Operator's Manual

Transonic®
Animal Research Flowmeters

T106/T206 Series

FLOWMETER SERIAL # _____

(FOR INVESTIGATIONAL USE)

AUT106 Manual Rev 3/97

Transonic Systems Inc.
Excellence in Quantitative Hemodynamics
34 Dutch Mill Road, Ithaca, NY 14850 USA; Tel: 800-353-3569, 607-257-5300;
Fax: 607-257-7256; Internet: www.transonic.com

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Transonic Systems Inc.
Excellence in Quantitative Hemodynamics
34 Dutch Mill Road, Ithaca, NY 14850 USA; Tel: 800-353-3569, 607-257-5300;
Fax: 607-257-7256; Internet: www.transonic.com

Warnings & Precautions

TRANSONIC FLOWMETERS AND FLOWPROBES
LISTED IN THIS MANUAL
ARE DESIGNED FOR USE IN ANIMALS ONLY
AND ARE NOT TO BE USED ON HUMANS.

THE USE OF THESE FLOWMETERS OR FLOWPROBES
ON HUMANS MAY RESULT IN ELECTRICAL SHOCK
TO THE PATIENT OR TO MEDICAL PERSONNEL.

For use on human patients, Transonic flowmeter
models HT107 or HT207 are required.

Contact the Transonic applications support staff
Tel: (607) 257-5300 or Fax: (607) 257-7256

Declaration of Conformity

Product: Blood Flowmeter Model #T106 *(single channel)* and T206 *(dual channel)*, perivascular flowsensors and sterile tubing flowsensors

Manufacturer's Name: Transonic Systems Inc.

Manufacturer's Address:34 Dutch Mill Road, Ithaca, NY 14850 USA

Contact in the EEC: Transonic Systems France SARL
Direct inquiries to Geránt
01-44-88-15-10

Applicable Council Directive: 89/336/EEC

Standards to which conformity is declared: EN55011 Conducted and Radiated Emissions
EN60601-1-2 consisting of:
IEC1000-4-2: ESD Susceptibility
IEC1000-4-3: Radiated Susceptibility
IEC1000-4-5: Surge Susceptibility
IEC801-4: Electrical Fast Transient Susceptibility

I, the undersigned, hereby declare that as of serial #T106-96-0860/T206-96-0860 the equipment specified in this owner's manual and on the data sheet enclosed with this shipment conforms to the above Directive and Standards.

Signature: Mark S Alsberge **Date:** 3/24/00

Name: Mark S. Alsberge

Position: Vice President
Medical and Regulatory Affairs
Transonic Systems Inc.

Contents: Section A

Transonic Systems Inc.

Excellence in Quantitative Hemodynamics

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Transonic® Animal Research Flowmeter (T106/T206) packages consists of a bench-top **electronic flow detection unit** with enhanced frequency resolution and volume flowsensing probes in three styles: **perivascular flowprobes** for intraoperative use; **in-line flowprobes** and **sterile tubing (clamp-on) flowsensors** for extracorporeal use with flexible laboratory tubing. Patented by Cornell University, the flowmetering system uses an ultrasonic transit-time principle to sense liquid volume flow in vessels or tubing largely independent of flow velocity profile, turbulence and hematocrit.

A. ELECTRONIC FLOW DETECTION UNIT

The line-powered flowmeter automatically identifies the scaling factor and individual calibration factor of the flowprobe connected to it. Front panel push button switches engage four modes of operation: **Measure Mode** (to display volume flow); **Test Mode** (to analyze the ultrasonic performance of the flowsensor and report electronic diagnostics); and **Calibrate External Recording Devices for Zero and Full Scale**. A digital readout, an analog meter, and analog signal outputs present flow readings (pulsatile and average), test/error messages and calibration signals.

B. FLOWSENSORS

Transonic flowsensors connect to the flow detection unit via a flexible cable. Two ultrasonic transducers within the flowsensor body transmit 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, and with low and stable zero flow offset and high resolution. Transonic flowsensors can measure flow in aqueous, non-aerated fluids and do not require particulate content or ionization of the monitored liquid.

1. PERIVASCULAR FLOWPROBES

Transonic perivascular flowprobes (R-, S-, V-, & A- Series) for use in acute or chronic animal research studies measure instantaneous and average volume flow in arteries, veins and ducts 0.25 mm to 36 mm in diameter. When several vessels are led together through a perivascular probe, total directional volume flow passing through the sensor is measured.

2. IN-LINE FLOWPROBES

Transonic N-Series flowprobes are spliced into laboratory tubing from .046 to .875 inch internal diameter (I.D.) to directly measure instantaneous and average volume flow. The probes are designed for general bench-top applications *(isolated organ preparations, in-line monitoring of pumped flows, etc)*.

3. STERILE TUBING (CLAMP-ON) FLOWSENSORS

Transonic sterile tubing flowsensors (C-Series) apply ultrasound energy through standard laboratory tubing to monitor instantaneous and average volume flow (see specifications, Appendix B) of blood or other liquids. With only ultrasonic contact required between probe and monitored flow, sterile tubing flowsensors maintain total physical and electrical isolation between sensor and liquid under study.

C. SAFETY PRECAUTIONS

Transonic research flowmeters and compatible probes are designed only for investigative use with animals and are not for use in humans. USE OF FLOWMETER WITH HUMANS MAY RESULT IN ELECTRICAL SHOCK TO THE PATIENT OR TO MEDICAL PERSONNEL.

For all human applications, only use Transonic products designated by the prefix "H" in the model or series number (i.e., HT107 [single-channel flowmeter], H6S [6 mm S-Series flowprobe], etc.).

1. 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. Factory recalibration of the flowprobe is necessary if the flowprobe is to be used at a different temperature or on a liquid other than the one for which it was calibrated.

2. Transonic in-line flowprobes are designed for **non-human laboratory use** only. Factory 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.

3. Transonic sterile tubing (clamp-on) 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 recalibration of a flowsensor is necessary if the flowsensor is to be used on a different tubings or liquid other those the one for which it was calibrated.

A Transonic R-, S-, V-, A-, N-, & C- Series flowprobe *(Fig. 1)* consists of a probe body which houses two 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 midway between the two transducers on the opposite side of the vessel or tube. V-Series probes are designed with a V-reflector for a more sensitive multiple reflection scheme. A-Series probes utilize a dual beam X-pattern of ultrasound illumination with four transducers and no reflector. The flowmeter's 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 "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 then 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 of the upstream cycle is repeated, but with the transmitting and receiving functions of the transducers reversed so that the liquid flow under study is bisected by an ultrasonic wave in the downstream direction. Again, the flowmeter derives and records from this transmit-receive sequence an accurate measure of transit time.

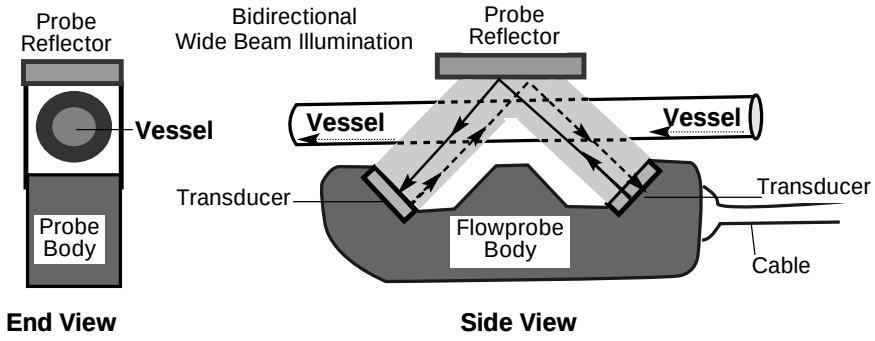


Fig. 1: Schematic views of the perivascular Transonic ultrasonic volume flow-sensor. Two transducers pass ultrasonic signals back and forth, alternately intersecting the flowing liquid in upstream and downstream directions. The difference in transit time between the upstream and downstream signals is a measure of volume flow.

