RADON IN WATER
USER'S MANUAL

Version 2.321

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CONTENTS

Introduction to Radon in Water Using the E-PERM® System

Even though the risk of developing cancer from ingesting radon in water is relatively low, the indoor levels of radon in air can be increased from the presence of radon in water.

The versatile E-PERM® System used in conjunction with the Radon in Water Test Kit provides the radon professional with all the equipment needed to perform radon in water measurements. Once familiar with the basic analytical procedures used in making radon in air measurements, radon in water measurements can then be made.

With the Radon in Water Test Kit water samples are taken in premeasured vials and exposed to a suspended E-PERM® placed inside a large sealed measurement jar. The radon in air is calculated and then the radon in water concentration is determined.

Components of the Radon in Water Test Kit

- Radon in Water Manual
- Two (2) 3.72 L Glass Measurement Jars with Rubber Sealing Collars
- Ten (10) 68 mL Sampling Bottles with Teflon® gasket screw caps
- Excel Templates on CD for Radon in Water calculations

Additional Equipment Required:
S Chamber, Electrets and a SPER1 Reader (not included in the Radon in Water Test Kit)
A basic working knowledge of the E-PERM® System is also required.

Optional Equipment:

- Ten (10) 136 mL Sampling Bottles with Teflon® gasket screw caps - recommended for low radon concentrations in water found usually in municipal water supplies

Sources of Radon in Water

Radon is a naturally occurring radioactive gas present in the soil underneath homes. When radon comes into contact with the subsoil water, some of the radon can dissolve into well water (drinking water). As a result, underground well water has more radon than water from rivers, lakes, or reservoirs because the radon in these bodies of water is released into the outdoor air through the aeration of the surface water.

Private wells are used as a source of domestic water supply in a large number of single family homes across the country. Wells are also used as a source of water supply for small and large communities. The community water supply agencies supply water after required processing. Radon in the municipal water supply is generally much lower than that from private wells supplying water directly to a home because most municipalities store water in reservoirs, where radon decays or escapes through the aerated water. In general, municipal water supplies range from 100 to 5000 pCi/L, with some exceptions.

Typically radon concentrations in private wells can be several hundred pCi/L to many thousands of pCi/L. In some geographic regions, depending upon the geology, the radon concentrations can be extremely high. As a general rule of thumb for homes, 10,000 pCi/L of radon in water can add 1 additional pCi/L of radon into the air. The primary health concern with radon in water is in the additional amount of radon added into the air; however there is also some risk from the ingestion of radon.

Risks from Radon in Water

The risk of developing cancer from ingesting water is relatively low; however, when the radon in water is released into the home environment from the use of basic appliances or bathroom fixtures, indoor radon levels can increase to unhealthy levels. Homes that receive water directly from private wells are most likely to be affected, and the generally accepted "rule of thumb" is that for every 10,000 pCi/L found in the water supply, approximately 1.0 pCi/L will be "released" to the home's indoor radon concentration. At present, the USEPA does not provide guidance for private homes regarding an action level for radon in water concentrations above which mitigation is recommended.

The National Academy of Sciences (NAS) released a report on "Risk Assessment of Radon in Drinking Water" on September 15, 1998. This report contains a comprehensive accumulation of scientific data on radon in drinking water. The key highlights by the EPA of this report can be found on the EPA's website and on Rad Elec's website under "Initial EPA Perspectives on the NAS Report: Risk Assessment of Radon in Drinking Water".

The NAS Report states that some cancer deaths result each year from exposure to radon in water. The primary health risk from radon in drinking water is lung cancer due to inhaling radon discharged from water used in the home. Although it is a small risk relative to the risk of breathing radon in indoor air, there is some risk of stomach cancer from drinking water contaminated with radon. Radon enters the indoor air of a home through normal water usage including showering, doing laundry, cooking, etc., with more radon being released with hot water usage. When water containing radon is brought into a home, the radon can outgas into the indoor air adding an additional 1 pCi/L per 10,000 pCi/L of radon in water. Due to this ratio, only about 1 to 2 percent of the total radon found in indoor air comes from the radon released to air from drinking water.

