

CO2 Rebreathing Measurement

Video: <https://vimeo.com/932134772>

Rebreathing Simplified



How is CO2 Rebreathing measured?

Since we cannot perform such measurements on live babies, we use a model. The model breathes at the respiratory rate and tidal volume characteristic of the baby under study. The design suggested uses a tidal volume of 35 ml, residual volume of 30 ml and respiratory rate of 44 per minute... like a sleeping infant.

CO2 is injected into the system at a rate characteristic of an infant's CO2 generation. (56 ml/min). The system breathes in and out through an infant face probe at a force of 10 Newtons, representing the force of an infant's head.

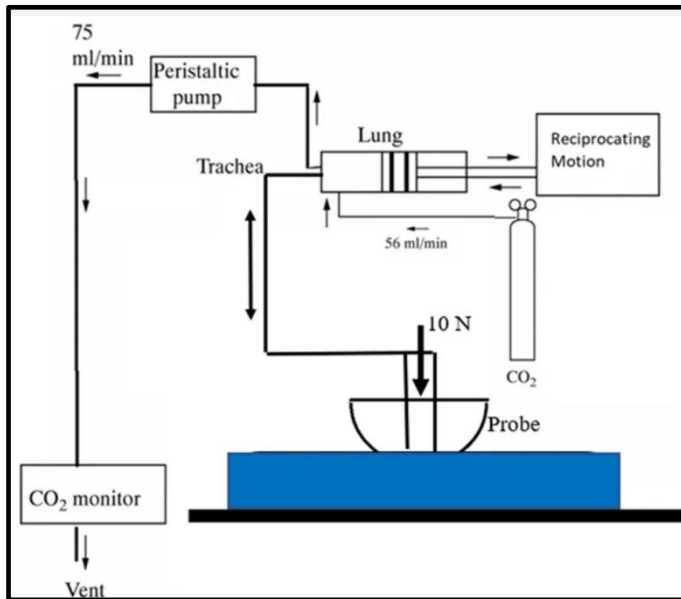
Sensitivities

When assembling the breathing machine, the tidal volume and residual volume are important specifications. Measure the inside diameter of the syringe barrel and calculate the starting and ending positions for the piston. A difference in these volumes will affect the measurement. More volume will reduce the CO2.

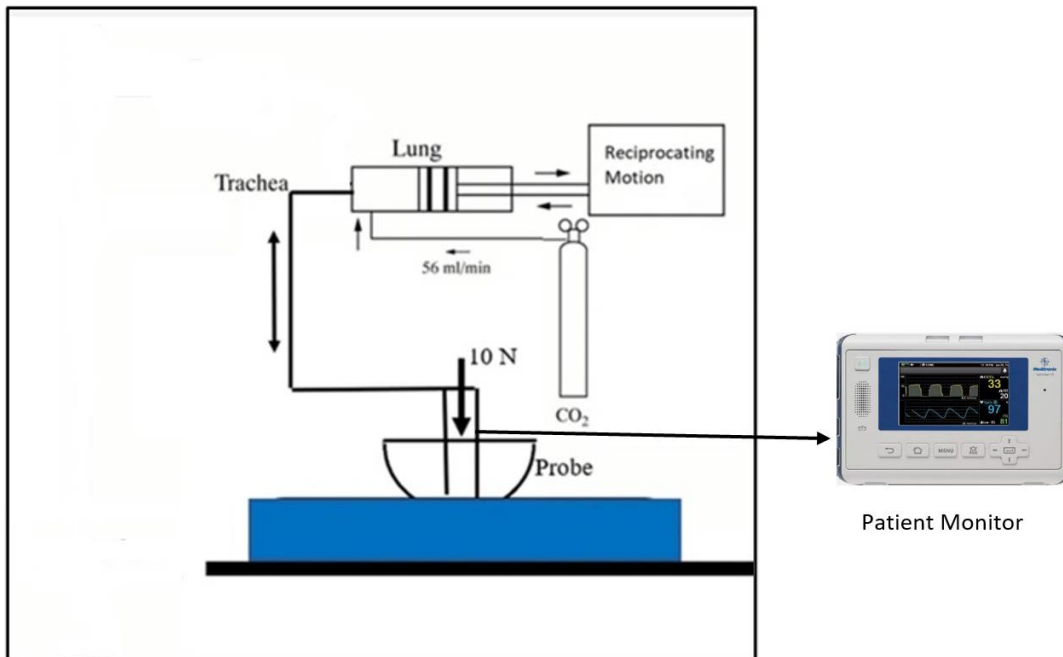
The volume of the tube connecting the breathing lung and probe is called the "dead space" and will affect the measurement. More volume will increase the CO2. So if the baseline

measurement is outside the 25 to 40 mm Hg range, you may need to adjust the tubing length/diameter or lung volume.