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 rather than velocity.

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 beam rays 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)* .

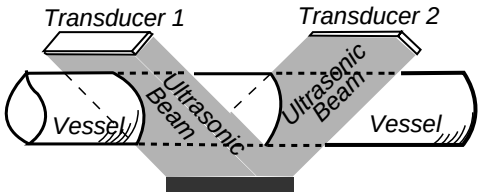


Fig. 2: The vessel is placed within a beam that fully and evenly illuminates the entire blood vessel. The transit time of the wide beam then becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.

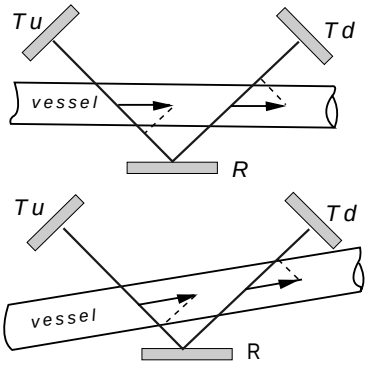


Fig. 3: Angle insensitivity of the Transonic flowprobe: T = transducer; R = reflector

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, that is, the 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.

Direct Quantification of Volume Flow

T106U / T206U, T106 / T206 Animal Research Flowmeters

For Acute/Chronic & Extracorporeal Flow Measurements

- Available in single or dual channel models
- Display average flow rate in ml or L/min
- Pulsatile and mean analog flow signals can be externally recorded from rear-panel BNC
- Provides at-a-glance monitoring of the quality of the ultrasound signal
- Low flow scale selection for increased sensitivity
- Proven transit-time ultrasound technology
- T106U/T206U provides low cost data acquisition and pressure recording.

Acute or Chronic *In Vivo* Animal Studies

One flowmeter to study multiple animal models with exceptional resolution and reliability.

- Measurement capability for vessels from 250 microns through 36 mm diameter
- Probes are non-constrictive and compatible for long-term implant
- New series of cardiac output flowprobes for highest accuracy in vessels with turbulent flow

Extracorporeal & *In Vitro* Flow Measurements

One flowmeter to measure a wide variety of liquids *(ie. blood, saline, urine, buffers)*.

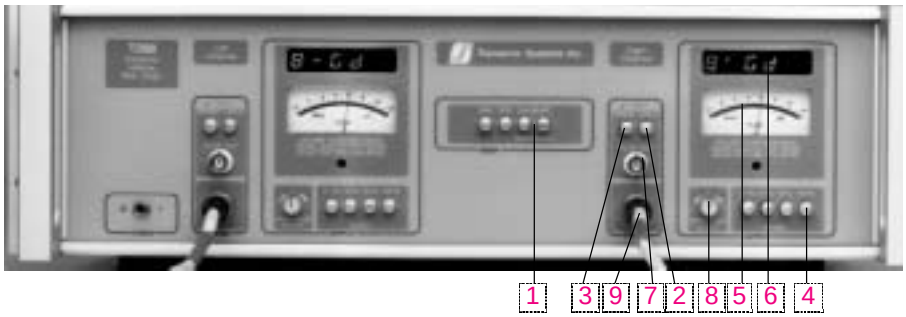
- high resolution in-line flowprobes for tubing I.D. from 0.046" *(1.2 mm)* through 0.875" *(20.8 mm)*
- sterile tubing flowsensors for flexible tubing I.D. from 1.8" *(3.2 mm)* up to 3/4" *(19.0 mm)*

Probe design dependent. See Accessories for Animal Research Flowmeters *(Appendix B)* for specifications effective at date of manual publication. Contact factory for latest specifications.

Specifications *cont.*

T206 Dual Channel Flowmeter

(*front panel)*



T106
single channel
10 lbs (4.5 Kg), 81/2"w x 5"h x 16"d
(90-130 Volts; 50-60Hz, single phase
(30 VA, 1.0 AMP slow-blow fuse);
200-260 Volts; 50-60Hz, single phase
(30VA, 0.4 AMP slow-blow fuse)

T206
dual channel
16 lbs. (7.2 Kg), 19"w x 5"h x 16"d
90-130 Volts; 50-60Hz, single phase
(60 VA, 1.6 AMP slow-blow fuse);
200-260 Volts; 50-60Hz, single phase
(60VA, 0.8 AMP slow-blow fuse)

T106U/T206U
single channel and dual channel model with data acquisition and pressure recording capability. Includes:

- **Computer Interface circuitry,** cable, and "WINDAQ" software to connect the flowmeter to an IBM compatible computer via its serial RS232 port;
- **Pressure** sensor amplification by flowmeter A/D board for acquisition of pressure data in addition to flow. RJ11 phone input jack for pressure transducers; 1 per flow channel.

Synchronization for multi-unit operation or simultaneous use with Doppler instrument is supplied as standard circuitry on all units.

Gating (-G) Option for use during MRI unit to eliminate cross-coupling interferences.

Bubble Alarm (-B) Option with audible alarm which sounds when gas bubbles pass through a sterile tubing flowsensor.

Electrical Isolation
Flowmeter is grounded. If accidentally ungrounded, line to ground leakage current is less than 50 µA. ETL listed.

1 **Push Button Control of**
Mode of operation: selects Measure, transducer Test, Calibrate External Recording Devices for Zero / Full Scale

2 Low Flow Range: expands displayed flow sensitivity by a factor of four;

3 Polarity of Displayed Flow: inverts polarity of analog flow outputs and flow displays

4 Output filtering: 0.1, 10, 30 and 100 Hz Low pass filtering applied to analog output signals

Automatic Meter Adjustments

- Probe size and corresponding flow output ranges (see flowprobe tables)
- Volume flow calibration of the applied probe
- Dual channel flowmeters synchronously monitor two flowprobes at the maximum rate without cross coupling interference

Flowmeter Displays

5 **Analog Meter** (taut-band needle)

6 **Digital Display**

- Volume flow (in Measure mode)
- Received signal amplitude (analog meter, Test mode)
- Diagnostic Data (digital display in Test mode)
- Probe scale data (in Zero and Scale factor Calibration modes)
- Test Light: indicates when acoustic signal and flow output signals do not meet specifications.

Multi-Unit Synchronization
Rear panel master/slave control and input cable to time ultrasound signals for concurrent operation with pulsed Doppler or sonomicrometry.

7 **Flow Monitor Outputs**
* Average volume flow; rear panel, BNC connector, 0.1Hz low-pass filtered
* Pulsatile/Average volume flow; front/rear panel, BNC connector, filtering controlled by front panel push buttons
Zero calibration = 0 Volts out
Scale factor flow = 1V ± 2%
Output resistance = 500 Ohm
Full range for flows = ± 5V (bi-directional flows, ± 5 times scale factor)

8 **Offset Adjustment Dial**
for Zero flow reading during occlusion or when no flow is passing through a sterile tubing flowsensor; front panel

9 **Probe Connector**
Accepts male CH10-style connector of probe or extension cable

Digital Identification
Probe identification and calibration parameters programmed into flowprobe connector.

Ultrasonic Frequency
Probe dependent (see probe tables)

Ultrasonic Transducers
R-, S-, Series: implantable (chronic/acute) perivascular flowprobes;
V-, Series: microcirculation flowprobes (T106/T206);
A-, Series: cardiac output flowprobes;
C-Series: sterile tubing (clamp-on) flowsensors for extracorporeal use with tubing.
N-Series: in-line flowprobes that splice into laboratory tubing

Extension Cable
1, 2, 3 meter cables available; supplied one per flowmeter channel purchased

Descriptions of the functions and controls for standard Transonic Animal Research flowmeters follow.

MODE SWITCHES

Determine the mode of operation when the instrument is connected to a functioning flowprobe.

