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Volumetric Flow Measurements of Stationary Sources: Common Mistakes, Corrective Measures

Presented By

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Measurement Challenges and Metrology for Monitoring CO_2 Emissions from Smokestacks

NIST, Gaithersburg, MD

April 20 – 21, 2015

GOLDEN SPECIALTY

"FLOW"

- **Stream flow - Stack flow (Emissions)**

  The conglomeration of gases with varying chemical structures and masses homogeneously (most often) mixed, under pressure (+ or -) in a kinetic state flowing through a confined structure such as a duct, pipe or stack.

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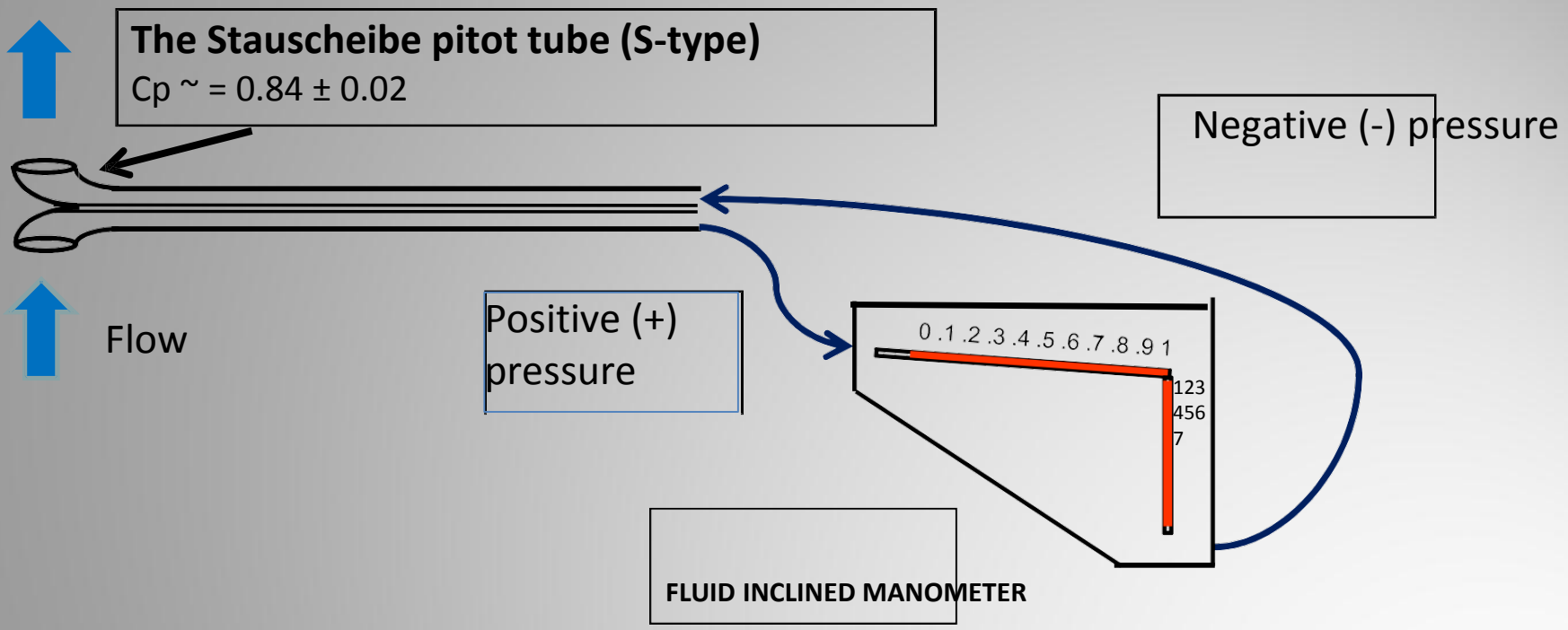
Flow Measurements



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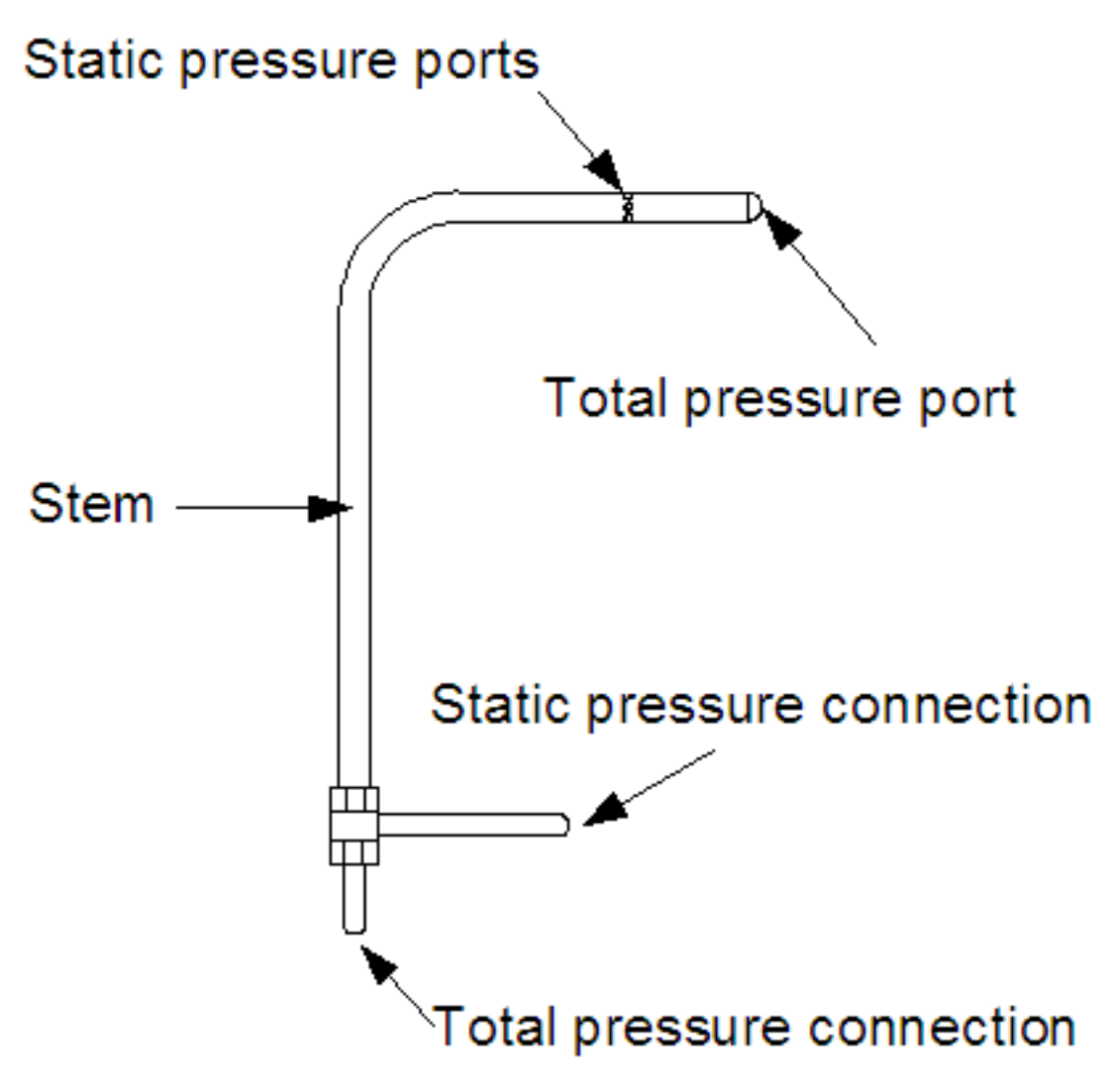
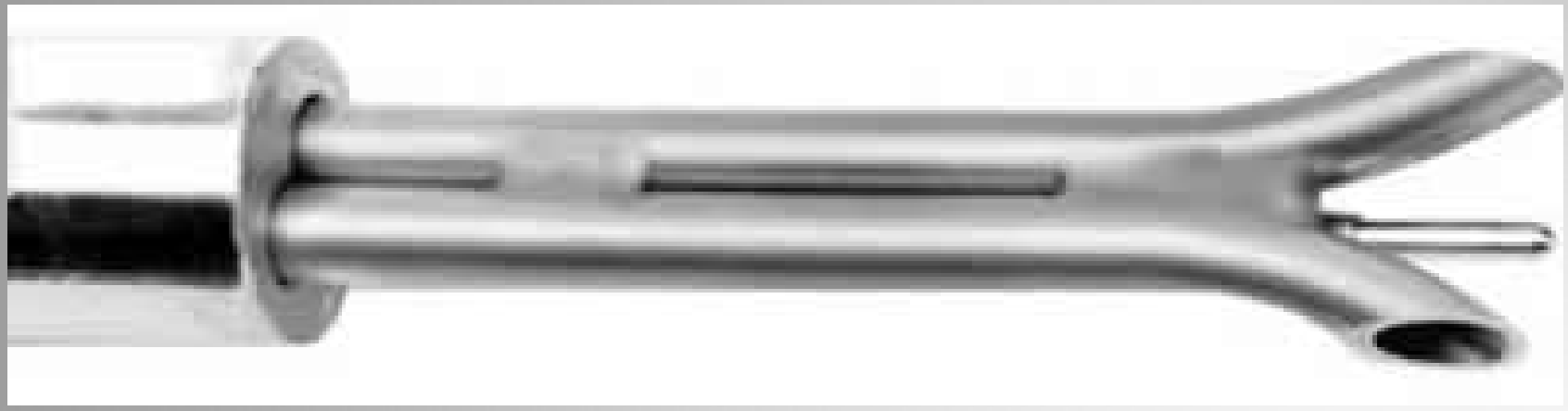
Standard Pitot



