



# Underground Injection Control Geologic Sequestration Rule Training Workshop: Injection Well Construction (40 CFR 146.86)

## Purpose: Well Construction

- Ensures that:
  - Class VI wells are constructed with materials compatible with injectate/formation fluids
  - Designed for the lifetime of the GS project
  - USDWs are isolated and no fluid movement occurs into/between USDWs or other unauthorized zones (prohibited by the regulations)
  - Class VI well owners/operators are able to meet construction and operating requirements of the GS Rule

40 CFR 146.86(a) – 146.86(c)

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Proper injection well construction has been the cornerstone of EPA's UIC Program and is also a critical component of the Class VI well requirements. The potential consequences of improper well construction include disrupting carbon dioxide injection operations and, more importantly, creating conduits for the migration of carbon dioxide out of the injection zone that may result in the endangerment of USDWs.

Therefore, a Class VI permit application must include a description and graphics of the well construction. The UIC Program Director reviews the proposed construction information to ensure that well design, materials, and construction will be appropriate for the injection of carbon dioxide and the lifespan of the GS project. Any deviations from the construction plan must be first approved by the UIC Program Director. After construction of the well and prior to authorizing injection, the Director reviews construction records and determines whether the well was constructed in a way that prevents the migration of fluids out of the injection zone.

## Class VI Well Construction

- Elements
  - Surface and long-string casings
  - Cement
  - Tubing and packer

40 CFR 146.86(a)

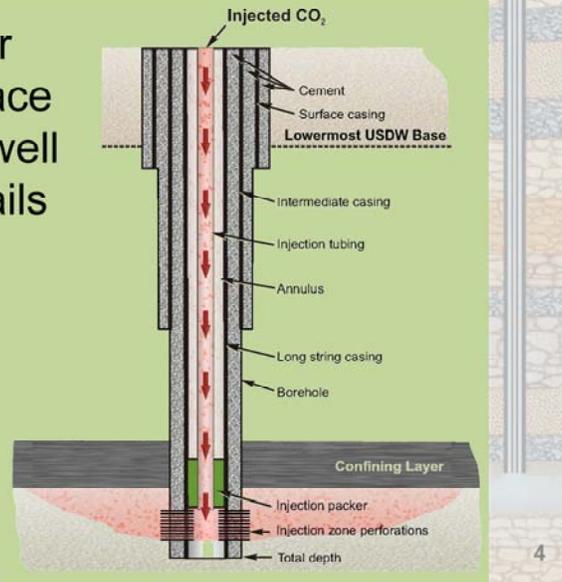
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Specific aspects of Class VI well construction that the Director must evaluate include the well's surface and long-string casing, cement, and tubing and packer. There are two concerns when reviewing these construction materials: the first is a prevention of fluid movement into or between USDWs or other unauthorized zones; the second consideration is that the well construction needs to be compatible with any injection well operations that will be required (i.e., use of testing devices and workover tools and monitoring of the annulus space).

## Well Construction: UIC Program Director Reviews

- Schematics/other drawings of surface and subsurface well construction details
- Construction procedures
  - With permit application

40 CFR  
146.82(a)(11)-(12)



In order for the Director to evaluate the well materials, design, and construction, a Class VI permit application must contain detailed well schematics and drawings, in addition to the construction procedures. The surface casing must extend through the base of the lowermost USDW and be cemented up to the surface [40 CFR 146.86(b)(2)]. The long-string casing must extend to the injection zone and be cemented to the surface [40 CFR 146.86(b)(3)].

Note: While this schematic depicts a Class VI injection well with an intermediate string, it is not a specific requirement of Class VI well construction. However, the UIC Program Director has the discretion to require that the owner/operator use an intermediate string on any proposed well that may benefit from it.

## Well Construction: UIC Program Director Reviews (cont'd.)

Casing and Cementing	Tubing and Packer
Depth to injection zone	Depth of setting
Proposed injection and external/internal pressures	Max proposed injection and annular pressures
Axial loading	Proposed carbon dioxide stream injection rate and volume
Hole size	Size of tubing and casing
Size/grade of casing strings; use of sufficient numbers of centralizers	Tubing tensile, burst, and collapse strengths
Down-hole temperatures	
Lithology of injection/confining zones	
Type/grade of cement	
Carbon dioxide stream characteristics	

40 CFR 146.86(b)  
and 146.86(c)

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This slide specifies the information the UIC Program Director must receive to determine and specify well construction requirements: Remember that “all well materials must be compatible with fluids with which the materials may be expected to come into contact” [40 CFR 146.86(b)(1)].

