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< Energy Management and Life Cycle Cost Analysis

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| Author Name | <W. Brewster Earle > |
| Title | < President > |
| Company | < Comfort Systems USA Energy Services > |
| Address | < 7 Waterside Crossing > |
| City/State/Country/Postal Code | < Windsor, CT 06095 > |
| Telephone | < 860-687-1586> |
| Fax Number | < > |
| E-mail | < bearle@comfortsystemsusa.com > |

KEY WORDS

< Energy Management and Life Cycle Cost Analysis

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ABSTRACT

ABSTRACT FOR ISPE 2010 Automation Forum

Topic: Energy Management and Life Cycle Cost Analysis in pharmaceutical facilities
The proposed paper and presentation will be based on an energy audit and analysis of feasible alternatives to lower energy and operating costs at the King Pharmaceutical facilities in Bristol Tennessee.

In 4th quarter 2009, King Pharmaceutical contracted Comfort Systems USA Energy Services to conduct an energy audit on the main facility and the distribution warehouse. The purpose of the audit was to identify measures to reduce energy and operating cost. In February of 2010 eight measures were presented to King Management for review. Lifecycle cost analysis was used to present the program and the cash flow impact on the business. Through an iterative process the program has been segmented into phases with Phase 1 expected to be installed in 2010. Each phase was subsequently analyzed with life cycle analysis. A significant DDC Controls project has been proposed and is being considered for subsequent phases.

Both a capital approach and a lease approach has been modeled and used in the analysis process. Environmental impact of specific measures as well as utility and maintenance cost savings have been evaluated as part of the process. The proposed paper and presentation will be submitted to King Pharmaceutical for authorization prior to submittal and presentation.

For questions or clarification please call:
W. Brewster Earle
President, LEED AP
Comfort Systems USA Energy Services
860-687-1586
bearle@comfortsystemsusa.com

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INTRODUCTION

In 4th quarter 2009, a Pharmaceutical firm contracted Comfort Systems USA Energy Services to conduct an energy audit on the main facility and the distribution warehouse. The purpose of the audit was:

1. To identify measures to reduce energy and operating cost
2. To develop an implementation plan that was both operationally viable and economically viable

Through a collaborative audit process the client team and the CSUSA team identified several measures that met the objectives identified. They were:

1. Upgrade Lighting to T8, Electronic Ballasts, and Occupancy Sensors
2. Install Occupancy Sensors in Distribution Center
3. Retrofit Steam Traps with Tunstall Retrofit Kits
4. Upgrade Chiller Controls
5. Install DDC and Demand Control Ventilation Controls in Administrative Buildings
6. Reduce Air Change Rate in Inactive Production Areas
7. Install Non-Chemical Water Treatment System
8. Retro-Commission All HVAC Controls

ECONOMIC ANALYSIS

This program has an installed cost of \$2,451,561 and results in \$572, 782 in annual energy savings and \$44,651 in annual maintenance savings. The maintenance savings is based on material savings that will result from decreased purchase for lamp replacement due to longer lamp life and reduced chemical costs for water treatment.

The following impacts on the business will result from implementation of the program:

- A 25% reduction in Utility Costs
- A payback of 2.55 years based on year 2 cash flows compared to current operations
- An improvement in the building environment
- Significant demonstration of environmental stewardship by way of reduction in greenhouse gases
- Eligibility for Energy Star[®] recognition at both the headquarters facility and the Distribution Center

These benefits are tangible and quantifiable. A life-cycle cost analysis was performed to demonstrate the impact this program would have on existing operations. To be useful a life-cycle cost analysis is compared to the base case operating cash flows, and then compared to a retro-fit cash flow case that reflects cash flow once the program is installed.

Accurately modeling an operational base case can be a challenge in the manufacturing environment. Typically, utility (energy) costs change as a factor of production. As production requirements fluctuate, so do run times of equipment and the occupied hours of facilities. Historical utility costs were used to establish a reasonable predictor of future use and cost profiles. Once established the annual utility costs became the basis of the base case cash flow. Also impacting the cash flow were the following:

- Operations and Maintenance Costs
- Depreciation Expense
- Utility Incentives
- Tax Incentives

The economic case for the project was made based on the resulting cash flow differences between the base case and the program case.

The life cycle analysis comparing base case and program case are shown in appendix 1.

