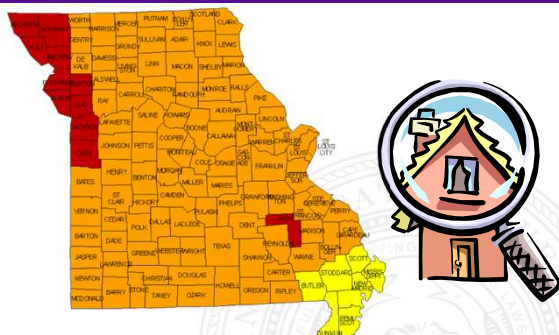


Radon for Real Estate Professionals



Sponsored by the Missouri Radon Program
Conducted by Engineering Extension at Kansas State University

**COLLEGE OF
ENGINEERING**

Engineering Extension Radon Programs

KANSAS STATE
UNIVERSITY

Radon and Real Estate Transactions

- What it is!
- What it does to us!
- What are the laws regarding it!
- How does it get into our homes!
- How do we measure it!
- How do we fix it!
- How do we deal with it in real estate transactions!



**COLLEGE OF
ENGINEERING**

Engineering Extension Radon Programs

KANSAS STATE
UNIVERSITY

Course Handouts

- Visit <https://kansasradonprogram.org/KSRadonEd>
- Downloadable pdf of the
- KS Radon and Real Estate course presentation
 - KS RRNC and ASD course presentation
- Downloadable pdf of the current
- EPA's Home Buyers and Sellers Guide
 - EPA's Consumer's Guide to Radon Reduction

**COLLEGE OF
ENGINEERING**

Engineering Extension Radon Programs



KANSAS STATE
UNIVERSITY

Radon

Periodic Table of the Elements

Rn 86 [222]
 F.E. Dorn, 1900
 Density: 9.73 g/cm³
 Boiling point: -62 °C
 Melting point: -71 °C

(Xe) 4f¹⁴ 5d¹⁰ 6s² 6p⁶
Radon

- Invisible, odorless, tasteless, colorless, inert, **radioactive** gas
 - Occurs from the **natural** breakdown of Uranium
 - **Travels** through soil
 - **Enters** homes, schools, other buildings
 - Elevated indoor levels found in **every** state
- 
- 



**COLLEGE OF
ENGINEERING**

Engineering Extension Radon Programs

KANSAS STATE
UNIVERSITY

Current Understanding: Radon Health Effects

- Radon causes lung cancer even below EPA's radon action level of 4 pCi/L (150 Bq/m³)
 - North American, European, and Chinese studies report 8 to 16% increase in lung cancer 2.7 pCi/L (100 Bq/m³)
- Most radon-induced lung cancer occurs below EPA's action level
- Protracted radon exposure increases the risk of all types of lung cancer
- Prevention and mitigation methods reduce the risk
- Susceptibility to radon-induced lung cancer varies (e.g., smoking, genetics)
- Protracted radon exposure appears to have adverse health effects beyond lung cancer (e.g., leukemia, stomach and liver cancer)

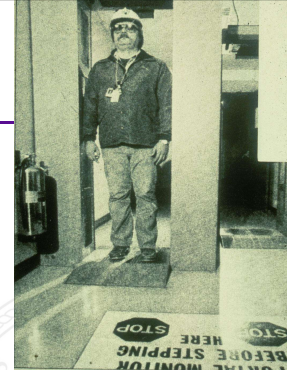
(Field, RW 2008 "Testimony Before the President's Cancer Panel," Charleston, SC [December 4])

Triggering Event Watras Home

In December 1984, the PA Bureau received a telephone call from the Health Physicist at the Limerick Nuclear Generating Station informing us that a construction worker at their still incomplete plant was setting off alarms when he attempted to enter the plant through portal radiation monitors.

Since the plant was not yet generating fission products, health physicists from the utility and their consultant performed a radiation survey in the home of the individual and found very high levels of radon daughters throughout the structure: 2700 pCi/L.

Radon daughter levels (concentration of decay products of radon in the uranium chain) ranged up to 13 Working Levels (WL) 2700 pCi/L of radon gas.

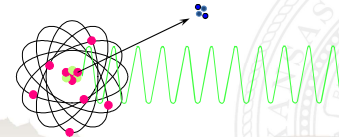


History of Radon

- 1556** Agricola - Miners in Europe
- 1879** Harting & Hesse - Lung Cancer in Miners
- 1921** Uhlig - Radium Emanations & Lung Cancer
- 1950s** Peller - First Review of Mining Related Cancers
- 1970s** Studies of Underground Miners (ongoing)
- 1990s** Residential Radon Studies
- 1994** NCI Pooled Analyses of Miners
- 1999** NAS BEIR VI Report
- 2005** North American and European Pooled Residential Radon Studies
- 2007** Global Pooling of Residential Radon Studies
- 2007** Pooling of Glass-based Residential Radon Studies

What Is Radioactivity?

- The spontaneous emission of energy or particles from the nucleus of an atom in an effort to become more stable.
- The atom changes identity, releasing radiation.



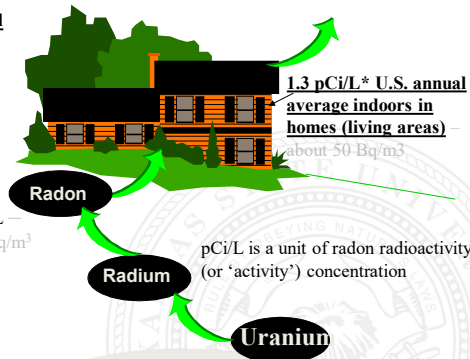
Radon Entry

0.4 pCi/L * U.S. annual average outdoors – about 15 Bq/m³

1.3 pCi/L * U.S. annual average indoors in homes (living areas) – about 50 Bq/m³

100s - 100,000s pCi/L – 1,000s - 1,000,000 Bq/m³

pCi/L is a unit of radon radioactivity (or 'activity') concentration

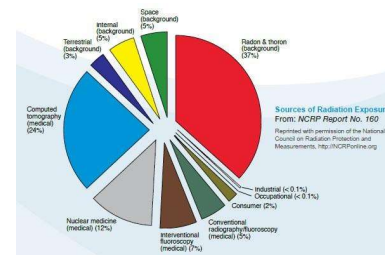


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Sources of Annual Radiation Exposure for the General U.S. Population



- Assumes average indoor radon concentration of 1.3 pCi/L.
- Radon is by far the greatest single source of radiation to the general public.

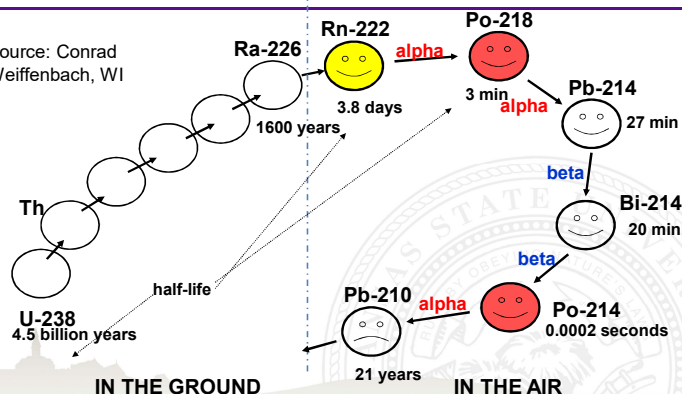
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Decay Chart

Source: Conrad Weiffenbach, WI

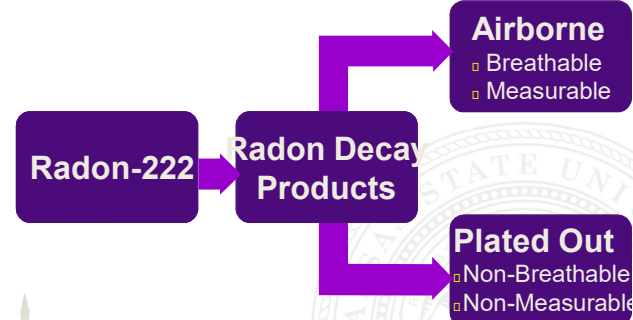


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Fate of Indoor Radon



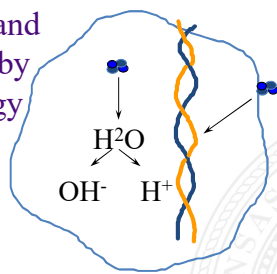
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

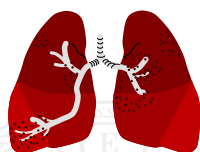
KANSAS STATE
UNIVERSITY

We Inhale Radon Decay Products

Double strand
DNA split by
alpha energy



Lung cell will:
Die
Heal Itself
Become Cancerous



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

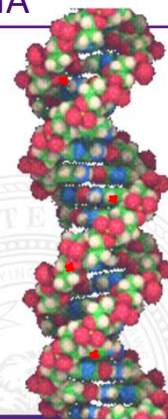
Ionizing radiation can directly and indirectly damage DNA

**Alpha
Particle**

**Defects in tumor
suppressor genes – p53**

At risk individuals—GSTM₁
(glutathione S-transferase M1)

Free radical
formation
Double-strand
DNA breaks



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Alpha Particles Can Pit Plastic



- Plastic chip from passive radon test (alpha track)
- Magnified only 100 times
- Exposure time is 3 months at EPA Action Level of 4 pCi/L.