- For casing and cementing:
  1. Depth to the injection zone.
  2. Proposed injection pressure, external pressure (formation pressure), and internal pressure (annular pressure).
  3. Axial loading of tubulars
  4. Hole size.
  5. Size and grade of all casing strings (wall thickness, external diameter, nominal weight, length, joint specification, and construction material) including use of a sufficient number of centralizers
  6. Down-hole temperatures.
  7. Lithology of the injection and confining zones.
  8. Type or grade of cement and cement additives; proper extension to the injection zone and cement circulating to the surface
  9. Quantity, chemical composition, and temperature of the carbon dioxide stream.
- For tubing and packer: fluids must be injected through tubing with a packer set at a depth opposite a cemented interval at the location approved by the UIC Program Director [40 CFR 146.86(c)2].
  1. Depth of setting.
  2. Maximum proposed injection (which is the internal) pressure.
  3. Maximum proposed annular (which is the external) pressure.
  4. Proposed injection rate (either intermittent or continuous) and volume (mass) of the carbon dioxide stream.
  5. Size of tubing and casing.
  6. Tubing tensile, burst, and collapse strengths.

## Well Construction: UIC Program Director Reviews (cont'd.)

### Additional Information on Cement

Is there a sufficient number of required centralizers to ensure uniform grouting in the long string casing?

In cases where cement cannot be recirculated to surface, demonstration must be made that cement will not allow fluid movement behind the well bore

Evaluation of cement quality, quantity, integrity and location

### Additional Information on Carbon Dioxide Stream and Formation Fluids

Characteristics of carbon dioxide stream (chemical content, corrosivity temperature, density)

Characteristics of formation fluids (geochemistry/chemical content, corrosivity)

40 CFR 146.86(b)(3)-(5), (b)(1)(v) & (ix) & (c)(3)(ii)

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The UIC Program Director will also need to evaluate:

Is there a sufficient number of required centralizers to ensure uniform grouting in the long string casing? [Required at 40 CFR 146.86(b)(3)].

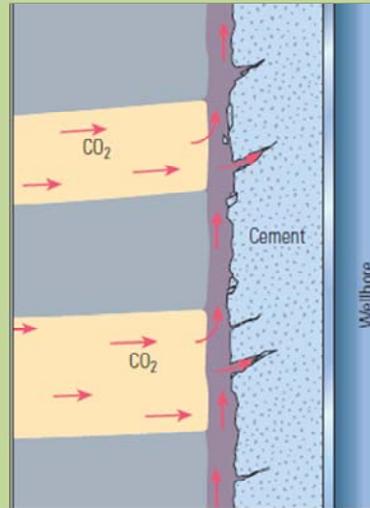
- Additional information regarding cement:
  1. In cases where the cement cannot be recirculated to the surface and an alternative cementing method is approved by the Program Director, he or she must then evaluate the owner/operators demonstration, based on well logs, that the cement will not allow fluid movement behind the well bore; and
  2. A technical evaluation of the quantity, quality of the cement and cement additives, cement bond, its integrity and location, and verification using technology capable of identifying channels or microannuli to ensure protection of USDWs and evaluation cement quality radially.

Note: In order to meet the Class VI requirements, the injection well **must be cemented to the surface**, although the Program Director may approve alternate methods of cementing.

- There is additional information that is, strictly speaking, not part of well construction, but it must be evaluated for compatibility with the carbon dioxide stream and injection formation fluids:
  1. Characteristics of the carbon dioxide stream (chemical content, corrosivity, temperature, and density).
  2. Characteristics of formation fluids (geochemistry/chemical content and corrosivity).