GOLDEN SPECIALTY

S-Type/Reverse/Stauscheibe



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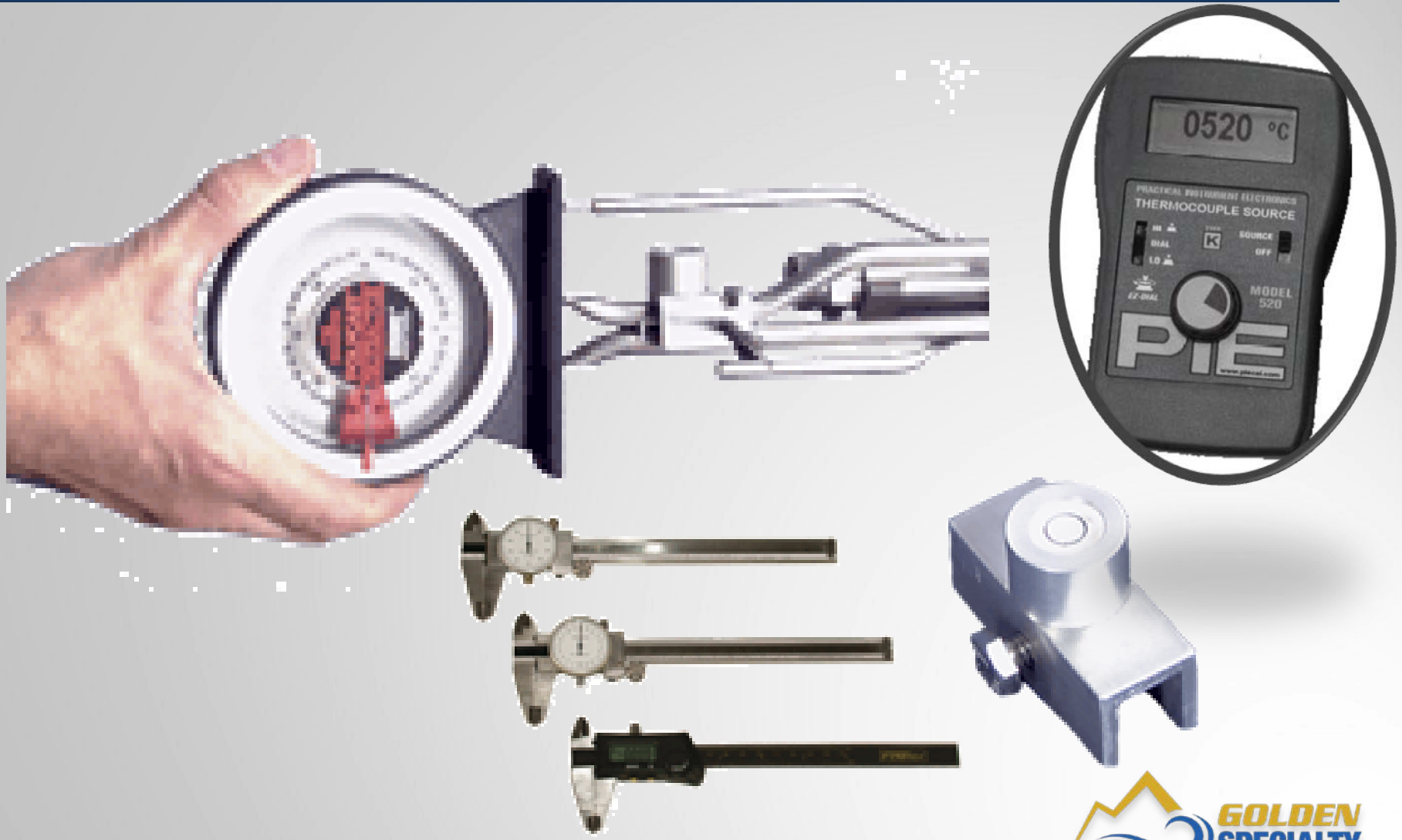
Inspection Tools



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10” Liquid Manometer Block

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Accuracy of Manometers

$$p = (g_t / g_o)\left(\frac{\rho_w - \rho_a}{\rho_o}\right)h$$

gt = gravity at instrument location
go = standard gravity (980.665 cm/sec2)
ρa = density of air at observed temperature
ρw = density of water at observed temperature
ρo = density of water at standard temperature
h = height of water column in inches

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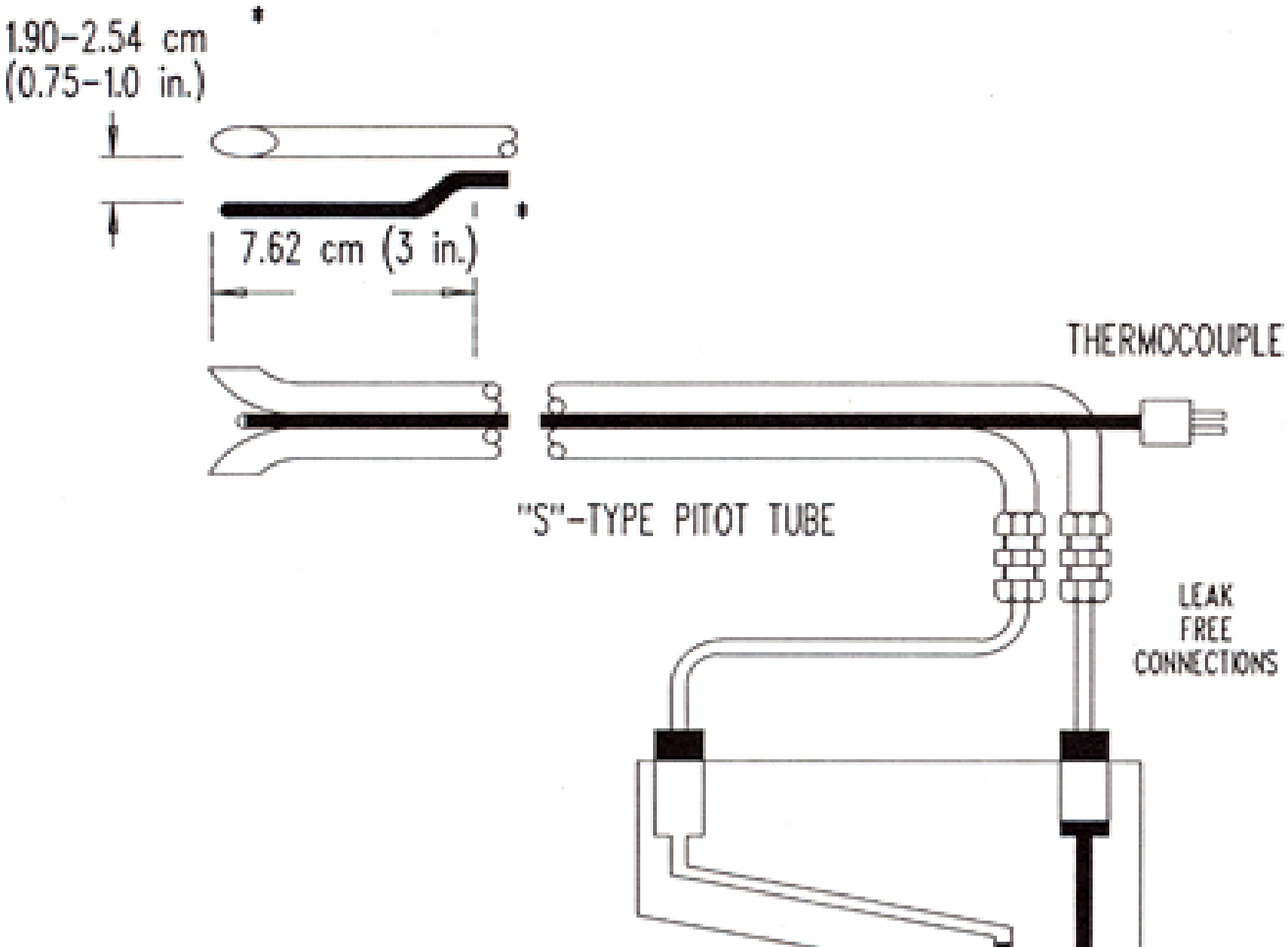
1.90–2.54 cm
(0.75–1.0 in.)
7.62 cm (3 in.)
THERMOCOUPLE
"S"-TYPE PITOT TUBE
LEAK
FREE
CONNECTIONS

