Innovative Industrial Projects: Successful Approaches to Reducing Electricity Consumption

Tuesday, May 10
11:15 – 12:30 pm
Electricity-saving Projects Continue to Provide Reliable Savings

- We have seen upwards of 30% savings in industrial systems
- Today we will explore three successful projects undertaken by leading companies
- Let’s keep this an open and interactive discussion
Average Consumer Price of Natural Gas

Reference – US Energy Information Administration
Average Retail Price of Electricity

Source: U.S. Energy Information Administration
Presentations From:

- Toyota – Dan Cooper
- CEMEX – Bhaskar Dusi
- Texas Instruments – Michael Braby
Using VFDs to Drive HVAC Energy

Dan Cooper
PE Facility Engineering, Toyota
Using VFDs to Drive HVAC Energy

May 10th 2016
Dan Cooper
Intro to Toyota North America

Camry
Camry Hybrid

Avalon
Avalon Hybrid

Corolla

Lexus RX 350/450h/ ES350

Sienna

Tacoma

Tundra

Highlander
Highlander Hybrid

Sequoia

RAV4

Venza
HVAC Energy at Toyota

14 Plants

660 HVAC units

Approx. 40K HP (30 MW)

Target HVAC energy by:
1. Optimizing run time (non production)
2. Reducing air flow
1. Remove
2. Install
3. Integrate

Install VFD to control fan motor
Fan Affinity Laws

Basic fans laws:
1. Flow varies directly with fan speed
2. Pressure varies with square of fan speed
3. Power varies with cube of fan speed

2.5 Hz = 44 HP
4% reduction in fan speed results in reduced HP (50 HP)
1. Design temperatures
2. Building set points are 81° F summer and 65° F winter.
3. Units operate M-F, setback on weekends
Savings Concept

Current condition –
- Constant volume
  100% cfm

Opportunity –
- Spring & Fall 40% cfm reduction
- Winter 50% cfm reduction
- Non production time 20%-60% cfm reduction
Project Summary

8 Plants

531 HVAC Units

659 VFDs

31K Horse Power

179,632 MMBTU Energy Reduction
BBBP Showcase Project

Showcase Project: Fan System Upgrade

SECTOR TYPE
Industrial

LOCATION
Georgetown, Kentucky

PROJECT SIZE
7,300,000 Square Feet

FINANCIAL OVERVIEW
$1.25 Million

<table>
<thead>
<tr>
<th>Plant Electricity</th>
<th>HVAC</th>
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</thead>
<tbody>
<tr>
<td><strong>Annual Plant Electricity Use</strong></td>
<td><strong>Annual Plant Electricity Cost</strong></td>
</tr>
<tr>
<td>450,000 MWh</td>
<td>$28,000,000</td>
</tr>
<tr>
<td>438,300 MWh</td>
<td>$27,300,000</td>
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<tr>
<td>Actual</td>
<td>Actual</td>
</tr>
<tr>
<td>Coming Soon</td>
<td>Coming Soon</td>
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</table>

Electricity Savings: **2.6%**

Cost Savings: **2.5%**
Objective: Reduce HVAC energy consumption

Scope: Install VFDs on 163 HVAC

Method: Seasonally adjust set points
Constraints

- Energy Savings
- Schedule
- Codes/Reg
- Install $
- Integrate $
- VFD $

2 Yr Payback
Issues / Challenges

1. Age of units
2. Motor compatibility
3. Line/Load Reactors
4. Integration

Fan Motor

Vortex Vanes

Building Mgmt. System

Reactors
Project Savings

Total kwh reduction: 11,715 MWh
Total savings: $702K

Project cost: $1.2M

Simple payback: 1.8

Total HP: 8898

# HVAC Units: 163
Future Opportunity

• Reduce speed during non production

• BMS integration
Summary

1. Energy opportunity with <2 year payback
2. Started as a pilot, replicated to other plants
3. M&V – confirm energy savings

Additional benefits:
1. Reduced maintenance - belt replacement
2. Improve control of building balance
3. Ability to monitor and adjust system performance
Thank You

Questions / Comments?
Compressed Air
"Air Over the Fence": A new concept for Optimization of Compressed Air Systems

Bhaskar Dusi, P. Eng., C.E.M, C.E.A
Corporate Energy Manager, CEMEX, Inc.
"Air Over the Fence": A new concept for Optimization of Compressed Air Systems

Bhaskar Dusi
Corporate Energy Manager
CEMEX, Inc.

