UNDERFLOOR AIR DISTRIBUTION (UFAD)
COOLING LOAD DESIGN TOOL – WEB VERSION
User Notes
3/4/2011

ABOUT THIS DOCUMENT
These user notes describe how to use web-based version of the UFAD design tool for calculating the design cooling load and zone design cooling airflow required for an Underfloor Air Distribution (UFAD) system.

BROWSER SPECIFICATIONS
The tool was created for recent versions of Firefox, Chrome, and Opera. Internet Explorer is not supported.

OVERVIEW OF THE UFAD COOLING LOAD DESIGN TOOL
The web-based version of the design tool is very simple to use. The tool is divided into three sections: Input, Results, and Graphs. The input section consists of many fields that the user supplies. Most fields require a valid number, and dropdown lists require a valid selection. For example, a plenum configuration must be chosen. All fields are required unless they are disabled (some browsers will gray disabled fields). Interior as well as perimeter values must be supplied.

Figure 1: Input section.

Input

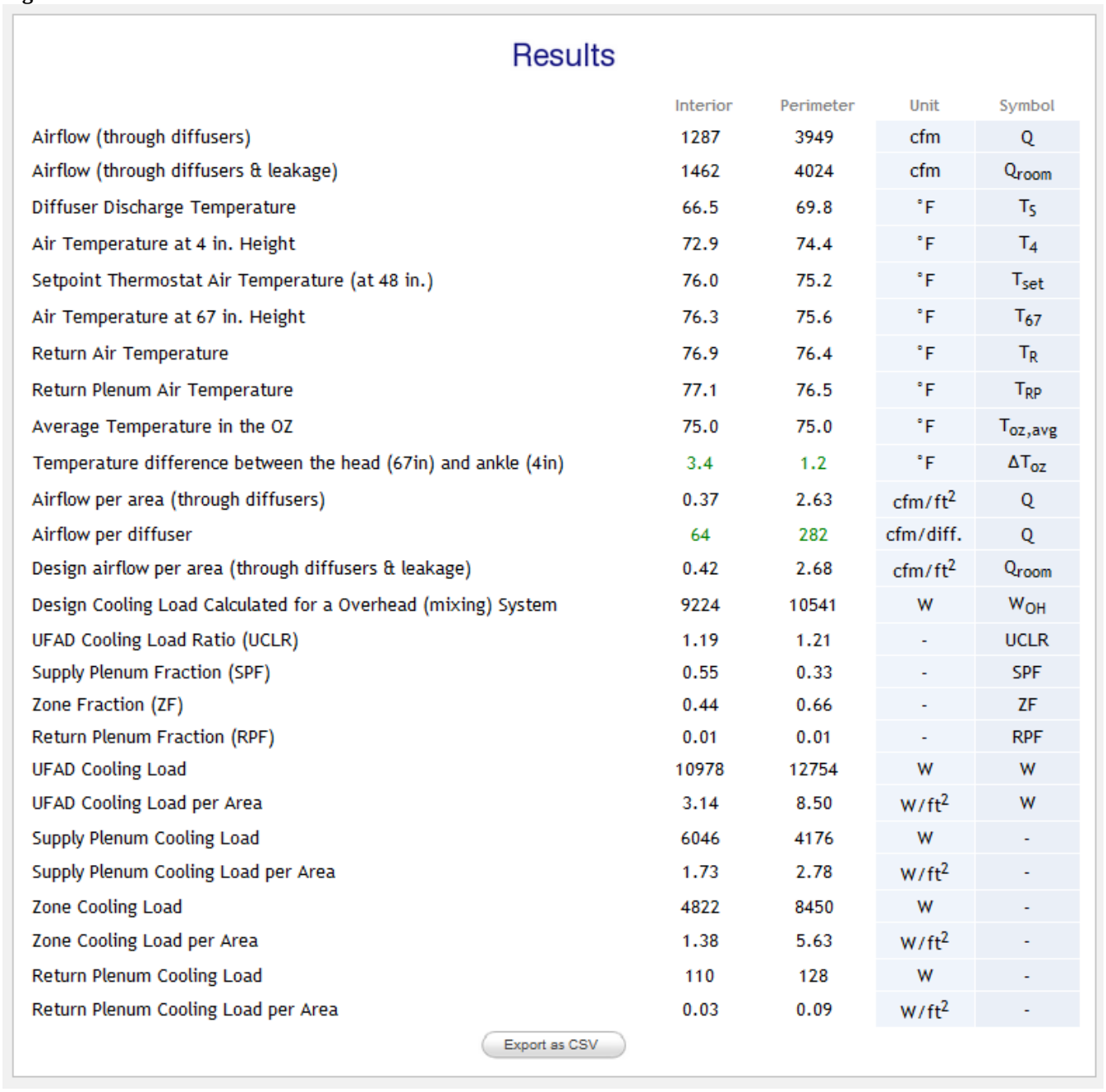
	Interior	Perimeter	Unit	Symbol
Plenum Configuration	Series			
Room Height	9	9	ft	H_{ft}
Floor Area	3500	1500	ft^2	A_f
Floor Level	Middle Floor	Middle Floor	-	-
DiffuserType	Swirl	Linear Bar Grille	-	-
Number of Diffusers	20	14	-	n
Design Cooling load for Overhead System	31.5	36	kBtu/hr	W_{OH}
Design Average Temperature in the Occupied Zone	75	75	°F	$T_{oz,avg,d}$
Estimated Category 2 Leakage	0.05	0.05	cfm/ft^2	$q_{leak,2}$
Setpoint Temperature of Air Entering the Supply Plenum	63		°F	T_{plenum}
Number of Occupants	20		-	m
Zone Orientation		South	-	-
Exterior Wall Length		100	ft	L^P

