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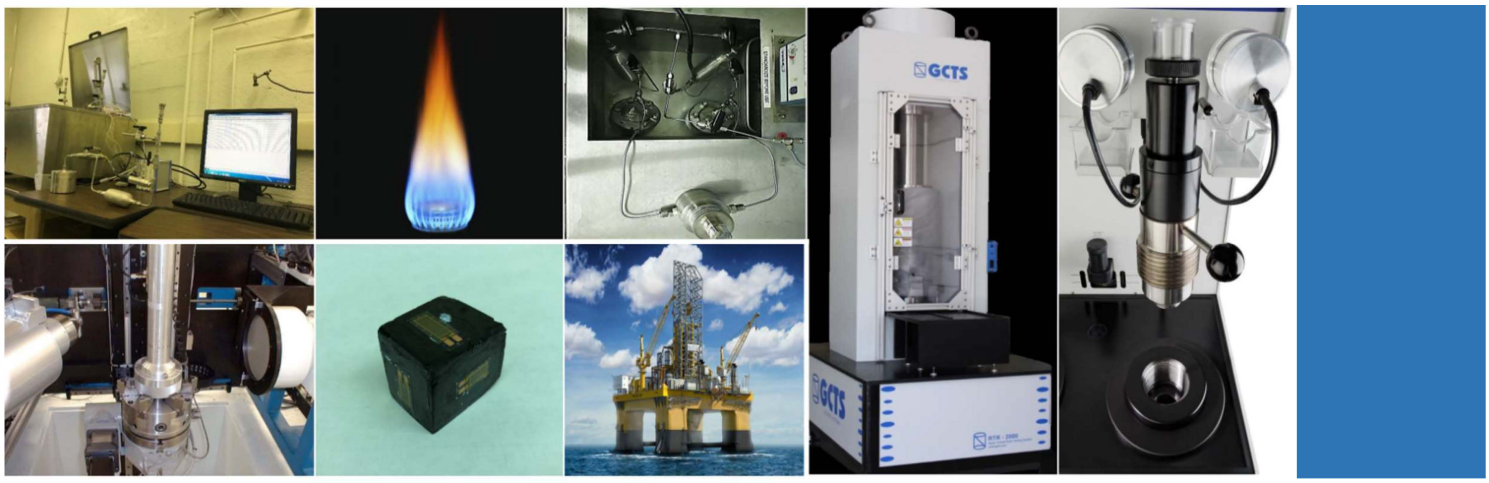

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CONTENTS

COAL GAS SORPTION SYSTEM

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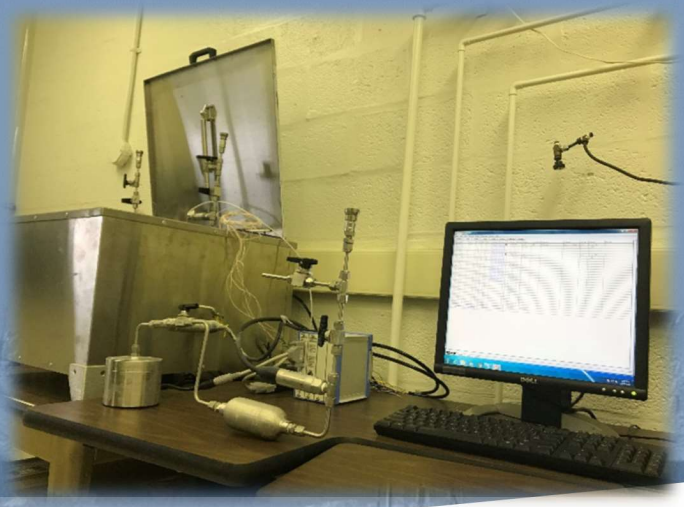
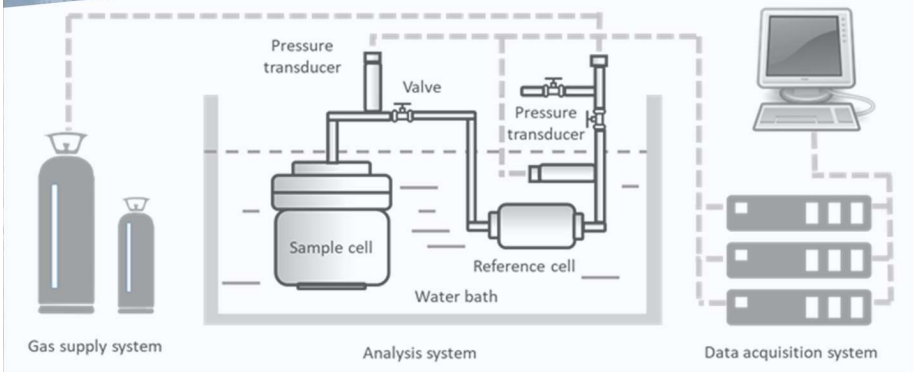
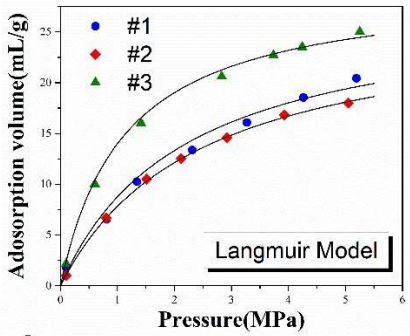
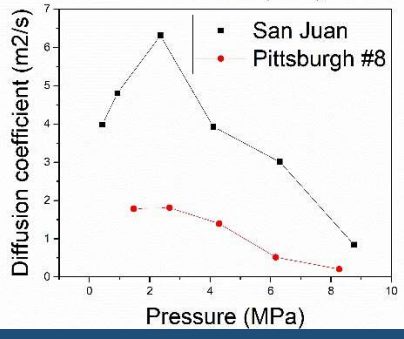




