Effective Building Operations

ASHRAE TN Valley

January 2020

Prepared by PMA Consulting, Inc.
**Why Do You Want To Do This?**

- Somebody told me to…
- I think it is a good idea…
- The current situation is untenable…
- I am bored…

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The past is gone; the present is full of confusion; and the future scares the hell out of me!

— David L. Stein
Where we have been…

- Addis Ababa
- Bangkok
- Berlin
- Singapore
- Ottawa
- Reykjavik
- Kampala
- Conakry
- Abidjan
- Cape Town
- Moscow
- St. Petersburg
- Lagos
- Helsinki
- Khartoum
- Ulaanbaatar

We rewrote the AEDG and SED to include Commissioning and RCM – we have worked with hundreds of DOS and NASA staff

- Vilnius
- Dublin
- Jeddah
- Bucharest
- Port au Prince
- Phnom Penh
- Lagos
- Hanoi
- Ho Chi Min City
- Valletta
- Athens
- Riga
- Sana’a
- Kabul
- NASA
Managing Expectations & Reality

The Organizational Power Factor©
System Performance Life Cycle

- **PHASE I**: Design & Construction
- **PHASE II**: Maintenance & Operations
- **PHASE III**: Proactive

- **System Performance Monitoring**
- **Start of Degradation**
- **Functional Failure**
- **Mean Time to Repair**
- **Transition Losses**
- **Minimum Required Performance**
- **Design/ Safety Margin**

- **Restoration Band**

- **Percent of System Function**

- **Time**

- **System Performance**

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New Construction (NC) - Defining Owner’s Requirements

- Full Time Equivalent (FTE): 281 Peak Period Transients: 25 (average 1 hour stay, FTE = 3.13)
- Indoor Design Conditions: 23ºC (73.4ºF) and 50% relative humidity, summer and winter.
- Outside Air Requirements: 5 liters/second (10.5 cubic feet/ minute) per person or ASHRAE Standard 62.1-2004 ventilation rates, whichever is more stringent.
- HVAC&R: Air handling systems provide 24/7 operations to maintain building pressurization. Chilled water cooling systems operate 24/7 as required to meet cooling demand (i.e. server rooms).
- The chillers generate 5.6ºC (42 ºF) chilled water. Each chiller is sized for 67% of the design building load, at 659 kW (187.4 tons).
- The outside air handling unit is sized to meet ventilation and pressurization requirements for the Building as well as to comply with ASHRAE standard 62.1-2004 per LEED certification requirements.
NC - Meeting Owner’s Requirements

Final Commissioning Report including, but not limited to:

• Basis of design narratives including Failure Modes and Effects Analysis (FMEA)
• Reliability analysis and Criticality designation
• Preventive Maintenance Plan using the Reliability Centered Maintenance (RCM) approach
• Derive the list from reliability analyses performed during design phase...
• Testing, Adjusting and Balancing reports
• Training and Demonstration Records
Overview

- Introduction to Commissioning
- The Process
- The Cx Team
- Roles & Responsibilities
- Key Submittal Dates
- PFT Sampling
- Cx Action Items
- Training
- Systems to be Tested
- Sample Cx Status Report
- Substantial Completion
- Lessons Learned
**Cx Process Example**

**Quality Control**

- Establish Requirements
  - Design Intent
  - Post Project Requirements
- Prepare Specifications
  - CX & S/U
  - Closeout
  - Tech. Library
- Construct
- Start-up
- Prefunctional Testing
- Functional Testing
- Completion
- Training
- O&M Deliverables
- Failure Modes & Effects Analysis (FMEA)
- Maintenance Plan - GMMS input
- Staffing recommendations
- Material for Repair & Operations
- Technical Library

*Specifications*
- 017705 – Closeout Procedures
- 017825 – Operations and Maintenance Data
- 019115 – Start-up and Commissioning
- 017905 – Demonstration and Training
- 230905 – HVAC Instruments and Controls
- 230593 – Testing, Adjusting, and Balancing for HVAC
- 260126 – Field Testing and Inspection of Electrical Systems

*All items will have "End of Phase" testing requirements as OBO intends on using the space as each phase is completed. Holistic systems will also have a "End of Project" testing requirement.*
O&M Deliverables

