APPENDIX 11
Class VI Injection Well: Quality Assurance and Surveillance Plan

CTV II

Update February 2nd, 2023

Prepared by:

Carbon TerraVault LLC

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Title and Approval Sheet

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at the Storage facility. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

THurst

February 2nd, 2023

Signature _______________________ Date _______________

Travis Hurst

Distribution List

The following project participants will receive the completed Quality Assurance and Surveillance Plan (QASP) and all future updates for the duration of the project.

Travis Hurst: CCS Project Manager

Carbon TerraVault
28590 Highway 119
Tupman, CA 93276

A. Project Management

A.1. Project/Task Organization

A.1.a/b. Key Individuals and Responsibilities

The CTV II Storage project, led by Carbon TerraVault LLC (CTV), includes participation from service providers. The responsibilities for Testing and Monitoring will be shared between CTV and the service providers.

CTV will be responsible for any data and submissions made to the EPA.

A.1.c. Independence from Project QA Manager and Data Gathering

CTV utilizes a third-party service provider to collect, transport and analyze samples as part of the Testing and Monitoring Plan.

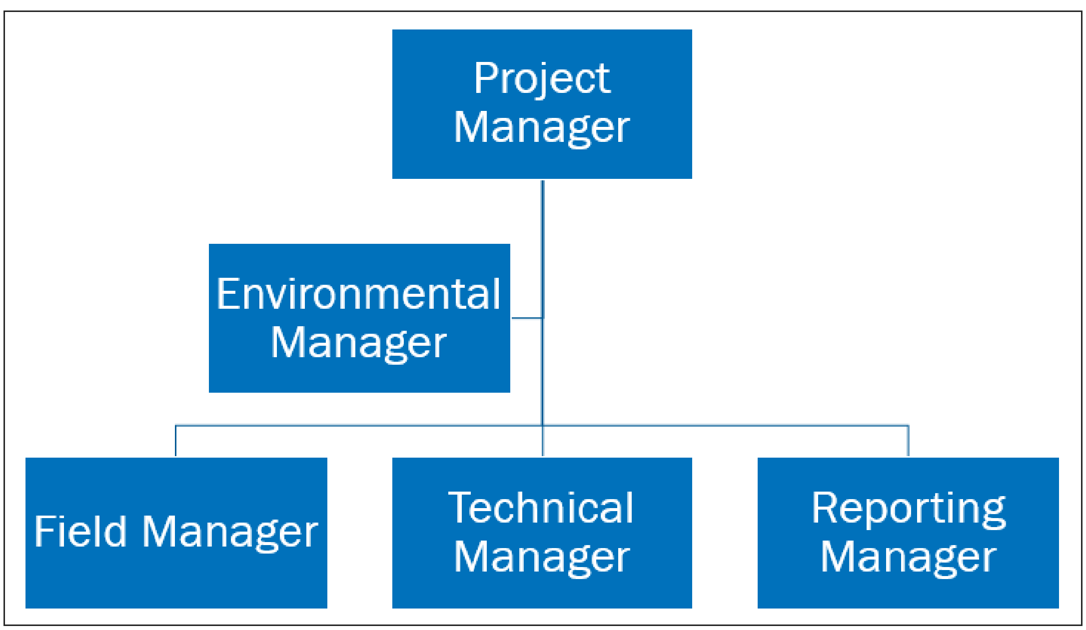
A.1.d. QA Project Plan Responsibility

CTV will be responsible for the Quality Assurance and Surveillance Plan. CTV will review the plan with service providers periodically.

A.1.e. Organizational Chart for Key Project Personnel

Figure 1 shows the organizational structure for the storage project. Although these roles have not been filled because the project is not operational, the chart shows the breakdown in responsibilities for future positions.

Figure 1: Organizational Chart.



A.2. Problem Definition/Background

A.2.a. Reasoning

The project will inject and sequester CO_2 from anthropogenic sources. The project requires a comprehensive monitoring plan that gathers data to assess confinement of the CO_2 injectate. To ensure accurate measurement and reporting this QASP outlines detail associated with the surveillance related to sampling, operating, and recording.

A.2.b. Reasons for Initiating the Project

CTV initiated the project for ESG purposes and to reduce carbon footprint for CTV operations and for external emissions. The project area has available pore space and confinement.

A.2.c. Regulatory Information, Applicable Criteria, Action Limits

CO_2 injection as per standard operating procedures and regulations requires that the injectate is confined in the reservoir and that groundwater is not impacted. As such the following monitoring is necessary:

1. Injection well mechanical integrity testing
2. Injection well testing and operating data collection
3. Groundwater monitoring
4. Validation of the CO_2 plume areal coverage as defined by numerical modeling

The information and data below define the steps to ensure that monitoring data quality provides the confidence and information to verify confinement.

A.3. Project/Task Description

A.3.a/b. Summary of Work to be Performed

Table 1. Summary of Testing and Monitoring.

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Injection well					
Carbon dioxide stream analysis	Compressor	Direct Sampling	Chemical Analysis	Eurofins	Monitor Injectate
Injection rate and volume	Injection Well	Flow meter	Direct Measurement	NA	Monitor rate and volume
Injection pressure	Injection Wellhead	Pressure gauge	Direct Measurement	NA	Monitor injection pressure
Annular pressure	Injection Wellhead	Pressure gauge	Direct Measurement	NA	Monitor annular pressure
Temperature	Along Wellbore	DTS	Direct Measurement	NA	Monitor temperature
Downhole pressure/ temperature	Injection Well	Downhole gauge	Direct Measurement	NA	Monitor reservoir pressure and temperature
Corrosion monitoring	Between compressor and wellhead	Corrosion Coupon	NA	Eurofins	Monitor corrosion of materials
Mechanical Integrity	Injection Well	Temperature	NA	NA	Wellbore Integrity
Internal MIT	Injection Well	SAPT	NA	NA	Wellbore Integrity
Pressure Fall Off Test	Injection Well	Pressure gauge	Pressure Transient Analysis	NA	Reservoir Assessment

Table 2. Monitoring Well Summary

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Monitoring Wells Above Confining Layer					
Fluid Sampling [redacted] (USDW)	USDW Monitoring Well	Direct Sampling	Chemical Analysis	Eurofins	Monitor water quality
Pressure/Temperature [redacted] (USDW)	USDW Monitoring Well	Guage	Direct Measurement	NA	Monitor pressure / temperature
Pressure/Temperature	Dissipation layer monitoring well	Gauge	Direct Measurement	NA	Monitor pressure/Temperature
Temerature	Dissipation layer monitoring well	DTS	Direct Measurement	NA	Monitor Temperature
Fluid Sampling	Dissipation layer monitoring well	Direct Sampling	Chemical Analysis	Eurofins	Monitor water quality

Storage Reservoir					
Pressure/Temperature	Monitor well (s)	Downhole gauge	Direct Measurement	NA	Monitor reservoir pressure/temperature
Temperature	Monitor well (s)	DTS	Direct Measurement	NA	Temperature
Fluid Sampling	Monitor well (s)	Direct Sampling	Chemical Analysis	Eurofins	Monitor water quality
Pulse Neutron Log	Monitor well (s)	Logging	Logging	NA	Saturation
Internal MIT	Monitor well (s)	SAPT	NA	NA	Wellbore Integrity

A.3.c. Geographic Locations

A.3.d. Resource and Time Constraints

CTV has obtained surface access for the duration of the project.

Wells to be utilized for the project are available, and will be re-purposed. These wells will be accessible for the life of the project and for the post injection monitoring timeframe.

