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Task 2.3: Title 24 Credit for Efficient Evaporative Cooling

Project Plan

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1 Document scope:

This document outlines the proposed implementation methodology for our hybrid cooling model. This document also describes how users of the model will configure it to represent novel hybrid cooling systems in EnergyPlus.

2 Background:

The goal of this task is to reduce the energy consumption of US commercial buildings by constructing modeling tools to support the broader adoption of hybrid air conditioning technologies. The model concept is developed specifically to address hybrid rooftop packaged air conditioners that incorporate indirect evaporative cooling, but should support the simulation needs for a range of hybrid systems. Future energy savings are anticipated to come from the incremental direct replacement of existing conventional packaged DX cooling units with hybrid units that provide a significant improvement in efficiency. An optimistic calculation of potential savings is given in appendix A. Laboratory and field studies of several different hybrid systems have demonstrated dramatic cooling energy savings with a sensible space cooling COP more than twice that of standard rooftop units under typical Western climate conditions. (Woolley 2012)

Our objective is to implement a flexible hybrid cooling system model in EnergyPlus that will allow Title-24 credit to be awarded for use of this novel low-energy cooling technology. We have gathered system performance data from field installations of various hybrid cooling systems and will use this data to describe an example hybrid cooling model using the new flexible EnergyPlus model.

In our experience, building energy simulation capabilities have lagged well behind the form and function of emerging technologies. This capability should accelerate the cycle of development, testing, simulation, feedback and evaluation, and should quicken the pace for developing the defensible basis for annual energy savings and peak demand reduction estimates in difference climate zones and building types.

3 Methods

3.1 Method summary

We plan to complete the development, implementation and testing of the model in three parts. First, we have now collected field data from several hybrid evaporative cooling systems, which include Coolerado H80, Coolerado M50, Integrated Comfort’s DualCool (on Trane Voyager, and Lennox Strategos), Munters’ Oasis, Munters’ EPX 5000, and

Seeley's ClimateWizard. These systems have been installed in a mix of office, retail and food service buildings, in various locations across California, under agreements with several of our commercial and industrial partners.

We will use field data from a Coolerado H80 together with models, to develop regression curves that are representative of that equipment's system performance over a complete range of operating conditions.

We will develop a modeling framework (a model that does not represent any specific system but can be tailored to meet the users requirements) and that is sufficiently flexible that it will allow users with sufficient system performance data to model any currently anticipated hybrid cooling systems within the EnergyPlus software. For the rest of this document we will refer to this modeling framework as our Hybrid-Black-Box model (HBBM). We will use the analysis of the field data from multiple system types to ensure our Hybrid-Black-Box model is compatible with all of hybrid rooftop units we have tested.

We will use our HBBM, along with our Coolerado H80 performance curves, to model the Coolerado H80. We will then use a limited set of the measured system performance data to validate this model.

3.2 Field Study method

In coordination with other California Energy Commission funded projects, and in collaboration with various equipment manufacturers, California Investor Owned Utilities, and commercial energy consumers, UC Davis Western Cooling Efficiency Center has facilitated the installation and pilot field demonstration of several hybrid rooftop packaged air conditioners. A more detailed description of the field study method is available in Appendix B.

3.3 HBBM implementation

Development of our HBBM was guided by three core requirements:

1. The model must be flexible enough to accommodate performance characteristics for a wide range of system types. This feature requires more than the capability to define nominal performance (EER) for different systems; it must also accommodate various operating modes and approximate control schemes appropriate for each unit. Hybrid systems commonly have different modes of operation with only certain components in the system active at any particular point in time. For example, the Coolerado H80 can operate in a mode that uses only indirect evaporative cooling only, or another mode that uses indirect evaporative cooling plus multiple compressor stages. At the same time, the primary and secondary fans in this system can operate as variable speed. Each of these modes can be characterized with distinct performance maps.

2. Model configuration for any particular system must be relatively easy for the user. It should not require the custom definition of multiple sub-components, nor should it require the definition of specific control sequences.
3. Any model that is produced by a user must be easily distributable to other users, and accessible in a common and comparable structure.

