UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1992/93

Oktober/November 1992

EMK 404 - Penyejukan dan Penyamanan Udara

Masa : [3 jam]

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH (7) soalan dan TUJUH (7) muka surat serta EMPAT BELAS (14) lampiran yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab LIMA (5) soalan sahaja.

Semua soalan mestilah dijawab dalam bahasa Malaysia.

Termasuk lampiran-lampiran:

1. Analisis Beban Penyamanan Udara.

2. Jadual: "Recommended NC (Noise Criteria)".

..2/-

1. [a] Terangkan dengan ringkas pengendalian sebuah kitar penyerapan Ammonia - Air dengan berbantukan sebuah rajah skima.

(30 markah)

[b] Sebuah loji mampatan wap menggunakan R12 sebagai bahan pendingin. Suhu tepu penyejat adalah -20°C dan suhu tepu pemeluwap adalah 50°C. Proses mampatan adalah isentropi. Dengan menggunakan rajah P-h yang disediakan tentukan kesan penyejukan dan pekali prestasi bagi keadaan-keadaan berikut:

[i] Kitar Carnot

[ii] jika wap adalah tepu kering selepas proses mampatan

[iii] jika wap adalah tepu kering sebelum proses mampatan

[iv] jika wap adalah tepu kering sebelum proses mampatan dan 10K subsejuk selepas proses pemeluwap.

[v] Bincangkan perbezaan nilai kesan penyejukan dan pekali prestasi.

(70 markah)

2. Sebuah sistem penyejukan mampatan wap menggunakan susunan yang ditunjuk pada Rajah S2. Sistem tersebut mengandungi 2 peringkat mampatan dengan pengantara sejuk diantara kedua-dua peringkat. Bahan pendingin yang digunakan adalah R12.

Wap tepu pada suhu -30°C memasuki pemampat peringkat pertama. Kebuk kilat dan kebuk campuran dikendalikan pada tekanan 4 bar. Tekanan pemeluwap adalah 12 bar. Cecair tepu memasuki injap pengembangan tekanan tinggi pada 12 bar dan injap pengembangan tekanan rendah pada 4 bar. Kedua-dua proses mampatan adalah isentropi. Muatan penyejukan adalah 10 ton.

..3/-

Tentukan:

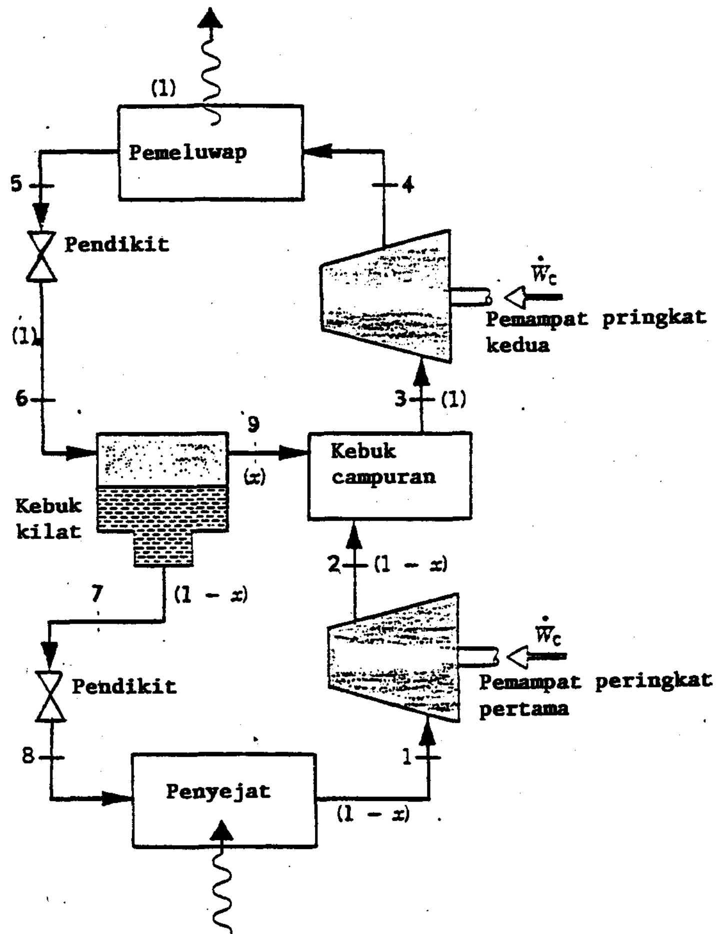
[a] kuasa masukan pada setiap pemampat dalam kW.

[b] pekali prestasi

[c] lakarkan kitar tersebut pada rajah P-h.

[d] terangkan kenapa sistem di atas mempunyai pekali prestasi yang lebih baik daripada sistem yang mempunyai satu peringkat mampatan.

(100 markah)



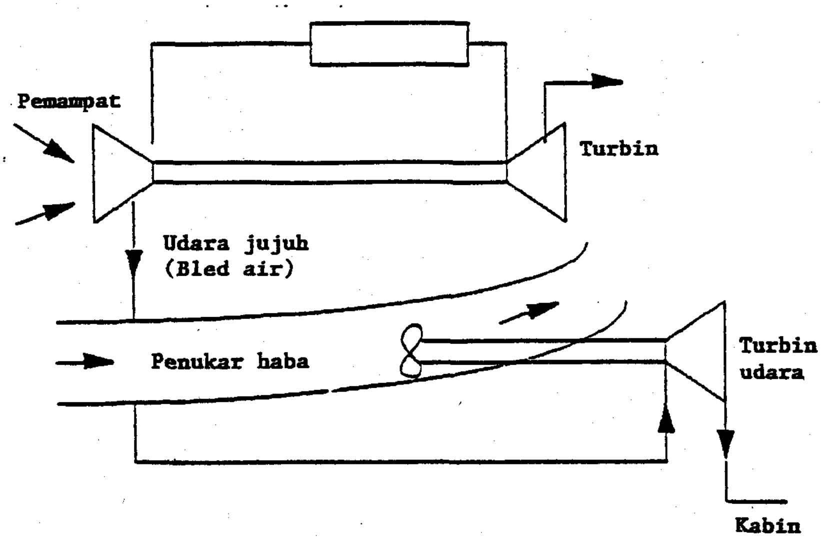
Rajah S2

3. [a] Terangkan dengan ringkas sistem penyejukan jet stim berbantukan rajah skima. Nyatakan 2 penggunaan sistem tersebut.

(30 markah)

..4/-

[b] Kapal terbang menggunakan kitar terbuka terbalik Brayton untuk menyejukan kabin. Di dalam unit ini, sedikit udara dikeluarkan daripada pemampat pada tekanan 4 bar dan suhu 280°C dan disalurkan melalui penukar haba tersejuk udara (air cooled heat exchanger) seperti Rajah S3[b].



Rajah S3[b]

Udara tersebut meninggalkan penukar haba pada tekanan 4 bar dan suhu 80°C dan dikembangkan melalui sebuah turbin udara ke tekanan 0.75 bar. Kecekapan turbin udara adalah 88%. Udara kemudiannya dihantar ke kabin pada suhu 16°C.

