9.3 Using Manual J

Module 9: Mechanical Equipment Sizing

Part 3

Objective: Identify required information in building and project plan documents and describe how climate data provided in the Manual J is used to determine loads.

9.3 Using Manual J (in practice): outline

A. How to perform an abridged Manual J
   - Climate data and information
   - Design conditions
   - Envelope
   - Heat gains

B. How to perform a detailed Manual J & common issues

A. How to perform an abridged Manual J

Manual J adds up BTUs lost and gained

Heat Losses:

Conductive Loads: Qc=U x A x HTD
(U-value x Area x Temp. Difference)
Infiltration Loads: Q_i=ACF x 1.1 x $ICFM_{heat}$ x HTD
(Altitude Correction Factor x unit conversion factor x infiltration CFM x Temp. Difference)

Cooling Gains:

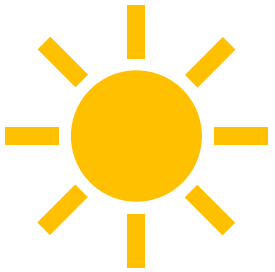
Conductive Loads: Qc=U x A x CTD
(U-value x Area x Temp. Difference)
Infiltration Loads: Q_i=ACF x 1.1 x $ICFM_{cool}$ x CTD

Plus:

Solar Loads: Q_s=PSF x CLF_{avg} x SC x A
(Peak Solar Factor x Cooling Load Factor x Coefficient x Area)
Latent (Dehumidification) Infiltration Loads: Q_i=ACF x 0.68 x $ICFM_{cool}$ x Δgrains
(Altitude Correction Factor x unit conversion factor x infiltration CFM x Difference in Air Moisture Content Measured in Grains)

Manual J information

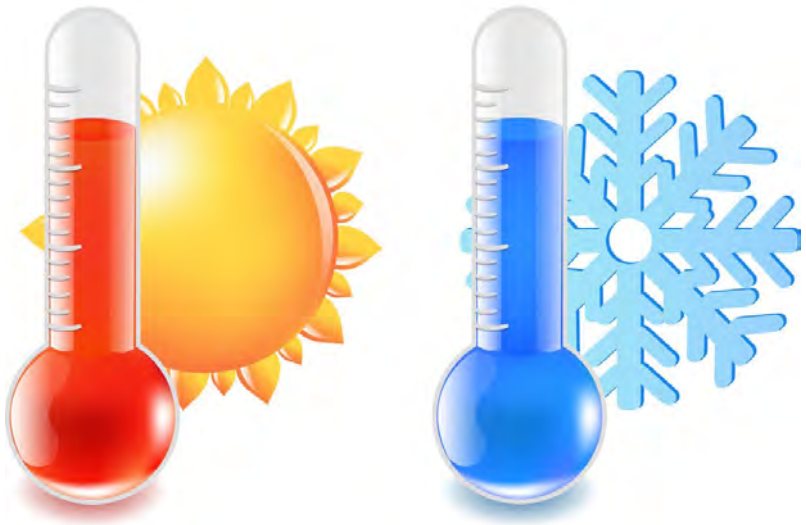
1. Climate	2. Design Conditions	3. Building Details
• Outdoor design conditions for heating and cooling	• Indoor design conditions • Indoor equipment loads • Occupant Loads	• Total area & orientation • R-values for opaque materials • U-values, SHGC and orientation for glazing • Air infiltration rate



Manual J - climate

Gather information:

- Heating design temperature
- Cooling design temperatures & humidity



Manual J – weather data

Step 1 – Find climate data - Section 3 of the Manual J contains weather data.

- Available online here

Table 1A

Outdoor Design Conditions for the United States

Location	Elevation Feet	Latitude Degrees North	Heating 99% Outdoor Dry Bulb	Cooling						$\frac{HDD_{65}}{CDD_{50}}$ Ratio
				Outdoor Air		Design Grains			Daily Range (DR)	
				1% Dry Bulb	Coincident Wet Bulb	55% RH Indoors	50% RH Indoors	45% RH Indoors		
Illinois										
Aurora Municipal AP	705	42	1	88	74	30	37	44	M	2.22
Belleville, Scott AFB	453	38	10	93	77	44	51	58	M	1.13
Bloomington (Peoria DD)	875	40	–2	90	74	31	38	45	M	1.80

Manual J – weather data terms

Heating 99% Outdoor Dry Bulb
This is the **design temperature** for heating – the minimum dry bulb temperature a site is expected to remain above for 99% of the hours of a year.

