PNNL-14383

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Energy Efficient and Affordable Small Commercial and Residential Buildings Research Program

Project 2.6 – Enhancement of the Whole-Building Diagnostician

Task 2.6.10 – Whole-Building Energy Enhancement Report

D. Chassin
K. Gowri
T. Carlon
N. Bauman

August 2003

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

 This document was printed on recycled paper.

Energy Efficient and Affordable Small Commercial and Residential Buildings Research Program

Project 2.6 – Enhancement of the Whole-Building Diagnostician

Task 2.6.10 – Whole-Building Energy Enhancement Report

David P. Chassin
Krishnan Gowri
Teresa A. Carlon
Nathan N. Bauman

August 2003

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

1 Introduction to the WBE Enhancements

This document is one of a collection of reports for Project 2.6: Enhancement of the Whole-Building Diagnostician (WBD). It documents parts of the task to enhance the Whole-Building Energy (WBE) Module to support tracking a greater variety of energy variables and increasing the flexibility of the models used for normalizing values of those variables. This report summarizes the technical elements and results of the work performed. Instructions for using the WBE are provided in the *Instructions for Configuration of the Whole-Building Diagnostician Software*.

Section 2 of this report provides a brief description of the WBE and the enhancements developed under this project. Section 3 provides a table of key software bugs fixed after initially implementing the enhancements, and Section 4 provides a brief description of the method used as the basis for modeling expected energy consumption.

2 WBE Background

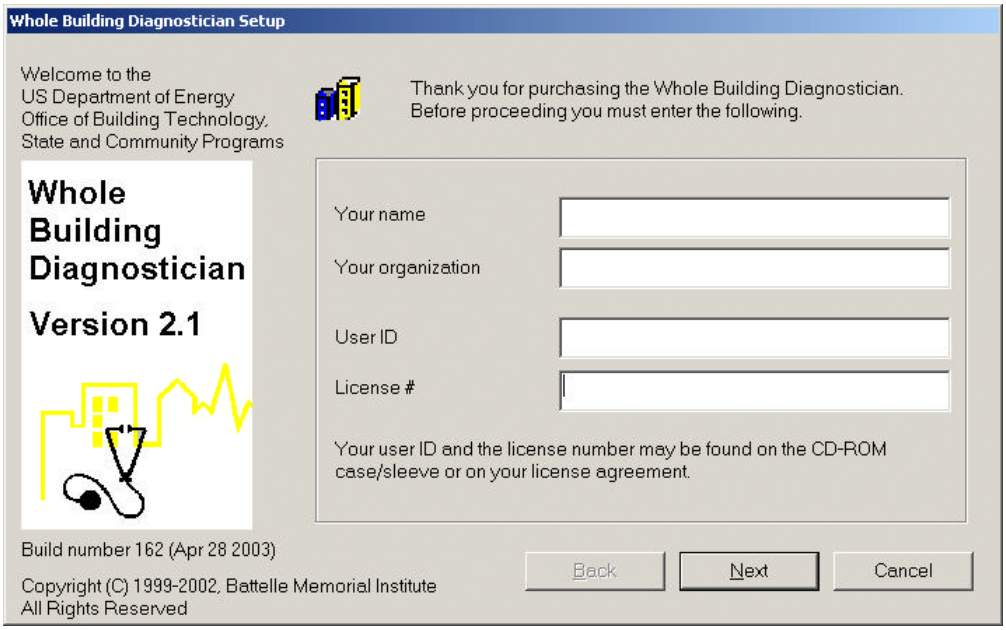
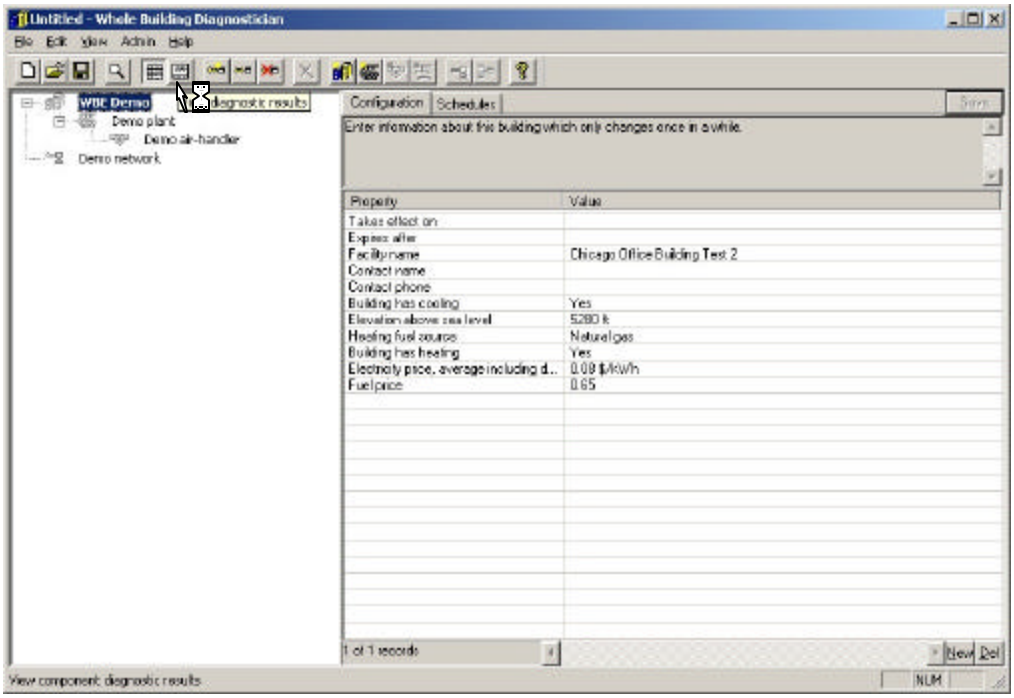
The WBE module tracks energy end uses at the whole-building level, specifically total building energy, electric energy, thermal energy, heating, ventilation, and air conditioning energy, and chiller energy. Analysis results are presented as an Energy Consumption Index (ECI) for each day. The ECI is the ratio of actual energy consumption to expected energy consumption. The values of excepted energy consumption are generated by a model that performs statistical analysis of a baseline set of historical data collected from the building or systems. Statistical properties of the expected value are compared to the actual value to determine whether the actual measurement is significantly different. In general, the baseline model uses time of day, day of the week, outdoor-air dry-bulb temperature, and relative humidity as independent variables.

