TECHNICAL FEATURE

Load Calculation Spreadsheets

Quick Answers Without Relying on Rules of Thumb

By Steven F. Bruning, P.E., Fellow ASHRAE

Most HVAC design engineers use an array of sophisticated software calculation and modeling tools for load calculations and energy analysis. These tools offer almost total flexibility for the engineer to define physical arrangement, thermal parameters, operating schedules, internal loads and zoning. To achieve that flexibility, the input parameters are extensive and time consuming.

Especially in the early stages of a project, a large number of load assumptions must be made. Because the schedule is usually tight, using sophisticated modeling tools appropriate for detailed design can be problematic. Experienced designers often fall back on their historical assumptions of cfm/ft^2 or ft^2/ton or heating Btu/ft^2 to provide initial design and budget input.

An alternative approach to traditional rules of thumb is the use of simplified input spreadsheets. These have proven quick and easy to use for early concept and helpful in evaluating impact of assumptions vs. rules of thumb (which may not be valid with new trends in code and agency requirements).

Basic Load Calculation Spreadsheets

A new cooling load calculation technique was introduced by ASHRAE Technical Committee (TC) 4.1, *Load Calculation Data and Procedures*, in *2001 ASHRAE Handbook—Fundamentals*. This method, radiant time series (RTS), effectively merged all previous "simplified" load calculation methods (TETD-TA, CLTD-CLF and transfer function). The RTS method and data were derived from fundamen-

About the Author

Steven F. Bruning, P.E., is a partner with Newcomb & Boyd, a consulting engineering firm in Atlanta. He is a past chairman of TC 4.1, Load Calculation Data and Procedures and is the TC 4.1 Handbook subcommittee chair.

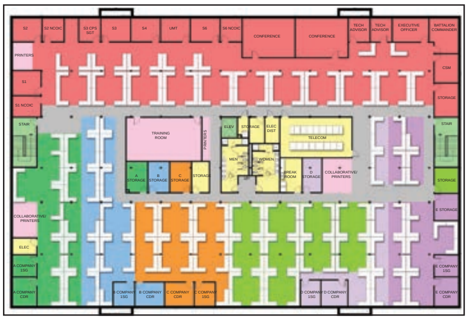

Figure 1 (above): Floor plan for example building used in the RTS calculation spreadsheet in *Figure 2*.

Figure 2 (right): Example RTS load calculation spreadsheet shows block load for a modular office building. The data took about 10 minutes to input.