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Health Effects

- Second leading cause of lung cancer after tobacco smoke
- Approximately 21,000 lung cancer deaths/year
 - Epidemiological data confirmed by: NAS, WHO, ICRP
- Combined effect of radon and smoking particularly dangerous
- ALA, AMA, Surgeon General all recommend lowering indoor radon levels

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Opinion Versus Science

Public Ranking

- 1. Active hazardous waste sites
- 2. Abandoned haz waste sites
- 3. Destruction of ozone
- 4. Oil spills
- 5. Industrial water pollution
- 6. Worker chemical exposure
- 18. Pesticide residues on food
- 26. Indoor air pollution
- 29. Radon

Scientific Ranking

- 1. Radon
- 1. Worker chemical exposure
- 3. Pesticide residues on food
- 4. Consumer exposure to chemicals
- 4. Indoor air pollutants other than radon
- 7. Depletion of stratospheric ozone
- 8. Abandoned haz waste sites
- 13. Active haz waste sites
- 23. Point source discharge to water
- 26. Oil spills

Human Studies

• *How do we know radon is a carcinogen?*

- WHO, HHS, EPA have classified radon as a “Class A” known human carcinogen.
- NCI led study examined the data on **68,000** miners
 - Miners dying of lung cancer at 5 times the rate of general population
- Exhaustive research has verified relationship and eliminated other causes

Home Exposures

• *How does this relate to exposures in my home?*

- Miners received exposures comparable to what people would receive over a lifetime in a home at EPA’s action level of **4 pCi/L**
- These human studies are the best scientific info available
- Based on this data, NCI led analysis has estimated that **21,000** people die each year due to lung cancer from residential radon

Initial Residential Study Results

- 1/1/97 Journal of the Nat’l. Cancer Institute published meta-analysis of 8 previous residential radon studies.
- Results are consistent with risk estimates from the miner studies which formed the basis for the EPA guideline of 4 pCi/L
- Analysis found that the risk of developing lung cancer increases 14% for people living in a house at 4 pCi/L for 30 years
- Case-control studies now being conducted will take several years to complete and pool.
- Nothing to change the classification as a class A carcinogen

Iowa Radon Lung Cancer Study

Between 1993 to 1997, the researchers studied 1,027 Iowa women:

- 413 who were newly diagnosed with lung cancer and
- 614 "controls" (no lung cancer at the start of the study)

Age range of the women was 40 to 84

- Who had lived in their homes for the past 20 years or more
- Included both smokers and non-smokers

Women were studied because they typically have less occupational exposures to substances that may cause lung cancer, and historically have spent more time in the home.

Iowa Radon Lung Cancer Study

The Iowa Study found a significant relation between radon exposure and lung cancer. In others word, as the radon exposure increases - lung cancer rates also increase.

For exposures that are roughly equivalent to **15 years** spent at an average radon exposure equal to the EPA's action level of **4 pCi/L**, we found about a **50% increased risk of lung cancer**.

(<http://www.cheec.uiowa.edu/misc/radon> -This web site has detailed info and FAQs)

European & North American Residential Pooling Studies

• European Pooling Study

- British Medical Journal 330: 223, Jan 2005
- The risk of lung cancer increased by **8.4%** (95% confidence interval 3.0% to 15.8%) per **2.7 pCi/L**

• North American Pooling Study

- Epidemiology 16(2):137-45. Mar 2005
- The **11% estimated risk at 2.7 pCi/L** is consistent with the predicted excess risk of 12% per 2.7 pCi/L based on a linear model developed by the National Research Council

Prolonged Radon Exposure Increases Risks of All Lung Cancer Types

Residential Study	Histologic type most associated with radon exposure
North American Pooled Analysis	Small Cell
European Pooled Analysis	Small Cell
Iowa Radon Lung Cancer Study	Large Cell Squamous

Your Chances of Getting Lung Cancer?

- How much radon is in your home?
- The amount of time you spend in your home
- Whether you are a smoker or have ever smoked
- Genetic predisposition to cancer



Lung Cancer Incidence

Lifetime Risk of Lung Cancer Death from Radon Exposure in Homes			
Risk Is Shown per 100,000 Individuals			
RADON LEVEL (pCi/L)	NEVER SMOKERS	CURRENT SMOKERS	GENERAL POPULATION
20	3,600	26,000	11,000
10	1,800	15,000	5,600
8	1,500	12,000	4,500
4	730	6,200	2,300
2	370	3,200	1,200
1.25	230	2,000	730
0.4	73	640	230
Estimated Risks at the EPA Action Level (4 pCi/L)			
Never Smokers 7/1000 Smokers 62/1000			

<http://www.radonleaders.org/sites/default/files/2020-11/HCPProvGuide%20Update%209-17-20.pdf>

Lung Cancer Incidence

Cancer Mortality 2020	
Cancer Type	Estimated U.S. Deaths in 2020
1. Lung and Bronchus	135,720
2. Colon and Rectum	53,200
3. Pancreas	47,050
4. Breast	42,690
5. Prostate	33,330
6. Liver and Intrahepatic Bile Duct	30,160
7. Leukemia	23,100
Radon-Induced Lung Cancer	21,100
8. Lymphoma	20,910
9. Brain & Other Nervous System	18,020
10. Urinary Bladder	17,980
11. Esophagus	16,170
12. Kidney and Renal Pelvis	14,830
13. Ovary	13,940

CA: A Cancer Journal for Clinicians
Volume 125, Number 1
Cancer Statistics, 2020
First published: September 2020 | <https://doi.org/10.3233/CLIN-200400>

<http://www.radonleaders.org/sites/default/files/2020-11/HCPProvGuide%20Update%209-17-20.pdf>

Personal Factors

- *Why is this all so difficult?*
 - Naturally occurring (no villains)
 - Long latency period
 - Not a disease affecting children
 - Not a dread hazard
 - Cancers occur one at a time
 - Voluntary risk
 - Lack of press – no sensational story
 - No sensory reminders to repetitively stimulate us to think about it

Testing is the Key

- *What can I be sure of?*
 - There are real exposures out there - 6% of US homes are over 4 pCi/L
 - The only way to know is to test - prediction is not viable.
 - The driving force for concern is liability and health risk.
 - There is no one to blame - it's naturally occurring

Are There Laws Regarding Radon in Missouri?

- None at this time
 - It is recommended that realtors identify nationally certified radon measurement and mitigation personnel in Missouri and maintain a current listing of these individuals for distribution to their clients
- However:
 - Statute 442.055 does now require the disclosure of known radon levels in homes to potential buyers
 - Contamination of premises, radioactive or hazardous material-disclosure to prospective lessees, purchasers, or transferees... In the event that any premises to be rented, leased, sold or transferred or conveyed is or was previously contaminated with radioactive material... landlord or transferor shall disclose in writing to the prospective lessee, purchaser or transferee the fact the premises is or was previously contaminated with radioactive material...

Are There Laws Regarding Radon in Missouri?

- None at this time
 - It is recommended that realtors identify nationally certified radon measurement and mitigation personnel in Missouri and maintain a current listing of these individuals for distribution to their clients
 - RNCC Code Adoptions in MO

Ballwin	Belton	Berkeley	Brentwood	Carl Junction
Carthage	Bowling Green	Clay County	Clinton	Columbia
Concordia	De Soto	Desloge	Eldon	Excelsior Springs
Fayette	Forsyth	Fredericktown	Grain Valley	Grandview
Green County	Herculaneum	Highlandville	Jackson Cnty	Kearney
Ladue	Lathrop	Laurie	Liberty	Maryland Hts
Maryville	Miner	Mound City	Neosho	Nevada
New Haven	Normandy	Pine Lawn	Platte Cnty	Portageville
Raymore	Reeds Spring	Riverside	Riverview	St Genevieve
Seymour	Smithville	St Ann	St Joseph	St Louis City
St Robert	Strafford	Tracy	University City	Merriam
Vinita Park	Warrensburg	Warsaw	Weatherby Lake	Webster Grove
Wentzville	Weston			

Are There Laws Regarding Radon in Kansas?

- K.S.A 58-3078a went into effect on July 1, 2009 which requires a specific paragraph to be included in all residential real property contracts (next slide)
- There are no laws requiring people to test, or fix high levels if found.
- Kansas does now require a state certification to provide professional radon measurement, mitigation, and laboratory services in the state (see following slides)
- Radon resistant new construction (RRNC) codes have been adopted in
 - Manhattan, Topeka, Lawrence, Salina, Junction City, Eudora, De Soto, Gardner
 - Shawnee County (unincorporated), Douglas County (unincorporated)

Radon Paragraph for KS Contracts 7/1/2009

"Every buyer of residential real property is notified that the property may present exposure to dangerous concentrations of indoor radon gas that may place occupants at risk of developing radon-induced lung cancer. Radon, a class-A human carcinogen, is the leading cause of lung cancer in non-smokers and the second leading cause overall. Kansas law requires sellers to disclose any information known to the seller that shows elevated concentrations of radon gas in residential real property. The Kansas department of health and environment recommends all home-buyers have an indoor radon test performed prior to purchasing or taking occupancy of residential real property. All testing for radon should be conducted by a radon measurement technician.

Elevated radon concentrations can be easily reduced by a radon mitigation technician. *For additional information go to www.kansasradonprogram.org.*"

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Kansas Radon Certification Law

- Effective date: **July 1, 2011**
 - Beginning July 1, 2011, no person may represent or advertise, nor may perform professional radon measurements, radon mitigations or provide radon laboratory services unless that person has been certified by the Kansas Department of Health and Environment (KDHE) as a radon measurement technician, a radon mitigation technician, or as a certified radon laboratory.

