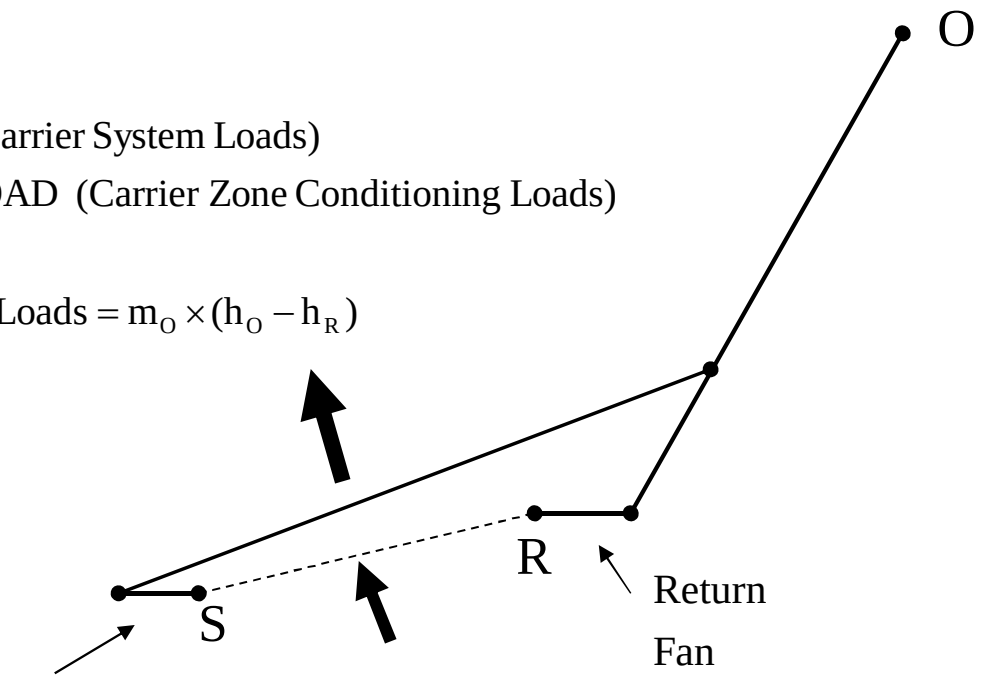
COIL LOAD (Carrier System Loads)

COOLING LOAD (Carrier Zone Conditioning Loads)

+ Fan Power

+ Ventilation Loads = $m_O \times (h_O - h_R)$



HEAT GAIN - into the zone

Unsteady Conduction Convection Radiation

walls, windows, roof, floor, doors

People

Lights

Equipment

Infiltration - cfm or ACH

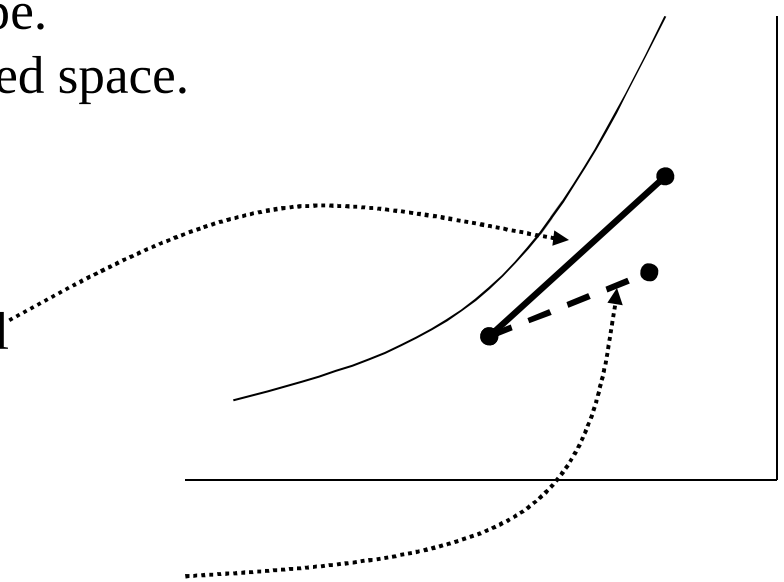
COOLING LOAD - into the air

(Carrier Zone Load)

(with adjustments Carrier Zone Conditioning Loads)

HEAT GAIN

- Sensible and latent heat into the conditioned space air.
  Heat load of the exterior envelope.
  Heat generation in the conditioned space.



COIL LOAD

- heat removed from the cooling coil
- cooling load plus ventilation air

COOLING LOAD

- heat removed from the conditioned space air.

Design Conditions Section 8.4 page 221

Typically outside temperatures are assumed to vary sinusoidally

$$T_{outside} = T_{design} - \text{Range} \times (\text{Table } 8-1) \qquad (8-2)$$

T_{design} (DB) and Range - AppendixB – 1a

Chicago

% year	hrs/yr	DB	Range
> .4%	35.0	91	
> 1%	87.6	88	19.6
> 2%	175.2	86	

$$T_{outside} = 91. - 19.6 \times (\text{Table } 8-1 \text{ values, } 0\% \text{ to } 100\%)$$

Table B-1a Heating and Cooling Design Conditions—United States, Canada, and the World—English Units

Station	Lat., deg	Long., deg	Elev., ft.	Heating DB,F 99.6%	Heating DB,F 99%	MWS/MWD to DB 99.6% MWS, mph	MWS/MWD to DB 99.6% MWD, deg	MWS/MWD to DB 0.4% MWS, mph	MWS/MWD to DB 0.4% MWD, deg	Cooling DB/MWB 0.4% DB, F	Cooling DB/MWB 0.4% MWB, F	Cooling DB/MWB 1% DB, F	Cooling DB/MWB 1% MWB, F	Cooling DB/MWB 2% DB, F	Cooling DB/MWB 2% MWB, F	WB/MDB 1% WB, F	WB/MDB 1% MDB, F	HR 1% HR, gr	Range of DB, F
United States																			
Alabama, Birmingham	33.57	86.75	630	18	23	7	340	9	320	94	75	92	75	90	74	77	88	131	18.7
Alaska, Anchorage	61.17	150.02	131	−14	−9	4	10	8	290	71	59	68	57	65	56	58	66	64	12.6
Arizona, Tucson	32.12	110.93	2556	31	34	7	140	12	300	104	65	102	65	100	65	71	87	111	29.4
Arkansas, Little Rock	34.92	92.15	312	16	21	9	360	9	200	97	77	95	77	92	76	79	91	137	19.5
California, San Francisco	37.62	122.38	16	37	39	5	160	13	300	83	63	78	62	74	61	63	75	73	16.7
Colorado, Denver	39.75	104.87	5331	−3	3	6	180	9	160	93	60	90	59	87	59	63	80	90	26.9
Connecticut, Bridgeport	41.17	73.13	16	8	12	14	320	14	230	86	73	84	72	82	71	74	81	120	14.1
Delaware, Wilmington	39.68	75.60	79	10	14	11	290	11	240	91	75	89	74	86	73	76	85	125	17.0
Florida, Orlando	28.43	81.32	105	37	42	8	330	9	290	94	76	93	76	92	76	79	88	139	16.6
Georgia, Atlanta	33.65	84.42	1033	18	23	12	320	9	300	93	75	91	74	88	73	76	87	128	17.3
Hawaii, Honolulu	21.35	157.93	16	61	63	5	320	15	60	89	73	88	73	87	73	75	84	120	12.2
Idaho, Boise	43.57	116.22	2867	2	9	6	130	11	320	96	63	94	63	91	62	64	89	72	30.3
Illinois, Chicago	41.98	87.90	673	−6	−1	10	270	12	230	91	74	88	73	86	71	75	85	123	19.6
Indiana, Indianapolis																			

hourly outdoor temperature is given by

$$t_o = t_d - \mathrm{DR(X)} \qquad (8\text{-}2)$$

where:

t_d = design dry bulb temperature, F or C
DR = daily range, F or C
X = percentage of daily range, from Table 8-1, divided by 100

Table 8-1 Percentage of the Daily Range

Time, hr	Percent	Time, hr	Percent	Time, hr	Percent	Time, hr	Percent
1	87	7	93	13	11	19	34
2	92	8	84	14	3	20	47
3	96	9	71	15	0	21	58
4	99	10	56	16	3	22	68
5	100	11	39	17	10	23	76
6	98	12	23	18	21	24	82

Source: Reprinted by permission from *ASHRAE Cooling and Heating Load Calculation Manual*, 2nd ed., 1992.

Table 8-2 Rates of Heat Gain from Occupants of Conditioned Spaces[a]

Degree of Activity	Typical Application	Total Heat Adults, Male		Total Heat Adjusted[b]		Sensible Heat		Latent Heat	
		Btu/hr	W	Btu/hr	W	Btu/hr	W	Btu/hr	W
Seated at theater	Theater—matinee	390	114	330	97	225	66	105	31
Seated at theater	Theater—evening	390	114	350	103	245	72	105	31
Seated, very light work	Offices, hotels, apartments	450	132	400	117	245	72	155	45
Moderately active office work	Offices, hotels, apartments	475	139	450	132	250	73	200	59
Standing, light work; walking	Department store, retail store	550	162	450	132	250	73	200	59
Walking; standing	Drugstore, bank	550	162	500	146	250	73	250	73
Sedentary work[c]	Restaurant	490	144	550	162	275	81	275	81
Light bench work	Factory	800	235	750	220	275	81	475	139
Moderate dancing	Dance hall	900	264	850	249	305	89	545	160
Walking 3 mph; light machine work	Factory	1000	293	1000	293	375	110	625	183
Bowling[d]	Bowling alley	1500	440	1450	425	580	170	870	255
Heavy work	Factory	1500	440	1450	425	580	170	870	255
Heavy machine work; lifting	Factory	1600	469	1600	469	635	186	965	283
Athletics	Gymnasium	2000	586	1800	528	710	208	1090	320

[a]Tabulated values are based on 75 F room dry bulb temperature. For 80 F room dry bulb, the total heat remains the same, but the sensible heat values should be decreased by approximately 20 percent, and the latent heat values increased accordingly.

[b]*Adjusted heat gain* is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85 percent of that for an adult male, and that the gain from a child is 75 percent of that for an adult male.

[c]Adjusted total gain for *sedentary work, restaurant*, includes 60 Btu/hr for food per individual (30 Btu/hr sensible and 30 Btu/hr latent).

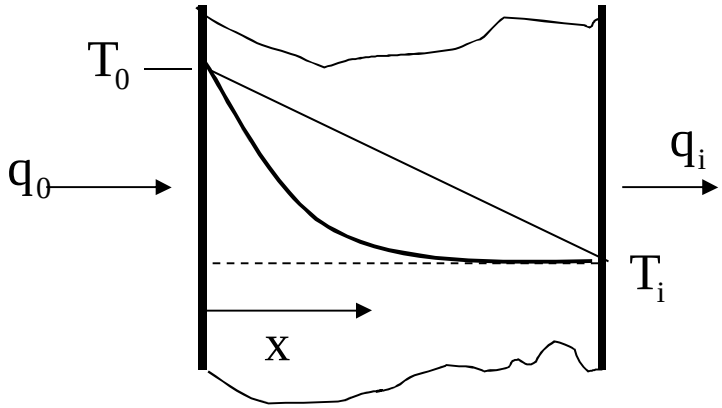
[d]For *bowling*, figure one person per alley actually bowling, and all others sitting (400 Btu/hr) or standing and walking slowly (550 Btu/hr).

Source: Reprinted by permission from *ASHRAE Cooling and Heating Load Calculation Manual*, 2nd ed., 1992.

Thick Wall, Step Temperature Change

Heat absorbed by wall $q_0 - q_i = A\,dx\,\rho\,c_p\,\frac{\partial T}{\partial t}$

Heat into the wall $q_0 - q_i = \left(\frac{\partial q}{\partial x}\right) dx$



$$q = -kA\frac{\partial T}{dx}$$

$$\frac{\partial q}{\partial x} = -k\,A\frac{\partial^2 T}{\partial x^2}$$

$$q_i - q_0 = -k\,A\frac{\partial^2 T}{\partial x^2}\,dx$$

$$A\,dx\,\rho\,c_p\frac{\partial T}{\partial t} = k\,A\frac{\partial^2 T}{\partial x^2}\,dx$$

$$\frac{\partial T}{\partial t} = \frac{k}{\rho\,C_p}\frac{\partial T^2}{\partial x^2}$$

T_i constant with time

T_0 = constant with time

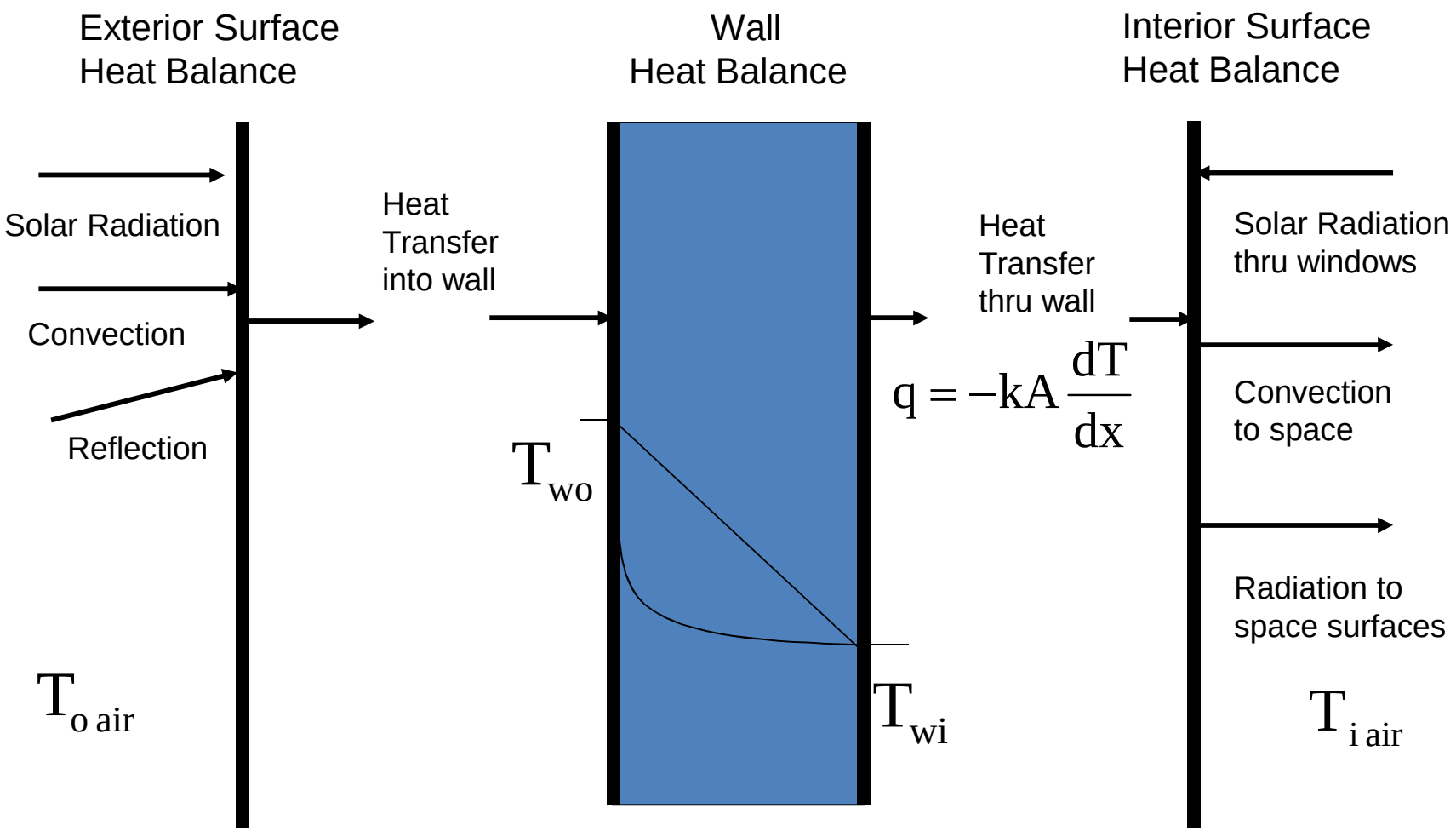
T(x) = constant at time t = 0

$$\frac{T - T_i}{T_0 - T_i} = \text{Gauss Error Function}\left(\frac{x}{2\sqrt{\frac{k}{\rho\,C_p}\,t}}\right)$$

$$\text{Gauss Error Function(t)} = \frac{2}{\sqrt{\pi}}\int_0^t e^{-x^2}\,dx$$

Heat Balance Method

$q_{\text{location, j th surface, d time}}$



$$q_{in} = \alpha E_{wall} + q_{out}$$

$$q_{in} = (mc_p \Delta T)_{wall} + q_{out}$$

No Mass Wall Heat Balance

Incident Solar Radiation 280 BTU/hrft^2

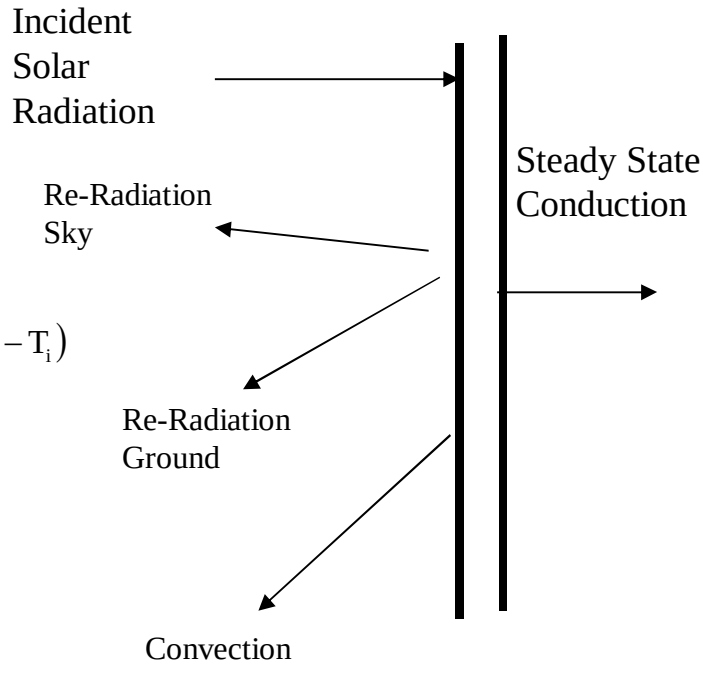
Outside 90^O F, Inside 70^O F

Solar Absorption .8

Wall Emmission .9

$U = .2$ BTU/ft^{2}hr^{O}F

$h = 3$ BTU/ft^{2}hr^{O}F



$$Q_{incident} = Q_{convection} + Q_{\substack{reradiation \\ sky}} + Q_{\substack{reradiation \\ ground}} + Q_{conduction}$$

$$Q_{incident} = hA(T_w - T_O) + \sigma F_{ws}(T_w^4 - T_{sky\,df}^4) + \sigma F_{wg}(T_w^4 - T_{ground\,df}^4) + UA(T_w - T_i)$$

$$T_{sky} = T_{db} - 10.8 = 78.2$$

$$T_{sky\,df} = (\cos(\alpha/2))T_{sky} + (1 - \cos(\alpha/22))T_O \quad (8-25)$$

$$T_{sky\,df} = (\cos(90/2))78.2 + (1 - \cos(90/2))90$$

$$T_{sky\,df} = .707 \times 79.2 + .293 \times 90 = 82.36$$

$$T_{sky\,df} = 82.36 + 460. = 542.36^O R$$

$$T_{ground} = T_o = 90$$

$$F_{ws} = (1 + \cos\beta)/2 = (1 + \cos 90)/2 = .5 \quad (7-20)$$

$$F_{wg} = (1 - \cos\beta)/2 = (1 - \cos 90)/2 = .5 \quad (7-24)$$

$$280 \times .8 = 3(T_w - 550) + .9 \times .1714 \times .5 \times (T_w^4 \times 10^{-8} - 865.5) + .9 \times .1714 \times .5 \times (T_w^4 \times 10^{-8} - 915.1) + .2(T_w - 530)$$

at $T_w = 140^O$ F, 600^O R

$$224 = 3 \times 49 + .07713(1296. - 865.5) + .07713(1296. - 915.15) + .2 \times 69$$

$$224 = \underset{\text{convection}}{150.} + \underset{\text{reradiation}}{32.2} + \underset{\text{conduction}}{29.38} + 14$$

$$224 = 226$$

Z TRANSFORM METHOD

$$\frac{\partial T(x,t)}{\partial t} = \frac{k}{\rho C_p}\frac{\partial T(x,t)^2}{\partial x^2}$$

$$q = -kA\frac{\partial T(x,t)}{\partial x} \qquad \text{boundary conditions}$$

Numerical solution with X_n, Y_n and Z_n constants.

Inside and outside heat loads of the series form,

$$q_{\substack{\text{outside}\\ \text{surface}}} = -Y_O T_i + \sum_{n=1}^{Ny} Y_n T_{i\delta-n\Delta\delta} + X_O T_o + \sum_{n=1}^{Nx} X_n T_{i\delta-n\Delta\delta} + \sum_{n=1}^{Nq} \Phi_n q_{\delta-nq\rho} \quad (8-6)$$

$$q_{\substack{\text{intside}\\ \text{surface}}} = -Z_O T_i - \sum_{n=1}^{Nz} Z_n T_{i\delta-n\Delta\delta} + Y_O T_o + \sum_{n=1}^{Ny} Y_n T_{i\delta-n\Delta\delta} + \sum_{n-1}^{Nq} \bar{u}_n q_{\delta-nq\theta} \quad (8-7)$$

Z TRANSFORM METHOD

$$q_{\substack{\text{outside}\\ \text{surface}}} = -Y_O T_i + \sum_{n=1}^{Ny} Y_n T_{i,d\text{-}n\Delta d} + X_O T_o + \sum_{n=1}^{Nx} X_n T_{i,d\text{-}n\Delta d} + \sum_{n=1}^{Nq} \Phi_n q_{d\text{-}nqp} \quad (8-6)$$

$$q_{\substack{\text{intside}\\ \text{surface}}} = -Z_O T_i - \sum_{n=1}^{Nz} Z_n T_{i,d\text{-}n\Delta d} + Y_O T_o + \sum_{n=1}^{Ny} Y_n T_{i,d\text{-}n\Delta d} + \sum_{n-1}^{Nq} \bar{u}_n q_{d\text{-}nq\theta} \quad (8-7)$$

subscripts :

(type of heat transfer - inside or outside

j - surface,

d - time,

n - number of previous temperatures and heat loads)

X, Y, Z CTF coefficients

AT EQUILIBRIUM

$$q_{\substack{\text{outside}\\ \text{surface}}} = q_{\substack{\text{intside}\\ \text{surface}}} \qquad \text{and} \qquad -Z_O T_i - \sum_{n=1}^{Nz} Z_n T_{i,d\text{-}n\Delta d} = -T_i \sum_{n=0}^{Nz} Z_n$$

$$\sum_{n=0}^{Nx} X_n = \sum_{n=0}^{Ny} Y_n = \sum_{n=0}^{Nz} Z_n \qquad U = \frac{\sum_{n=0}^{Nz} Z_n}{\left(1 - \sum_{n=1}^{N_q} \phi_n\right)}$$

	t, in	density	k	c_p	R = T/k
Brick	4.	130	7.	.19	.571
Hardboard, .5in	.5	1.	.8	.29	.625
MineralBoardR −11	3.5	.32	10.9375		
GypsumBoard	.5	1.11	.45		

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PRF RTF Generator Program (Periodic Response Factor ï Response Transfer Functions)

Conduction Transfer Function (Btu/[hr.ft^2.F])

CTFs for Wall N

X_n	Y_n	Z_n	$\bar{u}_n$
4.277368,	0.001585,	0.623812,	
-5.306364,	0.018775,	-0.933922,	0.628171
1.069140,	0.009743,	0.346143,	-0.010584
-0.009767,	0.000273,	-0.005657,	

$$q_{\substack{\text{outside}\\\text{surface}}} = -Y_O T_i - \sum Y_n T_{i\theta-n\Delta\theta} + X_O T_O + \sum X_n T_{O\theta-n\Delta\theta} + \sum_{n=1}^{N} \Phi_n q_{\theta-n\Delta\theta}$$

$$q_{\substack{\text{intside}\\\text{surface}}} = -Z_O T_i - \sum Z_n T_{i\theta-n\Delta\theta} + Y_O T_O + \sum Y_n T_{O\theta-n\Delta\theta} + \sum_{n=1}^{N} \Phi_n q_{\theta-n\Delta\theta}$$

		CTF	SUM							
	X0	4.277368								
	X1	-5.306364								
	X2	1.06914								
	X3	-0.009767	0.030377							
	Y0	0.001585								
	Y1	0.018775								
	Y2	0.009743								
	Y3	0.000273	0.030376							
	Z0	0.62381								
	Z1	-0.933922								
	Z2	0.346143								
	Z3	-0.005657	0.030374							
	PHI1	0.62817								
	PHI2	0.01058	0.63875							
	U	0.0840858								
hour	T out	Tin	S(Z* Tin)	S(Y *Tout)	S(PHI*Q)	Q inside	S(Y *Tin)	S(X*Tout)	S(PHI*Q)	Q outside
	86.20	70								
	83.40	70				0.0000	0			0
	81.30	70				0.0000	0			0
1	79.55	70	-2.12618	2.4885931	0	0.3624	-2.12632	-2.81841	0	-4.9447
2	77.80	70	-2.12618	2.4317384	0.227657	0.5332	-2.12632	-3.23551	-3.1061299	-8.4680
3	76.40	70	-2.12618	2.3790396	0.3387842	0.5916	-2.12632	-1.78817	-5.3716346	-9.2861
4	75.35	70	-2.12618	2.3335623	0.3772943	0.5847	-2.12632	-0.7044	-5.9228585	-8.7536
5	75.00	70	-2.12618	2.2991759	0.3735359	0.5465	-2.12632	1.890496	-5.5969849	-5.8328
6	75.70	70	-2.12618	2.2831018	0.3495007	0.5064	-2.12632	5.632958	-3.7566085	-0.2500

	t, in	k	R = t/k
Brick	4.	7.	.571
Hardboard, .5in	.5	.8	.625
MineralBoardR − 11	3.5	.32	10.9375
GypsumBoard	.5	1.11	.45
			12.5835

$$U = \frac{1}{\sum R} = \frac{1}{12.646} = .0795$$

$$U = \frac{\sum Y_n}{1 - \sum \bar{u}_n} \qquad (8-15)$$

$$U = \frac{.030376}{1 - .61759} = .0794$$

Conduction Transfer Function (Btu/[hr.ft^2.F])