A.4.Quality Objectives and Criteria

A.4.a. Performance/Measurement Criteria

Table 3. Summary of Analytical and Field Parameters for Fluid Samples

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations (Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Zn, Tl)	ICP-MS EPA Method 6020	0.05 to 5 mg/L	15%	Daily calibration of equipment/CCV/ Blank LCS, MS/MSD/ QC/ICV
Cations (Ca, Fe, K, Mg, Na, Si)	ICP-OES EPA Method 6010B	0.1 to 2 mg/L	15%	Daily calibration/CCV/ Blank LCS, MS/MSD/ QC/ICV
Anions (Br, Cl, F, NO3, SO4)	Ion Chromatography, EPA Method 300.0	0.02-0.13 mg/L	15%	Daily calibration/CCV/ Blank LCS, MS/MSD/ QC/ICV
Dissolved CO_2	Coulometric titration ASTM D513-11	10 mg/L	NA	Duplicate analysis
Total dissolved solids	Gravimetry; Method 2540 C	10 mg/L	10%	Daily balance calibration, duplicates, blanks
Alkalinity	Method 2320B	10 mg/L	10%	Duplicate analysis
pH (field)	EPA 150.1	2 to 12.5pH	0.2 pH	Daily calibration, duplicates
Specific conductance (field)	APHA 2510	0-200 mS/cm	1%	Daily calibration, duplicates
Temperature (field)	Thermocouple	-5 to 50 C	0.2 C	Monthly calibration
δ13C	Isotope ratio mass spectrometry	12.2 mg/L HCO_3	0.15%	Duplicate analysis
Hydrogen Sulfide	ISBT 14.0 (GC/SCD)	1 mg/L	5-10% of reading	Daily calibration, duplicates

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 4. Summary of Analytical Parameters for CO_2 Stream.

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Oxygen, Argon and Hydrogen	ISBT 4.0 (GC/DID) GC/TCD	50 ppmv	15%	Daily calibration/CCV, blank, QC sample
Nitrogen	ISBT 4.0 (GC/DID) GC/TCD	50 ppmv	15%	Daily calibration/CCV, blank, QC sample
Carbon monoxide	ISBT 5.0 (Colorimetric) ISBT 4.0 (GC/DID)	50 ppmv	15%	Daily calibration/CCV, blank, QC sample
Total hydrocarbons	ISBT 10.0 THA (FID)	10 ppmv	15%	Daily calibration/CCV, blank, QC sample
Ammonia	ISBT 6.0 (DT)	0.1 ppmv	15%	Daily calibration/CCV, blank, QC sample
Methane, Ethane, Ethylene	ISBT 10.1 (FID)	10 ppmv	15%	Daily calibration/CCV, blank, QC sample
Hydrogen sulfide and Sulfur Dioxide	ISBT 14.0 (GC/SCD)	10 ppmv/1 ppmv	15%	Daily calibration/CCV, blank, QC sample
Ethanol	ISBT 11.0 (GC/FID)	0.5 ppmv	20%	Daily calibration/CCV, blank, LCS, MS/MSD, ICV
Oxides of Nitrogen	ISBT 7.0 Colorimetric	0.2 ppmv	15%	Daily calibration/CCV, blank, QC sample
δ13C	Isotope ratio mass spectrometry	12.2 mg/L HCO_3	0.15%	Duplicate analysis
CO_2 purity	ISBT 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD	50 ppmv	15%	Daily calibration/CCV, blank, QC sample

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 5. Summary of Analytical Parameters for Corrosion Coupons.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE TM0169/ G31 EPA 1110A SW846	0.001 mg	10%	Duplicate analysis

Table 6. Summary of Measurement Parameters for Field Gauges.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Booster pump discharge pressure	ANSI Z540-1-1994	0.001 / 0 - 5,000 PSI	0.01 PSI	Annual calibration
Injection tubing temperature	ANSI Z540-1-1994	0.001 Fahrenheit / 0 – 500 Fahrenheit	0.01 Fahrenheit	Annual calibration
Injection tubing pressure	ANSI Z540-1-1994	0.001 / 0 - 5,000 PSI	0.01 PSI	Annual calibration
Annulus pressure	ANSI Z540-1-1994	0.001 / 0 - 5,000 PSI	0.01 PSI	Annual calibration
Injection mass flow rate	NA	0.1 % of flow rate	0.01 lbs/hour	Annual calibration

Table 7. Actionable Testing and Monitoring Outputs.

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
External and internal mechanical integrity (temperature log)	Temperature log indicates a mechanical integrity issue.	0.01 Fahrenheit	Results will be compared to baseline. Deviation may be indicative of mechanical issue.
Surface and downhole pressure	Action will be taken when pressure is outside of expected or modeled range.	0.001 PSI	No greater than the maximum operating pressure.
Water quality (USDW)	Action will be taken when water sample is outside of baseline analysis.	0.2 pH	CO_2 will decrease the water pH.
Above-confining-zone pressure	Action will be taken if the pressure of the Formation increases.	0.001 PSI as per installed pressure gauge.	Reservoir pressure.

A.4.b. Precision

Field blanks will be collected once per sampling event to assess water sampling analysis accuracy. Service provider will be responsible for analytical precision as per their standard operating procedures.

A.4.c. Bias

Laboratory analysis bias will be assessed and addressed by the individual service provider as per their procedures and methodology.

There is no bias for direct pressure, temperature, and logging measurements.

A.4.d. Representativeness

CTV designed the monitoring network to ensure that samples acquired were representative of site conditions. Standard operating procedures during acquisition at the wellsite will ensure that samples are representative of the formation.

A.4.e. Completeness

Data completeness (amount of data obtained versus the expected data) of 90% for ground water sampling will be acceptable.

Direct measurements, such as pressure and temperature data, will be recorded 90% of the time.

A.4.f. Comparability

Data sets will always be compared to the baseline and previous analysis. Individual threshold changes will be assessed as well as small trend changes.

A.4.g. Method Sensitivity

The following tables provide detail on gauge sensitivities.

Table 8. Pressure and Temperature—Downhole Gauge Specifications.

Parameter	Value
Calibrated working pressure range	0 – 10,000 PSI
Initial pressure accuracy	< 2 PSI
Pressure resolution	0.005 PSI
Pressure drift stability	< 1 PSI per year
Calibrated working temperature range	77 – 266 degrees Fahrenheit
Initial temperature accuracy	< 0.9 Fahrenheit
Temperature resolution	0.009 Fahrenheit
Temperature drift stability	0.1 degrees Fahrenheit per year
Max temperature	302 degrees Fahrenheit
Instrument calibration frequency	Annual

Table 9. Representative Logging Tool Specifications.

Parameter	RST (Pulse Neutron)	CBL
Logging speed	200 feet/hour	1,800 feet/hour
Vertical resolution	15 inches	6 inches
Investigation	Mechanical integrity	Cement bond with casing and formation
Temperature rating	302 Fahrenheit	350 Fahrenheit
Pressure rating	15,000 PSI	20,000 PSI

Table 10. Pressure Field Gauge.

Parameter	Value
Calibrated working pressure range	0 to 5,000 PSI
Initial pressure accuracy	< 0.05 %
Pressure resolution	0.01 PSI
Pressure drift stability	0.125% of upper range limit for 60 months

Table 11. Pressure Field Gauge—Injection Tubing Pressure.

Parameter	**Value**
Calibrated working pressure range	0 to 5,000 PSI and 4-20 mA
Initial pressure accuracy	< 0.05 %
Pressure resolution	0.01 PSI and 0.00001 mA
Pressure drift stability	0.125% of upper range limit for 60 months

Table 12. Pressure Field Gauge—Annulus Pressure.

Parameter	**Value**
Calibrated working pressure range	0 to 5,000 PSI
Initial pressure accuracy	< 0.05 %
Pressure resolution	0.01 PSI
Pressure drift stability	0.125% of upper range limit for 60 months

Table 13. Temperature Field Gauge—Injection Tubing Temperature.

Parameter	**Value**
Calibrated working temperature range	0 to 500 degrees Fahrenheit and 4-20ma
Initial temperature accuracy	<0.0055%
Temperature resolution	0.001 degrees Fahrenheit and 0.0001 mA
Temperature drift stability	0.15% of output reading or 0.15 degrees Celsius

Table 14. Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate.

Parameter	**Value**
Calibrated working flow rate range	Range spanning maximum anticipated injection rate per well with typical precision and accuracy of 0.5%
Initial mass flow rate accuracy	0.5 % of upper range limit
Mass flow rate resolution	0.5% of upper range limit
Mass flow rate drift stability	Estimate <0.5% of output reading for 12 months

A.5. Special Training/Certifications

A.5.a. Specialized Training and Certifications

CTV will utilize lab and logging companies to acquire field data samples. All equipment will be provided and operated by the service provider.

A.5.b/c. Training Provider and Responsibility

Training will be provided and assessed by the individual service providers.

