national ground water association®

Water Well Construction and Service Practices for the Safety of the Contractor, the Property Owner, and Others

STRAY GAS IN WATER WELL SYSTEMS

Presentation Overview

- NGWA: what we are
- What gases are likely to be problematic to a water well system professional?
- So-called “breather” wells

What is the National Ground Water Association?

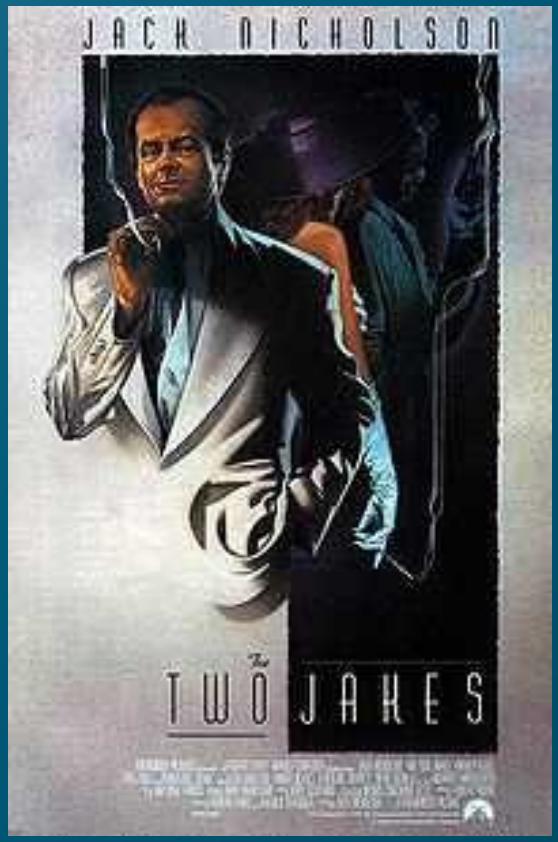
- Largest membership organization of groundwater professionals
- U.S. and international membership
- Dedicated to advancing groundwater knowledge

Disclaimer

- Products depicted in this presentation are for illustrative purposes and do not constitute an endorsement by the National Ground Water Association of that particular design, configuration, or producer.

Stray gas, water wells, and Hollywood

- Private Investigator Jake Gittes in the motion picture, *The Two Jakes*
- Here's a scene…