CTFs for Wall N

4.277368,	0.001585,	0.623812,	
-5.306364,	0.018775,	-0.933922,	0.628171
1.069140,	0.009743,	0.346143,	-0.010584
-0.009767,	0.000273,	-0.005657	

X_n	Y_n	Z_n	$\bar{u}_n$

$$q_{\substack{\text{outside}\\ \text{surface}}} = -Y_O T_i - \sum Y_n T_i + X_O T_O + \sum X_n T_O + \sum_{n=1}^{N} \Phi_n q_{\theta\text{-n}\Delta\theta}$$

$$q_{\substack{\text{intside}\\ \text{surface}}} = -Z_O T_i - \sum Z_n T_i + Y_O T_O + \sum Y_n T_O + \sum_{n=1}^{N} \Phi_n q_{\theta\text{-n}\Delta\theta}$$

Problem 8-4 and 8-12

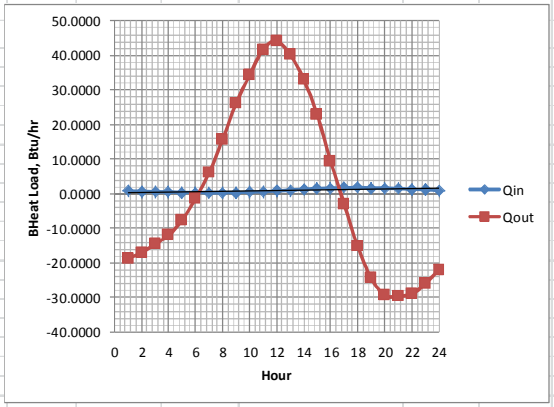
hour	T out	Tin	SUM (Z* Tin)	SUM (Y*Tout)	SUM (PHI*Q)	Q inside	Load Explorer	SUM (Y*Tin)	SUM (X*Tout)	SUM (PHI*Q)	Q outside
1	79.55	70	-2.12618	2.489	0.956	1.32	1.32	-2.126	-2.818	-12.988	-17.93
2	77.80	70	-2.12618	2.432	0.812	1.12	1.12	-2.126	-3.236	-11.042	-16.40
3	76.40	70	-2.12618	2.379	0.688	0.94	0.95	-2.126	-1.788	-10.114	-14.03
4	75.35	70	-2.12618	2.334	0.579	0.79	0.80	-2.126	-0.704	-8.639	-11.47
5	75.00	70	-2.12618	2.299	0.484	0.66	0.67	-2.126	1.890	-7.056	-7.29
6	75.70	70	-2.12618	2.283	0.404	0.56	0.56	-2.126	5.633	-4.459	-0.95
7	77.45	70	-2.12618	2.295	0.346	0.51	0.50	-2.126	9.040	-0.521	6.39
8	80.60	70	-2.12618	2.340	0.317	0.53	0.49	-2.126	13.979	4.026	15.88
9	85.15	70	-2.12618	2.423	0.328	0.63	0.54	-2.126	18.590	9.907	26.37
10	90.40	70	-2.12618	2.548	0.387	0.81	0.68	-2.126	20.253	16.397	34.52
11	96.35	70	-2.12618	2.702	0.502	1.08	0.89	-2.126	22.679	21.408	41.96
12	101.95	70	-2.12618	2.875	0.668	1.42	1.17	-2.126	20.628	25.993	44.50
13	106.15	70	-2.12618	3.046	0.878	1.80	1.50	-2.126	15.188	27.507	40.57
14	108.95	70	-2.12618	3.185	1.114	2.17	1.84	-2.126	10.806	25.013	33.69
15	110.00	70	-2.12618	3.282	1.346	2.50	2.16	-2.126	4.876	20.736	23.48
16	108.96	70	-2.12618	3.328	1.549	2.75	2.42	-2.126	-2.192	14.396	10.08
17	106.50	70	-2.12618	3.316	1.702	2.89	2.59	-2.126	-6.100	6.082	-2.14
18	102.65	70	-2.12618	3.254	1.787	2.91	2.66	-2.126	-10.637	-1.454	-14.22
19	98.10	70	-2.12618	3.150	1.800	2.82	2.63	-2.126	-12.289	-8.908	-23.32
20	93.55	70	-2.12618	3.019	1.743	2.64	2.50	-2.126	-11.699	-14.501	-28.33
21	89.70	70	-2.12618	2.882	1.626	2.38	2.30	-2.126	-8.850	-17.547	-28.52
22	86.20	70	-2.12618	2.759	1.469	2.10	2.05	-2.126	-8.212	-17.618	-27.96
23	83.40	70	-2.12618	2.650	1.295	1.82	1.80	-2.126	-5.688	-17.260	-25.07
24	81.30	70	-2.12618	2.559	1.120	1.55	1.55	-2.126	-3.517	-15.455	-21.10
						38.7054					38.70

Example Problem 8-4 and 8-12

	CTF	SUM
X0	4.277368	
X1	-5.306364	
X2	1.06914	
X3	-0.009767	0.030377
Y0	0.001585	
Y1	0.018775	
Y2	0.009743	
Y3	0.000273	0.030376
Z0	0.62381	
Z1	-0.933922	
Z2	0.346143	
Z3	-0.005657	0.030374
PHI1	0.62817	
PHI2	-0.01058	0.61759
U	0.0794331	

hour	T out	Tin	S(Z* Tin)	S(Y *Tout)	S(PHI*Q)	Q inside	S(Y *Tin)	S(X*Tout)	S(PHI*Q)	Q outside
	86.20	70								
	83.40	70				0.0000	0			0
	81.30	70				0.0000	0			0
1	79.55	70	-2.12618	2.4885931	0	0.3624	-2.12632	-2.81841	0	-4.9447
2	77.80	70	-2.12618	2.4317384	0.227657	0.5332	-2.12632	-3.23551	-3.1061299	-8.4680
3	76.40	70	-2.12618	2.3790396	0.3311156	0.5840	-2.12632	-1.78817	-5.2670042	-9.1815
4	75.35	70	-2.12618	2.3335623	0.3611942	0.5686	-2.12632	-0.7044	-5.6779507	-8.5087
5	75.00	70	-2.12618	2.2991759	0.3509843	0.5240	-2.12632	1.890496	-5.2477537	-5.4836
6	75.70	70	-2.12618	2.2831018	0.323133	0.4801	-2.12632	5.632958	-3.3545972	0.1520
7	77.45	70	-2.12618	2.2953213	0.2960123	0.4652	-2.12632	9.039953	0.15352356	7.0672
8	80.60	70	-2.12618	2.3398949	0.2871166	0.5008	-2.12632	13.97934	4.43776737	16.2908

		CTF	SUM		
	X0	4.277366			4 in brick
	X1	-5.350657			.5 in plywood
	X2	1.104895			3.5 in mineral fiber insulation
	X3	-0.01342			.5 in gypsum
	X4	-0.00001	0.018174		
	Y0	0.000421			70 F inside
	Y1	0.009171			
	Y2	0.007994			
	Y3	0.000583			
	Y4	0.000006	0.018175		
	Z0	0.608875			
	Z1	-0.947377			
	Z2	0.363597			
	Z3	-0.006917	0.018174		
	Z4	-0.000004			
	PHI1	0.63844			
	PHI2	-0.01321	0.62523		
U =	SUM(X)/(1- SUM(phi))	=		0.0111824	



CTF
Wall Analysis
Outside temperature given

$$q_{\substack{\text{intside}\\\text{surface}}} = -Z_O T_i - \sum Z_n T_i + Y_O T_O + \sum Y_n T_O + \sum_{n=1}^{N} \Phi_n q_{\theta\text{-n}\Delta\theta} \qquad q_{\substack{\text{outside}\\\text{surface}}} = -Y_O T_i - \sum Y_n T_i + X_O T_O + \sum X_n T_O + \sum_{n=1}^{N} \Phi_n q_{\theta\text{-n}\Delta\theta}$$

hour	T out	Tin	SUM (Z*Tout)	SUM (Y*Tout)	SUM (PHI*Q)	Q inside	SUM (Y*Tin)	SUM (X*Tout)	SUM (PHI*Q)	Q outside	Load Explorer BTU/100 ft 2 ,TSS Room Load
1	79.55	70	-1.27218	1.4965853	0.6140165	0.8384	-1.27225	-3.75341	-13.67423	-18.6999	86.4
2	77.80	70	-1.27218	1.4613585	0.522263	0.7114	-1.27225	-4.15782	-11.648711	-17.0788	73.5
3	76.40	70	-1.27218	1.4294892	0.4431372	0.6004	-1.27225	-2.68783	-10.656749	-14.6168	62.3
4	75.35	70	-1.27218	1.4011854	0.3739508	0.5030	-1.27225	-1.59821	-9.1063607	-11.9768	52.3
5	75.00	70	-1.27218	1.3791862	0.3131755	0.4202	-1.27225	0.999552	-7.4533929	-7.7261	43.8
6	75.70	70	-1.27218	1.3670506	0.2616167	0.3565	-1.27225	4.725103	-4.7744319	-1.3216	37
7	77.45	70	-1.27218	1.3707886	0.2220452	0.3207	-1.27225	8.092426	-0.7416869	6.0785	32.5
8	80.60	70	-1.27218	1.3935495	0.200009	0.3214	-1.27225	12.98061	3.8982085	15.6066	31.2
9	85.15	70	-1.27218	1.4387492	0.200945	0.3675	-1.27225	17.51223	9.88356264	26.1235	33.8
10	90.40	70	-1.27218	1.508893	0.2303903	0.4671	-1.27225	19.07984	16.4721546	34.2797	41.4
11	96.35	70	-1.27218	1.5977654	0.2933626	0.6189	-1.27225	21.4242	21.5404705	41.6924	54
12	101.95	70	-1.27218	1.6993305	0.3889907	0.8161	-1.27225	19.28065	26.1652761	44.1737	71.1
13	106.15	70	-1.27218	1.8031086	0.5128808	1.0438	-1.27225	13.78553	27.6514853	40.1648	91.6
14	108.95	70	-1.27218	1.8910724	0.6556285	1.2745	-1.27225	9.396909	25.0592607	33.1839	113.2
15	110.00	70	-1.27218	1.9540685	0.7999164	1.4818	-1.27225	3.471652	20.6553654	22.8548	133.6
16	108.96	70	-1.27218	1.9881256	0.9292071	1.6452	-1.27225	-3.55771	14.1530378	9.3231	150.7
17	106.50	70	-1.27218	1.9876034	1.0307566	1.7462	-1.27225	-7.39283	5.6503125	-3.0148	162.6
18	102.65	70	-1.27218	1.9557371	1.0930987	1.7767	-1.27225	-11.8613	-2.0479048	-15.1814	168.2
19	98.10	70	-1.27218	1.8982479	1.1112211	1.7373	-1.27225	-13.4274	-9.6526108	-24.3522	167.1
20	93.55	70	-1.27218	1.822387	1.0856852	1.6359	-1.27225	-12.7647	-15.346886	-29.3838	159.9
21	89.70	70	-1.27218	1.7404061	1.0214694	1.4897	-1.27225	-9.86266	-18.43813	-29.5730	147.9
22	86.20	70	-1.27218	1.6645758	0.9294711	1.3219	-1.27225	-9.19958	-18.492452	-28.9643	133
23	83.40	70	-1.27218	1.5978417	0.8242538	1.1499	-1.27225	-6.64165	-18.101299	-26.0152	116.9
24	81.30	70	-1.27218	1.5410279	0.7166902	0.9855	-1.27225	-4.4577	-16.226525	-21.9565	101
						23.6300				23.6197	2265.0000

Wall Energy Balance + Unsteady Conduction

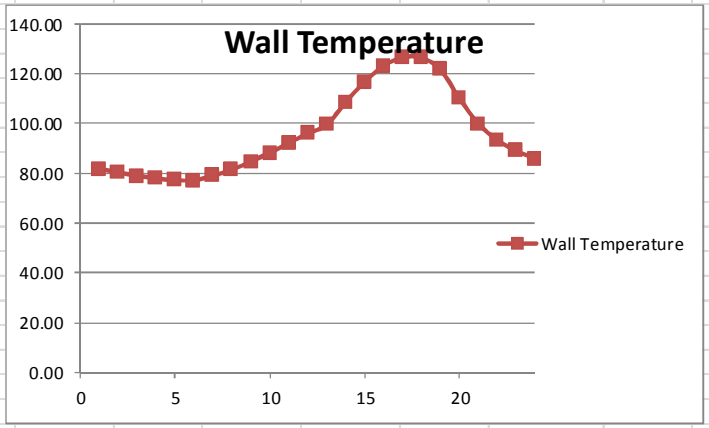
		CTF	SUM			
	X0	4.277366			Tdesign	99.0000
	X1	-5.350657			Range	21.6000
	X2	1.104895			emissivity	0.9000
	X3	-0.01342			absorbtivity	0.8000
	X4	-0.00001	0.018174		ho	3.0000
	Y0	0.000421			Fws	0.5000
	Y1	0.009171			Fwg	0.5000
	Y2	0.007994			Alpha	90.0000
	Y3	0.000583				
	Y4	0.000006	0.018175			
	Z0	0.608875				
	Z1	-0.947377				
	Z2	0.363597				
	Z3	-0.006917	0.018174			
	Z4	-0.000004				
	PHI1	0.63844				
	PHI2	-0.01321	0.62523			
U =	SUM X/1- SUM phi		0.011182			

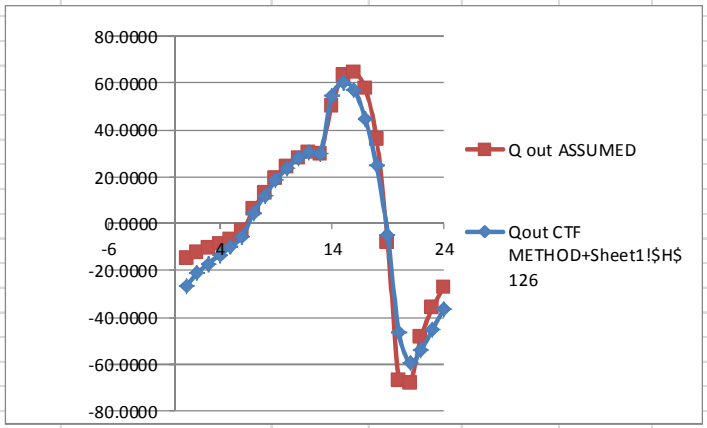
$$Q_{\text{outside ASSUMED}} = hA(T_w - T_O) + \text{ů}\text{Ů}F_{ws}(T_w^4 - T_{\text{sky d}}^4) + \text{ů}\text{Ů}F_{wg}(T_w^4 - T_{\text{ground d}}^4) + UA(T_w - T_i)$$

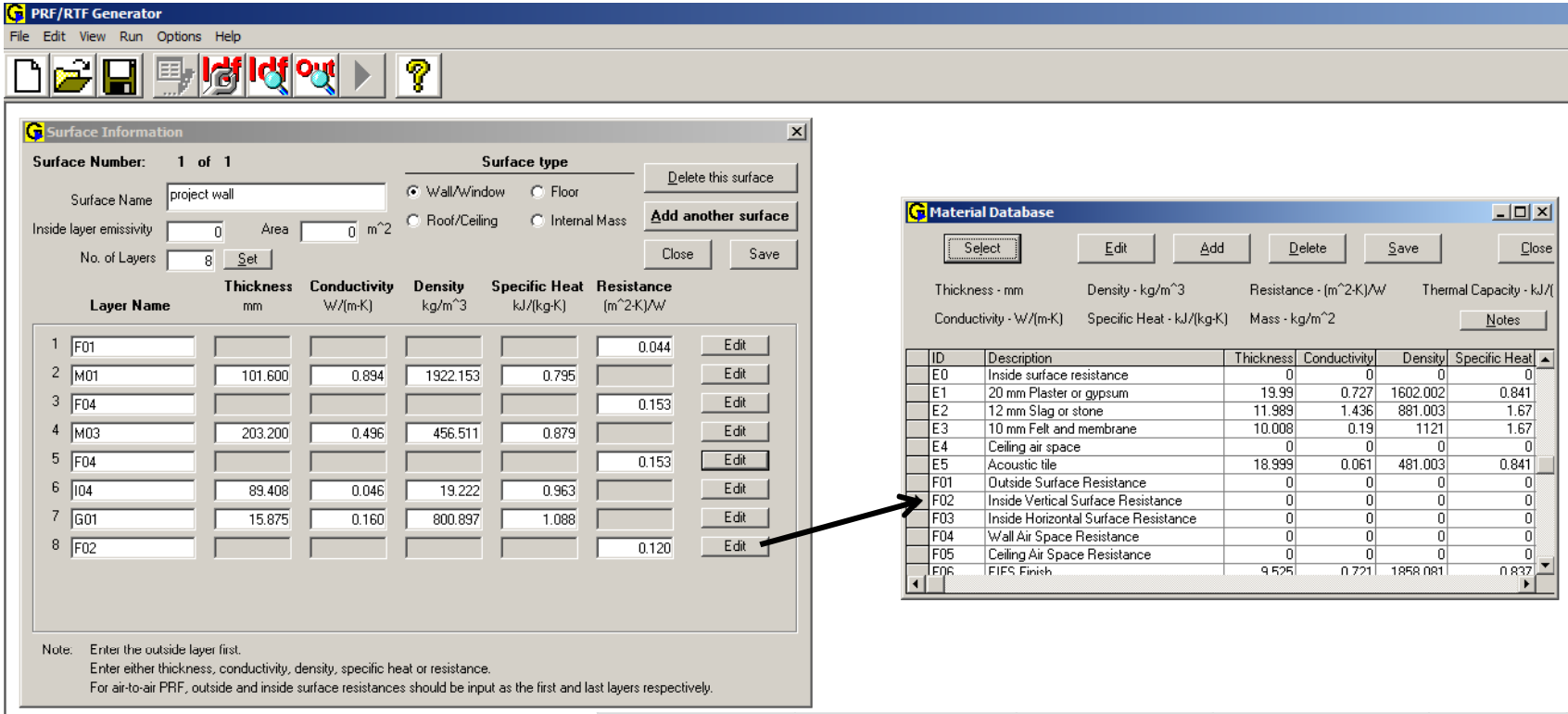
hour	To	Qrad	Tin	Ts	Tsky	Tground	Q outside ASSUMED	T assumed	S(Z* Tin)	S(Y *Tout)	S(PHI*Q)	Q inside	S(Y *Tin)	S(X*Tout)	S(PHI*Q)	Q outside CTF METHOD
		0	70	-10.80	17.768805	0.0000		86.74								
		0	70	-10.80	17.057074	0.0000		84.31				0.0000	0			0
		0	70	-10.80	16.550369	0.0000		82.58				0.0000	0			0
		0	70	-10.80	16.172537	0.0000		81.29				0.0000	0			0
1	80.21	0	70	69.41	72.571247	80.2080	-7.2557	80.21	-1.27218	1.4890958	0	0.2169	-1.27225	-1.766014	0	-3.0383
2	79.13	0	70	68.33	71.491247	79.1280	-7.2119	79.13	-1.27218	1.4673827	0.138487754	0.3337	-1.27225	-1.998232	-1.93975	-5.2102
3	78.26	0	70	67.46	70.627247	78.2640	-7.1770	78.26	-1.27218	1.4477023	0.210175885	0.3857	-1.27225	-1.093334	-3.28628	-5.6519
4	77.62	0	70	66.82	69.979247	77.6160	-7.1510	77.62	-1.27218	1.4302337	0.24183712	0.3999	-1.27225	-0.420853	-3.53955	-5.2327
5	77.40	0	70	66.60	69.763247	77.4000	-7.1423	77.40	-1.27218	1.416657	0.250211232	0.3947	-1.27225	1.182337	-3.26607	-3.3560
6	77.83	1.8	70	67.03	70.195247	77.8320	-5.7196	77.83	-1.27218	1.4091677	0.246702212	0.3837	-1.27225	3.481535	-2.07347	0.1358
7	78.91	16.9	70	68.11	71.275247	78.9120	6.3168	78.91	-1.27218	1.4114745	0.239749128	0.3790	-1.27225	5.559654	0.13104	4.4184
8	80.86	29.4	70	70.06	73.219247	80.8560	16.2380	80.86	-1.27218	1.4255212	0.236928093	0.3903	-1.27225	8.576364	2.819117	10.1232
9	83.66	39.2	70	72.86	76.027247	83.6640	23.9631	83.66	-1.27218	1.4534159	0.244156381	0.4254	-1.27225	11.37302	6.404708	16.5055
10	86.90	47.1	70	76.10	79.267247	86.9040	30.1490	86.90	-1.27218	1.4967047	0.266431993	0.4910	-1.27225	12.34046	10.40403	21.4722
11	90.58	53.7	70	79.78	82.939247	90.5760	35.2751	90.58	-1.27218	1.5515516	0.307826946	0.5872	-1.27225	13.78727	13.4907	26.0057
12	94.03	59.2	70	83.23	86.395247	94.0320	39.5284	94.03	-1.27218	1.6142318	0.368405512	0.7105	-1.27225	12.46439	16.31944	27.5116
13	96.62	63.8	70	85.82	88.987247	96.6240	43.0972	96.62	-1.27218	1.6782777	0.445827468	0.8519	-1.27225	9.073115	17.22096	25.0218
14	98.35	132	70	87.55	90.715247	98.3520	97.5824	98.35	-1.27218	1.7325639	0.534517986	0.9949	-1.27225	6.364707	15.6115	20.7040
15	99.00	192	70	88.20	91.363247	99.0000	145.5542	99.00	-1.27218	1.7714416	0.623931251	1.1232	-1.27225	2.707976	12.8877	14.3234
16	98.35	236.2	70	87.55	90.715247	98.3520	180.9424	98.35	-1.27218	1.7924571	0.703948564	1.2242	-1.27225	-1.656544	8.871147	5.9424
17	96.84	256.6	70	86.04	89.203247	96.8400	197.3278	96.84	-1.27218	1.7920808	0.766757233	1.2867	-1.27225	-3.963939	3.604624	-1.6316
18	94.46	242.6	70	83.66	86.827247	94.4640	186.2300	94.46	-1.27218	1.772422	0.805281929	1.3055	-1.27225	-6.761453	-1.12015	-9.1539
19	91.66	173.6	70	80.86	84.019247	91.6560	131.1495	91.66	-1.27218	1.7369887	0.816501934	1.2813	-1.27225	-7.721047	-5.82264	-14.8159
20	88.85	47.3	70	78.05	81.211247	88.8480	30.2278	88.85	-1.27218	1.6901752	0.800793988	1.2188	-1.27225	-7.312179	-9.33816	-17.9226
21	86.47	0	70	75.67	78.835247	86.4720	-7.5130	86.47	-1.27218	1.6395813	0.761197676	1.1286	-1.27225	-5.5212	-11.2468	-18.0402
22	84.31	0	70	73.51	76.675247	84.3120	-7.4236	84.31	-1.27218	1.5927832	0.704442548	1.0250	-1.27225	-5.111987	-11.2808	-17.6651
23	82.58	0	70	71.78	74.947247	82.5840	-7.3526	82.58	-1.27218	1.5515987	0.639521419	0.9189	-1.27225	-3.533376	-11.0398	-15.8454
24	81.29	0	70	70.49	73.651247	81.2880	-7.2996	81.29	-1.27218	1.5165365	0.573147278	0.8175	-1.27225	-2.185566	-9.88299	-13.3408
1	80.21	0	70	69.41	72.418668	80.2080	-4.9813	79.69	-1.27218	1.4888897	0.509787915	0.7265	-1.27225	-3.979157	-8.30798	-13.5594
2	79.13	0	70	68.33	71.419804	79.1280	-6.1491	78.88	-1.27218	1.4624889	0.453025929	0.6433	-1.27225	-0.256475	-8.48063	-10.0094
3	78.26	0	70	67.46	70.573406	78.2640	-6.3774	78.08	-1.27218	1.4412224	0.401133631	0.5702	-1.27225	-1.150035	-6.21125	-8.6335
4	77.62	0	70	66.82	69.912089	77.6160	-6.1550	77.39	-1.27218	1.4261977	0.355524753	0.5095	-1.27225	-0.680554	-5.37977	-7.3326

