TESTING SYSTEMS
Wellbore stability requires evaluation of the rock’s competence and its potential for failure, resulting in wellbore collapse, unwanted hydro/shear fracturing, and wellbore breakouts. The mechanical behavior of relevant rock samples is investigated in the laboratory under simulated in-situ conditions of stress and temperature to evaluate the potential for failure. Laboratory triaxial testing equipment and techniques have been developed to measure and calculate rock competence and susceptibility to failure. Static and dynamic properties are measured during the experiment to generate a stress-strain curve, calculate Young’s modulus, Poisson’s ratio, as well as other geomechanical properties. Additionally, other testing methods are available such as (but not limited to): Thick Wall Collapse (TWC), Uniaxial, Isostatic and Brazilian strength testing.

**Understanding Compaction and Surface Subsidence and its Effects on Permeability**

This phenomenon is primarily caused by volumetric changes in the reservoir pore space brought about by reservoir pressure reduction during depletion. To quantify the magnitude of these changes, the rock’s volumetric compressibility is calculated by measuring stress and strain behavior. These values are also essential for estimation of oil in place, reservoir maintenance, and production drive assessments.
Uniaxial Testing

A uniaxial laboratory testing technique at estimated in-situ stress condition was developed to measure and compute rock Pore Volume Compressibility (PVC). Both static and dynamic properties are measured during the experiment to generate all essential geomechanical properties. Utilizing MetaRock Laboratories’ high precision flow pumps, permeability measurement can be produced for the duration of the experiment.
Uniaxial Measurements

\[ \Delta PV = \Delta BV - \Delta GV \]

\[ C_p \Delta BV = C_m \Delta BV - C_g (1 - \phi) \Delta BV \]

\[ C_p = \frac{1}{\phi} \left[ C_m - C_g (1 - \phi) \right] \ldots (1) \]

\[ C_p = \frac{C_m}{\phi} \quad \text{when} \quad C_b \gg C_g \ldots (2) \]

\[ C_m = \frac{\Delta \varepsilon_{ax}}{\Delta \sigma} \]

for Uniax stress path where \( \Delta \varepsilon_{r} = 0 \)

Sample Name= X
Length=1.984(in.)
Diameter=1(in.)
Weight=64.03 (g)

Pore Volume Compressibility and Permeability

Estimated Pore Volume Compressibility (Cp/L/psi)

Axial Stress (psi)
Biot Measurements in Permeable Sample

**Biot Experiment**

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300</td>
<td>0</td>
</tr>
<tr>
<td>1200</td>
<td>5</td>
</tr>
<tr>
<td>1100</td>
<td>10</td>
</tr>
<tr>
<td>1000</td>
<td>15</td>
</tr>
<tr>
<td>900</td>
<td>20</td>
</tr>
<tr>
<td>800</td>
<td>25</td>
</tr>
<tr>
<td>700</td>
<td>30</td>
</tr>
</tbody>
</table>

**Effective Stress (psi)**

- Confining
- PorePres
- Sigma1
- S1'
- S2'
- Devitonic

**Poroeastic Constant**: $1 - (Cg/Cb) = 0.627$

- $y = 1.06E-06x - 3.64E-01$
- Bulk Compressibility = $9.43 \times 10^4$ PSI

- $y = 3.95E-07x - 7.86E-02$
- Grain Compressibility = $2.53 \times 10^6$ PSI
Unconventional

In-situ Stress Determination

Subsurface stress, orientation, and magnitude plays a major role in controlling wellbore stability, fracture permeability, and production processes. Subsurface stress or in-situ stress determination plays a vital role in the exploitation for existing reservoirs and in the definition of fractured reservoirs. Utilizing proven laboratory techniques, natural field stress can be measured and detected. Radial and axial acoustic velocity measurements on oriented core samples were developed primarily as a method to compare with the field observations and ultimately determine the in-situ stress. This technique was based on the recognition of microcracks induced during the coring process. The occurrences of micro-cracks and orientation are assumed to be a direct function of the in-situ stress. A dominant population of microcracks is interpreted to indicate the orientation of the maximum principle stress.

What Does Anisotropy Look Like in an Unconventional Reservoir?