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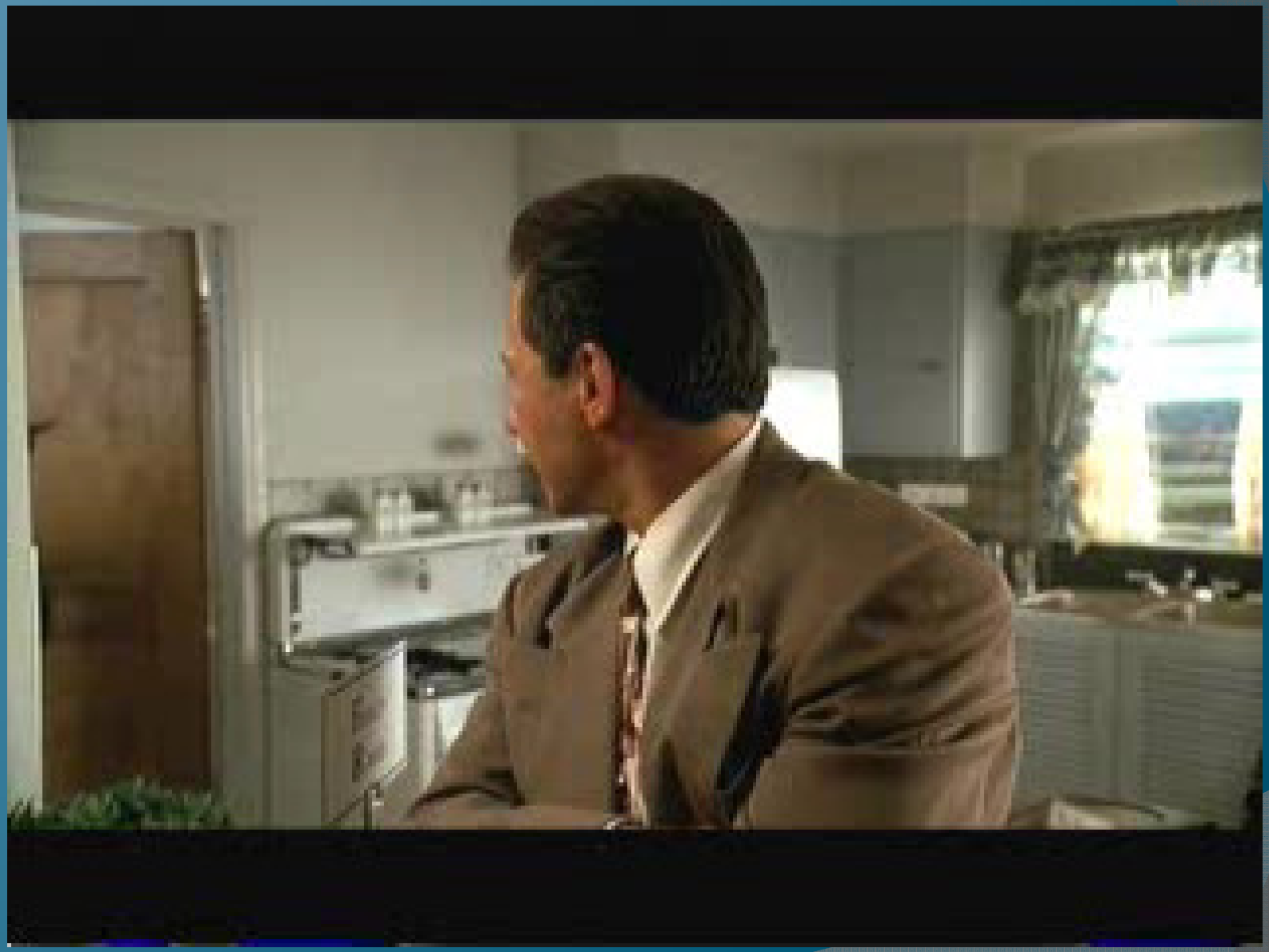

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What gases?

- Carbon dioxide
- Carbon monoxide
- Dissolved oxygen
- Hydrogen sulfide
  - Sulfur-reducing bacteria
- Methane
- Radon
- Sulfur dioxide

A little preparation may be a lot of prevention

Image courtesy of MSA, Inc.

- Water well professionals can be taught what they may encounter in a service area, and how to protect themselves and their equipment if they encounter the unexpected or hazardous downhole surprise.
- Water well construction and water well service professionals can be prepared to handle known possible gas hazards by being provided with simple test instruments to use after uncapping a well, or if they will be working in a confined space.

Carbon dioxide (CO_2)

- Presence in groundwater significant where calcium and bicarbonate ions are in solution
- Carbon dioxide is odorless and heavier than air
- Carbon dioxide is not toxic or explosive
- Can be a deadly health threat in high concentrations

Carbon dioxide and water wells

- Under ambient pressure conditions, the amount of carbon dioxide in solution remains constant.
  - Pressure near a well is reduced by pumping and carbon dioxide then comes out of solution as bubbles of gas
- Corrosive water when carbon dioxide is in excess of 50 mg/L

Carbon dioxide and water wells

- Calcium carbonate may precipitate when chemical equilibrium is disturbed
- To minimize calcium carbonate deposition when a well is pumped, head losses must be kept as low as possible
  - Low entrance velocities through well intakes of maximum inlet area

Carbon dioxide and water well site safety

- In calm weather conditions, carbon dioxide will settle in low areas such as large-diameter wells under construction, pits, and trenches
- Can be deadly in a confined space situation

Carbon dioxide and water well site safety

- Can cause unconsciousness or asphyxiation
  - Exposed workers may suffer several symptoms, including headache, dizziness or unconsciousness
- Ventilation of the well, pit, or trench will remove the carbon dioxide threat to well site workers

Carbon monoxide (CO)

- Highly toxic and explosive if ignited
- Sometimes formed by slow oxidation of organic material such as peat, lignite, or coal
- Produced from internal combustion engines as exhaust
  - Gasoline-powered motors near wellhead
  - Can not be detected by sight, odor, or taste
    - Headache, dizziness, nausea, “cherry-red” flushed face, unconsciousness