A.6. Documentation and Records

A.6.a. Report Format and Package Information

CTV will prepare and submit semi-annual reports to the EPA. The reports will include all testing, data, and monitoring information as specified in the Testing and Monitoring Plan.

A.6.b. Other Project Documents, Records, and Electronic Files

CTV will prepare and provide all necessary documents, records or electronic files as required.

A.6.c/d. Data Storage and Duration

CTV will maintain the required project data collected in a datastore.

A.6.e. QASP Distribution Responsibility

The project manager will be responsible for ensuring that those on the distribution list, and other essential staff, receive the most current copy of the QASP.

B. Data Generation and Acquisition

B.1. Sampling Process Design

B.1.a. Design Strategy

Shallow Groundwater Monitoring Strategy

A groundwater monitoring well will assess potential changes in the lowermost USDW within the undifferentiated nonmarine sediments. Although the proposed monitoring zone is a USDW (based on having groundwater less than 10,000 ppm TDS) the water supply wells in the AoR are completed above the base of fresh water. Monitoring of the lowermost USDW is more protective than monitoring the fresh water aquifers because impacts would occur in the lowermost USDW before the fresh water aquifers. The location of the monitoring wells are near potential conduits.

CTV will also monitor pressure changes associated with the storage project and fluid analysis.

Deep Formation Water Monitoring Strategy

Between the [redacted] confining layer and the USDWs is the [redacted] A laterally continuous [redacted] sand will be pressure monitored for potential CO2 leakage. The sands have adequate continuity, porosity and permeability to ensure that the AoR is monitored.

Any unlikely leakage from the storage reservoir up through the [redacted] confining layer will dissipate in the [redacted] and increase the formation pressure.

B.1.b. Type and Number of Samples/Test Runs

The sampling activities are summarized in Table 1.

B.1.c. Site/Sampling Locations

Locations for sampling are shown on the map below (Figure 2).

Figure 2: Monitoring well locations.

[redacted]

B.1.d. Sampling Site Contingency

CTV owns the mineral rights, pore space and surface access to the storage project.

B.1.e. Activity Schedule

The sampling activities are summarized in Table 1.

B.1.f. Critical/Informational Data

Documentation of information will include the following:

1. Sampling metadata that includes sample label, purging time and other sample collection procedures.
2. Data collected in the field (temperature and pH).
3. Chain of custody.

4. Data and analysis collected in the laboratory.
5. Calibration of Instrumentation and equipment.

B.1.g. Sources of Variability

Potential sources of variability include the following:

1. Natural and operational variability in fluid quality, temperature, and pressure.
2. Reservoir changes from outside the AoR (outside operator, precipitation/drought)
3. Changes in the sampling methods, service provider and instrumentation.

Variability will be minimized by the following:

1. Adhering to standard operating procedures.
2. Assessing data and results against baseline and previous results for trend and changes.
3. Service provider staff training.
4. Assessing calibration and calibrating procedures.
5. Quality control checks for samples.

B.2. Sampling Methods

B.2.a/b. Sampling SOPs

Refer to the table below for stabilization criteria during well purging.

Laboratory SOPs have been developed by the service provider.

All procedures for sampling shall be consistent with the U.S. Environmental Protection Agency (US EPA) Groundwater Sampling Guidelines for Superfund and RCEAA Project Mangers (May 2002).

Table 15. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

Field Parameter	**Stabilization Criteria**
pH	+/- 0.01
Temperature	+/- 1 C
Specific conductance	+/- 3%

B.2.c. In-situ Monitoring

In-situ monitoring of water chemistry is not currently planned.

B.2.d. Continuous Monitoring

Pressure will be collected from monitoring wells.

B.2.e. Sample Homogenization, Composition, Filtration

To obtain a representative sample, each well will be purged at a flow rate between 10 GPM and 5- GPM. Samples will be collected within 24 hours of the well being purged. If a monitoring well will not supply adequate water for sampling, the condition of the well will be investigated and it may be considered for replacement.

Purging will continue until three successive measurements of the indicator parameters meet the stabilization criteria per Table 15.

B.2.f. Sample Containers and Volumes

Sample collection devices will be carefully chosen to minimize the potential for altering the quality of the sample. Teflon and stainless steel are preferred materials, although PVC, HDPE and other similar materials are considered sufficient in some cases.

Refer to the tables below as needed for sample container, preservation, and holding time information.

B.2.g. Sample Preservation

Samples will be preserved as per Table 17.

B.2.h. Cleaning/Decontamination of Sampling Equipment

Equipment used for sampling and other activities associated with on-site work will be de-contaminated before and after performance of a given activity. Disposable items will be disposed of as solid waste in an approved, permitted client facility.

B.2.i. Support Facilities

Support facilities will be provided by the service provider responsible for sampling and analysis.

B.2.j. Corrective Action, Personnel, and Documentation

The service provider will be responsible for testing instruments and equipment and preforming corrective action on defective equipment. Corrective action taken on equipment will be documented.

B.3. Sample Handling and Custody

B.3.a. Maximum Hold Time/Time Before Retrieval

See Table 16 and 17 for holding times.

B.3.b. Sample Transportation

CTV will ensure that samples are delivered to the laboratory for analysis by the service provider as soon as possible following sample collection. Samples will be transported to the laboratory on the same day as the sample collection.

During transportation, precautions will be implemented to ensure that sample integrity is not affected by extreme temperatures and/or excessive vibration.

Upon arrival at the service provider the samples will be reviewed to ensure the following:

1. The sample arrived intact without container leakage or breakage.

2. Chain of custody documentation and sample labels agree
3. Confirmation that the sample was preserved correctly.

B.3.c. Sampling Documentation

For each test in the field, a worksheet will be compiled for each test interval documenting the procedures and results.

B.3.d. Sample Identification

Samples will be identified with the well location, date sample identification, sampler, and sample type.

Table 16. Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Gas Stream Analysis.

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 gas stream	One-liter tedlar bag	None	72 hours

Table 17. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Ca, Fe, Mg, K, Na, Si, Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Zn, Tl	100 mL plastic	Nitric acid	180 days
Anions: Br, Cl, F, NO_3 and SO_4	100 mL plastic	None	48 hours
Dissolved CO_2	100 ml plastic	None	14 days
Isotopes: Carbon isotope 13	100 ml plastic	None	14 days
Alkalinity	100 mL plastic	None	14 days

B.3.e. Sample Chain-of-Custody

Sample transport and handling will be strictly controlled by the service provider field technician to reduce the opportunity for tampered samples. Upon delivery to the laboratory samples will be given unique laboratory sample numbers and recorded in a logbook indicating the client, well number, date, and time of delivery.

B.4. Analytical Methods

B.4.a. Analytical SOPs

All procedures to sample and analyze groundwater will be consistent with the U.S. Environmental Protection Agency Groundwater Sampling Guidelines for Superfund and RCRA Project Managers (May 2002).

B.4.b. Equipment/Instrumentation Needed

Service providers are expected to provide and utilize the equipment and instruments necessary to perform the required testing and analysis.

Examples of equipment and instrumentation includes safety equipment, sample jars, decontamination supplies, pH meter, EC meters, temperature gauges, and materials to document chain of custody, results, and labels.

B.4.c. Method Performance Criteria

All analytical methods employed by CTV at the Storage project are industry standard and well define. Method performance criteria is not necessary.

B.4.d. Analytical Failure

Service providers conducting analysis are responsible for assessing and addressing analytical failure per their internal procedures and standards.

B.4.e. Sample Disposal

Service providers conducting analysis are responsible for proper sample disposal per internal procedures and standards.

B.4.f. Laboratory Turnaround

Laboratory turnaround times will vary by the analysis being conducted. CTV will communicate to service providers that a 30-day turnaround time for most analysis' is expected.

B.4.g. Method Validation for Nonstandard Methods

All analytical methods employed by CTV at the Storage project are industry standard and well defined. Method performance criteria is not necessary.

B.5. Quality Control

B.5.a. QC activities

Field quality control may involve the collection of two types of QC blanks, trip, and field blanks, to verify that the sample collection and handling processes have not impaired quality of the final samples.

Trip blank – Trip blanks are prepared for VOC analysis and transported with the empty sample container.