Based on the information contained in the NAS Report, the EPA did its' own risk assessment, and estimated that 168 cancer deaths occur each year, with 89% being attributed to lung cancer from inhalation of radon and 11 % attributed to stomach cancer from ingestion of radon.

NAS recommends that the Alternative Maximum Contamination Level (AMCL) be set at a level which would "result in a contribution of radon from drinking water to radon levels in indoor air equivalent to the national average concentration in outdoor air". This means that (according to the 10,000 to 1 ratio) an AMCL of 4,000 pCi/L leads to an indoor radon concentration of 0.4 pCi/L.

USEPA Recommendations

The USEPA proposed regulations to reduce public health risks by limiting exposure to radon in 1999. Under this proposal, individual States were encouraged to develop a Multimedia Mitigation Program (MMP) to reduce exposure to radon, concentrating on the reduction of radon in indoor air, while also reducing radon in drinking water to 4,000 pCi/L or lower. If a State does not have an MMP, the individual municipalities in that State will be required to reduce radon levels in drinking water to 4,000 pCi/L or lower.

The USEPA recommended regulations for radon in water only applies to public water supplies and are not applicable to private wells.

The analysis of water samples to determine the radon concentrations found in drinking water is a useful tool in trying to diagnose the cause of high radon in air concentrations in homes. Radon in water analysis can be used to confirm or rule out radon in water as the cause of high radon levels in the home.

If the radon in water is determined to be the cause for high indoor air radon concentrations, then mitigation of the problem may have to include treating well water for removal of radon. The most effective radon in water reduction method is point-of-entry treatment, which removes radon from the water right before it enters a home. There are two main types of point- of-entry devices that remove radon from water:

- Granular activated carbon (GAC) filters (which use activated carbon to remove the radon)
- Aeration devices (which bubble air through the water and carry radon gas out into the atmosphere through an exhaust fan)

If indoor radon concentrations are already low, then measurement of radon from well water may not be necessary.

The E-PERM® Method of Measuring Radon in Water

To perform radon in water measurements, it is necessary that the radon professional is already familiar with the E-PERM® System and capable of making radon in air measurements. The first step will be to take small water samples using 68 mL (or 136 mL) sample vials, which will then be placed in the bottom of two large glass measurement jars. An E-PERM® is then placed in each of the measurement jars, suspended in the air above the water. The lids of the measurement jars are closed and sealed to make them radon-tight. Radon reaches equilibrium between the water and air, which the E-PERM® measures. At the end of the desired exposure period, the measurement jars are opened and the E-PERM®s are removed. The information gathered and recorded will then be entered into an Excel spreadsheet provided with the Radon in Water Test Kit and the radon concentration in the air is calculated. Using the radon in air concentration with the other data will then calculate the radon concentration of the water sample.

E-PERM®s are widely used as indoor radon detectors and are not affected by 100% relative humidity. Therefore because of this property it is possible to do measurements of radon in water using E-PERM®s. P. Kotrappa and W. Jester describe the basis for the analysis in detail in the following publication which can be found on Rad Elec's website (www.radelec.com):

P. Kotrappa and W. A. Jester, "Electret Ion Chamber Radon Monitors Measure Dissolved ^{222}Rn in Water" Health Physics 64:397-405 (1993)

Collecting a Radon in Water Sample

The basic sampling and analysis process must be carried out carefully to minimize the loss of radon during collection and transport. Keep the delay between the collection time and the analysis time as short as possible to minimize measurement errors. The analysis of the sample should be initiated as soon as possible after receiving the sample in the lab. To ensure accuracy, no more than 2-3 days should elapse between sample collection and the beginning of the analysis if the water sample is to be mailed.

If the sample is being collected from a private well use the 68 mL sample bottles for the water samples. Collect (3) three samples from the water supply at the same time. Use two S Chambers with short-term electrets (SST E-PERM®) and a TA (Test Analysis) period of approximately 24 hours. If you have reason to believe that the radon in water levels are going to be greater than 10,000 pCi/L, use SLT E-PERM®s (S Chamber with an LT Electret) and a TA of approximately 24 hours. Generally, a voltage drop of about 20 V or more gives a result with a precision of better than 10%.

