Underground Injection Control Program; Water-Brine Interface Mechanical Integrity Test for Class III Salt Solution Mining Injection Wells

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SUMMARY: The Director of the Office of Ground Water and Drinking Water, Environmental Protection Agency (EPA), is granting final approval for the use of the Water-Brine Interface mechanical integrity test as an alternative to the tests specified in the Code of Federal Regulations, 40 CFR 146.8(b), for the demonstration of no significant leaks in the casing, tubing, or packer. The Agency intends this approval to apply only to Class III salt solution mining injection wells on a national basis. The test is referred to as the Water-Brine Interface Method.

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 146

(FRL-4091-7)

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The Agency intends this approval to apply only to Class III salt solution mining injection wells on a national basis. The test is referred to as the Water-Brine Interface Method.

DATES: The final approval for this alternative mechanical integrity test becomes effective January 10, 1992.

FOR FURTHER INFORMATION CONTACT: Jeffrey B. Smith, Office of Ground Wate and Drinking Water (WH-550G), U.S. EPA, Washington, DC 20460 at: (202) 260- 5586.

SUPPLEMENTARY INFORMATION:

I. Background

The Safe Drinking Water Act (SDWA) (42 U.S.C. 300h, et seq.) is intended to protect underground sources of drinking water (USDWs) from contamination by underground injection. One of the cornerstones of the Underground Injection Control (UIC) Program is the assurance that the mechanical integrity of the wells is maintained. Mechanical integrity (MI) is defined as the absence of significant leaks in the casing, tubing, or packer, and the absence of significant fluid movement into a USDW through vertical channels adjacent to the injection well bore. This movement can occur from either the injection zone, from other salt water formations or aquifers. Acceptable methods of evaluating mechanical integrity are specified in 40 CFR 146.8 for State programs administered by EPA and in the program applications of the States with primary enforcement responsibility for injection wells. Section 146.8(d) states that the Director may allow alternative mechanical integrity tests if the Administrator approves the alternative method. The Administrator has delegated authority to approve alternative test procedures to the Director of the Office of Ground Water and Drinking Water.

Operators of Class III salt solution mining wells need an alternative mechanical integrity test to the standard annular pressure test because of the great difficulty using conventional tubing and packer techniques.
Typically, a tubing and packer would have to be installed in the well in order to conduct a standard annular pressure mechanical integrity test.
Scale, or hardened mineral deposits, formed on the interior surface of the casing often makes establishment of a seal between the packer element and the inside diameter of the casing very difficult. Thus, wells that actually possess mechanical integrity may not pass the test because the packer cannot be properly seated. In addition, operators that use the standard annular pressure test must shut down production in a cavern and bleed off the pressure to enable the tubing and packer test string to be installed in the well. These physical requirements can interrupt the production of brine from a cavern for several days and cause major logistical problems at the processing facility due to the loss of feedstock.

EPA granted interim approval for a period of two years (from September 18, 1989 to September 18, 1991) for the use of the alternative mechanical integrity test known as the Water-Brine Interface Method. EPA accepted written comments and referenced data on test results through February 19, 1991. The Salt Institute and Ohio Department of Natural Resources submitted results from 54 Class III wells that were tested using the prescribed Water- Brine Interface methodology during the period from September 18, 1989 through February 19, 1991. Only test data was submitted; neither party offered any comments on the test methodology. EPA reviewed and carefully evaluated all submitted test results. As a result of this review, EPA made several modifications to the overall test procedure and incorporated those modifications in this final approval. The modified procedures are identified under C. Procedures.

Although the Water-Brine Interface test is not a mandatory technique for demonstrating mechanical integrity, the methodology, subject to the conditions and procedures discussed in this notice, does provide the necessary information to demonstrate reliably whether a well has a leak in the casing or tubing. The ultimate discretion and authority for specifying MIT procedures that will ensure safeguarding USDWs rests with the appropriate UIC Director. EPA approves the amended Water-Brine Interface Test Method as an alternative MIT for Class III salt solution mining wells only.

