HVAC Performance Test Kit
Operating Guide

Featuring the testo 435 HVACR multifunction analyzer

DRAFT

i. Preface

This manual was written as a general guide. The author and publisher have neither liability nor can they be responsible to any person or entity for any misunderstanding, misuse, or misapplication that would cause loss or damage of any kind, including the loss of rights, material, or personal injury, or alleged to be caused directly or indirectly by the information contained in this publication.

The author and publisher do not assume and expressly disclaim any obligations to obtain and include any additional information. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by activities herein, and to avoid all potential hazards. By following instructions contained herein, the reader willingly assumes all risks in connection with such instructions.

WARNING

Information contained is only for use by formally trained competent technicians practicing within the HVAC/R community. The manufacturers' installation, operation, and service information should always be consulted, and should be considered the first and best reference for installing, commissioning and servicing equipment. The author and publisher assume no liability for typographical errors or omissions of information in this guide.

For additional information please contact:

Testo, Inc.
35 Ironia Rd.
Flanders, NJ 07836
+1 800-227-0729
+1 973 252 1720
Fax +1 973 252 1729
www.testo.com
info@testo.com

For QUESTIONS on this DRAFT MANUAL please contact:

Bill Spohn: mobile 412 721 5544 bspohn@testo.com
Jim Bergmann: Mobile 330 618 3472 jbergmann@testo.com

Author:
James L. Bergmann
HVAC/R Technical Specialist
Testo, Inc.

Equipment capacity testing

As energy costs rise, the practice of assessing equipment and system performance and the relatively new practice of residential building commissioning will drive technicians to measure actual operating equipment capacity.

Most new and existing heating and cooling appliances are installed or serviced each year without knowing if they are operating at or delivering their designed and/or rated capacity. Operational measurements are made to verify temperature rise and drops, airflow, superheat and/or subcooling, but often the total system performance is never quantified. Equipment is sized for a minimum delivery, yet usually never tested after installation for actual performance verification. Equipment performance testing should be the final step of the commissioning process and the first step for accurate equipment troubleshooting. Equipment capacity testing validates all of the preliminary data measured during the system commissioning process by verification of the final equipment or system performance.

Measuring the capacity is simply a verification of the BTUh, tons, or KWh of heating or cooling the equipment is producing. It is not a measure of efficiency such as SEER, COP, or AFUE, which cannot be field calculated. One exception is EER - a field calculable number so long as an accurate instrument is used to measure total system electrical power consumption including that of the outdoor condensing unit and indoor evaporator fan. Normally capacity is only one of the measurements required to calculate any of the DOE recognized efficiency calculations. What is important to remember, however, is that efficiency and capacity go hand in hand. The equipment will produce its rated capacity only when operating at its optimal efficiency. Any adjustment or deficiency in equipment operation outside of design will degrade capacity or allow equipment to operate with compromised safety. It is imperative that the ***equipment is always setup to the manufacturer's specifications*** including airflow, charging, and gas manifold or oil nozzle pressure. If these procedures are carefully followed and accurate instrumentation is used to verify the initial measurements, equipment operation will produce the manufacturer's specified results. The rated capacity should be very close to actual capacity on most properly commissioned systems. Equipment will operate with differing capacities under different load conditions. The rated capacity under these conditions is normally stated by the manufacturer in the engineering data available for each specific piece of equipment or condenser, air handler and coil combination. Nominal capacities and actual capacities do vary; therefore the rated capacity for the load conditions and equipment selection should always be verified against the actual field measured capacity.

Smart analyzer

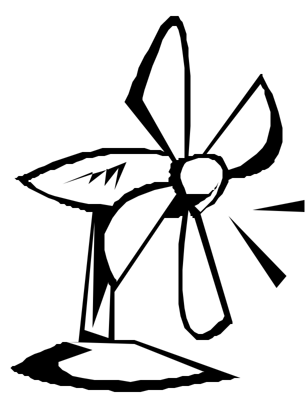
The testo 435 is a "smart instrument". It will only allow configuration of probes and features if the probes are directly connected by hard wire or recognized via a wireless channel. Before any configuring can be completed, or the instrument is turned on for commissioning, all probes must be connected and wireless handles switched to the ON position.

