Ultrasonic Flow Measurement Technology

AALSO
Aquatic Animal Life Support Operators

Presentation Overview

- History of the technology
- Operating principles
- Transducer installation
- Pipe requirements
- Fluid requirements
- User interface and communications

History of the Technology

History of the Technology

Shigeo Satomura *^*

超音波による末梢循環の検査法[1-2]

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（昭和34年6月29日受理）

Study of the Flow Patterns in Peripheral Arteries by Ultrasonics

Shigeo SATOMURA

(Institue of Scientific and Industrial Research, Osaka University)

(Received June 29, 1959)

When an ultrasonic beam is radiated into the bloodvessel by a transducer placed on the surface of the skin, the reflected waves are produced from the blood-flow.

Hence they can be detected as a kind of tone by means of a sensitive receiver.

Because the intinsity and the frequency character of this tone is proportional to the velocity of the bloodflow, it is possible to investigate the behavior of the blood-flow through this method.

Tones are consisted of two kinds, one of them being produced by the carotid arterial system while the other produced by the limbs arterial system.

The author suggests to make a diagnosis of Arterial sclerosis utilizing this method.

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.

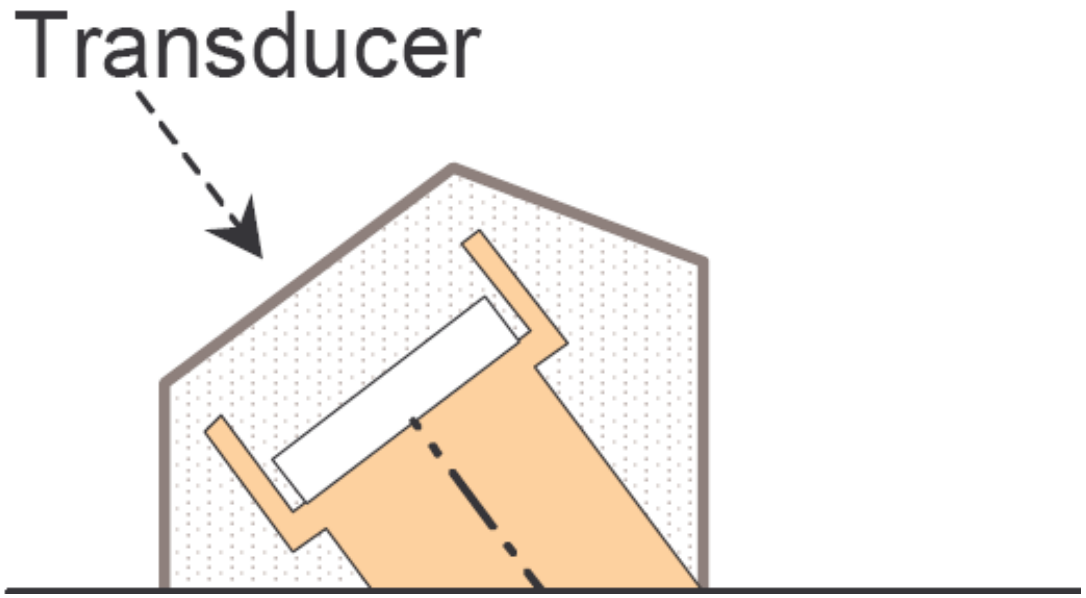
History of the Technology

The 1998, AGA (American Gas Institute) approves Ultrasonic meters for use in gas custody transfer applications.

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.

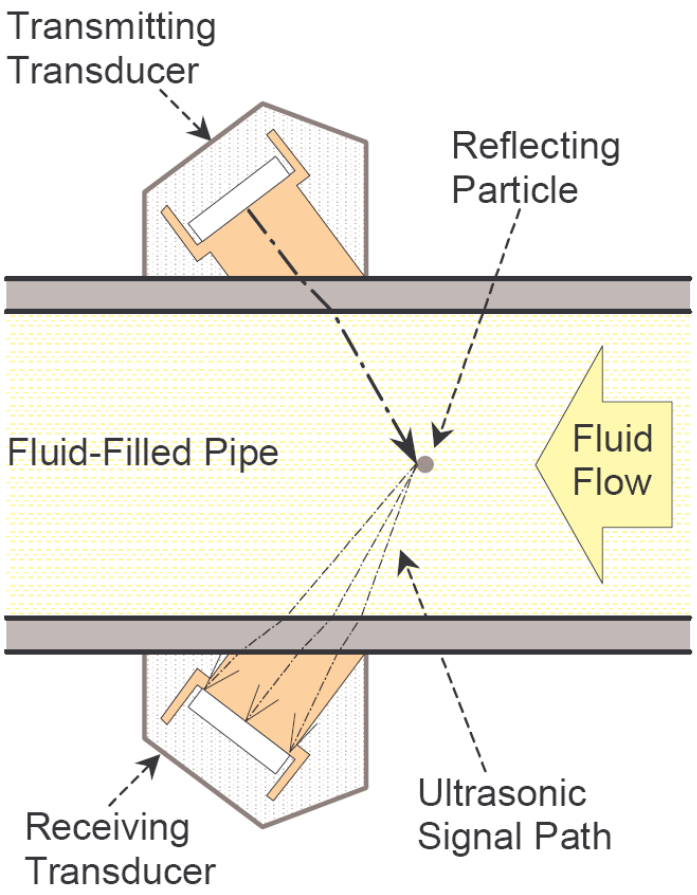
Operating Principles

Two distinctly different types of operating principles are used in most ultrasonic flow measurement applications…