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Kansas Radon Certification Law

- KDHE Certification Requirements
 - Previous successful completion of KDHE-approved radon measurement and/or mitigation course
 - Previous passing grade on a radon measurement/mitigation exam offered by NRSB, AARST-NRRP or other KDHE-approved exam
 - Individuals currently certified by NRSB or AARST-NRRP on July 1, 2011

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Kansas Radon Certification Law

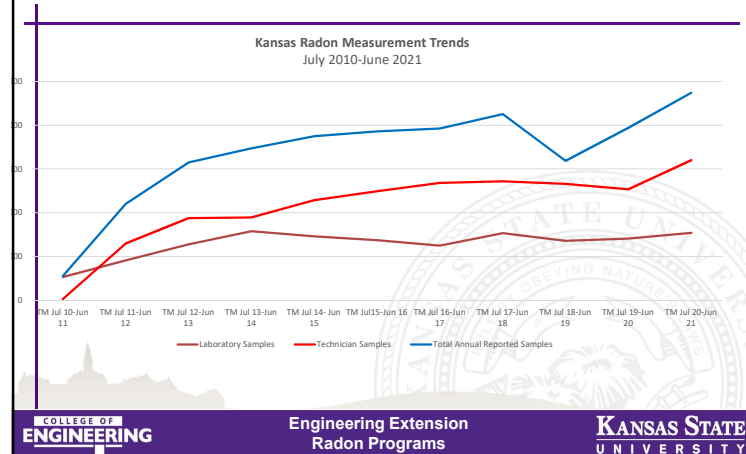
- Owner-Occupied Radon Testing and Mitigation
 - Homeowners may perform radon testing or mitigation on their own properties without KDHE certification
 - A person may perform radon measurements for another individual as long as
 - The individual receives no remuneration and
 - The measurements are NOT related to a real estate transaction

COLLEGE OF
ENGINEERING

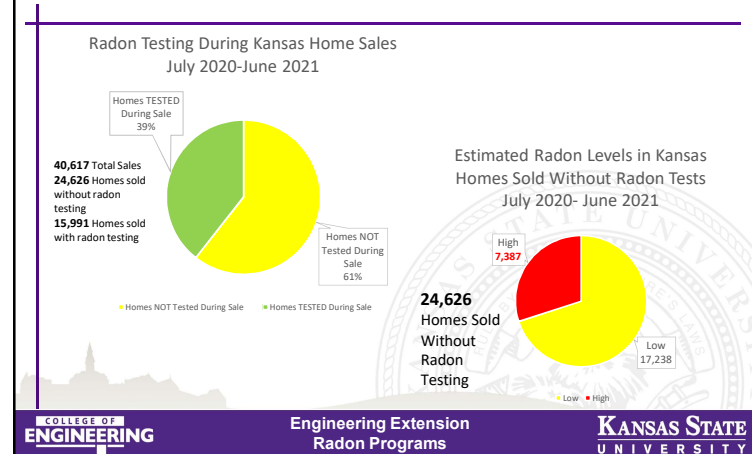
Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Kansas Radon and Real Estate Data



Kansas Radon and Real Estate Data



HUD Multifamily Housing Radon Notice

- HUD Radon Announcement 2/4/2013
 - Requires radon testing be included in environmental reports for FHA-insured multi-family housing mortgages
 - Elevated levels will have to be mitigated
 - Refinances of multi-family housing in low risk areas excepted

HUD Multifamily Housing Radon Notice

- HUD Radon Information Notice
 - Notice provided to public housing agencies on radon
 - Health risks
 - Testing
 - Prevention and mitigation
 - Encourages proactive planning by agencies
 - Test all public housing
 - Mitigate elevated units

OSHA – Radon Occupational Exposure Limit

The OSHA radon exposure limit for adult employees is 100 pCi/L averaged over a 40-hour workweek [29 CFR 1910.1096(c) (1); 29 CFR 1926.53], which would result in a cumulative radon decay product exposure of 12 WLM/yr (assuming 100% radon decay product equilibrium) if the worker was exposed at this concentration for one working year (i.e., 2,000 hours).

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10098

29 CFR Part 1910.1096

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

U.S. Worker Regulations

Agency	Coverage	Annual Level (WLM)
OSHA	Workers not covered by the DOE, MSHA, or NRC	12
DOE	DOE Workers	10
NRC	Licensee workers	4
MSHA	Underground miners	4

OSHA's 12 WLM limit is over 3.5 times higher than any country with a regulation for occupational exposure and over 12 times higher than most European Countries.

<https://apps.who.int/gho/data/node.main.RADON03?lang=en>

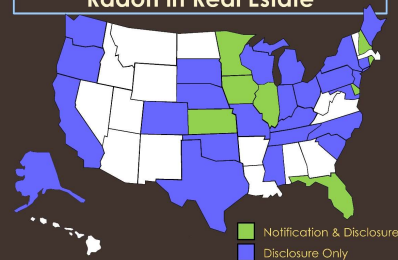
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Disclosure During Real Estate Transactions

Homebuyers Protections: Radon in Real Estate



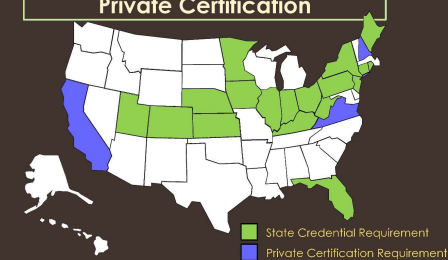
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

State Licensing/National Proficiency Requirements

State Credentials & Private Certification

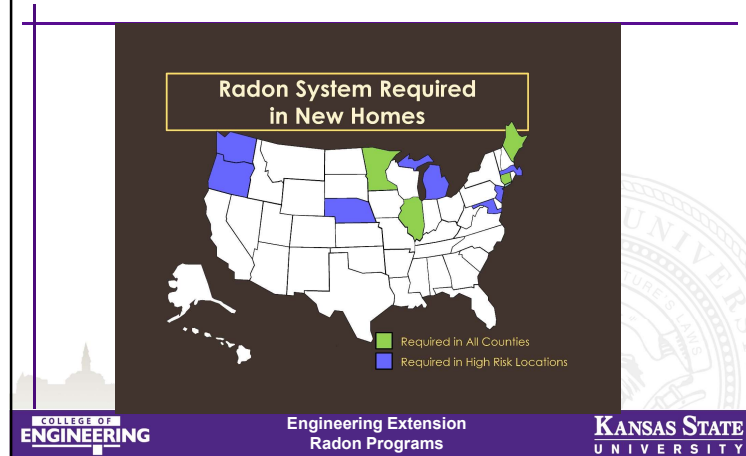


COLLEGE OF
ENGINEERING

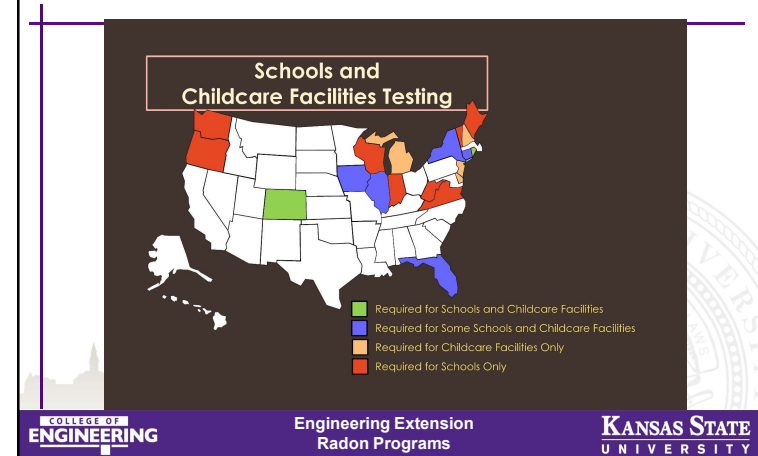
Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Resistant New Construction



School & Daycare Testing

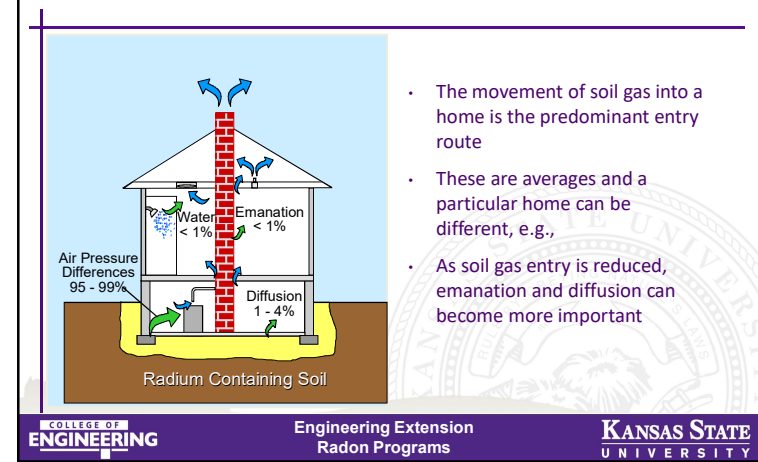


Indoor Radon Levels Depend On:

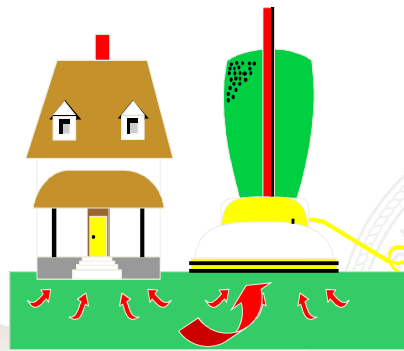
- 1 - Radon Strength in the Soil
- 2 - Soil Porosity
- 3 - Building-to-Soil Pressure Difference
- 4 - Building Ventilation Rate
- 5 - Openings into the Soil



What Contributes Radon to Indoor Air?



