

Practical Experience with CEMS Measurement

Challenges Associated with making:

Reliable
Believable
CONTINUOUS

Flow Measurements in Large Utility Stacks

Ultrasonic Flow Monitor



1900-0090		REVISONS	
ZONE	SYM.	DESCRIPTION	DATE APPD.
A		PER DCV M90P-0090A	10-14-02 ELM

TIE MOTHERBOARD W/COMPUTER MODULE 1903-D100

LCD DISPLAY 1803-1400

PC BOARDS 1803-0200, 1803-0500 AND 1803-0300 MOUNT INTERNALLY



FRONT VIEW

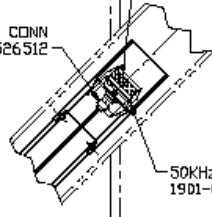


REAR VIEW

FUSE 52743B, 2 PLACES

BNC COAX CONN 526512

ACOUSTIC FOAM INSERT 1001-0103



50KHZ XDUCER ASSY 1901-0200

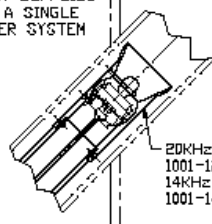
ENHANCED REMOTE PANEL 1/4 SCALE

STACK OR DUCT

FLOW

VIEW A 50KHZ XDUCER 3/8 SCALE

IS NOT SUPPLIED WITH A SINGLE BLOWER SYSTEM



20KHZ XDUCER ASSY 1001-1200 OR 14KHZ XDUCER ASSY 1001-1400

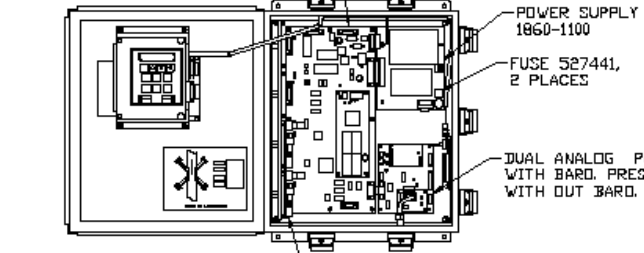
VIEW A 20/14KHZ XDUCER 3/8 SCALE

SPARE PARTS LOCATION

CONFIDENTIAL TOLERANCES UNLESS OTHERWISE SPECIFIED	ASSEMBLY	DATE	BY	APPROVED
ASSEMBLY	DATE	BY	APPROVED	
ALL DIMENSIONS ARE TO FACE UNLESS OTHERWISE SPECIFIED				
DO NOT SCALE THIS DRAWING				
AUTHORIZATION				
DESIGN	EAS	5-9-02		
DESIGNED BY	EAS	02-08		
DESIGNED BY	EAS	05-08		
DESIGNED BY	ELM	10-26-02		
DESIGNED BY	PD	10-26-02		
DESIGNED BY	AC	10-26-02		
PROJECTION	1/8	1 of 1		
DRAWING NO.		1900-0090		REVISED
PROJECT		A		

1901-0600 IS USED WITH SINGLE 42CFM BLOWER SYSTEM ONLY.

