New Technologies for Monitoring UCG


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New Technologies for Monitoring UCG


Lawrence Livermore National Laboratory (LLNL), USA

UCG – Underground Coal Gasification

Alternative to surface gasification

- UCG uses the coal seam as the gasification reactor to convert coal to syngas underground.
- Coal $+O_2+H_2O \rightarrow H_2, CO, CH_4, CO_2, H_2O \ldots$ (syngas)
- Syngas can be burned for electric power or converted to methane, liquid fuels, methanol, ammonia, or hydrogen.
- Gasification is a leading approach for clean use of abundant coal.
- Well-suited to pollutant and CO2 capture.
- First U.S. patents in 1909 (Betts).
- Industrial-scale operations in Soviet Union.
LLNL has been active in UCG for decades

**Past Tests** (1970’s and 1980’s)
- 16 field tests at Hoe Creek, Centralia, Rocky Mountain
- Invented CRIP* process
- Extensive instrumentation and monitoring
- Cavity excavation
- UCG models and simulations

**Current Activities**
- Next generation UCG simulator
- Next generation UCG monitoring capabilities
- UCG program planning and site selection
- Site characterization and conceptual design
- Multi-disciplinary UCG team of 12 scientists and engineers

*Controlled Retractable Injection Point (CRIP)
Why monitor?

**Operate more efficiently and responsibly**
- Product gas quality
- Cost reduction
- Accelerate permitting
- Shield against liabilities
- Meet regulatory requirements

**Inform control decisions**
- Injection rate, composition, temperature, pressure
- Water pumping locations and rates
- Where to inject and produce
- Cavity size and growth; fractures
- When to stop
What to monitor?

- Process parameters
- Groundwater quality
- Hydrologic pressure field
- Surface subsidence
- Cavity characteristics
  - Size, shape, temperature
  - Extent of fractures
Surface subsidence

Managed with site selection
- Coal and rock properties
- Coal seam thickness, depth, and dip

Design and operations
- Cavity/module widths
- Pillar widths
- Affects percentage of processed coal

Similar issues as in underground coal mining
Surface subsidence

- Avoid damage to infrastructure
- Infer potential roof collapse
- Liability

Several modes of failure are possible:
- Roof collapse
- Chimneying
- Plastic deformation

Bell et al. (1988)
Crown hole/chimney over coal mining operations.
Types of subsidence monitoring

- Survey
- GPS
- LIDAR
- TDR
- InSAR
- Tiltmeters
Subsidence monitoring by InSAR

- **InSAR** - Interferometric synthetic aperture radar, a satellite based technology for deformation monitoring

Coal mining collapse observed with InSAR
Candall Canyon, Utah

- Millimeter level of deformation accuracy
- Large-area coverage (~10,000 km²/scene, 8m × 8m pixel)

ALOS L-band PALSAR
UCG deformation observed with InSAR

InSAR image showing surface deformation over an on-going UCG project
Tilt – real-time subsidence monitoring tool

- High data sampling rate
- High resolution
- Install near surface or in borehole
- Yields spatial derivative of deformation

Tilt monitoring of enhance oil recovery (EOR)
LLNL, 2011
Cavity geometry and fracture detection

- Variety of methods possible
- Seismic reflection
- Passive microseismic
- In-seam seismic
- Electrical resistivity tomography
Passive microseismic monitoring

- Locate fracturing and spalling
  - Micro-seismic used in coal mines
  - Hydro-fracs and geothermal
- UCG signal
  - Low-amplitude continuous ‘noise’ with burst-like signals
  - Requires geophones within 50 m
  - Localized acoustic activity near burn front
  - Micro-seismic activity in overburden
  - Caused by both geomechanical and thermal effects
- Processing algorithms leverage extensive LLNL expertise in seismic monitoring

Overburden core from Hoe Creek UCG site after heating to 1000°C (ORNL, 1977)
Microseismic monitoring development at LLNL

Improved detection
- Empirical matched filter detection
- 300% improvement over standard methods
- Robust to source differences

Improved location
- Multi-event location algorithm
- Bayesian error estimation for realistic error

Wang et al, (GRC, 2011)
Seismic tomography and in-seam seismic

- Possible to delineate reaction region with tomography
  - Variations observed in amplitude and travel times
- In-seam seismic evaluates seam thickness and continuity
  - Changes in seismic velocity
  - Changes in scattering, attenuation, and waveforms

Essen et al., 2007
Beckham et al., 1979
Electrical Resistivity Tomography (ERT)

- Resistivity is a function of temperature, air/fluid saturation, salinity, and porosity
- Inexpensive sensors (metal stakes)
- ERT arrays can be collocated with thermocouple or groundwater monitoring wells
- Data collection and processing can be automated

UCG Monitoring Objectives by ERT
- Locate burn front
- Delineate cavity boundary
- Resolve temperature distribution

VEA – Vertical Electrode Array
- Transmitter injects current into the earth
- Receiver measures voltage
Linking monitoring and simulation: geomechanical modeling

- Infer cavity shape from geophysical data
- Combine observational data (e.g., geology, subsidence, seismic, ERT) to constrain models
Conclusions

- **Goals of UCG Monitoring**
  - Increase efficiency
  - Operate more responsibly

- **New monitoring methods being developed**
  - InSAR and tilt
  - Passive microseismic
  - Seismic tomography and in-seam
  - Electrical resistance tomography