Tuesday, May 10, 2016

Better Buildings Summit
Washington D.C.
A Global Building Materials Company

- Presence in 50 countries
  - >44,000 employees

- Annual production capacity of
  - 94.8 million metric tons of cement
  - 55 million cubic meters of ready-mix concrete
  - 159 million metric tons of aggregates

- Operate globally
  - 57 cement plants
  - 1,899 ready mix concrete facilities
  - 371 aggregate quarries
  - 221 land-based distribution centers
  - 69 marine terminals

- U.S. operations in 33 states
  - 13 cement manufacturing facilities
  - 355 ready-mix concrete plants
  - 77 aggregate quarries
  - 46 cement terminals

% worldwide product sales 2012
Typical Cement Plant Energy Consumption

Energy Consumption (Equivalent MWh)

- Coal: 53%
- Coke: 22%
- Gas: 3%
- Tires: 5%
- Others: 4%
- Electricity: 13%

Energy Expenditure (US $)

- Coal: 34%
- Coke: 12%
- Gas: 4%
- Others: 2%
- Electricity: 48%
• Structured approach for Energy Management” has helped us in
  ✔ Formalizing our Energy Management Program
  ✔ Organizing our energy teams
  ✔ Maintaining focus
  ✔ Sustaining momentum

• What distinguishes CEMEX as an industry leader in energy efficiency?
  ✔ Commitment to smart energy management
  ✔ Ability to measure and track progress
  ✔ Efforts to communicate the importance of energy efficiency to a wide audience
  ✔ Recognize achievements
Real Cost of compressed Air

Energy Cost represents approximately 70% of Real Costs
Compressed Air Savings potential

- **APPROX. 6-10%**
  - Leak Reduction and better control practices

- **APPROX. 10%**
  - Optimal Pressure level through a Master Control (pressure reduction and stabilized pressure)

- **APPROX. 10%**
  - Better Equipment Performance (compressors, cooling system, lubrication, pipe optimization network)
• CEMEX started an initiative in 2005 to review the way in which CEMEX procured its compressed air

• Traditionally just bought equipment and CEMEX to maintain

• CEMEX’s Global Sourcing department along with Commodity

• Team reviewed the opportunity to change the focus to buying ‘compressed air over the fence’

• In 2006 the first ‘Air Over the Fence’ contract was signed for the Hidalgo Plant in Mexico. Since then the program has been rolled out to new projects and other existing operations all over the globe
Air Over the Fence Strategy offers a good potential to reduce compressed air unit costs and supplier base. The strategy followed involve:

- To see Air Requirements as a Total System instead of an isolated solution.
- A reliable compressed air system in terms of quantity, quality and availability of air.
- To focus on minimizing the highest operational cost which is Energy, and to reduce the equipment maintenance costs, spare parts, inventories, etc.
- Air over the fence possibilities, as a main change to operate air compressed systems in CEMEX.
Objective

To reduce total compressed air costs in CEMEX through equipment improvement and outsourcing of compressed air through an “air utility” similar to paying for water or electricity.

Another important benefit is to avoid allocating / spending CAPEX in auxiliary equipment.

Structure of Outsourcing Model

Analysis
- Air Demand Analysis. Establish a baseline from current conditions
- RFP / Proposals. Proposal submission and evaluation

Installation
- Award mid/long term contract to supplier.
- Operation. Supplier installs and operates system
- Monthly fee payment

Follow up
- kWh savings guarantee follow up
- Periodic air leaks audits and repairs
Economic and Technological Improvements

**Expected Savings**

- **Energy Consumption Reduction.**
- **Zero Maintenance Cost.** Supplier is responsible for its own equipment. Spare parts inventory reduction.
- **CAPEX Avoidance.** Supplier owns equipment, CX possibly needs to invest in minor modifications.

