

INTRODUCTION

This manual describes the function, theory of operation, and operating procedures for the System 6 Active Redirection Transit Time (ART²) Flow Module.

Section 1 briefly describes the function of the ART² Flow Module and its specifications. This section also describes and cross-references each control, indicator or connector, to a number keyed to the panel illustrations.

Section 2 discusses the basic ART² principle, and provides a brief description about the operation of the ART² Flow Module.

Section 3 provides information about additional equipment necessary to operate the ART² Flow Module. This section also describes how to connect the transducer and chart recorder, how to calibrate the system, and how to perform an end-to-end test to ensure the system is ready for data collection.

The Table of contents provides easy access to information in the body of this manual (the manuals for each module type have their own table of contents).

The Appendix provides in depth information pertaining to application of the ART² Flowmeter Module.

1. ART² FLOW MODULE

1.1 FUNCTION

The ART² flowmeter uses bursts of high frequency sound traveling across a blood vessel to measure blood flow in the vessels of experimental animal preparations. The Flowmeter generates an analog output voltage proportional to the volume flow (in liters/min).

The ART² flowmeter module operates with a range of eleven cuff type transducers.

These probes are ideally suited for both acute and chronic implantation. At the time of purchase, the user selects a probe terminated with either a bullet-type connector or a titanium skin button.

The ART² module automatically recognizes the connected transducer size and adjusts its internal circuitry accordingly.

A digital panel meter indicates flow in liters/min. when the instrument is in the RUN mode. In the calibration (CAL) mode, the display indicates the flow calibration in incremental steps. When the probe identification (ID) switch is pressed, the panel meter displays the diameter of the attached probe.

Signal quality is continuously monitored and displayed on the front panel. Acceptable signal quality is displayed as a green light, while a red light indicates received signal level is below the acceptable threshold.

1.2 SPECIFICATIONS

ULTRASONIC FREQ	Factory set at 5 MHz. The frequency is controlled by a $\pm 0.01\%$ crystal TTL oscillator.
PULSE REPETITION FREQ (PRF)	Factory set at 1.923KHz.
TRANSMIT OUTPUT	30V p-p RF burst into 50 OHM load from a transformer-coupled, single-ended source with an isolated ground.
TRANSMIT PULSE BURST	The transmit burst is factory set at 75 cycles of RF.
ANALOG OUTPUT	Bipolar; zero flow = zero volts; scale factor fixed at 0.1volt/liter/min. Output may be offset between approximately ± 3 liter/min. using the front panel zero control.
FILTERS	The output signal is available with any one of the four low pass active filters: 0.1Hz, 10Hz, 30Hz, and 100Hz. The 0.1Hz (MEAN) output is always available at the "B" output jack while any of the four filter outputs can be switched to "A" output jack.

1.3 FRONT PANEL CONTROLS

NOTE: The number preceding each item corresponds to its location on the ART² FLOWMETER

80 *MODULE FRONT AND REAR PANELS illustration.*

ID

The IDENTIFY button is a momentary push button switch that causes the display to indicate the size of connected probe in millimeters. An indication of "019" means that a 19mm or "L" probe is connected. The probe must have a sonic path for this indication to be

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valid. The probe must be implanted or in cup of water and the signal light must be green.

FILTER

The FILTER selects one of the four internal filters (0.1Hz, 10Hz, 30Hz, or 100Hz) and

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directs the output to the System 6 rear panel output jack A.

DISPLAY

A four digit liquid crystal display that indicates the measured flow, the calibrate values in the

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CAL mode and the probe size when the ID button is pressed.

RUN/CAL

Select RUN for making measurements or CAL positions which cause the module to output

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calibrated steps from 0 to 20 liters/min.

METER

85

A switch selecting either the 0.1Hz (mean) or 100Hz (phasic) filter for the digital display.

POLARITY

86

This switch that reverses the ouput voltage polarity sense.

ZERO

87

A 10 turn offset control that provides approximately +15% of full scale adjustment range.

SIGNAL

Green indicates a usable ultrasound signal for normal measurement. Red indicates

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inadequate signal level, check probe and connections.

PROBE

Input connector for Transition Cable.

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1.4 REAR PANEL OUTPUTS FOR ART² MODULES

"A" FLOW OUT (PHONE)

The analog output voltage scaled 0.1V/liter/min.. The front panel FILTER switch selects the filter output connected to this jack.

90

"B" FLOW MEAN OUT (PHONE)

The analog output voltage scaled 0.1V/liter/min. continuously available through the MEAN filter (0.1Hz).

