Operator's Manual

T403 Console with two T420 Modules

Transonic® 400-Series Multi-channel Flowmeter Consoles & Modules for Laboratory Research

(For Investigational Use)

AUT400-Series Manual Rev D, 12/05

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Warnings & Precautions

- ✔ Read manual before use. Failure to follow the instructions and the Warnings and Precautions below may result in risk of fire or electric shock.
- ✔ **Transonic Research flowmeter consoles, flowmeter modules and compatible probes are designed only for investigative use with animals and are not for use in humans.**
  For all human applications, only use Transonic products designated by the prefix “H’ in the model or series number (i.e., HT312 (single channel medical flowmeter), HQC6MP (6 mm Handle Flowprobe), etc.)
- ✔ Transonic perivascular Flowprobes are designed for acute and chronic implants in animals. Excessive vessel manipulation or constrictive Flowprobe fit may cause vessel spasm or damage and thus should be avoided. Recalibration of Flowprobe is necessary if the Flowprobe is to be used at different temperature or on a liquid other than the one for which it was calibrated.
- ✔ Transonic inline Flowprobes are designed for laboratory use only. Factory or on-site recalibration of the Flowprobe is necessary if the Flowprobe is to be used at a different temperature or on liquids other than the ones for which it was calibrated.
- ✔ Transonic sterile tubing Flowsensors are designed for measuring liquid flow in tubing and should not be applied to blood vessels or other internal ducts. They should be used only on tubings and for liquids for which they were calibrated. Sterile tubing Flowsensors are not designed to measure liquid flow in metal or hard plastic pipes or to measure non-liquid (gaseous) fluid flow. Transonic sterile tubing Flowsensors should not be immersed in liquids for extended periods of time. Factory or on-site recalibration of a Flowsensor is necessary if the Flowsensor is to be used on a different tubing, liquid or temperature other than for which it was calibrated.
- ✔ Safe and effective use of the Transonic flowmeter depends on correct application technique, adequate precaution and readiness for emergencies. Prevent vapors from entering the meter.
- ✔ The flowmeter is fragile. It must be transported and stored at temperatures between -40ºC — 70ºC. Rated altitude: 2000 meters.
- ✔ **SAFE ELECTRICAL USE**
  - Use only with grounded power receptacle to reduce risk of shock.
  - Position instrument so that rear panel switch and plug are accessible for quick disconnect.
  - Do not turn on console unless modules are installed and panel covers are in place for empty module slots.
  - Install only Transonic modules in the 400-Series Consoles.
  - Do not remove or replace modules with power turned on.
  - All repair on console or modules must be performed by qualified electrical technicians authorized by Transonic Systems, Inc.
  - Keep flammable liquids and vapors away from meter. They may cause a fire in the meter.

Warning	Definition	Transonic Notation
	Attention, consult accompanying documents	The specific directions in this manual and in the package inserts included with each Flowsensor must be observed. Periodic testing of Flowsensors must be performed to assure the validity of flow measurements.
CE	CE Conformity Mark	This flowmeter conforms to 73/23 EEC. Transonic Systems is an ISO9001/EN46001-certified facility.
	Dangerous voltage	The flowmeter may not be modified or serviced except by qualified Transonic repair persons.
AP	Not category AP equipment	Danger: Explosion risk if used with flammable anesthetics.
	Equipotentiality	This ground pin is connected to the metal cabinet of the monitor. It provides the User with a signal ground reference point.

Section I.

400-Series Multi-channel Flowmeters

T402 Consoles
T403 Consoles

Transonic Systems' 400-Series Multi-channel Flowmeter Consoles and Flowmeter Modules: Introduced in 2001, this new generation of animal research volume flow measurement devices, senses liquid volume flow:

1) in vessels with perivascular Flowprobes or
2) in tubing with inline and sterile tubing Flowsensors.

The modular 400-Series allows researchers to configure multiple-channel flowmeters with mix and match capabilities to fit individual application requirements.

T402 Console with two installed modules

The 400-Series utilizes gold standard transit-time ultrasound technology which is largely independent of vessel diameter, flow velocity profile, turbulence and hematocrit. Additional acoustical velocity phase signals are available for experimental ultrasound dilution measurements; applications include density measurement and cardiac output.

A. 400-Series Flowmeter Consoles

Multi-Channel Console: 2 channel (T402) and 3 channel (T403) cases with card guides for flowmeter modules include proprietary backplane with power supply and terminal block analog outputs for signal data collection. Consoles are line powered with convenient carrying handles and tiltable front feet.

I-B. 400-Series Multi-channel Flowmeters

B. 400-Series Electronic FlowMeter Modules

Tubing (TS410) and Perivascular (TS420) Flowmeter Modules are compatible with 400-series consoles.

1. TS410 Transit-Time Tubing Flowmeter Module

The TS410 plug-in module operates inline and sterile tubing Flowsensors for volume flow measurement in tubing circuits, flow chambers and isolated organ apparati. The module automatically identifies the size and scale of the attached Flowsensor connected to it.

TS410 Module

Front panel button switches navigate two modes of operation:

- **Measurement & Status Mode:** LCD text displays Flowsensor information and status while the digital display reports average volume flow.
- **Program Mode** allows the user to select preconfigured calibration options, change the gain to recalibrate the Flowsensor onsite, and set parameters and alarms. Acoustical velocity phase signals are also available for ultrasound dilution measurements.

2. TS420 Transit Time Perivascular Flowmeter Module

The TS420 plug-in module operates perivascular Flowprobes for instantaneous volume flow measurement in arteries, veins and ducts. The module automatically identifies the size, scale and calibration of the Flowprobe connected to it. A digital display, analog meter, and analog signal outputs present flow readings *(pulsatile and average)*, test/error messages and calibration signals. Acoustical velocity phase signals are also available for ultrasound dilution measurements. Front panel button switches engage four modes of operation:

TS420 Module

- **Test Mode:** analyzes the ultrasonic performance of the Flowprobe
- **Measure Mode:** displays volume flow
- **Zero & Scale Modes:** calibrates external data recording devices

C. Multi-channel Flowmeter Configurations

Flowmeter consoles and modules may be mixed and matched to meet individual application requirements. Components are sold individually or in preconfigured combinations.

Flowmeter Consoles

T402 Dual Channel Console with power supply
T403 Triple Channel Console with power supply

Flowmeter Modules

TS410 Tubing Flowmeter Module (T-suffix below)
TS420 Perivascular Flowmeter Module (P-suffix below)

T402 - Dual Channel Combinations

T402-PP: Dual Channel Flowmeter Console with two TS420 Perivascular Modules

T402-PT: Dual Channel Flowmeter Console with one TS420 Perivascular Module & one TS410 Tubing Module

T402-TT: Dual Channel Flowmeter Console with two TS410 Tubing Modules

T402-PB: Dual Channel Flowmeter Console with one TS420 Perivascular Module & one blank slot for further expansion

T402-TB: Dual Channel Flowmeter Console with one TS410 Tubing Module & one blank slot for further expansion

T403 - Triple Channel Combinations

T403-PPP: Triple Channel Flowmeter Console with three TS420 Perivascular Modules

T403-PPT: Triple Channel Flowmeter Console with two TS420 Perivascular Modules & one TS410 Tubing Module

T403-PTT: Triple Channel Flowmeter Console with one TS420 Perivascular Module & two TS410 Tubing Modules

T403-TTT: Triple Channel Flowmeter Console with three TS410 Tubing Modules

T403-PPB: Triple Channel Flowmeter Console with two TS420 Perivascular Modules & one blank slot for future expansion

T403-PTB: Triple Channel Flowmeter Console with one TS420 Perivascular Module & one TS410 Tubing Module & one blank slot for future expansion

T403-TTB: Triple Channel Flowmeter Console with two TS410 Tubing Modules & one blank slot for future expansion

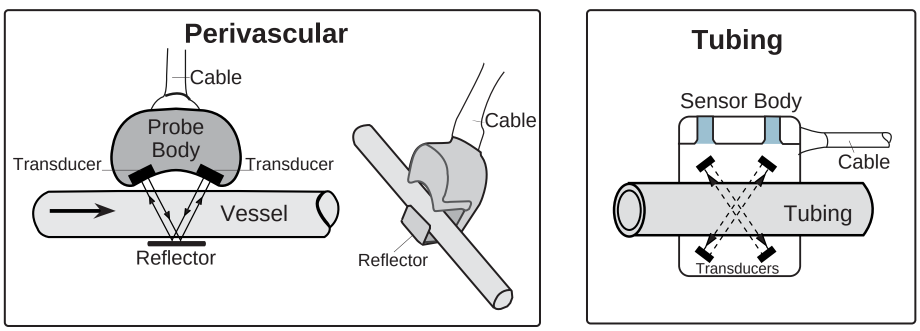
T403-PBB: Triple Channel Flowmeter Console with one TS420 Perivascular Module & two blank slots for future expansion

T403-TBB: Triple Channel Flowmeter Console with one TS410 Tubing Module & two blank slots for future expansion

D. 400-Series Flowprobes and Flowsensors

Transonic Flowprobes and Flowsensors connect to flowmeter modules by the probe's flexible cable or extension cable. Two or four ultrasonic transducers within the probe housing alternately transmit and receive a minimum level of ultrasound through a rectangular sensing window and sense volume flow of all liquid passing through the window, irrespective of where the flow occurs within the window. Transonic transit-time Flowprobes are known for low and stable zero flow offset and high resolution. Transonic Flowprobes can measure flow in aqueous, non-aerated fluids and do not require particulate content or ionization of the monitored liquid. See the Appendix for Flowprobe/Flowsensor specifications for each module.

Transit Time Ultrasound Theory of Operation

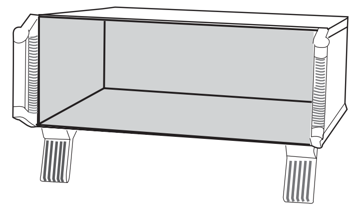


How It Works! TRANSIT TIME ULTRASOUND TECHNOLOGY

The transducer (a piezoelectric crystal) within the Flowprobe emits sound rays to form an ultrasound beam. As the beam traverses a vessel, each ray undergoes a phase shift in transit time proportional to the average velocity of the liquid times the path length over which this velocity is encountered.

With wide-beam ultrasonic illumination the receiving transducer sums (integrates) these velocity - chord products over the vessel's full width and yields **volume flow**.

E. Multi-channel Flowmeter Specifications



T403 Console without Modules

GENERAL FEATURES

WEIGHT/ SIZE — **T402** Dual Channel Console
5.21"high x 9.25" wide x
12" deep, 5.8 lbs.
T403 Triple Channel Console
5.21" high x 13.46" wide x
12" deep, 7.6 lbs

BENCH-TOP MODEL — Consoles have side panel handles and tiltable front feet for easy viewing

MODULE COMPATIBILITY Accepts 400-Series Flowmeter Modules

ELECTRICAL ISOLATION — Flowmeter console is grounded. If accidentally left ungrounded, line to ground leakage current is less than 50 microamperes.

POWER

AC Input:	100-240 VAC; 50-60 Hz, 50 watts
Fuses:	0.8 Amp fast blo, mfg bussman # GMA0.8, 250 VAC

POWER CORD

USA/Japan:	Feller 458-H161 or equivalent
Europe:	Feller 199-000 or equivalent
United Kingdom:	Feller 209-000 or equivalent
Australia:	Feller 198-000 or equivalent

MODULE CAPACITY — **T402 Dual Channel Console:**
Accepts 2 wide flowmeter modules of 20HP width or 4 narrow flowmeter modules of 10 HP width or a combination of wide and narrow modules.

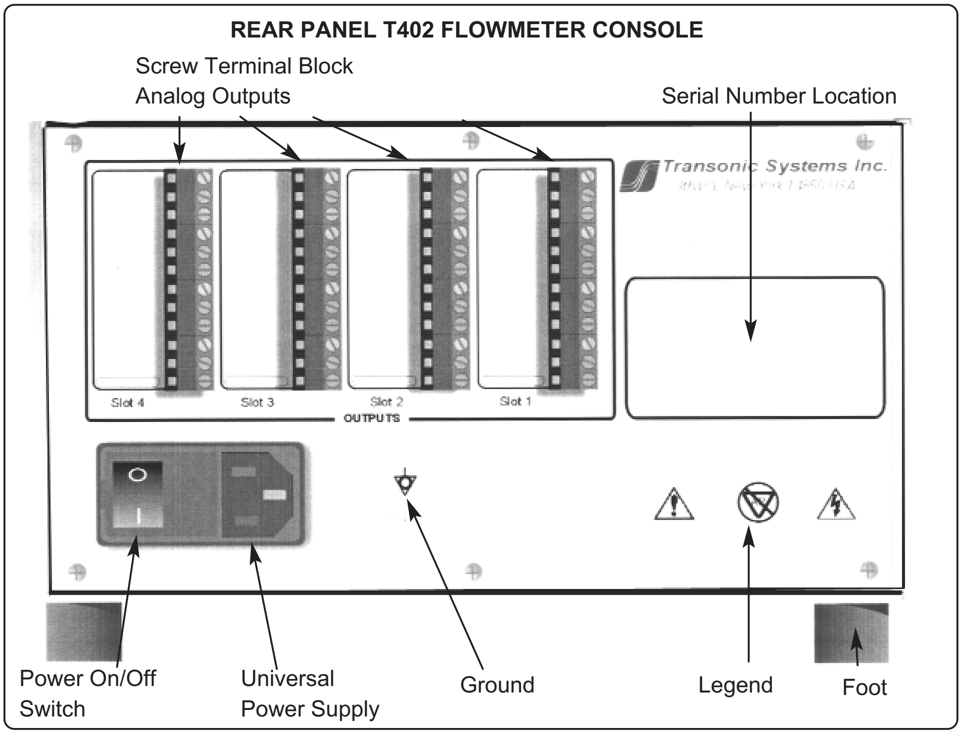
MODULE CAPACITY — **T403** Triple Channel Console:
Accepts 3 wide flowmeter modules of 20HP width or 3 narrow flowmeter modules of 10 HP width or a combination of wide and narrow modules.

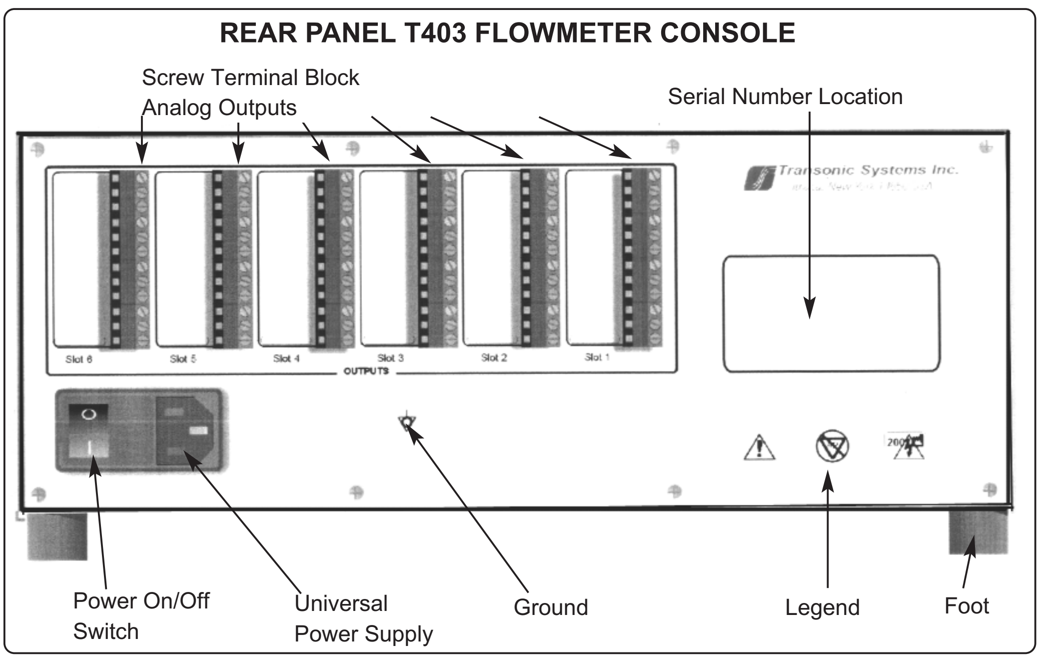
CONSOLE TO MODULE CONNECTION
96-pin DIN connector on proprietary backplane

SIGNAL OUTPUT — backpanel screw terminal block to receive signal outputs from module(s) via DIN 96-pin connection with console;
12 output connections per flowmeter module, two dedicated for ground;
See module specifications for signal definition and voltage rating.
Use with general purpose hookup wire; stranded wire is preferred
Wire: UL 1007 or equivalent; 24- 14 gauge
Minimum strip length: 6 mm (.236 inches)

AUDIBLE ALARM — Beeping alarm, non-adjustable volume.
Trip level, on/off setting activated through TS410 program.

F. 400-Series Flowmeter Consoles Rear Panels





G. Synchronization: Setting Up the 400-Series Modular Flowmeter Console

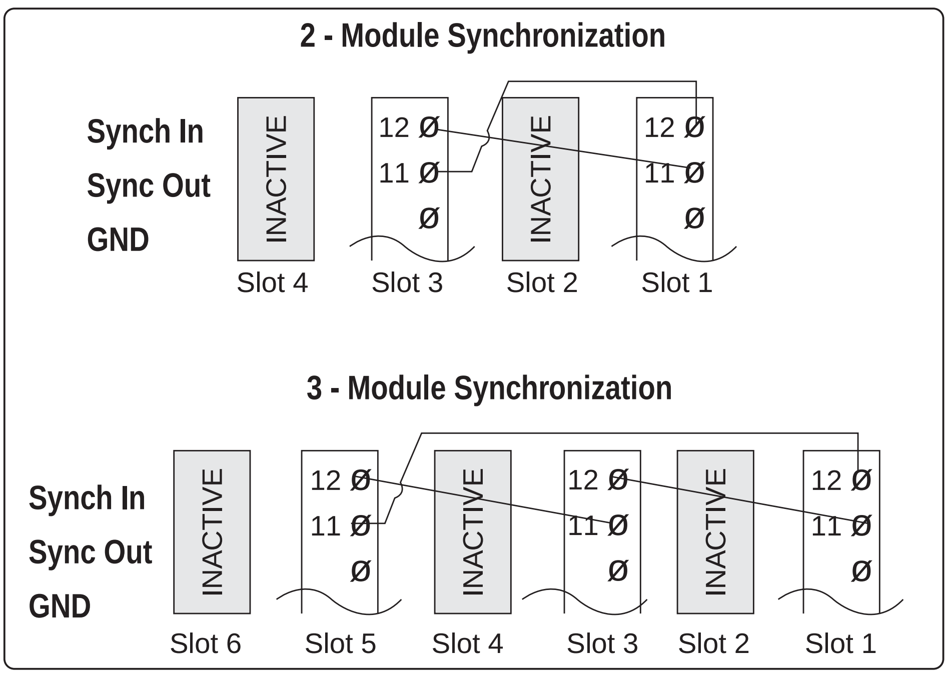
INTERNAL 400 MODULE SWITCH

Flowmeter modules have a (labelled T400/T500) switch on the rear panel that is not accessible until the module is pulled out of the console. This switch must be set to “T400” *(in the down position)* before the module is inserted in the T402 or T403 console. This sets the timing of the flowmeter module to be synchronized. If the switch has been jostled or bumped out of the “T400” position during shipment , the flowmeter may exhibit considerable drift in Measure Mode and low or no signal from the Flowprobe or Flowsensor.

The Synchronization Mode of 400-series modules must be selected via jumper cables on the console’s back panel terminal blocks.

SELF-TRIGGERING: Connect Terminal block pin 11 to pin 12 via jumper “Synch In” to “Synch Out” on same terminal block
This gives the lowest flow noise and is selected when a flowmeter module runs by itself, or multiple Flowprobes on multiple modules run simultaneously with sufficient distance (20 cm) between probes. *(Flowmeter modules are shipped from the factory in self-trigger mode unless otherwise specified.)*

SEQUENTIAL TRIGGERING: Interconnect the 2 or 3 flowmeter modules on the rear panel with jumpers between modules (pins 11 & 12) from “Synch In” and “Synch Out” as shown. *Note: Be careful to choose the active terminal connections that correspond to the installed modules (TS410 & TS420 modules use the odd numbered terminal connector positions.)* This wiring avoids the flow offsets that could result from ultrasonic cross-talk between adjacent probes.



Section II.

TS410 Tubing Flow Module

TS410 Module

A. TS410 Tubing Flowmeter Module

The TS410 plug-in module operates inline and sterile tubing Flowsensors for volume flow measurement in tubing circuits, flow chambers and isolated organ apparati. The module automatically identifies the size and scale of the Flowsensor connected to it.

B. TS410 Flowmeter Module Flowsensors

ME-PXL *Clamp-on* Tubing Flowsensors


PXL-Series

Transonic "precision" PXL-Series clamp-on tubing Flowsensors apply ultrasound energy through standard laboratory or extracorporeal tubing to monitor instantaneous and average volume flow of blood, glycerine/water blood analogs, cell culture media, saline, buffer or other solutions. Only ultrasonic contact with the liquid is required; clamp-on tubing Flowsensors maintain total physical and electrical isolation between the sensor and the liquid under study.

PXL-Series *Clamp-on* Tubing Flowsensors

4-crystal sensors that clamp on the outside of tubing

Clamp-on TUBING SENSOR	Tubing Specifications					
	Tubing ID		Wall Thickness		Tubing OD	
Catalog #	inches	mm	inches	mm	inches	mm
ME 2PXL	In sizes 2PXL - 4PXL ratio of tubing tubing must not exceed 1:5 for PVC; 1:3 for silicone				1/8 - 5/32	3.1 - 4.0
3PXL					3/16 - 7/32	4.7 - 5.5
4PXL					1/4 - 9/32	6.3 - 7.7
5PXL	3/16	4.7	1/16	1.6	5/16 - 11/32	7.8 - 8.7
6PXL	1/4	6.4	1/16	1.6	3/8	9.5
7PXL	1/4	6.4	3/32	2.4	7/16	11.1
8PXL	3/8	9.5	1/16	1.6	1/2	12.7
9PXL	3/8	9.5	3/32	2.4	9/16	14.3
10PXL	1/2	12.7	1/16	1.6	5/8	15.9
11PXL	1/2	12.7	3/32	2.4	1/16	17.5
12PXL	1/2	12.7	1/8	3.2	3/4	19.0
14PXL	5/8	15.9	1/8	3.2	7/8	22.2
16PXL	3/4	19.0	1/8	3.2	1	25.4
20PXL	1	25.4	1/8	3.2	1 1/4	31.8

ME-PXN *Inline* Flowsensors

Transonic Precision PXN-Series Inline Flowsensors splice into laboratory tubing from 0.046 to 1.0 inch internal diameter to directly measure instantaneous and average volume flow. The sensors are designed for general bench-top application *(perfused isolated organ preparations, mock circulatory models, etc.)* Inline Flowsensors are especially sensitive for measurements in low flow applications.

PXN-Series Inline Flowprobes

4-crystal flow through probes with a smooth, round flow round channel.

Cat #	for tubing ID mm	for tubing ID inches
ME1 PXN	1.2	3/64
ME2 PXN	1.8	1/16
ME3 PXN	2.4	3/32
ME4 PXN	3.2	1/8
ME5 PXN	4.8	3/16
ME6 PXN	6.4	1/4
ME10 PXN	9.5	3/8
ME13 PXN	12.7	1/2
ME16 PXN	15.9	5/8
ME19 PXN	19.1	3/4
ME25 PXN	25.4	1

II-C. TS410 Tubing Module: Specifications

C. TS410 Tubing Module Specifications

GENERAL FEATURES

WEIGHT/ SIZE 5.125” high x 4” wide x 12” x 9.062” deep; 2.3 lbs.
Module is 2 console slots (20HP) wide.

CONSOLE COMPATIBILITY 400-Series Flowmeter Consoles (T402 and T403)
500-Series Instrumentation Rack (TEAM21)
Requires seating in 2 card guides
96-pin DIN connector to proprietary backplane
Thumb-screw to lock into console on front panel

AUTOMATIC FLOWMETER ADJUSTMENTS

Sensor size identification and corresponding flow output ranges
(See Flowsensor tables in Appendix)
Volume flow calibration of applied sensor; serial number displayed of active Flowsensor

SET/UP STATUS PROGRAM PARAMETERS

STATUS MODE: White button labels - Status message displayed on LCD.
Sensor Status: sensor type & calibration
Meter Status: Active flowmeter settings & alarm status
Alarm Mute: Audible alarm On/Off

PROGRAM MODE: Blue button labels - - EXIT; SCROLL; SELECT.
See chart (page II-19) for Program Navigation

C. TS410 Tubing Module Specifications *cont.*

SET/UP STATUS PROGRAM PARAMETERS *cont.*

SENSOR CONTROLS

Select factory preprogrammed calibration options
Adjust Flowsensor gain to change calibration onsite

METER CONTROLS

1/4 Flow Scale: increases flow gain by factor of 4 for low flow measurements

Calibrate Scale: sets output to 0 and 1 Volt to calibrate external recording devices with scale factor flow.

Invert flow: inverts polarity of analog outputs & flow display

Alarms Menu: 3 level program to select, set thresholds, and activate Alarms for "Low Flow", "High Flow" and "Received Signal" Interruption

FILTER PROPERTIES 0.1, 10, 40 Hz: 2nd order Butterworth, with a third passive pole at 160 Hz
160 Hz: 3rd order Butterworth

ZERO FLOW ADJUST momentary push button recessed to avoid inadvertent adjustment of zero flow reading

DIGITAL DISPLAY **LED:** 4 Digit (14 segment); displays Volume Flow/Sensor data/Error Messages

Bar Indicator Light: Displays received signal amplitude for continuous monitoring of sensor signal quality

LCD DISPLAY One line 16-character alpha numeric LCD displays program parameters, sensor & meter status, alarm settings. Default displays sensor serial number.

