US 2 4090

ANSI/ASHRAE 119-1988

ASHRAE™ STANDARD

AN AMERICAN NATIONAL STANDARD

AIR LEAKAGE PERFORMANCE FOR DETACHED SINGLE-FAMILY RESIDENTIAL BUILDINGS

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Approved by the ASHRAE Standards Committee June 26, 1988, by the ASHRAE Board of Directors June 30, 1988, and by the American National Standards Institute August 19, 1988.

ASHRAE Standards are updated on a five-year cycle; the date following the Standard number is the year of approval. The latest copies may be purchased from the ASHRAE Publications Sales Department, 1791 Tullie Circle, NE, Atlanta, GA 30329.

 ISSN 1041-2336

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

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ASHRAE STANDARDS PROJECT COMMITTEE 119-1988

ASHRAE STANDARDS COMMITTEE 1987-88

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CONTENTS

1.0 PURPOSE

1.1 The purpose of this Standard is to establish performance requirements for air leakage of residential buildings to reduce the air infiltration load.

1.2 This Standard provides a method to classify the air tightness of residential buildings.

2.0 SCOPE

2.1 This Standard sets upper limits of leakage area and provides a method of classifying air tightness for detached, single-family residential buildings.

2.2 This Standard does not apply to buildings which are conditioned for human comfort less than 876 hours of the year.

2.3 Although this Standard is intended to reduce energy use associated with air leakage through the envelope of residential buildings, use of this Standard may preclude the use of air infiltration alone to achieve adequate indoor air quality. The reduction of air leakage is separate from the need to provide adequate ventilation, adequate combustion air, and adequate indoor air quality. Consideration of these issues is the responsibility of the user.

3.0 DEFINITIONS

Acceptable Leakage Class: The leakage classes (as calculated in Section 5) which comply with this Standard (as stated in Section 4).

Air Change Rate: Air flow in volume units per hour divided by the building space volume with idential volume units (normally expressed in air changes per hour: ACH or ACPH). Air change rate at a specific time can be measured using ASTM E741-83. "Test Method for Determining Air Leakage Rate By Tracer Dilution."[1]

Air Infiltration: The uncontrolled inward air flow through openings in the building envelope, caused by the pressure effects of wind, or the effect of differences in indoor and outdoor air density, or both (cfm) [m^3/s].

Air Leakage: The flow of air through the building envelope caused by a specified pressure difference; a measure of air tightness (cfm at fixed pressure) [m^3/s at fixed pressure].

Air Tightness: A qualitative term describing the integrity of the building envelope relative to air permeation; the resistance of the building envelope to the flow of air.

Average Specific Infiltration: The value of the specific infiltration that is typical for an average climate in the U.S. and Canada (ft/s) [m/s].

Building Envelope: The boundary or barrier separating the building volume from the outside environment.

Building Height: The vertical distance from the lowest grade level to the highest ceiling of building space. In cases where this is uncertain, the vertical distance from the lowest to the highest leakage site within the building envelope shall be used (ft) [m].

Building Space/Building Volume: The volume of a building that exchanges air with outside (ambient) air. For the purposes of this standard, the building volume is the space which is deliberately conditioned for human comfort (ft^3) [m^3].

Fan-Pressurization Test: A means for determining the air leakage of a building, using a fan-induced pressure difference. Either ASTM E779-87[2] or Canadian General Standards Board Standard CAN/CGSB-149.10-M86[3] may be used.

Infiltration Degree Days: A measure of the severity of the climate (defined in Section 6) as it relates to infiltration (°F-day) [°C-day].

Floor Area: The horizontal area within the inside perimeter of the exterior walls of the building space. This definition is in accordance with the ASTM E631-85c[4] definition of gross floor area which is used in ASTM E779-87 (ft^2) [m^2].

Leakage Area: The equivalent amount of open area (assuming unit discharge coefficient) that would let pass the same quantity of air as would pass collectively through the building envelope at a reference pressure of 4 Pa (ft^2) [m^2].

Leakage Class: One of the ten divisions of air tightness (as described in Section 5) based on the normalized leakage.

Normalized Leakage: The dimensionless value calculated from the leakage area, building height, and floor area that describes the relative air tightness of the envelope. (See Section 5.)

Specific Infiltration: The ratio of infiltration to leakage area; a normalized quantity which indicates the intensity of the weather relative to infiltration (ft/s) [m/s].

Ventilation: The process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

4.0 STANDARD COMPLIANCE

Compliance with the Standard may be demonstrated in either of three ways: the locations table; the infiltration degree-day calculation method; or the classification map. The locations table is the primary means of compliance and shall be used for those locations listed in it. The degree-day calculation method shall be used for those locations not listed in the locations table, but for which hourly weather data is available for a typical year. The classification map shall be used in all remaining cases.

Regardless of which of the three methods is used, this section specifies the leakage classes which are acceptable. If the measured leakage class as described in Section 5 is within the acceptable range, the building is deemed to comply with this standard.

4.1 Locations Table

Table 1 contains a number of selected locations and the acceptable leakage classes for each one. Compliance with this Standard is demonstrated if the measured leakage class for the structure in question is acceptable for its location.

4.2 *Degree-day Calculation*

For those locations not in the locations table, an infiltration degree-day calculation shall be made. Section [illegible] describes the method to be used to calculate infiltration degree-days, which are then to be used in the following table to find the acceptable leakage classes:

TABLE 2: ACCEPTABLE LEAKAGE CLASS

Infiltration Degree-Days [°C-day]	[°F-day]	Acceptable Classes
<1250	<2250	A-J
1250-1768	2250-3182	A-I
1769-2500	3183-4500	A-H
2501-3536	4501-6364	A-G
3536-5000	6365-9000	A-F
5001-7071	9001-12728	A-E
7072-10000	12729-18000	A-D
>10000	>18000	A-C

When using this table, all infiltration degree-days should be rounded to the nearest whole number.

