

# Technical Reference Note



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## Computing Manual J Infiltration Loads Based Upon a Target Envelope Leakage Requirement

### Overview

This bulletin defines proper use of ANSI/ACCA 2 *Manual J* - 2016 (Ver 2.50) procedure (A.K.A. *Manual J*®) when the infiltration load for a dwelling that is proposed for construction (i.e., not yet built) is based on a maximum air change per hour (ACH) value established by code (e.g., International Energy Conservation Code, IECC), a standard (e.g., PHIUS+2015 Passive House Building Standard), or a performance-based "above-code" or "utility-based" incentive program (e.g., ENERGY STAR®, Home Energy Rating System (HERS) Index).

For example, a code or standard may state that the envelope ACH value shall not exceed 3.0 when a 50 pascal blower door test is used to measure envelope leakage.

- Since the ACH value is for a 50 pascal pressure difference, it is an ACH50 value.
- The ACH50 value is based on the leakage CFM for a 50 pascal test (CFM50 value).
- The CFM50 value equals the blower door CFM value for the 50 pascal test.
- While the measurements of pressure difference (at 50Pa) and airflow (in CFM50 or ACH50) can be used to determine airtightness and other leakage characteristics of the envelope, they do not "directly" reflect the "as-built" condition caused by natural infiltration (ELA at 4 Pa).
- In accordance with prevailing codes and standards, natural infiltration is related to the leakage that is caused by a 4 pascal pressure difference (see Section 2.0).

This bulletin shows how to convert a maximum allowable leakage limit (ACH50) to a *Manual J* infiltration CFM value (ICFM), and then to the

infiltration loads (Btuh) for sensible heating, sensible cooling, and latent cooling. It also discusses the use of blower data for two or more test points.

### 1.0 Summary of Procedure

These steps convert an allowable leakage threshold (in ACH50) to natural infiltration loads for winter and summer design conditions.

- When engineered ventilation causes a positive or negative space pressure, the infiltration CFM values, in accordance with this procedure, shall be adjusted for the space pressure effect, when using *Manual J* Worksheet H and Worksheet E procedures.

**Step 1:** Determine the appropriate above and below grade volume for the specific home. See Section 6 for details.

$$\text{Volume} = \text{Floor Area} \times \text{Ceiling Height (for the conditioned spaces)}$$

**Step 2:** Convert the target ACH50 value to a CFM50 value using the volume from Step 1. See Section 6 for details.

$$\text{CFM50} = (\text{ACH50} \times \text{Volume}) / 60.$$

See Section 6 for details.

**Step 3:** Determine the natural condition equivalent leakage area (ELA4). See Section 5.3 for details, and for Figure 2.

$$\text{ELA4} = \text{Figure 2 Factor} \times \text{CFM50}$$

**Step 4:** Determine the natural condition infiltration CFM (ICFM4) values to be used in the load calculations. See Section 4 for details.

$$ICFM4 = ELA4 \times (Cs \times \text{Indoor-Outdoor Temp Difference} + Cw \times \text{Wind velocity}^2)^{0.5}$$

Use the *Cs* and *Cw* values from **Manual J Table 5D or 5E** (see page 4)

**Step 5:** Calculate the **Manual J** Infiltration Loads using the ICFM4 values. See Section 7 for details.

**Sensible heating load (Btuh) = 1.1 x altitude adjustment factor x ICFM<sub>heat</sub> x (Indoor-Outdoor temperature difference)**

**Sensible cooling load (Btuh) = 1.1 x altitude adjustment factor x ICFM<sub>cool</sub> x (Indoor-Outdoor temperature difference)**

**Latent cooling load (Btuh) = 0.68 x altitude adjustment factor x ICFM<sub>cool</sub> x (Indoor-Outdoor humidity ratio difference)**

## 2.0 Leakage vs. Pressure Difference Curve

Structural leakage CFM depends on blower door pressure difference, per a curve that can be produced by blower door software. Tests at two or more pressure difference values are required. Figure 1 (next page) provides an example of a multipoint curve.