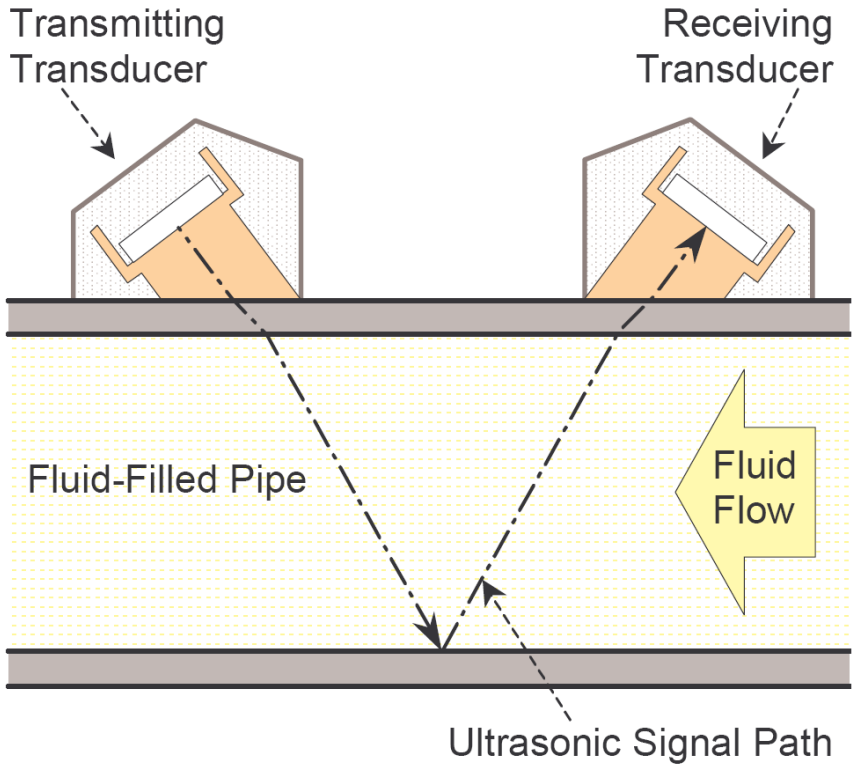
Resulting in much confusion!

