Simplified Procedure For Estimating Air-Conditioning Cooling Load In Ghana

Felix A. Uba, YesuenyeagbeA. K. Fiagbeand Emmanuel A. Sarsah

Abstract: Undersized or oversized air conditioning equipment leads to high operational cost, frequent breakdown and accelerated wear of equipment. Wrong sizing of equipment is often the result of inaccurate procedures employed to estimate the cooling load of the air conditioned space. Today, computer programs are available on the market for more accurate estimation of cooling load. All the same, what appears to be the established practice among service providers in the air conditioning industry in Ghana is to size air conditioners for all applications by multiplying the net floor area by cooling load factor to estimate space cooling load. Availability of cooling load factors that take into account the space operating conditions will be a more accurate and user-friendly tool for such service providers. The Transfer Function Method (TFM), a well-known cooling or heating load estimation procedure that has been adopted by ASHRAE, was used in this research to predict the hourly and daily average cooling load due to different types of walls, roofs and fenestration that are typically found in building construction in Ghana. This has been used to develop cooling load factors that simplify load estimation with a worksheet. The outputs of the worksheet were compared with the result of cooling load estimated using a computer program and the results were found to be satisfactory. The present work will help minimize the problems of higher initial investment and larger energy consumption by auxiliaries, due to over-sizing A/C equipment and the general discomfort during the peak hot season in Ghana, due to under-sizing of A/C equipment.

Key Terms: Cooling load,worksheet, load factors, design condition.

1 INTRODUCTION

Ghana has been experiencing a steady growth in electric power demand as a result of increasing economic activity and improvement in the standard of living such as the use of air conditioners (A/C) in both commercial and residential buildings. As a result, demand for electricity today far outstrips supply resulting in unstable and poor quality supply and load shedding. To meet this increasing demand for electricity and improve supply quality requires two approaches, namely, generate more power and/oreconomize the use of available power by avoiding wastage [1].From surveys carried out by the Energy Foundation in Ghana, among others, air conditioners represent over 60% of the power usage in air conditioned buildings. Thus, energy-efficient air-conditioner usage in buildings will contribute immensely to reduce energy misuse in buildings and thereby reduce the strain on the national electricity grid. Selection of energy-efficient air conditioner depends on two factors, namely, energy-efficiency of the equipment and correct size or cooling capacity of the equipment for any particular application. On the issue of efficiency of A/C equipment, energy labeling has been introduced in the country which requires manufacturers to affix energy labels on air conditioners and other similar energy-consuming appliances coming onto Ghanaian market to enable buyers to make informed choice.

- Uba Felix is a lecturer in the Mechanical Engineering Department, Wa Polytechnic, Wa, Ghana. E-mail: felix_uba@yahoo.com.
- Fiagbe Yesuenyeagbe is a lecturer in the Mechanical Engineering Department, KNUST, Kumasi, Ghana. E-mail: yakfiagbe@yahoo.com.
- Sarsah Emmanuel is a lecturer in the Mechanical Engineering Department, Wa Polytechnic, Wa, Ghana. E-mail: emmanuelsarsah@gmail.com.

Thus, selecting an efficient brand of air conditioner is no more a problem of lack of knowledge other than what level of energy rating the purchaser is prepared to pay for. Selection of the appropriate size or capacity is where the problem is because it is not backed by accurate estimation of the space cooling load [2]. A rule of thumb approach that many service providers apply in Ghana is to determine the space cooling load by multiplying the floor area by a cooling factor of 600 Btuh/m^2 which takes no account of the effect of important load influences such as wall glazing and its orientation, sun exposure, internal heat generating devices and the usage pattern of the space. When selection is not based on reasonable estimate of the space cooling load, what is more likely to occur is over-sizing or under-sizing of the air conditioner which in either case results in increased power consumption and accelerated equipment wear [3].For accurate estimation of cooling load which is the first requirement for correct sizing of cooling equipment, computer-based programs are available on the market today. One major problem with computer-based programs is the cost which the average A/C service provider considers to be prohibitive. In Ghana, consultations carried out show that only a few A/C companies that are local agents or branches of multinational A/C companies have load estimation software supplied by their mother companies. Computer-based softwares give correct estimation of the cooling load of a building. They are, however, not practical tools because they require more time for data input and the knowledge of computer skill by the user [4]. For this reason, user-friendly load estimating tools have been developed by the air-conditioning industry in several countries to aid their local technician and general service providers to carry out quick load estimation and equipment selection to reasonable accuracy.One example of this is the worksheet developed by Trane, a major A/C equipment manufacturer in the United State of America [5]and is attached in the appendix A. This worksheet is a user-friendly practical load estimating tool that service providers find very handy and efficient for day to day activities. Unfortunately, this worksheet and accompanying load factors are based on American conditions where materials of wall construction and solar heat loads are different from what pertains in Ghana, thereby rendering its application for our local conditions inaccurate.In this work, our aim is to develop a simplified air-conditioning load estimation worksheet and accompanying load factors for use by air conditioning service providers in the practical estimation of air conditioning cooling load inGhana.