Submit Set Defaults Reset

At the bottom of the input area, there are three buttons. The "Submit" button will initiate the calculation and populate the output, located below the input. The "Set Defaults" button will populate the fields with some standard input values. The default values are shown filed in above. The "Reset" button will simply remove all input from the fields. If any of the input is invalid, a window alert will give you information about your input error.

Below the Input area is the Results area. If the tool is successfully run with valid inputs, the Results area will be populated. Details about all of the inputs and outputs can be found in the latter half of this document. Two of the results will be validated: Temperature difference between the heat and ankle, and Airflow per diffuser. If the result is valid, it will be shown in green, as below. If the Temperature difference between head and ankle is too large, or if the Airflow per diffuser exceeds design capacity, it will be shown in red.

Figure 2: Results section.



Results

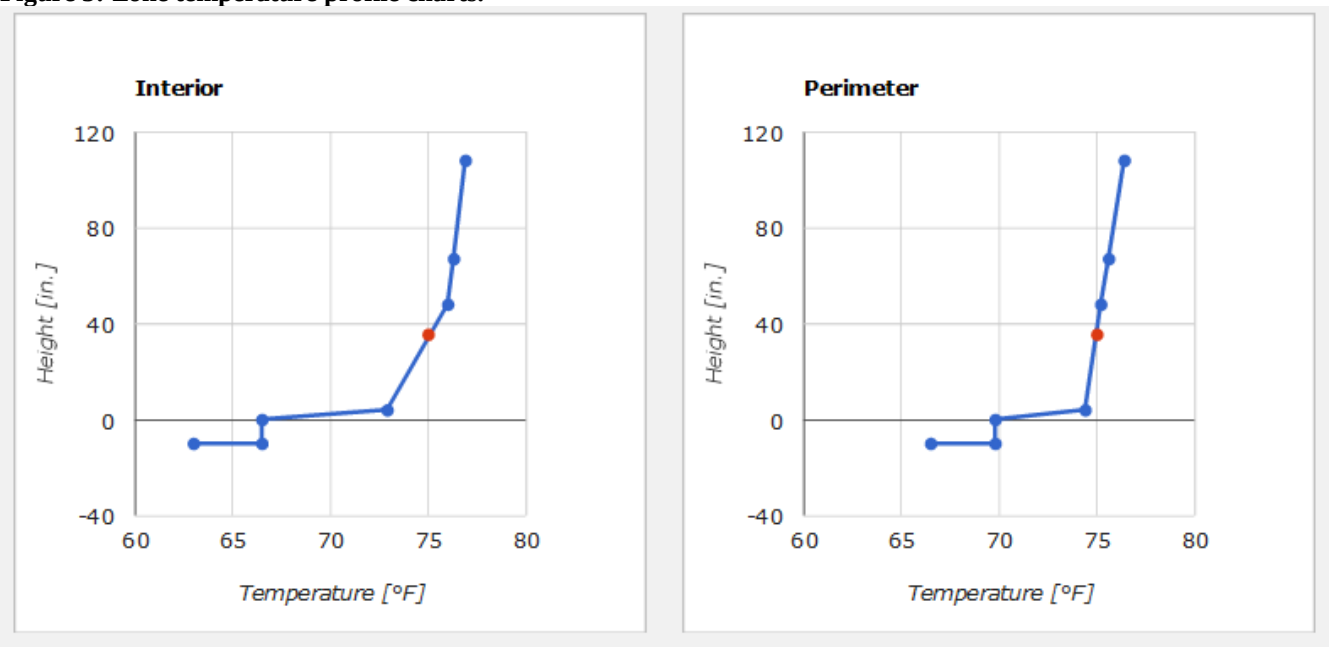
	Interior	Perimeter	Unit	Symbol
Airflow (through diffusers)	1287	3949	cfm	Q
Airflow (through diffusers & leakage)	1462	4024	cfm	Q_{room}
Diffuser Discharge Temperature	66.5	69.8	°F	T_S
Air Temperature at 4 in. Height	72.9	74.4	°F	T_4
Setpoint Thermostat Air Temperature (at 48 in.)	76.0	75.2	°F	T_{set}
Air Temperature at 67 in. Height	76.3	75.6	°F	T_{67}
Return Air Temperature	76.9	76.4	°F	T_R
Return Plenum Air Temperature	77.1	76.5	°F	T_{RP}
Average Temperature in the OZ	75.0	75.0	°F	$T_{oz,avg}$
Temperature difference between the head (67in) and ankle (4in)	3.4	1.2	°F	ΔT_{oz}
Airflow per area (through diffusers)	0.37	2.63	cfm/ft^2	Q
Airflow per diffuser	64	282	cfm/diff.	Q