![Diagram showing isotropic and anisotropic media with natural fractures, bedding fabrics, stress-induced fractures, and stress-induced compaction and fractures.](image-url)
GEOMECHANICS TESTING

1D Mechanical Earth Model

CORE Measurements

Ultrasonic Acoustics Velocity

\[ V_p(90), V_p(45), V_s(90), V_s(45) \]

\[ V_p(0), V_s(0) = \frac{V_p(90) + V_p(45)}{2} \]

Static Mechanical Properties

\[ E_v^S, v_v^S, E_h^S, v_h^S \]

Dynamic to Static Correlation

\[ E_v^{(d-s)}, v_v^{(d-s)} \]

Using Eaton's equation calculate log minimum horizontal stress

\[ \sigma_h = \left( \frac{v_v}{1 - v_v} \right) \left( \sigma_v - \alpha P_p \right) + \alpha P_p \] .... Isotropic

Build necessary correlations to obtain pseudo \( V_p(90), V_s(90), V_p(45) \)

\[ V_p(90) = \{ V_p(0) \} ; V_s(90) = \{ V_s(0) \} ; V_p(45) = \{ V_p(0) \} \]

Calculate Elastic Stiffness Tensors \( C_{ij} \) & dynamic anisotropic mechanical properties \( E_v^{d,a}, E_h^{d,a}, v_v^{d,a}, v_h^{d,a} \)

Build dynamic to static mechanical properties correlations

\[ E_v^{(d-s)}, E_h^{(d-s)} \]

Utilizing correlations convert \( E_v^{d,a}, E_h^{d,a}, v_v^{d,a}, v_h^{d,a} \) (dynamic) to \( E_v^{S,a}, E_h^{S,a}, v_v^{S,a}, v_h^{S,a} \) (static)

& calculate anisotropic static mechanical properties for lab and log

Using Eaton's equation calculate log minimum horizontal stress \( \sigma_h \)

\[ \sigma_h = \left( \frac{v_v}{1 - v_v} \right) \left( \sigma_v - \alpha_P P_p \right) + \alpha_p P_p \] .... Anisotropic

---

2703 Highway 6 S Suite 280 Houston, TX 77082 • Ph (713) 664-7916 • Fx (832) 415-0358 • info@metarocklab.com • www.metarocklab.com
GEOMECHANICS TESTING

Minimum Horizontal Stress Model (Sh), psi

- Ben Eaton
- Modified Ben Eaton with Correction Factor
- Vernik
- Jaeger and Cook
- Hubbert and Willis
- Thiercelin
- Segall
- Penebaker's

Isotropic
Anisotropic

From MC Envelope
From Elastic Stiffness Tensors Cij

Minimum Horizontal Stress (Sh) Models, psi

4% error bars added to DFIT to match with anisotropic Ben Eaton Model

TVD (ft)

Sh (psi)

- Ben Eaton ISO
- Modified Ben Eaton with Correction Factor
- Vernik-0.4
- Jaeger and Cook
- Hubbert and Willis
- Thiercelin using Cij
- Segall
- Penebaker's
- Ben Eaton ANISO
- Vernik-0.4
- Jaeger and Cook
- Hubbert and Willis
- Thiercelin using Cij
- Segall
- Penebaker's
- DFIT
Velocity as a Function of Stress history
Radial Compressional Velocity Measurement in Aluminum – A Perfect Circle in an Isotropic Media

Radial Velocity Anisotropy in Shale – An Ellipse in an Anisotropic Media

Radial Compressional Velocities (ft/sec) as a Function of Azimuth (°) Under Isostatic Loading at S3 = 4000psi

Difference between Vmax and Vmin = 11%
• Inputs to Obtain Elastic Stiffness Tensors (Cijkl): \( V_{P0}, V_{S0}, V_{P45}, V_{P90}, \text{and } V_{S90} \)
• \( V_{S90} \): Lab build correlations can be used to complete the tensors
Input for Geomechanics Models

In recent decades, geomechanics has become a significant consideration in the petroleum industry. From extended horizontal drilling with multi-lateral junctions in fields that are tectonic and fractured, to severely depleted reservoirs with compaction and altered rock permeability, the analysis from a geomechanical perspective provides solutions to such problems that could adversely impact hydrocarbon recovery as well as the environment. Modeling capabilities support the analysis of wellbore stability and rock integrity problems of multi-lateral wellbore systems. With relevant reservoir data, geomechanical models can also simulate reservoir conditions to study compaction, surface heave, and subsidence and seal integrity.

Planning for Sand Control Protocol

For unconsolidated sand, the ability to predict the likelihood and on-set of sand production as a function of rock strength, changes in in-situ stresses, and reservoir depletion is an important aspect of production engineering. It requires specialized skills and knowledge to test friable and unconsolidated samples for triaxial rock strength and thick-wall cylinder strength properties. Specialized industry protocols for unconsolidated sands are typically followed for handling, additional protocols have been developed for handling of samples in the geomechanical testing systems.

Plan Reservoir Management Programs, Designing Waste Injection Well Specifications and Procedures

In reservoir modeling where geomechanical behavior is coupled with reservoir fluid, rock strength, and in-situ stress data are often required. These stresses can be estimated based on log data, field data, and laboratory measurements on representative core material. For example, the changes in rock permeability as a function of effective stress increase over production cycle may become an important consideration in reservoir management.

Core Handling and Sampling

MetaRock Laboratories recognizes the importance in obtaining high-quality samples from whole core segments. Core handling and sampling is a critical aspect of maintaining sample integrity throughout the retrieval process, testing, and post-testing analysis.

