



**NITROGEN/BRINE INTERFACE MECHANICAL
INTEGRITY TEST (MIT)
PART I: CASING (INTERNAL) MIT
PART II: CAVERN (EXTERNAL) MIT**

Procedure #: UICLPG-20
(6/11)

Narrative:

K.A.R. 28-45-16 requires that each well and each cavern be tested for integrity every five years. The nitrogen/brine interface test is designed to evaluate the internal (well) mechanical integrity and/or the external (cavern) mechanical integrity. The MIT procedure consists of filling the cavern with brine and then injecting nitrogen into the well and establishing an interface at a depth appropriate for either a well or cavern test. The nitrogen test pressure should be equal to the maximum allowable operating pressure gradient based on the casing seat. The interface, temperature and pressure data are used to calculate the pre-test and post-test nitrogen volumes. Comparison of the pre-test and post-test nitrogen volumes and movement of the nitrogen/brine interface are used to evaluate the well/cavern integrity.

**TEST PROCEDURE SUMMARY
NITROGEN/BRINE INTERFACE MECHANICAL INTEGRITY TEST (MIT)
PART I: CASING (INTERNAL) MIT
PART II: CAVERN (EXTERNAL) MIT**

All nitrogen/brine mechanical integrity tests must be conducted by a party that has experience in conducting this type of test due to the complexity of the test and associated safety requirements. The test contractor must have knowledge of: 1) the pressure rating of the well and wellhead components; 2) the use of dead-weight tests or calibrated data loggers to verify brine and nitrogen pressure; 3) methods to track the volume of nitrogen injected before and during the test; 4) differential pressure monitoring to prevent collapse of the tubing; and 5) a working knowledge of other procedural tasks that ensure a viable and safe test.

The permittee is responsible for verifying that the party/company contracted to conduct the mechanical integrity test has experience and is qualified to conduct the test in a safe manner. Failure to follow test procedure and failure to submit any supporting data required by KDHE may result in the test being considered invalid by KDHE. An invalid test will not meet the regulatory requirement.

Submit a test plan as specified in Procedure #UICLPG-21 to KDHE for review and approval at least 30 days prior to test commencement. Do not commence test operations until approval for the plan is received from the Kansas Department of Health and Environment (KDHE).

TEST PREPARATION:

- Certify that pressure ratings of the wellhead and the tubulars are adequate for the test pressures.
- Visually inspect the wellhead.
- Ensure fittings are adequate to facilitate wireline equipment, nitrogen injection, and pressure instrumentation. Install an accurate electronic pressure recording system on the well's annulus and brine tubing.
- Remove all product (feasible) from the cavern prior to conducting the test.
- Note the presence of any product in the annulus.
- Coordinate the test time with KDHE so that KDHE may have the opportunity to witness the test.

PRE-PRESSURIZATION: (Typically for cavern test)

Prepressure the cavern with brine prior to nitrogen injection, if necessary. The compressibility of the cavern and the volume of nitrogen to be injected must be considered (estimated) in calculating the pressure required prior to nitrogen injection.

1. Record the volume of fluid injected and the rate of pressurization. The fluid used for pre-pressuring should be saturated brine. The rate of pressurization typically should not exceed 2.5 psi/min. The casing seat pressure is not to exceed the regulatory MAOP of either 0.75 or 0.8 psi/ft. K.A.R. 28-45-12 requires that a wellhead be equipped with a continuous pressure monitoring system that is capable of maintaining a pressure history before the well can be operated with a MAOP greater than 0.75 psi/ft. The well should be tested at the MAOP allowed by regulation.
2. Record the tubing and annulus pressures.
3. Monitor the cavern pressure until the rate of pressure change is 10 psi/day or less. Stabilization period must be a minimum of 24 hours.

PRE-NITROGEN INJECTION:

4. Check with nitrogen supplier for the nitrogen volume required for equipment “cool down”.
5. Nitrogen must be measured with a meter. Connect pressure and flow recording equipment to the wellhead so that accurate nitrogen pressure and volume data can be obtained for the test analysis.
6. Prior to nitrogen injection, conduct a temperature survey (base log) from the surface to 50 ft below the expected nitrogen interface for the casing or cavern MIT.
7. Conduct a density survey from 50 feet below the lowest expected nitrogen interface to 50 feet above the uppermost. Note the location of any product present in the annulus. Optimal logging speed for the density log is approximately 15 – 20 ft/min. Subsequent logging runs with the density tool should be at approximately the same speed as the initial logging run for accuracy and correlation purposes.

PART I: CASING TEST

NITROGEN INJECTION:

8. Inject nitrogen into the annulus between the cemented casing and the hanging string at a constant rate and at (approximately) the same temperature indicated by the temperature log. Measure nitrogen with a nitrogen meter.
9. Position the logging tools at regular depth intervals and record the annulus, brine pressure, nitrogen temperature and time as the nitrogen interface passes.
10. Terminate nitrogen injection when the interface depth is just above the casing seat (if this is the only interval being tested). If multiple intervals are to be tested, test shallow intervals before testing the deep intervals.
11. If a single test interval is used to test the casing, use the following formula to calculate the time required to achieve a minimum detectable leak rate (MDLR), or test sensitivity, of less than 100 barrels of nitrogen per year.

$$T = \frac{V * R * 365 \text{ days / year} * 24 \text{ hours / day}}{100 \text{ bbls / year}}$$

T = Duration of test in hours

V = Unit annular volume of casing, bbls/ft

R = Resolution of the interface tool in feet

Note: reference programs or tables and show calculations for converting weight or volume (SCF) of nitrogen to barrels (bbls) of nitrogen.