Buildings Generate Vacuum



- Buildings can create vacuums that will draw in soil gas
- These vacuums may be very small and are referred to as air pressure differentials

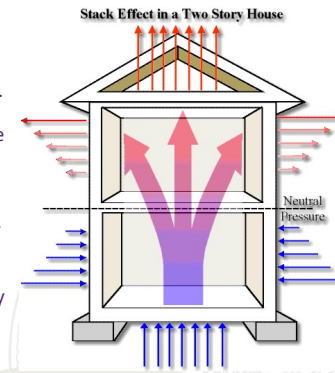
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

The Stack Effect and Negative Pressure

- ACH is an acronym for Air Changes per Hour and is a measurement of air infiltration. It is the total volume of air in a home that is turned over in one hour. Tightly constructed homes may have an ACH of 0.25 to 0.35 ACH,
- A typically built new home may have an ACH of around 1.75 ACH. Older poorly weather-stripped and sealed homes may have higher than 2.5 ACH.

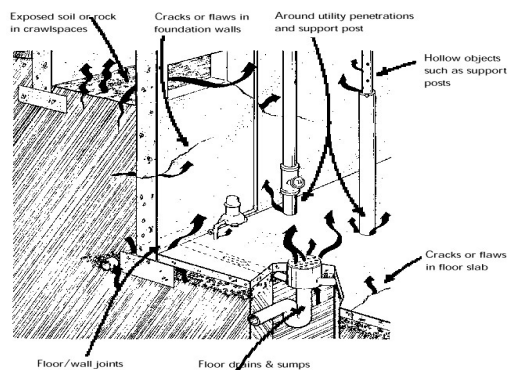


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

How Radon Enters Your Home



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Entry Points Seen and Unseen

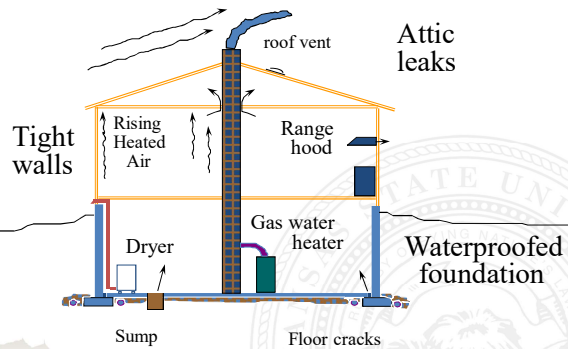


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

What Affects the Home's Vacuum Pressure?



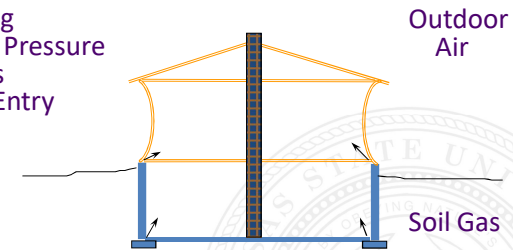
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

What If My House Is Drafty?

Increasing
Negative Pressure
Increases
Soil Gas Entry



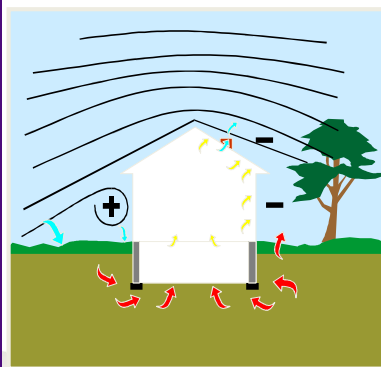
No correlation between radon levels and
house age or house ventilation levels

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Wind Can Cause Several Effects



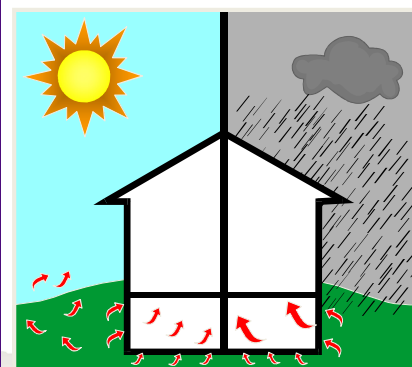
- Indoors negative
 - Bernoulli effect, and leeward (down-wind) openings
- Indoors positive with windward (upwind openings)
- Soil positive
 - Wind pushing beneath

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Rain Effects



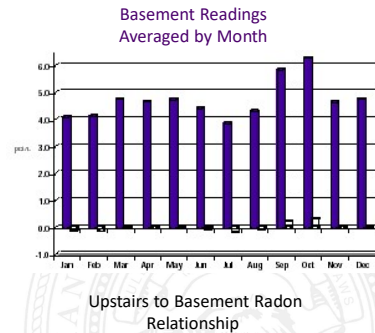
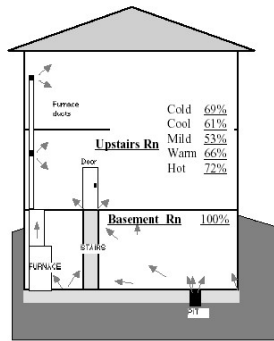
- Can "cap" the soil
- Can displace and force soil gas into building
- Often accompanied with barometric pressure changes

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Levels



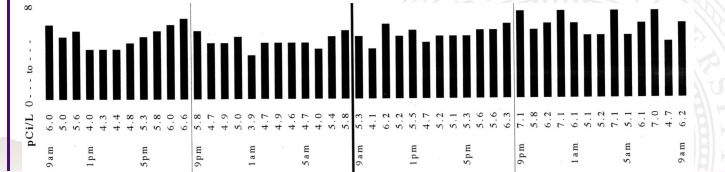
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Levels Are Variable Driving Forces Are Variable

- Pressure differentials can change rapidly
 - Temperature changes
 - Weather changes
 - Occupant use of exhaust equipment
- Minimum two day integrating measurements



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

What If My House Has...?

You cannot predict radon levels based on:

- Heating System
- Foundation Type
- Age of Structure
- Air-tightness
- Style of House
- Presence of Sumps, Cracks or Other Features



You just have to test to find out!

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Measurement Units

- Radon is measured in picocuries per liter of air - pCi/L
- One picocurie is equal to the decay of two radioactive atoms per minute
- 4 pCi/L is equal to 8-9 atoms decaying every minute in every liter of air inside the house -- a 1,000 sq.ft. house at 4 pCi/L has 2 million decays per minute

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Typical Radon Levels

- Radon in soil air ranges from 20 to 100,000 pCi/L
- Most soils range from 20 to 2000 pCi/L
- Outdoor air is 0.2 to 1 pCi/L
- Radon in indoor air ranges from less than 1 to 3,000 pCi/L
- Average indoor level is 1.3 pCi/L
- 4 pCi/L is EPA's guideline level

How Many Homes?

- Statistically valid national research, done with long term tests indicate that -
- More than 60,000 homes have radon levels above 20 pCi/L
- More than 1 million homes have radon levels above 8 pCi/L
- More than 6 million homes have radon levels above 4 pCi/L (EPA's action level)

What Test Results Mean

- There's no "safe" level of radon exposure
- 4 picocuries per liter is the "action level"
- Almost all radon problems can be easily fixed - levels can be reduced to between 2-4 picocuries per liter

EPA Has Defined Radon Zones

Each of 3100 counties in the U.S. classified as:

Zone 1 - expect 4.0 pCi/L or greater

Zone 2 - expect 2.0 to 4.0 pCi/L

Zone 3 - expect 2.0 pCi/L or less

Zone designations based on five factors: indoor radon measurements, geology, aerial radioactivity, soil parameters, and foundation type.

U.S. Radon Zone Map

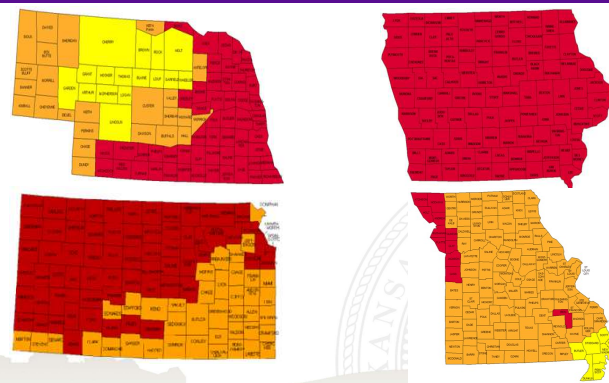


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

EPA Region VII States



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

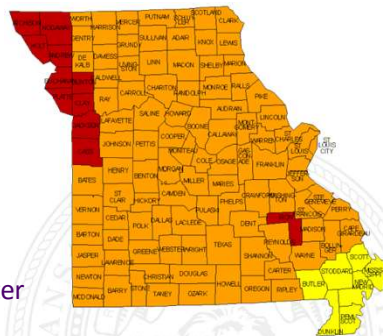
KANSAS STATE
UNIVERSITY

Missouri Radon Potential by County

- Rating(pCi/L):
 - Zone 1: > 4.0
 - Zone 2: $> 2 < 4.0$
 - Zone 3: < 2.0

83% of housing units are
less than 4 pCi/L

17% of housing units greater
than 4 pCi/L



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Kansas Radon Potential by County

- Rating(pCi/L):
 - Zone 1: > 4.0
 - Zone 2: $> 2 < 4.0$
 - Zone 3: < 2.0

75% of housing units are less than 4 pCi/L

25% of housing units between 4 and 20 pCi/L

Approximately 2% of housing units will be 20 pCi/L
or greater



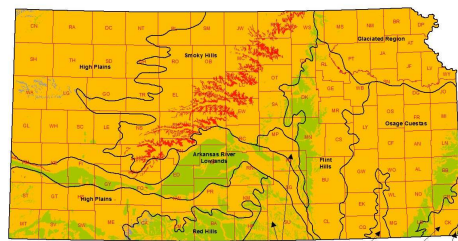
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