The Recommended Program in this case results in free cash flows in the second year (once installation is complete) when compared with the existing operation (base case). The free cash flows are the result of utility cost savings and maintenance savings, as well as the tax benefits. The year one difference between the Base Case operating costs and the Program Case annual operating costs represents the investment to achieve the free cash flows. A common mistake in economic analysis based on cash flows is to consider the year one investment represented by the project cost. The fact is, there are quantifiable year 1 incentives and savings that are a direct result of the project, and their impact should be accounted for in any "investment" style analysis. In this case comparing those second year cash flows, the Recommended Program results in a 2.55 year payback.

Even based on "whole project costs" the economics of such a program are attractive. The actual ROI based on two scenarios follows:

1. Using 5 years of free discounted cash flows that result from the initial program investment. ROI for this scenario is 95%. That equals annualized returns of 18.9%.
2. Using just the first year of free discounted cash flows that result from the initial program investment. (Year 2 free cash flow). ROI for this scenario = 23%

The financial model isolates the cash flow effect of each alternative. Net Present Value (NPV) analysis is used to determine if the year 1 installed cost results in a net positive or a net negative, that is, are the additional annual savings dollars generated by the program sufficient to justify the added year 1 cost/investment?

This is captured in the row "Net Present Value of Cash Flows" under the proposed alternative in the model shown in appendix 1. This row identifies the return on the incremental cost of the proposed program alternative when compared to the "business as usual" case (Current Operations). We then discounted the annual "Cash Flow Relative to Base Case" of the Recommended Program over a 10 year period. The NPV value in year one dollars is positive and therefore indicates that the investment (incremental cost to upgrade the system) is worth pursuing. It makes money.

Another more general way to view this program is to look at the gross annual cash flows. They can be found in the Total Column of each model below. The Base Case has a ten year cash flow of (\$24,352,982). The proposed system has a ten year cash flow of (\$19,382,990) for real dollar savings of \$4,969,993 over ten years. These values represent the total installed cost and annual energy (operating) costs for each system in actual dollars.

Explanations of the assumptions used for the economic model:

1. Program Cost: This is the installed cost for the Recommended Program.

2. Estimated Current Energy Costs: This is a compilation of the bills provided for previous calendar year 2009.
3. Annual Energy Savings: Based on our preliminary calculations with the information that has been provided, we have estimated the annual energy savings that would result from the recommended program.
4. Maintenance Costs Savings: We calculated actual maintenance cost savings that will result from our proposed program. The savings result from three measures; Measure #1, #2, and #7. The first two are lighting measures and are calculated using the manufacturer's lamp and ballast life. By replacing lamps with those that have longer life and will have a cost savings of less frequent lamp and ballasts replacements. The last measure will save maintenance cost by eliminating annual chemical purchases for treating water.
5. Energy Escalation Rate: This is a conservative estimate. While energy rates are expected to increase significantly in the short term, ten and twenty year historic data shows that energy costs typically mirror cost of living adjustments. Higher escalation of energy costs will mean that savings will be higher than our estimates and the return on investment will improve.
6. Maintenance Escalation Rate: This again is a conservative estimate. Historical data over ten and twenty year terms shows that maintenance costs typically mirror cost of living adjustments. Higher escalation of maintenance costs will mean that your savings will be higher than our estimates and the return on your investment will improve.
7. Annual Benefit of Depreciation: We have made the assumption that the client is a U.S. Taxpayer. We assume our Program will meet the qualifications for claiming depreciation expense. We have taken a conservative approach by calculating straight-line depreciation of the full Program value over 39 years. We then assumed a tax rate of 35% to determine the bottom line impact. We encourage you to consult with your tax attorney or accountant to help us determine the correct value for this parameter
8. Discount Rate: We have used a discount rate of 15% per our meeting with you to determine your cost of capital for comparison projects.

Other potential economic benefits of our Recommended Program include eligibility for the EPCRA 2005 tax deduction and potential energy incentives.

Energy Policy Act of 2005 (EPACT) incentivized areas:

- Lighting
- HVAC
- Building envelope

Available for New Construction and Existing Buildings. Credits are based on improvements over ASHRAE 90.1 2001. Energy efficient improvements must be depreciable assets and you may convert 39 year depreciation to current deduction. EPACT tax credits are available through 2013. Credit amounts are the lesser of total cost or up to \$1.80/sq.ft. of the whole building or up to \$0.60/sq.ft. for individual systems, in this case, lighting.

Building Controls: Administration Areas and Production Areas

Two measures proposed focus on installing modern building automation controls to control delivery and conditioning of air to both the administration area and to more efficiently condition required air to production area by controlling those areas more tightly aligned with production schedules. Below is discussion and description of each control strategy.