Operating Principles

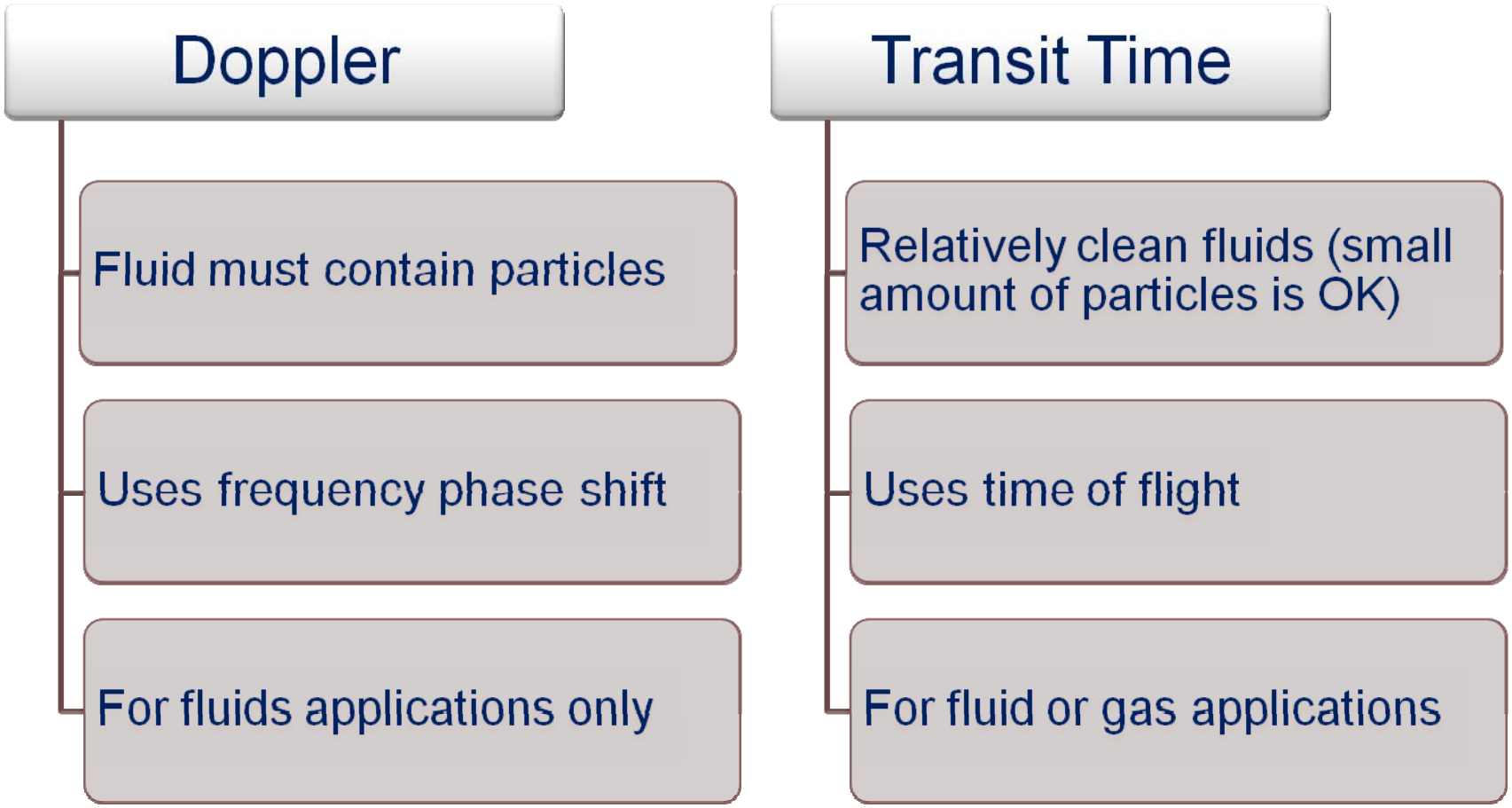
Doppler



Transit Time



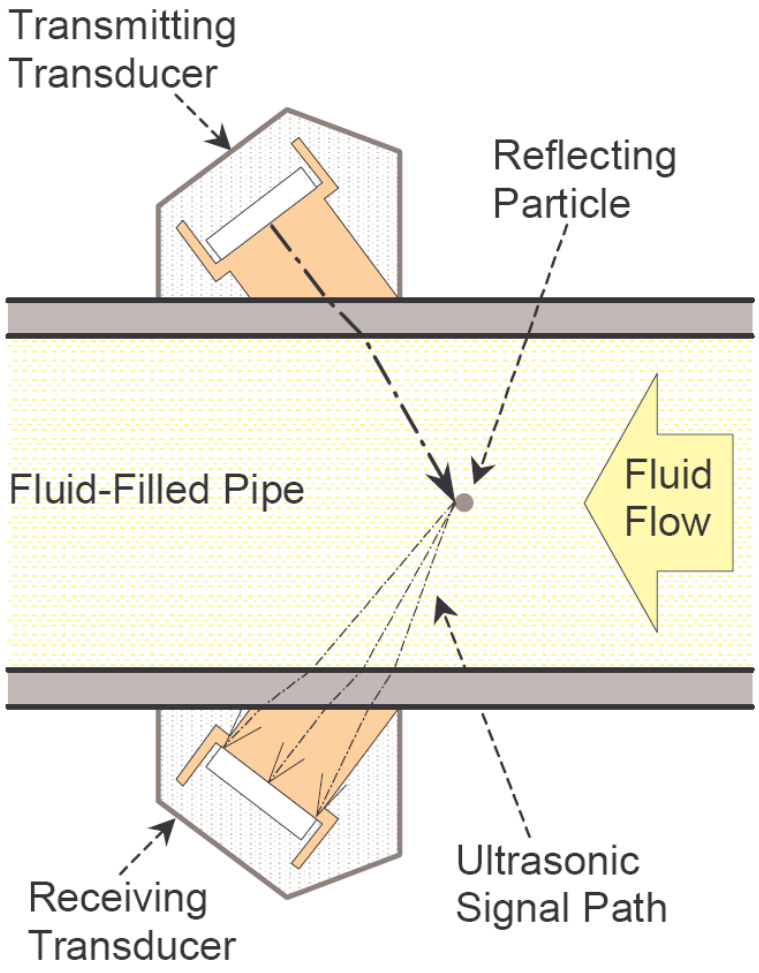
Operating Principles



Operating Principles

Doppler

Fluid must contain particles

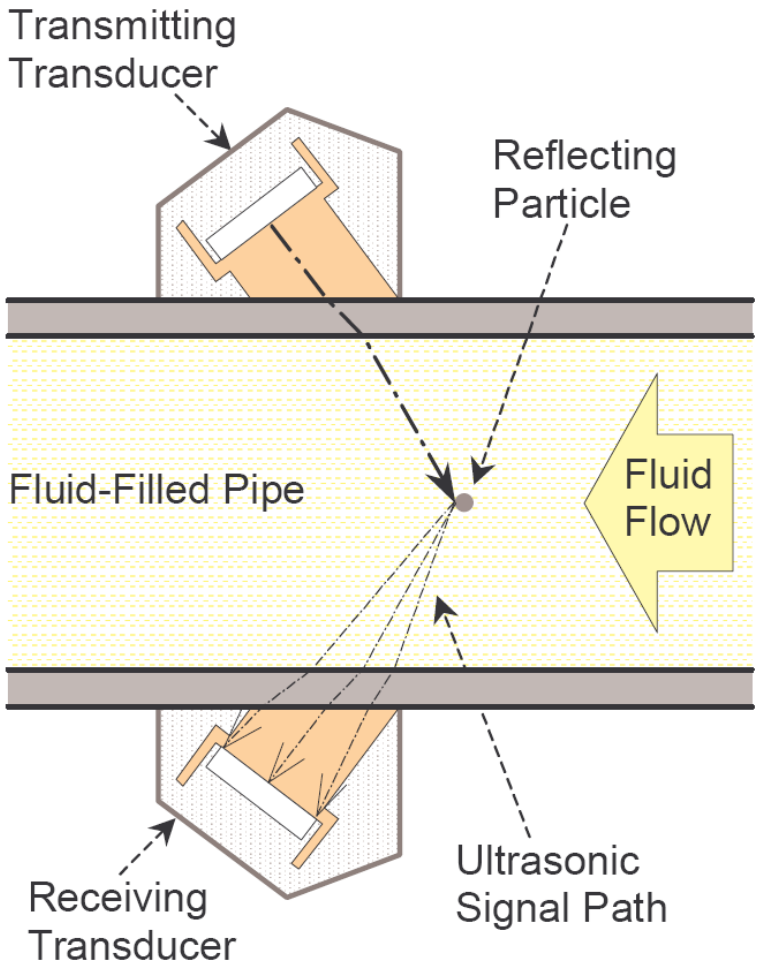


- **Must stay in suspension**
- **Must reflect sound waves**
- **Must move at the same velocity as the fluid**

Operating Principles

Doppler

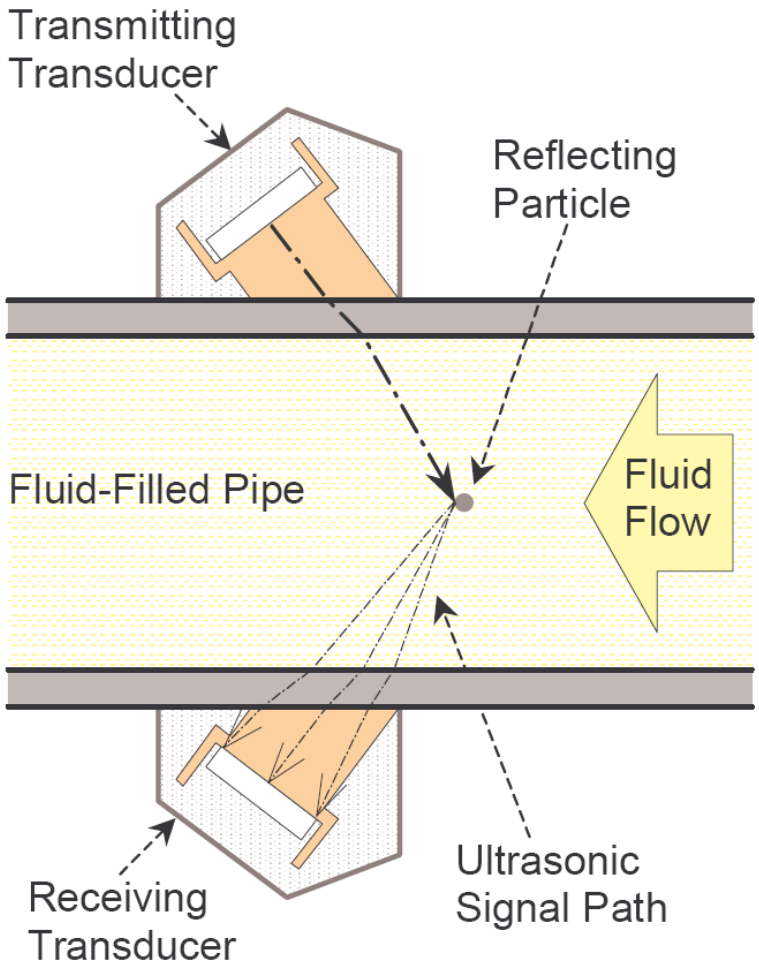
- Fluid must contain particles
- Uses frequency phase shift



