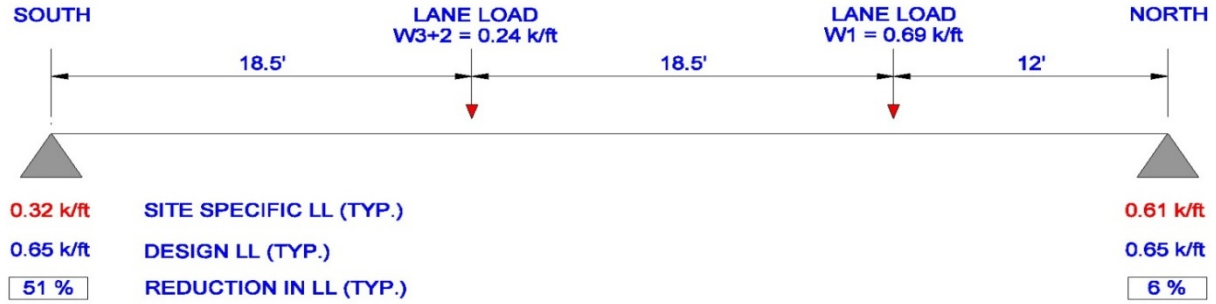
Suspension Bridge Main Cable Preservation

- Cable Condition
- Live Load Demands: Site Specific Live Load Study & Analysis



POSITION OF LIVE LOAD



LIVE LOAD DISTRIBUTION TO MAIN CABLES

Suspension Bridge Main Cable Preservation

- Cable Condition
- Live Load Demands
- Preservation Methods:
  - Galvanized Wire
  - Wire wrapping
  - Cable Pastes
  - Paint
  - Wedging and Oiling Cables
  - Main Cable Dehumidification

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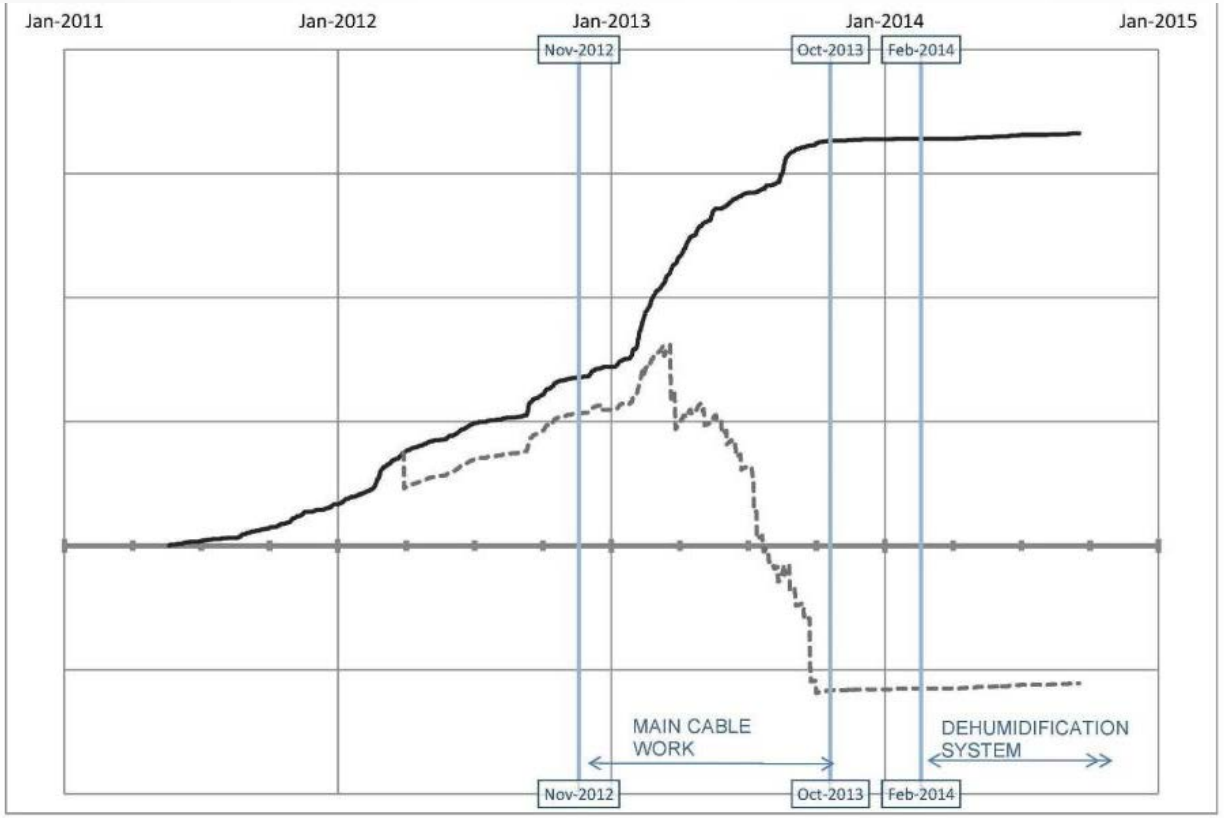
Suspension Bridge Main Cable Preservation

- Cable Condition
- Live Load Demands
- Preservation Methods
- Health Monitoring: Acoustic Monitoring