Tentukan kesan penyejukan per kg udara dan kuasa yang dihasilkan oleh turbin udara per kg udara per saat.

(70 markah)

4. [a] Nyatakan jenis-jenis pemampat yang digunakan di dalam sistem penyejukan.

(10 markah)

..5/-

[b] Bincangkan dengan ringkas 3 ciri bahan pendingin.

(10 markah)

[c] Terangkan sebabnya mengapa bahan pendingin dipanas lampaukan sebelum proses mampatan.

(10 markah)

[d] Sebuah sistem mampatan wap dikendalikan diantara suhu tepu 40°C dan -10°C. Darjah panas lampau sebelum proses mampatan isentropi adalah 20K. Terdapat 10K darjah subsejuk selepas proses pemeluwapan. Tentukan kesan penyejukan, kerja mampatan dan pekali prestasi bagi bahan pendingin berikut:

[i] R12
[ii] Ammonia

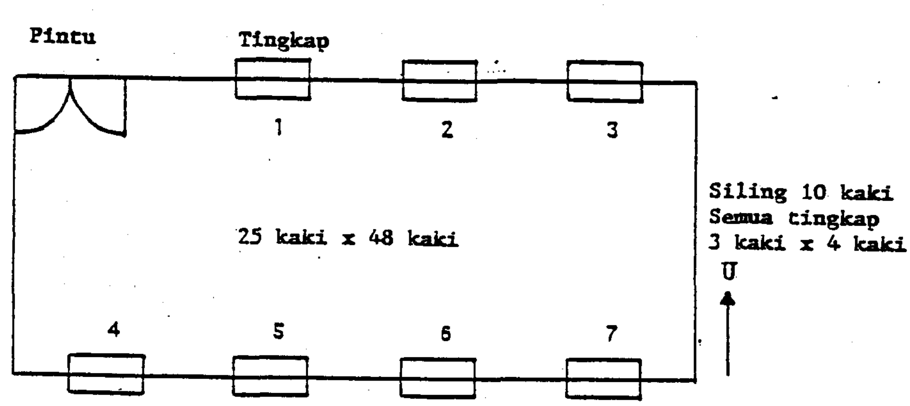
Bincangkan jawapan yang anda perolehi.

(70 markah)

5. [a] Nyatakan 5 faktor yang menyebabkan pertambahan haba deria dan 4 faktor yang menyebabkan pertambahan haba pendam.

(30 markah)

[b] Sebuah pejabat di Universiti Sains Malaysia adalah ditunjukkan pada Rajah S5[b].



Rajah S5[b]

..6/-

Data yang dikumpulkan adalah seperti berikut:

[i] keadaan terekabentuk dalaman 78°F, 50% kelembapan relatif.

[ii] keadaan terekabentuk luaran 93°F (bebuli kering), 82°F (bebuli basah).

[iii] Bilangan penghuni 12

[iv] Tembok: 8 inci (plain hollow concrete wall with no interior facing and no interior finish).

[v] Tingkap: 'single-strength glass shaded by light colour venetion blinds on the inside wall'

[vi] Lampu: 70 lampu fluorescent (dipasang selama 8 jam daripada pukul 8.00 pagi sehingga 4.00 petang). Setiap lampu adalah 36W x 1.2 untuk 'ballast'

[vii] Pengalihudara bagi 12 orang adalah 15 kaki^3/min setiap orang

[a] Tentukan beban penyejukan dalam Btu/hr dan kW menggunakan jadual dalam lampiran 1.

[b] Tentukan bilangan alat penyamanan udara jenis tingkap. Setiap satu alat mempunyai muatan penyejukan 2 ton.

(70 markah)

6. [a] Apakah 6 proses asas di dalam psikrometri? Beri contoh penggunaan setiap proses tersebut.

(30 markah)

[b] Aliran udara luar dicampur dengan aliran balik udara di dalam sebuah sistem penyamanan udara. Kadar alir udara luar adalah 2 kg/s dan keadaan udara luar adalah 35°C bebuli kering. Kadar alir balik udara adalah 3 kg/s dan keadaannya adalah 24°C bebuli kering dan 50% kelembapan relatif. Garis nisbah bilik adalah 0.72. Udara selepas melalui gelung penyejuk adalah 90% tepu.

Lukiskan proses tersebut di atas Carta psikrometri (lampiran 1).

Tentukan:

[i] titik embun udara
[ii] suhu selepas gelung penyejuk
[iii] kadar penyejukan
[iv] amaun bendalir terpeluwap setiap jam

(70 markah)

7. [a] Senaraikan komponen utama sebuah sistem pengagihan udara.

(15 markah)

[b] Terangkan istilah-istilah untuk menerangkan prestasi sebuah sistem pengagihan udara.

(15 markah)

[c] Terangkan jenis-jenis peranti mencuci udara.

(15 markah)

[d] Sebuah restoran berukuran 60 kaki x 80 kaki dan memerlukan 15 ton beban penyejukan. Tentukan bilangan penyelerak siling yang diperlukan bagi siling 12 kaki jika perbezaan suhu diantara luar dan dalam adalah 22°F. Rujuk lampiran 2.

(55 markah)

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LAMPIRAN 1

ANALISIS BEBAN PENYAMANAN UDARA
(ANALYSIS OF THE AIR CONDITIONING LOAD)

$$1 \text{ Btu/hr} = 0.293 \text{ W}$$
$$= 2.93 \times 10^{-4} \text{ kW}$$
$$= 7 \times 10^{-5} \text{ kcal/sec}$$