KGS Soil Geology Radon Potential

Average Indoor Radon Measurements with Respect to the Surficial Geology of Kansas

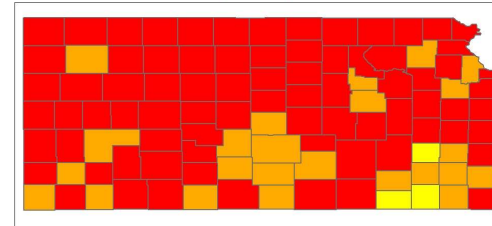


Average Indoor Radon (pCi/L)
 Less than 2.0
 2.0 to 3.9
 4.0 to 9.9
 Greater than 10.0
 No Data

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

2019 Kansas Radon Average Values by County



Average Radon Level = 4.6
 Maximum Reported Radon Level = 1,121.6
 Total Number of Measurements = 161,690
 Total Measurements 4 pCi/L or greater = 62,555
 Total Measurements 20 pCi/L or greater = 3,296
 Total Est. Mitigations (2005-2018) = 33,066

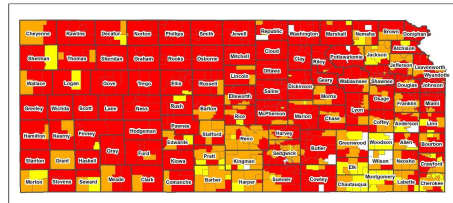
RADON
 0.0 - 1.9 pCi/L
 2.0 - 3.9 pCi/L
 4.0 pCi/L or more
 No Data

Engineering Extension
Radon Programs

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

2016 Kansas Radon Average Values by County and Zipcode



Average Radon Level = 5.3
 Maximum Reported Radon Level = 1,121.6
 Total Number of Measurements = 112,425
 Total Measurements 4 pCi/L or greater = 46,133
 Total Measurements 20 pCi/L or greater = 2,694

RADON
 0.0 - 1.9 pCi/L
 2.0 - 3.9 pCi/L
 4.0 pCi/L or more
 No Data

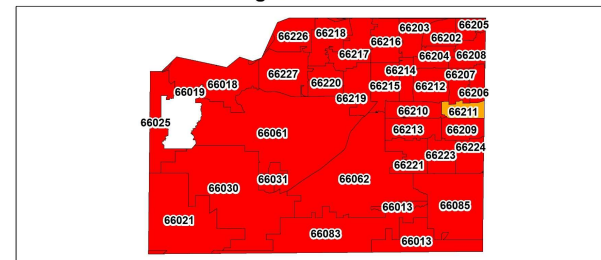
Copyright 2016, KDHE and Kansas State University. Caution: This map has been produced using data collected by KDHE through June of 2016. As further data becomes available, revision will be necessary. This map is provided free of charge to the public and is generated for study purposes only. Permission is hereby given to reproduce this map provided it is reproduced in its entirety without modification. This map cannot be used to characterize or predict indoor radon levels at any specific area or location. Measurement must be performed to determine radon levels in any given residence or building. Contact the Kansas Radon Program at (800) 690-5343.

Engineering Extension
Radon Programs

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

2019 Johnson County Average Radon Values



Average Radon Level = 5
 Maximum Reported Radon Level = 309
 Total Number of Measurements = 52,647
 Total Measurements 4 pCi/L or greater = 22,558
 Total Measurements 20 pCi/L or greater = 1,339

RADON
 0.0 - 1.9 pCi/L
 2.0 - 3.9 pCi/L
 4.0 pCi/L or more
 No Data

Copyright 2018, KDHE and Kansas State University. Caution: This map has been produced using data collected by KDHE through June of 2018. As further data becomes available, revision will be necessary. This map is provided free of charge to the public and is generated for study purposes only. Permission is hereby given to reproduce this map provided it is reproduced in its entirety without modification. This map cannot be used to characterize or predict indoor radon levels at any specific area or location. Measurement must be performed to determine radon levels in any given residence or building. Contact the Kansas Radon Program at (800) 690-5343.

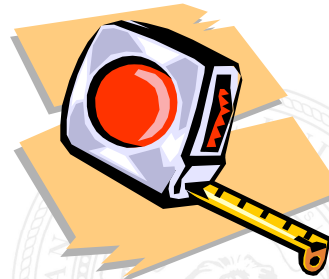
Engineering Extension
Radon Programs

Engineering Extension
Radon Programs

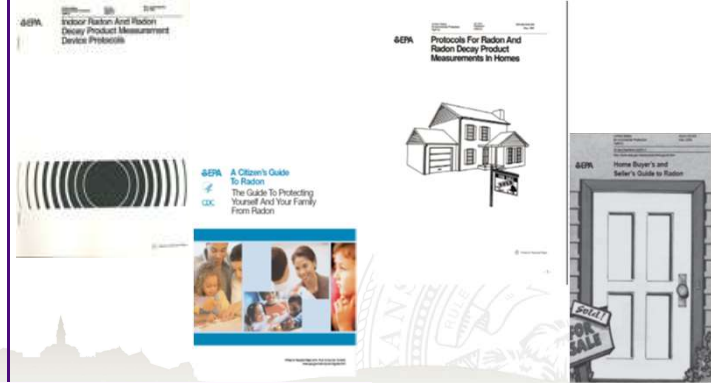
KANSAS STATE
UNIVERSITY

Measuring Radon

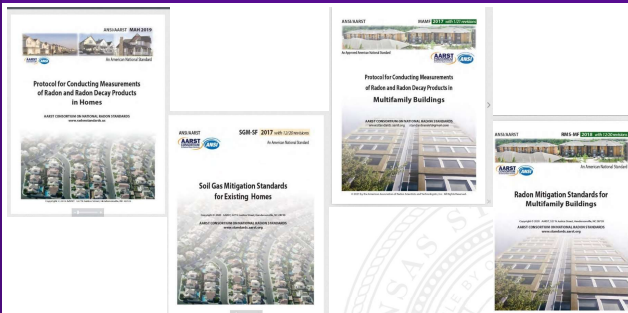
- Procedures
 - Time
 - Conditions
 - Costs
- Devices
- Locations



EPA Radon Measurement Protocols and Parallel Consumer Documents



AARST Radon Standards



<https://standards.aarst.org/>

Long-term Versus Short-term Testing

- Long Term - greater than 90 day exposure
- Short Term - typically 2 - 7 day exposure
- Short Term cannot be less than 2 days
- Both tests can provide accurate results
- Long Term tests average seasonal variations

94% of the time Short Term tests provide the same mitigation decision as a Long Term test

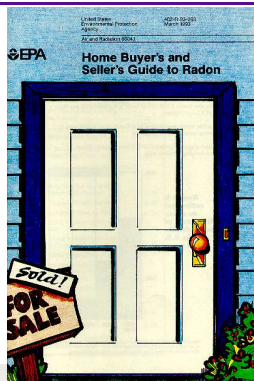
Test Results?

- **What assures the quality of the test results?**
- Use of protocols and device manufacturers guidance – read and follow instructions
- Initial evaluation of the test device by EPA
- Quality control measures conducted by the tester – calibration, duplicates, blanks, spikes
- Closed house conditions and steps that deter and detect tampering

Should You Recommend Long or Short Term Testing?

- Short Term tests must be done with Closed House conditions
- Short Term tests should be tamper resistant (reduces liability)
- Long Term tests are done with normal living conditions but require money in Escrow for possible mitigation

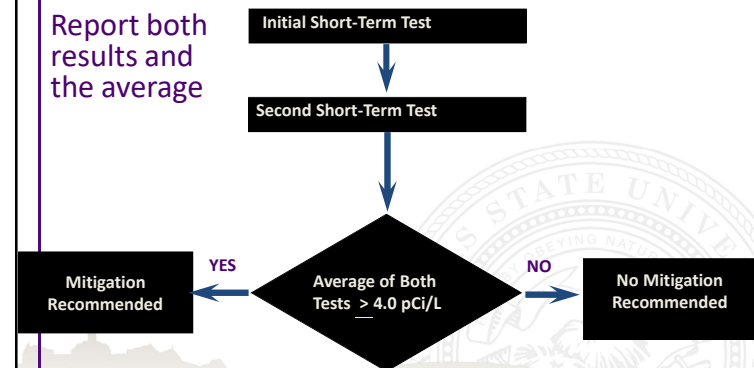
Real Estate Testing Testing Options

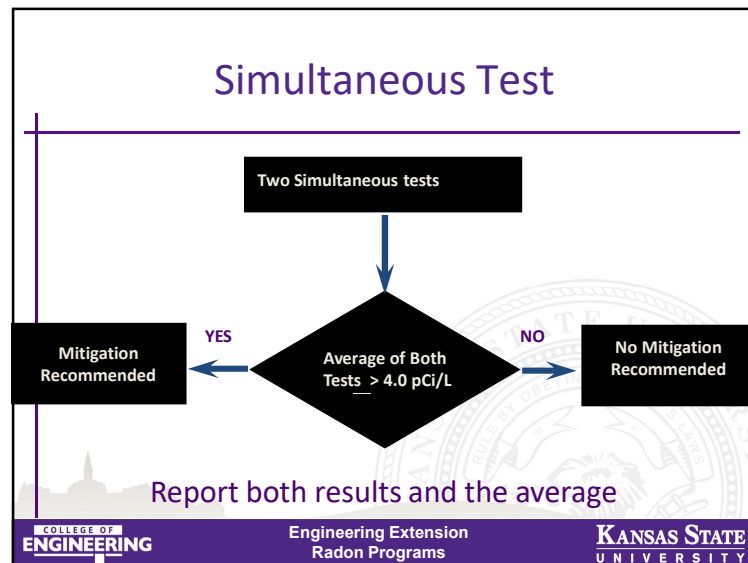


- Sequential testing
- Simultaneous testing
- Single test with Continuous Radon (CR) or Continuous Working Level Monitor (CW).
- Outlined in EPA's Home Buyer's and Seller's Guide