The test duration may be shortened if a leak is identified.

A one-hour casing test may be conducted if it is followed by a cavern nitrogen/brine interface test. The minimum test duration for the cavern test is 24 hours.

12. Record the time, nitrogen pressure, tubing pressure and the interface depth. Initialize the test for the calculated test duration.
13. At the end of the test, relog the interface depth with the density tool and record the surface pressures. Down-hole movement of the interface may indicate that the test length should be extended.
14. If the nitrogen interface test is being run on the casing only, run a final temperature log.
15. Any up-hole movement of the interface accompanied by a loss in nitrogen pressure indicates nitrogen is being lost from that portion of the casing in contact with the nitrogen. Any interface movement greater than the resolution of the tool should be explained. If a leak is located in the casing above the interface depth, the interface may move up hole to the location of the leak. If multiple leaks are present in the casing, the interface may rise to the location of the greatest leak, however, conclusive determination of the leak location may not be possible.

If the casing test is not followed by a cavern test, calculate the MDLR and the CNLR.

16. Calculate the minimum detectable leak rate (MDLR):

$$\text{MDLR (bbls/yr)} = \frac{V * R * 365 \text{days} / \text{year}}{T}$$

V = Unit volume of borehole, bbls/ft
R = Resolution of the interface tool, ft
T = Duration of test, days

17. Calculate the nitrogen leak rate (CNLR). Submit supporting data for determination of nitrogen volume (charts, conversion tables, weight measurements, mass-balance calculations accounting for temperature and pressure, source for values used in equation, data from software packages, etc)

$$\text{CNLR (bbls/day)} = \frac{1}{T} \left[(VS) - \frac{(PF)(VF)}{(PS)} \right]$$

CNLR = Calculated nitrogen leak rate
T = test duration, days
VS = nitrogen volume at test start (bbls)
VF = nitrogen volume at test finish (bbls)
PS = nitrogen pressure at the test start (psia)
PF = nitrogen pressure at test finish (psia)
CNLR (bbls/yr) = CNLR (bbls/day) * 365 days/year

Pass/fail criteria: The MDLR must be less than 100 barrels of nitrogen per year.
The CNLR must be less than the MDLR to demonstrate integrity.

PART II: CAVERN TEST

1. Resume the nitrogen injection and monitor the interface location with the logging tools. Record the time and surface pressures as the interface crosses the casing seat.
2. Spot the nitrogen below the casing seat and terminate the nitrogen injection.
3. Calculate the initial nitrogen volume at the start of the test. Submit formulas (PVT) and calculations used to determine nitrogen volume. The unit volume of the borehole can be determined from casing and tubing sizes. The open-hole volume below the casing seat may be determined with a sonar survey. Another method for determining the annular or borehole unit volume is as follows:

Pump a finite volume of nitrogen into the annulus and log the interface.

Calculate unit volume:

$$\left[\frac{\text{nitrogen}(bbls)}{\text{depth}(ft)} \right] \text{ Nitrogen pumped/change in interface depth}$$

4. Run the post-nitrogen injection density survey to log the nitrogen interface.
5. Record the nitrogen and brine wellhead pressures.
6. Conduct a temperature survey over the test interval.
7. The test length is typically not less than 24 hours. Monitor the brine and nitrogen wellhead pressures during the test period. The test duration should ensure that the leak rate can be resolved with the accuracy of the instrumentation used.
8. At the end of the test, record the final brine and nitrogen wellhead pressures.
9. Run a density survey to determine if the nitrogen interface has moved. Down-hole movement of the interface may indicate that the test length should be extended.
10. Run a final temperature log over the test interval.
11. Calculate the final nitrogen volume. Submit formulas (PVT) and calculations used to determine nitrogen volume. Accurate nitrogen volume is necessary to determine if pressure changes were affected by temperature, salt leaching, salt creep or from volume loss in the cavern system.
12. Calculate the minimum detectable leak rate (MDLR).

$$\text{MDLR (bbls/yr)} = \frac{V * R * 365 \text{days} / \text{year}}{T}$$

V = Unit volume of borehole, bbls/ft

R = Resolution of the interface tool, ft

T = Duration of test, days

Pass/fail criteria: The MDLR must be less than 1000 barrels of nitrogen per year.
The CNLR must be less than the MDLR to demonstrate integrity.

13. Calculate the nitrogen leak rate (CNLR):

$$\text{CNLR (bbls/day)} = \frac{1}{T} \left[(VS) - \frac{(PF)(VF)}{(PS)} \right]$$

CNLR = Calculated nitrogen leak rate

T = test duration, days

VS = nitrogen volume at test start (bbls)

VF = nitrogen volume at test finish (bbls)

PS = nitrogen pressure at the test finish (psia)

PF = nitrogen pressure at test start (psia)

CNLR (bbls/yr) = CNLR (bbls/day) * 365 days/year

References:

Mechanical Integrity Test-Nitrogen Interface Method; SMRI Short Course; Spring 1998 Meeting
Goin, Kenneth L., 1983, A Plan For Certification and Related Activities For The Department of Energy
Strategic Petroleum Reserve Oil Storage Caverns: SPR Geotechnical Division 6257, Sandia National
Laboratories, Albuquerque, New Mexico

McDonald, Larry K., Nitrogen Leak-Rate Testing; Subsurface Technology, Inc.: 2003 KDHE/KCC
Underground Liquid Hydrocarbon and Natural Gas Cavern Well Technology Fair

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