After 4 iterations

22	84.31	0	70	73.51	78.186849	84.3120	-30.3079	89.47	-1.27218	1.8434423	1.542975218	2.1142	-1.27225	-8.086779	-49.9729	-59.3319
23	82.58	0	70	71.78	76.014489	82.5840	-23.4210	86.23	-1.27218	1.6796043	1.317171964	1.7246	-1.27225	-6.426459	-36.8268	-44.5255
24	81.29	0	70	70.49	74.383736	81.2880	-18.2826	83.79	-1.27218	1.5973306	1.07312213	1.3983	-1.27225	-5.39703	-27.6431	-34.3124
1	80.21	0	70	69.41	73.062356	80.2080	-14.5954	81.88	-1.27218	1.5449388	0.869931344	1.1427	-1.27225	-4.003497	-21.3182	-26.5940
2	79.13	0	70	68.33	71.83685	79.1280	-12.3622	80.31	-1.27218	1.5053906	0.7110679	0.9443	-1.27225	-3.210834	-16.5254	-21.0085
3	78.26	0	70	67.46	70.830701	78.2640	-10.2017	78.96	-1.27218	1.4736989	0.587770257	0.7893	-1.27225	-2.616644	-13.0613	-16.9502
4	77.62	0	70	66.82	70.070753	77.6160	-8.5089	77.93	-1.27218	1.4471609	0.491439866	0.6664	-1.27225	-1.520061	-10.5442	-13.3365
5	77.40	0	70	66.60	69.719897	77.4000	-6.4996	77.25	-1.27218	1.4257108	0.415043177	0.5686	-1.27225	-0.370748	-8.29064	-9.9336
6	77.83	1.8	70	67.03	70.015759	77.8320	-3.0578	77.22	-1.27218	1.4104618	0.354196962	0.4925	-1.27225	1.988117	-6.16586	-5.4500
7	78.91	16.9	70	68.11	71.297262	78.9120	5.9893	78.99	-1.27218	1.4048893	0.306907305	0.4396	-1.27225	8.992359	-3.34827	4.3718
8	80.86	29.4	70	70.06	73.424097	80.8560	13.1758	81.56	-1.27218	1.4215218	0.274163155	0.4235	-1.27225	10.49067	2.863153	12.0816
9	83.66	39.2	70	72.86	76.341431	83.6640	19.2363	84.74	-1.27218	1.4605244	0.264575178	0.4529	-1.27225	12.31034	7.655609	18.6937
10	86.90	47.1	70	76.10	79.670175	86.9040	24.0429	88.28	-1.27218	1.5127527	0.283567497	0.5241	-1.27225	13.2569	11.77521	23.7599
11	90.58	53.7	70	79.78	83.401915	90.5760	28.2064	92.16	-1.27218	1.5738163	0.328648983	0.6303	-1.27225	14.35903	14.9223	28.0091
12	94.03	59.2	70	83.23	86.983454	94.0320	30.4696	96.04	-1.27218	1.641191	0.395475467	0.7645	-1.27225	14.10789	17.56825	30.4039
13	96.62	63.8	70	85.82	89.824707	96.6240	30.1136	99.48	-1.27218	1.7113355	0.479752678	0.9189	-1.27225	12.28459	19.04106	30.0534
14	98.35	132	70	87.55	93.714786	98.3520	50.4794	108.59	-1.27218	1.780081	0.576568839	1.0845	-1.27225	37.06824	18.78566	54.5816
15	99.00	192	70	88.20	96.555053	99.0000	63.1496	116.73	-1.27218	1.8968623	0.68023016	1.3049	-1.27225	26.86408	34.4501	60.0419
16	98.35	236.2	70	87.55	97.981148	98.3520	64.7609	123.16	-1.27218	2.0490116	0.818782451	1.5956	-1.27225	20.88503	37.61215	57.2249
17	96.84	256.6	70	86.04	97.915139	96.8400	57.6289	126.58	-1.27218	2.1798001	1.001465939	1.9091	-1.27225	9.975427	35.74153	44.4447
18	94.46	242.6	70	83.66	96.20723	94.4640	36.1791	126.49	-1.27218	2.2673948	1.197758801	2.1930	-1.27225	-1.757484	27.61934	24.5896
19	91.66	173.6	70	80.86	92.795236	91.6560	-8.0105	121.62	-1.27218	2.2956515	1.37486302	2.3983	-1.27225	-18.38293	15.11187	-4.5433
20	88.85	47.3	70	78.05	87.421989	88.8480	-66.5931	110.05	-1.27218	2.2473938	1.502223536	2.4774	-1.27225	-41.94862	-3.22546	-46.4463
21	86.47	0	70	75.67	82.78902	86.4720	-68.2568	99.97	-1.27218	2.0981079	1.550013078	2.3759	-1.27225	-28.56453	-29.5932	-59.4300
22	84.31	0	70	73.51	79.358179	84.3120	-48.2365	93.47	-1.27218	1.907611	1.484168789	2.1196	-1.27225	-15.13288	-37.3289	-53.7340
23	82.58	0	70	71.78	76.83532	82.5840	-35.8748	89.03	-1.27218	1.7587733	1.321851101	1.8084	-1.27225	-10.34269	-33.5209	-45.1358
24	81.29	0	70	70.49	74.989556	81.2880	-27.4158	85.86	-1.27218	1.6588021	1.126583315	1.5132	-1.27225	-7.193385	-28.1067	-36.5723
							113.8188					29.5376				49.1216
hour	To	Qrad	Tin	Ts	Tsky	Tground	Q outside ASSUMED	Twall	S(Z* Tin)	S(Y *Tout)	S(PHI*Q)	Q inside	S(Y *Tin)	S(X*Tout)	S(PHI*Q)	Q outside CTF METHOD







Surface Name	PROJECT WALL			
Construction Name	PROJECT WALL			
No. of CTF Terms	10			
CTF	X-Exterior (W/m^2-K)	Y-Cross (W/m^2-K)	Z-Interior (W/m^2-K)	Flux
0	11.82941341	-7.42398E-07	3.270902634	0
1	-28.35542297	9.67286E-05	-9.006444931	2.033258915
2	23.56908798	0.001478773	8.942708015	-1.39770174
3	-8.256293297	0.003223035	-3.789560318	0.387009412
4	1.303383112	0.001554109	0.617812514	-0.044122197
5	-0.085096784	0.000183172	-0.029231144	0.001714425
6	0.001476981	4.92601E-06	0.000354466	-1.57141E-05
7	-7.37688E-06	2.52536E-08	-1.04261E-06	9.69663E-09
8	3.55339E-09	2.04873E-11	5.3928E-10	-1.60853E-12
9	-4.03135E-13	2.49616E-15	-8.02642E-14	6.87596E-17

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PRF RTF Generator Program (Periodic Response Factor ï Response Transfer Functions)

Radiant Time Series Method

1) No exterior or interior heat balance
2) Periodic Response Factors (PRF) replace Conduction Transfer Functions (CTF)
3) PRFòs are derivable from CTFôs

sol - air temperature, T_e – replaces wall heat balance

T_e – outdoor air temperature that would give an equivalent heat flux.

$$q_{conduction,ext,j,cf} = \text{ŬG}_t + h_o(T_o - T_{es,j,cf}) - \text{Ůdp}R \quad (8-61)$$

$$q_{conduction,ext,j,cf}(\text{from heat balance}) = h_o\left(T_e - T_{es,j,cf}\right) \quad (8-62)$$

combining,

$$T_e = T_o + \frac{\text{ŬG}_t}{h_o} - \frac{\text{Ůdi}R}{h_o} \qquad (8-63)$$

$$\frac{\text{Ůdi}R}{h_o} = 7^o \text{ horizontal}, 0^o \text{ vertical}$$

Radiant Time Series Method

$$q_{conduction,in,j,df} = \sum_{0}^{23} Y_{Pn}\left(T_{e,j,df-nŭ} - T_i\right) \qquad (8-64)$$

Y_{Pn} = Periodic Response Factors p 261 derived from Conduction Transfer Functions

$$q_{conduction,in,j,df} = Y_{Po}\left(T_{e,j,hour} - T_i\right) + Y_{P1}\left(T_{e,j,hour-1} - T_i\right) + Y_{P2}\left(T_{e,j,hour-2} - T_i\right) + ..\text{to } n = 23$$

$$q_{conduction,windows} = UA\left(T_o - T_i\right) \text{ ignoring window thermal mass} \quad (8-66)$$

Radiant Time Series Method over predicts when there is a large amount of glass

can be executed with a spread sheet and table of response factors Y_{Pn}.

Carrier Hourly Anlaysis Program (HAP) is based on Radiant Time Series Method .

RADIANT TIMED SERIES (RTS)

Wall 1 **Figure 8-17a,Table 8-18**

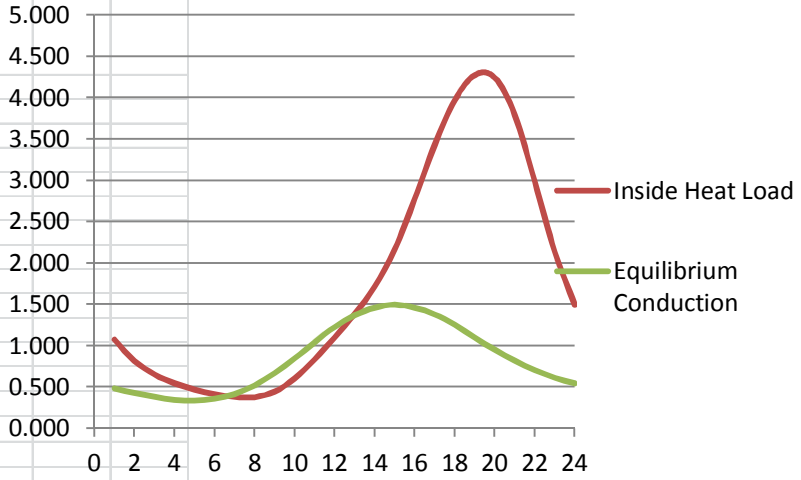
				Sol-Air Temperature Te			
				80.73			
				79.68			
	Tdesign	99		78.84			
	Range	21		78.21			
	Alpha	0.9		78			
	ho	3		78.42			
	Tinside	72		80.7			
	edR/ho	0		87.15			
				92.88			
				98.34			
				106.821			
				108.87			
				120.33			
				138.12			
				151.17			
				152.13			
				157.26			
				148.62			
				131.01			
				101.4			
				86.82			
				84.72			
				83.04			
Hou r Hr	Periodic Response Facror Ypn	Incident Solar Load Gt	Outside Tempeerature To	81.78	Inside Heat Load Qin		Equilibrium Conduction Heat Load Qequlib
1	0.000156	0	80.73	80.73	1.070		0.484
2	0.0056	0	79.68	79.68	0.813		0.425
3	0.014795	0	78.84	78.84	0.653		0.379
4	0.014441	0	78.21	78.21	0.545		0.344
5	0.009628	0	78	78	0.468		0.332
6	0.005414	0	78.42	78.42	0.413		0.356
7	0.002786	4.1	79.47	80.7	0.379		0.414
8	0.001363	19.3	81.36	87.15	0.377		0.518
9	0.000647	29.3	84.09	92.88	0.443		0.670
10	0.000301	37	87.24	98.34	0.602		0.844
11	0.000139	42.8	93.981	106.821	0.834		1.217
12	0.000063	49	94.17	108.87	1.119		1.228
13	0.000029	78.8	96.69	120.33	1.433		1.367
14	0.000013	132.5	98.37	138.12	1.758		1.461
15	0.000006	173.9	99	151.17	2.196		1.495
16	0.000003	198.1	92.7	152.13	2.791		1.146
17	0.000001	201.2	96.9	157.26	3.406		1.379
18	0.000001	180.1	94.59	148.62	3.893		1.251
19	0	130.5	91.86	131.01	4.197		1.100
20	0	40.9	89.13	101.4	4.190		0.949
21	0	0	86.82	86.82	3.762		0.821
22	0	0	84.72	84.72	2.968		0.705
23	0	0	83.04	83.04	2.128		0.611
24	0	0	81.78	81.78	1.487		0.542
U=SUM Y	0.055386	1317.5			41.92644		20.038

$$q''_{in,j,d} = \sum_{n=0}^{23} T_{Pn}\,(T_{e,j,d-n\check{u}} - T_{inside})$$

$$T_e = T_o + \frac{\check{U}G_t}{h_o} + 0\ (\text{verticalwall})$$

T_o from $(8-1)$

G_t West facing wall



6.1

Consider a ceiling space formed by an infinite flat roof and a horizontal ceiling. The inside surface of the roof has a temperature of 135 F and the top of the ceiling insulation has a temperature of 115 F. Estimate the heat transferred by radiation and convection separately and compare to the combined values in the text. Use ceiling emittances of .9 and .05. Assume the emissivity of the roof is .9.

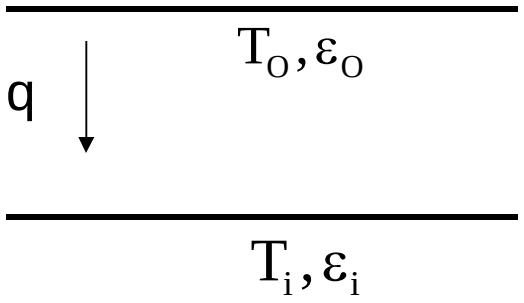
for $\varepsilon_o = .9, \quad \varepsilon_i = .9$

$$U = \frac{1}{\frac{1-\varepsilon_o}{\varepsilon_o} + \frac{1}{F_{io}} + \frac{1-\varepsilon_i}{\varepsilon_i}} = \frac{1}{2\frac{1-.9}{.9} + 1} = .82$$

$$q_{rad} = U\sigma\left(T_O^4 - T_i^4\right) = .82 \times .1713 \times 10^{-8}\left(595^4 - 575^4\right)$$

$$q_{rad} = 22.5\,\text{Btu/ft}^2\,\text{hr}$$

$$q_{conv} = U\Delta T = \frac{1}{\sum R}\phi T = \frac{1}{.92 + .92} \times 20 = 10.87\,\text{Btu/ft}^2\text{hr}$$



for $\varepsilon_o = .9, \quad \varepsilon_i = .05$

$$U = \frac{1}{\frac{1-\varepsilon_o}{\varepsilon_o} + \frac{1}{F_{io}} + \frac{1-\varepsilon_i}{\varepsilon_i}} = \frac{1}{\frac{1-.9}{.9} + 1 + \frac{1-.05}{.05}} = .0497$$

$$q_{rad} = U\sigma\left(T_O^4 - T_i^4\right) = .497 \times .1713 \times 10^{-8}\left(595^4 - 575^4\right)$$

$$q_{rad} = 1.363\,\text{Btu/ft}^2\,\text{hr}$$

$$q_{conv} = U\Delta T = \frac{1}{\sum R}\phi T = \frac{1}{4.55 + 4.55} \times 20 = 2.20\,\text{Btu/ft}^2\text{hr}$$

Mean Radiant Temperature Method - RMT

f – ficticious surface

n – number of surfaces in ficticious group

j – surface interacting with thefictioious surface

Ficticious Surface Areas = Sum of areas

$$A_{f,j} = \sum_{i=1}^{n} A_i (1 - \breve{u}_i) \qquad (8-35)$$

Ficticous Surface Emissivity – area weighted emmisivity

$$\mathring{U}_{f,j} = \frac{\sum_{i=1}^{n} A_i \times \mathring{U}_i (1 - \breve{u}_i)}{\sum_{i=1}^{n} A_i (1 - \breve{u}_i)} \qquad (8-36)$$

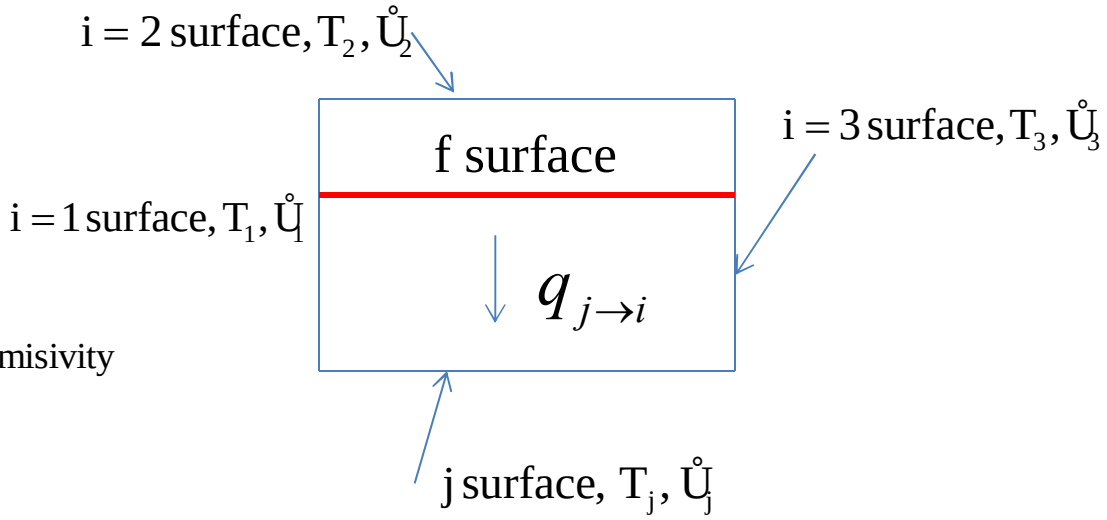
Ficticious Surface Temperature – Area × emissivity weightef

$$T_f = \frac{\sum_{i=1}^{n} A_i \times \mathring{U}_i \times T_i \times (1 - \breve{u}_i)}{\sum_{i=1}^{n} A_i \times \mathring{U}_i \times (1 - \breve{u}_i)} \qquad (8-37)$$

$F_{i,j}$ view factor ficticous surface to j surface

$$F_{i,j} = \frac{1}{\frac{1-\mathring{U}_j}{\mathring{U}_j} + 1 + \left(\frac{A_j}{A_f}\right)\left(\frac{1-\mathring{U}_f}{\mathring{U}_f}\right)} \qquad (8-38)$$

$$q_{j \to i} = \mathring{u} \times e_j \times F_{i,j} \times (T_f^4 - T_j^4)$$



Mean Radiant Temperature Method - RMT

Radiation coefficient for surface j

$$h_{r,j} = \mathring{u} \times F_{j,f} \times \frac{T_i^4 - T_{i,j}^4}{T_i - T_f} \quad (8-39)$$

Radiation on to surface j

$$q_{radiation,\,j} = h_{r,j} \times (T_j - T_{f,j}) \quad (8\text{-}40)$$

The net of radiation between all surfaces should be 0.

$$\sum_{j=1}^{n} A_j \times h_{r,j} \times (T_j - T_{f,j}) = 0$$

The correction is the net excess radiation divided by the sum of the area of all surfaces.

$$q_{baalance} = \frac{\sum_{j=1}^{n} A_j \times h_{r,j} \times (T_j - T_{f,j})}{\sum_{j}^{n} A_j} \quad (8-41)$$

Corrected Radiation to j surfaces is,

$$q_{radiation,\,j} = h_{r,j} \times (T_j - T_{f,j}) - q_{balance} \quad (8-42)$$

CARRIER HAP PROGRAM

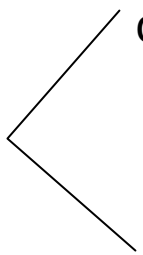
WEATHER – location, design conditions, yearly weather tape

SPACES - conditioned spaces assembled into zones.
Can be rooms, part of rooms, zones or
part of zones.

SYSTEMS – type of equipment and operating conditions
VAV, supply conditions, etc

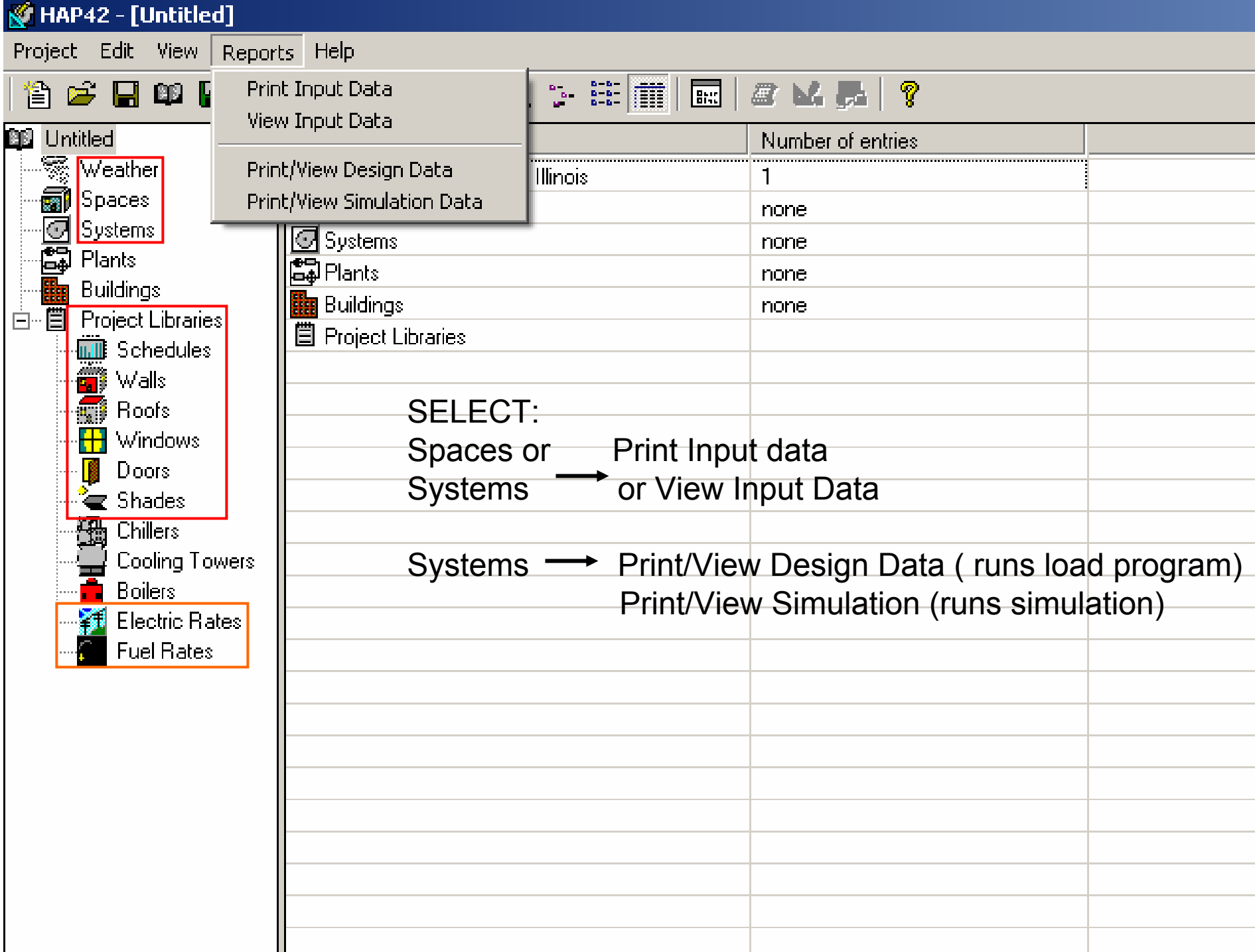
LIBRARIES – components can be selected for each space
Schedules – for people. lights, equipment occupation,
thermostat

