Flow Conditioning

- There is no flow meter on the market that needs flow conditioning.
- All flow meters are effective without any type of flow conditioning.
Flow Conditioning

Why do we want to use flow conditioners then?

- Can eliminate up to 80 – 90% of pipeline swirl.
- Restore flow profile symmetry and eliminate distortions.
- Isolates the flow meter from upstream disturbances.
- Allows much shorter meter runs to be used with much higher repeatability.
- Improves the benefits of many USM diagnostics by providing flow stability.
- Helps with noise or pulsation problems.
- Helps balance the pressure, velocity and flow rate of meter tubes running in parallel.

- They UNLOAD the flow meter, helping it become even more accurate.

Flow Conditioning

What if we have debris in our pipe?

- The debris has to go somewhere, ignoring the flow conditioner won’t make it disappear.
- Install a filter (or another flow conditioner UPSTREAM of the meter run to catch the debris).
- Without something to catch debris, we risk damaging or destroying any sample probes, thermo wells or any other equipment in the pipe.
- Better hope there isn’t a compressor or turbine downstream somewhere.
- If the gaskets are unraveling, recommend switching to Flexitallic CGI gaskets with an inner ring to keep the windings intact.
What is a Flow Conditioner?
What is a Flow Conditioner?
What is a Flow Conditioner?

Why should we use a Flow Conditioner?

When dealing with flow measurement, we cannot simply stick a flow meter in the pipe, turn it on and expect perfect results.

In the real world, we have to deal with:

- Installation effects
- Swirl
- Flow profile distortion
- Pulsation
- Noise

All of these combine in different ways to generate measurement errors!
Fully Developed Flow

- Fully developed pipeline flow is the ideal state of a fluid in a pipe.
- If we had an infinitely long pipe, this is the flow we would always see.
- It is mathematically predictable.
- It is perfectly symmetrical around the center of the pipe.
- It has no swirl.
- This *should* guarantee us perfect, error free, repeatable measurement.
- Installation effects take us away from this state.
Fully Developed Flow

Swirl

- Swirl is the rotation of fluid in a pipe.
- It is caused by any change in piping direction!
- It can also be caused by any partial restriction of a pipe.
Swirl

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Swirl

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Swirl

[Image of swirling flow pattern]

Swirl

[Image of swirling flow pattern]
Swirl

- Swirl causes unpredictable distortions in the flow profile that change over time.
- Swirl flattens and then inverts flow profiles due to centripetal force. The harder the fluid is spinning, the more energy that is pushed to the pipe walls.
- Swirl can cause local effects due to the location of pressure taps (dP measurement) or in the case of Ultrasonic Meters (adding to or subtracting to local path velocity).

Installation Effects

Every pipe fitting generates an installation effect.

- Tees
- Elbows
- Expanders
-Reducers
- Valves
- Probes

All of these objects can combine to create a deviation from perfect fully developed flow.
Installation Effects - Elbows

Installation Effects - Tees
Installation Effects – Tees

Installation Effects – Tees /w Turbulence
Installation Effects - Probes

Installation Effects – Valves
Installation Effects – Elbows & Orifice Plates

Installation Effects – Reducers
Measurement Errors

- The further we get from our perfect, swirl free, fully developed flow, the more uncertain our measurement becomes.
- Error due to flow profile distortion – deviation from baseline state.
- Error due to swirl itself.
- What if we want to shorten our meter run?
- What do we do?

Without Flow Conditioning
A properly designed Flow Conditioner converts this flow... 

...Into this.
How They Work

• Hole pattern is arranged so that the resulting downstream condition is a fully developed profile, the same as would be achieved by a long length of straight, uniform pipe.

• Stream is forced towards the holes in the plate which forces the pressure field to balance immediately upstream of the flow conditioner.

• Fluid accelerates to over twice its initial velocity where the flow through each hole is roughly proportional to its area.

• If swirl is present, this is cut out by the acceleration of the gas, and the thickness of the plate.
Meter Types

- All volumetric flow meters can be flow conditioned: Orifice, Ultrasonic, Venturi, Coriolis Vortex, Turbine, Cone, Mag, etc.

- Every meter type responds differently to the effects of swirl and flow profile distortion.

- Volumetric flow meters are looking for ‘good flow’. Flow with minimal swirl and good flow profiles.

- A flow conditioner is simply trying to improve the flow that the meter is seeing.

CPA once said....