Field Blank- the field blank will be taken in the field to evaluate if certain sampling or cleaning procedures result in cross-contamination of site samples or if atmospheric contamination has occurred.

B.5.b. Exceeding Control Limits

In the case that control limits are exceeded, CTV will review the sampling procedures and results. In the case of a valid test, refer to the Emergency Response Plan for water contamination procedures.

B.5.c. Calculating Applicable QC Statistics

Charge Balance - Solutions must be electrically neutral, the total sum of all the positive charges (cations) must equal the total sum of all negative charges (anions).

$$\text{Charge Balance:} \qquad \sum cations = \sum anions$$

Charge balance error (shown below) will be less than ±5% for acceptable water analyses.

$$CBE = \frac{\sum cations - |\sum anions|}{\sum cations + |\sum anions|} \times 100$$

B.6. Instrument/Equipment Testing, Inspection, and Maintenance

The service provider will test, inspect, and maintain the instrumentation and equipment used for testing, this will be completed as per the manufacturer's guidelines and the standard operating procedures.

B.7. Instrument/Equipment Calibration and Frequency

B.7.a. Calibration and Frequency of Calibration

Pressure and temperature gauges will be calibrated according to the manufacturer's recommendations. Calibration certificates will be kept on file.

Lab instrumentation and calibration will be checked weekly to ensure that results are within the control range of parameters.

B.7.b. Calibration Methodology

Instruments will be calibrated for accurate readings. Calibrations will be conducted with individual instrument SOP's and in accordance with the manufacturer's supplied manual for each instrument.

B.7.c. Calibration Resolution and Documentation

Instrument calibration resolution will be consistent with the manufacturer's recommendations. Documentation for instrument calibration will be maintained in a database.

B.8. Inspection/Acceptance for Supplies and Consumables

B.8.a/b. Supplies, Consumables, and Responsibilities

The service provider responsible for completing sample collection and analysis will be responsible for supplies and consumables.

Supplies and consumables used for sample collection and analysis will be selected to minimize the potential for altering the quality of the sample and analysis results.

B.9. Nondirect Measurements

B.9.a. Data Sources

Induced seismicity will be monitored continuously to ensure data consistency. CTV will partner with or use a third party to process the data.

B.9.b. Relevance to Project

Passive seismic monitoring will be used to assess induced seismicity events as an indicator of stress changes in the subsurface. Thresholds and response for induced seismic eventsare discussed further in the Emergency Response Plan.

B.9.c. Acceptance Criteria

Industry standard practices will be utilized for data gathering, processing and interpretation.

B.9.d. Resources/Facilities Needed

CTV will use a service provider for all necessary resources and facilities for passive seismic monitoring.

B.9.e. Validity Limits and Operating Conditions

CTV and service provider professionals will ensure that all results and processes are conducted as per standard industry practices.

B.10. Data Management

B.10.a. Data Management Scheme

CTV will maintain the Storage project data internally. Data will be backed up and held on secure servers.

B.10.b. Recordkeeping and Tracking Practices

All data associated with the project will be held securely and associated meta-data will be gathered and maintained to ensure tracking purposes.

B.10.c. Data Handling Equipment/Procedures

CTV employs robust data management procedures to ensure security of data gathered from the field and external data sources.

B.10.d. Responsibility

Project managers will be responsible for ensuring data management is properly maintained.

B.10.e. Data Archival and Retrieval

CTV will hold all data associated with the Storage project. A data store will be developed for reporting and retrieval.

B.10.f. Hardware and Software Configurations

CTV will ensure that software and hardware are appropriate to integrate the multiple data sources and maintain large quantities of data.

B.10.g. Checklists and Forms

CTV will generate forms, checklists, and procedures as necessary to ensure management, security and quality of all data collected.

C. Assessment and Oversight

C.1. Assessments and Response Actions

C.1.a. Activities to be Conducted

Monitoring results will be obtained as per Table 1. Results will be reviewed for QC criteria as per section B.5. In the case of data failure, new samples will be collected and analyzed. Evaluation for data consistency will be performed per the USEPA 2009 Unified Guidance (USEPA, 2009).

C.1.b. Responsibility for Conducting Assessments

CTV will utilize service providers to analyze sample data. These organizations will be responsible for conducting their own internal assessments.

C.1.c. Assessment Reporting

Assessment information will be reported to the project leads as outlined in A.1.

C.1.d. Corrective Action

Corrective action issues, data collection, and monitoring data will all be handled by CTV.

C.2. Reports to Management

C.2.a/b. QA status Reports

CTV will notify the EPA and project leaders of QA report status if there are changes to the Testing and Monitoring Plan or the QASP.

D. Data Validation and Usability

D.1. Data Review, Verification, and Validation

D.1.a. Criteria for Accepting, Rejecting, or Qualifying Data

Data validation will include the review of the results, chain of custody information, and review of the blank and duplicate information. All results will be stored in a database and compared to baseline and previous results. Data will be graphed to inspect trends and anomalies.

D.2. Verification and Validation Methods

D.2.a. Data Verification and Validation Processes

Data will be verified by CTV upon receipt of results.

If anomalous data is suspected, CTV and the service provider will review the metadata associated with the sample to assess whether sampling, collection and the analysis conducted caused spurious results. In addition, instrument calibration will be reviewed if necessary.

D.2.b. Data Verification and Validation Responsibility

Data will be verified by CTV upon receipt of results.

D.2.c. Issue Resolution Process and Responsibility

CTV will oversee sample handling and assessment process. CTV management will determine actions necessary to resolve issues.

D.2.d. Checklist, Forms, and Calculations

CTV will develop checklists and a GIS database to store data, complete surveillance and ensure that permit requirements are met.

D.3. Reconciliation with User Requirements

D.3.a. Evaluation of Data Uncertainty

CTV will develop a GIS database that will be used for surveillance. The database will ensure data quality using methods consistent with USEPA 2009 Unified Guidance.

D.3.b. Data Limitations Reporting

Service provider management will be responsible for ensuring that analysis in their laboratory is presented with data use limitations for reporting.

Project leaders and managers will be responsible for ensuring that results are vetted and evaluated to determine if performance criteria are met.

References

ASTM, 2005, Method D6517-00 (reapproved 2005), Standard guide for field preservation of groundwater samples, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

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Appendices

Schlumberger Wireline Log Quality Reference Manual

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Wireline Log Quality Control Reference Manual

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RST and RSTPro

Overview

The dual-detector spectrometry system of the through-tubing RST* and RSTPro* reservoir saturation tools enables the recording of carbon and oxygen and Dual-Burst* thermal decay time measurements during the same trip in the well.

The carbon/oxygen (C/O) ratio is used to determine the formation oil saturation independent of the formation water salinity. This calculation is particularly helpful if the water salinity is low or unknown. If the salinity of the formation water is high, the Dual-Burst measurement is used. A combination of both measurements can be used to detect and quantify the presence of injection water of a different salinity from that of the connate water.

Calibration

The master calibration of the RST and RSTPro tools is conducted annually to eliminate tool-to-tool variation. The tool is positioned within a polypropylene sleeve in a horizontally positioned calibration tank filled with chlorides-free water.

The sigma, WFL* water flow log, and PVL* phase velocity log modes of the RST and RSTPro detectors do not require calibration. The gamma ray detector does not require calibration either.

Specifications

Measurement Specifications

	RST and RSTPro Tools
Output	Inelastic and capture yields of various elements, carbon/oxygen ratio, formation capture cross section (sigma), porosity, borehole holdup, water velocity, phase velocity, SpectroLith* processing
Logging speed[†]	Inelastic mode: 100 ft/h [30 m/h] (formation dependent) Capture mode: 600 ft/h [183 m/h] (formation and salinity dependent) RST sigma mode: 1,800 ft/h [549 m/h] RSTPro sigma mode: 2,800 ft/h [850 m/h]
Range of measurement	Porosity: 0 to 60 V/V
Vertical resolution	15 in [38.10 cm]
Accuracy	Based on hydrogen index of formation
Depth of investigation[‡]	Sigma mode: 10 to 16 in [20.5 to 40.6 cm] Inelastic capture (IC) mode: 4 to 6 in [10.2 to 15.2 cm]
Mud type or weight limitations	None
Combinability	RST tool: Combinable with the PL Flagship* system and CPLT* combinable production logging tool RSTPro tool: Combinable with tools that use the PS Platform* telemetry system and Platform Basic Measurement Sonde (PBMS)

[†] See Tool Planner application for advice on logging speed.
[‡] Depth of investigation is formation and environment dependent.

