Flow Research and Test Center
Creating resource technology for today and tomorrow.
Measurement Solutions’ test center guarantees optimum verification of meter performance.

To ensure that a meter can operate accurately over a wide flow and viscosity range it is important that the meter is tested over the dynamic operating range. Measurement Solutions’ comprehensive flow research and test center located in Erie, Pennsylvania is capable of testing meters over the widest dynamic measurement range of any test facility in the world.

PD meters, conventional turbine meters, helical turbine meters, and ultrasonic meters can be tested under dynamically similar operating conditions to guarantee performance in any crude oil application.

Measurement Solutions’ High Flow (HF), Multi-Viscosity (MV), and Low Flow - MV Test Systems can provide dynamic testing on petroleum products over a 5 to 42,000 bph (1 to 6,680 m³/h) flow range; 2 to 500 cSt (2 to 500 mm²/s) viscosity range; meter sizes 1 to 30 inches (25 to 750 mm). This translates to a dynamic Reynolds Number range of 100 to 1,000,000.

Flow Research and Test Center Features

- NVLAP (Lab Code 200939-0) accredited to ISO/IEC 17025:2005
- Flow to 42,000 bph (6,675 m³/h)
- Viscosity 2 to 500 cSt (mm²/s)
- Traceable to international standards
- Dynamic range 100 to 1,000,000 Reynolds Number
The “Meter Under Test” (MUT) can be directly proven with the Master Prover or with Master Meter Prover(s), which are calibrated with the Master Prover. The Master Provers are calibrated gravimetrically.

<table>
<thead>
<tr>
<th>High Volume Master Meter Prover</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>SYNCROTRAK S120</td>
</tr>
<tr>
<td>Type</td>
<td>Small Volume Displacement Prover</td>
</tr>
<tr>
<td>Flow Max.</td>
<td>17,500 bph (2,775 m³/h)</td>
</tr>
<tr>
<td>Inside Diameter</td>
<td>32&quot; (813 mm)</td>
</tr>
<tr>
<td>Volume</td>
<td>120 gallons (454 liters)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low Volume Master Meter Prover</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>SYNCROTRAK S35</td>
</tr>
<tr>
<td>Type</td>
<td>Small Volume Displacement Prover</td>
</tr>
<tr>
<td>Flow Max.</td>
<td>1,700 bph (270 m³/h)</td>
</tr>
<tr>
<td>Inside Diameter</td>
<td>17.625&quot; (324 mm)</td>
</tr>
<tr>
<td>Volume</td>
<td>25 gallons (95 liters)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M16 Master Meter Prover</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Smith Meter® M16</td>
</tr>
<tr>
<td>Type</td>
<td>Rotary Vane Positive Displacement Prover</td>
</tr>
<tr>
<td>Flow Max.</td>
<td>14,000 bph (2,220 m³/h)</td>
</tr>
<tr>
<td></td>
<td>170 bph (27 m³/h)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K12 Master Meter Prover</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Smith Meter® K12</td>
</tr>
<tr>
<td>Type</td>
<td>Rotary Vane Positive Displacement Prover</td>
</tr>
<tr>
<td>Flow Max.</td>
<td>8,000 bph (1,270 m³/h)</td>
</tr>
<tr>
<td></td>
<td>170 bph (27 m³/h)</td>
</tr>
</tbody>
</table>
Gavimetric Calibration Facility for Small Volume Provers

The Measurement Solutions’ Gavimetric Calibration Facility is used to accurately establish the base volume of the master provers and to establish direct traceability to the National Institute of Technology (NIST), the US National Meteorology Institute. The provers are then used to calibrate the Master Meter Provers or to directly prove a meter. The room, environment, instruments, and techniques have been selected to provide the highest level of accuracy. The calibration procedures are per API MPMS 4.9.1 “Calibration of Small Volume Provers” and NIST SOPSVP, which address the gravimetric calibration of small volume provers via a mass comparison method.