Implementation and Integration

RCM Deliverable Inputs

- Update Equipment Inventory
- Failure Modes & Effects Analysis
- Maintenance Job Plans
- Maintenance Tools
- Maintenance Staffing

Input to MAXIMO

- Equipment Inventory
- PM Procedures
- PM Frequency
- MRO Requirements
- Tool Requirements
- Training Requirements

O&M Requirements

- Staffing Requirements
- Other Requirements

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O&M Deliverables – Spare Parts Turnover

What not to do….
**Age Related Failure Curves**

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<thead>
<tr>
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<tbody>
<tr>
<td>4%</td>
<td>3%</td>
<td>3%</td>
<td></td>
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<tr>
<td>2%</td>
<td>1%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>4%</td>
<td>3%</td>
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</table>
Random Failure Curves

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Conditional Probability of Failure</td>
<td>7%</td>
<td>11%</td>
<td>6%</td>
</tr>
<tr>
<td>Time</td>
<td>14%</td>
<td>15%</td>
<td>42%</td>
</tr>
<tr>
<td></td>
<td>68%</td>
<td>66%</td>
<td>29%</td>
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</tbody>
</table>
At Times, We are Performing the Wrong PM on the Wrong Equipment Components

**Thirty Identical 6309 Deep Groove Ball Bearings Run to Fatigue Failure Under Test Load Conditions**

![Bar Chart](chart.png)

- **Bearings’ lubrication is one of our more common tasks - Should it be?**

John Wiley & Sons. 1985
HEGA Filter Broken Door Dog Bolt – Air Leaks
Generator Sets – Example 100% Step Load Test

• Check voltage and frequency recovery requirements
  o $\leq 15\%$ transient voltage change - voltage shall recover to 95 percent of rated voltage within 2 seconds, and recover to 100 percent within 5 seconds
  o Frequency shall not dip or rise more than 10% of rated frequency. The frequency shall recover to rated frequency within 2 seconds
Corroded AHU Door Dogs
Corroded AHU – Tarp Covering Rusted out Roof
Corroded AHU Floor and Coil
AHU Coil
“Although preserving museum collections is vital, it is equally important to consider the failure mechanisms of the buildings that house those collections. A combination of research, survey, and experience with high-profile buildings at the Smithsonian Institution has led to broadening the indoor environmental guidelines. The new environmental guidelines are 45% RH ±8% RH and 70°F (21°C) ±4°F (2°C).” – *Perserving Legacy Buildings* by Marion F. Mecklenburg, Ph.D.; Charles S. Tumosa, Ph.D.; and Alan Pride, HVAC Retrofit | A Supplement to The ASHRAE Journal, June 2004

![Painting damaged by improper temperature and RH control](image)
Using Data to Create Metrics

**Total Data Points for February = 3,360**

99.7% of time

95% of time

Danger Zone = Region where damage to artifacts possible

Data Points < 30% RH for February = 218

Data Points > 60% RH = 0

Desired RH Range 37 – 53 %

Distribution of NMAH RH for February 2007

<table>
<thead>
<tr>
<th>Range of RH (%)</th>
<th>Hours in Range</th>
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<tbody>
<tr>
<td>19 – 56.2%</td>
<td>670 hrs</td>
</tr>
<tr>
<td>25.2 – 50.0%</td>
<td>638 hrs</td>
</tr>
<tr>
<td>31.4 – 43.8%</td>
<td>457 hrs</td>
</tr>
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</table>

**TOTAL HOURS for February = 672**
Building the Case – Team Prep

DEVELOP INTEGRATED BROWN PAPER

UNDERSTANDING CYCLE TIME

IDENTIFY MEASURES

B/P PRESENTATION TRAINING

H2 PERFORM DILO

DETERMINE WHAT MEASURES ARE KEY AND WHAT IS MISSING

BROWN PAPER VALIDATION TOUR

COMPLETE AND ANALYZE DILO

COMPLETE KPI MODEL

QA/QC SAFETY PLANNING MISSION REGULATORY

DAY IN THE LIFE OF A DOCUMENT

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Building the Case – Team Prep