Walls
Roof
Windows
Doors



conductivity, density
specific heat
thickness,
emissivity

Shades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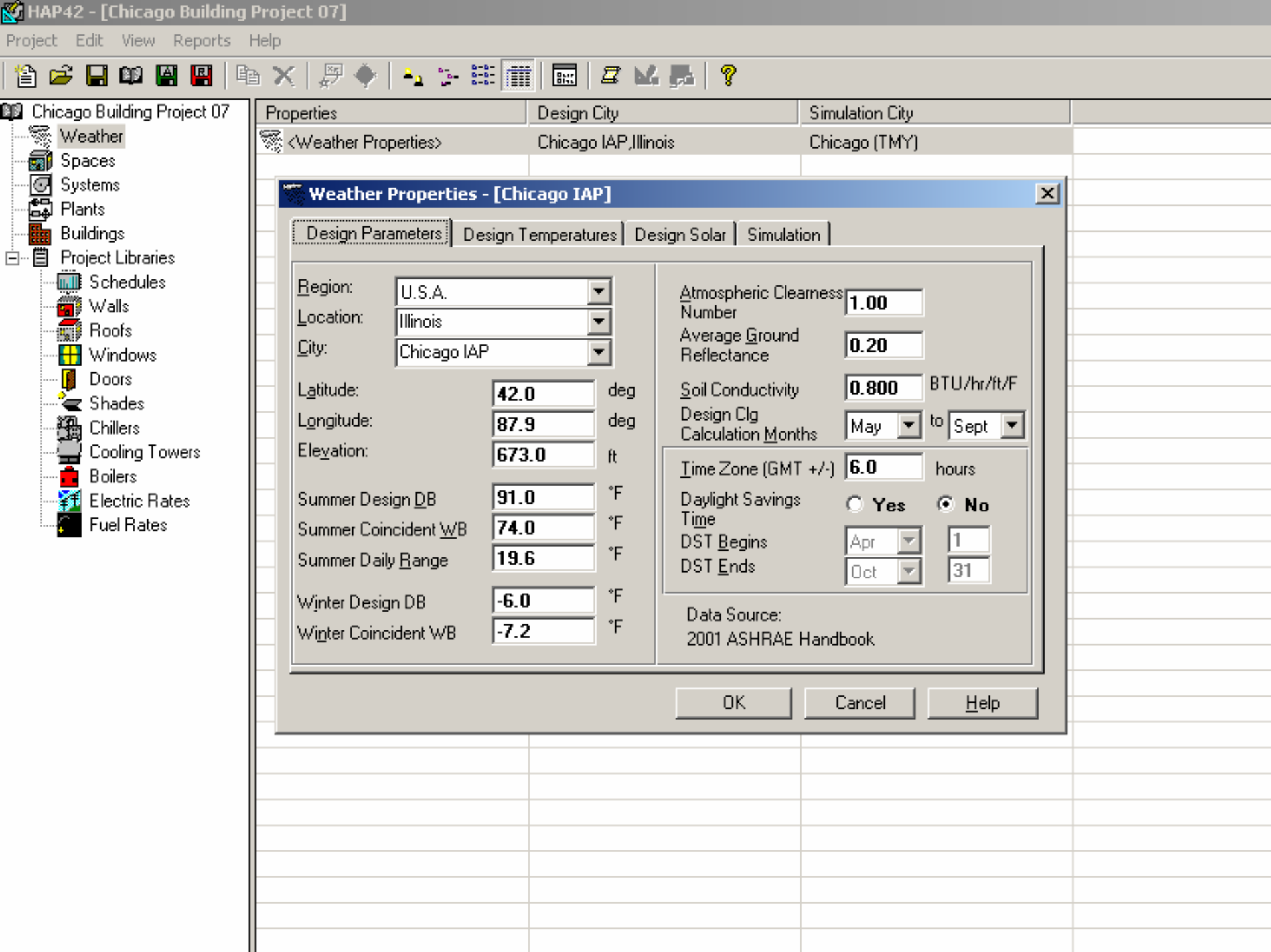
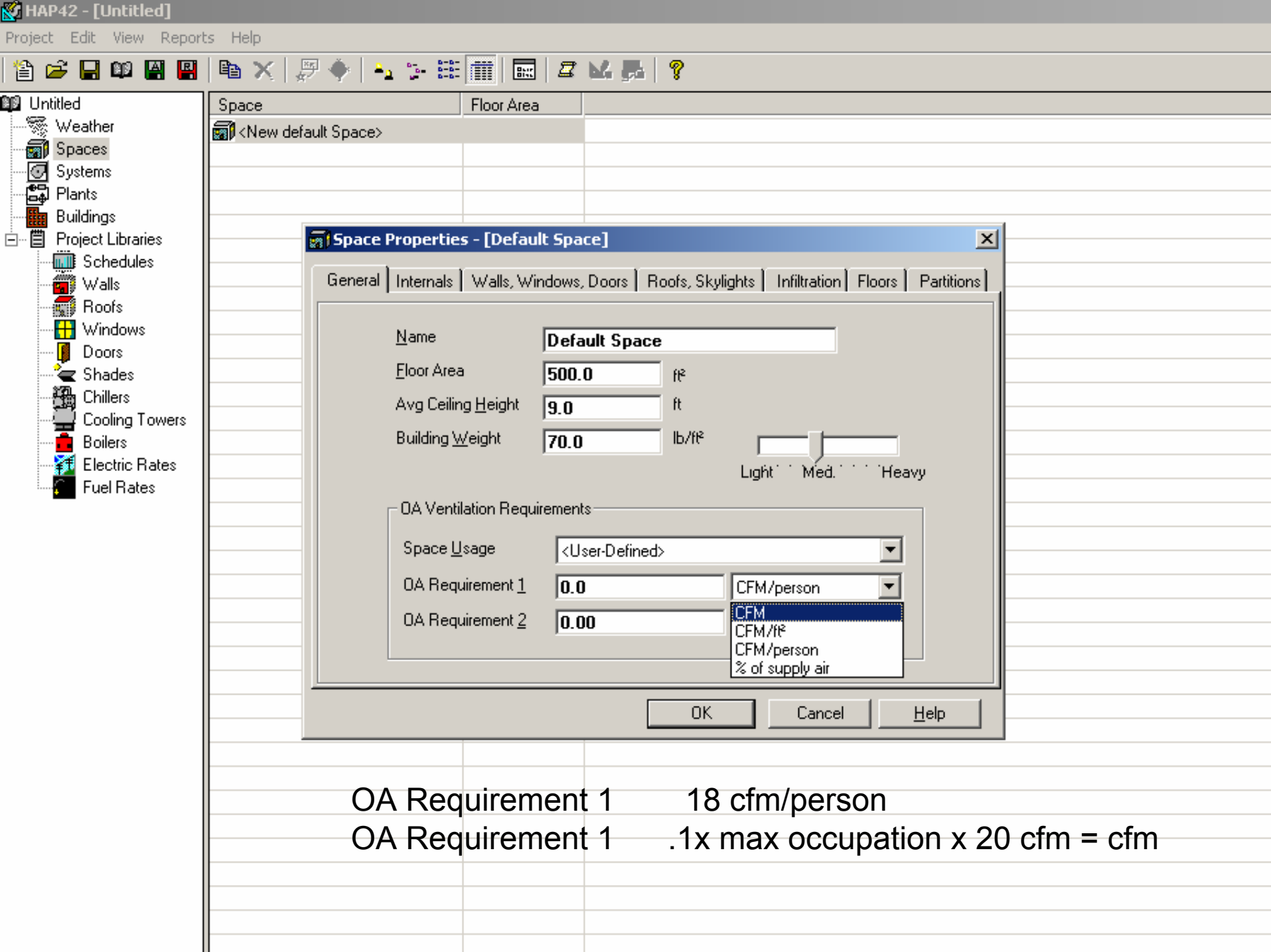
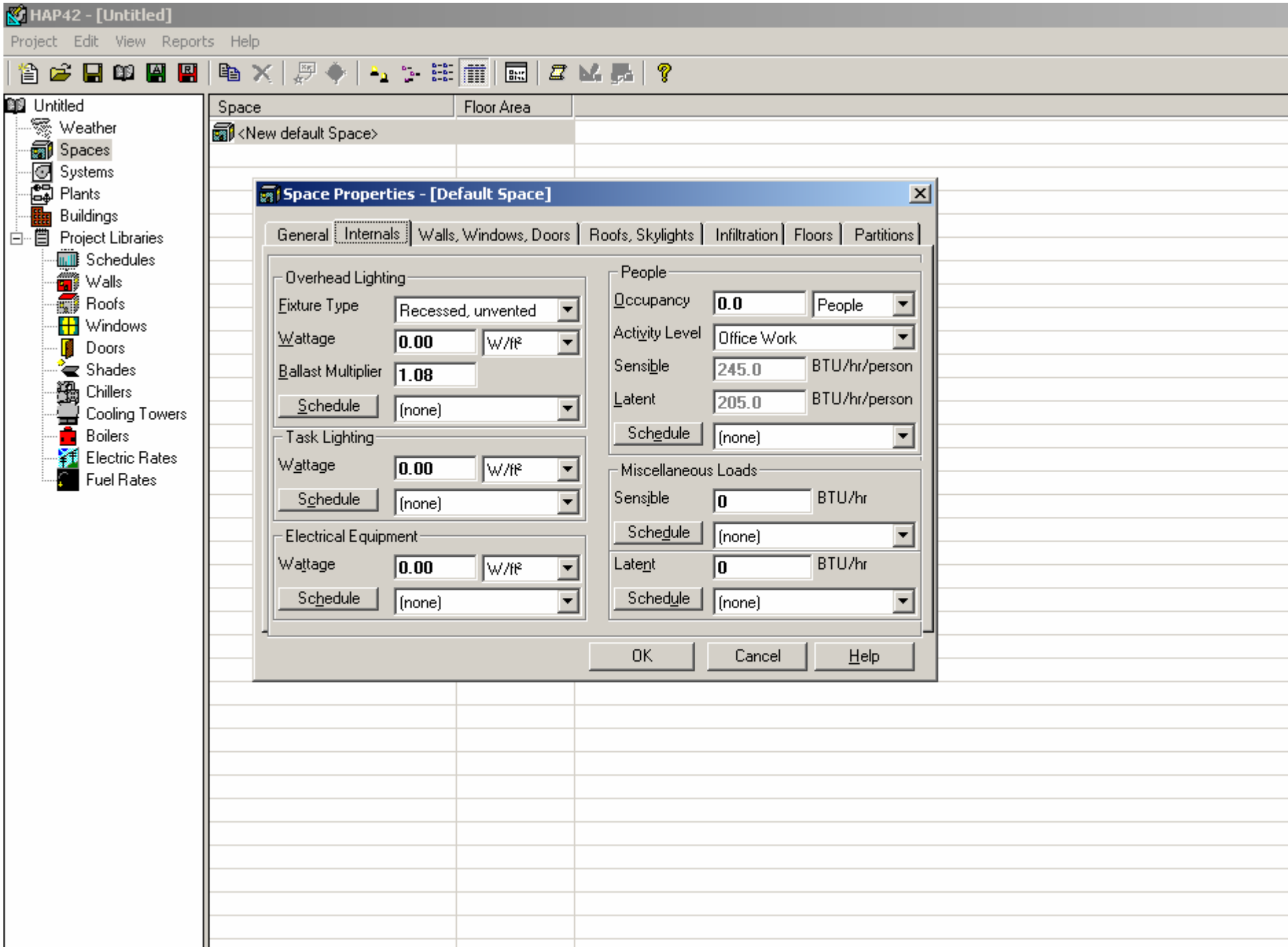
Project
Edit
View
Reports
Help
Print Input Data
View Input Data
Print/View Design Data
Print/View Simulation Data
Untitled
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Number of entries
Illinois
1
none
Systems
none
Plants
none
Buildings
none
Project Libraries
SELECT:
Spaces or
Systems
Print Input data
or View Input Data
Systems
Print/View Design Data (runs load program)
Print/View Simulation (runs simulation)


HAP42 - [Chicago Building Project 07]
Project Edit View Reports Help
Chicago Building Project 07
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Properties
Design City
Simulation City
<Weather Properties>
Chicago IAP,Illinois
Chicago (TMY)
Weather Properties - [Chicago IAP]
Design Parameters
Design Temperatures
Design Solar
Simulation
Region: U.S.A.
Location: Illinois
City: Chicago IAP
Latitude: 42.0 deg
Longitude: 87.9 deg
Elevation: 673.0 ft
Summer Design DB 91.0 °F
Summer Coincident WB 74.0 °F
Summer Daily Range 19.6 °F
Winter Design DB -6.0 °F
Winter Coincident WB -7.2 °F
Atmospheric Clearness Number 1.00
Average Ground Reflectance 0.20
Soil Conductivity 0.800 BTU/hr/ft/F
Design Clg Calculation Months May to Sept
Time Zone (GMT +/-) 6.0 hours
Daylight Savings Time Yes No
DST Begins Apr 1
DST Ends Oct 31
Data Source:
2001 ASHRAE Handbook
OK
Cancel
Help



OA Requirement 1 18 cfm/person

OA Requirement 1 .1x max occupation x 20 cfm = cfm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Project Edit View Reports Help
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Weather
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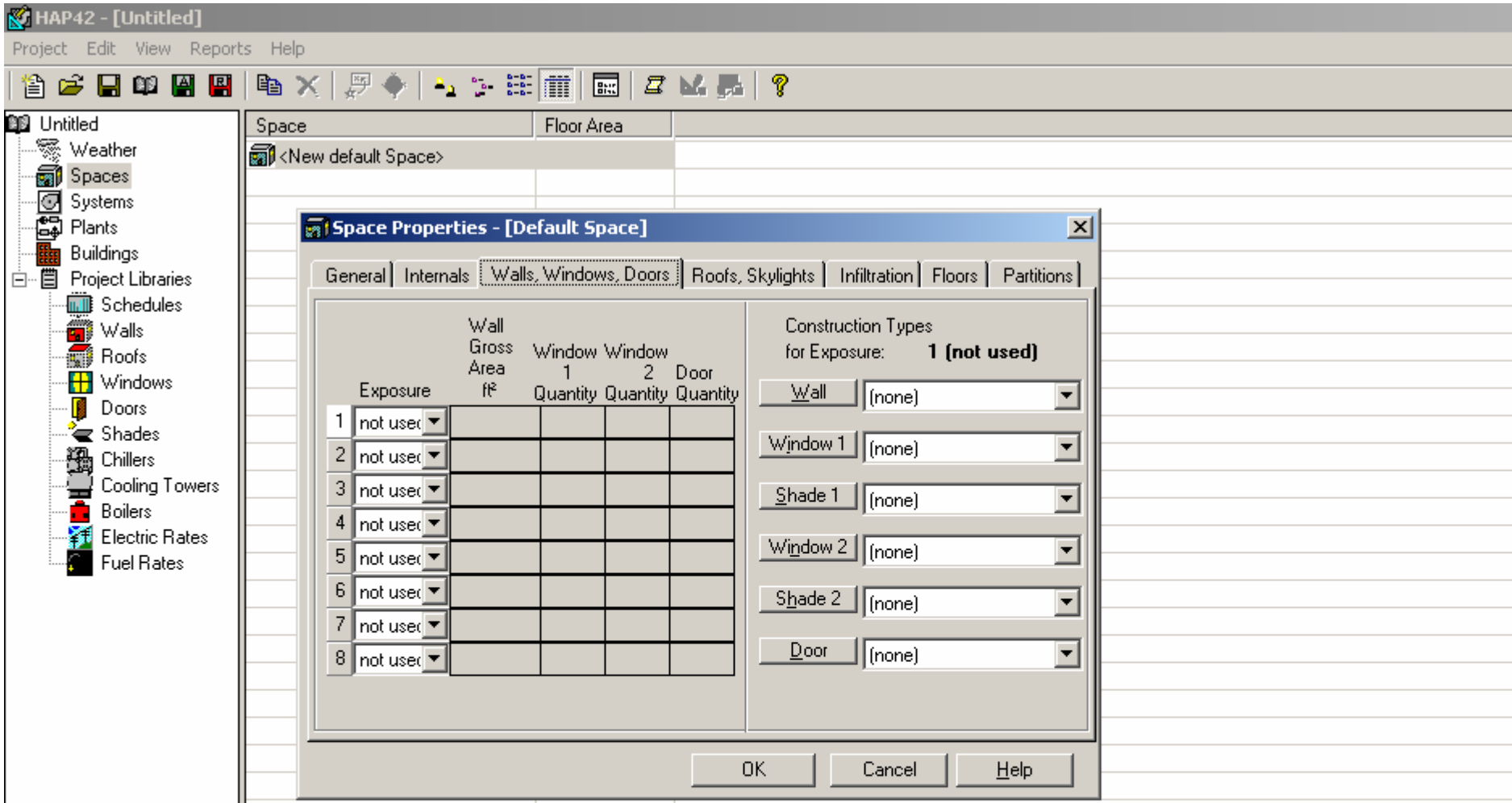
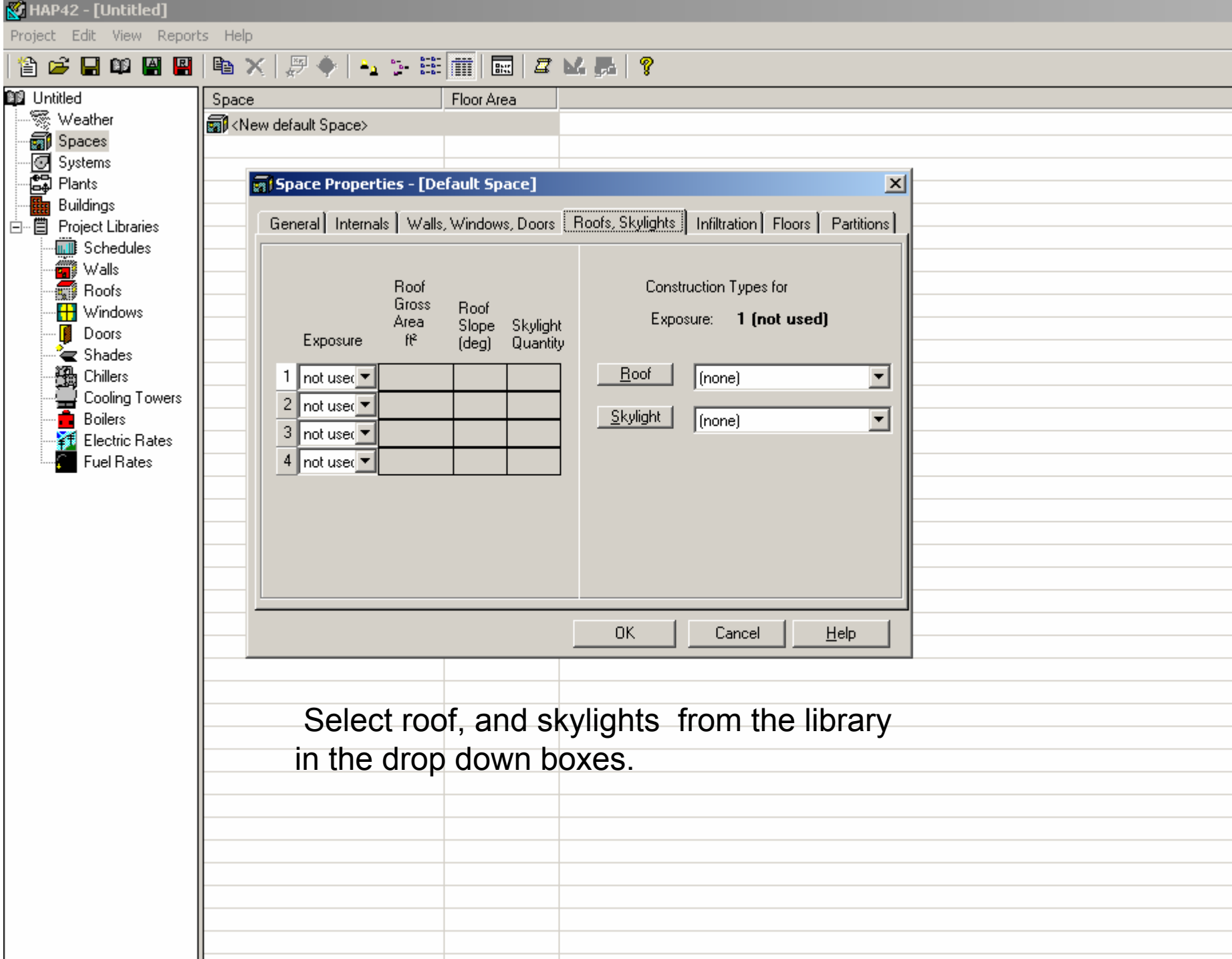
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Space
Floor Area
<New default Space>
Space Properties - [Default Space]
General
Internals
Walls, Windows, Doors
Roofs, Skylights
Infiltration
Floors
Partitions
Overhead Lighting
Fixture Type
Recessed, unvented
Wattage
0.00
W/ft²
Ballast Multiplier
1.08
Schedule
(none)
Task Lighting
Wattage
0.00
W/ft²
Schedule
(none)
Electrical Equipment
Wattage
0.00
W/ft²
Schedule
(none)
People
Occupancy
0.0
People
Activity Level
Office Work
Sensible
245.0
BTU/hr/person
Latent
205.0
BTU/hr/person
Schedule
(none)
Miscellaneous Loads
Sensible
0
BTU/hr
Schedule
(none)
Latent
0
BTU/hr
Schedule
(none)
OK
Cancel
Help

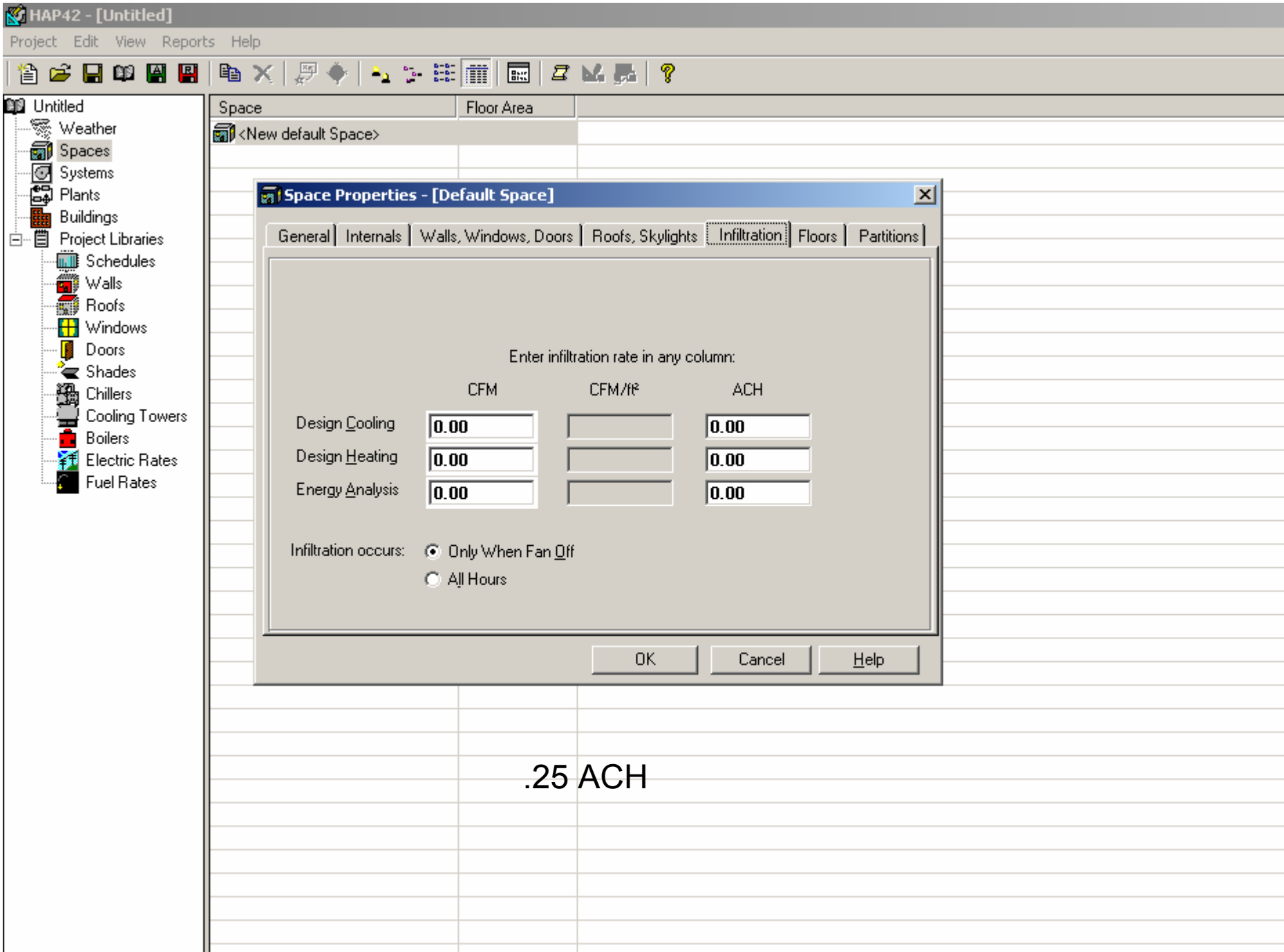


Gross wall area is input. The program calculates the wall Heat transfer area by subtracting window area from gross wall area.

Select walls, windows, doors and shades from the library in the drop down boxes.



Select roof, and skylights from the library in the drop down boxes.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Project Edit View Reports Help
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Weather
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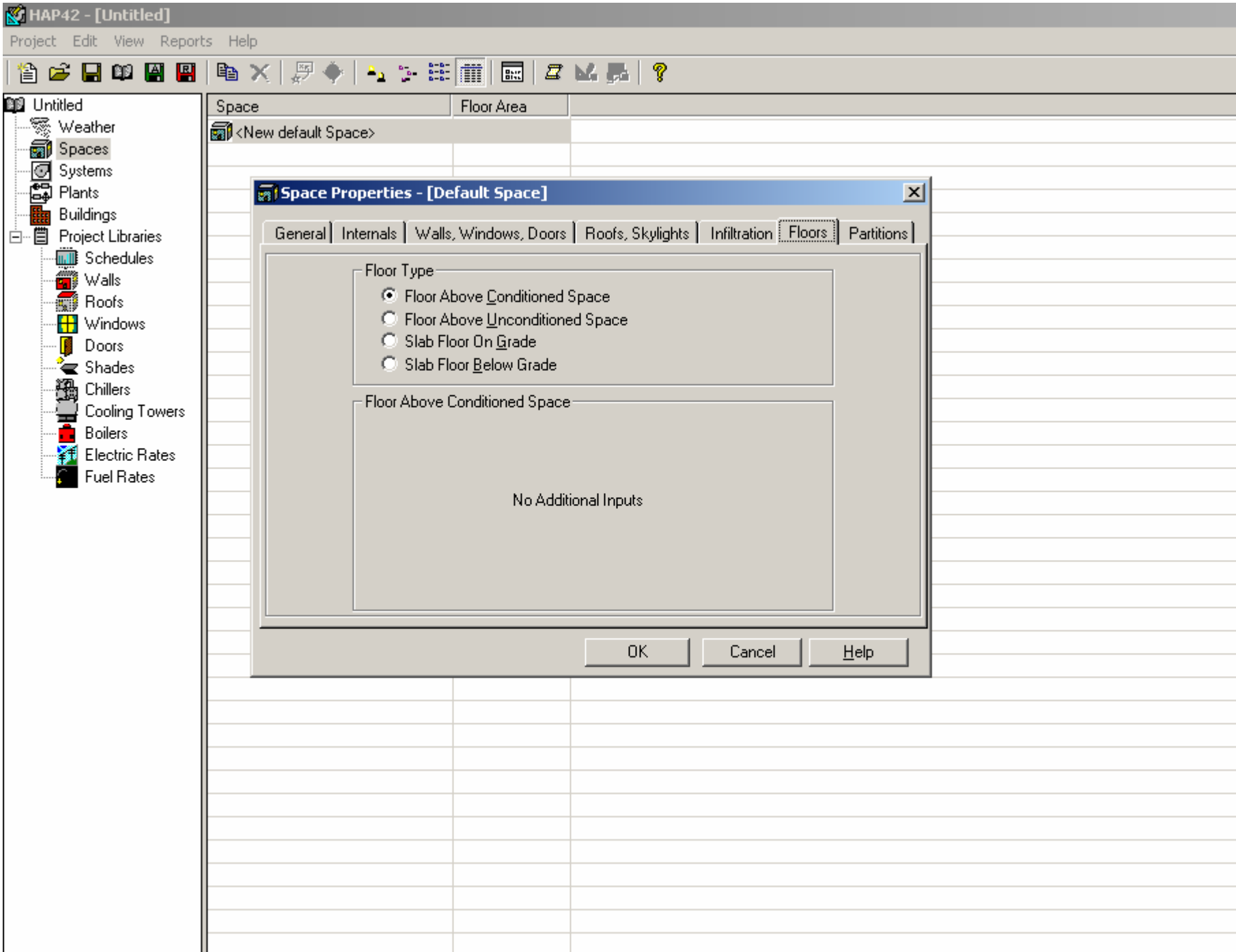
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Space
Floor Area
<New default Space>
Space Properties - [Default Space]
General
Internals
Walls, Windows, Doors
Roofs, Skylights
Infiltration
Floors
Partitions
Enter infiltration rate in any column:
CFM
CFM/ft²
ACH
Design Cooling
0.00
0.00
Design Heating
0.00
0.00
Energy Analysis
0.00
0.00
Infiltration occurs:
Only When Fan Off
All Hours
OK
Cancel
Help