PURGE BLOWER 980142, DUAL 42CFM OR SINGLE 42CFM BLOWER SYSTEM
PURGE BLOWER 980111, SINGLE 110CFM BLOWER SYSTEM



POWER SUPPLY 1860-1100

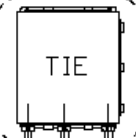
FUSE 527441, 2 PLACES

DUAL ANALOG PC BOARD ASSY WITH BARD. PRESS. OPTION 1903-0300-01, WITH OUT BARD. PRESS. OPTION 1903-0300-02

PREAMPS 1903-0200 (50KHZ) OR 1903-0400 (20/14KHZ) PLUG INTO MOTHERBOARD

TRANSDUCER INTERFACE ENCLOSURE 1/4 SCALE

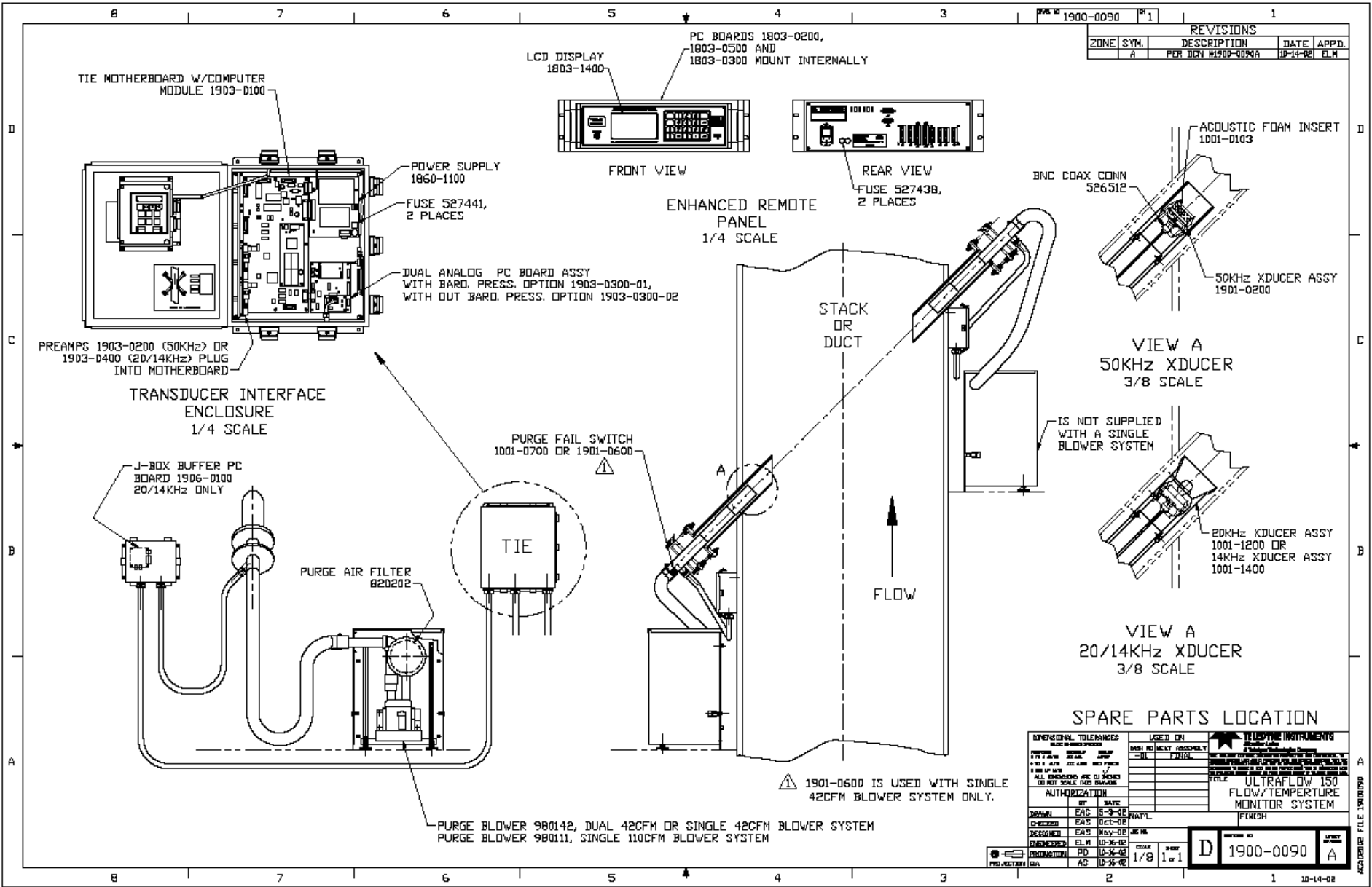
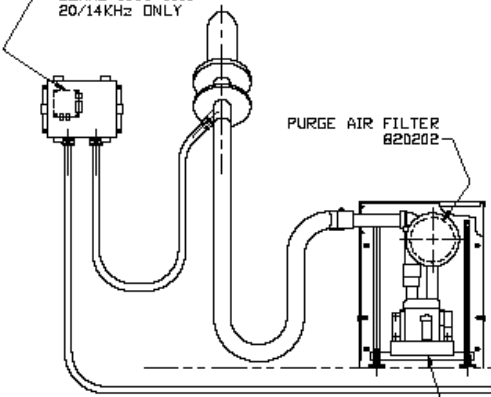
PURGE FAIL SWITCH 1001-0700 OR 1901-0600