MetaRock possesses the in-house capability to receive samples of any type—from plugs to whole core samples. MetaRock can also work with/handle samples in any condition (consolidated, poorly consolidated, and/or nonconsolidated).
MetaRock has a wide array industry-specific equipment which enables the technician team to cut samples per client request. This includes, but is not limited to: cutting vertical, horizontal, and angles to bedding, end facing of samples, and sample extraction with axial loading.

The extensive range of cutting fluids include (but are also not limited to) liquid or gas phase N2, lab or crude oils, air, water/brine, and special provisions for unique samples and circumstances. Our laboratory resources for sample storage available include freezers, refrigerators, vacuum/pressure saturators, dry ice, and oil baths.

**Thin Section Capabilities**

MetaRock is also capable of handling the preparation of sections from ultra-thin (shales/mudstones) to thick (fluid inclusion sections including removable wafers for FIT). Standard finish or polished surfaces for SEM/microprobe are also available, in addition to impregnation at reservoir overburden pressures to 10,000psi.

**X-Ray Diffraction Analysis**

Among MetaRock’s extensive offerings of testing services includes X-Ray diffraction analysis. MetaRock has the in-house capabilities to provide semi-quantitative determination of sample mineralogy. Bulk and clay X-ray diffraction analysis is performed to assist in reservoir description and evaluation of reservoir diagnosis.

**Brazilian Testing**

MetaRock’s Brazilian test clamps, made from stainless steel, are custom-machined clamps for standard sample sizes of up to 2 inches diameter. However, on request, custom pieces can be designed and fabricated as per customer specification.

External LVDTs can be mounted on the sides of the clamp to measure axial strain in addition to load cell readings. The high precision machining allows for accurate piston alignment.
Brazilian Test Results to Determine Tensile Strength

Vertical Test
- Tensile Strength = 1768 psi
- Bulk Density = 2.66 g/cc

Horizontal (Load applied perpendicular to bedding)
- Tensile Strength = 1873 psi
- Bulk Density = 2.65 g/cc

Horizontal Test (Load applied parallel to bedding)
- Tensile Strength = 1536 psi
- Bulk Density = 2.65 g/cc
Known for delivering premium products and services, MetaRock Laboratories’ strengths arise from high-caliber professionals. Committed to surpassing current industry best practice and quality standards, MetaRock’s engineering team hails from diverse academic backgrounds with a wide range of skills and years of expertise.

Deeply integrated within the oil & gas industry, MetaRock’s professionals offer their services to clients by consulting on projects (turnkey or phase-by-phase) involving mechanical, chemical and/or electrical engineering.

A large portion of MetaRock’s team is made of Information Management professionals who are able to help clients with their records management, information and knowledge management needs. Their contribution to client projects has proved to be a critical aspect to project development, maintenance and completion.

MetaRock Laboratories makes for the perfect choice when seeking a partner in Automated Integration Solutions and Knowledge Management.

**SERVICE OFFERINGS INCLUDE:**

- Schematic design and systems’ lifecycle cost analysis
- Turnkey project planning and feasibility studies
- Automation and integration solution
- Data acquisition and process control software services
- Laboratory logistics management
- Design and development of custom products
- Consulting on experiments involving use of high pressures and high temperatures
- Core and data analysis
In addition to testing services, MetaRock Laboratories also provides consulting services for wellbore stability modeling, hydraulic fracturing, lateral well design and well optimization by utilizing specific stress analysis developed using unique rock testing techniques. Determining down-hole stresses can be accomplished using five different well published methods or based upon specific clients’ needs. Isotropic and anisotropic stress profiles have been characterized as an input for hydraulic fracturing models—particularly for shale plays such as Bakken, Eagle Ford, Woodford, etc. For high clay rich organic rocks like shale, 40-60% variations were observed in peak strength, Young’s modulus, and velocities between vertical and horizontal rock samples.

Based on internally developed rock testing observations on shale reservoirs and utilizing field measured DFIT data on several wells, MRL have clearly concluded that the anisotropic model provides a more accurate representation along with the field data. For the anisotropic stress profile, Eh/Ev, is a key factor which precisely determines stress magnitude. The traditional isotropic model could be misleading due to the imbedded assumption of Eh/Ev = 1, which can’t be used for anisotropic rocks/laminated rocks such as shale.

THE PROCESS

Acoustic velocities (Vp(0), Vs(0) and Vp(45) ) on vertical and (Vp(90) and Vs(90) ) horizontal samples are measured on selected core plugs. Utilizing sonic well logs, lab-measured acoustic velocities necessary calibrations can be obtained to check for thermal, dispersion, and fluid effects. Based on lab measurements, correlations between static and dynamic anisotropic properties are quantified to calculate isotropic and anisotropic stress magnitudes.