Secondary references or tools often used

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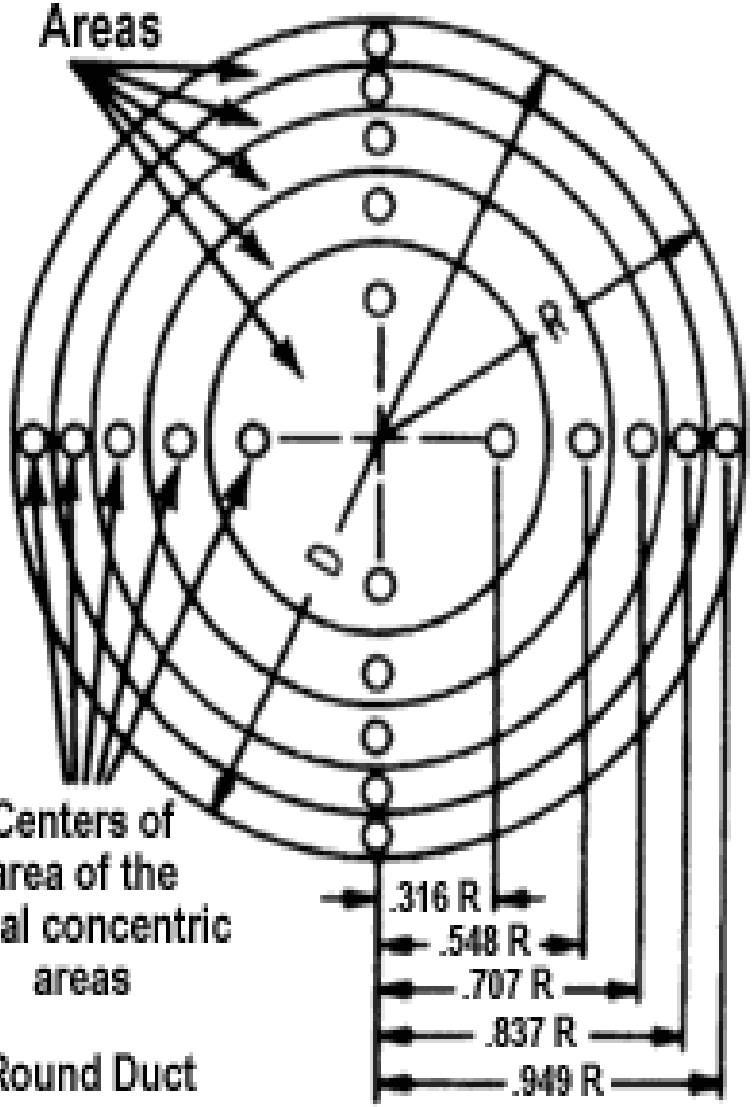
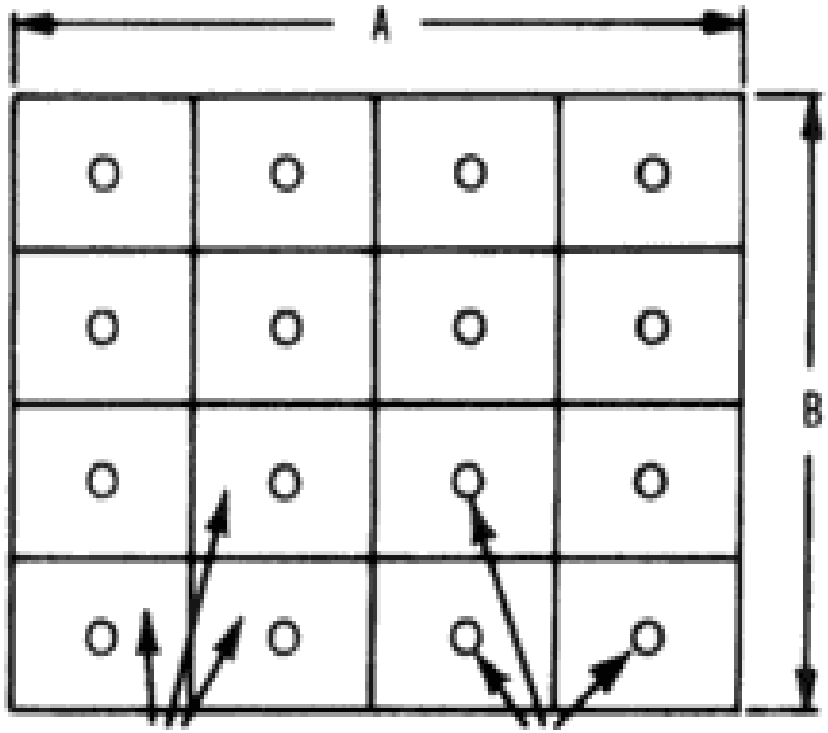
Equal Concentric Areas



Centers of area of the equal concentric areas

Round Duct

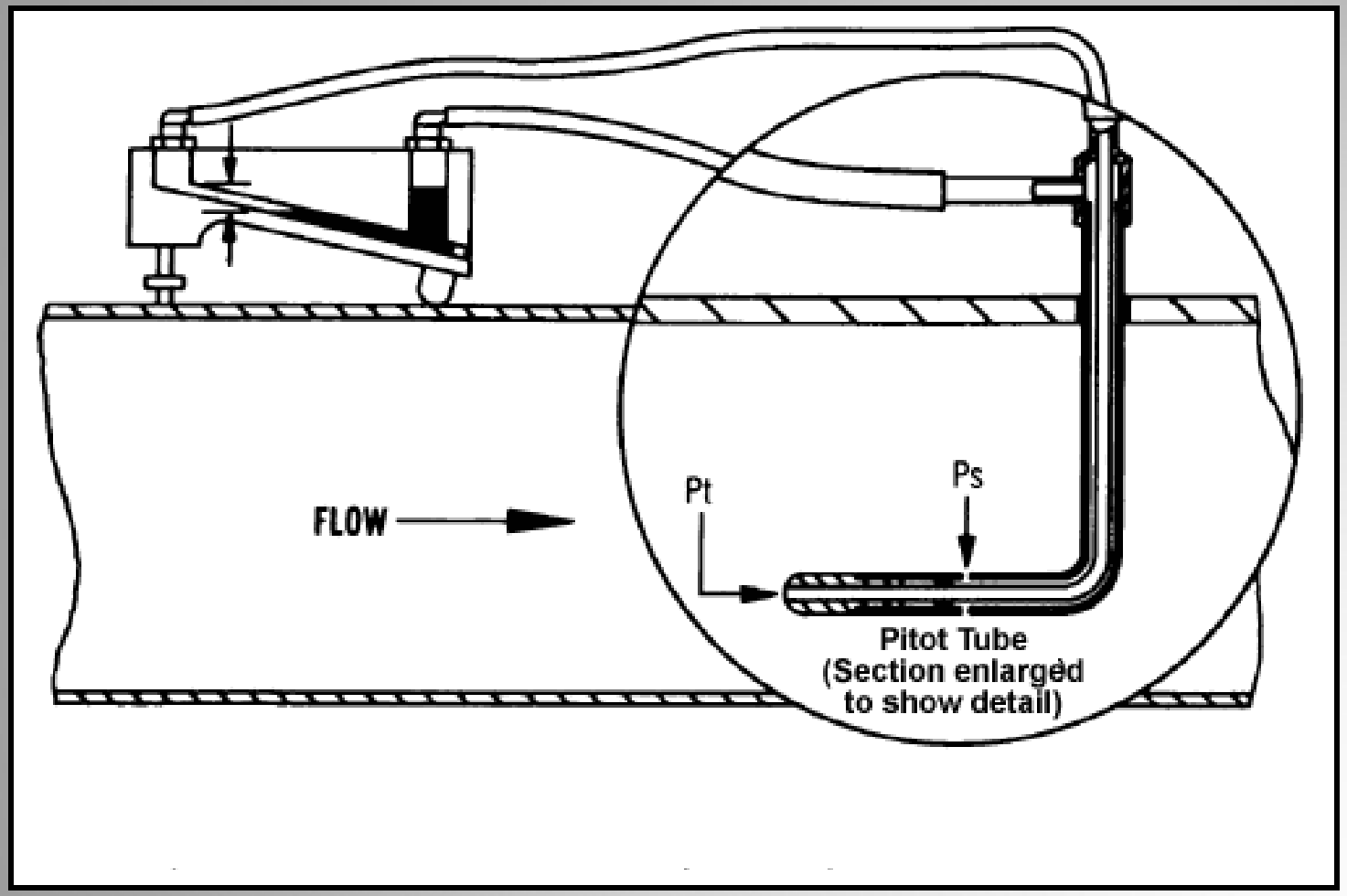
Pitot Tube Stations Indicated by ○



16-64 equal rectangular areas

Centers of areas

Standard Pitot in Pipe



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Typical Equipment

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Types of Errors

- Systematic
- Random
- Mistakes

Problems/Mistakes/Errors

- Leaks and leak checks
- Calibrations: pitot, thermocouples, Fyrite, Barometer, tape measure
- Diameter measurements
- Operator error: eye position, leveling, consistent measurements, documentation, pinching of lines.
- Coefficient assignments: 0.84
- Flow turbulence and cyclonic
- Changing ID of stack due to material buildup
- Equations, units of measure, bad macro