TIE

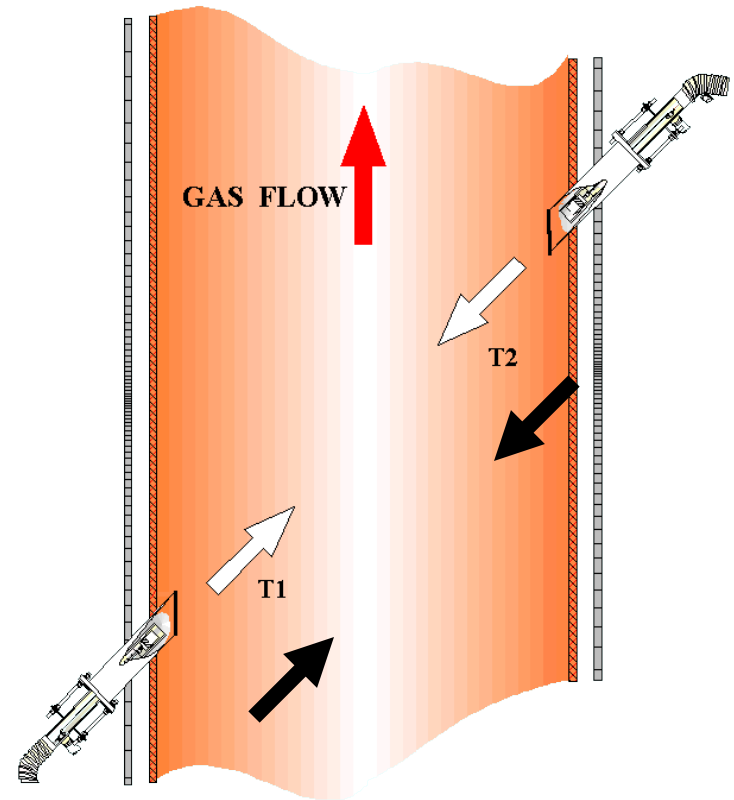
J-BOX BUFFER PC BOARD 1906-0100 20/14KHZ ONLY

PURGE AIR FILTER 820202



Overview

- What is an Ultrasonic Flow Monitor?
 - It is a device that measures velocity based on the time-of-flight of signals t_1, t_2
 - By determining t_1, t_2 , the monitor calculates velocity, volumetric flow and temperature