Potential error can be present by utilizing well logs to estimate in-situ stress due to limited information to estimate parameters such as C13 tensor, horizontal Young’s modulus and Poisson’s ratio. Using the proper stress analysis model for a particular well, stress barriers above the target zones can be better characterized. Based on many publications, it is reported that a lack of accurate in-situ stress magnitudes during the design of hydraulic fracturing can result in as much of a 50% error in the actual fracture length/width/direction upon implementation\(^1\).

MetaRock Laboratories provides precise stress magnitude and orientations (Fracture angle and Breakout angle) as a function of depth and their stress contrast in order to help the completion engineer land safely on the target zones. Higher stress contrast results in the higher fracture height, and confined and longer fracture growth. In addition, MetaRock Laboratories has the capability to conduct pore pressure prediction analysis and can estimate fair Biot effective coefficients (both vertical and horizontal Biot’s).

---

Biot’s Effective Coefficients and Pore Pressure Prediction are two primary inputs to the stress profile analysis that are normally assumed. In order to avoid inaccuracies stemming from random assumptions, MetaRock estimates these parameters carefully by utilizing our anisotropic data.
Understanding Isotropic and Anisotropic stress magnitudes is very significant for hydraulic fracturing. Inaccurate stress magnitudes can lead to incorrect fracture propagation/development. The depiction above showcases a significant difference between the two stress models.
Lab Manager is a dynamic information management system. A highly scalable and secure web portal, Lab Manager creates a single, off-site repository to manage and share large volumes of information across the globe.

Universally compatible across Windows XP, Vista, Windows 7, Linux, Unix and Mac, Lab Manager has user-friendly interfaces that make the application easy-to-use, laboratory-wide with minimal training.

**FEATURES**
- 100% web based
- Data capture & warehousing
- Highly scalable
- Exceedingly secure and encrypted
- Universally compatible
- Unlimited custom fields
- Custom data entry forms
- Custom reports (search/query)
- Exporting tool

**BENEFITS**
- Replace dispersed files and archives with a single repository
- Consolidate multiple information chains into a single interface
- Ensure data integrity
- Share content across the globe
- Elevate administrator productivity
- Automate expensive, time-consuming, manual processes
- Reduce costs & manage backlog
- Secure access to laboratory information in real-time
- Reduce duplication of tasks
- Speed up the decision making process

**HOW CAN LAB MANAGER HELP YOU?**

**Highly Effective Resource Management Tool**

Its high scalability will ensure effective management of both outgoing and incoming samples. It will enable the user to track core samples in real-time and receive reports as soon as they are completed. This eliminates the need to outsource functions to outside vendors, and Lab Manager is ideal for in-house use.

**Reporting Tool**

Real-time status updates, the ability to track samples and generate reports based on dynamic queries, makes Lab Manager a valuable way to deliver information to colleagues and customers.

**Data Warehousing Tool**

Manage valuable data in a single repository in a secure manner. Lab Manager is web-enabled and roles-based authenticated access makes it a secure and safe way to store digital assets.
COMPONENT SYSTEMS
The FlowQube is a programmable precision fluid flow pump. The pump is designed with the flexibility and versatility to meet a variety of industry needs. The unit is capable of operating in a continuous injection or constant pressure mode.

Mechanically, the syringe pump is driven via stepper motor and precision ball screw. It has a 60mm stroke and is available in three resolutions. The pump can be coupled with a variety of valves and syringes up to 2,000psi working pressure, as well as PC board selections to meet specific needs.

**SPECIFICATIONS**

**Physical**
- Height 12”
- Width 8.75”
- Depth 8.75”
- Weight 12lbs

**Environmental**
- Operating temperature of 0° to 50°C
- Operating humidity of 5 to 95% RH, non-Condensing at 50°C
- Storage temperature of –25°C to 85°C
- RoHS & WEEE compliant

**Mechanical**
- Speed:
  - Maximum 10,000 steps /sec.
  - Minimum 60 steps /sec.
  - Default 5000 steps / sec.
- Syringe size: 1.25ml to 50mL
- Valve type: 2-way to 12-way

**Interface**
- RS-485 or RS-232 communications
- Data terminal or OEM protocol
- 1200 to 38.4K baud, 8 data bits, 1 stop bit, no parity, half duplex

<table>
<thead>
<tr>
<th>1/10 Stroke Dispenses</th>
<th>Full Stroke Dispenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>0.10% CV, 0.20% max.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.20% CV, 0.60% max.</td>
</tr>
</tbody>
</table>
**SYRINGE OPTIONS**

The FlowQube is designed to couple to a syringe pump and standard valve assembly. These syringes are typically used in various types of instruments and analyzers serving clinical, medical, and analytical instrumentation applications. An array of syringe volumes are available that can be dispensed and/or aspirated over a full 6cm stroke.

