Test and Measurement Selection Guide

Badger Meter

Precision Flow Measurement

Configuring High Performance Systems

Cox
Turbine Flow Meters

About Us

Flow measurement and control you can count on.
Badger Meter Flow Instrumentation understands that companies cannot manage what they cannot measure—and leverages more than a century of flow measurement expertise and a technology-rich portfolio to optimize customer applications worldwide.

An industry leader in both mechanical and electrical flow metering technologies, Badger Meter offers one of the broadest flow control and measurement portfolios in the industry—a portfolio that includes eight out of the ten major flow meter technologies.

Simply put, Badger Meter Flow Instrumentation provides technology to measure and control whatever moves through a pipe or pipeline—including water, air, steam, oil, other liquids and gases. And we apply our expertise to further enhance our products' ease-of-use, accuracy and effectiveness.

Customers can rely on Badger Meter Flow Instrumentation for application-specific solutions that deliver accurate, timely and dependable flow data and control essential for product quality, cost control, safer operations, and regulatory compliance.

Cox precision metering products by Badger Meter provide flow measurement solutions for the test and measurement market and precision industrial applications, such as:

- Automotive testing
- Heavy hydraulic equipment
- U.S. defense and aircraft fuel metering
- Aircraft flight testing
- Aircraft hydraulics
- Aircraft component testing
- Equipment testing and verification

Credentials

Cox Flow Measurement is certified compliant to AS9100 and ISO 9001 and accredited to ISO/IEC 17025 and accredited to ANS/ NCSL Z540 by NVLAP (Lab Code 200668-0).

FM 78587
AS9100 Rev. C and
ISO 9001:2008

CALIBRATION
NVLAP LAB CODE 200668-0

*NVLAP accreditation applies only to the Badger Meter Flow Dynamics calibration Lab, located in Racine WI.

Cox
Turbine Flow Meters

Precision Calibrations

A flow meter's performance is dependent on the quality of its calibration. Badger Meter delivers precision primary standard liquid and gas calibrations of the highest standard as a NVLAP accredited (Lab Code 200668-0) calibration facility.

Note: NVLAP accreditation applies only to the Badger Meter Flow Dynamics calibration Lab, located in Racine, WI.

The calibration criteria are based on ISO/IEC 17025 International Standard, used to evaluate the competence of calibration laboratories throughout the world. This specifically assesses factors relevant to the ability to produce precise and accurate calibration data including:

- Correct equipment – properly calibrated and maintained
- Adequate quality assurance procedures
- Proper correlation practices
- Appropriate testing methods
- Traceability of measurements to NIST
- Accurate recording and reporting procedures
- Suitable testing facilities
- Technical competence of staff

- Bi-annual NVLAP accreditation audits ensure competency.
- Calibration uncertainty statements are posted on the NIST government website.

Cox Turbine Flow Meters

Product Configuration Step-By-Step

Flow meter systems are configured to achieve the best solution to measure the most difficult flow applications. Cox flow meters are available with an assortment of pickoffs to meet temperature requirements and signal transmission distance, which is complemented by an assortment of electronic processors and indicators. Installation is accomplished by selecting from several standard end connections along with custom designs. The following guidelines will make system configuration simple, while presenting alternatives to maximize accuracy and minimize cost.

Steps to Specify the Flow Meter System for the Application
The following criteria must be determined to develop the correct flow meter configuration for any given test and measurement application.

Step 1 – Define Fluid Parameters
Step 2 – Determine Meter Type
Step 3 – Consider Flow Meter Ranges
Step 4 – Specify Pickoffs
Step 5 – Define Pickoff Temperature Ranges
Step 6 – Select End Connections
Step 7 – Determine Need for Flow Straighteners
Step 8 – Select Calibration Option
Step 9a – Select Preamplifier
Step 9b – Select Flow Processor
Step 9c – Select Field Indication Display
Step 9d – Select Panel Mount Flow Processor
Step 10 – Consider OEM Options
Step 11 – Ask for Application Support

Product Configuration

Step 1 – Define Fluid Parameters

Fluid properties vary from one application to another and must be defined in order to properly develop the correct meter configuration and calibration specification. Fluid parameters include:

Fluid Type

- Affects the wetted parts
- Defines filtration
- Determines water, solvent or oil blending calibration
- Provides fluid density, required for inferred mass flow

Operating Fluid Temperature (minimum and maximum)

- Defines fluid viscosity range
- Identifies the amount of calibrations required to develop a UVC calibration
- Is required to select pickoff type (cryogenic to high temperature applications)
- Determines if remote electronics are required

Static Line Pressure

- Over 1000 psig — changes viscosity and density properties (requires a flow processor)

Flow Range

- Determines the best operating range in combination with the pressure drop and UVC capability

Once this fluid information is defined, the flow meter can be specified to meet the application demands.