Operating Principles

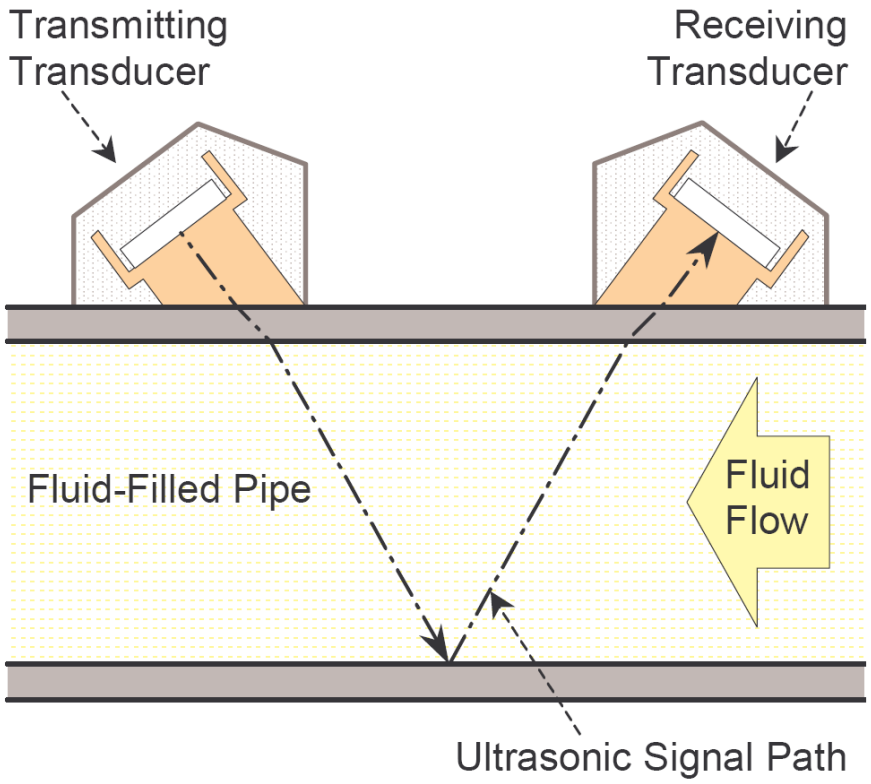
Doppler

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



Doppler phase shift

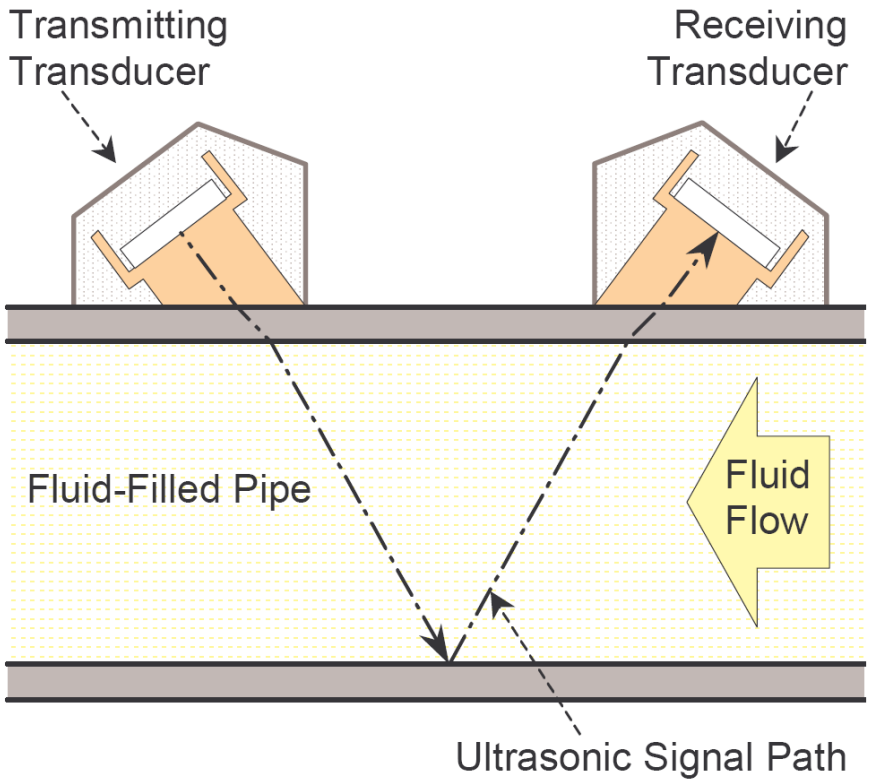
Operating Principles



Transit Time

Relatively clean fluids (small amount of particles is OK)

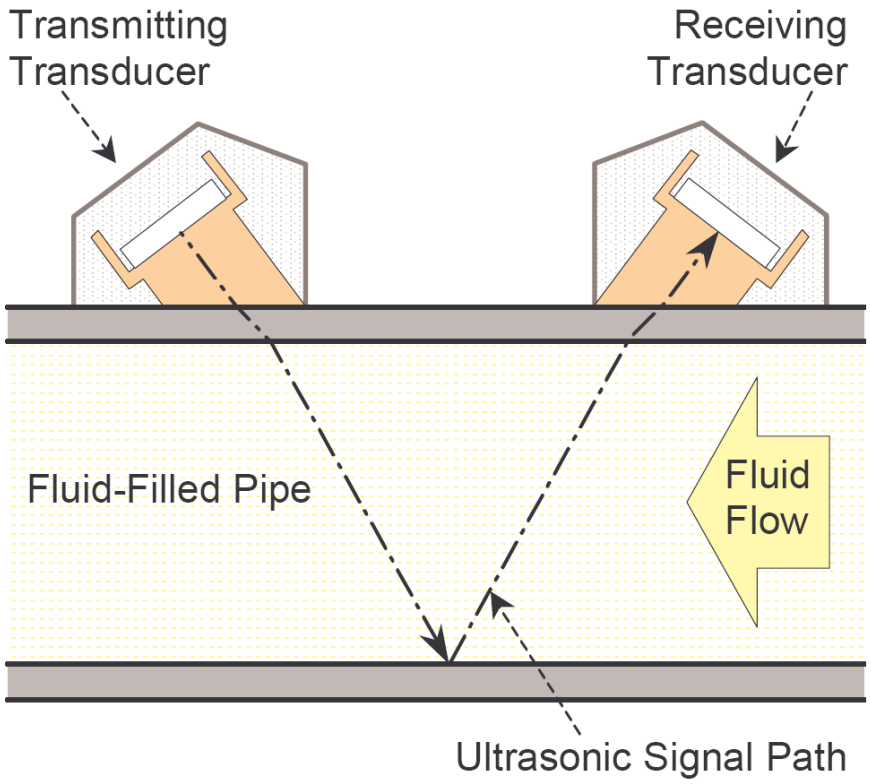
Operating Principles



Transit Time

- Relatively clean fluids (small amount of particles is OK)
- Uses time of flight