4.3 Classification Map

For those cities not listed in the locations table and for which typical hourly weather data is not available, the classification map may be used to determine acceptable leakage classes. The classification map, Fig. 1, is a map of the United States and Canada indicating the zones of acceptable leakage classes.

5.0 CLASSIFICATION OF AIR TIGHTNESS

This section uses the concept of normalized leakage to classify air tightness. Measured data (leakage area, floor area, exponent, building height) is used to calculate the normalized leakage which then determines the leakage class.

5.1 Leakage Area Calculation

Leakage Area can be calculated from using either of the two procedures described below:

5.1.1 ASTM Procedure

To calculate the leakage area from the ASTM E779-87[2] standard, the leakage area for pressurization and depressurization (using a 4 Pa reference pressure) should be averaged as follows:

$$L = \frac{L_{press} + L_{depress}}{2} \qquad (1)$$

where

L = the leakage area for use in this standard (ft²) [m²]

L_{press} = the leakage area from pressurization (ft²) [m²]

$L_{depress}$ = is the leakage area from depressurization (ft²) [m²]

5.1.2 CGSB Procedure

To calculate the leakage area for use in this standard from CAN/SGSB-149.10-M86[3] some modifications to the test procedure must be made: 1) all vents and intentional openings must be in the same configuration as specified in the ASTM standard (i.e. HVAC dampers and registers should be in the normal operating position; fireplace and other dampers should be closed unless they are required for test operation); 2) height and floor area must be reported consistently with the definitions of this standard (i.e. ASHRAE Standard 119); and 3) the leakage area as calculated from the CGSB procedure must be converted using the following expression:

$$L = 0.61(0.4)^{n-0.5} L_{cgsb} \qquad (2)$$

where

L = the leakage area for use in this standard (ft²) [m²]

n = the exponent measured from the CGSB standard

L_{cgst} = is the CGSB leakage area as modified above (ft²) [m²]

5.2 Normalized Leakage

Normalized leakage is to be calculated from the leakage information as follows:

$$L_n = 1000 \frac{L}{A}\left(\frac{H}{H_o}\right)^{0.3} \qquad (3)$$

where

L_n = the normalized leakage

H_o = the height of a single story (8 ft) [2.5m]

H = the height of the building (ft) [m]

L = the leakage area of the space (ft²) [m²]

A = the floor area of the space (ft²) [m²]

5.3 Leakage Class

The Leakage Class is determined using the following table:

TABLE 3: CLASSIFICATION OF LEAKAGE

Normalized Leakage Range	Leakage Class
$L_n < 1.10$	A
$0.10 \leq L_n < 0.14$	B
$0.14 \leq L_n < 0.20$	C
$0.20 \leq L_n < 0.28$	D
$0.28 \leq L_n < 0{,}40$	E
$0.40 \leq L_n < 0.57$	F
$0.57 \leq L_n < 0.80$	G
$0.80 \leq L_n < 1.13$	H
$1.13 \leq L_n < 1.60$	I
$1.60 < L_n$	J

error? should be < 0.1

6.0 INFILTRATION DEGREE-DAYS

Infiltration degree-days are a measure of the severity of the climate as it affects infiltration loads in much the same way that heating degree-days are a measure of the severity of the heating season as it affects conduction through the building envelope.

The method of calculating infiltration degree-days requires the following hourly data for a typical year: outdoor dry-bulb temperature, and humidity. The total infiltration degree-days is the sum of the heating and cooling infiltration degree-days:

$$IDD = IDD_h + IDD_c \qquad (4)$$

where:

IDD = total infiltration degree-days (°F-day) [°C-day]

