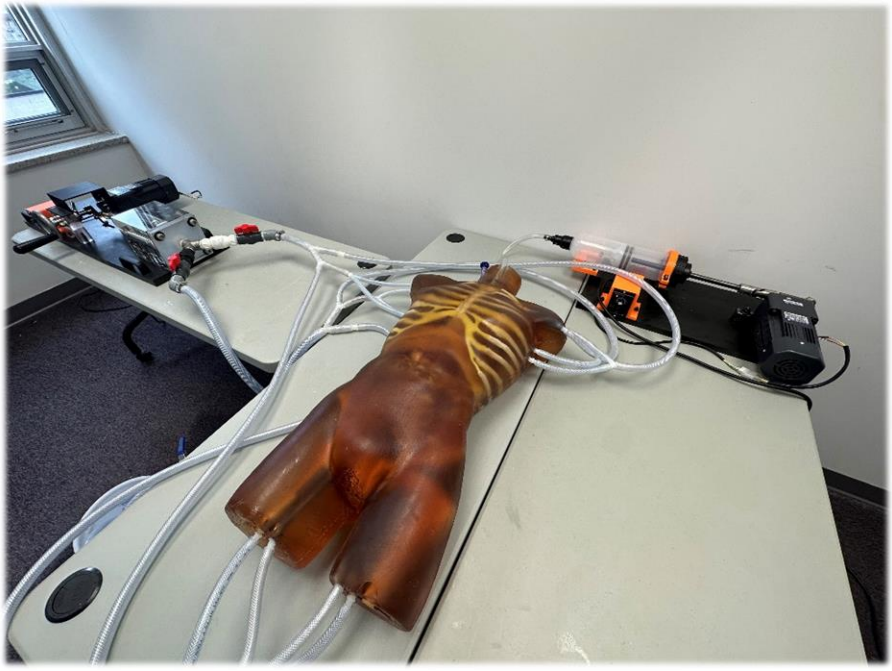
TRUE PHANTOM SOLUTIONS



User Manual

Adult Torso (Dynamic) for X-Ray CT, MRI

[TO-A05]

VERSION 2.0 ■ 30 Nov 2023

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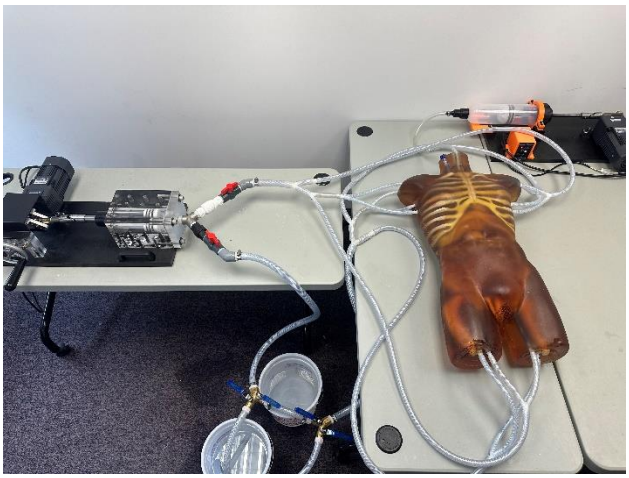
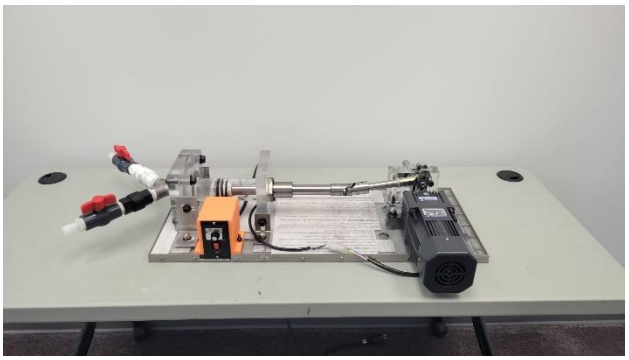
Description

Adult Human Torso (Dynamic) with a beating heart and breathable lungs is a lifelike, anatomically realistic, from neck to pelvic area phantom/simulator with all the essential organs present inside. This phantom is compatible with MRI and X-Ray/CT, and it is an ideal tool for conducting medical research under the guidance of medical imaging. The organs are made from realistic urethane-based tissue-mimicking materials, and the bones are made from a patented ceramic-reinforced epoxy-based composite material. The skeleton is assembled from individually cast bones with vertebrae that have a realistic three-layered structure and inner porosity.

In terms of MRI applications, the phantom tissues have realistic T2 relaxation time values, which makes this product to be the best fit for any T2-weighted MRI imaging methods. Very good results can also be achieved with proton-density imaging methods. The phantom can still be imaged with T1-weighted methods, but the T1 values are less realistic, and they are within the range of about 100 ms.

The design of this phantom includes a realistic heart with all major heart vessels and internal heart chambers. The TPS heart pump is included with this phantom, and it enables the realistic heartbeat and motion of heart walls. The TPS lung pump is also included to provide lifelike breathing motion in the torso.





Anatomy

- Complete Spine
- Complete Ribcage
- Shoulders and Clavicles
- Pelvis
- Partial Femoral Bones
- Trachea
- Realistic Heart with:
  - 2 Atria, 2 Ventricles:
  - Right Ventricle
    - Moderator Band that runs from the anterior wall to the septum bridge
  - Left Ventricle
    - Papillary muscles to the anterior and posterior walls
  - Right Atrium
    - Right atrial appendage with distinct muscle structures
  - Left Atrium
    - Unique muscle structure to the appendage of the left atrium
- Appendage Feature
- Aorta
- Jugular vessels
- Pulmonic and Pulmonary Veins attached to LA
- Flexible Valvular Structures
- SVC
- IVC
- Inflatable Breathing Lungs
- Diaphragm
- Liver
- Gallbladder
- Stomach
- Kidneys
- Spleen
- Pancreas
- Large and Small Intestines
- Bladder
- Prostate

Beating Heart Features

- Access to intravenous catheter insertion
- Cyclic motion of the heart walls
- Average heart rate (70 BPM)
- Adjustable heart rate (0 BPM – 140 BPM)
- Chambers fillable with water with minimal air pockets
- Asymmetrical heart motion between left and right chambers