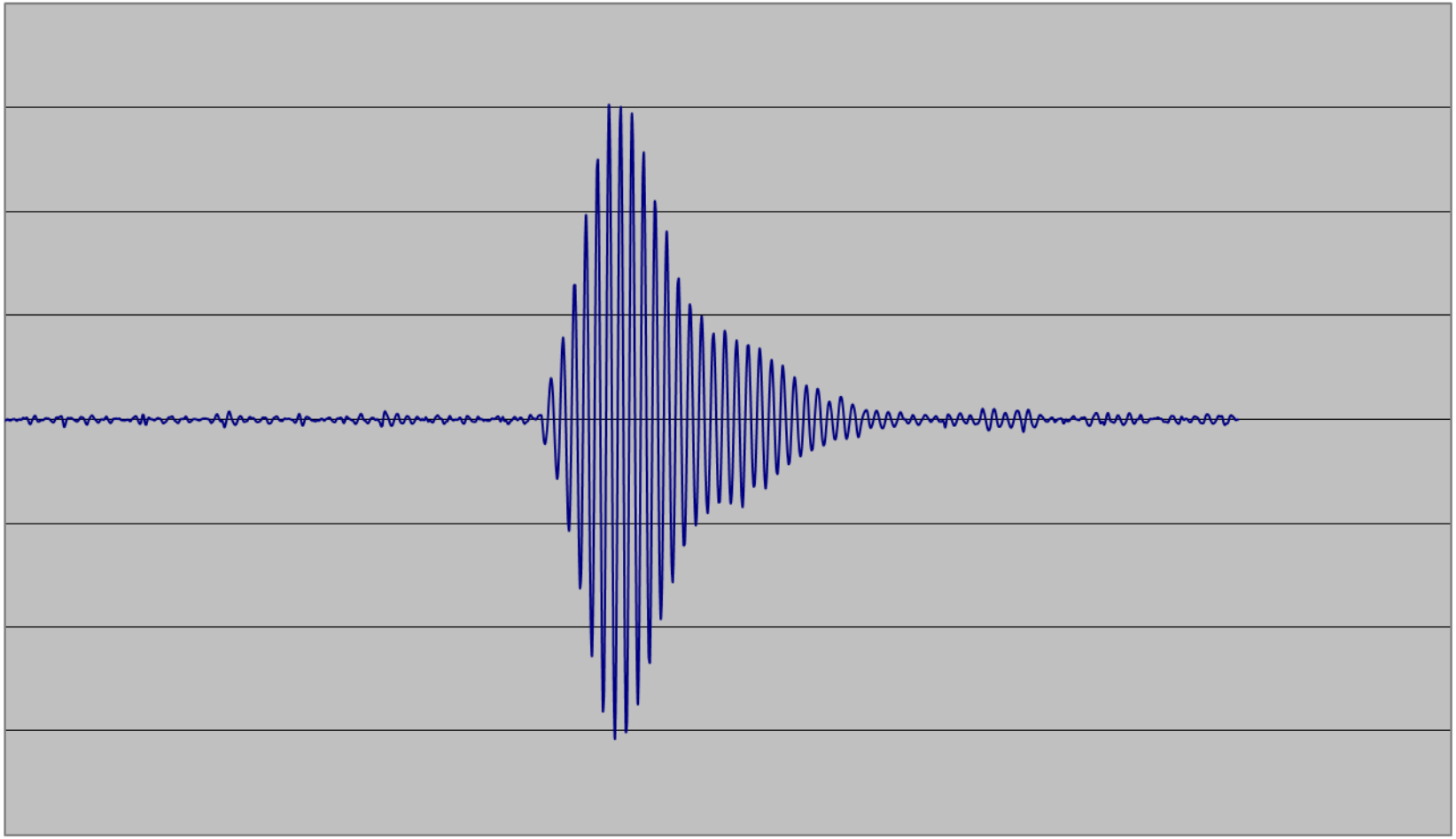
Operating Principles



Transit Time

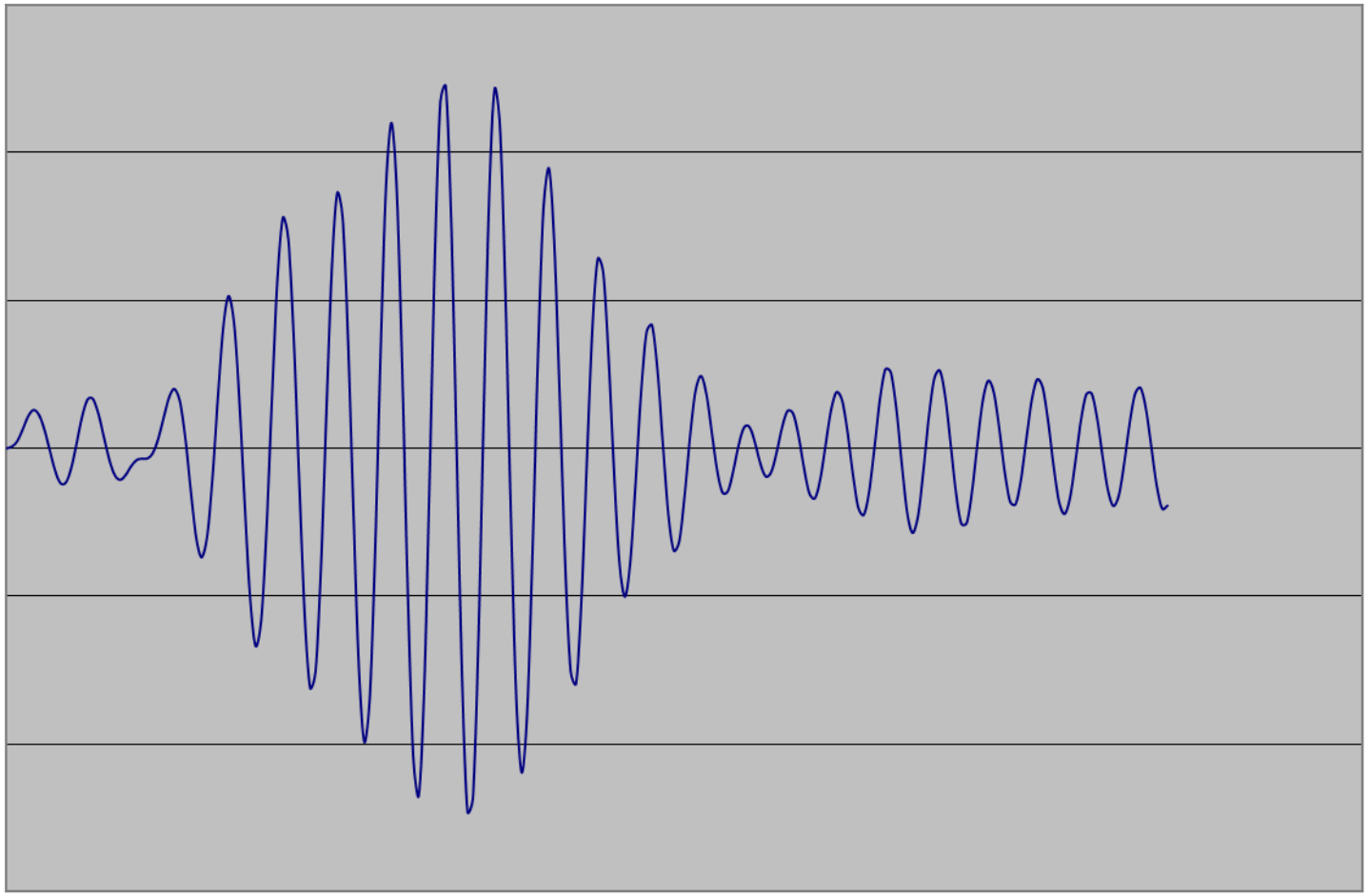
- Fluid must be clean (small amount of particles is OK)
- Uses time of flight