ACCEPTABLE LEAKAGE CLASSES

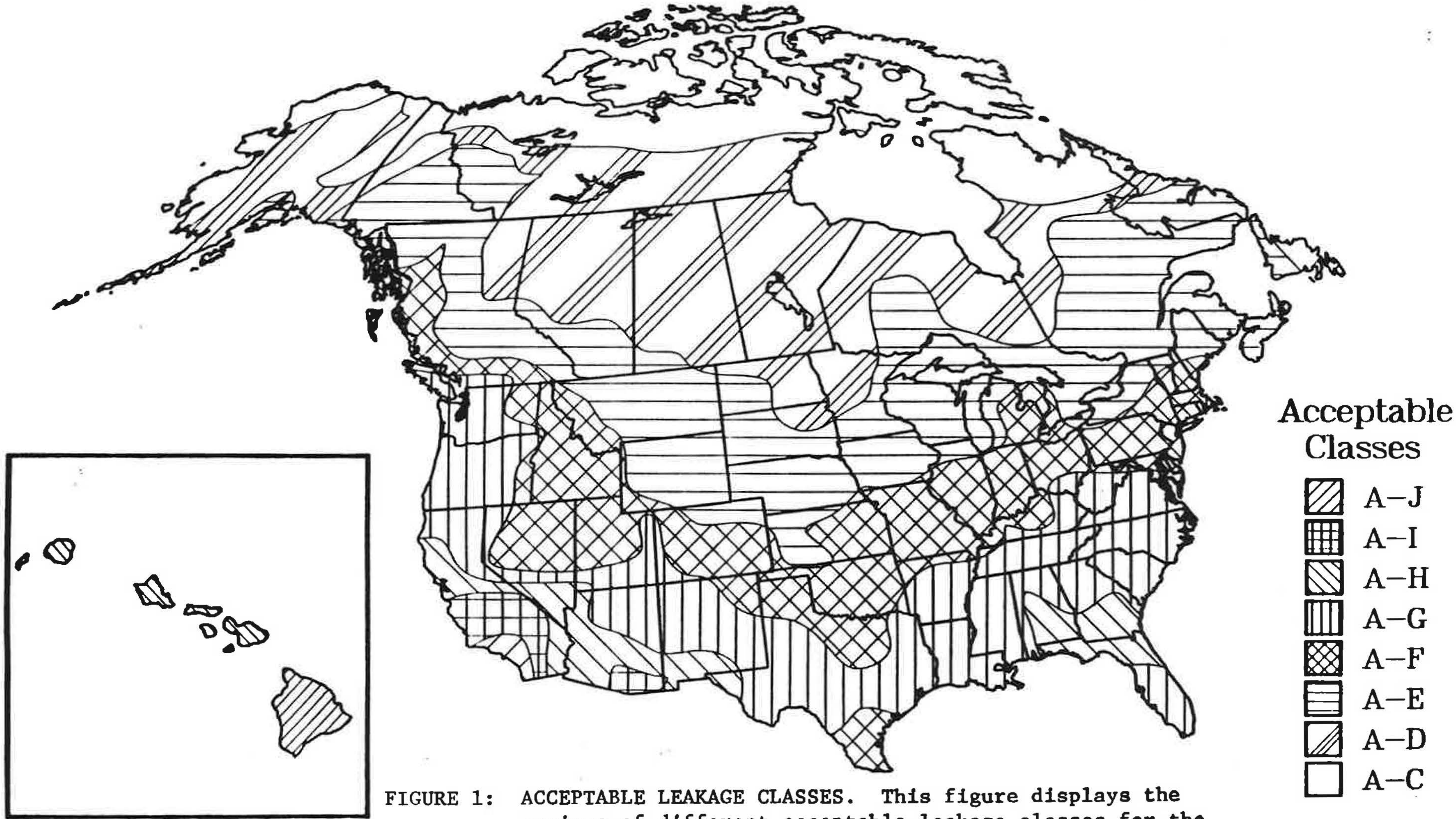

FIGURE 1: ACCEPTABLE LEAKAGE CLASSES. This figure displays the regions of different acceptable leakage classes for the U.S. and Canada as described in section 4. See section 5 for a description of these leakage classes.

TABLE 1a: LOCATIONS TABLE (USA)

STATE	CITY	ACCEPTABLE CLASSES	CITY	ACCEPTABLE CLASSES
ALABAMA				
	Birmingham	A-H	Mobile	A-H
	Montgomery	A-H		
ALASKA				
	Annette	A-F	Bethel	A-C
	Big Delta	A-C	Fairbanks	A-D
	Gulkana	A-D	Homer	A-E
	Juneau	A-E	King Salmon	A-D
	McGrath	A-D	Nome	A-C
	Yakutat	A-E		
ARKANSAS				
	Forth Smith	A-G	Little Rock	A-G
ARIZONA				
	Phoenix	A-H	Tucson	A-I
	Winslow	A-G	Yuma	A-H
CALIFORNIA				
	Bakersfield	A-I	Fresno	A-I
	Los Angeles	A-J	Mount Shasta	A-G
	Oakland	A-I	Red Bluff	A-H
	San Diego	A-J	San Francisco	A-H
	Santa Maria	A-I		
COLORADO				
	Colorado Springs	A-F	Denver	A-F
	Grand Junction	A-G	Pueblo	A-G
CONNECTICUT				
	Hartford	A-F		
DELAWARE				
	Wilmington	A-F		
FLORIDA				
	Apalachicola	A-G	Daytona	A-H
	Jacksonville	A-G	Miami	A-G
	Orlando	A-G	Tallahassee	A-H
	Tampa	A-G	W. Palm Beach	A-G
GEORGIA				
	Augusta	A-G	Atlanta	A-G
	Macon	A-H	Savannah	A-H
HAWAII				
	Hilo	A-J	Honolulu	A-H
	Lihue	A-H		
IDAHO				
	Boise	A-F	Lewiston	A-G
ILLINOIS				
	Chicago	A-F	Moline	A-F
	Springfield	A-F		
INDIANA				
	Evansville	A-G	Fort Wayne	A-F
	Indianapolis	A-F	South Bend	A-F
IOWA				
	Des Moines	A-E	Sioux City	A-E
KANSAS				
	Dodge City	A-E	Goodland	A-E
	Topeka	A-F		
KENTUCKY				
	Lexington	A-F	Louisville	A-F
LOUISIANA				
	Baton Rouge	A-G	Lake Charles	A-G
	New Orleans	A-G	Shreveport	A-G
MAINE				
	Caribou	A-E	Portland	A-F
MARYLAND				
	Baltimore	A-F		
MASSACHUSETTS				
	Boston	A-F		
MICHIGAN				
	Alpena	A-F	Detroit	A-F
	Flint	A-F	Grand Rapids	A-F
	Sault Ste. Marie	A-E		
MINNESOTA				
	Duluth	A-E	International Falls	A-D
	Minneapolis	A-E	Rochester	A-E
MISSISSIPPI				
	Jackson	A-G	Meridian	A-H
MISSOURI				
	Columbia	A-F	Kansas City	A-F
	Springfield	A-F	St. Louis	A-F
MONTANA				
	Billings	A-E	Glasgow	A-E
	Great Falls	A-E	Helena	A-F
	Miles City	A-E	Missoula	A-F
NEBRASKA				
	Grand Island	A-E	North Platte	A-E
	Omaha	A-F	Scottsbluff	A-E
NEVADA				
	Elko	A-F	Ely	A-E
	Las Vegas	A-H	Reno	A-G
	Winnemucca	A-F		
NEW HAMPSHIRE				
	Concord	A-F		
NEW JERSEY				
	Newark	A-F		
NEW MEXICO				
	Albuquerque	A-G	Clayton	A-F
	Roswell	A-G		
NEW YORK				
	Albany	A-F	Buffalo	A-E
	New York	A-F	Rochester	A-E
	Syracuse	A-E		
NORTH CAROLINA				
	Asheville	A-G	Cape Hatteras	A-G
	Charlotte	A-G	Greensboro	A-G
	Raleigh	A-G		
NORTH DAKOTA				
	Bismarck	A-E	Fargo	A-D
OHIO				
	Akron	A-F	Cincinnati	A-F
	Cleveland	A-F	Columbus	A-F
	Dayton	A-F	Toledo	A-F
	Youngstown	A-F		
OKLAHOMA				
	Oklahoma City	A-F	Tulsa	A-F
OREGON				
	Astoria	A-G	Medford	A-G
	Portland	A-G	Salem	A-G
PENNSYLVANIA				
	Allentown	A-F	Avoca	A-F
	Erie	A-F	Harrisburg	A-F
	Philadelphia	A-F	Pittsburgh	A-F
RHODE ISLAND				
	Providence	A-F		
SOUTH CAROLINA				
	Charleston	A-G	Columbia	A-G
SOUTH DAKOTA				
	Huron	A-E	Rapid City	A-E
	Sioux Falls	A-E		
TENNESSEE				
	Chattanooga	A-G	Knoxville	A-G
	Memphis	A-G	Nashville	A-G