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MONITOR LABS**

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Stack Geometry

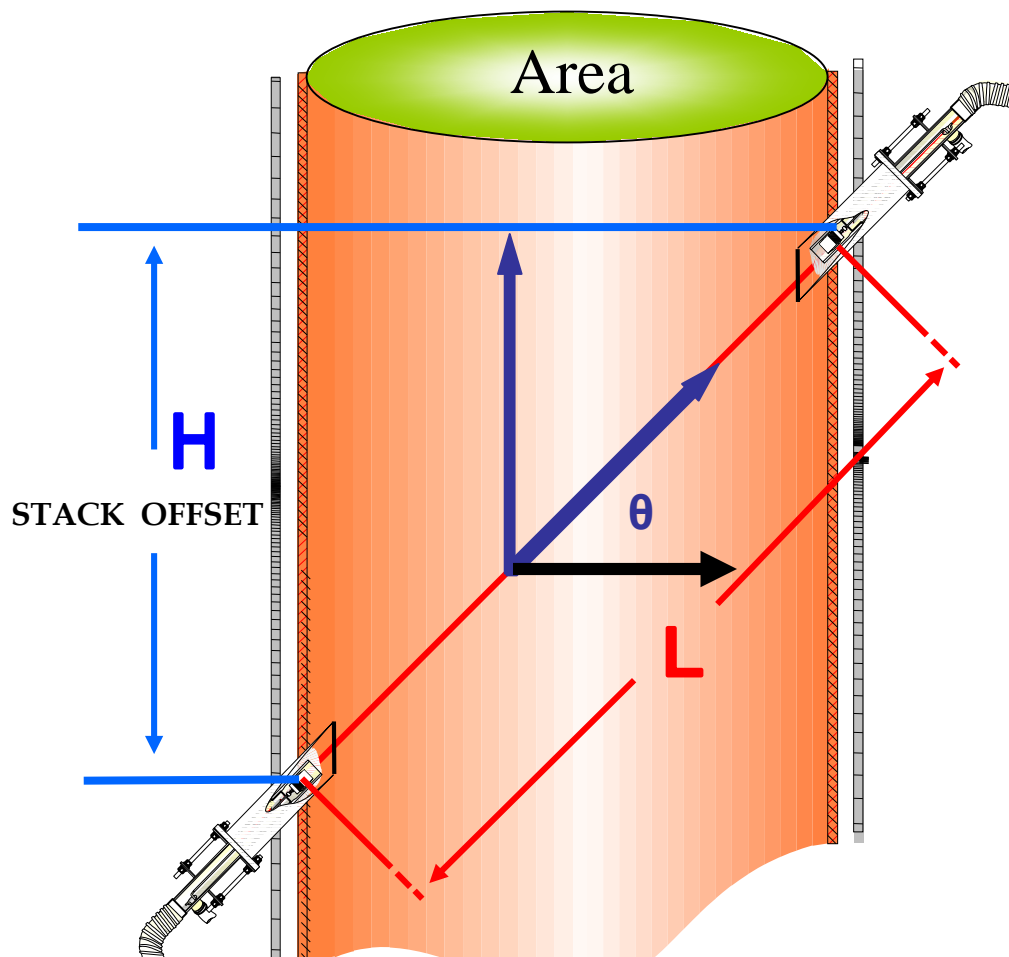
- $L = \text{Pathlength}$

Transducer to Transducer

- $H = \text{Offset}$

- $\text{Area} = \text{Cross Sectional Area}$

- $\theta = \text{Angle}; <45^\circ$



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RELIABILITY CONCERNS

Utility smokestacks are harsh environments:

- Hot /Dry scrubbed or unscrubbed stacks
- Cool/Wet scrubbed stacks
- Corrosive gases present (SO₂)
- THEY ARE BIG.....diameter & height