Mechanical Specifications

	RST-A and RST-C	RST-B and RST-D
Temperature rating	302 degF [150 degC] With flask: 400 degF [204 degC]	302 degF [150 degC]
Pressure rating	15,000 psi [103 MPa] With flask: 20,000 psi [138 MPa]	15,000 psi [103 MPa]
Borehole size—min.	1 13/16 in [4.60 cm] With flask: 2 1/4 in [5.72 cm]	2 7/8 in [7.30 cm]
Borehole size—max.	9 5/8 in [24.45 cm] With flask: 9 5/8 in [24.45 cm]	9 5/8 in [24.45 cm]
Outside diameter	1.71 in [4.34 cm] With flask: 2.875 in [7.30 cm]	2.51 in [6.37 cm]
Length	23.0 ft [7.01 m] With flask: 33.6 ft [10.25 m]	22.2 ft [6.76 m]
Weight	101 lbm [46 kg] With flask: 243 lbm [110 kg]	208 lbm [94 kg]
Tension	10,000 lbf [44,480 N] With flask: 25,000 lbf [111,250 N]	10,000 lbf [44,480 N]
Compression	1,000 lbf [4,450 N] With flask: 1,800 lbf [8,010 N]	1,000 lbf [4,450 N]

Tool quality control

Standard curves

The RST and RSTPro standard curves are listed in Table 1.

Table 1. RST and RSTPro Standard Curves

Output Mnemonic	Output Name
BADL_DIAG	Bad level diagnostic
CCRA	RST near/far instantaneous count rate
COR	Carbon/oxygen ratio
CRRA	Near/far count rate ratio
CRRR	Count rate regulation ratio
DSIG	RST sigma difference
FBAC	Multichannel Scaler (MCS) far background
FBEF	Far beam effective current
FCOR	Far carbon/oxygen ratio
FEGF	Far capture gain correction factor
FEOF	Far capture offset correction factor
FERD	Far capture resolution degradation factor (RDF)
FIGF	Far inelastic gain correction
FIOF	Far inelastic offset correction factor
FIRD	Far inelastic RDF
IC	Inelastic capture
IRAT_FIL	RST near/far inelastic ratio
NBEF	Near beam effective current
NCOR	Near carbon/oxygen ratio
NEGF	Near capture gain correction factor
NEOF	Near capture offset correction factor
NERD	Near capture RDF
NIGF	Near inelastic gain correction
NIOF	Near inelastic offset correction factor
NIRD	Near inelastic RDF
RSCF_RST	RST selected far count rate
RSCN_RST	RST selected near count rate
SBNA	Sigma borehole near apparent
SFFA_FIL	Sigma formation far apparent
SFNA_FIL	Sigma formation near apparent
SIGM	Formation sigma
SIGM_SIG	Formation sigma uncertainty
TRAT_FIL	RST near/far capture ratio

Operation

The RST and RSTPro tools should be run eccentered. The main inelastic capture characterization database does not support a centered tool, thus it is important to ensure that the tool is run eccentered. However, for a WFL water flow log, a centered tool is recommended to better evaluate the entire wellbore region.

Formats

The format in Fig. 1 is used mainly as a hardware quality control.

- Depth track
  - Deflection of the BADL_DIAG curve by 1 unit indicates that frame data are being repeated (resulting from fast logging speed or stalled data). A deflection by 2 units indicates bad spectral data (too-low count rate).
- Track 1
  - CRRA, CRRR, NBEF, and FBEF are shown; FBEF should track openhole porosity when properly scaled.
- Track 6
  - The IC mode gain correction factors measure the distortion of the energy inelastic and elastic spectrum in the near and far detectors relative to laboratory standards. They should read between 0.98 and 1.02.
- Track 7
  - The IC mode offset correction factors are described in terms of gain, offset, and resolution degradation of the inelastic and elastic spectrum in the near and far detectors. They should read between –2 and 2.
- Track 8
  - Distortion on these curves affects inelastic and capture spectra from the near and far detectors. They should be between 0 and 15. Anything above 15 indicates a tool problem or a tool that is too hot (above 302 degF [150 degC]), which affects yield processing.

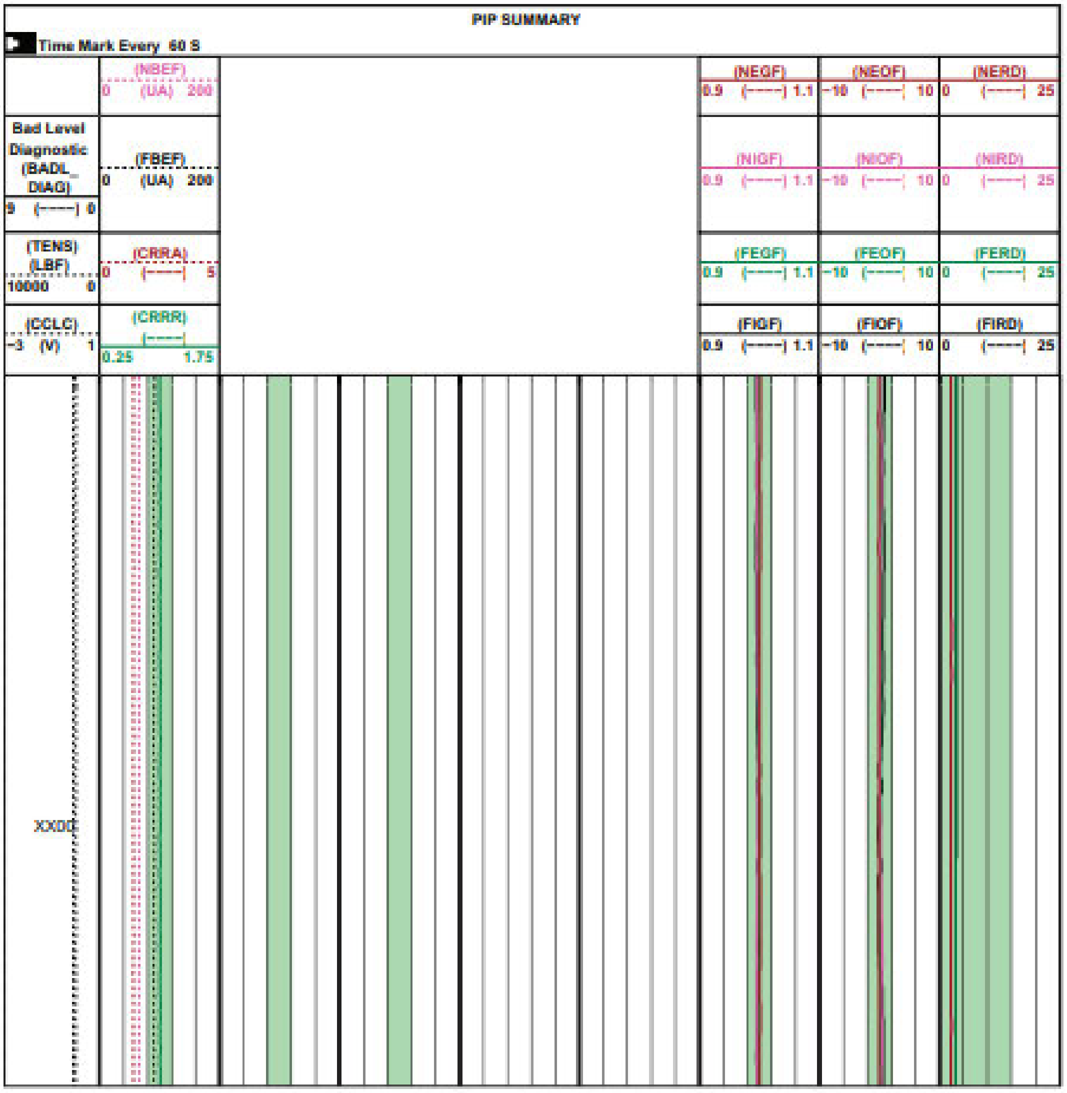

Figure 1. RST and RSTPro hardware format.