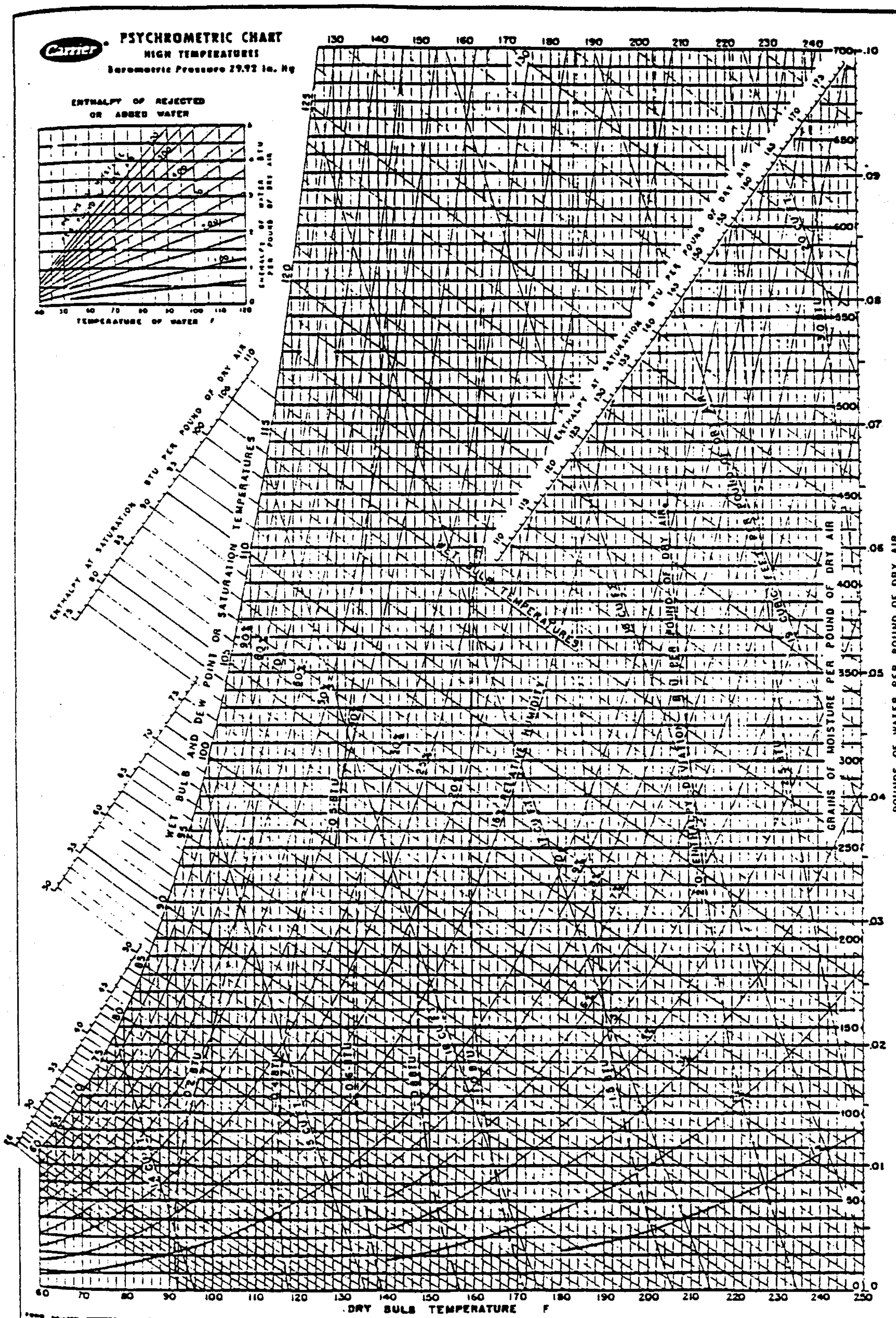


FIG. 7-20 Psychrometric chart for high temperatures—USCS units.

[redacted]

TABLE 8-1 Recommended Inside Design Conditions,* Summer and Winter—Present Practice and Possible Future Trends

	Summer					Winter				
	Present Practice		*Future Trends (Energy-Dictated)*			*Present Practice*			*Future Trends (Energy-Dictated)*	
Type of Application	*Dry Bulb, °F*	*Rel. Hum., %*	*Dry Bulb, °F*	*Rel. Hum., %*	*Temp. Swing,† °F*	*Dry Bulb, °F*	*Rel. Hum., %*	*Temp. Swing,‡ °F*	*Dry Bulb, °F*	*Temp. Swing,‡ °F*
General comfort										
Apartment, house, hotel, office, hospital, school, etc.	78–80	50	80–82	50	2 to 4	72–74	40–30	−3 to −4	68–70	−4
Retail shops (short-term customer occupancy)										
Bank, barber or beauty shop, department store, supermarket, etc.	78	50	78–80	50	2 to 4	70–72	40–30§	−3 to −4	68–70	−4
Low sensible-heat-factor (SHF) applications (high latent load)										
Auditorium, church, bar, restaurant, kitchen, etc.	78	60–50	78–80	60–50	1 to 2	70–72	40–35	−2 to −3	68–70	−4
Factory comfort										
Assembly areas, machining rooms, etc.	78–80	60–50	80–85	60–50	2 to 4	68–72	35–30	−3 to −5	66–68	−4

* The room design dry-bulb temperature should be reduced when hot, radiant panels are adjacent to the occupant and increased when cold panels are adjacent, to compensate for the increase or decrease in radiant heat exchange from the body. A hot or cold panel may be unshaded glass or glass block windows (hot in summer, cold in winter) and thin partitions with hot or cold spaces adjacent. An unheated slab floor on the ground or walls below the ground level are cold panels during the winter and frequently during the summer also. Hot tanks, furnaces, or machines are hot panels.

† Temperature swing is above the thermostat setting at peak summer load conditions.

‡ Temperature swing is below the thermostat setting at peak winter load conditions (no lights, people, or solar heat gain).

§ Winter humidification in retail clothing shops is recommended to maintain the quality texture of goods.

Sources: Carrier Air Conditioning Co., *Handbook of Air Conditioning System Design*, McGraw-Hill Book Company, New York, 1966; and current federal, state, and local standards.

TABLE 8-3 Suggested Outside Design Conditions for Selected Localities throughout the World

		Summer				Summer	
Place	*Winter, Dry Bulb, °C*	*Dry Bulb, °C*	*Wet Bulb, °C*	*Place*	*Winter, Dry Bulb, °C*	*Dry Bulb, °C*	*Wet Bulb, °C*
Athens, Greece	31	34	22	Panama City, Panama	22	33	27
Bogota, Columbia	7	21	16	Paris, France	−6	30	20
Bombay, India	18	34	28	Rio de Janeiro, Brazil	14	33	26
Buenos Aires, Argentina	0	32	24	Riyadh, Saudia Arabia	3	42	25
Cairo, Egypt	7	38	24	Rome, Italy	−1	33	23
Capetown, South Africa	4	32	22	Shanghai, China	5	32	28
Caracas, Venezuela	11	28	21	Singapore	22	33	27
Kuala Lumpur, Malaysia	21	34	28	Stockholm, Sweden	−15	24	17
London, England	−4	27	19	Sydney, Australia	4	29	23
Madrid, Spain	−4	33	21	Tel Aviv, Israel	4	34	23
Manila, Philippines	20	33	27	Tokyo, Japan	−3	32	27
Melbourne, Australia	2	33	21	Vienna, Austria	−14	30	21
Mexico City, Mexico	2	27	16				

ASHRAE Handbook, 1977 Fundamentals.