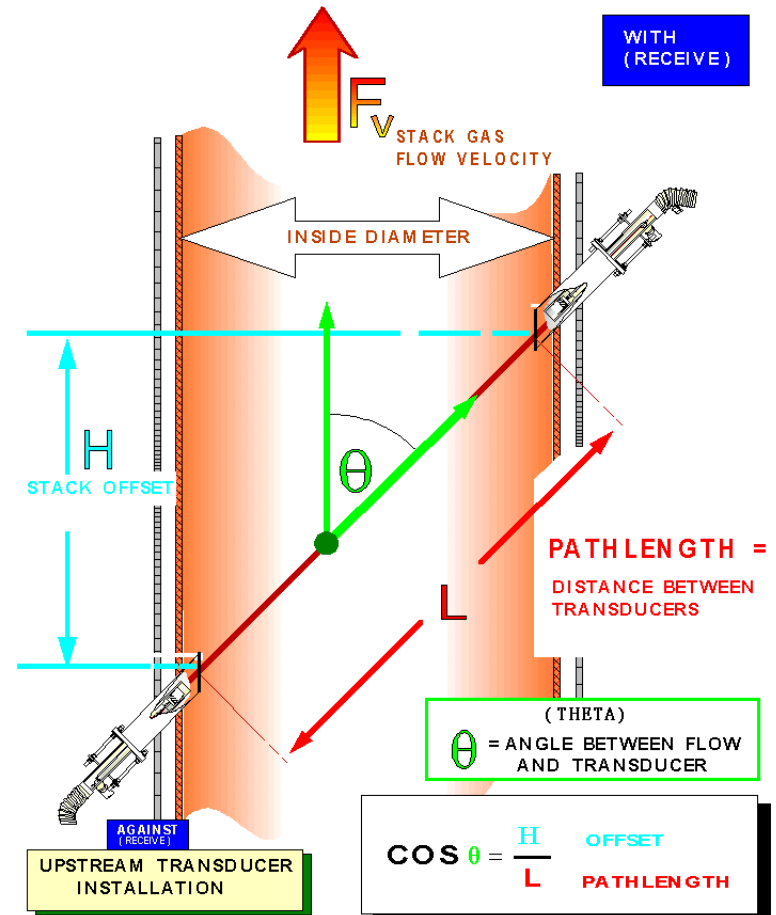


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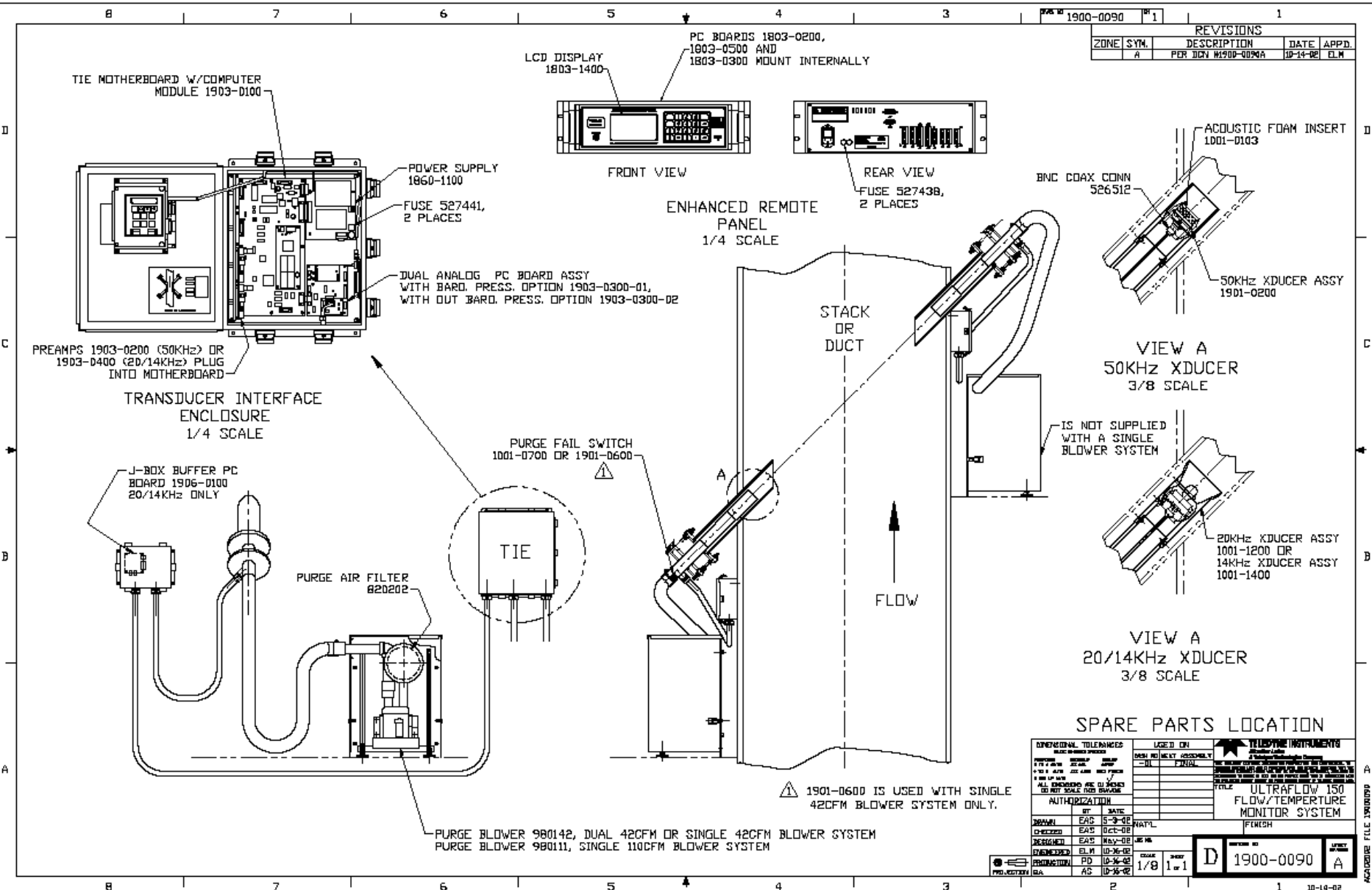
Limitations of Ultrasonic Flow