Main components of the facility

- Environmentally controlled to ΔT +/- 1°C/h, ΔH +/- 10%/4h
- Air density determination – Vaisala PTU 300
- Accuracy – temperate 0.1°C humidity 1%
- Mass comparator – Metler Toledo KC500
- High capacity RoDI system
- Stainless steel piping
- Temperature and pressure measurement equipment

Instruments and References

Weights: The tolerance class for the used weights is ASTM E617 Class F. The tolerance can be found in document ASTM E617 (1997) standard specification for laboratory weights and precision mass standards [14].

Mass comparator: Maximum capacity 600 kilogram (kg)

Readability: 100mg

Temperature instruments: 0.1°C

Pressure instruments: Interval is 0.1 psig

Reference water: NIST GLP 10
The Measurement Solutions’ High Flow (HF) Test System is a high accuracy open loop system used to validate the performance of liquid meters on a hydrocarbon fluid. This system includes a master small volume displacement prover that is traceable to NIST (USA - National Institute of Standards and Technology), three master meter provers, one hydrocarbon fluid ranging in viscosity from 10 cSt to 25 cSt, and one test loop that can accommodate meters in sizes 6 to 30 inches.

### Specifications

<table>
<thead>
<tr>
<th><strong>Type</strong></th>
<th>Open Loop System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flow Range</strong></td>
<td>170 to 42,000 bph (30 to 6,675 m³/h)</td>
</tr>
</tbody>
</table>
| **Meter Sizes** | Positive Displacement Meters (PD): 6 inch to 16 inch (150 mm to 400 mm)  
Turbine and Ultrasonic Meters Standard: 6 inch to 30 inch (150 mm to 760 mm)  
*For additional technologies consult factory.* |
| **Pumps/Drives**| Two multi-stage vertical turbine pumps with 500 HP motors  
One multi-stage vertical turbine pump with 75 HP motor |
| **Tank**        | One 30,000 gallon (114 m³)            |
| **Chiller**     | 160-ton chiller system                |
| **Fluids**      | Brad Penn blend oil with an ideal range from 9 cSt to 25 cSt where the viscosity of the blend is varied by a temperature over a 70°F to 110°F (21°C to 43°C) range |
| **Master-Meter Prover** | Three Smith Meter® 16 inch PD meters |
| **Master Prover**| SYNCROTAK SVP 120 gallon (454 liter)  |
Multi-Viscosity Test System

Measurement Solutions’ Multi-Viscosity (MV) Test System is a high accuracy closed loop system used to validate the performance of liquid meters on a range of hydrocarbon fluids. This system includes a master small volume displacement prover that is traceable to NIST (USA - National Institute of Standards and Technology), two master meter provers, four hydrocarbon fluids ranging in viscosity from 2 cSt to 500 cSt, and two test runs that can accommodate meters in sizes 3 to 30 inches.

Specifications

<table>
<thead>
<tr>
<th>Type</th>
<th>Closed loop system with approximately 5,000 gallon (18.9 m³) capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Range</td>
<td>170 to 8,000 bph (30 to 1,270 m³/h)</td>
</tr>
<tr>
<td>Meter Sizes</td>
<td>Positive Displacement Meters (PD): 6 inch to 16 inch (150 mm to 400 mm)</td>
</tr>
<tr>
<td></td>
<td>Turbine and Ultrasonic Meters Standard: 6 inch to 30 inch (150 mm to 762 mm)</td>
</tr>
<tr>
<td></td>
<td>Smaller: 3 inch and 4 inch (75 mm to 100 mm) with special 6 inch inline master meter prover</td>
</tr>
<tr>
<td>Pumps/Drives</td>
<td>Two positive displacement pumps with 200 HP variable speed drives</td>
</tr>
<tr>
<td>Tanks</td>
<td>Four 15,000 gallons (94.6 m³ each)</td>
</tr>
<tr>
<td>Chiller</td>
<td>25-ton chiller system</td>
</tr>
<tr>
<td>Fluids</td>
<td>Four blended oils with an ideal range from 2 cSt to 500 cSt where the viscosity of each blend is varied by temperature over a 70°F to 110°F (21°C to 43°C) range</td>
</tr>
<tr>
<td>Master-Meter Prover</td>
<td>Smith Meter® PD meters: one 12 inch and one 16 inch meter</td>
</tr>
<tr>
<td>Master Prover</td>
<td>SYNCROTRAK SVP 120 gallon (454 liter)</td>
</tr>
</tbody>
</table>
Low Flow Multi-Viscosity Test System