"MEA" button (or no button) pushed in:
The instrument is in its Measure Mode and provides information on volume flow passing through a connected flowprobe's sensor window:
The **digital display** presents absolute average (0.1 Hz low-pass filtered) volume flow in ml/min or L/min.
The **"AVERAGE" BNC connector** (rear panel) presents average volume flow (0.1 Hz low-pass filtered) as a fraction 1 of the scale factor (S.F.) on analog meter face.
The **analog mete**r and **"FLOW OUT"** (front panel))/ **"PULSATILE"** (rear panel) **BNC connectors** provide fractional instantaneous or average volume flow as selected by the user (0.1, 10, 30, or 100 Hz low-pass filtered).

"CALIBRATE ZERO" button pushed in:
Digital display reads "C 0" to inform user that flowmeter is in calibrate 0 mode;
Analog meter, "FLOW OUT" (front panel) / **"PULSATILE"** (rear panel) **BNC connectors** and **"AVERAGE" BNC connector** (rear panel) provide zero baseline flow signal, 0.02 Volts ± 0.12.

"CALIBRATE SCALE" button pushed in:
Digital display shows a "C" followed by scale factor for the connected flowprobe (in ml/min or L/min) to inform user:
1) that the flowmeter is in the calibrate scale factor mode and
2) the magnitude of the scale factor for the flowprobe in use.
Analog meter, "FLOW OUT" (front panel) / **"PULSATILE"** (rear panel) **BNC connectors** and **"AVERAGE" BNC connector** (rear panel) provide a 1 Volt ± 0.12 reading that corresponds to full scale flow for the flowprobe in use.

"TEST" button pushed in:
Digital display presents a diagnostic message that identifies the probe size in mm and an assessment of the level of the received signal:
"Gd" = sufficiently strong received signal;
"Lo" = marginally adequate received signal;
"No" = insufficient or no received signal.
Analog meter indicates received signal amplitude of the flowprobe in use.
"FLOW OUT" (front panel) / **"PULSATILE"** (rear panel) and **"AVERGAE" BNC connectors** provide volume flow signals as in "MEA" mode.

ANALOG METER

In "MEA" mode: Indicates fractional[1] volume flow passing through a connected flowprobe's sensing window.

In "CALIBRATE" mode(s): Indicates a reading corresponding to zero flow ("ZERO") or to full scale flow ("SCALE") for the flowprobe in use (absolute volume flow equals analog meter reading times the scale factor shown on the digital display).

In "TEST" mode: Indicates received signal amplitude of connected flowprobe in volts-peak-to-peak.

[1]Absolute volume flow equals analog meter reading times the scale factor shown on the digital display.

DIGITAL DISPLAY _____

In all modes

"Ac. Er" ("acoustic error") when no flowprobe is connected, or when the ultrasonic signal's pathway in the flowprobe's sensing window is blocked by air or fat; the reflector is misaligned; the probe or extension cable is malfunctioning, etc.

When the flowmeter identifies a functioning flowsensor

In "MEA" mode: Indicates absolute average (0.1 Hz low-pass filtered) volume flow in ml/min or L/min;
In "CALIBRATE SCALE" mode: Indicates scale factor multiplier by which the fractional indications of analog meter and analog outputs are multiplied to determine absolute flow of flowprobe in use (for instance, "C 25 ml/min" for a 2 mm flowprobe with the "LO FLO" push button depressed);
In "CALIBRATE ZERO" mode: Displays "C 0" when connected to flowprobe;
In "TEST" mode: Indicates diagnostic messages of probe and signal condition, i.e.:

"6-Gd" = The instrument identifies a connected 6 mm flowprobe with good acoustic signal coupling strength;
"6-Lo" = The electro-acoustic pathway of connected 6 mm flowprobe produces a marginal received signal strength;
"6-No" = The electro-acoustic pathway of a connected 6 mm flowprobe is blocked and there is no signal strength.

"√TEST" LIGHT advises operator to check readings, in TEST mode _____

Illuminates when no acoustic signal is received from sensor or when the amplitude of the received signal lies between the "Lo" and "Gd" signal levels. In the latter case, the **"√TEST"** light warns that the flow signals recorded by the flowmeter may not meet the flowmeter's stated accuracy specifications.

"INVERT" PUSH BUTTON _____

Inverts signal polarity, reversing the indicated direction of flow presented by the digital display, analog meter and "FLOW OUT" and "AVG. FLOW" BNC connectors. Push in to invert polarity; push again to restore original flow indication.

"LO FLO" PUSH BUTTON _____

Increases displayed flow sensitivity by decreasing flowmeter's scale factor by a factor of four.
In "CALIBRATE SCALE" mode: digital display at "LO FLO" will read 25% of its former scale factor flow level.

In "MEA" mode: digital display will continue to present absolute volume flow directly in ml/min or L/min. At the analog meter and "AVG. FLOW" and "FLOW OUT" BNC connectors, the same flow will be represented by a four times stronger electrical signal. To reset function to normal scale, push button.

"ZERO FLOW ADJUST" BUTTON _____

Used to adjust flowmeter to read zero flow during occlusion or when no flow is passsing through a sterile tubing flowsensor.

"OUTPUT FILTER" PUSH BUTTONS _____

Determine low-pass cut-off frequency of signals presented on analog meter and at the front panel "FLOW OUT" and rear panel "PULSATILE" BNC connectors.

"0.1 Hz" setting: provides average flow indication (making the "FLOW OUT" and "PULSATILE" signals equal to the signal on the "AVERAGE" connector).

Other settings (10, 30, 100 Hz): analog flow outputs represent pulsatile volume flow within the instrument's accuracy specifications if the filter cut-off frequency (in Hz) is at least ten times the animal model's pulse repetition rate in beats per second. Filter type: third order (3 pole) Butterworth in the 100 Hz setting; second order (2 pole) Butterworth in the 0.1, 10, and 30 Hz settings.

"FLOW OUT", "AVERAGE" AND "PULSATILE FLOW MONITOR CONNECTORS

BNC-type connectors: supply flow information to accessory instrumentation (strip-chart recorder, digital voltmeter, etc.):

Front panel **"FLOW OUT"** connector and rear panel **"PULSATILE"** connector: presents analog meter signal when meter is engaged in all modes of operation

(Measure, Calibrate Zero and Calibrate/Scale Factor);
- in "MEA" or "TEST" mode: provides instantaneous or average flow signal as determined by output filter (1 Volt or equal scale factor);
- in "CALIBRATE SCALE" and "CALIBRATE ZERO" modes: provides calibration signals.

Rear panel **"AVERAGE"** flow monitor connector: presents average flow signals (0.1 Hz second order Butterworth low-pass filtered). Zero flow = zero Volts nominal; Scale factor flow = 1.0 Volts nominal; Output resistance = 500 Ohms.

COMPUTER INTERFACE PORT

T106U/T206U Flowmeters are equipped with the Computer Interface port, a rear panel 25-pin D-shell connector, RS-232 format, so that the meter can be connected directly to a serial port of an IBM PC-compatible computer. Older T106/T206 Series meters are offered this Computer Interface as an option (-P Option).

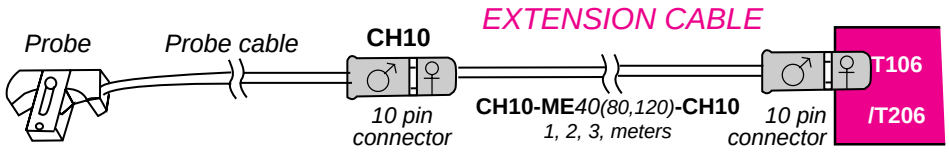
OPTIONAL CONNECTORS

Multi-Unit Synchronization Selector: Optional rear panel low frequency (LF) stereo earphone jack and high frequency (HF) BNC connector and mode dial allow operation of a connected flowprobe in close proximity to other pulsed ultrasonic devices such as distance gauges, other flowprobes. The synchronized flowmeter can either supply timing signals or derive its timing signals from other instruments.