## Well Construction: UIC Program Director Reviews (cont'd.)

- Considerations for adequacy of Class VI construction:
  - Sufficient well material strength
  - Compatibility of materials with carbon dioxide stream
  - Appropriate isolation of injection zone from USDWs



To continue the idea of compatibility of well materials, the materials used for well casing, cement, and tubing and packer must also be evaluated to ensure compatibility with down-hole operational pressures, temperatures and stresses. The information submitted must be reviewed by the UIC Program Director in three important areas to determine the adequacy of the Class VI well:

1. That the well materials have sufficient strength;
2. That the materials are compatible with the carbon dioxide stream, native formation fluids; and
3. That the well construction will properly isolate the injection zone from USDWs.

*Image: "Carbon Dioxide Capture and Storage—A Solution Within." Autumn 2004.*

## Some Class VI Program Well Construction Resources

- For more information on Class VI well construction, refer to:
  - Draft UIC Program Class VI Primacy Application and Implementation Manual
  - Draft UIC Program Class VI Well Construction Guidance
  - EPA's Class VI Web site:  
<http://epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>

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This slide lists three Class VI well construction resources that are currently available:

- The Draft UIC Program Class VI Primacy Application and Implementation Manual to be posted soon to EPA's website.
- The Draft UIC Program Class VI Well Construction Guidance available on EPA's website.
- And EPA's Class VI website:  
<http://epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>.



## Pre-Injection Activities (40 CFR 146.87)

Logging, Sampling, and  
Testing Prior to Injection Well  
Operation

## Purpose: Pre-Injection Activities

- Determine fluid characteristics in relevant geologic formations to assure conformance with construction requirements
- Establish accurate baseline data
- Verify construction specifications

40 CFR 146.87(a)

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The owner or operator of a Class VI injection well is required by the regulations to conduct several tests of the injection well and surrounding formations prior to injection. The purposes of these testing activities are to: 1) ensure that the properties of the injection & confining zones that serve as input parameters in the computational modeling, such as depth, thickness, porosity, permeability, lithology, and salinity of any formation fluids, are accurately known; 2) establish accurate baseline data against which future measurements (for monitoring and testing purposes) may be compared; and 3) verify the construction specifications of the injection well.

## Pre-Injection Activities: UIC Program Director Reviews

- Descriptive report of well logs
- Detailed report regarding cores and formation fluid samples
  - Both reports prepared by a knowledgeable log analyst
- Results of formation testing
- Results of additional tests
  - All prior to authorizing injection well operation

40 CFR 146.87(a)

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The owner or operator must submit to the UIC Program Director a descriptive report of well logs conducted prior to injection, a detailed report regarding cores and formation fluid samples taken during well construction, and the results of formation testing and additional tests. These reports must be prepared by a knowledgeable log analyst. Following review of these data, and in consideration of all other submitted data and site-specific conditions, the Director may make a determination regarding whether injection is authorized. The following slides discuss these requirements in greater detail.

## Report of Well Logging, Sampling, & Testing Results

- Results of deviation checks for wells constructed by enlarging pilot holes
- Results of well logging conducted before/upon installation of surface/long-string casing
- Internal and external MITs
- Schedule of testing activities

40 CFR 146.87(a)(1)-(4) & (f)

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This slide lists the data and information that must be submitted to the UIC Program Director in the descriptive report of well logging, sampling, and testing results:

**First, the results of deviation checks for wells constructed by enlarging a pilot hole.** In cases where the injection well borehole is constructed by enlarging a pilot hole, a deviation check is recommended to ensure that the enlarged well bore does not diverge from the pilot well bore. The deviation checks may include testing of the well bore in three dimensions, and/or the depth, inclination, and hole direction at certain intervals through the hole. Instruments used for deviation checks include accelerometers, magnetometers, gyroscopes and inclinometers. The Director may evaluate the results of deviation checks, including the quality and quantity of data provided, and independently assess the presence of divergences within the holes. If the Director suspects divergences, he or she may request further action be taken by the owner or operator. Checks must be at sufficiently frequent intervals to determine the location of the borehole and to ensure that avenues for fluid movement in the form of diverging holes are not created during drilling.

**The second bullet refers to the open and cased hole logs conducted before and upon installation of the surface and long-string casings.** The owner or operator must submit to the Director results of the following tests:

- Resistivity, spontaneous potential, and caliper logs before surface casing is installed.
- Cement bond and variable density log and a temperature log after surface casing is set and cemented.
- Resistivity, spontaneous potential, caliper, gamma ray, and fracture finder logs, and any other logs before the long-string casing is installed.
- Cement bond and variable density log and a temperature log after long-string casing is set and cemented.