The objective of this task was to develop an enhanced WBE so that advanced users can add other independent variables, such as occupancy and plug loads, to the models. The enhanced capabilities are as follows:

- ✓ Enable the user to specify any independent variable (not just date, time, temperature and humidity) in the models
- ✓ Allow the tracking of any variable (not just whole-building thermal and electric meter readings)
- ✓ Manage the collection of data for all the variables now supported
- ✓ Enhance the user interface to support the enhanced features.

These enhancements provide a flexible tool for monitoring and diagnosing whole-building and system-level energy consumption in new and existing commercial buildings of all sizes.

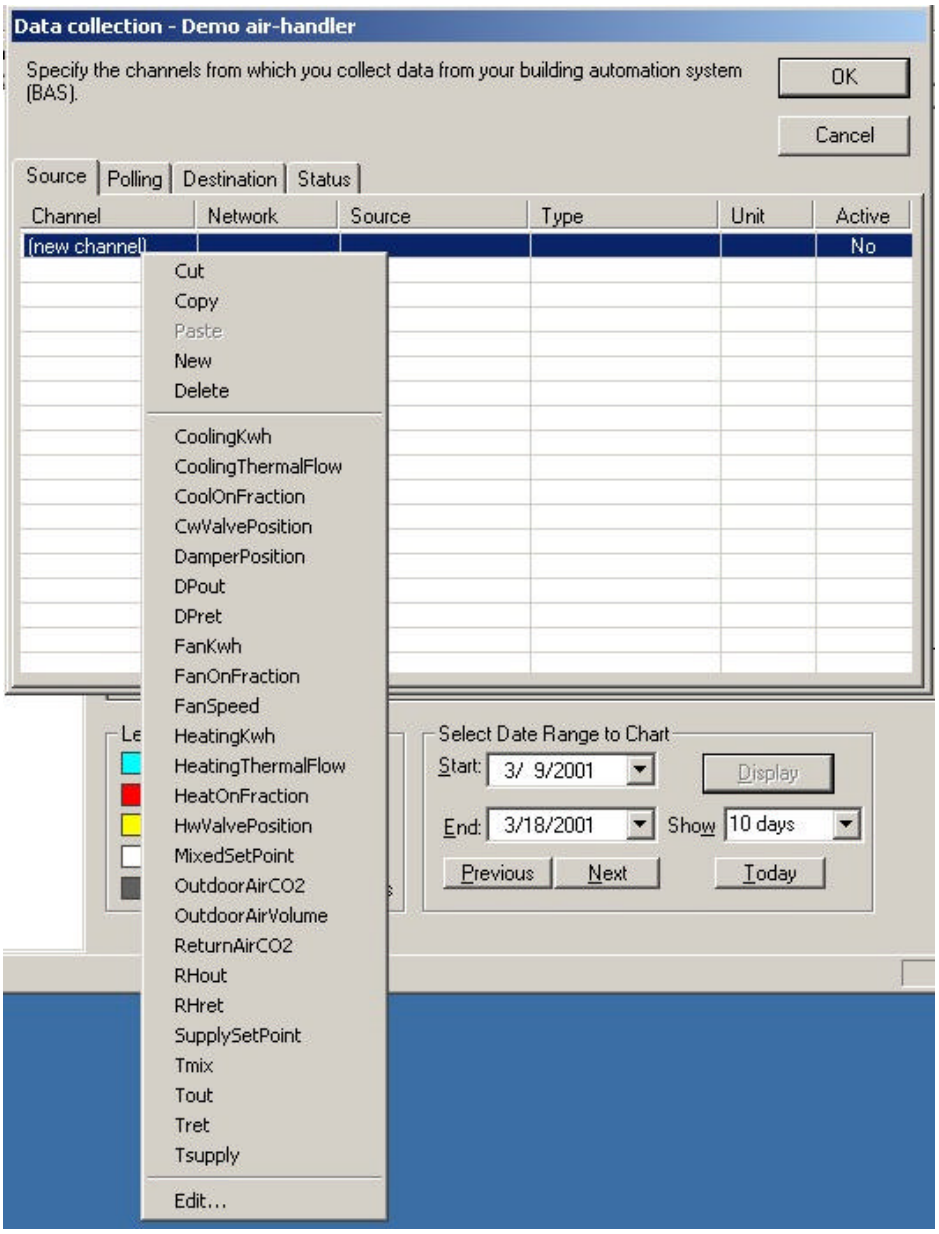
3 WBE Software Bugs Fixed

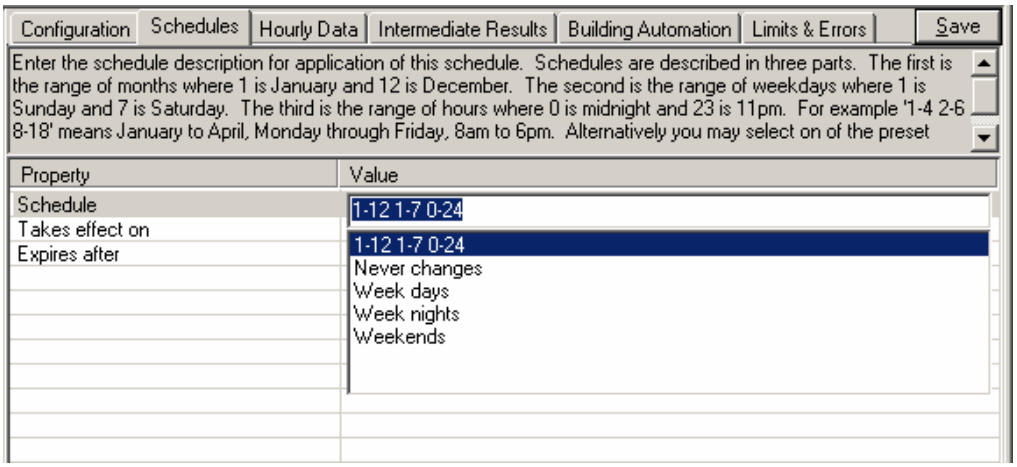
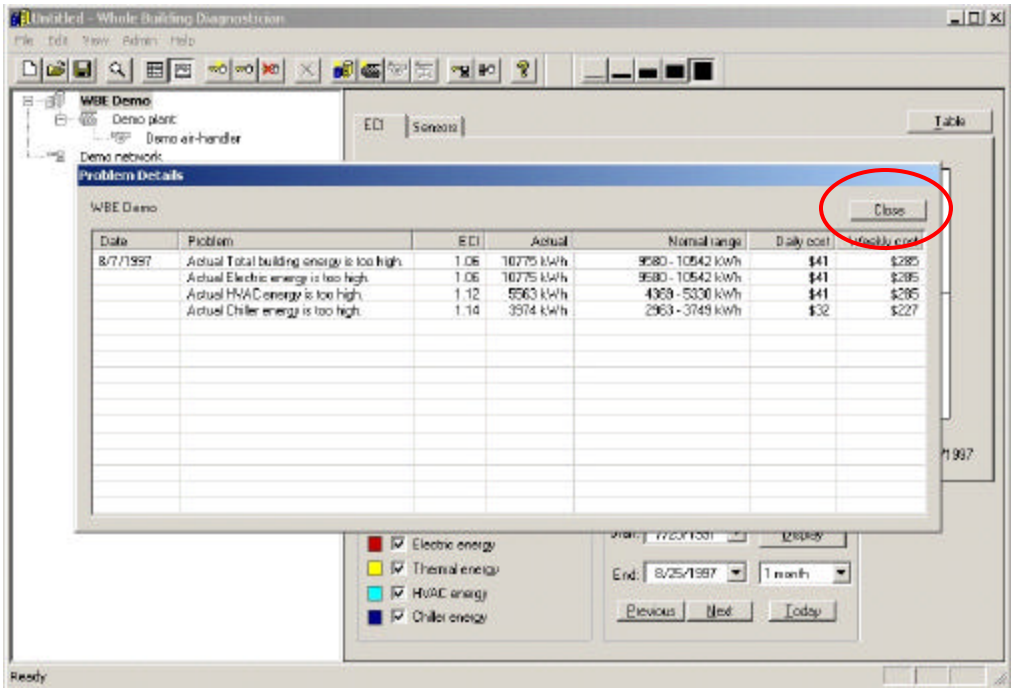
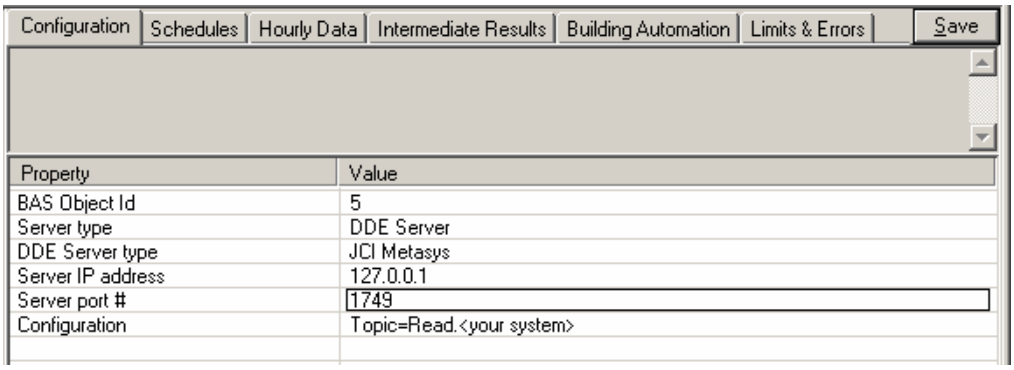
Description of Enhancement	Change in Screen Image
Removed the word "Diagnostic Configuration" and replaced it with "Diagnostician Setup".	
Placing your cursor over the icons on the toolbar will momentarily give you a brief description of the icon function.	