2 MATERIALS AND METHODS

Calculating the load of a building's envelope is complicated by the effect of heat storage in the mass of the building due to its thermal inertia to heat response. Thus, sizing heating, ventilation and air conditioning (HVAC) equipment for space conditioning should start with a review of the theory of air conditioning load estimation in buildings, analysis of sample computer-based program for estimation of air conditioning load and analysis of heat transfer in typical sample(s) of building construction in Ghana. In this research, the Transfer Function Method (TFM) is employed to account for the transient storage effects and limits of static analysis of the enclosure components. This approach was developed by [6]. The conductive transferacross the wall surfaces or roof isdefined in the form of the equation [7]:

$$\dot{Q}_{cond,t} = -\sum_{n\geq 1} d_n \dot{Q}_{cond,t} - n\Delta t + A\left(\sum_{n\geq 0} b_n T_{sol,t} - n\Delta t - T_i \sum_{n\geq 0} c_n\right) \quad (1)$$

where A is the area of roof or wall (m^2), Δt is the time step (= 1 h), $T_{sol,t}$ is the sol-air temperature of outside surface at time t, b_n, c_n, d_n are coefficients of conductive transfer function of the wall or roof attachedin appendix B and $\dot{Q}_{cond,t}$ is the conductive heat gain at time t.The heat available (released into the room after storage in the material) for the equipment to extract at time, t, is dependent on the time-delay characteristics, v_n and $w_n$shown in Table 1.Therefore, $\dot{Q}_{c,t}$, the cooling load (heat available for the equipment to extract at time, t) is given by;

$$\frac{\dot{Q}_{c,1}}{A} = v_o \frac{\dot{Q}_{cond,1}}{A} + v_1 \frac{\dot{Q}_{cond,1-1}}{A} - w_o \frac{\dot{Q}_{c,1-1}}{A} \quad (2)$$

where the subscript in $\dot{Q}_{c,1}$ represent the heat available per unit area at time, $t_{loc,\ civ.}$ = 1: 00 AM (local civil time on longitude 0°) that is to be extracted by the HVAC equipment.

Table 1. Coefficients of room transfer functions

Heat Gain Component	Room Envelope Construction	v_0	v_1	v_2
		Dimensionless		
Solar heat gain through glass with no interior shading and heat generated by equipment and people, which is dissipated by radiation	Light	0.224	$=1+w_1-v_0$	0
	Medium	0.194	$=1+w_1-v_0$	0
	Heavy	0.187	$=1+w_1-v_0$	0
Conduction heat gain through exterior walls, roofs, partitions and doors, and windows with blinds or drapes	Light	0.703	$=1+w_1-v_0$	0
	Medium	0.681	$=1+w_1-v_0$	0
	Heavy	0.676	$=1+w_1-v_0$	0
Heat generated by lights	Light	0	="a" in Table 3.12	$=1+w_1-v_1$
	Medium	0	="a" in Table 3.12	$=1+w_1-v_1$
	Heavy	0	="a" in Table 3.12	$=1+w_1-v_1$
Heat generated by equipment and people, which is dissipated by convection, and energy gain due to ventilation and infiltration air	Light	1	0	0
	Medium	1	0	0
	Heavy	1	0	0

Source**:** [9]

Sample spaces of two halls in the terminal building of theKotoka International Airport in Ghana were used for validation of the accuracy of the cooling load factors. The Kotoka International Airport (KIA) underwent a major rehabilitation that was completed in 2004 to improve general infrastructure and increase passenger handling capacity. As part of the rehabilitation, the Check-in hall and the Meeters& Greeters hall of the Terminal building at the airport were restructured and new air conditioning units provided.The cooling load of the two halls calculated by the project Consultants using *Carrier load estimation software*, HAP v3.07, was compared with that obtained from the developed worksheet. The loads estimated were also compared with the capacity of air conditioning units installed and successfully operating at the various halls. The design data of the air conditioning system in the two spaces are tabulated in Table 2.

Table 2. Air Conditioning Design Data of the Sample Spaces

ITEM	SAMPLE SPACE	
	CHECK-IN	MEETERS & GREETERS
Design space temp.	24°C	26°C
Occupancy	800	445 persons
Activity	Standing	Walking through
Lighting heat gain	20 W/m² of net area	20 W/m² of net area
Equipment Load	20 W/m² of net area	20 W/m² of net area
Fresh Air/person	6 L/s	6 L/s
Air Change (ACH)	0.25	0.25
Shading Coefficient	1	1
Wall	Hollow sandcrete block (non-insulated)	Hollow sandcrete block (non-insulated)
Floor	Basement plant room below floor	On the ground
Roof	4-in concrete slab over concrete beams underneath, above is air conditioned Departure/Immigration area	Underground space beneath car park area for passenger offloading at main entrance to Terminal building

2.1 Air Requirement Air

2.1.1 Air Change Rate (ACH) for Check-in Hall

With a space volume of 8,313m^3, the 6 l/s fresh air per person for 800 persons corresponds to 17,200m^3 per hour which is equivalent to 2.08 ACH. Thus actual ACH used in the estimation is 2.33. Fig. 1 is the schematic diagram of the check-in hall. The South and West facing walls of the Check-in hall border air conditioned areas and half of the space above (first floor) is air conditioned.