Breathable Lungs Features

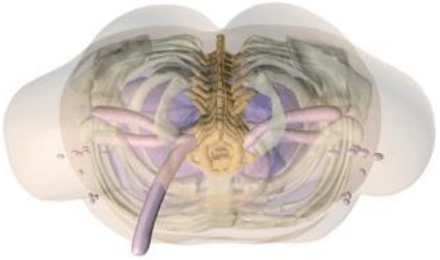
- Enabling breathing capability by modifying static lungs to dynamic inflatable lungs
- Realistic cyclic respiratory motion
- Custom duration of the breathing cycle
- Adjustable cyclic respiratory motion (0 – 45 breaths per minute)
- Adjustable breath volume (0.25L, 0.5L, 0.75L, 1 L)
- Complete system installed on a secure plexiglass base

Design

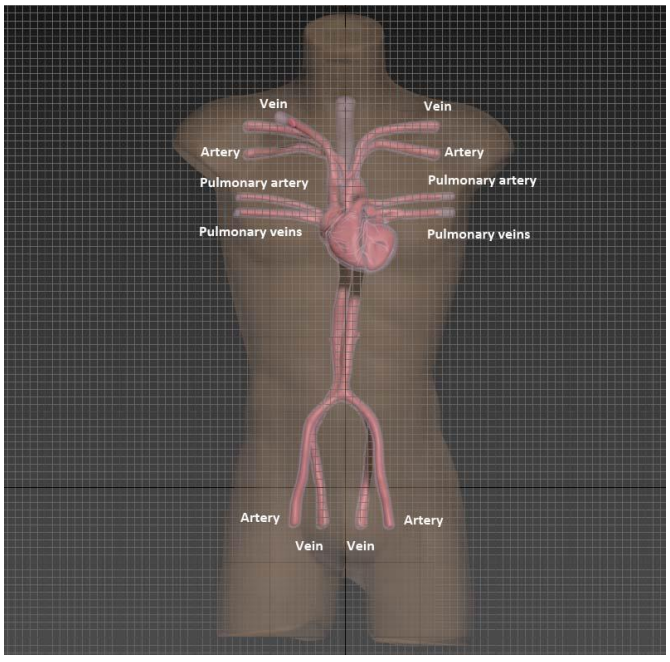
Front View

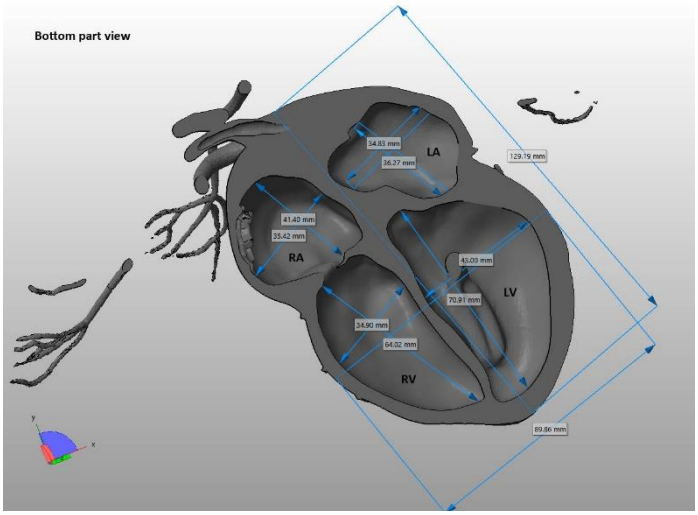
Lateral View

Perspective View



Top View

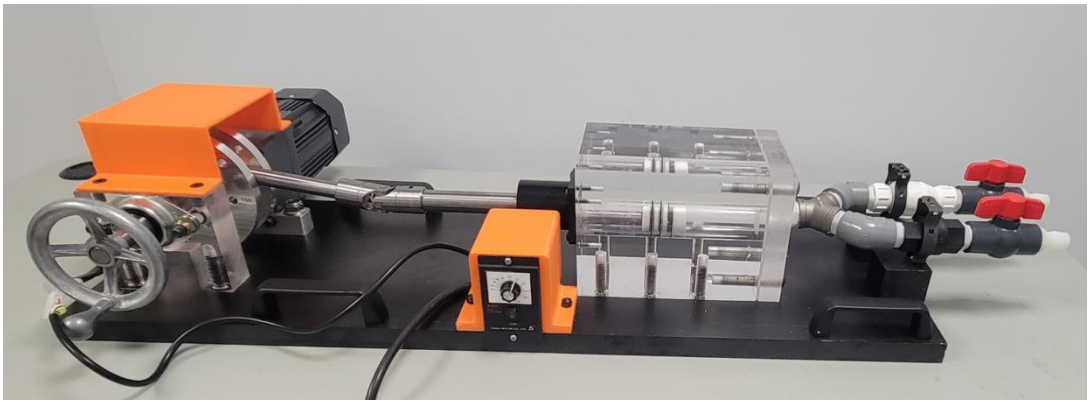




Components Included

- Adult Torso

- Variable Displacement Heart Pump with Speed Controller

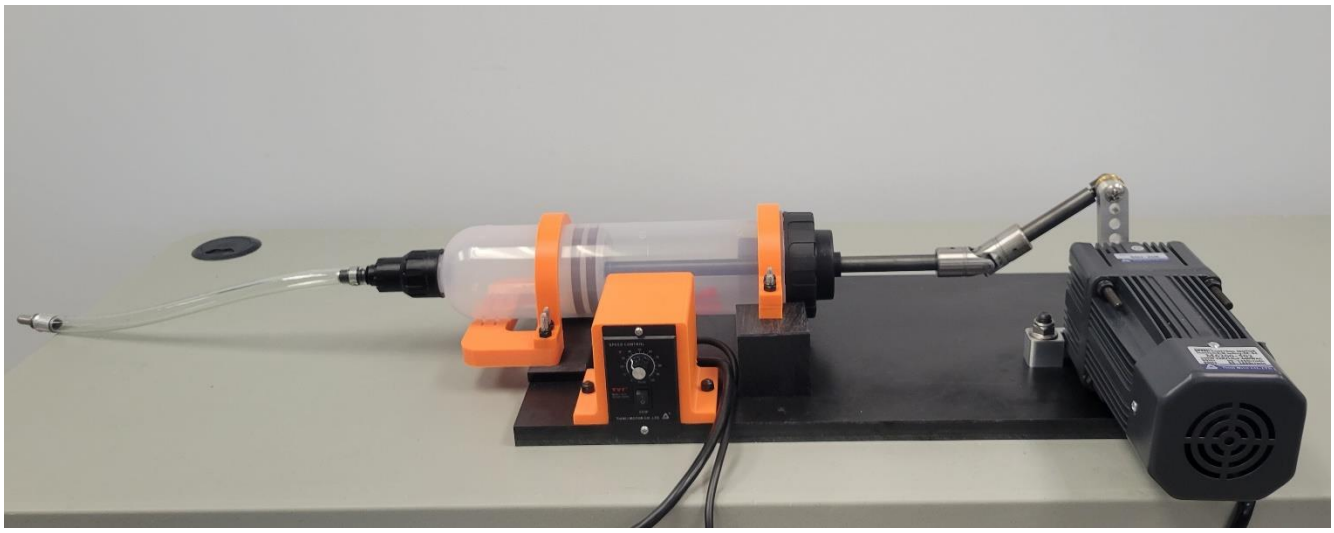


- Primary Tubes for Connecting Pump to Heart Tubing

✓ Secondary Tubes for Connecting the Primary Tubing to the Heart/Water Tank

✓ Thread locker, thread tape, pump lubricants, hex wrenches. With spare piston rings, seals, machine barrel, end bolt, sleeve bearing, and thrust bearings.