2009 ASHRAE FUNDAMENTALS EXAMPLE-IP UNITS						rev 2009.05.25		28-Nov-11
	Burdell Engineering Associates							George P. Burdell, P.E.
11N202	Modular Office Building							Baltimore, MD
ROOM NO./NAME:		100	Modular Office Block Load					
	Length:	204	feet				Infiltration cfm	
	Width:	280	feet	Area	57120	sq. feet	Cooling:	Heating:
	Ceiling Height:	9	feet	Volume	514080	cubic feet	1000	2000
INTERNAL LOADS:			Btuh/person:	Lighting,	Equipment,	Inside Design Conditions:		
		# People:	Sensible:	watts:	watts:	Cooling:	DB, F	75
	Over-ride Room Input:	0	250	0	0		RH	50%
	Default:	408	Latent:	62832	171360	Heating:	DB, F	72
	Use:	408	200	62832	171360	Outside Cooling Weather:		
EXPOSURES:		North	South	East	West	USA - MD - BALTIMORE BLT-WASHNGTN INT'L - 5%		
	Nominal Azimuth:	-180	0	-90	90	Heating 99.6%, F:		12.9
	Actual Azimuth:	-180	0	-90	90	Supply	Cooling, F	57
	Tilt:	90	90	90	90	Air:	Heating, F	100
	Type 1 Wall Area, sf:	5712	5712	3920	3920	Frame with EIFS		
	Type 2 Wall Area, sf:	0	0	0	0	Frame with EIFS		
	No. Type 1 Windows:	0	0	0	0	Dbl glazed, low-E, bronze		
	No. Type 2 Windows:	0	0	0	0	Dbl glz, low-E, brnz		
	Roof Area, sf:	28560	0%	= Roof % to RA		0%	= Lights % to RA	
ROOM LOADS:		Peak Rm.Sens. Occurs:			Room	Ret. Air	Room	Room
		Month:	7	Per Unit	Sensible	Sensible	Latent	Sensible
		Hour:	18	Cooling	Cooling:	Cooling:	Cooling	Heating:
INTERNAL LOADS:			No. People:	Btuh/pers	Btuh	Btuh	Btuh	Btuh
		People:	408	247	100,776		81,600	
			watts:	Btuh/room sf				
		Lighting:	62,832	3.7	212,200			
		Lightiing % to RA:	0%	0.0		-		
		Equipment:	171,360	10.2	580,832			
ENVELOPE LOADS:								
			Roof Area,sf	Btuh/roof sf				
ROOF:	0.05	U factor	28,560	1.2	35,544			84,395
		Roof % to RA:	0%			-		
WALLS:			Wall Area,sf	Btuh/wall sf				
	Wall Type 1:	Frame with EIFS						
0.08	U factor	North	5712	1.8	10,037			27,006
		South	5712	2.2	12,289			27,006
		East	3920	1.8	7,161			18,534
		West	3920	3.3	12,827			18,534
	Wall Type 2	Frame with EIFS						
0.08	U factor	North	0	0.0	-			-
		South	0	0.0	-			-
		East	0	0.0	-			-
		West	0	0.0	-			-
WINDOWS:			Window Area,sf:	Btuh/win sf				
	Window Type 1:	Dbl glazed, low-E, bronze						
1	sf/window	North	0	0.0	-			-
29%	SHGF(0)	South	0	0.0	-			-
0.46	U factor	East	0	0.0	-			-
74%	IAC	West	0	0.0	-			-
	Window Type 2:	Dbl glz, low-E, brnz						
1	sf/window	North	0	0.0	-			-
29%	SHGF(0)	South	0	0.0	-			-
0.46	U factor	East	0	0.0	-			-
74%	IAC	West	0	0.0	-			-
INFILTRATION LOADS:			cfm	Btuh/cfm				
		Cooling, Sensible:	1000	12.5	12,540			
		Cooling, Latent:	1000	24.8			24,813	
		Heating:	2000	65.0				130,020
					=====	=====	=====	=====
				ROOM LOAD TOTALS =	984,206	-	106,413	305,495
				COOLING CFM =	49,707	HEATING CFM =		9,919
				CFM/SF =	0.9			
BLOCK LOADS:		TOTAL ROOM SENS+RA+LATENT =			1,074,790		ROOM HTG:	305,495
Peak Block Load Occurs:		OUTSIDE AIR:		OA Sensible:	231,000		OA Heating:	812,625
Month:	7	OA cfm =	12500	OA Latent:	331,979			=====
Hour:	15	FAN HEAT:	50	HP to S. Air:	127,305		TOT HEATING,btuh=	1,118,120
		PUMP HEAT:	0	HP to CHW:	-		Heating btuh/sf =	19.6
					=====	tons	sf/ton	
		TOTAL BLOCK COOLING LOAD, btuh -			1,765,074	147.1	388	

tal heat balance calculations while maintaining simple concepts and component-by-component results. The new method was the result of years of ASHRAE research projects.

In 2003, TC 4.1 was asked by the ASHRAE Technical Activities Committee (umbrella group over all TCs) to develop a real-world building example load calculation for *ASHRAE Handbook*. The ASHRAE headquarters building, (two stories, 30,000 ft^2 [2787 m^2]) was chosen as representative of many commercial office buildings.

To prepare that example, a series of demonstration RTS calculation spreadsheets were used. The spreadsheets were updated to incorporate results of additional ASHRAE research projects (new weather data, clear sky solar models, interior shading models, lighting heat to return air, etc.) for the *2009 Fundamentals*. The *2013 Fundamentals* example will be updated to incorporate the new addition and renovation of the ASHRAE headquarters building.

Those example RTS spreadsheets ("Radiant Time Series Method Load Calculation Spreadsheets" from the ASHRAE bookstore) are limited in function and are intended for educational purposes, but not to be used for full-blown commercial load calculations. While the procedures, techniques and data included in the spreadsheets are state-of-the-art, they would be impossibly cumbersome for use in typical projects involving hundreds or thousands of spaces. However, sometimes a quick analysis using the spreadsheets saves time, and the following are a few examples.

Quick Block Load Comparisons

At the earliest stage of a project, a quick block load calculation can be useful for defining mechanical spaces and cost modeling. This has been especially useful in the pricing phase of design-build competitions.