The format in Fig. 2 is used mainly for sigma quality control.

- Depth track
  - Deflection of the BADL_DIAG curve by 1 unit indicates that frame data are being repeated (resulting from fast logging speed or stalled data). A deflection by 2 units indicates bad spectral data (too-low count rate).
- Tracks 2 and 3
  - The IRAT_FIL inelastic ratio increases in gas and decreases with porosity.
  - DSIG in a characterized completion should equal approximately zero. Departures from zero indicate either the environmental parameters are set incorrectly or environment is different from the characterization database (e.g., casing is not fully centered in the wellbore or the tool is not eccentered). Shales typically read 1 to 4 units from the baseline of zero because they are not characterized in the database.

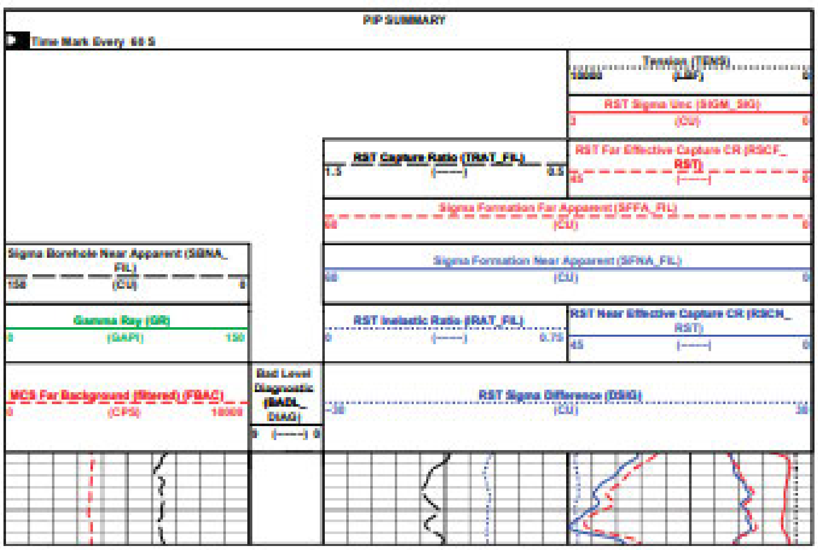

Figure 2. RST and RSTPro sigma standard format.

Response in known conditions

In front of a clean water zone, COR is smaller than the value logged across an oil zone. Oil in the borehole affects both the near and far COR, causing them to read higher than in a water-filled borehole. In front of shale, high COR is associated with organic content.

The computed yields indicate contributions from the materials being measured (Table 2).

Table 2. Contributing Materials to RST and RSTPro Yields

Element	Contributing Material
C and O	Matrix, borehole fluid, formation fluid
Si	Sandstone matrix, shale, cement behind casing
Ca	Carbonates, cement
Fe	Casing, tool housing

Bad cement quality affects readings (Table 3). A water-filled gap in the cement behind the casing appears as water to the IC measurement. Conversely, an oil-filled gap behind the casing appears as oil to the IC measurement.

Table 3. RST and RSTPro Capture and Sigma Modes

Medium	Sigma, cu
Oil	18 to 22
Gas	0 to 12
Water, fresh	20 to 22
Water, saline	22 to 120
Matrix	8 to 12
Shale	35 to 55

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Cement Bond Tool

Overview

The cement bond log (CBL) made with the Cement Bond Tool (CBT) provides continuous measurement of the attenuation of sound pulses, independent of casing fluid and transducer sensitivity. The tool is self-calibrating and less sensitive to eccentering and sonde tilt than the traditional single-spacing CBL tools. The CBT additionally gives the attenuation of sound pulses from a receiver spaced 0.8 ft [0.24 m] from the transmitter, which is used to aid interpretation in fast formations.

A CBL curve computed from the three attenuations available enables comparison with CBLs based on the typical 3-ft [0.91-m] spacing. This computed CBL continuously discriminates between the three attenuations to choose the one best suited to the well conditions. An interval transit-time curve for the casing is also recorded for interpretation and quality control.

A Variable Density* log (VDL) is recorded simultaneously from a receiver spaced 5 ft [1.52 m] from the transmitter. This display provides information on the cement/formation bond and other factors that are important to the interpretation of cement quality.

Specifications

Measurement Specifications	
Output	Attenuation measurement, CBL, VDL image, transit times
Logging speed	1,800 ft/h [549 m/h][†]
Range of measurement	Formation and casing dependent
Vertical resolution	CBL: 3 ft [0.91 m] VDL: 5 ft [1.52 m] Cement map: 2 ft [0.61 m]
Accuracy	Formation and casing dependent
Depth of investigation	CBL: casing and cement interface VDL: depends on bonding and formation
Mud type or weight limitations	None

[†] Speed can be reduced depending on data quality.

Measurement Specifications	
Temperature rating	350 degF [177 degC]
Pressure rating	20,000 psi [138 MPa]
Borehole size—min.	3.375 in [8.57cm]
Borehole size—max.	13.375 in [33.97 cm]
Outside diameter	2.75 in [6.985 cm]
Weight	309 lbm [140 kg]

Calibration

Sonde normalization of sonic cement bond tools is performed with every Q-check. Q-check frequency is also dependent on the number of jobs run, exposure to high temperature, and other factors.

The sonic checkout setup used for calibration is supported with two stands, one on each end. A stand in the center of the tube would distort the waveform and cause errors. One end of the tube is elevated to assist in removing all air in the system, and the tool is positioned in the tube with centralizer rings.

Tool quality control

Standard curves

CBT standard curves are listed in Table 1.

Table 1. CBT Standard Curves

Output Mnemonic	Output Name
CCL	Casing collar locator amplitude
DATN	Discriminated BHC attenuation
DBI	Discriminated bond index
DCBL	Discriminated synthetic CBL
DT	Interval transit time of casing (delta-*t*)
DTMD	Delta-*t* mud (mud slowness)
GR	Gamma ray
NATN	Near 2.4-ft attenuation
NBI	Near bond index
NCBL	Near synthetic CBL
R32R	Ratio of receiver 3 sensitivity to receiver 2 sensitivity, dB
SATN	Short 0.8-ft attenuation[†]
SBI	Short bond index[†]
SCBL	Short synthetic CBL[†]
TT1	Transit time for mode 1 (upper transmitter, receiver 3 [UT-R3])
TT2	Transit time for mode 2 (UT-R2)
TT3	Transit time for mode 3 (lower transmitter, receiver 2 [LT-R2])
TT4	Transit time for mode 4 (LT-R3)
TT6	Transit time for mode 6 (UT-R1)
ULTR	Ratio of upper transmitter output strength to the lower transmitter output strength
VDL	Variable Density log

[†] In fast formations only

Operation

The tool should be run centralized.

A log should be made in a free-pipe zone (if available). Where a micro-annulus is suspected, a repeat section should be made with pressure applied to the casing.

Formats

The format in Fig. 1 is used both as an acquisition and quality control format.

- Track 1
  - DT and DTMD are derived from the transit-time measurements from all transmitter-receiver pairs. They respond to eccentralization of any of the six measurements modes and are a sensitive indicator of wellbore conditions. In a low-quality cement bond or free pipe, both readings are correct. In well-bonded sections, the transit time may cycle skip, affecting the DT and DTMD values.
  - CCL deflects in front of casing collars.
  - GR is used for correlation purposes.
- Track 2
  - DCBL is related to casing size, casing weight, and mud. As a quality control DCBL should be checked against the expected responses in known conditions (see the following section). Also, DCBL should match the VDL image readings.
- Track 3
  - VDL is a map of the waveform amplitude versus depth and it should have good contrast. It provides information on the cement/formation bond, which is important for cement quality interpretation. The VDL image should be cross checked that it matches the DCBL readings. For example, in a free-pipe section, the DCBL amplitude reads high and VDL shows strong casing arrivals with no formation arrivals. In a zone of good bond for the casing to the formation, the CBL amplitude reads low and the VDL has weak casing arrivals and clear formation arrivals.