**Expected Benefits**

- **Air Quality and Quantity guarantee**
- **Reliability.** Air demand and energy consumption online monitoring.
- **System improvement.** Air leak audits.
- **Right to purchase equipment** at the end of the agreement at book or market value.
- **CO₂ Tons Emissions.** Footprint reduction.

**Technology**

- **Operation Efficiency:** systems designed to operate centrally controlled compressors, where possible, at full load to provide stable system pressure and air quality, while reducing energy consumption.
- **Centralized Control (24/7):** Online & SMS monitoring ensuring prompt response when needed.
- **Supply Guarantee:** Through a back-up compressor and adequate maintenance, supplier assures compressed air delivery. Supplier subject to penalty in case of failure to deliver air.
- **Periodic Leak Audits:** Performed to the piping system for the plant to take corrective actions, and minimize costly air leaks.
CEMEX “AOF” Installations in US

• 6 plants with 8 lines of production are in operation under AOF
  ✓ 1 production line is new line started about 6 months back
  ✓ 1 production line is green field start and in operation for about 7 years
  ✓ 2 production lines are running for 6 years
  ✓ 2 production line is running for 5.5 years
  ✓ 2 production lines are running for 5 years
  ✓ 2 plants are under review for possible AOF implementation
## Savings Results

### Air Over the Fence (AOF)

<table>
<thead>
<tr>
<th>Plant</th>
<th>Prior AOF</th>
<th>After AOF</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg kWh/month</td>
<td>Avg CF/month</td>
<td>Avg kWh/month</td>
</tr>
<tr>
<td>A</td>
<td>613,193</td>
<td>141,609,600</td>
<td>489,539</td>
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<tr>
<td>B</td>
<td>617,043</td>
<td>109,663,996</td>
<td>327,018</td>
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<tr>
<td>C</td>
<td>526,136</td>
<td>156,964,617</td>
<td>440,366</td>
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<tr>
<td>D</td>
<td>1,152,752</td>
<td>309,492,655</td>
<td>900,383</td>
</tr>
<tr>
<td>E</td>
<td>796,907</td>
<td>218,421,548</td>
<td>673,563</td>
</tr>
<tr>
<td>F</td>
<td>1,438,655</td>
<td>198,000,000</td>
<td>840,921</td>
</tr>
</tbody>
</table>

**Compressed Air Energy Cost reduced from 18.5 kW/ 100 CFM to 17 kW/ 100 CFM**
# Savings Follow up and Review

**CEMEX / KAESER Monthly Report**

**Plant Name:**

**Contract Start:** 03/02/2015

<table>
<thead>
<tr>
<th>Prior to SAU Installation</th>
<th>Annually Contracted Amounts</th>
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<tbody>
<tr>
<td>kW*</td>
<td>CF minimum</td>
</tr>
<tr>
<td>1,438,655</td>
<td>2,248,171,200</td>
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</table>