FLOW OUTPUT Front panel mounted BNC output connector & rear panel terminal block:
Pulsatile/Average Volume Flow
Filtering controlled by front panel selectable filters
Voltage range: -5 to + 5 volts

Calibration Modes (see page II-14)
Output resistance: 500 Ohm
Full Range for Flow: -5 to +5 V
(bidirectional flows, with range of 5 x scale factor flow)

MODES OF OPERATION *(See page II-14)*

SENSOR CONNECTOR Front panel 16-pin connector
Accepts research inline and sterile tubing Flowsensors and extension cables with male ODU 16-pin connectors.

AUTOMATIC DIGITAL SENSOR IDENTIFICATION & CALIBRATION

TS410 circuitry reads sensor operational data *(size, scale & calibration)* programmed in the sensor's EPROM.

C. TS410 Tubing Module Specifications *cont.*

ULTRASONIC FREQUENCY RANGE

600 KHz to 14.4 MHz
Sensor size dependent – see sensor specification tables

FLOWSENSOR COMPATIBILITY

Accepts Transonic "Precision" Tubing Flowsensors with 16-pin ODU connectors
ME-prefix: Extracorporeal Sensors for 400-Series Flowmeters.
PXL-Series: Precision XL-Series Sterile Tubing Flowsensors with 4 transducers
PXN-Series: Precsion XN-Series Inline Flowsensors with 4 transducers
N-Series: T106/T206 2-transducer Inline Flowsensors

SIGNAL OUTPUTS 8 accessible signals via 400-series Flowmeter Console's back panel odd numbered terminal block connection: Pulsatile Volume Flow; Mean Volume Flow; Received Signal Amplitude (2); Phase (4)

SYNCHRONIZATION

Module rear panel switch for selecting synchronization mode
"T400" position: T400-series flowmeter consoles use this setting.
"**T500" position:** Utilized for 500-Series backplane synchronization by TEAM21 program and backplane processor

T400-Series Multi-Module synchronization via jumper cables between console's back panel terminal block connections:"
Self-triggering Mode: "SYNCH IN" to "SYNCH OUT" jumper on each module:
Sequential Triggering Mode: "SYNCH IN"crossed to "SYNCH OUT" between modules.

(See console directions for use for complete synchronization instructions (page I-7)

C. TS410 Tubing Module Specifications *cont.*

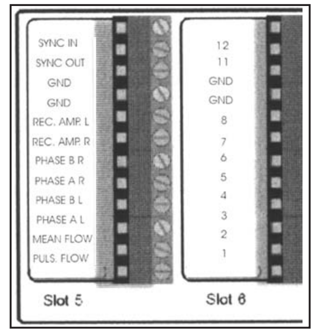
TS410 FLOWMETER MODES OF OPERATION

MODE	OUTPUTS LCD DISPLAY[1] *with functioning sensor*		LED DIGITAL DISPLAY[2]	Mean & Pulsatile Flow[3]
MEASURE (default)	Flow Module & Sensor Identification	**FUNCTIONAL ERROR MESSAGES**	Average flow in ml/min or L/min Bar indicator shows signal quality	Flow = Recorded Voltage x Scale Factor
STATUS	Flowsensor calibration parameters Meter settings			Bidirectional flow output between -5 Volts and +5 Volts
PROGRAM SENSOR	Select and change calibration gain			
PROGRAM METER	1/4 flow scale		Expands resolution of average flow display	Flow = Recorded Voltage x Scale Factor (changes scale factor x 1/4)
	Calibrate Ø Volt scale		Ø ml/min	Ø V = Ø ml/min
	Calibrate 1 Volt scale		Scale factor flow value	1V = Scale factor flow
	Invert		Inverts value of flow display	Inverts Polarity of Voltage Signal
	Alarm set-up LoFlow HiFlow Rec Signal		Default Measure Mode	

[1]LCD Display: module front panel
[2]LED Display: module front panel
[3]Voltage Signal Ouput for Recording:
1) BNC mounted on front panel
2) Terminal Block on console rear panel

C. TS410 Tubing Module Specifications *cont.*

REAR ANALOG PANEL SIGNALS



Note: TS410 modules connect to terminal block outputs on the T402 & T403 rear panels for recording analog signals.
TS410 modules use terminals in "ODD" number positions (T402: slots 1 and 3); (T403: slots 1, 3 and 5)

12 = SYNCH IN Multi-flowmeter synchronization input
(See Console, page I-7, for wiring instructions)

11 = SYNCH OUT Multi-flowmeter synchronization input
(See Console, page I-7, for wiring instructions)

GROUND

GROUND

8 = REC AMP 1 Companion signal to 7 = REC AMP 2.
Identical to REC AMP 2 for 2-transducer N-Series sensors;
representing transducer pair # 1 in 4-transducer PXL & PXN-Series sensors.

7 = REC AMP 2 Ultrasound received amplitude of the two transducers of N-Series sensors,
or transducer pair #2 in a 4-transducer PXL & PXN-Series sensor.
0 to 4V , 500 Ω output, 2 V = 100% signal amplitude

6 = PHASE 2 B Same signal as 5: PHASE 2 A, but offset by + 4.5V or -4.5V. The two signals combined provide continuity and high resolution for indicator dilution signals.

5 = PHASE 2 A Companion signal to Phase 1A: identical to Phase 1A for N-Series sensors; representing transducer pair # 2 in 4-transducer PXL & PXN-Series sensors.

4 = PHASE 1 B Same signal as 3: PHASE 1A, but offset by + 4.5V or -4.5V. The two signals combined provide continuity and high resolution for indicator dilution signals.

3 = PHASE 1 A A -5 to +5V (500Ω) analog output signal representative of changes in acoustic velocity of fluid between the two transducers of N-Series sensors,
or transducer pair # 1 in 4-transducer PXL & PXN-Series sensors.

2 = MEAN FLOW Average volume flow output, filtered at 0.1 Hz.
-5 to + 5 V (500Ω) "Calibrate Scale Mode" *(see Table, page II6)* reveals the voltage-to-flow conversion factor.

1 = PULS FLOW Pulsatile volume flow output, filtered at 10, 40, or 160 Hz per front panel setting. (160 Hz in the 0.1 Hz setting);
-5 to + 5 V (500Ω) "Calibrate Scale Mode" *(see Table, page II6)* reveals the voltage-to-flow conversion factor.

II-D. TS410 Module: Directions for Use

1. INITIAL BENCH-TOP OPERATION

These functional tests are suggested to acquaint a new user with Transonic Systems 400-Series Flowmeters and Transonic ultrasonic Flowprobes and to check for damage incurred during shipment. If the apparatus does not function as described during this initial operation, please call Transonic Systems' customer service or your authorized Transonic Systems provider or sales representative

a. Flowmeter Tests

1) **Verify that the console's rear panel synchronization terminals are properly connected.** *(See console synchronization instructions, page I-7.)*

2) **Connect console power cord to grounded power receptacle.**
Do not operate unless flowmeter console is electrically grounded via supplied power cable.

3) **Turn on power switch on back panel of console**

TS410 Tubing Flowmeter Module
Digital Display will scroll TSI ¶ and display "NO.PR." The LCD will read "TS410 Flowmeter." Pressing menu and status buttons will change display to "No Sensor."

4) **Connect a tubing Flowsensor to the front panel mounted self-aligning 16-pin connector.** The digital display will scroll sensor size and series and signal coupling status " No Sig."*(no signal)* until liquid is present in the Flowsensor. The LCD will display sensor serial number. When liquid is present in the Flowsensor, the digital display will report average volume flow in milliliters/minute or liters/minute. Acoustic signal quality is displayed by the number of illuminated bars on the digital display and can be continuously monitored for the presence of air, or change in Flowsensor performance.

SIGNAL QUALITY INDICATORS

Signal Strength	Signal Quality	Bar-display	"REC AMP" Voltage *rear panel*
over 80%	Good	5 bars lit	over 0.8 V
60% to 80%	Good	4 bars lit	
30% to 60%	Good	3 bars lit	(proportional
20% to 30%	Low	2 bars lit	reading)
10% to 20%	Low	1 bars lit	
under 10%	No Signal	no bar lit	under 0.1V

1. INITIAL BENCH-TOP OPERATION *cont.*

a. Flowmeter Tests *cont.*

5) Check Flowmeter's Operational Modes

The TS410 Tubing flowmeter has 3 modes of operation:
MEASURE, STATUS, and PROGRAM *(see page II-14)*

MEASURE MODE ____

Install a tubing sensor in a flow loop filled with liquid. Allow a sterile tubing Flowsensor to equilibrate on the tubing about 5 minutes before taking a reading.

If the sensor is properly coupled, you will observe a volume flow measurement reading on the digital display and illuminated bars indicating adequate ultrasound signal transmission.

With flow stopped, the flow reading will be 0 *(zero)* or close to 0. This is the zero offset of the sensor. The zero offset should be low, stable under stable conditions, and not exceed the value indicated on the sensor certificate of calibration.

The zero offset is affected by the fluid type, fluid temperature and tubing type *(if using a sterile tubing Flowsensor)*. Flowsensors are calibrated specifically for these parameters. A high zero offset may indicate that the sensor is being used with fluid or tubing other than that which it was calibrated for, or may indicate a change in sensor performance.

After equilibration of the sensor, you may adjust the flowmeter to read zero with flow stopped by depressing the recessed "Zero Adjust."button on the front of the module with a pointed instrument. The digital display will flash "Zero Adj." for approximately 10 seconds while the adjustment to the circuitry is being made and the ADJ will be illuminated on the module panel indicating that the zero has been adjusted.
Note: Once the zero has been adjusted, the sensor cannot be adjusted again until the sensor has been disconnected. Pressing the button a second time will not change the offset setting.

Establish flow in the tubing circuit. The digital display will now report average volume flow in milliliters/minute or liters/minute. If the sensor has been postitioned on the tube with the arrow in the direction of the flow, the reading will be positive. A negative flow value can be corrected by changing the direction of the Flowsensor or by using the "Invert" function in the flow module program *(see Program Mode section)*. Transonic Flowsensors measure bidirectional flow and will indicate both positive and negative flow.

II-D. TS410 Module: Directions for Use *cont.*

1.INITIAL BENCH-TOP OPERATION *cont.*

a. Flowmeter Tests *cont.*

5) Check Flowmeter's Operational Modes *cont.*

STATUS MODE

The white labels on the TS410 Flow Module Buttons indicate their primary function in the Status Mode. Use these to access the status of the Flowsensor and flowmeter.

SENSOR STATUS
Press this button to check the calibration setting of the active Flowsensor. The LCD will scroll to display the fluid type and temperature for which the active sensor is calibrated. The percentage of the factory calibration gain will be displayed. "Sensor Gain 100%" is the factory calibration. If the sensor calibration has been adjusted on-site, the percentage of the new gain will be displayed to show that it has been changed. Sterile tubing Flowsensors will also show the tubing type and tubing dimensions for which the sensor has been calibrated. Other parameters that affect the selected calibration may be programmed into the sensor eprom at the factory and will be displayed during Sensor Status. They include:

Fluid type, Temperature, Tubing Type, Tubing dimensions, Flow range, Gain %

METER STATUS
Press this button to display the active settings for the flowmeter. The flowmeter operational adjustments are accessed and set up in the flow module program *(See Program Mode section below)*. The LCD will scroll to display the status of: *Invert, 1/4 Flow Scale, and active Alarms.*

ALARM MUTE
Press this button to turn On/Off the audible alarm. Alarms are set in the TS410 flow module program *(See Program Mode section below)*. *Alarm Audio On, Alarm Audio Off*

PROGRAM MODE

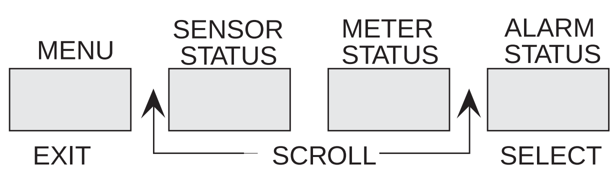
Press the "Menu" button to enter the Program Mode.

The blue labels on the TS410 Flow Module Buttons indicate their secondary function to navigate the program and set up the Flowmeter and Sensor Calibration in the Program Mode. Program messages are displayed on the LCD. There are three levels to the program. Use the flow chart on the following page to navigate through the options.

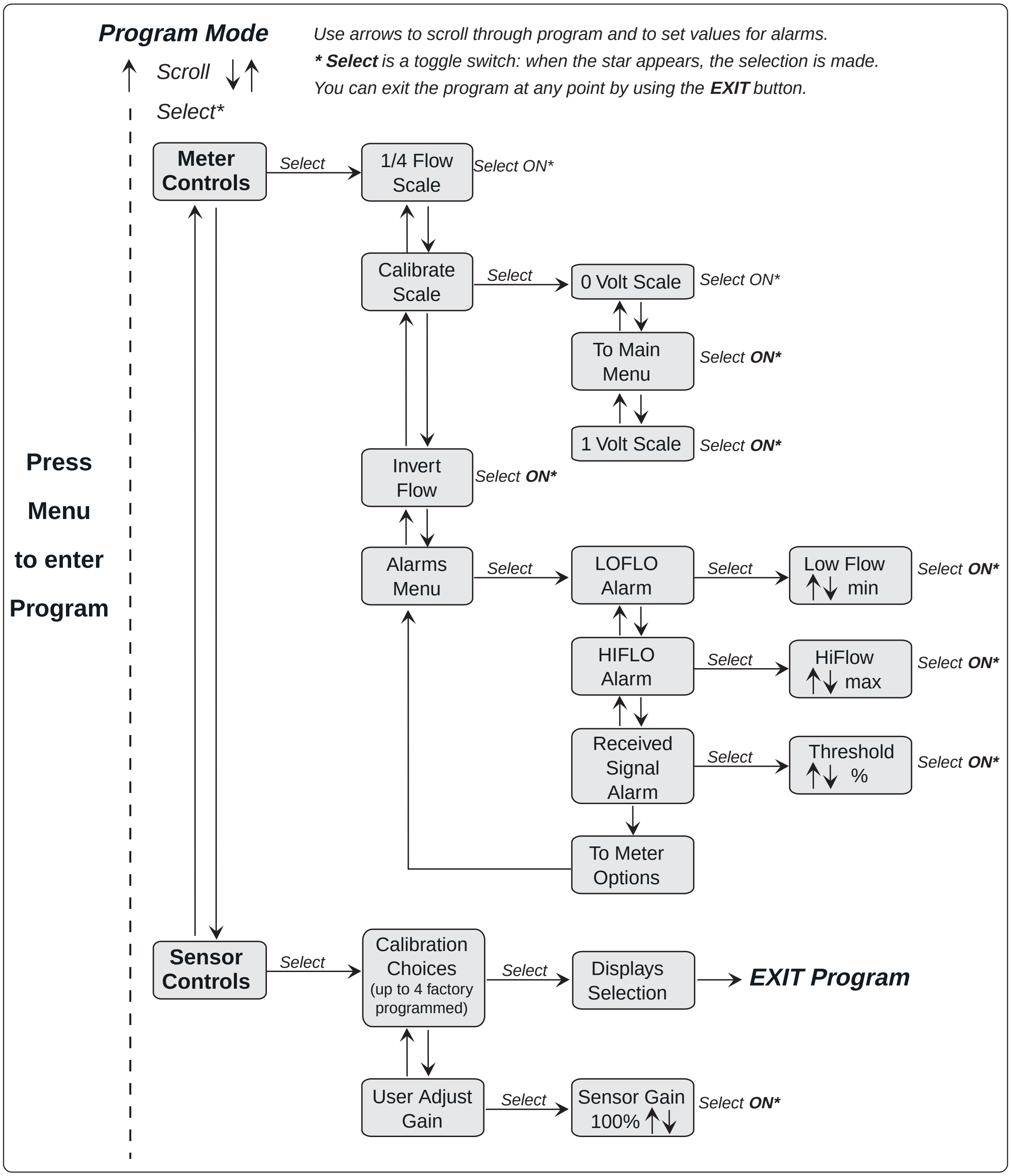
Exit Press to exit the program and return to Measure Mode.

Scroll Use the up and down arrows to scroll through choices in the program or set threshold values for alarms and calibration gain adjustment. Holding the button down will stream through the values more quickly than individual presses.

Select Press "Select" to activate a choice in the program or turn an alarm on or off. When an option or value is selected or activated, a star will appear next to the choice.



PROGRAM MENU: TS410 FLOW MODULE



2. METER OPTIONS

1/4 FLOW SCALE (LOW FLOW SCALE)

This option increases the flow gain by a factor of 4 to increase sensitivity for low flow measurement. Transonic Flowsensors are scaled to operate in two flow ranges. Normal flow range and Low flow range. The scale factor for each size sensor is indicated in the table of sensor specifications and is displayed on the digital display in the “Calibrate Scale” function. When the 1/4 flow scale is activated for low flow measurement, the normal scale factor is multiplied by 1/4. The voltage range of the flowmeter remains +5 volts to -5 volts, but the scale factor has changed. It is important to note this limited flow range so that peak flow values are measured accurately. Recording devices should also be rescaled if the 1/4 Flow Scale is activated during an experiment. See “Calibrate Scale.”

CALIBRATE SCALE

Select this option to send calibration signals to external recording devices or data acquistion programs.

0 Volt Scale * Zero volt output is generated to calibrate zero flow. Press “select”to activate. The digital display will show 0.0 ml/min. *Note: this is an electronic zero. Zero offset of the Flowsensor must be adjusted in Measure Mode.*

1 Volt Scale * This generates a 1 volt signal to calibrate the Flowsensor scale. Press “Select”to activate. The digital display will show the scale factor for the Flowsensor (either normal scale factor or 1/4 flow scale factor if the option is selected). Recorded analog voltages should be scaled by the displayed value. Flow = voltage x scale factor.

INVERT FLOW

Select this feature to reverse the polarity of the voltage signal and invert the displayed flow.
Note: Transonic Flowsensors measure bidirectional flow. Tubing Flowsensors have an arrow to indicate flow direction. If a sensor is reversed and positive flow is recorded in the negative direction, the signal may be inverted using this feature.

ALARMS MENU

The TS410 has 3 alarm settings: **Low Flow, High Flow** and **Received Signal**. Alarm threshold values are set in the Program Mode. Use the Scroll buttons to adjust the threshold from the default value. Default values are scaled by sensor size. Alarms are turned on/off in the Program Mode. A star (*) indicates an alarm is set.

When an alarm condition is met, the LCD will flash alarm messages for the specific condition. The LCD will continue to flash until the condition is cleared. The message will continue to be displayed on the LCD *(not flashing)* to show that the condition occurred. Clear the LCD by pressing any button.

If the audible alarm is turned on *(see Alarm Mute)*, an alarm will sound when the condition is met. The audible alarm will stop if the condition is cleared *(the LCD will continue to display the alarm message)*. Press the Alarm Mute button to disable the audible alarm.

Low Flow Alarm “LOFLO”
The Low flow alarm is activated when the pulsatile flow signal is lower than the set threshold level.

High Flow Alarm “HIFLO”
The High flow alarm is activated when the pulsatile flow signal is higher than the set threshold level.

Received Signal Alarm “Rec Sig Alarm”
The Received Signal Alarm is activated when the acoustic signal falls below the set threshold. This alarm can be used as a gross bubble alarm or detector. The signal amplitude will fall or be interrupted by air or gas bubbles in the flow circuit.

D. INITIAL BENCH-TOP OPERATION *cont.*

3. SENSOR OPTIONS

CALIBRATION CHOICE

Transonic Tubing Sensors for the TS410 are calibrated at the factory and can be programmed with up to 4 different calibration choices that can then be selected when the Flowsensor is used. Calibration parameters include:

Fluid type, Temperature, Flow range
Tubing Type, Tubing dimensions (for sterile tubing Flowsensors)

Use the arrow buttons to scroll through the programmed options. A star (*) will indicate that a selection has been made.

USER ADJUST GAIN

This function allows the user to adjust the calibration gain of the Flowsensor for different fluids, tubing or variable conditions. Original factory calibration of the Flowsensor is specified for fluid type and temperature and is programmed in the connector ROM.

The factory calibration is normalized and expressed as 100%. Adjustments to this value should be done only following a comparison of the flowmeter reading against a timed flow of a known volume under the true conditions requiring the calibration change. Several data points should be taken to establish a linear calibration curve.
Note: the OFFSET should be adjusted for zero flow prior to making the calibration adjustment.

Select “User Adj. Gain”. The original factory calibration is indicated as “Sensor Gain 100%”. Use the arrow buttons to adjust this percentage. A star (*) appears when the percentage value has been selected. Exit the program.

Note: This new calibration value is stored in the sensor ROM and becomes the default calibration for the sensor until it is reset to 100%. A percent symbol (%) after the calibration choice displayed indicates that the gain has been adjusted.

4. USE OF CLAMP-ON TUBING FLOWSENSOR

SENSOR SELECTION

Flowsensor size and calibration is determined by the tubing on which it will be used. Each Transonic clamp-on tubing Flowsensor is custom designed and calibrated for use on particular tubing *(silicone rubber, latex, polyurethane, or polyvinyl chloride [pvc])*. Use on tubing other than specified generally yields inaccurate measurements and may cause erratic zero baseline drift.

CLEANING & STERILIZATION

A clamp-on tubing Flowsensor may be cleaned by wiping with a solution of soap and water (60°C, 140°F) followed by a ethyl alcohol rinse to promote drying. Because no physical contact is required between the liquid under observation and the Flowsensor, sterilization for hospital use is not usually necessary. STERRAD or standard hospital cold *(ethylene oxide)* **gas** sterilization may be used (≤ 60°C, 140°F).
The sterile-tubing Flowsensor can be damaged by saline immersion or wet storage and should not be boiled, autoclaved, or sterilized by cold *liquid* sterilization.

SENSOR CALIBRATION

Flowsensors are precalibrated for a particular liquid at a certain temperature *(see Flowsensor's data sheet)*. Recalibration is necessary for accurate measurements at other temperatures or in other liquids. If a more precise zero baseline than that specified is needed, the meter must be zeroed by stopping the flow momentarily and re-zeroed every time operating conditions change *(change in fluid temperature, re-mounting probe on tube, etc).*

SITE SELECTION

The Flowsensor may be applied on straight tubing segments, near side branches or on curved tubing segments to produce measurements within its accuracy specifications. The best application site for the Flowsensor is a point well below the highest elevation of the tubing (*where gas bubbles might lodge)*. The Flowsensor will deform the tube slightly. If the tubing site becomes permanently deformed at one clamping position, choose another site to achieve better ultrasonic (acoustic) coupling.

TUBING PREPARATION

Apply a layer of petroleum jelly, or silicone grease over the tubing surface to enable ultrasonic transmission between tube and sensor. Note: Water-based ultrasonic gels should not be used for coupling clamp-on tubing sensors since they dry out and may build up on the transducer faces. This can cause additional offset in the measurement.

SENSOR APPLICATION

To apply the Flowsensor to tubing, open the Flowsensor's hinged lid, insert **lubricated** tubing into the sensing cavity, and close the lid. Fit should be tight, with the full tubing cross section contacting all inner surfaces of the sensing window. Once the tubing is filled with the liquid to be measured, Flowsensor operation and signal quality can be confirmed on the flowmeter. Check that the signal quality bars are illuminated. Low signal quality may indicate that an air or gas bubble is lodged in the tube. Since gas bubbles block ultrasonic transmission, tilt the tubing and Flowsensor vertically before operating the flowmeter to **flush** any bubbles from the sensing window.

Section III.

TS420 Perivascular Flow Module

TS420 Perivascular Flow Module

A. TS420 Module

The TS420 plug-in module operates perivascular Flowprobes for instantaneous volume flow measurements in animal research applications. Transonic "precision" *in vivo* perivascular Flowprobes (PS-Series, PR-Series, PAX- Series) are designed to fit loosely around arteries, veins and ducts. Standard configurations are available for acute application, and custom configurations for chronic implant. Flowprobes are sized for vessels from 0.25 mm to 36 mm diameter.

B. Perivascular Flowprobes

Acute use and chronically implantable Flowprobes for arteries, veins and ducts are sized to fit vessel outer diameter: 0.25 mm - 36 mm

MA-prefix: standard acute configuration with CRA10 connector

MC-prefix: custom configuration - specify options for acute or chronic use; reflector style, cable length, connector style, calibration, MRI compatibility

(For configurating Flowprobes to construct complete part #s, see ordering information in Appendix.)

PS & PR -Series

- **0.5 - 0.7 mm Nanoprobes for Mice**

0.7 PSB

The smallest probes imaginable!
MA-acute use probes supplied with handle. Easily stabilize probe position under the microscope with a micromanipulator for experiments in anesthetized mice and rats.
MC-custom implantable flowprobes for conscious mouse studies.

- **1 - 20 mm Precision Probes for Any Vessel**

MA-Standard Acute Use Probe

MC-Custom Implantable Configuration

PS-Series

See probe configuration tables for options.

V-Series

- **0.5 - 0.7 mm Microcirculation Probes for Acute Use Only**

V-Series

Transonic Systems' original probe series that pioneered flow measurements in small vessels < 0.7 mm. Mirrored ultrasonic illumination; robust design. Flowprobes come with stabilizing handle and will require more acoustic coupling gel than Nanoprobes. MA 0.5 VB , MA 0.7 VB

PAX-Series

- **8-36 mm Precision Cardiac Output Flowprobes**

Accurate volume flow measurements for non-laminar or turbulent flow profiles of the ascending aorta and pulmonary artery. Low profile, 4-active transducer X-illumination design.

PAX-Series

PMP -Series

- **2 - 14 mm Handle Probes**

For intraoperative measurements in preclinical animal trials where devices that match those used in clinical surgical settings are preferred.

R-Series

- **2 - 8 mm Original Flowprobes**

Large body probes still available upon request.