Dissolved oxygen

- Solubility of oxygen in water decreases with higher temperatures and becomes almost zero at boiling point
- Oxygen of groundwater at depths greater than 150 feet is generally considered to be quite low
  - May be found in shallow wells in unconfined aquifers

Dissolved oxygen and water wells

- Water in a pressure tank may contain far more than 10 mg/L of oxygen
- Dissolved oxygen may cause water to attack galvanized iron and some brass
  - >/= 2 mg/L corrosive water
  - Dissolved oxygen is more corrosive when pH is low
- Iron oxide scale may accumulate on the inner surfaces of iron pipes when iron is put into solution by low pH water combined with dissolved oxygen
  - Reduces water carrying capacity of pipe
  - Injected air effective for iron and sulfur precipitation

Dissolved oxygen and water well site safety

- No direct human risk

Hydrogen sulfide (H_2S)

- Easily absorbed by water
- Rotten egg odor
- One of few water contaminants human senses can detect at low concentrations
  - As little as 0.5 mg/L in cold water is noticeable
- Highly toxic and flammable
  - 30 second exposure to 1000 ppm can kill; 5 times as toxic as carbon monoxide
  - No lasting odor in very high concentrations due to olfactory fatigue

Hydrogen sulfide and water wells

- Small amounts can be corrosive
  - Less than 1 mg/L can cause severe corrosion
- Well rehabilitation acids can create hydrogen-rich environment leading to metal embrittlement
  - Damages well screens
- Treat
- Deepen well
- Replace well

Hydrogen sulfide and water wells

- Removal by:
  - Aeration
  - Carbon filters
    - Small amounts only
  - Chlorination
  - Ion exchange
  - Manganese greensand filtration
  - Oxidation and oxidizing filters
  - Ozone and standard filter tank with an automatic vent mounted on top

Hydrogen sulfide and water well site safety

- Poisonous and flammable
  - High concentrations can kill
- Safety precautions in the oil and gas field
  - Continuous monitoring systems
    - Personal monitoring devices
  - Wind direction indicators
  - Means for igniting the gas

Sulfate-reducing bacteria

- Absence of oxygen and high sulfate content
  - Bacteria gain energy from oxidation of organic compounds
    - Reduction of the sulfate ions (removal of oxygen) produces hydrogen sulfide gas
    - In iron pipe, water attacks the metal to form iron sulfide, which is deposited as insoluble iron scale in the pipe
    - Creates staining
  - Not a direct human health risk

Methane (CH_4)

- Methane is a natural gas formed by the decomposition of organic material. It is a byproduct of the same process that forms coal and oil and is often associated with coal seams, oil reservoirs, and shale deposits
  - Atmospheric gas with low pressure
- Methane is trapped by certain sequences of rock underground.
  - Sand and gravel formations

Methane and water well site safety

- Water well system professionals have reported employees being burned or having equipment damaged because methane gas venting from the well ignited as they uncapped a well, or were doing work that created a spark in the well or at the wellhead
  - Stories of burning methane flames singing eyebrows, damaging electrical wires, and sometimes having enough gas pressure to force the flame several feet into the air above the wellhead are rare but have occurred in multiple areas
  - An energized well pump with damaged wiring can create an electrical spark and serve as a source of ignition for methane gas in the well.

Methane and water well site safety

- Not a health problem; but a safety problem
- Methane is explosive and flammable
- Methane is not detectable by smell. It is often combined with small amounts of hydrogen sulfide
- Detection of methane can be made only by a methane monitor
- Symptoms:
  - Headache, dizziness, nausea, unconsciousness

Methane solutions

- Venting
  - Well above the wellhead
    - Seven feet or more
- Aeration

Radon (Rn)

- Radon is a colorless, odorless gas produced by the radioactive decay of the element radium, which has itself been formed by the decay of uranium
- All rocks contain some uranium, although most contain a very tiny amount, between 1 and 3 ppm.
  - Radon present in all rocks and soils as daughter products formed by uranium's radioactive decay
- Radon is found in groundwater in areas that have high levels of uranium in the underlying rocks, such as granites and shales.