Figure 1 is a floor plan issued in an RFP. *Figure 2* is the RTS spreadsheet block load for this two-story building, which took about 10 minutes to input. What was unusual about this RFP is the building was to be constructed of modular units that could be disassembled and shipped to installations all over the

Figure 3: Block loads for a secure building in 14 locations.

Location	No Windows						with 40% Windows					
	supply cfm	cfm/gsf	Cooling tons	gsf/ton	Heating 1000/Btuh	btu/gsf	supply cfm	cfm/gsf	Cooling tons	gsf/ton	Heating 1000/Btuh	btu/gsf
Baltimore, MD	49,707	0.87	147	388	1,118	19.6	57,438	1.01	163	350	1,291	22.6
Bangkok, Thailand	50,730	0.89	175	326	108	1.9	59,060	1.03	192	297	125	2.2
Colorado Springs, CO	47,667	0.83	110	519	1,375	24.1	55,871	0.98	125	456	1,588	27.8
Darwin, Austrailia	50,210	0.88	170	337	161	2.8	57,979	1.02	184	311	186	3.3
El Paso, TX	51,009	0.89	125	456	935	16.4	60,038	1.05	144	397	1,079	18.9
Fairbanks, AK	46,759	0.82	96	597	2,181	38.2	53,384	0.93	110	517	2,519	44.1
Frankfurt, Germany	48,013	0.84	107	534	1,116	19.5	55,002	0.96	122	467	1,289	22.6
Honolulu, HI	49,479	0.87	143	401	204	3.6	56,698	0.99	158	362	236	4.1
Key West, FL	49,855	0.87	168	339	324	5.7	56,810	0.99	183	312	374	6.5
Kuwait City, Kuwait	54,416	0.95	151	377	617	10.8	66,594	1.17	175	327	712	12.5
Naples, Italy	49,431	0.87	144	398	689	12.1	57,138	1.00	160	357	795	13.9
Seattle, WA	47,324	0.83	101	567	899	15.7	53,268	0.93	114	501	1,038	18.2
Seoul, Korea	49,406	0.86	159	360	1,260	22.1	57,244	1.00	175	326	1,455	25.5
Tashkent, Uzbekistan	50,773	0.89	127	452	1,076	18.8	59,948	1.05	145	393	1,243	21.8

Figure 4 (left): Typical floor plan for military barracks project. **Figure 5 (right):** Site plan for military barracks project.

world. What impact would different climates have on the heating and cooling loads?

Design weather data for the 5,564 worldwide locations included in the *2009 ASHRAE Handbook—Fundamentals CD+* is embedded in the RTS spreadsheet and selected with a simple drop-down menu. So, in another 20 minutes, block loads were identified for 14 locations (*Figure 3*). This particular building is a secure facility with no windows, so variations due to climate were mostly due to outside air conditions.

For curiosity's sake, the same block loads were run for a building with 40% glass (*Figure 3*). This was quick because the spreadsheet includes the tabulated fenestration solar heat gain coefficient data from Chapter 15 of the *2009 ASHRAE Handbook—Fundamentals* selected in a simple drop-down box.

Orientation	supply cfm	cfm/gsf	Cooling tons	gsf/ton
0	14,553	0.55	52.4	508
15	14,816	0.56	52.9	503
30	15,149	0.57	53.4	498
45	15,539	0.58	53.7	495
60	15,839	0.60	54.1	492
75	16,018	0.60	54.2	491
90	16,068	0.60	54.2	491

Figure 6: This shows the difference orientation makes in load for the military barracks project.

Another useful quick evaluation is multiple identical buildings with different orientations on the same site. While the ASHRAE spreadsheet only includes four orientations (NSEW), it does include an orientation correction factor that effectively allows quick "rotation" of those orientations.

Figure 4 is a typical floor plan, and *Figure 5* is a site plan for a multiple barracks project. How much difference did the various orientations make in the building block load? *Figure 6* includes the results. In this case, this 10-minute exercise confirmed impact on peak due to orientation for this location and particular building type.

Using Spreadsheets for Zone Load Model

While the RTS spreadsheets are useful for simple block load calculations, with a little front-end effort, the ASHRAE RTS Example spreadsheets can provide a tool useful in evaluating peak loads for each perimeter zone vs. block loads for each floor and the building as a whole. Again, at the early concept stage of a project, this is useful, particularly for design-build competitions and space allocation input.