Cooling 1% Dry Bulb
This is the **design temperature** for cooling – the maximum dry bulb temperature a site is expected to exceed only 1% of the hours of a year.

Wet Bulb Temperature
The lowest temperature that can be obtained by evaporating moisture from a surface; related to outdoor humidity.

Table 1A
Outdoor Design Conditions for the United States

Location	Elevation Feet	Latitude Degrees North	Heating 99% Outdoor Dry Bulb	Cooling						
				Outdoor Air		Design Grains			Daily Range (DR)	$\frac{HDD_{65}}{CDD_{50}}$ Ratio
				1% Dry Bulb	Coincident Wet Bulb	55% RH Indoors	50% RH Indoors	45% RH Indoors		
Illinois										
Aurora Municipal AP	705	42	1	88	74	30	37	44	M	2.22
Belleville, S					77					
Bloomingto					74					

Relative Humidity
The ratio of the actual moisture content to the maximum moisture content that air at a given temperature and pressure can hold.

Grains
A measure of the absolute moisture content of a mass of air. 7,000 grains = 1 lb of water.

Impact of weather: same house, different locations

Location	BTUH Heating	BTUH Cooling Sensible	BTUH Cooling Latent	BTUH Cooling Total
Cedar Rapids AP, IA	40,453	18,004	1,805	19,809
Albuquerque AP, NM	27,580	17,290	0	17,290
Atlanta AP, GA	25,529	18,090	1,723	19,813
Daytona Beach, FL	18,173	18,670	2,291	20,961
Seattle-Tacoma AP, WA	24,018	16,812	800	17,612

Reminder:

Sensible Heat: Heat related to the dry bulb temperature of the air.

Latent Heat: Heat related to the evaporation or condensation of moisture from the air.

Location design temperatures and humidity cause loads to vary widely! Make sure the values are correct!

Manual J – design conditions

Gather information:

Information on heat gains inside the building:

- **Peak internal equipment & occupant loads.** Appliances and electronics, human body heat, and moisture addition.
- **Mechanical system loads.** Duct leakage and ventilation

Information on the desired temperature and humidity inside the building:

- **Typical ACCA design values:**
  - Winter design: 70F and 30% RH
  - Summer design: 75F and 50% RH

B. How to perform a detailed Manual J & common issues

Internal loads

Occupant load = # of Bedrooms +1 (Master BR assumed to have two occupants)

Appliance loads

- For block load there are some options: enter known values if possible.
  - If unknown, most software has a base load and a high load option.
- Don’t forget ceiling fans, large misc. electric loads (gaming room, large stereo systems, etc.).

Duct leakage loads

Duct Sealing Benefit										
Atlanta, Georgia	*Manual J* Loads		Seasonal Performance Summary						Annual Energy Cost	
$ 0.08 / Kwh $ 0.58 / Thrm Scale cost estimates for other rates.	Heating	Cooling Sensible Latent	Fossil Fuel Heating		Air Source Heat pump Heating		Electric Cooling		Gas Heat Electric Cooling	Air Source Heat Pump
	Btuh	Btuh	Therms	Cost	KWH	Cost	KWH	Cost	Cost	Cost
Attic 15% Leak	43,108	32,665 6,257	830	$ 543	9,834	$ 790	6,675	$ 469	$ 1,012	$ 1,333
Attic 5% Leak	34,988	25,161 3,827	656	$ 426	7,662	$ 616	4,430	$ 369	$ 795	$ 1,042
Crawl Space 15% Leak	49,175	33,327 6,542	971	$ 636	11,580	$ 929	5,737	$ 473	$ 1,109	$ 1,565
Crawl Space 5% Leak	38,829	26,419 3,975	742	$ 495	8,753	$ 703	4,545	$ 378	$ 873	$ 1,198