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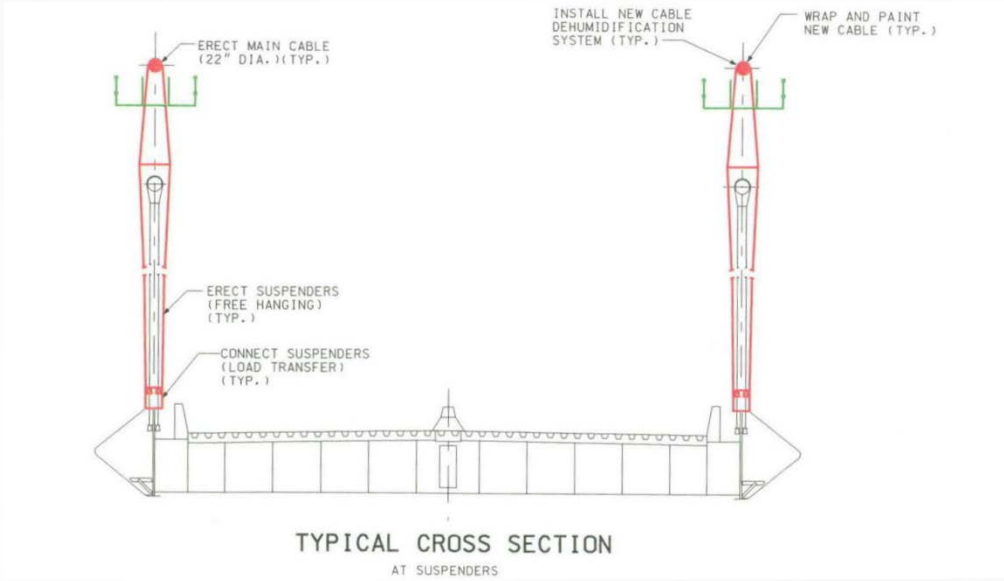
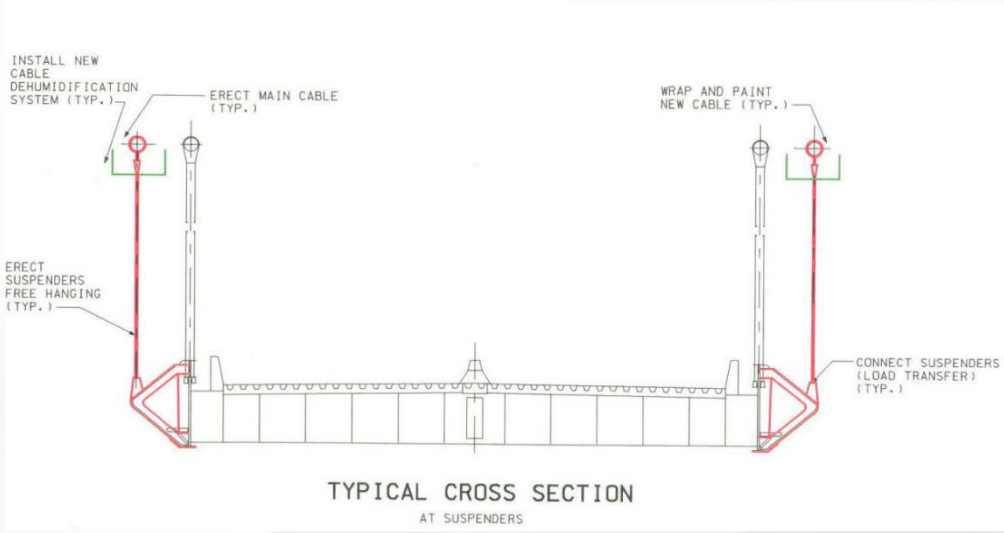
Suspension Bridge Main Cable Preservation

- Cable Condition
- Live Load Demands
- Preservation Methods
- Health Monitoring
- Load Re-distribution: Supplemental Cable System





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Main Cable Dehumidification

Question & Answer

1. When is the right time to implement main cable dehumidification techniques?
   - Cable Condition effects how air flows through the cables
   - Corrosion creates resistance to air flow
   - Resistance to air flow reduces how much air reaches exhaust
   - Less air reaching exhaust creates challenges for an effective system

Answer: Now.

Main Cable Dehumidification

Question & Answer

2. How should dehumidification techniques be tailored to benefit a specific bridge, while taking into account various impacts?
   - Decision making process
   - Consider three cases

Dehumidification Decision Process

Step-by-step process

1. What are the conditions of the wires in the cable?
   - Conditions may vary throughout the cable
   - Advanced corrosion
   - Broken wires
   - Original and current cable safety factor

   - Cable capacity dictates urgency and comprehensiveness of dehumidification.

Dehumidification Decision Process

Step-by-step process

2. Condition of Existing Cable Sealing:
   - Existing wrapping may be in good shape
   - Material: No. 9 wire; S-wire; Hypalon Wrap; Neoprene Wrap
   - Cable Band sealing: Packed lead wool; Hot poured lead; caulk

Over-wrapping the existing cable is an option.

Dehumidification Decision Process

Step-by-step process

3. Access to perform works:
   - Specific configuration of the bridge:
     - Cable over traffic
     - Cable over sidewalk
     - Access to the Cables
   - Minimize impacts to traveling public

Dehumidification Decision Process

Step-by-step process

4. Mechanical and Electrical Constraints:
   - Available space for dehumidification equipment
     - Locate within Anchorages or on Superstructure;
     - Create Building for Plant Room
   - Available electrical power supply
   - These dictate limitations on the system.

Dehumidification Decision Process

Step-by-step process

5. Phasing with other projects:
   - Cash flow constraints
   - Conflicts between contractors in adjacent areas
   - Sequence projects to be harmonious

Dehumidification Decision Process

Step-by-step process

6. Anchorage/Cable Splay Condition and Configuration:
   - Ambient atmosphere within the anchorage
   - Wire condition within this atmosphere
   - Dry air from the cable is passive
   - Separate Anchorage Dehumidification is active

   - Main Cable and Anchorage Dehumidification Systems could be done separately.