Based on these requirements, we decided it would be unrealistic to attempt to develop a first principals model that mirrors the approach used to model the other evaporative cooling models in EnergyPlus. A first principals model can serve as valuable and reliable tool, but any particular model it is not flexible enough to accommodate the wide variety of components and innovative system architectures that are emerging with hybrid air conditioners.

Instead we chose to develop an empirical modeling framework that can manage all of the input and output conditions for a wide variety of system types, regardless of their internal components. In order to model performance of a hybrid air conditioner, the user must define multiple empirical curves to describe the performance of each distinct mode of system operation. The mode of operation and the operating conditions (outside air fraction and supply airflow rate) in real world systems are determined by the control software of the specific system. In our model implementation, for any given operating scenario (outdoor conditions, zone conditions, sensible room cooling load, ventilation requirement) the HBBM will choose the most energy efficient mode of operation that will satisfy all load and ventilation requirements for the time step.

This approach should allow for annual simulation of any new hybrid rooftop air conditioner, as long a certified performance map is available for each system mode. We envision that manufacturers would publish certified performance maps for new hybrid equipment in order to support specification, design, and application of their technology. This would be available through engineering design manuals, or could be downloaded from web-resources in the same way that many manufacturers publish design drawings, 3D models, and sample design specifications. Further, manufacturers could choose to publish results of their own EnergyPlus simulations for a system, using certified performance maps, standard building types (as available from PNNL), standard climates (as guided by ASHRAE and AHRI), and using the HBBM to incorporate all elements in a standard way.

The approach we've developed mirrors some of the methods used to in the current DX cooling coil model in EnergyPlus. The performance curves used for the new model have more terms than those typically used to describe a DX cooling coil, however the basic approach similar.

3.4 Using the HBBM

The HBBM will not be a new EnergyPlus feature in the conventional sense, but will use EnergyPlus's native ability to interface with external models or programs through its implementation of the Functional Mockup Interface (FMI). FMI is an independent and nonproprietary standard to support both model exchange and co-simulation of dynamic models using a combination of XML-file, C-header files, and C-code in source or binary form (Nouidui 2013).

The HBBM will come in the form of a Functional Mockup Unit (FMU), and example IDF that demonstrates the use of the FMU. Figure 1 shows how our HBBM and EnergyPlus interact.

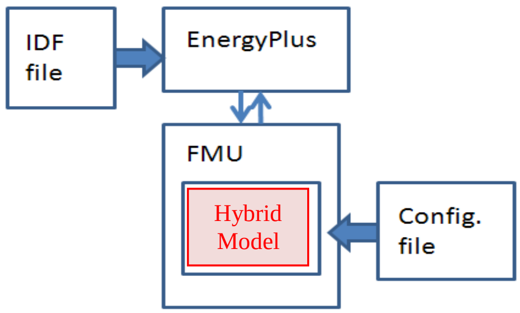

Figure 1 Model overview

This FMU will be written in C++, (with a C shell). Our HBBM will be tested using one or more sets of system performance curves developed from field and laboratory data. This data will be specified in a model specific configuration file. A configuration file that represents a new model will be based on a template excel work sheet. Users will be required to download the HBBM model from our website, populate a sheet with the appropriate system performance data definition, and then save their model specific data.

The performance data required to be input by the user includes:

1. Regression coefficients for equations to describe three performance metrics in each mode of operation:
    a. System Total Cooling Capacity
    b. Energy Intensity Ratio
    c. Sensible Heat Ratio
2. Nominal cooling capacity (*kW*). This is the measured cooling capacity at specific rating conditions. We select the *Western Cooling Challenge* “Peak” scenario as the nominal rating condition for this model.
3. The rated supply air mass flow rate (m^3/s)
4. Functional operating constraints for the equipment in each mode of operation
    a. Minimum and maximum outside air fraction
    b. Minimum and maximum supply airflow rates
5. Limits on the environmental conditions within which the regression model defined predicts system performance appropriately.
    a. Minimum and maximum outside air temperature
    b. Minimum and maximum outside air relative humidity

c. Minimum and maximum return air temperature
d. Minimum and maximum return air relative humidity

In cases where manufactures are only able to provide performance lookup tables. Some general guidance on how to generate regression curve coefficients from a performance table will be provided. A more detailed explanation of the curve requirements are given in Appendix C.