Savings of $508/yr

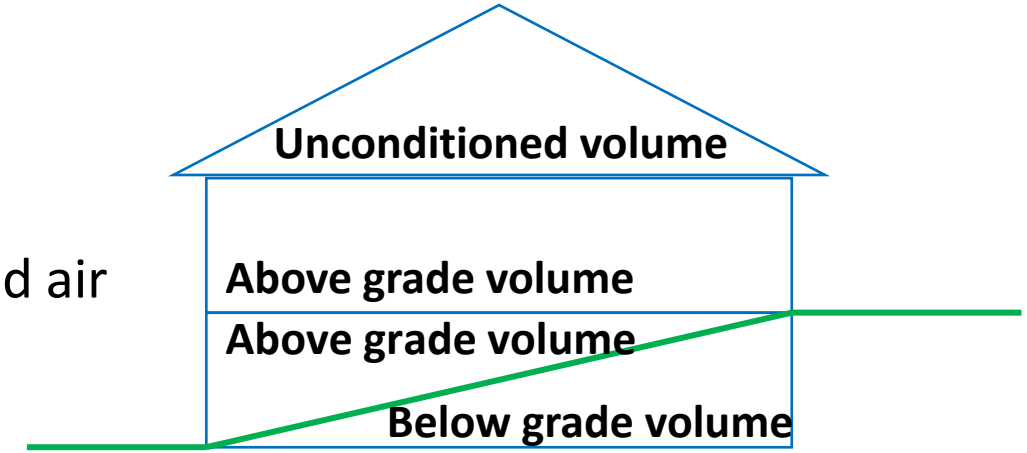
Savings of $516/yr

Mechanical ventilation loads

Need to know above grade conditioned volume, not full volume, of home.

Know infiltration rate from previous section

- Some jurisdictions allow infiltration to count as ventilation air.
- Some jurisdictions only allow mechanical/engineered air for ventilation.
- Check with local building office.



Per IRC 2021, minimum ventilation is **0.01cfm/square foot of home + 7.5cfm/per occupant (usually BR+1)**.

IRC states airflow must be provided by the mechanical system, not infiltration. This will be the most common scenario as municipalities move to modern codes.

Manual J – envelope & building

Gather information:

Information on thermal envelope:

- **R-values** for wall, roof, foundation assemblies
- **SHGC and U-factor** for window and skylight assemblies
- **Air infiltration rate** from a blower door test or estimated

Information on building size and orientation

- **Areas** of assemblies
- **Orientation** of the building

Opaque envelope definitions

Above grade walls can be framed or mass walls between indoor and outdoor conditions.
Partition walls are between indoor and unconditioned spaces (i.e. - garage or attic).

Below grade walls are walls greater than 2ft below grade.

Ceilings can be below attic, below roof deck with exposed beams, or below deck with sandwiched beams.
Partition ceiling is ceiling under unconditioned space or encapsulated attic (foamed deck, unfinished attic space).

Passive floors are any floors without radiant heating.
Partition floors are above closed (unvented) crawl, unconditioned basement, or garage
Exposed floors apply to cantilevered floors over outdoor air, vented crawlspaces, or carports (no garage door or door always open).
Basement floors have no insulation underneath, if passive.
Slab floors are on grade (<2ft below soil surface)

Types of Surfaces – From ACCA Speedsheet

8	Above Grade Walls	a
		b
		c
		d
		e
	Partition Walls	f
		g
9	Below Grade Walls	a
		b
10	Ceilings	a
		b
		c
	Partition Ceilings	d
		e
11	Passive Floors	a
		b
	Exposed Floors	c
	Slab (Perimeter Ft.)	d
	Basement Floor	e
	Partition Floors	f
		g

U-values of opaque assemblies

Knowing building information, look up construction types in look-up tables in Manual J to determine correct values for Manual J entry.

Example: 2x4 wood stud wall with R-13 fiberglass, R-5 insulation board and vinyl siding

Framed walls can be found in Table 4A, Construction #12-Frame Walls and Partitions

Construction Number 12
Frame Walls and Partitions

Wall or partition with brick veneer, plus interior finish (40 to 50 Lb / SqFt)
Wall with siding or stucco, or light partition, plus interior finish (7 to 20 Lb / SqFt)
Exterior finish code: b = brick veneer; s = stucco or siding
Framing code: w = wood, m = metal (studs 16 Inches on center, 75% cavity, 25% framing)
Reference Area = Gross Wall Area - Area of Window and Door Openings