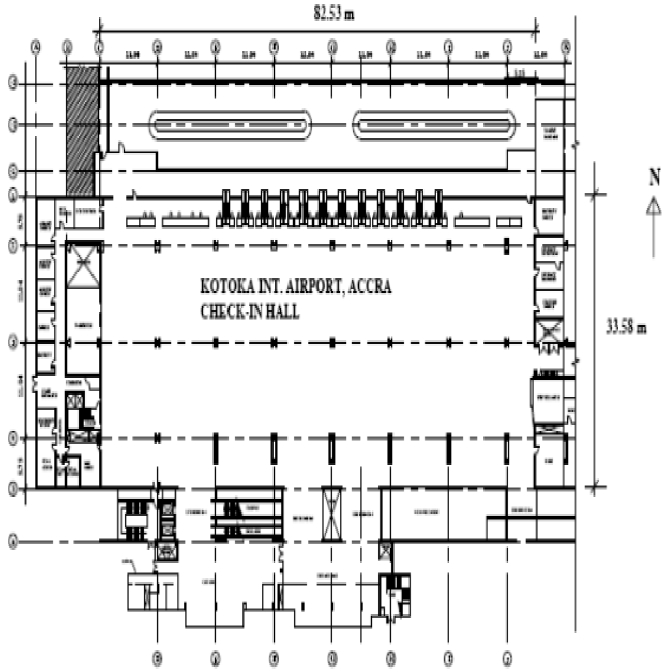

Fig. 1. Check-In Hall, Kotoka Int. Airport, Accra.

2.1.2 Air Change Rate (ACH) for Meeters& Greeters Hall

With a space volume of 4394 m^3, the 6 l/s fresh air per person for 445 persons corresponds to 9,6123m^3 per hour which is equivalent to 2.19 ACH. Thus actual ACH used in the estimation is 2.44. In addition, because it is a transition space with high door opening rate, the space temperature is maintained at 26 °C. This is reckoned by reducing the rate due to ventilation and air change while the other factors calculated based on 24°C are maintained at their value in the verification. Fig. 2 is the schematic diagram of the Meeters& Greeters hall. The South wall of the Meeters& Greeters hall border shows air conditioned areas and two thirds of the space above (first floor) is air conditioned.

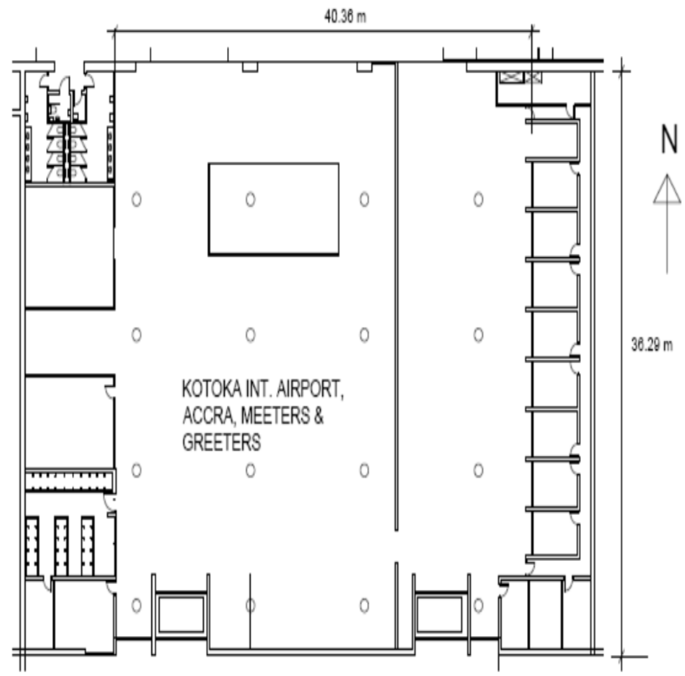

Fig. 2. Meeters& Greeters Hall, Kotoka Int. Airport, Accra.

3 RESULTS AND DISCUSSIONS

The main aim of the worksheet is to account for all the thermal loads without a safety factor. To achieve that, all the components of the heat load must be estimated to reasonable accuracy. If the estimation is more accurate, the need for unusually large safety factor becomes unnecessary. The developed worksheet isshown in appendix C. It is a simplified tool which accounts for all the load components in estimating the space cooling load.

3.1 Load Estimation Factors

The summary of the load estimation factors for the various components of the loads are produced from the Transfer Function Method and all cooling loads are given in W/m^2 except for occupancy. In the case where usage is used, it means time schedules. The cooling loadfactors are provided inappendix D.