Radon

- Radon moves more rapidly through permeable soils, such as coarse sand and gravel, than through impermeable soils, such as clays. Granites, gneisses, limestones (particularly dolomitic limestones), black shales, and phosphate rocks are particularly linked to the potential for high radon concentrations.

- There are three major sources from which naturally occurring radon can enter a household:
  - Via a groundwater supply with subsequent release into the indoor air through water use activities
  - Via soil gas diffusion through cracks and other openings in foundations or floors above crawl spaces and via dewatering sumps located inside of basements
  - Via direct release from construction materials used in the home, principally in foundations or thermal storage materials that contain radium.

Radon and water wells

- U.S. EPA estimates that in homes served by wells, groundwater contributes about five percent of the radon found in the household air. Compared to radon entering the home through water, radon entering through the soil represents a much larger risk

- Testing requirements for residential wells vary widely from state to state. If there is no local or state testing requirement, the responsibility for testing lies with the homeowner

- EPA and the U.S. Surgeon General recommend testing for radon in all rooms below the third floor.

Radon and water wells

- A 2009 USGS study of groundwater used by residential water wells reported the following findings related to radon
  - *"Concentrations of radon greater than the lower U.S. Environmental Protection Agency proposed Maximum Contaminant Level (MCL) of 300 picocuries per liter (pCi/L) were found in 65 percent of wells, which are located throughout the United States and in all 30 principal aquifers sampled. Concentrations greater than the proposed MCL of 4,000 pCi/L were found in 4.4 percent of wells, and generally were associated with crystalline-rock aquifers located in the Northeast, the central and southern Appalachians, and central Colorado. Concentrations were highest in crystalline-rock aquifers located in the Northeast, in the central and southern Appalachians, and in central Colorado; in these aquifers, about 30 percent of the sampled wells had concentrations greater than 4,000 pCi/L. High radon concentrations in groundwater and their relation to regional aquifer lithology in these areas are well documented."*

Radon and water well site safety

- Ventilation is the best available well site safety practice

Sulfur dioxide (SO_2)

- Sulfur dioxide is a colorless, toxic gas with a pungent odor
- It is a liquid when under pressure
- Sulfur dioxide dissolves in water very easily
- Once dissolved in water, sulfur dioxide can form sulfurous acid
  - Sulfurous acid is a colorless solution of sulfur dioxide in water, H_2SO_3, characterized by a suffocating sulfurous odor

Sulfur dioxide and water wells

- Can lead to sulfate-reducing bacteria
  - Can result in a buildup of scale
  - Will react with steel pipe and lead to pipe failure
  - The sulfur gases (normally hydrogen sulfide) typically come from sulfate reducing bacteria reacting with the sulfate compounds in the groundwater.
    - Treated by shock chlorination, or by a chlorine feed system on the incoming water. Hydrogen sulfide is readily adsorbed by activated carbon, but it's important to go after the source.

Sulfur dioxide and water well site safety

- Sulfur dioxide is a colorless, toxic gas with a pungent odor
  - Aqueous solutions of sulfur dioxide, which sometimes are referred to as sulfurous acid, are used as reducing agents and as disinfectants, as are solutions of bisulfite and sulfite salts. They are also mild bleaches, and are used for materials which may be damaged by chlorine-containing bleaches.

Sulfurous acid and water well site safety

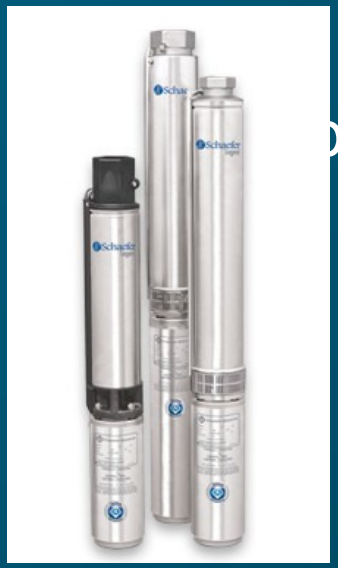
- Characterized by a suffocating sulfurous odor
  - **Inhalation:**
    Mists and vapors cause irritation of respiratory tract. Can cause systemic acidosis or pulmonary edema at moderate concentrations.
    Ingestion:
    Corrosive to the mouth, throat, and esophagus, with immediate pain and burning. Uncontrolled vomiting may occur.
    Skin contact:
    Corrosive; symptoms of redness, pain, and severe burn can occur.
    Eye contact:
    Corrosive; contact can cause blurred vision, redness, pain, and severe tissue burns.