TABLE 1a (Contd.): LOCATIONS TABLE (USA)				
STATE	CITY	ACCEPTABLE CLASSES	CITY	ACCEPTABLE CLASSES
TEXAS				
	Abilene	A-F	Amarillo	A-F
	Austin	A-G	Brownsville	A-F
	Corpus Christi	A-F	Del Rio	A-G
	ElPaso	A-H	Forth Worth	A-F
	Houston	A-G	Lubbock	A-G
	Midland Odessa	A-G	Port Arthur	A-G
	San Angelo	A-G	San Antonio	A-G
	Waco	A-F	Wichita Falls	A-F
UTAH				
	Salt Lake City	A-F		
VERMONT				
	Burlington	A-E		
VIRGINIA				
	Norfolk	A-G	Richmond	A-G
	Roanoke	A-G		
WASHINGTON				
	Olympia	A-G	Seattle	A-G
	Spokane	A-F	Yakima	A-G
WEST VIRGINIA				
	Charleston	A-G		
WISCONSIN				
	Green Bay	A-E	La Crosse	A-E
	Madison	A-E	Milwaukee	A-E
WYOMING				
	Casper	A-E	Cheyenne	A-E
	Sheridan	A-F		
DISTRICT OF COLUMBIA				
	Washington	A-G		

TABLE 1b: LOCATIONS TABLE (CANADA)				
PROVINCE	CITY	ACCEPTABLE CLASSES	CITY	ACCEPTABLE CLASSES
ALBERTA				
	Calgary	A-E	Edmonton	A-D
BRITISH COLUMBIA				
	Fort St. John	A-D	Prince Rupert	A-F
	Vancouver	A-G	Victoria	A-G
	Williams Lake	A-E		
MANITOBA				
	Thompson	A-D	Winnipeg	A-D
NEW BRUNSWICK				
	Saint John	A-E		
NEWFOUNDLAND				
	St. John's	A-D	Stephenville	A-E
NORTHWEST TERRITORIES				
	Frobisher Bay	A-C		
ONTARIO				
	Kapuskasing	A-D	Ottawa	A-E
	Sault Ste. Marie	A-E	Thunder Bay	A-E
	Toronto	A-E	Windsor	A-F
PRINCE EDWARD ISLAND				
	Charlottetown	A-E		
QUEBEC				
	Montreal	A-E	Quebec	A-E
SASKATCHEWAN				
	Regina	A-D	Saskatoon	A-D

IDD_h = the heating season infiltration degree-days (°F-day) [°C-day]
IDD_c = the cooling season infiltration degree-days (°F-day) [°C-day]

Heating (season) infiltration degree-days are compiled for every hour in which the dry-bulb temperature is below the (heating) base temperature:

$$IDD_h = \frac{1}{24} \sum_{hours}^{T<T_{bh}} \frac{s}{s_o} (T_{bh} - T) \qquad (5)$$

where:

T = the (hourly) dry-bulb temperature (°F) [°C]
T_{bh} = the (heating) base temperature (°F) [°C]
s = the specific infiltration (ft/min) [m/s]
s_o = is the typical specific infiltration (ft/min) [m/s]

The specific infiltration is to be calculated using the following equation:

$$s = \sqrt{f_w^2 v^2 + f_s^2 |T_{in} - T|} \qquad (6)$$

where

v = the hourly wind speed measured at 20 ft height (ft/m) [m/s]
T_{in} = a typical average interior temperature (°F) [°C]
f_s, f_w are constant form factors (See below).