Cox Turbine Flow Meters

Product Configuration

Step 2 – Determine Meter Type

Badger Meter offers numerous meter configurations made up of essentially three types of meters, depending on the application.

- Precision LoFlo axial turbine meter
- Precision single rotor turbine meter
- Exact dual rotor turbine meter
- Plus, OEM flow meters for custom applications

The following will guide you to select the correct meter, based on range and features.

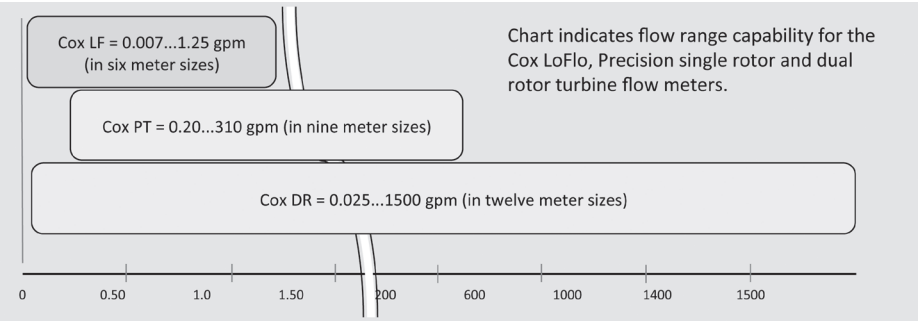


Chart indicates flow range capability for the Cox LoFlo, Precision single rotor and dual rotor turbine flow meters.

Features	Precision LoFlo Axial Single Rotor	Precision Single Rotor	Exact Dual Rotor
Flow Straighteners	Recommended	Recommended	Not Required
Ceramic Ball Bearings Water & Hydrocarbon Service	Standard	Standard	Standard
Repeatability	± 0.25%	± 0.02%	± 0.02%
Extended Linearity (NOTE: Repeatability added to linearity)	Inherently non-linear ± 0.35% with electronic linearizer	Superior ± 0.05% Mechanically linear over a wide extended range (± 0.12% with electronic linearizer)	± 0.12% with electronic linearizer over a wide extended range up to 500:1
Turndown Flow Ranges	12.5:1 smallest meter increasing to 20:1 on the largest meter	60:1 smallest meter increasing to 150:1 on 1 in. and larger	120:1 smallest meter increasing to 500:1 on larger meters
UVC Turndown Flow Range	Standard 10:1	Standard 10:1	Extended from 30:1 on the smallest meter and increasing up to 60:1 on 1 in. or larger meters
High Shock Design	N/A	N/A	Standard
Bearing Diagnostics	N/A	N/A	Rotor ratio technique

Precision LoFlo Axial Turbine

Precision Turbine Single Rotor

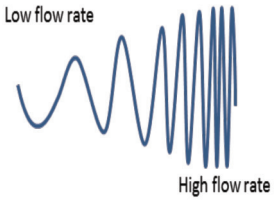
Exact Dual Rotor Turbine

Cox Turbine Flow Meters

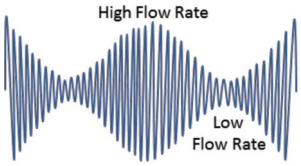
Product Configuration

Step 3 – Consider Flow Meter Ranges

Flow Range Effects for Magnetic & Carrier Pickoffs

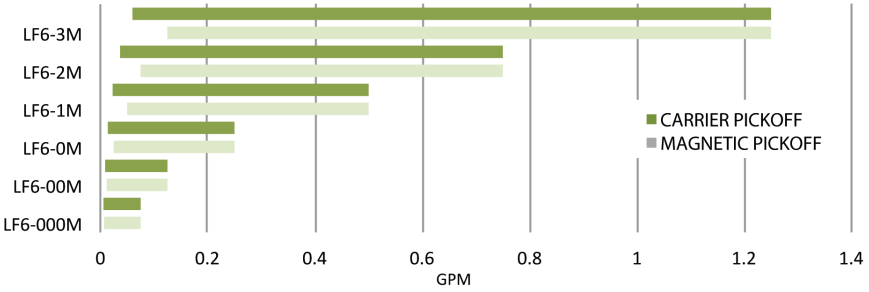


Magnetic pickoffs operate at a wider temperature range (–450...450° F) and they do not require power, however, they drop off at the low end due to magnetic drag.