- It’s far easier to measure good flow with a bad meter, than trying to measure bad flow with a good meter.
Ultrasonic Meters

- Rely on a noise pulse that is transmitted through the fluid and the flow rate is computed using the transit time.
- Transit time is affected by velocity disturbances within the pipe, slowing or speeding up the pulse.
- Multiple paths help to generate a complete picture of the cross sectional flow within the pipe.
- The meter only knows how long it took for the pulse to travel from point A to point B.
- It cannot guess the state of the flow along the way.

CFD Ultrasonic Simulation

- SawchukSonic™ CFD Ultrasonic Flow Meter
- 7 path layout (every 1/8 pipe diameter).
- 45 degree path angle.
- Dual, redundant meters (14 paths total).
- Ability to switch paths on and off at will to show effect on final flow meter output.
- Path layout, angle and weighting has not been optimized for accuracy, reynolds number shifts or ability to handle installation effects. Meter is for demonstration purposes only.
Computational Fluid Dynamics (CFD)

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Computational Fluid Dynamics (CFD)
Computational Fluid Dynamics (CFD)
Computational Fluid Dynamics (CFD)
Computational Fluid Dynamics (CFD)

OIML R137 Piping

- Dual elbows/bends out of plane (DBOOP)
- Half moon plate separating the elbows. Opening is towards the outside of the turn radius.
- Expander at the meter run inlet is no longer used; the elbows are the same pipe diameter as the flow meter.
OIML R137 Piping

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OIML R137 Piping

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OIML R137 Piping

OIML R137, DBOOP & HMP, No FC
OIML R137, DBOOP & HMP, No FC
OIML R137, DBOOP & HMP, No FC

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OIML R137, DBOOP & HMP, No FC

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OIML R137, DBOOP & HMP, No FC

OIML R137, DBOOP & HMP
OIML R137, DBOOP & HMP, No FC, 10D Downstream

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OIML R137, DBOOP & HMP, CPA 55E, 10D Downstream

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OIML R137, DBOOP & HMP, No FC

Crossflow Significance

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OIML R137, DBOOP & HMP, No FC

Swirl %

OIML R137, DBOOP & HMP, CPA 55E

Velocity Flow Profiles
OIML R137, DBOOP & HMP, CPA 55E

Crossflow Significance

Swirl %

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Swirl %

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7 Path USM CFD Simulation, Flow Profiles

No FC

FC, CPA 55E

7 Path USM CFD Simulation, Swirl Profiles

No FC

FC, CPA 55E
7 Path USM CFD Simulation, USM Flow Profiles

No FC

FC, CPA 55E

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7 Path USM CFD Simulation, USM Swirl

No FC

FC, CPA 55E

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7 Path USM CFD Simulation, 2 Path Error

No FC, -1.29%  CPA 55E, -2.38%

7 Path USM CFD Simulation, 3 Path Error

No FC, -3.29%  CPA 55E, 0.37%
7 Path USM CFD Simulation, 4 Path Error

- No FC, 1.86%
- CPA 55E, -0.16%

7 Path USM CFD Simulation, 7 Path Error

- No FC, -0.41%
- CPA 55E, 0.07%
### Ultrasonic Meters

- Since ultrasonic meters cannot actually determine what the transducer pulse is seeing, we want to guarantee the best flow profile possible.

- A flow conditioner helps ensure that this is possible. It helps create a reference state so that no matter what the upstream conditions are, the ultrasonic meter is measuring a more predictable and repeatable flow profile shape.

- Deviations from this baseline result in errors that add to the complexity of calculating flow rate.

### Plate Based Isolating Flow Conditioners

- A properly designed flow conditioner is recommended for use in a range of Reynolds numbers.

- All fluid flows can improve from some sort of flow conditioning.

- While highly viscous flows are extremely resilient to swirl and flow profile distortions, the use of a flow conditioner quickly eliminates the remaining bulk rotation.

- What is the downside? How much pressure drop are we willing to spend?
Flow Conditioning Swirl Removal

Flow Conditioner Swirl Reduction

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Flow Conditioning Swirl Removal

Flow Conditioner Swirl Reduction

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Pressure Drop

• All fittings, obstructions, even pipe itself has a “k factor”.

• The k factor is the pressure loss coefficient for a particular piece of piping.