Many buildings boil down to mostly rectangular floor plans of one or more stories. In most cases, cooling and heating loads are broken into interior and perimeter zones. Using the ASHRAE RTS Example worksheets, a simple model with eight perimeter zones and one interior zone per floor can be assembled. A master input worksheet links dimensional data to the individual zone worksheets, and their results link back to a single-page summary. For buildings that fit within a simple rectangular concept, this provides a tool

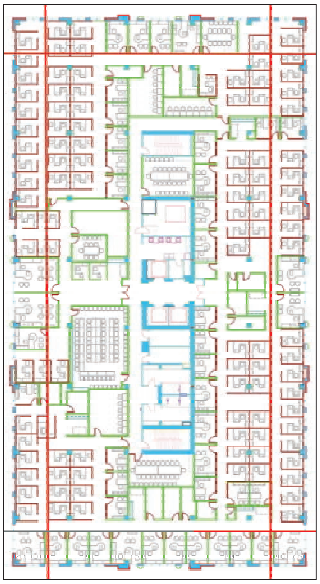

Figure 7: Floor plan from a design-build project.

RTS COOLING LOAD CALCULATIONS			BLOCK ZONE INPUT DATA			November 28, 2011
2009 ASHRAE FUNDAMENTALS EXAMPLE-IP UNITS			rev 2011.11.13		Page:	1
IDENTIFICATION:		Design Firm:	Burdell Engineering Associates			
		Project Engineer:	George P. Burdell, P.E.			
		Project Name:	Headquarters Addition			
		Project Location:	USA - GA - COLUMBUS METROPOLITAN ARPT - 5%			
		Project Number:	09N240			
Floor Plate Size:		INTERNAL LOADS		WALL		
N side, ft	250	sf per person:		Input Actual "U" :	0.05	
E side, ft.	134	People:	100	Absorbtance:	0.45	
	degrees		Brick, R-5 Insulation Board, Sheathing, R-11 Batt Insulation, Gyp Board			
Rotation:	0	watts per sf:		Wall #:	13	
# Stories	4	Lighting:	1.1		ROOF	AHU FAN HEAT
Perimeter	Depth, ft	% to RA:	26%	Input Actual "U" :	0.04	hp/1000 cfm
Zone:	15			Absorbtance:	0.45	1.0
Unconditioned Core:		watts per sf:		% to RA:	30%	
% Interior	15%	Plug Load:	3	Membrane, Sheathing, R-15 Insulation Board, Metal Deck		
Floor to	Height, ft			Roof #:	11	
Floor:	14	OUTSIDE AIR			WINDOW	BUILDING PUMP HEAT
Ceiling:	9	cfm/pers:	10	SHGC (0) =	22%	hp/ton
Percent of Below Clg:		+ cfm/sf	0.1	Input Actual "U" :	0.39	0.1
% Glazing:	20%					

Figure 8: The front-end input required for the RTS spreadsheet for the design-build project.

RTS COOLING LOAD CALCULATIONS				BLOCK ZONE INPUT DATA			November 28, 2011	
2009 ASHRAE FUNDAMENTALS EXAMPLE-IP UNITS					rev 2011.11.13		Page:	1
IDENTIFICATION:		Design Firm:	Burdell Engineering Associates					
		Project Engineer:	George P. Burdell, P.E.					
		Project Name:	Headquarters Addition					
		Project Location:	USA - GA - COLUMBUS METROPOLITAN ARPT - 5%					
		Project Number:	09N240					
ZONE	Area,sf	Peak Month	Peak Hour	Cooling cfm	Cooling cfm/sf	Room heating		
North Perimeter-Top floor	3,300	7	15	3,104	0.94	19,728		
South Perimeter- Top Floor	3,300	9	14	3,301	1.00	19,728		
East Perimeter-Top Floor	1,560	7	15	1,507	0.97	9,326		
West Perimeter-Top Floor	1,560	7	17	1,673	1.07	9,326		
NW corner-Top Floor	225	7	17	267	1.19	2,268		
NE Corner-Top Floor	225	7	15	245	1.09	2,268		
SE Corner-Top Floor	225	8	14	254	1.13	2,268		
SW Corner-Top Floor	225	8	16	271	1.21	2,268		
Interior-Top Floor	19,448	7	16	15,950	0.82	36,484		
		Sum of Zone cfm =		26,571			OA cfm	Tons
Top Floor AHU	30,068	7	16	26,376	0.88	103,665	6014	81.8
				99%		413,906	=Htg w OA	367
						14	=Htg btu/sf	sf/ton
North Perimeter-Typ floor	3,300	7	16	2,881	0.87	13,537		
South Perimeter- Typ Floor	3,300	10	14	3,166	0.96	13,537		
East Perimeter-Typ Floor	1,560	7	10	1,469	0.94	6,399		
West Perimeter-Typ Floor	1,560	7	17	1,579	1.01	6,399		
NW corner-Typ Floor	225	7	17	254	1.13	1,846		
NE Corner-Typ Floor	225	7	11	230	1.02	1,846		
SE Corner-Typ Floor	225	8	14	240	1.07	1,846		
SW Corner-Typ Floor	225	8	16	257	1.14	1,846		
Interior-Typ Floor	19,448	1	18	14,766	0.76	-		
		Sum of Zone cfm =		24,841			OA cfm	Tons
Typ Floor AHU	30,068	7	17	24,405	0.81	47,257	6014	76.6
				98%		357,499	=Htg w OA	393
						12	=Htg btu/sf	sf/ton
							OA cfm	Tons
Building Block Load	120,272	7	16	99,477	0.83	245,436	24054	318.1
						1,486,403	=Htg w OA	378
						12	=Htg btu/sf	sf/ton