Sequential Testing

Report both
results and
the average

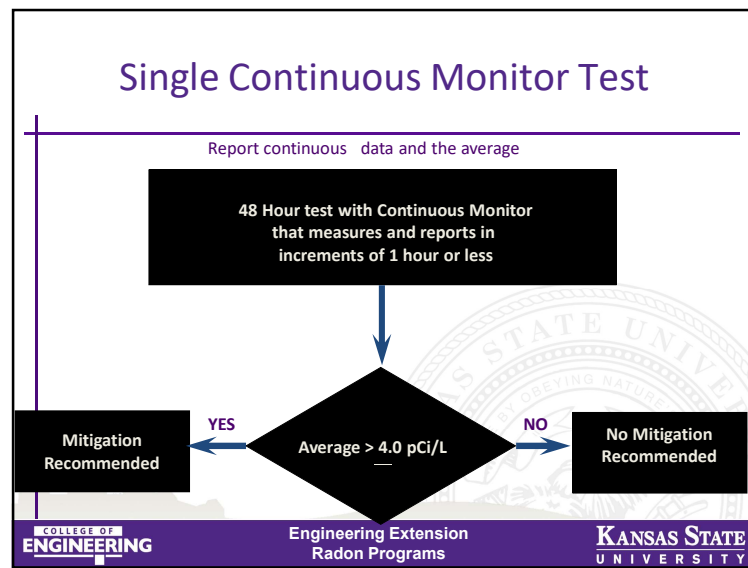




What Is a Typical Variation in Duplicates?


- Duplicate radon results greater than 4 pCi/L should be within 10% to 30% of each other
- If duplicates have a greater variation than this, contact the tester
- The lower the radon levels, the greater the variation between duplicate results

COLLEGE OF ENGINEERING Engineering Extension Radon Programs KANSAS STATE UNIVERSITY



Closed House Conditions

- All windows & doors closed except for normal entry and exit
- Operate the home's heating and cooling systems normally during the test.
- Window air conditioners recycle only
- Fireplace damper closed
- Fans that are part of a radon-reduction system or small exhaust fans operating for only short periods of time may run during the test.
- Attic fans are OK but can't use window or whole house fans



COLLEGE OF ENGINEERING Engineering Extension Radon Programs KANSAS STATE UNIVERSITY

Preparing for Short-Term Test – Closing House Prior to Test

Days: 2 3

Prior to Testing, Closed House:

Required
12 hours before

4 5 6

Prior to Testing, Closed House:

Recommended
12 hours before

- Allows house to come to dynamic equilibrium

Important!

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Can You Run Exhaust Fans During a Radon Test?

	Typical cfm
Downdraft range exhaust	300-400
Wood Fireplace	170
Clothes Dryer	100
Bathroom Fan	25-90
Combustion Appliance	20-70
Air-tight Wood Stove	30

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

EPA Recommends Using Non-interference Controls

Use CRM to detect unusual radon changes

Seal on basement windows

Detector movement indicator

Have homeowner sign Non-Interference Agreement

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Ways to Prevent or Detect Tampering

- A print-out of continuous monitor helps detect unusual measurement swings
- Motion detectors can determine if device is moved
- Proximity detectors reveal presence of people
- Record barometric and weather conditions
- Record room temperatures to assess the opening of windows

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

More Ways to Deter Tampering

- Specialty tapes on exterior doors and windows can be used to detect their being opened
- Place device in a particular position that handling would be difficult or detectable
- Don't use devices that provide a read-out to occupant
- Notify the occupants of the importance of proper testing conditions. Give the occupants written instructions and explain the directions carefully

Consider Re-testing If During the Test:

- Test conditions were not maintained
- Extended heavy rain or wind speeds greater than 30 mph took place for a significant period of the test (a severe storm)
- One test result is less than 4 pCi/L and the other is greater, and the greater is twice the level of the lesser result - *RARE*

(for example - 2.5 pCi/L & 6.0 pCi/L)

Devices

- Charcoal canisters and bags
- Alpha Track detectors
- Electret Ion Chambers
- Continuous Radon Monitors



Activated Charcoal Device Examples



- Activated charcoal devices are for short-term tests.
- Open face devices are optimally 2 - 3 days.
- Diffusion barrier are optimally 5 - 7 days.

Are Charcoal Detectors OK?

- Convenient, easy to use, less expensive
- They have a long shelf life
- Lab analyzes the results
- They have reasonable accuracy
- Must be exposed specific amount of time
- Requires external tamper controls

Continuous Monitors



Are CRM's the Best Choice for Real Estate Testing?

CRM's can have Tamper Resistant features and have demonstrated excellent accuracy, but their reliability is dependent on manufacturer and care of the user.

CRM's vary in sensitivity and need to be calibrated yearly & checked with a duplicate at least every 10th measurement

Costs

- | | |
|------------------------------|-------------|
| • Test kits in bulk | \$5-\$25 |
| • As part of home inspection | \$100-\$150 |
| • With continuous monitor | \$150-\$250 |

Device Placement

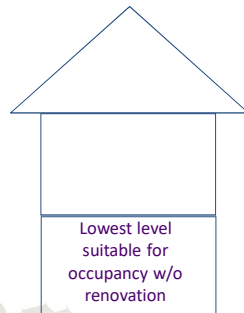
- EPA recommends that testing device(s) be placed in the lowest level of the home that could be used regularly, whether it is finished or unfinished.
- Conduct the test in any space that could be used by the buyer as a bedroom, play area, family room, den, exercise room, or workshop.
- Based on their client's intended use of the space, the qualified testing professional should identify the appropriate test location and inform their client (buyer).

What Does “Lowest Livable” Mean?

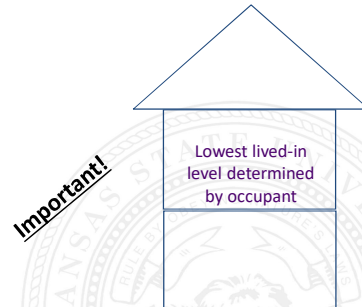
- Lowest area of the home that could be used as a playroom, family room or office without needing major structural change such as the addition of a concrete floor or more headroom
- A small furnace room is not livable
- If a basement only needs a carpet for children to play in, it is considered “livable”

Test Location Depends On Purpose

Real Estate

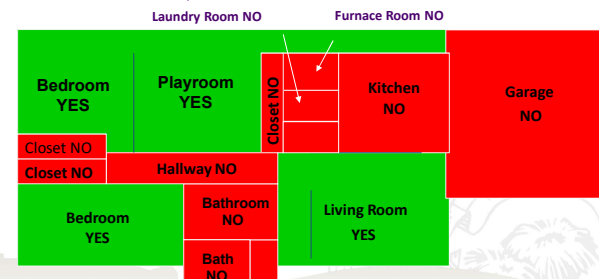


Non-Real Estate



Home Measurement Locations

- Test normally occupied rooms, e.g., bedrooms, living rooms
- Do not test spaces not commonly occupied, e.g., closets, crawl spaces, hallways, laundry rooms
- Do not test kitchens, bathrooms



Where in the Room is the Device Placed?

Good Practices

- Away from heat sources
- Not near electronic equipment
- Not in direct sunlight
- Avoid placing test device on stone surfaces

20"+ above the floor

If suspended, 6' to 8' above the floor

3'+ from outdoor openings

1'+ from an exterior wall

Test Device Stand

Away from heat, drafts, and humid areas

Exterior Wall

4'+ from any other object

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

What Rooms Should Be Tested?

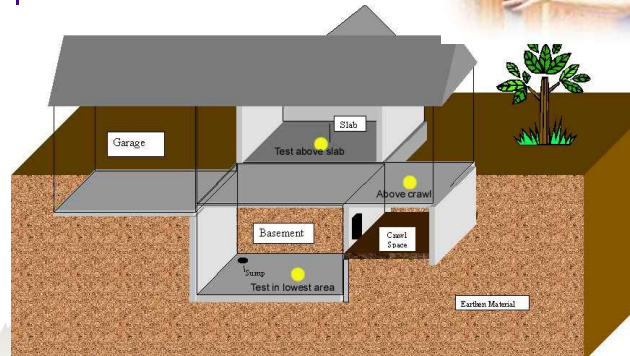
- As a minimum, one test must be done in the "Lowest Livable" area
- It is also recommended to test other living areas, especially those over other foundation types.
- If upper floors test low, it may relieve Buyer's anxiety