Capacity Specifications

- Pressure range: 0-3000 psi
- Measured accuracy: 0.01 psi
- Temperature range: -20°C to 95°C
- Pressure sampling rate: up to 1000/s
- Gas content range: >100 scf/t
- Gas types: CH_4, CO_2, N_2 and other hydrocarbon gases





Description

- **Gas sorption isotherm** is essential to determine the maximum gas holding capacity of a coal sample. It is used to estimate the gas-in-place (GIP) for a coalbed methane reservoir. The Unconventional Geomechanics Lab has measured various coal sorption isotherms (both adsorption and desorption) for different clients. The Lab also provides gas **diffusion coefficient and diffusive permeability** estimation services.
- The Lab also provided modeling services. We can use **Langmuir, BET, D-A, D-R models** to describe the sorption behavior of coals.

GAS PERMEABILITY SYSTEM

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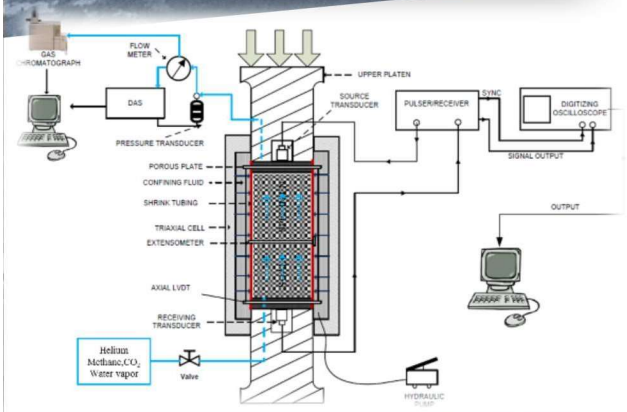
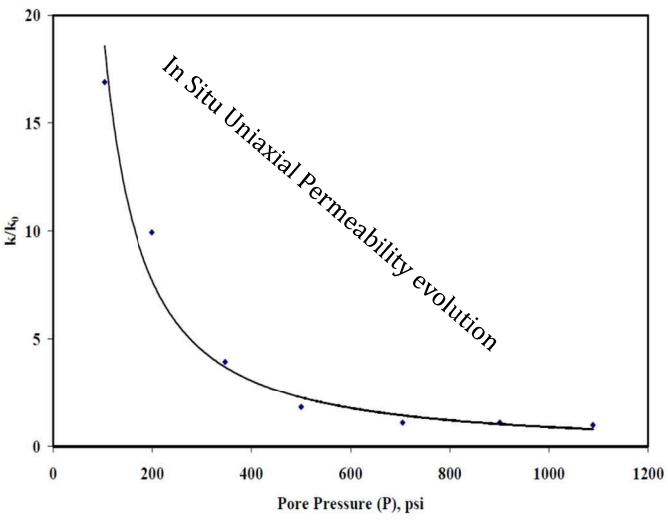


Capacity Specifications

- Axial load capacities up to 4,500 kN
- Pore pressure up to 210 MPa
- Pressure-dependent permeability measurement
- Temperature range: ambient to 200°C
- In situ uniaxial strain condition
- Servo-controlled applied stresses
- Pulse-decay permeability measurement (coal and shale)
- Steady-state permeability measurement (high permeability rocks



Description

The Lab can simulate the *in situ* reservoir rock stress/strain boundary conditions. We can measure the pressure dependent rock permeability under different stress conditions, including, hydrostatic condition, uniaxial strain condition, different deviatoric stress conditions. We have measured coal, tight sand and shale permeability

HYDRAULIC FRACTURING SYSTEM

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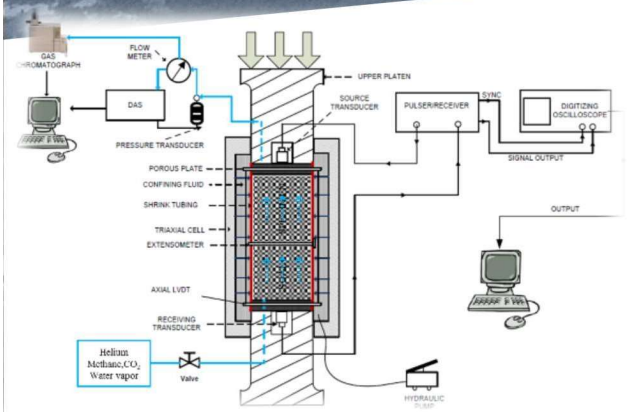
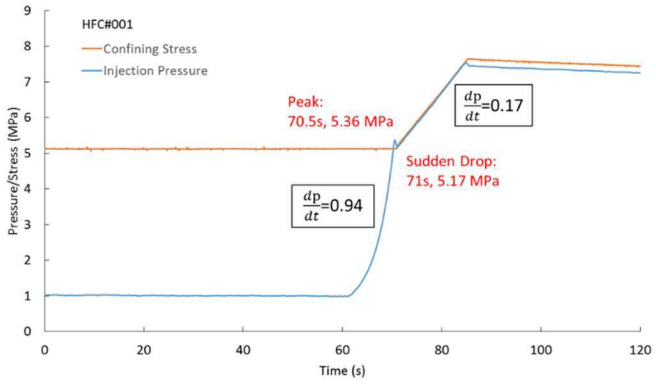


Capacity Specifications

- Axial load capacities up to 4,500 kN
- Pore pressure up to 210 MPa
- Specimen size: 25 mm to 100 mm
- Different fracturing fluids experiments
- Fracturing morphology characterization
- Different deviatoric stress fracturing experiments

Reservoir Rock Breakdown Pressure Responses



Description

The hydraulic fracture system was established to simulate the hydraulic fracturing fluid pumping, fracturing closure, and to measure the fracturing permeability. The fracturing fluids can be single phase gas (CO_2 and N_2), slick water, water, active water, VES-fracturing fluid, cross-link gel, and different foams. We can study the break-down pressure, fracturing propagation behavior using different fracturing fluids.