If an SST E-PERM® is used for making an analysis of a water sample with a very high radon concentration, the electret can have such a large voltage drop that it may totally discharge leaving one with no data. On the other hand, if you use an SLT E-PERM® for a water sample which contains a low level of radon, the voltage drop may be so small that the precision may be poor.

Use of Large-Volume Sampling Bottles – 136 mL

If it is believed that the radon in water concentrations are going to be very low, such as with municipal water supplies which are generally less than 300 pCi/L, better accuracy will be achieved using 136 mL water sample jars and a measurement period (TA) of 48 hours.

Steps to Collect a Radon in Water Sample

1. Remove the faucet aerator, if present, from the tap closest to the entry way of the water into the home. It is best to go to the closest source to the well; typically the hose outside the house (if available) is considered a good option.

2. Allow the cold water to run approximately ten minutes at a medium rate in order to ensure the water sample will come directly from the well and not from connecting pipes or water tanks. Taking a sample after a period of greater than normal water use (e.g., morning activities) will aid in obtaining a representative sample.

3. Gently fill three sampling bottles, allowing each to overflow for a few seconds. Carefully remove the sampling bottle from the flow stream maintaining a meniscus (a slight protrusion of the water) above the bottle brim. An alternative procedure is to gently fill a larger container and then immerse the sampling bottle under the water and screw on the cap; do this at the lowermost position of the container. Three samples are recommended, two samples are to perform a duplicate radon in water measurement, and the third sample bottle is in case the measurement has to be repeated for any reason.

4. Immediately screw the cap tightly on the sampling bottle, being careful to avoid trapping any air bubbles. The bottle is made of glass and has a screw cap with a Teflon®-faced compression seal at the top.

5. Record the location where the sample was taken and the date and time when the water sample was taken (this is called the "Sample Collected" field on the Excel Template).

6. If the water is to be analyzed at the sampling site, skip to the next section on **Performing the Radon in Water Measurement Analysis**.

7. If the water is to be analyzed at a lab or back at the office, pack the bottles carefully to ensure no damage in transit. **Keep the delay between the collection time and the analysis time as short as possible to minimize measurement errors. Sample analysis should be initiated as soon as possible after receiving in the lab.**

8. If the sample is to be mailed, use express service. To ensure accuracy, no more than 2-3 days should elapse between the time of sample collection and the beginning of the analysis.

Performing the Radon in Water Measurement Analysis

The following procedures should be carried out as soon as possible after collecting the water samples. The radon in water measurement should be conducted in an area of low radon background, such as upper floors or outside, to minimize the residual radon in the measuring jar. The following steps must be repeated for the second water sample in order to perform a duplicate radon in water measurement.

1. Immediately prior to the start of the measurement, prepare the E-PERM® by measuring the initial voltage (IV) of the electrets, loading the electret into the S Chamber, and unscrewing the top of the S Chamber to the "ON" position.

2. Lay the large glass measuring jar horizontally on its' side on a table. Have the glass measuring jar's lid (screw cap), sealing collar, and a screwdriver close by.

NOTE: STEPS 3 AND 4 SHOULD BE DONE QUICKLY - WITHIN 30 SECONDS - SO AS TO KEEP THE LOSS OF RADON TO A MINIMUM.

3. While the measurement jar remains in a horizontal position, gently open the cap of the sampling bottle. Insert the open bottle all the way to the bottom of the jar into the clip. (See Figure 1, Position 1 on the next page).

4. Hang the open E-PERM® on the "hook" on the inside of the cap of the large measurement jar and screw the cap onto the jar. Carefully bring the measurement jar to the vertical position permitting the water in the sampling bottle to spill to the bottom. It does not matter if part of the water remains in the sampling bottle. (See Figure 1, Position 2 on next page). Quickly tighten the cap onto the large measurement jar to avoid loss of radon from the measurement jar.