- The values for the constant C and the exponent n can be determined by a two-point blower door test (see ASTM E1827, Section 9.4).
- Blower door software can produce C and n values per a multipoint test. See **Manual J** 2.50, Section 21-5.
- For a single point test, n is assumed to equal 0.65, and C is determined by this equation:

$$C = \text{Test CFM} / PD^{0.65}$$

- For a 50 pascal test, C is determined by this equation:

$$C = CFM50 / 50^{0.65} = 0.079 \times CFM50$$

## 3.0 Leakage for a 4 Pascal Test

Per industry research, the pressure difference value for natural infiltration circumstances is about 4 pascal, so the envelope leakage test should be a CFM4 test. However, the 4 pascal pressure difference produced by the blower door apparatus is not the only pressure acting on the envelope.

- The pressure difference value for the momentary wind effect can be similar to the 4 pascal blower door value.
- The pressure difference value for the momentary stack effect can be similar to the 4 pascal blower door value.
- A 4 pascal test that has interference from two other, uncontrolled, pressure difference effects, which may be some combination of positive and

## Example - Demonstrates 1.0 Procedure

A single family home has one level that is totally above grade, rooms that are partially below grade, rooms that are mostly below grade, and a closed crawlspace below the first floor bedrooms and bath rooms. (Attachment 1 provides sketches of the structure.)

### 1.1 Test Volume

$$\text{Upper Level Volume} = 56 \times 32 \times 8 = 14,336 \text{ CF}$$

$$\text{Volume of lower level rooms} = 33 \times 32 \times 10 = 10,560 \text{ CF}$$

Crawlspace volume = Not applicable:

$$\text{Total test volume} = 24,896 \text{ CF}$$

### 1.2 CFM50

The Maximum ACH value, per the AHJ, is 3.0 ACH.

$$CFM50 = 3.0 \times 24,896 / 60 = 1,244.8$$

### 1.3 ELA4

The local altitude is 955 feet (1,000 feet). Figure 2 (next page) provides the CFM50 to ELA4 conversion factor for various altitudes.

$$ELA4 = 0.054 \times 1,244.8 = 67.2 \text{ sq In}$$

### 1.4 Infiltration CFM (ICFM)

**Manual J**, Table 5D provides ICFM values for heating and for cooling (see page 4). Make the calculation for two stories. Use Wind Shielding Class 4 (**Manual J** default) if site plan circumstances are unknown. Use the default values for winter wind (15.0 MPH), and summer wind (7.5 MPH) if the 20-year record of local NOAA weather data shows that the average winter wind velocity and summer wind velocity values do not exceed the default values. For this example, the **Manual J** Worksheet A values for HTD, CTD, and grains are 76°F, 15°F, and 38 grains.

$$ICFM \text{ for heating} = 67.2 \times (0.0299 \times 76 + 0.0051 \times 15^2)^{0.5}$$

$$ICFM \text{ for heating} = 124.3$$

$$ICFM \text{ for cooling} = 67.2 \times (0.0299 \times 15 + 0.0051 \times 7.5^2)^{0.5}$$

$$ICFM \text{ for cooling} = 57.8$$

### 1.5 Infiltration Loads

ACF per **Manual J** Table 10A = 0.97 (see page 5)

$$\text{Heating Btuh} = 1.1 \times 0.97 \times 124.3 \times 76 = 10,080 \text{ Btuh}$$

$$\text{Sensible Cooling Btuh} = 1.1 \times 0.97 \times 15 \times 57.8 = 925 \text{ Btuh}$$

$$\text{Latent Cooling Btuh} = 0.68 \times 0.97 \times 38 \times 57.8 = 1,449 \text{ Btuh}$$

negative pressures acting on the various structural surfaces, may not be very accurate.

- A 50 pascal test overwhelms the effect of the pressure differences cause by the momentary wind and stack effects. So a test that uses a large

pressure difference is a more accurate way to measure envelope leakage.

### 4.0 Infiltration CFM for Load Calculations

This equation, plus values from *Manual J* Table 1A or Table 1B (project design conditions), and from Table 5D or Table 5E (see next page), determines the infiltration CFM (ICFM) values for heating and cooling.

$$ICFM = ELA_4 \times (C_s \times TD + C_w \times V^2)^{0.5}$$

Where:

Section 5.0 (below) provides the  $ELA_4$  value.

$C_s$  depends on the number of stories.

Shielding Class 4 is the default shielding class for  $C_w$ .

$TD$  for heating is the *Manual J* Worksheet A HTD value.

$TD$  for cooling is the *Manual J* Worksheet A CTD value.

The default wind velocity for heating is 15 MPH.

The default wind velocity for cooling is 7.5 MPH.

See also:

*Manual J*, Section 21.