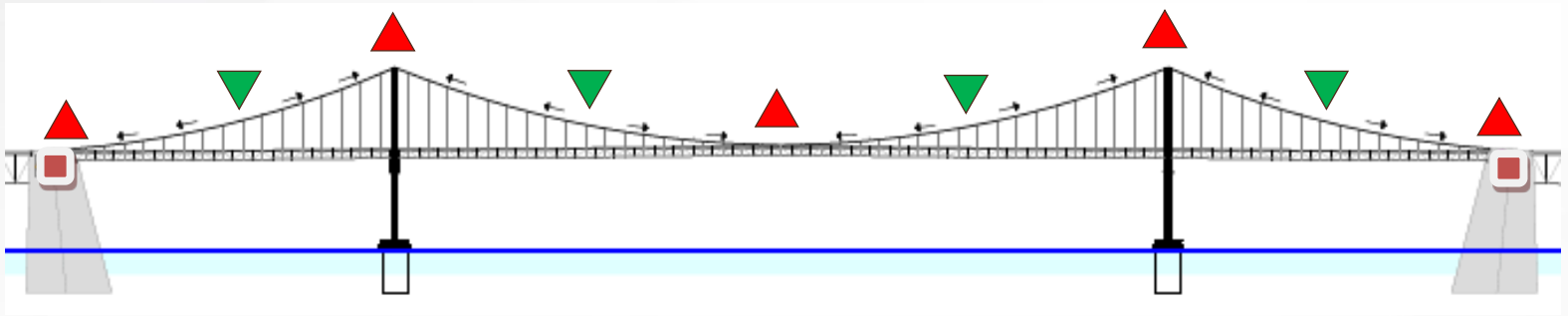
Dehumidification Decision Process

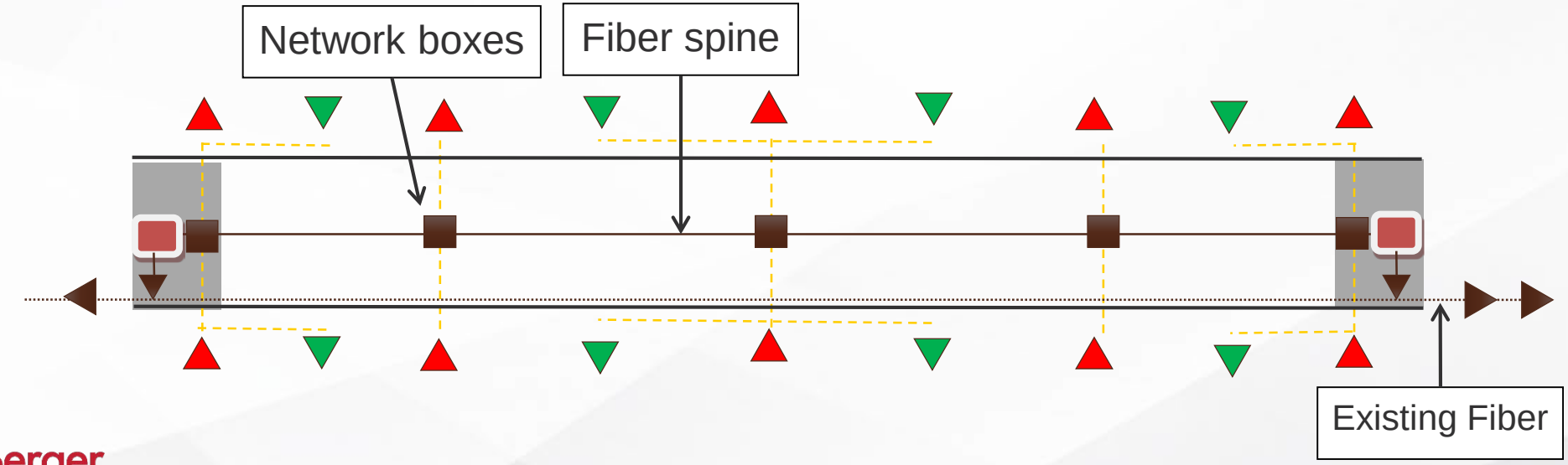
Step-by-step process

7. Data Collection:
   - Simple Systems
     - Constant Air Flow at lower pressures (keeps sealing in tact)
     - Periodic Manual readings to validate operation
   - Complex Systems
     - Programming to provide variable air flow based on higher pressure set point to main cable sealing is not over pressurized.
     - SCADA Communications to collect and record all data
     - Active control of the system remotely