<table>
<thead>
<tr>
<th>Syringe Sizes</th>
<th>10uL</th>
<th>25uL</th>
<th>50uL</th>
<th>100uL</th>
<th>250uL</th>
<th>500uL</th>
<th>1.0mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice Diameter (in)</td>
<td>.016</td>
<td>.016</td>
<td>.024</td>
<td>.032</td>
<td>.039</td>
<td>.076</td>
<td>.076</td>
</tr>
<tr>
<td>Syringe Diameter (in)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>*Max Drag Force (lbs)</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>PTFE UHMW</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Syringe Sizes</th>
<th>1.25mL</th>
<th>2.5mL</th>
<th>5.0mL</th>
<th>10mL</th>
<th>25mL</th>
<th>50mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice Diameter (in)</td>
<td>.076</td>
<td>.076</td>
<td>.076</td>
<td>.076</td>
<td>.076</td>
<td>.076</td>
</tr>
<tr>
<td>Syringe Diameter (in)</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.75</td>
<td>1.12</td>
<td>1.5</td>
</tr>
<tr>
<td>*Max Drag Force (lbs)</td>
<td>3.0</td>
<td>3.0</td>
<td>6.0</td>
<td>6.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>PTFE UHMW</td>
<td>7.0</td>
<td>7.0</td>
<td>10.0</td>
<td>10.0</td>
<td>15.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

* Add 1 pound drag force to non-lubricated plunger tip requests

**Physical**
- Length (Dispensed): 4.370”
- Thread Type: 1/4-28 UNF-2A
- Test Pressure: 80psi

**Environmental**
- Operating Temperature of 10° to 40°C
- Storage Temperature of -25° to 85°C
- Relative Humidity: Up to 100%

**Chemical**
- Standard Syringe Seal: PTFE
- Wetted Materials: Borosilicate Glass, Kel-F, PTFE (or UHMW) (smaller sizes ZDV tips are Teflon coated 316L)
- Syringe tips lubricated with laboratory-grade Silicone
A very popular product, the MetaRock Temperature Controller is built to last. Custom-designed and tailor-made to customer specifications, MetaRock is able to provide controllers to heat up to 256 independent zones.

Available in both rackmount and benchtop options, the temperature controllers offer uniform heating and accurate temperature control. Automatic shutdown and high-limit controllers are built in for each zone for added safety, an important feature especially in laboratory applications.

**FEATURES**

- Single or multi-zone controllers
- 110-240VAC input/output
- Linear (SSR) or proportional (SCR) output
- Indoor/outdoor use
- Process controller using Cal or Watlow temperature controllers
- Integrated high limit shutdown available
- Thermocouple type choice
- Available in different enclosure sizes
- RS-485 or RS-232 communications
- USB connectivity upon request
The axial frame loading is designed as a research solution to evaluate geomechanical rock properties. The instrument offers an exceptional performance package in a single innovative frame and facilitates a wide range of testing solutions utilizing twin precision aligned ball screws, low backlash gears, and servo motor control. Refining necessary enhancements over the years allowed superior accuracy, reliability, and repeatability by increasing the overall frame stiffness, higher load capacity, overrun stop limits, and multiple process variable control options. Comprehensive data acquisition and PID control software provides the necessary intelligence to the frame and allows the test instrument a wide range of fracture mechanics, civil engineering structures, fatigue, and static and dynamic testing applications.

The precision mechanical system combined with the advanced PID control provides integrated turnkey solutions to meet the most demanding applications.

The software provides PC control including full data acquisition, storage, real-time display, graphical user interface, cyclic tests, and unattended segment list control. An integrated linear, sinusoidal, or user specified ramps is provided to deliver flexibility for all applications. The graphical user interface is designed to provide a real-time analysis for strain controlled test such as Young’s modulus or Poisson’s ratio calculations. The software is capable of integrating acoustics velocity measurement as part of the frame control.
FEATURES

- Twin high precision ball screws to provide stiff frame for high strength materials testing
- Stiff frame to minimum energy stored during test and report accurate modulus and strain values
- Up to 500Kips axial force capacity
- High accuracy gear to minimize backlash and synchronous movement of the ball screws
- 4 alignment posts to eliminate crosshead tilt and system alignment
- Servo motor for high precision low strain rates 1X10-7 in
- Open software architecture to servo off any measured or calculated variable. This provides any stress path loading (Triax, Uniax, Isostatic)
- Integrated load cell and position measurement for automatic overload/over travel shut down

TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>General</th>
<th>Four post press design with load plate driven via 2 precision ball screw and nut Assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Capacity Drive</td>
<td>Press is designed for 50,000 lbs. Maximum load capacity</td>
</tr>
<tr>
<td>Strain Rods</td>
<td>2” diameter, precision ground 1045 steel rods stressed to a maximum of 4000 psi in tension</td>
</tr>
<tr>
<td>Top Head</td>
<td>4” thick solid steel, Blanchard ground top and bottom. Design is heavy duty to limit deflection to 0.0001” center point of head at 50,000lbs load</td>
</tr>
<tr>
<td>Load Plate</td>
<td>5” x 6” cross section, solid steel Blanchard ground top, bottom and both sides. Design is heavy duty to deflection to 0.0001” at 90,000lbs load</td>
</tr>
<tr>
<td>Bottom Plate</td>
<td>4” thick solid state, Blanchard ground top and bottom. Bottom plate must be supported uniformly under 37” x 29” area. Bottom Plate will be machined with a Counter notched pilot diameter to assist in centering apparatus furnished by others. Bottom plate will also be drilled and tapped for future clamping of test fixtures</td>
</tr>
<tr>
<td>Assembly</td>
<td>Basic press will be assembled and tested for motion, speed and accuracy on a load basis prior to final painting. Paint shall be customer’s standard. All unpainted surfaces shall be rust proofed prior to shipping</td>
</tr>
<tr>
<td>Overall Dimensions</td>
<td>47-3/4” R-L</td>
</tr>
<tr>
<td>Weight</td>
<td>2,650lbs</td>
</tr>
</tbody>
</table>
The MetaRock Autosampler (MRAS) is an automated high-performance sample collection solution suited for a wide variety of applications. The MRAS is controlled through an intuitive and user-friendly PC-based software application, while also allowing for use in a simple time-based manual mode.

Standard wetted materials include 316 stainless steel for flow lines and glass for collection vials, which ensure compatibility with a variety of fluids. Hastelloy, Titanium, Monel, Teflon and other materials are available for applications with extremely reactive or corrosive materials. The MRAS utilizes pneumatic actuators and low voltage DC controls to minimize associated risks with the collection of flammable or combustible fluids and gases.

The MRAS consists of a 24-position rotor controlled by a precision indexing pneumatic actuator with a non-accumulating error of +/- 0.1 degrees per 15° step; and a pneumatically actuated dual-needle probe to penetrate the septum-sealed sample vial. The dual needle probe design provides a means for continuous measurement of gas production rates and volumes when connected to external measurement devices such as the MRL Flow Qube syringe pumps or Thermal Mass Flow Meters.

Up to 24 sample vials can be loaded at any given time, while filled sample vials can be quickly and easily replaced with empty ones at any time, allowing for an unlimited number of samples to be taken. Standard calibrated sample vials are available in 10ml and 25ml sizes, however, custom sizes can be provided for customer specifications as needed.
INSTRUMENTATION
This page left intentionally blank
MetaRock Laboratories’ testing solutions include (but are not limited to) a proven, top quality pressure vessel specifically designed for the Geo-Mechanics testing field. This product enables in-situ condition simulation (stress, temperature, pore fluid pressure) as well as study of the stress strain behavior in any stress path (Uniaxial, Triaxial, Isostatic, etc.).

The pressure vessel is designed for standard ISRM NX specimen diameters from 1.0” to 4” with a length to diameter ratio 2:1. The upper piston spherical seat serves to minimize stress concentration due to non-parallel specimen ends. The precision guided frame is specifically designed for sample alignment and ensure repeatable results. Top and bottom platens have O-ring grooves for sealing the specimen jacket. Acoustic transducers and fluid lines are also integrated in the platens for effective stress, saturation, or permeability measurement.

Multiple electrical feed-throughs for in-vessel instrumentation transducers are rated for high pressure and temperature. Customized cantilever bridge and high accuracy LVDT’s are incorporated in the vessel for radial and axial strain measurement. An in-vessel internal load cell is used to measure actual deviatoric stress and eliminate external force error measurement which is caused by confining pressure and external piston seals friction.

The pressure vessel requires a minimum of a 500mL pressure generator unit and ball screw frame to apply radial and axial stresses.

**FEATURES**

- Lateral confining pressures up to 30,000psi
- Axial loads ranging from 50,000lbs to 300,000lbs
- Upper platen provided with a spherical seat to compensate for specimens with non-parallel ends
- Accepts sample diameters up to 4” with a length of 2 times the diameter
- Electrical feed through connectors for axial, circumferential deformation, load measurement devices or other special transducers such as acoustic measurements
- Platens available for ultrasonic velocity measurements
- Components constructed of stainless steel. All components are precision machined, heat-treated and ground
- Proof-tested and certified
- Heating jacket systems available for testing to 842°F (450°C)
ULTRASONIC ACOUSTIC VELOCITY

Acoustic measurements of samples (both dry and saturated) can be conducted under both uniaxial and triaxial stress paths. Ultrasonic velocity measurements in rock samples are performed utilizing piezoelectric crystals (P&S) of 1MHz resonant frequency. Each transducer is excited independently utilizing a switch matrix as well as a high voltage short duration electrical pulsar. The applied electrical pulse transforms into mechanical pulse and propagates through the rock sample in the form of ultrasonic elastic waves.