[3/12]

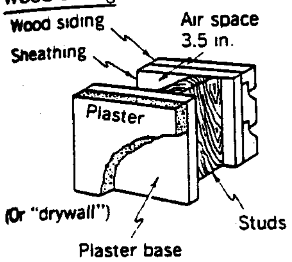
TABLE 8-4 Conductivities *K*, Conductances *C*, and Resistances *R* of Common Building Materials [Units of *K*, Btu/(hr)(ft²)(F°/in.); Units of *C*, Btu/(hr)(ft²)(F°) for Thickness Stated, Not per Inch Thick; Units of *R*, (hr)(ft²)(F°)/Btu]

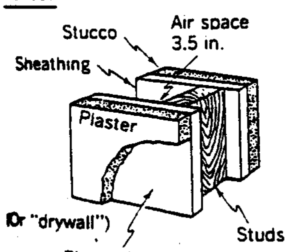
Material	*Description*	*Conductivity K*	*Conductance C*	*Resistance R*
Building boards	Gypsum board,	1.41		
	0.5 in.		2.22	0.45
	0.625 in.		1.78	0.56
	Plywood:	0.81		
	0.5 in.		1.60	0.62
	0.75 in.		1.07	0.93
	Wood:			
	Fir or pine sheathing, $^{25}/_{32}$ in.		1.02	0.98
Flooring materials	Asphalt tile, vinyl tile		20.0	0.05
	Carpet with fiber pad		0.48	2.08
	Ceramic tile, 1 in.		12.5	0.08
	Cork tile	0.45		
	Linoleum, ⅛ in.		12.0	0.083
	Plywood subfloor, 0.75 in.		1.07	0.93
	Terrazzo, 1 in.		12.5	0.08
	Wood, hardwood, ¾ in.		1.47	0.68
Glass		5.5		
Insulating materials:				
Blanket and batt	Mineral wool, fiberglass	0.23–0.27		
	3.5 in.		0.091	11
	6 in.		0.045	22
	8–10 in.		0.033	30
Board	Cork	0.34		
	Polyurethane	0.16		
	Wood or cane fiber	0.35		
	Polystyrene	0.20		
	Acoustical tile:			
	0.5 in.		0.80	1.25
	0.75 in.		0.53	1.9
	Interior finish boards:	0.35		
	0.5 in.		0.70	1.43
Loose fill	Mineral wool	0.27		
	4 in.			11
	6 in.			20
	10 in.			28
	Wood pulp	0.30		
Masonry materials	Cement mortar	5.0		
	Stucco	5.0	6.6 for ¾ in. thick	0.15
Masonry units	Brick, common, low-density	5.0		
	Brick, high-density (face brick)	9.0		
	Concrete blocks:			
	Sand and gravel aggregate:			
	8 in.		0.90	1.11
	12 in.		0.78	1.3
	Cinder aggregate:			
	8 in.		0.58	1.7
	12 in.		0.53	1.9
	Stone	12.5		
Plastering materials	Gypsum plaster, sand aggregate*	5.6		
	Gypsum lath ("button board," 0.5 in.) and plaster, plaster thickness 0.625 in.		1.52	0.66
	Metal lath and plaster, plaster thickness 0.75 in.		2.13	0.47
Roofing materials	Asphalt roll roofing, 70 lb		6.50	0.15
	Asphalt shingles, 70 lb		2.27	0.44
	Built-up roofing, 0.375 in.		3.00	0.33
	Slate, 0.5 in.		20.00	0.05
	Wood shingles, cedar		1.06	0.94
Siding materials	Shingles, wood, 16 in, 7.5 in. to the weather		1.15	0.87
	Siding, redwood, or cedar, lap, average		1.20	0.83
	Board and batt, cedar, 1 in.		0.95	1.05
	Aluminum, applied on 0.375 insulating board		0.55	1.82
Woods	Maple, oak, and similar hardwoods	1.20		
	Fir, pine, and similar softwoods	0.84		
	Plywood, 0.625 in.		1.29	0.77
	California redwood	0.74		

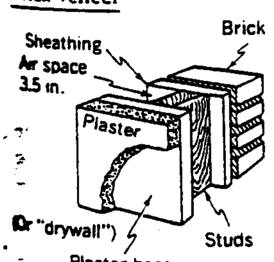
American Society of Heating, Refrigerating, and Air Conditioning Engineers, *ASHRAE Handbook, 1977 Fundamentals*, and various industry sources.

TABLE 8-5 **Coefficients of Heat Transmission U of Selected Frame Walls [in Btu/(hr)(ft²)(F°) Difference between the Air on the Two Sides, Effect of Studding Neglected; Effect of Air Films Included]**

Diagram of Wall and Exterior Finish	*Interior Finish*	*Type of Exterior Sheathing and Wall Insulation*			
		Plywood 0.5 in. and Building Paper		*Insulating Board 25/32 in.*	
		No Insulation	*3.5 in. Insulation (R-11) in air space*	*No Insulation*	*3.5 in. Insulation (R-11) in air space*
Wood siding	Gypsum board (dry wall)	0.25	0.069	0.20	0.062
	Gypsum lath and plaster	0.24	0.067	0.19	0.06
	Metal lath and plaster	0.28	0.075	0.24	0.07
	Plywood or wood paneling, 0.5 in.	0.35	0.082	0.26	0.075
	Insul. board 0.5 in.	0.22	0.064	0.16	0.057
Also applicable to: Wood shingles 7-in. exposure; Board and batt siding ¾ in. thick					
Stucco	Gypsum board (drywall)	0.32	0.072	0.22	0.071
	Gypsum lath and plaster	0.30	0.070	0.21	0.067
	Metal lath and plaster	0.36	0.080	0.23	0.073
	Plywood or wood paneling, 0.5 in.	0.38	0.083	0.22	0.076
Brick veneer	Gypsum board (drywall)	0.30	0.071	0.21	0.068
	Gypsum lath and plaster	0.28	0.070	0.20	0.065
	Metal lath and plaster	0.34	0.078	0.22	0.072
	Plywood or wood paneling, 0.5 in.	0.34	0.083	0.24	0.07
	Wood lath and plaster	0.33	0.083	0.21	0.07





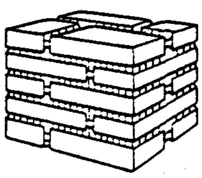
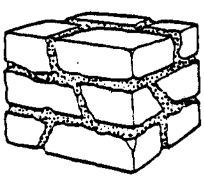
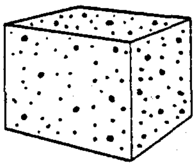
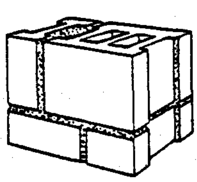
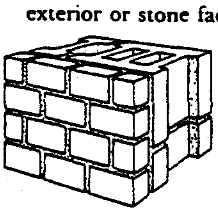


Source: *ASHRAE Handbook, 1977 Fundamentals*, and manufacturers' data.

Lights

For incandescent lamps the value 3.4 Btu/(hr)(W) of installed lamps should be used.

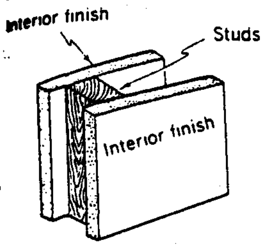
TABLE 8-6 Coefficients of Heat Transmission U of Masonry Walls [in Btu/(hr)(ft²)(F°) Difference between the Air on the Two Sides; Effects of Air Films Included]

		Interior Finish and Insulation (If Indicated)			
Diagram of Wall and Type of Masonry	*Thickness of Masonry, in.*	*Plain Wall, No Interior Finish*	*Metal Lath and Plaster, Furred*	*Gypsum Lath and Plaster, Furred*	*Gypsum Drywall on 1 x 3 Furring Strips with 0.75-in. Rigid Board Insulation*
Solid brick	8	0.50	0.32	0.30	0.15
	12	0.35	0.25	0.24	0.14
	16	0.28	0.21	0.20	0.13
Stone	8	0.70	0.39	0.36	0.16
	12	0.57	0.35	0.33	0.15
	16	0.49	0.32	0.30	0.14
Poured concrete	6	0.79	0.42	0.39	0.16
	8	0.70	0.39	0.36	0.15
	12	0.58	0.35	0.33	0.14
Hollow concrete blocks (no exterior facing)		*Sand and Gravel Aggregate*			
	8	0.56	0.34	0.32	0.14
	12	0.50	0.32	0.30	0.13
(with 4-in. face brick exterior or stone facing)	8	0.33	0.26	0.24	0.13
	12	0.31	0.24	0.23	0.12

ASHRAE Handbook, 1977 Fundamentals, and manufacturers' data.