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Multiple Device Placement

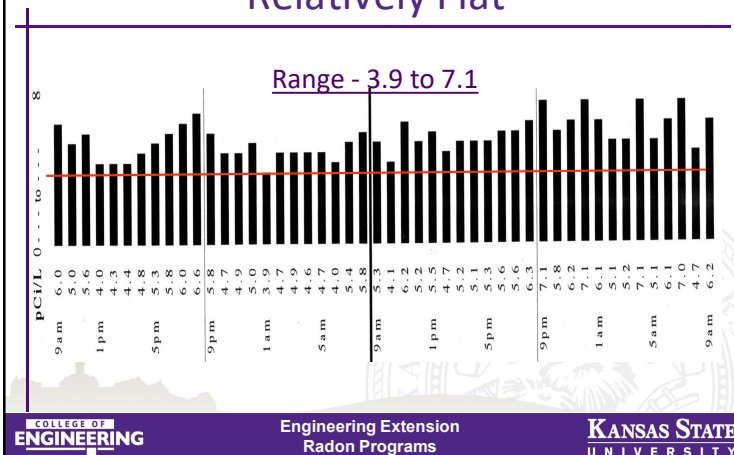


COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

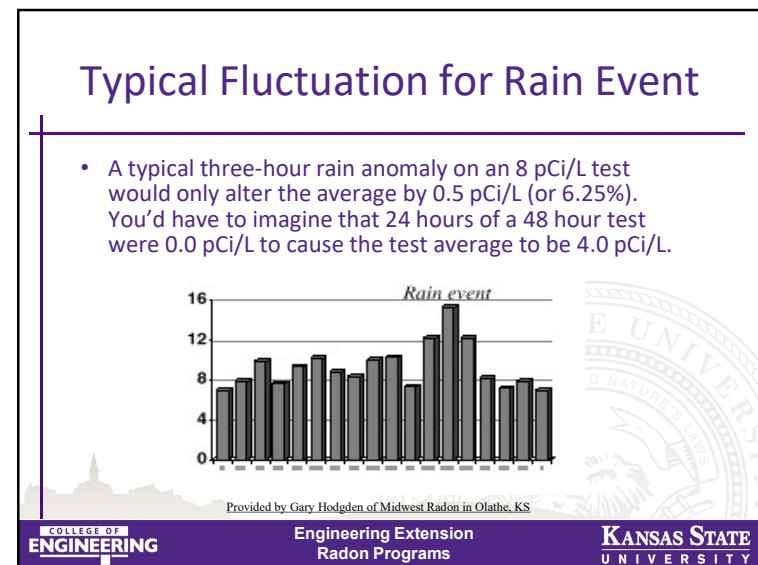
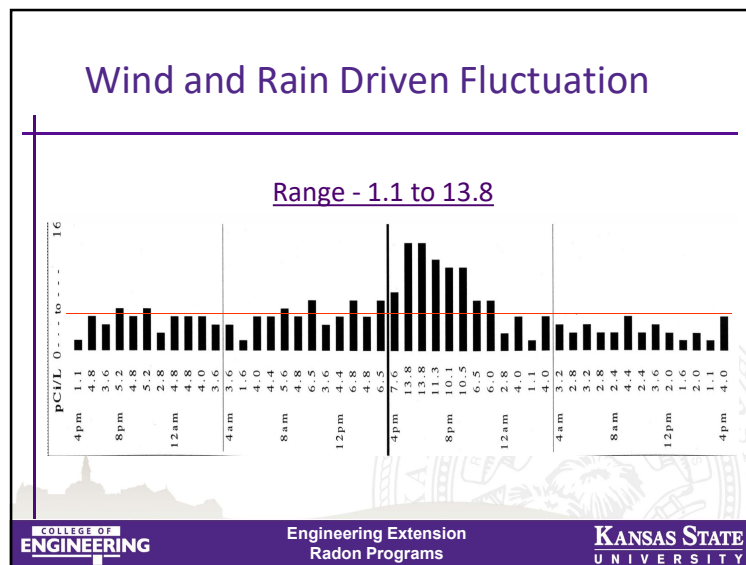
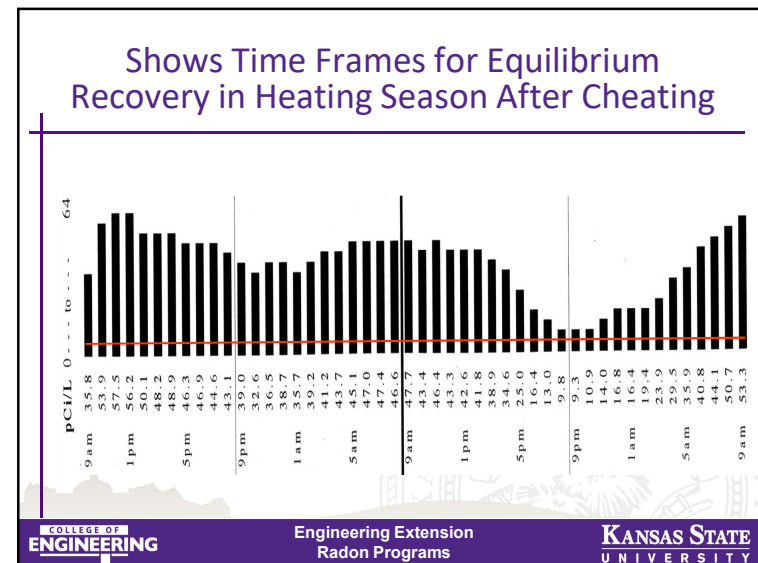
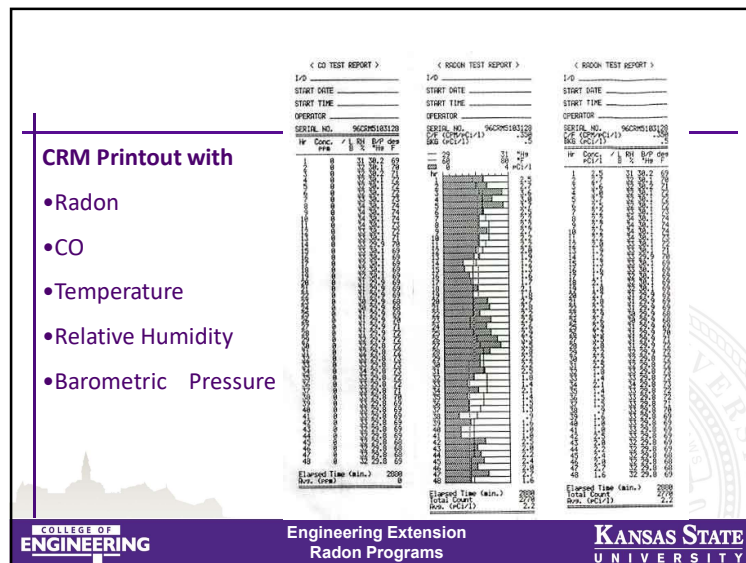
Basic Heating Season Graph - Relatively Flat



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY



Empty House Testing

- Vacant house can be tested.
- Factors which might increase/decrease the radon level in unoccupied home.
- Setup
- Typical operation mode

Radon Professionals

- ***What are the key questions for those who are testing and fixing homes for your clients?***
 - Have you taken any national radon program training or exams?
 - Are you licensed/certified with the state? (if required)
 - MO –no
 - IA, KS, NE- yes
 - Are you listed with NRPP or NRSB?
 - Has your CRM been calibrated within the last 12 months?
 - Are you certified or a member of a home inspection association?

Questioning Test Results?

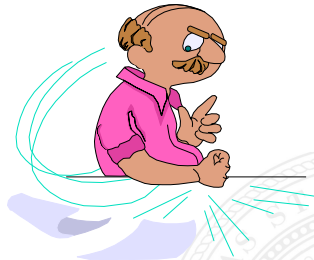
- Why?
- Too high? Too low????
- Not following protocols and guidance?
- Is the result typical in terms of fluctuations?
- Confusion on purpose – citizen based or real estate based test?
- Evidence of tampering?

Radon Proficiency Programs

- National Radon Proficiency Program- AARST
 - Measurement and mitigation
 - Training, exams/CE
 - <https://nrpp.info/>
- National Radon Safety Board
 - Measurement and mitigation
 - An independent, nonprofit organization modeled on the American Board of Health Physics
 - <https://www.nrsb.org/>



Radon Mitigation Overview



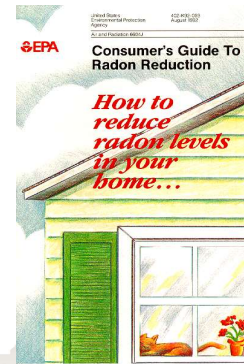
So, you tell the homeowner that they have elevated radon.
Now what do you tell them?

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

EPA's Consumer's Guide



- What is radon mitigation?
- How to hire a contractor.
- Cost estimates.
- Good overview.
- Takes the tester out of the realm of being an expert.
- Free!

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Homes With Radon Can Be Fixed!

- Techniques have been developed to reliably reduce radon to less than 4.0 pCi/L.
- Almost all systems can be installed in one day by a qualified contractor.
- The repairs take 24 hours to take effect before retesting can occur.
- EPA & state offices maintain lists of qualified contractors.

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Mitigation

- Active Soil Depressurization (ASD) is the most common approach.
 - Employs a method for creating a vacuum beneath the foundation greater in strength than the vacuum applied to the soil by the building.
- Caulking and Sealing is not a stand-alone technique.
- Ventilation approaches have proven more costly and less effective.

