

- I. FORMATION TESTING PROGRAM** - Describe the proposed formation testing program. For Class I wells the program must be designed to obtain data on fluid pressure, temperature, fracture pressure, other physical, chemical, and radiological characteristics of the injection matrix and physical and chemical characteristics of the formation fluids.

For Class II wells the testing program must be designed to obtain data on fluid pressure, estimated fracture pressure, physical and chemical characteristics of the injection zone. (Does not apply to existing Class II wells or projects.)

For Class III wells the testing must be designed to obtain data on fluid pressure, fracture pressure, and physical and chemical characteristics of the formation fluids if the formation is naturally water bearing. Only fracture pressure is required if the program formation is not water bearing. (Does not apply to existing Class III wells or projects.)

## **WELL LOGGING, CORING, AND TESTING PROGRAM**

### **Proposed Well Logging Program**

The following geophysical well logs will be run in the open-hole section of the surface casing hole of the CO<sub>2</sub> Injection Well:

- Platform Express (AITH Induction/Spontaneous Potential/Gamma Ray/Compensated Neutron/Triple Litho Density/Borehole Caliper)
- Modular Formation Dynamics Tester (MDT)

The following geophysical well logs will be run in the open-hole section of the protection casing (long string) hole of the CO<sub>2</sub> Injection Well:

- Platform Express (AITH Induction (or laterolog)/Spontaneous Potential/Gamma Ray/Compensated Neutron/Triple Litho Density/Borehole Caliper)
- Combinable Magnetic Resonance (Naco and Martin Formations from 2,960 to 3,660 feet or minimum run)
- Formation Micro-Imager survey (lower Supai to base of Martin Formations from 1,800 to 3,660 feet)
- Dipole Shear Imager

*Additional diagnostic logs and/or formation cores (whole core or sidewall cores) may be run at the discretion of the Arizona Utilities Project Team.*

The following cased hole geophysical well logs will be run after cementing the protection casing in place:

- Cement evaluation and casing inspection log
- Gyroscopic survey

- Differential temperature survey

*Additional diagnostic logs (such as a video log) may be run at the discretion of the Arizona Utilities Project Team.*

## **INJECTION ZONE AND CONFINING ZONE TESTING**

A whole core is proposed for the CO<sub>2</sub> Injection Well in the Martin Formation, based on anticipated funding. The core depth will be picked based on correlation from the offset wells and the mud log. The proposed conventional core may be supplemented or replaced with sidewall cores or horizontal rotary cores.

### **Conventional Coring**

<u>Core Size</u>	<u>Depth</u>	<u>Formation/Lithology</u>
7-7/8" x 4" x 30 feet	+/-3,600 feet	Martin Formation

Supplemental conventional coring in the injection zone may be conducted to obtain additional reservoir data. The Arizona Utilities Project Team will select the actual core point during the drilling of the CO<sub>2</sub> Injection Well, in consultation with the mud logger's correlation to offset wells. If insufficient formation core is recovered in any core run, the core run may be repeated at the discretion of the team, or sidewall coring may be conducted in the interval. The core depth will be adjusted relative to actual drilling depths encountered.

### **Sidewall Coring/Horizontal Rotary Coring**

Sidewall coring or horizontal rotary coring may be taken in the injection zone or the confining zone during the open-hole logging of the protection hole to supplement the conventional core data. The Arizona Utilities Project Team, based on the evaluation and percent recovery of the conventional core, will determine if sidewall coring is necessary and select actual core depths. If sufficient whole core is recovered, sidewall cores may not be taken in the CO<sub>2</sub> Injection Well.

### **Formation Fluid Sampling**

The CO<sub>2</sub> Injection Well will be back flowed (pumping or via nitrogen) to obtain background native formation fluids from the Martin Formation. The decision to collect fluid samples in other intervals, via either wireline or drillstem testing, will be made based on open-hole logging and the condition of the borehole at the time of logging operations. Any fluid samples collected will be transported to a selected laboratory for detailed analysis.

### **Step Rate Injection Test**

A step rate injection test using formation brine (recovered during well development operations) will be performed on the injection interval. An initial low rate, low injection pressure injectivity test will be performed to assess receptivity of the injection interval.