Dehumidification Decision Process

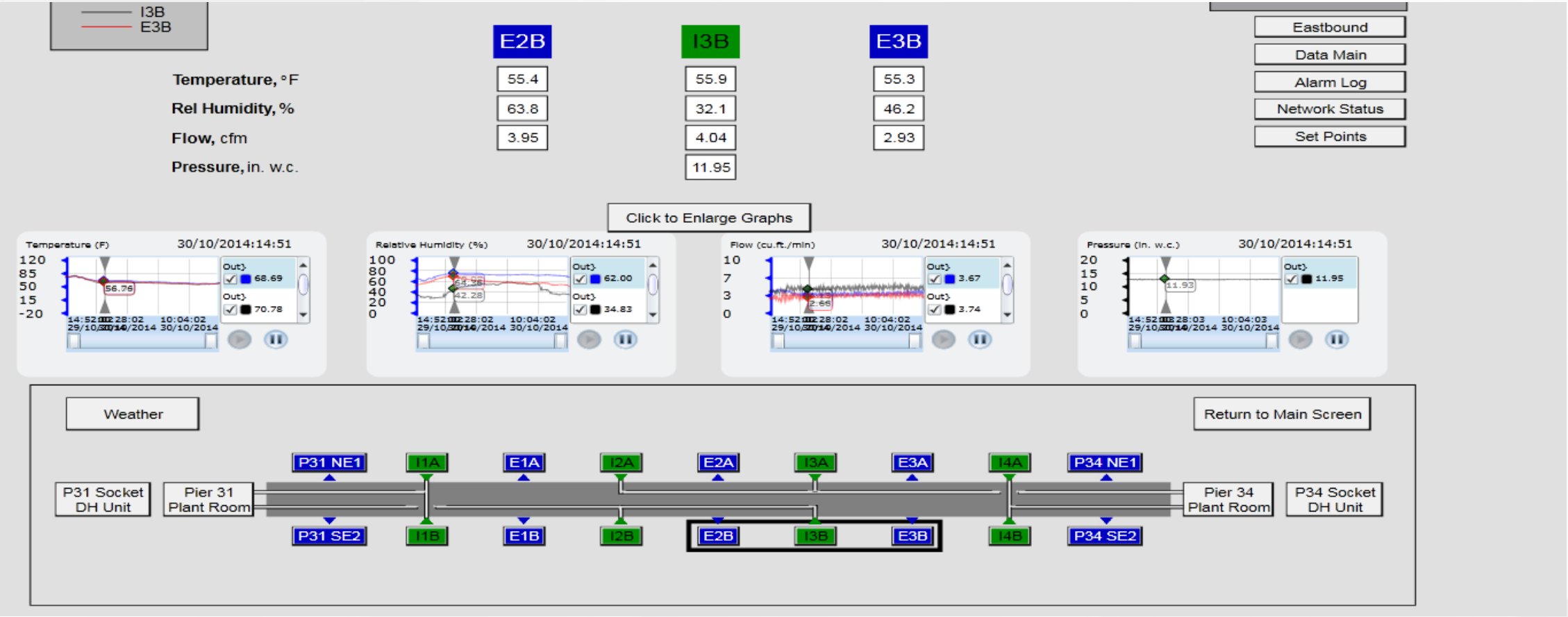
Step-by-step process





Dehumidification Decision Process

Step-by-step process



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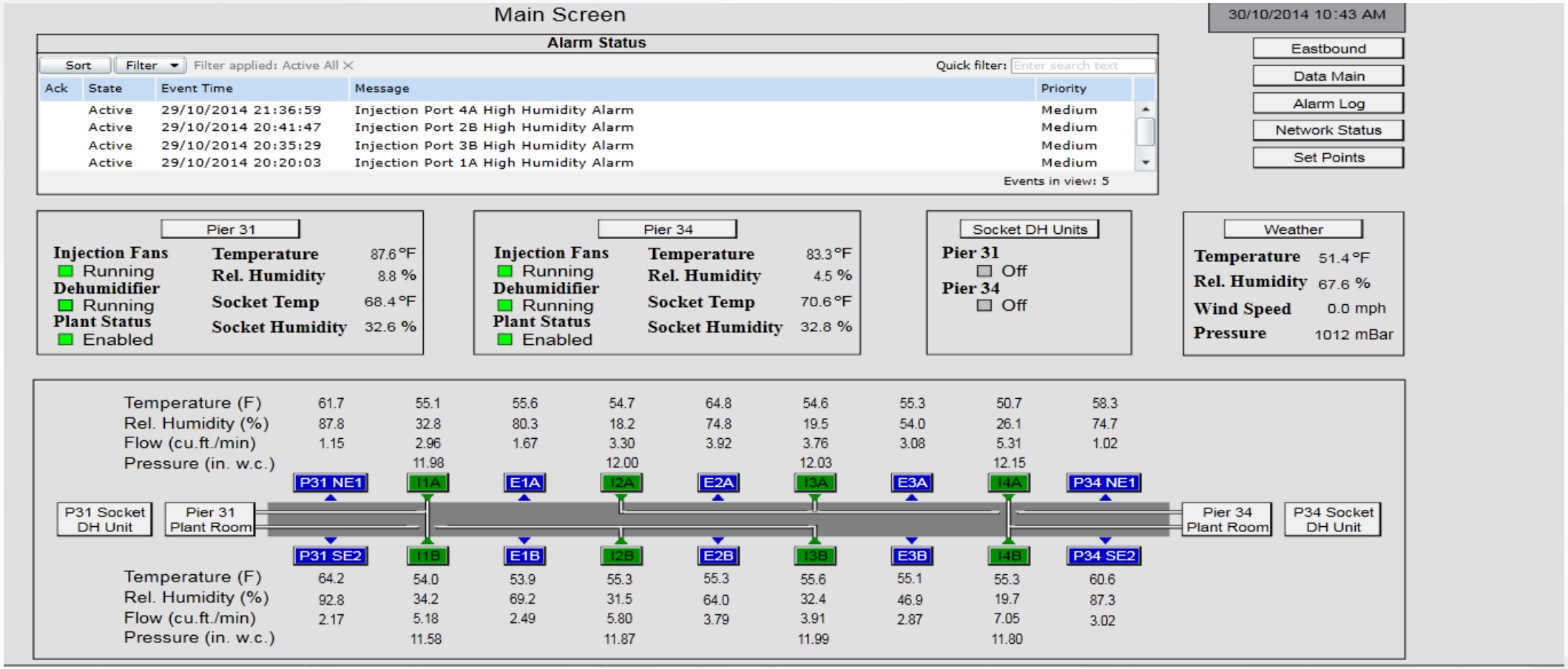
Dehumidification Decision Process