### 5.0 Effective Leakage Area ( $ELA_4$ )

This equation determines the  $ELA_4$  value (sq in) for locations at altitude:

$$Altitude\ ELA_4 = 2.929 \times C \times (PD)^n - 0.5 \times (d/2)^{0.5}$$

Where:  $PD = 4$  pascal; and  $d =$  air density (lb/cf)

This equation determines the  $ELA_4$  value (sq in) for sea level air:

$$Sea\ level\ ELA_4 = 0.2835 \times C \times (PD)^n$$

Where:  $PD = 4$  pascal.

#### 5.1 $ELA_4$ for a Single Point, 50 Pascal Test

The Section 5.0 equations require a two point, or multipoint, test to produce a  $C$  value and an  $n$  value. The last equation in the following string of equations determines the  $ELA_4$  value for a single point, 50 pascal test, conducted at sea level.

$$Sea\ level\ ELA_4 = 0.2835 \times C \times (4)^{0.65}$$

Per Section 2.0,  $C = 0.079 \times CFM50$

So:

$$Sea\ level\ ELA_4 = 0.2835 \times 0.079 \times CFM50 \times (4)^{0.65}$$

Or:

$$Sea\ level\ ELA_4 = 0.2835 \times 0.079 \times CFM50 \times 2.46$$

Therefore:

$$Sea\ level\ ELA_4 = 0.055 \times CFM50$$

#### 5.2 $ELA_4$ for other Test Pressures - Sea Level

Figure 2 shows conversion factors for other test pressures. For example, if the test pressure is 30 pascal, the conversion factor is 0.077.

$$Sea\ level\ ELA_4 = 0.077 \times CFM50$$

Multipoint Blower Door Test

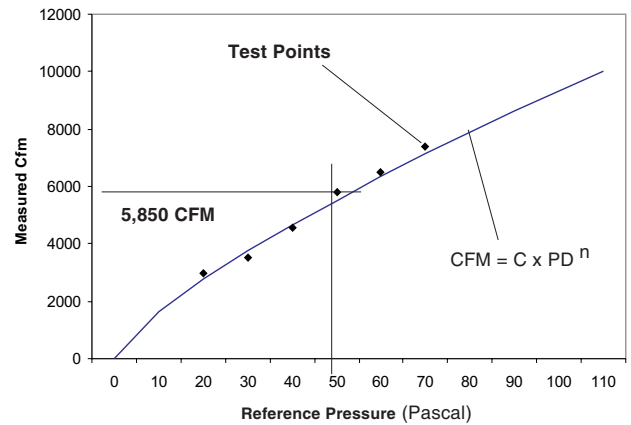


Figure 1

Conversion Factors for $ELA_4$ Calculations for Various Altitudes and Test Pressures					
Altitude (Feet)	Test Pressure (Pascal)				
	30	40	50	60	70
0	0.077	0.063	0.055	0.049	0.044
1,000	0.075	0.063	0.054	0.048	0.043
2,000	0.074	0.061	0.053	0.047	0.043
3,000	0.073	0.060	0.052	0.046	0.042
4,000	0.072	0.059	0.051	0.046	0.041
5,000	0.070	0.058	0.050	0.045	0.041
6,000	0.069	0.057	0.050	0.044	0.040
7,000	0.068	0.056	0.049	0.043	0.039

Air density at altitude (lb/cf) =  $0.075 \times (1.0 - 0.0000308 \times \text{feet})$

Figure 2

#### 5.3 $ELA_4$ vs. Test Pressure and Altitude

The conversion factor for converting a test CFM value to an  $ELA_4$  value depends on the test pressure and the altitude. Figure 2 provides conversion factors for various test pressure and altitudes. For example, if the test pressure is 50 pascal and the site altitude is 5,000 feet, the conversion factor is 0.050.

$$Altitude\ ELA_4 = 0.050 \times CFM50$$

### 6.0 Test Volume for Load Calculations

A blower door leakage test cannot be performed on a building under construction until all penetrations in the building thermal envelope have been sealed. Accordingly, either the maximum ACH50 allowed by the AHJ, or the target ACH50 specified by a code or performance-based program is used to determine the

maximum acceptable CFM50 value for a blower door test that will be performed in accordance with this equation:

$$\text{Maximum CFM50} = (\text{ACH50} \times \text{Test Volume}) / 60$$

Where:

The ACH50 value is specified by the code, standard or performance-based criteria established by the AHJ.