Users wishing to implement a new hybrid cooling model would need to obtain curves (or sufficient performance data to generate a performance curve) from the system manufacturer, or from independent laboratory or field testing.

A first-principles component-by-component model could also be used as the basis for developing these empirical performance curves, if a user wished to use this model to simulate annual performance of a theoretical machine. However, presumably the model would only be allowed for compliance if it utilized a certified performance map as the basis for input.

The use of a text based configuration file is a departure from convention, where typically the model input parameters are defined using data structures (curves or lookup tables) that are defined in the idf file. This approach was considered difficult to avoid, because firstly the current data structures were poorly suited to the

3.5 Method justification

In addition to meeting our four core requirements, this method has several other advantages. The approach requires no changes to the EnergyPlus source code. Release of the model will be solely the responsibility of our team, and any future changes to the model can be then published as an updated FMU without the need to wait for the next EnergyPlus release. EnergyPlus is expected to migrate to C++ over the next few years, and so developers are encouraged to develop new features in C++. Once EnergyPlus is natively C++, and our model has been extensively trialed by prospective users, fully integrating our HBBM into the release version of EnergyPlus (rather than the FMU implementation) would be a relatively straightforward option if this is desired by the EnergyPlus community.

3.6 Limitations

To be clear, there are some limitations to the modeling approach we have developed. Most significantly, the model currently does not integrate with the EnergyPlus air node network. Each instance of our HBBM will be instituted within an EnergyPlus model as a Zone HVAC module and will therefore only service a single thermal zone with no pressure-airflow interactions with adjacent zones. For DOAS equipment designed to operate by a displacement ventilation scheme, this could be considered a significant limitation. Multiple instances of our model could be applied on a single building model with multiple zones (this is a native capability for EnergyPlus) but the model would not easily accommodate airflow interactions between zones (airflow related thermal energy transfer between zones is also therefore not possible).

The model describes steady state performance, but does not accommodate the transient characteristics associated with equipment cycling. For hybrid systems that operate at variable speed to match equipment capacity to instantaneous cooling loads transient dynamics should not have a substantial impact, but equipment that relies on cycling full-capacity operation to meet hourly loads on average would not be modeled accurately.

Further, the approach developed does not model the specific control sequence for any given equipment. As described, the model chooses its operating conditions from all modes possible at a given set of conditions, in order to minimize electrical energy use. Hopefully, this is what a good system’s sequence of operations would accomplish, though it is more likely that real controls would not always select optimal operating strategies. This is already a limitation for most HVAC modules that are currently packaged in EnergyPlus, but the characteristic should be noted for our model as well.

Finally, the HBBM does not capture some potential variations in system performance, such as those which result from filter soiling, or from applications with high static resistance. These are also limitations for most existing EnergyPlus HVAC modules.

3.7 Coolerado model implementation

As described, we are developing an example implementation of the HBBM in order to test and verify that the model functions, that it predicts the performance measured in field studies, and to identify and resolve any challenges related to the user definition of appropriate performance data. We chose the Coolerado H80 as the subject for this example implementation. It was one the earlier installations in a series of field evaluations with various hybrid equipment, there is a substantial body of data surrounding the system, the product is complex (with variable speed fans, modulating dampers, and several modes of operation), our team is familiar with the detailed control sequence for the system, there are already multiple studies and publications surrounding this equipment, and it’s performance has been analyzed with great clarity.

Figure 2 illustrates schematic of the main physical components in the packaged Coolerado H80 system.