Step-by-step process



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Dehumidification Decision Process

Step-by-step process

8. Costs:
   - Big Ticket Items:
   - Main Cable Temporary Access
   - Labor to re-wrap and seal the length of the main cables

   - Dehumidification operation and maintenance costs are relatively low

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Dehumidification Decision Process

Step-by-step process

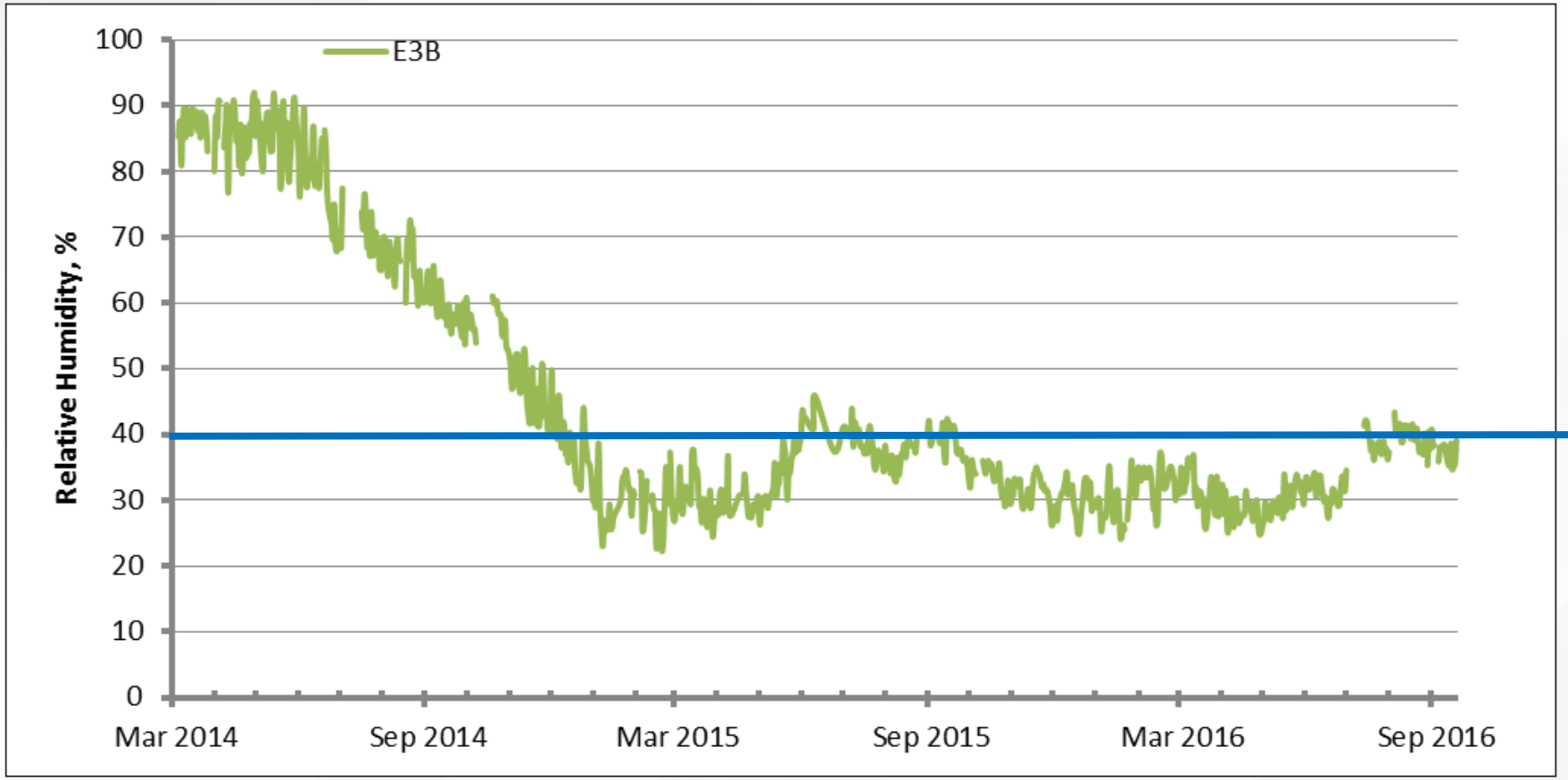
8. Costs (breakdown):

- Maintenance Impacts:
  - Maintenance Frequency Reduced
    - (8 hrs system check every 3 Months)
  - Active Information to indicate system performance (i.e. cable condition)
  - Ability to locate and address areas that are underperforming where sealing problems may be present
    - (i.e. takes the guess work out of what locations need preventative maintenance corrective actions)

Dehumidification Costs		Cable Rehab Costs	
$14M Total			
1) Wrapping	45%-65%	Main Cable Painting	$1.5M
a) Sleeves	4%		
b) Access	10%	Supplemental Cable	$30M
2) Dehumid Equipment	30%-40%	Cable Replacement	$200M +
3) Control System	10%-15%		
4) Maintenance	1%		