.25 ACH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Project Edit View Reports Help
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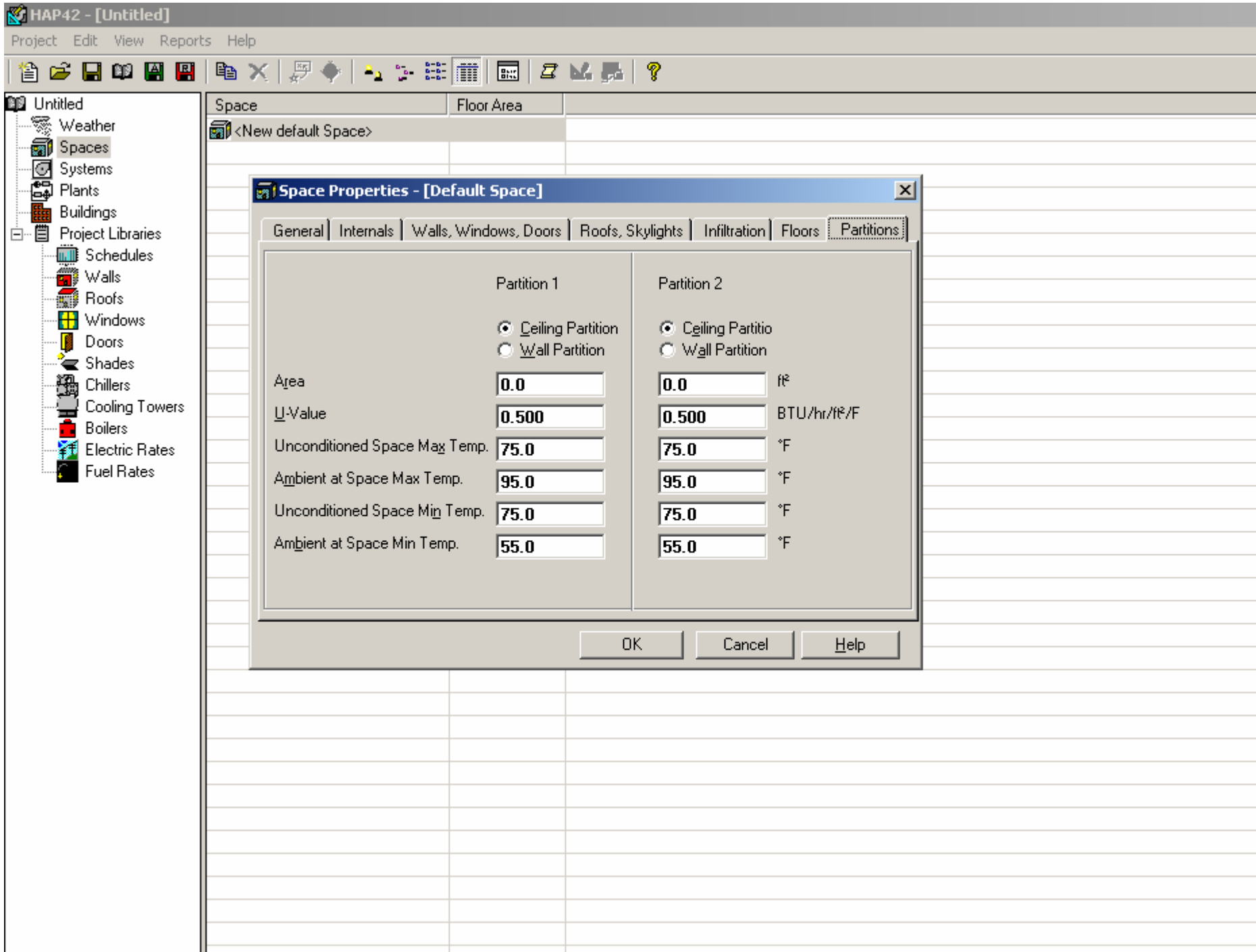
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Space
Floor Area
<New default Space>
Space Properties - [Default Space]
General
Internals
Walls, Windows, Doors
Roofs, Skylights
Infiltration
Floors
Partitions
Floor Type
Floor Above Conditioned Space
Floor Above Unconditioned Space
Slab Floor On Grade
Slab Floor Below Grade
Floor Above Conditioned Space
No Additional Inputs
OK
Cancel
Help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Project Edit View Reports Help
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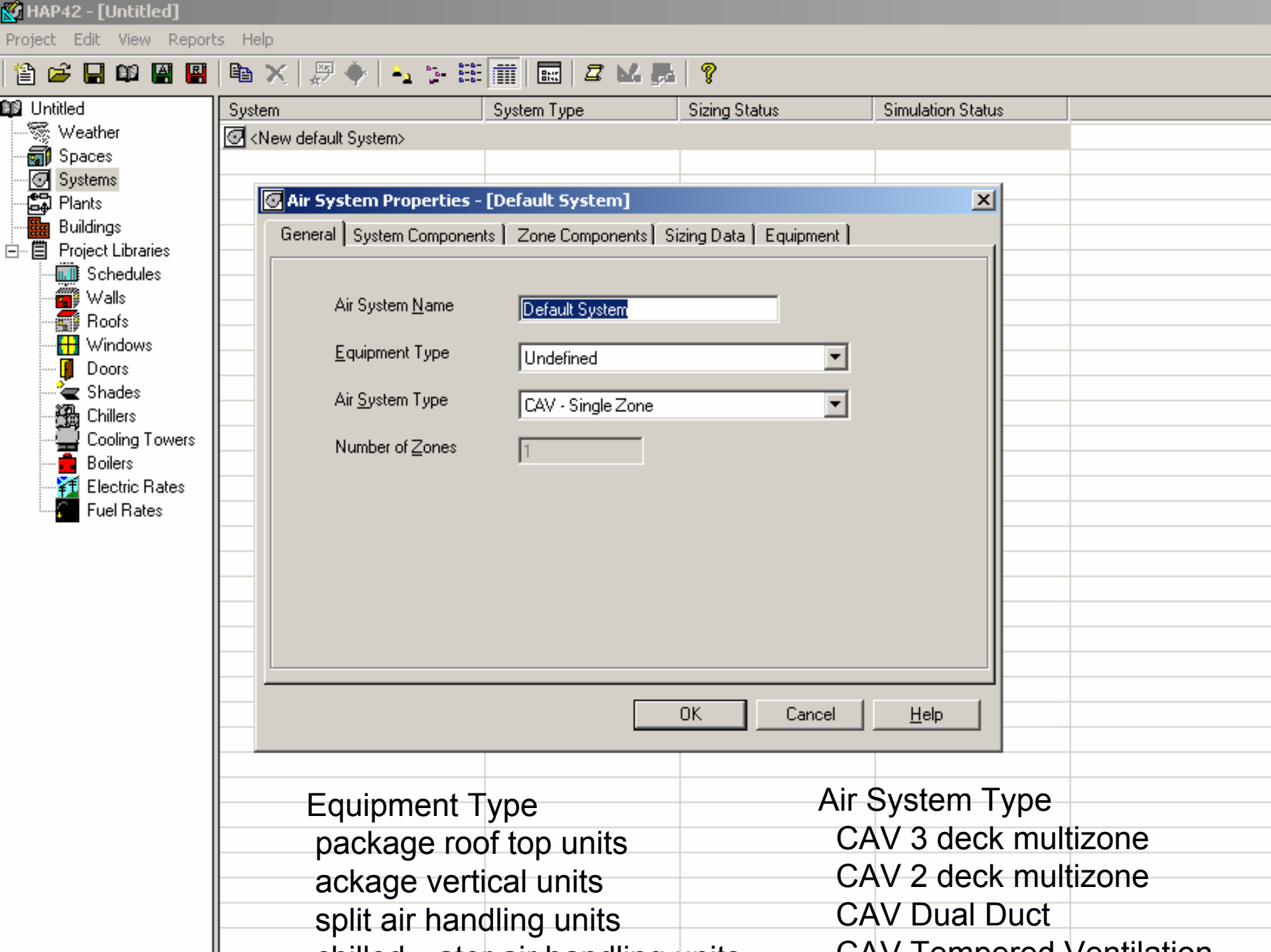
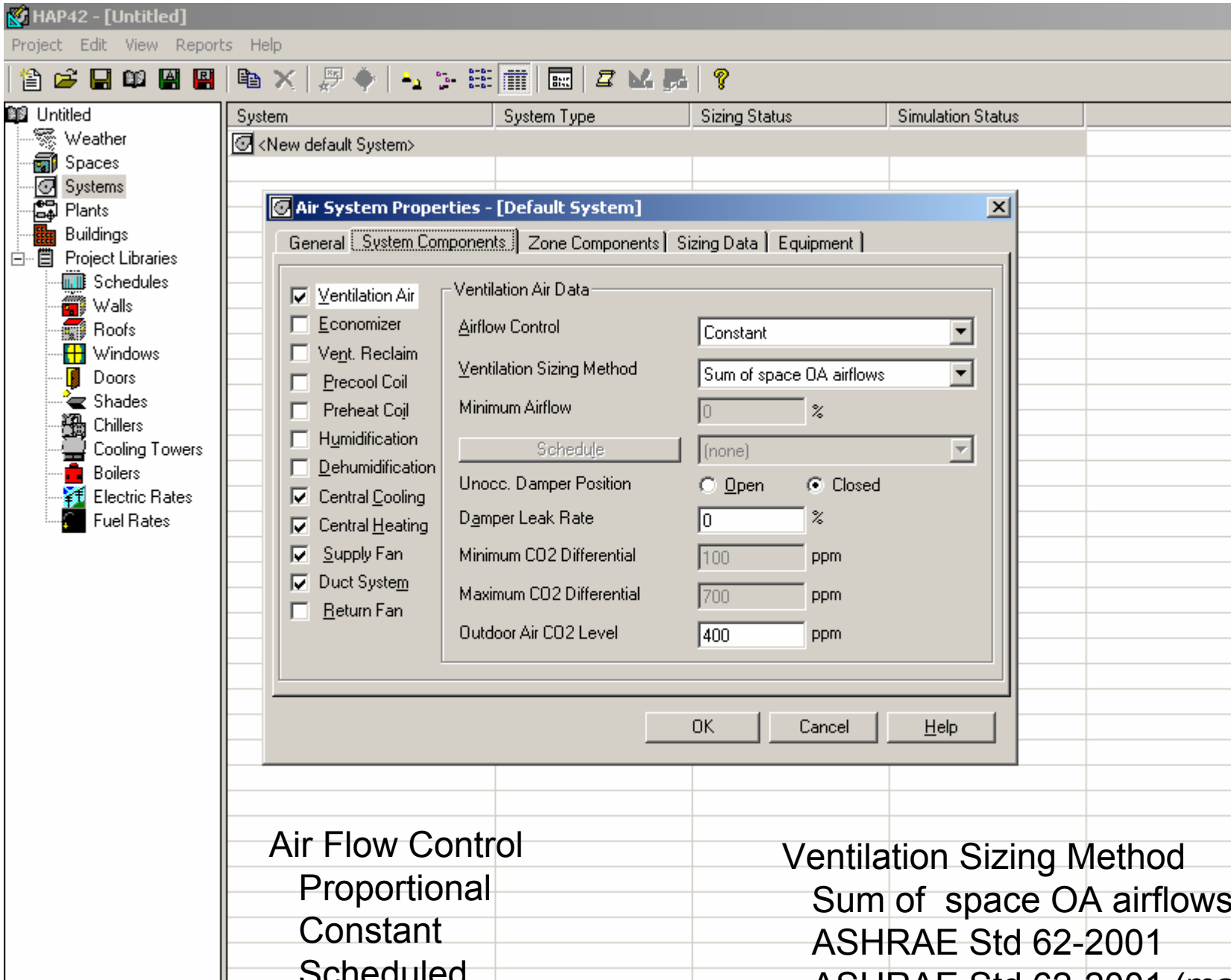
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Space
Floor Area
<New default Space>
Space Properties - [Default Space]
General
Internals
Walls, Windows, Doors
Roofs, Skylights
Infiltration
Floors
Partitions
Partition 1
Partition 2
Ceiling Partition
Wall Partition
Ceiling Partitio
Wall Partition
Area
0.0
0.0
ft²
U-Value
0.500
0.500
BTU/hr/ft²/F
Unconditioned Space Max Temp.
75.0
75.0
°F
Ambient at Space Max Temp.
95.0
95.0
°F
Unconditioned Space Min Temp.
75.0
75.0
°F
Ambient at Space Min Temp.
55.0
55.0
°F
OK
Cancel
Help



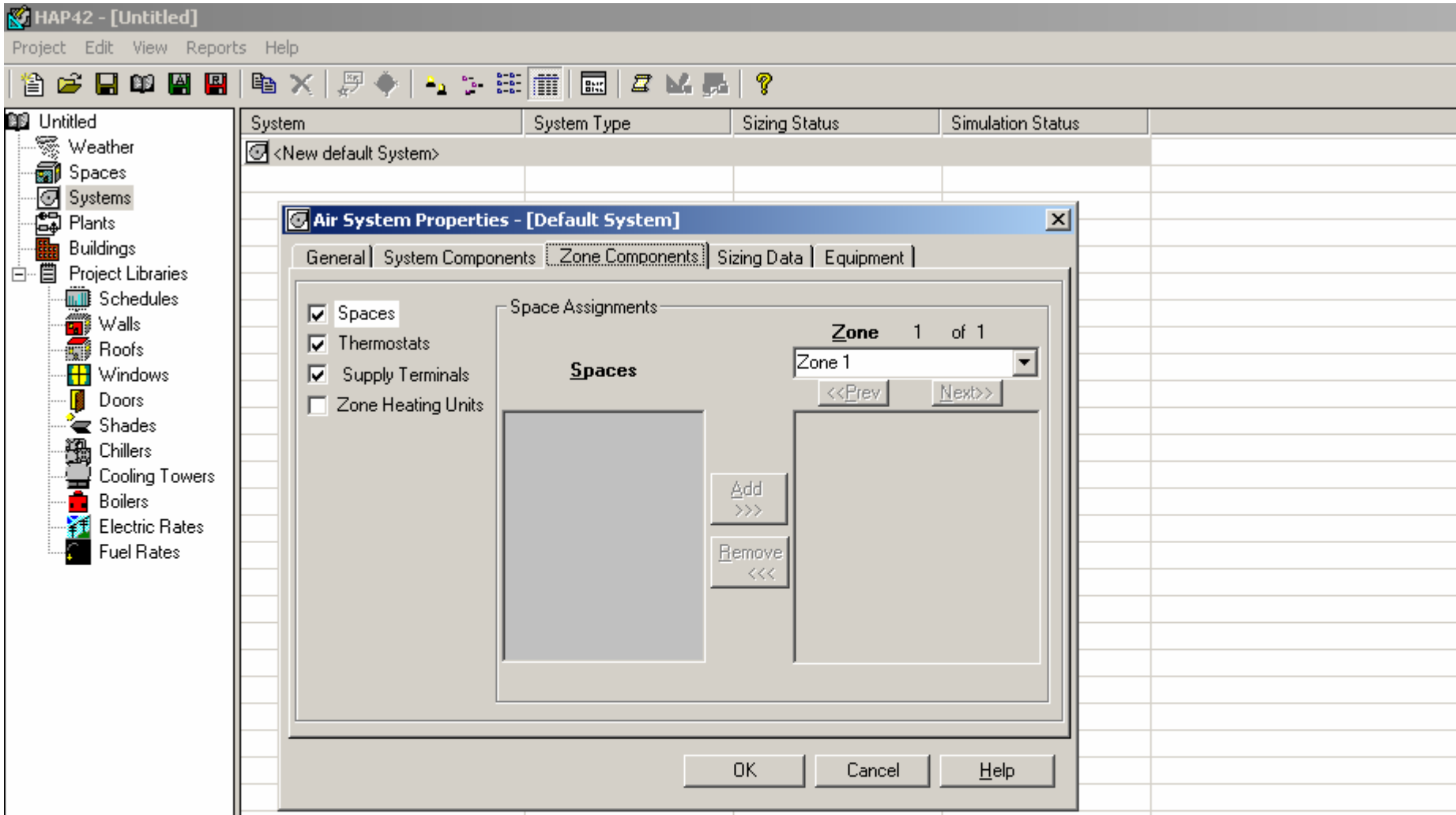
Equipment Type
- package roof top units
- ackage vertical units
- split air handling units
- chilled ...ater air handling units

Air System Type
- CAV 3 deck multizone
- CAV 2 deck multizone
- CAV Dual Duct
- CAV Tempered Ventilation

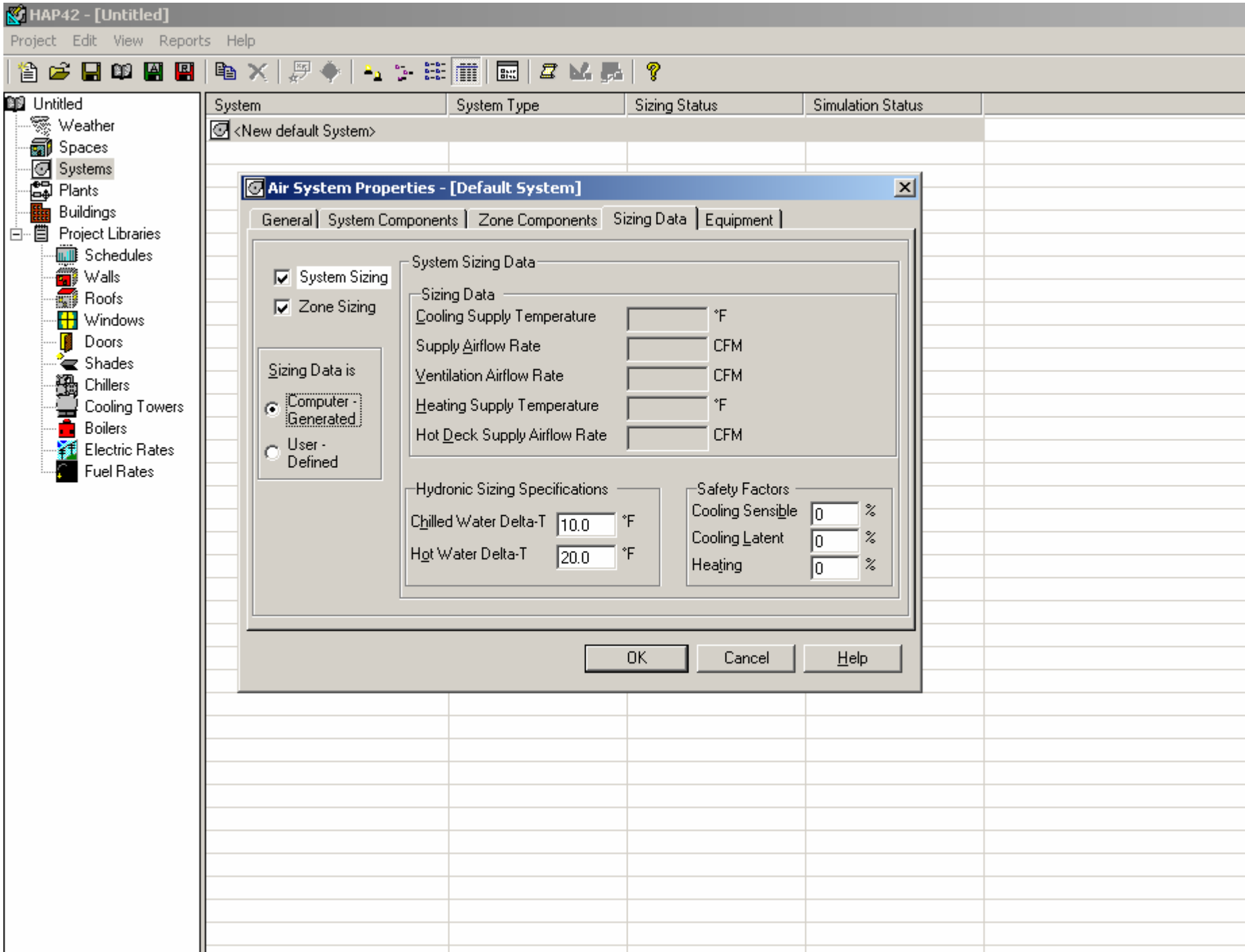


Air Flow Control
- Proportional
- Constant
- Scheduled

Ventilation Sizing Method
- Sum of space OA airflows
- ASHRAE Std 62-2001



All spaces must be assigned to a numbered zone after each system change.


HAP42 - [Untitled]
Project Edit View Reports Help
Untitled
Weather
Spaces
Systems
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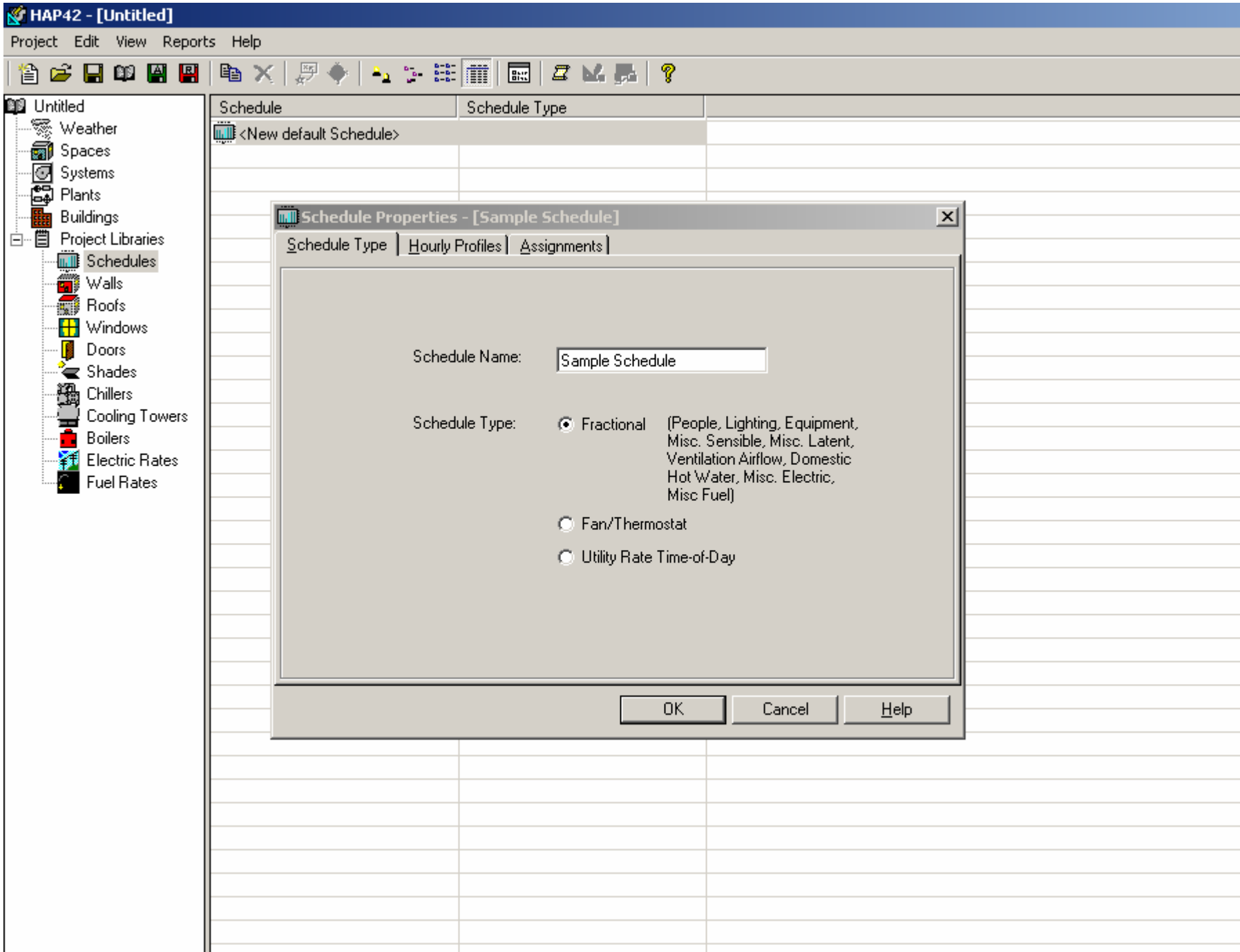
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
Air System Properties - [Default System]
General
System Components
Zone Components
Sizing Data
Equipment
System Sizing
Zone Sizing
Sizing Data is
Computer - Generated
User - Defined
System Sizing Data
Sizing Data
Cooling Supply Temperature
°F
Supply Airflow Rate
CFM
Ventilation Airflow Rate
CFM
Heating Supply Temperature
°F
Hot Deck Supply Airflow Rate
CFM
Hydronic Sizing Specifications
Chilled Water Delta-T
10.0
°F
Hot Water Delta-T
20.0
°F
Safety Factors
Cooling Sensible
0
%
Cooling Latent
0
%
Heating
0
%
OK
Cancel
Help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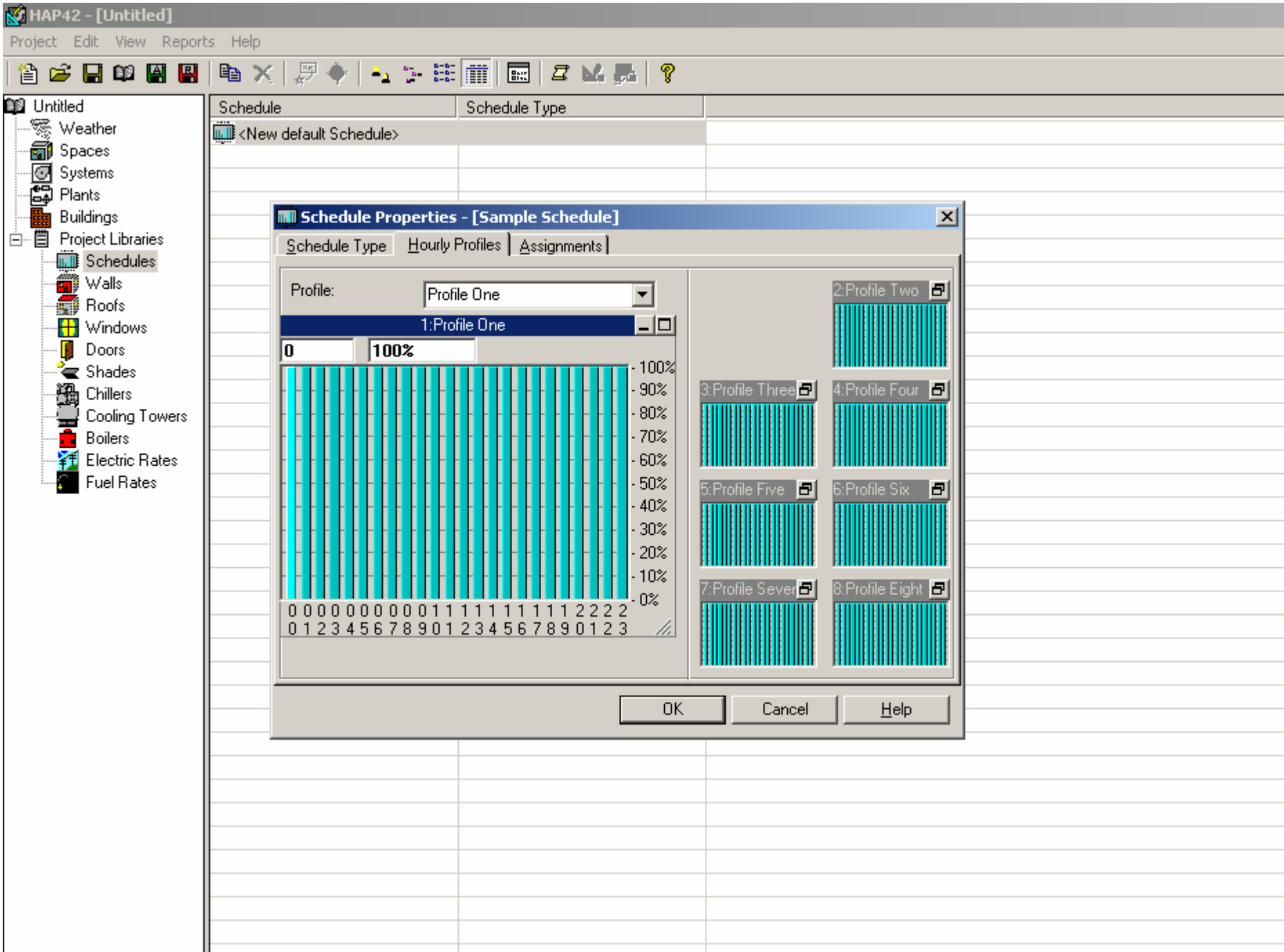
Project Edit View Reports Help
Untitled
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Schedule
Schedule Type
<New default Schedule>
Schedule Properties - [Sample Schedule]
Schedule Type
Hourly Profiles
Assignments
Schedule Name:
Sample Schedule
Schedule Type:
Fractional
(People, Lighting, Equipment, Misc. Sensible, Misc. Latent, Ventilation Airflow, Domestic Hot Water, Misc. Electric, Misc Fuel)
Fan/Thermostat
Utility Rate Time-of-Day
OK
Cancel
Help