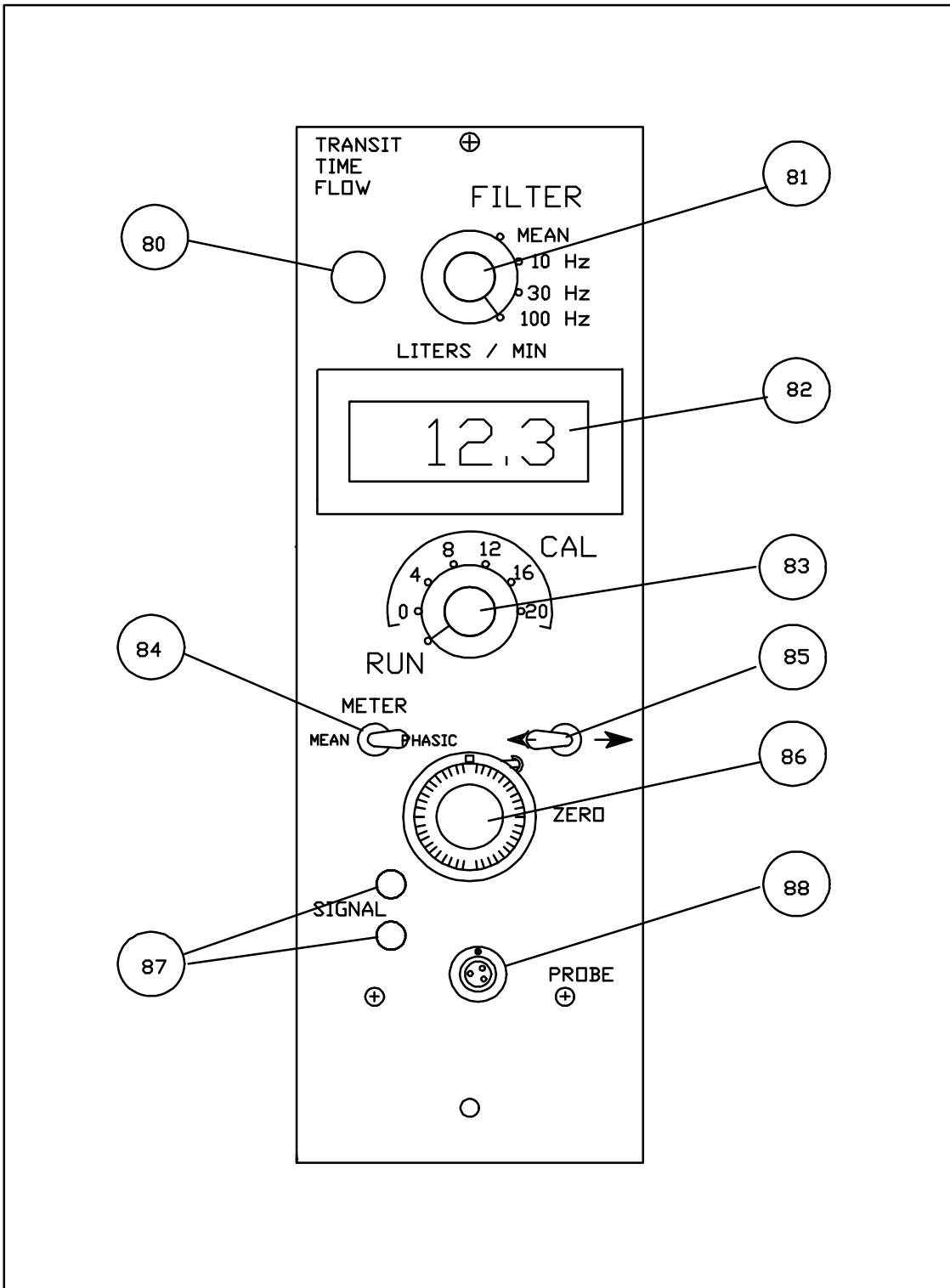


Figure 1 Flowmeter Module Front Panel

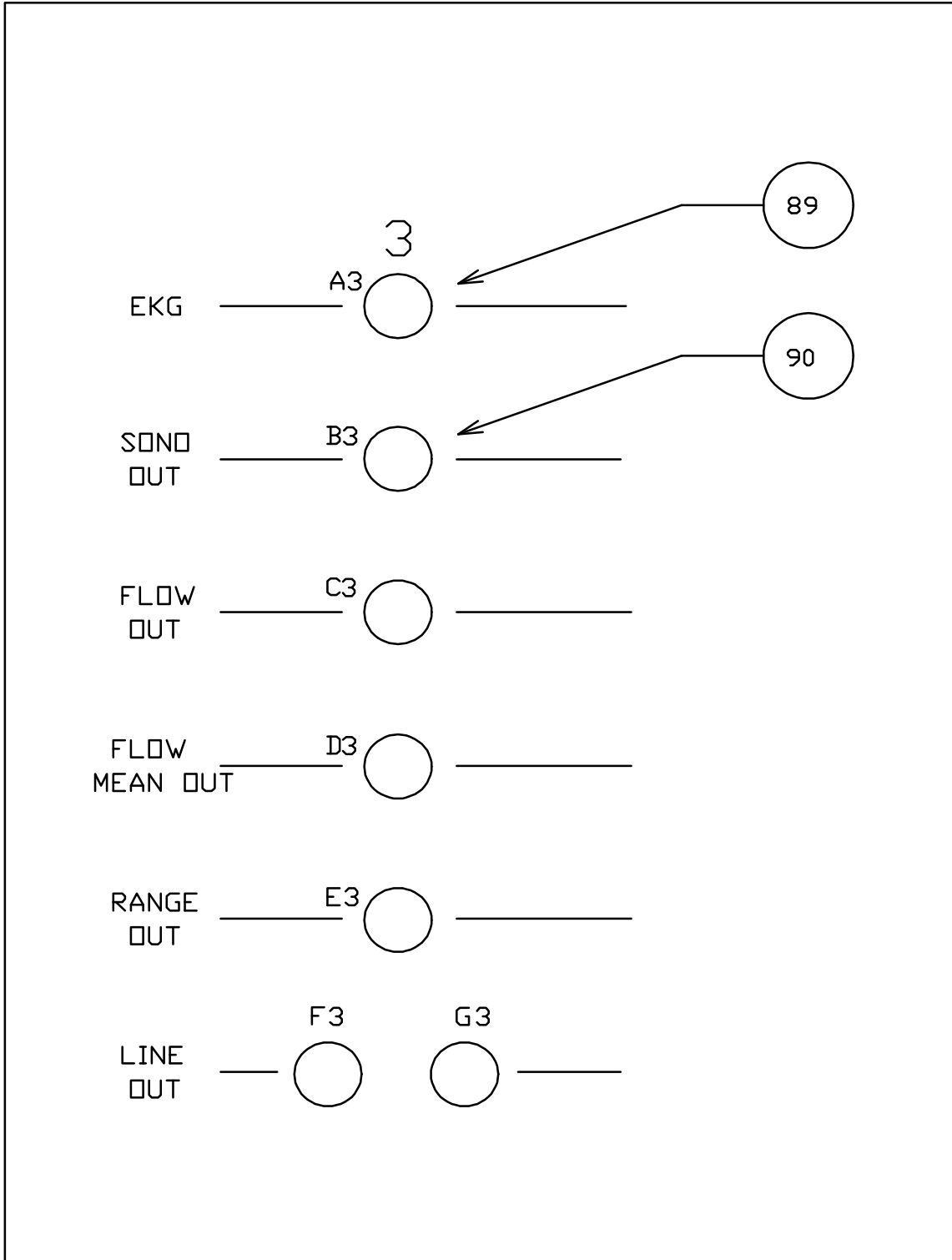


Figure 2 System 6 Rear Panel

2. THEORY OF OPERATION

OPERATING PRINCIPLE

Ultrasound bursts are projected through a vessel with flow at an angle relative to the flow. The sound velocity through the vessel wall and the blood is constant, however the transit time is changed by the flow. The transit time is shortened when the flow is in the same direction as the sound and lengthed when the flow is in the opposite direction of the sound.. Figure 3 shows the cross section of Tritons Art² transducers. Four piezo electric crystals are arranged in an "X" pattern so that they form two pairs of transmitters and receivers; A and C are one pair , B and D comprise the other. The path length, A to C and its relative angle to the flow are equal to the path length, B to D and its relative angle to the flow. The piezo elements of A and B are connected to the electronics module while C and D are connected to each other. All the piezo elements operate as both transmitters and receivers.

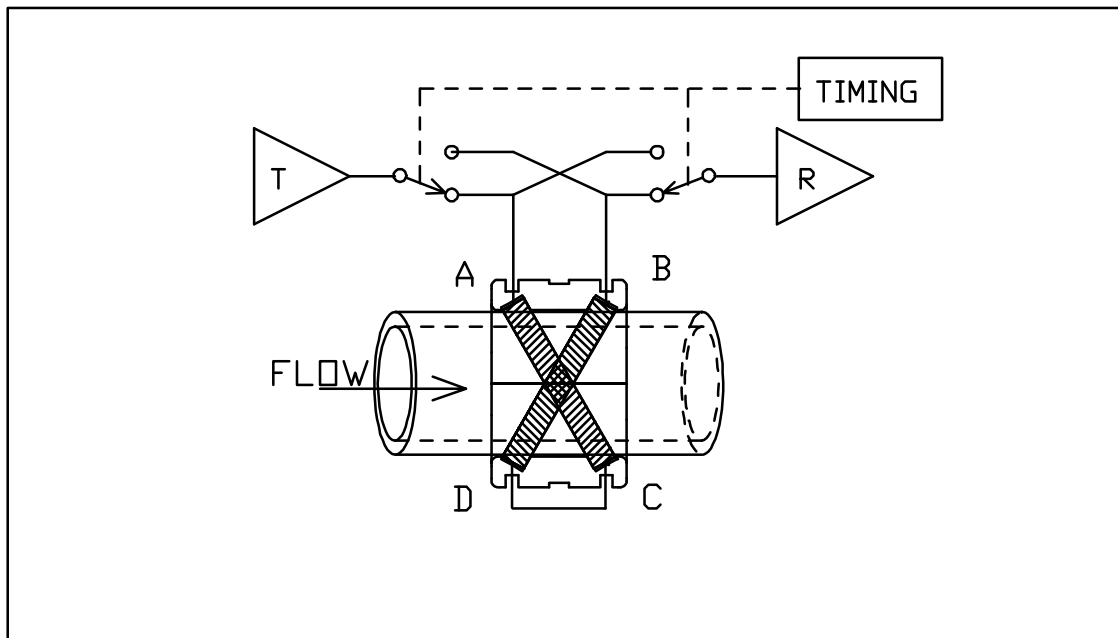


Figure 3 Ultrasound Paths

A measurement of transit time in the same direction as flow would start with a 5MHz transmit signal applied to crystal A launching ultrasound toward crystal C. When the sound burst arrives at crystal C, it generates a voltage signal replicating the transmit signal. This signal is directly connected to crystal D which relaunches the ultrasound burst toward crystal B. When the sound burst arrives at B, it generates another voltage signal replicating the transmit signals. This signal is sent to the electronics module where it is converted to a voltage proportional to the transit time, and stored as the "downstream" sample. (Both legs of this sample are in the downstream direction.) The result of this measurement is stored for subsequent processing. The upstream sample starts with the transmit signal applied to crystal B, ultrasound moving in a cross path through the vessel and arriving at crystal A as the receiver. The upstream signal is processed in the same manner. The voltage difference between the upstream and downstream signal is proportional to bloodflow. Of course, if there is zero flow the upstream and downstream samples are the same and the differential voltage is

zero. The measurement, storing and comparing of upstream and downstream samples, repeats continuously at the rate of 1,920 samples per second. The differential voltage is amplified, filtered, and results in a true voltage analog of volume flow in the vessel.