Pump cavitation

- Gas adheres to the impellers and blocks water
- Cavitation reduces volume of water pumped
- Damages impellers when the gas bubble collapses, leading to premature pump failure

Pump cavitation

- When impeller is at rest, gas will migrate off the impeller and float up
  - Why *check valve* is taken out of the pump head and placed one joint above pump head
  - Shroud on *submersible pump*
    - Shroud is not as effective as just setting at a deeper depth in the water well



Images courtesy of Danfoss Flomatic and Franklin Pumps

Water wells that “breathe”

- Wells typically have a surface casing and a top of completion interval that is above the nonpumping water level in the well
- Unsaturated permeable rock above the water level and below the top of the completion interval
- With exposure of unsaturated permeable rock to the completion interval, air can move into or out of the rock

Water wells that “breathe”

- Affected by barometric pressure
  - High – wells take in oxygen
  - Low – wells expel oxygen
  - Volume of air depends on factors such as:
    - Magnitude of pressure change
    - Permeability of exposed rock
    - Size of permeable reservoir into which air is flowing

Water wells that “breathe”

- Can lead to oxygen deprivation for workers at well site in pit
- Deadly low oxygen levels as low as five percent
  - Norm is 20.95%
  - Anything below this level is not normal
  - Below 16% can be life-threatening
- Nitrogen levels as much as 90 percent
  - Norm is 78.08%

Can a gas-producing water well be used for water supply?