5. Install the rubber sealing collar around the cap with the smaller (less thick) portion of the collar flush with the white cap and the thicker side closest to the glass jar. Tighten the clamp around the collar with a screwdriver, while keeping the measuring jar vertical. (See Figure 1, Position 2 on the next page)

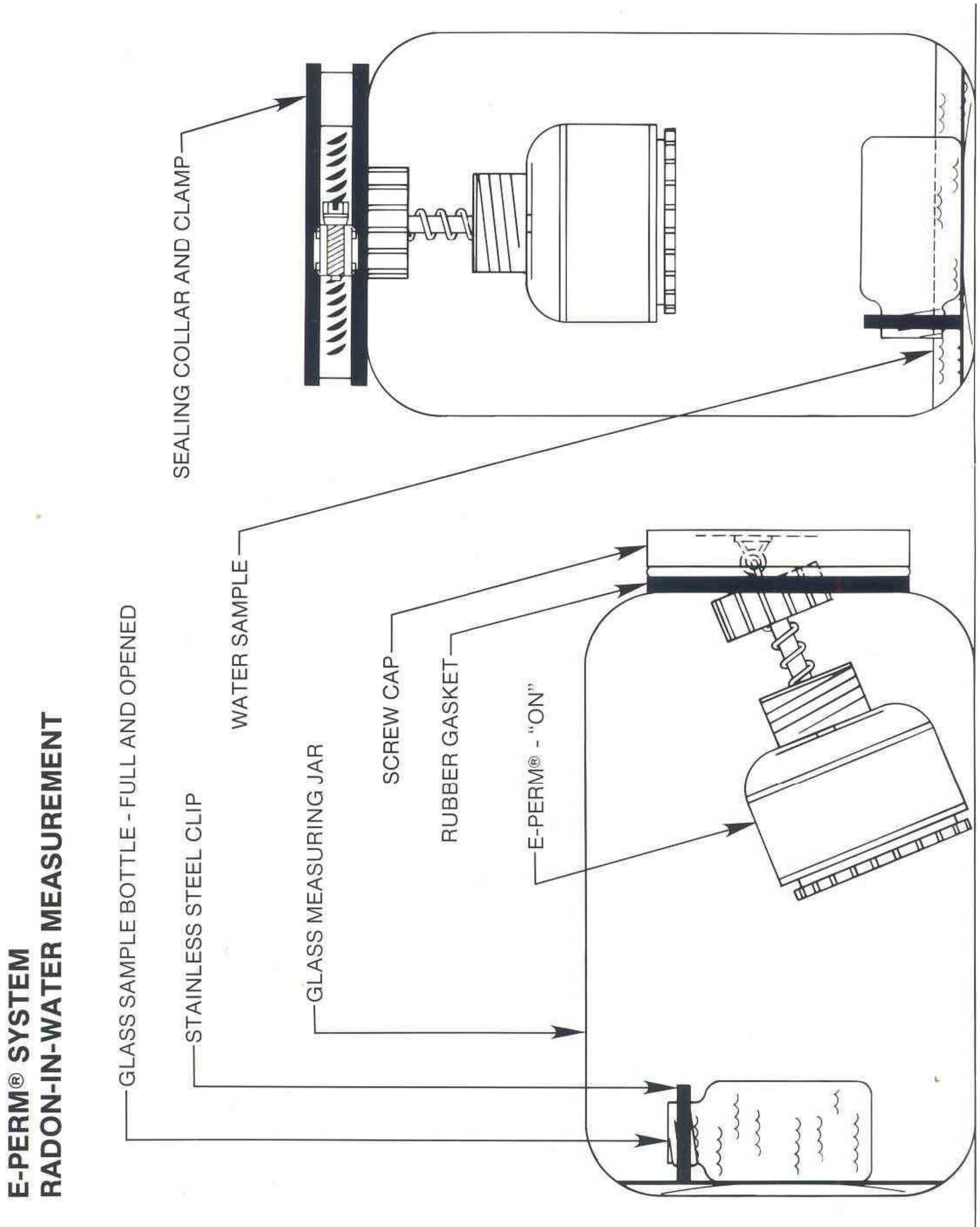
E-PERM® SYSTEM
RADON-IN-WATER MEASUREMENT
GLASS SAMPLE BOTTLE - FULL AND OPENED
STAINLESS STEEL CLIP
WATER SAMPLE
GLASS MEASURING JAR
SCREW CAP
RUBBER GASKET
E-PERM® - "ON"
SEALING COLLAR AND CLAMP
Position - 1
Position - 2

Fig. 1

6. Record the date and time of the start of the test. (This is called the "Start Test Date and Time" field in the Excel Template.)