The receiving transducer, at the opposite end of the rock specimen, is converted back to an electrical pulse and measured as an electrical waveform using a high precision digital oscilloscope. Using the calibration data and the received waveform from each transducer (compressional or shear), the P-wave, S-wave, P&S-wave at 45°, and arrival time is measured and velocities, dynamic properties, and $C_{ij}$ are calculated.

Dynamic measurements are derived from the acoustic data. For isotropic medium, two dynamic elastic constants are obtained from the acoustic measurements. For transversely isotropic (TI) medium, five dynamic elastic constants are found from the ultrasonic acoustics velocity measurements. The elastic constants calculated from the dynamic measurements will indicate the changes in rock fabrics and other physical properties. The front face of the transducer’s epoxy thickness is estimated based on the wavelength ($\lambda/4$) calculated using bench-top measurements.

FEATURES

- Capable of testing Vp and Vs at 45° angles
- Loading/reloading can be performed without removing the samples from the pressure vessel to generate hysteresis loop
- Stainless steel metal casing protects the active element of a transducer, and is designed to provide better stress concentration and to eliminate back-wall reflections
- Dynamic parameters are calculated from the acoustic measurements to elucidate the stress-induced anisotropy in the rocks at elevated pressure and temperature conditions
- Tests can be performed up to 50,000lbs axial load and 15,000psi confining pressure (if used with MRL external ball screw press)
- Transducers can withstand temperatures up to 300°C
- Custom software built by MetaRock to acquire, monitor, and analyze wave forms
Acoustics Velocity Acquisition

P-Waveform under Isostatic Loading/ S3=4,000psi
S1- Waveform under Isostatic Loading / S3 = 4,000psi

S2- Waveform under Isostatic Loading/ S3 = 4,000psi

P(45)- Waveform under Isostatic Loading / S3 = 4,000psi
The Cantilever Bridge is designed and calibrated to maintain high functionality in high stress environments with minimal pressure effects. Extensive testing has been undertaken to ensure the delivery of accurate diameter measurements and repeatability. Custom cantilever bridges can be fabricated to accommodate nearly any specimen size.

**SPECIFICATIONS**

- Ranges 35% (dia): 1.0”, 1.5”, 3.0” or custom
- Linearity: 0.03%
- Hysteresis: < 0.03%
- Non-Repeatability: ± 0.03% FS
- Output: 2m V/V
- Creep (max): 0.03% (20 min)
- Operating Temperature: 0° to 200° C
- Strain Gauge Type: Bonded Foil
- Excitation (calibration): 5VAC
- Bridge Resistance: 350 ohms
- Resolution: Infinite
The Metarock Helium Porosimeter is a precision instrument used to accurately determine the grain volume of porous materials via the Helium Expansion method. Sample properties such as grain volume, grain density, bulk volume, bulk density, pore volume, and porosity are automatically calculated and recorded when the sample length, diameter, and weight are input into the advanced data acquisition and control software.

MetaRock’s advanced design incorporates thermal control to minimize temperature effects, multiple gas calibration ability, and robust long life metal diaphragm valves with exceptionally low leakage rates which minimize errors and reduces downtime.

The MetaRock Helium Porosimeter is available in both a standard laboratory grade for production work, and as a research grade unit for measurement of difficult samples such as shales and tight gas sands where the absolute highest precision is required.

**FEATURES**

- 200 PSIA digital pressure transducer with +/- .02 % full scale accuracy
- Fully automated operation
- Internal on-board PC and data acquisition minimizes footprint and cables
- Helium thermal equilibration chamber
- 0.5 micron filtration of incoming helium with a 0.5 micron unit fitted between the matrix cup and valves
- Low maintenance metal seal diaphragm valves, surface mounted for easy access
- Advanced PC-based data acquisition and control software calculates real time grain volume, grain density, pore volume, and porosity
- All calibration values are recorded in each file with the raw data for each test
- Custom MetaRock Laboratories, Inc. software
- Three internal reference volumes
- External pressure port for stressed PV measurements (optional external type core-holder)
- Matrix cups and calibration billets to run 1” diameter x 3” length and 1.5” diameter x 3” length samples
- Vacuum ports available
Optional Enhancements

- Temperature control (heat only) to maintain an elevated constant temperature (minimum 5°C above ambient) within =/± 0.2°C
- Paroscientific transducer with +/- 0.005% of reading accuracy
- Custom multi-channel plate-type heat exchanger for fast temperature equilibration of incoming Helium
- One reference volume cell has been replaced with an additional external pressure port for connection to external reference volumes and/or pumps
SSK-300

Standard industry permeameters can have results range from 0.001 to 30,000 millidarcy. Due to limitations within instrumentation resolution and accuracy, the rates for error grows higher for results at or lower than 0.001 millidarcy.