II. Application and Description of the Test

A. Application

The field design of a salt solution mining operation is dependent upon the morphology of the salt formation being mined. If the salt formation is an isolated dome or a very thick layer with limited lateral extent, single producing wells are commonly used. In these instances, one well is drilled and equipped to leach out a single cavern. The well employs a string of surface casing to protect underground sources of drinking water (USDWs). A string of production casing is installed inside the surface casing to the salt-bearing formation. Both casings are cemented to the surface. The well is then drilled to the desired depth and a string of tubing is installed inside the production casing.

Water or partially saturated brine is injected through either the tubing or the casing-tubing annulus to dissolve the salt formation. The brine is then produced up the casing-tubing annulus or the tubing, respectively. As salt dissolution proceeds, the tubing string may then be raised or lowered into the cavern to facilitate dissolving and removal of brine. Upon reaching the surface, the brine flows through a dedicated pipeline to a nearby processing plant.

If the salt formation is bedded and geographically extensive, two or more wells are usually drilled and then linked horizontally. In a cavern containing two wells, one well is used for injection and the other for production. Large caverns developed by two or more wells are termed galleries. Once the wells are interconnected, fresh water or partially saturated brine is pumped down one well into the gallery to dissolve the salt formation. The brine is withdrawn from the gallery and transported to the surface by another well (or wells). If there are more than two wells in the gallery, the additional wells may be used for either injection or production.

Wells are constructed almost exactly like those employed in single well caverns; a string of surface casing is set below the base of the USDWs and an inner production casing is set into the top of the salt formation. A tubing string may or may not be run inside the production casing.

Well operators maintain pressure within the cavern that is sufficient to cause the produced brine to flow through the wells, up to the surface and through surface pipelines to the processing facilities. This practice creates a pressure differential between the well bore and any aquifer adjacent to it.
This pressure differential would result in loss of fluid out into a formation if there was a failure of the outer casing string. To ensure that USDWs are protected from possible degradation, the wells must periodically undergo testing for mechanical integrity.

None of the variations in geology, well construction, field design or operating pressure requirements affect the proposed alternative test.

B. Testing Method

Fresh water, or a fluid of lower specific gravity (e.g., oil) approved for use by the Director, is loaded into the casing or tubing string between the wellhead assembly and the cavern brine. Pressure must be applied to the fresh water column to displace the denser brine from the casing. In instances where a low specific gravity oil is substituted for fresh water, in order to provide accurate results, special conditions will be required. These conditions are specified in a following section.

Due to the density contrast and buoyancy forces, a relatively distinct interface between the two liquids (fresh water and brine) is established. The contribution of the buoyant force to the pressure at the wellhead can be determined by measurements using a precision pressure gauge before and after the fresh water is introduced into the well. Since the fresh water fluid column is under pressure (i.e., application of pressure is necessary to displace the brine out of the casing and into the cavern), the loss of any fresh water from the casing, through a leak or by intentional release, will cause the interface between the water and the brine to move upward in the casing. This upward movement of the column of brine will cause a drop in wellhead pressure. The Water-Brine Interface Method indicates leakage through changes in the wellhead pressure which result from the upward movement of the water-brine interface. A monitoring methodology, which can accurately detect very small pressure changes using deadweight pressure gauges or electronic pressure transducers, have been developed.

By measuring the change in pressure, the upward movement of the water-brine interface in the casing can be calculated. The extent of movement is obtained by dividing any pressure drop observed during the test by the product of the difference of the specific gravities of the two liquids (above and below the interface) and a conversion constant (based upon the pressure gradient for fresh water) of 0.4331 psi per foot.