CALIBRATE MODE

An internal tapped precision delay line generates differential signals to be processed by the measurement circuitry. Each step of the tapped delay line is equal to a 4 liters/min. differential signal.

SIGNAL QUALITY MONITOR

The received signal for each measurement sample must be greater than a fixed minimum threshold and meet other requirements before further processing is allowed. The results of these tests are displayed by the signal indicators; green = good; red = low signal, check connections and transducers.

PROBE SENSING

The measurement parameters of the electronics are configured differently for each probe size. The Flow module accomplishes this automatically by measuring the average transit time through the probe that is connected. Since transit signal time is directly proportional to the sound path length, each probe size will have a characteristic average transit time. This measured time is used to address a memory chip which in turn outputs the probe ID code and gain control values. Operation of this feature is verified by activating the ID button on the front panel.

SCALING, OFFSET, AND FILTERS

The prime analog signal is scaled for each probe size to 0.1v/liters/min.. This signal may be offset by the front panel control over the range of $\pm 15\%$ of full scale. The scaled/offset signal is simultaneously applied to the inputs of four active low pass filters having cutoffs at : 0.1Hz (MEAN), 10 Hz, 30 Hz, and 100 Hz (PHASIC). The outputs of the filters may be selected by the front panel FILTER switch and directed to the "A" output of the System 6 chassis. The MEAN is always available at the "B" output. The display may be driven by the MEAN or PHASIC outputs.

3. FIRST TIME START-UP AND OPERATION

3.1 EQUIPMENT REQUIRED

- 1 chart recorder (or A/D converter)
- 1 cup water
- 1 transition cable (see Appendix A)
- 1 chart recorder cable
- 1 ART² transducer

NOTE: Figure 2 shows outputs when the module is installed in position 3.

3.2 INITIAL SETUP

The initial setup ensures a standard starting point for operating the ART² Flow module. The System 6 comes from the factory with the ART² modules installed. However, you may wish to change module positions to suit your application, or add other modules at a later time.

This procedure will guide the new user through the initial setup, verification of operation, and calibration.

*******CAUTION*******

DO NOT REMOVE OR INSTALL MODULES WITH THE POWER ON

3.2.1 MAINFRAME REAR-PANEL SETUP

- These instructions ensure proper power-up.
 1. Connect the power cable to the appropriate power mains.
 2. Connect the chart recorder input cable to the A output jack at the position where the transit time module is plugged into the mainframe.
 3. Turn the SYSTEM 6 power switch ON.
 4. The LED power indicator light should light. If it doesn't, check the power cord, fuse, voltage selector, and mains receptacle. Contact Triton Technology if problem cannot be resolved.
 5. Return the power switch to OFF.

3.2.2 MAINFRAME FRONT-PANEL SETUP

1. The mainframe controls are not used with transit time flow measurements.

3.2.3 ART² FLOW MODULE FRONT-PANEL SETTINGS

- “ Set the selected Flowmeter module front panel controls as listed below in Table 4.

<u>CONTROL</u>	<u>POSITION</u>
FILTER	100 Hz
RUN/CALIB	CAL 0
METER	PHASIC
POLARITY	LEFT
ZERO	CENTER

Table 1 ART² Front-Panel Initial Settings

3.3 CALIBRATION

3.3.1 CHART RECORDER SETUP

1. Turn the chart recorder power ON with the paper drive off. Turn System 6 power ON.
2. Set the chart recorder to a DC gain level appropriate for a 2 volt deflection.
3. Verify the transit time module display reads "00.0".
4. Use the chart recorder position or offset control to position the pen at the bottom of the chart tracing.

3.3.2 CALIBRATE CHART RECORDER (or A/D CONVERTER)

- “ After performing the setup above, the chart recorder can be calibrated to a full scale level appropriate for the expected maximum flow. In this example a full scale of 20 liters/ min. will be used.
1. Rotate RUN/CALIB switch to "20".
 2. The chart pen should deflect upward, if it does not, verify the polarity switch is toward the left.
 3. Rotate the CALIB switch to "0" and adjust the recorder zero or offset control to place the pen at the zero reference line on the chart.
 4. Rotate the CALIB switch to "20". If the pen has deflected beyond the top of the chart paper, the chart recorder gain must be decreased. Decrease the chart gain until the pen is at the

desired chart line. Conversely, if the chart gain is too low, it will have to be increased until the pen is at the desired level for 20 liters/min..

5. Rotate the CALIB switch back to zero to ensure the pen returns to the correct zero level. If it does not, repeat steps 3 and 4 until the pen positioning for 0 and 20 liters/min. are correct. It may be necessary to run the chart recorder at slow speed to final check these levels.
6. Rotate the CALIB switch to "12". The pen should deflect to a position 60% of full scale.
7. Set the CALIB switch to zero and start the chart paper at slow speed. Slowly rotate the RUN/CALIB switch clockwise, forming a stair step on the chart recorder as shown in Figure 4.

NOTE: There may be overshoot as the signal transitions between steps.