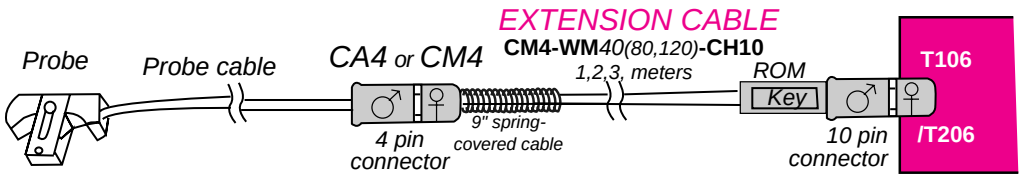
Pressure Port: When equipped with a Computer Interface or (-P) Option, the meter can also be equipped with an optional pressure transducer.

"PROBE" CONNECTOR

Accepts CH10 (10-pin) connector of probe or probe extension cable (CH10-WE80-CH10).



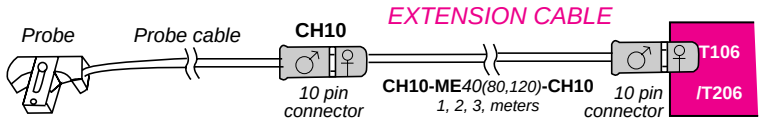
Accepts CM4 (4-pin) probe connectors via a CM4-WM40-CH10 extension cable.



PROBE EXTENSION CABLES

CH10 - ME40 (80,120) - CH10: Polyurethane-jacketed 10-conductor cable with CH10 (10-pin) connectors, male and female to connect probe to meter; 2 meter cable (CH10-ME80-CH10) is standard; longer cables available by special order.

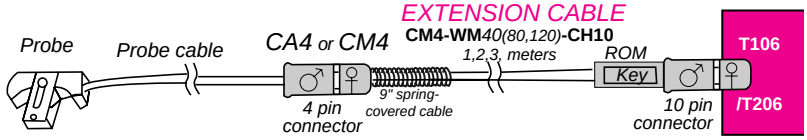
CH10 - ME40 - CH10
CH10 - ME80 - CH10
CH10 - ME120 - CH10



CH10 - ME40 (80, 120) **- CH10:** 1, 2, or 3 meter cable CH10 (10-pin) connectors on both ends. ROM calibration is embedded in the probe connector.

CM4-WM40-CH10: Polyurethane-jacketed cable with CM4 (4-pin) female connector at probe end and CH10 (10-pin) male connector at flowmeter end. Must be used to connect CM4 connectors to flowmeter.

CM4 - WM40 - CH10
CM4 - WM 80- CH10
CM4 - WM120 - CH10



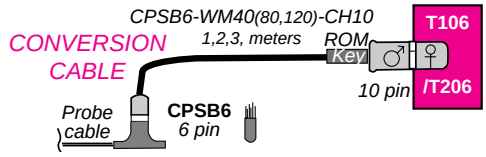
CM4 - WM40(80,120) **- CH10:** 1, 2, or 3 meter cable with CM4 (4-pin) connector to probe and CH10 (10-pin) connector to meter. Includes ROM port for probe calibration keys.

extension cable used with CM4 and CA4 *(micro-4-pin)* connectors.

Conversion cableless: available for use with skin buttons or flowprobes with 9-pin connectors.

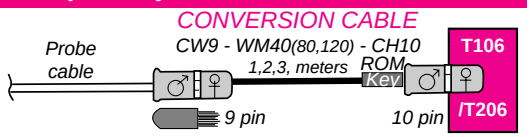
Conversion Cable
CPSB6 - WM40 - CH10
CPSB6 - WM80 - CH10
CPSB6 - WM120 - CH10

conversion cable for Pettinger Skin Buttons *(special order)*



T101D/T201D Flowprobe Compatibility with T106/T206 Flowmeters

Conversion Cable
CW9 - WM40 - CH10
CW9 -WM80 - CH10
CW9 - WM120 - CH10



Flowprobes with 9-pin connectors purchased for T101D / T201D flowmeters can be used on the T106/T206 and T108/T208 model flowmeters with a 9-pin CW9 to 10-pin CH10 conversion cable. Each probe requires a ROM key to supply the probe specific digital information required by the T106 and T108. The ROM port is on the extension cable. Probes must be returned to the factory for the programming of calibration keys and quality assurance check of calibration.

T206 FLOWMETERS

The T206 2-channel flowmeter consists of two complete T106 flowmeters mounted in one casing, with synchronized ultrasonic sampling of both channels flow.

MODE SWITCHES *(front panel, push-button)*
Switches control MODE of operation (MEA, TEST, CALIBRATE) of left and right flowmeter channels simultaneouly.

Flowmeter controls and operation are summarized in ***Fig. 4.1*** on page 17. The following steps are designed to acquaint a new user with the flowmeter and flowprobes and to check for possible damage incurred during shipment. If the apparatus does not function as described during this initial operation, please call Transonic Systems Inc. Customer Service at 1-800-353-3569 (USA) or 607-257-5300 for advice.

A. FLOWMETER

1. Check Power Entry Module (rear flowmeter panel).

The numbers visible through a small window indicates input line voltage for flowmeter operation: 100, 120, 220, or 240 V. If this is not set for your line voltage, remove power cord and pry open cover with a screw driver. Remove cam with pair of narrow pliers, rotate numbers to correct line voltage settings and reinsert in meter. Also remove and change both fuses to correspond to corrected line voltage (fuse data inscribed above power entry module). Reinsert fuses (arrows down). Close cover and again plug into power source.

2. Connect power cord of flowmeter to a grounded power receptacle.

Do not operate unless flowmeter is electrically grounded via the supplied power cord.

3. Turn front panel power switch "ON".

The "POWER ON" light and the "√ TEST" light will illuminate and the analog meter needle will point to "0".

The digital display will read "No-Pr" (no probe).

4. Connect a flowprobe, via the supplied probe extension cable, **to the PROBE connector port on the meter's front panel.**

The connection between meter, extension cable and probe is made with 10-pin self-aligning push-lock connectors.

To connect: align male and female pins together by holding connector by rubber boot and lightly pressing while rotating. When connector aligns, press to lock in place.

To unlock: hold the flowmeter; grasp the male connector by the knurled retainer ring and pull out. The connector should unlock.

B. FLOWPROBE TESTS

Procedures for R-, S-, V and A-Series perivascular flowprobes and C-Series sterile-tubing (clamp-on) flowsensors differ. N-Series in-line flowprobes may be tested by total submersion in liquid, similar to perivascular flowprobes (described below); N-Series probes may also be tested by splicing them into a liquid-filled line of tubing.

Protocols follow for testing:

Perivascular (R-S-V- and A-Series) and In-Line (N-Series) flowprobes &

Sterile tubing (C-Series) flowsensors.

B. PERIVASCULAR (R-, S-, V- AND A-SERIES) & IN-LINE (N-SERIES) FLOWPROBES

1. Preparing the Flowprobe

Place flowprobe in a soft plastic beaker **filled with degassed water**.
Dislodge any air bubbles from the probe's surfaces. A fine gauge paint brush is useful for this especially with V-Series probes.
Observe flowmeter's front panel indicators.
The "Ac.Er" message on the digital display will be replaced by another message as acoustic conduction is established within the probe. A dry probe may have to be immersed in water for several minutes before this occurs; sloshing helps to speed up the process; the probe's received signal stabilizes when probe body surfaces are entirely wet.

2. "MEA" Mode

Engage "MEA" (Measure) mode button.
Digital display presents average volume flow in ml/min or L/min. It accurately measures flow to levels five times the displayed scale factor.
Analog meter indicates flow as a fraction of scale factor (S.F.) on analog meter face.
Depress 10 Hz. "OUTPUT FILTER" button.
Move flowprobe back and forth through water bath.
Digital display numbers change slowly (due to the averaging process).
Analog meter needle moves rapidly back and forth indicating pulsatile flow.