1. Install DDC and DCV Controls in Administration Buildings

Heating, cooling, and ventilation are provided to the majority of the plant by air handling units (AHUs). These AHUs generally are equipped with steam heating coils, chilled water or DX cooling coils, and steam reheat coils. About 60% of the existing AHUs are controlled with pneumatic controls, another 10% have obsolete electric or electronic controls, and about 30% are controlled with Direct Digital Controls (DDC).

Pneumatic controls were state-of-the-art in the 1960s and 1970s but have several operational shortcomings, including leaking pneumatic lines, the need to recalibrate controls on a semi-annual basis, and lack of control feedback for most applications. DDC controls offer stable and reliable operation, continuous feedback, little or no recalibration, and maximum flexibility for changes to schedule, setpoints, and types of points controlled.

We proposed to replace the existing pneumatic and older DDC controls with an upgraded front end and new controllers for all major AHUs in the administrative sections of the plant. The scope also includes new control valves on AHU steam coils as necessary to eliminate leaks and uncontrolled heat loads on the system.

Demand-controlled Ventilation (DCV) is an energy conservation strategy that reduces the amount of outdoor air (OA) needed to heat or cool a conditioned space by monitoring and controlling carbon dioxide (CO₂) levels. Since people exhale carbon dioxide, they cause CO₂ levels to rise. Through the use of CO₂ sensors, the DCV system can effectively monitor the actual occupancy in a given space. This enables the system to supply the conditioned space with only the amount of outside air required to maintain adequate outdoor air.

To maintain proper air quality, it is recommended that indoor CO₂ levels be maintained within 500 to 750 parts per million (ppm) of the outdoor CO₂ level. When the sensors detect that the indoor CO₂ concentration is about to rise above the recommended level, the control system introduces more outside air. This drives the CO₂ levels in the conditioned space back down, thereby maintaining suitable air quality.

By controlling the air in this way, less outside air is supplied to the space at times of lower occupancy. The reduction of outside air use results in energy savings; the energy that would have been used to heat or cool the extra volume of outside air is saved, as well as the fan energy of the system that is supplying the air. In the administration buildings there are 100% outdoor air systems that provide all of the ventilation air for the spaces, which are heated and cooled by fan coil units.

Modifications to the existing system will include the installation of CO₂ sensors and installation of new digital controls to modulate the outdoor air dampers and the speed of the AHU fans. Also, the 100% OA makeup units will need to be retrofitted with variable speed drives, and the standard Air Handling Units (AHUs) will need to have modulating damper actuators installed.

2. Reduce Air Change Rate in Inactive Production Areas

The production rooms and the production processes have been validated through a rigorous inspection and approval process. Compliance with the validated procedures, which are specific for the product being manufactured, is a regulatory requirement to ensure the safety and

integrity of the products. Any substantive changes to the manufacturing process for any product will require, at minimum, a review of the validation procedure and at most, a complete revalidation of the revised process. In order to minimize potential variations from the validated procedures, each product is manufactured in its own area with minimal sharing of facilities or processing components.

The production areas of the facility are heated and cooled by air supplied from either a rooftop unit or an air handler. In addition, many of the rooms are connected to small DX air handlers or fan coil units that provide additional air circulation in the rooms. These additional air circulators are used to provide a fairly high air change rate, typically 20 air changes per hour (ACH), because this air change rate was specified as part of the validation process, although there are no specific parameters or measured results that this air change rate is intended to provide. The production areas are also maintained under slight negative pressure by continuously exhausting air through exhaust fans or dust collectors.

For most pharmaceutical manufacturers product is produced in batch process in which a specified amount of the product is prepared, processed, and packaged. When a batch is in process some portions of the production area may be in operation for 24 hours per day while others may run for 8 to 12 hours per day. The amount of time any given batch is in active production is a function of the number and sizes of sales orders received, the time it takes to fulfill the orders and maintain stock, and the availability of the materials needed to prepare the batch for processing.

While the number and sizes of orders varies over the year, most products are in production for less than 6 months per year. However, as part of the effort to ensure that there are no changes to any validated processes, the HVAC systems in the production areas remain on and at their full production setpoints 24 hours per day, all year long. The energy consumed by the HVAC systems serving the inactive production areas is substantial and largely unnecessary, except for the exhaust systems needed to maintain negative pressure.

We proposed to establish two conditions for all of the production spaces: 1) the active condition, that meets the current operating procedures and all of the validated process requirements, and 2) the inactive condition, which maintains the required negative pressure, a setback temperature, and room relative humidity within a specified deadband. The inactive space conditions will keep the rooms ready for production while significantly reducing energy consumption.