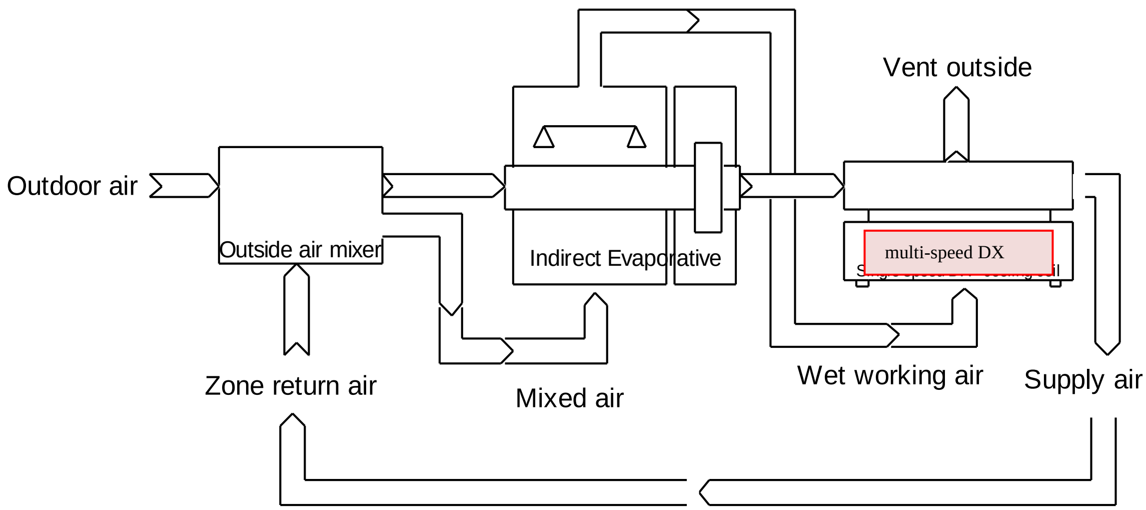

Figure 2 Coolerado HMX component model

We used 3 months of field data to develop regression coefficients for equations to describe performance of the system over a wide range of operating conditions. This approach yielded a model that functioned well but which did not accurately predict performance for the same conditions that were used to train the model. These inaccuracies resulted from the fact the three months of data was limited to a surprisingly narrow set of operating conditions for each mode. While the system ran in all modes of operation, across the full range of fan speeds, and with a wide range of outside air fractions these variables all tended to shift together such that their independent effects were confounded. There were a large range of ‘possible’ system operation combinations that which never occurred through the in-field operations. Therefore, the regression equations were under-constrained, and the resulting predictions for conditions that were not experienced were wildly inaccurate. Consequently, the HBBM selected inappropriate operating modes for some conditions.

These observations led us to stipulate that performance curves must be generated from a broad set of input data that comprehensively covers all operating and environmental conditions that model is intended for. While this may not be directly available from field studies, we believe it is reasonable to expect that manufacturers of hybrid air conditioners could provide these complete performance maps. In time, we expect industry consortiums such as ASHRAE, ANSI, and AHRI can provide the standard methods of test for developing the certified system performance curves that could be used in the ways proposed by the HBBM.

4 <u>Potential points for discussion</u>

- We called the flexible model the Hybrid-Black-Box mode. Does this name sit comfortably with you as a potential user or stake holder. What would you have liked to be called?
- Do you feel the use of FMI is too large of a departure from conventional modeling methods?

- Based on the description in this document of how the HBBM is used, do you expect users will be comfortable implementing a new model?
- Do you believe the expectation that manufacturers will publish certified performance maps for new hybrid equipment is realistic/possible?
- At the core of the model is an assumption that the systems will seek the mode of operation and operating conditions that meet the required minimum ventilation and load requirements, for the lowest electrical energy consumption. Do you see this as being a serious limitation?

5 Financial Support

The research reported here was supported by the California Energy Commission Public Interest Energy Research Program, Energy-Related Environmental Research Program, award number 500-10-052.

6 References

California Energy Commission. (CEC). 2006. California Commercial End-Use Survey (CEUS): Consultant Report. Table 7-2, CEC-400-206-05. http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.pdf

California Energy Commission. (CEC) 2013. Building energy efficiency standards for residential and nonresidential buildings: Sacramento CA, California Energy Commission.