R-Series

III-C. TS420 Module: Specifications

C. TS420 Perivascular Module Specifications

GENERAL FEATURES

Weight/ Size	5.125" high x 4" wide x 12" x 9.062" deep 2.2 lbs. Module is 2 console slots (20HP) wide.
Console Compatibility	400-Series Flowmeter Consoles (T402 and T403) 500-Series Instrumentation Rack (TEAM21) Requires seating in 2 card guides 96 pin DIN connector to proprietary backplane Thumb-screw to lock into console on front panel
Power	Derives input power from 400- and 500-Series Consoles

AUTOMATIC FLOWMETER ADJUSTMENTS

Probe size identification and corresponding flow output ranges (see probe tables)
Volume flow calibration of applied probe

PUSH BUTTON CONTROLS

MODE SWITCHES	for selection of modes of operation of displays and outputs (see table, page III6)
Measure Mode	Displays current volume flow values Indicator light bar shows received signal strength
Test Mode	Displays probe size & received signal amplitude
Zero Mode	Sets outputs to zero flow to calibrate external recording device
Scale Mode	Sets outputs to scale factor flow to calibrate external recording device

SELECTABLE SCALE

Low Range	increases flow gain by a factor of 4
Filter Properties	0.1, 10, 40 Hz: 2nd order Butterworth, with a third passive pole at 160 Hz 160 Hz: 3rd order Butterworth
Polarity of Flow Invert	inverts polarity of analog flow outputs and flow displays
Zero Flow Adjust	momentary push button recessed to avoid inadvertent adjustment of zero flow reading

DIGITAL DISPLAY **4 Digit** (14 segment) **LED**
Displays Volume flow / Probe data / Error Messages (see table, page III6)
Bar Indicator Light:
Displays received signal amplitude for continuous monitoring of probe signal quality

ANALOG DISPLAY **Taut-band needle** (-.2 volts to +1.2 volts)
Displays Volume flow / Received Signal Amplitude/Calibration information (see table, page III-27)

C. TS420 Perivascular Module Specifications *cont.*

PROBE CONNECTOR Front panel 10-pin connector

Accepts research perivascular Flowprobes and extension cables
with male Redel 10-pin connectors.

AUTOMATIC DIGITAL PROBE IDENTIFICATION & CALIBRATION

TS420 circuitry reads probe operational data (size, scale & calibration) programmed in the probe's EPROM.
Probes with 10-pin connectors contains the EPROM installed in the connector.
4-pin probe connectors require separate EPROM calibration keys

CAL KEY Socket:

Front panel socket accepts 3-pin EPROM calibration keys programmed for use with TS420 modules.
Flowprobes with 4-pin connectors require calibration keys.
Flowmeter reads and uses "CAL KEY" data if both a separate calibration key and 10-pin connector EPROM are present.

Calibration Key

ULTRASONIC FREQUENCY RANGE

600 KHz to 14.4 MHz
Probe size dependent – see probe tables in Appendix

FLOWPROBE COMPATIBILITY

Accepts Transonic "Precision" Perivascular Flowprobes with 2 & 4 transducers.
Prefix: MA- (standard acute) and **MC-** (custom configuration)
PS-Series: Precision S-series Flowprobes
PAX-Series: Precision cardiac output probes with 4 independent active transducers
V-Series: Acute use only.
Also accepts T106/T206 perivascular probes via CH10-CRA10 conversion cable and 400-series calibration keys

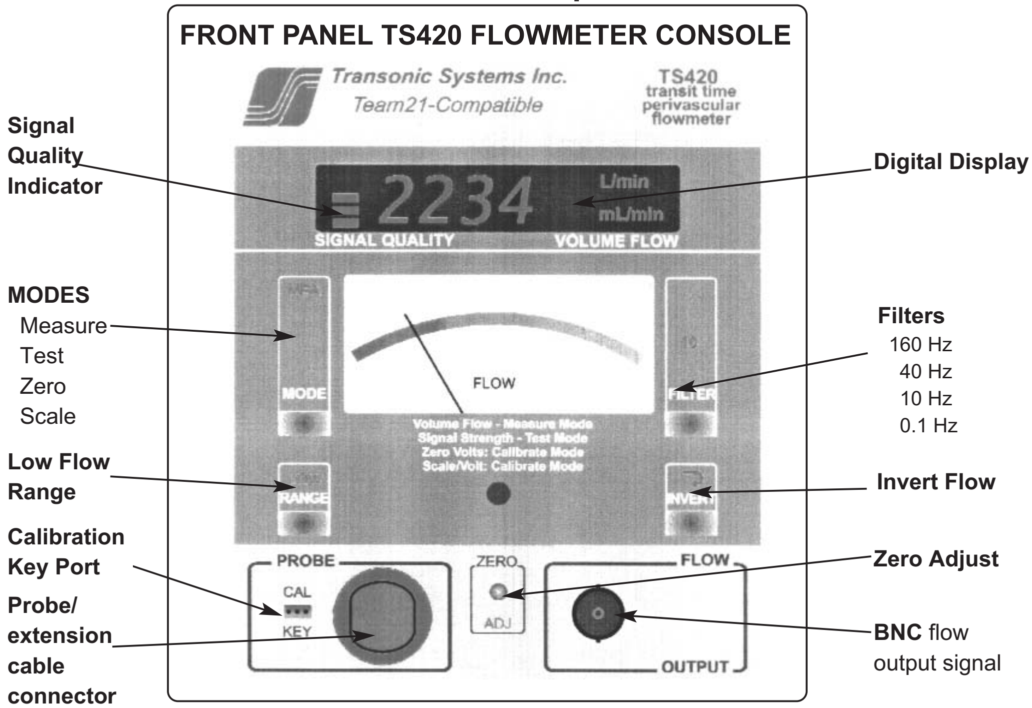
SIGNAL OUTPUTS 8 accessible signals via 400-series Flowmeter Console's back panel odd numbered terminal block connection

Pulsatile Volume Flow
Mean Volume Flow
Received Signal Amplitude (2)
Acoustical Velocity Phase (4)

SYNCHRONIZATION

Module rear panel switch for selecting synchronization mode
"T400" position: T400-series flowmeter consoles use this setting.
"T500" position: Utilized for 500-Series backplane synchronization by TEAM21 program and backplane processor
T400-Series Multi-Module synchronization via jumper cables between console's back panel terminal block connections:
Self-triggering Mode: "SYNCH IN" to "SYNCH OUT" jumper on each module:
Sequential Triggering Mode: "SYNCH IN" crossed to "SYNCH OUT" between modules.
(See console directions for use for complete synchronization instructions.)

C. TS420 Perivascular Flowmeter Module Specifications *cont.*



Flowmeter Modes of Operation

MODE	OUTPUTS			
	DIGITAL DISPLAY[1] *with functioning probe*	*Other*	**ANALOG DISPLAY**[2] Needle indicates voltage	**MEAN & PULSATILE FLOW**[3]
MEASURE	Average Flow (in ml/min or L/min) Bar graph for signal quality	Functional error messages	Reading multiplied by scale factor = instantaneous volume flow	Flow = Recorded Voltage x Scale Factor
TEST	Probe size and received signal quality		Proportional value of received signal amplitude: 1.0 V = standard normalized level	Bidirectional flow, between -5 and +5 Volts
ZERO	Ø ml/min		0.0V = Zero flow	Ø V = Ø ml/min
SCALE	Scale factor flow value		1.0V = Scale factor flow	1V = Scale factor flow

C. TS420 Perivascular Flowmeter Module Specifications *cont.*

DIGITAL DISPLAY FUNCTIONAL TEST AND ERROR MESSAGES

TEST and MEASURE MODES

TSI✓ Transonic Systems Inc. Start-up, Check Test

NO.PR. "No Probe" is plugged in

No Sig. "No Signal"
Flowmeter is reading probe eprom, but there is no signal transmission. Check acoustic coupling; check for broken wire.

Low Sig. "Low Signal"
Signal transmission is minimal; less than 30% of normal. Check acoustic coupling of probe for air bubble. If low signal persists when tested in water, send probe to Transonic Systems for renormalization or repair.

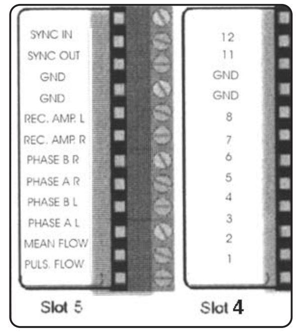
Good Sig. "Good Signal"
There is good acoustic signal transmission for flow measurement.

SIGNAL QUALITY INDICATORS

Signal Strength	Signal Quality	Bar-display	Analog Display	"REC AMP" Voltage *rear panel*
over 80%	Good	5 bars lit	over 0.8 V	over 0.8 V
60% to 80%	Good	4 bars lit		
30% to 60%	Good	3 bars lit	(proportional	(proportional
20% to 30%	Low	2 bars lit	reading)	reading)
10% to 20%	Low	1 bars lit		
under 10%	No Signal	no bar lit	under 0.1V	under 0.1V

C . TS420 Perivascular Flowmeter Module Specifications *cont.*

REAR PANEL ANALOG SIGNALS



Note: TS420 Modules connect to terminal block outputs on the T402 and T403 rear panel for recording analog signals
TS420 modules use terminals in "ODD" numbered positions
(T402: slots 1 and 3); (T403: slots 1, 3 and 5)

12 = SYNCH IN Multi-flowmeter synchronization input
(see console, page I-7 for wiring instructions)

11 = SYNCH OUT Multi-flowmeter synchronization input
(see console, page I-7 for wiring instructions)

GROUND

GROUND

8 = REC AMP 1 Companion signal to 7 = REC AMP 2.
Identical to REC AMP 2 for 2-transducer PS-Series probes;
representing transducer pair # 1 in the 4-transducer PAX-Series probes.

7 = REC AMP 2 Ultrasound received amplitude of the two transducers of a PS-Series probe,
or transducer pair #2 in a 4-transducer PAX-Series probe.
0 to 4V , 500 Ω output, 2 V = 100% signal amplitude

6 = PHASE 2 B Same signal as 5: PHASE 2 A, but offset by + 4.5V or -4.5V. The two signals combined provide continuity and high resolution for indicator dilution signals.

5 = PHASE 2 A Companion signal to Phase 1A: identical to Phase 1A for PS-Series probes; representing transducer pair # 2 in a 4-transducer in a PAX-Series probe.

4 = PHASE 1 B Same signal as 3: PHASE 1A, but offset by + 4.5V or -4.5V. The two signals combined provide continuity and high resolution for indicator dilution signals.

3 = PHASE 1 A A -5 to +5V (500Ω) analog output signal representative of changes in acoustic velocity of fluid between the two transducers of a PS-Series probe,
or transducer pair # 1 in a 4-transducer PAX-series probe.

2 = MEAN FLOW Average volume flow output, filtered at 0.1 Hz.
-5 to + 5 V (500Ω) "Scale Mode" (see Table D1) reveals the voltage-to-flow conversion factor.

1 = PULS FLOW Pulsatile volume flow output, filtered at 10, 40, or 160 Hz per front panel setting.
(160 Hz in the 0.1 Hz setting);
-5 to + 5 V (500Ω) "Scale Mode" (see Table D1) reveals the voltage-to-flow conversion factor.

III-D. TS420 Module: Directions for Use

1. INITIAL BENCH-TOP OPERATION

These functional tests are suggested to acquaint a new user with Transonic Systems 400-Series Flowmeters and Transonic ultrasonic Flowprobes and to check for damage incurred during shipment. If the apparatus does not function as described during this initial operation, please call Transonic Systems' customer service or your authorized Transonic Systems provider or sales representative

a. Flowmeter Tests

1) **Verify that the console's rear panel synchronization terminals are properly connected.** (See synchronization instruction page)

2) **Connect console power cord to grounded power receptacle.** Do not operate unless flowmeter console is electrically grounded via supplied power cable.

c) **Turn on power switch on back panel of console**

The TS420 starts up in TEST Mode to encourage testing of the Flowprobes prior to use.

Digital Display will scroll TSI ¶ and display "NO.PR."

d) **Connect a Flowprobe (or extension cable with a Flowprobe) to the front panel mounted self** aligning Redel 10-pin connector. If a 4-pin chronic connector is used, also insert the calibration key into the Cal Key socket on the front panel next to the probe connector.

Digital Display will scroll "No Sig." and "probe size"

b. Perivascular Flowprobes

1) Preparing the Flowprobe in Test Mode

Immerse the probe in a soft plastic beaker filled with degassed water.

Note: hard containers reflect the ultrasound signals and will cause the probe to appear to have high or drifting zero offset values. Sponge may be inserted in the container to absorb extraneous signal.

Dislodge any air bubbles from the surfaces of the probe.

Shaking the probe under water may be sufficient. A fine gauge paint brush is useful especially with smaller probes which can hold air bubbles.

Observe Flowmeter's front panel indicators.

The TS420 starts up in TEST Mode to encourage testing of the Flowprobes prior to use. The "No Sig."message will be replaced with "Good Sig" as good acoustic conduction is established with the probe. A dry probe may need to be immersed in water for several minutes before this occurs. Swishing the probe back & forth helps to speed up the process. The probe's received signal stabilizes when the surfaces are sufficiently wetted and confirms acoustic transmission of the ultrasound signal.

The **Signal Quality Indicator** should be fully illuminated — all 5 bars will be lighted. If the received signal drops below 30 % only 2 bars will be lighted and the digital display will scroll "LOW Sig." Measurement accuracy cannot be guaranteed under such signal conditions. The flowmeter looses acoustic coupling with the probe at less than 10% and no bars will be lighted. The display will scroll "No Sig."

1. INITIAL BENCH-TOP OPERATION *cont.*

b. Perivascular Flowprobes *cont.*

Observe Flowmeter's front panel indicators *cont.*

In Test Mode, the analog meter indicates received signal quality. This received signal amplitude is an indication of acoustic coupling. Low received signal generally means there is an air bubble in the Flowprobe. It is also an indication of the functionality of the probe. A sudden drop in signal may indicate a failing probe. Transonic Flowprobes are normalized to read 1.0 Volt in Test Mode (1.0 Volt on the back panel REC AMP output). As signal drops, the needle meter will indicate a proportional drop in the received signal amplitude.

2) **Press Mode button to change mode function to "Zero."**
The analog needle will deflect back to 0 volts and "0" will be displayed on the digital display.

3) **Press Mode button to change mode function to "Scale."**
The digital display will indicate the volts-to-flow conversion for the active probe, the analog meter will deflect to 1 volt, the analog outputs will read 1.0 Volt. This routine should be performed to scale external recording devices. The flowmeter will accurately measure flow to five times the scale factor of the probe.

4) **Switch to "Measure "Mode on the TS420 Flowmeter Module**
The digital display presents average volume flow in ml/min or L/min.
The analog meter registers flow proportional to the Flowprobe scale.
The Signal Quality Indicator will be illuminated to monitor acoustic coupling.

Choose a filter setting other than 0.1 Hz (average) on the flowmeter.
Move the probe back & forth in the water. The digital display will change slowly (due to the average process) as the flowmeter measures flow; the needle on the analog meter will move rapidly back and forth indicating instantaneous pulsatile flow.

5) **Invert Button reverses the polarity of the probe.**
Move the submerged probe toward you:
The meter will register flow in either a positive or negative direction.
Move the submerged probe in the opposite direction.
The meter indicated flow of opposite sign.
Press the Invert button so that the directional arrow is illuminated.
Notice how the apparent direction of flow has changed when the probe is now moved through the water.

6) **Low Range button changes the scale of the probe to measure low flow ranges.**

Observe how the displayed flow reading becomes more sensitive when the Low Flow Range is engaged. Probe movement in the water will produce 4 times the needle deflection on the analog meter.

Switch flowmeter mode to "Scale." Notice that the scale is reduced to 25% or 1/4 the normal scale of the probe .

2. Flowmeter Operation

FLOWMETER OPERATION

Once the perivascular Flowsensor is submerged:

Connect flowmeter to power source.

Turn on “Power” switch *(*rear panel, power entry module).

Plug Flowprobe into “PROBE” connector on the flowmeter’s front panel using supplied probe extension cable.

Engage TEST mode. Verify that the DIGITAL DISPLAY indicates the proper probe size with “Gd” signal strength and that the ANALOG METER shows proper (near 1.0) ultrasonic signal coupling in the probe.

Operate “CALIBRATE ZERO” and “SCALE” modes to calibrate external recording apparatus, in volume flow units (See following Data Acquisition Section).

Engage “MEA” mode to take volume flow measurements.

Use function buttons as needed:
“INVERT” (to reverse sign of recorded flow);
“LO FLO” (to give a 4-fold gain to analog flow signals);
“OUTPUT FILTER” functions (to select the proper band width for average/pulsatile flow registration).

FLOWMETER CARE

Exterior flowmeter surfaces can be cleaned using a cloth or brush dampened with soapy water, followed by damp wiping with clear water. For disinfection, the surface can be damp-wiped clean with isopropyl alcohol.

Do not drip liquids into the meter cabinet. A flowmeter exposed to accidental spillage should be unplugged immediately from its power source. Remove the cover. If the spilled fluid is potentially corrosive or may leave a residue, flood the area of the spill with water, using care not to disturb components or wires. Compressed air may be used to blow liquid off components, repeating the rinse and air-blowing if the spilled liquid is other than water. Remove remaining moisture with a heat gun. **Do not operate the flowmeter in a wet condition; keep it in a dry environment.**

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3. Using Perivascular Flowprobes

CLEANING AND STERILIZATION

Disassemble probe before use, keeping all of parts of each probe together because parts are not interchangeable among probes. Thoroughly wash the Flowprobe and its reflector bracket in soap and warm water (≤ 55°C, 130°F). Remove any visible foreign material with a soft-bristled brush. Reinstall the reflector bracket in the alignment groove recessed on either side of the probe body taking care not to distort the shape of the groove or bracket. Proper reflector alignment is crucial for measurement accuracy. The CM4-style (4-pin) implantable connector can be cleaned following standard scrubbing procedures but cannot be taken apart because it is hermetically sealed. The CRA10-style (10-pin) connector should not be submerged but may be cleaned with alcohol-wipes. To aid drying, rinse briefly in 90% ethanol. The Flowprobe should never be boiled or autoclaved. STERRAD or standard hospital cold (≤ 60°C, 140°F) ethylene oxide gas sterilization is acceptable. The probe may be rinsed and wiped in 90% ethanol alcohol before sterilization.

INTRA-OPERATIVE PREPARATION

At least 10 minutes before acute use, submerge the perivascular Flowprobe in sterile saline. This “soaking” of the probe eliminates a random drift in zero offset which a dry probe may exhibit when applied to a vessel. *(If only chronic measurements are needed, the 10-minute probe soak may be omitted.)* The Flowprobe has been factory calibrated to meet Transonic Flowprobe Specifications when applied to a living vessel *(see package insert sheet)*. If a more precise zero baseline than that specified is needed, the probe’s zero must be obtained in situ by vessel occlusion. A zero reading in a beaker of liquid generally will differ from an *“in situ”* zero.

VESSEL SITE SELECTION

The Flowprobe is largely insensitive to turbulence and/or vessel/probe alignment and may be applied effectively on straight segments or near side branches of the vessel. When applied on a curved segment of the vessel, the plane defined by the probe’s transducers and reflector bracket should be perpendicular to the plane defined by the curve of the vessel.

VESSEL PREPARATION

Use blunt dissection to free just that section of the vessel to which the probe will be applied; you need not “clean” it for ultrasonic permeability, but carefully remove all fatty tissue in the probe’s acoustic pathway. Try not to deflect the vessel from its natural course. If absolute flow into or out of an organ is a study parameter, all unligated side branches between the measurement site and the organ must be occluded during flow measurements.

FLOWPROBE CARE

Wash a perivascular Flowprobe thoroughly after use according to instructions for cleaning and sterilization. If a connector becomes wet, drying overnight in an incubator oven (≤ 60°C, 140°F) is recommended. Inspect cables routinely for damage. Store the dry probe at room temperature.

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3. Using Perivascular Flowprobes *cont.*

PROBE APPLICATION

The Flowprobe is applied so that the vessel under observation lies within the sensing window formed by the probe's transducer body and the attached reflector bracket. The optimal alignment is to have the vessel run perpendicularly through the probe's window. The Flowprobe may be oriented in either direction relative to upstream/downstream flow; a preferred orientation allows an easy exit for the cable.

Acute Application

Excessive vessel manipulation may cause vessel spasm and should be avoided. Often, securing the Flowprobe in place with a temporary suture is helpful for preventing vessel occlusion or twisting. For proper function, the space between the circular vessel and the rectangular reflector bracket must be filled with a suitable ultrasonic couplant.

Standard Couplants

For acute applications, proper ultrasonic contact between probe and vessel must be provided using an acoustically matched couplant (see Acoustical Couplants for Acute Measurements [Technical Note #9]. Surgilube, H-R Lubricating Jelly are recommended couplants. Banked blood (if the site's geometry is suitable) may be applied to provide this acoustic coupling between vessel and Flowprobe but should not be used for small vessels. At a highly pulsatile site, movement of a liquid couplant within the sensing window will be measured as flow and will affect net measurement. For accurate measurements, the vessel should fill 75% - 99% of the Flowprobe lumen. This will eliminate probe positional sensitivity. It is also easier to maintain coupling with a close fitting probe as less gel is required and surface tension will hold gel in place. Proper coupling is verified by observing the meter's diagnostic messages in "TEST" mode. On the digital panel meter, the (probe size)-"Gd" must be displayed. The analog panel meter must indicate a probe relative received signal strength which exceeds 60% of the probe's reading in saline *(e.g., a new probe will show around 1.0 in saline; its acute reading must exceed 0.6.)* A low signal strength reading indicates that air bubbles and/or fat particles are in the acoustic window. They must be removed before the probe can attain its stated measurement accuracy.

Chronic Application

For chronic implants, the probe must be secured in place to maintain its proper alignment with the vessel without impeding flow once the preparation is closed. Standard probe/reflector combinations come factory-prepared with suture holes and eyelets to allow for this suturing. The proper method to secure a probe in place depends on the application site: Transonic Surgical and Technical Application Notes offer for some tried and proven methods. Generally, three sutures suffice to secure a probe's position and orientation *(often for an R-Series probe with sliding cover, two sutures through the reflector brackets and one around the probe cable)*. For probes supplied with silicone sheathing, sutures also may be made through the silicone. If standard suture placements are not satisfactory for your application, contact the factory for a custom probe modification. For only chronic measurements, no ultrasonic couplant is necessary during implantation. Fibrous encapsu-lation of the probe within the first week of implant will yield a stable, air bubble-free coupling.

IV. Guarantee, Service, Warranty

LIMITED WARRANTY

1. Transonic Systems Inc. warrants for a period of one (1) year from date of shipment that the electronic flowmeter is free from defects which are the result of faulty material or workmanship by Transonic Systems Inc.
2. Transonic Systems Inc. warrants for a period of six (6) months from date of shipment that the perivascular ultrasonic Flowprobe, in-line Flowprobe and the clamp-on tubing Flowsensor are free from defects which are the result of faulty material or workmanship by Transonic Systems Inc.
3. The warranty of Transonic Systems Inc. shall not apply to:
   a) Defects caused by abuse, neglect or misuse
      (e.g., cut cable, pulled cable, broken probe body);
   b) Damage due to accident or casualty; or
   c) Unauthorized alterations; repairs made by anyone other than Transonic Systems Inc.
4. Transonic Systems Inc. will, at no cost to the user, either repair or replace a defective flowmeter or Flowprobe during its warranty period. The Buyer pays shipping charges to the Transonic Systems Inc. plant. Transonic will pay for return shipment charges.

4\. No other warranty oral or written, expressed or implied. Transonic Systems is not liable for incidental or consequential damages.

5\. Warranty is valid only if equipment is purchased through Transonic Systems or its duly appointed distributor or licensed representative.

1 - YEAR FREE MAINTENANCE AGREEMENT

Annual recalibration (available for a modest fee) is recommended for all Transonic research flowmeter products. If measurement accuracy is questioned during one year, Transonic Systems Inc. shall inspect and recalibrate the electronic flowmeter free of charge provided that Buyer pays for all freight in shipping the electronic flowmeter to the Transonic Systems Inc. factory (in Europe: to European Services).

V. Factory Repair

Telephone assistance is provided to help customers analyze problems. Factory repair service is available for malfunctioning equipment. Before returning a product for repair, call Transonic Customer Service for a RMA (return material authorization) number. Equipment returned to manufacturer per instructions below.

EQUIPMENT RETURN INSTRUCTIONS

(1) Call Transonic Systems Customer Service for a RMA (return material authorization) number.

(2) Please use the Transonic Systems shipping carton for returning meter equipment. If you need a carton, contact Customer Service at 800-353-3569 or 607-257-5300.

(3) Lift the instrument with its foam padding into the box.

(4) Place between meter and box, in the space around the flowmeter,
Extension cords,
Power cords,
Probes (individually packaged with their parts).

(5) On top of the flowmeter place:
PROBE RECORD OF USE and any correspondence you would like to include.
Seal the cover of the box.

(8) As a carrier for return, United Parcel Service (UPS) is recommended for all shipping.
Ship to our factory address:

TRANSONIC SYSTEMS INC.
34 Dutch Mill Road
Ithaca NY 14850

(9) If you have any questions, please call Customer Service at:
TEL: 800-353-3569 or 607-257-5300; or FAX: 607-257- 7256.

