



# **CRANFIELD PHASE III WELL & INSTRUMENT DESIGN**

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# ABSTRACT

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The Phase III program included construction of two deep, highly instrumented monitor wells for real-time monitoring of the advancing CO<sub>2</sub> plume. Instruments to monitor the Tuscaloosa Sand injection interval were deployed on the outside of the casing and cemented in place during the construction phase, and also deployed on the tubing as part of the completion phase.

Unique well completion assemblies with purpose-designed packers allowed an array of multiple monitoring instrumentation and instrumentation lines to be set across the injection interval.

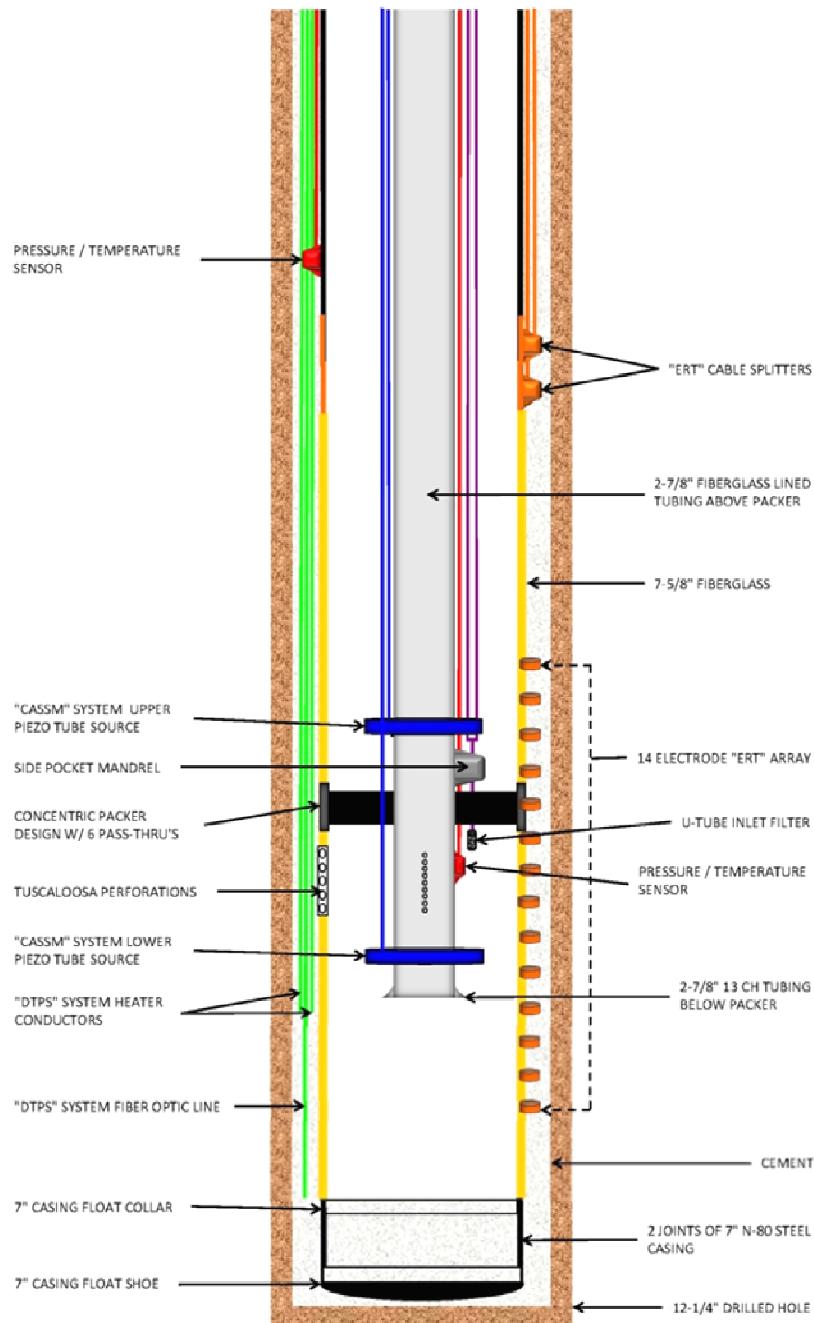
# ABSTRACT

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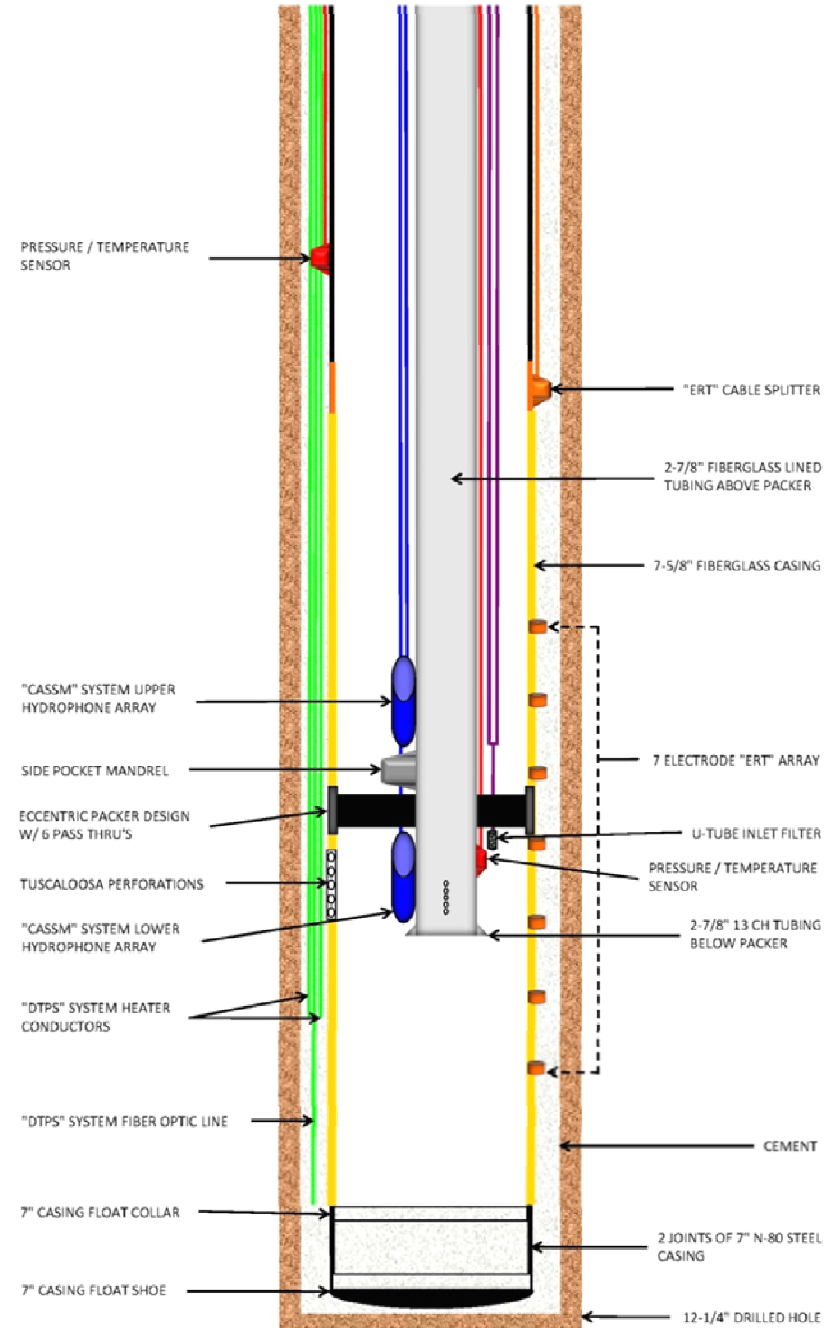
Downhole instrumentation was the primary factor in the final design of the monitoring wells drilled and completed at Cranfield. Instruments mounted on the exterior wall (casing deployed) of the protection casing as well as instruments to be installed on the completion tubing within the inside diameter (ID) of the protection casing (tubing deployed) dictated the required casing size and drilled hole size to accommodate the casing and instrumentation. Additionally, non-conductive casing was specified to be set across the Tuscaloosa Formation injection interval to integrate the Electrical Resistance Tomography experiment.

Incorporating all of the desired instrumentation into the well design required considerable effort and necessitated certain compromises with regards to the final instrumentation selection. This was the major task accomplished by Sandia as Field Services Provider.