COAL MATRIX SHRINKAGE/SWELLING SYSTEM

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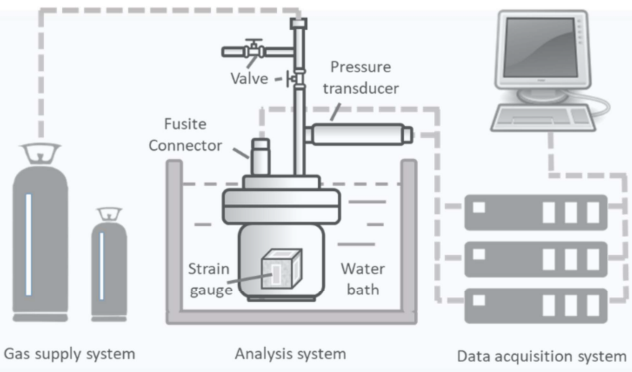
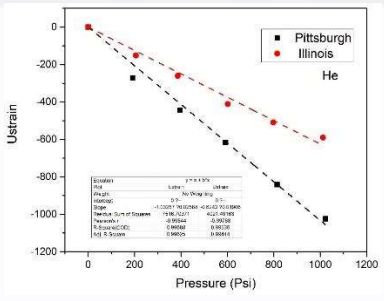


Capacity Specifications

- Pressure range: 0-2000 psi
- Measured accuracy: ±0.0001 micron strain
- Temperature range: ambient to 95°C
- Pressure sampling rate: up to 1000/s
- Gas mixture matrix shrinkage/swelling

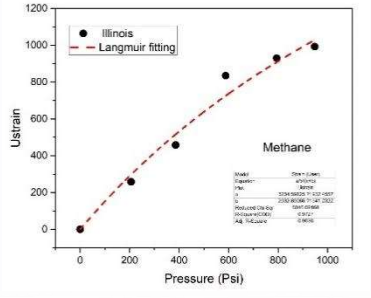
TYPICAL RESULTS



Description

Coal matrix compressibility - Helium

- The Lab can measure coal matrix compressibility due to mechanical compression by using non-sorbing Helium.



Description

CH_4 and/or CO_2 matrix shrinkage/swelling

- CH_4-/CO_2-/N_2-induced coal matrix shrinkage and swelling measurements
- Gas mixture coal matrix shrinkage and swelling

MTS ROCK TESTING SYSTEM

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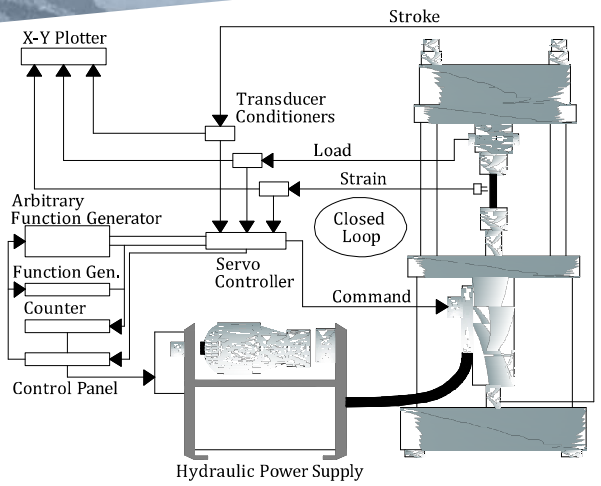
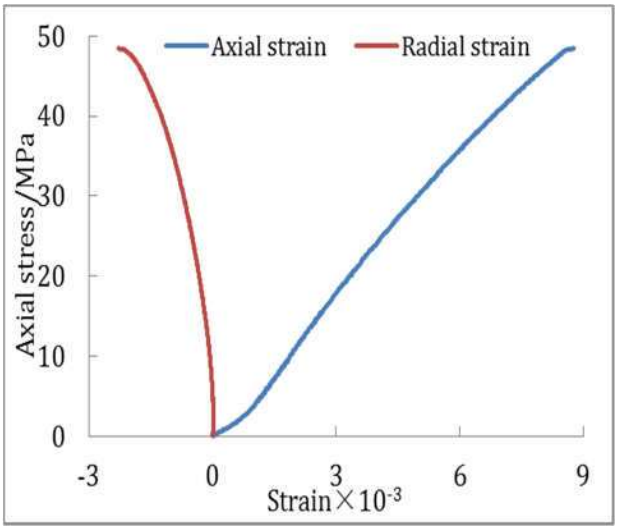
Capacity Specifications

- Compression rating: 200 kip
- Tension rating: 150 kip
- Actuator displacement: 4 inch
- Spring rate: 1.5×10^{7} lb/inch