- **Typical Installation:**
 - $\theta \geq 45^\circ$ angle but depends on:
 - pitch angle
 - # diameters down
 - # flues feeding the stack
 - Gas temperature
 - Gas velocity
 - **Need Vertical Offset (H) to be No Less Than 4-5 Ft.**
 - **Max. Temp 850°F**
 - **Min. Diameter 3 Ft.**
 - **Max Diameter 45 Ft.**



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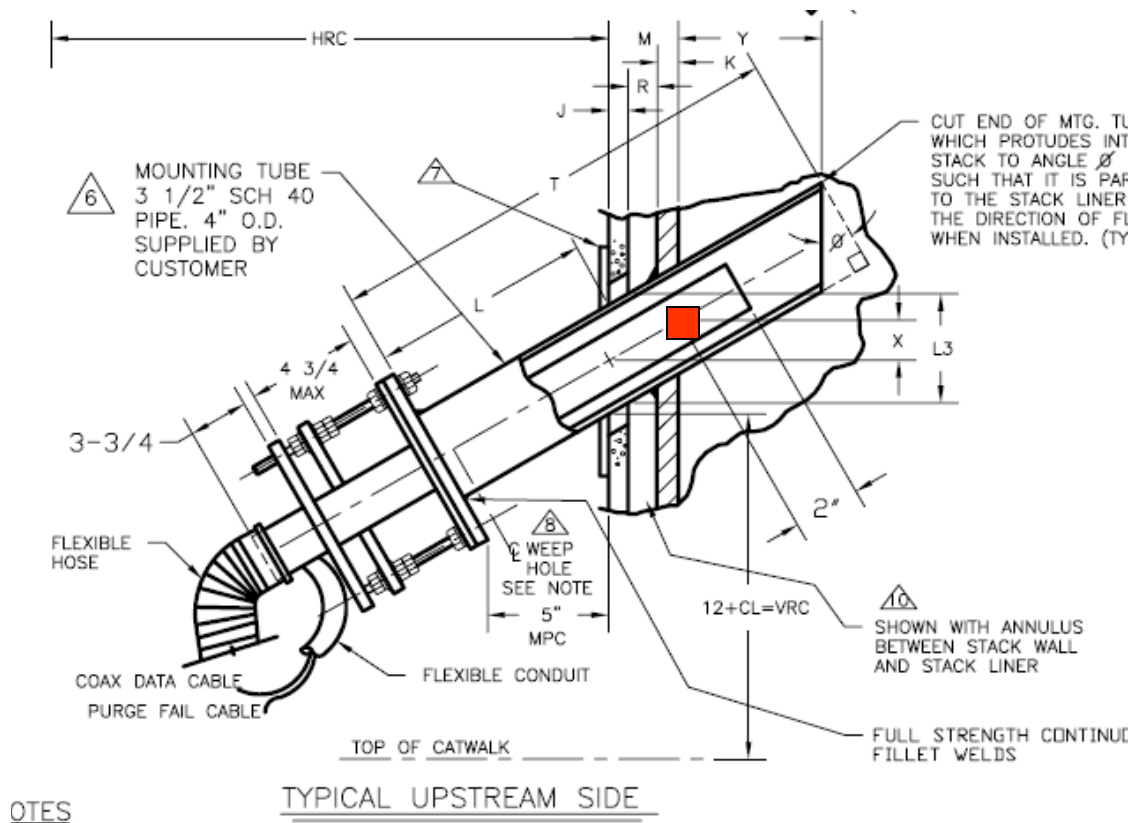
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1900-0090		1	
REVISIONS			
ZONE	SYM.	DESCRIPTION	DATE APPD.
A		PER DCV M90P-0090A	10-14-92 ELM

TELEDYNE INSTRUMENTS A Teledyne Technologies Company			
ULTRAFLOW 150 FLOW/TEMPERATURE MONITOR SYSTEM			
AUTHORIZATION		FINISH	
REVISED	EAS	5-3-92	MP/L
DESIGNED	EAS	02-08-92	
ENGINEERED	EAS	04-01-92	
MANUFACTURED	ELM	10-26-92	
INSPECTED	PD	06-26-92	
PRODUCTION	AC	10-26-92	
SCALE		SHEET	
1/8		1 of 1	
D		1900-0090	
		A	