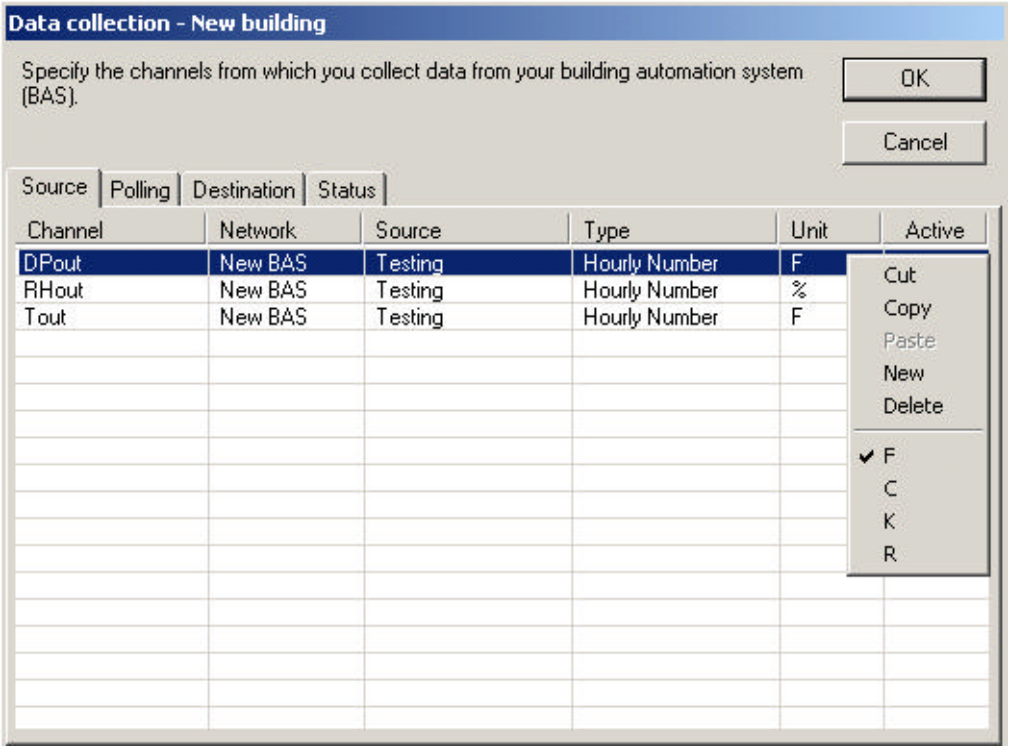
Description of Enhancement

All data units will be displayed with a right-mouse click in the “new channel” box. Adding a new channel can be done by clicking “new” on the list.