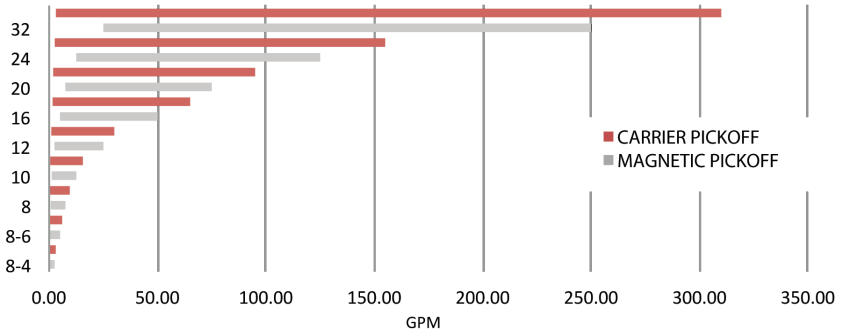


Carrier amplifier pickoffs require power and will transmit up to 100 feet. They eliminate magnetic drag, which extends the usable flow range.

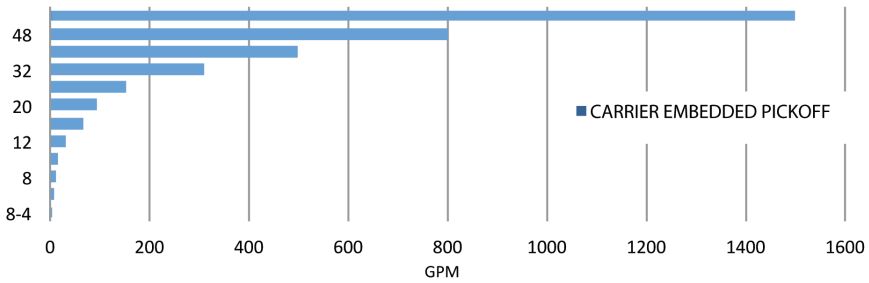
COX PRECISION LOW FLOW, MAGNETIC VS CARRIER PICKOFF FLOW RANGE



COX PRECISION, MAGNETIC VS CARRIER PICKOFF FLOW RANGE



COX EXACT DUAL ROTOR FLOW RANGE



Precision LoFlo Axial Turbine

Precision Turbine Single Rotor

Exact Dual Rotor Turbine

Cox Turbine Flow Meters

Product Configuration

Step 4 – Specify Pickoffs

Because application requirements vary so greatly, Badger Meter offers over 100 pickoff choices to meet specific needs. When specifying a pickoff, there are many factors to consider.

The following list outlines the consideration process:

Specifications:

- RF carrier pickoff (requires carrier amplifier)
- Magnetic pickoff (no power required)
- Pickoff fluid temperature ranges from –450...850° F (–268...454° C)
- Embedded temperature sensor (RTD or thermistor)
- Transmission distance 100 feet (30.5 meters), when amplified
- High vibration pickoff coils (Exact meters only)
- FM, CSA, CE, ATEX approvals for EMI, explosion-proof and intrinsically safe

An RTD thermowell temperature probe can also be inserted into the flow straighteners to provide improved temperature monitoring, in place of an embedded pickoff temperature sensor.

Pickoff Choices:

- High or low temperature
- Amplified output
- Embedded RTD
- Bayonet or MS connectors
- NPT wire leads
- High vibration

High Temp 850º F (454º C)
Low Temp –450º F (–268º C)