7. Shake the jar *very gently* (move only the water; make sure that there is no damage to the water sample bottle) to accelerate the release of radon into the measuring jar. Store the measuring jar in a vertical position (See Figure 1, Position 2 on the next page) where it will not be disturbed for the desired exposure period (usually 1-2 days). It is <u>not</u> recommended to use an exposure period of less than 24 hours.

8. After the desired exposure period, loosen the clamp and remove the collar. Unscrew the lid of the measurement jar and remove the E-PERM®.

9. Record the time and date of removal. (This is called the "Finish Test Date and Time" field in the Excel Template.)

10. Measure the electret voltage and record the final voltage (FV).

11. Remove the sample bottle and discard the water from the measuring jar and from the sample bottle. Rinse with low-radon water and allow them to dry.

You can reuse the E-PERM® for another measurement after waiting at least three hours to allow the radon progeny inside it to decay. You can reuse the sampling bottle and cap.

If the measuring jar is used for measuring a water sample containing an unusually high concentration of radon, rinse it well with municipal water or water that has been boiled.

Calculating the Radon in Water

Rad Elec has provided Excel Templates to calculate the radon concentration in water in both US units (pCi/L, feet, and µR/Hr) and SI units (Bq/m³, Bq/L, meters, and nGy/Hr). There is a Master Template that contains two worksheets (one in US units and one in SI units) with all E-PERM® configurations (SST and SLT) and sample bottle volumes (68 mL and 136 mL). There are also two additional folders (one in US units and one in SI units) that contain individual templates for each configuration, sample bottle volume, and provide an area to record the Test Site Information.

Open the folder with the Excel Template for the Units of measurement (US) or (SI) desired. Then select the template for the E-PERM® configuration and sample bottle volume that was used. Enter the data required in the specific fields:

1. Enter any pertinent customer, location, and deployment information.
   a. Customer Information: Enter the customer's name and address
   b. Test Site Information: Enter the test site location
   c. Deployment Information: Enter who collected the sample and analyzed the results

2. Fill in the following colored fields in the Excel Template:
   a. Electret #: Enter the Electret Serial #'s used for the two radon measurements
   b. Sample Collected: Enter the Date and Time that the samples were taken
   c. Start Test Date and Time: Enter the Date and Time that the radon measurement analyses were started
   d. Finish Test Date and Time: Enter the Date and Time that the radon measurement analyses were ended
   e. Gamma: Enter the Gamma background where the measurement analysis was performed, not where the water sample was taken. (US States & Canadian Provinces and Territories can be found on the last page of this manual)
   f. Elevation: Enter the elevation where the measurement analysis was performed, not where the water sample was taken.
   g. IV: Enter the Initial Voltage reading of each electret
   h. FV: Enter the Final Voltage reading of each electret

3. The individual radon in water concentration for each E-PERM® and the average radon concentration of the two E-PERM®s in water are calculated and displayed in the last columns.

The following fields in the Exel Template are calculated based on the information given in the color coded fields:

a. Days — Calculated from subtracting the Finish Test Date from the Start Test Date.
b. Elev CF — Elevation Correction Factor, depends upon the type of chamber being used and the elevation at which the measurement is conducted
c. CF — Calibration Factor, defined as the decrease in electret voltage when a specific electret and chamber are exposed for one day at a concentration of 1 pCi/L of radon
d. Radon — The radon in air concentration, displayed in either pCi/L or Bq/m^3
e. (+/-) pCi/L or (+/-) Bq/m^3 — The error associated with the radon in air concentration being displayed
f. TA — Time of Analysis is determined from the time the sample bottle was inserted into the measurement jar until the E-PERM® was removed from the measurement jar for analysis
g. TD — Time Delay period is determined from the time the sample was collected to the time of inserting the sample bottle into the measurement jar for analysis
h. C1 — The constant based on the Time Delay period (TD)
i. C2 — The constant based on the Time Analysis period (TA)

The average radon concentration in the air is calculated using the standard E-PERM® procedure. A calculation using this air concentration in conjunction with the other parameters gives the radon concentration of the water. Refer to the E-PERM® Manual for detailed instructions on how to calculate the radon in air concentration.