3. "TEST" Mode

Engage "TEST" mode button.
Digital display shows a diagnostic message with flowprobe size (the initial digits of the serial number), followed by "Gd" when the received acoustic signal is strong; or "Lo" when the amplitude of the received signal is marginal.

To illustrate this feature:
1) Pull flowprobe operating with a "Gd" signal slowly out of water bath.
The "Gd" message is replaced by "Lo" when the probe's acoustic signal path is partially blocked by air and the signal amplitude is below 30% nominal.
The "√ TEST" indicator will light to warn user that the system's measurement accuracy is below performance specifications.
2) Pull flowprobe further out of water bath.
The message changes to "no" for no signal and flowmeter no longer records flow.

Analog meter displays the relative received signal strength of the probe's ultrasonic signal. When the probe is new, and no air bubbles are present in the ultrasonic sensing window, the meter needle will point to 1.0 ± 10%. Observe signal strength as flowprobe is slowly pulled out of bath.
The "Gd" to "Lo" trip point occurs at 0.3 V meter indication; the "Lo" to "no" trip point is at an 0.10 V meter indication.

[1] If a glass, metal beaker or styrofoam cup is used for this purpose, ultrasound signals reflected by the walls give rise to an erratic zero-flow baseline.
[2] Use water/saline that has been degassed or has been standing at room/incubator temperature for more than 24 hours. If fresh tap water is used, the operator must periodically dislodge any small air bubbles which form on the tubing's interior surface within the sensing window.
[3] Volume flow can be read from the analog meter by multiplying its indication by the scale factor.

B. PERIVASCULAR / IN-LINE FLOWPROBES *cont*:

4."CALIBRATE" Modes _____

Calibrate modes serve to calibrate output data recorders by presenting the voltage equivalents of zero flow and scale factor flow on the analog outputs.

Depress "CALIBRATE ZERO" button

Digital display reads "c 0" to indicate that flowmeter is in zero calibration mode;
Analog meter needle points to /0 (if it does not, adjust the mechanical (calibration screw located below the analog meter face);
The two analog flow output connectors (front panel FLOW OUT and rear panel AVERAGE) carry 0 Volt ± 3 Mv.

Depress "CALIBRATE SCALE FACTOR" button

Digital display reads "c number", where number equals the scale factor in ml/min or L/min for the connected flowprobe.
Analog meter needle points to the "S.F." mark at 1.0.
The two analog connectors present a 1.0 V signal ± .01V.

Move the flowprobe back and forth in water bath

Analog meter needle remains at 1 even though there is flow through the flowprobe.

5. "INVERT" Button _____

Re-engage Measure Mode

Set the "INVERT" and "LO FLO" push buttons (located above the "FLOW OUT" connector) to the unengaged position. (If these buttons are depressed, they can be released to the out position by pushing once.)

Move the submerged flowprobe toward you

Meter will register flow in either positive or negative direction.

Move probe in opposite direction

Meter indicates flow of opposite sign.

Push "INVERT" button

Notice how the apparent direction of flow has changed.

6. "LO FLO" Button _____

Engage "LO FLO" button

Observe how the displayed flowprobe reading becomes more flow sensitive;
Probe movement now produces 4 times the needle deflection on analog meter.

Press "CALIBRATE SCALE" button

Notice that the scale factor reading is reduced four times.

7. "OUTPUT FILTER" Buttons _____

In "MEA" mode with "LO FLO" button pushed in, engage "100 Hz OUTPUT FILTER" button.

When water is at rest:

Digital display will read approximately 0 ml/min (within specifications).
Analog meter will read 0.0. Notice that the analog meter indicates a slight amount of zero "noise".

Push in "0.1 Hz" button;

Now the analog meter reads average flow and the zero "noise" vanishes.

Move probe back and forth through its bath with long, slow strokes.

The analog meter and digital display both average flow over several seconds.

C. STERILE TUBING (CLAMP-ON) FLOWSENSOR (C-SERIES)

1. Preparing the Flowprobe

Lubricate tubing with a layer of petroleum jelly, silicone grease or other non-drying acoustic couplant to promote ultrasonic transmission between the tube and sensor.

Mount the sensor mid-way on about 1 ft. of tubing of proper type and size (see sterile tubing probe's specification sheet in Appendix B) and follow instructions on page A 23.

Clamp tubing at one end.

Hold unclamped tube end up and fill with water.

Observe front panel indicators of meter.

The "Ac.Er" message on the digital display will be replaced by another message as acoustic conduction is established within the probe.

Caution: do not immerse a sterile tubing (clamp-on) flowsensor liquid for an extended period.

2. "MEA" Mode

Engage "MEA" (Measure) mode button.

The digital display presents average volume flow in ml/min or L/min. It can accurately measure flow to a level five times the displayed scale factor.

The analog meter indicates flow as a fraction of scale factor (S.F. on analog meter).

Depress the 10 Hz. "OUTPUT FILTER" button.

Create flow in the sterile tubing flowsensor by squeezing tubing below flowsensor.

Digital display numbers change slowly (due to the averaging process).

Analog meter needle vibrates back and forth to indicate pulsatile flow.

3. "TEST" Mode

Engage "TEST" mode button

The digital display shows a diagnostic message with flowprobe size (first digits of the serial number), followed by "Gd" when the received acoustic signal is strong; or "Lo" when received signal amplitude received is marginal.

To illustrate this feature:

1) Introduce air bubble into tube. Tilt tubing to force bubble into flowsensing window.
   The "Gd" message is replaced by "Lo" when the probe's acoustic signal path becomes partially blocked.
   The "√ TEST" indicator lights to warn that measurement accuracy has fallen below performance specifications.
2) When fluid in the sterile tubing flowsensor is replaced by air:
   The "no" message appears; the flowmeter no longer records flow.

Analog meter presents acoustic received signal amplitude in peak-to-peak volts.

Observe the signal strength as air is forced into flowsensor.

Signal strength depends upon material and thickness of tubing wall.

"Gd" to "Lo" point occurs at the 0.3 V indication on the meter;

"Lo" to "no00" trip point occurs at the 0.03 V indication on the meter.

A signal strength below the 0.3 V meter indication will set off the meter's bubble alarm when the (-B) option is installed on the meter

[2]Use water/saline that has been degassed or has been standing at room/incubator temperature for more than 24 hours. If fresh tap water is used, dislodge any small air bubbles which foam on the tubing's interior surface within the sensing window.

[3]Volume flow can be read from the analog meter by multiplying its indication by the scale factor.

C. STERILE TUBING FLOWSENSOR *cont.*

4.“CALIBRATE” Modes _____

The calibrate modes serve to calibrate output data recorders by presenting the voltage equivalents of zero and scale factor flows on the analog outputs.

Depress “CALIBRATE ZERO” button.

Digital display will read “c 0” to show that the flowmeter is in zero calibration mode;
Analog meter needle will point to /0 (if it does not, adjust the mechanical-zero calibration screw located below the analog meter face);The two analog flow output connectors (front panel FLOW OUT and rear panel AVERAGE) carry 0 Volt.

Depress “CALIBRATE SCALE” FACTOR button.

The digital display will read “c number”, where number equals the scale factor in ml/min or L/min for the attached sterile tubing flowsensor.
The analog meter needle points to the “S.F.” mark at 1.0.
The two analog connectors (FLOW-OUT and AVERAGE) present a 1.0 V signal.

Squeeze tubing below the probe to create water movement.

The analog meter needle remains at 1.0 even though there is flow through the sensor.

5. “INVERT” Button _____

Re-engage Measure Mode.

Set “INVERT” and “LO FLO” push buttons (located above “FLOW OUT” connector) to unengaged position. (If buttons are depressed, release to out position by pushing.)

Squeeze tubing below the sterile tubing flowsensor.

Meter will register flow in either positive or negative direction. When flow is forced in opposite direction, the sign (+ or -) of flow is reversed.