Construction Number	Insulation R-Values	Description of Construction	Exterior Finish	U-Value with Wood Studs	U-Value with Metal Studs	Group Number
12A — No Insulation In Stud Cavity						
12A-0b w/m 12A-0s w/m	Cavity: None Board: None	Frame construction, no cavity insulation, no board insulation, wood sheathing	Brick Siding	0.253 0.240	0.315 0.295	E A
12C — R-13 Insulation In 2 x 4 Stud Cavity						
12C-5b w/m 12C-5s w/m	Cavity: R-13 Board: R-5	Frame construction, R-13 cavity insulation, R-5 board insulation	Brick Siding	0.064	0.078	K F

Proper assembly code for this wall type is 12C-5s w, the U-value is 0.064

Windows and skylights – default HTM

Manual J uses a **Heat Transfer Multiplier (HTM)** for windows and skylights. The HTM is the U-factor multiplied by the design temperature difference (HTD & CTD respectively).

Heating Eqn: $HTM=U_{NFRC} \times HTD$
Cooling Eqn: $HTM = PSF \times CLF_{avg} \times (SHGC_{NFRC}/0.87)+U_{NFRC} \times CTD$

PSF = peak solar factor (Table 3D-2)
CLF_{avg} = average cooling load factor (Table 3D-3)
$SHGC_{NFRC}$ = NFRC-rated solar heat gain coefficient
U_{NFRC} = NFRC-rated window U-factor
HTD = Heating temperature difference
CTD = Cooling temperature difference

Windows and skylights – default HTM

For windows that are not NFRC rated, there are default tables in Manual J.

Match design temperature difference for heating and cooling (HTD & CTD resp.), type of window and projected interior blinds. Use CTD column and select exposure row to obtain HTM value.

Cooling HTM look-up table example at right.

Table 3A-3 — Reflective Glass

No Internal Shade

Default Assembly Performance	Single Pane						Double Pane					
	U-Value		SC		SHGC		U-Value		SC		SHGC	
	0.98		0.40		0.35		0.56		0.34		0.30	
Design CTD	10	15	20	25	30	35	10	15	20	25	30	35
Exposure	HTM for Rough Opening						HTM for Rough Opening					
North	17	21	26	31	36	41	11	14	17	20	23	25
NE or NW	32	36	41	46	51	56	24	27	30	33	35	38
East or West	43	48	53	57	62	67	34	37	40	42	45	48
SE or SW	37	42	47	52	57	62	29	32	35	38	40	43
South	24	29	34	39	44	49	18	21	24	26	29	32