NPC M = ------------- (SG1-SG2) x k
where:
M = the upward movement of the interface (in ft) NPC = the net pressure change in pounds per square inch (psi) SG1 = the specific gravity of the cavern brine SG2 = the specific gravity of the injected fluid, and k = 0.4331 psi/ft, a conversion constant (the pressure gradient for fresh water)

The rate of leakage can be determined by multiplying the casing volume per foot of length by the distance which the interface has moved up, and dividing the result by the length of the test period.

Cv x M L = ------ Hrs
where:
L = the rate of leakage (in gals/hr) Cv = the casing volume per foot of length (in gals/ft) M = the upward movement of the interface (in ft), and Hrs = the length of the test period in hours

The sensitivity of the test is a function of two factors--(1) the duration of the test; and, (2) the sensitivity of the pressure gauges.

With proper design, almost any sensitivity can be achieved, particularly by extending the duration of the test.

C. Procedure

The prescribed test procedure is as follows:

1. Preflush the well by pumping a minimum of one casing volume of fresh water through the well to ensure that no salt crystallization remains in the casing string.

2. Withdraw brine from the test well until the specific gravity of the brine remains constant. Measure and record the specific gravity value.

3. Measure and record the test wellhead pressure.

4. Withdraw brine from a reference well until the specific gravity of brine is constant. Shut in the reference well and take a pressure reading. Record the wellhead pressure. Tubing may serve as the reference well and the casing- tubing annulus functions as the test well.

5. Inject fresh water (or oil) into the test well in sufficient quantities to fill all but the bottom 50 ft of the production casing. To achieve this, inject fresh water (or oil) until the wellhead pressure increases by an amount calculated using the following formula:
Pressure increase = (D-50) x (SG1-SG2) x k where:
D = depth of the well (in ft) SG1 = the specific gravity of the cavern brine SG2 = the specific gravity of the injected fluid (water or oil), and k = 0.4331 psi/ft, a conversion constant (pressure gradient for fresh water)

Determine whether there has been any change in the measured pressure in the reference well during the injection phase. Add the net pressure change to the calculated pressure increase for the test well to obtain the final pressure necessary for proper placement of the interface. (Where the presence of a partially saturated brine could adversely affect the accuracy of test results, an oil with a low specific gravity may be substituted for fresh water in order to provide a sufficient density contrast. The use of oil under these specific circumstances represents a modification to the original interim test procedure).

6. In order to avoid mixing and maintain a sharp interface, inject the fresh water (or oil) at a rate which will not cause the interface to move downward at a rate greater than 20 feet per minute.

7. Wait a minimum of 36 hours for the test and reference wells to come to

temperature equilibrium.

8. At the conclusion of the waiting period, compare the pressures of both the test and reference wells against the initial pressures at the start of the waiting period to assure that there has been no significant movement of the interface. If pressure differences can be explained by the wells coming to temperature equilibrium, then the test may proceed. The UIC Director shall determine whether the submitted explanation is accurate and adequate. If pressure differences cannot be explained by changes caused by the wells coming to temperature equilibrium, the operator must withdraw a minimum of one casing volume of fluid from both the test and reference wells and restart the test at step 1.

9. The operator must simultaneously measure the wellhead pressures for both the test and reference wells. The pressure readings must be taken using a deadweight pressure gauge or pressure transducer system having a sensitivity of 0.1 psi or greater. If a deadweight pressure gauge is used, then a minimum of ten readings should be taken, at one minute intervals, over a ten minute period. If an electronic pressure transducer system is used then one reading during the ten minute measurement period is sufficient. (Since electronic pressure transducers continuously calculate an averaged signal response, only one reading is required. This is a modification to the original interim test procedure).

10. Calculate the average pressure at the test well and the reference well and the difference between them. Record all data in a standard format.

