From lab to production, providing a window into the process
On-Line Viscosity Measurement

ViscoSensor Continuous Melt Rheometer (CMR IV) Flow Characterization Rheometer (FCR)
A Window into the Process

The Benefits of On-Line Rheometers

▪ Provides a “window” into the extrusion process
  • Allows for in-process product adjustments
  • Reduces waste stream

▪ Eliminates the need for laboratory testing:
  • Increases production throughput
  • Reduced laboratory costs
Dynisco Online Viscosity Measurement

- ViscoSensor
  - Return Stream or “Zero Discharge” Rheometer
- Continuous Melt Rheometer – CMR IV
  - Single Capillary Rheometer
- Flow Characterization Rheometer – FCR
  - Dual Capillary Rheometer
  - Calculate Extensional Stress, Rate and Viscosity
  - Optional Return Stream (FCRR)
Dynisco Online Viscosity Measurement

All systems provide

- Continuous, real-time, Melt Flow & Apparent Viscosity Data
- Correlation from Melt Index to IV for PET applications
- Modular capillaries for highest resolution
- DCS Communication & Control Integration
  - PROFIBUS
  - Modbus TCP/IP
  - Modbus RS-485
All systems require a Process Isolation Valve (PIV)

- Allows the sampling head to be serviced or removed without interrupting the process
- All PIVs can be configured to:
  - Offer bypass operation
  - Interface to the process via a single, annular or dual hole (ViscoSensor) sampling port pattern
  - Provide a drain for rapid Rheometer / sample line purge
  - Interface to existing competitors Rheometers sampling port patterns
Process Isolation Valve – Visco Sensors

PIV (In closed position)
Mounting Bolts
Rupture Plug

Process Pipe or Extruder

Annular Sampling Line in Standard M18 Tap
(May be modified for specific process)

PIV (In closed position)
Mounting Bolts
Rupture Plug
Polymer Drain
Sampling Line in Standard M18 Tap

Process Pipe or Extruder
Rheometer Control Unit Communications Standard and Optional I/O

ViscoSensor, CMR IV and FCR

- 7 Analog Output Signals, 4-20mA DC
  - Pump Speed
  - Rheometer Pressure 1
  - Rheometer Pressure 2 (excluding CMR)
  - Rheometer Pressure 3 (FCR only)
  - Melt Temperature Average
  - MFR
  - Apparent Viscosity
  - PIV Temperature (Visco)
  - Optional: Pump Temperature, Capillary Temperature, Delta P, Shear Rate, Shear Stress, Intrinsic Viscosity, Relative Viscosity
- 2 Analog Input Signals 4-20mA DC
  - Pressure
  - Speed

- Optional: Capillary temp., Pump temp., Pressure
- 5 Digital Output, 24 VDC, 2A max.
  - System fault alarm
  - Warning Signal
  - Local / Remote Operation
  - Pump Status
  - Material Status
- 3 Digital Input Signals, 24VDC 10mA
  - Remote Heat ON/OFF
  - Remote Motor ON/OFF
  - Remote mode PRESSURE/SPEED

Dynisco
<table>
<thead>
<tr>
<th>ViscoSensor</th>
<th>CMR IV</th>
<th>FCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. temp.: 350°C</td>
<td>Max. temp.: 400°C</td>
<td>Max. Temp.: 400°C</td>
</tr>
<tr>
<td>0.02 – 1,500 g/10 minutes range</td>
<td>0.02 – 5,000 g/10 minutes range</td>
<td>0.02 – 5,000 g/10 minutes range</td>
</tr>
<tr>
<td>Return stream</td>
<td></td>
<td>Dual capillary</td>
</tr>
<tr>
<td>Horizontal or vertical mount</td>
<td></td>
<td>Optional return stream</td>
</tr>
<tr>
<td>Optional reaction vessel mounting</td>
<td></td>
<td>Largest shear rate range for single sample</td>
</tr>
<tr>
<td>Unique annular melt transfer line</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ViscoSensor Zero Discharge Rheometer

- Designed specifically for thermoplastics resin industry
- No waste stream
- Applications:
  - Extruders
  - Compounders
  - Reaction Vessels
- Mounts either horizontally or vertically
- Mounts to an existing pressure port, M18 or equivalent
ViscoSensor Principal of Operation

Process Flow Molten Polymer

- Standard M18 Sensor Port
- Annular Transfer Line
- Temperature Control (Max. = 350 °C)
- Pressure Vent Plug/Port
- Temperature Control
- Pressure Plug/Port

- Gear Pumps
  - Common Drive Shaft
  - Discharge Pump
- Servo-Motor
- RTD
- Temperature Sensor
- Removable Capillary Die
- Transducer #1
- Transducer #2