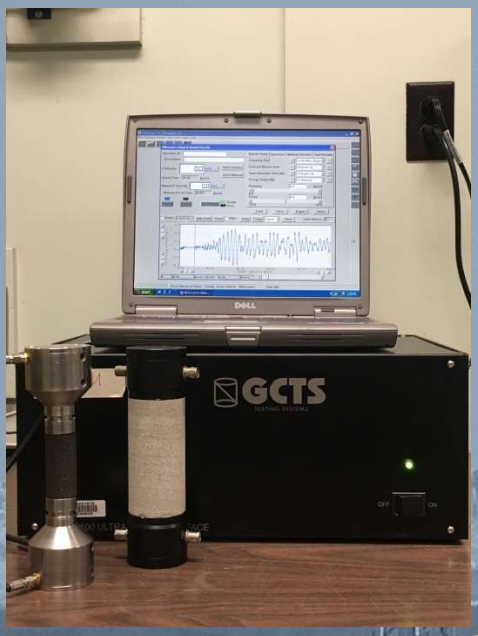




Mechanical Properties

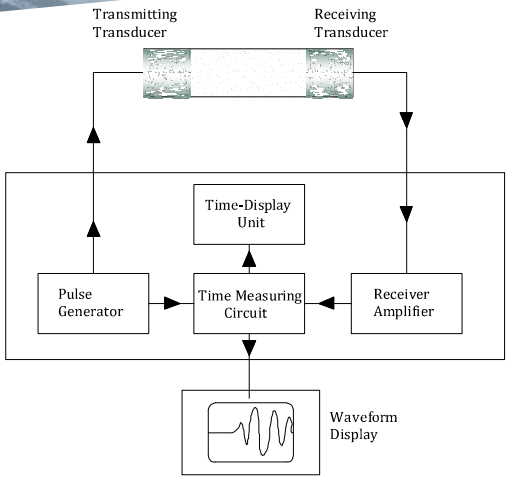
- Uniaxial compressive strength
- Young's modulus
- Poisson's ratio
- Strain-stress relationship

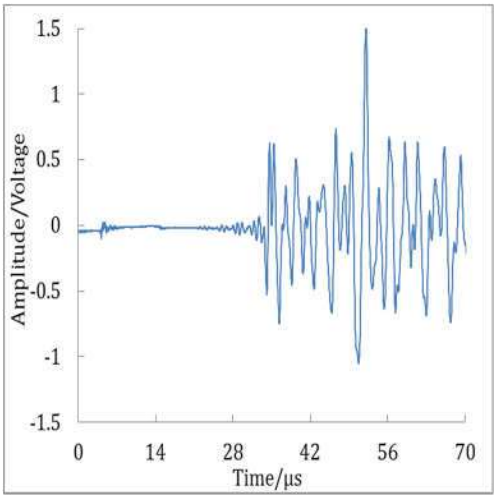
ULTRASONIC ROCK TESTING SYSTEM

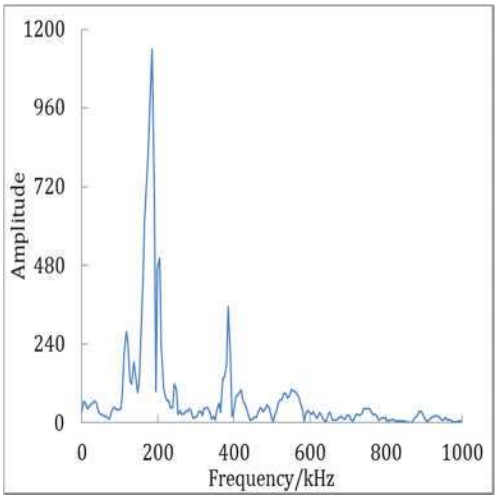


Capacity Specifications

- Maximum resolution: 20 MHz
- Minimum resolution: 156 kHz
- Acquisition rate: 20 MHz
- Receiver bandwidth: 10 MHz







Measurable Properties

- P- and S-wave velocities
- Attenuation
- Dynamic modulus
- Rock dynamics
- Saturation measurement
- Fracture characteriation

SHALE SORPTION AND DIFFUSION SYSTEM

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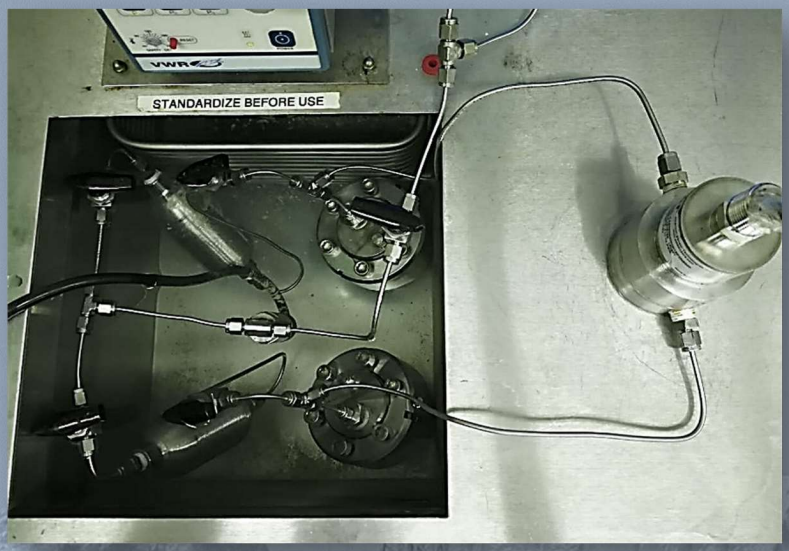
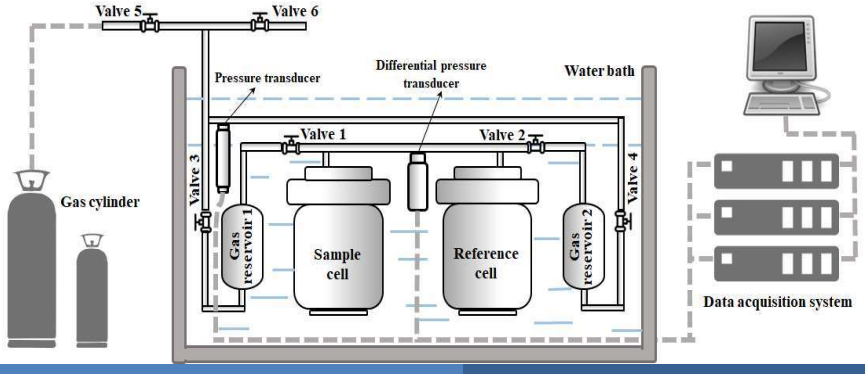