HAP42 - [Untitled]
Project Edit View Reports Help
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Weather
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Project Libraries
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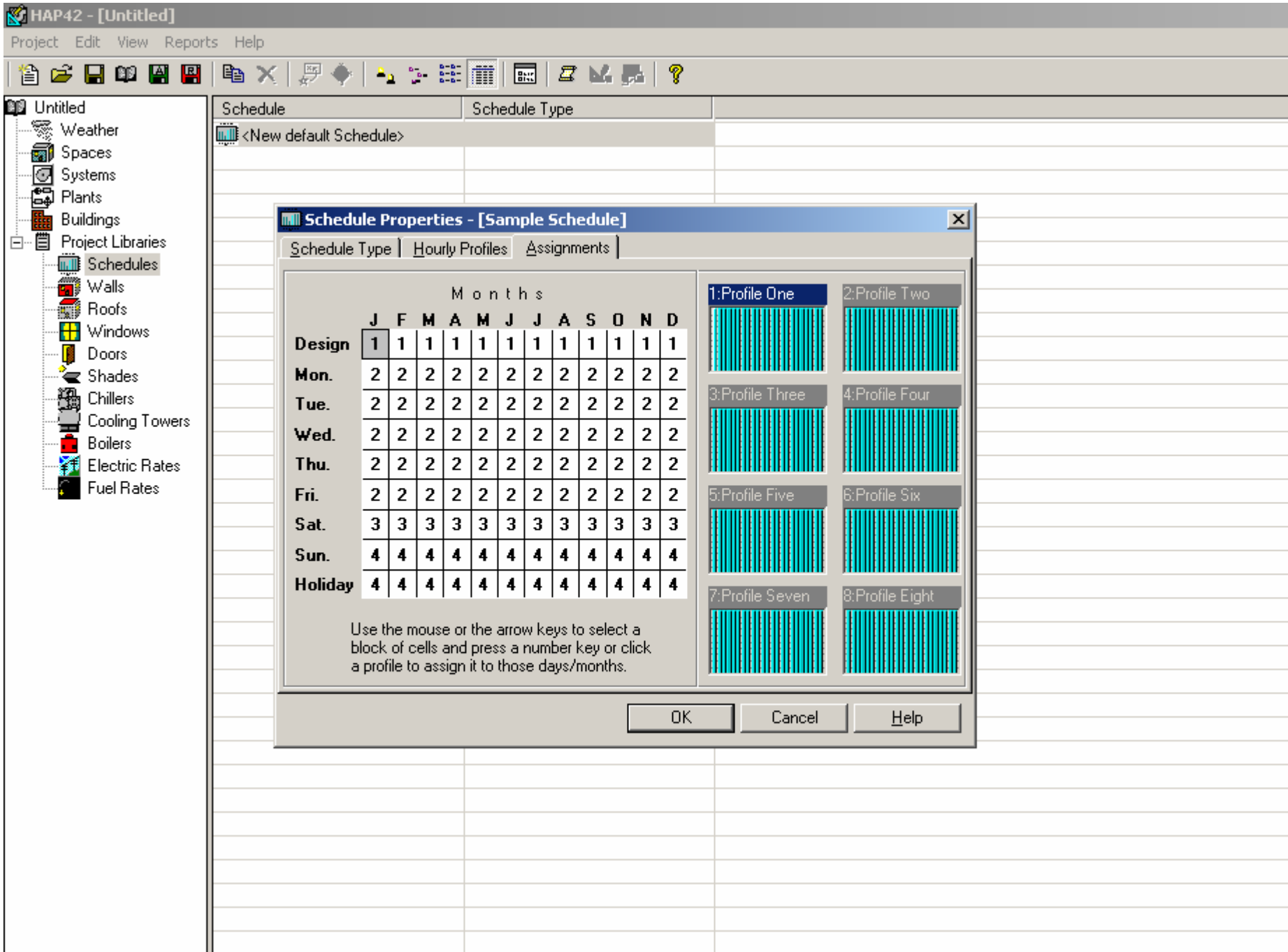
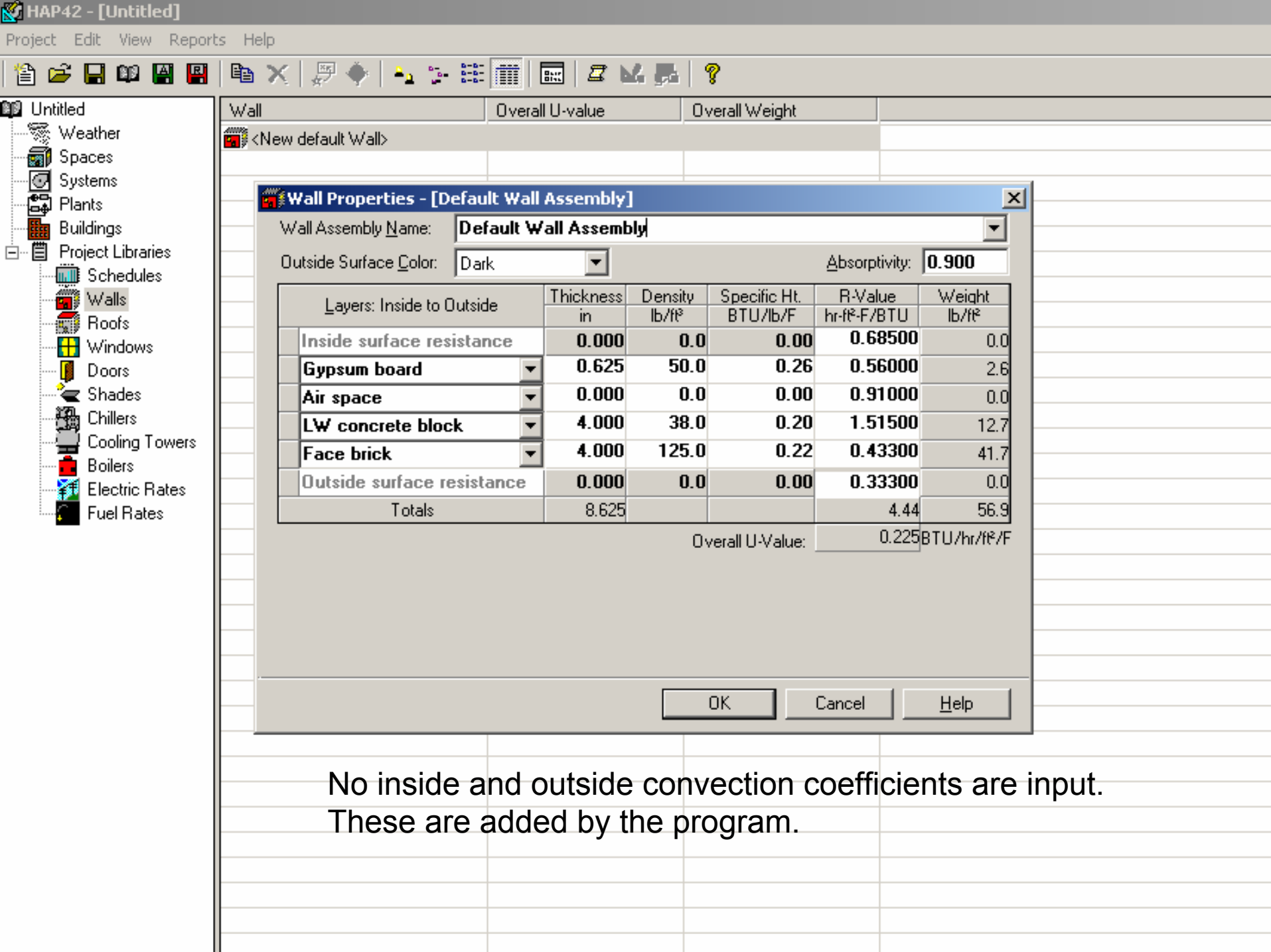
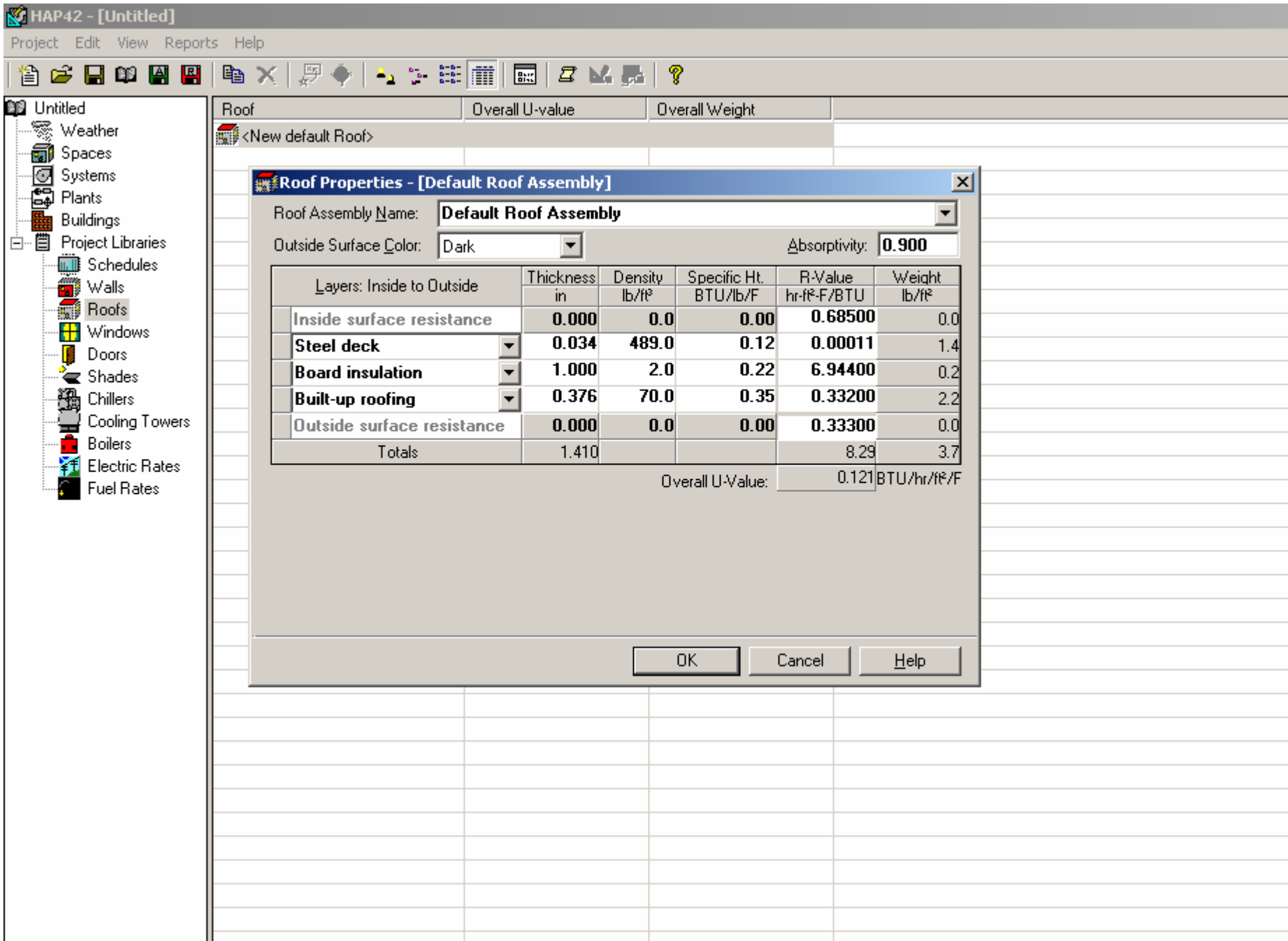
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Schedule
Schedule Type
<New default Schedule>
Schedule Properties - [Sample Schedule]
Schedule Type
Hourly Profiles
Assignments
Profile:
Profile One
1:Profile One
0
100%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 2 2 2 2
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
2:Profile Two
3:Profile Three
4:Profile Four
5:Profile Five
6:Profile Six
7:Profile Seven
8:Profile Eight
OK
Cancel
Help


HAP42 - [Untitled]
Project Edit View Reports Help
Untitled
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Schedule
Schedule Type
<New default Schedule>
Schedule Properties - [Sample Schedule]
Schedule Type
Hourly Profiles
Assignments
Months
J F M A M J J A S O N D
Design 1 1 1 1 1 1 1 1 1 1 1 1
Mon. 2 2 2 2 2 2 2 2 2 2 2 2
Tue. 2 2 2 2 2 2 2 2 2 2 2 2
Wed. 2 2 2 2 2 2 2 2 2 2 2 2
Thu. 2 2 2 2 2 2 2 2 2 2 2 2
Fri. 2 2 2 2 2 2 2 2 2 2 2 2
Sat. 3 3 3 3 3 3 3 3 3 3 3 3
Sun. 4 4 4 4 4 4 4 4 4 4 4 4
Holiday 4 4 4 4 4 4 4 4 4 4 4 4
Use the mouse or the arrow keys to select a block of cells and press a number key or click a profile to assign it to those days/months.
1:Profile One
2:Profile Two
3:Profile Three
4:Profile Four
5:Profile Five
6:Profile Six
7:Profile Seven
8:Profile Eight
OK
Cancel
Help



No inside and outside convection coefficients are input.
These are added by the program.


HAP42 - [Untitled]
Project Edit View Reports Help
Untitled
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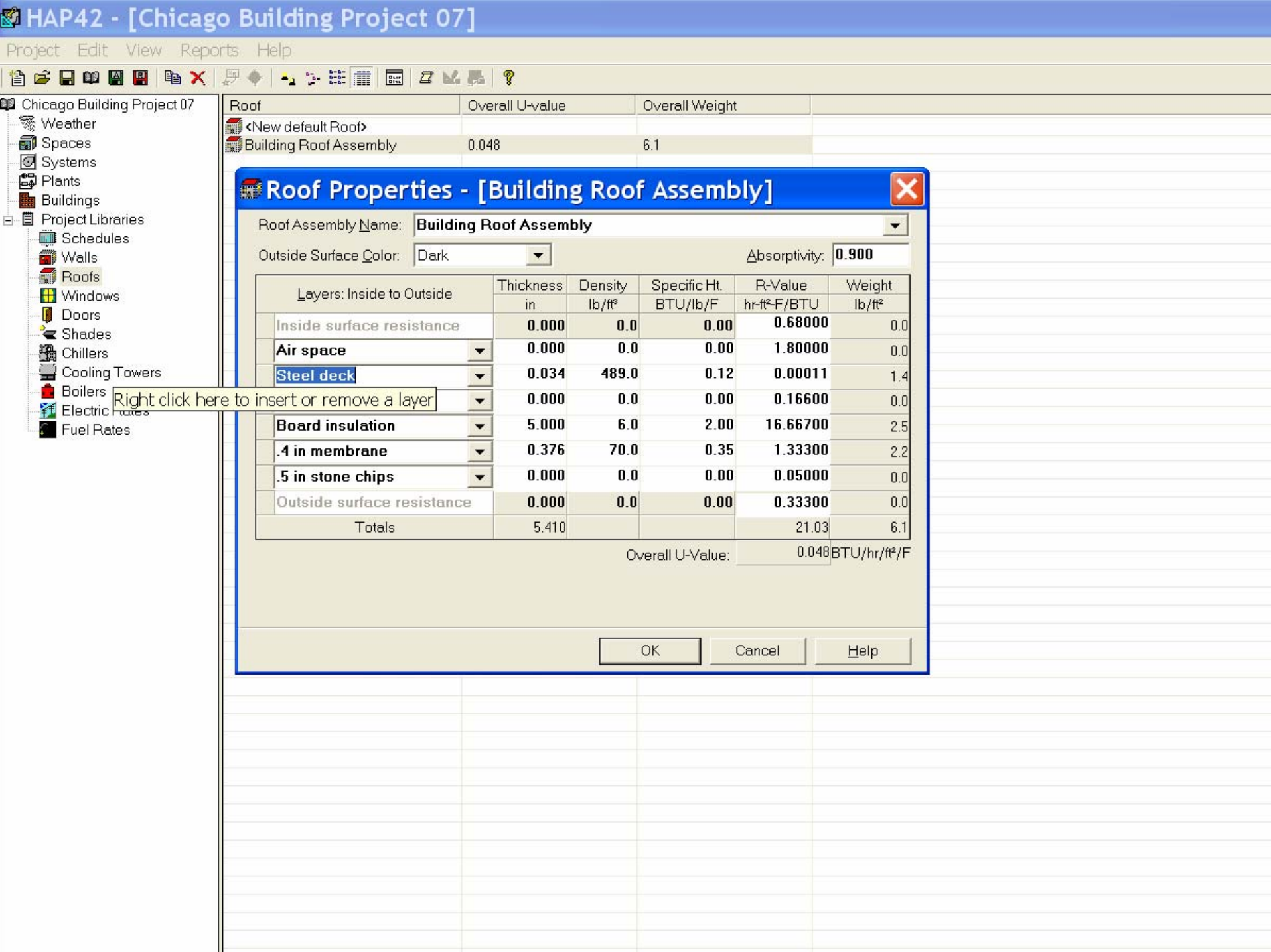
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Roof
Overall U-value
Overall Weight
<New default Roof>
Roof Properties - [Default Roof Assembly]
Roof Assembly Name: Default Roof Assembly
Outside Surface Color: Dark
Absorptivity: 0.900
Layers: Inside to Outside
Thickness in
Density lb/ft³
Specific Ht. BTU/lb/F
R-Value hr-ft²-F/BTU
Weight lb/ft²
Inside surface resistance 0.000 0.0 0.00 0.68500 0.0
Steel deck 0.034 489.0 0.12 0.00011 1.4
Board insulation 1.000 2.0 0.22 6.94400 0.2
Built-up roofing 0.376 70.0 0.35 0.33200 2.2
Outside surface resistance 0.000 0.0 0.00 0.33300 0.0
Totals 1.410 8.29 3.7
Overall U-Value: 0.121 BTU/hr/ft²/F
OK
Cancel
Help


HAP42 - [Chicago Building Project 07]
Project Edit View Reports Help
Chicago Building Project 07
Weather
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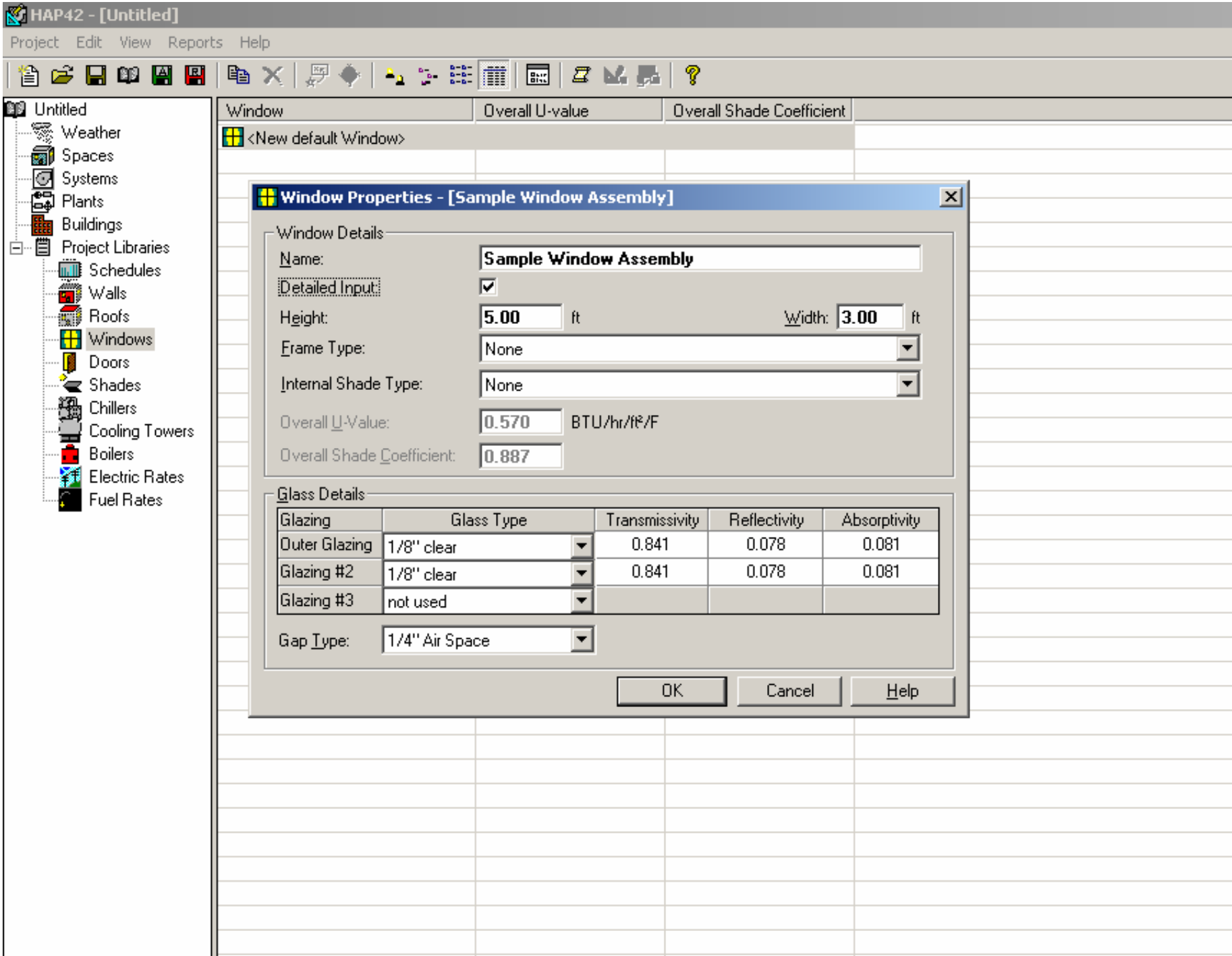
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Fuel Rates
Roof | Overall U-value | Overall Weight
<New default Roof>
Building Roof Assembly | 0.048 | 6.1
Roof Properties - [Building Roof Assembly]
Roof Assembly Name: Building Roof Assembly
Outside Surface Color: Dark
Absorptivity: 0.900
Layers: Inside to Outside | Thickness in | Density lb/ft³ | Specific Ht. BTU/lb/F | R-Value hr-ft²-F/BTU | Weight lb/ft²
Inside surface resistance | 0.000 | 0.0 | 0.00 | 0.68000 | 0.0
Air space | 0.000 | 0.0 | 0.00 | 1.80000 | 0.0
Steel deck | 0.034 | 489.0 | 0.12 | 0.00011 | 1.4
0.000 | 0.0 | 0.00 | 0.16600 | 0.0
Board insulation | 5.000 | 6.0 | 2.00 | 16.66700 | 2.5
.4 in membrane | 0.376 | 70.0 | 0.35 | 1.33300 | 2.2
.5 in stone chips | 0.000 | 0.0 | 0.00 | 0.05000 | 0.0
Outside surface resistance | 0.000 | 0.0 | 0.00 | 0.33300 | 0.0
Totals | 5.410 | | | 21.03 | 6.1
Overall U-Value: 0.048 BTU/hr/ft²/F
OK
Cancel
Help
Right click here to insert or remove a layer


HAP42 - [Untitled]
Project Edit View Reports Help
Untitled
Weather
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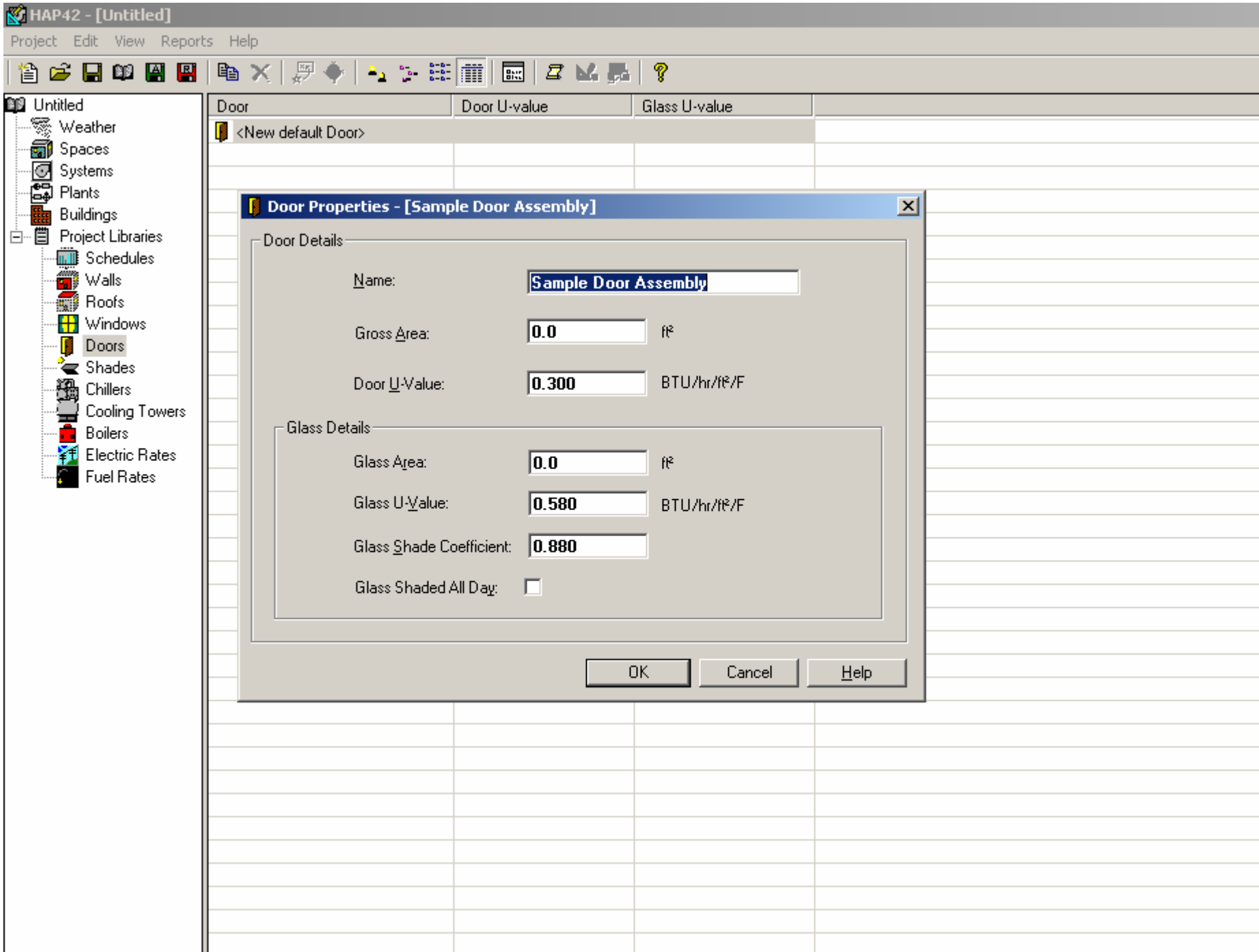
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Window
Overall U-value
Overall Shade Coefficient
<New default Window>
Window Properties - [Sample Window Assembly]
Window Details
Name: Sample Window Assembly
Detailed Input:
Height: 5.00 ft
Width: 3.00 ft
Frame Type: None
Internal Shade Type: None
Overall U-Value: 0.570 BTU/hr/ft²/F
Overall Shade Coefficient: 0.887
Glass Details
Glazing | Glass Type | Transmissivity | Reflectivity | Absorptivity
Outer Glazing | 1/8" clear | 0.841 | 0.078 | 0.081
Glazing #2 | 1/8" clear | 0.841 | 0.078 | 0.081
Glazing #3 | not used
Gap Type: 1/4" Air Space
OK
Cancel
Help