Measuring CO₂ Rebreathing involves a source of CO₂, a breathing machine, a probe representing the baby's face, and a way of measuring the resulting CO₂ in the breathing circuit. The apparatus looks like this:



This alternative method uses a patient monitor, connected at the probe.



What is etCO2?

Medical monitors can measure CO₂ breath-by-breath at the nose and display the end tidal CO₂ (etCO₂), measured in mmHg. As shown in Table 1, inhaled fresh air has a partial pressure pO₂ of 160 mmHg and a pCO₂ of 0.3 mmHg. Exhaled air in contrast has a pO₂ of 116 mmHg and a pCO₂ of 35 mmHg.

	Partial pressure (mm Hg)	Concentration (Vol %)
O ₂ Fresh air	160.0	21.0
O ₂ Exhaled breath	116.0	16.4
CO ₂ Fresh air	0.3	0.04
CO ₂ Exhaled breath	35.0	4.4

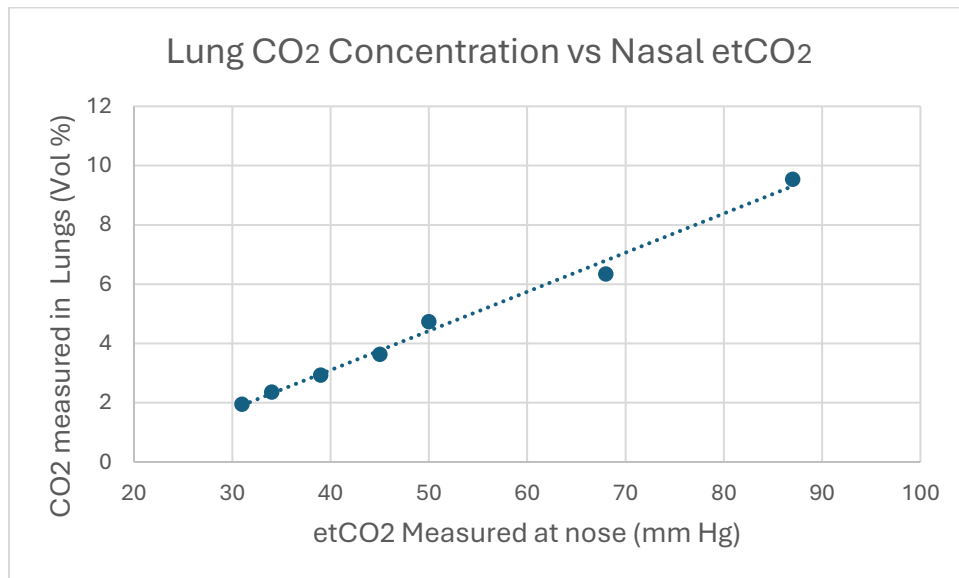
When I breathe into the etCO₂ monitor, the waveform looks like this... 32 mm Hg partial pressure CO₂ and 15 breaths per minute. Whatever I do, the etCO₂ remains pretty constant.



I am told that it is the same for a baby, only a faster respiratory rate.

These “normal” values are important benchmarks. For example, when the probe (or manikin) is breathing freely, we should expect a lung sample of about 3.75 to 4.5% CO₂, and/or an etCO₂ measurement of about 35 mm Hg.

With the probe engaged in a test specimen, the measured CO₂ will rise, indicating a measure of rebreathing, whether measured as % or mm Hg.



Why use a patient monitor instead of a CO₂ analyzer? When an infant breathes into an etCO₂ analyzer, we see a waveform that normally looks like this:



25 mm Hg partial pressure is a normal level, equivalent to about 3.75% by volume. (End tidal = the end of the exhale.)

When rebreathing occurs, you see it immediately as the etCO₂ walks off the screen...



And the etCO2 rises. (If you also use a CO2 analyzer to sample the lung, it can be used as well.)