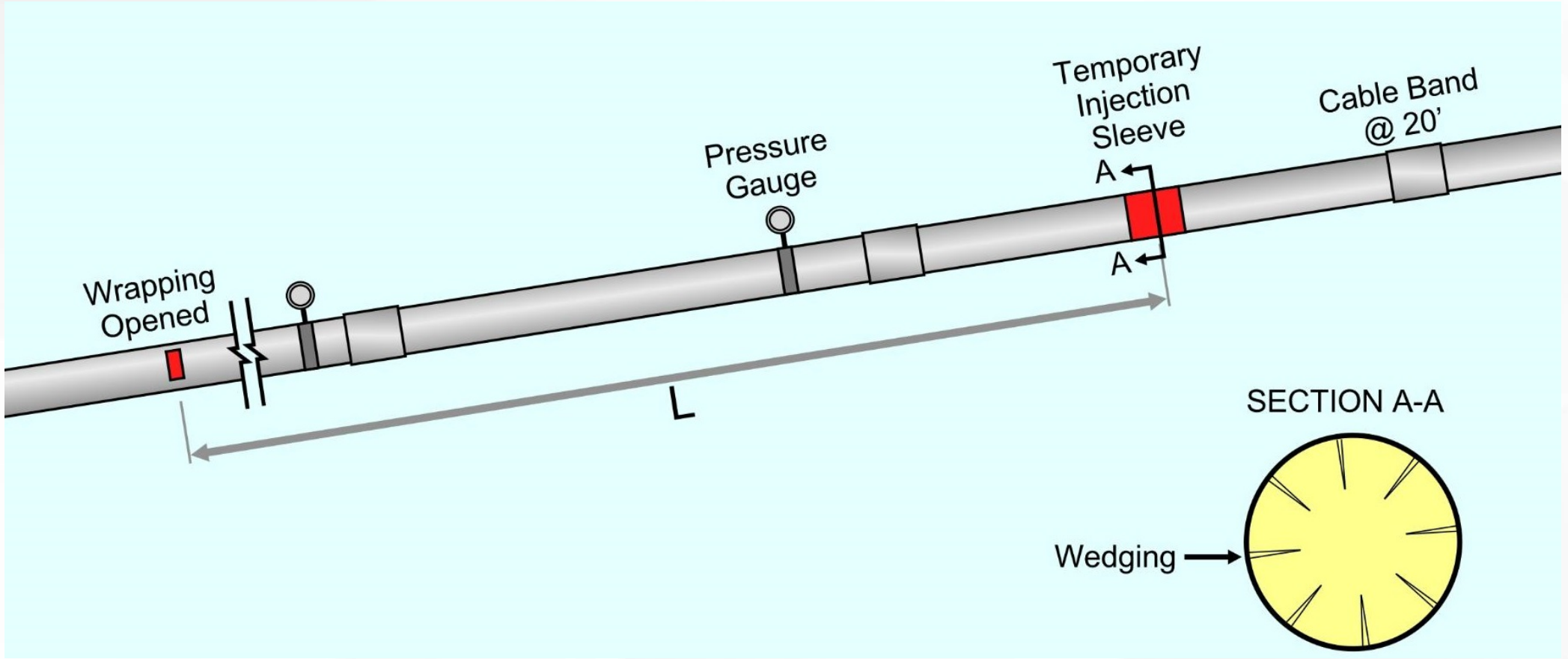
Dehumidification Layout

Cable Dry Phase can take months



Dehumidification Layout

Cable Air Flow Testing will inform the Design



Dehumidification Layout

- Cable in-situ porosity determine by flow rate between sleeve and opening
- A/G is determined based on the following:

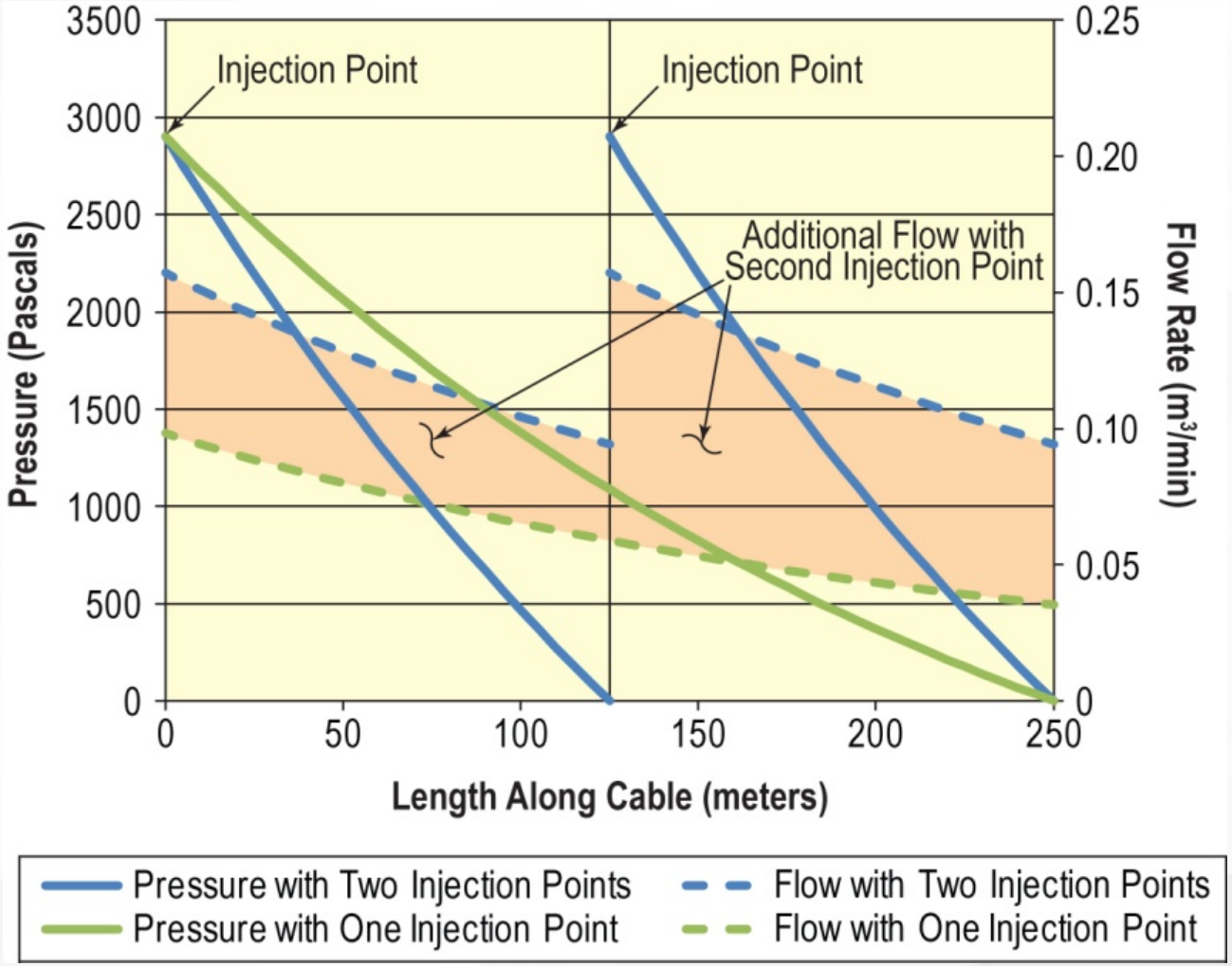
$$Q_0 \cong \frac{P_0 A k}{G[1-e^{-kL}]} \quad \text{or,} \quad Q_0 \cong \frac{P_0 A}{GL}$$