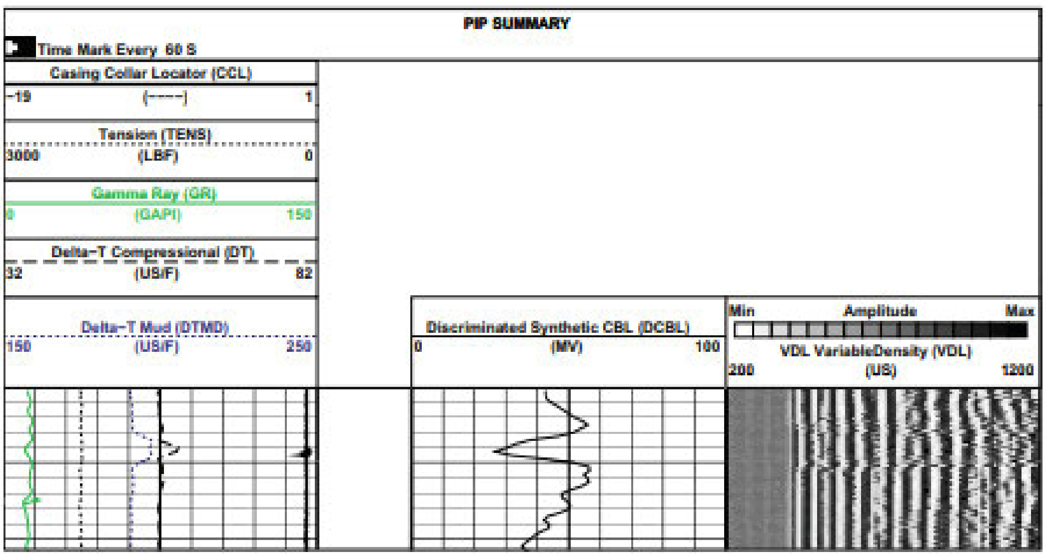

Figure 1. CBT standard format for CBL and VDL.

The format in Fig. 2 is also used both as an acquisition and quality control format.

- Track 1
  - The transit time pairs should overlay (TT1C overlays TT3C, and TT2C overlays TT4C) because these pairs are derived from equivalent transmitter-receiver spacings. In very good cement sections, the transit-time curve may be affected by cycle skipping. DT and DTMD may be also affected.
- Track 2
  - The ULTR and R32R ratios are quality indicators of the transmitter or receiver strengths. They should be 0 dB ± 3 dB, unless one of the transmitters or receivers is weak. Both curves should be checked for consistency and stability.
- Track 3
  - DATN should equal NATN in free-pipe sections. In the presence of cement behind casing and in normal conditions, NATN reads higher than DATN.
- Track 4
  - VDL is a map of the waveform amplitude versus depth that should have good contrast. It provides information on the cement/formation bond, which is important for cement quality interpretation. The VDL image should be cross checked that it matches the DCBL readings.

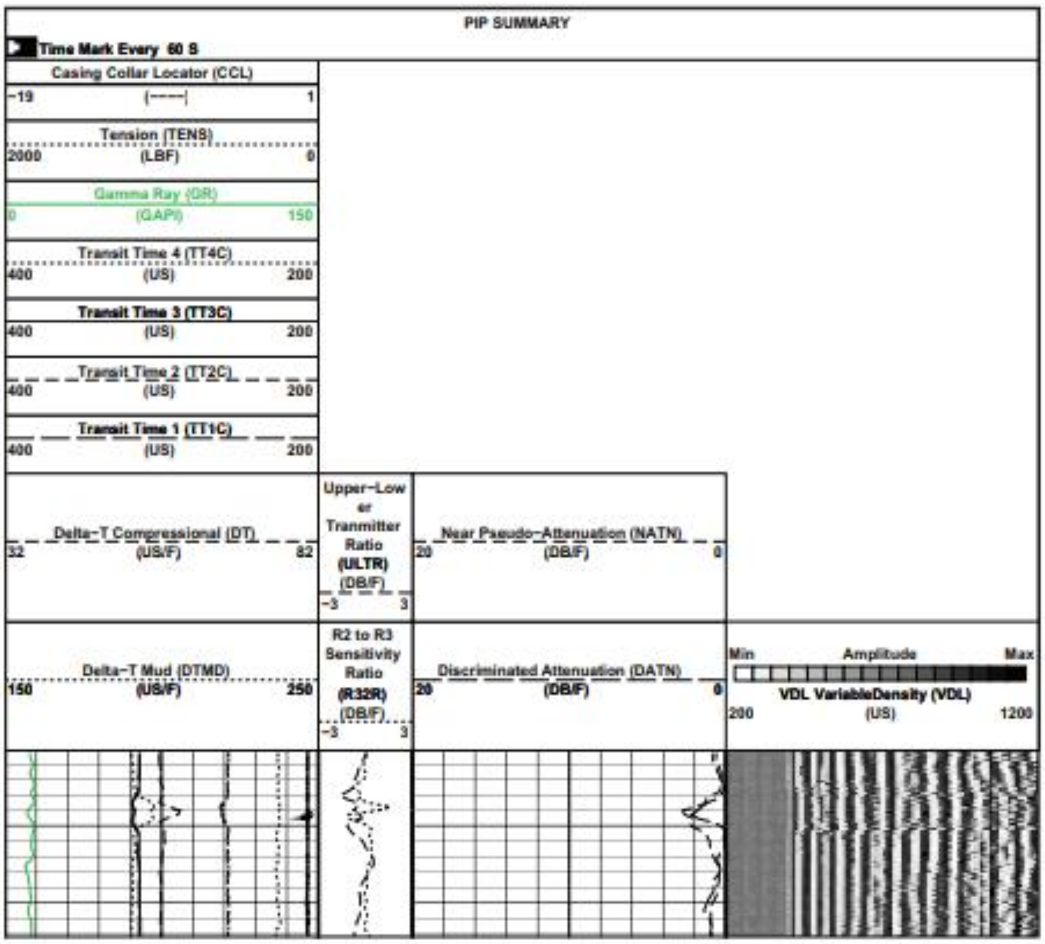

Figure 2. Additional CBT standard format for CBL and VDL.

Response in known conditions

- DT in casing should read the value for steel (57 us/ft ± 2 us/ft [187 us/m ± 6.6 us/m]).
- DTMD should be compared with known velocities (water-base mud: 180–200 us/ft [590–656 us/m], oil-base mud: 210–280 us/ft [689–919 us/m]).
- Typical responses for different casing sizes and weights are listed in Table 2.

Table 2. Typical CBT Response in Known Conditions

Casing Size, in	Casing Weight, lbm/ft	DCBL in Free Pipe, mV	TT1, us	TT2, us	TT5, us
4.5	11.6	84 ± 8	252	195	104
5	13	77 ± 7	259	203	112
5.5	17	71 ± 7	267	210	120
7	24	61 ± 6	290	233	140
8.625	38	55 ± 6	314	257	166
9.625	40[†]	52 ± 5	329	272	NM[‡]

[†] Although the CBT operates in up to 13⅜-in casing, the VDL presentation mainly shows casing arrivals where casings of 9⅝ in and larger are logged.
[‡] NM = not meaningful

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Cement Bond Logging

Overview

Cement bond tools measure the bond between the casing and the cement placed in the annulus between the casing and the wellbore. The measurement is made by using acoustic sonic and ultrasonic tools. In the case of sonic tools, the measurement is usually displayed on a cement bond log (CBL) in millivolt units, decibel attenuation, or both. Reduction of the reading in millivolts or increase of the decibel attenuation is an indication of better-quality bonding of the cement behind the casing to the casing wall. Factors that affect the quality of the cement bonding are

- cement job design and execution as well as effective mud removal
- compressive strength of the cement in place
- temperature and pressure changes applied to the casing after cementing
- epoxy resin applied to the outer wall of the casing.

The recorded CBL provides a continuous measurement of the amplitude of sound pulses produced by a transmitter-receiver pair spaced 3-ft [0.91-m] apart. This amplitude is at a maximum in uncemented free pipe and minimized in well-cemented casing. A transit-time (TT) curve of the waveform first arrival is also recorded for interpretation and quality control.