✔ Lung Pump with Motor and Speed Controller

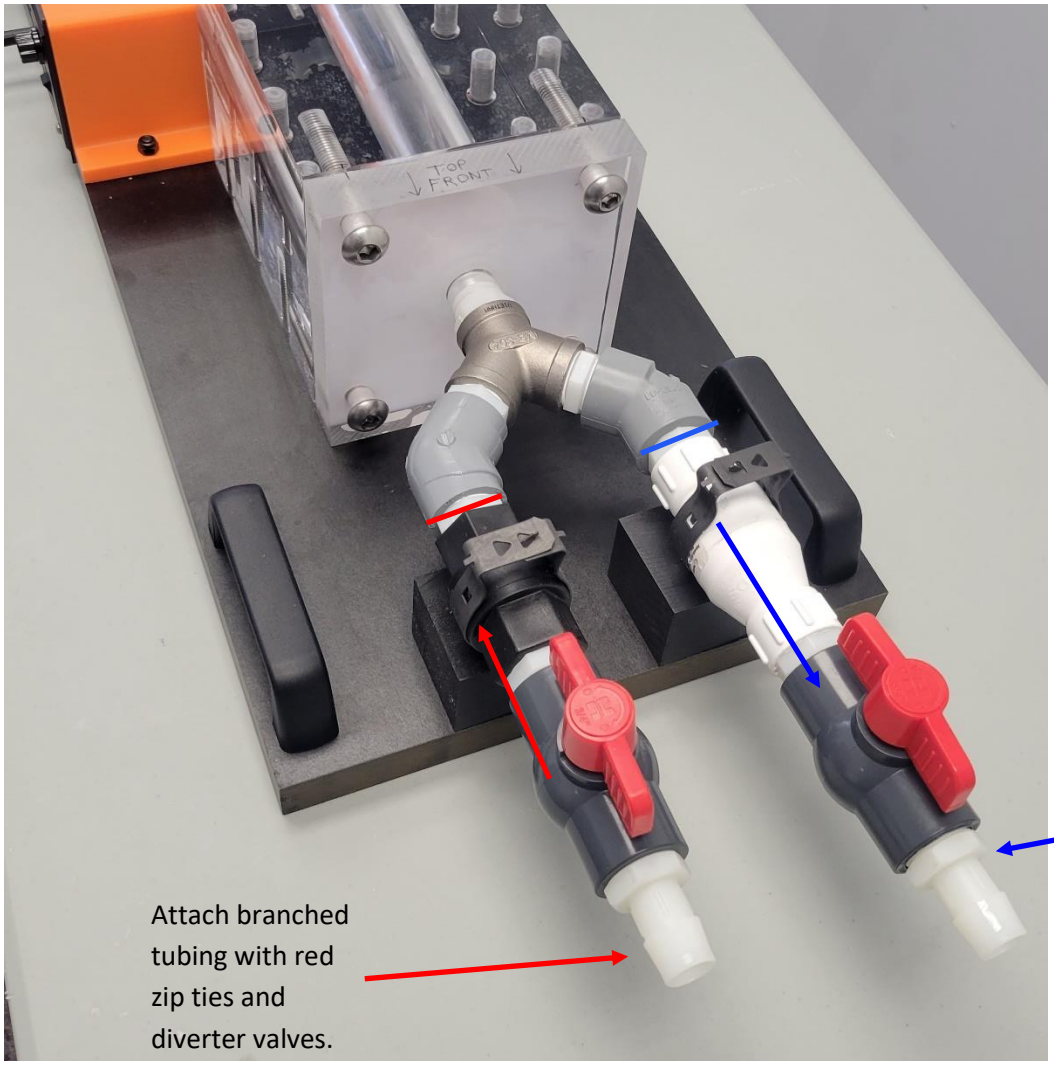


✔ 3/8” ID Extension Tubing to Connect the Pump to the Phantom

Operating the Heart Pump

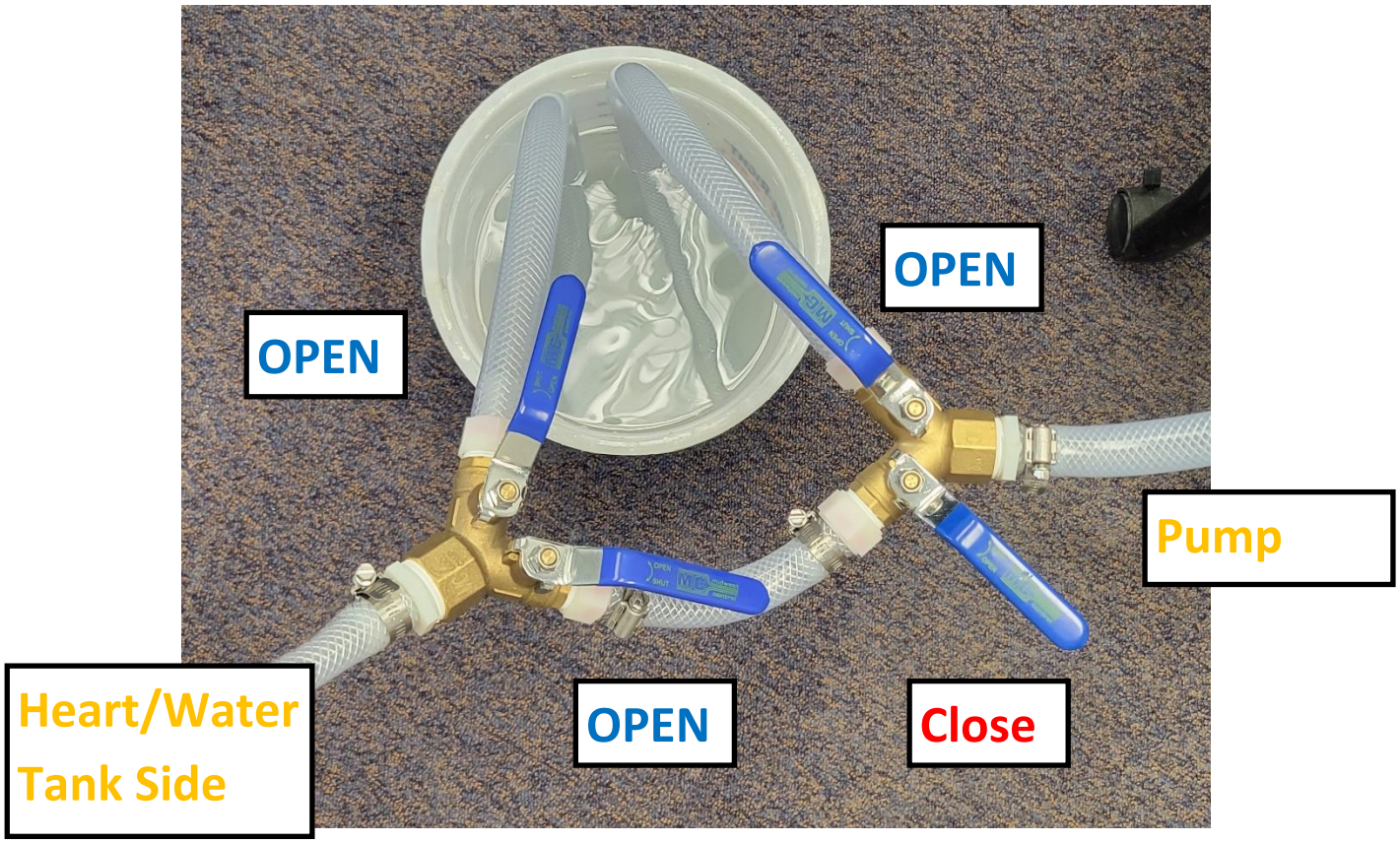
✓ Assembling the Pump with the Heart

- Using thread tape, attach the Wye Split check valve assembly to the front of the pump chamber.
- Connect the primary tubes to the pump following the color coding indicated by the zip ties. The red indicates arterial flow (away from the heart), and the blue indicates venous flow (towards the heart). Attach the single tube with the blue zip tie to the barbed fitting connected to the white check valve using the included worm gear clamp. Attach the branched tubing with 2 diverter valves and red zip ties to the barbed fitting connected to the black check valve using the included worm gear clamp.