To achieve highest accuracy when measuring heating or cooling system capacity the instrument should be configured with high accuracy wireless probes (+/- 2%Rh), and a mini-vane anemometer. Probe (1) must be identified, as measurements will be used to calculate air density at the fan inlet.

Air density depends on several factors: temperature, humidity and elevation, and, to be very precise, absolute pressure. In the testo 435, pressure is corrected for by altitude and is input in feet above sea level rather than absolute pressure. (see table on pages 14-16 with elevation for 314 cities in North America). Error inherent with the measurement process by using elevation rather than barometric pressure is negligible but can be accounted for if desired by entering the elevation that corresponds to the local barometric pressure using the chart on page 13. Once the HVAC system fan speed is set, changes in normal barometric pressure due to weather are not normally compensated for. Because the elevation of the HVAC system is a constant, this will provide a gross measurement and is satisfactory for all field measurements and psychrometric applications.

Fans and their relation to air density

A fan or blower is a constant volume machine; it will move the same CFM of air no matter what density of the air. However, a fan or blower is not a constant mass flow machine. Therefore, mass flow changes as the density changes. This becomes important because equipment must operate at various altitudes and with varying inlet air conditions. The mass flow is directly proportional to density change, while the volume flow (CFM) remains constant. As air density is decreased, mass flow decreases and the effective cooling or heating capacity will diminish in proportion. Therefore, equivalent mass flow is needed for accurate cooling and



heating calculations. Simply, the volume flow (CFM) required at a high altitude (low density) will be greater than what required at sea level to obtain equivalent heat transfer.

Comparing traditional measuring techniques

Because of the complexity of accurate field measurement and inaccuracies associated with traditional measurement procedures particularly in airflow and humidity, the capacity measurement obtained with the 435 should be considered the reference measurement against which others field and lab methods can be compared. In real world applications air is never "standard air" (68°F, 0%Rh, 29.92" Hg) the standard air equations cannot be applied to obtain the high degree of accuracy often desired and achievable with the 435. If using the standard air equations to compare measurements made with a 435, the "constants" in the standard air equations must be recalculated and the air measurement be compensated for fan air inlet density. Air measurements made via a Pitot tube, hotwire, or flow grid will have significant error if the air density is not considered and corrected for. Humidity measurements made with sling psychrometers and less sophisticated digital equipment can produce significant error if proper air velocity, distilled water, clean wicks and/or proper technique are deviated from.

Why measure air with a vane?

The vane is ideal for the air measurement, as it is a non-density dependant measure of the air velocity. The user inputs the duct dimensions for the point where air measurements will be made in and volume and a true mass flow rate will be automatically calculated by the 435. The change in enthalpy (BTU/lb) will be measured from return to supply via the wireless probes, and using the mass flow rate a change total heat will be measured and displayed in tons, BTUh, or KW.

> Note: ECM fans automatically correct for changes in air density (mass flow rate) by increasing or decreasing the RPM based upon the torque (as created by the fan) that is measured by sensors in the motor system. As the air density decreases, the motor and or fan will speed up because of the lower torque. In turn, a higher CFM will be measured through the system. The mass flow rate however will remain constant allowing the coil or heat exchanger to operate at its optimal efficiency. Where a standard fan operates at a constant volume and variable mass flow rate, an ECM operates with a constant mass flow rate and varies the CFM as the air density changes.