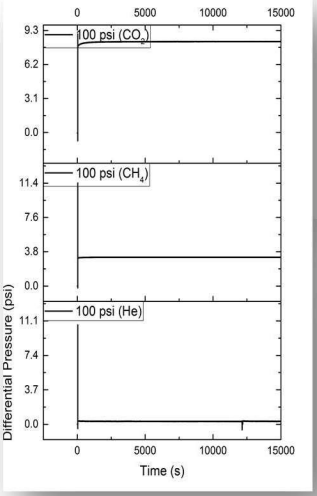
Challenges for Shale Sorption

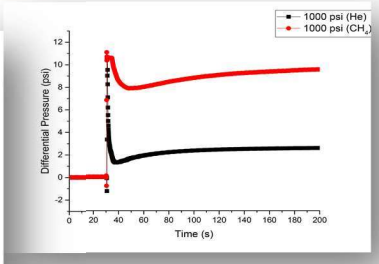
Since the shale sorption capacity is very low compared to coal, the accurate measurement of shale sorption capacity is very challenging. Shale sorption capacity is 10~100 scf/t, and conventional method will involve large error. We established a high accuracy, high-line pressure shale sorption system which can measure gas sorption capacity less than 10 scf/t with accuracy of ±3%.



Capacity Specifications

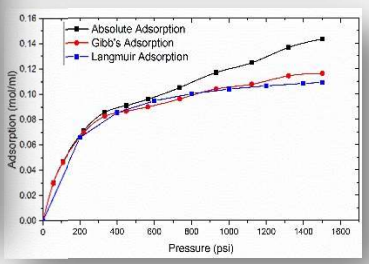
- Capable of monitoring the **small pressure** reduction (**0-10 psi**) induced by adsorption.
- Pressure range: **0~2000 psi**
- Pressure Accuracy: **0.01 psi**
- Temp range: **-20~100 ℃**
- Modelling: Langmuir, Diffusion coefficient, Adsorption potential energy, Multicomponent gas adsorption





Description

- Adsorption induced pressure reduction
  - Differential pressure vs time
  - Single phase and multi-phase shale adsorption induced pressure drop with time



Description

- Adsorption isotherm curves
  - Shale adsorption capacity under various temperature conditions
  - Fitting curves of Langmuir and Gibb's adsorption isotherm curves

X-RAY CT ROCK CORE TESTING SYSTEM

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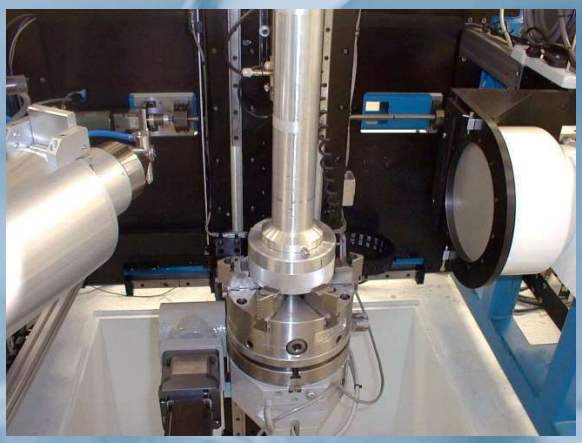
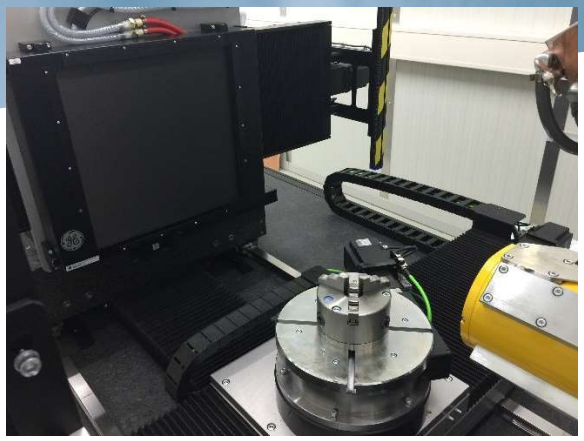
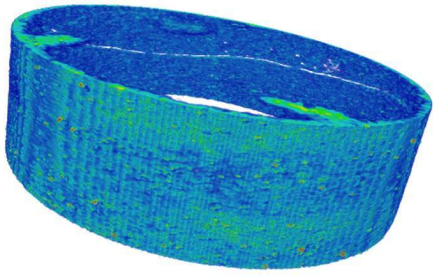
GE v|tome|x L300 multi-scale nano/microCT system