Bill of Materials

	Cost	Example	Link
CO2 Cylinder	\$90	5 pound empty	https://www.ebay.com/itm/323649755570
Regulator, CGA Fitting & Valve	\$40	Includes CGA 320 and valve	https://www.amazon.com/FERRODAY-Regulator-Pressure-Ke-4435ff64d03b&pf_rd_p=352fa4e9-2aa8-47c3-b5ac-8a90ddbec
Flowmeter & Valve	\$759	Matheson Part Number: SEQ E13C151E100	https://store.mathesongas.com/fm-1050-series-high-accuracy-fl

Breathing Lung	\$16	Amazon	https://www.amazon.com/CynaMed-Premium-Ear-Removal-System-VWxpPhmcRD2vEmE6n1iZpZwNL3ppzQpsYcFdtPLL4_IZYl6gBNpVTpjchG6GqZnzRd9sUFJVuMi73c2L9jXTVQ&dib_tag=se
	\$50	(+ modifications and mounting)	
Ball Bearing Slide	\$12	Amazon Minimum travel 50 mm	https://www.amazon.com/LML12B-Linear-Bearing-Variety-Pack-10-Pack-ww9Z1t1m25S28g0&dib_tag=se&keywords=linear+slide&qid=1570115701

Linkages	\$14	Amazon	https://www.amazon.com/Stainless-Threaded-Thread-Length-Threads/dp/B00G3OHKOG/ref=sr_1_4?crid=2QOI3G1GG9364N9063HMPQeW0j_frdUuGZO8cK_QigC97YEQvK3LB2pnu32%2Bthreaded%2Brod&qid=1723671092&srefix=10-32%2
Gearmotor & Crank Arm	\$80	Amazon	https://www.amazon.com/gp/product/B09Y8SHMJ9/ref=ppx_y
Test Stand	\$38	Amazon	https://www.amazon.com/dp/B00HUUWYIO/ref=sspa_dk_det73d3809141a2&pf_rd_r=EH8D1JVTAZKX0TP1Q77D&pd_r
Probe	\$16	Amazon + modifications	https://www.amazon.com/gp/product/B08GCZTZ6R/ref=ppx_y

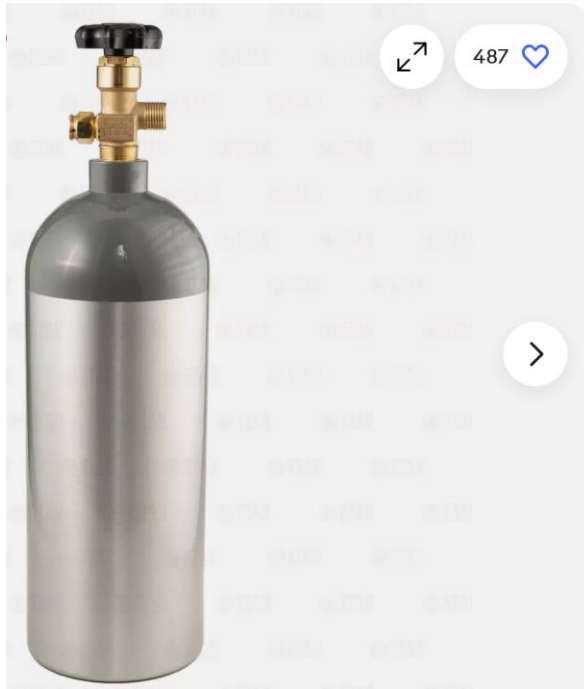
Patient Monitor	\$2,500	Ebay	https://www.ebay.com/itm/176520997455?_nkw=medtronic+c&d7Mhegun5Pt6591zV88L5sY3QEKIcDibVJvaAMu1WNeu18e1h4IrzOjNR4Est3v5R2JVCSvgdxCXZDKlOOa117uEGFupN
Fittings, tubing	\$20	Brass	
Weight	\$20	Steel	
Lung Fixture	\$20	Plywood	

Total \$3,675

This is the equipment for testing CO2 Rebreathing with a Patient etCO2 Monitor

An aluminum cylinder for CO2 is portable and easily exchanged at the welding supply store. Beverage grade is OK. I buy an empty one online and exchange it for a full one locally. About \$35 for the gas.

A larger cylinder will last longer – 100's of hours.



5LB CO2 Tank Aluminum Gas Cylinder For Kegerator Keezer USA DOT CGA320 Valve

 **Star Beverage Supply Co.** (6794)
100% positive · [Seller's other items](#) · [Contact seller](#)

US \$80.99

Condition: **New**

Quantity: More than 10 available · **1,008 sold**

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You will need a pressure regulator with a CGA 320 fitting and valve.

10 psi is enough and this gas goes through the flowmeter. The valve on the flowmeter is used to set the CO2 injection flow to 56 ml/min. Note: For flowmeters calibrated for air, set 81 ml/min to compensate for the CO2 density.