3.2 Comparison of Results

Due to the limitation of space,the worksheet result for Check-in Hall is shown in Table 3. A summary of results showing the comparison of the two estimating tools: Carrier Load Estimation software by consultant and UBAs Air-Conditioning Load Estimation worksheet is in Table 4.

Table 3. Estimating cooling load by worksheet for KIA, Check-in Hall

CUSTOMER NAME:	SAMPLE 1: KIA, CHECK-IN HALL	HOUSE No.:	
ADDRESS:	ACCRA	TEL:	
CITY:			

SECTION A: WALL TRANSMISSION

ITEM		WEST	EAST	NORTH	SOUTH	FLOOR	CEILING
		W_1	W_2	W_3	W_4	W_5	W_6
Total Area (m^2)	A	248	248	101	101	2771	2771
Win. Area (m^2)	B	0	0	0	0	0	0
Net Area (m^2)	C=A-B	248	248	101	101	2771	10
Load Factor (Table A)	D	0	50.43	14.89	0	8.37	3.85
Total Load (W)	E=D*C	0	12,507	1,503	0	23,192	10,668
Total Load for Section A = $\Sigma W_i = W_1 + W_2 + W_3 + W_4 + W_5 + W_6 =$							47870

SECTION B: OCCUPANCY

No. of People	A	800
Load Factor (Table B)	B	185
Total Load (W)	C = A * B	148,000

SECTION C: LIGHT & EQUIPMENT

Floor Area (m^2)	A	2771
Light (W)	B = 20 * A	55,420
Equipment (office and Commercial space) (W)	C = 20 * A	55,420
or		
Equipment (known heat generation) (W)	D	
Total Load for SECTION B(W)	E = B + C	110,840
	or	
	E = B + D	

SECTION D: INFILTRATION & VENTILATION

Volume of Space (m^3)	A	8313
ACH	B	2.33
Inf. Vol.	C = B * A	19,369
Total Inf. Load (W)	D = C * 12.5	242112

SECTION E: SOLAR LOAD

ITEM		WEST	EAST	NORTH	SOUTH	
Area (m^2)	A	0	0	0	0	
Load Factor (Table F)	B	0	0	0	0	Total Load for Section E
Total Solar Load (W)	C=A*B	0	0	0	0	0

SUMMATION OF SECTIONAL LOADS

ITEM	SECT. A	SECT. B	SECT. C	SECT. D	SECT. E	ESTIMATED LOADS (W)
Total Load (W)	47,870	148,000	110,840	242,112	0	548,822

Factor of Safety (Ranges from 0-5%)	f = 1 - Range	5%
Estimated Cooling Load (W)	A	548,822
Corrected Estimated Load (W)	B = A * F	576,263
Corrected Estimated Load (Btu/h)	C = B * 3.412	

Table 4. Comparison of estimated loads from the two estimating tools

Item	Sample Space	Installed A/C	Estimated (Project Consultant),		Estimated, UBA	
		Q (kW)	Q (kW)	Deviation (%)	Q (kW)	Deviation (%)
1	Check-In	564	541	-3.7	576	+2.1
2	Meeters & Greeters Hall	234	230	-1.7	240	+2.6

From table 4 the cooling load estimated by the worksheet is 576 kW and the estimated load from the consultant software is 541 kW. However the installed air-conditioning capacity is 564 kW. This result gave positive deviation of 2.1% and negative deviation of 3.7% by the worksheet and the consultant software respectively from the installed capacity. The deviation of the worksheet result from the consultant software is 6.5% for the Check-in Hall. The deviation of the worksheet result from the consultant software is 4.3% for the Meeters and Greeters Hall. These results show that the worksheet can be used for initial cooling load estimation within reasonable accuracy. Also, in both cases, the results deviated from the capacity of the air conditioner installed were less than 4%. The use of the worksheet provides reasonable factor of safety.

4 CONCLUSION

Calculating the cooling load in the design of air-conditioning system for buildings is a tough job and carries high risk because of reliance on many tables and formulas. Using computer for this calculation reduces design time and minimizes the risk of mistakes. However, use of the computer is not a handy and fast estimate for field work. The use of simplified estimation sheet from other developed countries also provides erroneous cooling load estimate. The new cooling load estimation sheet with accompanying tables provides a convenient alternative for easy and fast estimation within Ghanaian conditions. The worksheet is handy and requires no special skills for its usage. The cooling load factors provided with the worksheet are based on the transfer function method and account for various principal spaces cooling load. The results from the sheet compare well with that from commercial load estimation software. In order to enhance and expand the load estimation factors, future work will involve looking into five and six inches thick walls although these are reasonably approximated by the 4 inches thick wall. Since the meteorological data used for developing the load factors is for the southern part of Ghana, further work will be necessary to test the simplified load estimation factors for air conditioning application in the northern part of the country where the weather is generally dry and hot

ACKNOWLEDGEMENT

The authors will like to acknowledge the contribution ofDr. K. Owusu-Achaw, the supervisor of the research and also Mr. PadmoreOwusuAsare, a service engineer, who was part of the team that carried out the KIA rehabilitation works.