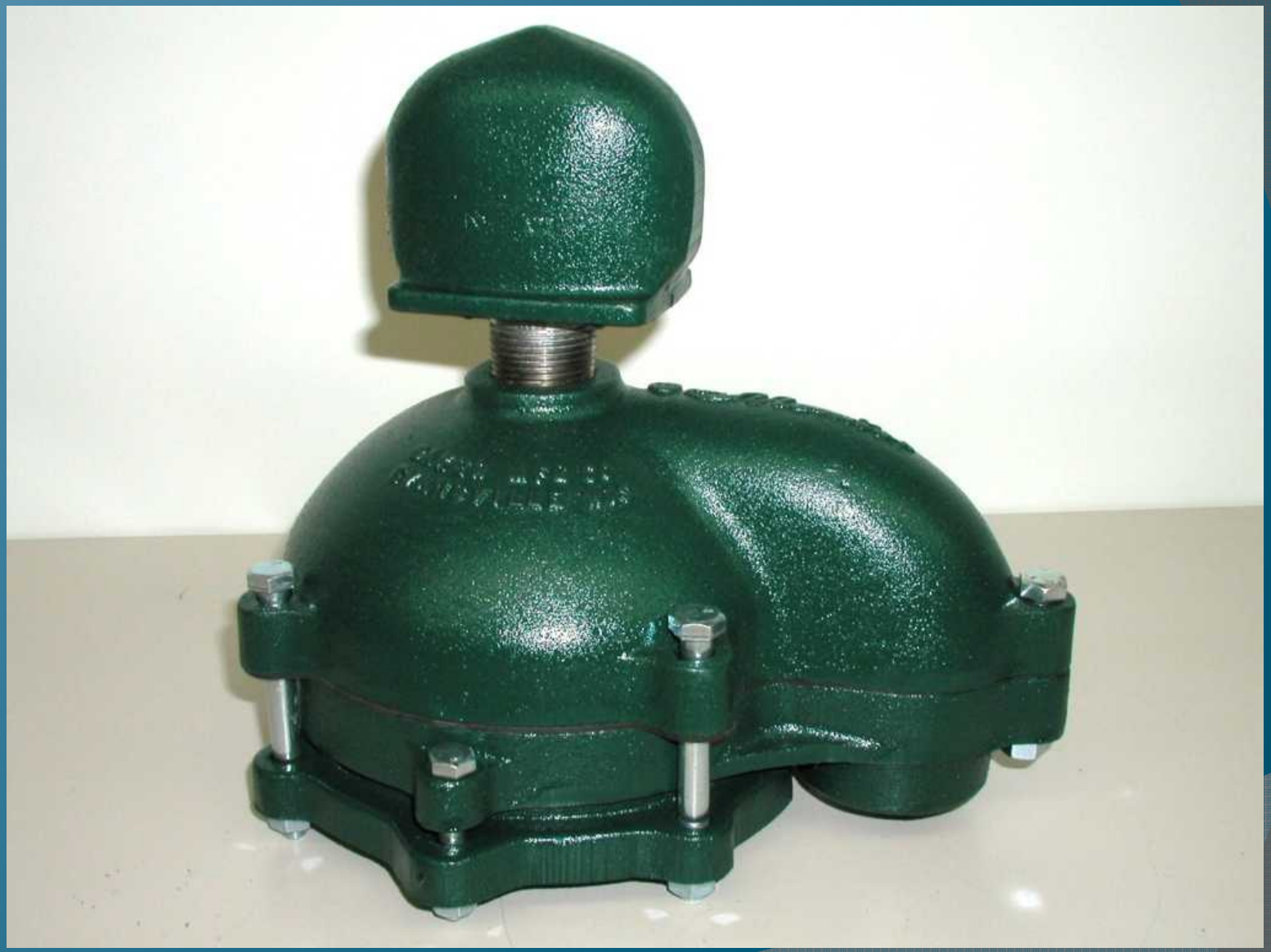
- Yes

Can well design mitigate the risks?

- Not unless the gas formation is cased off and water obtained from another aquifer

Can well design mitigate the risks?

- What to do when gas is present in the water well?
  - Notify the property owner
  - Vent to atmosphere – not to an enclosed space!
    - Vent through well cap
      - Normally wellhead is outside and normal vent is adequate. If wellhead is inside an enclosure or a well house, vent wellhead to outside and above eave height of the well house.



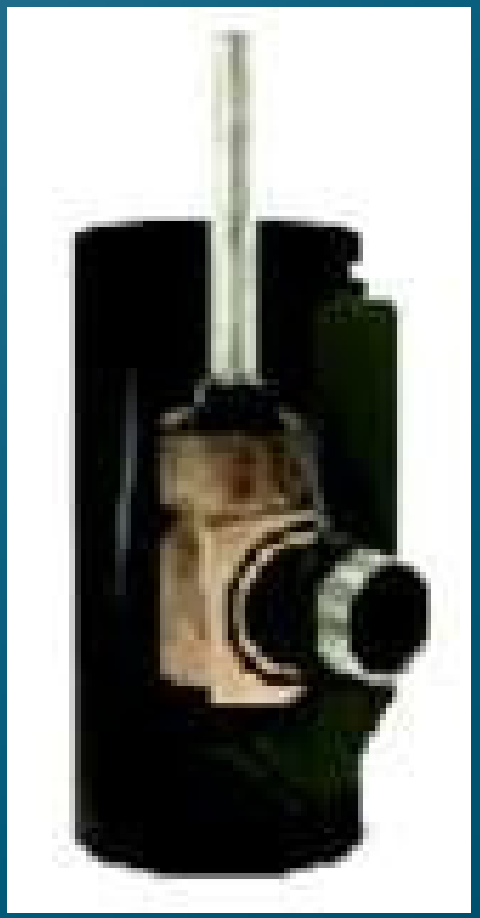
Vented well cap image courtesy of Baker Monitor Manufacturing

Well houses, well pits, and basement wells

- Gas concentration in confined spaces
  - Gas will build up in the air until such density that it will ignite.
  - A contractor's war story
    - Tenant farmer winterized a well pit by blocking the well pit vents with insulation.
    - On a spring evening farmer was sitting on the porch just admiring the scene.
    - Water was used, pressure switch engaged causing a spark, and the well pit cover was launched 50 feet straight up.
    - After farmer changed underwear, contractor got a call.

Why were there well pits?

- Predate pitless adapters
- Frost- and freeze-proof the pumping system, including pressure system



Pitless adapter image courtesy of Baker Manufacturing

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