Dual Gauge Co2 Regulator Beer Kegerator Co2 Regulator Beer Keg Dual-stage Kegerator Regulator CGA-320 Beer Regulator Co2 Kegerator Part Beer Keg Regulator Co2 Beer Gas Regulator Beer Tap Tool

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The flowmeter should be in the range to measure 81 ml/min air (56 ml/min CO₂)



FM-1050 Series High Accuracy Flowmeter (150 mm Reference), Brass

USD \$721.55

Part Number: SEQE13C151E100

Availability: Ships within 24 hours from Montgomeryville, PA

- Flow Tube:
E100 (6-150 sccm Air) ▼
- Valve Type:
High Accuracy Valve on Inlet ▼
- Connections:
1/8" NPT Female (standard) ▼

Include base plate stand?

Yes

The breathing machine is made from a 4 oz ear syringe (or equivalent). The syringe is mounted on both ends of the barrel. Two ports are installed as shown below.



Roll over image to zoom in



CynaMed -Premium Ear Wax Removal Syringe 8 OZ,6 OZ,4OZ,3 OZ - Brass with Chrome Finish Ideal for Household, EMT, Firefighter, Police, Medical Student, School and Hobby (4 OZ)

Visit the Cynamed Store

4.4 ★★★★★ 64 ratings

| Search this page

\$15⁹⁹ (\$15.99 / Item)

Get a \$200 Amazon Gift Card upon approval for the Amazon Business Prime Card. Terms apply. Learn more

Size: 4 OZ

3 OZ \$14.99 (\$5.00 / Item)	4 OZ \$15.99 (\$15.99 / Item)
6 OZ \$16.99 (\$16.99 / Item)	8 OZ \$18.49 (\$18.49 / Item)

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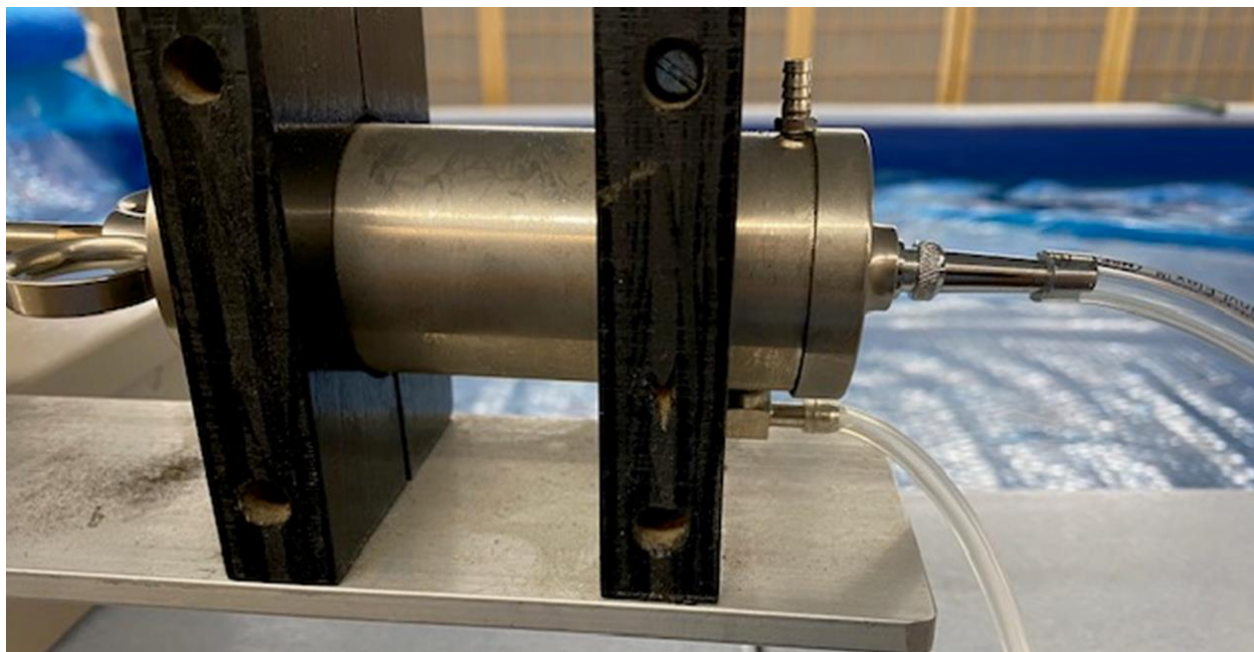
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Sold by Avon Surgical
Returns 30-day refund/replacement
Customer service Avon Surgical
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Add to List

Make a fixture to mount the syringe securely at both ends of the barrel. Add fittings at the end for tubing connections for injection of CO₂ and withdrawal of the sample.