• It is experimentally determined using the measured pressure drop.

\[ \Delta P = \frac{k \rho V^2}{2} \]

• K = Pressure loss coefficient.
• \( \Delta P \) = Pressure drop across a section of pipe or a fitting.
• \( \rho \) = Bulk fluid density, kg/m³.
• \( V \) = Bulk fluid velocity, m/s.

Pressure Drop

• For natural gas applications, most plate flow conditioners have a K factor of approximately 2.

• Tube bundles are closer to 0.75 – 1.5.

• What if we are worried about the pressure drop across the flow conditioner?
Pressure Drop

- The CPA 50E K factor ~ 2.0 (dP same as roughly 277 feet of pipe, 12” ID).
- CPA 65E K factor ~ 1.0 (dP same as roughly 140 feet of pipe, 12” ID)
- Long radius Elbow K factor ~ 0.6 – 0.8
- Tee, flowing straight through ~0.5
- Tee, flow turning 90 degrees from inlet to outlet ~ 1.2 – 1.8
- Flow from a inlet header into a meter run ~ 1.0
- Flow from a meter run into an outlet header ~ 0.78

Pressure Drop

- The uni-directional meter run on page 27 of AGA9, excluding the flow conditioner, will have a total K factor of at least 3.0 – 4.0.
- This is ignoring the fittings that would be needed to connect up to the tees.
- Adding two additional tees would nearly double the pressure drop.
- This is assuming fully developed flow. Swirl and profile distortion will change the pressure drop!
Pressure Drop

Relative Pressure Drop
Pressure Drop – Tube Bundle vs CPA

<table>
<thead>
<tr>
<th>Wall Thickness (Inches)</th>
<th>19-Tube Bundle</th>
<th>CPA 50E/55E</th>
<th>CPA 65E</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.125</td>
<td>11.938</td>
<td>11.938</td>
<td>11.938</td>
</tr>
<tr>
<td>0.25</td>
<td>11.938</td>
<td>11.932</td>
<td>11.932</td>
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<tr>
<td>0.298</td>
<td>11.938</td>
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<td>11.932</td>
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<tr>
<td>Pipe Diameter (Inches)</td>
<td></td>
<td>111.932</td>
<td>111.932</td>
</tr>
<tr>
<td>Pipe Area (Inches^2)</td>
<td>94.957</td>
<td>79.848</td>
<td>74.493</td>
</tr>
<tr>
<td>Flow Area (Inches^2)</td>
<td></td>
<td>74.493</td>
<td>53.450</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65.206</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>84.84%</td>
<td>71.34%</td>
<td>66.55%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>47.75%</td>
<td>58.25%</td>
</tr>
</tbody>
</table>

Surface Area

• The 19-Tube Bundle has multiple sets of fluid passages:
Surface Area

- Per unit length (1") the 19-Tube Bundle used has about 287 in² of wetted surface area.
- A plate flow conditioner such as the CPA 50E has 128 in²

Surface Area...it gets worse.

- Most plate flow conditioners have a thickness of 10 – 20% of the pipe diameter.
- In a 12 Schedule 40 pipe, a 19-Tube Bundle will have a length of twice the pipe NPS, giving a thickness of 25.5 inches, resulting in a overall wetted surface area of 7322 in².
- Roughly 34 times the surface area of a plate flow conditioner!
Pressure Drop – Tube Bundle vs CPA

Pressure Loss Coefficient vs Reynolds Number (Viscosity)

Pressure Drop

Flow Conditioner K Factor (Pressure Loss Coefficient)
Plate Based Isolating Flow Conditioners

Total Life Cycle Costs (Capital + Operating + Compression)

Pipe Porosity or Pipe Open Area (%)

Fuel Gas Driven (Compression Costs To Overcome Severe Pressure Drop)
Capital Cost Driven (Longer Meter Stations)

Optimal Flow Conditioner Porosity

Measurement Value Graph

Single Path
Multipath
Error Cost

Meter Cost
Uncertainty
High
Low

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Flow Conditioning Conclusion

- Can eliminate up to 80 – 90% of pipeline swirl.
- Help restore flow profile symmetry and eliminate distortions.
- Isolates the flow meter from upstream disturbances.
- Allows much shorter meter runs to be used with much higher repeatability.
- Are applicable for all liquid or gas flows!

The flow conditioner is merely helping out the meter, providing higher reproducibility and lower uncertainty!

Thank You

- For Further information
  
  www.flowconditioner.com
  www.cpacfd.com

  Danny Sawchuk
  danny@cpacl.ca
  403.236.4480