The Measurement Solutions’ Low Flow Multi-Viscosity (MV) Test System provides dynamic testing on petroleum products over a 5 to 1,700 bph (1 to 270 m³/h) flow range; 2 to 225 cSt (2 to 225 mm²/s); meter sizes 1 to 6 inches (25 to 150 mm) and based on size and Low Flow - MV capacity a Reynolds Number range of 50 to 500,000.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Open loop system with approximately 2,000 gallon (7.6 m³) capacity</td>
</tr>
<tr>
<td>Flow Range</td>
<td>5 to 1,700 bph (1 to 270 m³/h)</td>
</tr>
<tr>
<td>Meter Sizes</td>
<td>Positive Displacement Meters (PD): 2 inch to 6 inch (25 mm to 150 mm)</td>
</tr>
<tr>
<td></td>
<td>Turbine and Ultrasonic Meters: 1.5 inch to 4 inch (40 mm to 100 mm)</td>
</tr>
<tr>
<td>Pressure</td>
<td>Less than 100 psig (6.9 bar)</td>
</tr>
<tr>
<td>Pumps/Drives</td>
<td>Two vertical turbine pumps one 15 HP and one 40 HP motors</td>
</tr>
<tr>
<td>Tanks</td>
<td>Five 2,500 gallons (7.6 m³ each)</td>
</tr>
<tr>
<td>Chiller</td>
<td>30-ton chiller system</td>
</tr>
<tr>
<td>Fluids</td>
<td>Five blended oils with an ideal range from 2 cSt to 225 cSt where the viscosity of each blend is varied by temperature over a 70°F to 110°F (21°C to 43°C) range</td>
</tr>
<tr>
<td>Master-Meter Prover</td>
<td>Four Smith Meter® 2 inch to 6 inch PD meters (not illustrated)</td>
</tr>
<tr>
<td>Master Prover</td>
<td>SYNCROTRAK Model 535</td>
</tr>
</tbody>
</table>
Unsurpassed Dynamic Test Range

Validating a meter’s accuracy over its operating range is an essential part in the manufacture of high performance custody transfer meters. The key parameters that determine the performance of flowmeters and other hydrodynamic devices are size, flow rate, and viscosity. While these parameters affect the performance of all metering technologies, turbine and ultrasonic meters are especially sensitive to high viscosity fluids.

To ensure performance of Smith Meter® turbine and ultrasonic meters for crude oil service, these meters are tested dynamically over a range of fluids from 2 to 500 cSt depending on the required service. This method uses the concept of Dynamic Similitude allowing the performance to be validated for service on a higher or lower viscosity than the test fluid.

To do this, the testing method relies on a well established fluid dynamic parameter – Reynolds Number (Re No), which (illustrated by the equation below) defines the relationship between the flow rate, meter size, and viscosity. Simply stated, performance at a given Reynolds Number is the same no matter the combination of flow, meter size, and viscosity.

\[
\text{Re No} = \frac{\text{Flow Rate}}{(\text{meter size} \times \text{viscosity})}
\]

Therefore, by utilizing the three (3) test systems, Dynamic Tests can be run to determine measurement accuracy over a wide range of conditions. The below table illustrates the Dynamic Test for the three meters with high viscosity operating conditions.

The below Reynolds Number Test illustrates a four (4) product dynamic test of a helical turbine meter utilizing the HF Test System for the high flow / high Reynolds Numbers and the MV Test System for the high viscosity / low Reynolds Numbers.