Specifications for the starting and ending volumes are 65 and 30 ml, for a tidal volume of 35 ml. The stroke should be about 39 mm, with a barrel diameter of 42 mm. Adjust the stroke and starting point to achieve the starting and ending volumes specified.



Use fittings like these



5PCS 2.5mm 3mm 4mm 5mm
6mm 8mm 10mm OD Hose
Barb M3 M4 M5 M6 M8 Metric
Male Thread Brass Pipe Fitting
Coupler Connector Adapter -
(Color: M4 to 4mm)

Brand: Xucus

5.0 ★★★★★ 3 ratings

-17% \$5³²

Typical price: \$6.42 ⓘ

Size M4 to 4mm

\$5³²

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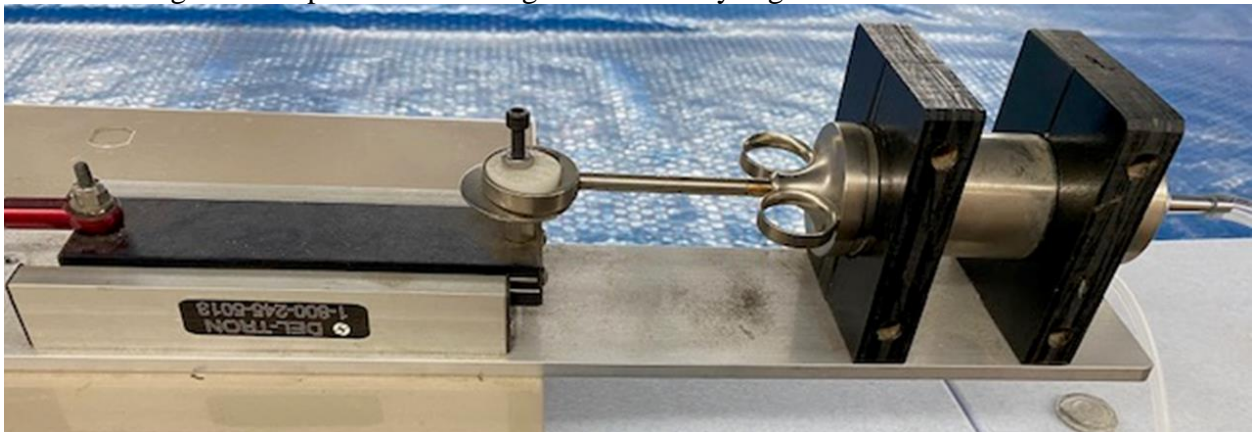
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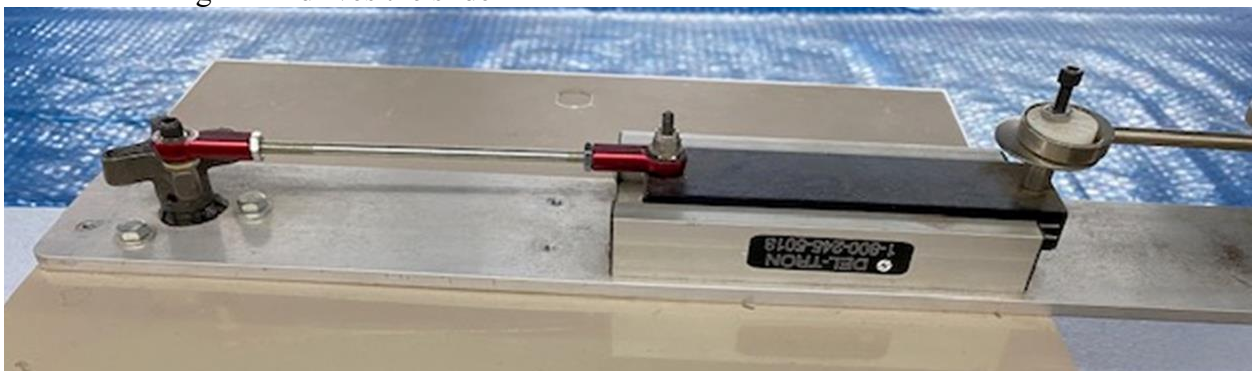
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A ball bearing slide keeps the motion aligned with the syringe



...and a rotating crank drives the slide



This slide should work...



