BEST Methodology - Fundamentals

What is the Building Efficiency System Tool™?

The Building Efficiency System Tool (BEST™) is a dynamic, interactive technology software that is designed to provide a practical, quick, and reliable tool to the HVAC professional for comparison of various system and product design candidates during the conceptual design phase to include the impact of cost.

Whenever a parameter is changed, e.g., type of heating or cooling source or type of terminal unit the program recalculates all parameters and displays them. Unlike other energy analysis software, this allows the user to immediately see the results of any change in the system configuration. This results in the ability to quickly model different systems to determine which system best meets the needs of the project.

The program gives the designer a clear measure of annual energy costs for up to four different configurations without a prohibitive amount of data input. This will assist in developing recommendations and options before extensive detailed design work has been completed.
A primary feature of the program is ease of use. There is a minimum of data entry required. Most system design details are selected from lists provided by the program. The available choices in these lists are updated interactively as the user works through the design so that they are consistent with the other system elements already specified.

Methodology – Full Discussion and formulas - "Help" BEST software

Energy Calculation, Bin Method

BEST™ calculates energy consumption of HVAC systems using the Bin method. The data used is hourly TMY3 (Typical Meteorological Year) weather data from NOAA (National Oceanic and Atmospheric Administration) for over 1000 locations in the United States, Canada and Mexico and is available online. The Bin Method converts the daily hourly data to monthly bin data. Reduction of daily hourly weather data to monthly bin data reduces the number of calculations required and permits the program to be entirely interactive.

The bin data for the climatological location selected can be viewed by choosing the Bin Data button on the Project screen in the Nearest Climatological Location box.

Balance Temperature

The balance point temperature T_{bal} of a building is defined as that value of the outdoor temperature T_o at which, for the specified value of the interior temperature T_i, the heat loss Q_{loss} is equal to the heat gain from sun, occupants, lights, etc.

In BEST™ the balance point is a user selectable parameter to allow the user to model a building and its individual thermal characteristics.

Horsepower Calculations

As part of the effort to quickly model different systems the BEST™ calculates equipment horsepower's for the user, based on the system the user models. However, unlike some energy analysis software that calculate equipment horsepower's based on rules of thumb of horsepower/gpm or horsepower/cfm, the BEST™ calculates equipment horsepower's from actual system parameters.

For a fluid system the horsepower's of the equipment are calculated as a function of head/pressure and flow rate.

The mass transfer or flow rate, $\dot{M}$, is calculated as a function of input loads

For hydronic systems the head pressure difference, ΔH, is calculated using the following components:

- Pump and hydronic system accessories
- Boiler/Chiller
- Heating/Cooling coil
- Control valve
- Balance valve
- Piping distribution system

For air systems the static pressure, ΔH, is calculated using the following components:

- Louvers and dampers
- Filter
- Heating/Cooling coil
- Duct furnace
- Air handling unit casing
- Grilles/Registers
- Duct distribution system

Pressure drops for both the piping and duct distribution systems are calculated based on the building's geometry (length, width and height) for the length of the piping or duct system and using standard industry pressure drop calculations. The pressure drop factor (head per foot of pipe) for a hydronic system is user selectable in the user Preference file. The user Preference file is found under the "Edit" drop down menu on the main toolbar.

For a refrigerant system the compressor serves double duty, it serves to change the pressure and temperature of the refrigerant, but also as the pump to move the refrigerant around the system. The pumping horsepower is derived from manufacturer's data and AHRI Standard 1230 Performance Rating of Variable Refrigerant Flow (VRF) Multi-split Air-conditioning and Heat Pump Equipment.

Part Load and BEER

BEST™ uses heating and cooling efficiency data for compressorized equipment using AHRI published efficiencies. This is typically in units of EER (btuh/watt) for cooling and COP (watt/watt) for heating equipment.

AHRI standards now rate compressorized equipment for part load. The standards typically define the temperature of the heat sink that the part load will occur. These part load ratings are expressed as IEER (Integrated EER) or IPLV (Integrated Part Load Value) for cooling and HSPF (Heating Seasonal Performance Factor) for heating. The units for these ratings are btuh/watt.

However, the standards don't always include all factors that determine the performance of the component in an actual system or operating conditions. This view into the system efficiency "as applied" in a building versus a lab is what sets the BEST™ tool apart. AHRI publishes equipment efficiencies only at the conditions specified in the particular rating standard for that type of equipment. These are not efficiencies for a system once installed nor are they designed to make an apples-to-apples comparison between different types of equipment.

For instance, air cooled equipment is rated at 80F DB/67F WB entering air temperature (EAT) to the evaporator. Most equipment experiences EAT at room conditions. This is typically 73F DB/61F WB. The difference in efficiency for this actual operating condition over the "laboratory" standard can be over 10%.

Published AHRI efficiencies includes only the components that the manufacturer installs in its' "box". Therefore, not all EER's are created equal since there is often more than just the compressor (evaporator fan, condenser fan, etc.) in the box. The AHRI published efficiencies also need to be adjusted for this extra equipment over just the compressor.