Design airflow per area (through diffusers & leakage)	0.42	2.68	cfm/ft^2	Q_{room}
Design Cooling Load Calculated for a Overhead (mixing) System	9224	10541	W	W_{OH}
UFAD Cooling Load Ratio (UCLR)	1.19	1.21	-	UCLR
Supply Plenum Fraction (SPF)	0.55	0.33	-	SPF
Zone Fraction (ZF)	0.44	0.66	-	ZF
Return Plenum Fraction (RPF)	0.01	0.01	-	RPF
UFAD Cooling Load	10978	12754	W	W
UFAD Cooling Load per Area	3.14	8.50	W/ft^2	W
Supply Plenum Cooling Load	6046	4176	W	-
Supply Plenum Cooling Load per Area	1.73	2.78	W/ft^2	-
Zone Cooling Load	4822	8450	W	-
Zone Cooling Load per Area	1.38	5.63	W/ft^2	-
Return Plenum Cooling Load	110	128	W	-
Return Plenum Cooling Load per Area	0.03	0.09	W/ft^2	-

Export as CSV

At the bottom of the Results area is the “Export as CSV” button. Click this, and a window will open containing a text field with the data. This can be copied and pasted into the spreadsheet program of your choice.

The graph section located below the Results contains two temperature profile graphs, one for the interior, and one for the perimeter.

Figure 3: Zone temperature profile charts.



These graphs represent the temperatures at different heights in the room. The points with negative height are temperature points in the plenum. The user can hover over a point on the graph to view the temperature and height values for that point. The point in red is the calculated average temperature in the zone that is intended to meet the design setpoint. If a user wants to capture graphical results as-is, they may take a screenshot. Otherwise the data can be plotted as desired using the tabular output.

INPUT AND OUTPUT DESCRIPTIONS

Table 1 lists and describes the user input data in the order of appearance in the worksheet. The output data are listed and described in Table 2.