TABLE 8-7 Coefficients of Heat Transmission U of Frame Partitions and Interior Walls [in Btu/(hr)(ft²)(F°) Difference between the Air on the Two Sides]

Diagram of Wall

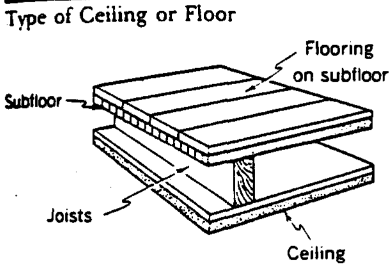


	Double Partition (Finish Both Sides)	
	No Insulation between Studs	*3.5 in. Blanket Insulation between Studs (R-11)*
Type of interior finish		
Gypsum lath and plaster	0.27	0.082
Metal lath and plaster	0.31	0.095
Plywood or wood paneling (⅜ in.)	0.33	0.105
Gypsum board (drywall), decorated	0.29	0.085

Source: ASHRAE Handbook, 1977 Fundamentals, and manufacturers' data.

TABLE 8-8 Coefficients of Heat Transmission U of Frame Construction Ceilings and Floors [in Btu/(hr)(ft²)(F°) Difference between the Air on the Two Sides]

Type of Ceiling or Floor

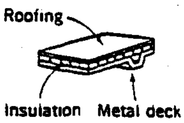


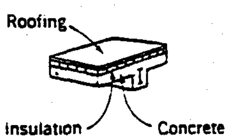
	No insulation	*6-in mineral wool blanket between Joists (R-19)*	*8–10 in. Blown mineral wool (R-30)*
Ceilings (unheated attic space above)			
Plaster on gypsum board, on wood joists	0.63	0.055	0.045
Plaster on metal lath on wood joists	0.74	0.057	0.05
Gypsum board (drywall) decorated	0.75	0.057	0.05
Floors (over crawl space or basement)			
Hardwood on 25/32-in. subfloor on wood joists	0.37		
Carpet on fiber pad on ¾-in. plywood subfloor on wood joists	0.24		
Linoleum or asphalt tile on 1-in. plywood subfloor on wood joists	0.57		

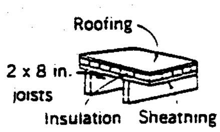
Floor-ceiling combinations	Type of Floor			
	Hardwood on 25/32-in. Subfloor	*Carpet on Fiber Pad on ¾-in. Plywood Subfloor*	*Linoleum or Asphalt Tile on ¾-in. Plywood Subfloor*	*Linoleum or Asphalt Tile on 4-in. Concrete*
Type of ceiling				
Plaster on gypsum board on wood joists	0.22	0.17	0.28	
Plaster on metal lath on wood joists	0.25	0.20	0.26	
Gypsum (drywall)	0.23	0.19	0.25	
Plaster on metal lath on furring strips				0.33

ASHRAE Handbook, 1977 Fundamentals, and manufacturers' data.

TABLE 8-9 Coefficients of Heat Transmission U of Typical Flat Roofs Covered with Built-up Roofing [in Btu/(hr)(ft²)(F°) Difference between the Air on the Two Sides]







Type of Roof Deck (Ceiling Not Shown)	*Thickness of Roof Deck, in.*	*Type of Suspended Ceiling*	*Insulation on Top of Deck (Covered with Built-up Roofing), in.*		
			None	*1*	*2*
Flat metal roof deck		None	0.67	0.23	0.15
		Gypsum bd. and plaster (½ in.)	0.32	0.17	0.12
		Acoustical tile (¾ in.)	0.23	0.14	0.11
Concrete slab (light-weight aggregate)	2	None	0.30	0.18	0.11
		Gypsum bd. and plaster (½ in.)	0.18	0.12	0.09
		Acoustical tile (¾ in.)	0.15	0.11	0.08
	4	None	0.24	0.11	0.09
		Gypsum bd. and plaster (½ in.)	0.13	0.10	0.08
		Acoustical tile (¾ in.)	0.12	0.09	0.07
Wood, on 2 x 8 joists	1	None	0.40	0.19	0.13
		Gypsum bd. and plaster (½ in.)	0.24	0.15	0.11
		Acoustical tile (¾ in.)	0.19	0.13	0.10
	2	None	0.28	0.16	0.11
		Gypsum bd. and plaster (½ in.)	0.19	0.13	0.10
		Acoustical tile (¾ in.)	0.16	0.11	0.09

ASHRAE Handbook, 1977 Fundamentals, and manufacturers' data.

TABLE 8-11 Effect of Various Shading Conditions on Solar-Radiation Heat Gain (Multiply the SCs by Solar-Heat-Gain Factors from Table 15)

Type of Shading Device	*Shade Coefficients (SC)*
Canvas awning	0.25
Inside venetian blinds, set at 45°, light color	0.55
Inside venetian blinds, set at 45°, dark color	0.64
Roller shades, fully drawn, light color	0.25
Roller shades, fully drawn, dark color	0.59
Single glass: regular sheet	1.00
¼-in. plate glass	0.95
⅜-in. plate glass	0.91
½-in. plate glass	0.88
Roof overhang or marquee, full shading	0.25
Windows shaded by normal setback from external building surface	0.90
Outside shading screen	0.30
Wood sash (85% gross area equals net glass area)	0.85

ASHRAE handbooks and manufacturers' data.

TABLE 8-12 Coefficients of Heat Transmission U of Vertical Windows (Exterior)

Type of Glass	*U, Btu per (hr)(ft²)(F°)*	
	No Indoor Shade	*Indoor Shade*
Single-strength glass	1.04	0.81
Double-strength (single-pane) glass	0.85	0.70
Extra-heavy plate glass	0.78	0.55
Double glass, insulating, ¼-in. air space	0.61	0.54
Triple glass, insulating, ¼-in. air spaces	0.44	0.40
Storm windows, 1 to 4 in. air space	0.50	0.48

ASHRAE handbooks and manufacturers' data.

TABLE 8-13 Calculation of Outside-Air Infiltration—Air-Change Method

H = room height L = length
W = width G = wall factor

Room with:
One outside wall, $G = 1$
Two outside walls, $G = 1.5$
Three outside walls, $G = 2$

$$\text{cfm} = \frac{W \times H \times L \times G}{60}$$

Notes:
1. For rooms with good weatherstripping on windows and doors, use 50 percent of the value calculated.
2. For commercial establishments where doors are opened frequently, add 100 ft³ per person per passage for each 36-in. swinging door.
3. Vestibules—reduce by 25 percent, revolving doors by 75 percent.
4. Residences—three-quarters air change per hour.