Appendices: Flowprobes & Flowsensors

Appendix A: Precision Flowprobes and Flowsensors for 400-Series Flow Modules

Precision Perivascular Flowprobes

Precision PXL Clamp-on Tubing Flowsensors

Precision PXN Inline Tubing Flowsensors

Appendix B: Technical Notes

General

Perivascular Flow Measurement

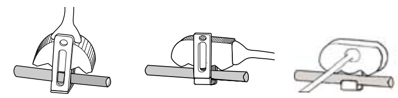
Tubing Flow Measurement

Cable Orientation

CABLE: MC1.5PSL-JN-WM40-CA4S-GC

Code	Orientation	PS-Series	PR-Series
B	Back	0.5 - 20	1 - 1.5
S	Side	0.5 - 20	1
L	Lateral	1.5 - 2.5	NA

Description



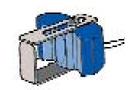
B-Back perpendicular to vessel — S-Side: parallel to vessel — L-Lateral (for thoracotomy)

Reflector Styles

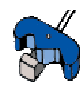
***REFLECTOR STYLE: MC1.5PSL-JN-WM40-CA4S-GC** *PS & PR-Series only

Code	Description	PS-Series	PR-Series
LS	L reflector w/slide cover	3 - 20	NA
LSF	L w/slide & silicone flange	3, 4, 6	NA
JN	J reflector, no slide (lateral cable orientation)	0.5 - 16	1 - 1.5
JS	J reflector with slide cover	2 - 16	1 - 1.5
JSF	J w/slide & silicone flange	2, 2.5	NA
U	Stainless U reflector	3 - 20	NA
U SW	U w/wide silicone shield	6 - 20	NA
U SN	U w/narrow silicone shield	6 - 20	NA
MRI	non-magnetic reflector	2 - 20	NA

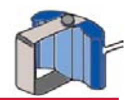
Styles



L with slide



J



U

Probe Cable Lengths

CABLE LENGTH: MC1.5PSL-JN-WM40-CA4S-GC

Code	Description	PS-Series	PR-	PAX-
WM xxx	Up to 600 mm (60 cm)	Nanoprobes	NA	NA
WC xx	Up to 60 cm	NA	1 - 1.5	NA
WC xxx	Up to 100 cm	2 - 20	custom	NA
WC xxx	Up to 200 cm	NA	NA	8 - 36

(Substitute desired cable length in cm or mm for xx)

Connector Styles

CONNECTORS: MC1.5PSL-JN-WM40-CA4S-GC

Code	Description	400 Key required	PS-	PR- Series	PAX-
	10-Pin for Use with CRA10 extension cables				
CRA10	Redel acute connector	No	— all sizes —		
CRS10	Redel sealed connector w/cap	No	— all sizes —		
	12-Pin for Use with CM12 extension cables				
CB12	Titanium skin button w/cap	No	— all sizes —		
	4-Pin for Use with CM4 or CA4 extension cables				
CM4B	Mini connector w/cap (straight)	Yes	— all sizes —		NA
CM4S	Mini connector w/cap (right angle)	Yes	— all sizes —		NA
CA4B	Micro connector (straight)	Yes	0.5 - 10		NA
CA4S	Micro connector (right angle)	Yes	0.5 - 10		NA
CTSB4	Delrin skin button	Yes	— all sizes —		NA
CB4	Titanium skin button	Yes	— all sizes —		NA

(for descriptions, see connector page)

Calibration

CALIBRATION: MC1.5PSL-JN-WM40-CA4S-GC

Code	Description	PS-Series	PR-Series	PAX-Series
GA	Acute Calibration	— All sizes—		
GC	Chronic Calibration	— All sizes—		Acute only
GX	Custom Calibration	— All sizes—		

Standard calibration for perivascular probes is blood at 37ºC
Specify custom temperature or fluid.

Acute Use Flowprobes

Catalog # MA ___ ___ *___ * PR & PS-Series only

size series cable orientation

Examples:

MA 2 PS S (Acute use 2 mm PS-Series probe, side cable exit)

MA 0.5 PS B (Acute use 0.5 mm PS-Series Precision probe, back cable exit)

MA 20 PAX (Acute use 20mm PAX-Series cardiac output probe)

Provided with standard configuration for acute use

- Size determined by vessel outer diameter in mm
- Maximum cable length for size
- CRA10 Redel connector to TS420 Flow Module
- Acute Calibration

Custom Configured Flowprobes

Custom configured probes are available for most probe series to meet individual application and implant needs. Contact Customer Service for species/vessel recommendations or configure probes from the table codes. Please note intended application for confirmation when ordering custom probes. Custom probes cannot be exchanged.

Catalog # MC ___ ___ *___ - *___ - ___ - ___ - ___

size series cable orient. reflector cable length connector calibration

* PR & PS-Series only

Application (species/vessel) ______________

Custom constructed catalog numbers help for reordering flowprobes

Examples:

MC 1.5 PS L - JN - WM40 - CA4S - GC

(1.5mm PS-Series, lateral cable, J-reflector, 40 mm probe cable, CA4S connector, chronic calibration)

Configured for chronic implant on mouse ascending aorta.

MC 20 PAX - WC60 - CRS10 - GA

(20 mm PAX probe, 60 cm cable length, CRS10 connector, acute calibration)

Cardiac output probe for implant in dog.

MC 3 PS B - MRI - WC100 - CRA10 - GA

(3 mm PS-Series probe with back cable orientation, non-magnetic components, 100 cm probe cable, CRA10 connector, acute calibration)

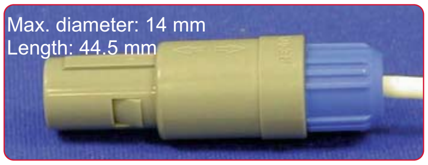
Probe configured for acute pig coronary flow during MRI.

Transonic Systems Inc.
Tel: 800-353-3569(USA); Fax 607- 257-7256; www.transonic.com
Europe: Tel: 31 43 407 7200; e-mail: info@transonic.nl; Fax: 3143 407 7201

Appendix A: Flowprobe Connectors

10-Pin Connectors

CRA10 Redel Plastic Acute Connector



Standard for Acute Use (MA-) Probes: Plugs directly into flowmeter or extension cable. 10-pin; Probe ID eprom inside.

CRS10 Redel Sealed Connector & Cap

10-pin Implantable plastic connector has conical threaded cap with suture hole for easy subcutaneous tunneling. Cap contains sealing gasket. Plugs directly into flowmeter or extension cable. Probe ID eprom inside.

Cap diameter: 15.3 mm
Shank diameter: 11.1 mm
Length: 40.3 mm

Accessories for Acute Applications

Acoustic couplant gel is used to displace the air between the flowprobe and the vessel during acute application because air will block transmission of the ultrasound signal. Appropriate coupling gels for use with Transonic flowprobes have acoustic properties at various temperatures that closely match blood. See TN #9 for complete listing.

Surgilube: (# ZC510 4.25 oz. tube**)** Bacteriostatic Surgical Lubricant from E. Fougera & Co.

H-R Jelly (discontinued): Water soluble hospital lubricant

NALCO 1181 (# APNALCO 6 oz.**)**: Superabsorbant powder to thicken Surgilube gel for long experiments. For terminal use only.

MRI Compatibility

Transonic ultrasonic transit time flowprobes can be made from nonmagnetic components for flow measurements during magnetic resonance imaging.

Contact Customer Service to special order: ceramic or brass reflector, nonmagnetic connector, probe ID key for use with extra long extension cables.

4-Pin Connectors

CA4B & CA4S
Micro 4-pin Connector

Diameter: 4.1 mm
Height:10 mm

CA4B (straight), **CA4S** (right angle): Minimal impact connectors, the 4-pins terminate the probe cable with a bare minimum of housing. Use with 4-pin extension cables. Comes with probe ID eprom key. CA4B (straight cable entry) can be threaded into spring stock for use with electrical swivels. CA4S connectors have a right angle cable entry and can be stabilized in the mid-scapular region with a rigid or silicone cuff. For rats and mice.

CM4S & CM4B
Mini Sealed Connector with Cap

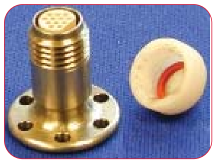
CM4S (right angle), **CM4B** (straight): Implantable plastic connectors come with a threaded cap with suture hole, sealing gasket, and probe ID eprom key. Use with 4-pin extension cables. CM4B has a straight cable entry to ease tunneling subcutaneously and can be stored in an animal jacket pocket when not in use. The CM4S connector has a right angle cable entry and is used with silicone or rigid cuffs to stabilize connector in mid-scapular region. Can be used for rats, rabbits, dogs and most small animal species.

Probe ID Key for TS420 Flow Module

Flowprobes configured with 4-pin and skin button connectors require probe ID Keys. Probe scale, signal normalization and calibration gain are programmed into the serialized eprom key. Keys plug into a port on the TS420 module during probe use.

Skin Button Connectors

CB12 Titanium Skin Button with Cap


CB12 open


CB12 with flat cap

Cap diameter.: 11.5 mm;
Shank diameter: 9.4 mm;
Total height:with cap: 21.5 mm
Flange diameter. 18.3 mm

For long term implantation. Available for any style perivascular probe including PAX-Series cardiac output probes. The probe ID eprom is integrated in the connector and there is no need for a separate eprom key. The connector comes with a flat Delrin cap. A pointed cap (CB-12-PC) can also be ordered separately. Use with 12-pin extension cables. For dogs, pigs and other large animals.

CTSB4 Delrin Skin Button

A low cost skin button with anchor flange made from Delrin plastic. 4-pin connector comes with probe ID eprom key. Use with 4-pin extension cables. For rabbits, dogs & similar species. Not for use with PAX-Series probes.

CB4 Titanium Skin Button

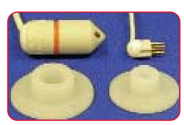
For long term implantation. 4-pin connector comes with probe ID eprom key. Can be ordered with initial anchor cuff; special order. Use with 4-pin extension cables. For dogs & pigs. Not for use with PAX-Series probes.

Cap diameter: 8 mm
Shank: diameter 7.2 mm
height: 24 mm
Flange diameter: 15.9 mm

Accessories for Chronic Probe Implants

Silicone Cuffs for CM4S (# AAPC102); CA4S (# AAPC103)

Soft silicone cuffs for stabilizing mini connectors for short-term implant. Suture holes in base flange for attachment on top of skin. Supplied in packages of 10.



AAPC102
Diameter: 18.9 mm
Height: 5.4 mm
AAPC103
Diameter: 15 mm
Height: 5.4 mm

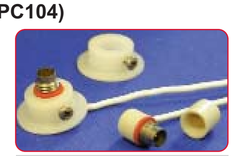
Rigid Cuff for CA4S Connector (# AAPC105)

Delrin cuff converts CA4S to a skin button for mice or rats. Four suture holes in corners; set screw to hold connector in place. Robust for long term or multiple use.

Dimensions
Diameter: 9 mm;
Height: 3.7 mm

Rigid Cuff for CM4S Connector (# AAPC104)

Delrin cuff converts CM4S mini-connector to a skin button for rats and rabbits. Suture holes for attachment on top of skin; set screw to hold connector in place. Robust for long-term or multiple use.



Dimensions:
Diameter: 19 mm
Height: 7.1 mm

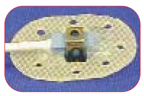
Appendix A: Probe Customization

Probe Customizations for Chronic Implant

Silicone Flange (-SF)

for coronary implants.

Mesh-reinforced silicone flange cemented around the perimeter of probe is sutured to the myocardium to stabilize the probe on the heart in LAD artery application; also used in umbilical artery (fetal sheep) application. Can also be used to hold coupling gel in place during acute experiments and to keep the probe riding on the beating heart.



2PSS (back view)

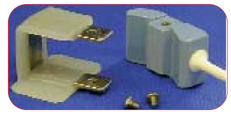
3PSB (back view)

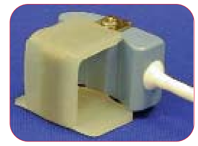
3PSB (front view)

Silicone Shields

U-reflectors on PS-Series probes may be silicone encapsulated for chronic implant.

Narrow Shield (-USN)





Cushions vessel for ascending aorta and pulmonary artery implant.

Wide Shield (-USW)

Stabilizes probe on collapsible vessels (i.e portal vein); keeps fat from infiltrating probe.

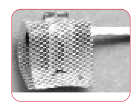
Probe & Connector Stabilization Products

Mersilene Mesh: (# APMERSILENE): 6 x 6” square soft interlocked polyester fiber mesh implanted under connector fortifies thin skin for cuff or button sutures. Also available from Ethicon (RM-L).

Prolene Mesh: (# APPROLENE): 6 x 6” square non-absorbable polypropylene mesh. For use with 14 - 36 mm PAX probes for chronic implant to protect the ascending aorta against long-term erosion. (Ethicon PMH)

Ultracell Sponge (# APSPONGE): Soft absorbable sponge for use with PAX-probes for chronic implant to cushion the ascending aorta against erosion. Package of 5.

Silicone Wrapping Strip (# APWRAP): Thin silicone strip reinforced with mesh wraps around outside of a probe to stabilize the probe on a vessel. Provides additional suture points to surrounding tissue and keeps fat from infiltrating the probe over long implants.



 # APWRAP

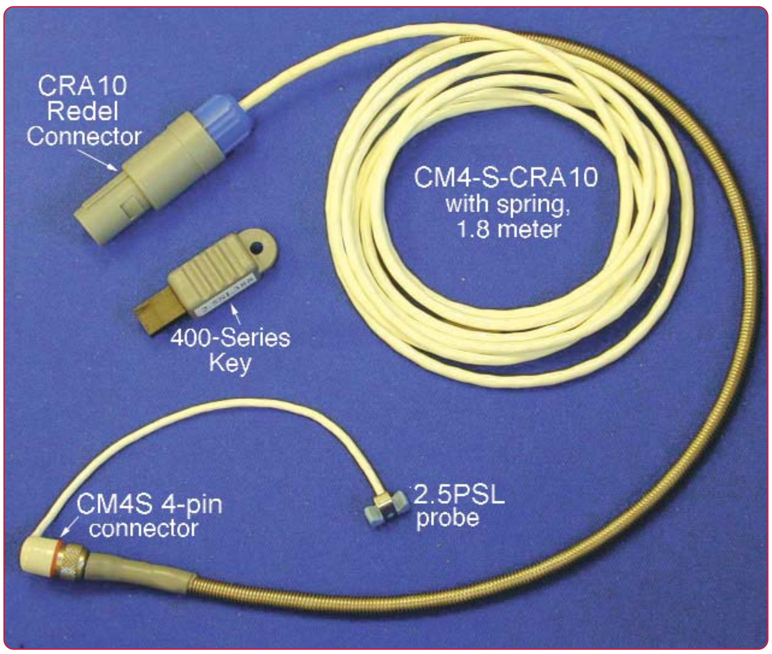
Extension Cables: TS420 Perivascular Probes

Catalog #	Type	Description
CRA10-S-CRA10	10-pin	1.25 meter standard length
CRA10-M2-CRA10	10-pin	2 meter (not for use with nanoprobes)
CRA10-M3-CRA10	10-pin	3 meter (not for use with nanoprobes)
CRA10-X-CRA10	10-pin	Custom length for MRI - specify
CM12-S-CRA10	12-pin	1.8 meter cable
CM12-X-CRA10	12-pin	Custom length specify
CM4-S-CRA10	4-pin	1.8 meter standard length
CM4-M3-CRA10	4-pin	3 meter (not for use with nanoprobes)
CM4-X-CRA10	4-pin	Custom length, no spring
CA4-S-CRA10	4-pin	Mouse cable, 1.8 meter standard length
CH10-M2-CRA10	Conversion for TX06 probes	2 meter length; probes require 400 ID keys

A Word about the Calibration of Our Flowprobes

Transonic Precision Perivascular Flowprobes are precalibrated for absolute blood flow measurement at 37 Cº using a gravity-fed constant flow bench setup with water at prescribed temperatures (see TN # 5). We calibrate probes for their intended use (acute vs. chronic) to compensate for the different acoustic conditions when using an acoustic gel in acute applications versus fibrotic tissue infiltration that stabilizes the probe in a chronic implant. Probes calibrated for acute use are calibrated to read 10% higher than probes for chronic implant (exception: PAX- and A-series are only calibrated for acute use). Sub-acute applications of only 1 – 2 days more closely mimic an acute preparation and should be calibrated for such. Acute calibration is also recommended for probes that are used for both acute and chronic application since acute measurements are more often interpreted in absolute terms. Chronic protocols are generally evaluated in relative terms as changes in flow over time. Custom calibration for atypical use is available (ex: calibration for fish at 10 degrees Cº).

Probe with Connector and Accessories



Probe & Accessories: Composite picture of a 2.5PSL probe (MC2.5PSL-JN-WC10-CM4S-GC) connected to a CM4-S-CRA10 (1.8 meter) extension cable. The extension cable plugs into the front of the TS420 flowmeter module. The Probe ID key (for 4-pin connectors or skin buttons) must also be plugged into a port on the flowmeter module to provide probe calibration information.

Appendix A: Flowprobe Accuracy Specs

PS-Series, PR-Series, PAX-Series, PMP- & V-Series

Precision Probe Series	Vessel OD mm MA-Probes acute application	Vessel OD mm MC-Probes chronic application	Bidirectional Flow: Resolution[1] ml/min	Bidirectional Flow: Scale Settings[2] Low Flow ml/min	Bidirectional Flow: Scale Settings[2] Normal Flow ml/min	Bidirectional Flow: Maximum Range[3] ml/min	Accuracy: Zero Offset[4] ml/min	Accuracy: Absolute Accuracy[5] %	Accuracy: Relative Accuracy %	Ultrasound Frequency MHz
PS-Series Nanoprobes										
0.5PS	0.3 - 0.5	0.3 - 0.48	0.03	1.5	6	30	± 0.12	± 15	± 2	14.4
0.7PS	0.5 - 0.7	0.4 - 0.7	0.05	2.5	10	50	± 0.2	± 15	± 2	9.6
1.5PS	1.2 - 1.5	1.2 - 1.5	0.075	10	40	200	± 0.8	± 15	± 2	4.8
V-Series										
0.5 V	0.25 - 0.5	NA	0.05	2.5	10	50	± 0.25	± 15	± 3	7.2
0.7 V	0.35 - 0.7	NA	0.075	5.0	20	100	± 0.5	± 15	± 3	4.8
PR-Series										
1PR	0.7 - 1.2	0.7 - 1.0	0.05	5	20	100	± 0.2	± 10	± 2	7.2
1.5PR	1.2 - 1.8	1.0 - 1.5	0.075	10	40	200	± 0.4	± 10	± 2	4.8
PS-Series										
2PS	1.5 - 2.0	1.3 - 1.8	0.1	25	100	500	± 1	± 10	± 2	3.6
2.5PS	1.8 - 2.5	1.5 - 2.4	0.1	25	100	500	± 1	± 10	± 2	3.6
3PS	2.5 - 3.7	2.4 - 3.4	0.4	50	200	1L	± 2	± 10	± 2	3.6
4PS	3.3 - 4.4	3.0 - 4.0	0.8	100	400	2L	± 4	± 10	± 2	2.4
6PS	4.4 - 6.6	4.0 - 6.0	2.0	250	1L	5L	± 10	± 10	± 2	1.8
8PS	6.6 - 8.8	5.8 - 8.0	4.0	500	2L	10L	± 20	± 10	± 2	1.2
10PS	8.3 - 11.0	7.3 - 10.0	8.0	500	2L	10L	± 20	± 10	± 2	1.2
12PS	9.8 - 13.0	8.6 - 12.0	8.0	1L	4L	20L	± 40	± 10	± 2	0.9
14PS	11.3 - 15.0	10.0 - 14.0	16.0	1L	4L	20L	± 40	± 10	± 2	0.9
16PS	13.3 - 17.7	12.0 - 16.0	20.0	2.5L	10L	50L	± 100	± 10	± 2	0.6
20PS	16.0 - 21.0	14.0 - 19.0	40.0	2.5L	10L	50L	± 100	± 10	± 2	0.6
PAX-Series Cardiac Output Probes										
8 PAX	6 - 8	6 - 7	4	500	2L	10L	± 20	± 10	± 2	3.6
10 PAX	8 - 10	8 - 9	4	500	2L	10L	± 20	± 10	± 2	3.6
12 PAX	9 - 12	9 - 11	8	1L	4L	20L	± 40	± 10	± 2	2.4
14 PAX	11 - 14	11 - 13	8	1L	4L	20L	± 40	± 10	± 2	2.4
16 PAX	12 - 16	12 - 15	20	2.5L	10L	50L	± 100	± 10	± 2	1.8
20 PAX	16 - 20	16 - 19	20	2.5L	10L	50L	± 100	± 10	± 2	1.8
24 PAX	19 - 24	19 - 23	40	5L	20L	100L	± 200	± 10	± 2	1.2
28 PAX	22 - 28	22 - 27	40	5L	20L	100L	± 200	± 10	± 2	1.2
32 PAX	25 - 32	25 - 31	80	10L	40L	200L	± 400	± 10	± 2	0.9
36 PAX	28 - 36	28 - 35	80	10L	40L	200L	± 400	± 10	± 2	0.9
PMP-Series Handle Probes										
2 PMP	1.5 - 2.5	NA	0.1	25	100	0.5	± 1	±15	±2	3.6
3 PMP	2.5 - 3.7	NA	0.4	50	200	1.0	± 2	±15	±2	3.6
4 PMP	3.3 - 4.4	NA	0.8	100	400	2.0	± 4	±15	±2	2.4
6 PMP	4.4 - 6.6	NA	2.0	250	1L	5.0	± 10	±15	±2	1.8
8 PMP	6.6 - 8.8	NA	4.0	500	2L	10.0	± 20	±15	±2	1.2
10 PMP	8.3 - 11.0	NA	4.0	500	2L	10.0	± 20	±15	±2	1.2
12 PMP	9.8 - 13.0	NA	8.0	1L	4L	20.0	± 40	±15	±2	0.9
14 PMP	11.3 - 15.0	NA	16.0	1L	4L	20.0	± 40	±15	±2	0.9

[1] Resolution: represents the smallest detectable change in flow, a factor in accuracy.

[2] Transonic Flowprobes operate in one of two scales: low flow or normal flow, determined by the range of flow under study. Flowprobes measure bidirectional flow up to 5 times the selected scale setting. The scale settings calibrate the 1 volt reference signal for data collection; the linear range of the flowmeter is equal to ± 5 volts. By using the "low flow button", measurement sensitivity is increased by a factor of four. For example, a 3PS probe set on "lo flo" can process and display up to 5 x 50 ml/min, or 250 ml/min. This linear overrange is important for the proper recording of highly pulsatile peak flows.

[3] Maximum Range for each probe reflects the highest flow rate that can be processed and displayed via the analog connector.

[4] Zero offset on individual probes is often lower than this value and will be specified in the Probe Data Sheet supplied with the probe.

[5] In all cases, the Absolute Accuracy percentage can be raised to relative accuracy levels (± 2%) by *in situ* calibration.

RL-20a Precision Probe Accuracy Specs, Rev. 8-05

RL-20b Physical Probe Specifications, Rev. 8.03

PS-Series, PR-Series, PAX-Series, PMP- & V-Series

Nanoprobe	Weight gram	Length mm	Width mm	Depth mm	Lumen mm	Max. Cable Length cm	Cable Diameter mm
0.5 PS	0.09	3.2	2.3	1.0	0.47	60	1.0
0.7 PS	0.12	3.2	2.7	1.2	0.70	60	1.0
1.5 PS	0.23	4.25	3.75	2.0	1.65	60	1.25

V-Series	Probe Body			Reflector				Cable	
	Wgt gram	Length mm	WidthP mm	Height1 mm	Height2 mm	WidthR mm	Handle cm	Length cm	Diameter mm
0.5 V	0.2	6.5	4.0	1.1	1.5	2.0	5	60	1.5
0.7 V	0.25	7.6	3.5	1.8	1.7	2.5	5	60	1.5

PR-Series	Probe Body			Reflector			Cable	
	Wgt gram	Length mm	WidthP mm	Height1 mm	Height2 mm	WidthR mm	Length m	Diameter mm
1 PR	0.2	6.5	4.0	1.1	1.5	2.0	60	1.5
1.5 PR	0.25	7.6	3.5	1.8	1.7	2.5	60	1.5

PS-Series	Probe Body			Reflector			Cable	
	Wgt gram	Length mm	WidthP mm	Height1 mm	Height2 mm	WidthR mm	Length m	Diameter mm
2 PS	0.3	8.7	3.3	2.5	2.0	3.3	1.0	1.5
2.5 PS	0.3	8.7	3.3	2.5	3.2	3.3	1.0	1.5
3 PS	1.2	9.0	5.0	3.7	4.0	3.5	1.0	1.5
4 PS	1.5	13.3	6.0	4.4	5.5	3.8	1.0	2.0
6 PS	2.7	13.5	6.7	6.6	7.8	4.0	1.0	2.5
8 PS	5.0	18.8	7.5	8.8	8.2	6.0	1.0	2.5
10 PS	5.3	18.7	8.5	11.0	10.0	6.0	1.0	2.5
12 PS	9.3	22.5	8.5	13.0	12.0	6.2	1.0	3.0
14 PS	11.6	26.2	8.5	15.0	14.5	7.5	1.0	3.0
16 PS	16.6	36.0	10.0	17.7	17.0	9.0	1.0	3.0
20 PS	20.2	31.0	9.0	21.0	21.0	9.0	1.0	3.0

PAX-Series	Probe			Cable	
	Wgt gram	ID inner diameter mm	Width mm	Length m	Diameter mm
8 PAX	3	8	5	2.0	1.5
10 PAX	5	10	7.4	2.0	1.5
12 PAX	7	12	8	2.0	1.5
14 PAX	12	14	9	2.0	1.5
16 PAX	14	16	10	2.0	2.0
20 PAX	15	20	12	2.0	3.0
24 PAX	20	24	15	2.0	3.0
28 PAX	30	28	17	2.0	3.0
32 PAX	40	32	20	2.0	3.0
36 PAX	50	36	22	2.0	3.0

PMP Series	Probe Body			Reflector			Length	Cable	
	Wgt gram	Length mm	WidthP mm	Height1 mm	Height2 mm	WidthR mm	w/Handle mm	Length m	Diameter mm
2 PMP	14	7	5.1	2.7	3.0	3.0	175	2.0	2.2
3 PMP	17	9	7.2	3.5	4.0	4.0	175	2.0	2.2
4 PMP	17	12	9.8	4.7	5.0	5.3	175	2.0	2.2
6 PMP	17	14	9.3	6.6	7.8	4.3	175	2.0	2.2
8 PMP	21	19	9.3	8.8	8.2	6.0	175	2.0	2.2
10 PMP	21	19	8.5	11.0	10.0	6.1	175	2.0	2.2
12 PMP	21	22	9.5	13.0	12.0	6.3	175	2.0	2.2
14 PMP	26	27	11.0	17.5	14.5	7.6	175	2.0	2.2

Key

Probe Body

L = length of probe body along vessel

WP = width of probe body

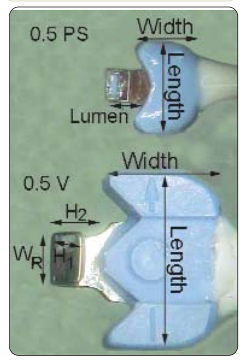
Wgt = without connector

Reflector

WR = width of reflector

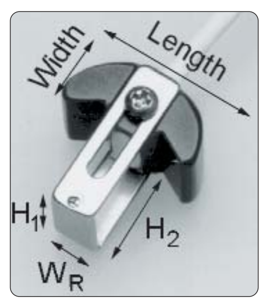
H1 = height of reflector

H2 = distance from end of reflector to body of probe. Approximates the probe's lumen.