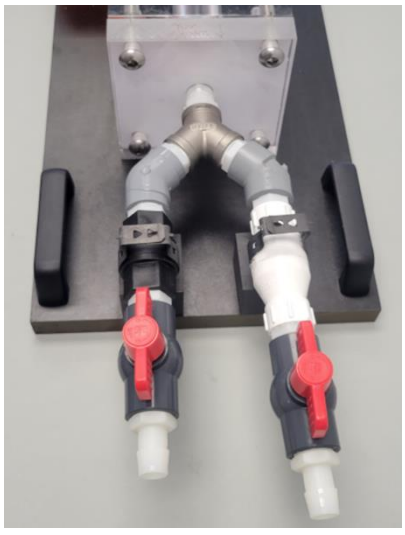


✓ System Operating

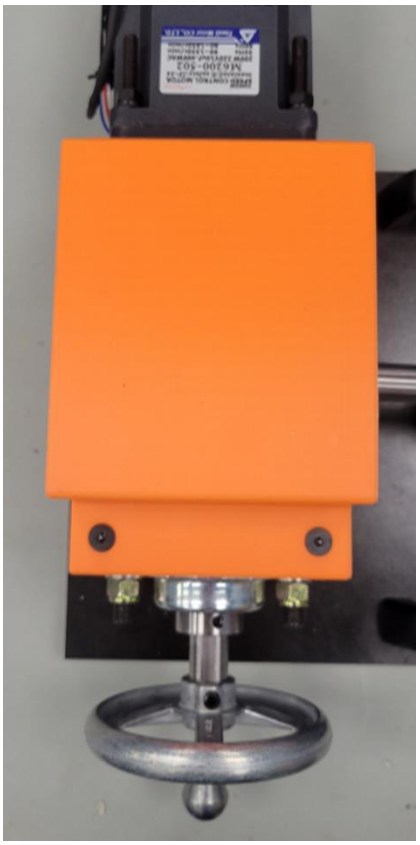
- Using a large, filled reservoir (~10L or more) insert the 2 exposed end of the primary tubes connected to the pump and diverter valves. Set the diverter valves to the below configuration. Where the valves attached to the open-ended tubes are open, and the first branch of the diverter is open, but the connecting valve is closed.



- Ensure that all ball vales, the ones closest to the pump, and the one connected to the coronary arteries (if applicable) are open as well. Valve position indicates flow, in line with tubing = open, 90 degree to tubing = closed.



