PNNL-17615

# GridLAB-D Technical Support Document: Commercial Module Version 1.0

DP Chassin

May 2008

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
*operated by*
BATTELLE
*for the*
UNITED STATES DEPARTMENT OF ENERGY
*under Contract DE-AC05-76RL01830*

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(9/2003)

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# Acronyms and Abbreviations

| | |
|---|---|
| ODE | ordinary differential equation |
| ETP | equivalent thermal parameters |
| UA | thermal conductance (surface area x thermal conductivity) |

# Contents

# 1.0 Introduction

The Commercial Module implements commercial building models. Version 1.0 of this module only supports single-zone office buildings. Support for additional commercial buildings types is planned, including multi-zone office, schools, stores, and refrigerated warehouses.

# 2.0 Single-Zone Office Building

The Commercial Module uses a simple Equivalent Thermal Parameters (ETP) model (Taylor and Pratt 1988) with first-order ordinary differential equations (ODEs):

$$T_i' = \frac{1}{c_a}\left[T_m h_m - T_i(UA - h_m) + \Sigma Q_x + T_o UA\right] \tag{2.1}$$

$$T_m' = \frac{h_m}{c_m}\left[T_i - T_m\right] \tag{2.2}$$

where
$T_i$ = the temperature of the air inside the building
$T_i'$ = $\frac{d}{dt}T_i$
$T_m$ = the temperature of the mass inside the building (for example, furniture, inside walls)
$T_m'$ = $\frac{d}{dt}T_m$
$T_o$ = the ambient temperature outside air
$UA$ = the UA of the building envelope
$h_m$ = the UA of the mass of the furniture, inside walls, etc.
$c_m$ = the heat capacity of the mass of the furniture inside the walls, etc.
$c_a$ = the heat capacity of the air inside the building
$Q_i$ = the heat rate from internal heat gains of the building (for example, plugs, lights, people)
$Q_h$ = the heat rate from heating, ventilating, and air conditioning unit
$Q_s$ = the heat rate from the sun (solar heating through windows, etc.)

The general first order ODEs ($C_1$-$C_5$ defined by inspection above) is

$$T_i' = T_i C_1 + T_m C_2 + C_3 \; T_m' = T_i C_4 + T_m C_5 \tag{2.3}$$

The general form of the second-order ODE is

$$p_4 = p_1 T''_i + p_2 T_i' + p_3 T_i \tag{2.4}$$

The solutions to second-order ODE for indoor and mass temperatures are

$$T_i(t) = K_1 e^{r_1 t} + K_1 e^{r_2 t} + \frac{p_4}{p_3} \tag{2.5}$$

$$T_m(t) = \frac{T_i'(t) - C_1 T_i(t) - C_3}{C_2} \tag{2.6}$$

where:

$$r_1, r_2 = roots(p_1 p_2 p_3)$$
$$K_1 = \frac{r_2 T_{i0} - r_2 \frac{p_4}{p_3} - T'_{i0}}{r_2 - r_1}$$
$$K_2 = \frac{T_{i0} - r_1 K_1}{r_2}$$

$p_1 = \frac{1}{C_2}$
$p_2 = -\frac{C_3}{C_2} - \frac{C_1}{C_2}$
$p_3 = C_5 \frac{C_1}{C_2} - C_4$
$p_4 = -C_5 \frac{C_3}{C_2}$
$t$ = the elapsed time
$T_i(t)$ = the temperature of the air inside the building at time $t$
$T_o$ = $T_i(t = 0)$, for example, the initial temperature of the air inside the building
$T_o'$ = $T_i'(t = 0)$, for example, the initial temperature gradient of the air inside the building

# 3.0 References

Taylor, ZT and RG Pratt. 1988 "The effects of model simplifications on equivalent thermal parameters calculated from hourly building performance data." In *Proc. 1988 ACEEE Summer Study on Energy Efficiency in Buildings,* pp. 10.268-10.285.