Amplified Output
Square Wave Pulse
0...5 or 0...10V DC

Embedded RTD or Thermistor

RTD Thermowell
inserted in Flow Straightener

Bayonet Connector

MS Connector

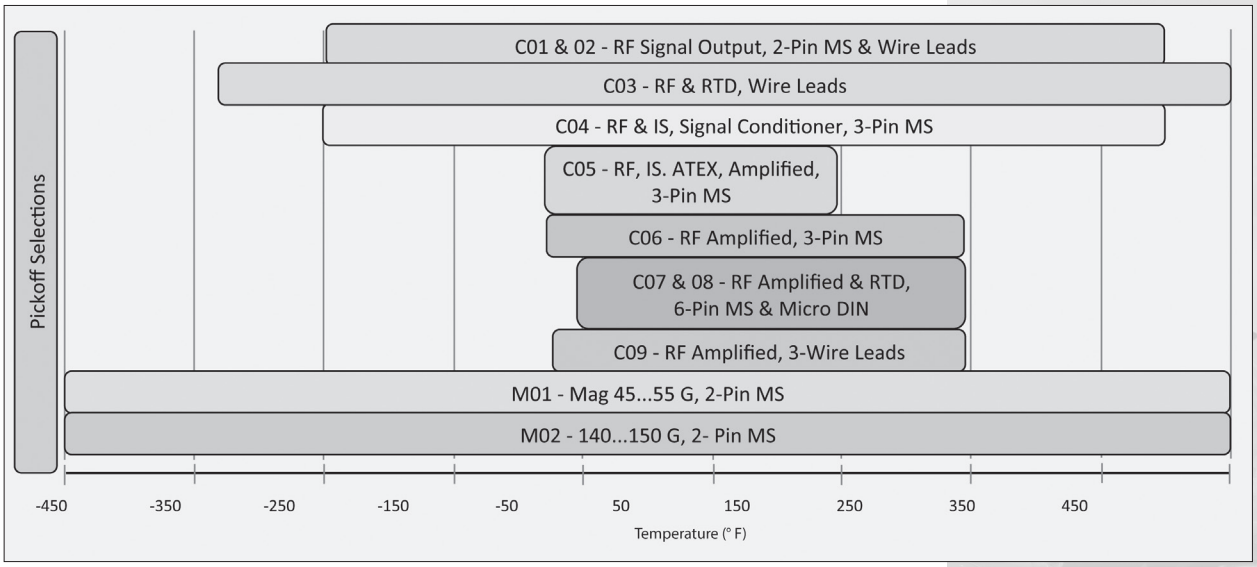
NPT Wire Leads

Embedded RF Coil
(high vibration)

Product Configuration

Step 5 – Define Pickoff Temperature Ranges

Defining the fluid temperature range for an application will help determine which pickoffs are compatible with the given parameters.

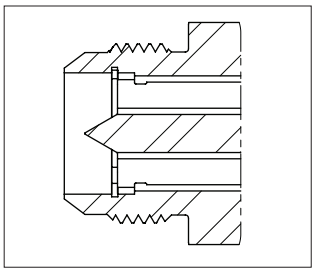


Product Configuration

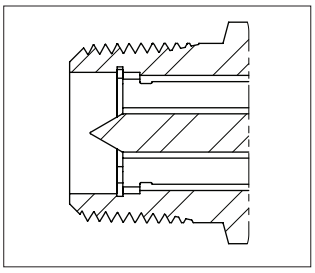
Step 6 – Select End Connections

End connections are determined by the pipeline pressure, pipe size, ease of removal, and custom requirements. Adjoining pipe and end connection pressure rating also must be considered. Note that high temperature will reduce the pressure rating on all fittings.

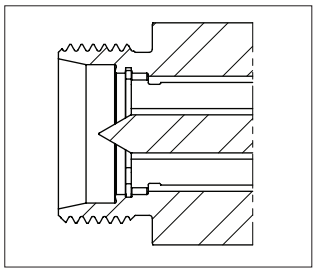
Standard End Fittings



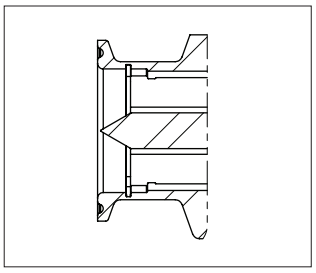
AN 37° Flare
– Pressure rating
– 1760...7000 psig (121...483 Bar)
– Size dependent



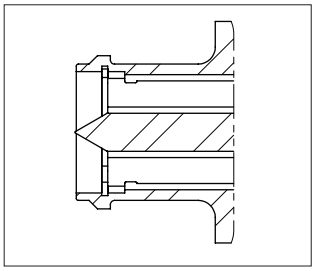
NPT Pipe, Male
– Pressure rating
– 3760...7614 psig (259...525 Bar)
– Size dependent



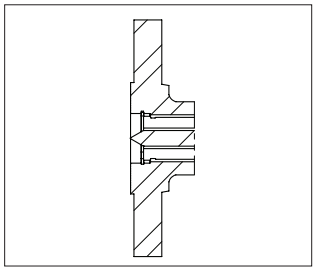
High Pressure
– Pressure rating
– Continuous 5000 psig (345 Bar)
– Burst 25,000 psig (1724 Bar)



Tri-Clamp
– 550...2220 psig (38...153 Bar)
– Size dependent

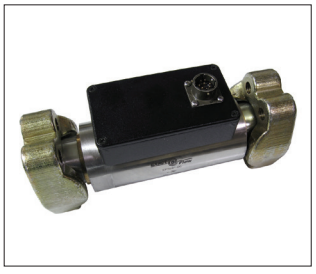


Hose Barb
– Low pressure <300 psig (21 Bar)
– Clamp dependent



ANSI 150, 300 and 600 Flanges
– Raised face and ring joint
– 275...6000 psig (19...414 Bar)
– Class dependent

Custom High Pressure End Fittings



High Pressure SAE 62
6000 psig (414 Bar)

High Pressure Manifold
6000 psig (414 Bar)

Custom Hydraulic Fitting
3000 psig (207 Bar) operating and
6000 psig (414 Bar) burst

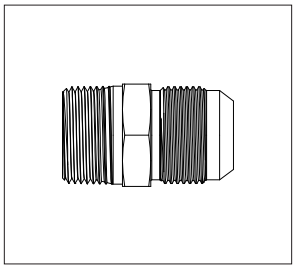
Product Configuration

Step 7 – Determine Need for Flow Straighteners

Flow straighteners are recommended on single rotor turbine meters to negate swirl from influencing the accuracy of the meter. Cox flow straighteners have a six-bladed insert to prevent swirl and minimize pressure drop. In addition, they offer pressure and temperature taps.