Typical Transducer Installation



OTES

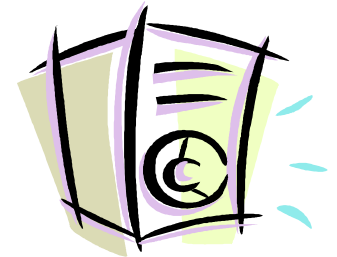


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Transducer Types

- Short Range
 - **50Khz** Electrostatic
- Long Range
 - **20Khz** Piezo Electric
- Extended Long Range
 - **14Khz** Piezo Electric
- Select based on stack dia., max temp, and max velocity
- **Lower Frequency Provides MORE Power**



Ultrasonic Flow Monitor



Believable Concerns

Inherent accuracy of time-of-flight technology

Wall effects, Pitch, Swirl, Multiple Units feeding a common stack

RELATIVE Accuracy.....



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Overview

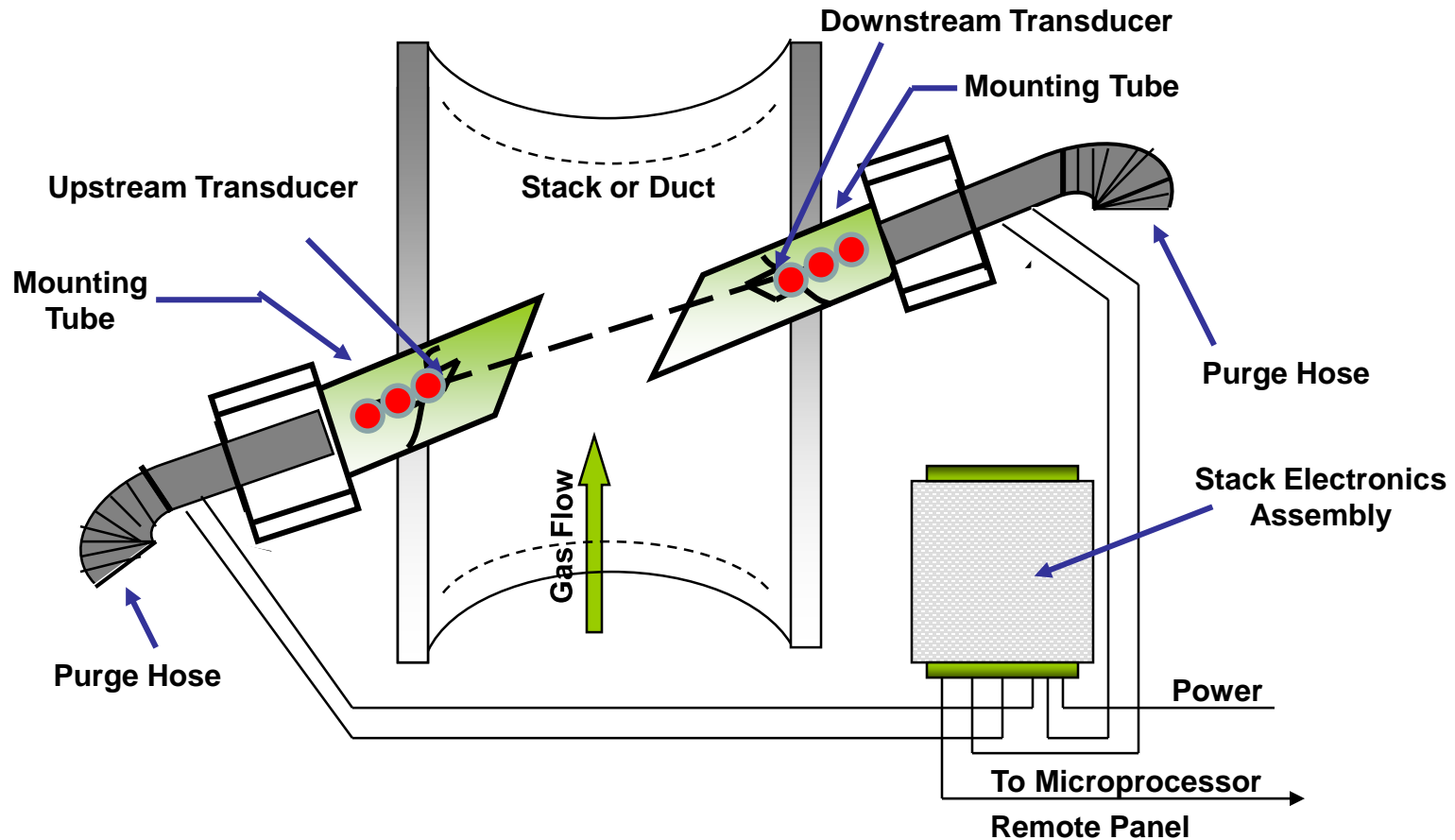
- **How Does the Ultrasonic flow monitor Work to Calculate Velocity ?**