435 Setup and Capacity Commissioning

Configuration for cooling/heating capacity:

Step 1, Configuring / finding probes: (vane, wireless)

1) Plug mini vane anemometer into the 435
2) Turn on two wireless probes
3) Turn on the testo 435 (press the 1/0 key) (see pages 10-11 for probe and analyzer set up notes.)
4) **Hold** orange center key to enter *deep* configuration menu (Profile is displayed)
5) Use up arrow key to enter “Probe” menu (2 presses)
6) Select OK; “Radio C” displayed
7) Hit OK; “Radio P.1” displayed
8) Hit OK; Use up/down arrow to select probe
9) Press OK (record which probe is probe 1) (________________) Probe selected (**RECORD PROBE DESIGNATION HERE**. YOU WILL NEED IT LATER. PROBE DESIGNATION IS ALSO ON PROBE LABEL: RFD: XXX) *****
10) Use up arrow to go to probe P.2
11) Press OK (record which probe is probe 2) (________________) Probe selected (**RECORD PROBE DESIGNATION HERE)**
12) Press escape 3 times to return to measurement menu
13) Use up arrow key to search for probe (1) radio. The icons to the left of the displayed values indicate which probe is being displayed. A radio probe is designated by an antenna shown above the circle indicating the probe number to the left of the measured value)
14) Use down arrow key to search for probe (2) radio

***** HINT: *Use the probe with the lower number RFID as Probe #1, that way it is easier to remember which is which when you are testing. Analyzer configurations are saved when the 435 is powered off.)*

Step 2, Configure units of measure for US customary units of measure: power, length, volume, velocity, pressure, and temperature

1) Hold center orange key to go to deep menu
2) Toggle to UNITS (up/down arrows)
3) Press OK
4) US/ISO Press OK, “ISO is displayed
5) Use up/down arrow to select (US, ISO) as desired

   Note if U.S. is selected, default units will be:
   - Power, BTU/h
   - Length, inch
   - Volume, ft^3/min (CFM)
   - Velocity, fpm
   - Pressure, inchH20

6) Press OK
7) Use up/down arrow to go to POWER
8) Press OK
9) Select units (BTU/h, KW, TONS)
10) Press OK
11) Press ESC two times to return to measurement menu

Step 3, Configuring calculated parameters:
Dewpoint, enthalpy, Psyc °F = Wetbulb

Press and hold center orange key to enter configuration menu

1. On Profile, press OK
2. Toggle to Standard and press OK
3. Press Esc to exit
4. Press center Orange Key to enter Menu
5. Toggle up to CALC
6. Press OK
7. Dewpoint is displayed
8. Press OK
9. Off is displayed

10. Toggle up to ON
11. Press OK
12. Toggle up and repeat this procedure for Enthalpy, Psyc°F (Wetbulb) and Vol
13. Press ESC to return to measurement Menu

Step 4, Entering duct area for CFM calculation
Press center orange key once to enter configuration menu

1. Toggle up to Parameter
2. Press OK
3. Toggle up to Area
4. Press OK
5. Toggle to desired parameter (Area, Circle 1Rect. 1, Rect. 2, or Area)
6. If using Rect. 1 or 2, (a) and (b) (length and width) need to be entered and area will be calculated. If using Area, enter in^2 as required.
7. Press escape 4 times to return to measurement menu.

Measuring cooling / heating capacity:
The heating and cooling capacity calculation is a dynamic calculation. Airflow, air density, and enthalpy are simultaneously accounted for to provide a real time capacity calculation. As with all measurements, proper technique and procedures are critical to the success of the measurement. Positioning of the probes and location of the airflow measurement are critical to the success of the operator. When making measurements of equipment capacity it is also important to consider that no appliance will instantaneously perform at rated capacity. Usually 6-10 minutes of continuous uninterrupted operation are required to reach steady-state efficiency. The time may be longer for higher mass heat exchangers, coils and/or systems that are operating outside of their design conditions. Usually when the discharge air temperature stabilizes in the cooling or heating mode, it is safe to assume that heat transfer is occurring at a constant rate. Also, it should be considered that heat is added by the blower motor in the form of resistive heating and may or may not affect the calculation depending on where the measurement is taken.

Locating Wireless Probe (1)

Be sure probe 1 is ON (flashing blue LED on bottom of probe handle). (*See notes on wireless probes on page 12*.) Secure the probe close to the fan inlet with the tip in the airstream. This will allow for an accurate mixed air temperature if any duct leakage is present or there is air leakage of conditioned air from a humidifier bypass. An alternative location is to drill a small hole in the fan volute at the discharge side of the fan or insert the probe into a predrilled hole slightly downstream of the desired point of air measurement in the return air duct. If measurement is made in the duct, make sure the probe is inserted far enough into the duct to be fully in the air stream. (An 11/16" hole works well.)