When flow straighteners are impractical due to space, a flow meter can be calibrated before installation using the same piping found in the application environment to compensate for fluid swirl. The Cox Exact dual rotor meter cancels out fluid swirl and can be used without flow straighteners. Flow straighteners are required with the Cox Exact dual rotor meter when implementing bearing diagnostics, which monitors the ratio of both rotor frequency outputs. Flow straighteners are also required when the dual rotor meter is used as a master meter or a calibration check standard.

Flow straightener set



AN to NPT adapter

RTD thermowell inserted in downstream flow straightener

Technical Tip

When using NPT threads, consider using flared (37° AN) fittings on the flow meter and flow straighteners. Use an AN to NPT adapter on the pipe connection ends. This will avoid a step in the internal dimension of the piping close to the turbine meter and will facilitate removal of the turbine meter for calibration.

Flow Straightener Specifications

Straightener Vanes	• 6 bladed
Length	• Upstream: 10 diameters Downstream: 5 diameters
Materials of Construction	• 304 SST
Pressure Rating	• 3000 psi for AN 37° flare fittings • All others conform to the end fitting rating
End Fittings	• AN 37° flared, 150# flange, 300# flange and 600# flange, NPT adaptor and others, as required
Taps	• Upstream: 1 pressure tap standard • Downstream: 1 temperature tap standard or 2 taps (1 pressure and 1 temperature)

Product Configuration

Step 8 – Select Calibration Option

Turbine meters are viscosity sensitive and may need a calibration that accounts for temperature/viscosity effects on the output. This type of calibration is commonly accomplished by blending solvent and oil to simulate the kinematic viscosity of the fluid at a given temperature. Wide temperature variations might require multiple calibrations to develop a Universal Viscosity Curve (UVC). This UVC data is used by a flow processor to provide fully temperature-compensated precision flow output.

Most Common Calibrations for Turbine Meters

Single Fluid – Stable Temperature

If the meter is used in the linear range, the viscosity variance is minimized. Therefore, a single fluid viscosity calibration will produce accurate flow measurements.

Multiple Blend – Temperature Variance

Requires two or more blended fluids, with a kinematic viscosity differential contained within a 10:1 ratio, to cover the temperature/viscosity span. The results is a blended UVC, which compensates for temperature viscosity effects on the output.

Additional Calibration Options

Single Fluid Universal Viscosity Curve – Single Blend

Allows one viscosity to be used to determine temperature-induced kinematic viscosity shifts. By extending the calibration of a single fluid beyond the operating range, one fluid can be used to develop a UVC calibration, thereby reducing cost.

Multiple Single Fluid Calibrations – Stable Temperature

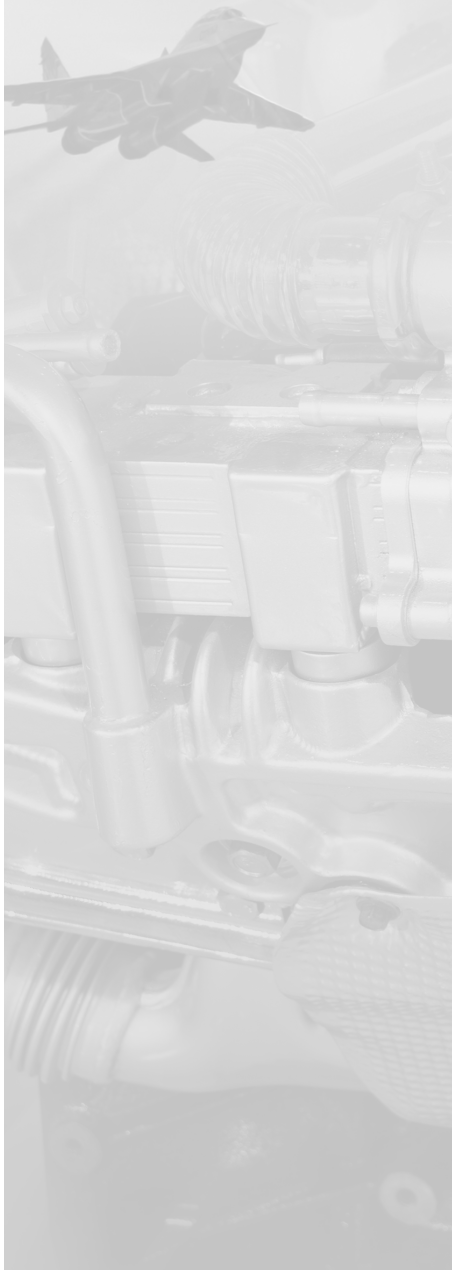
Used when different fluids are measured in the same piping or when the meter is relocated to piping using a different fluid.