- Tone bursts (Sound) are transmitted from the upstream transducer to the downstream transducer and then visa versa
- Tone bursts are transmitted approximately every 30 milliseconds in this alternating fashion (33/sec)
- The number of tone bursts sent in each direction is programmable (response time <5.0 seconds)
- The large # of tone bursts enhances accuracy, i.e., a larger statistical sample



Ultrasonic Flow Installation

Typical Installation



Time of Flight Principle

- What are the governing equations that model the time-of-flight of the tone bursts?

Velocity (With Gas Flow)

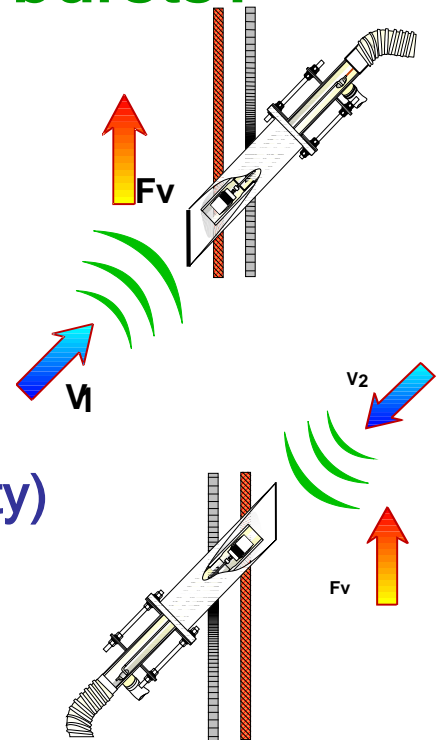
$$V1 = Cs + Fv \cos\theta \quad (\text{added velocity})$$

Velocity (Against Gas Flow)

$$V2 = Cs - Fv \cos\theta \quad (\text{subtracted velocity})$$

- Where

- Cs is the speed of sound
- Fv is Nominal flow velocity up stack
- θ is the angle of installation



Velocity (Fv) Calculations

- Cs falls out of the subtracted equations
- Substitute Pathlength/Time for V_1 &

$$V_2 \quad Fv = \frac{L/t_1 - L/t_2}{2(\cos \theta)}$$

- Rearrange

$$Fv = \frac{L}{2(\cos \theta)} \left[\frac{t_2 - t_1}{t_1 t_2} \right]$$



Believable Concerns

Statistical average over time (adjustable response time) leads to accurate flow measurement. Typically 1-5 minutes

Multiple transducers used for mitigation of flow anomalies in stacks (X-Pattern Config.)



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Continuous Concerns

Non-Intrusive nature leads to long mean time before failure.

Mitigate the effects of condensing moisture in wet scrubbed stacks. “Weep Holes”

Blower Maintenance to maintain system performance



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Field Experience with Ultrasonic

Port Alignment within 1-2 degrees

Consider a “Link-Rod” assembly for large annulus spaces.

Error on the side of a “larger than needed” flow port. Inserts are available!



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Field Experience with Ultrasonic

Temperature and pressure will be needed for SCFM calculation. From the monitor or from external devices/inputs.

Safe and accessible mounting locations with “decent” air available for blower intakes.

Questions?

Thank you!

Don Giel
Teledyne Monitor Labs, Inc.