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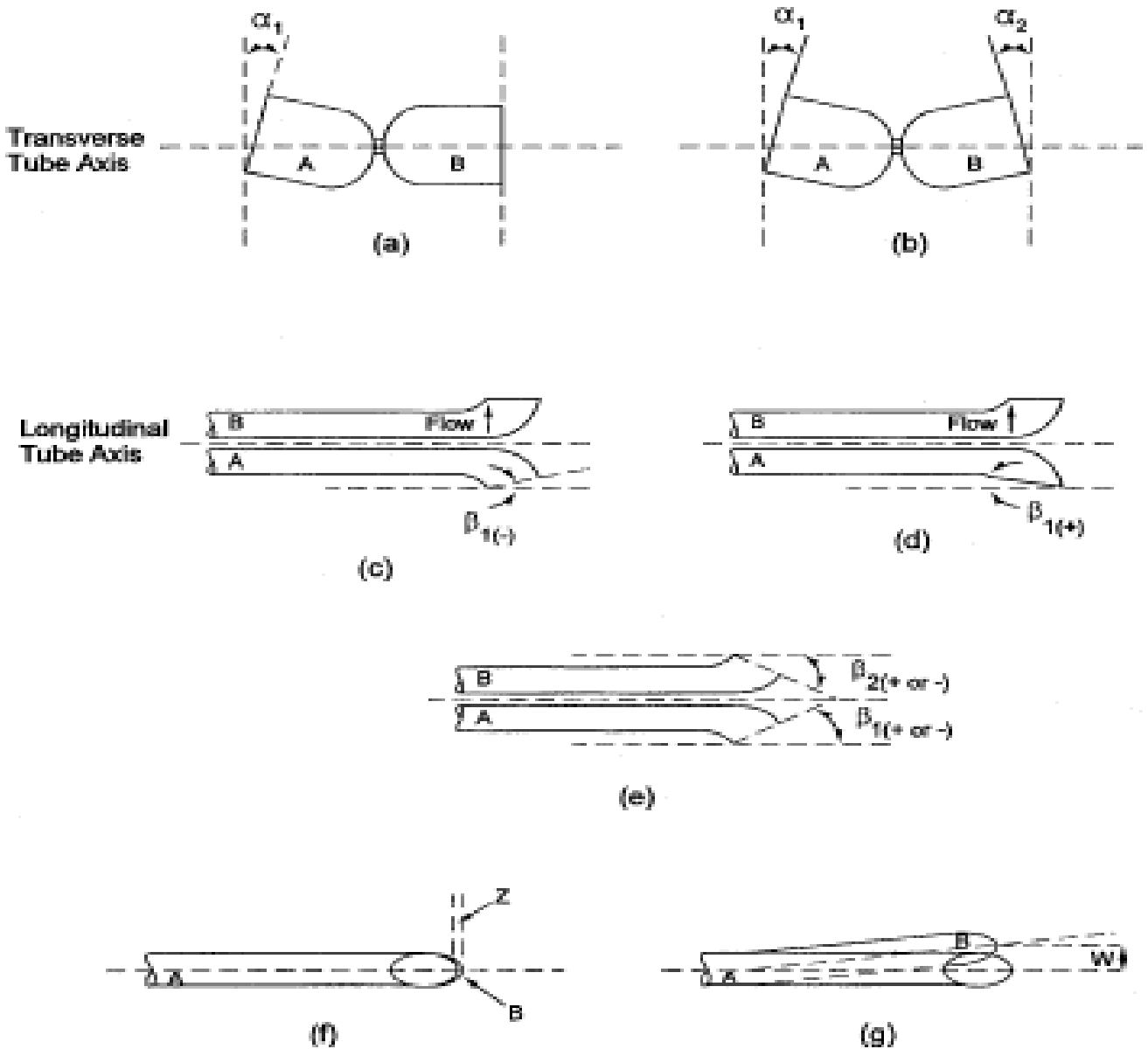
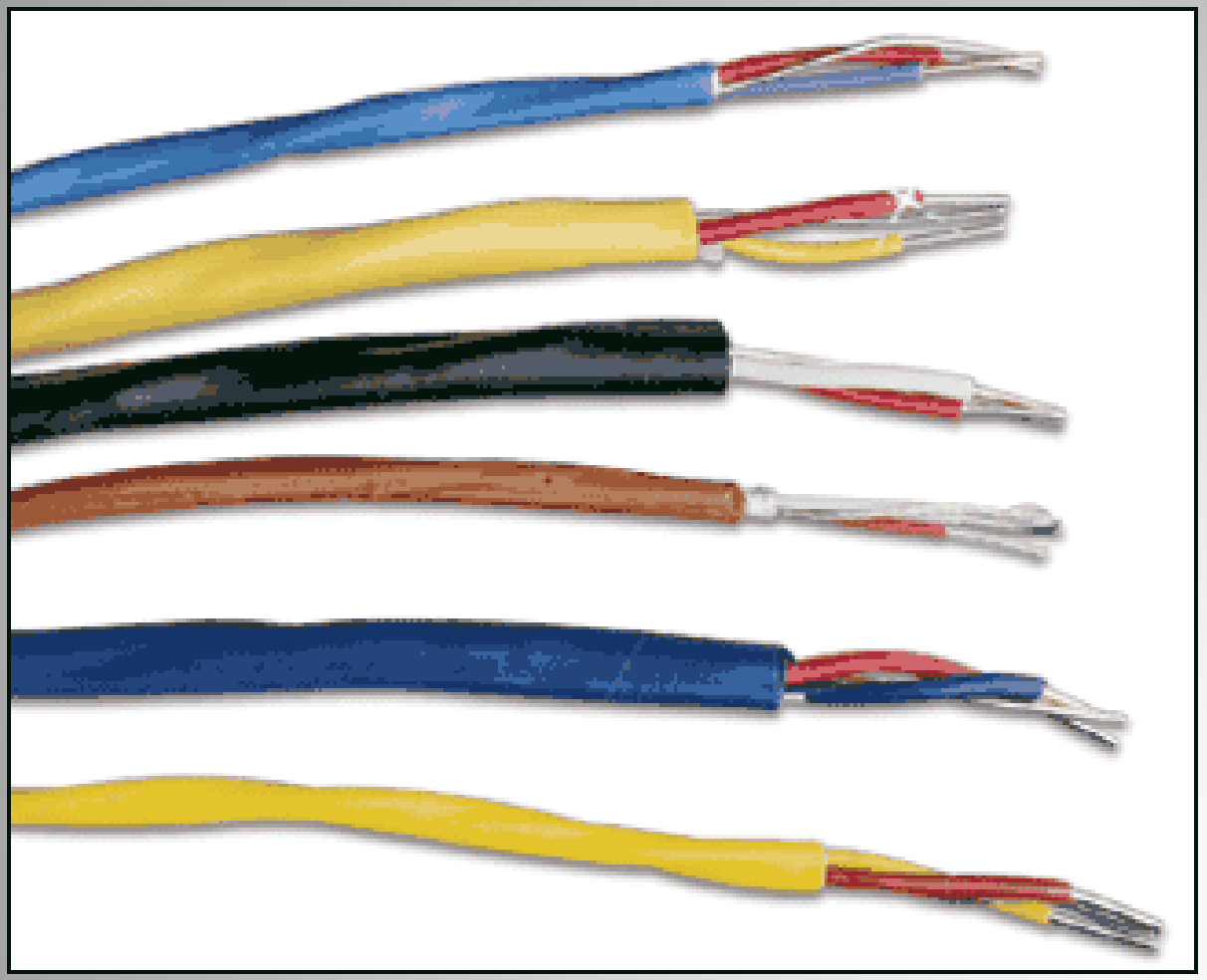

Transverse
Tube Axis
α1
A
B
(a)
α1
α2
A
B
(b)
Longitudinal
Tube Axis
B
Flow
A
β1(-)
(c)
B
Flow
A
β1(+)
(d)
B
A
β2(+ or -)
β1(+ or -)
(e)
Z
A
B
(f)
B
A
W
(g)

Thermocouple wires



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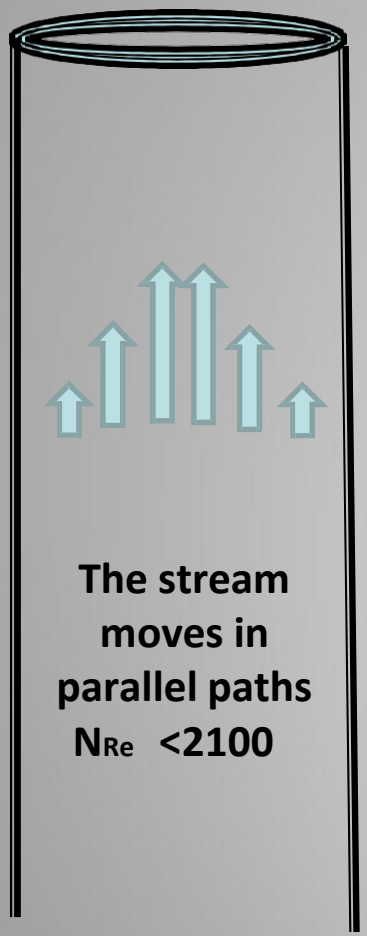
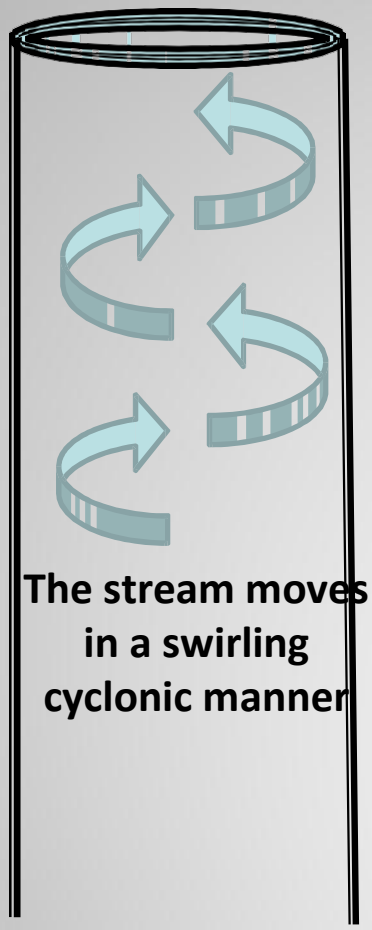
FLOW