Fortunately, MetaRock Laboratories’ Steady State Permeameter, the SSK-300, is designed to overcome the challenges associated with quantifying low permeability measurements and avoiding major pitfalls. By incorporating digital pressure transducers, mass flow controllers, an oven enclosing a core holder, coupled with the MRL custom software, the user is able to calculate permeability without sacrificing time and accuracy.

Additionally, the SSK-300’s software takes into account the Klinkenberg Effect, which can often skew true permeability results. The software and hardware work seamlessly and allow to utilize low-cost gas solutions to test in low permeability situations without sacrificing accurate testing results.

FEATURES

- Short circuit, overload, over-voltage and over-temperature protection
- Internal flashcard equipped with power failure protection and global wear-leveling algorithms
- Full PID auto tuning temperature controllers with bright, LCD displays enable maximum resolution and accuracy for upstream and downstream pressure measurements
- Equipped with four mass flow controllers which allow the user to select the proper resolution based on sensed permeability value
- Oven-enclosed core holder maintains constant temperature for the duration of the test
- Can be connected to any testing system, including high temperature, high pressure or compaction cell
- Built-in, internal CPU to maximize lab space
Advantages of the MetaRock Method

- Utilizing gas rather than water to determine steady state (SS) permeability in conventional cores eliminates potential reactions with the rock and samples remain clean at the conclusion of measurements.
- The MetaRock custom designed automated control and data acquisition system built specifically for SS permeability.
- Gas viscosity is calculated at measured pressure and constant temperature to calculate steady state permeability.
- Testing is conducted independent of sample orientation.

Permeability and Klinkenberg’s Principles

Permeability is determined by using water flowing through a sample, but the risk of sample corrosion is high. As a compressible fluid, gas does not carry the risk of eroding the sample, but the technician often runs into gas slippage, or the Klinkenberg Effect. Glass slippage can be controlled by sampling multiple permeability measurements throughout the testing cycle and plotting the points on a graph. The points should align along a definitive line and intersect the y-axis, indicating Klinkenberg’s Permeability. The MetaRock software included with the SSK-300 allows the operator to easily control for gas slippage and calculate Klinkenberg’s Permeability by utilizing multiple sample measurements and graphically mapping data results.
MetaRock Laboratories has designed and engineered high pressure generators to meet the demands of the core analysis spectrum of the industry. MRL pressure generators have been modified to accommodate other general industrial high pressure applications as well. The pressure generator allows for easy use in the laboratory environment and ensures a convenient means to provide an automatic source of high pressure.

In addition to pressure control, the data acquisition application allows for the tool to provide volume control-or any other measured or calculated process variable-in the system. The initial design was based on a piston screw pump for compressing liquids and some gases at small volumes in order to build pressure. All wetted parts are made of 316 stainless steel and 17-4PH stainless steel.

An upgraded and enhanced design was crafted utilizing the ball screws for high pressure (15,000psi) and high volume (2L) applications. This product has been utilized in the rock mechanics field to provide axial deviatoric and radial stress.

**Pressure ranges and maximum pump volume include:**

<table>
<thead>
<tr>
<th>Pressure Range (psi)</th>
<th>Volume (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5,000</td>
<td>93</td>
</tr>
<tr>
<td>0-10,000</td>
<td>48</td>
</tr>
<tr>
<td>0-15,000</td>
<td>35</td>
</tr>
<tr>
<td>0-30,000</td>
<td>18</td>
</tr>
<tr>
<td>0-60,000</td>
<td>10</td>
</tr>
<tr>
<td>0-75,000</td>
<td>7</td>
</tr>
<tr>
<td>0-100,000</td>
<td>4.5</td>
</tr>
</tbody>
</table>

### 1 Liter Pressure Generator

The high pressure positive displacement ball screw pump can be used in almost every industrial and oilfield application where pressure control is required. It has a larger volume capacity and can be used for multiple laboratory applications.

**Features**

- Connection: High pressure coned and threaded opening for ¼” OD tubing and XF4 connections
- Automated instrumentation
- 316 stainless steel and 17-4PH stainless steel on parts subjected to moisture
- High precision gear and servomotor
- Pressure reading gauges
- Pressure measurement studies
- Liquid catalyst injection
- Available up to 2L
Thank you for your interest in MetaRock Laboratories, Inc. To inquire more about the products, services and capabilities seen in this catalog, or to schedule a laboratory visit, please feel free to contact us by any of the following options:

**By Post Mail**
MetaRock Laboratories
2703 Highway 6 S Ste 280
Houston, TX 77082

**By Website**
http://www.metarocklab.com

**By Email**
info@metarocklab.com

**By Phone/Fax**
Phone: +1 (713) 664-7916
Fax: +1 (832) 415-0358