11. Repeat Steps 9 & 10, at two hour intervals, for a total test period of eight hours (5 averaged readings).

12. For each two hour intervals, and the eight hour test period, calculate the net pressure change rate at the test well as follows:

P (start) - P(end) NPCR = ------- Hrs
where:
NPCR = Net Pressure Change Rate (psi/hr)

P(start) = average pressure of test well at the beginning of the test minus average pressure of reference well at the start of the test (psi)

P(end) = average pressure of the test well at the conclusion of the test minus the average pressure of the reference well at the conclusion of the test (psi)

Hrs = hours in the test period

13. If the calculation for the eight hour test period indicates a net pressure change rate of less than 0.05 psi/hr, the well has demonstrated mechanical integrity. Pressure change rates that are greater than 0.05 psi/hr indicate a lack of

mechanical integrity.

III. Basis for Determination

EPA developed the initial requirements and limitations of the testing method to demonstrate mechanical integrity pursuant to 40 CFR 146.8(b) after considering test results for demonstration wells at the Morton Salt Plant at Rittman, Ohio on July 5-13, 1988. Additional confirmation tests were run on June 16-20, 1989. Fifty-four (54) independent well tests using the methodology were conducted during the interim approval period from September 18, 1989 to February 19, 1991. Test results were submitted to the EPA for independent review and analysis by The Salt Institute and the Ohio Department of Natural Resources.

Further consideration was given to the following technical documents:
(1) "Significance of Regulatory Constraints on the Operation of Packerless Injection Wells." K.I. Kamath, et. al. SPE #17047.

(2) "Solar Ponds Collect Sun's Heat." R.K. Multer, Chemical Engineering, March, 1982.

(3) "The Salt Stabilized Solar Pond for Space Heating--A Practical Manual." Peter R. Flynn and Ted H. Short, Ohio State University, Department of Agricultural Engineering.

IV. Special Conditions

A. Limitations for Conducting the Water-Brine Interface Method Mechanical Integrity Test

The following are limitations for running the Water-Brine Interface Method mechanical integrity test:

1. The brine in the test well must have a specific gravity >/=1.1 (be at least 50% saturated) for the test to be run using fresh water (S.G.=1.0). If the brine has a specific gravity <1.1, then an oil having a specific gravity <0.9 must be substituted for the fresh water.

2. Adequate precautions should be taken, as necessary, to ensure that there is no salt crystallization inside the casing prior to starting the test procedure.

3. A reference well must be used.

4. All wells must be tested at pressures that are equal to or greater than the normal operating pressures, but be no less than 100 psi. If a facility has a normal operating pressure that is less than 100 psi, the Director has the discretion to

permit testing at the lower pressure.

5. The test well must be filled with a lower specific gravity fluid to within fifty feet of the bottom of the casing. However, if the casing or tubing string extends >/=50 feet below the top of the salt cavern, then the interface may be established up to 50 feet above the estimated top of the cavern.

6. The test and reference wells must be shut in for a minimum of 36 hours to ensure that the wells reach temperature equilibrium prior to initiation of the test. Failure of the wells to reach temperature equilibrium will result in "false negative" test results and the wells will fail the mechanical integrity test.

7. Deadweight pressure gauges or electronic pressure transducer systems may be used to record pressure changes. Pressure measuring devices must have a certified minimum sensitivity of 0.1 psi.

8. Wellhead pressures for the reference well and the test well must be read simultaneously. If a deadweight pressure gauge is used then at least 10 readings should be taken every two hours.

9. The maximum test period shall be 8 hours. The average hourly pressure change should be calculated based upon a continuous 8 hour test period.
Averaging results from test periods greater than 8-hours may be authorized only by the Director.

B. Determination

The Water-Brine Interface Method, subject to the conditions and procedures discussed in this notice, provides the necessary information to demonstrate reliably whether a well has a leak in the casing or tubing. EPA is approving the test for Class III salt solution mining injection wells in all States.

Dated: January 2, 1992.

James R. Elder,
Director, Office of Ground Water and Drinking Water.

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Legal Publications:

- Pub. Law 78-410 SEC. 1401 -- Public Health Service Act (Act of 7/1/44)
- Pub. Law 93-523 SEC. 2 -- Safe Drinking Water Act (Act of 12/16/74)

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