Vertical or Horizontal Blinds with Slats At 45 Degrees

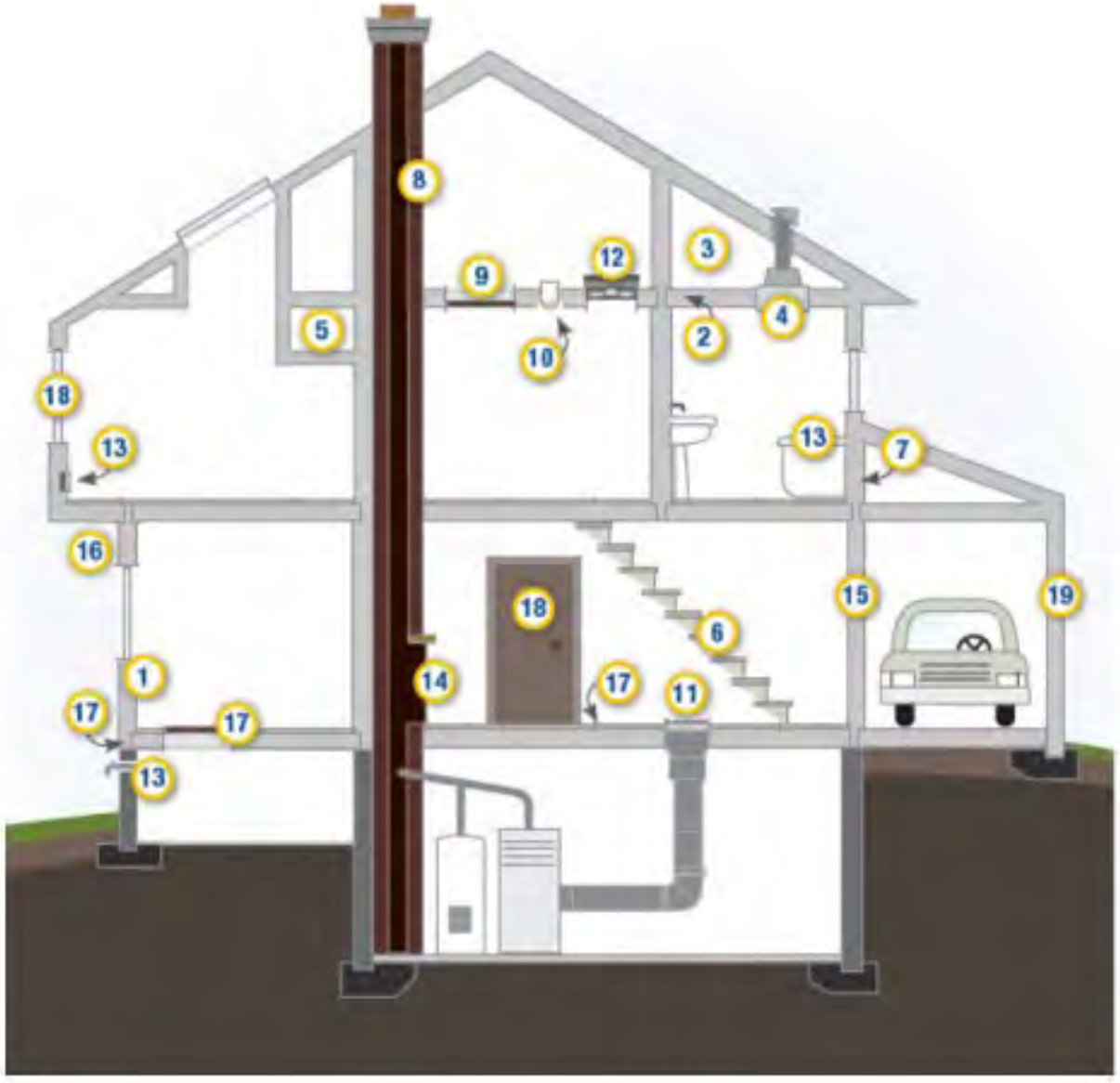
Default Assembly Performance	Single Pane						Double Pane					
	U-Value		SC		SHGC		U-Value		SC		SHGC	
	0.98		0.33		0.29		0.56		0.30		0.26	
Design CTD	10	15	20	25	30	35	10	15	20	25	30	35
Exposure	HTM for Rough Opening						HTM for Rough Opening					
North	13	18	23	28	33	38	9	11	14	17	20	23
NE or NW	24	29	34	39	44	49	19	21	24	27	30	33
East or West	33	38	43	47	52	57	27	29	32	35	38	41
SE or SW	29	34	38	43	48	53	23	26	28	31	34	37
South	18	23	28	33	38	43	13	16	19	22	24	27

Air infiltration

For the Manual J, air infiltration loads must be calculated or estimated.

- All homes have some amount of air exchange with outdoors driven by wind, temperature and pressure differences, ventilation, and mechanical systems.
- Air Infiltration loads apply to above grade portions of the envelope only. Ignore walls/volumes below grade for this load calculation.

Common Locations of Air Leaks



https://www.energy.gov/energysaver/air-sealing-your-home

Air leakage in Manual J calculator

For new construction, a blower door test will determine the actual number of Air Changes per Hour (ACH).

Speedsheet/abridged load calculation can be used for renovations and offers default values for air leakage in the home (see below). Modern homes are mostly tight or semi-tight.

Manual J Table 5A

Default Air Change Values for Single Story Construction					
Construction	Air Changes per Hour — Heating				
	Floor Area of Heated Space (SqFt)				
	900 Or Less	901 to 1500	1501 to 2000	2001 to 3000	3001 or More
Tight	0.21	0.16	0.14	0.11	0.10
Semi-Tight	0.41	0.31	0.26	0.22	0.19
Average	0.61	0.45	0.38	0.32	0.28
Semi-Loose	0.95	0.70	0.59	0.49	0.43
Loose	1.29	0.94	0.80	0.66	0.58

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