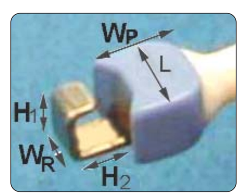


Nanoprobe & V probe Comparison

PAX-Series



PS-Series

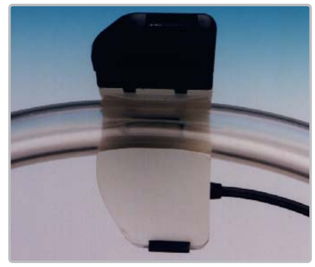


PMP-Handle Probe Body

Appendix A: PXL Tubing Flowsensors

ME-PXL *Clamp-on* Flowsensors *(Sterile Tubing Flowsensors)*

Transonic Precision ME-PXL-Clamp-on Tubing Flowsensors clip on the outside of flexible laboratory. No physical contact is made with the fluid media. ME-PXL-Series flowsensors can be calibrated and programmed for up to 4 different fluid, temperature, tubing, flow rate combinations. Sensor size is determined by outside diameter of the tubing. Standard MEPXL sensors are sized in 1/16” increments. (Custom sizes are available for metric tubing).



How to Chose the Most Appropriate Clamp-on Sensor

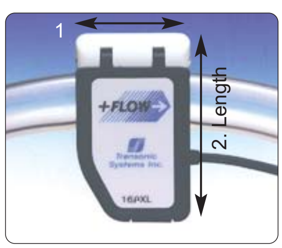
Flowmeter Compatibility: TS410 400-Series Flowmeter Module

Size: Sensors are scaled to clamp around outer flexible tubing diameter. Transmitting the ultrasound signal through the tubing wall requires a snug fit, so the sensor size is dependent on the tubing of the circuit. PXL sensors are sized in 1/16 inch increments to match the standard tubing diameters used in medical and laboratory settings. PXL sensors may be special ordered for tubing sized in mm.

Tubing: Medical grade and laboratory tubings (PVC, silicone, polyurethane) are generally compatible for use with PXL-Sensors. Rigid PVC and acrylic (Lucite) are not. We stock several standard tubing types. For other tubing types, a 30-60 cm sample is required for sensor calibration.

Expected Flow Rate: All PXL sensors have two dynamic flow ranges: standard flow range (full scale) and low flow range (1/4 scale). PXL sensors are factory calibrated for the highest accuracy in the specified flow range. To meet performance specifications, indicate low or standard flow when ordering. If no flow range is indicated, PXL sensors will be calibrated in the standard flow range. Calibration for accuracy at flows below the lower linear limit may be requested and will be assessed an extra charge.

Fluid / Temperature Calibration: Since fluid density and temperature alter the transit time of the ultrasound signal and affect the acoustic properties of the tubing, we calibrate the sensor specifically for these parameters. Specify up to 4 tubing, fluid, temperature, flow rate combinations for calibration. Fluid samples and MSDS information may be required for custom calibration requests.



Physical Specifications*

Sensor Size	1. Dimension Along Tube		2. Height		3. Length	
Catalog #	inch	mm	inch	mm	inch	mm
2PXL, 3PXL	0.82	20.8	0.67	17.0	1.25	31.6
4PXL, 5PXL	0.89	22.7	0.80	20.3	1.39	35.2
6PXL	0.96	24.3	0.88	22.3	1.54	39.1
7PXL	1.01	25.6	0.97	24.5	1.66	42.1
8PXL	1.09	27.7	0.95	24.0	1.74	41.3
9PXL	1.30	32.6	0.97	24.6	1.83	46.5
10PXL	1.24	31.6	1.06	26.9	1.99	50.5
11PXL	1.37	34.8	1.11	28.3	2.19	55.8
12PXL	1.50	38.1	1.21	30.7	2.40	60.9
14PXL	1.63	41.2	1.40	35.5	2.59	65.8
16PXL	1.85	46.9	1.54	39.3	2.95	74.9
20PXL	2.29	58.2	1.79	45.6	3.67	93.4

* Subject to modification

Catalog # ME ___ PXL ___ - ___ ___ - ___ ___ - ___ ___ - ___ ___

Size — * suffix if OD = mm — Fluid/Temperature + Flow Rate Calibration Codes (up to 4)

Tubing: ________________________________

Example 1: **ME9PXL - BL37 SF – GL23 SF – GL23 LF**
calibrated for 3 different uses:
1. Blood at 37ºC at Standard Flow Rate;
2. 40% Glycerine/60%Water at Standard Flow Rate;
3. 40% Glycerine/60%Water at Low Flow Rate.

Example 2: **ME9PXL - M14 – BL37 SF – H2023 LF**
for 14 mm OD tubing
calibrated for 2 different uses:
1. Blood at 37º C at Standard Flow Rates
2. Water at 23º C at Low Flow Rates

How to Order

- Choose the sensor size that matches your tubing OD;
- Specify tubing type. Supply sample if your tubing is not on our standard tubing list;
- Specify anticipated flow range;
- Specify fluid and temperature for calibration;
- Use the codes below to construct catalog number;
- Contact Customer Service for any non-standard requests.

Sensor	Tubing (inches) OD	ID x Wall	Stock Tubing
2 PXL	1/8	3/32 x 1/32	Tygon S-50-HL, Tygon R-3603
3 PXL	3/16	1/8 x 1/32	Tygon R-3603
4 PXL	1/4	- x -	No Stock Tubing
5 PXL	5/16	3/16 x 1/16	Tygon R-3603
6 PXL	3/8	1/4 x 1/16	MEDIFLEX, Tygon R-3603, Tygon S-50-HL
7 PXL	7/16	1/4 x 3/32	MEDIFLEX, Tygon R-3603, Tygon S-50-HL
8 PXL	1/2	3/8 x 1/16	Tygon R-3603, Tygon S-50-HL
9 PXL	9/16	3/8 x 3/32	BENTLY BYPASS 70, MEDIFLEX, Tygon R-3603, Tygon S-50-HL
10 PXL	5/8	1/2 x 1/16	Tygon R-3603, Tygon S-50-HL
11 PXL	11/16	1/2 x 3/32	BENTLY BYPASS 70, Tygon R-3603 Tygon S-50-HL
12 PXL	3/4	1/2 x 1/8	Tygon R-3603, Tygon S-50-HL
14 PXL	7/8	5/8 x 1/8	Tygon R-3603
16 PXL	1	3/4 x 1/8	Tygon R-3603
20 PXL	1 1/4	1 x 1/8	Tygon R-3603

Metric Tubing OD	Clamp-on # with Suffix
4 mm	ME2PXL-M4
5 mm	ME3PXL-M5
6 mm	ME4PXL-M6
8 mm	ME5PXL-M8
9 mm	ME6PXL-M9
10 mm	ME7PXL-M10
12 mm	ME8PXL-M12
14 mm	ME9PXL-M14
16 mm	ME10PXL-M16
20 mm	ME12PXL-M20
23 mm	ME14PXL-M23
25 mm	ME16PXL-M25

Information Needed to Calibrate Sensor
- Tubing Type
- Fluid (blood, saline, other)
- Operational temperature
- Flow ranges expected

Clamp-on Flowsensor Calibration Ranges[1]

Sensor Size mm	Low Flow (1/4 Scale)[2] Lower Linear Limit[3,4]	Low Flow Maximum Measurement Range[5]	Standard Flow (Full Scale) Lower Linear Limit[4]	Standard Flow Maximum Measurement Range[5]
2PXL	50 ml/mm	-250 to +250 ml/mm	100 ml/mm	-1 to +1 L/mm
3PXL,4PXL,5PXL	100 ml/mm	-500 to +500 ml/mm	200 ml/mm	-2 to +2 L/mm
6PXL	250 ml/mm	-1.25 to +1.25 L/mm	500 ml/mm	-5 to +5 L/mm
7PXL,8PXL,9PXL	500 ml/mm	-2.50 to +2.50 L/mm	1 L/mm	-10 to +10 L/mm
10PXL,11PXL,12PXL	1 L/mm	-5 to +5 L/mm	2 L/mm	-20 to +20 L/mm
14PXL,16PXL	2.5 L/mm	-12.5 to +12.5 L/mm	5 L/mm	-50 to +50 L/mm
20PXL	5 L/mm	-25 to +25 L/mm	10 L/mm	-100 to +100 L/mm

[1]To meet accuracy specifications, flowsensors should be calibrated for the flow rate range of use.
[2]Flowsensors calibrated for the low flow range should be used with the flowmeter in "1/4 Scale Mode."
[3]Measurements below the Lower Linear Limit may deviate from +/-4% relative accuracy specification.
[4]Custom calibration is available for average flow rates below the lower limit. This may compromise accuracy for the maximum measurement range.
[5]Any flow peaks exceeding the Max Flow Value (-5 volt to + 5 volt flowmeter range) will be clipped.

Specifications

TUBING SENSOR	TUBING SPECIFICATIONS						ACCURACY SPECIFICATIONS							
	TUBING ID		WALL THICKNESS		TUBING OD		BIDIRECTIONAL FLOW OUTPUTS				ACCURACY[1]			ULTRA-SOUND
Catalog #	inches	mm	inches	mm	inches	mm	Resolution[2] ml/min	Low Flow (1/4 scale) 1 volt = ml/min	Standard Flow (Full Scale) 1 volt = ml/min	Max Flow in Standard Range 5 volt = L/min	Maximum Zero Offset ml/min	Absolute Accuracy %	Relative Accuracy %	Frequency MHz
ME 2PXL	In sizes 2PXL - 4PXL ratio of tubing				1/8 - 5/32	3.1 - 4.0	0.5	50	200					
3PXL	wall thickness to OD must not exceed				1	± 4.0	± 10	± 4	3.6					
	1:5 for PVC; 1:3 for silicone				3/16 - 7/32	4.7 - 5.5	1	100	400	2	± 8.0	± 10	± 4	3.6
4PXL	3/16	4.7	1/16	1.6	1/4 - 9/32	6.3 - 7.7	1	100	400	2	± 8.0	± 10	± 4	2.4 - 3.6
5PXL					1/4	6.4	1/16	1.6	3/8	9.5	2.5	250	1 L	5
6PXL	± 15	± 10	± 4	2.4										
7PXL	1/4	6.4	3/32	2.4	7/16	11.1	5	500	2 L	10	± 30	± 10	± 4	1.8
8PXL	3/8	9.5	1/16	1.6	1/2	12.7	5	500	2 L	10	± 30	± 10	± 4	1.8
9PXL	3/8	9.5	3/32	2.4	9/16	14.3	5	500	2 L	10	± 30	± 10	± 4	1.8
10PXL	1/2	12.7	1/16	1.6	5/8	5.9	10	1 L	4 L	20	± 60	± 10	± 4	1.2
11PXL	1/2	12.7	3/32	2.4	11/16	17.5	10	1 L	4 L	20	± 60	± 10	± 4	1.2
12PXL	1/2	12.7	1/8	3.2	3/4	19.0	10	1 L	4 L	20	± 60	± 10	± 4	1.2
14PXL	5/8	15.9	1/8	3.2	7/8	22.2	25	2.5 L	10 L	50	± 150	± 10	± 4	1.2
16PXL	3/4	19.0	1/8	3.2	1	25.4	25	2.5 L	10 L	50	± 150	± 10	± 4	1.2
20PXL	1	25.4	1/8	3.2	1 1/4	31.8	50	5 L	20 L	100	± 300	± 10	± 4	0.9

Calibration is dependent on tubing material, wall thickness, ultrasound velocity of liquid flowing through the tube, and temperature.

1a Absolute Accuracy is composed of zero stability, sensitivity and linearity errors. Stated values apply when flow rate is greater than 5% of maximum range and zero offset is nulled.

1b If the sensor is calibrated on-site for the tubing and liquid in use, absolute accuracy is further improved to the value listed as "Relative Accuracy."

1c On-site calibration is recommended if the sensor is routinely used to measure flows less than 5% of the maximum range to account for non-linearities associated with flow profile.

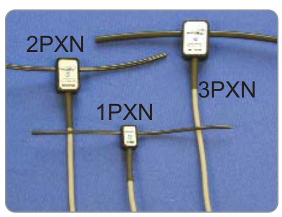
2 Resolution represents the smallest detectable flow change at 0.1Hz filter (average flow output).

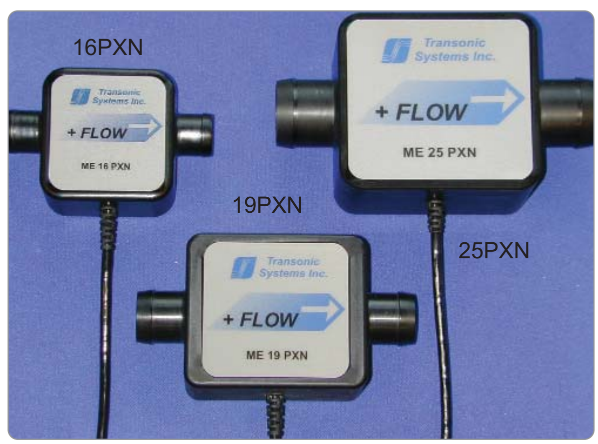
PXL specs RL-21, Rev. C 8-05

ME-PXN *Inline* Flowsensors *(InlineFlowsensors)*

PXN Inline Flowsensors splice into laboratory tubing and measure absolute volume flow of blood and other fluids. PXN inline sensors offer the most flexibility for flow measurement in circuits where tubing requirements have not been formalized. The new four-transducer sensor design offers precision flow accuracy for < 1 ml/min to 100 liters/min steady state and pulsatile flows. Flow range sensitivity is scaled to sensor size and flow is measured consistently across the sensor's full dynamic range with little effect from turbulence. The sensor's smooth round flow channel is easy to clean and and does not trap air bubbles that can degrade ultrasonic performance. Sizes 4PXN - 25PXN have barbed ultem tubing ends to mate easily with flexible laboratory tubing. Miniature sizes 1PXN - 3PXN sensors are fabricated around flexible Pebax tubing which may be cut to length for insertion into small tubing circuits or perfusion apparati. PXN-inline sensors can be calibrated and preprogrammed for up to 4 fluid, temperature, flow rate combinations for highest accuracy performance in:

- ✔ **Isolated organ studies**
- ✔ **Flow phantoms & circulatory models**
- ✔ **All applications requiring maximum volume flow sensitivity**





PXN Family of Inline Flowsensors

Appendix A: PXN Tubing Flowsensors cont.

Catalog # ME ___ PXN ___ ___ - ___ ___ - ___ ___ - ___ ___

Size — Fluid/Temperature + Flow Rate Calibration Codes (up to 4)

Example: ME4PXN - BL37 SF – KR37 SF – FX37 LF is calibrated for 3 different uses:
(Blood at 37ºC at standard flow rate; Krebs at 37ºC at standard flow rate;
custom cell culture at 37ºC at low flow rate)

How to Order

- *Choose the sensor size that will best match the circuit ID and anticipated flow rates;*
- *Specify the anticipated flow range when ordering;*
- *Specify calibration for fluid type and temperature;*
- *Use the codes below to construct catalog number.*
- ***Contact Customer Service for any non-standard***

INFORMATION NEEDED TO CALIBRATE SENSOR

- Fluid (blood, saline, other)
- Operational temperature
- Flow ranges expected

How to Choose the Most Appropriate Inline Sensor

Flowmeter Compatibility: TS410 400-Series Flowmeter Module

Size: Sizes are scaled to insert into flexible tubing internal diameter.
(See PXN specification table for ID and barb spec.)

Tubing Diameter: The sensor that most closely matches the circuit tubing ID should be used so that perturbations in fluid dynamics are minimized. Narrowing or steps down in tubing diameter can add resistance to flow.

Expected Flow Rate: Transonic flowsensor sizes are scaled to achieve the highest resolution in flow measurement. The smaller the sensor, the higher the sensitivity to low volume flows and the lower the offset at zero flow (see specifications table). All PXN sensors have two dynamic flow ranges: standard (full scale) and low flow (1/4 scale) (see table at right). PXN sensors are factory calibrated for highest accuracy in the specified flow range. To meet performance specifications, indicate low or standard flow range when ordering. If no flow range is indicated, PXN flowsensors will be calibrated for the standard range. Calibration for accuracy at flows below the Lower Linear Limit may be requested and will be assessed an extra charge.

Fluid / Temperature Calibration: Inline sensors for the TS410 may be calibrated for up to 4 fluid, temperature combinations. Fluid samples and a MSDS may be required for custom calibration requests.

INLINE FLOWSENSOR CALIBRATION RANGES[1]

SENSOR		LOW FLOW (1/4 SCALE)[2]		STANDARD FLOW (FULL SCALE)	
SIZE	ID mm	Lower Linear Limit[3,4]	Maximum Measurement Range[5]	Lower Linear Limit[4]	Maximum Measurement Range[5]
1PXN	1.2	5 ml/mm	-25 to +25 ml/mm	10 ml/mm	-100 to +100 ml/mm
2PXN	1.8	10 ml/mm	-50 to +50 ml/mm	20 ml/mm	-200 to +200 ml/mm
3PXN	2.4	25 ml/mm	-125 to +125 ml/mm	50 ml/mm	-500 to +-500 ml/mm
4PXN	3.2	50 ml/mm	-250 to +250 ml/mm	100 ml/mm	-1 to +1 L/mm
5PXN	4.8	100 ml/mm	-500 to +500 ml/mm	200 ml/mm	-2 to +2 L/mm
6PXN	6.4	250 ml/mm	-1.25 to +1.25 L/mm	500 ml/mm	-5 to +5 L/mm
10PXN	9.5	500 ml/mm	-2.5 to +2.5 L/mm	1 L/mm	-10 to +10 L/mm
13PXN	12.7	1 L/mm	-5 to +5 L/mm	2 L/mm	-20 to +20 L/mm
16PXN	15.9	2.5 L/mm	-12.5 to +12.5 L/mm	5 L/mm	-50 to +50 L/mm
19PXN	19.1	2.5 L/mm	-12.5 to +12.5 L/mm	5 L/mm	-50 to +50 L/mm
25PXN	25.4	5 L/mm	-25 to +25 L/mm	10 L/mm	-100 to +100 L/mm

[1]To meet accuracy specifications, flowsensors should be calibrated for the flow rate range of use.
[2]Flowsensors calibrated for the low flow range should be used with the flowmeter in “1/4 Scale Mode.”
[3]Measurements below the Lower Linear Limit may deviate from +/-2% linearity specification.
[4]Custom calibration is available for average flow rates below the lower limit. This may compromise accuracy for the maximum measurement range.
[5]Any flow peaks exceeding the Max Flow Value (-5 volt to + 5 volt flowmeter range) will be clipped.

Specifications

INLINE SENSOR	Physical Specifications						Accuracy Specifications							
	Tubing ID		Barb OD[1]		Dimensions[2]		Bidirectional Flow				Accuracy			Ultra-sound
Catalog #	inches	mm	inches	mm	Total Length w/ tube ends mm	Case Length w/out ends mm	Resolution at 10 Hz ml/min	Low Flow 1 Volt = ml/min	Standard Range 1 Volt = ml/min	Max Flow in Standard Range ml/min	Maximum Zero Offset[3] ml/min	Absolute Accuracy %	Non-Linearity[4] %	Frequency MHz
ME1PXN	3/64	1.2	Pebax		100	8.1	± 0.02	5	20	100	± 0.4	± 8	± 2	9.6
ME2PXN	1/16	1.8	Pebax		100	11.9	± 0.02	10	40	200	± 0.6	± 4	± 2	9.6
ME3PXN	3/32	2.4	Pebax		100	14	± 0.05	25	100	500	± 1	± 4	± 2	7.2
ME4PXN	1/8	3.2	0.16	4.0	24.9	15.7	± 0.1	50	200	1 L	± 2	± 4	± 2	4.8
ME5PXN	3/16	4.8	0.23	5.8	31.5	20.3	± 0.2	100	400	2 L	± 4	± 4	± 2	3.6
ME6PXN	1/4	6.4	0.3	7.6	40.6	25.9	± 0.5	250	1 L	5 L	± 10	± 4	± 2	2.4
ME10PXN	3/8	9.5	0.44	11.1	50.8	32.5	± 1	500	2 L	10 L	± 20	± 4	± 2	1.8
ME13PXN	1/2	12.7	0.58	14.7	69.1	44.7	± 2	1 L	4 L	20 L	± 40	± 4	± 2	1.2
ME16PXN	5/8	15.9	0.72	18.3	83.3	52.3	± 5	2.5 L	10 L	50 L	± 70	± 4	± 2	0.9
ME19PXN	3/4	19.1	0.86	21.9	101.1	64	± 5	2.5 L	10 L	50 L	± 100	± 4	± 2	0.9
ME25PXN	1	25.4	1.14	29.0	128	79.8	± 10	5 L	20 L	100L	± 200	± 4	± 2	0.6

[1]Subject to minor modification
[2]Standard cable length: 1.85 meters.
[3] Zero offset can be eliminated by Zero Adjustment prior to measurement.
[4] Within specified calibration range.

PXN specs RL-22, Rev. B 8-05

Tubing Sensors: Calibration, Connectors, Extension Cables

Calibration of Inline and Clamp-on Flowsensors

All Transonic flowsensors are supplied with a Certificate of Calibration traceable to NIST standards listing and dating any calibration that was performed. Tubing flowsensors are individually custom calibrated for your use. Calibration is performed for the specified fluid at a specified temperature/flow range. Blood calibrations are performed with an analog that matches the acoustic velocity of blood and a correction for blood is applied. Calibration is valid for 1 year. Recertification can be scheduled as required for GLP studies. The customer supplies any custom tubing or fluid samples.

Fluid/Temperature	**23ºC**	**37ºC**	**Custom Temp**
Water/Saline	H_2023	H_2037	H_20TX
Blood	BL23	BL37	BLTX
Glycerine 40%, Water 60% (by volume)	GL23	GL37	GLTX
Glycerine Custom Conc	GLX23	GLX37	GLXTX
Krebs Solution	KR23	KR37	KRTX
Custom Fluid	FX23	FX37	FXTX

Calibration Flow Range	**Catalog Number Code**
Standard Flow	**SF**
Low Flow	**LF**
Custom Lower Flow	**XF**

Glycerine calibration: custom for 1PXN, 2PXN, 3PXN

X = extra charge

TS410 Compatible Connectors

CP16: Plastic 16-pin for TS410
Standard on 1PXN-6PXN

CC16: Metal 16-pin for TS410
Standard on 10PXN - 25PXN;
Standard on small PXL sensors.

TS410 Extension Cables

Tubing sensors are normalized for use without extension cables. Extension cables are available for use with sensors size ME2PXN and larger.

CC16-S-CC16 — Standard 1 meter length
CC16-X-CC16 — Custom length for MRI use (specify; may not apply for all sensor sizes)

TN-30: Theory of Operation

TN#30-2 Rev. 10/02, Printed in the USA

A Transonic® perivascular Flowprobe (Fig. 1) consists of a probe body which houses ultrasonic transducers and a fixed acoustic reflector. The transducers are positioned on one side of the vessel or tube under study and the reflector is positioned at a fixed position between the two transducers on the opposite side. Electronic ultrasonic circuitry directs a Flowprobe through the following cycles:

Upstream Transit-Time Measurement Cycle

An electrical excitation causes the downstream transducer to emit a plane wave of ultrasound. This ultrasonic wave intersects the vessel or tubing under study in the upstream direction, then bounces off the fixed "acoustic reflector," again intersects the vessel and is received by the upstream transducer where it is converted into electrical signals. From these signals, the flowmeter derives an accurate measure of the "transit time" it took for the wave of ultrasound to travel from one transducer to the other.

Downstream Transit-Time Measurement Cycle

The same transmit-receive sequence is repeated, but with the transmitting and receiving functions of the transducers reversed so that the flow under study is bisected by an ultrasonic wave in the downstream direction. The flowmeter again derives and records from this transmit-receive sequence an accurate measure of transit time.

Just as the speed of a swimmer depends, in part, on water currents, the transit time of ultrasound passing through a vessel/conduit is affected by the motion of liquid flowing through that vessel. During the upstream cycle, the sound wave travels against flow and total transit time is increased by a flow-dependent amount. During the downstream cycle, the sound wave travels with flow and total transit time is decreased by the same flow-dependent amount. The Transonic flowmeter subtracts the downstream transit time from the upstream transit time utilizing wide-beam ultrasonic illumination. This difference of integrated transit times is a measure of volume flow.

Wide Beam Illumination

One ray of the ultrasonic beam undergoes a phase shift in transit time proportional to the average velocity of the liquid times the path length over which this velocity is encountered. With wide-beam ultrasonic illumination *(Fig. 2).*, the receiving transducer sums (integrates) these velocity - chord products over the vessel's full width and yields volume flow: average velocity times the vessel's cross sectional area. Since the transit time is sampled at all points across the vessel diameter, volume flow measurement is independent of the flow velocity profile. Ultrasonic beams which cross the acoustic window without intersecting the vessel do not contribute to the volume flow integral. Volume flow is therefore sensed by perivascular probes even when the vessel is smaller than the acoustic window *(Fig. 2).*

Bidirectional Wide Beam Illumination

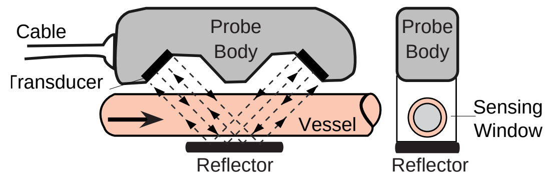


Fig. 1 **Side View** **End View**

Schematic views of a perivascular Transonic ultrasonic volume Flowsensor. Using wide beam illumination, two transducers pass ultrasonic signals back and forth, alternately intersecting the flowing liquid in upstream and downstream directions. The flowmeter derives an accurate measure of the "transit time" it took for the wave of ultrasound to travel from one transducer to the other. The difference between the upstream and downstream integrated transit times is a measure of volume flow rather than velocity.