- For fluid or gas applications

Transit-Time pulse burst



Operating Principles

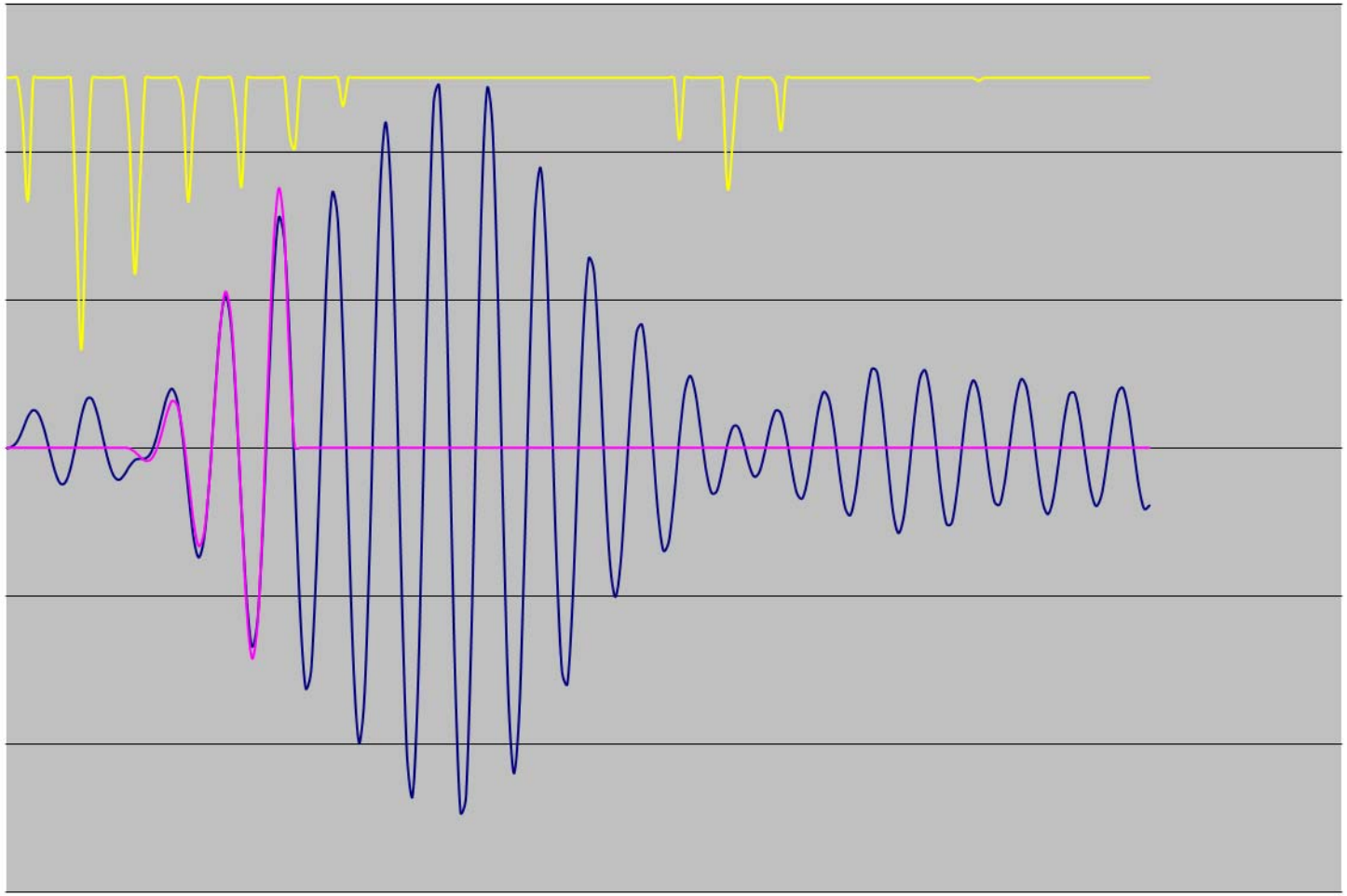
Onset of the wave (or where is that guy with the red hat?)