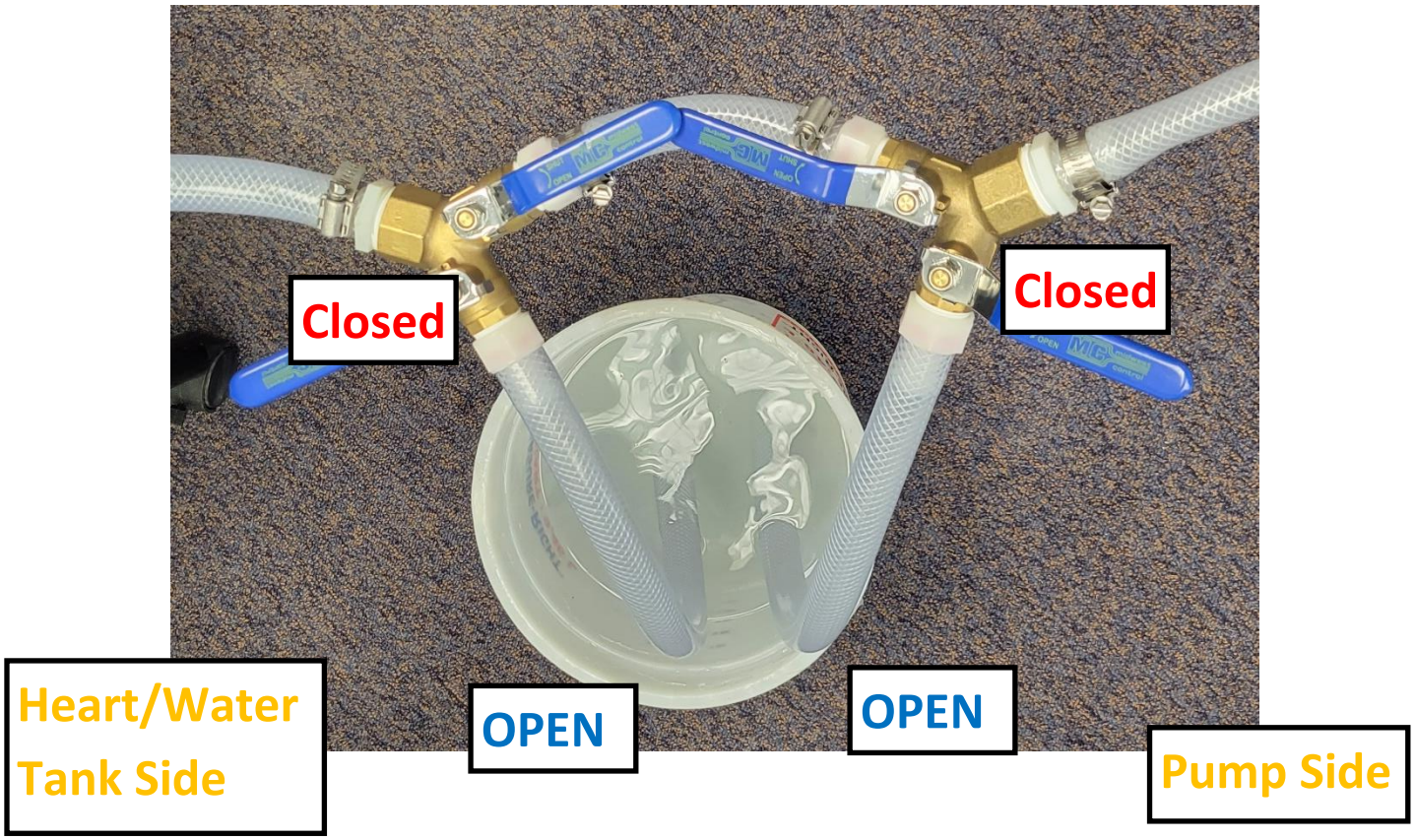
- With the reservoir full and the valves set according to the manual. If the pump has not been used in a while the piston can become stuck to the cylinder wall and require more torque than the motor is capable of breaking it free. In which case it is recommended that the piston be manually actuated via the handwheel attached to the rotating assembly to free the piston and provide a small degree of lubrication to the cylinder walls. Once this is completed, then the pump can be turned on, and the speed slowly increases.



Handwheel used to break piston free/used during adjustment and alignment. Rotational direction of the handwheel for manual operation does not matter.

Motor speed control with calibrated bpm increments.

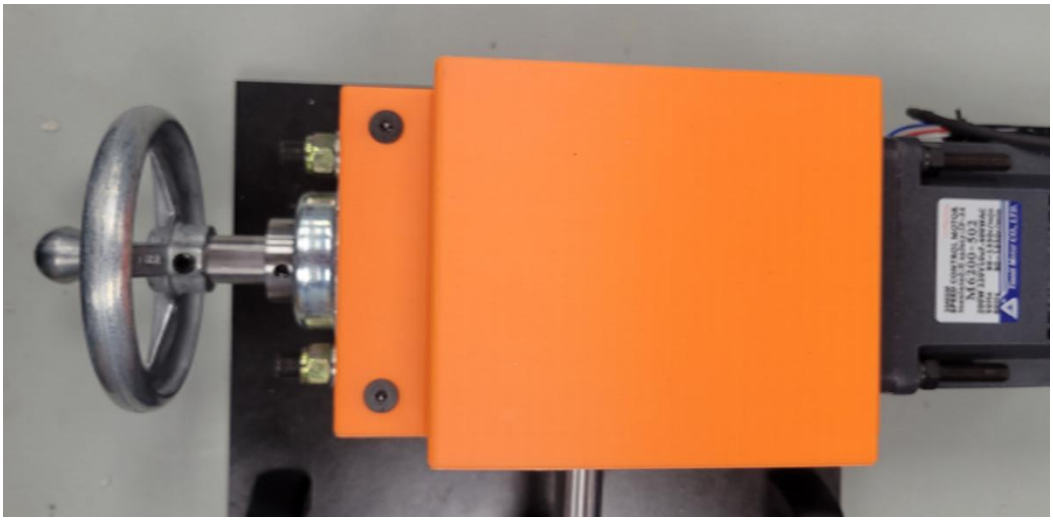
- It is recommended that the pump displacement be set to a minimum 100ml or higher, and speed of 70bpm for the initial priming/filling of the system. Allow the pump to run for several minutes in order to clear as much air from the system as possible. Please note that the system is susceptible to getting air trapped at various points due to positioning of the tubes, pump, reservoir, etc. It is the responsibility of the operator to raise, lower, agitate, etc. the system in a manner that allow the trapped air to reach a high point close to a return line so that it can be directed towards the pump and degassed into the reservoir.
- Once the degassing procedure is complete then it is time to adjust the diverter valves to change the system to a closed loop. In quick succession (a second person will aid in this procedure), open the one remaining closed connecting valve, and close the 2 valves connected to the reservoir, as illustrated below.



- If any bubbles or air are present in the system are it has been configured to a closed loop, then the degassing procedure will have to be partially repeated. You can leave the pump running at operating speed and switch the valving back to the reservoir until you see the air bubble out into the reservoir. This step may need to be repeated several times in order to completely degas the system.
- Please note that incorrect operation of the pump and valving can result in damage to the pump and/or heart. If the system is unable to circulate the pressure in a effective manner the increase in pressure without release can cause damage to crucial components.