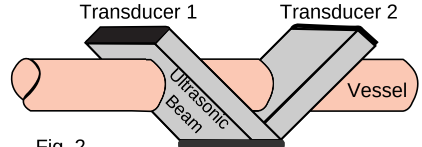


Fig. 2

The vessel is placed within a beam that fully and evenly illuminates the entire blood vessel. The transit time of the wide beam then becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.

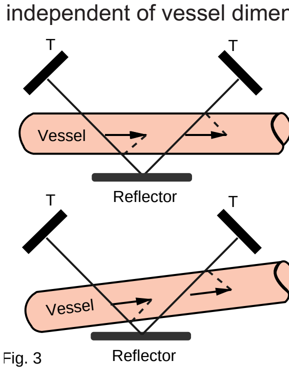


Fig. 3

Fig. 3: Angle insensitivity of: Transonic probe
T = transducer

a) The ultrasonic beam intersects the vessel twice on its reflective pathway. During each intersection, the transit time of the beam is modified by a vector component of the flow. The full transit time of the ultrasonic beam senses the sum of these two vector components, flow itself.

b) With misalignment, one vector component of the flow becomes greater and the second vector component diminishes, with little consequence to their sum.

Drost, C.J., "Vessel Diameter-Independent Volume Flow Measurements Using Ultrasound", Proceedings San Diego Biomedical Symposium, 17, p.299-302, 1978.
U.S. PATENT 4,227,407, 1980.

TN-94: Frequency Response

TN#94 Frequency Rev. 7-03

The frequency response and phase delay of Transonic Systems' flowmeters are a function of the sampling frequency, signal frequency and filter cutoff frequency.

The sampling rate of Transonic flowprobes ranges from 3.6 KHz (3600 samples/second) in the smallest probes to 225 Hz (225 samples/second) of the largest probe sizes. These sample rates allow Transonic flowmeters to fully resolve pulsatile flow.

The voltage signal output of Transonic flowmeters is filtered to exclude high frequency noise in the measurement that may be generated from the circuitry and is not flow related. As a general rule, the harmonic content of a pulsatile signal such as heart flow is well described by the first 10 harmonics of the signal. Therefore, a 10 Hz filter should be used for or a 1 Hz heart beat (60 beats/min) to characterize the components of the pulsatile flow signal. For the highest quality measurement, the filter band width chosen should correspond to the frequency cycle of the measurement. The 400-series flowmeters have a 160 Hz filter to fully resolve flow at higher frequencies as required in conscious mouse studies where heart rates can reach 750 beats per minute.

Filter Setting	Application
0.1 Hz	Average
10 Hz	Heart rate to 60 BPM
30 Hz	Heart rate to 180 BPM
40 Hz	Heart rate to 240 BPM
100 Hz	Heart rate to 600 BPM
160 Hz	Heart rate to 960 BPM

Measuring the impedance of a blood vessel is done by measuring pressure and flow volume and dividing the pressure by the flow volume. This calculation implies that the measurements are performed simultaneously; yet different instruments may have different delays on the output signal which can add error to the measurement.

The largest component of the time delay in Transonic research flowmeters is the result of the low-pass 3 pole Butterworth output filter. The table below gives the delay in the output signal for the various research flowmeters at each filter setting.

Flowmeter	Filter Frequency (msec)				
Model	10Hz	30Hz	40Hz	100 Hz	160 Hz
T106/T206	26	9	———	4	———
T110/R	25.2	7.7	———	2.3	———
T420/T410	23.9	———	6.8	———	2.75

Frequency response and phase delay graphs are available for the various filters.

TN-95: Data Acquisition for 400-Series

TN#95 Rev B 2/04

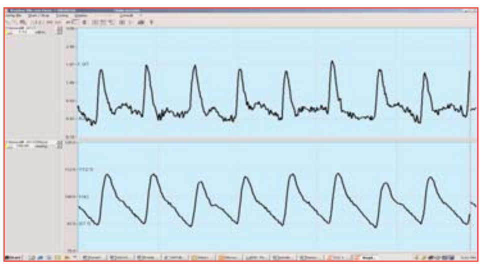
Recording Flow Data: Manual, Analog or Digital?

Manual Data Recording

Transonic 400-Series flowmeter modules display average flow on the LED digital display which can be read and manually recorded. This provides quick, but limited information in an experiment.

Analog Data Output Signals

Flowmeter modules provide analog voltage output signals which can be recorded by a strip chart recorder or converted to digital signals for more automated recording by a computer. Modules provide a flow signal on their front BNC connector. This signal tracks the low-pass output filter selected on the meter module (0.1, 10, 40, 160 Hz). A broader range of output signals is available on the rear panel of T402 and T403 consoles via screw terminal connections (see below and in the flow module manual). Terminal output connections may be made with general purpose hookup wire (stranded wire preferred, UL 1007 or equivalent, 24-14 gauge, stripped end: 6mm minimum length).



Digital Data Collection

A computer record of a study typically combines signals from multiple instruments such as flow, pressure, temperature and other physiological data. This requires a separate Analog-to-Digital (A/D) converter and computer software. Both the software and A/D interface must be matched to the user's study requirements. These computer interface components are not included in the Transonic T400 flowmeter system, but are available from companies specializing in data collection software. The following notes provide guidance to select software to meet the requirements of Transonic T400 flowmeter modules.

Analog Signals on Flow Modules

Transonic flowmeter modules provide the following analog signals on the rear panel of the T400 console.

- **Volume Flow:** Both average (0.1 Hz) and pulsatile (filtered at 10 Hz, 40 Hz, or 160Hz) flow signals are provided. For some chronic studies, average flow values may be adequate, but in many cases researchers will want to collect the full pulsatile flow signal for beat-to-beat calculations such as stroke volume, vascular resistance etc. This signal has a voltage range of -5V to +5 V, scaled to match a flow probe's flow range. To calibrate or scale the voltage output properly in the data acquisition recording, see Transonic Technical Note #10 for specific details. See below for guidelines to selecting the optimal frequency filter and sample rate.
- **Received Signal Amplitude** These signals represent the strength of the ultrasonic beam passing through the flowprobe and are useful in testing the quality or functionality of a probe. Low signal strength may indicate an ultrasonic obstruction (such as an air bubble) or a failing probe and may affect the measurement quality with increases in noise or zero offset. For quality tracking, a very low sampling rate should be adequate. A 2kHz sampling rate is recommended for bubble detection. There are 2 signal outputs: 1 per transducer pair for 4 transducer probes. These two signals are identical to each other for 2-transducer probes. These signals are "normalized" or standardized for the applied probe use under its factory calibration conditions (see probe data sheet). The signal ranges from 0V to +5V, 2V = 100% factory-calibration signal strength.
- **Phase (= Ultrasound Indicator Dilution) Signals** These signals represent changes in the acoustic velocity of the fluid and are used for ultrasound indicator dilution studies. Transonic Hemodialysis Monitors use a 16 Hz per channel sampling rate for human indicator dilution measurements (1 Hz beat frequency). For smaller animal models, the sampling rate may be scaled up proportionally to the higher heart beat rate. There are 4 signal outputs; 2 per transducer pair (1 offset for reference) for 4 transducer probes. Two-transducer probes provide 2 identical signal output pairs.

Guidelines for Selecting Flow Signal Frequency Filter & Data Acquisition Sampling Rates

The frequency spectrum of a flow signal with a strong pulsatile component consists of a base "beat" frequency and up to 9 higher harmonics. For instance, a human heart rate of 60 beats/minute has a base frequency of 1 Hertz (= 1 beat/second). A 10 Hertz frequency band contains this base frequency and the 9 higher harmonics and should be used to characterize the pulsatile flow components of a human heart beat.

A frequency band of X Hertz must be sampled digitally at a rate higher than 2X. A safe minimum sampling rate is 3X. This leads to the following sampling rate table for flow signals collected from the flow modules.

Flow Cutoff Frequency/ Flowmeter Filter Setting	Heart Rates up to	Recommended Minimum Sampling Rates
0.1 Hz	Average	0.3 Hz
10 Hz	60 beats/min	30 Hz
40 Hz	240 beats/min	120 Hz
160 Hz	1000 beats/min	500 Hz

TN-29: Extending Probe Life

TN#29, Rev. 3/00

Whether your measurement device be a fine Swiss watch or a Transonic flowprobe, proper care is crucial to its continued reliable functioning. Because of their size, it is sometimes easy to forget that Transonic flowprobes are highly technological pieces of equipment. The exact alignment of the reflector in relationship to the probe is critical for accurate measurements. Abuse of the probe can result in inaccurate measurements, malfunction or non-function of the probe. We recommend that you carefully examine your probes when you receive them and store them in their boxes when they are not being used.

Never boil or autoclave your probes. Also, do not attempt to clean them in an ultrasonic cleaner.

Cleaning Perivascular Probes

S, R, A, V-Series Probes (after use)

a) Disassemble the probe, keeping all parts of each probe together because parts are not interchangeable amongst probes.

b) Thoroughly wash the flowprobe and its reflector bracket in soap and warm water (≤55ºC, 130º F). Remove any visible foreign material with a soft bristled brush.

c) Reinstall the reflector bracket in the alignment groove recessed on either side of the probe body taking care not to distort the shape of the groove or bracket.

M-Series (handle style) intraoperative probes before sterilization:

a) Thoroughly wash the flowprobe in soap and warm water (≤55ºC, 130º F). Remove any visible foreign material with a soft brush.

b) Wrap carefully for sterilization.

Extracorporeal Sensors

X-, or C-Series Sterile Tubing Flowsensors;
N-Series In-line probes

Extracorporeal sensors can be damaged by immersion in saline or wet storage. They should not be boiled, or autoclaved. Nor should they be sterilized by cold liquid sterilization.

a) Wipe with soap and water (60ºC, 140º F).

b) Rinse with ethyl alcohol to promote drying.

Ethylene Oxide (EO) Gas Sterilization

Ethylene oxide, standard hospital cold (≤60ºC, 140ºF), gas sterilization can be used for sterilization. Before sterilization, the probe may be rinsed and wiped in 70% alcohol.

Follow the standard sterilization cycle time for your EO system. **Recommended parameters:**

• Chamber temperature	119º - 131ºF
• Chamber humidity	45 - 75 % RH
• Load temperature	104º - 141ºF
• Load humidity	20 - 90% RH
• Gas Mix	10%EO, 90%HCFC
• Pressure	24.2 - 27.2 PSIA
• Aeration Time	
Heated Aeration	12 - 48 Hours
Ambient Aeration	47 hours minimum

STERRAD Sterilization

Transonic Systems flowprobes are also sterilizable with STERRAD (not Steris). Total process time is a little over one hour. No aeration is required, and there are no toxic residues or emissions.

Liquid Sterilization and Disinfecting Solutions

Various solutions are widely used to disinfect surgical equipment. Great care should be used when applying any of these agents to Transonic Systems probes. Note: Transonic Systems has not performed any tests to determine the efficacy of any of these solutions for disinfecting our research flowprobes and we firmly recommend sterilization of flowprobes destined for chronic implantation. Additionally, Transonic Systems has not tested the following solutions to determine the effect on flowprobe performance.

Use of any solution should be undertaken with great care. In general, soaking for a relatively short time at low temperature, in dilute solution will be safer for the probes. It is up to the customer to determine if this will result in a satisfactory degree of decontamination without damage to the flowprobe.

Early Transonic flowprobes (dark blue), manufactured with a formulated resin epoxy, absorbed liquid agents and damaged probe performance. In recent years, we have used Conap epoxy (light blue color) which is more resistant to liquid absorption. Conap probes have been soaked by customers in the following solutions without damaging effects. Details about concentration, temperature and soak time have not been given:

Formaldehyde
Glutaraldhyde
Commercial Preparations
Cidex

TN-5: Bench Calibration

TN#5, Rev. D, 4/02

Precalibration

Transonic Systems' perivascular flowprobes are precalibrated in the factory using a calibration set up and procedure similar to the one described on the reverse side. Each probe is calibrated individually prior to shipping to the customer to determine the proper calibration gain for true flow reading. The gain is then programmed into the probe connector or, for flowprobes with chronic connectors, into the serialized calibration EPROM key. Calibration is performed under controlled procedures traceable to National Institute of Standards and Technology.

The volume flow measurement by Transonic Systems' ultrasonic transit-time probes is a function of the angles of the piezoelectric crystals and the reflective pathway. Theoretically, this dimension is fixed in the flowprobe and does not change over time. Therefore, flowprobes that meet operational tests and specification do not require recalibration.

Recommended Tests

Transonic Systems recommends testing of its flowprobes on a routine use basis to determine if any changes have occurred in the probe to warrant recalibration or repair. These tests are simple and can be performed by the end user in minutes.

1. **Received signal:** This is a test of the flowprobe's ultrasound signal utilizing the flowmeter's TEST mode. Probes are normalized in production to read 1 volt in TEST using a 1 meter extension cable, unless they are specified by the customer to be used with a 2 or 3 meter cable. Lowered signal may be indication of probe degradation over time or misalignment of the reflector. See the flowmeter manual for more specific instruction.

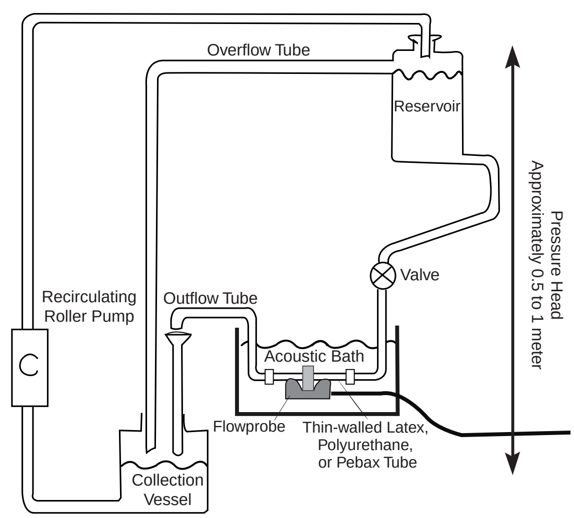
2. **Zero offset:** This is also a test of the integrity of the probe and ultrasonic pathway. Transonic flowprobes meet a maximum offset specification; an increase in offset may be indicative of reflector misalignment or changes to the piezoelectric transducer/epoxy interface which may affect the flowprobe's function. Offset testing can be performed in a non-reflective plastic vessel that is lined with sponge of other sound absorbing material.Test the zero offset with the flowmeter in "MEA" (measure) mode. Submerge the flowprobe and allow sufficient time for the water to quiet and the probe to equilibrate. When the reading on the digital display has stabilized, it should be ≤ the maximum offset specification for the flowprobe size/series. (See the flowprobe data sheet or table of specifications in the flowmeter manual.)

Certification

For quality assurance and to meet GLP (Good Laboratory Practices) guidelines as outlined by the FDA , Transonic Systems' provides Certificates of Calibration for customers who require these. Calibration certification is valid for one year and encompasses factory recalibration of Transonic flowprobes.

Bench Calibration Procedure

The calibration of Transonic perivascular probes can be confirmed using a gravity-fed constant flow set-up. Mount a thin-walled Penrose drainage tubing or Pebox polyurethane tubing within a water bath and position the probe around it. Observe the received signal amplitude on the front panel analog meter with the flowmeter in "TEST" mode. If the signal amplitude drops less than 10% when the tube is introduced into the probe's acoustic window, the walls of the tubing are sufficiently transparent to ultrasound to be used in the test set-up. Calibrate the constant flow set-up by collecting the outflow into a graduated cylinder over a measured period of time, and by calculating the volume rate of flow. *(Make sure that the pressure head is not altered when the outflow tube is moved from the collection vessel to the graduated cylinder.)*

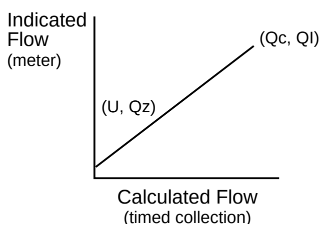


TN #5, Rev. D, 4/02

Gravity-fed Constant Flow Set-up

- The temperature of circulating water and water within the bath should be approximately the same.
- A roller pump is preferred over a centrifugal pump, as the latter heats up the circulating liquid.
- Tap water that has been standing long enough so it does not form air bubbles on the surfaces of probe and containers should be used in both the water bath and the circulating system.
- Sponge or other sound absorbing material should be used to line the basin. Extraneous sound reflections from the basin walls may cause drift or signal noise.
- Positioning the flowprobe so that the reflector is facing up will also help avoid reflections.
- Use a straight length of tube 10 x the diameter on either side of the probe to avoid turbulence in the flow stream from tubing junctions or bends.

Record the calculated flow and the indicated flow and graph the data as shown in the figure below.



Once graphed, correct the flow for the zero offset and compute the slope of the curve by taking the difference between the indicated zero and the indicated flow and dividing it by the calculated flow.

$$\text{SLOPE} = \frac{(QI - QZ)}{QC}$$

This slope of the calibration graph should be approximately one. There will be small deviations because the ideal of a constant ultrasonic field within the flowsensing area is not fully achieved.

Correction for Blood:

Bench calibration may be performed using water at room temperature (23°C) for most probes. An adjustment to the calibration is applied to correct for the acoustical velocity of blood vs. water and measurement conditions.

Acute vs. Chronic:

Transonic R and S-Series flowprobes precalibrated for acute use will read 10% higher (using water at 23ºC) than probes calibrated for chronic use to compen-sate for lowered sensitivity in acute conditions. See TN # 11.

Micro-probe Calibration:

Transonic high frequency probes (0.5, 0.7, 1, 1.5 mm) are calibrated using water at 40º C to optimize signal transmission through tubing. Confirm probe calibration *in vivo* or on isolated vessel segments using blood at 37ºC.

Tubes Used in Flow Calibration of Perivascular Probes

Probe Size	Calibration Tubing	Supply #, Type
0.5S, 0.5V	.020"/0.5 mm od	Pebax (3)
0.7S, 0.7V	.028"/0.7 mm od	Pebax (3)
1R, IV	.039"/1 mm od	Pebax (3)
1.5S,1.5R	.059" /1.5 mm od	Pebax (3)
2S, 2.5S	0.080" od.	polyurethane (1)
2R, 3R, 3S	0.120" od	polyurethane (1)
4R, 4S	0.188" od.	polyurethane (1)
6R, 6S	1/4" od.	9787 (2)
8R, 8S, 8A	5/16" od	9788 (2)
10S, 10A	3/8" od	9789 (2)
12A, 14S, 14A	1/2" od	9790 (2)
16S, 16A	5/8" od	9791 (2)
20S, 20A	3/4" od	9792 (2)
24A, 28A, 32A, 36A	1" od	9794 (2)

(1) POLYURETHANE TUBING:* custom made by Thermedics Inc., Woburn, MA

(2) LATEX TUBING:* .006" wall* Penrose draining tubing from: Mohawk Hospital Supply P.O. Box 27 335 Columbia St. Utica, NY 13503

(3) PEBAX TUBING* (custom): *samples available from Transonic Systems Inc.*

TN-9: Acoustical Couplants

TN #9 Rev D 8-05

Because air attenuates ultrasound transmission, it is necessary to fill the acoustical window within a flowprobe with an acoustical couplant during acute use. For chronic application this is not necessary because fibrous connective tissue fills in the window and serves both to stabilize the probe and facilitate ultrasonic signal transmission.

Acoustical Jellies, *Recommended*

Transonic Systems has tested a number of brands of acoustic jellies. These products are viscous enough to loosely adhere between the probe and vessel. Unfortunately, the combination of temperature and time eventually overcomes surface tension to melt out the jelly. Best results are achieved with snug probe-vessel fits.

Aquasonic-100 in sterile pouches is an excellent match.

HR Lubricating Jelly also matches the acoustical velocity of blood and vessel wall. HR Lubricating Jelly is available from:

Mohawk Hospital Supply
335 Columbia St., Box 27, Utica, NY 13503
Tel: (800) 962-5660, (315) 797-0570

Surgi-lube is not as good but is still acceptable.

Saline

Sterile saline is often used as an acoustical couplant because it is inexpensive, safe, and readily available. However, certain restrictions govern its use. First, the vessel of interest must be in the bottom of a body cavity that can be filled with fluid. Secondly, the vessel of interest and surrounding fluid must be fairly calm to prevent motion artifact. Since the flowprobe will detect any flow through its acoustical window, saline flowing around the vessel will affect apparent blood flow. **If these other acoustical deviations exist within the probe window, one could see strong loss of acoustic signal, zero or even strong reversal of flow!**

Coagulated Blood

(Can cause vessel spasm. Do not use on small vessels)

Blood that is collected beforehand and allowed to partially clot may also be used as an acoustical couplant. If coagulated blood is desired, the following procedure may be used:

1) draw an appropriately sized syringe of blood from the subject before the beginning of the surgical procedure;
2) place the syringe in a test tube rack, needle up, to allow coagulation while the procedure begins;
3) with the needle still pointing up, depress the plunger to decant the serum; then apply the coagulum to fill the acoustic window.

Since clotting times vary greatly between individuals, species and containers, some experimentation will probably be required to establish optimal timing. One consequence of using clotted blood is that the clot eventually fibroses.

Synthetic Superabsorbent

Another agent used as an acoustical couplant is a synthetic compound named Nalco 1181. This is a superabsorbent powder that expands into a thick viscous gel when exposed to fluids. The compound has a low biotoxicity rating (it is used in disposable diapers). **We recommend it only for acute and terminal animal research**. The compound is prepared as follows:

1) Weigh the N1181 powder and add sterile saline with stirring until the desired consistency is obtained. (approx. 0.5 g plus 20 ml saline).
2) Allow to stand 15 minutes then stir again.
3) Transfer the gel to a luer lock syringe and centrifuge for 10 minutes to remove air bubbles.
4) Result should be a translucent gel with no visible air bubbles
5) Filled syringes can be capped and stored at 4^{0}C for 4 months with no apparent alteration in flow characteristics or performance as an acoustic couplant.

Transonic Systems Inc.
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Europe: Tel: 31 43 407 7200; e-mail: info@transonic.nl; Fax: 3143 407 7201

TN-26: Keys to Flowprobe Accuracy

Accurate flow measurements with ultrasonic transit time technology depend on careful attention to several variables. These include:

Acoustical Coupling

Highest accuracy with ultrasonic transit-time flowprobes is achieved when the ultrasound signal is transmitted under uniform acoustic conditions. This occurs when the acoustic properties of the coupling media and tissue are stable and most closely match the acoustic properties of the liquid being measured. Since volume flow measurement with Transonic Systems' flowprobes is derived from a phase shift *(the difference in upstream and downstream transit times)* and is impacted by changes in the acoustical velocity of the ultrasonic beam, discrete sources of error from acoustical mismatch can be eliminated by following these guidelines in your experimental preparation.

Air

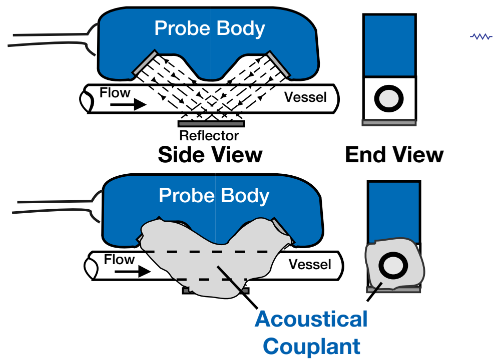
Air attenuates the probe's ultrasound signal and effectively blocks ultrasound transmission. With large air pockets in the path of the ultrasound beam, little or no transmitted signal is received back to the flowprobe and accurate flow measurements cannot be made. Even small air bubbles can compromise measurement accuracy. Therefore, all spaces between the vessel and probe must be filled with a suitable coupling agent.

Couplant

Media with lower acoustical velocity and impedance than blood are poor coupling agents for blood flow measurement with current ultrasonic transit time flowprobes. These agents include saline, water, and NALCO 1181 mixed with saline. Aquasonic 100, an acoustic coupling agent used for sonography proved to be only on the borderline of acceptability for use with transit time probes. Acoustically mismatched media cause reflections of the ultrasound at the vessel boundary, can substantially change the acoustical beam direction within the probe, and impose uneven changes in the ultrasonic transit time. Measurements may be unstable and unpredictable in both positive and negative directions.

Fat

Fatty tissue also has a low acoustic velocity and affects the ultrasonic beam similarly. A pad of fat on the vessel wall in the acoustic pathway of the ultrasonic beam can act like a lens, reflecting or defocusing the ultrasound and altering the transit time nonuniformly.



Temperature

Temperature also effects the velocity of ultrasound and should be controlled for the most accurate measurements. Acoustical velocity increases with temperature increase. However, transitions of the ultrasound beam from room temperature coupling agent to body temperature vessel wall and blood will alter the transit time and may exacerbate errors from other sources.

Optimizing Conditions - Conclusion

Subtle phase shifts in the ultrasonic beam may be caused by inappropriate acoustic conditions during the experiment and will affect the accuracy of the measurement. Acoustically tested and approved coupling agents listed below should be used with Transonic Systems flowprobes. Fatty tissue should be carefully cleaned from the vessel where the probe is placed. Controlling temperature in the acute experiment makes excellent physiological sense, in addition to being good acoustic practice. Transonic perivascular flowprobes are calibrated for measurements of blood at 37 degrees C and will give the most accurate readings if used within a +/- 2 - 3 degree range. Gels may be warmed on a heating plate and the probe itself should be allowed to equilibrate to this temperature for about an hour prior to use.

Suitable Coupling Agents:

Surgilube by E. Fougera & Co.
(available from most hospital supply stores)

TN #9: Acoustical Couplants for Acute Measurements

Optimizing Conditions

Choice of a Perivascular Probe

Choosing the best flowprobe for the application will help eliminate accuracy errors that result from compromised acoustic or nonuniform conditions. Certain flowprobes have increased sensitivity inherent for the flowprobe design and the effects of acoustic mismatch are minimized. These may be used in exceptional cases where preferred acoustic coupling agents cannot be used. Choose:

- PAX & A-Series Flowprobes for highly turbulent nonlaminar flow profiles (ascending aorta and pulmonary artery)
- V-Series Flowprobes for small vessels (<700 micron diameter) as vessel length and surgical space allows.