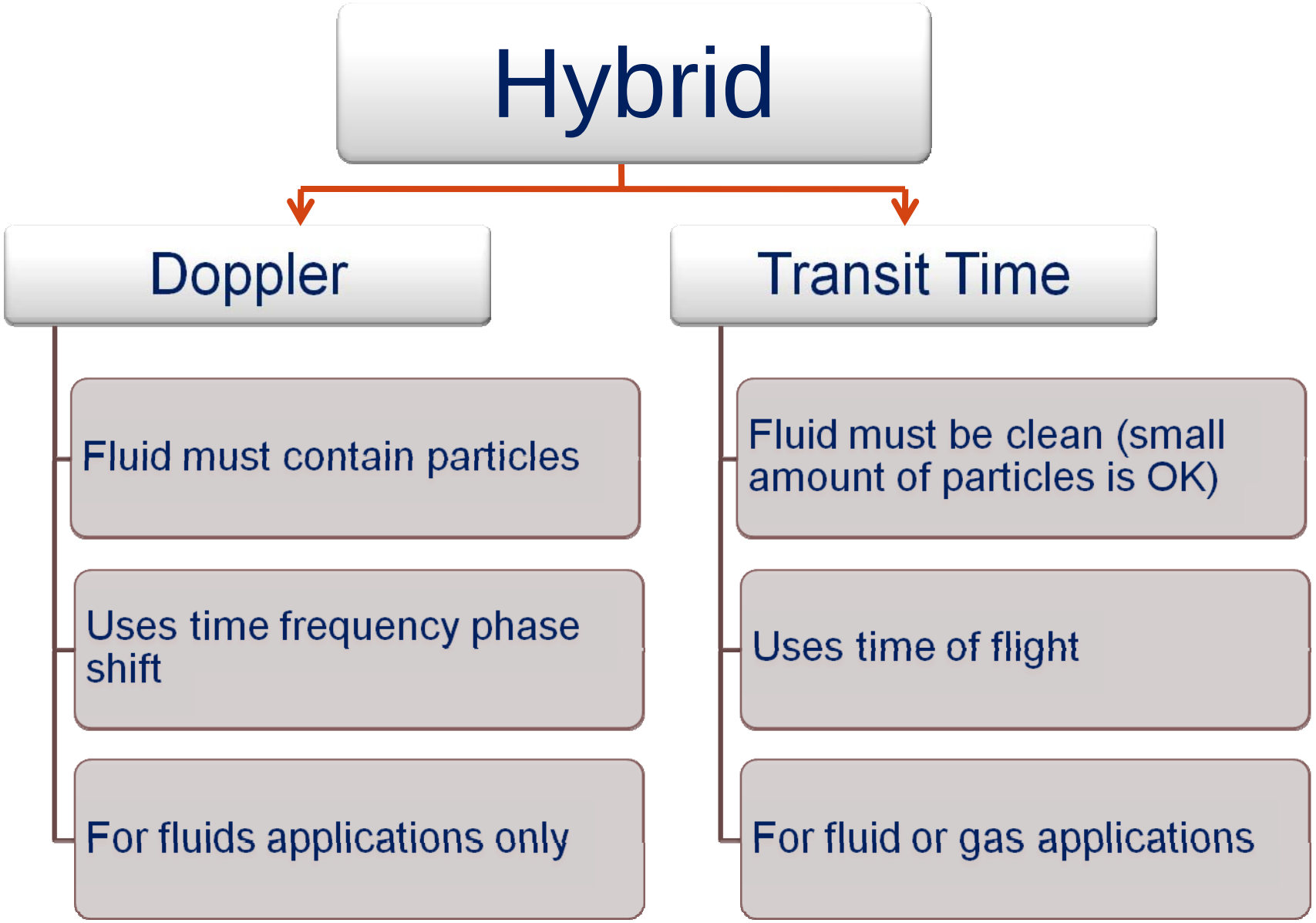
Where is that guy with the red hat?

Operating Principles

Onset of the wave (finding the guy with the red hat)



Operating Principles



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

Spool Piece

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

Piping Considerations

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

Transducer Installation

Clamp on

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

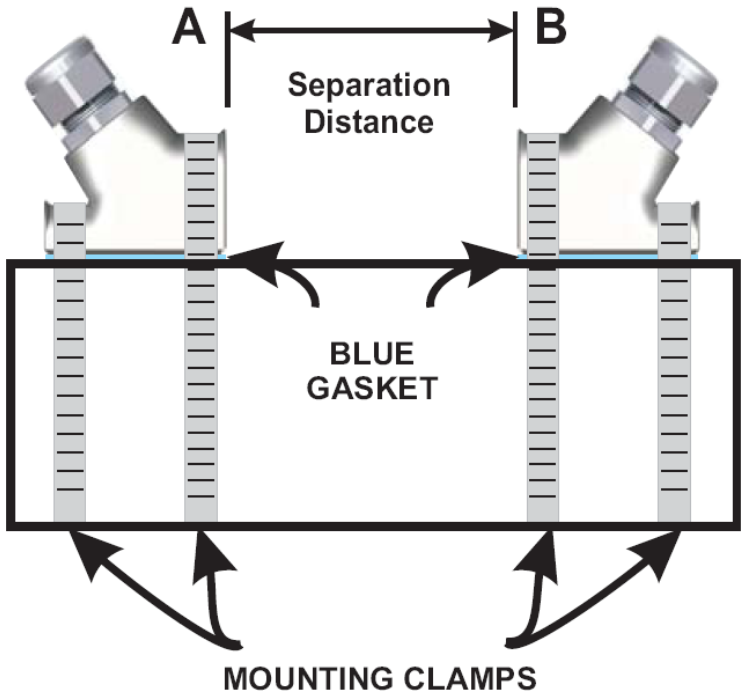
Piping Considerations

- **Accurate measurement and placement is required.**
- **Pipe material and dimensions must be known.**
- **Acoustic coupling material is required.**