Roll over image to zoom in

LML12B Linear Rail Mini Bearing Steel Guide Rail Slide Rail+ Slide Block Variety Length (100mm)

Visit the Hilitand Store

3.1 ★★★★★ 14 ratings | Search this page

\$11.92

prime One-Day

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Brand	Hilitand
Material	Stainless Steel
Item dimensions L x W x H	3.94 x 0.79 x 0.39 inches
Bearing Type	Ball Bearing

Delivery

Pickup

\$11.92

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In Stock

Quantity: 1

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...and these rod end fittings and threaded rod will work. Metric equivalents available 5 mm.



Roll over image to zoom in



PHSB3 Rod End Bearing 3/16 Inch Bore and #10-32 Right Hand Thread, Self-Lubricating Female Heim Joint Rod Ends, Includes Jam Nuts 2pcs

Visit the HIPICCO Store

4.7 ★★★★★ 88 ratings | Search this page

\$8.99 (\$4.50 / Item)

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Size: 3/16

1/2 1/4 3/4 3/8 3/16 5/8 5/16 7/16

Style: Right Hand

Left Hand Right Hand

Delivery

Pickup

\$8.99 (\$4.50 / Item)

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Metric - https://www.amazon.com/HiPicco-Bearing-Pre-Lubricated-M5x0-8mm-Metric/dp/B0BL7P7BGJ/ref=sr_1_9?crid=IHZC21XEJBIQ&dib=eyJ2IjojMSJ9.JIr6SR3cDm_fGaoOGj3emXZjJjxTYmzem0z0vzP0bQvMx7c57-NPSItLLNSrcFekT_24XP6GxPDXyWCu8OYTVJL_3Wir2Vvry5Jd7L_NTXmQMNpOykkzFig9s1fOrWIFY-sB2EMgnFnf2gqwF4oAc-v3_afkqZHNEedUN8vJiPqCcOY5rBIKQC7qvaY2LbPwBsVXaxjU5kMLRTNU8XMm3lyaUtfDspBShd0AQuuCxno.G-o-WQSdqhxzUwetJkSfD5dan5Ufhr_iScFVC8qeUY4&dib_tag=se&keywords=rod%2Bend%2Bbearing%2Bmetric&qid=1723756021&srefix=rod%2Bend%2Bbearing%2Bmetric%2Caps%2C125&sr=8-9&th=1



Roll over image to zoom in



316 Stainless Steel Fully Threaded Rod, #10-32 Thread Size, 12" Length, Right Hand Threads

Brand: Small Parts

4.6 ★★★★★ 242 ratings | Search this page

Amazon's Choice Popular Brand Pick

\$13⁹⁸

Item Length String: 12 Inches

12 Inches 24 Inches 36 Inches 72 Inches

Thread Size:

#10-32

Number of Items: 1

Material Stainless Steel
Thread Size #10-32
Grade Rating 316
Thread Coverage Fully Threaded
Exterior Finish Plain

\$13⁹⁸

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Metric https://www.amazon.com/LWCUSNJ-250mm-Threaded-Stainless-Threads/dp/B0CMZR9L1Y/ref=sr_1_1_sspa?crd=3LNWS7TRV1JDO&dib=eyJ2IjoiMSJ9.KO4PAzCRAFRgwqqKr-Pv6hcS9f8wvVhEr8FrPlbO7kv2ogURx_ey3C5eqhVO5KvujIUvGRo1jfp1pqaEp-IMQukRrtSRUGQaISMP_hAiNC79jVXqv1033TIGy7bGd7dKHQjoUVzLUJkcYf5gt2r9FFpkwRueNKiXz0Vai9hLPLU3H-LsBDz3nE-kDTDpqLRAITIXDw4reSo6vTArzWEHiavBJLVa6g9kEK0o6hCx9M.jkH6M8UwBw0Cg3gE8q4HMyM3DLQeKq_APQSxdzNXPE0&dib_tag=se&keywords=5%2Bmm%2Bthreaded%2Brod&qid=1723756135&sprefix=5%2Bmm%2Bthreaded%2Brod%2Caps%2C112&sr=8-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&th=1

The gearmotor will need a crank arm with 0.75 in radius (19 mm)



Roll over image to zoom in



40W 110V Gear Reduction Motor high Torque Motor Electric Variable Speed Controller Low RPM Electric Motor 1:15 90RPM Single-Phase (40W 15K)