Push “INVERT” button. Notice how flow direction changes.

6. “LO FLO” Button _____

Engage “LO FLO” button.

Observe how displayed flowsensor reading becomes more flow sensitive;
Probe movement now produces 4 times the needle deflection on the analog meter.
Flow > than scale factor (S.F.) will cause analog needle to be on S.F.

Depress the “CALIBRATE SCALE” button.

Notice that scale factor reading is reduced four times.

7. “OUTPUT FILTER” Buttons _____

In “MEA” mode with “LO FLO” button pushed in, engage “100 Hz OUTPUT FILTER” button.

With water at rest:

The digital display will read approximately 0 ml/min (within specifications).
The analog meter will read 0.0. Notice that analog meter indicates a slight amount of zero “noise”.

Push in the “0.1 Hz” button.

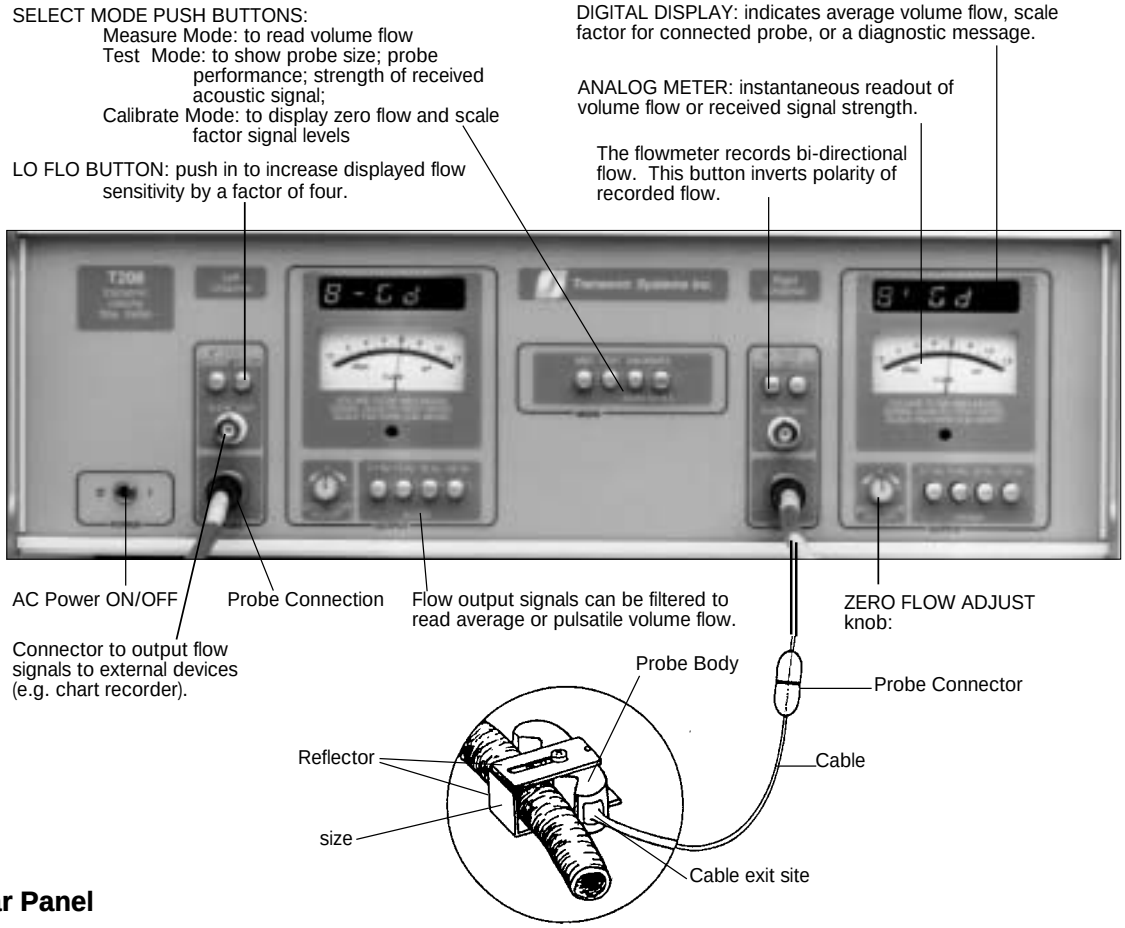
Analog meter now reads average flow and the zero “noise” vanishes.

Slowly squeeze and release tubing on which sterile tubing flowsensor is mounted to create a net flow, first upward, and then downward.

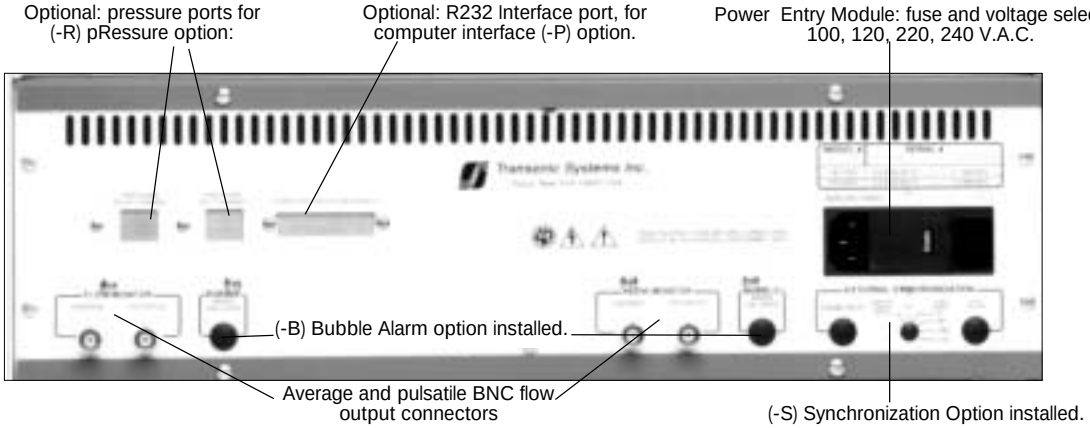
Notice how the analog meter and digital display average flow over several seconds.

D. FIG. 4.1: CONTROLS: TRANSONIC DUAL CHANNEL RESEARCH FLOWMETER

Front Panel



Rear Panel



A. INITIAL FLOWPROBE CHECK

Transonic flowmeter circuitry can check for proper functioning of flowprobes. First, provide proper acoustic coupling within the probe's ultrasonic window: for perivascular and in-line probes, submerge probe in degassed water and remove air bubbles from the acoustic window; for sterile tubing (clamp-on) flowsensors, apply to a liquid-filled tube. Engage "TEST" mode. For new probes, the reading should be between 0.9 and 1.1. During a probe's life, the received signal reading should be measured and recorded monthly. A sudden drop greater than 15% in received signal strength may indicate malfunction; a probe with received signal strength indication of 0.3V or lower is unsuitable for reuse and should be returned to the factory for troubleshooting.

B. USE OF FLOWMETER WITH A PERIVASCULAR FLOWPROBE

Flowprobe Selection

The flowsensing window of a probe must be selected to fit the animal model's vessel. Other mechanical features of the probe may be selected to facilitate probe application at specific surgical sites. The flowprobe price list provides an overview of all options which are partially encoded in a probe's part number.

8 S B 1 2 3

- 1 2 3 — Serial number: unique to this probe
- B — Cable exit orientation: "S" (side exit, cable runs parallel to vessel) "B" (back exit, cable perpendicular to vessel).
- S — Series: R-Series (45° angle of illumination); S-Series (65° angle of illumination); A-Series (cardiac output); V-Series (micro-probes).
- 8 — Size: of probe's rectangular window in mm.