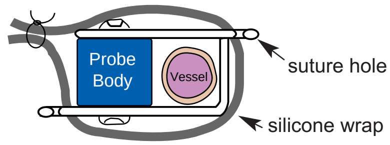
Correct vessel/probe fit also influences accuracy significantly. For acute applications, the vessel must fill at least 75% of the flowprobe lumen. A close or snug fit will result in the least measurement accuracy. A close fit also lessens the amount of acoustic gel needed and minimizes its effect on the measurement. Choose:

- A range of flowprobe sizes to cover variability in vessel diameter between subjects.
- Nanoprobes for a close fit on small vessels (<700 micron) to maintain acoustic coupling more easily.

Advantage of Chronic Implants

Many of the sources of error listed here are associated with acute use of ultrasonic flowprobes and can be effectively eliminated when the probes are implanted for long term measurements and chronic protocols. No coupling gel is required unless measurements are taken during the intra-operative procedure. Within 3 - 5 days during an animal's surgical recovery, the air spaces are filled with fibrous connective tissue. This tissue is a good acoustic conductant and also serves to center the vessel in the most sensitive position of the probe. As in acute applications, the vessel should be stripped of fatty tissue prior to flowprobe implantation and preventative measures should be taken to keep fat from infiltrating into the acoustic pathway over time. In species or vessel sites predisposed to fatty tissue deposits, a thin sheet of silicone wrapped around the outside of the probe and sutured to adjacent tissues at the time of implant will keep the probe fat free and also aid in stabilization.

In a chronic experimental design, the cardiovascular system will also be freed from intraoperative stresses. Conscious measurements may be made without cardiovascular influences from anesthesia.



Silicone wrap around a probe, leaving the probe suture holes exposed.

Under these stable acoustic and physiologic conditions, our customers have pushed the measurement capabilities of Transonic flowprobes to record low flow states in difficult applications such as bile flow in the cystic and common bile ducts in a dog model, and esophageal *(amniotic fluid)* flow in fetal lamb swallowing.

Scientific Protocol

While the ease of use of Transonic precalibrated flowprobes have earned plug and play status, the rigors of scientific protocol should not be ignored. Transonic Systems specifies its probe for +/- 10%-15% absolute accuracy *(see specification tables for individual probe series)*. Careful attention to the above considerations will ensure that measurements reliably meet these standards. Absolute accuracy may be further enhanced by

in situ calibration of the flowprobes to validate the measurement under their specific conditions of use.

TN-16: A-Series Flowprobe Validation

TN #16 Rev. B. 12/03

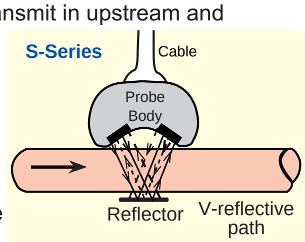
Introduction

Customers have reported low flow measurement with our S-Series probes during acute use on the ascending aorta and pulmonary artery. S-Series probes utilize a V-shaped pattern of ultrasonic illumination and also show a position dependent sensitivity, with maximum flows obtained when the V-shape path of the ultrasonic beam is perpendicular to the curvature of the vessel. The variability in flow readings when the probe is rotated on the ascending aorta or pulmonary artery has not been reported for any other vessels.

Several factors have been identified which contribute to this lowering in probe sensitivity during acute measurements on the ascending aorta and pulmonary artery. To overcome the limitations of the S-Series probe for these applications, Transonic Systems has introduced an A-Series 4-crystal probe with an X-shaped pattern of ultrasonic illumination.

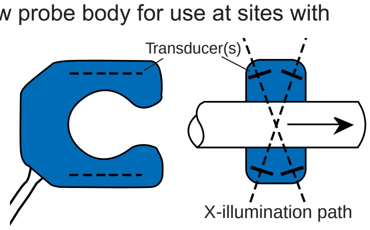
Theory: V-Beam Illumination

- 1 pair of transducers positioned on the same side of the vessel alternately transmit in upstream and downstream directions.
- exhibits positional sensitivity in acute cardiac output measurements: readings vary approximately 30% with 90º rotation on the curve of the ascending aorta.
- underestimates flow on ascending aorta (up to 40%) compared with thermodilution, in acute use.
- square opening; good for chronic implants, but requires acoustic couplant to fill in rectangular spaces during acute measurements.



Theory: X-Beam Illumination

- 2 pair of transducers positioned on the opposite sides of the vessel alternately transmit in upstream and downstream directions.
- positional sensitivity is eliminated by the use of redesigned crystals and a X-beam pattern of ultrasonic illumination.
- light weight, narrow probe body for use at sites with limited anatomical access.
- round opening: reduces need for acoustic couplant during acute measurements.



Validation Using Right Heart Bypass Model

A right heart bypass model was used to validate ascending aortic flow measurements with the 20A probe.[1] This model was modified to include an in-line flowprobe in the inflow tubing to the left atrial cannula, thus allowing the experimenters to validate volume flow during a normal, pulsatile ascending aortic ejection pattern. At the end of the experiment the in-line probe and the roller pump were calibrated by timed collection.

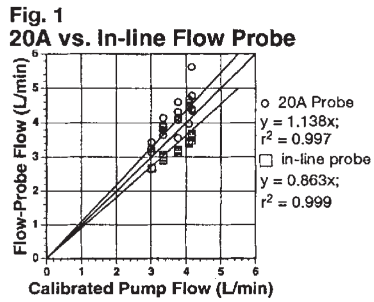


Fig. 1: Correlation between the Test 20A probe and the in-line flowprobe versus calibrated pump flow. A correction factor applied during pre-calibration would position these points around the line of identity.

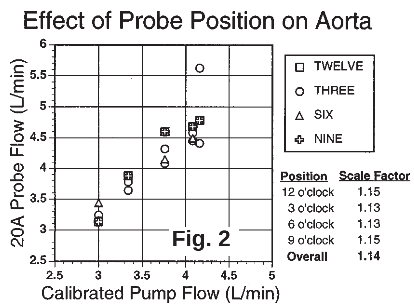


Fig. 2: Comparison of 20A readings versus position of the probe on the aorta with 12 o'clock defined as being the centerline of the greater curve of the ascending aorta.

Conclusions

1) The 20A probe initially appears to measure ascending aortic flow in a linear fashion, with a 3.8% over-estimation compared to calibrated pump flow.
2) The 20A probe measurements do not appear to be affected by rotation of the probe around the orthogonal axis to the ascending aorta.
3) More extensive examination of the accuracy and position-insensitivity of the A-series probes is forthcoming in the near future.

Acknowledgment

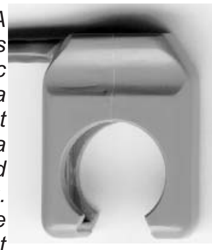
We wish to thank Louis A. Brunsting, M.D., University of Michigan, Ann Arbor, and his staff for their collaboration on this preliminary validation. Figures 1 & 2, courtesy of Dr. Brunsting.

References

1Lekven, J, Brunsting, L.A, Jessen, ME, Abd-Elfattah, AS, Doherty, NE, Wechsler, AS, "Myocardial Oxygen Use during Epinephrine Administration to Ischemically Injured Canine Hearts", Circulation 1998; 78(Sppl III):125-136.

Dean, DA, Jia, C-X, Cabrereza, SE, D'Alessandro, DA, Dickstein, ML, Sardo, MJ. Chalik, N, Spotnitz, HM, "Validation Study of a New Transit Time Ultrasonic Flow Probe for Continuous Great Vessel Measurements," ASAIO Journal 1996: 42:M671-M676. (29V)

TN-28: Cardiac Output Flowprobe Use



Transonic Systems' PAX & A Series perivascular flowprobes were designed to measure cardiac output on the great vessels with a higher level of accuracy. Turbulent flow profiles in the ascending aorta and pulmonary artery necessitated a probe with uniform sensitivity. The lightweight, narrow probe body provides low impact instrumentation for vessel sites with non-uniform flow profiles or limited anatomical access.

Ascending Aorta   Pulmonary A   Portal Vein

Choice of Size

8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 20 mm,
24 mm, 28 mm, 32 mm, 36 mm.

An exact fit on the vessel is not required, but the vessel should fill at least 80% of the probe opening. Probes implanted for measurements at a later date should fit loosely and not constrict the vessel.

Acute Application

Vessel preparation for use of Transonic PAX & A Series probes is typical. Dissect around the vessel for placement of the probe. Be sure to clean the vessel of fat which can alter the signal and have an affect on accuracy. You may fill the probe cavities with acoustic gel (Surgilube or HR jelly) before placing the probe on the vessel or use a syringe with a catheter tip to deposit gel and. Trapped air bubbles can affect accuracy

Replace the clip by sliding or snapping into place. Adjust probe placement so that it rides perpendicular to the vessel and is not twisted, misaligned or rocking on the vessel.

Verify adequate signal in Test Mode on the flowmeter. The probe size will be displayed and signal amplitude should read about 1 Volt.

Chronic Implant

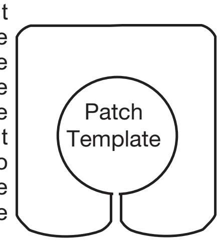
The PAX & A Series probes are now also preferred for long term implantation because of their lightweight construction and clean signals. Successful implants of 1 year or more are reported. Modifications to the probes and to protocol should be followed to ensure healthy probe seating on the vessel and stabilization by fibrotic encapsulation. Encircling a high pressure vessel like the ascending aorta with a flowprobe warrants special treatment. Careful attention must be made to dissect the vessel. Small surgical injuries can become catastrophic events during recovery.

Vessel Padding

Although there are surgeons who are successful using no interface between the vessel and probe, we do recommend padding the flowprobe edge to protect the vessel from irritation and possible erosion.This extra step during surgery is a minor inconvenience compared with the loss of a chronically instrumented animal. Various materials and techniques are available for this (see table below).

Wrap: The most common method is to wrap the vessel with the material before placement of the probe. Since the material is within the acoustic beam of the probe, it can have an affect on the signal. Higher frequency probes are attenuated more by this treatment.

Patch: Polyester felt patches attached to the outside surface of the probe do not interfere with the acoustic signal . In this alternative approach, patches are cut to fit the outside flat surface of the probe with the circle for the vessel cut slightly smaller than the diameter of the probe. These are attached to the outside of both flat surfaces of the probe with silicone cement and slit at the opening to allow placement on the vessel. Fibrous tissue adheres to the outside of the probe and seats the vessel well without interfering with the acoustic signal.



Inside diameter cut
2 mm less than probe

Clip Fixation: The PAX & A Series probe closure "clip" can be snapped or slid into place, and should be seated firmly in the probe. Bone wax (medical grade orthopedic wax) applied to the groove of the probe helps fix the clip in place. If after several uses, the clip becomes loose from wear, it is now possible to order additional clips without returning the probe.

Chronic Connectors: Small connectors are preferred for subcutaneous tunneling. Available connectors for:

PAX-Series for 400-Series Flowmeters
- CRS10 (sealed connector with cap)
- CRB10 (plastic skin button)

A-Series for T106/T206
- CM4B (sealed mini connector)
- CB4 (titanium skin button),
- CS10 (sealed)
- CB10 (plastic skin button)

Validated In Vivo

Dean, D.A., Cabreriza, S.E., Jia, C-X, D'Alessandro, D.A., Sardo, M.J., Chalik, N., Soto, P.F., Dickstein, M.L., Spotnitz, H.M., "Validation Study of a New Transit-Time Ultrasonic Flow Probe for Continuous Measurements on the Great Vessels," ASAIO Journal Abstracts, Vol. 42, No. 2, p. 26, 1996. *(pig, ascending aorta, CO probe, right heart bypass model, calibrated roller pump)* (29V)

Remond, D., Ostigues, M.I., Isserty, A., Lefaivere, J., "Technical Note: Measuring Portal Blood Flow in Sheep Using An Ultrasonic Transit Time Flow Probe," Journal of Animal Science, Vol. 76, No. 10, p. 2712-1216, 1998. (sheep, portal vein) (39V)

Calibration

Transonic PAX-Series flowprobes were validated in vivo in acute application in rigorous protocols and tested extensively during design to achieve probes that would accurately measure flow under the most challenging conditions. These conditions include acoustical variations of coupling agents, misalignment and highly pulsatile, perturbed flow.

Acute/Chronic

Transonic Systems calibrates all PAX & A-Series flowprobes to standards for acute application regardless of the intended use. This is an exception to the calibration standards of other Transonic perivascular flowprobes. We offer two calibration values for R and S-series flowprobes: probes that will be chronically implanted are calibrated 10% lower than acute use probes (see Technical note # 11). This difference in calibration compensates for the decreased sensitivity of Transonic R & S- Series probes when the vessel is not centered in the flowprobe and when using acoustic gel (versus implanted probes coupled by fibrotic tissue). By design, Transonic PAX & A Series flowprobes exhibit uniform sensitivity and are affected less by acoustical variation of coupling agent.

Transonic Systems stands behind the validated calibration of the PAX & A Series probes and does not recommend applying a correction factor for chronic use without data to support a calibration change. Several customers have proposed such studies to validate the flowprobes in chronic application.

	Product	Description	Probe Recommendations	Effects on Probe Performance	Product Source
Vessel Padding	Ultracell	Soft, biodegradable, surgical wipe	all sizes	Attenutates signal at implant air absorbed longterm 20A: 10% signal loss 10A: 15% signal loss	Transonic Catalog # **APSPONGE**
	Mersilene Mesh	Soft, interlocked, polyester fiber; Nonabsorbable	all sizes	Attenutates signal: 20A: 4% signal loss no offset change 10A: 25% signal loss offset noisy	Transonic Catalog # **APMERSILENE**
	Prolene Mesh	Soft, polypropylene mesh; Nonabsorbable	Do not use for 8, 10, 12 mm probes	Attenutates signal: 20A: 30% signal loss no offset change 10A: 82% signal loss offset noisy	Transonic Catalog # **APPROLENE** **Ethicon PMH**
Probe Patch	Polyester Felt (Medical Grade)	Soft felt, Nonabsorbable	all sizes	Apply to outside of probe; No affect on signal	Sold by Impra C.R. Bard #008972
Clip Fixation	Bone Wax	Medical grade wax for orthopedic surgery	all sizes	none	Ethicon W-31
	Probe Clips	closure piece	size dependent	keeps vessel within probe	Transonic Catalog # **FAC (probe size) A**

TN #23, Rev.11/99, page 1.

Transonic Systems' V-Series probes for microcirculation produce repeatable high resolution volumetric blood flow measurements on vessels as small as 250 micron diameter, but also in vessels as large as 1000 microns. This designated diameter range overlaps with our 1 mm R-Series flowprobe. Choosing the appropriate series, size and style probe for your application will enhance the absolute accuracy of the flow measurement.

Acute Protocols: V-Series probes are designed to overcome the difficulties in obtaining stable, small volume measurements in vessels ranging from 250 - 900 microns diameter. Micro-vessels are positioned in the V-groove of the reflector, the position of highest sensitivity. Stainless steel handles are recommended to help stabilize the probe with a micromanipulator for lengthy acute procedures. Suitable acoustic couplant *(Surgilube)* is used to transmit the ultrasound.

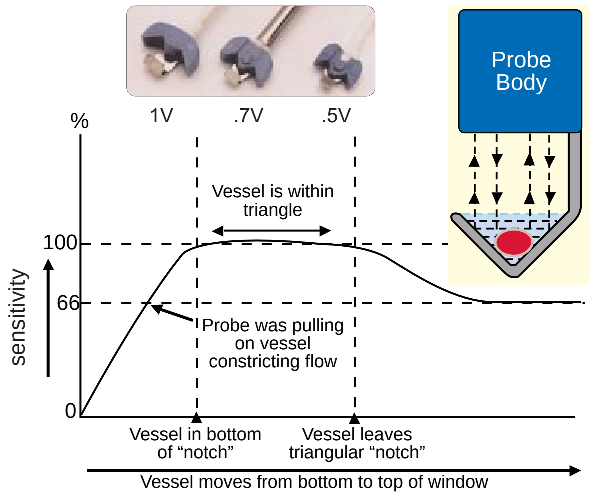
Choosing Probe Size: Probe size should be chosen so that the full diameter of the vessel nestles within the triangle formed by the V-reflector (see diagram below). It is also important that the vessel can be isolated a sufficient length along the vessel without side-branching to fit the width of the reflector (see probe dimensions and required vessel segment lengths). For acute measurements in larger vessels (750 microns and larger) R- and S-Series probes may be used.

V-Series Reflective Path

If you look into a 90º corner consisting of two mirrors, you see a coherent picture of yourself *(but flipped over, so your right ear is on the left side of the image).* This is the reflective path of the V-probes; light scattered off your face first hits one mirror, then the other, before it returns to your eye. In V-probes, these rays intersect the flow four times: the incident beam intersects the flow; then, on the first reflection off the mirror surfaces, part of the beam traverses the vessel from right to left, another traverses it from left to right; the flow is sampled a fourth time when these two halves of the beam, are reflected back to the receiving transducer. **This 4X sampling of the flow enhances resolution for micro-sized vessels.**

Affect of Vessel Diameter on Flow Measurement Accuracy

With all Transonic probes, flow sensitivity is optimized for a specific range of vessel diameters. In V-probes, the permissible vessel diameter is small compared to the physical vessel window. Substantial errors result when the vessel fills the full probe window.



Flow Sensitivity Profile within V-Probe Window
For proper flow readout, the vessel must be positioned within the reflector bracket's high-sensitivity triangle. For easy alignment, the preferred position is in the bottom of the V-groove.

Accurate Selection of V-Probe

Before flow measurements are made, vessel diameter must be measured in order to select the proper probe size. For instance, it is possible to fit a 1 mm diameter vessel inside a 0.5V probe. However, this would lead to erroneous measurement results since most of the vessel would be positioned outside the high intensity triangle. Optical pieces *(2.5 to 4X magnification)* and a calibrated microsurgical scale are necessary to do this accurately.
Probe size is selected according to the following chart.

0.5V: for vessels 250 - 500µm diameter
0.7V: for vessels 350 - 700µm diameter
1.0V: for vessels 500µm - 1 mm diameter

V-Series Probes with Flexi-Handles

The new flexi-handle on V-Series probes allow easier application of the V-probe on a vessel. The stainless steel handle is positioned on the cable 5 mm from the probe head. This extra cable segment allows the probe tip to be flexible and compliant on tissues without sacrificing the stability provided by the rigid handle. Probes resist twisting and are easily mounted in a micromanipulator.

V-probes with the new flexi-handle style deter tugging on the micro-vessel and its consequent vessel spasm and shutdown. Positioned so that the probe opening faces up permits:
- better visualization of the vessel;
- easier application of acoustic gel;
- easier elimination of trapped air bubbles.

V-Series Probes with Rigid Handles

The rigid handle style ensures the maximum amount of control when using a micromanipulator. The stainless steel handle is fixed to the probe head for rigidity and ultra-fine positioning.

Positioning of V-Probe on Vessel

Accurate flow measurement requires that the micro-vessel is carefully positioned in the high sensitivity portion of the probe. The vessel should be “suspended” in the notch of the V-reflector, without causing a constriction of the vessel. Use of a micro-manipulator for this is helpful.

- Prefill the probe with acoustic couplant to insure that all air pockets in the probe are removed. *(Transonic flowmeters will indicate good received test signal when all air bubbles are filled).*
- Mount the probe handle in the micro-manipulator and position the vessel approximately in the notch of the “V”. Add couplant, if necessary.
- Gently “pull” the probe into position using the micro-manipulator. If the flow reading on the flowmeter starts to decrease during this procedure, the reflector may now be constricting the vessel. Back off slightly to restore full flow.
- Verify position of vessel with the optical magnification of an eye piece or microscope.

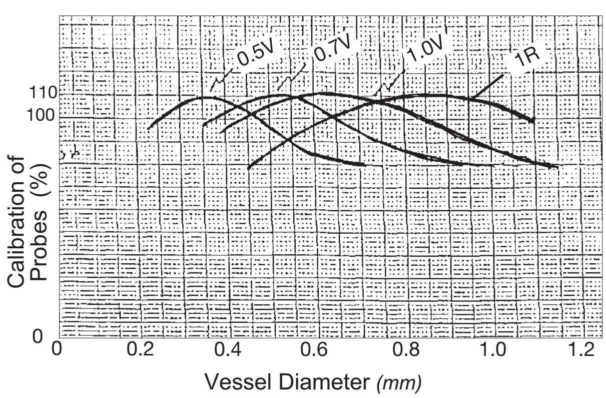
Handles on V-probes allow for stable position with a micromanipulator.

The flexi-handle is a robust improvement to a delicate precision flowprobe.

Specifications: V-Series Probes

CAT # Probe	VESSEL O.D. mm acute application	BIDIRECTIONAL FLOW Scale Settings Low Flow ml/min	Normal Flow ml/min	Max. Range ml/min	ACCURACY Zero Offset ml/min	Absolute Accuracy %	Relative Accuracy %	ULTRA SOUND Frequency MHz
0.5V	0.25 - 0.50	2.5	10	50	0.2	± 15	± 3	7.2
0.7V	0.35 - 0.70	5.0	20	100	0.5	± 15	± 3	4.8
1.0V	0.5 - 1.0	10	40	200	1.0	± 15	± 3	3.6

Probe Size	Vessel segment length (width of V-reflector)	Length of probe body
0.5VB	2.0 mm	6.5 mm
0.7VB	2.5 mm	7.6 mm
1.0VB	3.3 mm	8.7 mm



Typical (± 5%) Sensitivity Curves for 1R & V-probes

Handles on V-probes allow for stable position with a micromanipulator.

TN-101: Custom Programming for Graft Materials and Other Conditions

TN #101 Custom Programming Flowprobes 8/04

Some research applications (ventricular assist device implants, or bench flow testing) require perivascular probes that will measure through an artificial vessel. Transonic perivascular probes are normally calibrated, normalized and programmed for use on native tissue vessel to measure blood flow at body temperature. Using these probes on artificial graft materials or tubing can affect the performance of the flowprobe by attenuating the acoustic signal. Calibration for absolute accuracy may also be affected.

The following services can be ordered for Transonic perivascular flowprobes to minimize these effects.

- **Custom Normalization**

  "Test and Normalize Probe on Graft Material: Provide "Graft Chip" if needed. Include sample. The sample will be returned to customer with order".
  A sample of the graft is required for this test.
  The probe will be tested in a waterbath for adequate signal and if necessary the transmit level will be increased.

- **Normalization from Historical Data**

  Normalization from Historical Data:
  "Normalize probe for use on ______graft same as for probe serial # __________. Include "Graft Chip".
  No test on the graft is performed. This is only valid for repeat orders of same size probe and graft type. Customer should be informed to test signal & accuracy.

- **Custom Calibration on Graft**

  Provide "Graft Chip" if needed. Sample included.
  Return sample to customer with order."
  This is a full calibration on the graft.

Note:

There are many types and sizes of vascular graft materials. The relationship of the size of graft and frequency of the probe is important so that generalized formulas cannot be used to optimize probe performance without adequate testing. Graft materials which we have some experience with are listed below. Transonic's Manufacturing Engineer will keep graft normalization and calibration data on file.

- Dacron double velour
  (improved signal with 2 x transmit)
- Dacron double woven
  (improved signal with 2 x transmit)
- PTFE or Gortex:
  (acute measurements difficult; improves with chronic implant)

Transonic Recommendations

- *In situ* calibration of the probe should be performed to verify absolute accuracy
- Customers may choose to perform tests themselves. See Surgical Protocol #42 for method for treating graft material to achieve best signal.

Transonic solicits feedback on custom normalization and calibration to validate our procedure.

Nomenclature for Special Eprom Calibration and Normalization Keys

"Superchip"

Eprom is programmed with 2 x transmit signal.
This key is generally ordered for probes that are chronically implanted to boost received signal on probes that have lost signal over the duration of the implant. (It can extend the life of the implant so the researcher can continue getting data rather than terminate an experiment). Information for the programming of the key is obtained from the probe data sheet.

"Graft Chip"

This is custom normalization for perivascular probes used on some types of artificial grafts that attenuate or block the ultrasound signal. (Not all grafts require this treatment). Probes should be tested on the graft for best results. Received signal may vary from standard 1 volt normalization when used on graft with blood. Generally the transmit signal is increased.

"1/2 Gain Key" or "Half Gain Chip"

The calibration is multiplied by 0.5 for applications where the peak flow exceeds the maximum range of the flowprobe and the corresponding voltage exceeds 5 volts. Peak flow waveforms appear flattened or clipped. A 1/2 gain key may be substituted so that complete data can be collected, however, the customer must then multiply his data by 2 or change the scale factor to correctly record and scale voltage data.

TN-99: Extension Cable Use: Effects on Probe Received Signal

Received Signal Normalization

The Received Signal Amplitude of Transonic Systems' flowprobes and flowsensors used with the 400-series flow modules and previous models T106 and T206 are normalized to read 1 volt in Test mode on standard use extension cables. Standardizing the test signal voltage for probes helps the user to identify poor acoustic conditions and to track signal quality and the functional status of the probe. Low received signal may affect measurement quality with increases in noise and zero offset.

Signal Level Thresholds

Transonic flowmeters present signal quality through various indicators: the LED displays signal quality ("Good", "Low", "No Signal" or "Acoustic Error") in Test mode and the analog meter (models TS420, T106, T206) measures the voltage. 400-Series flowmeters continuously display a light bar indicator of signal level.