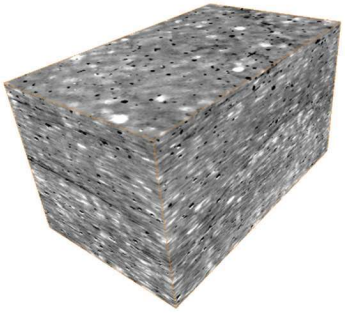


Capacity Specifications

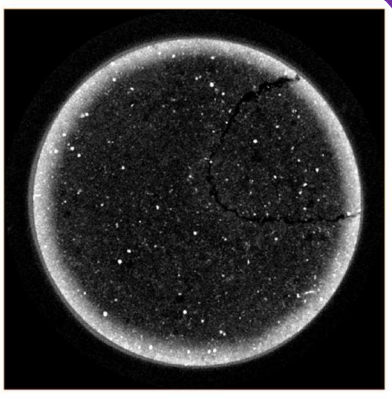
- 300kV unipolar microfocus X-ray tube
- 180kV nanofocus X-ray tube with transmission target and a high contract digital flat detector
- 3D image rock core data
- High pressure core holder is available
- Fracture characterization of rocks
- 3D visualization for rock structures



Gas transport in rock core



Nano-porosity quantification



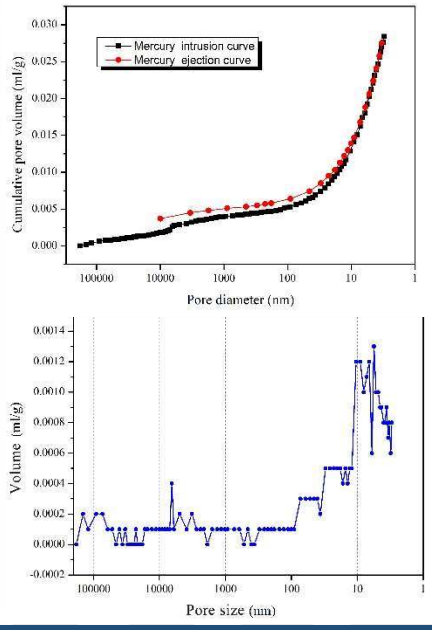
Rock Fracture Characterization

MERCURY POROSIMETRY

Capacity Specifications

- Four low pressure ports
- Two high pressure ports (60,000 psi)
- Measurements can occur in 30 to 60 minutes
- Pore size diameters can be measured between 0.003 and 360 microns
- Measurements include pore volume, pore area, material density and percent porosity.

TYPICAL RESULTS

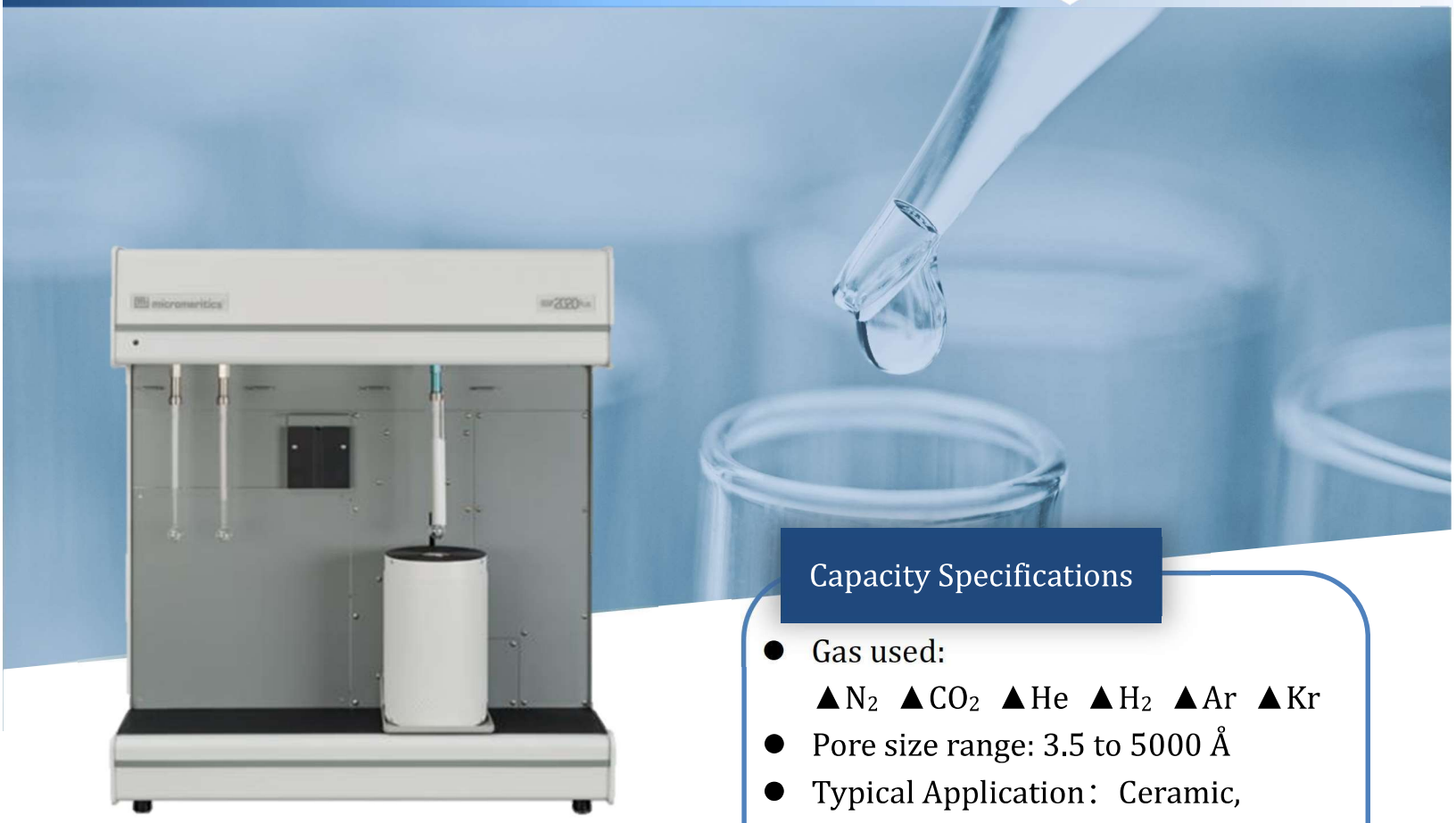


Description

Mercury injection/ejection curve

- Mercury porosimetry is used to measure the porosity of a material by applying controlled pressure to a sample immersed in mercury. External pressure is required for mercury to penetrate into the pores of a material due to high contact angle of mercury. The amount of pressure required to intrude into the pores is inversely proportional to the size of the pores. The larger the pore the smaller the pressure needed to penetrate into the pore.