1. Re No = \( \frac{(2,214 \times \text{flow in bph})}{(\text{meter size in inches} \times \text{viscosity in cSt})} \)
2. Re No = \( \frac{(13,925 \times \text{flow in m}^3/\text{h})}{(\text{meter size in inches} \times \text{viscosity in mm}^2/\text{s})} \)

Note: 1 mm$^2$/s = 1cSt

### Dynamic Test Example

#### Field Operating Conditions

<table>
<thead>
<tr>
<th>Meter (Inches)</th>
<th>Flow Range</th>
<th>Viscosity (cSt)</th>
<th>Reynolds Number Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1,500</td>
<td>240</td>
<td>690</td>
</tr>
<tr>
<td></td>
<td>4,500</td>
<td>720</td>
<td>2,080</td>
</tr>
<tr>
<td>12</td>
<td>6,330</td>
<td>1,010</td>
<td>1,170</td>
</tr>
<tr>
<td></td>
<td>19,000</td>
<td>3,020</td>
<td>3,510</td>
</tr>
<tr>
<td>20</td>
<td>14,000</td>
<td>2,230</td>
<td>1,550</td>
</tr>
<tr>
<td></td>
<td>42,000</td>
<td>6,680</td>
<td>4,650</td>
</tr>
</tbody>
</table>

#### Dynamic Test

<table>
<thead>
<tr>
<th>Meter (Inches)</th>
<th>Flow Range</th>
<th>Viscosity (cSt)</th>
<th>Reynolds Number Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>560</td>
<td>90</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>1,690</td>
<td>270</td>
<td>690</td>
</tr>
<tr>
<td>12</td>
<td>1,900</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>5,710</td>
<td>910</td>
<td>1,170</td>
</tr>
<tr>
<td>20</td>
<td>4,200</td>
<td>670</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>12,600</td>
<td>2,000</td>
<td>1,550</td>
</tr>
<tr>
<td></td>
<td>350,550</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Dynamic Number Test

<table>
<thead>
<tr>
<th>Meter (In)</th>
<th>Test System</th>
<th>Flow (bph)</th>
<th>Viscosity (cSt)</th>
<th>Reynolds Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>MV</td>
<td>1,900</td>
<td>8,000</td>
<td>1,170</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>6,330</td>
<td>19,000</td>
<td>64,880</td>
</tr>
</tbody>
</table>

Total Range: 1,900 to 19,000 bph (1,170 to 350,550 m$^3$/h)

Flow Research and Test Center 8
Laboratory Accreditation

Accredited to ISO/17025 through NVLAP (Lab Code 200939-0)

Factory calibrating high performance ultrasonic or helical turbine meters to operating conditions requires a technically capable high-accuracy test laboratory. The National Voluntary Laboratory Accreditation Program (NVLAP) run by the US National Institute of Standards and Technology (NIST) ensures that a laboratory fully meets international laboratory standards defined by ISO/IEC 17025. All measurements must be traceable through a National Metrology Institute (NMI) such as NIST that is member of the International Organization of Legal Metrology (OIML). The accreditation addresses factors relevant to a laboratory’s calibration data, and quality management system including the:

- Technical competence of staff
- Validity and appropriateness of test methods
- Traceability of measurements and calibration to national standards
- Suitability, calibration and maintenance of equipment under test
- Handling and transportation of test items
- Quality assurance of test and calibration data

To ensure continued compliance, accredited laboratories are regularly reassessed to check that they are maintaining their standards of technical expertise.

The uncertainties of the test systems in the Measurement Solutions’ Flow Research and Test Center have been assessed based on the international “Guide to the Expression of Uncertainty of Measurement” or GUM as it is often called. The analysis estimates the expanded uncertainty of meter calibration based on the statistical combination of all related instrumentation, equipment, and process uncertainty estimations.

The laboratory accreditation status and current Scope of Accreditation is publicly available by searching the laboratory code (NVLAP Lab Code 200939-0) at www.nist.gov/nvlap.