Change in Screen Image



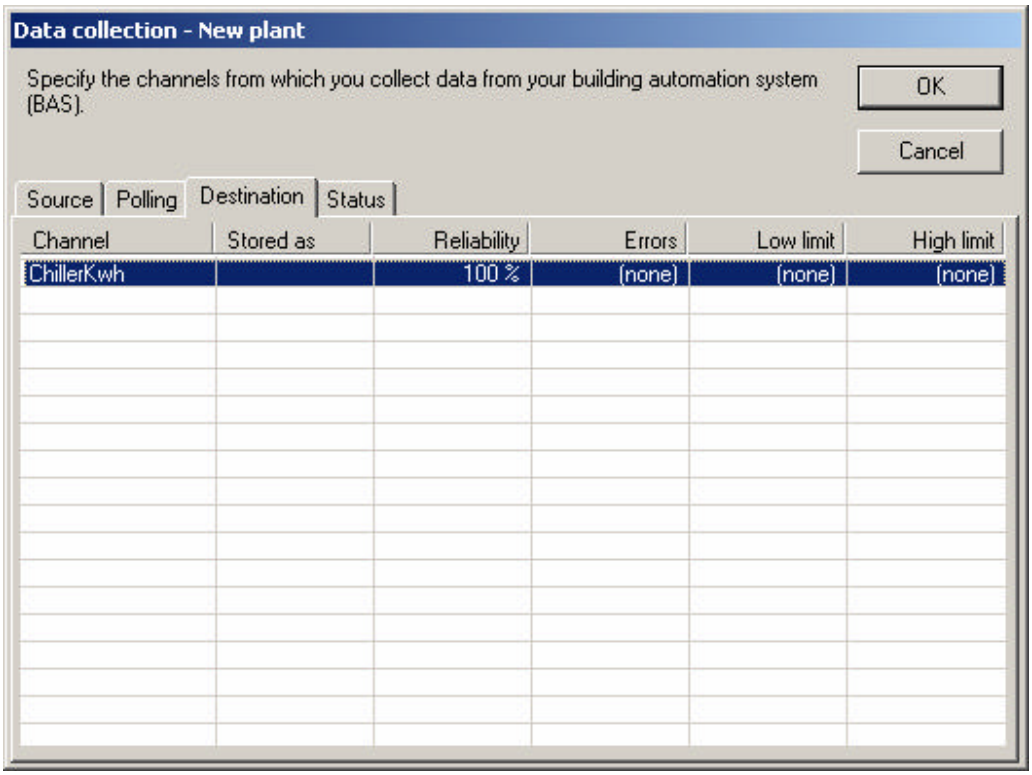
Description of Enhancement	Change in Screen Image
Existing value in the configuration screens remains in the dialogue box should you decide not to change the entry. Prior to this fix, the value was disappearing if you clicked on the background white space.	
Added a “Close” button to the ECI detailed problem tab.	
The configuration item of the network object is now being displayed.	