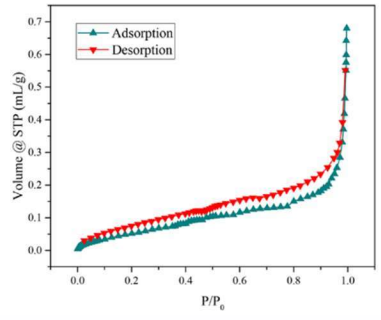
ASAP 2020 AUTOMATED SURFACE AREA AND POROSIMETRY SYSTEM



Capacity Specifications

- Gas used:
  ▲N_2 ▲CO_2 ▲He ▲H_2 ▲Ar ▲Kr
- Pore size range: 3.5 to 5000 Å
- Typical Application： Ceramic, activated carbons, carbon black, catalysts, nanotubes, electronics, aerospace, fuel cells, clays et al.

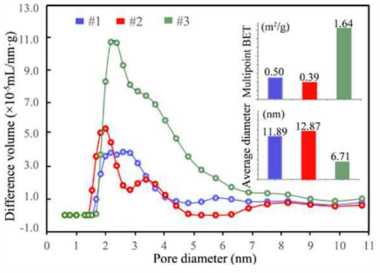
TYPICAL RESULTS



Description

Liquid N_2 adsorption curve

- Liquid N_2 adsorption curve is widely used in analyzing pore characteristics of shale and coal. Based on the hysteresis loop, the pore shape can be generally inferred.



Description

Pore size distribution

- With the theory of t-polt, BET, BJH, DFT and other methods, the pore size distribution (volume and surface area), BET surface area and average pore width et al. can be obtained precisely.

ROCK SWELLING TESTING SYSTEM

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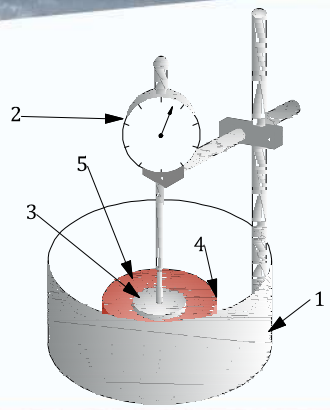
Geotechnical Testing – Mudstone Swelling for tunneling, mining industries.



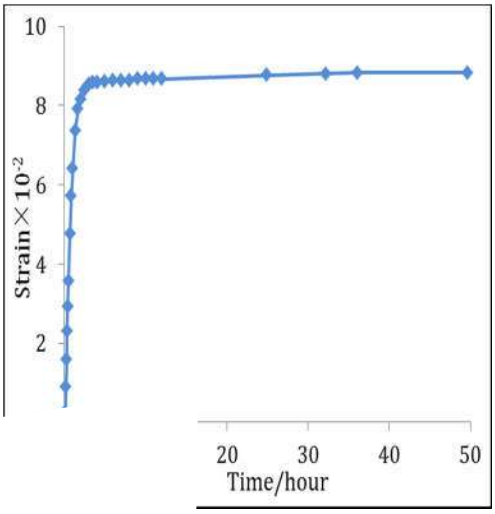
1. Stainless-steel container;
2. Dial gauge;
3. Stainless-steel plate;
4. Stainless-steel band;
5. Rock specimen.

Capacity Specifications

- Measuring range: 0-1 inch
- Resolution: 0.0005 inch
- Accuracy: 0.001 inch
- Repeatability: 0.0005 inch
- Maximum measuring speed: 1.5 m/s

Measurable Properties

- Axial free strain
- Radial free strain
- Volumetric free strain
- Time-dependent swelling



SLAKE DURABILITY TESTING SYSTEM

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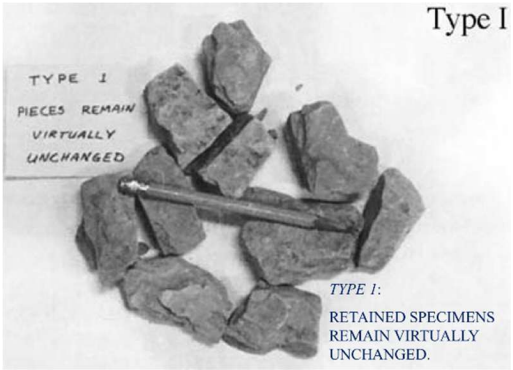
Slake Durability Index

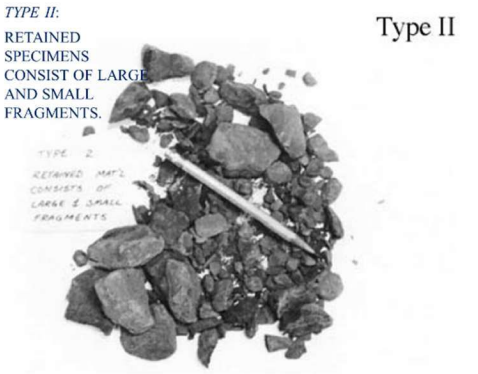
$$I_{d1} = [(W_{f1} - C)/(W_i - C)] \times 100$$
$$I_{d2} = [(W_{f2} - C)/(W_i - C)] \times 100$$