HAP42 - [Untitled]
Project Edit View Reports Help
Untitled
Weather
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Project Libraries
Schedules
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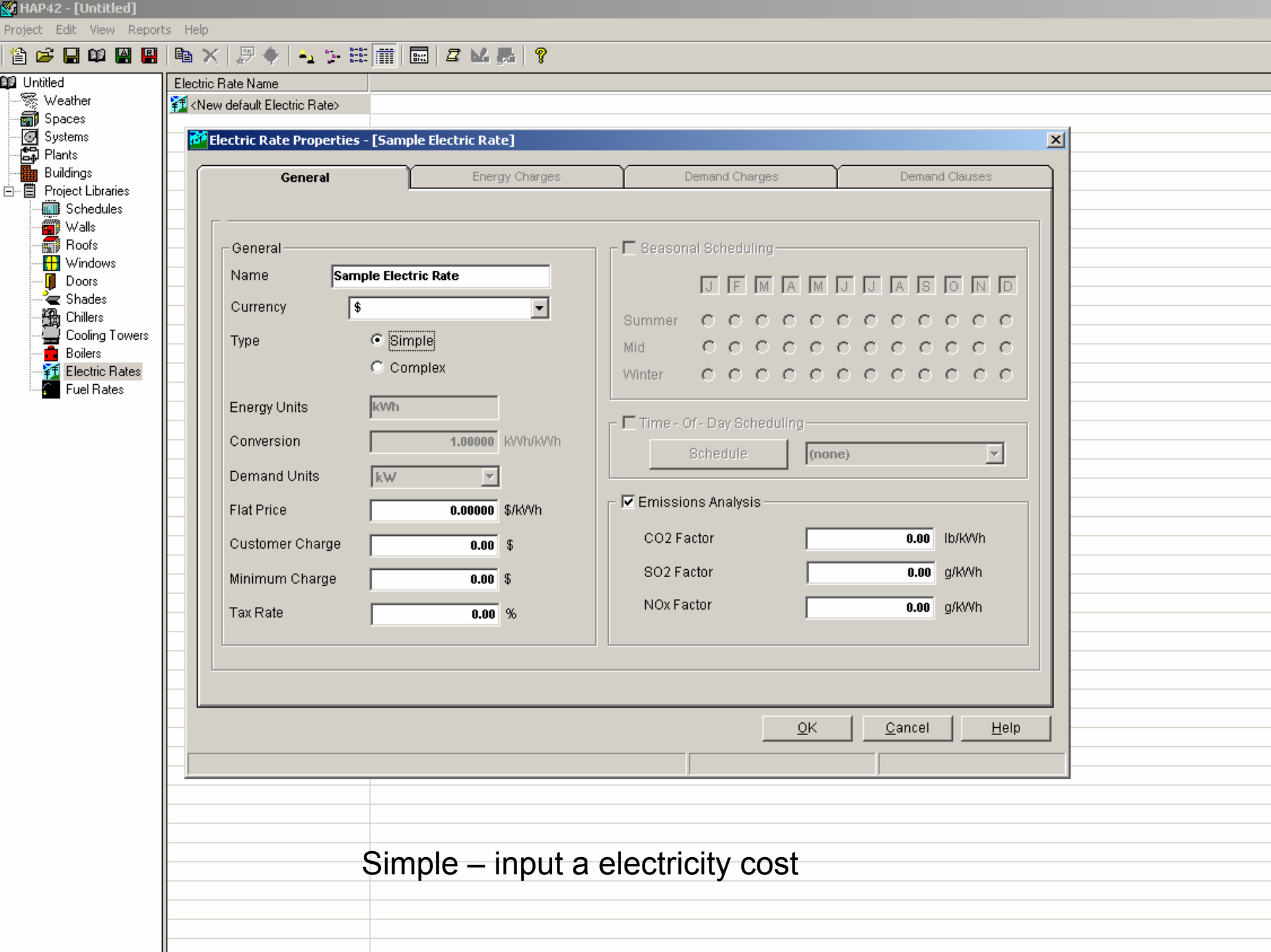
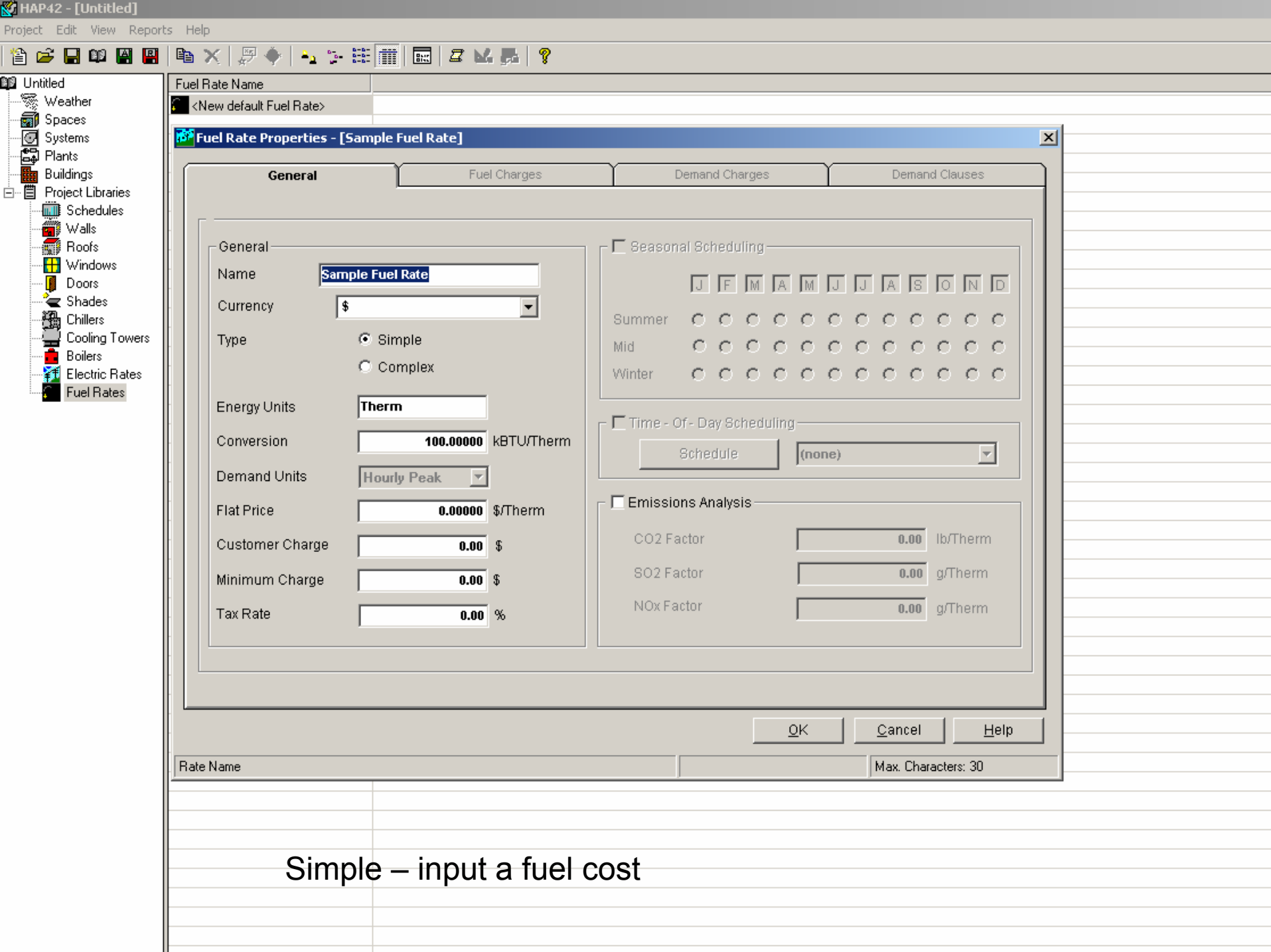
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
Door
Door U-value
Glass U-value
<New default Door>
Door Properties - [Sample Door Assembly]
Door Details
Name:
Sample Door Assembly
Gross Area:
0.0
ft²
Door U-Value:
0.300
BTU/hr/ft²/F
Glass Details
Glass Area:
0.0
ft²
Glass U-Value:
0.580
BTU/hr/ft²/F
Glass Shade Coefficient:
0.880
Glass Shaded All Day:
OK
Cancel
Help



Simple – input a electricity cost



Simple – input a fuel cost

To obtain cooling, heating and fan product specifications

http://www.carrier.com

Commercial Systems

Building Process Heating and Cooling Systems

Products

Packaged Outdoor

Rooftop Units

48 Z or 48 A

Documents and Downloads

Gasfired Heating and Electric Cooling

Product Data, Export and Domestic (162 pages)

Carrier HAP Building Project Energy Analysis

View

Options

Other Options

Enable Energy Analysis

Weather

Simulation Tab

Select Chicago

Systems

Supply Fan

Enter static pressure of selected fan (1 to 4 in water)

Humidification

Select self contained steam- natural gas

Electric Rates

Set up a Building Rate from the default

Rate - .03 to .13 $/ kw hr, my rate in buffalo is $.124/ kwhr

Fuel Rates

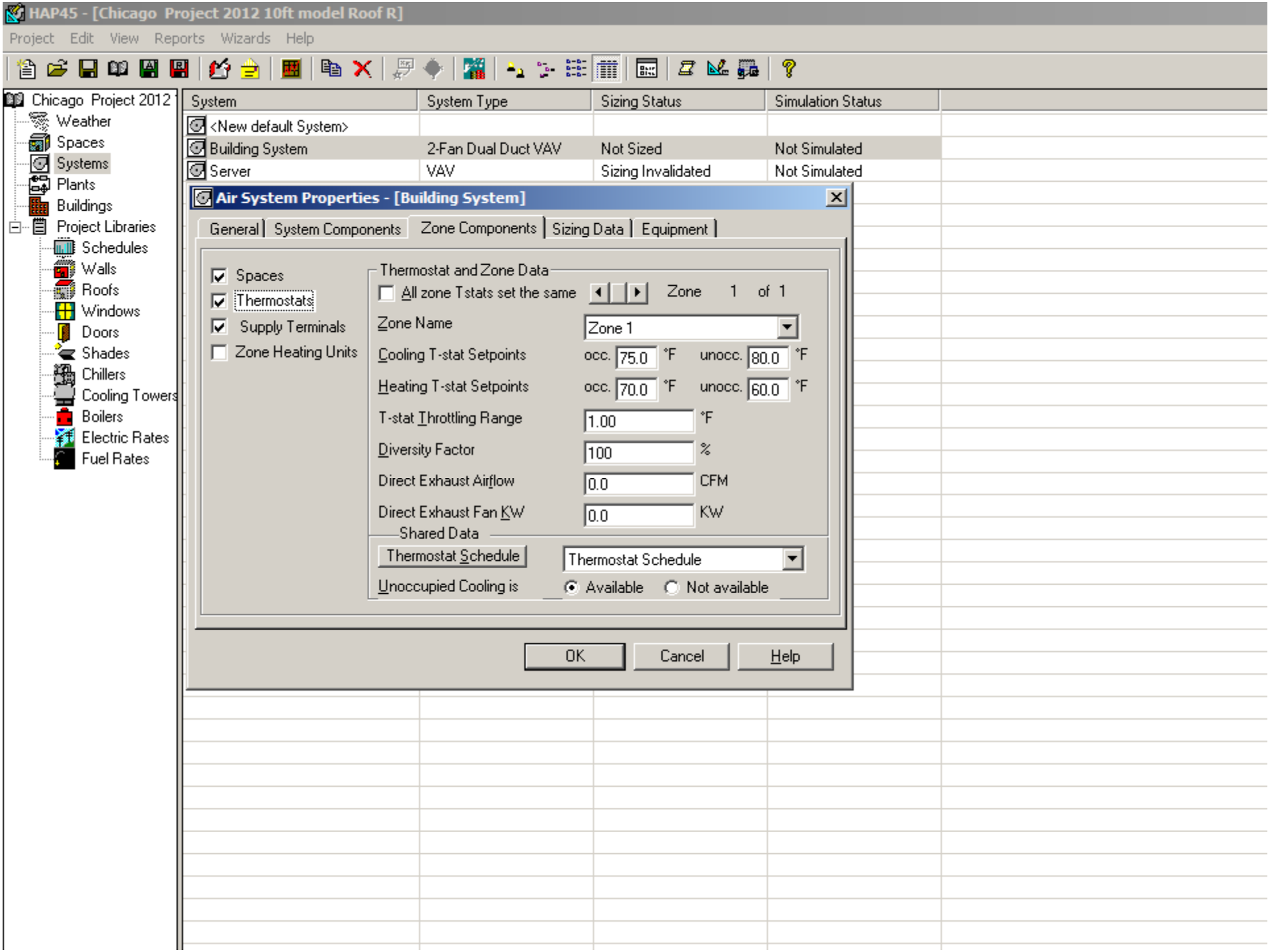
Set up building fuel rate

A therm is 100,000 BTU/hr

A cubic foot of natural gas has a heating value of about 950 BTU.

Rate -$.80 to $ 1.25/ therm, my rate in Buffalo is $1.21/therm

The May future price for natural gas is $.72/ therm


HAP45 - [Chicago Project 2012 10ft model Roof R]
Project Edit View Reports Wizards Help
Chicago Project 2012
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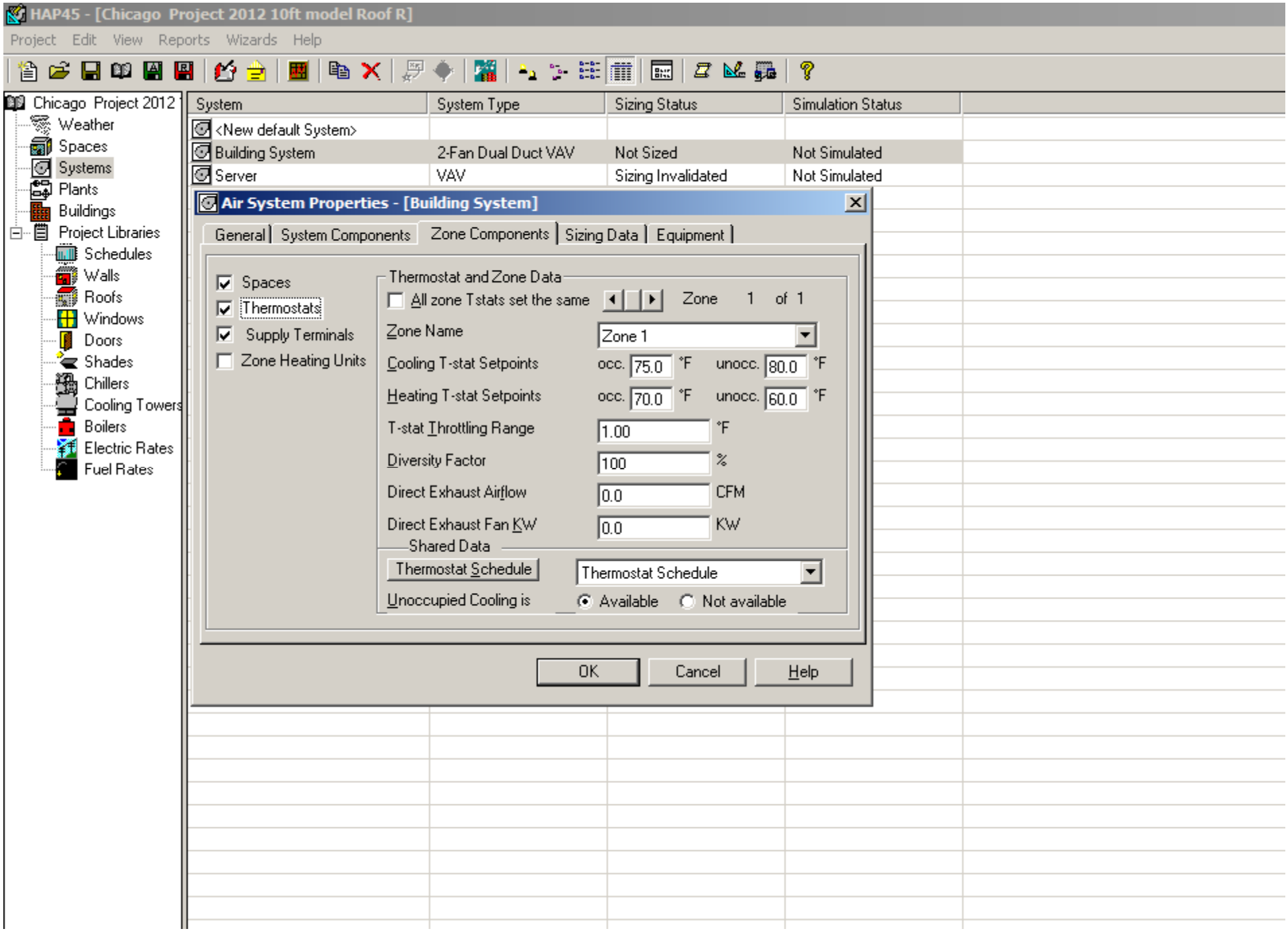
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
Building System
2-Fan Dual Duct VAV
Not Sized
Not Simulated
Server
VAV
Sizing Invalidated
Not Simulated
Air System Properties - [Building System]
General
System Components
Zone Components
Sizing Data
Equipment
Spaces
Thermostats
Supply Terminals
Zone Heating Units
Thermostat and Zone Data
All zone Tstats set the same
Zone 1 of 1
Zone Name
Zone 1
Cooling T-stat Setpoints
occ. 75.0 °F unocc. 80.0 °F
Heating T-stat Setpoints
occ. 70.0 °F unocc. 60.0 °F
T-stat Throttling Range
1.00 °F
Diversity Factor
100 %
Direct Exhaust Airflow
0.0 CFM
Direct Exhaust Fan KW
0.0 KW
Shared Data
Thermostat Schedule
Thermostat Schedule
Unoccupied Cooling is
Available
Not available
OK
Cancel
Help


HAP45 - [Chicago Project 2012 10ft model Roof R]
Project Edit View Reports Wizards Help
Chicago Project 2012
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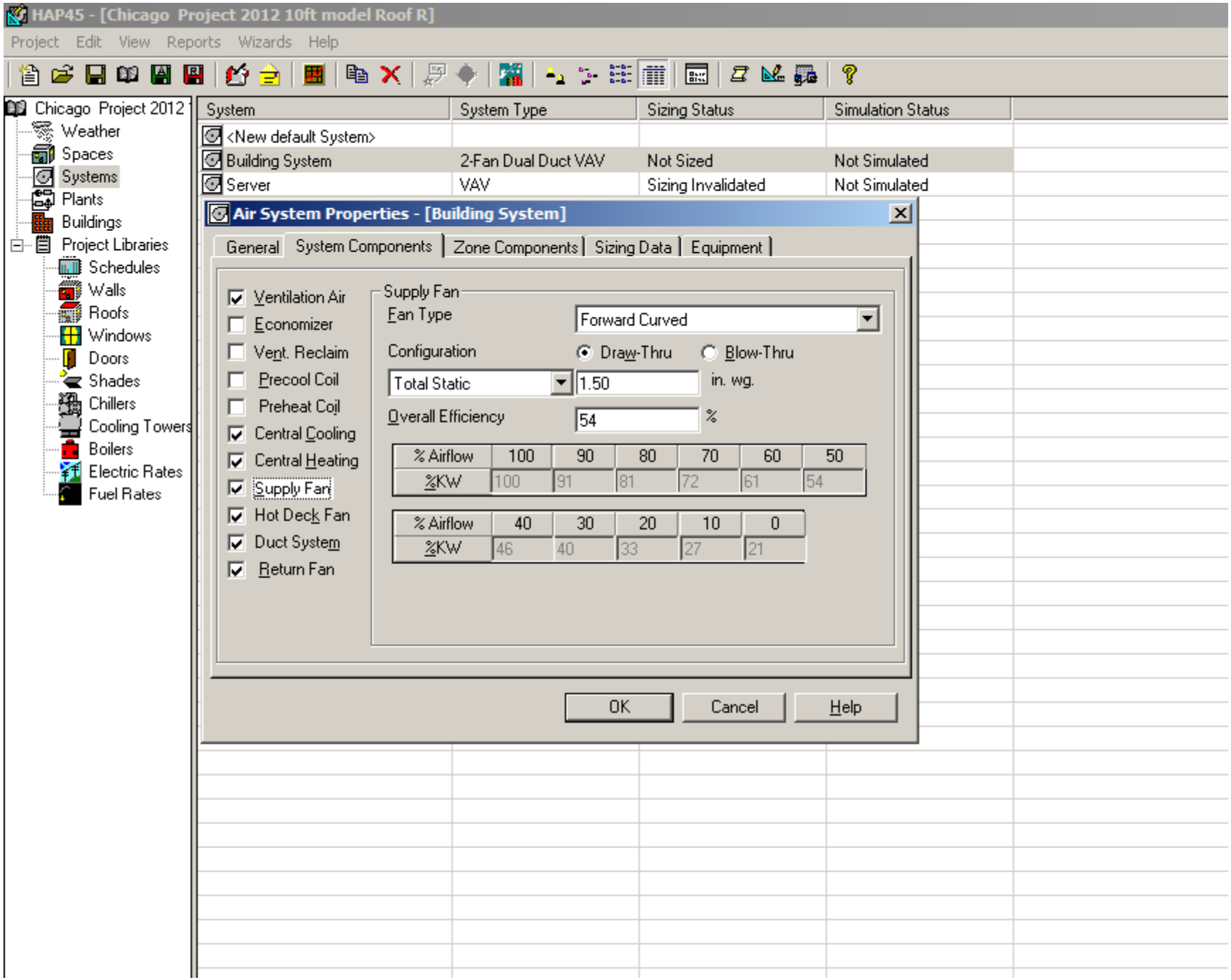
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
Building System
2-Fan Dual Duct VAV
Not Sized
Not Simulated
Server
VAV
Sizing Invalidated
Not Simulated
Air System Properties - [Building System]
General
System Components
Zone Components
Sizing Data
Equipment
Spaces
Thermostats
Supply Terminals
Zone Heating Units
Thermostat and Zone Data
All zone Tstats set the same
Zone 1 of 1
Zone Name
Zone 1
Cooling T-stat Setpoints
occ. 75.0 °F unocc. 80.0 °F
Heating T-stat Setpoints
occ. 70.0 °F unocc. 60.0 °F
T-stat Throttling Range
1.00 °F
Diversity Factor
100 %
Direct Exhaust Airflow
0.0 CFM
Direct Exhaust Fan KW
0.0 KW
Shared Data
Thermostat Schedule
Thermostat Schedule
Unoccupied Cooling is
Available
Not available
OK
Cancel
Help


HAP45 - [Chicago Project 2012 10ft model Roof R]
Project Edit View Reports Wizards Help
Chicago Project 2012
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Schedules
Walls
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Doors
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Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
Building System
2-Fan Dual Duct VAV
Not Sized
Not Simulated
Server
VAV
Sizing Invalidated
Not Simulated
Air System Properties - [Building System]
General
System Components
Zone Components
Sizing Data
Equipment
Ventilation Air
Economizer
Vent. Reclaim
Precool Coil
Preheat Coil
Central Cooling
Central Heating
Supply Fan
Hot Deck Fan
Duct System
Return Fan
Supply Fan
Fan Type
Forward Curved
Configuration
Draw-Thru
Blow-Thru
Total Static
1.50
in. wg.
Overall Efficiency
54
%
% Airflow 100 90 80 70 60 50
%KW 100 91 81 72 61 54
% Airflow 40 30 20 10 0
%KW 46 40 33 27 21
OK
Cancel
Help

Hourly Analysis Program v4.5

Hide Back Print Options

System Type

This item defines the kind of air system being entered. HAP offers features for analyzing a variety of common air handling systems. Choosing a system type is important because each type contains d

When performing system design work with HAP, the choice of a system type will influence system sizing calculations because the program tailors sizing procedures to the system type. This is re variable volume systems. In addition, the program will generate data to size the major components in each system. For example, a Two-Fan Dual Duct VAV system contains two supply fans which ea

When using HAP to perform operating cost studies, the choice of a system type will influence the system operation and energy consumption levels during the whole year energy simulation the progran

The contents of the drop-down list for system type vary according to the equipment type you chose. System types available within each equipment classification are shown below.