The UIC Program Director may want to ensure that all well logs were conducted properly and used the best available techniques. This is another opportunity to independently evaluate the formation and injection well properties based on the results of well logging for comparison to the owner's or operator's interpretation.

**Third, a report on the results of internal and external mechanical integrity tests.** This report will include results from tests performed during and after construction, such as pressure tests with liquid or gas, tracer surveys, oxygen-activation logging, temperature or noise logs, casing inspection logs, or any alternative tests approved by the UIC Director.

**And finally, Schedule of testing activities.** The owner or operator must provide the UIC Program Director with the opportunity to witness all logging and testing activities as they are being performed. The owner or operator must submit a schedule of such activities to the Director 30 days prior to conducting the first test, and submit any changes to the schedule at least 30 days prior to the next scheduled test. The UIC Program Director may approve (or disapprove) of the proposed schedule or any changes to it.

## Report on Rock Cores and Formation Fluids

- Data on cores from injection/confining zones
- Data on formation fluid samples from injection zone



40 CFR 146.87(b) & (c)

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Another report which must be submitted as part of Class VI injection well permit application materials describes the characteristics of the rock cores and formation fluids that were sampled. Remember that there is information required to be submitted prior to well construction [40 CFR 146.82(a)] and information required to be submitted prior to commencement of injection operations [40 CFR 146.82 (c)].

The report will present the data on the whole cores or sidewall cores that were collected from the injection and confining zone(s) during construction of the Class VI injection well, as well as in any other zones (as required by the Director). The report will need to detail characteristics of the collected cores, including permeability, porosity, and mineralogical characteristics. If cores from the injection well cannot be obtained, data based on cores from nearby wells may be accepted by the Director.

The concerns of the Director are to ensure that adequate cores have been collected, and that the results of the testing of the cores are appropriate. Furthermore, the Director may independently evaluate the data collected from coring and well logging, and arrive at his or her own independent analysis of the characteristics of the injection, confining, and any additional zones based on the data.

**The required data on formation fluid samples collected from the injection zone** include temperature, pH, conductivity, reservoir pressure, and static level of fluids. The UIC Program Director must ensure that the injection zone is not a USDW, based on the measured conductivity. Formation fluid data also provide a baseline with which to make future comparisons to the monitoring data collected over time, with the goal of assessing the impact of the injection project on fluid characteristics and pressures. Finally, these data provide inputs to the computational modeling.

## Formation Testing Program Review

- Proposed formation testing program
  - With permit application
- Results of formation testing program
  - Prior to authorizing injection well operation



40 CFR 146.82(a)(8) and 146.87

Just to reiterate, all of these pieces of the formation testing program must be proposed in the permit application. This gives the Program Director the opportunity to request that additional tests be planned, if he or she is not certain that the proposed testing program will collect sufficient data to adequately characterize the injection and confining zones. After the owner or operator conducts formation testing, her or she must submit the results to the Director, who will use the results to determine if injection well operation should be authorized

## Additional Tests Prior to Injection Well Operation

- Tests to determine hydrogeologic and physical properties of injection/confining zones
  - Fracture pressure test (in-situ formation stress test)
  - Pump or injectivity test

40 CFR 146.87(e)

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There are additional data and information about the hydrogeologic and physical properties of the injection and confining zones, which must be submitted by the owner or operator prior to injection. This information includes: the results of fracture pressure testing, and pump or injectivity testing.

## Some Class VI Program Pre- Injection Activities Resources

- For more information on pre-injection activities, refer to:
  - Draft UIC Program Class VI Primacy Application and Implementation Manual
  - Draft UIC Program Class VI Testing and Monitoring Guidance (forthcoming)
  - EPA's Class VI Web site:  
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>

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Some Class VI Program pre-injection activities resources that are currently available are:

- The Draft UIC Program Class VI Primacy Application and Implementation Manual.
- The Draft UIC Program Class VI Testing and Monitoring Guidance.
- And EPA's Class VI website:  
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>.