Molten Polymer
Continuous Melt Rheometer Single Capillary Rheometer

- Fast response time
- Easily change capillaries based on flow characteristics
- Single capillary extrudes to environment
- Applications:
  - Extruders
  - Compounders
- Mounts horizontally via process interrupt valve
Continuous Melt Rheometer Principle of Operation

Process Flow
Molten Polymer

Process Isolation
Valve
Heater Band
Pressure
Transducer

Melt Pump
RTD Sensor
Capillary Die
Flow Characterization Rheometer Dual Capillary Rheometer

- Dual capillaries extrude to environment
- Optional “return to process” in FCRR
- Applications:
  - Extruders
  - Compounders
  - Spandex / Elastane / Lycra
- Two capillaries allow for Rheology curves over more shear conditions
- Mounts horizontally using process interrupt valve
Flow Characterization Rheometer Principle of Operation

- Process Stream
- Three Gear Melt Pump
- Pressure Transducer #1
- Temperature Sensor #1
- Die #1 ("Zero" L/D) (For extensional measurements)
- Process Isolation Valve
- Pressure Transducer #2
- Temperature Sensor #2
- Die #2 (L/D > 15)
## On-Line Rheometers: Typical Polymer Applications

<table>
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<tr>
<th>ViscoSensor</th>
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<th>FCR</th>
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<tbody>
<tr>
<td>• PET</td>
<td>• PE</td>
<td>• PE</td>
</tr>
<tr>
<td>• PE</td>
<td>• PP</td>
<td>• Spandex</td>
</tr>
<tr>
<td>• PS</td>
<td>• PS</td>
<td>• Lycra</td>
</tr>
<tr>
<td>• Adhesives</td>
<td></td>
<td>• Elastane</td>
</tr>
</tbody>
</table>
A hypothetical plant processes PP on an extruder that runs 8 hours a day, 5 days per week, with average output of 1,000 pounds per hour:

8 hrs./day * 5 days * 1,000 lbs./hour = 40,000 lbs. / week

Incorporate three ingredients: cost of materials average to $4.03 per pound:

<table>
<thead>
<tr>
<th>Material</th>
<th>cost/lb</th>
<th>% used</th>
<th>cost/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virgin material</td>
<td>$4.00</td>
<td>85%</td>
<td>$3.40</td>
</tr>
<tr>
<td>Recycle material</td>
<td>$0.24</td>
<td>12%</td>
<td>0.03</td>
</tr>
<tr>
<td>Color and Additives</td>
<td>$20.00</td>
<td>3%</td>
<td>0.60</td>
</tr>
</tbody>
</table>

100% $4.03

$161,152.00 weekly material cost

If the plant produces 40 lbs of off-spec material a week (0.1% weekly output), they are losing:

40 lbs. * $4.03 = $161.15 Lost per week in material costs
If operational costs (labor, utilities, equipment) are calculated to be $0.25 per pound of material produced, at normal operating conditions, the cost per hour of the extruder is as follows:

\[
$0.25/hr. \times 1,000\text{lbs.}/\text{hour} = $250
\]

Idle extruder and re-stabilizing also needs accounted for. If the plant experiences 3 restores a day at 0.3 hours per restore, plus 1.5 hours to stabilize, the total loss on daily production time is:

\[
3 \text{ restores/day} \times 0.3 \text{ hrs/restore} + 1.5\text{hrs. Stabilization} = 2.4 \text{ hrs not producing product}
\]

Thus, if the plant is down for 2.4 hours a day, 5 days a week:

\[
(2.4\text{hrs.} \times $250/\text{hr}) \times 5 \text{ days} = $3,000/\text{week lost}
\]
Return on Investment: Savings Potential

Putting it all together:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-spec material</td>
<td>$161.15</td>
</tr>
<tr>
<td>+ Labor to produce</td>
<td>$0.25 * 40lbs = $10.00</td>
</tr>
<tr>
<td>+ Weekly Extruder loss</td>
<td>$3,000</td>
</tr>
<tr>
<td><strong>Total Weekly Lost Revenue</strong></td>
<td><strong>$3,171.15</strong></td>
</tr>
</tbody>
</table>

At this conservative rate of loss, an on-line rheometer will pay for itself in less than 6 months of operation!
Frequent Questions

• How do I decide which system is right for me?
  ▪ Qualified representatives will work with you to determine which system is best suited to your application requirements.

• Once a system is picked, how do I determine the right capillary for my process?
  ▪ Qualified product engineers will work with you to determine the most appropriate capillary (or capillaries) for your process.

• I need CE certification for my plant. Is this possible?
  ▪ Dynisco offers many certifications such as CE, IS, CSA and more.

• In order to better understand how this works, I need to see the system in operation; is this possible?
  ▪ All on-line systems are available for product testing and training at Alpha Technologies where these units are manufactures in Akron, Ohio.