Laminar – Cyclonic - Turbulent

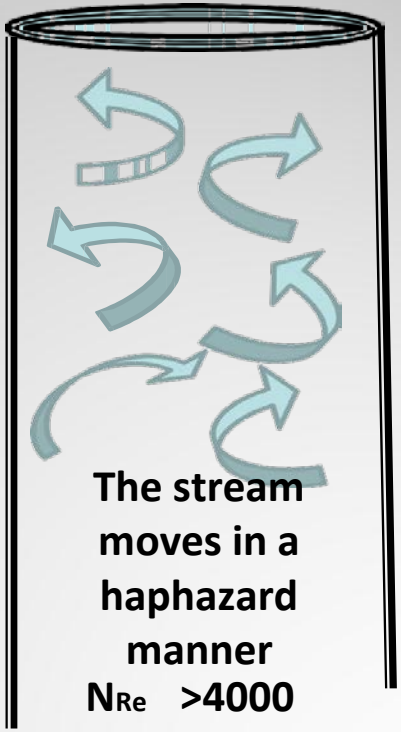


The stream moves in parallel paths

N_{Re} <2100



The stream moves in a swirling cyclonic manner



The stream moves in a haphazard manner

N_{Re} >4000

N_{Re} = Reynolds number

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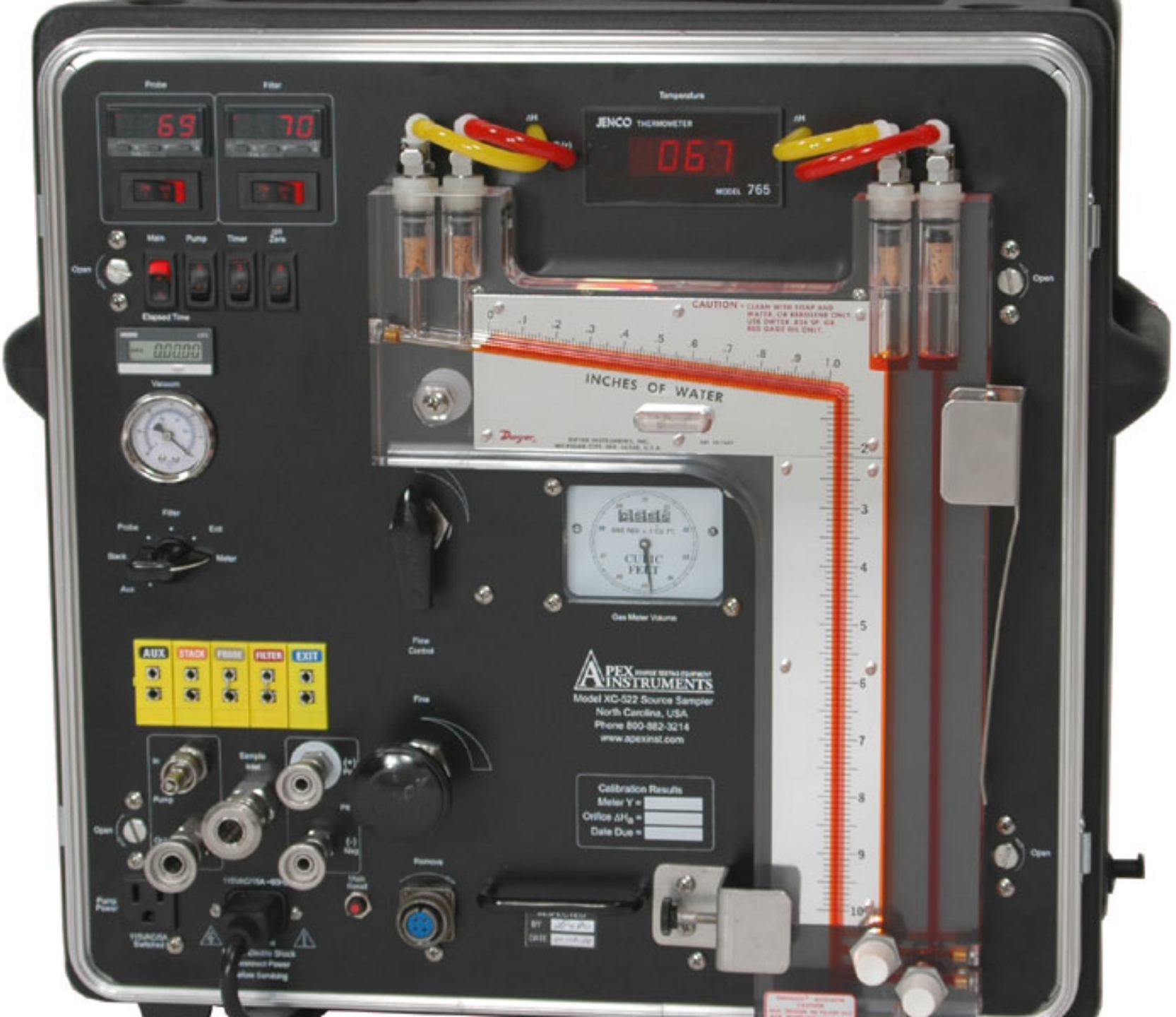
Stack buildup


Probe
Filter
69
70
Temperature
JENCO THERMOMETER
067
MODEL 765
Main
Pump
Timer
Open
Elapsed Time
Vacuum
INCHES OF WATER
CAUTION
Dwyer
Filter
Probe
Exit
Stack
Meter
Aux
CUBIC FEET
Gas Meter Volume
AUX
STACK
PROBE
FILTER
EXIT
Flow Control
Pump
Sample Inlet
Pitot
Remote
APEX INSTRUMENTS
Model XC-522 Source Sampler
North Carolina, USA
Phone 800-882-3214
www.apexinst.com
Calibration Results
Meter Y =
Orifice ΔH@ =
Date Due =

Damaged/Dented/Properly Built

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EPA METHOD 1

Method 1 states *"this method cannot be used when: (1) the flow is cyclonic or swirling…*

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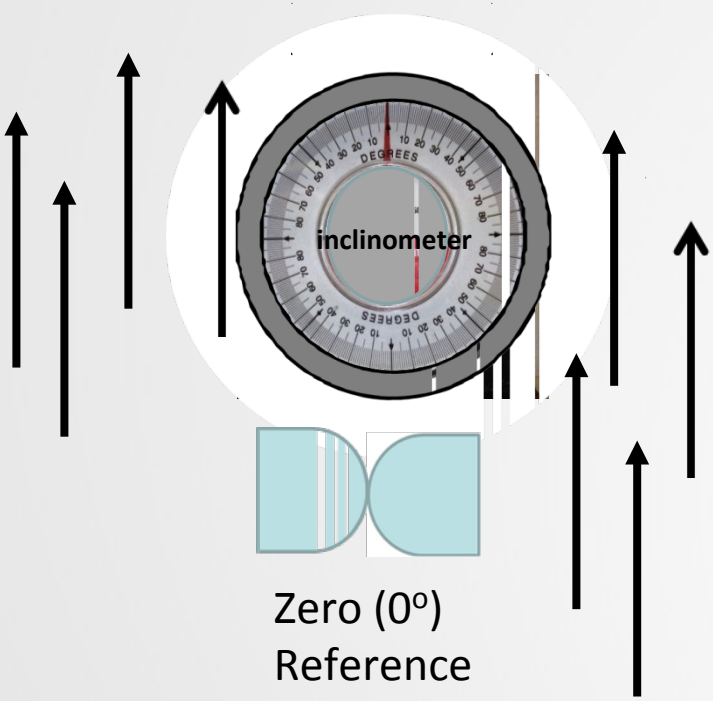
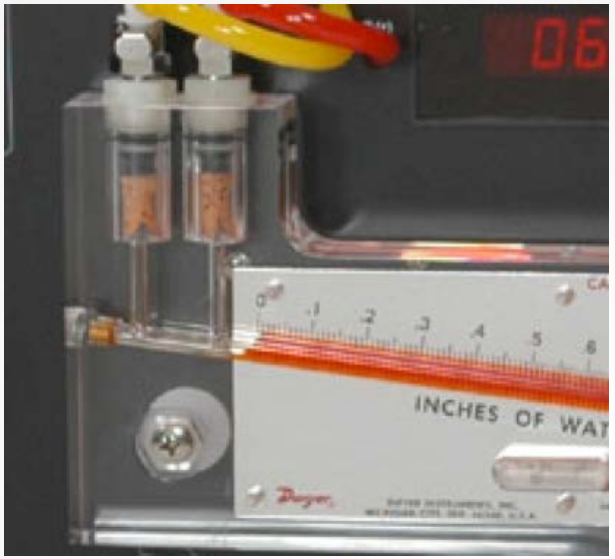
EPA Method 1

Verification of the Absence of Cyclonic Flow

The Pitot is positioned at the first traverse point and rotated so the planes of the face openings are perpendicular to the direction of the flow. This is the 0° reference or null.

