Ultrasonic Flow Measurement Technology
Presentation Overview

- History of the technology
- Operating principles
- Transducer installation
- Pipe requirements
- Fluid requirements
- User interface and communications
History of the Technology
An Ultrasonic flowmeter using the Doppler method was first developed by Shigeo Satomura in 1959 for use in blood flow analysis.
History of the Technology

- In 1963, the first ultrasonic meters are developed for use in industrial applications.
- In 1972, the first U.S. manufactured ultrasonic meters are offered.
History of the Technology


A multi-path ultrasonic flowmeter for gas measurement.
Operating Principles
Operating Principles

- High frequency sound.
- Both microphone and speaker.
- Both liquid (fluid) and gas.
- No moving parts.
Two distinctly different types of operating principles are used in most ultrasonic flow measurement applications…

Resulting in much confusion!
Operating Principles

Doppler

Transmitting Transducer
Reflecting Particle
Fluid-Filled Pipe
Flow Flow
Ultrasonic Signal Path
Receiving Transducer

Transit Time

Transmitting Transducer

Receiving Transducer
Fluid-Filled Pipe
Flow Flow
Ultrasonic Signal Path
Operating Principles

**Doppler**
- Fluid must contain particles
- Uses frequency phase shift
- For fluids applications only

**Transit Time**
- Relatively clean fluids (small amount of particles is OK)
- Uses time of flight
- For fluid or gas applications
Operating Principles

Doppler

- Must stay in suspension
- Must reflect sound waves
- Must move at the same velocity as the fluid
Operating Principles

Doppler

- Fluid must contain particles
- Uses frequency phase shift

Diagram:
- Transmitting Transducer
- Reflecting Particle
- Fluid-Filled Pipe
- Fluid Flow
- Ultrasonic Signal Path
- Receiving Transducer
Operating Principles

Doppler

- Fluid must contain particles
- Uses time frequency phase shift
- For fluids only
Operating Principles

Doppler phase shift
Operating Principles

Transmitting Transducer

Receiving Transducer

Fluid-Filled Pipe

Fluid Flow

Ultrasonic Signal Path

Transit Time

Relatively clean fluids (small amount of particles is OK)
Operating Principles

Transmitting Transducer

Receiving Transducer

Fluid-Filled Pipe

Ultrasonic Signal Path

Transit Time

Relatively clean fluids (small amount of particles is OK)

Uses time of flight
Operating Principles

Transmitting Transducer → Fluid-Filled Pipe → Ultrasonic Signal Path → Receiving Transducer

**Transit Time**

- Fluid must be clean (small amount of particles is OK)
- Uses time of flight
- For fluid or gas applications
Operating Principles

Transit-Time pulse burst
Onset of the wave (or where is that guy with the red hat?)
Where is that guy with the red hat?
Operating Principles

Onset of the wave (finding the guy with the red hat)
Hybrid Operating Principles

Doppler
- Fluid must contain particles
- Uses time frequency phase shift
- For fluids applications only

Transit Time
- Fluid must be clean (small amount of particles is OK)
- Uses time of flight
- For fluid or gas applications
Transducer Installation
Transducer Installation

Insertion
- Invasive. The pipe must be drilled and tapped. The transducer is installed directly into the flow stream.

Spool Piece
- Invasive. The transducers are pre-installed in a flanged spool piece. The spool piece is installed in a section of pipe.

Clamp on
- Non-invasive. The transducers are clamped onto the outside of the pipe. No cuts are made in the pipe.
Transducer Installations

Insertion

- Invasive. The pipe must be drilled and tapped. The transducer is installed directly into the flow stream.

Piping Considerations

- Material and wall thickness.
- Typically larger pipe sizes.
- Placement of transducers is critical.
Transducer Installations

Piping Considerations
- Flanged connections.
- Typically smaller pipe sizes.
- Transducers are pre-installed.

Spool Piece
- Invasive. The transducers are pre-installed in a flanged spool piece. The spool piece is installed in a section of pipe.
Transducer Installation

- Non-invasive. The transducers are clamped onto the outside of the pipe. No cuts are made in the pipe.

Piping Considerations
- Accurate measurement and placement is required.
- Pipe material and dimensions must be known.
- Acoustic coupling material is required.
Separation Distance

- Accurate placement is important.
- The distance between the transducers must be correct.
- The transducers must be properly aligned.