Source: Reprinted by permission of the Air Conditioning and Refrigeration Institute, Arlington, Va.

Infiltration

$$H_S = \text{cfm} \times 1.08 \times (t_o - t_r)$$

(sensible heat gain from outside air)

$$H_L = \text{cfm} \times 0.68 \times (W_o - W_r)$$

(latent heat gain from outside air)

TABLE 8-14 Infiltration through Cracks (Cubic Feet per Minute per Lineal Foot of Crack)

Type of Window or Door	*Remarks*	*Wind Velocity, mi/hr* 5	10	30
Double-hung wood sash	Average window in wood frame, non-weatherstripped	0.12	0.65	1.73
	Same, weatherstripped	0.07	0.40	1.05
	Poorly fitted window in wood frame, non-weatherstripped	0.45	1.85	4.20
	Same, weatherstripped	0.10	1.57	1.53
Steel sash, rolled section	Architectural, projected	0.25	1.03	2.30
	Industrial, pivoted	0.87	2.90	6.20
	Residential casement	0.23	0.87	2.10
	Heavy casement section, projected	0.13	0.63	1.53
	Hollow metal, vertically pivoted	0.50	2.40	4.00
Ordinary wood or metal door	Well fitted, non-weatherstripped	0.90	1.80	4.20
	Same, weatherstripped	0.45	0.90	2.10
	Poorly fitted, non-weatherstripped	0.90	3.70	8.40
	Same, weatherstripped	0.45	1.85	4.20
Glass door	Good installation	3.20	9.60	19.0
Factory door	⅛-in. crack	3.20	9.60	19.0
Metal-sash windows	Aluminum, double-hung or sliding, weatherstripped	0.10	0.53	1.27

Abstracted from Carrier Air Conditioning Co., *Handbook of Air Conditioning System Design*, McGraw-Hill Book Company, New York, 1966.

TABLE 8-15 Infiltration Due to Door Openings

	Cfm per Person entering Room per Door		
		36-in. Swinging Door	
Application	*72-in. Revolving Door*	*No Vestibule*	*With Vestibule*
Bank	6.5	8.0	6.0
Barber shop	4.0	5.0	3.8
Candy and ice cream	5.5	7.0	5.3
Cigar store	20.0	30.0	22.5
Department store (small)	6.5	8.0	6.0
Dress shop	2.0	2.5	1.9
Drug store	5.5	7.0	5.3
Hospital room		3.5	2.6
Lunch room	4.0	5.0	3.8
Men's shop	2.7	3.7	2.8
Restaurant	2.0	2.5	1.9
Shore store	2.7	3.5	2.6

Abstracted from Carrier Air Conditioning Co., *Handbook of Air Conditioning System Design*, McGraw-Hill Book Company, New York, 1966.

TABLE 8-16 Rates of Heat Gain from Occupants of Conditioned Spaces; Based on 78°F Room DB Temperature

Degree of Activity	*Typical Application*	*Total Heat Adults, Male, Btu/hr*	*Total Heat, Adjusted, Btu/hr*	*Sensible Heat, Btu/hr*	*Latent Heat, Btu/hr*
Seated, at rest	Theater	400	350	210	140
Seated, very light work	Offices, hotels, apartments	480	420	230	190
Moderately active office work	Offices, hotels, apartments	640	510	255	255
Standing, light work or walking slowly	Department store, retail store, dime store	800	640	315	325
Light bench work	Factory	880	780	345	435
Moderate dancing	Dance hall	1360	1280	405	875
Walking 3 mi/hr or moderate work	Factory	1040	1000	350	650
Bowling	Bowling alley	1200	960	345	615
Heavy work, vigorous sports	Factory, gymnasium	2000	1800	635	1165

Notes:

1 Adjusted total 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.

2 Adjusted total heat value for sedentary w[redacted]nt, includes 60 Btu/hr for food per individual (30 Btu sensible and 30 Btu latent).

Source: ASHRAE, Cooling and Heating Load Calculation Manual, New York, 1979.

TABLE 8-17 Recommended Rate of Heat Gain from Selected Cooking Appliances Located in the Air-Conditioned Space

Appliance	Capacity	Overall Dimensions, in. (Width × Depth × Height)	Miscellaneous Data	Rated Watts	Recommended Rate of Heat Gain, Btu/hr — Without Hood: Sensible	Without Hood: Latent	Without Hood: Total	With Hood: All Sensible
GAS-BURNING, COUNTER TYPE								
Coffee brewer per burner			With warm position		1750	750	2500	500
Coffee urn	5 gal	14-in dia.			5250	2250	7500	1500
Deep fat fryer	15 lb fat	14 × 21 × 15			7500	7500	15000	3000
Dry food warmer per ft² of top					560	140	700	140
Griddle, frying per ft² of top					4900	2600	7500	1500
Short order stove per burner			Open grates		3200	1800	5000	1000
ELECTRIC, COUNTER TYPE								
Coffee brewer per burner				625	770	230	1000	340
Coffee urn, electric	5 gal			3000	3850.	1250	5100	1600
Hotplate		18 × 20 × 13	2 heating units	5200	5300	3600	8900	2800
Toaster, continuous	720 slices/hr	20 × 15 × 28	4 slices wide	3000	2700	2400	5100	1600

ASHRAE Cooling and Heating Load Calculation Manual, New York, 1979.

TABLE 8-18 Rate of Heat Gain from Miscellaneous Appliances

Appliance	Miscellaneous Data	Manufacturer's Rating: W	Manufacturer's Rating: Btu/hr	Recommended Rate of Heat Gain, Btu/hr: Sensible	Latent	Total
Electrical Appliances						
Hair drier	Blower type	1580	5,400	2,300	400	2,700
Hair drier	Helmet type	705	2,400	1,870	330	2,200
Sterilizer, instrument		1100	3,750	650	1200	1,850
Large copying machine	Operating		12,000	12,000	0	12,000
	Standby		6,000	6,000	0	6,000
Gas-burning Appliances						
Lab burners, Bunsen	$\frac{7}{16}$-in. barrel		3,000	1,680	420	2,100

ASHRAE Cooling and Heating Load Calculation Manual, New York, 1979.