The test volume in cubic feet (CF) is the volume enclosed by the building thermal envelope and pressure boundary that will be tested for leakage (see Section 6.1).

60 minutes = 1 hour.

### 6.1 Test Volume

The test volume is the volume enclosed by the building thermal envelope and pressure boundary of

**Table 5D and 5E  
Effective Leakage Cfm Equation**

The following equation determines the infiltration flow rate (ICFM). This equation correlates the infiltration rate with square inches of effective leakage area (ELA<sub>4</sub>). Effective leakage area values are produced by the component leakage area method or the blower door method. Values for the stack coefficient (C<sub>s</sub>) are read from Table 5D or 5E, depending on the type of dwelling. Values for the wind shielding coefficient (C<sub>w</sub>) are read from Table 5D or 5E, depending on the number of exposures and the wind shielding scenario.

$$\text{ICFM} = \text{ELA}_4 \times (\text{C}_s \times \text{TD} + \text{C}_w \times \text{V}^2)^{0.5}$$

Cs and Cw Values for Three or Four Exposures			
Stack Coefficient	Height of Structure (Stories)		
	One	Two	Three
C <sub>s</sub> Value	0.0150	0.0299	0.0449
Wind Coefficient	C <sub>w</sub> Value		
	Height of Structure (Stories)		
Shielding Class	One	Two	Three
1	No shielding on any side.		
	0.0119	0.0157	0.0184
2	A few nearby obstructions: sheds, trees.		
	0.0092	0.0121	0.0143
3	A collection of obstructions within 25 feet: sheds, thick hedge, solid fence; or one near by house.		
	0.0065	0.0086	0.0101
4 Default for Table 5A	Substantial number of obstructions shield most of the perimeter: buildings, hedges, solid fences — typical suburban shielding.		
	0.0039	0.0051	0.0060
5	House surrounded by large structures — typical urban shielding.		
	0.0012	0.0016	0.0018

**Table 5D**

Cs and Cw Values for One or Two Exposures			
Stack Coefficient	Height of Structure (Stories)		
	One	Two	Three
C <sub>s</sub> Value	0.0150	0.0299	0.0449
Wind Coefficient	C <sub>w</sub> Value		
	Height of Structure (Stories)		
Shielding Class	One	Two	Three
1	Not applicable (No shielding on any side.)		
	~	~	~
2	Two unshielded exposures.		
	0.0092	0.0121	0.0143
3	One unshielded exposure, or two exposures shielding on one or both sides by trees or sheds.		
	0.0065	0.0086	0.0101
4	Two exposures with substantial shielding on both sides, or one exposure with some shielding.		
	0.0039	0.0051	0.0060
5 Default for Table 5B	House surrounded by large structures — typical urban shielding.		
	0.0012	0.0016	0.0018

**Table 5E**

**TD Value:** The TD value equals the indoor-outdoor temperature difference. For heating, use the winter design temperature difference. For cooling use the summer design temperature difference.

**Wind Velocity Value:** The default values for wind velocity are 15 MPH for heating and 7½ MPH for cooling. These velocities do not represent the most severe wind conditions that will be experienced when the outdoor temperature is equal to the winter or summer design temperature, but they do represent values that are compatible with normal weather patterns. An appropriate set of velocity values may be substituted for the defaults for locations that have a reputation for wind velocities that consistently exceed the default values.



the dwelling unit, or alternatively as determined by the AHJ. ACCA requirements for *Manual J* load calculations are cited here:

**6.1.1 Test Volume for Load Calculations**

For *Manual J* load calculations, and subsequent *Manual S* equipment sizing, the test volume shall include the rooms and spaces served by the HVAC equipment.

- For the heating load, the test volume shall include all rooms and spaces that are heated.
- For the cooling load, the test volume shall include all rooms and spaces that are air conditioned.

**7.0 Infiltration Loads**

These equations calculate the *Manual J* infiltration loads:

**Sensible heating Btuh = 1.1 x ACF x ICFM<sub>heat</sub> x HTD**  
**Sensible cooling Btuh = 1.1 x ACF x ICFM<sub>cool</sub> x CTD**  
**Latent cooling Btuh = 0.68 x ACF x ICFM<sub>cool</sub> x Δgrains**

Where:

ACF = Altitude Correction Factor,  
 see Table 10A;

or,  $ACF = 1.0 - 0.0000308 \times \text{Feet}$ .