REFERENCES

[1]. C. Koranteng and E. G. Abaitey, “The effect of form and orientation on energy performance of residential buildings in Ghana,” Journal of science and technology, vol. 30, no. 1, pp. 71-81.2010.

[2]. B. Kareem, “Load Estimation for Air-conditioning using Computer Software Approach,” International Journal of the Computer, vol. 16, pp. 35-43, 2002.

[3]. C. M. Sam and K. P. Cheung, “Application of Building Energy Simulation to air-Conditioning Design,”In Proc. Of the Mainland-Hong Kong

HVAC Seminar, 12-20,1998.

[4]. F. A.Ansari, K. A. Mokhtar and N. M. Adam, "A simple Approach for building Cooling Load Estimation,"American Journal of Environmental Sciences, vol. 3, pp. 209-212, 2005.

[5]. W.C. Whitman and W.M. Johnson, Refrigeration and Air Conditioning Technology, Delmar Publishers, Washington, 1995.

[6]. ASHRAE Handbook of Fundamentals,American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981.

[7]. J. F. Kreider and A. Rabl,Heating and Cooling of Buildings, McGraw-Hill, New-York, 1994.

[8]. ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1977.

[9]. ASHRAE Handbook of Fundamentals,American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.1989.

[10]. ASHRAE Handbook of Fundamentals,American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1972.

APPENDIX A: Worksheet prepared by TRANE

TRANE™

New Construction

Whole House Worksheet

Customer's Name ____________ Address ____________

City ____________ State ____________ Zip ____________ Telephone Number ____________

WINTER: Inside Design Temp ____________ °F—Outside Design Temp ____________ °F = Heating Temp Difference ____________ °F

SUMMER: Outside Design Temp ____________ °F—Inside Design Temp ____________ °F = Cooling Temp Difference ____________ °F

HEATING		COMMON DATA SECTION		COOLING	
BTUH LOSS	HEATING FACTOR	SUBJECT	SQ. FT.	COOLING FACTOR	BTUH GAIN
	FROM TABLE E	GROSS WALL		FROM TABLE E	
		DOORS & WINDOWS (Table A or B)			
		NET WALL			
		CEILING			
		FLOORS			
Infiltration Btu/hr =	Heating Table D	x 10 x 1.1/60 x Volume (Cu. Ft.)	Volume (Cu. Ft) x 1.1/60	x △T x Cooling Table D	= Infiltration Btu/hr
=		x 0.18333 x	x 0.01833	x x	=
		SUB-TOTAL BTUH LOSS (per 10°F)			
x		ADJUSTMENT FACTOR (Table C)			
		TOTAL BTUH LOSS			
		PEOPLE_____ x 300 BTUH GAIN (Assume 2 persons per bedroom)			
		APPLIANCES BTUH			1200
		SUB-TOTAL BTUH GAIN (room sensible only)			
x		DUCT LOSS/GAIN FACTOR (Table F)			x
		SUB-TOTAL BTUH (Sensible Gain)			
		MOISTURE REMOVAL (sub total x 1.3)			x 1.3
		TOTAL BTUH LOSS/GAIN			

TABLE A—HEATING—DOORS & WOOD FRAME WINDOWS (PER 10°F)

For sliding glass doors - use factors for the same type window construction.

Window & Door Types	Frames Wood	TIM	Metal	x Area	= Btuh Loss
Single Pane Clear	9.90	10.45	11.55		
With Storm	4.75	5.25	6.50		
Double Pane Clear	5.51	6.09	7.25		
With Storm	3.41	3.85	4.90		
Triple Pane Clear	3.80	4.39	5.46		
Jalousie Single	—	—	11.0		
Single w/storm	—	—	5.0		
Skylights Single	11.07	11.69	12.92		
Double	6.65	7.35	8.75		
Door Wood Only	4.60	—	—		
Wood w/storm	3.20	—	—		
Urethane Core (R-5)	—	—	1.90		
Urethane Core (R-5) w/storm	—	—	1.70		
			TOTALS		

TABLE B — COOLING — DOORS & WINDOWS

Factors assume windows have inside shading by draperies or venetian blinds and sliding glass doors are treated as windows.

	SINGLE GLASS TEMP. DIFF.			DOUBLE GLASS TEMP. DIFF.			TRIPLE GLASS TEMP. DIFF.			X Area	= BTUH GAIN
Direction	15°	20°	25°	15°	20°	25°	15°	20°	25°		
N	18	22	26	14	16	18	11	12	13		
NE & NW	37	41	45	31	33	35	26	27	28		
E & W	52	56	60	44	46	48	38	39	40		
SE & SW	45	49	53	39	41	43	33	34	35		
S	28	32	36	23	25	27	19	20	21		
Skylights	164	168	172	141	143	145	132	136	140		
Wood ①	8.6	10.9	13.2	8.6	10.9	13.2	8.6	10.9	13.2		
Metal ②	3.5	4.5	5.4	3.5	4.5	5.4	3.5	4.5	5.4		
									TOTALS		