The following equations give the constants C1 and C2 formulas:

$$\text{Constant } C1 = e^{0.1814 \text{ x } TD}$$

$$\text{Constant } C2 = \frac{55.55 \text{ x } 0.1814 \text{ x } TA}{(1 - e^{(-0.1814 \text{ x } TA)})}$$

Where 0.1814 is the decay constant of radon in units per day and e stands for exponential function.

(R x C1 x C2) x (1.15)

For 68 mL samples, once the radon in air (R), C1, and C2 formulas are all used to get the respective results, multiply them together and then multiply that result by the calibration correction of 1.15 to get the final radon in water concentration.

For 136 mL samples, divide the final radon in water concentration by 2 to achieve the correct result.

Literature Review

Electret Ion Chamber Radon Monitors Measure Dissolved ^{222}Rn in Water
P. Kotrappa, W. A. Jesters
Health Physics. 64(4):397-405, April 1993.

Calibration of Electret Based Integral Radon Monitors Using NIST PERE Standards
R.Colle´
Journal of Research of the NIST 100:629-638 (1995)

- Concentration 270,000 pCi/L
- Total number of comparisons 5
- Average corrected bias +1 %
- Precision < 5 %
- Laboratory: NIST

Operational Evaluation of the EIC Method for Determining Radon in Water
Gregory Budd and Craig Bentley
1993 International Radon Conference hosted by AARST

- Concentration 350-73,000 pCi/L
- Total number of comparisons 30
- Average corrected bias – 17%
- Precision < 10 %
- Laboratory EPA –LV

Electret Method for Continuous Measurement of Radon in Water
S.K.Dua
Health Physics 68:110-114 (1995)

4/8/11 **GAMMA TABLE TAKING INTO ACCOUNT BUILDING SHIELDING**

Taken from EPA Report "Population Exposure to External Natural Radiation Background in the USA" ORP/SEPD-80-12

by Kenneth T. Bogen and Abrahm S. Smith 1981

	State	AV uR/Hr
AL	Alabama	6.5
AK	Alaska	7.3
AR	Arkansas	6.5
AZ	Arizona	8.0
CA	California	6.6
CO	Colorado	11.8
CT	Connecticut	7.8
DC	Washington, DC	6.4
DE	Delaware	6.1
FL	Florida	5.3
GA	Georgia	7.0
HI	Hawaii	7.3
IA	Iowa	7.5
ID	Idaho	8.7
IL	Illinois	7.1
IN	Indiana	7.4
KS	Kansas	7.7
KY	Kentucky	7.3
LA	Louisiana	5.4
MA	Massachusetts	7.3
MD	Maryland	6.2
ME	Maine	7.5
MI	Michigan	7.4
MN	Minnesota	7.4
MO	Missouri	7.4
MS	Mississippi	5.4
MT	Montana	8.6
NC	North Carolina	6.9
ND	North Dakota	7.8
NE	Nebraska	7.7
NH	New Hampshire	7.4
NJ	New Jersey	7.1
NM	New Mexico	10.4
NV	Nevada	7.6

	State	AV uR/Hr
NY	New York	7.3
OH	Ohio	7.3
OK	Oklahoma	7.6
OR	Oregon	7.4
PA	Pennsylvania	6.6
RI	Rhode Island	7.0
SC	South Carolina	6.7
SD	South Dakota	7.8
TN	Tennessee	6.9
TX	Texas	6.1
UT	Utah	9.3
VA	Virginia	6.4
VT	Vermont	7.4
WA	Washington	7.4
WI	Wisconsin	7.5
WV	West Virginia	7.7
WY	Wyoming	10.4

Canadian Provinces and Territories		AV nGy/Hr
AB	Alberta	74.8
BC	British Columbia	69.6
MB	Manitoba	66.1
NB	New Brunswick	65.3
NL	Newfoundland & Labrador	65.3
NS	Nova Scotia	65.3
NT	Northwest Territories	73.1
NU	Nunavut	66.1
ON	Ontario	64.4
PE	Prince Edward Island	65.3
QC	Quebec	65.3
SK	Saskatchewan	71.3
YT	Yukon	69.6