Locating Wireless Probe (2)

Turn on probe 2 and insert the measurement probe into the supply air after the first turn in the ductwork, or 3-5 duct diameters away from the heat exchanger or evaporator coil. Measurements made too close to the coil or heat exchanger may not be indicative of the total change in enthalpy. Radiation from the heat exchanger or coil and/or hot or cold spots in the duct due to low or high airflow at the coil or heat exchanger can effect the final measurement. A measurement made further down the duct will have little if any measurable sensible heat loss and no latent heat losses do to duct loss or gain.

Airflow Measurement:

For capacity calculation the vane anemometer must be used to measure airflow. Vane anemometers have several advantages over any other method. The primary advantages are speed, accuracy, and ease of use. As stated before, vane anemometers do not require air density compensation due to air temperature, humidity, or atmospheric pressure. The mini vane allows for a full duct traverse with an automatic calculation of the CFM in the duct if the dimensions are input into the instrument before the measurement is taken. It is imperative that the ducting is securely attached to the appliance, and the base pan, if side return is used, is sealed. Air leaks up-stream of where the measurements are made will significantly alter the actual reading obtained with this method. If done carefully the measurement error will be less than 3%. Due to the mini-vane's aerodynamic design, changes of up to 10% in yaw and pitch of the probe head in the duct will result in less than 1% error in the measurement, making this the ideal probe for air measurement in the field.

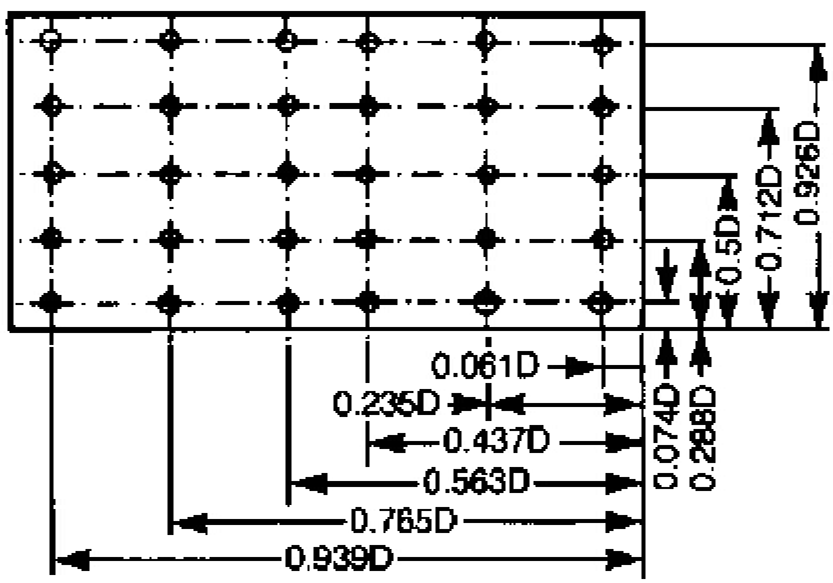
For accurate measurement, the best point of measure would be free of turbulent airflow. While a vane is tolerant to turbulence, a minimal amount of turbulence will provide a more accurate and repeatable measurement. Ideally the point of measure will be 6 to 10 straight duct diameters away from bends or fittings in the air stream that will cause turbulent airflow. In practical application this is not often possible so the "best" location may not always be ideal. Technicians will find if using a vane verses other measurement technique (specifically Pitot tube and hotwire) the error and repeatability of the measurement will not be drastically compromised.

The vane anemometer measures air speed and calculates volume based from duct measurements input by the user. The duct dimensions can be set independently or the area input directly. If the duct is round, only the diameter is required and the area will be calculated.