① For wood doors and polystyrene core metal doors

② For urethane core metal doors

TABLE C — ADJUSTMENT FACTORS — (HEATING)

°F. Temperature Diff.	30	40	50	60	70	80	90
Adjustment Factor	3	4	5	6	7	8	9

TABLE D — INFILTRATION MULTIPLIERS

Winter Air Changes Per Hour

Floor Area	900 or less	900-1500	1500-2100	over 2100
Best	0.4	0.4	0.3	0.3
Average	1.2	1.0	0.8	0.7
Poor	2.2	1.6	1.2	1.0

For each fireplace add: Best 0.1, Average 0.2, Poor 0.6

Summer Air Changes Per Hour

Floor Area	900 or less	900-1500	1500-2100	over 2100
Best	0.2	0.2	0.2	0.2
Average	0.5	0.5	0.4	0.4
Poor	0.8	0.7	0.6	0.5

 Pub. No. 22-8019-10 P.I. (L)

1080

Source: [5]

Appendix B: Some Transfer Function Coefficient for External Wall

CHAPTER 22 ASHRAE Handbook of Fundamental

Table 39 .... Transfer Function Coefficients for Exterior Walls

(Time interval = 1.0 hr)

No.	Construction (Note 1) Description	Code Numbers of layers		Coefficients b_n and d_n (Note 2) $n = 0$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$	U	$\sum_{n=0} c_n$
1	4″ face brick, 2″ insulation, and 4″ l.w. concrete block	A0, A2, B3, C2, E1, E0	b	0.00000	0.00046	0.00225	0.00150	0.00016				
			d	1.00000	−1.73771	0.90936	−0.13373	0.00496	−0.00001		0.102	0.00437
2	4″ l.w. concrete	A0, C14, E1, E0	b	0.0015	0.0299	0.0319	0.0034					
			d	1.0000	−0.8364	0.1360	−0.0026				0.225	0.0667
3	4″ face brick, air space, and 8″ common brick	A0, A2, B1, C9, E1, E0	b	0.00000	0.00001	0.00017	0.00068	0.00058	0.00013	0.00001		
			d	1.00000	−2.50273	2.25782	−0.88178	0.14098	−0.00804	0.00016	0.246	0.00158
4	4″ face brick, air space, and 8″ h.w. concrete block	A0, A2, B1, C8, E1, E0	b	0.00000	0.00037	0.00302	0.00334	0.00069	0.00003			
			d	1.00000	−1.90941	1.16519	−0.24119	0.01264	−0.00017		0.275	0.00745
5	4″ face brick, air space, and 8″ l.w. concrete block	A0, A2, B1, C7, E1, E0	b	0.00000	0.00030	0.00274	0.00344	0.00084	0.00004			
			d	1.00000	−1.89103	1.16153	−0.25248	0.01568	−0.00029		0.220	0.00736
6	4″ face brick, air space, and 8″ clay tile	A0, A2, B1, C6, E1, E0	b	0.00000	0.00003	0.00058	0.00150	0.00082	0.00011			
			d	1.00000	−2.25069	1.76504	−0.56434	0.06627	−0.00257	0.00003	0.221	0.00304
7	4″ face brick, air space, and 2″ h.w. concrete	A0, A2, B1, C5, E1, E0	b	0.00003	0.00239	0.00757	0.00316	0.00018				
			d	1.0000	−1.64772	0.74816	−0.06385	0.00147			0.350	0.01333
8	4″ face brick, air space, and 4″ common brick	A0, A2, B1, C4, E1, E0	b	0.00000	0.00086	0.00485	0.00378	0.00050	0.00001			
			d	1.00000	−1.79201	0.98014	−0.16102	0.00609	−0.00003		0.301	0.01000
9	4″ face brick, air space, and 4″ h.w. concrete block	A0, A2, B1, C3, E1, E0	b	0.00005	0.00387	0.01158	0.00460	0.00025				
			d	1.00000	−1.52669	0.64703	−0.05586	0.00128			0.309	0.02035
10	4″ face brick, air space, and 4″ l.w. concrete block	A0, A2, B1, C2, E1, E0	b	0.00003	0.00286	0.01029	0.00504	0.00037				
			d	1.00000	−1.50943	0.65654	−0.07415	0.00212			0.248	0.01859
11	12″ h.w. concrete	A0, A1, C11, E1, E0	b	0.00000	0.00029	0.00303	0.00412	0.00105	0.00005			
			d	1.00000	−1.86853	1.09284	−0.21487	0.01094	−0.00009		0.421	0.00854
12	8″ h.w. concrete with 2″ insulation	A0, A1, C10, B6, E1, E0	b	0.00000	0.00028	0.00155	0.00118	0.00015				
			d	1.00000	−1.71064	0.89735	−0.16643	0.00728	−0.00002		0.115	0.00316
13	8″ h.w. concrete with 1″ insulation	A0, A1, C10, B5, E1, E0	b	0.00000	0.00064	0.00303	0.00202	0.00023				
			d	1.00000	−1.66125	0.83196	−0.14508	0.00613	−0.00002		0.187	0.00592