7 Appendix A

7.1 Estimates of potential savings

Future energy savings from adoption of hybrid evaporative cooling are dependent on a number of factors, including how well these systems perform in practice, the performance of the conventional systems they replace, and how broadly these systems are adopted in the market. Estimates of projected annual energy saving benefits are based on input data detailed in **Error! Reference source not found.** below. Estimates of each of these factors include a significant degree of uncertainty. Field test data from our evaporative cooling units installed in buildings throughout California will provide system performance data that will lower the uncertainty in our estimates. Until these data are available, conservative estimates of hybrid system performance were used. Currently installed HVAC Rooftop Units (RTUs), use an estimated 2E+10 kWh per year of electricity, approximately 5% of these units are replaced each year. In addition, the total number of RTU's in use was estimated to be growing at 1.4% each year. Given an assumed market penetration of 35% of any newly installed RTUs, projected energy savings (reductions in energy use compared to baseline conventional RTUs) in the first year are estimated to be 1.45E+08 kWh. Each successive year that obsolete RTU are replaced, the number of hybrid systems in use is expected to increase, leading to increased energy savings over time (annual savings increasing approximately 1.5E+8 kWh each year following their introduction). After a period of 20 years, (the assumed typical lifespan of a conventional RTUs), savings are projected to have increased to 2.99E+09 kWh per year.

Table 1 Calculation inputs

Input	Value	Detail
Installed cooling tonnage (ICT)	1.08E+07 tons	Equals the total commercial floor area (A=5E+09) (CEC 2006 (CEC-400-2006-005, March 2006)), divide by, the average tonnage per square foot that are serviced by RTUs (325 ft2 per ton, CEC 2006 multiplied by fraction of commercial area serviced by RTUs 70%, (CEUS 2006) ICT=A/(325*0.7)
Cooling Load Factor (CLF)	20%	CLF for RTU's currently in service, (CEC 2006)
Conventional RTU Energy Efficiency Ratio (EER)	10	EER for RTU's currently in service, (CEC 2013)
Installed RTU energy use	2.26E+10 kWh per year	Equals the ICT, multiplied by the CLF, multiplied by 12 (months in a year), divided by the sum of the EER and 8760 (the number of hours in a year) RTU_Energy=ICT*CLF*12/(EER*8760)
Conventional RTU life-span	20 years	The typical (conservative estimate) lifespan of conventional RTU's currently in use. Estimate based on Mark Modera's industry experience.
Hybrid system efficiency gain	40%	Conservative figure of efficiency improvement possible with hybrid systems compared to

		conventional RTU's. Based on minimum performance specifications for the Western Cooling Challenge (http://wcec.ucdavis.edu/programs/western-cooling-challenge/)
New RTU installs	1.4%	Annual increase in RTU tonnage. Calculated by multiplying annual percentage growth in newly constructed commercial buildings (2%, a broadly used rule of thumb) area by the fraction serviced by RTU's (70%, derived from CEUS 2006 source data)
Hybrid system fraction of new RTU installations	35%	Estimated uptake of Hybrid systems based on exceeding California's energy efficiency strategic plan (15% of HVAC unit sales shall be optimized for climate appropriate technologies by 2015) by at least a factor of two
Annual energy savings	≈1.5E+8 kWh increase in savings each year	Each year 5% (1/20 year life span) of the total installed RTU tonnage is replaced, in addition to the 1.4% of new installs, totaling 6.4%. 35% of those newly installed systems are estimated will be hybrid systems with a 40% efficiency improvement.

8 Appendix B

The technologies installed each utilize some form of indirect evaporative cooling in conjunction with vapor compression cooling.

For each field demonstration, a package of instrumentation was deployed to measure key performance variables. Rather than focusing on a case study determination of the energy savings for the specific scenarios installed, field study efforts have aimed at carefully characterizing equipment performance as a function of independent variables such as environmental conditions, instantaneous cooling loads, and system operating modes.

Monitoring of these systems takes place over several months in order to observe system behavior and performance over a broad range of operating conditions and to assess performance variation over time. These projects have been executed as part of the Western Cooling Challenge program which provides technical and non-technical assistance and interpretive efforts related to the technologies, so monitoring has also been utilized to provide ongoing system commissioning and feedback to manufacturers and installers about opportunities and needs for improvement.