1. Collect Opportunities/Strengths
   Prioritize Areas of Focus

2. Present Key Findings to Champions

3. Develop To-Be Aspiration Model
   Through Workshops: By Areas, Key Users

4. Integrate To-Be Models

5. Validate To-Be Model

6. Early Win Identification

7. Early Win Plan

8. Early Win Implementation

9. Develop Phased Implementation Plan
# Identifying As – Is and To – Be

<table>
<thead>
<tr>
<th>STAGE</th>
<th>CLASS</th>
<th>Low Performing</th>
<th>Competent</th>
<th>High Performing</th>
</tr>
</thead>
</table>
| Stage 1 | Daily Maintenance | • “Fires” determine priorities  
• Breakdowns frequent  
• Maintenance equates to repair  
• No work orders, plans, controls  
• Stores service levels low  
• Poor O&M relationship  
• Poor customer service levels | • Most work planned, scheduled  
• PM in place  
• Trades competent at most repairs  
• CMMS  
• Stores service levels fair  
• Operators prep for repairs  
• Expedited orders infrequent | • All work prioritized  
• PM hours & WO’s exceed repairs  
• CMMS utilized, integrated with Purchasing, Stores  
• MRO Stores; 1x minimum turns  
• Operators inspect, create WO’s  
• Turnarounds well planned, executed |
| Stage 2 | Proactive Maintenance | • Condition-monitoring equipment purchased and installed  
• Little analysis performed on data  
• No preventive action taken  
• No analysis done to identify candidate equipment  
• Benefit tracking anecdotal | • Condition-monitoring equipment installed and used  
• Information analyzed, work orders created  
• Equipment high value to ops  
• Rational cost/benefit analysis | • Condition-monitoring intervals based on risk analysis  
• Proactive techniques employed (e.g., high-quality filtration)  
• CbM data integrated with CMMS |
| Stage 3 | Organizational Excellence | • Training emphasis disconnected from real work practices  
• Quality Program ineffective in changing work behaviors  
• “Team” implementation creates chaos  
• Anarchy replaces hierarchy | • Natural work teams perform most daily maintenance effectively  
• Operators perform TPM activities  
• Some program integration (e.g., Quality, PSM, EPA, ISO)  
• Crafts flexibility high priority  
• RCM adopted | • Work teams flexible, self-directed  
• Continuous improvement process embraced, understood, working  
• Programs rationalized, integrated  
• Reward/Recognition support best results  
• Skills predominate over functions |
| Stage 4 | Engineered Reliability | • RCM implementation creates confusion, increased downtime  
• Functional divisions prevent successful pooling of talent  
• Pedantic rigor creates paralysis through analysis  
• Vendor reduction | • Failure analysis routine activity  
• High-value production processes assessed via RCM techniques  
• Maintenance routines changed to increase value impact  
• Reliability becomes focus | • All staff systems competent  
• Concurrent engineering to address LCC  
• Reporting systems tie reliability to financial results through OEE  
• Complete equipment histories are used to trend and predict failures  
• Vendors participate in reliability |
| Stage 5 | Operational Excellence | • Executive and plant management fail to align and implement goals  
• Market pressures make short-term decisions predominate  
• Union resistance impedes high-performance organization | • Clear organizational alignment  
• Operational reliability is cross-functional responsibility; purchasing, production, engineering.  
• Activity-based management  
• Market impact of reliability measured | • Monitoring, process control, and information systems integrated.  
• Life expectancy analysis, lifecycle extension reengineering done  
• Automated, demand-driven plant production balancing implemented |
Lessons Learned

- Test instrumentation and calibration
- Personnel certification
- Baseline condition monitoring not always provided in correct format
- Last minute changes to specifications for major equipment – chillers
- Test and Balance – sensor/damper locations
- Diversity vs. purge and pressurization
- Subcontractor understanding of Cx process
- Owner’s expectations
- Integrating training and functional testing
- Potable water testing
- Factory testing
- Submittal reviews
- Do not dismiss the emotions and the politics

The Organizational Power Factor©
Summary

• Business orientated
• Know the products and/or mission
• Factual – Key Performance Indicators

• Be visual
• Promote shamelessly
• Identify and promote a champion
• Engage the entire work force
Questions & Dialogue

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Concerns</th>
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Any questions?