14	8″ h.w. concrete with air space	A0, A1, C10, B1, E1, E0	b	0.00002	0.00199	0.00817	0.00467	0.00044	0.00001			
			d	1.00000	−1.51622	0.64218	−0.08370	0.00288	−0.00001		0.339	0.01530
15	8″ h.w. concrete	A0, A1, C10, E1, E0	b	0.00009	0.00676	0.01821	0.00602	0.00024				
			d	1.00000	−1.37101	0.46271	−0.02787	0.00013			0.490	0.03132
16	4″ face brick, 8″ common brick with 1″ insulation	A0, A2, C9, B2, E1, E0	b	0.00000	0.00000	0.00008	0.00034	0.00035	0.00009	0.00001		
			d	1.00000	−2.50527	2.30575	−0.97167	0.19281	−0.01643	0.00046	0.154	0.00087
17	4″ face brick, 8″ common brick with air space	A0, A2, C9, B1, E1, E0	b	0.00000	0.00001	0.00022	0.00090	0.00080	0.00019	0.00001		
			d	1.00000	−2.35214	1.98104	−0.73353	0.12178	−0.00859	0.00021	0.243	0.00213
18	Wall with 4″ face brick, air space and 4″ l.w. block	A0, A2, B1, C14, E0	b	0.0000	0.0008	0.0049	0.0040	0.0006				
			d	1.0000	−1.6216	0.7861	−0.1094	0.0038			0.175	0.0103
19	Wall with fiberglass insulation and stucco outside finish	A0, A6, B4, *A6*, E0	b	0.0158	0.0447	0.0065						
			d	1.0000	−0.2480	0.0098					0.088	0.0670
20	Two sided brick wall	A0, A2, B1, A2, E0	b	0.0000	0.0024	0.0078	0.0034	0.0002				
			d	1.0000	−1.6620	0.7764	−0.0777	0.0019			0.358	0.0138
21	Brick wall, 8″ concrete block and no air space	A0, A2, C7, *A6*, E0	b	0.0000	0.0013	0.0077	0.0064	0.0009				
			d	1.0000	−1.5966	0.7590	−0.1067	0.0037			0.274	0.0163
22	Brick wall with 4″ concrete block	A0, A2, B1, C3, A6, E0	b	0.0000	0.0049	0.0130	0.0044	0.0002				
			d	1.0000	−1.4750	0.5870	−0.0394	0.0007			0.307	0.0225
23	Brick wall with 8″ concrete block	A0, A2, B1, C8, A6, E0	b	0.0000	0.0005	0.0034	0.0035	0.0006				
			d	1.0000	−1.8688	1.1013	−0.2127	0.0095	−0.0001		0.274	0.0080
24	Brick wall with 6″ concrete block	A0, A2, B1, C15, A6, E0	b	0.000000	0.000033	0.000664	0.001650	0.000863	0.000106	0.000003		
			d	1.000000	−2.080189	1.488946	−0.427814	0.045657	−0.001650	0.000017	0.133	0.003319
25	Frame wall with 4″ brick veneer	A0, A2, B6, A6, E0	b	0.00037	0.00823	0.00983	0.00125	0.00001				
			d	1.00000	−1.03045	0.20108	−0.00726				0.121	0.01969
26	Frame Wall	A0, A6, B6, A6, E0	b	0.1977	0.06317	0.01064	0.00006					
			d	1.00000	−0.25848	0.01072					0.124	0.09364
27	Metal curtain wall with 3″ insulation	A0, A3, B12, A3, E0	b	0.02704	0.05335	0.00337						
			d	1.00000	−0.07705	0.00013					0.091	0.08376
28	Metal curtain wall 2″ insulation	A0, A3, B6, A3, E0	b	0.06695	0.06049	0.00077						
			d	1.00000	−0.01493						0.130	0.12821
29	Metal curtain wall with 1″ insulation	A0, A3, B5, A3, E0	b	0.16228	0.06684	0.00008						
			d	1.00000	−0.00255						0.230	0.22920
30	Wall 12″ concrete with 2″ insulation on the outside	A0, A3, B6, C11, A6, E0	b	0.00000	0.00002	0.00030	0.00049	0.00015	0.00001			
			d	1.00000	−1.91762	1.12612	−0.20839	0.00847	−0.00005		0.114	0.00097
31	Wall 8″ curtain with 2″ insulation on the outside	A0, A3, B6, C10, A6, E0	b	0.00001	0.00060	0.00205	0.00084	0.00004				
			d	1.00000	−1.41996	0.47090	−0.02089	0.00006			0.118	0.00354
32	Wall 4″ concrete with 2″ insulation on the outside	A0, A3, B6, C5, *A6*, E0	b	0.00055	0.00735	0.00482	0.00021					
			d	1.00000	−0.94420	0.05025	−0.00008				0.122	0.01293

Note 1. Construction is defined by code number for various layers. The thermal properties of layers designated by code numbers are given in Table 41.
Note 2. U, b's and c's are in BTU/(hr) (sq ft) (F deg), and d is dimensionless. Blank space represents zero.