Undefined

- CAV - Single Zone
- CAV - Terminal Reheat
- VAV
- VVT

Packaged Rooftop Units

- CAV - Single Zone
- CAV - Terminal Reheat
- CAV - 2-Deck Multizone
- CAV - 3-Deck Multizone
- CAV - Dual Duct
- CAV - Tempering Ventilation
- VAV
- VAV - 1-Fan Dual Duct
- VAV - 2-Fan Dual Duct
- VVT

Packaged Vertical Units

- CAV - Single Zone
- CAV - Terminal Reheat
- VAV
- VVT

Split AHU

- CAV - Single Zone
- CAV - Terminal Reheat
- CAV - 2-Deck Multizone
- CAV - 3-Deck Multizone
- CAV - Dual Duct
- CAV - Tempering Ventilation
- VAV
- VAV - 1-Fan Dual Duct
- VAV - 2-Fan Dual Duct
- VVT

Chilled Water AHU

- CAV - Single Zone
- CAV - Terminal Reheat
- CAV - 2-Deck Multizone
- CAV - 3-Deck Multizone
- CAV - Dual Duct
- CAV - Tempering Ventilation
- CAV - 4-Pipe Induction
- VAV
- VAV - 1-Fan Dual Duct
- VAV - 2-Fan Dual Duct
- VVT

Terminal Units

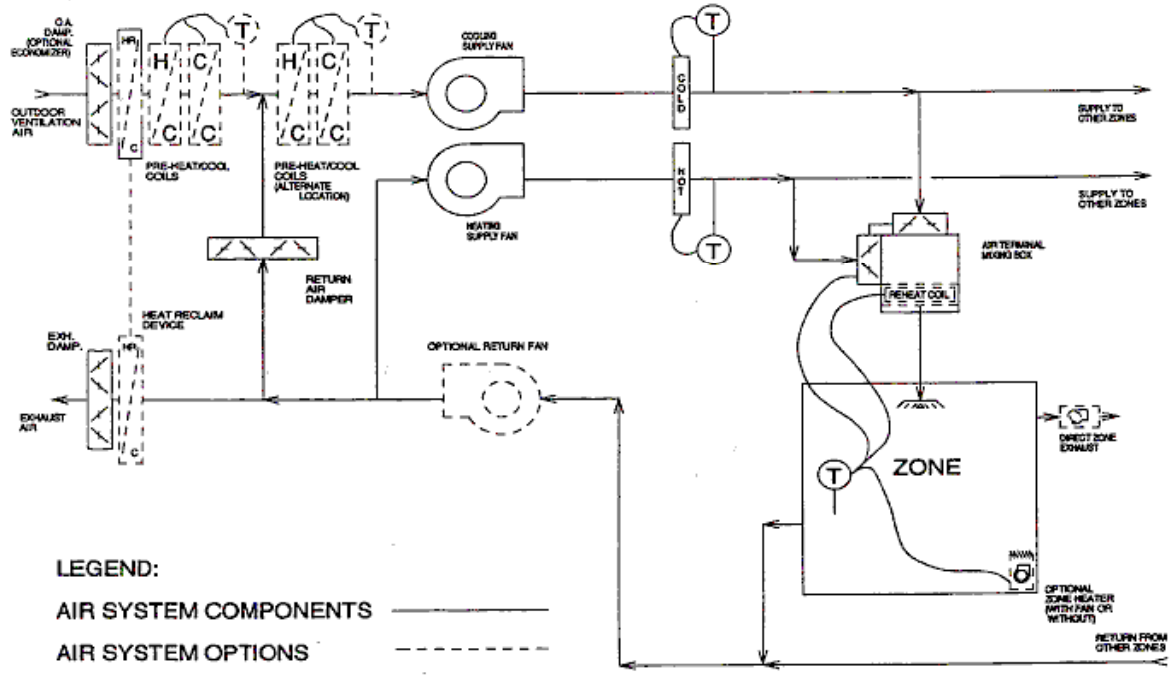
- Packaged DX Fan Coil
- Split DX Fan Coil
- Water Source Heat Pump
- Ground Water Source Heat Pump
- Ground Source Heat Pump
- 2-Pipe Fan Coil
- 4-Pipe Fan Coil

Hourly Analysis Program v4.5

Hide Back Print Options

VAV 2-Fan Dual Duct System

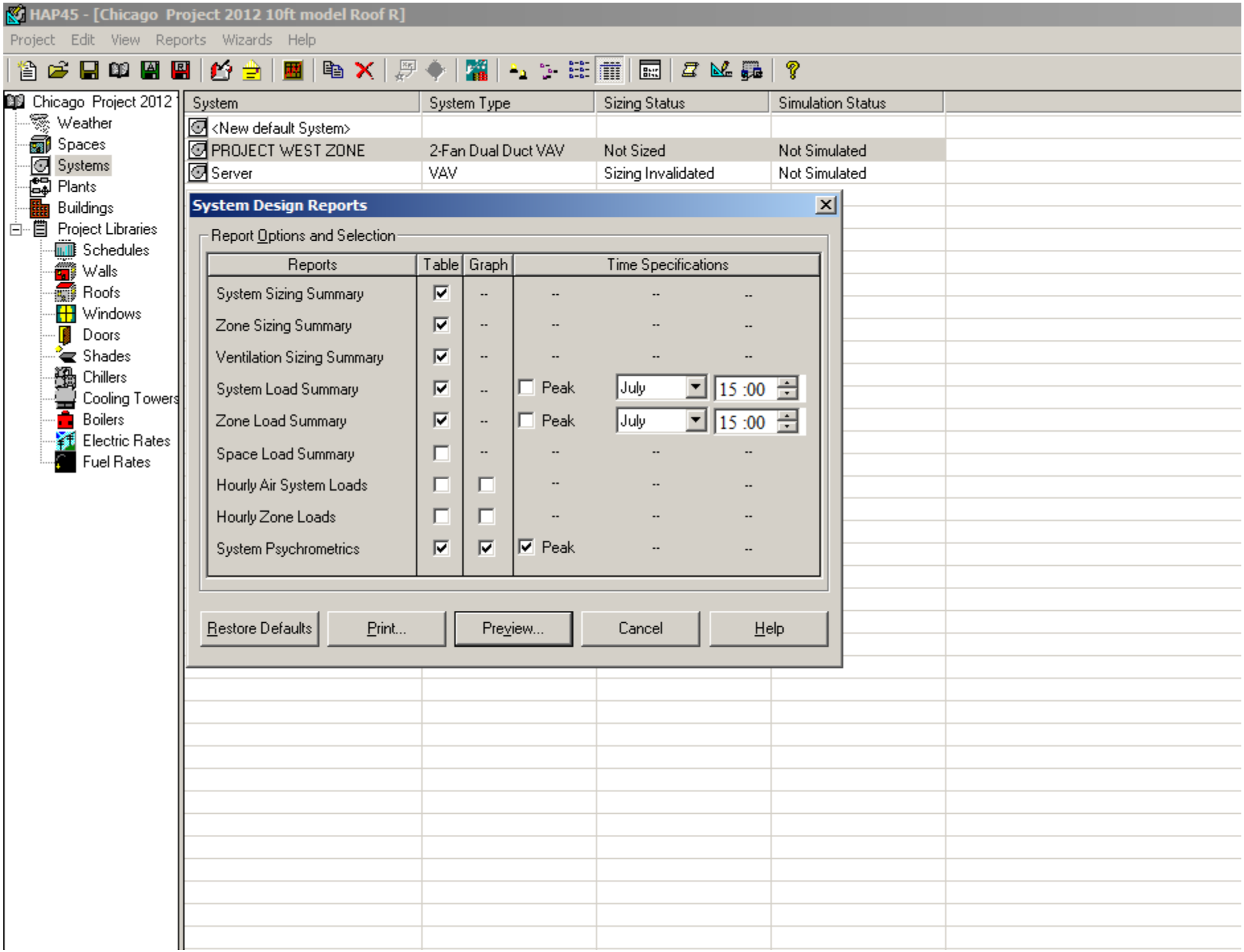
This help topic describes the operating assumptions for a VAV 2-Fan Dual Duct air system. This multiple-zone system uses a central two-deck, two-fan air handler which provides a variable volume of conditioned air to zone terminals. Air is distributed to the terminals through two parallel main ducts. The hot deck has its own VAV fan which supplies warm return air to the zones. A heating coil in the hot deck operates whenever the warm return air is insufficient to meet zone demand. The cold deck has its own VAV fan and cooling coil, and supplies cold air to the zones. The zone terminals mix air from the hot and cold supply ducts, providing air to the zones at a temperature sufficient to maintain comfort conditions. Depending on the user's description of the system, cooling and heating operation varies in the occupied and unoccupied periods as described in the following sections.



VAV 2-Fan Dual Duct System Schematic

A. Occupied Period Operation

1. The cold deck supply fan runs continuously to supply a variable volume of cold air to zone terminals.
2. The hot deck supply fan runs continuously during the hour whenever one or more zones call for heating; otherwise, the hot deck fan is off.
3. Hot deck and cold deck supply air temperatures are controlled according to user specifications.
4. Zone Thermostat Control


HAP45 - [Chicago Project 2012 10ft model Roof R]
Project Edit View Reports Wizards Help
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Fuel Rates
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System Type
Sizing Status
Simulation Status
<New default System>
PROJECT WEST ZONE
2-Fan Dual Duct VAV
Not Sized
Not Simulated
Server
VAV
Sizing Invalidated
Not Simulated
System Design Reports
Report Options and Selection
Reports
Table
Graph
Time Specifications
System Sizing Summary
Zone Sizing Summary
Ventilation Sizing Summary
System Load Summary
Peak
July
15 :00
Zone Load Summary
Peak
July
15 :00
Space Load Summary
Hourly Air System Loads
Hourly Zone Loads
System Psychrometrics
Peak
Restore Defaults
Print...
Preview...
Cancel
Help

Air System Sizing Summary for PROJECT WEST ZONE

Project Name: Chicago Project 2012 10ft model Roof R
Prepared by: University at Buffalo

03/25/2012
10:58AM

Air System Information

Air System Name	**PROJECT WEST ZONE**		Number of zones	**1**	
Equipment Class	**PKG ROOF**		Floor Area	**4410.0**	ft²
Air System Type	**2FDDVAV**		Location	**Chicago IAP, Illinois**	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	**Peak zone sensible load**		Calculation Months	**May to Sep**	
Space CFM	**Individual peak space loads**		Sizing Data	**Calculated**	

Central Cooling Coil Sizing Data

Total coil load	**13.7**	Tons	Load occurs at	**Jul 1600**	
Total coil load	**164.2**	MBH	OA DB / WB	**90.4 / 73.9**	°F
Sensible coil load	**136.0**	MBH	Entering DB / WB	**78.2 / 63.5**	°F
Coil CFM at Jul 1600	**5317**	CFM	Leaving DB / WB	**53.9 / 52.6**	°F
Max block CFM at Jul 1600	**5750**	CFM	Coil ADP	**51.2**	°F
Sum of peak zone CFM	**5750**	CFM	Bypass Factor	**0.100**	
Sensible heat ratio	**0.828**		Resulting RH	**45**	%
ft²/Ton	**322.2**		Design supply temp.	**55.0**	°F
BTU/(hr-ft²)	**37.2**		Zone T-stat Check	**1 of 1**	OK
Water flow @ 10.0 °F rise	**N/A**		Max zone temperature deviation	**0.0**	°F

Central Heating Coil Sizing Data

Max coil load	**85.0**	MBH	Load occurs at	**Des Htg**	
Coil CFM at Des Htg	**1663**	CFM	BTU/(hr-ft²)	**19.3**	
Max coil CFM	**1663**	CFM	Ent. DB / Lvg DB	**71.5 / 120.0**	°F
Water flow @ 20.0 °F drop	**N/A**				

Supply Fan Sizing Data

Actual max CFM at Jul 1600	**5750**	CFM	Fan motor BHP	**2.51**	BHP
Standard CFM	**5611**	CFM	Fan motor kW	**1.87**	kW
Actual max CFM/ft²	**1.30**	CFM/ft²	Fan static	**1.50**	in wg

Hot Deck Supply Fan Sizing Data

Actual max CFM at Des Htg	**1663**	CFM	Fan motor BHP	**0.73**	BHP
Standard CFM	**1623**	CFM	Fan motor kW	**0.54**	kW
Actual max CFM/ft²	**0.38**	CFM/ft²	Fan static	**1.50**	in wg

Return Fan Sizing Data

Actual max CFM at Jul 1600	**5750**	CFM	Fan motor BHP	**1.68**	BHP
Standard CFM	**5611**	CFM	Fan motor kW	**1.25**	kW
Actual max CFM/ft²	**1.30**	CFM/ft²	Fan static	**1.00**	in wg

Outdoor Ventilation Air Data

Design airflow CFM	**664**	CFM	CFM/person	**20.12**	CFM/person
CFM/ft²	**0.15**	CFM/ft²			

Air System Design Load Summary for PROJECT WEST ZONE

Project Name: Chicago Project 2012 10ft model Roof R — 03/25/2012
Prepared by: University at Buffalo — 10:58AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1500 COOLING OA DB / WB 91.0 °F / 74.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB -6.0 °F / -7.2 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	1120 ft²	69417	-	1120 ft²	-	-
Wall Transmission	1510 ft²	543	-	1510 ft²	4453	-
Roof Transmission	4410 ft²	4881	-	4410 ft²	15950	-
Window Transmission	1120 ft²	8346	-	1120 ft²	50790	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	4410 ft²	0	-	4410 ft²	1737	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	4763 W	13411	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	2205 W	6937	-	0	0	-
People	33	6145	6765	0	0	0
Infiltration	-	3099	4899	-	14719	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	112780	11664	-	87649	0
Zone Conditioning	-	109002	11664	-	87272	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	4963 CFM	3722	-	2306 CFM	-1965	-
Ventilation Load	573 CFM	8728	15277	77 CFM	4632	-28
Supply Fan Load	4963 CFM	5582	-	664 CFM	-1786	-
Hot Deck Supply Fan Load	0 CFM	0	-	1663 CFM	-1849	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	-	127035	26941	-	86304	-28
Central Cooling Coil	-	127034	26951	-	0	0
Central Heating Coil	-	0	-	-	84967	-
>> Total Conditioning	-	127034	26951	-	84967	0
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Ventilation Sizing Summary for PROJECT WEST ZONE

Project Name: Chicago Project 2012 10ft model Roof R
Prepared by: University at Buffalo

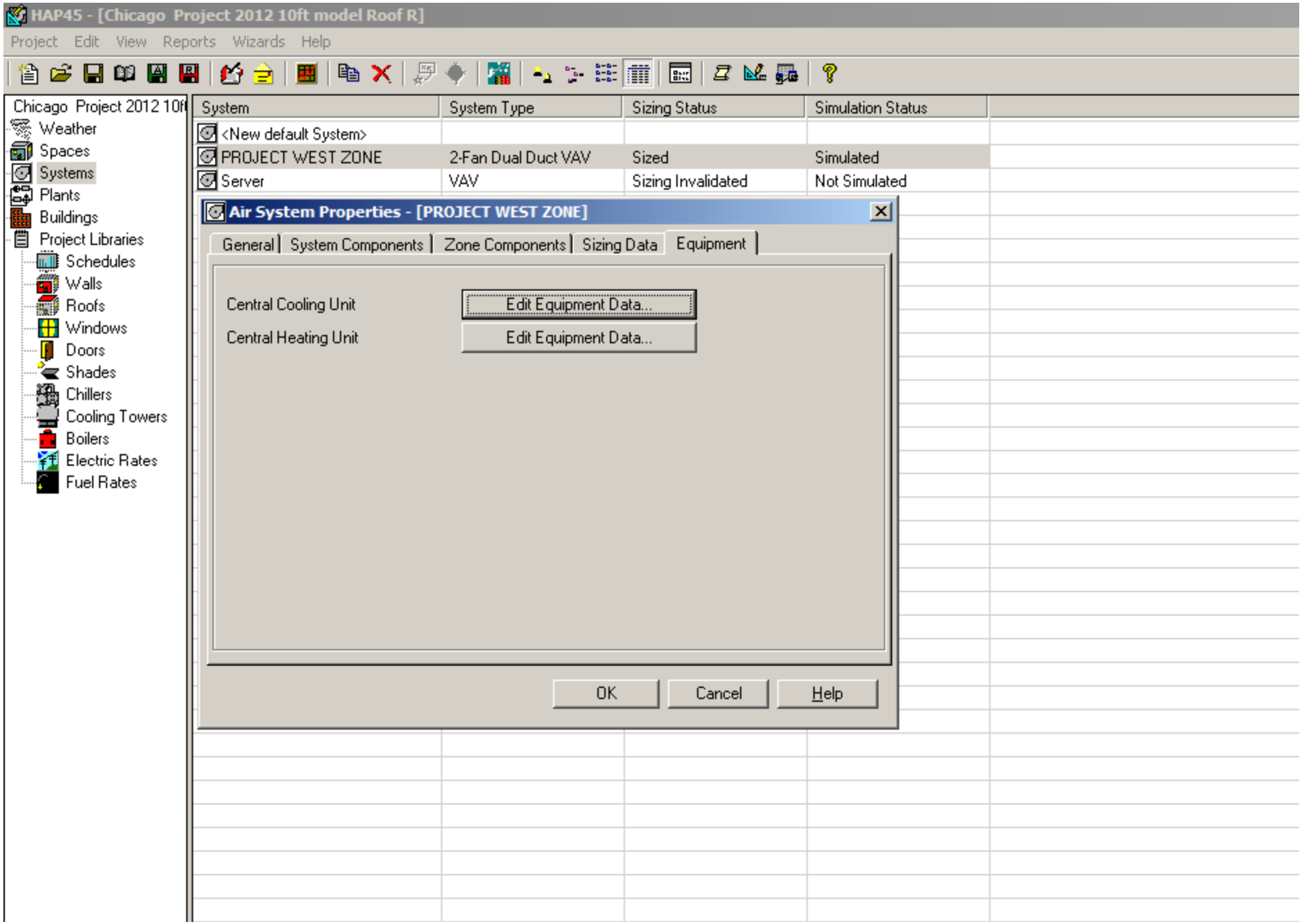
03/25/2012
10:58AM

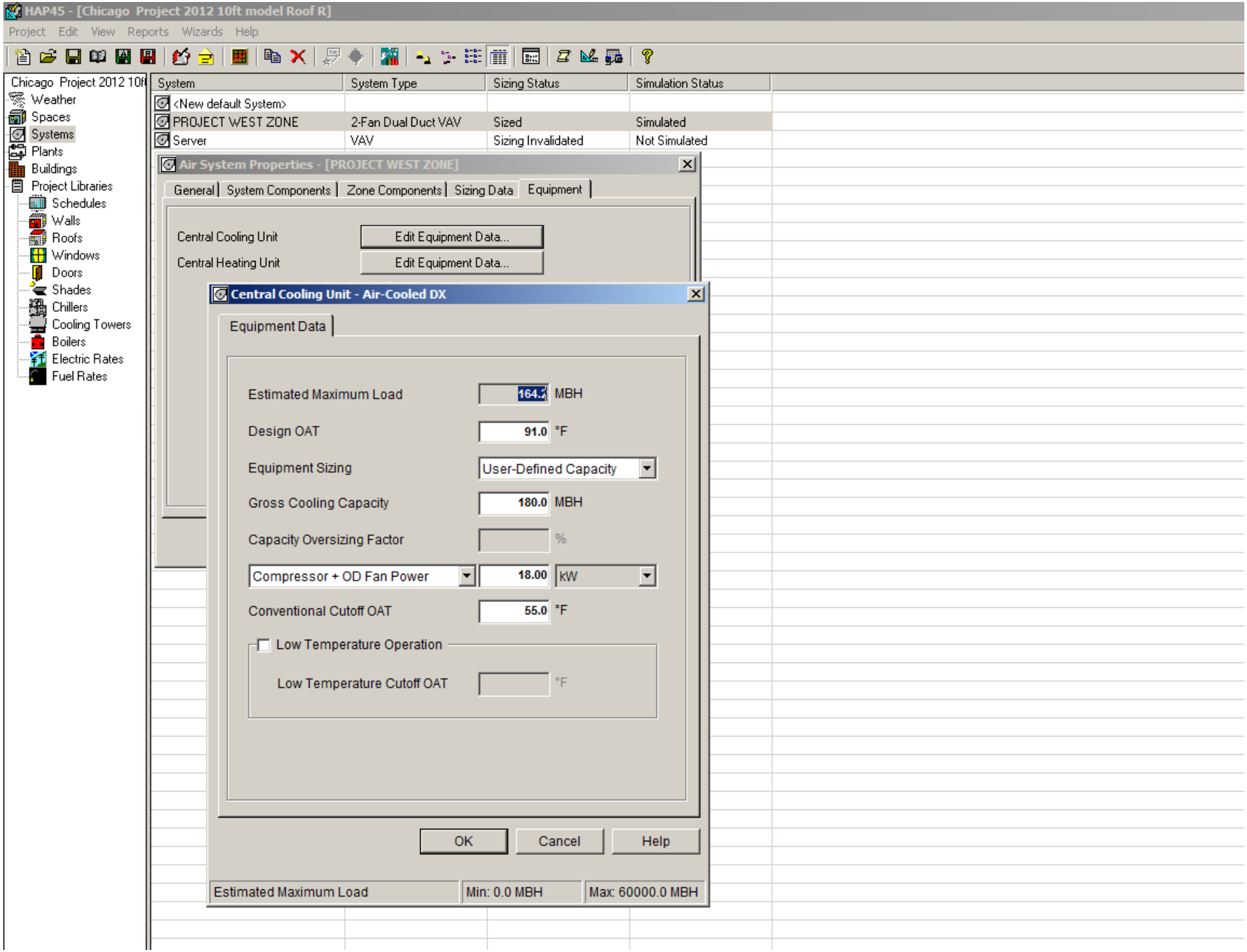
1. Summary

Ventilation Sizing Method ..... **Sum of Space OA Airflows**
Design Ventilation Airflow Rate ..... **664** CFM

2. Space Ventilation Analysis Table

Zone Name / Space Name	Mult.	Floor Area (ft^2)	Maximum Occupants	Maximum Supply Air (CFM)	Required Outdoor Air (CFM/person)	Required Outdoor Air (CFM/ft^2)	Required Outdoor Air (CFM)	Required Outdoor Air (% of supply)	Uncorrected Outdoor Air (CFM)
Zone 1									
Zone 1 W Offices	1	4410.0	33.0	5750.0	18.00	0.00	70.0	0.0	664.0
Totals (incl. Space Multipliers)				**5750.0**					**664.0**


HAP45 - [Chicago Project 2012 10ft model Roof R]
Project Edit View Reports Wizards Help
Chicago Project 2012 10ft
Weather
Spaces
Systems
Plants
Buildings
Project Libraries
Schedules
Walls
Roofs
Windows
Doors
Shades
Chillers
Cooling Towers
Boilers
Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
PROJECT WEST ZONE
2-Fan Dual Duct VAV
Sized
Simulated
Server
VAV
Sizing Invalidated
Not Simulated
Air System Properties - [PROJECT WEST ZONE]
General
System Components
Zone Components
Sizing Data
Equipment
Central Cooling Unit
Edit Equipment Data...
Central Heating Unit
Edit Equipment Data...
OK
Cancel
Help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Electric Rates
Fuel Rates
System
System Type
Sizing Status
Simulation Status
<New default System>
PROJECT WEST ZONE
2-Fan Dual Duct VAV
Sized
Simulated
Server
VAV
Sizing Invalidated
Not Simulated
Air System Properties - [PROJECT WEST ZONE]
General
System Components
Zone Components
Sizing Data
Equipment
Central Cooling Unit
Edit Equipment Data...
Central Heating Unit
Edit Equipment Data...
Central Cooling Unit - Air-Cooled DX
Equipment Data
Estimated Maximum Load
164.2
MBH
Design OAT
91.0
°F
Equipment Sizing
User-Defined Capacity
Gross Cooling Capacity
180.0
MBH
Capacity Oversizing Factor
%
Compressor + OD Fan Power
18.00
kW
Conventional Cutoff OAT
55.0
°F
Low Temperature Operation
Low Temperature Cutoff OAT
°F
OK
Cancel
Help
Estimated Maximum Load
Min: 0.0 MBH
Max: 60000.0 MBH

Monthly Simulation Results for PROJECT WEST ZONE

Project Name: Chicago Project 2012 10ft model Roof R — 03/25/2012
Prepared by: University at Buffalo — 11:28AM

Air System Simulation Results (Table 1) :

Month	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Clg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Eqpt Load (kBTU)	Central Heating Coil Input (kBTU)	Central Heating Misc. Electric (kWh)
January	0	0	0	21365	21365	25135	0
February	0	0	0	14972	14972	17614	0
March	0	0	0	6479	6479	7623	0
April	0	0	0	419	419	493	0
May	0	0	0	0	0	0	0
June	39697	39553	3591	0	0	0	0
July	45304	45304	4225	0	0	0	0
August	42220	42147	3899	0	0	0	0
September	24710	23743	2082	0	0	0	0
October	0	0	0	0	0	0	0
November	0	0	0	6374	6374	7499	0
December	0	0	0	20197	20197	23762	0
Total	**151930**	**150746**	**13797**	**69807**	**69807**	**82126**	**0**

Air System Simulation Results (Table 2) :

Month	Supply Fan (kWh)	Hot Deck Supply Fan (kWh)	Return Fan (kWh)	Lighting (kWh)	Electric Equipment (kWh)
January	389	173	317	1606	743
February	352	127	275	1432	663
March	389	69	277	1559	722
April	377	5	252	1548	717
May	389	0	260	1606	743
June	600	0	400	1501	695
July	637	0	425	1606	743
August	603	0	402	1606	743
September	469	0	313	1501	695
October	389	0	260	1606	743
November	377	69	268	1548	717
December	389	167	314	1559	722
Total	**5362**	**609**	**3762**	**18677**	**8647**

Unmet Load Report for PROJECT WEST ZONE

Project Name: Chicago Project 2012 10ft model Roof R
Prepared by: University at Buffalo

03/25/2012
11:28AM

Note: Data shown in this report is for diagnostic purposes only. Values represent total unmet hours for each cooling and/or heating unit. No deductions are made when unmet hours for one unit coincide with those in another unit.

1. Unmet Load Statistics - Central Cooling Unit - Air-Cooled DX

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	710	0	0	10	10	720
July	744	0	0	0	0	744
August	739	0	0	5	5	744
September	653	0	0	67	67	720
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
Total	**2846**	**0**	**0**	**82**	**82**	**2928**

2. Unmet Load Statistics - Central Heating Unit - Combustion

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	723	0	0	0	0	723
February	572	0	0	0	0	572
March	367	0	0	0	0	367
April	31	0	0	0	0	31
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	374	0	0	0	0	374
December	735	0	0	0	0	735
Total	**2802**	**0**	**0**	**0**	**0**	**2802**

Annual Cost Summary

Chicago Project 2012 10ft model Roof R
University at Buffalo

03/25/2012
11:29AM

Table 1. Annual Costs

Component	Chicago Building ($)
Air System Fans	973
Cooling	1,380
Heating	821
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	**3,174**
Lights	1,868
Electric Equipment	865
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**2,732**
Grand Total	**5,907**

Table 2. Annual Cost per Unit Floor Area

Component	Chicago Building ($/ft²)
Air System Fans	0.221
Cooling	0.313
Heating	0.186
Pumps	0.000
Cooling Tower Fans	0.000
HVAC Sub-Total	**0.720**
Lights	0.424
Electric Equipment	0.196
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**0.620**
Grand Total	**1.339**
Gross Floor Area (ft²)	4410.0
Conditioned Floor Area (ft²)	4410.0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	Chicago Building (%)
Air System Fans	16.5
Cooling	23.4
Heating	13.9
Pumps	0.0
Cooling Tower Fans	0.0
HVAC Sub-Total	**53.7**
Lights	31.6
Electric Equipment	14.6
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**46.3**
Grand Total	**100.0**