Guidelines for accurate airflow measurement

- Using standard selection criteria choose the best location for airflow measurement.

- Drill a minimum of three and a maximum of five ¾" holes for the airflow measurement. If possible, measure from the short side of the duct, and pull the probe across (perpendicular) the airstream. Use the table at right for measurement location in rectangular or square duct.



- Input the duct area into the 435

- Performing a point or timed traverse as desired. With practice, a timed traverse will produce, in less time, results as accurate as a point-by-point traverse.

- Use plastic plugs or foil tape available from most hardware stores to plug holes after measurement

Performing a timed or multipoint traverse with capacity calculation

Press center orange key once to enter configuration menu

1. Toggle up to Mean
2. Press OK
3. Using arrow keys select timed or Multipnt
4. Press OK
5. 435 will switch to measurement screen and "Mean" will be displayed at the top of the screen

Note:
If Multipnt is selected press PICK to store each point
If Timed, Press "Start" to commence measurement procedure and "End" to finish.

6. Press save to "Save", or "ESC" to repeat measurement
7. If desired, all results can be printed to a Testo IR Printer. Stored results maybe accessed via USB and a Windows® PC using the ComSoft PC software that come with the analyzer.
8. Pressing ESC 3 times will return to main measurement menu

NOTES on the testo 435
AUTO-OFF

Be sure the testo 435 is not configured for a timed auto off, as it will interrupt your measurement process.
To disable auto off for the testo 435 analyzer:

1 Press and hold Center Orange key (Profile appears)

2 Toggle up/down to Device menu, press OK

3 Toggle up/down to Auto OFF, press OK

4 Use up/down arrow to toggle OFF

NOTES on testo wireless probes
While the testo 435 will accept simultaneous input from 3 wireless probes* only 2 probes are required to perform work in the system performance mode.

**Wireless probe heads are modular and may be configured with temperature or temperature and humidity measurement using appropriate accessories/probes..*

TRANSMIT MODES
testo wireless probes have two transmit modes:

1. Transmit every 2 seconds (initiate by pushing the probe ON button briefly) (the blue LED on the probe handle will flash about every 2 seconds.)

2. Transmit every 10 seconds (initiate by pushing **and HOLDING** ON button) (the blue LED on the probe handle will flash about every 10 seconds.)

Proper system performance tests are done when the probe is in the 2 second transmit mode.

AUTO OFF FEATURE
If the *left DIP switch* is set UP (DIP switch is found under the wireless probe battery cover), the wireless probe will turn off at 10 minutes.

If the left DIP switch is set DOWN the wireless probe will remain on until turned off. *Proper system performance tests are done when the probe remains on until turned off.*