Cooling (season) infiltration degree days are compiled for every hour in which the dry-bulb temperature is above the (cooling) base temperature *and* the enthalpy is greater than base enthalpy.

$$IDD_c = \frac{1}{24C_p} \sum_{hours}^{\substack{H \geq H_b \\ T \geq T_{bc}}} \frac{s}{s_o} (H - H_b) \qquad (7)$$

where:

C_p = the heat capacity of air
T_{bc} = the (cooling) base temperature (°F) [°C]
H = the (hourly) enthalpy (Btu/lb) [J/kg]
H_b = the base enthalpy (Btu/lb) [kJ/kg]

The following constants are to be used in the above expressions:

C_p = 0.245 Btu/lb-°F (1.024 kJ/kg-°C)
T_{in} = 72 °F (22.2 °C)
T_{bh} = 65 °F (18.3 °C)
T_{bc} = 78 °F (25.6 °C)
H_b = 28 Btu/lb (65 kJ/kg)
s_o = 140 ft/min (0.71 m/s)
f_w = 0.132 [dimensionless]
f_s = 17.6 ft/min $-$°F$^{1/2}$ (0.120 m/s$-$K$^{1/2}$)

7.0 REFERENCES

[1] ASTM E741-83, Standard Test Method for Determining Air Leakage Rate by Tracer Dilution, American Society for Testing and Materials, 1983.
[2] ASTM E779-87, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization, American Society for Testing and Materials, 1987.
[3] CAN/CGSB-149.10-M86, Standard for Determination of Airtightness of Buildings by the Fan Depressurization Method, Canadian General Standards Board, 1986.
[4] ASTM E631-87, Standard Terminology of Building Constructions, American Society for Testing and Materials, 1987.

This Appendix is not part of this Standard but is provided for information purposes only.

APPENDIX A

BIBLIOGRAPHY

1. Exegesis of ASHRAE Standard 119, "Air Leakage Performance for Detached Single-Family Residential Buildings," BTECC/DOE Air Infiltration and Ventilation Symposium Proceedings, Building Thermal Envelope Coordinating Council, 1015 15th Street, NW, Suite 700, Washington, DC 20005, December 1986.

This Appendix is not part of this Standard but is provided for information purposes only.

APPENDIX B

WEATHER DATA

The Locations Table (Table 1) was calculated using weather data from three sources: WYEC, TMY, and 10-year average data. When more than one source of acceptable data existed for a specific location, TMY was used in preference to 10-year average, and WYEC was used in preference to them both. In the preparation of the Locations Table, IDDs and specific infiltration were calculated as intermediate results. Table B1 contains the infiltration degree-days for those sites listed in Table 1. Table B1 also contains the specific infiltration for each location averaged over the hours in which there are non-zero IDDs.

Fig. 1 displayed acceptable leakage classes to be used when specific weather data for locations not in Table 1 is lacking. Fig. 2 has plotted the location of each city (indicating the weather source) and the interpolated lines of IDDs at the class boundaries.

VENTILATION RECOMMENDATIONS

Although ASHRAE Standard 62 is to be considered as the reference for determining the sufficiency of ventilation, this appendix can be used to help *estimate* the contribution of *infiltration* toward meeting ventilation requirements.

For structures in Classes A–C, infiltration will almost never be sufficient to achieve adequate indoor air quality; specific mechanical ventilation will probably be required at all times (in which the windows are closed). For structures in Classes D–F, infiltration may or may not be sufficient depending on circumstances; mechanical ventilation may be required in some cases, but existing intermittent mechanical ventilation (i.e., bathroom/kitchen exhaust fans) may be sufficient. For structures in Classes G–J, infiltration will normally be sufficient to meet ventilation requirements; additional mechanical ventilation will usually not be required.

It is important to remember than when infiltration is the key mechanism for supply ventilation, window opening during periods of low driving forces will be necessary for adequate indoor air quality. Even if the average ventilation rate over the season is adequate to supply all ventilation needs, extended periods of low temperature difference may not supply sufficient ventilation. Thus, for all leakage classes and in all climates, there will be times when infiltation is insufficient to meet ventilation requirements, unless natural ventilation (i.e. window openings) or mechanical ventilation is used to augment the infiltration.

ESTIMATION OF AVERAGE AIR CHANGE RATES

This appendix gives a technique for the estimation of air exchange rates from normalized leakage values and climate. These air exchange rates are seasonal average ones based on the average climate; instantaneous values of air exchange may differ quite radically from the averages calculated herein. Several assumptions concerning the structure and the climate have been incorporated into these calculations. The results in this section assume a typical structure that is typically shielded from a typical 4 m/s wind; these factors can easily vary by a factor of two.

The following numerical *rule-of-thumb* may be useful for estimating seasonal average infiltration rates for buildings in which the climate is unknown:

$$ACH \approx L_n \qquad \text{(A1)}$$

If weather data is available and it is possible to construct a specific infiltration averaged over the time period of interest, the mean air change rate due to infiltration alone can be approximated by the following expression:

$$ACH = \frac{s}{s_o} L_n \qquad \text{(A2)}$$

If more detailed estimates are required, the literature should be consulted for an appropriate infiltration model.