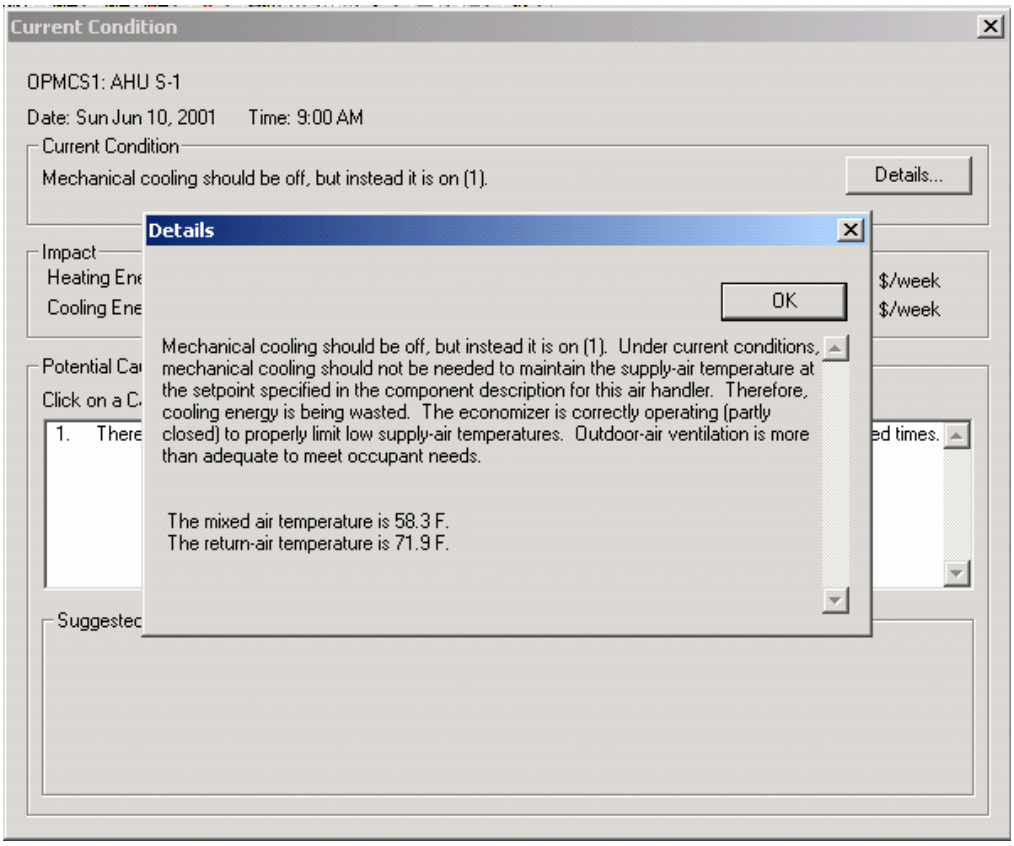
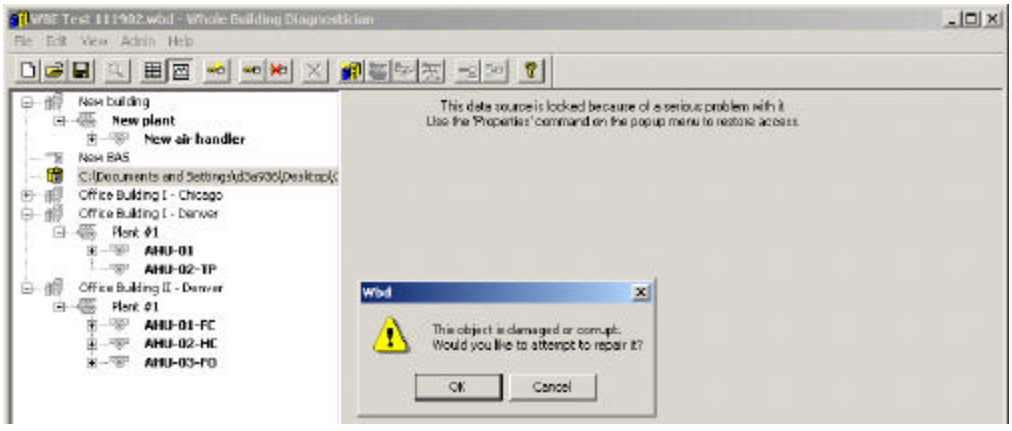
Description of Enhancement	Change in Screen Image
Using the data collection feature to set up data channels will no longer cause duplicates in the ChannelConfig table.	
Baslink is now able to reprocess raw data without manually clearing the LastPoll field in the ChannelConfig table.	No change in user interface.