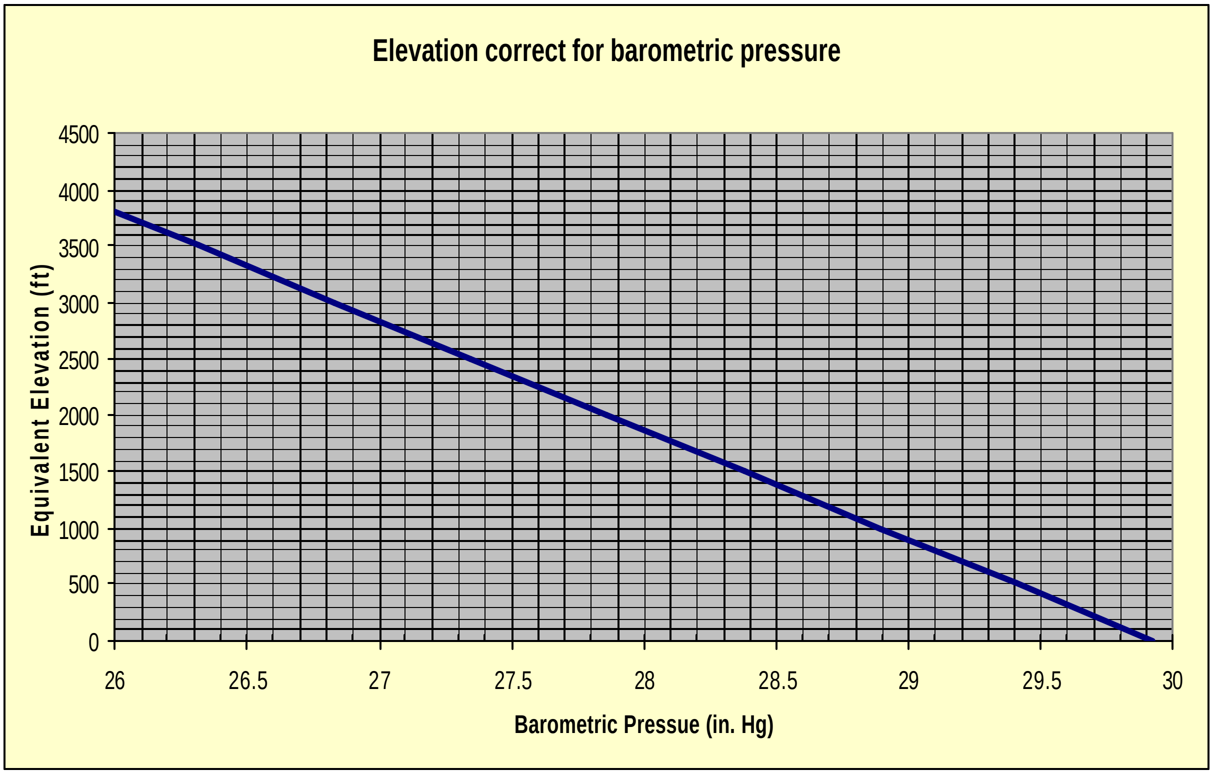
HIGH/LOW BIT for RFID:
If the right DIP switch is set UP (DIP switch is found under the wireless probe battery cover), the wireless probe will transmit a HIGH bit after its RFID number. (Shown as an "H: following the 3 digit RFID number in the Radio Probe select screens.)

If the right DIP switch is set DOWN wireless probe will transmit a LOW bit after its RFID number. (Shown as an "L: following the 3 digit RFID number in the Radio Probe select screens.)

The HIGH/LOW bit feature is to cover the outside chance that you own two radio probes with the same 3 digit RFID number.

435 Pressure Corrections

Correction for Barometric pressure



1 Determine local barometric pressure from a weather service (www.weather.com, etc.) (eg. 29.3 in. Hg)

2 Find this point on the X Axis of the chart above (eg. 600 feet equivalent)

3 Enter the equivalent feet in the 435 parameter menu.

Elevation above sea level for major US cities (sorted by state)

City	State	Feet above sea level
Anchorage	AK	118
Fairbanks	AK	448
Juneau	AK	50
Nome	AK	25
Birmingham	AL	600
Gadsden	AL	555
Huntsville	AL	640
Mobile	AL	5
Montgomery	AL	160
Ft. Smith	AR	440
Little Rock	AR	288
Flagstaff	AZ	6,900
Phoenix	AZ	1,090
Tucson	AZ	2,390
Yuma	AZ	160
Bakersfield	CA	400
Berkeley	CA	40
Eureka	CA	45
Fresno	CA	285
Los Angeles	CA	340
Oakland	CA	25
Pasadena	CA	630
Sacramento	CA	30
San Bernardino	CA	1,080
San Diego	CA	20
San Francisco	CA	65
San Jose	CA	90
Santa Barbara	CA	100
Santa Cruz	CA	20
Stockton	CA	20
Colorado Springs	CO	5,980
Denver	CO	5,280
CONTINUED ON NEXT PAGE		