INFILTRATION DEGREE DAY SITES

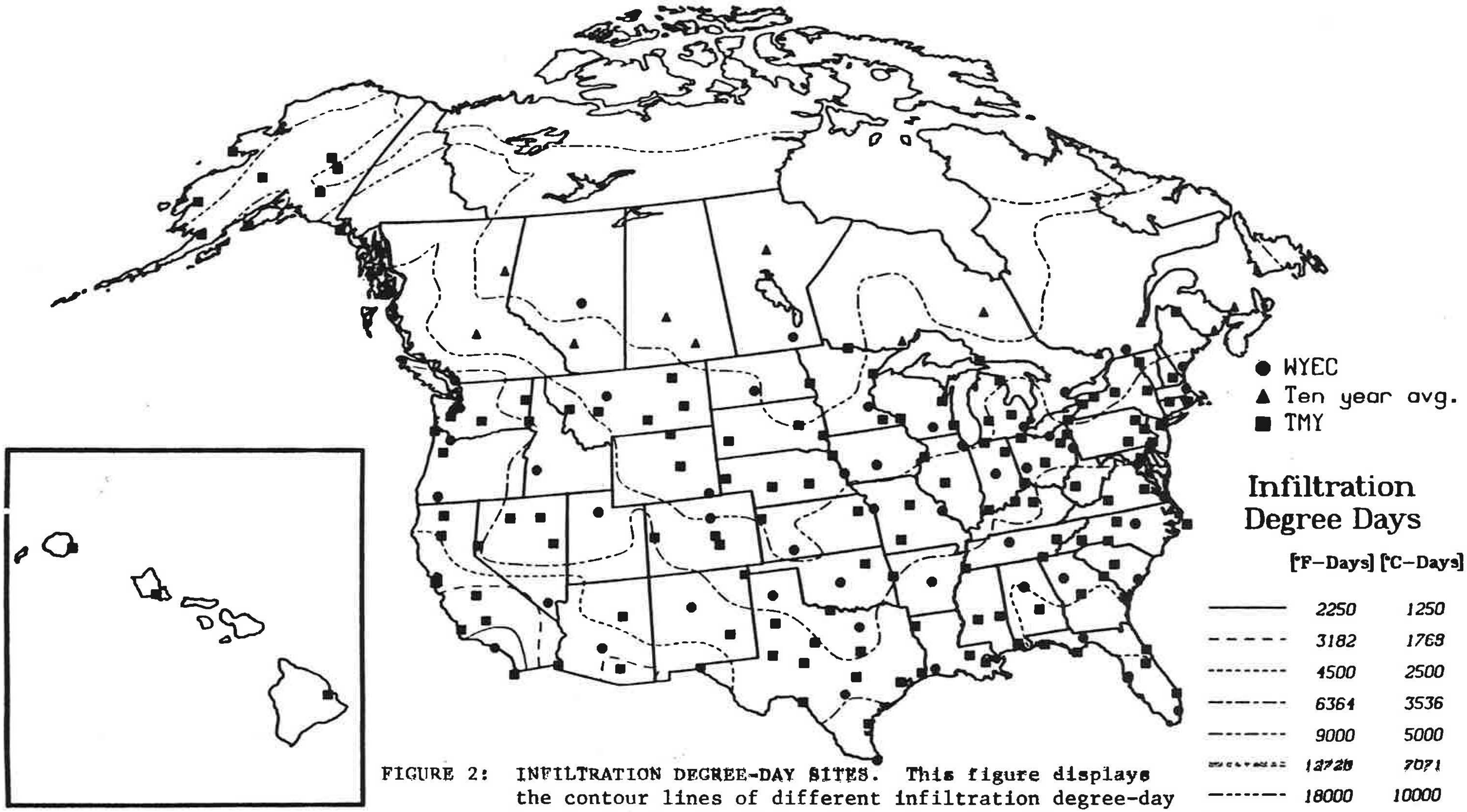

FIGURE 2: INFILTRATION DEGREE-DAY SITES. This figure displays the contour lines of different infiltration degree-day boundaries for the U.S. and Canada. The sites are those from table 1; the IDD and data source from table A1 are also indicated. (NOTE: Because of the paucity of data sites no contour lines are shown for the Hawaiian Islands.)

TABLE B.1a: LOCATIONS DATA (USA)					
CITY, STATE	INFILTRATION DEGREE-DAYS		SPECIFIC INFILTRATION		DATA SOURCE
	IDD [°F-days]	IDD [°C-days]	s [ft/min]	s [m/s]	
Annette, AK	8369	4649	151	0.77	TMY
Bethel, AK	19861	11033	188	0.95	TMY
Big Delta, AK	19263	10701	168	0.85	TMY
Fairbanks, AK	16609	9227	140	0.71	TMY
Gulkana, AK	15483	8601	147	0.74	TMY
Homer, AK	10382	5767	132	0.67	TMY
Juneau, AK	10175	5652	147	0.74	TMY
King Salmon, AK	15233	8462	171	0.86	TMY
McGrath, AK	16740	9300	140	0.71	TMY
Nome, AK	18364	10202	172	0.87	TMY
Yakutat, AK	10038	5576	141	0.71	TMY
Birmingham, AL	4468	2482	108	0.55	WYEC
Mobile, AL	4480	2488	128	0.65	TMY
Montgomery, AL	4463	2479	114	0.58	TMY
Fort Smith, AR	6008	3337	127	0.64	TMY
Little Rock, AR	6023	3346	117	0.59	WYEC
Phoenix, AZ	3305	1836	100	0.51	WYEC
Tucson, AZ	3093	1718	125	0.64	TMY
Winslow, AZ	5443	3023	136	0.69	TMY
Yuma, AZ	4264	2368	128	0.65	TMY
Bakersfield, CA	2600	1444	110	0.56	TMY
Fresno, CA	3103	1723	110	0.56	TMY
Los Angeles, CA	1698	943	117	0.59	WYEC
Mount Shasta, CA	5801	3222	128	0.65	TMY
Oakland, CA	2943	1635	128	0.65	TMY
Red Bluff, CA	3795	2108	134	0.68	TMY
San Diego, CA	1128	626	1203	0.52	TMY
San Francisco, CA	3692	2051	146	0.74	TMY
Santa Maria, CA	2801	1556	108	0.55	TMY
Colorado Springs, CO	7793	4239	156	0.79	TMY
Denver, CO	6806	3781	135	0.69	WYEC
Grand Junction, CO	6073	3373	133	0.67	TMY
Pueblo, CO	6229	3460	139	0.71	TMY
Hartford, CT	7881	4378	143	0.72	TMY
Wilmington, DE	6884	3824	146	0.74	TMY
Apalachicola, FL	4670	2594	104	0.53	TMY
Daytona, FL	4266	2370	127	0.64	TMY
Jacksonville, FL	4501	2500	126	0.64	TMY
Miami, FL	5906	3281	113	0.57	WYEC
Orlando, FL	4593	2551	126	0.64	TMY
Tallahassee, FL	3633	2018	95	0.48	WYEC
Tampa, FL	4629	2571	113	0.57	WYEC
W. Palm Beach, FL	5910	3283	132	0.67	TMY
Augusta, GA	4618	2565	121	0.61	TMY
Atlanta, GA	4906	2725	119	0.61	WYEC
Macon, GA	4453	2473	124	0.63	TMY
Savannah, GA	4387	2437	125	0.63	TMY
Hilo, HI	1767	981	110	0.56	TMY
Honolulu, HI	3626	2014	155	0.79	TMY
Lihue, HI	3200	1777	146	0.74	TMY
Des Moines, IA	9149	5082	142	0.72	WYEC
Sioux City, IA	10560	5866	165	0.84	TMY
Boise, ID	6746	3747	135	0.69	WYEC
Lewiston, ID	5643	3135	124	0.63	TMY
Chicago, IL	8781	4878	150	0.76	WYEC
Moline, IL	8634	4796	152	0.77	TMY
Springfield, IL	8382	4656	160	0.81	TMY
Evansville, IN	6326	3514	132	0.67	TMY
Fort Wayne, IN	8427	4681	155	0.79	TMY
Indianapolis, IN	7913	4396	137	0.69	WYEC
South Bend, IN	8257	4587	150	0.76	TMY