Table 1. Description of user inputs for UFAD cooling load design tool

Common Inputs				
Plenum Configuration	Using the drop-down menu, the user may choose among the following four plenum configurations: • "Series" – The conditioned air is first supplied to the plenum of the interior zone from which it flows to the perimeter zone. • "Reverse Series" – The conditioned air is supplied first to the plenum of the perimeter zone (directly from a shaft, duct, or air highway) and then flows to the interior zone. • "Design Interior and Perimeter as Independent Zones" – The conditioned air is supplied independently (different airflow rates and (optionally) different supply temperatures) to the interior and perimeter zones. • "Common" - The conditioned air is supplied to the plenum that is considered well-mixed. The average diffuser discharge temperature is the same in both the interior and perimeter zones.			
Zone Inputs				
Parameter	Zone[1]	*Unit*	*Sym*	*Description*
Room Height	I-P	ft	H_{ft}	Height between the raised floor and the suspended ceiling.
Floor Area	I-P	ft^2	A_f	Floor area of the zone analyzed.
Floor Level	I-P	-	-	Using the drop-down menu, the user may choose among the following three floor levels: • "Ground Fl." – The floor slab is in contact with the ground. • "Middle Fl." – The floor is between other floors. • "Top Floor" – The floor under the roof.
Diffuser Type	I	-	-	Using the drop-down menu, the user may choose among the following

				two diffuser types for interior zones: • "Swirl" – 'Standard' swirl diffusers • "VAV Directional I." – Diffusers that automatically vary the airflow rate and keep the throw height constant
Diffuser Type	P	-	-	Using the drop-down menu, the user may choose among the following two diffuser types for perimeter zones: • "Linear Bar Grille" – Linear bar grille diffusers are used. When this option is chosen the software will ask the user to enter the length of the bar grille. The default value is 18 in. • "VAV Directional P." – Diffusers that automatically vary the airflow rate and keep the throw height constant
Number of diffusers	I-P	-	n	Total number of diffusers for the analyzed zone.
Design Cooling Load Calculated for an Overhead (mixing) System	I-P	kBtu/hr or Btu/(hr ft^2)	W_{OH}	Design cooling load calculated using traditional cooling load software (e.g. ASHRAE RTS method, etc.). This cooling load is the sum of the zone and the return plenum cooling load. The design cooling load for the analyzed zone should be calculated using the assumption of well mixed air. The overhead cooling load should be calculated for the same setpoint temperature used for the UFAD system ("Design Average Temperature in the Occupied Zone - $T_{oz,avg,d}$). The user has the option to input the cooling load in kBtu/hr or Btu/(hr ft^2) by using the drop-down menu in the "Units" column.
Design Average Temperature in the Occupied Zone	I-P	°F	$T_{oz,avg,d}$	Room (or zone) design air temperature setpoint. In an overhead system this is the thermostat temperature setpoint. For a stratified environment, it is the average occupied zone temperature.
Estimated Category 2 Leakage	I-P	cfm/ ft^2	$q_{leak,2}$	Category 2 leakage is defined as uncontrolled air leakage from the pressurized underfloor plenum (through gaps between panels, electrical floor outlets, etc.) that enters the room and can still contribute to the removal of the heat load. For well sealed raised floors (carpet, tape, etc.), a typical range is 0.05-0.1 cfm/ft^2; for not well sealed raised floors, a typical value is ~ 0.25 cfm/ft^2 or greater.
Setpoint Temperature of Air Entering Supply Plenum		°F	T_{plenum}	Temperature of the air entering the supply plenum.
Number of Occupants	I	-	m	Design number of occupants in the interior zone; should be consistent with original overhead load calculations.
Zone Orientation	P	-	-	Using the drop-down menu, the user may choose among the following four zone orientations for perimeter zones:"North", "East", "South" and "West".
Length of the External Wall of the Perimeter Area	P	ft	L^P	Length of the outside wall of the selected perimeter zone.

[1]Zone. I-P = the description is applicable to both interior and perimeter zones; I = the description is applicable only to interior zone; P = the description is applicable only to perimeter zones.

Table 2. Description of output data for UFAD cooling load design tool

Results				
Parameter	*Zone[1]*	*Unit*	*Sym*	*Description*
Airflow (through diffusers)	I -P	cfm	Q	Total room airflow rate delivered by the diffusers only in the studied zone.
Design airflow (through diffusers & leakage)	I -P	cfm	Q_{room}	Total (combined) room airflow rate; sum of airflow rate through the diffusers (Q) and Category 2 leakage.
Temperature of Air Entering Supply Plenum	I -P	°F	T_{plenum}	Temperature of the air entering the supply plenum.
Diffuser Discharge Temperature	I -P	°F	T_s	Temperature of the air entering the room from the diffusers. This temperature is equal to the average temperature of the plenum.
Air Temperature at 4 in. Height	I -P	°F	T_4	Air temperature at 4 in. (ankle height).