City	State	Feet above sea level
Sioux City	IA	1,110
Waterloo	IA	850
Boise	ID	2,704
Pocatello	ID	4,460
Bloomington	IL	800
Champaign	IL	740
Chicago	IL	595
Decatur	IL	682
Peoria	IL	470
Rockford	IL	716
Springfield	IL	610
Urbana	IL	725
Evansville	IN	385
Ft. Wayne	IN	790
Gary	IN	590
Indianapolis	IN	710
Lafayette	IN	550
Muncie	IN	950
South Bend	IN	710
Terre Haute	IN	496
Dodge City	KS	2,480
Kansas City	KS	750
Salina	KS	1,229
Topeka	KS	930
Wichita	KS	1,290
Ashland	KY	536
Bowling Green	KY	510
Lexington	KY	955
Louisville	KY	450
Paducah	KY	345
Baton Rouge	LA	57
New Orleans	LA	5
CONTINUED ON NEXT PAGE		

City	State	Feet above sea level
St. Louis	MO	465
Biloxi	MS	20
Gulfport	MS	20
Jackson	MS	298
Natchez	MS	210
Billings	MT	3,120
Butte	MT	5,765
Great Falls	MT	3,340
Helena	MT	4,155
Asheville	NC	1,985
Charlotte	NC	720
Durham	NC	405
Greensboro	NC	839
Raleigh	NC	365
Wilmington	NC	35
Winston-Salem	NC	860
Bismarck	ND	1,674
Fargo	ND	900
Minot	ND	1,550
Lincoln	NE	1,150
Omaha	NE	1,040
Concord	NH	290
Manchester	NH	175
Portsmouth	NH	20
Atlantic City	NJ	10
Elizabeth	NJ	21
Jersey City	NJ	20
Newark	NJ	55
Paterson	NJ	100
Trenton	NJ	35
Albuquerque	NM	4,945
Gallup	NM	6,540
CONTINUED ON NEXT PAGE		

City	State	Feet above sea level
Allentown	PA	255
Erie	PA	685
Harrisburg	PA	365
Johnstown	PA	1,185
Lancaster	PA	355
Philadelphia	PA	100
Pittsburgh	PA	745
Reading	PA	265
Wilkes-Barre	PA	640
San Juan	PR	35
Providence	RI	80
Charleston	SC	9
Columbia	SC	190
Greenville	SC	966
Spartanburg	SC	875
Pierre, SD	SD	1,480
Rapid City	SD	3,230
Sioux Falls	SD	1,395
Chattanooga	TN	675
Knoxville	TN	890
Memphis	TN	275
Nashville	TN	450
Abilene	TX	1,710
Amarillo	TX	3,685
Austin	TX	505
Beaumont	TX	20
Corpus Christi	TX	35
Dallas	TX	435
El Paso	TX	3,695
Ft. Worth	TX	670
Galveston	TX	5
Houston	TX	40
CONTINUED ON NEXT PAGE		