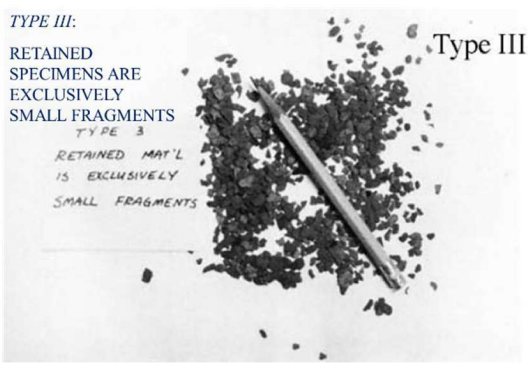
Where W_i = mass of drum plus oven-dried specimen before the first cycle, g, W_{f1} *and* W_{f2} = mass of drum plus oven-dried specimen retained after the first and the second cycles accordingly, g, and C is mass of drum.

Goal/Objective

To determine the slake durability index of water sensitive rocks after two drying and wetting cycles with abrasion.







TYPE I: Retained specimens remain virtually unchanged. TYPE II: Retained specimens consist of large and small fragments. TYPE III: Retained specimens are exclusively small fragments.

ASTM D4644-16

WATER VAPOR SORTION SYSTEM

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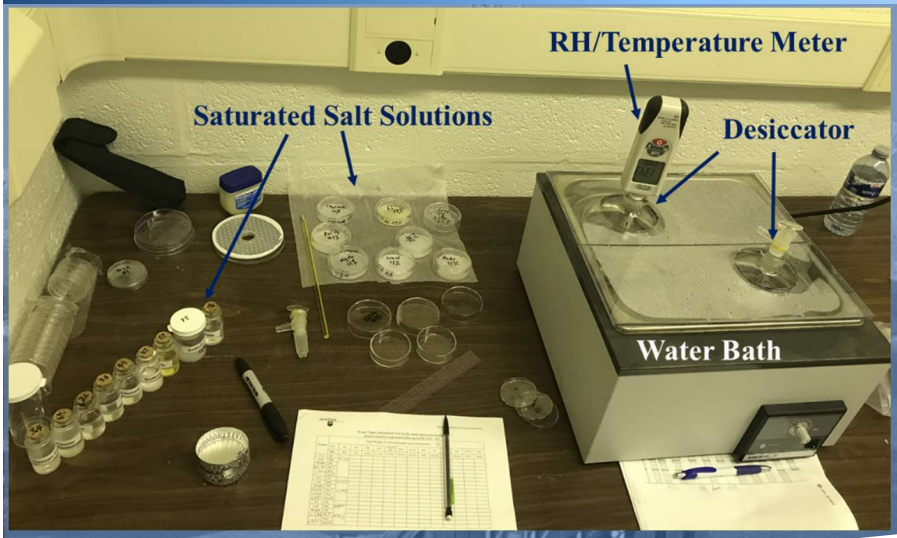
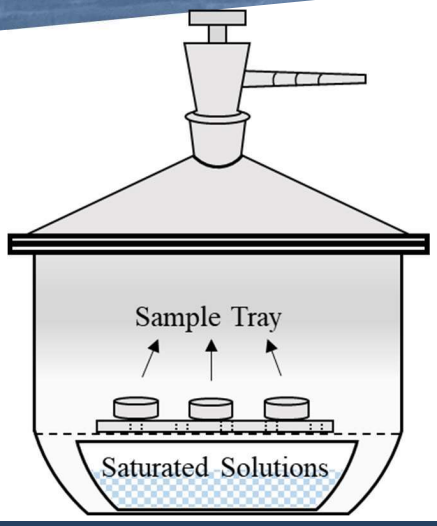


Capacity Specifications

- Relative humidity range: 0%-~97.3%
- RH accuracy: ±2%
- Temperature range: 5-80 °C
- Temperature accuracy: ±0.5 °C

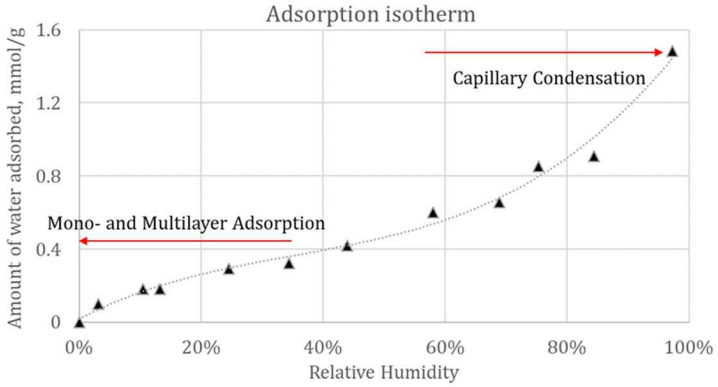


ASTM E104-02 (2012)

Equilibrium RH

Relative Humidity Generated by Different Saturated Salt Solutions at 25 °C

Salts	CsF	LiBr	LiCl	CH_3COOK	$MgCl_2$	K_2CO_3	NaBr	KI	NaCl	KCl	K_2SO_4
RH, %	3.4	6.4	11.3	22.5	32.8	43.2	57.6	68.9	75.3	84.2	97.3



Modeling

- Monolayer Adsorption
- Multilayer Adsorption

} BET Theory

- Capillary Condensation -- Kelvin Equation