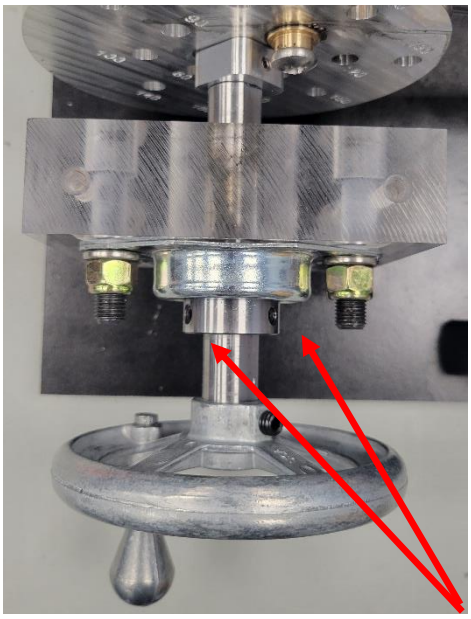
- Adjusting the Pump Displacement
  - The pump has pre-sets for volume displacements; 60-200ml, in 10ml increments.

- To access the rotating assembly, the shield must first be removed. Using a 5/32” hex key, remove the shield from around the rotating assembly.

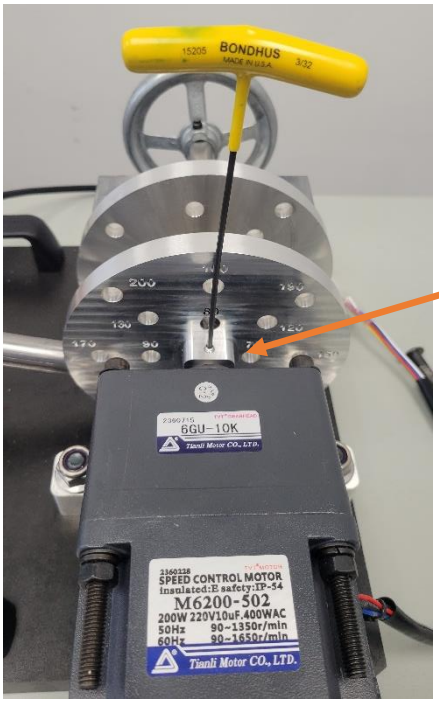


- Using a #2 Phillips, loosen the bolt and barrel assembly, and slide the barrel out as much as possible.

- Using a 1/8” hex key, loosen the set screw on the support bearing attached to the acrylic block, then slide the rod and flywheel towards the support bearing. Loosen the set screw on the bottom of the flywheel on the motor side with a 3/32” hex key. Remove the flywheel fully and insert the threaded barrel into the appropriate position (this step is only necessary when utilizing the low displacement (<130ml) settings where the barrel cannot be removed from the assembly without disassembly. If the barrel can be removed and inserted into its new position without removing the crank adapters then skip this step.)
- Ensure that the barrel/long portion is inserted from the motor side, this is to ensure that the rotational forces work with the pump and do not lend themselves to loosening the connecting hardware.