Figure 9: RTS spreadsheet results for design-build project.

to quickly assess zone and overall cooling and heating loads.

As an example, *Figure 7* is a floor plan from a design-build RFP with perimeter, corner and interior zones overlaid. *Figure 8* is the front-end input required for the spreadsheet and the results are in *Figure 9*. When the impact of increasing glazing from 20% to 50% was questioned, a single input was changed and total supply air increased 8% and total cooling 4.5% to 333 tons (1171 kW), a quick way to accurately respond to a client's questions.

Rules of Thumb

Most engineers develop a feel for building cooling and heating capacity over years of practice, forming rules of thumb: "400/ft^2 per ton," "1 cfm/ft^2," and "25 Btu/h·ft^2" heating. These rules have been fairly common for office buildings in some parts of the country. Two ASHRAE Standards: 90.1 and 62.1, have had a tremendous impact on the building industry over the past 30 years. But what kind of impact have they had on our rules of thumb?

Figure 10 is a compilation of criteria from Standards 90.1 and 62.1 over the years that impact peak heating and cooling loads. Likewise, plug load trends went up during the 1980s and 1990s, but have begun to reduce due to more

	Window	Window	Window	Wall	Roof	People	OA	OA	Lights	Plug	supply	Cooling	Heating
Time Frame	%	U	SHGC	U	U	sf/pers	cfm/pers	cfm/sf	w/sf	w/sf	cfm/sf	sf/ton	Btuh/sf
Common 1980	51%	0.8	0.6	0.150	0.100	100	15	0	3	1	1.07	311	19
1989	51%	0.45	0.45	0.130	0.072	143	20	0	1.57	2	0.98	380	14
1999	39%	0.45	0.29	0.124	0.063	143	20	0	1.3	2	0.81	436	13
2010	39%	0.65	0.24	0.084	0.048	200	5	0.06	0.9	1	0.53	671	11

Figure 10: A look back at criteria from Standards 90.1 and 62.1 that impact peak heating and cooling loads.

efficient desktop and laptop computers and use of LCD monitors. The RTS spreadsheets were used for block loads for a common suburban office building (five stories, 25,000 ft^2 [2323 m^2] per floor in Atlanta) with these parameters with results in *Figure 10*. The impact on overall block loads and resulting rules of thumb has been significant over the past 30 years.

Conclusions

Today's complex buildings require sophisticated load calculation software to account for the myriad variations in exposures, construction, zoning, load densities and occupancy.

However, there are cases where a simple load calculation spreadsheet can be a time-saving, useful tool. This is especially true in early concept stages for architectural planning input, sizing of equipment spaces, shafts, etc. Simple block loads are also especially helpful in developing cost models in competition phases of design-build projects or for evaluating parameters such as location and orientation.

Likewise, comparative studies of impact of trends due to standards (such as 90.1 and 62.1) or assumptions (plug loads) can be readily evaluated with a simple spreadsheet without investing the time and energy required for a full-blown commercial software calculation. The spreadsheets can illustrate impacts of individual components relative to the overall total loads, sometimes lost with more complex tools.■

Advertisement formerly in this space.