Where $G = 32 \dfrac{\mu}{D_H^2}$ or, D_H is the hydraulic diameter & A is the cable void area

- Variable depend on cable wire conditions & presence of oil
- This information provides a baseline for an effective design

Dehumidification Layout

- Flow Rate reduces as blowing length increases
- Humidity near exhaust depends on exhaust flow rate
- Effective Blowing Length requires consideration of cable geometry, condition, presence of oil and corrosion.



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Dehumidification Layout

- Cable wrapping may need to be repaired or replaced based on observed leakage

$$p(x) = \frac{P_0[e^{-kx} - e^{-kl}]}{[1-e^{-kL}]}$$

Leakage rate, k, is found from pressure gradient equation

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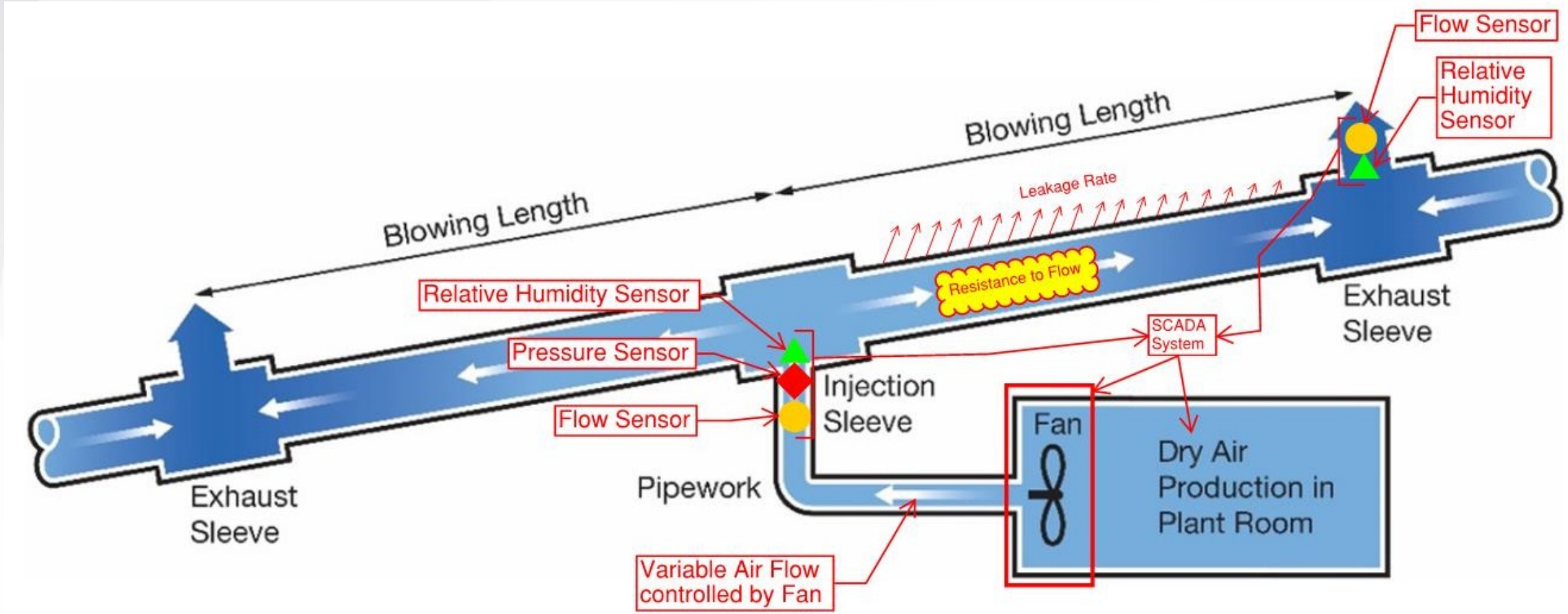
Dehumidification Layout