TABLE B.1a (Contd.): LOCATIONS DATA (USA)					
CITY, STATE	INFILTRATION DEGREE-DAYS IDD [°F-days]	IDD [°C-days]	SPECIFIC INFILTRATION s [ft/min]	s [m/s]	DATA SOURCE
Dodge City, KS	9025	5013	177	0.90	WYEC
Goodland, KS	9366	5203	177	0.90	TMY
Topeka, KS	8214	4563	149	0.75	TMY
Lexington, KY	6493	3607	140	0.71	TMY
Louisville, KY	6574	3652	138	0.70	TMY
Baton Rouge, LA	4692	2606	120	0.61	TMY
Lake Charles, LA	5324	2957	122	0.62	WYEC
New Orleans, LA	4652	2584	122	0.62	TMY
Shreveport, LA	5347	2970	129	0.65	TMY
Boston, MA	8472	4706	162	0.83	WYEC
Baltimore, MD	6570	3650	138	0.70	TMY
Caribou, ME	12550	6972	163	0.83	TMY
Portland, ME	8585	4769	136	0.69	WYEC
Alpena, MI	8805	4891	132	0.67	TMY
Detroit, MI	8624	4791	141	0.72	WYEC
Flint, MI	8936	4964	151	0.765	TMY
Grand Rapids, MI	8793	4885	151	0.77	TMY
Sault Ste. Marie, MI	11313	6285	150	0.76	TMY
Duluth, MN	12515	6952	158	0.80	TMY
International Falls, MN	13266	7370	158	0.80	TMY
Minneapolis, MN	10860	6033	155	0.79	WYEC
Rochester, MN	11663	6479	171	0.86	TMY
Columbia, MO	7507	4170	148	0.75	TMY
Kansas City, MO	7481	4156	132	0.67	WYEC
Springfield, MO	7539	4188	158	0.80	TMY
St. Louis, MO	7793	4329	136	0.69	WYEC
Jackson, MS	4896	2710	121	0.61	TMY
Meridian, MS	4399	2443	112	0.57	TMY
Billings, MT	10376	5764	176	0.89	TMY
Glasgow, MT	11597	6442	165	0.84	TMY
Great Falls, MT	10878	6043	175	0.89	WYEC
Helena, MT	8915	4952	144	0.73	TMY
Miles City, MT	9959	5532	154	0.78	TMY
Missoula, MT	7577	4209	125	0.64	TMY
Asheville, NC	5421	3011	127	0.64	TMY
Cape Hatteras, NC	5525	3069	157	0.80	TMY
Charlotte, NC	4539	2521	123	0.62	TMY
Greensboro, NC	4990	2772	123	0.62	TMY
Raleigh, NC	5103	2835	116	0.59	WYEC
Bismarck, ND	12419	6899	161	0.82	WYEC
Fargo, ND	13896	7720	179	0.91	TMY
Grand Island, NE	10175	5652	172	0.87	TMY
North Platte, NE	9200	5111	154	0.78	TMY
Omaha, NE	8950	4972	144	0.73	WYEC
Scottsbluff, NE	9374	5207	161	0.82	TMY
Concord, NH	8240	4577	129	0.66	TMY
Newark, NJ	6799	3777	149	0.75	TMY
Albuquerque, NM	4854	2696	126	0.64	WYEC
Clayton, NM	7206	4003	174	0.88	TMY
Roswell, NM	4989	2771	139	0.71	TMY
Elko, NV	7147	3970	123	0.62	TMY
Ely, NV	9432	5240	155	0.78	TMY
Las Vegas, NV	3524	1957	138	0.70	WYEC
Reno, NV	5929	3293	124	0.63	TMY
Winnemucca, NV	6901	3833	136	0.69	TMY
Albany, NY	8185	4547	141	0.72	TMY
Buffalo, NY	9840	5466	174	0.88	TMY
New York, NY	7518	4176	152	0.77	WYEC
Rochester, NY	9437	5242	156	0.79	TMY
Syracuse, NY	9047	5026	152	0.77	TMY

TABLE B.1a (Contd.): LOCATIONS DATA (USA)