*Manual J* Worksheet A provides the HTD value.

*Manual J* Worksheet A provides the CTD value.

*Manual J* Worksheet A provides the Δgrains value.

**7.1 Leakage Test vs. ACH4 Values**

While the measurements of pressure difference (at 50 Pascal) and airflow (in CFM50 or ACH50) can be used to determine airtightness and other leakage characteristics of the envelope, they do not "directly" reflect the "as-built" condition caused by natural infiltration (ELA at 4 Pascal).

**8.0 Summary**

As explained above, the ICFM values for calculating infiltration loads are derived from a set of equations that make these conversions:

**ACH50 to CFM50 to ELA4 to ICFM**

- For a home proposed for construction in a jurisdiction with a maximum air leakage rate not exceeding a 5ACH50 threshold, 5ACH50 is converted to a CFM50 value utilizing the volume of the conditioned space enclosed by the building thermal envelope and pressure boundary.
- The CFM50 value is then converted to an ELA4 value in accordance with *Manual J* Section 21-5.
- The ELA4 value is, in turn, converted to a set of ICFM (CFM<sub>inf</sub>) values (one for heating, and

<b>Altitude Correction</b> <b>For the Sensible and Latent Heat Equations</b> $ACF = 1.0 - 0.0000308 \times \text{Feet}$			
Altitude (Ft)	ACF	Altitude (Ft)	ACF
Sea Level	1.00	6,000	0.82
1,000	0.97	7,000	0.78
2,000	0.94	8,000	0.75
3,000	0.91	9,000	0.72
4,000	0.88	10,000	0.69
5,000	0.85	12,000	0.63