TABLE 15—SOLAR HEAT GAIN THRU ORDINARY GLASS

0° | Btu/(hr) (sq ft sash area) | 0°

0° NORTH LATITUDE Time of Year	Exposure	6 AM	7	8	9	10	11	Noon	1	2	3	4	5	6 PM	Exposure	0° SOUTH LATITUDE Time of Year
JUNE 21	North	0	45	65	74	78	80	82	80	78	74	65	45	0	South	DEC 22
	Northeast	0	119	156	154	133	95	53	20	14	13	11	6	0	Southeast	
	East	0	116	147	135	93	43	14	14	14	13	11	6	0	East	
	Southeast	0	37	42	27	15	14	14	14	14	13	11	6	0	Northeast	
	South	0	6	11	13	14	14	14	14	14	13	11	6	0	North	
	Southwest	0	6	11	13	14	14	14	14	15	27	42	37	0	Northwest	
	West	0	6	11	13	14	14	14	43	93	135	147	116	0	West	
	Northwest	0	6	11	13	14	20	53	95	133	154	156	119	0	Southwest	
	Horizontal	0	28	87	147	191	217	226	217	191	147	87	28	0	Horizontal	
JULY 23 & MAY 21	North	0	37	54	61	65	66	67	66	65	61	54	37	0	South	JAN 21 & NOV 21
	Northeast	0	118	153	150	124	86	43	16	14	13	11	6	0	Southeast	
	East	0	121	152	139	96	43	14	14	14	13	11	6	0	East	
	Southeast	0	46	52	36	18	14	14	14	14	13	11	6	0	Northeast	
	South	0	6	11	13	14	14	14	14	14	13	11	6	0	North	
	Southwest	0	6	11	13	14	14	14	14	18	36	52	46	0	Northwest	
	West	0	6	11	13	14	14	14	43	96	139	152	121	0	West	
	Northwest	0	6	11	13	14	16	43	86	124	150	153	118	0	Southwest	
	Horizontal	0	29	91	151	195	223	233	223	195	151	91	29	0	Horizontal	
AUG 24 & APR 20	North	0	17	28	31	33	34	34	34	33	31	28	17	0	South	FEB 20 & OCT 23
	Northeast	0	110	141	133	102	61	24	14	14	13	12	6	0	Southeast	
	East	0	129	163	148	103	46	14	14	14	13	12	6	0	East	
	Southeast	0	67	79	65	35	15	14	14	14	13	12	6	0	Northeast	
	South	0	6	12	13	14	14	14	14	14	13	12	6	0	North	
	Southwest	0	6	12	13	14	14	14	15	35	65	79	67	0	Northwest	
	West	0	6	12	13	14	14	14	46	103	148	163	129	0	West	
	Northwest	0	6	12	13	14	14	24	61	102	133	141	110	0	Southwest	
	Horizontal	0	31	97	150	206	234	245	234	206	150	97	31	0	Horizontal	
SEPT 22 & MAR 22	North	0	6	12	13	14	14	14	14	14	13	12	6	0	South	MAR 22 & SEPT 22
	Northeast	0	95	118	101	68	31	14	14	14	13	12	6	0	Southeast	
	East	0	134	167	151	107	47	14	14	14	13	12	6	0	East	
	Southeast	0	95	118	101	68	31	14	14	14	13	12	6	0	Northeast	
	South	0	6	12	13	14	14	14	14	14	13	12	6	0	North	
	Southwest	0	6	12	13	14	14	14	31	68	101	118	95	0	Northwest	
	West	0	6	12	13	14	14	14	47	107	151	167	134	0	West	
	Northwest	0	6	12	13	14	14	14	31	68	101	118	95	0	Southwest	
	Horizontal	0	32	100	163	210	240	250	240	210	163	100	32	0	Horizontal	
OCT 23 & FEB 20	North	0	6	12	13	14	14	14	14	14	13	12	6	0	South	APR 20 & AUG 24
	Northeast	0	67	79	65	35	15	14	14	14	13	12	6	0	Southeast	
	East	0	129	163	148	103	46	14	14	14	13	12	6	0	East	
	Southeast	0	110	141	133	102	61	24	14	14	13	12	6	0	Northeast	
	South	0	17	28	31	33	34	34	34	33	31	28	17	0	North	
	Southwest	0	6	12	13	14	14	24	61	102	133	141	110	0	Northwest	
	West	0	6	12	13	14	14	14	46	103	148	163	129	0	West	
	Northwest	0	6	12	13	14	14	14	15	35	65	79	67	0	Southwest	
	Horizontal	0	31	97	150	206	234	245	234	206	150	97	31	0	Horizontal	
NOV 21 & JAN 21	North	0	6	11	13	14	14	14	14	14	13	11	6	0	South	MAY 21 & JULY 23
	Northeast	0	46	52	36	18	14	14	14	14	13	11	6	0	Southeast	
	East	0	121	152	139	96	43	14	14	14	13	11	6	0	East	
	Southeast	0	118	153	150	124	86	43	16	14	13	11	6	0	Northeast	
	South	0	37	54	61	65	66	67	66	65	61	54	37	0	North	
	Southwest	0	6	11	13	14	16	43	86	124	150	153	118	0	Northwest	
	West	0	6	11	13	14	14	14	43	96	139	152	121	0	West	
	Northwest	0	6	11	13	14	14	14	14	18	36	52	46	0	Southwest	
	Horizontal	0	29	91	151	195	223	233	223	195	151	91	29	0	Horizontal	
DEC 22	North	0	6	11	13	14	14	14	14	14	13	11	6	0	South	JUNE 21
	Northeast	0	37	42	27	15	14	14	14	14	13	11	6	0	Southeast	
	East	0	116	147	135	93	43	14	14	14	13	11	6	0	East	
	Southeast	0	119	156	154	133	95	53	20	14	13	11	6	0	Northeast	
	South	0	45	65	74	78	80	82	80	78	74	65	45	0	North	
	Southwest	0	6	11	13	14	20	53	95	133	154	156	119	0	Northwest	
	West	0	6	11	13	14	14	14	43	93	135	147	116	0	West	
	Northwest	0	6	11	13	14	14	14	14	15	27	42	37	0	Southwest	
	Horizontal	0	28	87	147	191	217	226	217	191	147	87	28	0	Horizontal	

Solar Gain Correction	Steel Sash, or No Sash	Haze	Altitude	Dewpoint Decrease From 67 F	Dewpoint Increase From 67 F	South Lat. Dec. or Jan.
	× 1/.85 or 1.17	−15% (Max.)	+0.7% per 1000 Ft	+ 7% per 10 F	− 7% per 10 F	+ 7%

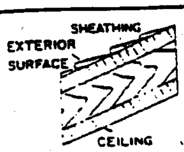
Bold Face Values — Monthly Maximums Boxed Values — Yearly maximums

TABLE 28—TRANSMISSION COEFFICIENT U—PITCHED ROOFS*

FOR HEAT FLOW DOWN—SUMMER. FOR HEAT FLOW UP—WINTER (See Equation at Bottom of Page)

Btu/(hr) (sq ft projected area) (deg F temp diff)

All numbers in parentheses indicate weight per sq ft. Total weight per sq ft is sum of component materials.