From these data, a detailed step rate test will be designed and performed, so that test injection pressures span the range from the measured initial shut-in pressure to a maximum pressure determined by multiplying the top of the completed injection interval depth by a value of 0.622 psi/foot of depth. It is expected that the 0.622 psi/foot of depth pressure gradient is below the parting pressure of the injection interval. For example, assuming a native background initial pressure equal to a freshwater gradient (0.433 psi/foot of depth) and a below ground depth of 3,445 feet to the top of the Martin Formation, the step rate test would be planned to span the pressure range of 1,492 psi (initial pressure) to 2,143 psi (maximum test pressure) at 3,445 feet below ground surface, or 651 psi above the native background pressure.

The step rate test will be initiated following pressure recovery from the low rate, low pressure initial injectivity test. Injection will be initiated and stepped up in equal rate increments using equal time intervals (one or two hours). The equal time increments should be sufficient to allow for proper rate stabilization of the injection pump(s) and allow sufficient time to overcome wellbore storage effects between each rate change (especially at the low rates when the well may be on a vacuum). General test procedure is as follows:

#### STEP-RATE TEST PROCEDURE:

1. The well will be shut in long enough prior to testing such that the bottom hole pressures approximate the initial shut-in formation pressure. Pressure gauges will be installed on the wellhead and downhole near the top of the perforated completion. The downhole gauge will include surface read-out, so that the test may be monitored.
2. A series of successively higher injection rates will be used. Both surface and downhole pressures will be read and recorded at the end of each rate and time step. Each rate step will last as long as the preceding rate (i.e., equal duration steps).
3. Injection rates will be controlled with a constant flow regulator that has been tested prior to use. Flow rates will be measured with a calibrated turbine flowmeter. Injection rates and surface and downhole pressures will be digitally recorded. Injection pressures will be measured and recorded for immediate evaluation and interpretation by recording and plotting each time step and corresponding pressure.
4. A plot of injection rates and the corresponding stabilized pressure values at the end of each step are expected to follow a constant slope straight line. If the slope reaches a point at which the formation fractures (i.e., “breakdown” pressure is exceeded), the slope of this plotted line will be observed to decrease. The injection pump(s) will be immediately stopped and the flow line valve will be quickly closed. Pressure will be allowed to bleed off into the injection interval.

The step rate test will be designed for either 5 steps (20 percent rate increase increments to 100 percent maximum rate) or 8 steps (15 percent rate increase increments to 100 percent maximum rate) to gather a sufficient number of points for valid test analysis. The step rate test results will be used to limit the maximum bottomhole injection pressure and surface injection pressure so that the reservoir and seal formations are not fractured.

### **Constant Rate Injection Test**

After the step rate injection test, a constant rate hydraulic test may be performed to further define aquifer properties. This may directly follow the last step of the step rate test. Pressure will be adjusted to maintain a steady injection rate for 8-12 hours, or until the remaining stored formation water is injected. Then the well will be shut in. Bottom hole pressure will be measured throughout the injection and recovery periods.

### **WELL TESTING PROGRAM**

Mechanical integrity tests will be performed during completion of the CO<sub>2</sub> Injection Well. The following tests will be performed:

- Pressure testing of the surface and protection casing to 70 percent of the manufacturer's rated internal yield pressure or one psi per foot of casing depth, which ever is less, for at least 30 minutes. A successful test is a drop of no more than 10 percent of the test pressure over the 30-minute time period. Test data will be digitally recorded and a copy of the test results will be maintained on location. The original copy of the pressure test record **MUST** be sent in to the Sandia Office and made part of the CO<sub>2</sub> Injection Well report.
- Pressure testing of the 5-1/2-inch protection casing by tubing annulus to confirm the mechanical integrity of the completion. The pressure test will be run at equal to the lesser of the maximum authorized injection pressure or 1,000 psi, provided that no testing pressure will be less than 300 psi. A successful test is a drop of no more than 10 percent of the test pressure over the 30-minute time period. Test data will be digitally recorded and a copy of the test results will be maintained on location. The original copy of the pressure test record **MUST** be sent in to the Sandia Office and made part of the CO<sub>2</sub> Injection Well report.
- Casing inspection and cement bond evaluation of the 5-1/2-inch protection casing from total depth to surface. Interpretation report to be prepared by the vendor.
- Radioactive tracer survey of the completed CO<sub>2</sub> Injection Well following perforation to show the absence of fluid movement in vertical channels adjacent to the well.
- Baseline and repeat reservoir saturation logging (RST log) to show the distribution of CO<sub>2</sub> adjacent to the well.