Source: [9]

Appendix C: UBAs A/C Load Estimation Worksheet

CUSTOMER NAME:	______________	HOUSE No.:	______________
ADDRESS:	______________	TEL:	______________
CITY:	______________	DATE:	______________

SECTION A: WALL TRANSMISSION*

ITEM		WEST	EAST	NORTH	SOUTH	FLOOR	CEILING
		W_1	W_2	W_3	W_4	W_5	W_6
Gross Area (m^2)	a						
Glazing Area (m^2)	b						
Net Area* (m^2)	c = a - b						
Load Factor (Table A)	d						
Load (W)	e = d * c						

Total Load for Section A = $\Sigma W_i = W_1 + W_2 + W_3 + W_4 + W_5 + W_6$ = ______________ W

SECTION B: OCCUPANCY

No. of People	a	
Load Factor (Table B)	b	
Total Load (W)	c = a * b	

SECTION C: LIGHT & EQUIPMENT

Floor Area (m^2)	A	
Light (W)	b = 20 * A	
Equipment (office and Commercial space) (W)	c = 20 * A	
Or		
Equipment (known heat generation) (W)	d	
Total Load for SECTION C (W)	e = b + c	
	Or	
	e = b + d	

SECTION D: INFILTRATION & VENTILATION

Volume of Space (m^3)	a	
ACH	b	
Inf. Vol.	c = b * a	
Total Inf. Load (W)	d = c * 12.5	

SECTION E: SOLAR LOAD

ITEM		WEST	EAST	NORTH	SOUTH	
Area (m^2)	a					
Load Factor (Table E)	b					Total Load for Section E
Total Solar Load (W)	c=a*b					

SUMMATION OF SECTIONAL LOADS

ITEM	SECT. A	SECT. B	SECT. C	SECT. D	SECT. E	ESTIMATED LOADS (W)
Section Load (W)						

Factor of Safety (Ranges from 0%-5%)	f = 1 - R	
Estimated Cooling Load (W)	a	
Corrected Estimated Load (W)	b = a * f	
Corrected Estimated Load (Btu/h)	c = b * 3.412	

* Wall here applies to the vertical walls, floor and ceiling and the net wall area is the wall area excluding area of glazing

APPENDIX D: TABLES

Table A. Cooling load factors for Walls, Floor and Roofs, W/m²

CONSTRUCTION (WALL, FLOOR AND ROOFS)	SUNLIT					SHADED
	NORTH	SOUTH	EAST	WEST	HOR.	
4-in. light weight concrete roof					24.11	3.03
6-in. heavyweight concrete roof					7.27	1.38
4-in. lightweight concrete wall	12.73	15.28	12.95	13.29		6.77
4-in. heavyweight concrete wall	28.65	33.79	50.45	55.22		14.89
4-in. common brickwall	21.61	25.77	40.43	38.80		10.89
4-in. heavyweight concrete block wall	27.56	32.26	41.72	56.92		14.93
4-in. hollow sandcrete block	14.83	17.58	23.32	28.69		7.84
frame with 3/4-in. gypsum board wall	24.15	27.09	29.60	63.41		14.11
4-in. heavyweight concrete floor deck					53.75	8.37
4-in. lightweight deck with false ceiling					25.52	3.85

Table B. Cooling load factors for Occupants, W/person (based on 24 °C indoor dry bulb temperature)

DEGREE OF ACTIVITY	SENSIBLE HEAT	LATENT HEAT	TOTAL
Seat at rest	60	40	100
Seated, very light work writing	65	55	120
Seated, eating	75	95	170
Seated, light work, typing	75	75	150
Standing, light work, or walking slowly	90	95	185
Light bench work	100	130	230
Walking, 1.3 m/s, light machine work	100	205	305
Bowling	100	180	280
Moderate dancing	120	255	375
Heavy work, heavy machine work, lifting (Factory)	470	300	770
Heavy work, athletics (Gymnasium)	185	340	525

Table C_1. Cooling load factors for equipment

USAGE	EQUIPMENT
Heavy	0.16
Medium	0.12

Table C_2. Cooling load factors for lamps

USAGE	CLF	FLUORESCENT
Heavy	1.00	1.20
Medium	0.81	0.98
Low	0.82	0.96

Table D. Air Change per Hour (ACH)

ACH	DOOR TRAFFIC INTENSITY		
	LIGHT	MEDIUM	HIGH
	0.23	0.32	0.4

Example: **Light** – office, **Medium** – conference room, **High** – waiting room, bank, etc.

Table E. Cooling load factors for clear glass, W/m²

SOLAR HEAT TRANSMISSION FOR CLEAR GLASS					
TYPE OF GLASS	WEST	EAST	NORTH	SOUTH	SHADED
Clear glass, single	331	198	133	111	133