8. Stop the chart recorder and return the RUN/CALIB switch to zero.

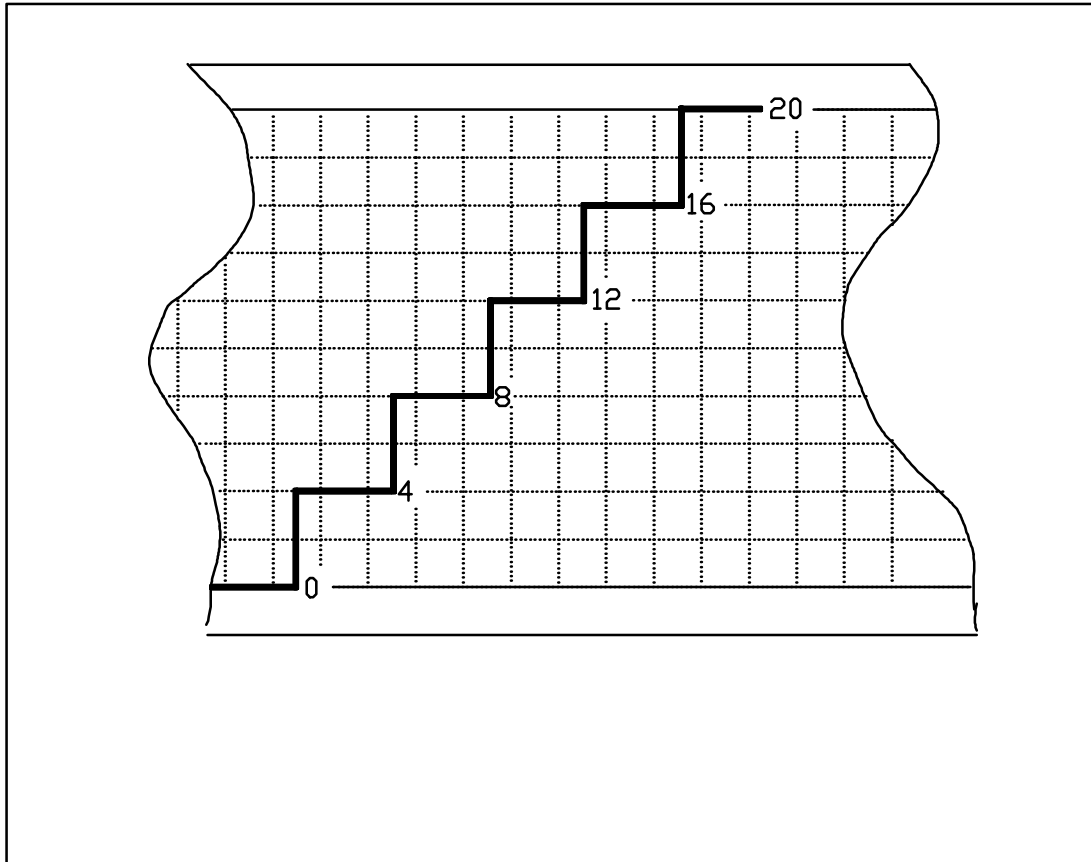


Figure 4 Chart Calibration

3.4 FINAL SETUP AND TEST

Now that the chart recorder is calibrated to the Transit Time Flowmeter it may be configured for operation in the RUN mode as follows:

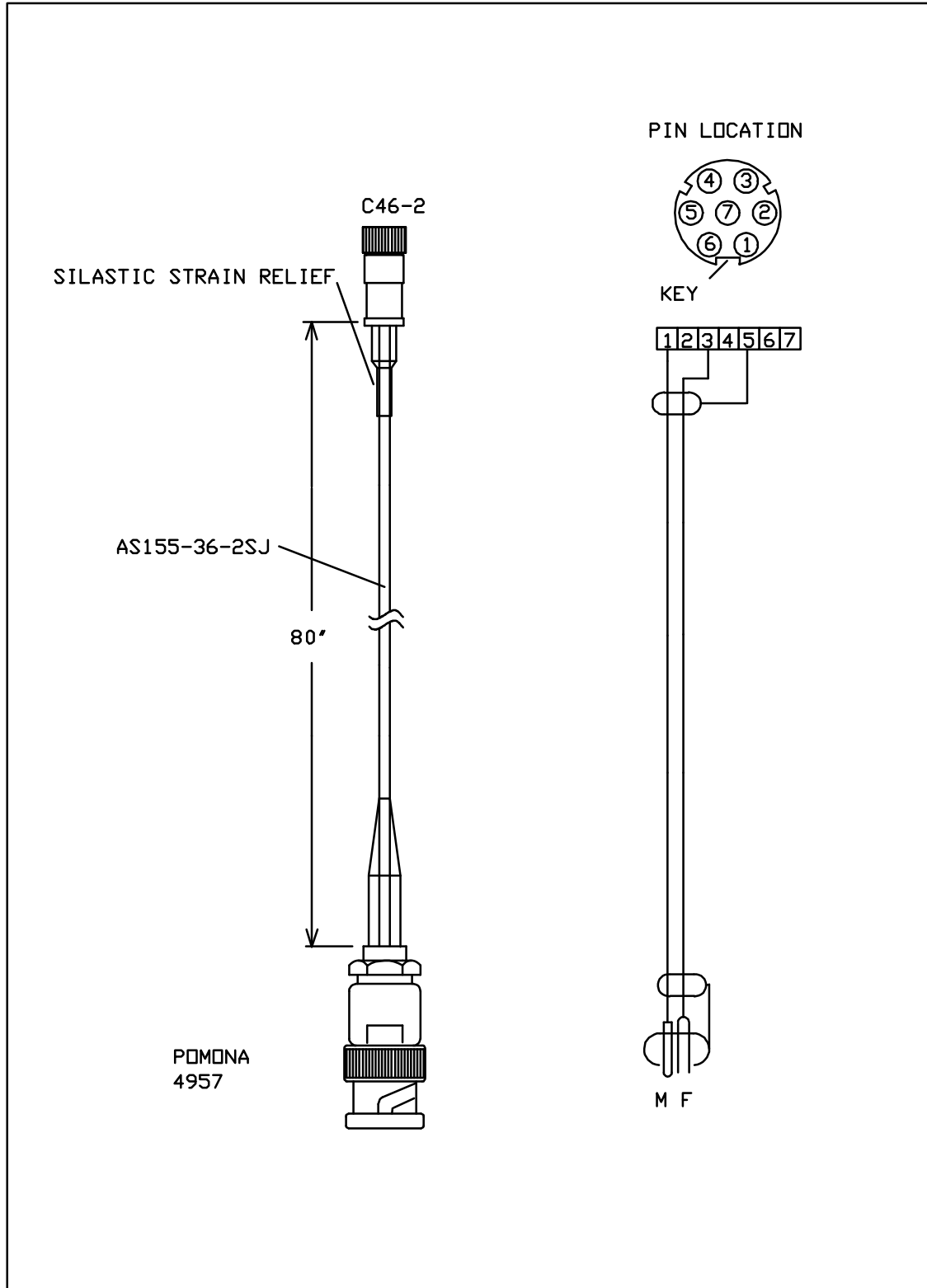
3.4.1 CONNECT TRANSDUCERS

- “ These instructions describe how to connect the appropriate flow probe to a module.

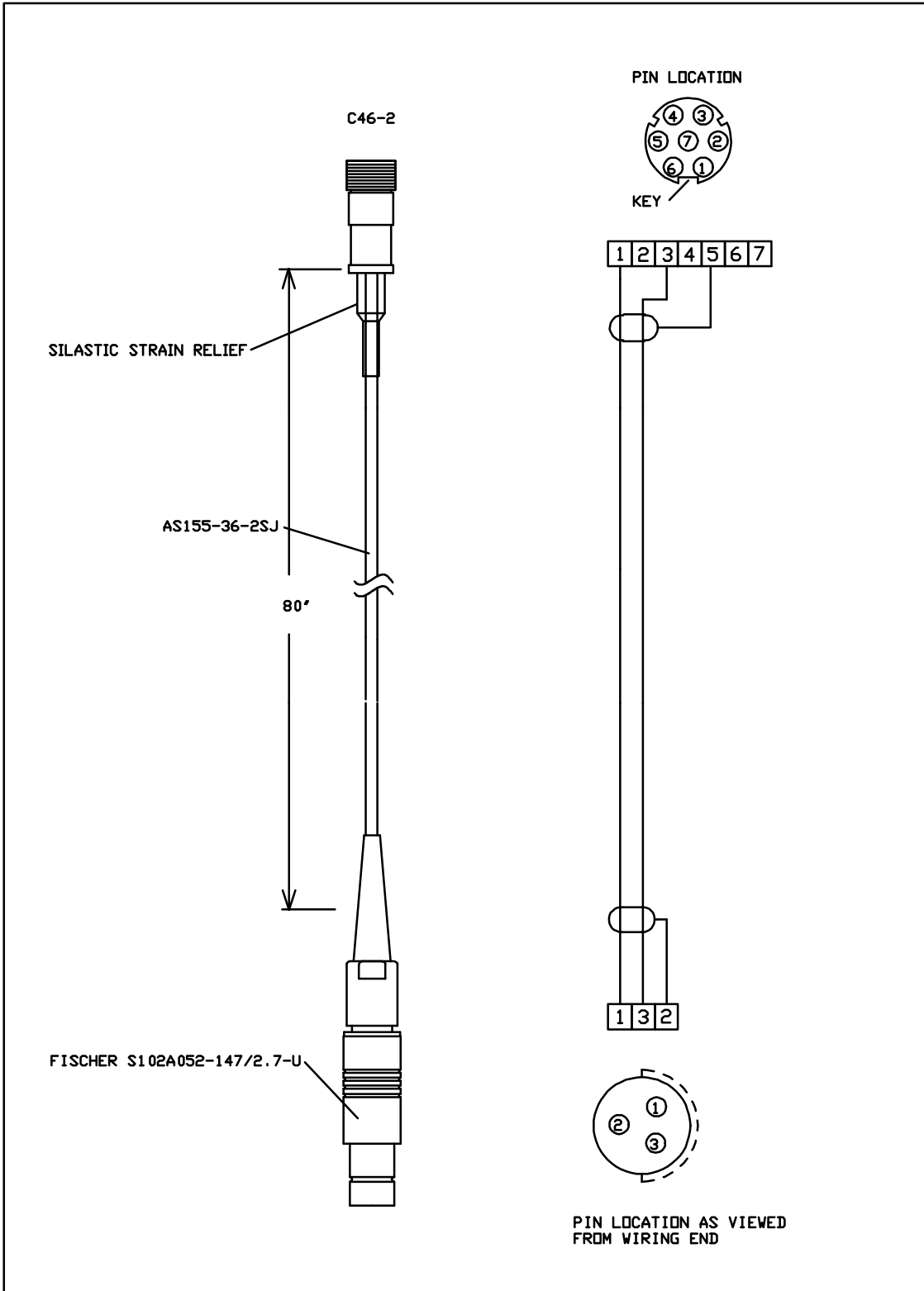
3.4.2 TRANSDUCER BENCH TEST

- “ This test ensures that the flowmeter, transducer, and chart recorder are working together as a volume measuring system.
 1. Submerge the transducer body in the container of water. Gently shake the probe to clear any trapped air bubbles.

