A Practical Design Approach to Main Cable Dehumidification

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Harrisburg, PA

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What is Main Cable Dehumidification

Corrosion ceases with Relative Humidity below 40%
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
What is Main Cable Dehumidification

Sleeve Installation
Suspension Bridge Main Cable Preservation

Cable Condition: Main Cable Inspection & Strength Evaluation
Suspension Bridge Main Cable Preservation

NCHRP Examples of Deterioration

STAGE 1

STAGE 2

STAGE 3

STAGE 4
Suspension Bridge Main Cable Preservation

- Cable Condition
- Live Load Demands:
  Site Specific Live Load
  Study & Analysis
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
Suspension Bridge Main Cable Preservation

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

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

Question & Answer

1. When is the right time to implement main cable dehumidification techniques?
   - Cable Condition affects 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.
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
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

<table>
<thead>
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<th>Contracts</th>
<th>Task</th>
<th>Start Date</th>
<th>End Date</th>
<th>Duration</th>
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<td>WB Suspension</td>
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<td>WB Stock Overlay (Lane 1)</td>
<td>Sun 12/12</td>
<td>Mon 12/19</td>
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</table>

Tasks:
- Sign Replacement: Sun 12/12
- Replace Lane Use Signals: Sun 12/12
- WB Stock Overlay (Lane 1): Sun 12/12
- WB Stock Overlay (Lane 1): Sun 12/12
- WB Stock Overlay (Lane 1): Sun 12/12
- WB Stock Overlay (Lane 1): Sun 12/12
- WB Stock Overlay (Lane 1): Sun 12/12
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

Network boxes
Fiber spine

Existing Fiber
Dehumidification Decision Process

Step-by-step process

[Diagram showing the decision process with data points, graphs, and maps for temperature, humidity, and flow.]

Louis Berger
Ammann & Whitney
Long Span Bridge Division
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
**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)

<table>
<thead>
<tr>
<th>Dehumidification Costs</th>
<th>Cable Rehab Costs</th>
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<td>$14M Total</td>
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<td>a) Sleeves</td>
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<td>b) Access</td>
<td>Supplemental Cable</td>
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<td>Cable Replacement</td>
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<td>3) Control System</td>
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<tr>
<td>4) Maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1%</td>
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</tbody>
</table>

*Louis Berger*

*Ammann & Whitney*

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Dehumidification Layout

Cable Dry Phase can take months
Dehumidification Layout

Cable Air Flow Testing will inform the Design
Dehumidification Layout

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

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

Where \( G = 32 \frac{\mu}{D_H^2} \) 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.
Dehumidification Layout

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

Leakage rate, $k$, is found from the pressure gradient equation:

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

Leakage rate, $k$, is found from pressure gradient equation.
Dehumidification Layout

- Relative Humidity Sensor
- Pressure Sensor
- Flow Sensor
- Exhaust Sleeve
- Injection Sleeve
- Pipework
- Fan
- Dry Air Production in Plant Room
- SCADA System
- Leakage Rate
- Resistance to Flow
- Variable Air Flow controlled by Fan
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!