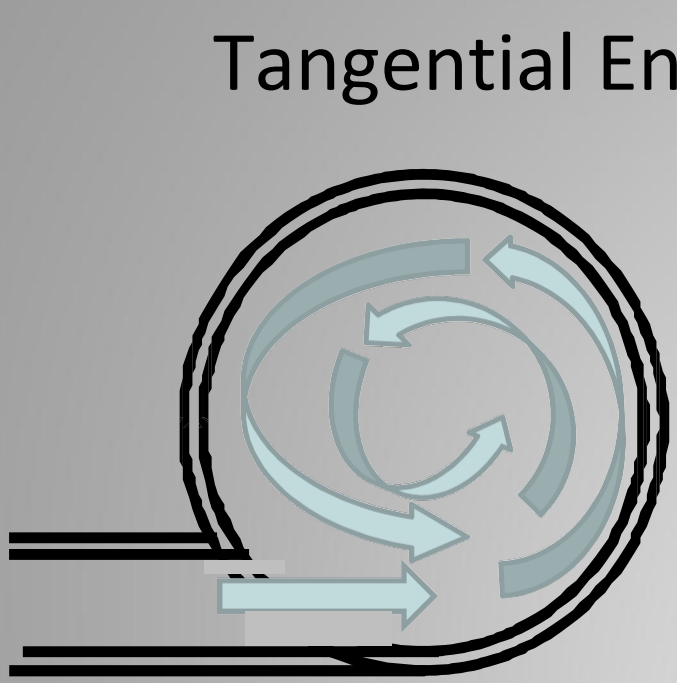


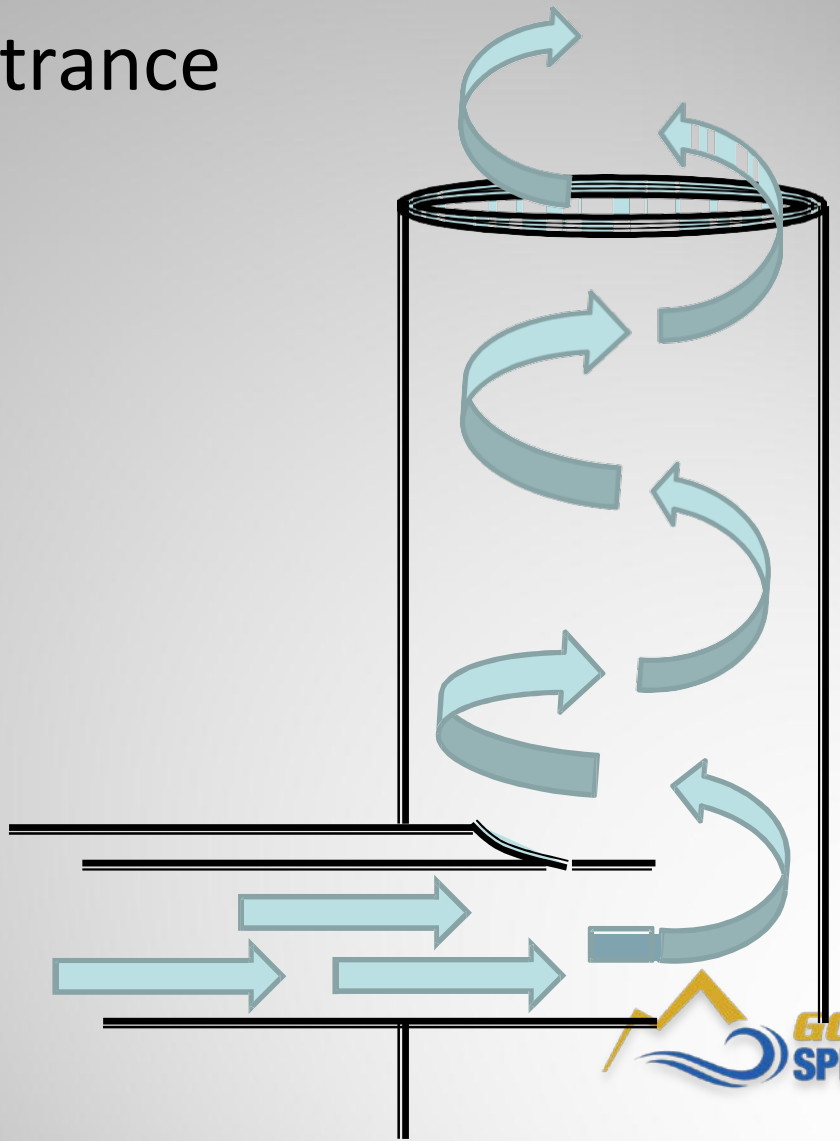
Zero (0°)
Reference



Cyclonic Flow May Exist

Tangential Entrance





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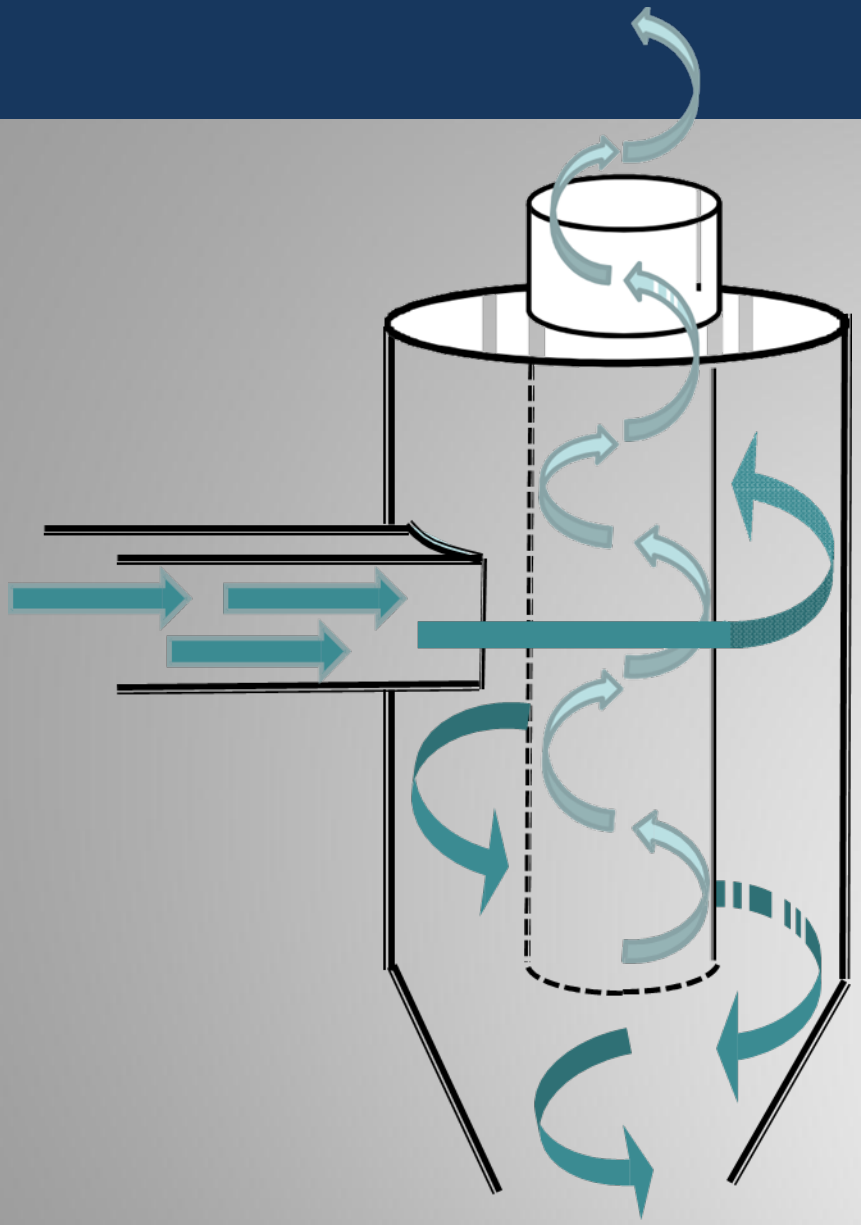

Cyclones
and
Demisters

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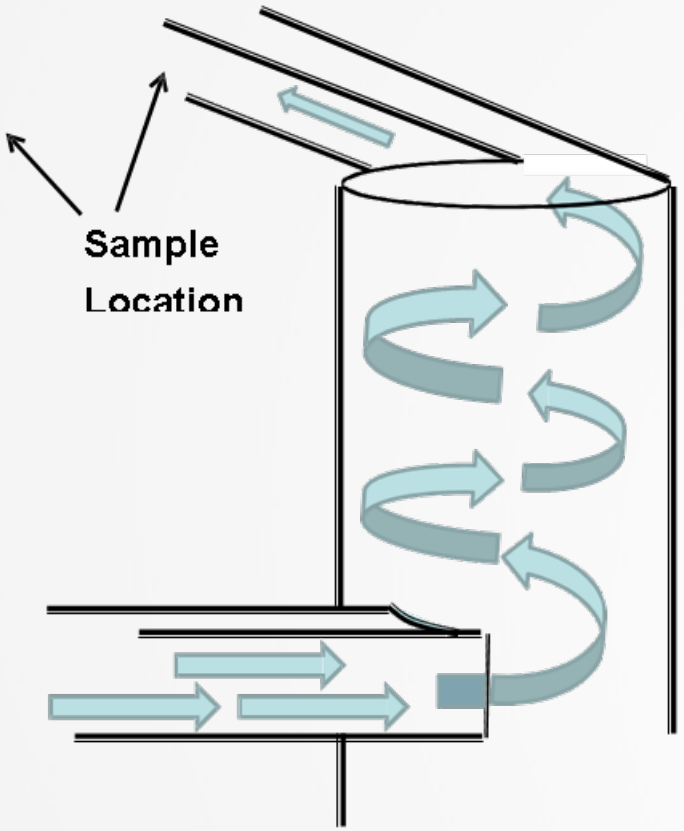
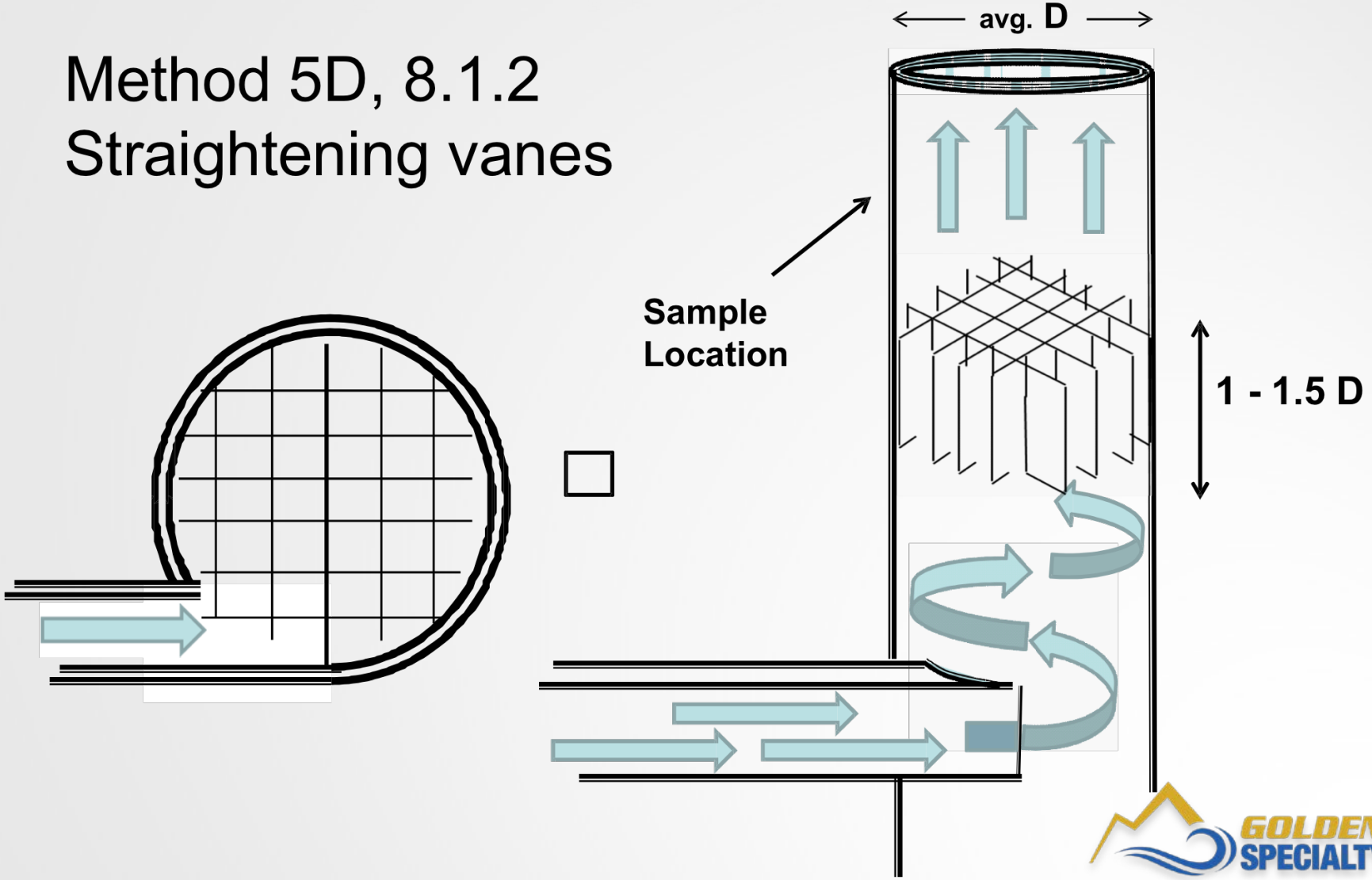
Source Modification