Clamp on

- Non-invasive. The transducers are clamped onto the outside of the pipe. No cuts are made in the pipe.
Pipe measurements

- Correct pipe OD and ID measurement is required.
- The pipe inside and outside surface must be clean and smooth.
- The beam angle changes as it passes through the various materials.
Transducer Installation

Clamp on

- Non-invasive. The transducers are clamped onto the outside of the pipe. No cuts are made in the pipe.

Acoustic coupling
- A special gasket or other coupling material is required.
- Silicone sealant is often used.
Pipe Requirements
Clamp-on Transducer Pipe Requirements

- Materials
- Dimensions
- Liners
- Coatings
- Straight lengths
Pipe Requirements

Acceptable clamp-on pipe materials

**Plastic pipes**
- Acrylic
- FRP (fiberglass reinforced plastic)
- Nylon
- Polyethylene (HDPE)
- Polyethylene (LDPE)
- Polypropylene
- PVC/CPVC
- PVDF

**Metal pipes**
- Aluminum
- Brass (Naval)
- Copper
- Iron (cast)
- Iron (ductile)
- Nickel
- Stainless Steel
- Steel (carbon)

- Some materials may only be acceptable up to a maximum thickness.
- The speed that sound travels in the material should be known.
- Liners, coatings, etc. should be carefully evaluated.
For high accuracy, straight lengths of pipe needed to reduce swirl patterns and vortices.

<table>
<thead>
<tr>
<th>Type of Disturbance</th>
<th>Straight Lengths of Pipe Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upstream from Transducers</td>
</tr>
<tr>
<td>Flange</td>
<td>5 x Nominal Pipe Size</td>
</tr>
<tr>
<td>Reducer</td>
<td>7 x Nominal Pipe Size</td>
</tr>
<tr>
<td>90° Elbow</td>
<td>10 x Nominal Pipe Size</td>
</tr>
<tr>
<td>Two 90° Elbows - 1 Direction</td>
<td>15 x Nominal Pipe Size</td>
</tr>
<tr>
<td>Two 90° Elbows - 2 Directions</td>
<td>20 x Nominal Pipe Size</td>
</tr>
<tr>
<td>Gate valve</td>
<td>25 x Nominal Pipe Size</td>
</tr>
<tr>
<td>Pump</td>
<td>25 x Nominal Pipe Size</td>
</tr>
</tbody>
</table>

- **Multi-path** units are even less susceptible to flow disturbances.
Ultrasonic meters offer good resistance to swirl patterns

- Less straight pipe lengths needed than paddlewheel and other insertion type meters.
- Larger percentage of fluid effects the flow measurement.
Fluid Requirements
Acceptable fluids

- Must conduct sound.
- Require particulates.
- Some manufacturers claim clean fluid acceptability by installing next to a flow disturbance such as an elbow.
- The fluid sound speed is usually not a factor in Doppler accuracy.
- Not all particulates are the same! Sand vs. bubbles vs. pulp.
- Low fluid velocity can be a challenge.
Acceptable fluids

- Theoretically, any fluid that can conduct sound.
- Typically acceptable with up to 10% particulates.
- Some fluids can be used with both Doppler and Transit Time methods.
- Fluid sound speed can be a factor in Transit Time accuracy.
- Temperature will effect the fluid sound speed.
- The larger the pipe the better!
- Low fluid velocities are typically not a challenge.
User Interface
and
Communications
User Interface and Communications

Display

• Flow rate and flow total.
• Velocity.
• Update time.
• Averaging.
Portable or fixed in place

- Portable clamp-on units for system testing.
- Power requirements.
- Battery life an issue.
- Fixed units often include security passwords and robust enclosure designs.
User Interface and Communications

Output signals

- 4-20 mA analog signal.
- High speed digital pulse.
- Contact closures.
- Relays.
User Interface and Communications

Smart (er) communications

• Serial ports.
  – RS-232
  – RS-485
  – USB

• Protocols.
  – Modbus
  – Profibus
  – Foundation Fieldbus
  – HART

• Ethernet connection.

• Proprietary software.
Other features

- Data logging.
- Process control.
- Alarms.
Re-cap
“New” technology not really new

Two primary operating principles
- Doppler
- Transit Time

Multiple transducer installation techniques
- Insertion is invasive
- Spool Piece is invasive
- Clamp-on is non-invasive

Acceptable with a variety of piping systems
Acceptable with a variety of fluids
Many communications options
Thank You!

Ultrasonic Flow Measurement Technology