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Comparison of Two Projects

Project 1

- Over-wrap main cables full length with Elastomeric Wrap
- Seal all cable bands, tower and anchorage hoods and saddles
- Re-tension cable band bolts
- Complex system with fiber spine SCADA System to collect and report data and Programming to vary air flow based on pressure set point.
- Continuous Single Lane Closure
- 20” Main Cable – Max Blowing Length = 537 feet
- 0.43 SF Free Area (20% void ratio)
- 234 CF (20% void ratio)
- Design Flow Volume = 28 CFM (3.6 exchanges per hour)
- Design Pressure = 3.0 kPa

Comparison of Two Projects

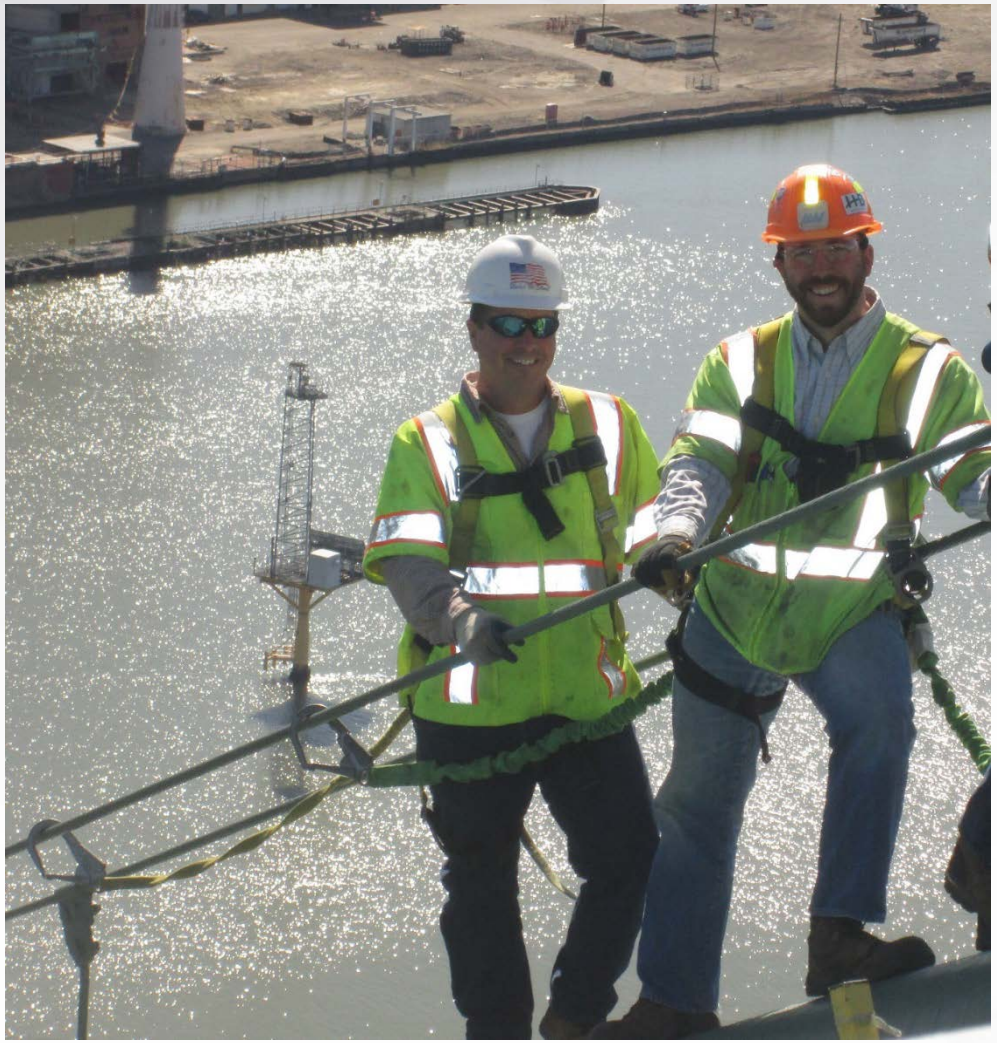
Project 2

- Over-wrap main cables full length with Elastomeric Wrap
- Seal all cable bands, tower and anchorage hoods and saddles
- Re-tension cable band bolts
- Create splay chamber: Dry air from Main Cable
- Separate Dehumidification of Socket Chamber
- Perform Main Cable Investigation at several locations
- Utilize AM wire break data to locate panel openings
- Complex system with fiber spine SCADA System to collect and report data and Programming to vary air flow based on pressure set point.
- Restricted Lane Closures
- 13” Main Cable – Max Blowing Length = 409 feet
- 0.18 SF Free Area (20% void ratio)
- 75 CF (20% void ratio)
- Design Flow Volume = 10 CFM (4 exchanges per hour)
- Design Pressure = 3.0 kPa

Comparison of Two Projects

Project 3

- Re-painted main cables (wire wrapping unknown)
- Thermo-hygrometers installed at sleeves
- Data is monitored and recorded through data logger
- 30” Main Cable – Max Blowing Length = 250 feet
- 0.98 SF Free Area (20% void ratio)
- 245 CF (20% void ratio)
- Design Flow Volume = 28 CFM (3.4 exchanges per hour)
- Design Pressure = 2.94 kPa



Thank you!

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