Visit the Gdrasuya10 Store

2.0 ★★★★★ 1 rating | Search this page

\$79⁹⁹

Or \$14.77 /mo (6 mo). Select from 1 plan

Thank you for being a Prime Member. Pay \$79.99 \$0.00 for this order; get a \$200 Amazon Gift Card upon approval for the Amazon Business Prime Card. Terms apply. Learn more

Style: 40W 15K

15W 50K \$89.99 40W 15K \$79.99 90W 20K \$115.00 250W 5K \$119.99

\$79⁹⁹

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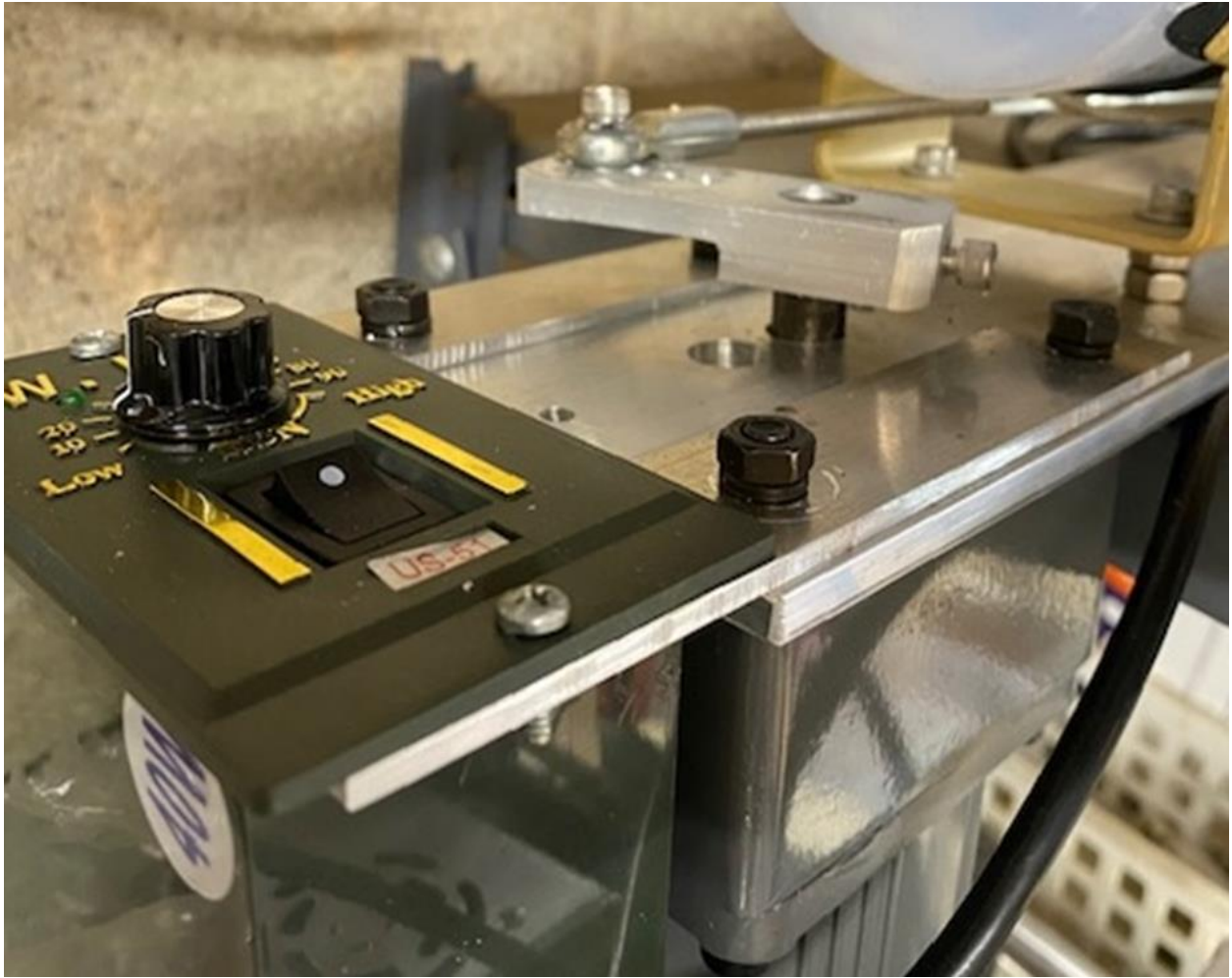
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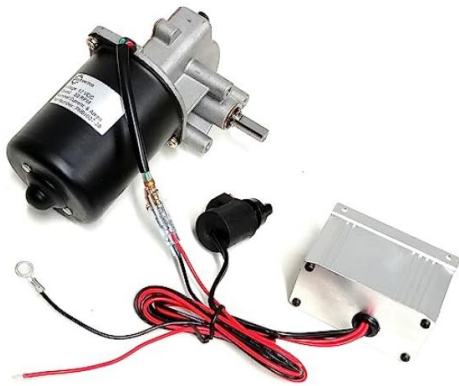
Crank arm. 12 mm hole - 19 mm radius to threaded hole for mounting rod end.