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Active Soil Depressurization (ASD)

- Suction of subslab soil
- 3 to 4 inch PVC

- Inline fan outside
- Discharge away from potential exposure

- Performance indicator
- Labeling

- Operating instructions
- Post mitigation testing

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Indoor Fan System

Outdoor Fan System

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Two Point Suction System

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Mitigation Examples

COLLEGE OF
ENGINEERING

KANSAS STATE
UNIVERSITY

Pipe Connected to Riser



- Hole cut through slab.
- Pit dug out.
- PVC pipe connected to hole.
- Pipe routed to suction fan.
- Pipe sloped to allow condensate drainage to soil

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Depressurization Fan



Installed in:

- attic,
- garage, or
- outside
- Quiet
- Less than 90 watts
- Expected life: 10-15 years

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

System Discharges Through Roof



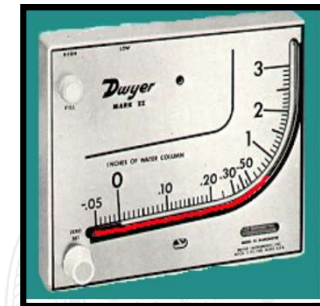
- Discharge should be high enough to avoid radon entering building
- No rain cap

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

A System Performance Indicator Is Needed

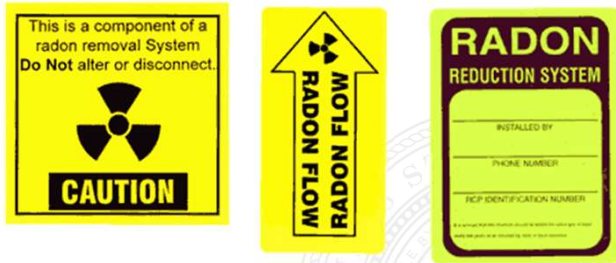


COLLEGE OF
ENGINEERING

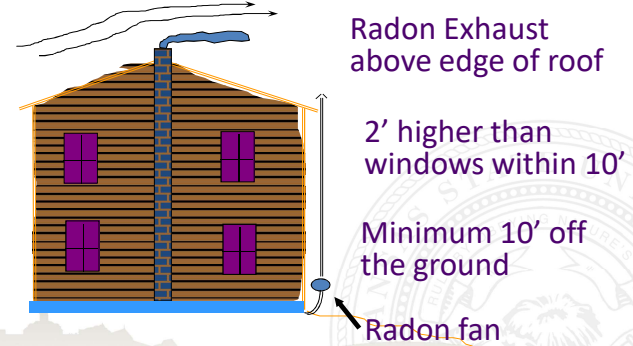
Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Labels



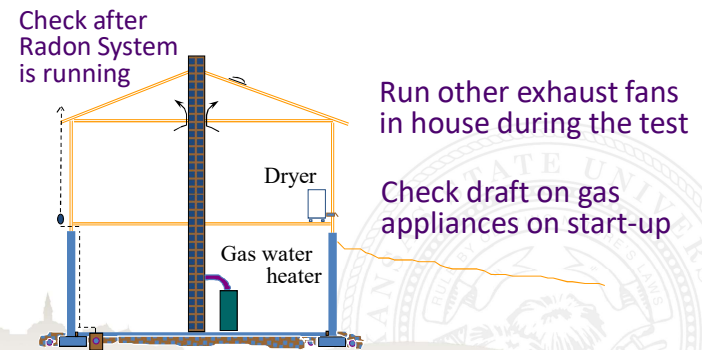
Radon Exhaust Requirements



Radon Fan Exhaust Moisture Issues



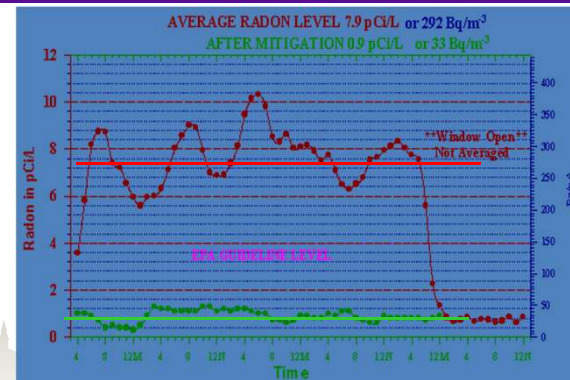
Gas Appliances Require a Backdraft Test



Post Mitigation Testing

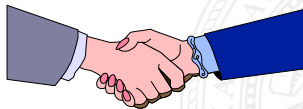
- Must wait 24 hours before starting test
- A short term test is placed in same location as the first test
- Must test system within 30 days
- Must recommend re-testing every 2 years

The Systems Work!



How Do You Know If a Contractor Is Qualified?

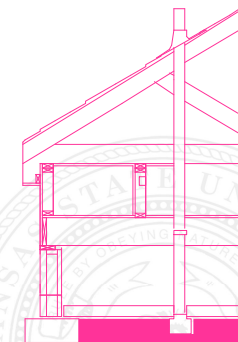
- Is he/she registered with a state or national proficiency program?
- Will the contractor be in business and provide good service over the length of their warranty?
- Does the contractor have referrals?



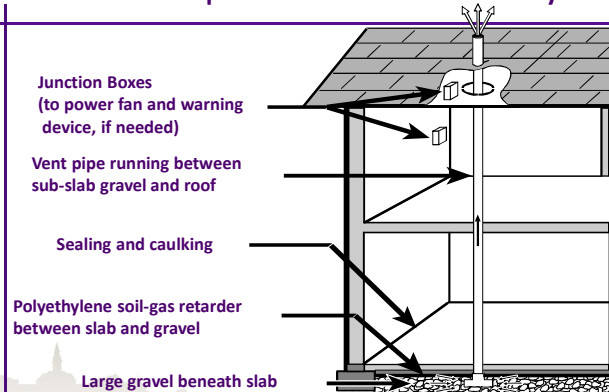
Radon-Resistant New Construction

- Promote adoption of techniques in national, state and local building codes
- Encourage voluntary application of the techniques by home builders
- Create consumer demand for radon-resistant new homes
- Required in
 - Manhattan, Topeka, Lawrence, Salina, Junction City, Eudora, De Soto, Gardner
 - Shawnee & Douglas Counties (unincorporated)

Priority area in the 2017 Kansas Comprehensive Cancer Plan



Basic Components of Passive System



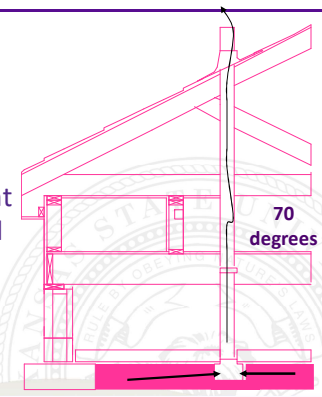
COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

How Does it Work?

- The pipe is warmed by house air creating a stack effect draft in the pipe
- The warmed air in the pipe rises, creating a slight vacuum on the cooler soil gas



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

55 degrees
KANSAS STATE
UNIVERSITY

Other Building Practices That Help

- Tight Concrete Slab With Control Joints Minimizing Cracks
- Cover and Seal Sump Pumps
- Seal Hollow Block Walls
- Seal Joints in HVAC Ductwork
- Seal Other Potential Radon Entry Routes

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Other Issues

- Vent for each separate foundation type
- Reduce building depressurization through duct sealing in unconditioned spaces, air infiltration control and fire-stopping
- Provide electrical supply box in attic for future fan and in anticipated locations of system failure alarms

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Activating a Passive System

1. Exhaust Fan in the Vent Pipe

- Standard radon control fans consume 70-90 Watts and exhaust 10-40 CFM of conditioned air
- A tiny fan is all that's needed in new construction - 20 CFM at 10 Watts

2. A Visible or Audible Warning System

Benefits of Using Radon-Resistant Techniques

- Low-Cost
- Prevention of Liability
- Marketing Advantage
- Aesthetics
- Changing Building Codes

Cost Comparison

New Home Construction

\$350 - \$500
per Home
(Labor and Materials)

Mitigate Existing Home

\$1000 - \$2500
per Home
(Labor and Materials)

Actors, Motivations & Intentions

- **Seller**
 - Wants to sell at highest price in a short time
- **Real estate Agent**
 - Wants successful transaction at agreed price in a short time
- **Buyer**
 - Wants to buy a radon "safe" house at lowest price in a short time
- **Home Inspector**
 - Wants to depict actual condition of property for his/her client
- **Radon Tester**
 - Wants accurate test of radon levels in short time
- **Radon Mitigator**
 - Wants to fix house in short time at good price -
- **Mortgage Lender**
 - Wants to lend money on a radon "safe" property
- **Relocation Company**
 - Wants to handle only radon "safe" property in a short time

Options for Radon Issues in Home Buying and Selling

- **Disregard-Ignore Approach**
 - Advantage - no additional requirements
 - Disadvantage - Radon is a recognized risk
 - Potential mitigation costs later
- **Simple Disclosure Warning Statement**
 - "There might be a problem"
 - Advantage - reduces liability
 - Disadvantage - may create buyer concern
- **Seller Testing Approach**
 - Advantage - Radon measurements ready at closing
 - Disadvantage - Buyer confidence in test



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Options for Radon Issues in Home Buying and Selling

- **Buyer Testing Approach- Contingency in purchase agreement**
 - Advantage - Meets buyers needs
 - Disadvantage - Confidence in results, high results
- **Corporate Relocation purchase of employee's house**
 - Advantage - Radon testing takes place
 - Disadvantage - Short term tests required mitigation if high or no sale
- **Seller Escrow - Buyer Testing Approach**
 - Radon testing/mitigation escrow clause
 - Advantage - Long term test more reliable
 - Disadvantage - Complexity in contract, amount held, by who, disbursements, testing

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radakovich Case in Pennsylvania

- Home purchased with radon inspection rider in purchase agreement
- Radakovich hired tester - Charcoal Canister test results of **1.5 and 1.6 pCi/L**
- 1 yr later, local mitigator calls offering to help lower radon levels
- Home had been previously tested in excess of **40 pCi/L**
- Suit alleges fraud, punitive damages, negligent misrepresentation, unfair trade, consumer protection against 3 defendants
- 10 day trial by jury ordered **\$10,000** per defendant

COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Radon Does Not Have To Be A Problem Nor A Deal Breaker



COLLEGE OF
ENGINEERING

Engineering Extension
Radon Programs

KANSAS STATE
UNIVERSITY

Resources for You

- Call Missouri Radon Program
 - 1-800-723-6427
 - <http://health.mo.gov/living/environment/radon/index.php>
- Brian Hanson
 - bhanson@ksu.edu
- NRPP web site with contractor lists <http://aarst-nrpp.com/wp/database-search/>
- NRSB web site
 - http://nrsb.org/find_a_professional.asp?action=go