Signal Strength	Signal Quality	Bar Display	Analog REC AMP Display Voltage
Over 80%	Good	5 bars lit	-- Over 0.8V --
60% - 80%	Good	4 bars lit	
30% - 60%	Good	3 bars lit	Proportional Readings
20% - 30%	Low	2 bars lit	
10% - 20%	Low	1 bar lit	
Under 10%	No Signal	No bars lit	-- Under 0.1V --

Conditions that Degrade Signal Level

- **Acoustic Conditions**
  Air in probe, fatty tissue deposits on the vessel, untreated artificial graft materials with imbedded air, using sensors on inappropriate tubing and fluids with atypical acoustic properties all decrease the signal amplitude.
- **Use of Inappropriate Extension Cable**
  Probes are normalized for typical extension cable use unless specified by the user. Deviations may effect received signal strength and renormalization on the desired extension cable may be recommended.
- **Proper Length**
  Nanoprobes must be used with the proper length extension cable (probe + cable = approximately 185 cm) to meet performance specifications.
- **NonStandard Electrical Configurations**
  These include using electrical swivels and switch boxes
- **Electrical Connection**
  Break in probe wire, corrosion in pins or wire connection.

Special Application Considerations

Cables longer than 3 meter length

Long cables are often requested for MRI applications where it is important to keep the flowmeter electronics away from the magnet or for monitoring tethered animals from an observation room. Flowprobes with high received signal may be used with cables as long as 7 -10 meters, but must be tested and normalized to operate on this length. In addition, transmission of the probe digital eprom data over long cables is not reliable. Use of separate eprom keys with long extension cables is recommended to locate the eprom at the flowmeter where it the digital information can be reliably read.

Super Keys

Extending Chronic Implant Life

Conditions in chronically implanted flowprobes (such as fatty tissue infiltration) can cause the probe signal to degrade over time. A probe with normalized signal that has become low may be boosted by increasing the transmit signal with specially programmed eprom "Super Keys". Super Keys may extend the functional life of an implanted probe so that data may continue to be collected. Researchers should evaluate new data with previous data to ensure that baseline has not shifted significantly and zero offset increased.

Using Electrical Swivels

Multiple electrical connections and impedance mismatch in the cable may also compound received signal loss. Super Keys may be used in these applications to overcome low signal conditions which cannot be resolved.

Prosthetic Graft Materials

Artificial graft conduits are woven or knitted of various materials which generally trap air in the graft wall and impede ultrasonic signal transmission. Grafts may be pretreated by vacuum or preclotted to absorb air prior to implant to allow flow measurement with Transonic flowprobes during surgery. Normalizing and calibrating flowprobes for specific use on a graft accelerates the signal transmission to achieve a measurement sooner on chronically implanted grafts.

Conclusions

- Flowprobe receive signal should be tested periodically for adequate signal levels.
- Flowprobes should be used with recommended extension cable lengths.
- Flowprobes with low signal should be serviced and renormalized at Transonic System
- Flowprobes for chronic implant should have a minimum signal level of 0.7 volts prior to implant.

TN-99: Extension Cable Use cont.

TN #99 Extension Cable Use Rev B 6/05, page2

400-Series Perivascular Flowprobes

Probes with CRA10 Connector	Standard 1.25 meter length	Extension Cable with 10-Pin Probe Connector: 2 meter length	3 meter length	Custom: > 3 meters
0.5 mm, 0.7 mm Nanoprobes	Standard Normalization = 1V	*Not recommended* Significant signal decrease and zero offset increase		*Not available*
1 mm, 1.5 mm probes	Standard Normalization = 1V	Normalize on 2 meter cable; signal may decrease	Normalize on 3 meter cable; signal may decrease	*Not recommended*
2 mm & larger probes	Standard Normalization = 1V	Normalize on 2 meter cable suggested	Normalize on 3 meter cable suggested	Normalize on custom length; Use separate Eprom Key

Probes with Chronic Connector	Standard 1.25 meter length	Extension Cable with 4-Pin or 12-Pin Probe Connector: Standard 1.8 meter length	3 meter length	Custom: > 3 meters
0.5 mm, 0.7 mm Nanoprobes	Not available	Standard Normalization = 1V	*Not recommended* Significant signal decrease and zero offset increase	
1 mm, 1.5 mm probes	Not available	Standard Normalization = 1V	Normalize on 2 meter cable; signal may decrease	*Not recommended*
2 mm & larger probes	Not available	Standard Normalization = 1V	Normalize on 3 meter cable; suggested	Normalize on custom length; Use separate Eprom Key

400-Series Tubing Sensors

Sensor Size	No Extension Cable	Extension Cable: 1 meter length	Custom: > 1 meters
1 PXN, 2PXN, 3PXN	Standard Normalization = 1V	*Not recommended* Significant signal decrease and zero offset increase	*Not recommended*
PXL Sensors 4 PXN & larger	Standard Normalization = 1V	Normalize on 1 meter cable; signal may decrease	Normalize on custom length; Contact Transonic for specification.

• Fluid temperature and tubing type also significantly affect tubing flowsensor received signal. Normalization should be performed at conditions of actual use.

T106 / T206 -Series Perivascular Flowprobes

Probes Size & Connector Type	Extension Cable Length: 1 meter length	2 meter length	3 meter length	Custom: > 3 meters
10-Pin Connector				
0.5V - 1.5 mm probes	Standard Normalization = 1V	*Not recommended* Significant signal decrease and zero offset increase		*Not available*
2 mm & larger probes	Standard Normalization = 1V	Normalize on 2 meter cable suggested	Normalize on 3 meter cable; signal may decrease	Normalize on custom length; Use separate Eprom Key
4-Pin Connector				
1 mm, 1.5 mm probes	Standard Normalization = 1V	Normalize on 2 meter cable; signal may decrease & zero offset may increase	*Not recommended* Significant signal decrease and zero offset increase	*Not available*

TN-92: Electronic Swivel Tether Use with Transonic Flowprobes for Rats

Three protocols are offered to achieve conscious flow measurements in the rat. The three protocols differ due to the type of spring tether and skin button used.

Instech PO135 Spring Tether and Instech Polysulfone Skin Button

For this protocol, the connector is cut off the probe and the cable is threaded through the skin button and spring tether. Cannulation tubes would also be threaded through these items at this time. The cable from the probe is then soldered to the Airflyte electronic swivel input leads and the connector is then soldered to the Airflyte electric swivel output leads.

Application	Probe	Reflector (Slide)	Connector	Cable
Cardiac Output:	2.5SL	J reflector (no)	CM4B	100 cm*
Renal/Carotid	1RB	J reflector (yes)	CM4B	60 cm*
Mesenteric	1RS or 1RB	J reflector (yes)	CM4B	60 cm*

*The probe cable will have to be cut to the desired length. **The connector comes installed so Transonic can test and calibrate the probe.**

* * *

Transonic #MCS11 Spring Tether and Transonic Silicone CA4 Cuff Skin Button

(#AAPC103)

For this protocol, the extension cable is cut and soldered to the Airflyte electronic swivel input leads. The extension cable connector is then soldered to the Airflyte electronic swivel output leads. The probe cable and connector are threaded through the silicone skin button and spring tether. The size and number of cannulation tubes may be limited using the Transonic spring. Once the connector has been threaded through the spring it can be plugged into the extension cable connector.

Application	Probe	Reflector (Slide)	Connector	Cable
Cardiac Output:	2.5SL	J reflector (no)	CA4	60 cm**
Renal/Carotid	1RB	J reflector (yes)	CA4	60 cm**
Mesenteric	1RS or 1RB	J reflector (yes)	CA4	60 cm**

**or your desired length; In this situation, you will NOT cut the cable on the probe. Instead, you will cut the connector off of the extension cable. It is important that you choose a suitable length for the cable on the probe itself. The Transonic #MCSS11 spring tether is 18 inches long. The polysulfone skin button will wear better on a longer implantation experiment than will the silicone skin button.

Exteriorization via Skin Button

(Transonic Single Rigid Saddleback Cuff, #AAPC104).

For this protocol, a short probe cable length is chosen and the probe connector is exteriorized through a Transonic Single Rigid Saddleback Cuff (#AAPC104) skin button. A spring-covered CM4-WM40-CH10, 1 meter extension cable is then plugged into the connector at the skin button and is then cut and soldered onto the swivel apparatus. This method is most appropriate if cannulas for measuring pressure or drug delivery are to be used or if continuous conscious measurements are needed.

Application	Probe	Reflector (Slide)	Connector	Cable
Cardiac Output:	2.5SL	J reflector (no)	CM4B	9-20 cm
Renal/Carotid	1RB	J reflector (yes)	CM4B	9-20 cm
Mesenteric	1RS or 1RB	J reflector (yes)	CM4B	9-20 cm

Pictures of the 1RS and 1RB flowprobes can be seen on www.transonic.com.

* * *

A 1996 publication: D'Aleida et al, "Validation of Transit-Time Ultrasound Flow Probes to Directly Measure Portal Blood Flow in Conscious Rats," 1996; Am J Physiol 271 (Heart Circ. Physiol. 40): H2701-H2709, has an excellent graphic showing where they positioned the flowprobe and how they exteriorized the connector.

* * *

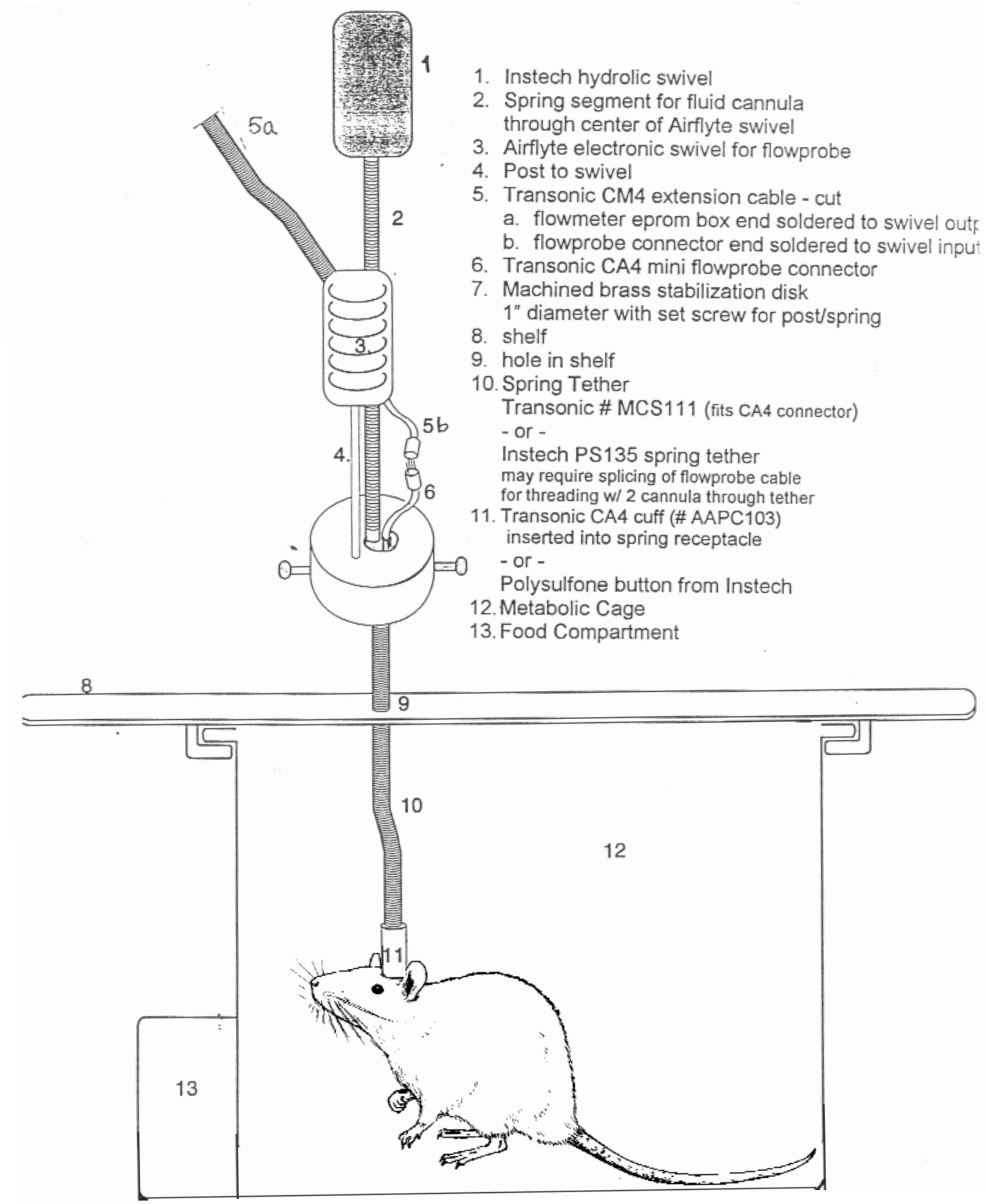
Instech and Airflyte equipment can be purchased directly from these companies:

Instech Laboratories Inc.
Tel: 215-941-1032; Fax: 215-941-0134;
www.instechlabs.com

Airflyte Electronics
Tel: 201-436-2230; Fax: 201-436-6024;
www.airflyteelectronics.com

TN-92: Electronic Swivel Tether Use with Transonic Flowprobes for Rats cont.

TN #92 Draft: 6/02, page 2



I1009: Nanoprobe Care

I1009 Rev. A 4/02

A Transonic Systems' Precision Nanoprobe is a delicate instrument for precision blood flow measurements in microsurgical research applications. Please handle this instrument with precision care to enjoy full use and trouble free maintenance over the lifetime of the product.

These probes are warranted for 3 months.

Handling the Probes during Acute/Chronic Use

✔ Handle the chronic style Nanoprobes by the cable just in back of the probe head, or by gently grasping the probe body — NEVER apply pressure or force on the reflector or the reflector hook, which is the most delicate part of the structure.

✔ Acute use Nanoprobes have a stainless steel shank along the cable to easily maneuver the probe head on the vessel and maintain position of the probe with a micromanipulator. As with chronic probes that have no handle, do not apply pressure or force to the probe head or reflector.

✔ We suggest using fine tweezers/forceps to lift the vessel into the probe lumen, rather than using the reflector hook to scoop the vessel into the probe lumen.

✔ Keep sharp objects away from the reflector face and probe body (scalpels can chip the reflector surface and cut the epoxy probe body).

Sterilization

Probes can be sterilized by:

1) Ethylene Oxide gas sterilization
2) Soaking in liquid sterilizing solutions (such as 2% glutaraldehyde), then rinsing thoroughly with sterile saline.

Probes cannot be steam-sterilized, since steam-sterilization temperatures will degrade the piezoelectric crystals embedded inside the probe.

For ethylene oxide sterilization, follow the standard sterilization cycle time for your EO system.

Recommended parameters:

• Chamber temperature	119º - 131ºF
• Chamber humidity	45 - 75 % RH
• Load temperature	104º - 141ºF
• Load humidity	20 - 90% RH
• Gas Mix	10%EO, 90%HCFC
• Pressure	24.2 - 27.2 PSIA
• Aeration Time	
Heated Aeration	12 - 48 Hours
Ambient Aeration	47 hours minimum

Cleaning

Probe can be cleaned of adhering tissue by soaking in a solution of Madacide-1.
Mada Inc., HYPERLINK
http://www.madainternational.com/us/prod14_us.html
http://www.madainternational.com/us/prod14_us.html

Probes can also be safely rinsed with isopropyl alcohol.

DO NOT place the probe in contact with acetone — this will dissolve the epoxies used in the probe.

Storage

Probes should be stored in dry, room-temperature locations in their original plastic boxes with padding to protect the probe from impact damage.

Probes should not be exposed to rapid temperature changes (such as immediately going from cold water to body-temperature water).

TN-27 Flowsensor Tubing Acoustics

TN #27, Rev. 7-03

Uniform Conditions

The acoustic principles used to determine the most accurate coupling agent for Transonic perivascular flowprobes are identical to those which govern the design, tubing-specific manufacture and proper use of our Sterile Tubing Flowsensors. Just as the acoustic properties of the coupling agent can affect ultrasonic transit time measurement accuracy on blood vessels, the acoustic properties of tubing will also affect accuracy. This is why we request a sample of tubing for flowsensor calibration and shudder when our perivascular flowprobes are "jury-rigged" for flow measurements on tubing. (Only glove-thin latex and custom-thin polyurethane can be used predictably with perivascular probes).

"Squaring Off"

Tubing can attenuate, reflect, focus or delay ultrasound timing dependent upon tubing material, density, wall thickness and temperature. Since the most accurate transit time measurements are achieved under uniform acoustic conditions, the challenge in flowsensor design is to ensure conditions where the tubing affects ultrasound transmission in a uniform predictable way. Thus, Transonic sterile tubing flowsensors "square off" the tubing circumference to minimize focusing of the ultrasound and variable path lengths of the acoustic beam. The ultrasound transmit level and received signal timing window, and calibration factor are determined and set specifically for the tubing to be used. Even so, there are conditions of acoustic mismatch which affect accuracy. If anticipated, these can be minimized.

Temperature

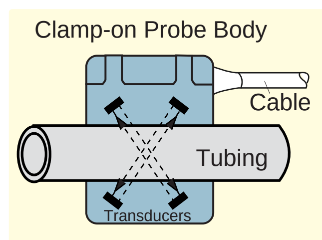
The most significant changes in uniformity of the acoustic beam occur at the sensor/tube border and the tube/liquid border. Fluctuations in temperature can affect the acoustic properties of these interfaces. To minimize these effects, we recommend that the sensor be allowed to equilibrate on the tube before measurement. Zero stability can be improved for measurement of circulating cold liquids by cooling the flowsensor as well. This can be as simple as insulating around the sensor and tube with foam or maintaining the tubing circuit and flowsensor in a controlled environmental chamber.

Vaseline Seal

We recommend a thin smear of Vaseline to acoustically couple sterile tubing flowsensors with tubing. Water-based gels will dry out and can build up on the sensor to contribute their own layer of offset and error.

Calibration

A discussion of accuracy in tubing flow measurement would not be complete without consideration of the acoustic properties of the liquid to be measured. Transonic Systems will custom calibrate the sensor for the specific liquid if a sample is provided. Changing the liquid (or temperature) will affect the calibration. Transonic Systems TS410, T110R Flowmeters allow the user to adjust the calibration gain on site; users of the T106/T206 should apply a correction factor to collected data. Adjustments to flow data should be made only after a comparison of flowmeter reading with timed collection.



Sterile Tubing Flowsensor
Ultrasonic transducer shell clamps onto tubing.

Ultrasound That Measures Volume Flow, Not Velocity

Using wide-beam illumination, transducers pass ultrasonic signals back and forth, alternately intersecting flowing blood in upstream and downstream directions. The transit time of the ultrasonic beam is decreased when traveling downstream with the blood flow and increased when traveling upstream against the flow. The difference between the integrated transit times is a measure of volume flow.

Transonic Systems Inc.
Tel: 800-353-3569(USA); Fax 607- 257-7256; www.transonic.com
Europe: Tel: 31 43 407 7200; e-mail: info@transonic.nl; Fax: 3143 407 7201

TN-34 Syringe Calibration - Tubing Sensors

TN #34, Rev. B 9-03

Fluid

PXL, PXN and XL-Series sensor calibrations should be performed using the actual fluid. A fluid separator diaphragm (latex works well) may be used to keep the syringe clean.

Temperature

Sensors should be calibrated within ± 2C° of the specified fluid temperature since the acoustic velocity of the fluid and tubing properties change with temperature. Constant temperature is maintained through a heat exchanger.

Tubing for PXL-Series & XL-Series Sterile Tubing Flowsensors

Calibration should be performed on the specific tubing to be used since tubing material and type can change the probe calibration.

Method

Tubing flow can be calibrated using a syringe with two switch points, with a known volume between the points. This volume is calibrated by weight, by drawing water from a reservoir sitting on a calibrated scale. The reservoir is gravity fed with an overflow hole to maintain constant reservoir height and constant pressure. The switch outputs are then fed to a computer or voltmeter, which calculates the time between the switches. The average volume flow of the syringe (volume flow = volume/time) is then known. At the same time the flowmeter's pulsatile flow output voltage is fed to the computer (or monitor the flow reading) to average the flow over the above time. The slope of that point is then calculated using the following equation:

$$\text{Slope} = \frac{\text{Measured Flow (of flowsensor)}}{\text{Real Flow (of Syringe)}}$$

Calibration Routine

A standard calibration routine consists of the following. First a zero flow point is taken. The zero flow reading is subtracted from each Measured Flow point. Data is taken at intervals near the typical flow range and the corre-sponding slopes are averaged together. The gain adjustment is calculated by the following:

$$\text{Calibrated Adjustment} = \frac{100\%}{\text{Average Slope}}$$

Since the PXL, PXN and XL sensor designs have two transducer pairs, each pair of transducers must be separately calibrated at the factory. This corrects for any slight angle changes between piezoelectric crystals and effects of slight differences in the glue layers. Since the percent difference between the trnasducer pairs is linear, a new calibration (different tube or fluid) can be made using the calibration adjustment of the flow program. Consult your manual for details on using the menus.

Please contact Transonic Systems Inc. for more information.

Note:

The "average of slopes" line fit is used rather than "linear regression" because the line fit needs to be forced through the zero flow point.

TN-31 PXN Inline Sensor Care

TN #31, Rev. A 9-03

Transonic Systems' PXN Inline Flowsensors are designed for laboratory use. The smooth cylindrical flow channel will not trap air bubbles or particulate material and can be easily flushed to keep it clean and free from a build up of material deposits on the interior surfaces.

Sizes 4PXN and larger are made with a rigid Ultem plastic tube with barbed ends to mate with flexible laboratory tubing. A variety of clamps are commercially available for high pressure applications.

Sizes 1PXN – 3PXN are manufactured with a flexible Pebax tubing channel that optimizes the ultrasound signal transmission for the highest accuracy and sensitivity for low flow applications. Pebax is a polyether block amide plastic with strong physical and mechanical properties. The tubing ends are supplied approximately 45 mm long, but may be cut to a preferred length without compromising the integrity of the sensor. Plastic connectors are available for, or the Pebax tubing ends may be expanded to fit over tubing in the experimental apparatus. Instructions for expanding the tubing ends follow.

Cleaning and Sterilization

The outside surface and internal channel of PXN inlines may be cleaned with mild soap and warm water (< 55ºC; 130ºF). Use a soft bristled brush to remove any foreign material. Avoid scratching the inner channel surface. A syringe with a plastic luer lock adapter, a pipe cleaner or small gauge covered wire may be used to mechanically clean the internal channel of the smaller inline sensors. The surfaces may be wiped or flushed with ethyl alcohol to promote drying. The electronic connector should be washed only when necessary; rinse briefly with 90% ethanol.

The PXN inline sensors may be sterilized by cold ethylene oxide gas (< 60ºC; 140ºF). **Avoid subjecting sensor housing to temperatures higher than 60ºC.** The PXN inline sensor should not be boiled, autoclaved or sterilized by cold liquid sterilization.

Mounting and Use

Transonic PXN inline sensors should be mounted into the tubing circuit so that they are supported on both ends. They should not be hung or supported by the flowsensor cable. The arrow indicates direction of positive flow. Use the invert feature of the TS410 if the sensor cannot be mounted in the positive position.

Larger sizes (4PXN and larger) have barbed ends to grip flexible laboratory tubing. The Ultem tubing edge is thin to provide a streamlined transition with circuit tubing. Protect these from sharp impact damage or dropping. Hard High durometer or thick walled tubes may slide onto the barbed ends more easily if the flexible tubing end is warmed prior to insertion. Nylon hose clamps are available to secure the junction for high pressure applications.

Smaller 1PXN - 3PXN probes are spliced into the flow circuit with short lengths of rigid plastic or metal tubing. Do not pull the flexible Pebax tubing from the sensor housing: damage may result. The Pebax tubing may be cut to a shorter desired length using a sharp blade. The ends may also be widened to mate with larger diameter tubing, if desired (such as glass perfusion apparatus).

PeBax Tubing

Pebax tubing becomes pliable at higher temperatures. To achieve a larger diameter tubing ends to fit tightly over custom apparati, the ends may be expanded by heating them over either a single gradually tapered rod or successively larger diameter rods. Transonic Systems recommends experimenting with this process on a sample of the Pebax tube cut from one of the tubing ends or a sample obtained from Transonic Systems **BEFORE** altering the sensor ends. Transonic Systems cannot be responsible for damage made to the inline sensor resulting from modification of the Pebax tubing.

Instructions for Expanding PeBax Tubing Ends

1) Mount the end of the tubing approximately 5 mm onto a metal rod that is slightly larger than the inner diameter of the Pebax tube (or a rod that tapers down to the tubing ID). The rod should not have sharp edges or come to a point. Dip the end of the rod in soapy water, and grip the Pebax tubing with a paper towel or cloth to make insertion easier. Expanding the Pebax tubing within 2 cm of the sensor housing is not recommended.
2) Vertically submerge the rod, but **not** the Pebax tubing in near-boiling water (about 95ºC) for 30 seconds. The metal rod will transfer the heat to the tubing end.
3) Keeping the assembly vertical, submerge the rod and Pebax tubing (but not the sensor housing) into cold water for 30 seconds. Grip the Pebax tubing with a paper towel and carefully remove the rod.
4) Repeat the process with successively larger diameter rods until the desired diameter is achieved. It is possible to expand the 1.2 mm diameter 1PXN tubing to 2.0 mm.

Sensor Storage

PXN inline sensors should be stored dry in their plastic shipping cases.

Calibration Guidelines

ME-PXN Flowsensors are precalibrated at the factory for use with customer specified fluid and temperature. This calibration is performed with equipment that has been calibrated traceable to the standards of National Institute of Standards and Technology and to Transonic Systems Inc. equipment performance standards. A Calibration Certificate, valid for 1 year, will be supplied with each flowsensor at the time of purchase. Up to 4 fluid/temperature combinations may be preprogrammed into the connector eprom. ME-PXN flowsensors may be recalibrated by the user for other fluid/temperature conditions using the gain adjustment program in the TS410 flowmeter.

Please note: the ultrasound signal amplitude is also normalized for the fluid/temperature use specified. Using the sensor at a different temperature or with fluid other than specified may show a significant reduction in the normalized received signal of the sensor. (Ultrasonic transmission is affected by the density of the fluid). Accurate measurements can be made even with a low received signal indication if a careful calibration is performed to correct the flow gain of the flowsensor.