Transducer Installation

Clamp on

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



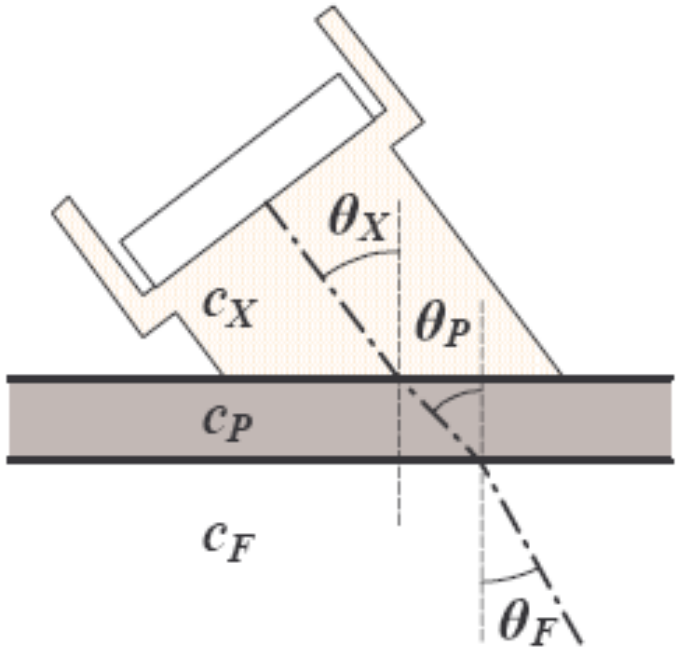
Separation Distance

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

Transducer Installation

Clamp on

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



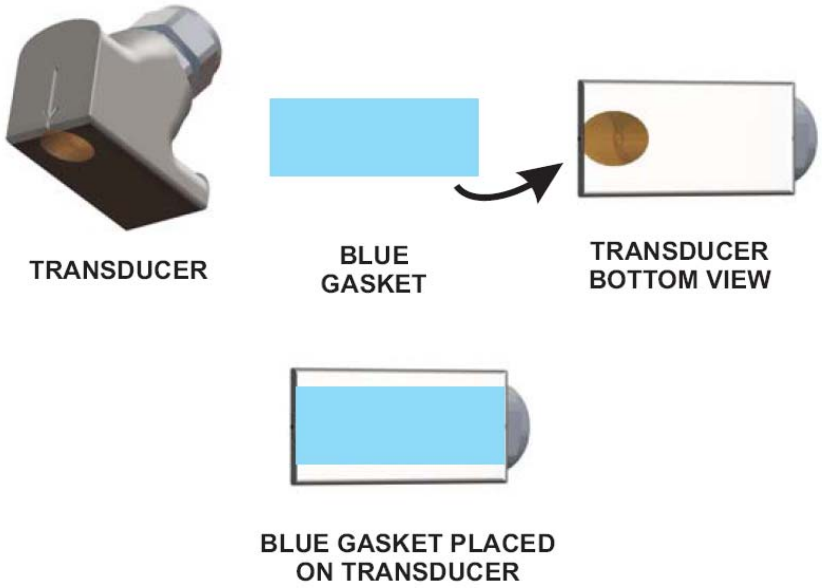
Pipe measurements

- **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**

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.**

Pipe Requirements

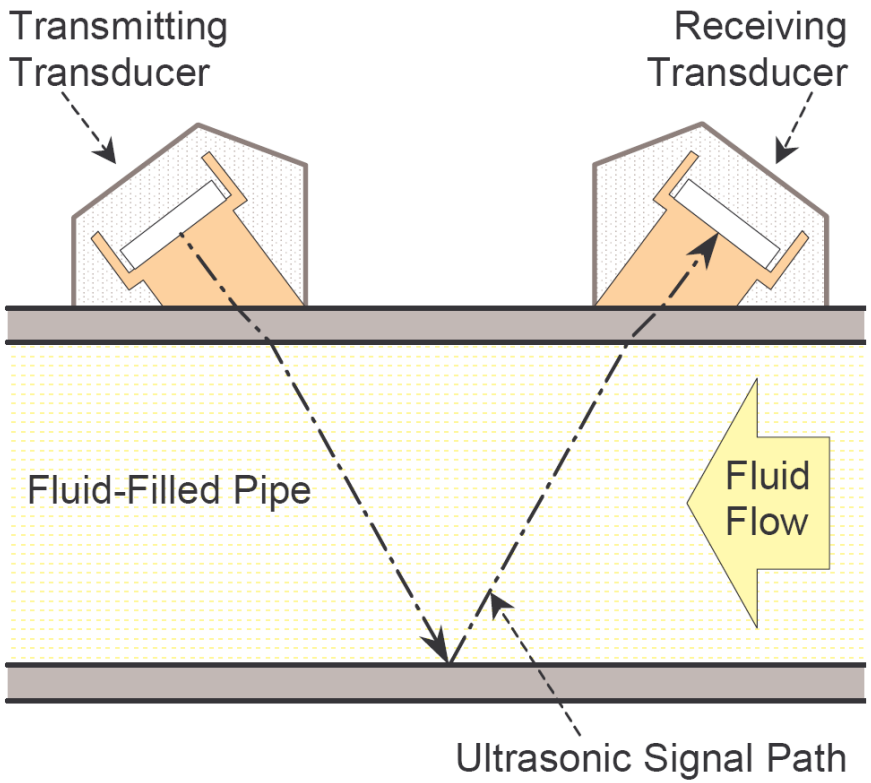
For high accuracy, straight lengths of pipe needed to reduce swirl patterns and vortices.

Type of Disturbance	Straight Lengths of Pipe Required	
	Upstream from Transducers	Downstream from Transducers
Flange	5 x Nominal Pipe Size	5 x Nominal Pipe Size
Reducer	7 x Nominal Pipe Size	5 x Nominal Pipe Size
90° Elbow	10 x Nominal Pipe Size	5 x Nominal Pipe Size
Two 90° Elbows - 1 Direction	15 x Nominal Pipe Size	5 x Nominal Pipe Size
Two 90° Elbows - 2 Directions	20 x Nominal Pipe Size	5 x Nominal Pipe Size
Gate valve	25 x Nominal Pipe Size	5 x Nominal Pipe Size
Pump	25 x Nominal Pipe Size	5 x Nominal Pipe Size

- ***Multi-path*** **units are even less susceptible to flow disturbances.**

Pipe Requirements

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

Fluid Requirements

Doppler

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.**

Fluid Requirements

Transit Time

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

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.

Output signals

- 4-20 mA analog signal.
- High speed digital pulse.
- Contact closures.
- Relays.

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

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!

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