*1/kWh/month

CF/month * not in contract

*1/kWh equivalent

**12 month Rolling Profile**

<table>
<thead>
<tr>
<th>kW</th>
<th>kWH equivalent decrease (increase)</th>
<th>CF</th>
<th>CF decrease (increase)</th>
<th>CF excess above (below) contract basic</th>
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</thead>
<tbody>
<tr>
<td>start 03/02/15</td>
<td><strong>Feb-16</strong></td>
<td>915,100</td>
<td>523,555</td>
<td>316,039,642</td>
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<tr>
<td></td>
<td><strong>Mar-16</strong></td>
<td>893,993</td>
<td>544,662</td>
<td>303,827,257</td>
</tr>
<tr>
<td></td>
<td><strong>Jan-16</strong></td>
<td>839,694</td>
<td>598,961</td>
<td>284,270,033</td>
</tr>
<tr>
<td></td>
<td><strong>Dec-15</strong></td>
<td>893,993</td>
<td>544,662</td>
<td>303,827,257</td>
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<tr>
<td></td>
<td><strong>Nov-15</strong></td>
<td>1,007,660</td>
<td>430,995</td>
<td>344,231,546</td>
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<td></td>
<td><strong>Oct-15</strong></td>
<td>893,060</td>
<td>545,595</td>
<td>306,531,505</td>
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<td></td>
<td><strong>Sep-15</strong></td>
<td>871,701</td>
<td>566,954</td>
<td>298,747,257</td>
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<tr>
<td></td>
<td><strong>Aug-15</strong></td>
<td>806,957</td>
<td>631,698</td>
<td>254,361,669</td>
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<tr>
<td></td>
<td><strong>Jul-15</strong></td>
<td>659,806</td>
<td>778,849</td>
<td>223,592,776</td>
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<td><strong>Jun-15</strong></td>
<td>680,316</td>
<td>758,339</td>
<td>228,241,216</td>
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<tr>
<td></td>
<td><strong>May-15</strong></td>
<td>558,339</td>
<td>758,339</td>
<td>228,241,216</td>
</tr>
<tr>
<td></td>
<td><strong>Apr-15</strong></td>
<td>839,694</td>
<td>598,961</td>
<td>284,270,033</td>
</tr>
</tbody>
</table>

**Year to date**

| 7,568,287 | 5,379,604 | 2,559,842,901 | 1,716,778,701 | 777,842,901 |

**Since startup**

| 7,568,287 | 5,379,604 | 2,559,842,901 | 1,716,778,701 | 777,842,901 |

**Performance since Startup**

Since startup May 30th the Kaeser SAU supply has averaged 6441 cfm at 17.7 kW/100 cfm

**Monthly Points of Interest**

February consumption averaged 7080 cfm, this exceeds basic continuous supply of 5000 cfm and is a result of all compressors being available, including backup.

**Savings Follow up and Review**

- **February consumption averaged 7080 cfm, this exceeds basic continuous supply of 5000 cfm and is a result of all compressors being available, including backup.**

- **KWH saved**

- **CF min**

- **CO2 Tons**

**Total Reduction since start of Contract**

- **KWH**

- **CF (increase)**

- **CO2 Tons**

**Savings per month to date based on kW decrease**

- **Electrical cost**

- **$/month**

- **$32,875.35**

- **0.55 kW**

- **to be confirmed as of 03/13/15**

**Anually Contracted Amounts**

- **2,376,000,000 CF basic - 3,564,000,000 CF max per annum**

- **198,000,000 CF/month basic, 5,000 CFM continuous**

- **$5.75 per 100,000CF above 2,376,000 CF**
ENERGY STAR Partner Teaming profile

Service/Product Provider
Kaeser Compressors, Inc
P.O. Box 946
Fredericksburg, VA 22404

Business Air Compressor Wholesaler
Michael Cumber
Marketing Services Manager
Phone: 540-634-4320
Email: michael.cumber@kaeser.com

Industrial Partner
CEMEX
920 Memorial City Way, Suite 100
Houston, TX 77024

Business: Building Materials
Shankar Dua
Corporate Technical Energy Manager
Phone: 713-722-2961
Email: shankar.dua@cemex.com

Kaeser's Sigma Air Utility cuts compressed air energy by 28.5% for CEMEX in Louisville, KY

Project Scope
Kaeser provided a complete air system designed and built to meet CEMEX's needs. Kaeser operates and maintains the air system, and CEMEX pays a fixed monthly cost for compressed air as a utility.

Project Summary
In designing the Sigma Air Utility for CEMEX, Kaeser conducted an initial plant walkthrough, an Air Demand Analysis, and provided a compressed air system proposal that guarantees performance, supply and energy savings for the contract period. The equipment supplied included high efficiency stationary rotary screw compressors (with EPA Act compliant motors), clean air treatment equipment, and an air distribution network designed for low pressure drop. Compressors and dryers are controlled by Kaeser's Sigma Air Manager (SAM), which optimizes equipment efficiency.