CITY, STATE	INFILTRATION DEGREE-DAYS		SPECIFIC INFILTRATION		DATA SOURCE
	IDD [°F-days]	IDD [°C-days]	s [ft/min]	s [m/s]	
Akron, OH	8118	4510	151	0.77	TMY
Cincinnati, OH	6756	3753	143	0.72	TMY
Cleveland, OH	8579	4766	151	0.77	WYEC
Columbus, OH	7328	4071	144	0.73	TMY
Dayton, OH	7681	4267	139	0.71	WYEC
Toledo, OH	8570	4761	149	0.76	TMY
Youngstown, OH	8688	4826	154	0.78	TMY
Oklahoma City, OK	7761	4311	156	0.79	WYEC
Tulsa, OK	7665	4258	150	0.76	TMY
Astoria, OR	5025	2701	130	0.66	TMY
Medford, OR	4721	2622	106	0.54	WYEC
Portland, OR	4860	2700	124	0.63	WYEC
Salem, OR	5027	2792	127	0.64	TMY
Allentown, PA	7841	4356	147	0.75	TMY
Avoca, PA	7680	4266	141	0.72	TMY
Erie, PA	8843	4912	167	0.85	TMY
Harrisburg, PA	6470	3594	132	0.67	TMY
Philadelphia, PA	6917	3842	146	0.74	TMY
Pittsburgh, PA	7462	4145	136	0.69	WYEC
Providence, RI	7679	4266	149	0.76	TMY
Charleston, SC	5072	2817	122	0.62	WYEC
Columbia, SC	4635	2575	117	0.59	TMY
Huron, SD	12605	7002	174	0.88	TMY
Rapid City, SD	10143	5635	168	0.85	TMY
Sioux Falls, SD	11326	6292	171	0.87	TMY
Chattanooga, TN	5102	2834	114	0.58	TMY
Knoxville, TN	5042	2801	121	0.61	TMY
Memphis, TN	5931	3295	134	0.68	TMY
Nashville, TN	5607	3115	119	0.61	WYEC
Abilene, TX	6655	3697	165	0.83	TMY
Amarillo, TX	7274	4041	164	0.83	WYEC
Austin, TX	5652	3140	133	0.67	TMY
Brownsville, TX	8193	4551	138	0.70	WYEC
Corpus Christi, TX	8128	4515	146	0.74	TMY
Del Rio, TX	5524	3068	143	0.72	TMY
El Paso, TX	3633	2018	128	0.65	WYEC
Fort Worth, TX	6383	3546	139	0.70	WYEC
Houston, TX	6189	3438	140	0.71	TMY
Lubbock, TX	6150	3416	160	0.81	TMY
Midland Odessa, TX	4957	2743	154	0.78	TMY
Port Arthur, TX	5449	3027	133	0.67	TMY
San Angelo, TX	5084	2824	141	0.72	TMY
San Antonio, TX	5138	2854	122	0.62	WYEC
Waco, TX	6916	3842	147	0.75	TMY
Wichita Falls, TX	7358	4087	158	0.80	TMY
Salt Lake City, UT	6632	3684	138	0.70	WYEC
Norfolk, VA	5829	3238	147	0.74	TMY
Richmond, VA	5119	2843	123	0.62	TMY
Roanoke, VA	5552	3084	131	0.66	TMY
Burlington, VT	9319	5177	145	0.74	TMY
Olympia, WA	5299	2943	122	0.62	TMY
Seattle, WA	5811	3228	136	0.69	WYEC
Spokane, WA	7823	4346	145	0.74	TMY
Takima, WA	5997	3331	128	0.65	TMY
Green Bay, WI	10434	5796	155	0.78	TMY
La Crosse, WI	9220	5122	147	0.74	TMY
Madison, WI	9785	5436	143	0.72	WYEC
Milwaukee, WI	9855	5475	166	0.84	TMY
Charleston, WV	5294	2941	116	0.59	TMY
Casper, WY	11511	6395	193	0.98	TMY
Cheyenne, WY	10503	5835	174	0.88	WYEC
Sheridan, WY	8523	4735	140	0.71	TMY

TABLE B.1a (Contd.): LOCATIONS DATA (USA)					
CITY, STATE	INFILTRATION DEGREE-DAYS IDD [°F-days]	IDD [°C-days]	SPECIFIC INFILTRATION s [ft/min]	s [m/s]	DATA SOURCE
Washington, DC	6341	3522	133	0.67	WYEC
Calgary, ALB	11269	6260	151	0.77	10 Year
Edmonton, ALB	13109	7282	144	0.73	WYEC
Fort St. Joh, BC	12921	7178	147	0.74	10 Year
Prince Rupert, BC	7668	4260	140	0.71	10 Year
Vancouver, BC	5405	3002	123	0.62	WYEC
Victoria, BC	4922	2734	107	0.54	10 Year
Williams Lake, BC	10016	5564	132	0.67	10 Year
Thompson, MAN	16350	9083	143	0.72	10 Year
Winnipeg, MAN	14758	8198	166	0.84	WYEC
Saint John, NB	10949	6082	155	0.79	10 Year
St. John's, NF	13544	7524	196	0.99	10 Year
Stephenville, NF	12118	6732	170	0.86	10 Year
Frobisher Bay, NWT	25705	14280	185	0.94	10 Year
Kapuskasing, ONT	13968	7760	144	0.73	10 Year
Ottawa, ONT	10216	5675	133	0.67	10 Year
Sault Ste. Marie, ONT	11295	6275	165	0.84	10 Year
Thunder Bay, ONT	11835	6575	135	0.69	10 Year
Toronto, ONT	9246	5136	137	0.69	WYEC
Windsor, ONT	8965	4981	162	0.82	10 Year
Charlottetown, PEI	11429	6349	165	0.84	10 Year
Montreal, QUE	10496	5831	143	0.72	WYEC
Quebec, QUE	11697	6498	140	0.71	10 Year
Regina, SAS	14752	8195	170	0.86	10 Year
Saskatoon, SAS	13605	7558	154	0.78	10 Year