Size: Transonic flowprobes are designed to measure volume flow independent of vessel diameter. For maximum resolution and ease of application, the ideal probe-to-vessel fit is snug but non-constrictive. For chronic applications, R-Series probes are designed for use on vessels with diameters 50% to 110% of the stated flowprobe size: S-Series probes, for vessels with diameters 66% to 110% of the stated flowprobe size (see Specification Tables, Appendix B). For acute applications probes are designed for use on vessels with diameters from 75% to 110% of the stated flowprobe size. This loose probe-to-vessel fit is acceptable for acute applications when an acoustic couplant, chosen for stability and close match to blood with respect to acoustic velocity (see Technical Note 9 [TN#9] Appendix C) is used; when probe/vessel alignment is conventional; and when the small vessel is not placed directly against the side of the reflector bracket.

Series: Transducers in R-Series flowprobes are positioned at a 45º angle to the vessel under study. This position optimizes a flowprobe's accuracy. R-Series probes excel wherever an application site allows ample space to locate and orient the flowprobe body. Transducers in S-Series flowprobes are positioned at a 60º to 65º angle to the vessel. This reduces the flowprobe body size for applications where space is limited, but also reduces the probe's resolution. V-Series probes have a V-shaped reflector for sensitive measurements in vessels under 1 mm in diameter. A-Series (cardiac output) probes have an ergonomically rounded body for application on highly pulsatile vessels such as the ascending aorta and pulmonary artery.

Cable exit orientation: Surgical access to a vessel often determines choice of cable exit orientation, either B (back exit, perpendicular to vessel) or S (side exit, parallel to vessel). V-Series and A-Series probes have back cable exits.

Reflector: Reflectors are available in a number of styles for R- & S-Series probes. Common selections include L-reflectors with sliding covers, J-reflectors and U-reflector's. *(For complete listings, see reflector's table in Appendix C of the manual and on page 19 of the 1997 Research Flowmeter catalog .*

B. …PERIVASCULAR FLOWPROBE *cont.*

Connector Selection

Several connector options are offered with flowprobes to be used with Transonic Animal Research Flowmeters. Selection of a particular connector depends upon the application. Consult Transonic application support for assistance in choosing the optimal connector. *(For complete listings, see connectors in Appendix C of the manual and on pages 20, 21 of the 1997 Research Flowmeter catalog.)*

Connectors include:

CH10 (10-pin connector with ROM)

Designed for ease of use in acute flowprobe applications, this snap-in connector houses the complete digital information for the flowprobe. It allows the probe to be plugged directly into the flowmeter or into a CH10 extension cable.

CS10 (10-pin sealed connector with ROM)

Implantable connector with conical threaded protective cap has suture hole for easy guiding during subcutaneous tunneling. Complete digital probe information is sealed with the connector which allows the probe to be plugged directly into the flowmeter or into a CH10 extension cable.

CB10 (10-pin skin button with ROM)

For chronic implantation, the skin button has a removable anchor flange and flat protective cap. Shank comes in 10 mm, 15 mm or 20 mm heights; the cable enters the connector at a right angle. Complete digital probe information sealed with the connector allows the probe to be plugged into a CH10 extension cable.

CM4 (Mini 4-pin sealed connector with separate ROM key)

The implantable 4-pin round mini-connector comes with two threaded protective caps and digital coded key specific to each probe. The conical cap with a suture hole is used for subcutaneous tunneling; a flat cap is provided for pin protection when the probe is not in use. Each probe must be used with its serial numbered key and a CM4 extension cable to the flowmeter. It is available in either side or back exit cable configurations.

CA4 (Micro 4-pin with separate ROM key)

Only available for 1R, 2S, 2R, 3R, 3S, and 4S probes these connectors are designed for minimal impact. The 4-pins terminate the cable end with a bare minimum of housing. A cap is provided for limited pin protection. These connectors are recommended where delicate chronic implantation requires the least impact from externalizing the connector end. Each probe must be used with its serial numbered key
and a CM4 extension cable to the flowmeter.

CTSB4 (4-pin skin button with ROM key)

For chronic implantation this skin button has a removable anchor flange and a flat cap to protect
the 4-pin connector when it is not in use. Each probe must be used with its serial numbered key and a CM4 extension cable to the flowmeter.

34 Dutch Mill Road, Ithaca, NY 14850 USA; Tel: 800-353-3569, 607-257-5300;
Fax: 607-257-7256; Internet: www.transonic.com

B. …PERIVASCULAR FLOWPROBE *cont.*

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 CH10-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.

Intraoperative 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.

B. …PERIVASCULAR FLOWPROBE *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 *(see Technical Note #9, in Appendix C, Research Support Section).*

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] in Research Support Section C). Surgilube, H-R Lubricating Jelly distributed by Mohawk Hospital Supply, Utica, NY, or coagulated blood are recommended couplants. Banked blood (if the site's geometry is suitable) may be applied to provide this acoustic coupling between vessel and flowprobe. However, at a highly pulsatile site, movement of a liquid couplant within the sensing window will be measured as flow and will affect net measurement. This motion artifact is eliminated if blood is allowed to clot before being used as a couplant. 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 in Appendix C 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 Transonic Systems for a custom probe modification. When only chronic measurements are planned, no ultrasonic couplant is necessary during implantation. Fibrous encapsulation of the probe within the first week of implant will yield a stable, air bubble-free coupling.

B. …PERIVASCULAR FLOWPROBE *cont.*

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).

Probe Maintenance

Wash a perivascular flowprobe thoroughly after use according to instructions for cleaning and sterilization (above). If a connector becomes wet, drying overnight in an incubator oven (≤ 60°C, 140°F) is recommended. Transcribe flow data to the Record of Probe Use sheets (Section A-VI, page 33) along with observations of the flowprobe's received signal strength. Inspect cables routinely for damage. Store the dry probe at room temperature.

Flowmeter Maintenance

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.**

C. USE OF FLOWMETER WITH A STERILE TUBING FLOWSENSOR

Sensor Selection

Flowsensor size and calibration is determined by the tubing on which it will be used. Each Transonic sterile 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 and Sterilization

A sterile tubing (clamp-on) 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 s tandard 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 into a rectangular shape. If the tubing site becomes permanently deformed at one clamping position, choose another site to achieve better acoustic coupling.

Tubing Preparation

Apply a layer of petroleum jelly, silicone grease or other non-drying acoustic couplant over the tubing surface to enable ultrasonic transmission between tube and sensor.

Sensor Application

To apply the flowsensor to tubing, open the hinged lid of the flowsensor, insert **lubricated** tubing in the sensing cavity, and close the lid. Fit should be tight, "squaring up" a tubing cross section for contact with all inner surfaces of the sensing window. When correctly positioned, the tubing will conform to the rectangular shape of the sensing window. Once the tubing is filled with liquid to be measured, flowmeter controls ("MEA", "TEST"etc.) can be operated. Gas bubbles block ultrasonic transmission. Tilting the tubing and flowsensor vertically before operation to flush any bubbles from the sensing window is therefore recommended.

C. … STERILE TUBING FLOWSENSOR *cont.*

Flowmeter Operation

Once the sterile tubing (clamp-on) sensor is mounted on a liquid-filled tube:

Connect flowmeter to hospital grade power source.

Turn on "Power" switch (rear panel, power entry module).

Plug flowprobe into the "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 Data Acquisition Section which follows).

Engage "MEA" mode for taking 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).

Sensor Maintenance

Examine the sterile tubing flowsensor after use for moisture—particularly for saline or corrosive fluid. The flowsensor can be wiped with 90% ethyl alcohol. See sterilization instructions above. Inspect cables for damage; verify availability of correct tubing stock. Note performance data in Record of Probe Use and store flowsensor at room temperature in a dry place.