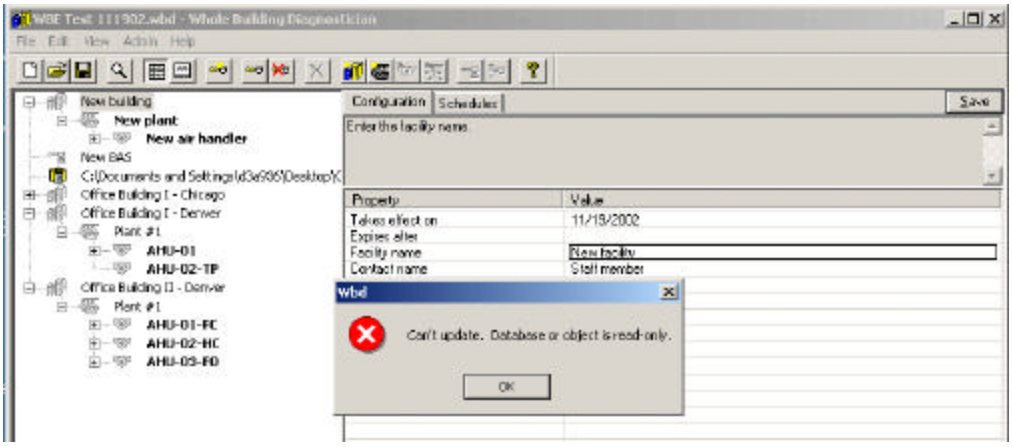
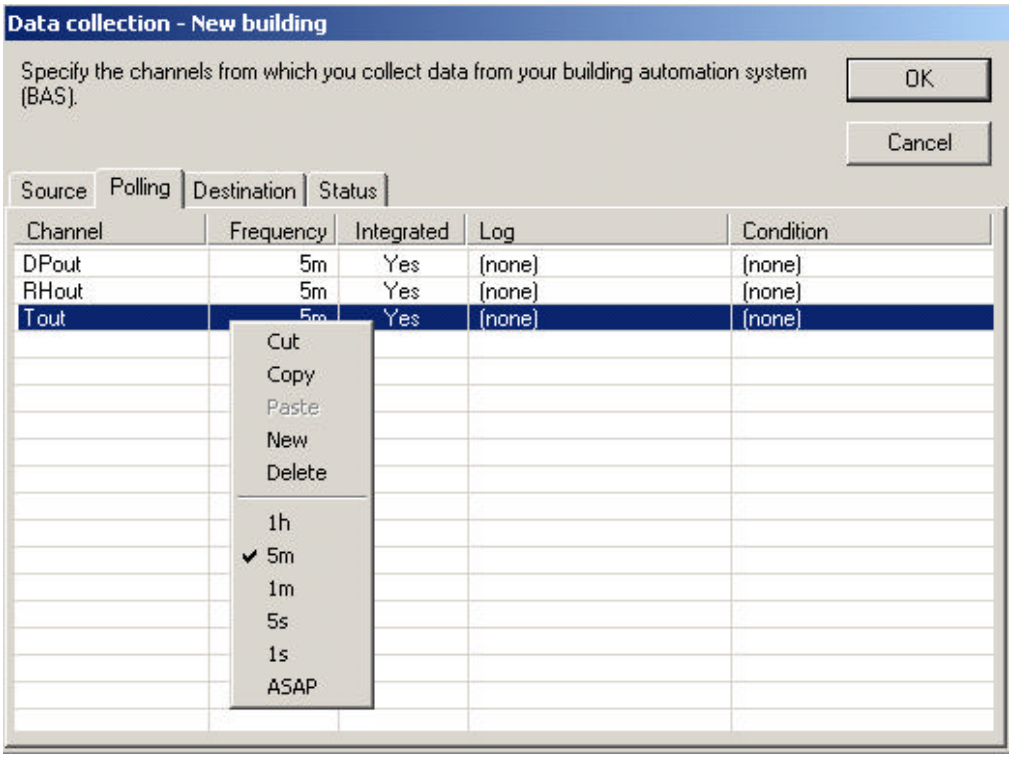
Description of Enhancement

The reliability column on the Destination tab under data collection will now hold a value of 100%.

Change in Screen Image



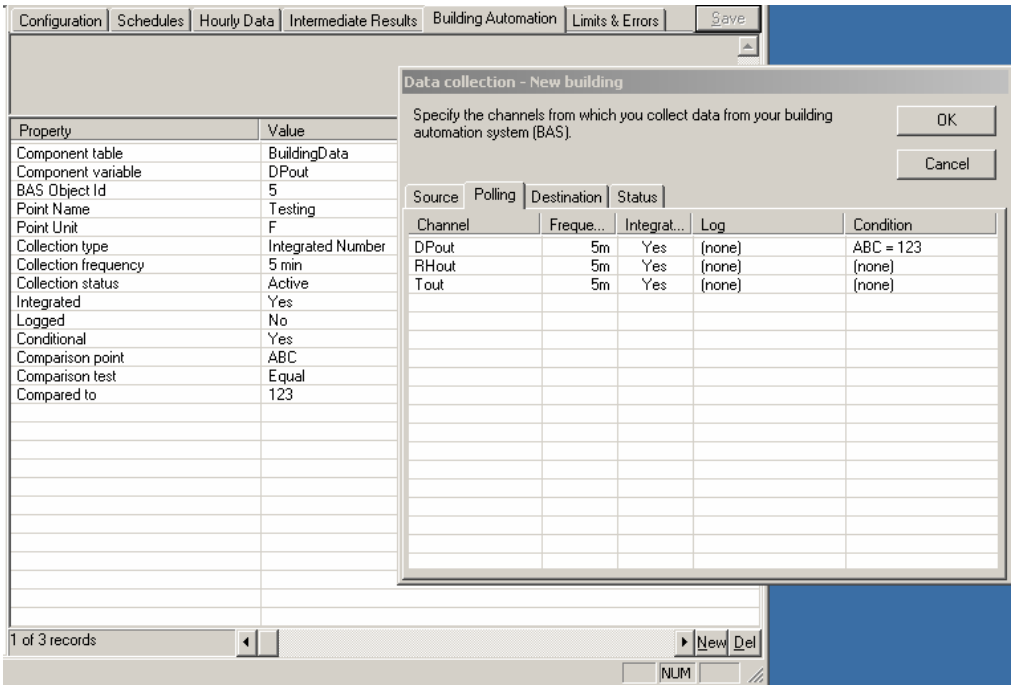
Description of Enhancement	Change in Screen Image
Attempting to display a message that does a database lookup on a "null" field will not crash the WBD.	
When displaying a corrupt database in the tree, the remaining objects below the corrupt database will now be displayed.	