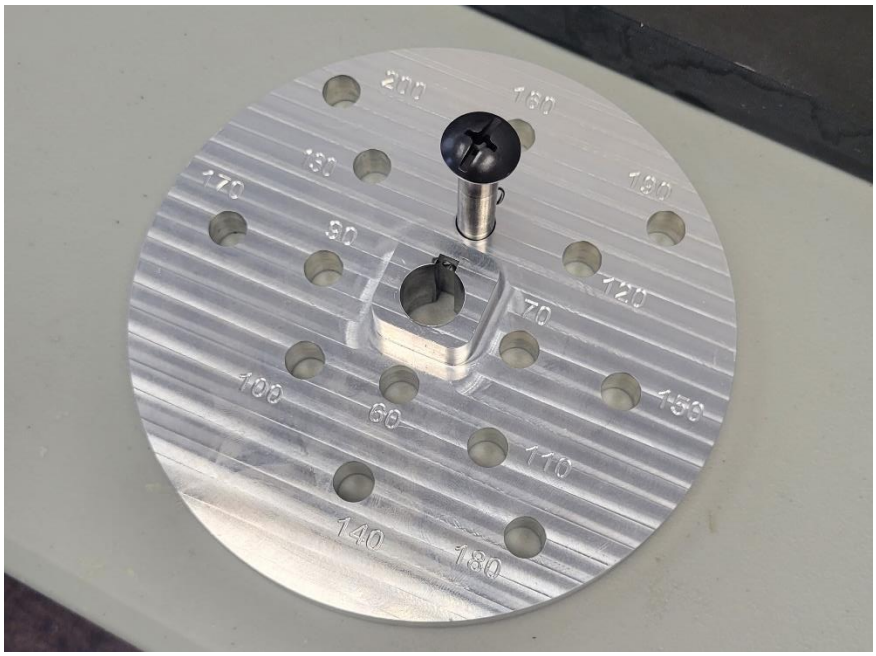


Support bearing shaft set screws

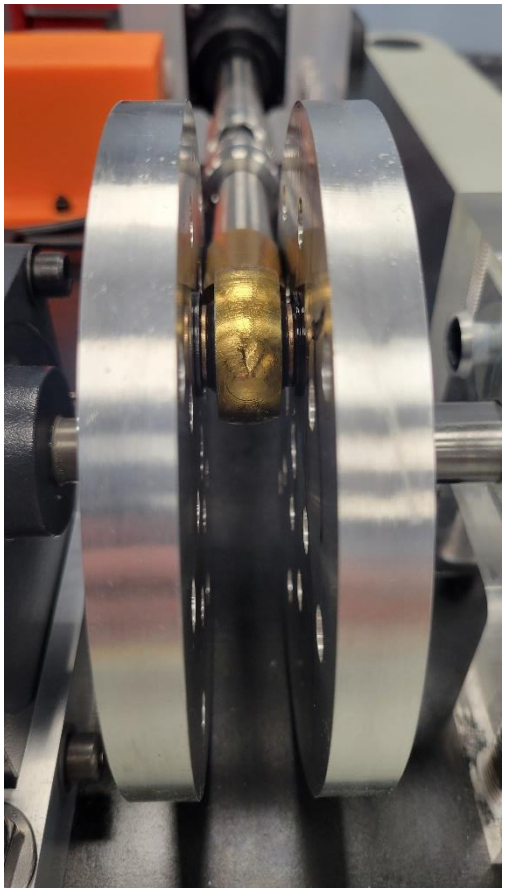


Pump flywheel with 3/32” set screw

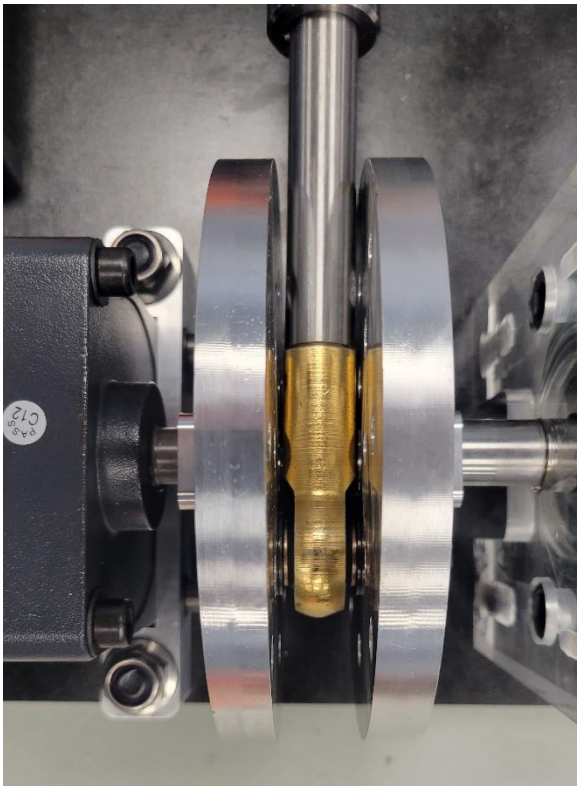
- Motor side flywheel removed, with machine barrel inserted at desired volume setting.



- With the barrel inserted at the right displacement value, replace the flywheel onto the motor shaft with flywheel face slightly proud of motor shaft (use straight edge to ensure motor shaft is not left proud), and retighten 3/32” set screw.
- With the flywheel reattached to the motor and the set screw secured. Slide the thrust bearing onto the machine barrel, followed by the rod end, and then the final thrust bearing.

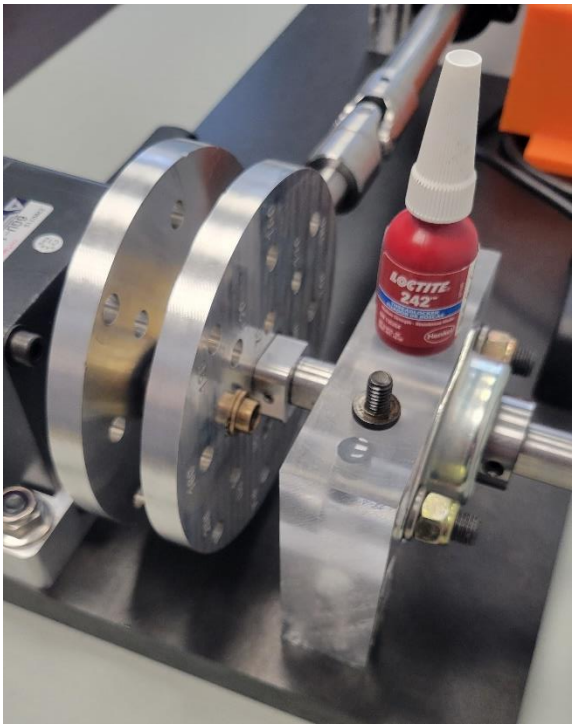


- Replace the bronze sleeve bearing and end bolt to the assembly, hand tight.
- Use the hand wheel to rotate the pump into the maximum contact orientation.



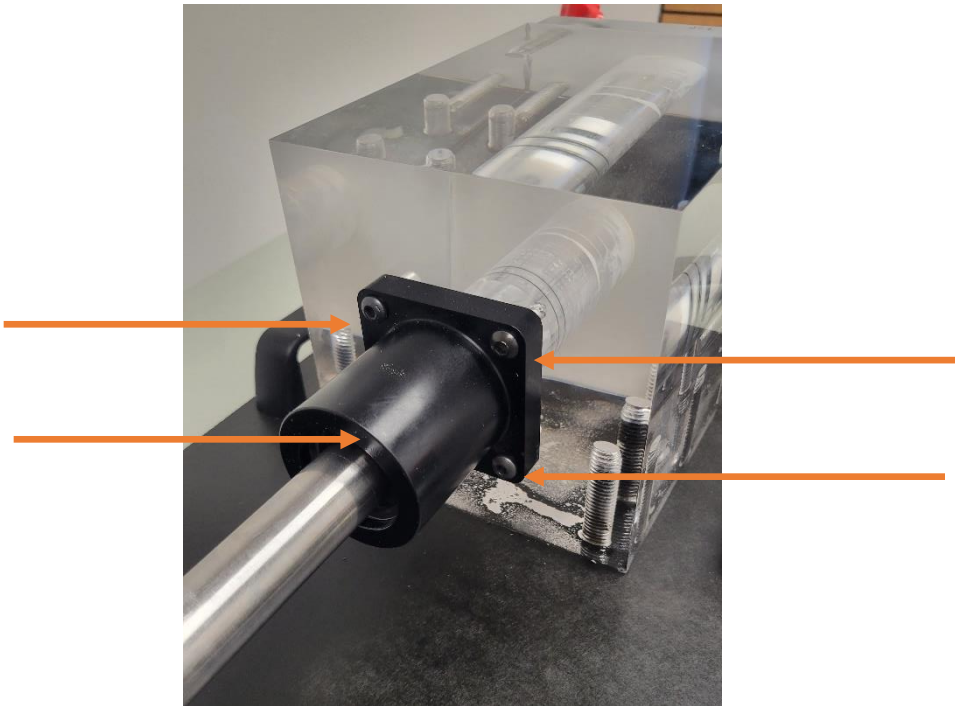
- Maximum contact orientation
- Applying light pressure, press the support bearing side flywheel towards the motor side, and retighten the 1/8” support bearing set screws.

- With the system aligned and set to the desired displacement, take the barrel bolt (clean and dry) and apply a few drops of a medium-strength thread locker. Allow for the thread locker to cure for a minimum of 30 minutes, 1 hour recommended, before beginning operation.



- Replace rotating assembly shield.

- Heart Pump Maintenance
  - In order to increase pump life, the rotating assembly should be lubricated regularly, before every use, and potentially during use if run for a long duration of time or you notice the system becoming strained. Any metal-compatible lubricant will be more than suitable for operation; however, a 50-weight oil or heavier is recommended to cling to the assembly. A small amount of suitable lubricant is included with the order.
  - The pump will also require the seals and rings to be changed when necessary. If you notice leaking from the back side of the piston, then the rings and seals will need to be replaced. If you notice excessive noise/friction without leaks, then the piston rings may need to be lubricated.
  - In order to do so, disassemble the rotating assembly as if you were going to change the displacement value. Once this is completed, using a 1/8” hex key, remove the set screw on the universal joint closest to the linear bearing and remove the universal and rod end portion of the assembly.
  - Using a 5/32” hex wrench, loosen and remove all 4 bolts from the linear bearing, and slide the linear bearing off the backside of the piston rod.