CFU 31F-2 WELL SKETCH



CFU 31 F-3 WELL SKETCH

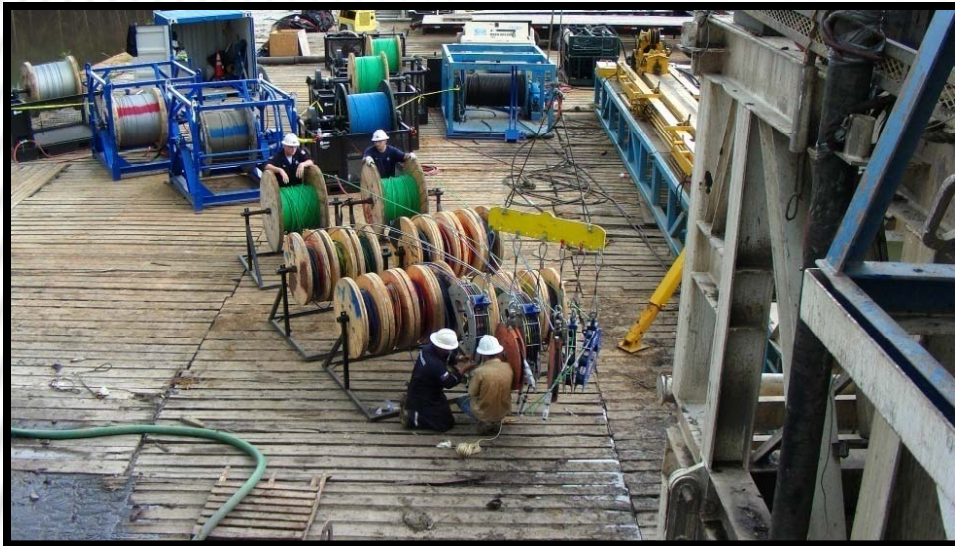


# CASING DEPLOYED INSTRUMENTATION

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- ❖ **Electrical Resistance Tomography (ERT) using fiberglass casing with external electrodes straddling the injection interval**
- ❖ **Distributed Temperature Perturbated Sensing (DTPS) using conventional fiber optic distributed temperature sensing with additional electrical conductor lines to increase the temperature across the injection interval**
- ❖ **Real-Time surface read-out Pressure/Temperature sensors were installed adjacent to an overlying sandstone horizon 400 feet above the injection interval for “above-zone” monitoring**

# MULTIPLE INSTRUMENT LINES BEHIND CASING



# **ELECTRICAL RESISTANCE TOMOGRAPHY (ERT)**

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- ❖ **Dual ERT ARRAYS** were mounted behind 7-5/8” fiberglass casing in each well
- ❖ **ERT ELECTRODES** designed to be integral part of fiberglass casing body
- ❖ **Electrodes** protected by molded centralizers integral to fiberglass casing design
- ❖ **Special design TEC/DAC “splitter”** to integrate multiple individual “tubing encapsulated conductors” into a single “double armored conductor” to surface
- ❖ **Electrode conductors** electrically insulated and shielded from TEC/DAC splitter

# FIBERGLASS CASING WITH 'ERT' AND 'DTPS' INSTRUMENTATION



# **DISTRIBUTED TEMPERATURE PERTURBATED SENSING (DTPS)**

- ❖ **Multi-Mode fiber optic lines were installed behind casing across the injection interval in each monitor well**
- ❖ **Heater conductors installed behind casing across the injection interval allow for increasing temperature and logging the subsequent temperature decay**
- ❖ **Variable Alternating Current Controller at surface controls temperature increase**
- ❖ **Stand-alone PC records DTPS data**

# FIBERGLASS CASING WITH 'ERT' AND 'DTPS' INSTRUMENTATION



# ABOVE – ZONE MONITORING

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- ❖ Pressure/Temperature gauges were mounted behind the casing in each monitor well
- ❖ Gauges were placed adjacent to a sand horizon 400 feet above the confinement layer
- ❖ Perforating charge option to assure communication to formation
- ❖ No down hole electronics
- ❖ High reliability

# TUBING DEPLOYED INSTRUMENTATION

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- ❖ U-Tube fluid and gas sampling in both wells
- ❖ Continuous Active-Source Seismic Monitoring (CASSM) with two hydrophone arrays in the F3 monitor well and two piezo tube sources in the F2 monitor well, straddling the injection interval
- ❖ Real-Time surface read-out quartz Pressure/Temperature sensors installed adjacent the injection interval for “in-zone” monitoring in both wells