- Energy Savings
  Estimated annual energy reduction of 28.5%

- Investment
  No capital investment required by CEMEX: company pays fixed monthly cost for compressed air supply for the length of its contract.

- Financial Return
  The yearly energy savings pays for at least 40% of the total annual compressed air supply cost. Furthermore, the customer assessed additional savings in maintenance and overhead costs.

- Other Benefits
  In addition to being the most energy efficient system possible, Sigma Air Utility guarantees air at the right pressure and quality for reliable plant operations and better product quality. It retains working capital for other projects, and the fixed monthly costs make for more accurate budgeting.

Monitoring & Verifying Energy Savings
Kaeser monitors compressors and system components through SAM. SAM features data storage and analysis software to record operating trends and energy consumption, enabling verification of energy savings initially projected, and detection of new usage patterns that can be further optimized.

Distinguishing Value
AOF Installations
CEMEX recognized for saving electricity

FAIRBORN — The local CEMEX USA cement plant has decreased electric power consumption used for compressed air by more than half, earning the company a $226,000 rebate from Dayton Power & Light (DP&L).

The amount of electricity consumed also reduces the amount of CO2 emitted into the atmosphere annually by more than 1.475 metric tons.

CEMEX USA’s rebate is the largest that DP&L has paid to date as part of its energy efficiency programs offered to customers to meet Ohio’s energy efficiency targets to reduce electricity consumption by 25 percent by the end of 2025.

CEMEX’s Fairborn plant replaced a compressed air system that consisted of five compressors running 24 hours a day and consuming more than a projected 600 kilowatt hours (kW-h) annually. The new, more efficient 200 horsepower unit now serves the compressed air needs at significantly less electricity, 3.04 million kWh annually for an expected

Success: CEMEX

"Energy efficient production was our goal, and TVA’s Major Industrial Program helped us make it a reality."

— Bradley Grice, Plant Manager, CEMEX, Knoxville, Tenn.

Compressed Air System Replacement (2009)

CEMEX USA’s global ranking cement company successfully implemented a major compressor replacement program to meet high-quality product, and innovative services for customer and communities throughout the Americas, Europe, Africa, the Middle East, and Asia.

- 159 kW Demand Reduction
- 1,300,000 kWh Annual Energy Reduction
- $143,000 Incentive
- $59,000 Annual Energy Savings
Thank you

*Help Make a Difference.*
*Conserve energy wherever you can!*
Cleanrooms
Cleanroom Air System Efficiency: Reducing Energy Consumption at Texas Instrument’s South Bldg.

Michael Braby
Energy Services Technical Lead, Texas Instruments
Cleanroom Air System Efficiency

Reducing Energy Consumption at Texas Instrument’s South Bldg.

Presented By: Mike Braby

Based on work by project manager Alexander Vega & South Building facilities team.
Cleanroom Air System Efficiency

• Background
  – Purpose of System
  – System Design
  – Efficiency Opportunities?

• Improvement Plan
  – Design
  – Potential Issues

• Results
  – Energy Saved

• Summary & Questions
Clean Room HVAC Functions

- The central idea in clean room environment conditioning is to tightly control a number of variables: Temperature, Humidity, Pressure, as well as submicron airborne particles are all important.

- A clean room HVAC system accomplishes these functions using two primary components.
  - Make-up Air Handling Units
  - Recirculating Air Units
Fab Air Circulation Cycle

OUTSIDE AIR

MUA

Heat Load

AHU/VLF/FFU

HEPA Filters

EXHAUST

Provides temperature, humidity, and pressurization control.

Provides temperature and particle control.
South Building Air System Design

- Single level fab
- Modular VLF design.
- Direct Drive Fans.
Opportunity to Improve Efficiency

• Average HEPA face velocity at the start of the project was measured at 95 fpm.

• If air flow is used to control particle then more is better, right?

• Not necessarily, more air flow can lead to turbulence which can cause localized particle problems.

• Moving all that air costs $.

• Goal: Minimize the amount of air flow to still be able to meet particle and temperature specifications and also not have a negative impact to worker comfort.

• Based on results from other locations, we felt that 50 fpm would achieve our goals.