tangential Entrance to a tangential Exit



Source Modifications

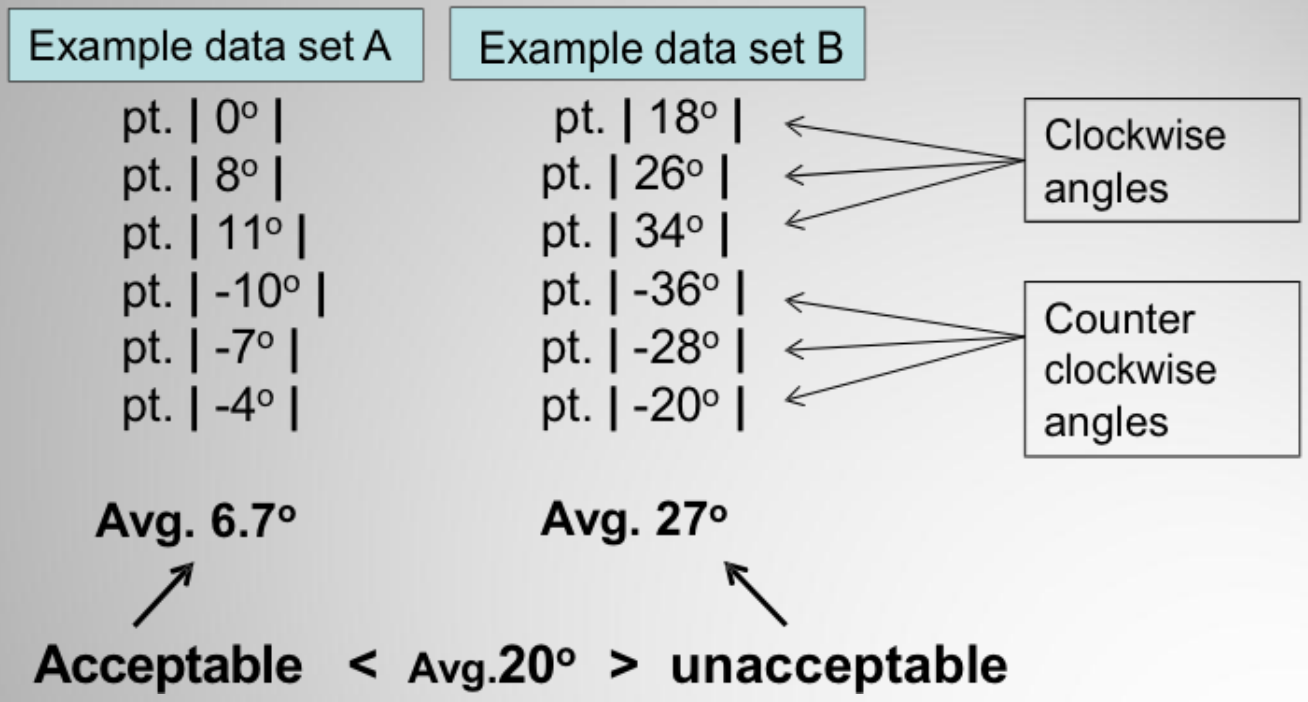
Method 5D, 8.1.2
Straightening vanes



EPA Method 1

Verification of the Absence of Cyclonic Flow

After null angle has been applied to each traverse point, average the absolute values including any zero readings.



EPA Method 1

Section 11.4 Verification of the Absence of Cyclonic Flow

If the average angle is greater than twenty degrees (>20°), the flow condition in the stack is unacceptable for Method 1 flow measurements.

It is cyclonic!

An alternative methodology must be used subject to the approval of the Administrator.

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Volumetric Flow

- Stack Diameter
- Velocity
- Stack Pressure
- Pitot Coefficient
- Stack Temperature
- Molecular Weight
- Moisture

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Temperature Impact on CERMS

Flow measurements @ ~100F

RATA Calculations		
Ten - 21 minute average		
	N_2O	Flow
	(ppmvd)	(SCFM)
D-Bar=	9.49	1,448.8
Sigma-D=	4.74	2,025.0
CC=	3.39	1,448.59
RA(%)=	0.74%	1.89%

Flow measurements @ ~250F

RATA Calculations		
Ten - 21 minute average		
	N_2O	Flow
	(lb/hr)	(SCFM)
D-Bar=	176.46	15,164.1
Sigma-D=	16.62	1,795.3
CC=	11.89	1,284.29
RA(%)=	11.73%	12.02%

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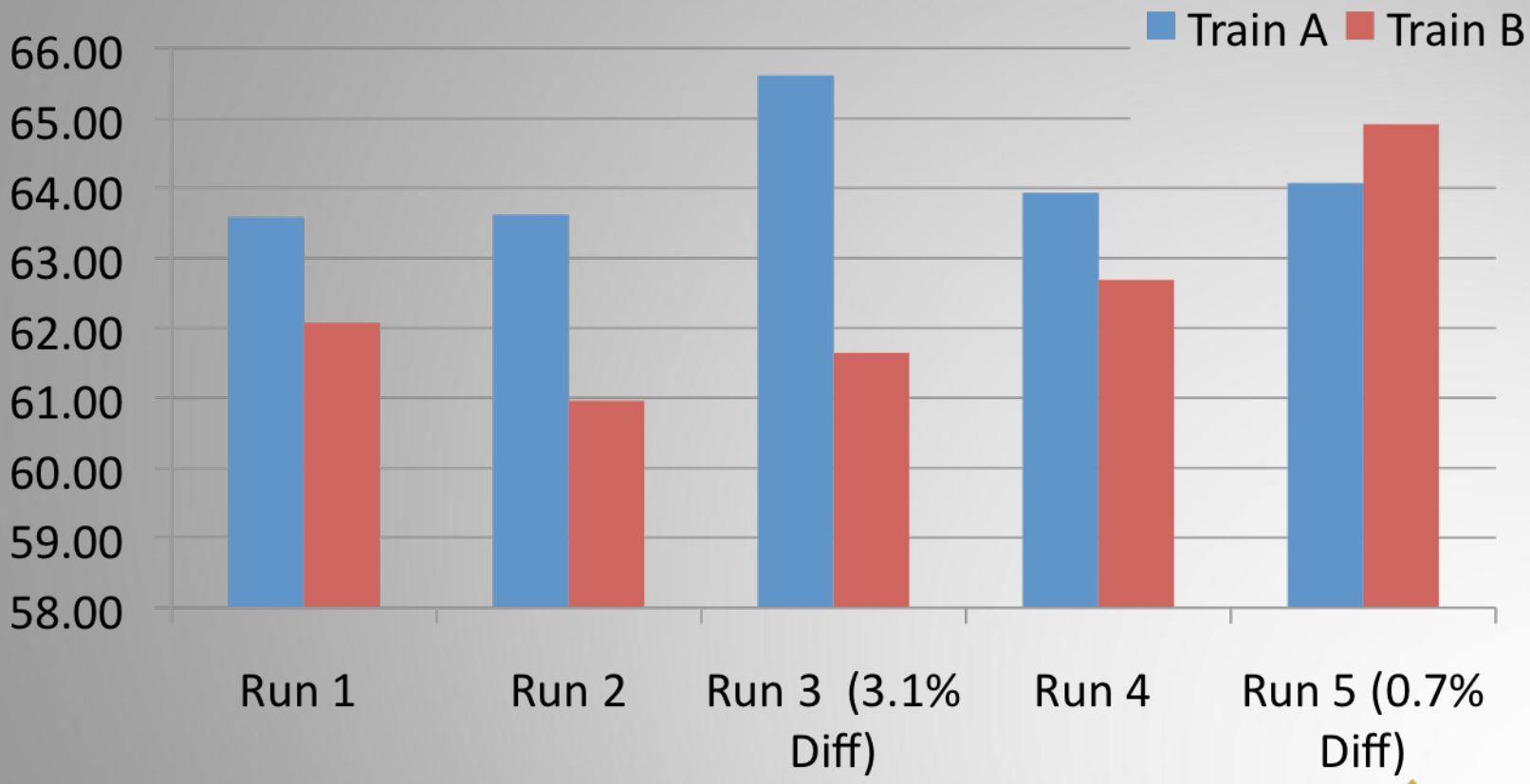
S-Type Pitot paired analysis (ft/sec)