Meter Maintenance

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

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.**

D. USE OF FLOWMETER WITH AN IN-LINE FLOWPROBE

Flowprobe Selection

Transonic in-line flowprobes have fittings for insertion into standard laboratory tubing. A flowprobe's linear flow range and the tubing size into which it will be inserted determines selection of flowprobe. The tubing fittings on a flowprobe are slightly tapered and can accommodate a range of tubing sizes with slightly different inner diameters. The probes have a linear range approximately 1.5 times the probe's specified "Hi Flo" scale factor *(flowprobe specifications in Appendix B of the manual or on page 39 of the 1997 Research Flowmeter Catalog).*

Cleaning and Sterilization

Before use, thoroughly wash the flowprobe in soap and warm water (≤ 55°C, 130°F). Remove any visible foreign material with a soft-bristled brush. The connector should be washed only when necessary. To wash: disassemble connector and wash in soap and warm water. 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 recommended. The probe may be rinsed and wiped in 90% ethanol alcohol before sterilization.

Flowsensor Calibration

Flowprobes are precalibrated for a particular liquid at a certain temperature *(see flowprobe's data sheet)*. Recalibration is necessary for accurate measurements if the flowprobe is to be used with any other liquids or at other liquid temperatures.

Flowsensor Application

Splice the flowprobe into laboratory tubing so that the liquid being tested flows through the flowprobe. In "TEST" mode, evaluate the probe's relative ultrasonic signal coupling. For new probes, this reading is 1.0 V. Over time, the reading may slowly change up or down without indicating degradation of probe performance. A low reading generally indicates that an air bubble is blocking the ultrasonic path of the flowprobe. Mounting the probe at an angle with the horizontal plane with the probe cable on the under side is recommended to dislodge any air caught in the probe's inside cavities. Tap the probe lightly, if needed, to free air bubbles. If the analog meter indication reads below 0.3 V *("Lo" message on the digital panel display)* while the probe is filled with liquid, a defect in the probe or cable is indicated.

D. ... IN-LINE FLOWPROBE *cont.*

Flowmeter Operation

Once the in-line flowprobe has been spliced in line on tubing and liquid is flowing through the tubing:

Connect flowmeter to hospital grade 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 Data Acquisition Section which follows).

Engage "MEA" mode for taking 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).

Flowsensor Maintenance

Examine the flowprobe after use for moisture, especially for saline or corrosive fluid. The flowprobe can be wiped or rinsed in mild soap and water, followed by 90% ethanol to promote drying. See above sterilization instructions. Inspect cables for damage. Note performance data in Record of Probe Use (page), and store flowprobe at room temperature in a dry place.

Flowmeter Maintenance

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

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.

E. DATA ACQUISITION

Direct Digital Flow Readout

In "MEA" mode, the average volume of flow (in ml/min or L/min) can be read directly from the flowmeter's front panel DIGITAL DISPLAY.

Flow Recording Using a Strip-Chart Recorder

Connect one of the rear panel FLOW MONITOR signals to a chart recorder.

If instantaneous flow is to be recorded, set the flow output low-pass filter to a frequency at least ten times the rate of the flow pulsation, and record the signal off the "pulsatile" connector (push in the "10 Hz" button for heart rates below 60 beats per minute; "30 Hz" for heart rates to 180 beats per minute, etc.). If average flow is to be recorded from the "PULSATILE" connector, depress the "0.1 Hz" filter button. In addition, the 0.1 Hz low-pass filtered flow is always available through the "AVERAGE" BNC connector on rear panel regardless of the filter push-button settings.

The following protocol calibrates the strip chart recorder to volume flow units.

1 . **Engage "CALIBRATE ZERO"** push button and align recorder pen with a convenient zero flow baseline setting on the chart paper near one extreme of the recorder range. Allow some room below this setting if flow is expected to pulsate through zero.

2. **Engage "CALIBRATE SCALE"** button. Use the recorder's range switch and continuous sensitivity dial to adjust the recorder pen for deflections on the strip chart paper which allow easy direct readout of flow in ml/min or L/min and accommodate anticipated peak flow recordings in "MEA" mode. The meter can track flows five times the scale factor flow identified on the DIGITAL DISPLAY. If the recorder is equipped with a range switch with discrete markings, the switch may be used to alter the chart scale during a recording run provided that the scale expansion or contraction factor is also recorded. (Put flowmeter in the "CALIBRATE ZERO" mode and switch through the recorder ranges of interest to confirm that the recorder pen maintains the same baseline position over these ranges.) The recorder's variable sensitivity dial should not be moved during a run without recalibrating the chart pen deflection.

3. **Engage "MEA" mode.** Select position of the "INVERT" button so that forward direction of recorded flow matches the polarity of the "CALIBRATE SCALE" recording. Push in "LO FLO" button if flow recorded on the strip chart occupies less than 25% of the full scale deflection available for positive flows. This will decrease the scale factor four-fold from the setting in step 2 above, and expand the flow trace vertically by a factor of four.

E. DATA ACQUISITION *cont.*

Flow Recording Using a Computer with an A-to-D Interface

The following describes protocols for interfacing a flowmeter without the Personal Computer (-P) option installed. See the P-Option manual in Appendix A of the manual if your meter is equipped with the (-P) computer interface.

A general purpose microcomputer with an Analog-to-Digital converter interface is easily adapted to read the flowmeter's output signals. The analog flow signal is available from either of two BNC connectors on the back panel. Mean flow only is available from the BNC connector labeled "AVERAGE" while pulsatile and mean flow is available from the connector labeled "PULSATILE". The frequency response of the "PULSATILE" flow signal is selected by depressing one of the four filter buttons on the front panel of the meter.

In order to capture the full information content of a digitized signal, sampling theory states that the sampling rate must be at least twice the highest frequency of interest. We recommend sampling three times as fast as the selected filter. As a rule of thumb, the harmonic content of a pulsatile signal such as the heart flow is well described by the first 10 harmonics of the signal. For instance, for a 1 Hz heart beat (60 beats/min) one would want to examine a 10 Hz band width which involves sampling at a 30 Hz rate. This leads to the following sampling rates:

CONNECTOR	APPLICATION	SUGGESTED SAMPLING RATE
Back ("Average") @ 0.1Hz Back ("Pulsatile")	Mean Flow	.3 Hz
Back ("Pulsatile") @ 10Hz	Heart rate to 60 BPM	30 Hz
Back ("Pulsatile") @ 30Hz	Heart rate to 180 BPM	90 Hz
Back ("Pulsatile") @ 100Hz	Heart rate to 600 BPM	300 Hz

The analog flow output may range from - 5 V to + 5 V: Zero Volt corresponds to zero flow; 1 V corresponds to the scale factor. The scale factor or the amount of flow per Volt (in ml/min/Volt) varies with probe size and the position of the gain button. To determine the scale factor for a particular probe size, press the calibrate-scale button and record the value displaced on the digital display. For example, if a 4 mm R-Series flowprobe is installed with the "LO FLO" button pushed in, the scale factor is 100

A - TO - D CALIBRATION

Calibration of the A-to-D system prior to use is recommended to compensate for any analog drift in the Voltage reference of the computer's data acquisition board and to validate that the A-to-D converter references are properly selected.

The following is a suggested procedure to calibrate the A-to-D converter in volume flow units.

1. **Depress the CALIBRATE ZERO BUTTON.** When the signal is present and has stabilized (the average-reading output requires approximately 10 seconds to settle from previous value to a new level), the computer is instructed to sample the flow signal for several seconds and to calculate an average reading. This reading (in Volts or in A-to-D output bits) equals the zero-flow signal amplitude "CZ".
2. **Depress the CALIBRATE SCALE BUTTON.** When the signal is present and has stabilized, the computer is instructed to sample this signal for several seconds and to calculate the average scale factor reading, "CS" (in Volts or A-to-D output bits).
3. The computer then requests the operator to enter the ml/min equivalent scale factor (SF) displayed on the meter LEDS. The conversion factor, "CF", which converts an A-to-D output reading into flow in ml/min, can then be calculated: CF = SF/(CS-CZ).
4. Measured flow samples "SN" may then be taken in the flowmeter's measure mode, and converted to true flow with the equation:

True Flow = CF (measured flow - CZ)