City	State	Feet above sea level	City	State	Feet above sea level	City	State	Feet above sea level	City	State	Feet above sea level
Grand Junction	CO	4,590	Shreveport	LA	204	Santa Fe	NM	6,950	Laredo	TX	440
Pueblo	CO	4,690	Boston	MA	21	Carson City	NV	4,690	Lubbock	TX	3,195
Bridgeport	CT	10	Brockton	MA	130	Las Vegas	NV	2,030	Marshall	TX	410
Hartford	CT	40	Cambridge	MA	20	Reno	NV	4,490	Pt. Arthur	TX	10
Meriden	CT	190	Fall River	MA	40	Albany	NY	20	San Antonio	TX	650
New Britain	CT	200	Lawrence	MA	65	Binghamton	NY	865	Texarkana	TX	324
New Haven	CT	40	Lowell	MA	100	Buffalo	NY	585	Waco	TX	405
Stamford	CT	35	Pittsfield	MA	1,015	Central Islip	NY	80	Ogden	UT	4,295
Washington	DC	25	Springfield	MA	85	New York	NY	55	Provo	UT	4,650
Wilmington	DE	135	Worcester	MA	476	Rochester	NY	515	Salt Lake City	UT	4,390
Daytona Beach	FL	7	Baltimore	MD	20	Schenectady	NY	245	Norfolk	VA	25
Gainesville	FL	175	Augusta	ME	45	Syracuse	NY	400	Portsmouth	VA	10
Jacksonville	FL	20	Bangor	ME	20	Troy	NY	35	Richmond	VA	160
Key West	FL	5	Portland	ME	25	Utica	NY	415	Roanoke	VA	905
Miami	FL	10	Ann Arbor	MI	880	White Plains	NY	220	Brattleboro	VT	300
Orlando	FL	70	Battle Creek	MI	820	Akron	OH	874	Burlington	VT	110
Pensacola	FL	15	Bay City	MI	595	Canton	OH	1,030	Montpelier	VT	485
Sarasota	FL	20	Detroit	MI	585	Cincinnati	OH	550	Bellingham	WA	60
St. Petersburg	FL	20	Flint	MI	750	Cleveland	OH	660	Seattle	WA	10
Tallahassee	FL	150	Grand Rapids	MI	610	Columbus	OH	780	Spokane	WA	1,890
Tampa	FL	15	Jackson	MI	940	Dayton	OH	574	Tacoma	WA	110
West Palm Beach	FL	15	Kalamazoo	MI	755	Hamilton	OH	600	Walla Walla	WA	936
Atlanta	GA	1,050	Lansing	MI	830	Lima	OH	865	Yakima	WA	1,060
Augusta	GA	143	Saginaw	MI	595	Springfield	OH	980	Eau Claire	WI	790
Columbus	GA	265	Duluth	MN	610	Steubenville	OH	660	Green Bay	WI	590
Macon	GA	335	Minneapolis	MN	815	Toledo	OH	585	Kenosha	WI	610
Savannah	GA	20	Rochester	MN	990	Youngstown	OH	840	Madison	WI	860
Hilo	HI	40	St. Cloud	MN	1,040	Zanesville	OH	720	Milwaukee	WI	635
Honolulu	HI	21	St. Paul	MN	780	Enid	OK	1,240	Racine	WI	630
Lihue	HI	210	Columbia	MO	730	Oklahoma City	OK	1,195	Sheboygan	WI	630
Cedar Rapids	IA	730	Joplin	MO	990	Tulsa	OK	804	Superior	WI	630
Des Moines	IA	803	Kansas City	MO	750	Eugene	OR	422	Charleston	WV	601
Dubuque	IA	620	Springfield	MO	1,300	Portland	OR	77	Wheeling	WV	650
Iowa City	IA	685	St. Joseph	MO	850	Salem	OR	155	Cheyenne	WY	6,100
									Sheridan	WY	3,740

Elevation above sea level for major Canadian cities (sorted by Province)

City	Prov.	Feet above sea level		City	Prov.	Feet above sea level		City	Prov.	Feet above sea level		City	Prov.	Feet above sea level
Calgary	AB	3,427		Dartmouth	NS	24		Niagara Falls	ON	590		Laval	QC	142
Edmonton	AB	2,188		Sydney	NS	25		North Bay	ON	670		Montreal	QC	90
Lethbridge	AB	2,985		Alert	NWT	95		Ottawa	ON	185		Quebec City	QC	163
Prince Rupert	BC	125		Yellowknife	NWT	674		Peterborough	ON	673		Sherbrooke	QC	627
Vancouver	BC	141		Belleville	ON	257		Sault Ste. Marie	ON	589		Trois-Rivieres	QC	115
Victoria	BC	57		Brantford	ON	705		St. Catharines	ON	362		Moose Jaw	SK	1,784
Brandon	MB	1,343		Burlington	ON	284		Sudbury	ON	879		Regina	SK	1,894
Churchill	MB	94		Guelph\	ON	1,065		Thunder Bay	ON	616		Saskatoon	SK	1,587
Winnipeg	MB	762		Hamilton	ON	329		Toronto	ON	300		Dawson	YT	1,050
Fredericton	NB	29		Kingston	ON	264		Windsor	ON	3		Whitehorse	YT	2,050
Moncton	NB	38		Kitchener	ON	1,100		Charlottetown	PEI	31				
St. John	NB	27		London	ON	822		Hull	QC	185				
St John's	NF	200		Mississauga	ON	510		La Salle	QC	110				