A Variable Density* log (VDL) is recorded simultaneously from a receiver spaced 5 ft [1.52 m] from the transmitter. The VDL display provides information on the cement quality and cement/formation bond.

Specifications

Measurement Specifications

	Digital Sonic Logging Tool (DSLT) and Hostile Environment Sonic Logging Tool (HSLT) with Borehole-Compensated (BHC)	Slim Array Sonic Tool (SSLT) and SlimXtreme* Sonic Logging Tool (QSLT)
Output	SLS-C, SLS-D, SLS-W, and SLS-E[†] 3-ft [0.91-m] CBL Variable Density waveforms	3-ft [0.91-m] CBL and attenuation 1-ft [0.30-m] attenuation 5-ft [1.52-m] Variable Density waveforms
Logging speed	3,600 ft/h [1,097 m/h]	3,600 ft/h [1,097 m/h]
Range of measurement	40 to 200 us/ft [131 to 656 us/m]	40 to 400 us/ft [131 to 1,312 us/m]
Vertical resolution	Amplitude (mV): 3 ft [0.91 m] VDL: 5 ft [1.52 m]	Near attenuation: 1 ft [0.30 m] Amplitude (mV): 3 ft [0.91 m] VDL: 5 ft [1.52 m]
Depth of investigation	Synthetic CBL from discriminated attenuation (DCBL): Casing and cement interface VDL: Depends on cement bonding and formation properties	DCBL: Casing and cement interface VDL: Depends on cement bonding and formation properties
Mud type or weight limitations	None	None
Special applications		Conveyed on wireline, drillpipe, or coiled tubing Logging through drillpipe and tubing, in small casings, fast formations

[†] The DSLT uses the Sonic Logging Sonde (SLS) to measure cement bond amplitude and VDL evaluation.

Mechanical Specifications				
	DSLT	HSLT	SSLT	QSLT
Temperature rating	302 degF [150 degC]	500 degF [260 degC]	302 degF [150 degC]	500 degF [260 degC]
Pressure rating	20,000 psi [138 MPa]	25,000 psi [172 MPa]	14,000 psi [97 MPa]	30,000 psi [207 MPa]
Casing ID—min.	5 in [12.70 cm]	5 in [12.70 cm]	3½ in [8.89 cm]	4 in [10.16 cm]
Casing ID—max.	18 in [45.72 cm]	18 in [45.72 cm]	8 in [20.32 cm]	8 in [20.32 cm]
Outside diameter	3⅝ in [9.21 cm]	3¾ in [9.53 cm]	2½ in [6.35 cm]	3 in [7.62 cm]
Length	SLS-C and SLS-D: 18.7 ft [5.71 m] SLS-E and SLS-W: 20.6 ft [6.23 m]	With HSLS-W sonde: 25.5 ft [7.77 m]	23.1 ft [7.04 m] With inline centralizers: 29.6 ft [9.02 m]	23 ft [7.01 m] With inline centralizers: 29.9 ft [9.11 m]
Weight	SLS-C and SLS-D: 273 lbm [124 kg] SLS-E and SLS-W: 313 lbm [142 kg]	With HSLS-W sonde: 440 lbm [199 kg]	232 lbm [105 kg] With inline centralizers: 300 lbm [136 kg]	295 lbm [134 kg] With inline centralizers: 407 lbm [185 kg]
Tension	29,700 lbf [132,110 N]	29,700 lbf [132,110 N]	13,000 lbf [57,830 N]	13,000 lbf [57,830 N]
Compression	SLS-C and SLS-D: 1,700 lbf [7,560 N] SLS-E and SLS-W: 2,870 lbf [12,770 N]	With HSLS-W sonde: 2,870 lbf [12,770 N]	4,400 lbf [19,570 N]	4,400 lbf [19,570 N]

Calibration

Sonde normalization of sonic cement bond tools is performed with every Q-check. Scheduled frequency of Q-checks varies for each tool. Q-check frequency is also dependent on the number of jobs run, exposure to high temperature, and other factors.

The sonic checkout setup used for calibration is supported with two stands, one on each end. A stand in the center of the tube would distort the waveform and cause errors. One end of the tube is elevated to assist in removing all air in the system, and the tool is positioned in the tube with centralizer rings.

Tool quality control

Standard curves

CBL standard curves are listed in Table 1.

Table 1. CBL Standard Curves

Output Mnemonic	Output Name
BI	Bond index
CBL	Cement bond log (fixed gate)
CBLF	Fluid-compensated cement bond log
CBSL	Cement bond log (sliding gate)
CCL	Casing collar log
GR	Gamma ray
TT	Transit time (fixed gate)
TTSL	Transit time (sliding gate)
VDL	Variable Density log

Operation

The tool must be run centralized.

A log should be made in a free-pipe zone (if available). Where a microannulus is suspected, a repeat section should be made with pressure applied to the casing.

Formats

The format in Fig. 1 is used for both acquisition and quality control.

- Track 1
  - TT and TTSL should be constant through the log interval and should overlay. These curves deflect near casing collars. In sections of very good cement, the signal amplitude is low; detection may be affected by cycle skipping. GR is used for correlation purposes, and CCL serves as a reference for future cased hole correlations..
- Track 2
  - CBL measured in millivolts from the fixed gate should be equal to CBSL measured from the sliding gate, except in cases of cycle skipping or detection on noise.
- Track 3
  - VDL is a presentation of the acoustic waveform at a receiver of a sonic measurement. The amplitude is presented in shades of a gray scale. The VDL should show good contrast. In free pipe, it should be straight lines with chevron patterns at the casing collars. In a good bond, it should be gray (low amplitudes) or show strong formation signals (wavy lines).

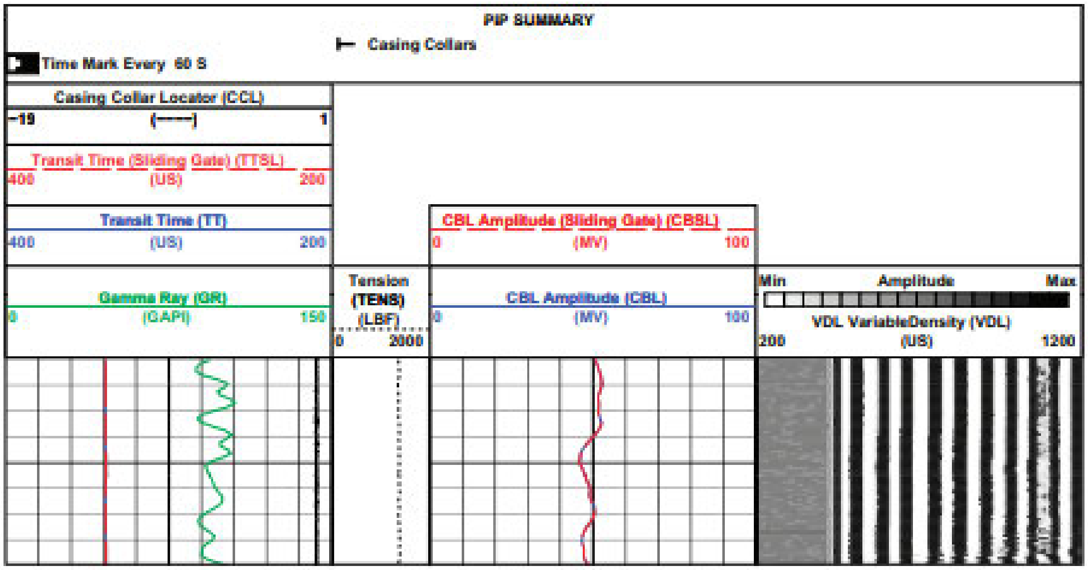

Figure 1. DSLT standard format.

Response in known conditions

The responses in Table 2 are for clean, free casing.

Table 2. Typical CBL Response in Known Conditions

Casing OD, in	Weight, lbm/ft	Nominal Casing ID, in	CBL Amplitude Response in Free Pipe, mV
5	13	4.494	77 ± 8
5.5	17	4.892	71 ± 7
7	23	6.366	62 ± 6
8.625	36	7.825	55 ± 6
9.625	47	8.681	52 ± 5
10.75	51	9.850	49 ± 5
13.375	61	12.515	43 ± 4
18.625	87.5	17.755	35 ± 4