And mount the gearmotor, slide and syringe on a common rail.



Alternative gearmotor – 12 VDC



Makermotor 3/8" D Shaft Variable Speed Electric Gear Motor 12VDC Max. 50RPM

[Visit the Makermotor Store](#)

4.6 ★★★★★ 26 ratings | 29 answered questions

\$106⁰⁰

Get a \$200 Gift Card instantly: Pay \$0.00 upon approval for Prime Visa. No annual fee.

You will need some kind of stand to keep the probe vertical





Roll over image to zoom in



EISCO Chemical Resistant Steel Ring Stand Set - Lab Stand Support with Clamp - 8 Inch x 5 Inch Base, 24 Inch Rod - Use as Glass Funnel Stand or Test Tube Holder

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The probe is connected to a tee fitting with a branch for the etCO2 monitor



Make probes from hardwood blanks



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Wooden Split Balls 3 inch, Pack of 6 Wood Half Balls for Crafting and DIY Wreaths, by Woodpeckers

Visit the Woodpeckers Store

4.7 ★★★★★ 344 ratings | Search this page

\$15⁹⁹

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Item Package Quantity: 6

1 6 10 12 25 50 100 250

Size: 3 inch

1 inch 2 inch 2-1/2 inch 3 inch 1-1/2 inch

Delivery

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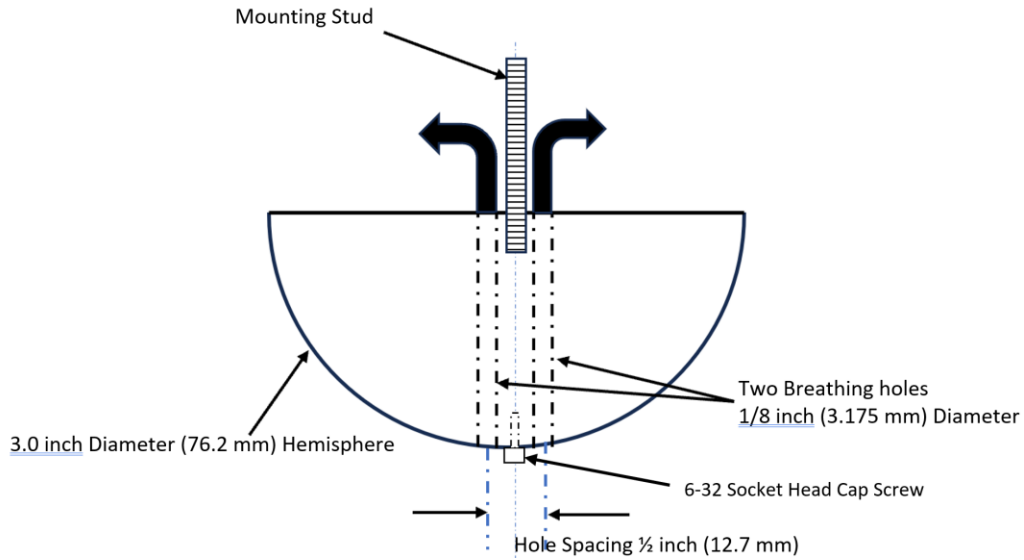
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orders over \$25. Order within 7
hrs 20 mins

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Quantity: 1



I use a Medtronic Capnostream 35 Patient Monitor. They can appear on ebay for \$200 to \$2,500

Medtronic Capnostream 35 Portable Respiratory Monitor Etco2 Capnography
 scoop10.1 (394)
 100% positive · Seller's other items · Contact seller
US \$2,500.00
 0 bids · Ends in 4d 15h · Monday, 09:01 AM
 Condition: **New**
 Place bid
 Add to watchlist
 Breathe easy. Returns accepted.
 Shipping: **US \$758** USPS Priority Mail®. See details
 Located in: Conyers, Georgia, United States

Shipping and delivery
 Click "see details" for additional shipping and returns information.