Multiple Fluid UVC Calibrations– Multiple Blends

When using more than one fluid in a varying temperature environment, multiple UVC calibrations can be accomplished so that each fluid type blends into one single curve fit. The flow processor will need to know which fluid is being used in order to match the proper temperature/viscosity table.

Kinematic Viscosity

The ratio of a fluid's absolute viscosity to its density – or the absolute viscosity divided by the density.



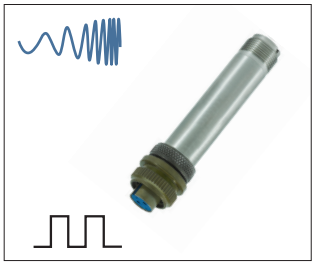
Product Configuration

Step 9a – Select Preamplifier, if Necessary

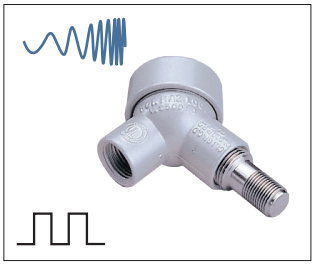
A preamplifier may be required to transmit the signal output, up to 100 feet. Preamplifiers in explosion-proof enclosures contain a module with terminal screws. The Model 92-242 (magnetic) and 92-243 (carrier) are attached to the pickoff, using MS connectors, which makes for easy replacement or for repurposing with other flow meters. The 92-244, -245, -250, and -252 all have pickoffs assembled into the explosion-proof housing.

The EC80 flow processor could also be integrally mounted, which will amplify the signal outputs for transmission (see flow processors, Step 9b).

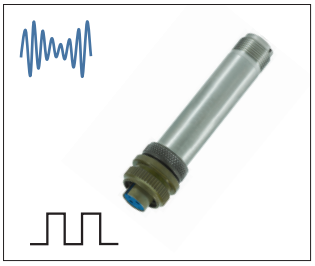
Types of Pickoff Amplifiers



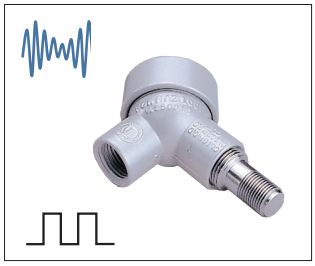
MS Connector, Magnetic
- Model No. 92-242
- Attaches to pickoff
- MS connectors



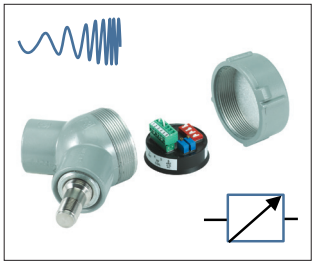
Wire Terminal, Magnetic
- Model No. 92-244
- Explosion-proof Y1 housing, with pickoff
- Screw wire terminals



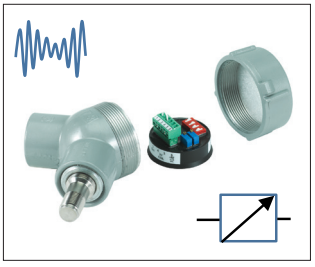
MS Connector, Carrier
- Model No. 92-243
- Attaches to pickoff
- MS connectors



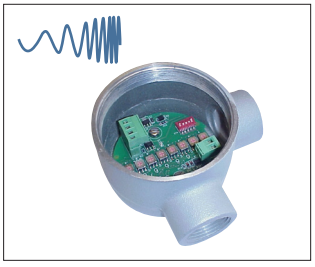
Wire Terminal, Carrier
- Model No. 92-245
- Explosion-proof Y1 housing, with pickoff
- Screw wire terminals



Digital to Analog, Magnetic
- Model No. 92-250 Y3
- Output 0...50 mA or 0...20 mA
- Current mode, 2-wire analog
- Supply Voltage: 11...30V DC
- Screw wire terminals



Digital to Analog, Carrier
- Model No. 92-252 Y3
- Output 10...50 mA or 4...20 mA
- Current mode, 3-wire analog
- Supply Voltage: 11...38V DC
- Screw wire terminals



Programmable K Factor Scaler
- Model No. B220-885
- The Programmable K Factor Scaler takes the raw frequency flow meter output and scales it to the desired K Factor
- Input: Magnetic pickoff
- Output: Amplified pulse square wave 30V DC max.
- Power: 8.5...30V DC
- Temperature: –22°...158° F (–30°...70° C)
- Screw wire terminals

Specifications Common to Both Digital to Analog Convertors

Response Time: Full scale change to 95% is 180 ms. Zero and span adjustments (no interaction). All outputs are jumper selectable.