• How to get there?
Air Flow Reduction Approach

• Before the project started, we had 19 of 52 VLFs in the two areas that were already off-line for energy savings.
• To achieve a lower flow of 50 fpm, it was estimated that an additional 9 VLFs could be turned off.
• Why not just go ahead and idle the remaining fans?
Problems

- Coil and Fan configuration eliminates cooling capacity when fan is turned off
  - “NO FAN, NO COIL”
- Turning off adjacent fans causes air flow balance issues
- Diminished cooling capacity and lack of balanced airflow ultimately affects fab temperature, tools, and people comfort
- Fan Rotation program is difficult to maintain, fans that remain off for extended periods of time develop flat bearings and shafts
- Turning off fans eliminates system redundancy
  - Loss of N+1
Proposed Solution

• Install Variable Frequency Drives to slow down the fans to desired speed.
• Expect power savings to be proportional to the cube of fan speed.
• $\frac{1}{2}$ speed = 1/8 power.
Scope of Work

- Retrofit existing MCC buckets to fusible disconnects
- Build unistrut racks and install 52 VACON 100 VFDs
- Install 4 Hirschman Network Switches and tie all VFDs into network for monitoring
- Evaluate, design, build, and install cabinets for 52 Sine Wave filters to support VFDs
- Modify SCADA screens to show new configuration, setup alarming and feedback
- Decrease average velocity to 50 fpm per procedure outlined in DFAB CCB
Why use Sine Wave Filters?

- Found Multiple electrical runs within one conduit from pipe space down to ground floor level
- Reduce risk of electrical induced bearing failure
  - Cleanroom wall removal required to access motors
- Cleans PWM waveforms generated by Variable Frequency Drives (VFDs).
- Eliminates high frequency content and voltage peaks
- Could easily not test power quality at motor
Project Results

• No major issues with VFD installations. Drives were installed and commissioned on a fan by fan basis over the course of two months.

• Other than testing operating range during commissioning, drives were left at 60 Hz after installation until all drives were installed.

• Once all drives were ready and individually commissioned, speed was reduced incrementally while monitoring particle counts.

• During the course of speed reduction, it was noted that some locations started having issues with air flow laminarity even though particle counts remained good.

• Further review determined that air flow issues were being caused by underfloor obstructions. Flow reductions halted before reaching targeted 50 fpm, but did still result in substantial savings.
32 of 52 VLFs running
Drives running are at 60 Hz and drawing average of 16 Amps.
Average HEPA face velocity = 95 fpm.
Total Power = 383 kw.
Post Project State

52 of 52 VLFs running @ 45 Hz
Drives running are drawing average of 7.9 Amps.
Average HEPA face velocity = 80 fpm.
Total Power = 307 kw. 76 kW reduction from original state.
• Both bays remained in spec and actually showed an improvement in 0.1μ and 0.2μ counts.
• No impact on temperature and humidity.
• No worker complaints or concerns.
Project Summary

- Achieved 76 kw (20%) power reduction. Equal to 665,760 kwh per year.

- Did not achieve full goal of reducing air flow to 50 fpm, but the VFDs provide the flexibility to continue to optimize and reduce energy further in the future.

- Less time required by operations to manage rotation of equipment. Will equalize run time between fans.

### Approximate Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
<th>Extended Price</th>
</tr>
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<tbody>
<tr>
<td>Vacon 100 15 HP Drives</td>
<td>52</td>
<td>$52,000.00</td>
</tr>
<tr>
<td>Sine Wave Filters</td>
<td>53</td>
<td>$51,000.00</td>
</tr>
<tr>
<td>Mechanical &amp; Electrical Installation</td>
<td>1</td>
<td>$73,000.00</td>
</tr>
<tr>
<td>Controls</td>
<td>1</td>
<td>$71,000.00</td>
</tr>
<tr>
<td>Commissioning</td>
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<td>$10,000.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td><strong>$257,000.00</strong></td>
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Questions?

M-braby1@ti.com
Open Discussion - Questions
Thank you!

Enjoy the Remainder of the Summit!