Setpoint Air Temperature (at 48 in.)	I -P	°F	T_{set}	Thermostat setpoint temperature. This temperature is different from the average temperature in the occupied zone. This is the temperature that has to be set at the thermostat to obtain $T_{oz,avg}$ in a thermally stratified environment.
Air Temperature at 67 in. Height	I -P	°F	T_{67}	Air temperature at 67 in. (head height for a standing person).
Return Air Temperature	I -P	°F	T_R	Temperature exiting the room at ceiling height and entering the return plenum.
Return Plenum Air Temperature	I -P	°F	T_{RP}	Temperature exiting the zone return plenum. This is not the air temperature going to the AHU. The return plenum air temperatures for the different zones on a given floor have to be properly weighted (depending on airflow rates) to calculate the average air temperature returning to the AHU from that floor. This calculation is not performed in the design tool.
Average Temperature in the Occupied Zone	I -P	°F	$T_{oz,avg}$	Average temperature in the occupied zone. The design tool determines the airflow rate that, for the given boundary conditions, makes $T_{oz,avg} = T_{oz,avg,d}$. We believe that this temperature is closer to the one perceived by people in a thermally stratified environment, as opposed to the setpoint temperature at the thermostat height of 48 in. (1.2 m).
Temperature difference between the head and the ankle (from 67 in. to 4 in.)	I -P	°F	ΔT_{oz}	Air temperature difference between head (67 in.) and ankle (4 in.) heights of a standing occupant. According to ASHRAE 55-2004, the maximum allowable temperature difference between head and ankle is 5.4°F (3°C). If the temperature difference is higher than 5.4°F a red circle appears next to the number, if it is lower than 5.4°F a green circle appears, and if it is equal a yellow circle appears.
Airflow (through diffusers)	I -P	cfm/ ft^2	Q	Airflow rate through the diffusers expressed in cfm/ft^2.
Airflow per diffuser	I -P	cfm/ diff.	Q	Airflow rate per diffuser. In the design condition this value should be equal to or less than the value recommended by the diffuser vendor.
Design airflow (through diffusers & leakage)	I -P	cfm/ ft^2	Q_{room}	Total (combined) room airflow rate (Q_{room}) expressed in cfm/ft^2.
Design Cooling Load Calculated for an Overhead (mixing) System	I -P	W	W_{OH}	Design cooling load calculated for an overhead (mixing) system expressed in W.
UFAD Cooling Load Ratio (UCLR)	I -P		UCLR	The UFAD Cooling Load Ratio (UCLR) is the ratio of the cooling load calculated for UFAD to the cooling load calculated for a well mixed system (e.g. Overhead or mixing ventilation).
Supply Plenum Fraction (SPF)	I -P	-	SPF	The Supply Plenum Fraction (SPF) is the ratio of the cooling load removed in the supply plenum to the total UFAD cooling load.
Zone Fraction (ZF)	I -P	-	ZF	The Zone Fraction (ZF) is the ratio of the cooling load removed in the zone (room) to the total UFAD cooling load.
Return Plenum Fraction (RPF)	I -P	-	RPF	The Return Plenum Fraction (RPF) is the ratio of the cooling load removed in the return plenum to the total UFAD cooling load.
UFAD Cooling Load	I -P	W	W	Design cooling load that the UFAD system has to remove.
UFAD Cooling Load	I -P	W/ft^2	W	Same as above, but expressed in W/ft^2.
Supply Plenum Cooling Load	I -P	W	-	Cooling load in the supply plenum.
Supply Plenum Cooling Load	I -P	W/ft^2	-	Same as above, but expressed in W/ft^2.
Zone Cooling Load	I -P	W	-	Cooling load in the zone (room).
Zone Cooling Load	I -P	W/ft^2	-	Same as above, but expressed in W/ft^2.
Return Plenum Cooling Load	I -P	W	-	Cooling load in the return plenum.
Return Plenum Cooling Load	I -P	W/ft^2	-	Same as above, but expressed in W/ft^2.

Length of the Linear Bar Grill	P	In.	-	Length of the Linear Bar Grille in inches. The value is input in a pop-up box when in the “Linear Bar Grille” option is selected in "Diffuser Type" input field for the perimeter zone. The default value is 18 in.

[1]Zone. I-P = the description is applicable to both interior and perimeter zones; I = the description is applicable only to interior zone; P = the description is applicable only to perimeter zones.