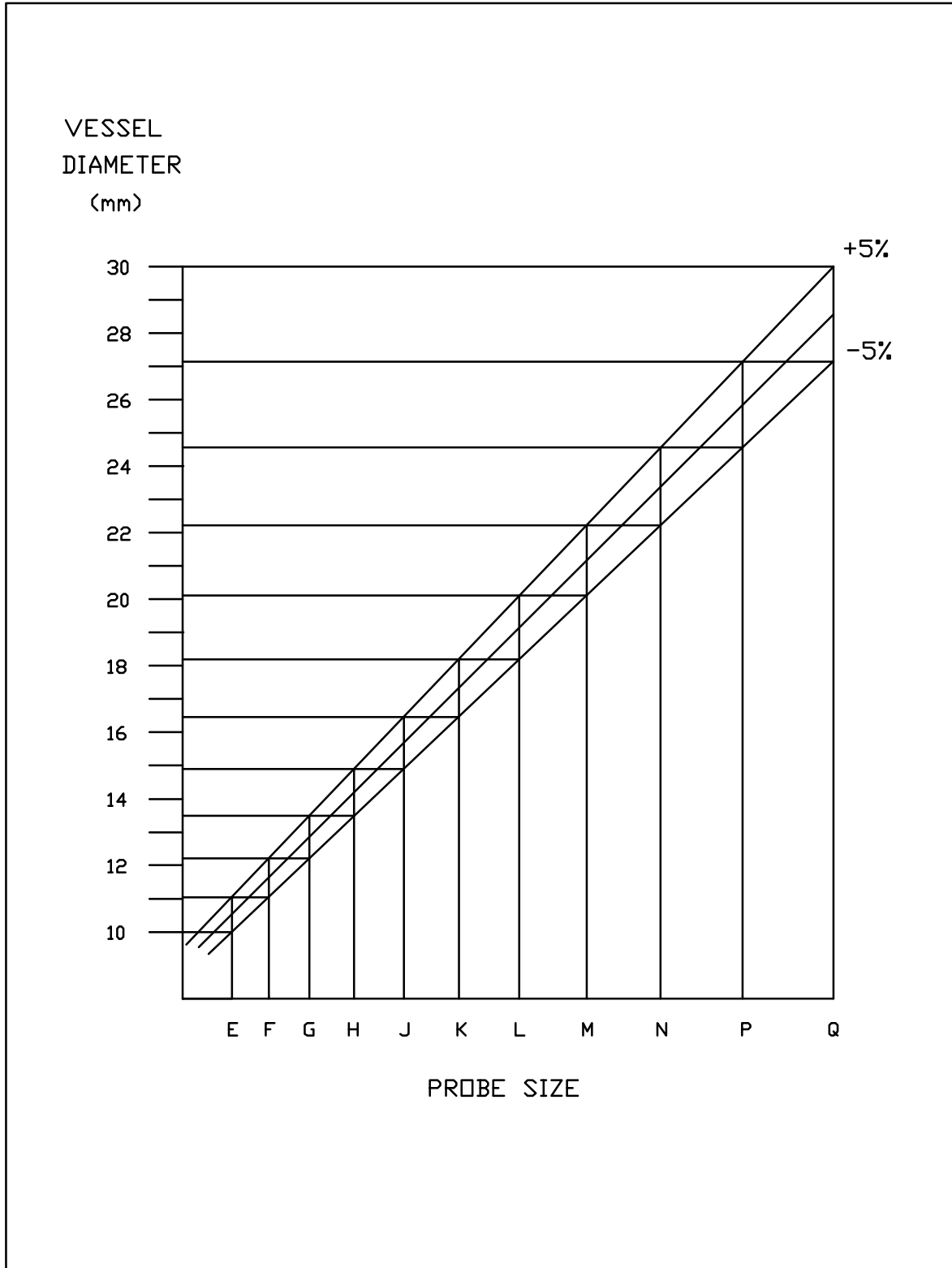
2. Switch the RUN/CALIB switch to the RUN position and verify a green signal indicator is displayed.
3. Depress the ID button; the display should indicate the probe size to the closest mm. (i.e. 017 if a K probe is connected).
4. Lift the probe out of the water. The red signal indicator should be displayed indicating a loss of signal.
5. Return the probe as in Step 1, clearing any trapped air.
6. With the probe motionless in the container of water, adjust the ZERO potentiometer until the display reads 00.0. The polarity (-) indicator will come on when the offset is negative.
7. While keeping the probe submerged, move the probe back and forth creating relative motion of water through its lumen. The display should become active showing alternately positive and negative values. The chart recorder should follow both positive and negative directions of flow, if the chart "zero" is placed mid-scale.