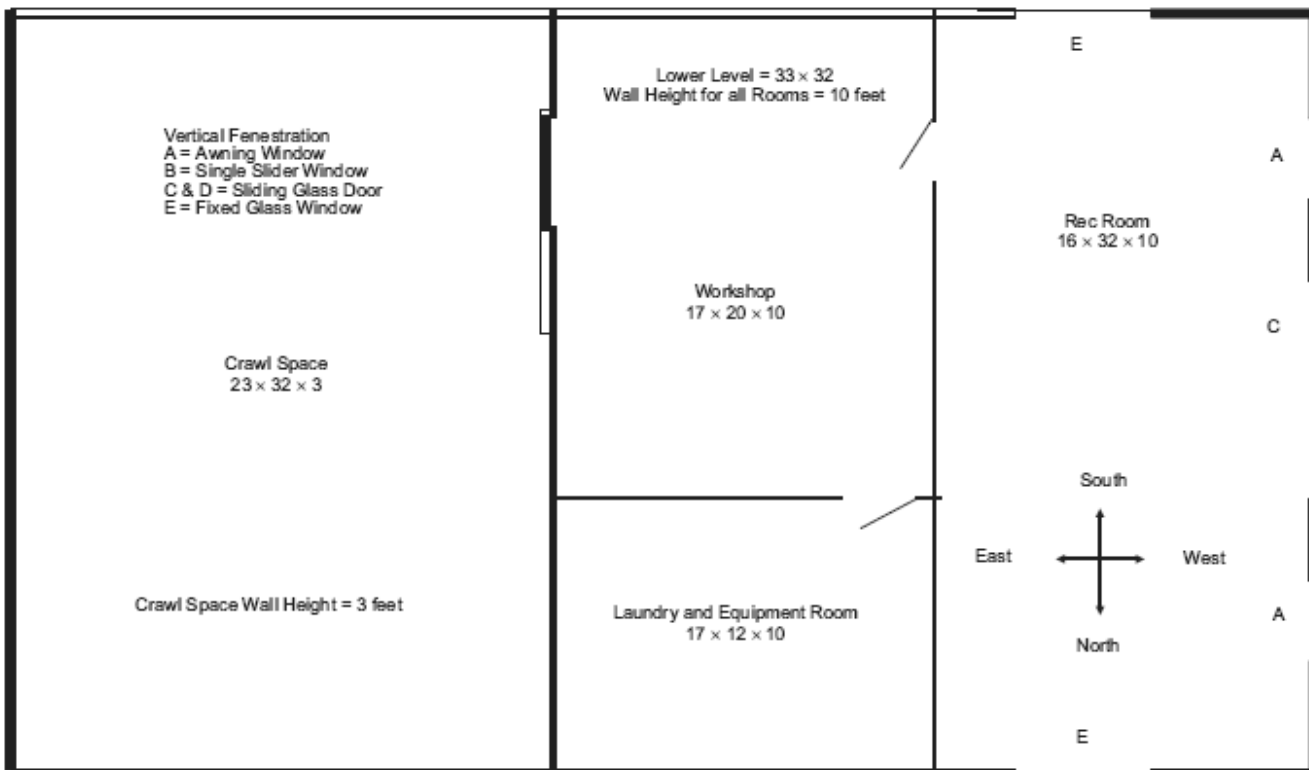
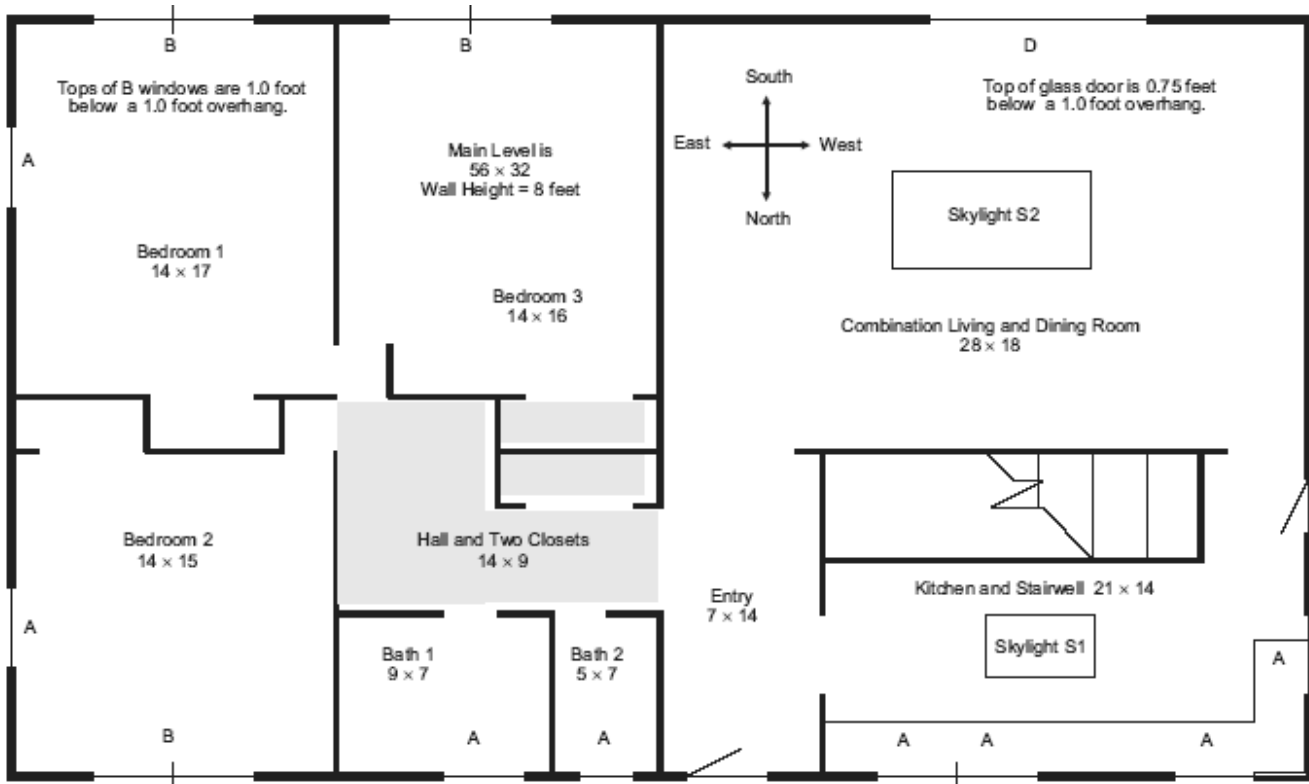
Specific heat of air approximately 0.24 Btu per pound.  
 Latent heat of condensation = 1,076 Btuh per pound.

**Table 10A**

another for cooling), in accordance with *Manual J* Section 21 5.

- The ICFM values are then used in the psychrometric equations for calculating the heating load (Btuh), sensible cooling load (Btuh), and latent cooling load (Btuh), in accordance with *Manual J* Section 21-6.

### Attachment 1



### Attachment 1 - Continued