Description of Enhancement	Change in Screen Image
A user now has a read-only status to view the file configuration settings. The user is unable to change any setting without being in Admin or Expert mode.	
Data collection column values no longer populate themselves back onto the list.	

Description of Enhancement

The Building Automation tab now reflects the same settings as in the Data Collection Logged and Conditional properties under the Polling tab.

Change in Screen Image



4 Methodology for Multi-Variate Whole-Building Energy Diagnostics

Determining whether actual building energy use is as expected requires a model of building end-use energy consumption. Such a model is used to produce expected consumption against which actual consumption is compared. The result of the comparison is then used to indicate to building operators whether actual building energy usage is abnormal and requires further investigation. Several modeling techniques have been employed to produce expected energy use for a given set of conditions. This report documents the current modeling technique used in the Whole-Building Energy Diagnostician (WBE) and the changes proposed to make the modeling technique work better for buildings other than the class of light commercial and office buildings for which it was originally designed.

The ASHRAE Handbook of Fundamentals (ASHRAE 1997) specifies that a bin-method is an energy estimating technique wherein energy usage for different temperature intervals and time periods is evaluated separately. Hours of the day, days of the week, and outdoor conditions are grouped to form bins for which energy usage is calculated. For example, typical daily hour bins might be three 8-hour bins for 12 am to 8 am, 8 am to 4 pm, and 4 pm to 12 am. Temperature bins might be for 5°F increments in temperature.

For a bin-based energy model, the energy usage for each bin is calculated and multiplied by the number of hours it occurs during the year. When the results are summed over all bins, the result yields a total annual energy usage for a building.

This method is preferred over the simpler use of degree-day energy estimating because it is better at considering the variations in system efficiency in response to load variations, occupancy and outdoor conditions.

The method used by the WBE for estimating energy use in a building (whole building or partial end-use load) based on its past performance during a baseline period is called a bin method, although it is basically the reverse of the ASHRAE-type process described above. In the WBE we essentially bin the loads (instead of the hours) into bins defined by temperature, relative humidity (RH), and hour of week--a three-way split. Instead of counting hours, we essentially average the energy use in each bin. Thus, the baseline model reflects the building's or end-use's time-of day and day-of-week schedule, and the influence of outdoor temperature and relative humidity.

If we used the same size bins as in the previous example, there would be 27,216 bins (24 hours per day x 7 days per week x 18 temperature intervals x 9 relative humidity intervals). This would require data from too long a time period or take far too long to populate with hourly data to be practical.

The WBE's pseudo-bin method introduces a few significant variations on the basic concept of a bin method—hence, the term pseudo-bin. First of all, it does not pre-compute the population of loads in each bin. Instead, it uses "sliding" bins, created "on-the-fly." For example, assume the temperature bins are 5°F-wide, and the RH bins are 10%-wide. Then, if it is 9 am on a Monday and the current temperature and relative humidity are 58°F and 61%, the WBE's baseline load estimate is the median of all the loads in the baseline period that meet the following criteria: hour of week = 33, temperature = 58°F±2.5°F and RH = 61%±5%.

Tests against field data have shown that models using bin medians produce more stable expected loads than those using bin averages, particularly when the number of observations in a bin is small or many of the loads are zero. Therefore, we use bin medians to represent expected energy consumption for conditions in each bin.

The advantage of sliding bins is that they produce a smooth energy-use trajectory as conditions change, instead of the lumpy, step-wise changes in loads that would result if you crossed the boundary from one

fixed bin to another. In addition, sliding bins require less data because the data are used for more than one bin and the bins can be somewhat wider to include more data points but without a loss in accuracy.

Overall the WBE's energy bin method does not assume a linear (or any prescribed functional) response of energy to the input variables. It is completely free to follow the empirical data without mathematical constraints. Further, like a neural-net, it ignores variables that don't explain the energy consumption's variations.

The WBE's bin method can be generalized to any variable and any number of explanatory variables. For example, many industrial loads have nothing to do with either time of day or day of week. So, those variables can be replaced with others that might be useful in explaining a load. This is what we mean by a generic pseudo-bin method--it is a varying multi-way split--purely statistical and unrelated to any *a priori* variables, such as weather.

References

ASHRAE. 1997. *1997 ASHRAE Handbook of Fundamentals (SI)*, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia, p. 30.20.