Appendix A -- Transition Cable Twin BNC

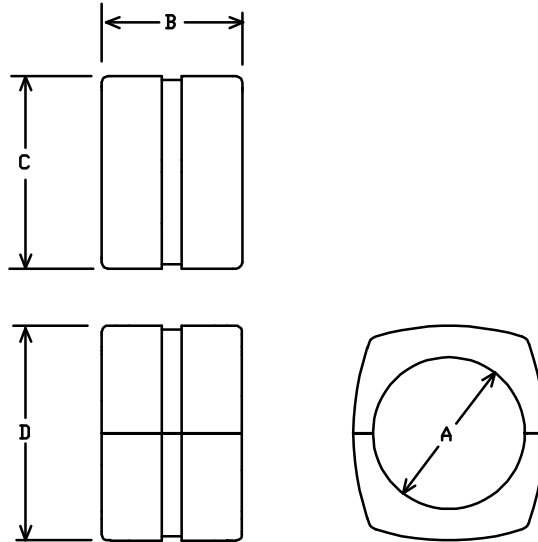


Appendix A -- Transition Cable Fischer



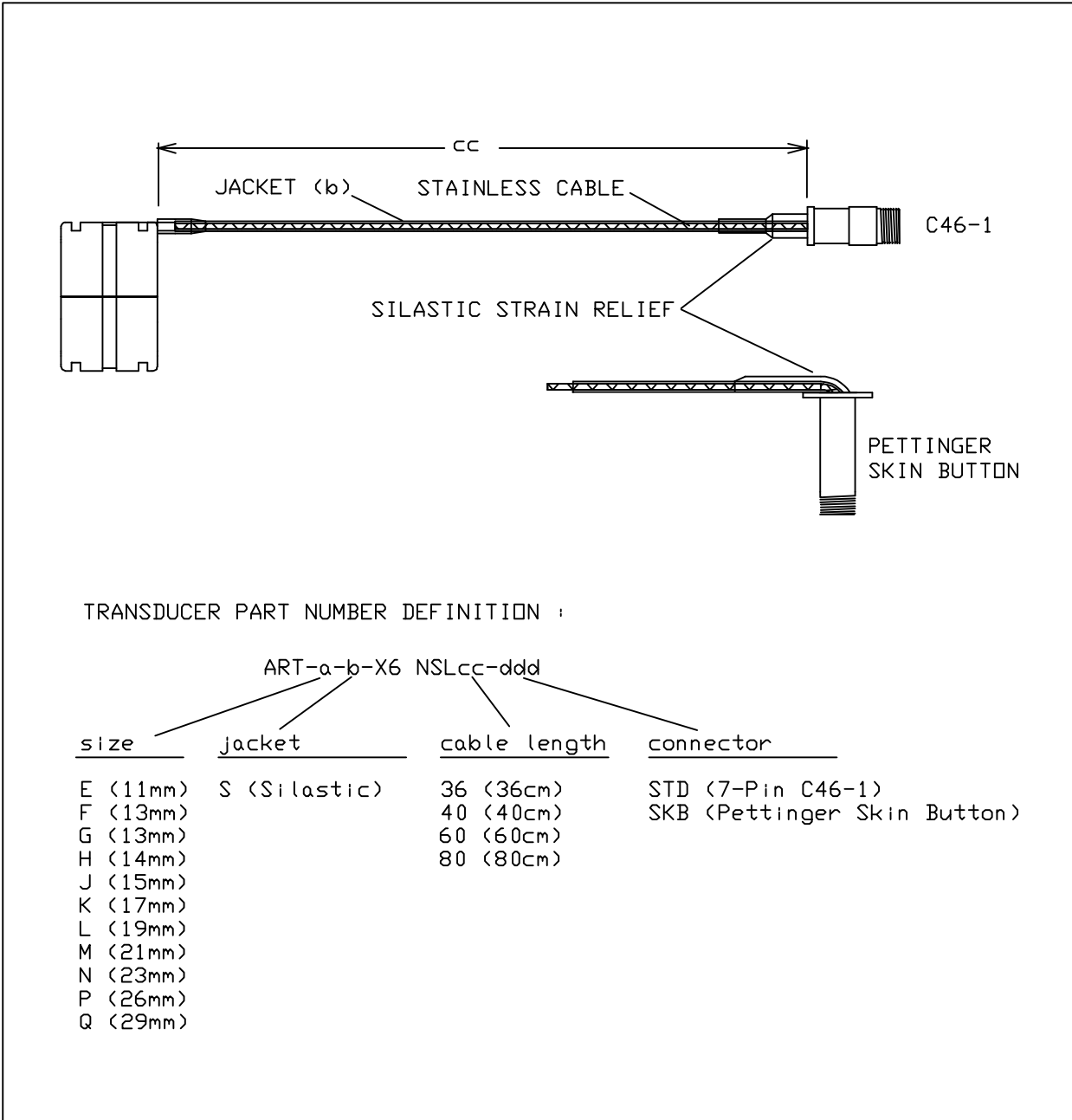
Appendix B -- Probe Size Graph

TRANSIT TIME PROBE DIMENSIONS



SIZE	A	B	C	D	Wt (gr) Less cable
E (11mm)	.412 10.5	.405 10.3	.515 13.1	.696 17.7	1.46
F (12mm)	.456 11.6	.436 11.1	.570 14.5	.740 18.8	1.81
G (13mm)	.504 12.8	.470 11.9	.630 16.0	.788 20.0	2.21
H (14mm)	.557 14.6	.536 13.6	.696 17.7	.866 22.0	2.93
J (15mm)	.616 15.6	.577 14.6	.770 19.5	.926 23.5	3.65
K (17mm)	.681 17.3	.623 15.8	.851 21.6	.990 25.1	4.49
L (19mm)	.753 19.1	.674 17.1	.941 23.9	1.062 27.0	5.56
M (21mm)	.832 21.1	.725 18.4	1.032 26.2	1.142 29.0	6.81
N (23mm)	.920 23.4	.776 19.7	1.120 28.4	1.230 31.2	8.83
P (26mm)	1.017 25.8	.832 21.1	1.217 30.9	1.326 33.7	10.08
Q (29mm)	1.125 28.6	.895 22.7	1.325 33.6	1.272 32.3	12.23

Appendix B -- Probe Dimensions



Appendix B -- Probe Part Number Definition