We proposed a control strategy that requires temperature and relative humidity sensors in every controlled space, differential pressure sensors between the production spaces and the adjacent hallways or common areas, variable speed drives on the dust collectors and exhaust fans, and new controls to allow the AHUs and RTUs to respond to the setback signal. When a given production batch is finished and the rooms cleaned up, the supervisor will enter a code into the control system indicating that production is finished. The DDC system will maintain production level ventilation for a pre-determined time, perhaps 24 hours, to ensure that all product residue has been removed from the space and the ductwork. After the purge period, the AHU serving the area will modulate its fan speed to 30% (adjustable) while the exhaust fans and/or dust collectors modulate to a slightly higher speed to maintain negative pressure. The DX circulators will cycle off until either the room temperature or RH reaches its unoccupied setpoint at which time the DX unit or the AHU will energize its cooling or heating coils to maintain the unoccupied condition. When a new batch is ready for production, the supervisor will enter a code to signal the systems to return to active mode.

The energy savings for this measure were estimated by modeling the HVAC, lighting, and process equipment and adjusting the model until there was reasonable correlation to the utility billing data. Once the model was developed, we estimated the savings by reducing the amount of outdoor air by 20%, reducing chilled water AHU fan speed to 30%, reducing DX cooling by 10%, and reducing reheat energy by 10%.

Summary

To develop a business case to perform energy projects, a thorough economic analysis should be performed using life-cycle cost analysis based on cash flows. Modern building control strategies can be applied to provide efficiency to operating costs in the production environment.

APPENDIX 1: LIFECYCLE COST ANALYSIS

| Assumptions | |
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| Program Cost | \$2,451,561 |
| Estimated Current Energy Cost | \$2,124,323 |
| Estimated Annual Energy Savings | \$572,782 |
| Estimated Program Annual Maintenance Savings | \$44,651 |
| Annual Benefit of Depreciation | \$20,785 |
| Estimated EPACT Tax Credit | \$135,524 |
| Estimated Utility Incentive | TBD |
| Maintenance Escalation Rate | 3% |
| Energy Escalation Rate | 3% |
| Discount Rate | 15% |

| Base Case (Current Conditions) | | | | | | | | | | | |
|--------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
| Annual Energy Costs | (\$2,124,323) | (\$2,188,053) | (\$2,253,694) | (\$2,321,305) | (\$2,390,944) | (\$2,462,673) | (\$2,536,553) | (\$2,612,649) | (\$2,691,029) | (\$2,771,760) | (\$24,352,982) |
| Total Annual Cash Flow | (\$2,124,323) | (\$2,188,053) | (\$2,253,694) | (\$2,321,305) | (\$2,390,944) | (\$2,462,673) | (\$2,536,553) | (\$2,612,649) | (\$2,691,029) | (\$2,771,760) | (\$24,352,982) |

| Recommended Program Capitalization | | | | | | | | | | | |
|--------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
| Program Cost | (\$2,451,561) | | | | | | | | | | (\$2,451,561) |
| Annual Energy Cost | (\$1,551,541) | (\$1,598,087) | (\$1,646,030) | (\$1,695,410) | (\$1,746,273) | (\$1,798,661) | (\$1,852,621) | (\$1,908,199) | (\$1,965,445) | (\$2,024,409) | (\$17,786,676) |
| Annual Maintenance Costs Improvement | \$44,651 | \$45,991 | \$47,370 | \$48,791 | \$50,255 | \$51,763 | \$53,316 | \$54,915 | \$56,563 | \$58,259 | \$511,874 |
| Benefit of Depreciation Expense | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$20,785 | \$207,849 |
| EPACT Tax Credit | \$135,524 | | | | | | | | | | |
| Estimated Utility Incentive | | | | | | | | | | | |
| Total Annual Cash Flow | (\$3,802,142) | (\$1,531,312) | (\$1,577,874) | (\$1,625,834) | (\$1,675,233) | (\$1,726,113) | (\$1,778,520) | (\$1,832,499) | (\$1,888,098) | (\$1,945,364) | (\$19,382,990) |
| Cash Flow Relative to Base Case | (\$1,677,819) | \$656,741 | \$675,820 | \$695,471 | \$715,711 | \$736,559 | \$758,033 | \$780,150 | \$802,931 | \$826,395 | \$4,969,993 |
| NPV of 10 Yr Cash Flow | \$1,526,408 | | | | | | | | | | |

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