PITCHED ROOFS		CEILING											
		None	¾" Wood Panel (2)	⅜" Gypsum Board (Plaster Board) (2)	Metal Lath Plastered		½" Gypsum or Wood Lath Plastered		Insulating Board Plain or ½" Sand Agg Plastered		Acoustical Tile on Furring or ⅜" Gypsum	
EXTERIOR SURFACE	SHEATHING				¾" Sand Plaster (7)	¾" Lt Wt Plaster (3)	½" Sand Plaster (5)	½" Lt Wt Plaster (2)	½" Board (2)	1" Board (4)	½" Tile (2)	¾" Tile (3)
Asphalt Shingles. (2)	Bldg paper on 5/16" plywood (2)	.51	.27	.30	.32	.29	.29	.28	.22	.17	.23	.21
	Bldg paper on 25/32" wood sheathing (3)	.30	.23	.26	.27	.25	.25	.24	.20	.16	.21	.19
Asbestos-Cement Shingles (3) or Asphalt Roll Roofing (1)	Bldg paper on 5/16" plywood (2)	.59	.28	.34	.37	.33	.33	.31	.25	.18	.25	.22
	Bldg paper on 25/32" wood sheathing (3)	.45	.25	.29	.31	.28	.28	.27	.22	.17	.22	.20
Slates (8) Tile (10) or Sheet Metal (1)	Bldg paper on 5/16" plywood (2)	.64	.29	.36	.38	.34	.35	.47	.26	.19	.26	.23
	Bldg paper on 25/32" wood sheathing (3)	.48	.25	.29	.31	.28	.28	.27	.22	.17	.23	.20
Wood Shingles (2)	Bldg paper on 1" x 4" strips (1)	.53	.26	.31	.33	.30	.30	.28	.23	.17	.24	.21
	Bldg paper on 5/16" plywood (2)	.41	.23	.27	.29	.26	.27	.25	.21	.16	.21	.19
	Bldg paper on 25/32" wood sheathing (3)	.34	.21	.24	.25	.23	.23	.22	.19	.15	.19	.17

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Equations: Summer (Heat Flow Down) Heat Gain, Btu/hr = (horizontal projected area, sq ft) × (U value) × (equivalent temp diff, Table 20).

TABLE 18-2 Recommended NC (Noise Criteria) for Selection of Diffusers and Various Applications

Recommended Noise Criteria (dB Attenuation)		
NC Curve	*Communication Environment*	*Typical Occupancy*
Below NC 25	Extremely quiet environment, suppressed speech is quite audible, suitable for acute pickup of all sounds. Recording and performing studios require NC levels below 20	Broadcasting studios, concert halls, music rooms, church sanctuaries
NC 30	Very quiet office, suitable for large conferences, telephone use satisfactory. Levels below NC 30 are considered "very quiet"	Residences, theaters, libraries, executive offices directors' rooms
NC 35	Quiet office; satisfactory for conference at a 15-ft table; normal voice 10–30 ft; telephone use satisfactory	Private offices, schools, hotel rooms, courtrooms, hospital rooms
NC 40	Satisfactory for conferences at a 6–8-ft table; normal voice 6–12 ft; telephone use occasionally difficult	General offices, labs, dining rooms, building lobbies
NC 45	Satisfactory for conferences at a 4–5-ft table; normal voice 3–6 ft; raised voice 6–12 ft; telephone use occasionally difficult	Retail stores, cafeterias, corridors, large drafting & engineering offices, noisy reception areas
Above NC 50	Unsatisfactory for conferences of more than two or three persons; normal voice 1–2 ft; raised voice 3–6 ft; telephone use often difficult. Levels above NC 50 are considered "noisy"	Noisy offices, stenographic pools, print machine rooms, process areas, manufacturing

Source: Tuttle and Bailey Manufacturing Company.

TABLE 18-5. Selection and Performance Data for Round Ceiling Diffusers (a Portion of a Manufacturer's Table with NC Numbers Added)

Size, in.; Neck Area, ft²	*Neck Vel., fpm*	*700*	*800*	*900*	*1000*	*1100*	*1200*	*1300*	*1400*	*1600*	*1800*	*2000*
	CFM	95	110	120	135	150	165	175	190	220	245	270
5	SP	0.07	0.09	0.12	0.15	0.18	0.21	0.25	0.29	0.37	0.47	0.58
0.136	RAD	3–5	3–5	3–5	3–6	3–6	3–7	4–7	4–8	5–10	6–12	7–14
	NC	18	22	25	28	31	34	36	37	41	44	46
	CFM	135	155	175	195	215	235	255	275	315	355	390
6	SP	0.07	0.09	0.11	0.14	0.16	0.2	0.24	0.27	0.36	0.45	0.56
	RAD	3–5	3–6	3–6	3–7	4–7	4–8	4–9	5–10	6–12	6–14	7–15
	NC	18	22	26	29	31	34	36	37	41	44	46
	CFM	245	280	315	350	385	420	455	490	560	630	700
8	SP	0.06	0.08	0.1	0.13	0.16	0.19	0.22	0.25	0.33	0.42	0.52
0.349	RAD	4–7	4–8	4–9	5–10	5–11	5–12	6–12	6–13	7–15	9–18	10–20
	NC	19	23	29	30	33	35	37	39	43	46	49
	CFM	380	435	490	545	600	655	710	765	870	980	1090
10	SP	0.05	0.07	0.09	0.11	0.13	0.16	0.19	0.22	0.28	0.36	0.44
0.545	RAD	5–11	6–12	6–13	7–14	7–15	8–15	8–17	8–18	10–20	11–22	13–26
	NC	21	25	29	32	34	37	39	41	44	48	51
	CFM	550	630	705	785	865	940	1020	1100	1260	1410	1570
12	SP	0.05	0.06	0.08	0.1	0.12	0.14	0.17	0.19	0.25	0.32	0.39
0.785	RAD	7–14	7–15	8–16	8–17	9–18	9–19	13–20	10–21	12–25	13–27	15–30
	NC	23	26	30	33	36	38	41	43	47	50	53
	CFM	860	980	1100	1230	1350	1470	1600	1720	1960	2210	2450
15	SP	0.04	0.05	0.06	0.08	0.09	0.11	0.13	0.15	0.19	0.24	0.3
1.227	RAD	8–17	9–18	9–19	10–21	11–22	12–24	13–26	13–27	15–30	17–35	18–39
	NC	24	28	32	35	38	40	41	43	48	51	54
	CFM	1240	1410	1590	1770	1940	2120	2300	2470	2830	3180	3530
18	SP	0.03	0.04	0.05	0.06	0.08	0.09	0.11	0.12	0.16	0.2	0.25
1.767	RAD	11–22	12–25	13–26	14–28	15–30	15–32	16–33	17–34	19–38	21–43	23–46
	NC	26	30	32	35	38	41	43	45	49	52	54
	CFM	1680	1920	2160	2400	2650	2890	3130	3370	3850	4330	4810
21	SP	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.12	0.15	0.19
2.405	RAD	12–24	14–28	15–30	16–32	17–34	18–36	19–38	20–40	22–44	24–48	27–55
	NC	27	30	34	37	40	43	45	46	50	54	57
	CFM	2200	2510	2830	3140	3460	3770	4080	4400	5030	5660	6280
24	SP	0.04	0.06	0.07	0.09	0.1	0.12	0.15	0.17	0.22	0.28	0.35
3.142	RAD	15–30	16–33	17–35	18–37	19–38	20–40	21–42	23–45	25–51	28–57	31–63
	NC	28	32	35	38	40	43	45	47	51	55	58

Source: Anemostat Products Division, Dynamics Corporation of America