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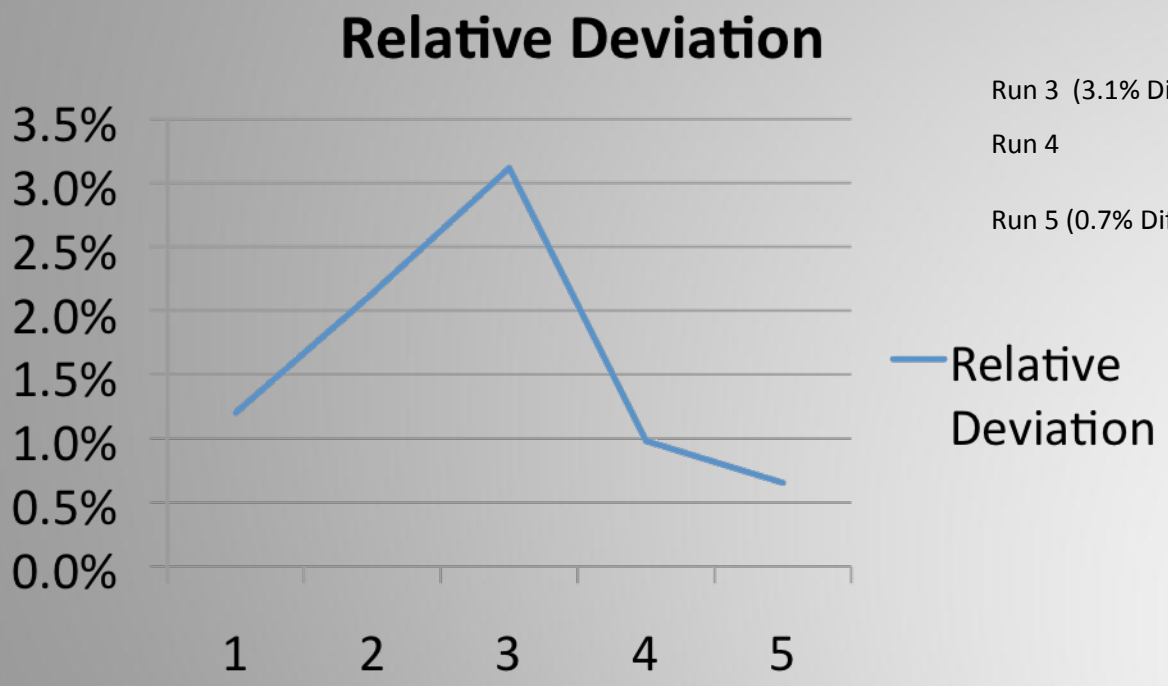
S-Type Pitot paired analysis

Dry Standard Cubic Feet Minute

GOLDEN SPECIALTY

S-type pitot paired analysis



Stack Gas Velocity (ft/sec)

	Train A	Train B	Relative Deviation
Run 1	63.58	62.07	1.2%
Run 2	63.62	60.96	2.1%
Run 3 (3.1% Diff)	65.61	61.65	3.1%
Run 4	63.93	62.69	1.0%
Run 5 (0.7% Diff)	64.07	64.91	0.7%

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Same Source Temperature Measurement Error

Stack Temp ~100F

RATA Calculations		
Ten - 21 minute average		
	N_2O	Flow
	(ppmvd)	(SCFM)
D-Bar=	9.49	1,448.8
Sigma-D=	4.74	2,025.0
CC=	3.39	1,448.59
RA(%)=	0.74%	1.89%

Stack Temp ~250F

RATA Calculations		
Ten - 21 minute average		
	N_2O	Flow
	(lb/hr)	(SCFM)
D-Bar=	176.46	15,164.1
Sigma-D=	16.62	1,795.3
CC=	11.89	1,284.29
RA(%)=	11.73%	12.02%

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Low Flow Rate, RA S-Type Pitot

First time test (6-28-13) the MW lower and static pressure positive. The second time test (12-3-13), MW was higher and static pressure negative. Consistent RM data, obvious change to CERMS

RATA Calculations	
Nine - 21 minute average	
	Flow
	(ft/sec)
*Average RM Data	18.61
*Average CERMS Data	7.92
D-Bar=	10.69
Sigma-D=	0.71
CC=	0.55
RA=	60.40%

RATA Calculations	
Nine - 21 minute average	
	Flow
	(ft/sec)
*Average RM Data	19.94
*Average CERMS Data	18.33
D-Bar=	1.61
Sigma-D=	0.37
CC=	0.29
RA=	9.52%

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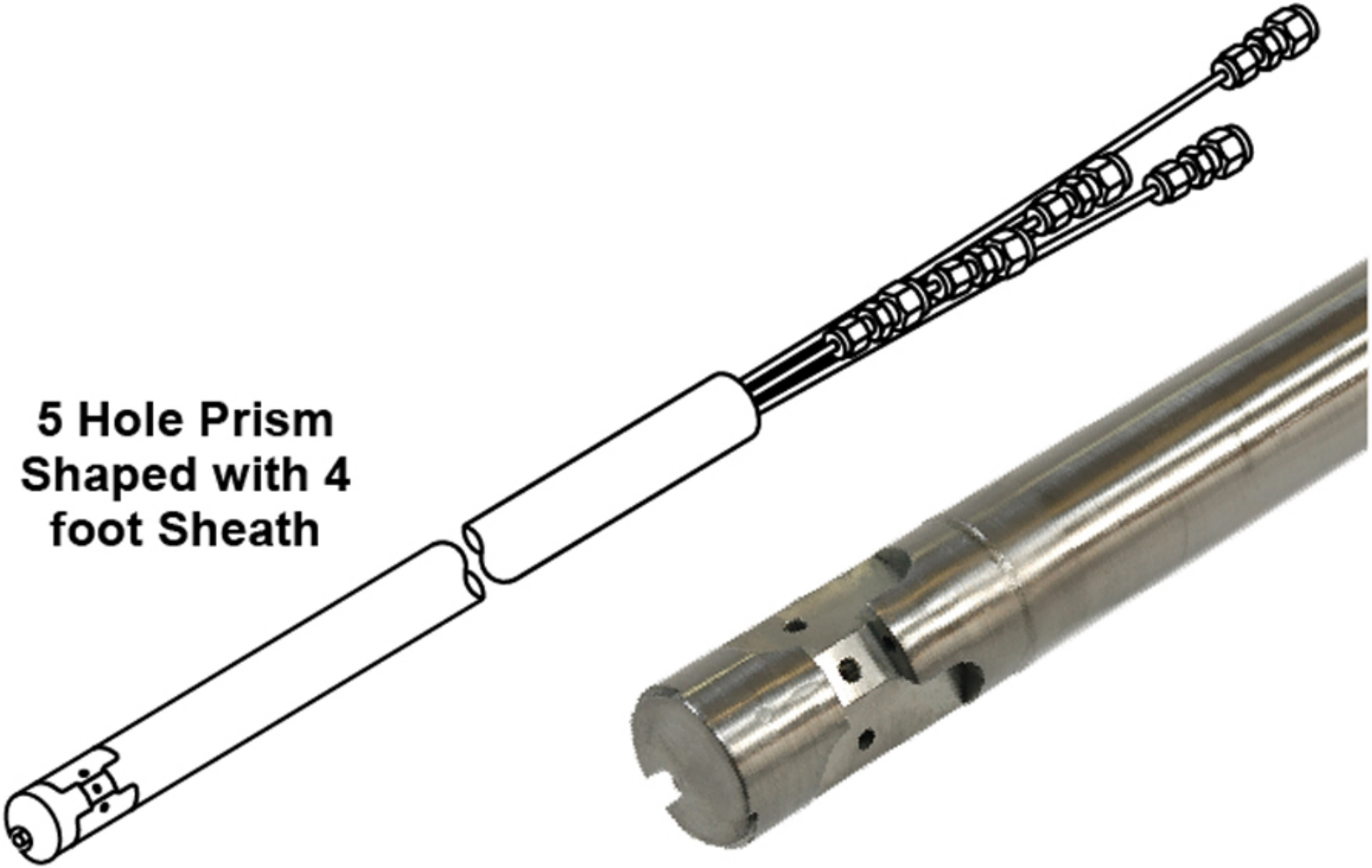
5 Hole Prism Shaped with 4 foot Sheath



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GOLDEN
SPECIALTY


ZRF
ZRF


480 VOLTS
SINGLE PHASE

Ways to Improve Accuracy in Measurement

1. Make the measurement with an instrument that has the highest level of precision. The smaller the unit, or fraction of a unit, on the measuring device, the more precisely the device can measure. The precision of a measuring instrument is determined by the smallest unit to which it can measure.
2. Know your tools! Apply correct techniques when using the measuring instrument and reading the value measured. Avoid the error called "parallax" -- always take readings by looking straight down (or ahead) at the measuring device. Looking at the measuring device from a left or right angle will give an incorrect value.
3. Repeat the same measure several times to get a good average value.
4. Measure under controlled conditions. If the object you are measuring could change size depending upon climatic conditions (swell or shrink), be sure to measure it under the same conditions each time. This may apply to your measuring instruments as well.

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