# UNIQUE TUBING DEPLOYED COMPLETION ASSEMBLY



# U-TUBE FLUID AND GAS SAMPLING SYSTEM

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- ❖ Single 1/4" line penetrating the packer with sintered stainless steel filter at the inlet
- ❖ Y-Block and Check Valves mounted above packer
- ❖ Dual 1/4" lines above Y-Block to surface
- ❖ A 8' by 20' Systems Container on surface houses all computer controlled valves, allowing the sampling sequence to be continuous and automated
- ❖ All monitored parameters, including valve positions and pressures, are continuously logged for Post-Test analysis

# **CONTINUOUS ACTIVE-SOURCE SEISMIC MONITORING (CASSM)**

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- ❖ **Dual hydrophone arrays above and below packer, straddling the injection interval**
- ❖ **Eccentric packer design implemented to deploy tubing-mounted hydrophone arrays in 7 inch casing**
- ❖ **Eccentric bladed stabilizers designed to protect hydrophone arrays**
- ❖ **Dual piezo-tube sources, one above and one below packer**
- ❖ **Source “carriers” designed to protect sources during deployment**

# U-TUBE "Y" BLOCK AND ECCENTRIC BLADED STABILIZERS



# IN - ZONE MONITORING

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- ❖ High resolution quartz pressure/temperature gauges
- ❖ Gauges placed below packer, adjacent to injection interval, for in-situ data
- ❖ Surface interrogator has capability to log data for redundancy
- ❖ Surface interrogator has built-in display and plotting for real-time viewing

# **SURFACE DEPLOYED INSTRUMENTATION**

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- ❖ **Wireless surface transducers to monitor casing pressures, tubing pressures, ambient temperature, and atmospheric pressure**
- ❖ **Coriolis mass flow meter to accurately monitor CO<sub>2</sub> flow rates and total mass injected into the injection interval**
- ❖ **Data logger with satellite modem to transmit data to web site for remote viewing**

# SCREEN SHOT OF WEBSITE

Welcome, ellaglee7

Default Refresh: 5 Minutes

Sound: None on No Comms



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SITE ONLINE

SANDIA 2

SHOW STATS...

CFU31 DAS

ELLA G. LEES No. 7

Home > Sandia 2 > CFU31 DAS

System Time Apr 01, 2010 14:31 CST

[Favorite] [Logout]

LATEST READING HISTORY ALARMS SETTINGS

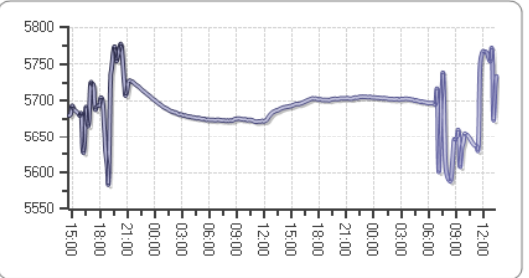
All Data

Input	4/1/2010 1:26 PM	4/1/2010 1:16 PM	Status	2 Day Avg	2 Day Max	2 Day Min
31F1 Mass Flow Rate (Kg/Min)	327.57	322.81	Normal	321.71	374.74	248.0
31F1 Density (Kg/m3)	851.02	846.29	Normal	844.03	895.26	802.0
31F1 Mass Flow Total (Kg)	49,442,608	49,439,360	Normal	48,991,260	49,442,600	48,538,0
31F1 Flowline Temp (C)	29.19	29.08	Normal	29.56	30.96	27.0
31F1 Flow Pressure (psig)	2,981.22	2,949.11	Normal	2,894.82	3,000.59	2,449.0
31F1 Inj. Invl. BHP (psig)	5,733.94	5,719.18	Normal			
31F1 Inj. Invl. BHT (F)	164.82	164.91	Normal			
31F1 Casing Pressure (psig)	-.72	-.44	Normal			

Time: 1 2 7 15 30 60 90 305

Scale: Auto Max/Min StDev High/Low

Show Extras View by: Log values



Sandia 2 > CFU31 DAS > 31F1 Inj. Invl. BHP (psig)

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**THANK YOU**