The technologies studied include packaged hybrid rooftop units and indirect evaporative cooling retrofits for existing conventional rooftop air conditioners. The field study methods deployed characterize performance of the various technologies and system types according to similar independent variables with the specific intent to feed the modeling efforts in development here. Key independent variables include:

1. Temperature Outside Air Dry Bulb
2. Outside air Absolute Humidity
3. Temperature Return Air Dry Bulb
4. Return air Absolute Humidity
5. Outside Air Fraction
6. Supply Airflow Rate

A range of parameters are measured to determine system operating mode, sensible cooling capacity, sensible heat ratio, and electric power. Further, these field studies collect information about ancillary variables that help to describe system operation and response.

A field study of several hybrid systems has progressed in cooperation with a range of partners including Southern California Edison, Pacific Gas & Electric, California Energy Commission, and California Institute for Energy & Environment. We have installed test equipment to service several commercial end users including: University of California, US Navy, WalMart, Target, Simon Property Group, Starwood Property Group, City of Temecula, and two independently owned restaurants.

Table 1 summarizes the technologies, locations, and building types where field monitoring efforts are currently underway. The Western Cooling Challenge program is currently advancing a number of other installations which will be monitored in 2014. The installed systems listed in Table 1 will be collecting data that will be available to support the development and validation of our EnergyPlus module. Given the appropriate performance curves the configurable model will be capable of representing all of the listed system types, however the detailed regression curves required to specify the system performance will only be generated for the Coolerado H80 model within the scope of this project.

Technology	*Location*	*Principal Activity*	*Data Period*
Coolerado H80	Davis	Small Office	July 2012 -
Coolerado H80	Ridgecrest	Small Office	July 2012 -
DualCool (retrofit) *x4*	Palmdale	Large Retail	August 2012 -
DualCool (Trane Voyager) *x2*	Ontario	Mall	July 2013 -
DualCool (Trane Voyager)	Ontario	Restaurant	July 2013 -
DualCool (Trane Voyager)	Fairfield	Mall	June 2013 -
Coolerado M50 *x3*	Bakersfield	Large Retail	June 2013 -
Seeley ClimateWizard *x3*	Bakersfield	Large Retail	June 2013 -
Munters Oasis	Temecula	Large Office	July 2012 -
Muntesr EPX 5000	San Ramon	Grocery	June 2014 -

9 Appendix C

For each mode of operation, the users will be required to provide a minimum of 7 coefficients for each of three curves (up to 27 coefficients can be provided for improved accuracy). These curves describe how the system total cooling capacity ($\Delta\dot{H}_{TOT|\,SYS}$), energy intensity ratio ($EIR_{TOT|SYS}$), and sensible heat ratio (SHR) relate to six different environmental and system variables. The variables are the outdoor dry bulb temperature ($T_{db,OSA}$) the, the outdoor absolute humidity, ω_{OSA} the, room air dry bulb temperature ($T_{db,RA}$) the, the room air absolute humidity, (ω_{RA}) the supply air supply mass flow rate ratio ($\frac{\dot{m}_{SA}}{\dot{m}_{SA}^{RATED}}$), and finally the outside air fraction ($OSAF$).

The core of the model is a group of polynomial functions to describe each performance output of interest (Yi)as a function of our multiple independent environmental variables ($\mathrm{X}_{\mathrm{i}}^{\varepsilon}$), and multiple independent system variables $\left(\mathrm{X}_{\mathrm{i}}^{\mathrm{S}}\right)$. Each equation will be of the form:

$$
\begin{aligned}
&Y_i^{mode} = \beta_{0\,(Y_i\,|\,mode)} + \cdots \\
&\left(\beta_{1\,(Y_i\,|\,mode)} \cdot X_1\right) + \left(\beta_{2\,(Y_i\,|\,mode)} \cdot X_2\right) + \left(\beta_{3\,(Y_i\,|\,mode)} \cdot X_3\right) + \left(\beta_{4\,(Y_i\,|\,mode)} \cdot X_4\right) + \cdots \\
&\left(\beta_{5\,(Y_i\,|\,mode)} \cdot X_5\right) + \left(\beta_{6\,(Y_i\,|\,mode)} \cdot X_6\right) + \cdots \\
&\left(\beta_{7\,(Y_i\,|\,mode)} \cdot (X_1)^2\right) + \left(\beta_{8\,(Y_i\,|\,mode)} \cdot (X_2)^2\right) + \left(\beta_{9\,(Y_i\,|\,mode)} \cdot (X_3)^2\right) + \left(\beta_{10\,(Y_i\,|\,mode)} \cdot (X_4)^2\right) + \cdots \\
&\left(\beta_{11\,(Y_i\,|\,mode)} \cdot (X_5)^2\right) + \left(\beta_{12\,(Y_i\,|\,mode)} \cdot (X_6)^2\right) + \cdots \\
&\qquad \left(\beta_{13\,(Y_i\,|\,mode)} \cdot X_1 \cdot X_2\right) + \left(\beta_{14\,(Y_i\,|\,mode)} \cdot X_1 \cdot X_3\right) + \left(\beta_{15\,(Y_i\,|\,mode)} \cdot X_1 \cdot X_4\right) + \left(\beta_{16\,(Y_i\,|\,mode)} \cdot X_1 \cdot X_5\right) + \cdots \\
&\qquad \left(\beta_{17\,(Y_i\,|\,mode)} \cdot X_1 \cdot X_6\right) + \left(\beta_{18\,(Y_i\,|\,mode)} \cdot X_2 \cdot X_3\right) + \left(\beta_{19\,(Y_i\,|\,mode)} \cdot X_2 \cdot X_4\right) + \left(\beta_{20\,(Y_i\,|\,mode)} \cdot X_2 \cdot X_5\right) + \cdots \\
&\qquad \left(\beta_{21\,(Y_i\,|\,mode)} \cdot X_2 \cdot X_6\right) + \left(\beta_{22\,(Y_i\,|\,mode)} \cdot X_3 \cdot X_4\right) + \left(\beta_{23\,(Y_i\,|\,mode)} \cdot X_3 \cdot X_5\right) + \left(\beta_{24\,(Y_i\,|\,mode)} \cdot X_3 \cdot X_6\right) + \cdots \\
&\qquad \left(\beta_{25\,(Y_i\,|\,mode)} \cdot X_4 \cdot X_5\right) + \left(\beta_{26\,(Y_i\,|\,mode)} \cdot X_4 \cdot X_6\right) + \left(\beta_{27\,(Y_i\,|\,mode)} \cdot X_5 \cdot X_6\right)
\end{aligned}
$$

Where:

$$
\begin{aligned}
X_1^{\varepsilon} &= T_{db,OSA} \\
X_2^{\varepsilon} &= \omega_{\,OSA} \\
X_3^{\varepsilon} &= T_{db,RA} \\
X_4^{\varepsilon} &= \omega_{RA} \\
X_5^{S} &= \frac{\dot{m}_{SA}}{\dot{m}_{SA}^{RATED}} \\
X_6^{S} &= OSAF
\end{aligned}
$$

The model is a second order polynomial allowing for sensitivity to each input variable, the square of each input variable, and the combination of any two input variables. If the user determines that a simpler equation (fewer terms) is adequate to describe performance of a certain system, the coefficients for higher order elements in the function can be defined as zero, and coefficient definitions can be limited to $\beta_0 – \beta_6$. The outputs (Yi) from these polynomial equations are defined as fractional modifiers, not absolute values. For example, $Y_{\Delta\dot{H}_{TOT\,|\,SYS}}$ (generally a value from 0-1) will be multiplied by the nominal (rated) cooling capacity for the system in order to determine the actual cooling capacity at the condition.

Table 1 gives an example of these coefficients determined using regression analysis.

Table 1 Example coefficient table.

Coefficients for polynomial model to describe outputs (Y_i) according to Equation 1								
Mode	Y_i	β_0	β_1	β_2	β_3	…	…	B_{27}

A	$Y_{\Delta\dot{H}_{TOT\,|\,SYS}}$
	Y_{SHR}
	Y_{EIR}
B	$Y_{\Delta\dot{H}_{TOT\,|\,SYS}}$
	Y_{SHR}
	Y_{EIR}

where:

$$\Delta\dot{H}_{TOT\,|\,SYS} = Y_{\Delta\dot{H}_{TOT\,|\,SYS}} \cdot \Delta\dot{H}_{TOT\,|\,SYS}^{RATED}$$
$$SHR = Y_{SHR}$$
$$EIR = Y_{EIR}$$