The user can override the full load EER's and COP's and part load IEER's and HSPF's if manufacturer's data is available.

BEST[TM] then calculates a System IEER. This is defined as a BEER (Building Energy Efficiency Ratio). BEER is the building EER as opposed to an equipment EER. It is the annual cooling required by the building divided by the annual work to create this cooling or:

$BEER = Cooling\ Out_{annual} / Work\ In_{annual}.$

Where
Cooling Out = Building Cooling Peak Load (btu/hr) x Cooling Annual Equivalent Full Load Hours (hr)
Work In = Sum of all the cooling system equipment electrical consumption (watt)

Equivalent Full Load Hours

Equivalent full load hours is defined as the number of hours a system designed for the peak or design heating/cooling load would operate at full load during one year even though it cycles with the load or operates variable speed. It is the annual energy consumption divided by the peak or design load:

$$EFLH = E_{annual} / Q_{design}$$

$$= S_{annual}\ DE_{bin} / Q_{design}$$

$$= S_{annual}\ U \times A \times (T_{bal} - T_{bin}) \times Bin\ Hours / U \times A \times (T_{bal} - T_{design})$$

$$= S_{annual}\ (T_{bal} - T_{bin}) / (T_{bal} - T_{design}) \times Bin\ Hours$$

$$= S_{annual} \times DT_{bin} / DT_{design} \times Bin\ Hours$$

Once the equivalent full load hours are determined it is a straightforward calculation to multiply the EFLH times the design or peak capacity of the equipment capacity or horsepower to obtain the annual energy consumption for the piece of equipment (boiler, chiller, pump, fan, etc.) or:

$$E_{annual} = C_{design} \text{ or } HP_{design} \times EFLH$$

The EFLH for heating and cooling for the climatological location selected can be viewed by choosing the Bin Data button on the Project screen in the Nearest Climatological Location box.

Variable Speed Calculations

Moving energy or BTU's around a building in the form of pumps, fans and compressors are a major component of the energy consumption of a building's HVAC system. For a typical commercial building this can approach 50% of the total.

These components were generally operated constant volume or constant speed to simplify the control of an HVAC system. Operating this equipment variable volume or variable speed can significantly reduce the energy consumption of this equipment.

The affinity laws can calculate the savings in energy consumption by variable speed operation or control.

For a fluid the power required to move the fluid is the product of flow times pressure or head or:

$P = Q \times p / h$

Where:

- P = power
- Q = flow
- p = pressure
- h = efficiency

For a fluid in a duct or pipe the differential pressure to move the fluid is a function of the flow squared:

Dp » DQ^2

Therefore, the power to move the fluid is a function of the flow cubed or:

DP » $DQ \times Dp / h$

» $DQ \times DQ^2 / h$

The efficiency of the fluid mover is a function of the type of variable speed control. There are three basic types of control algorithms employed in the HVAC industry.

The first is cycle on/off.
The second is Delta Temperature or Delta T.
The third is Delta Pressure or Delta P
The equivalent full load hours for a variable speed control can then be defined as:

$$EFLH = \text{Sum for all bins } S\, Q \times Dp \times h_{bin} \times Dt$$
$$= S\, Q \times Dp \times h_{bin} \times Dt$$
$$= S\, Q \times Q^{2} \times h_{bin} \times Dt$$
$$= S\, LF_{flow} \times LF_{pressure}^{2} \times h_{bin} \times Dt$$

Where:

- $EFLH$ = Equivalent full hours
- LF_{flow} = Load factor applied to flow using a minimum percent flow
- $LF_{pressure}^{2}$ = Load factor applied to pressure using a minimum percent pressure
- h_{bin} = Efficiency at bin
- Dt = Bin hours

The EFLH for On/Off, Delta T and Delta P flow control for the climatological location selected can be viewed by choosing the Bin Data button on the Project screen in the Nearest Climatological Location box.

Defaults – Examples: There are "Knowns" before design

The systems descriptions are the result of recommendations accumulated from 50 contractors throughout North America and the advice of Engineering and Design consultants provided to the initial 12 HIA-C.org committee members.

Why? Most HIA-C members manufacture system components with certified performance, but do not have an EER as non-compressor bearing. Critical to system efficiency BEST™ includes all major components as relevant to efficiency, cost and life expectancy.
As provided above the calculations follow basic thermodynamics, published ASHRAE guidelines, AHRI product certification, with only certified manufactures published correction factors.
Initial releases of BEST required the user to input all system data. This meant that "owners" could not use, and that those familiar with only one system detail could not use BEST 1.0. Therefore, the decision was made to input all the relevant key data as changeable defaults. The user is encouraged to change any of over 100 defaults from weather, efficiency, and utilities to system cost when available.

Early planning is the lowest cost and many details are unknown – with BEST™ current industry practice and published data is readily available and easily updated.