Temperature: –20˚...160˚ F (–0˚...7˚ C)

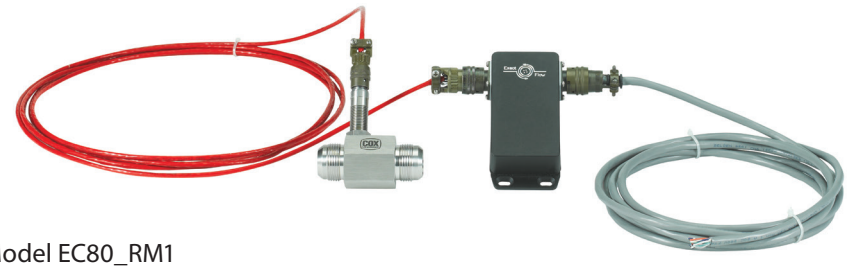
Product Configuration

Step 9b – Select Flow Processor

The EC80 is a powerful field-mounted flow processor, which extends the measuring capability of the flow meter by providing:

- Flow meter output to be linearized within 0.1% of reading
- Temperature compensation, with RTD input (internal RTD amplifier)
- Configurable outputs comprised of two frequency, two analog and three raw frequency
- Multiple outputs, frequency and analog
- UVC temperature/viscosity tables
- Rotor blade running average, to enhance low flow resolution
- Dual rotor input
- Improved measurement accuracy with Strouhal-Roshko correlation
- Configurable interface software for fluid selection, configuration of outputs and scaling
- Dynamic response (100 µs latency)

Packaging allows for integral mounting or remote mounting. Remote mounting provides a solution when space is limited or when environmental temperatures are excessive. OEM meters are typically designed with an embedded EC80 flow processor, allowing for 100 percent interchangeability of the meter system. The EC80 requires 24V DC nominal, 3 watts maximum.



Model EC80_RM1
Typical system, with remote mounted EC80 flow processor.
Cables ordered separately.

EC80 remote mount

EC80 integral mount

Model EC80_XP1
Explosion-proof housing mounted directly on the flow meter.

Product Configuration

Step 9c – Select Field Indication Display

The CUB 5 is a basic scalable indicator and will display either rate or total, using the toggle select button. Units can be mounted in a panel or NEMA 4 enclosure. Flow meter raw frequency or amplified square wave input is scaled internally.

The RT 200 is battery powered and offers simultaneous rate and total display, having five digits of rate and eight digits of total. An optional 20-point linearization capability extends the use of the flow meter beyond that of its linear range. The RT 200 has high and low set point alarms to notify user of abnormal changes in flow. The input is a direct connection to a magnetic pickoff or pre-amp square wave signal conditioner. An optional RS-485 card utilizes Modbus RTU protocol to access a variety of process parameters. Battery life is up to 10 years and protects settings during power loss. The display can also be powered in a 4...20 mA flow loop (loop burden 8.5V max.) with 4...20 mA analog output. The RT200 is housed in a NEMA 4X or explosion-proof enclosure.

The RT 200-XP explosion-proof enclosure has been tested by CSA and approved for:

- Class I, Division 1, Groups B, C, D; Class II, Division 1 Groups E, F, G; Class III for US and Canada
- Maximum ambient temperature 70° C
- Input: 8...30V DC, 4...20 mA

CUB 5 rate & total display

RT200/RT rate & total display

RT200-XP explosion-proof

Cox
Turbine Flow Meters

Product Configuration

Step 9d – Select Panel Mount Flow Processor

Panel-mounted flow processors display rate and total, and provide additional functions such as:

- Linearizing flow meter output
- Fluid temperature compensation
- Batching capabilities
- Manifold control up to three meters (4050 only)

4010 and 4020 Panel-mounted Liquid Flow Processor

4010

- Total and rate display
- Linearizer
- Selectable engineering units
- NEMA 4 housing, panel-mounted
- Power 110 or 220V AC
- 24V DC auxiliary power

4020

Same as 4010 plus:

- Temperature compensation
- Optically isolated 4...20 mA
- DC analog output

FC30 Panel-mounted Liquid and Gas Flow Processor

- Total and rate display
- Linearizer
- Batcher
- Selectable engineering units
- Output alarms
- Pulse and analog outputs
- NEMA 4 housing, panel-mounted
- Power input 110 or 220V AC
- 12 and 24V DC

4050 Panel-mounted Liquid Manifold Flow Processor

- Controls up to three independent flow meters
- Provides automatic valve switching
- Total and rate display
- Linearizer
- Selectable engineering units
- NEMA 4 housing, panel-mounted
- Power 110 or 220V AC
- 24V DC output

4010 and 4020 Flow Processors

FC30 Flow Processor

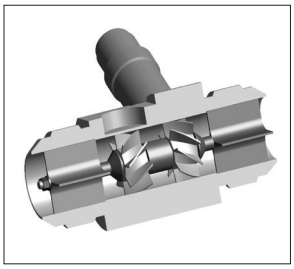
4050 Flow Processor

Product Configuration

Step 10 – Consider OEM Options

Cox Exact Dual Rotor Meter

A host of meters have been developed from the dual rotor platform, of which many fly on advanced aircraft, such as the Joint Strike Fighter STOVL, X51 Wave Rider Scram Jet and UACV Predator Avenger. A patented dual rotor turbine mass meter has been developed to provide the aircraft industry with an onboard mass flow fuel measurement system.



Base Dual Rotor Flow Meter

OEM Custom Packaging with Integrated Electronic Processor

Many applications require very unique specifications. If the standard set of options found in this guide do not meet your needs, consult with the factory for custom fitting.

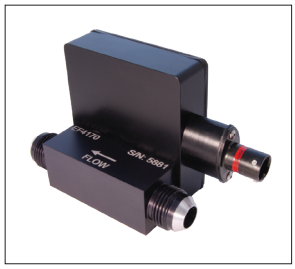
Tactical Fighter Flight Hydraulics

UACV Flight Fuel Meter

Flight Mass Turbine Flow Meter

Defense Flight Fuel Meter

Test Bench Fuel Meter



Race Car Flow Meter

Cox Turbine Flow Meters

Product Configuration

Step 11 – Ask for Application Support

Badger Meter provides a knowledgeable technical sales staff to assist in specifying the correct flow meter and calibration for the application. Their experience and attention to details will guide you into the proper electronics to meet an array of power and output configurations.

Cox Precision flow meters are designed and manufactured to provide a building block system approach to resolve the most difficult applications. This approach takes into consideration fluid temperature, environmental conditions, vibration, shock, bi-directional flow, and a host of tube and pipe connections, which solve a multitude of application challenges. This thorough approach results in successful installations employed in aircraft, Formula 1 race cars, defense missiles, unmanned aircraft, engine test cells, and precision blending.

When precision means everything, count on Cox products and NVLAP (Lab Code 200668-0) calibrations to complement your flow measurement system requirements.

Note: NVLAP accreditation applies only to the Badger Meter Flow Dynamics calibration Lab, located in Racine WI.

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The Americas | Badger Meter | 4545 West Brown Deer Rd | PO Box 245036 | Milwaukee, WI 53224-9536 | 800-876-3837 | 414-355-0400
México | Badger Meter de las Americas, S.A. de C.V. | Pedro Luis Ogazón N°32 | Esq. Angelina N°24 | Colonia Guadalupe Inn | CP 01050 | México, DF | México | +52-55-5662-0882
Europe, Eastern Europe Branch Office (for Poland, Latvia, Lithuania, Estonia, Ukraine, Belarus) | Badger Meter Europe | ul. Korfantego 6 | 44-193 Knurów | Poland | +48-32-236-8787
Europe, Middle East and Africa | Badger Meter Europa GmbH | Nurtinger Str 76 | 72639 Neuffen | Germany | +49-7025-9208-0
Europe, Middle East Branch Office | Badger Meter Europe | PO Box 341442 | Dubai Silicon Oasis, Head Quarter Building, Wing C, Office #C209 | Dubai / UAE | +971-4-371 2503
Slovakia | Badger Meter Slovakia s.r.o. | Racianska 109/B | 831 02 Bratislava, Slovakia | +421-2-44 63 83 01
Asia Pacific | Badger Meter | 80 Marine Parade Rd | 21-06 Parkway Parade | Singapore 449269 | +65-63464836
China | Badger Meter | 7-1202 | 99 Hangzhong Road | Minhang District | Shanghai | China 201101 | +86-21-5763 5412
Switzerland | Badger Meter Swiss AG | Mittelholzerstrasse 8 | 3006 Bern | Switzerland | +41-31-932 01 11

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