- With the piston shaft free, and the piston chamber open, slide the linear bearing off the piston rod, and then slide the piston and rod out of the rear of the cylinder housing.
- If replacing the rings and seals, clean up the piston and remove the rings and seals, they will be discarded so simply pry them off and dispose of them. Carefully replace the one piece split seal first, then place the rubber potion of the 3 piece rings in their respective grooves, and assemble the remaining portion of the 3 piece rings.
- If only lubricating the assembly, then simply clean the piston, inspect it for any damage, and then apply a thin layer of the included white lithium PTFE grease.
- Inspect the piston to see that it is still fully threaded tightly onto the shaft, if it has come loose, then remove, add thread locker, and replace. With all the seals and rings replaced, use the provided piston ring compressor to squeeze the rings for installation. Insert the shaft through the rear of the cylinder housing . Align the piston with compressor up to the rear of the assembly, and gently tap the head of the piston with a rubber mallet to coax the piston back into place. You may also use a thin layer of lubricant applied inside the piston cylinder chamber to aid with reassembly. With the piston installed, re-assemble the system in reverse order.
- Upon reassembly, it is recommended to prime and run the system, not attached to the heart, in water for ~15 minutes to ensure that the system is fully lubricated and running properly, as well to ensure that any excess lubricant isn't circulated into the heart.

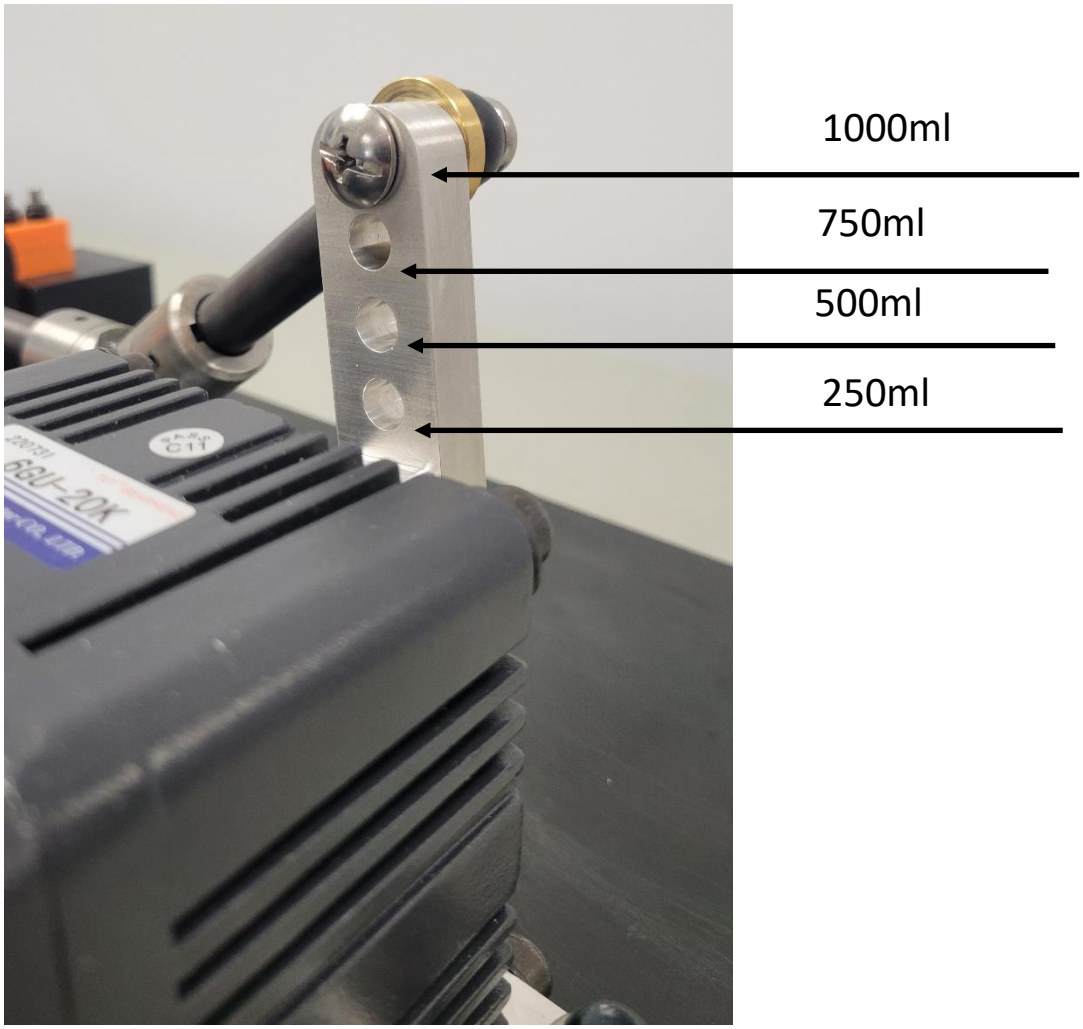
All user hardware should be set to only hand-tight. Excessive torque on hardware can cause damage to the pump/hardware, especially the threads in the acrylic parts. While it is better to have them loose and tighten them more if required, below is a table of all the torque specifications for each user-adjusted component. A torque wrench or similar tool for measuring and applying torque would be required.

Component	Torque (Lbs.)
Linear bearing bolts	30
Bulkhead bolts	80
U-joint set screws	30
Connecting rod	10
Crank adapter set screws	10
Support bearing set screws	10

Operating the Lung Pump

Using the Lung Pump

- Using 2 Phillips head screwdrivers, loosen the threaded barrel and end bolt.
- Insert the threaded barrel into the desired volume position.
- Reinstall the brass thrust bearing between the motor crank and the rod end.
- Reinstall the end bolt and tighten down just past hand tight.



- Connect the extension tubing from the hose fitting on the front of the pump, to the lung fitting on the torso.

- Note: connecting the pump establishes the equilibrium point. The lungs in the torso have a static resting position. Connecting the tubing when the piston is at its maximum displacement will make lungs inflate on from static. Connecting the tubing when the piston is at the minimum placement will make the lungs deflate from static.
- Connect the power cord to a sufficient electrical outlet.
- Turn on the pump via the toggle switch on the front of the speed controller.
  Set desired speed on speed controller (timing can be determined via observation).

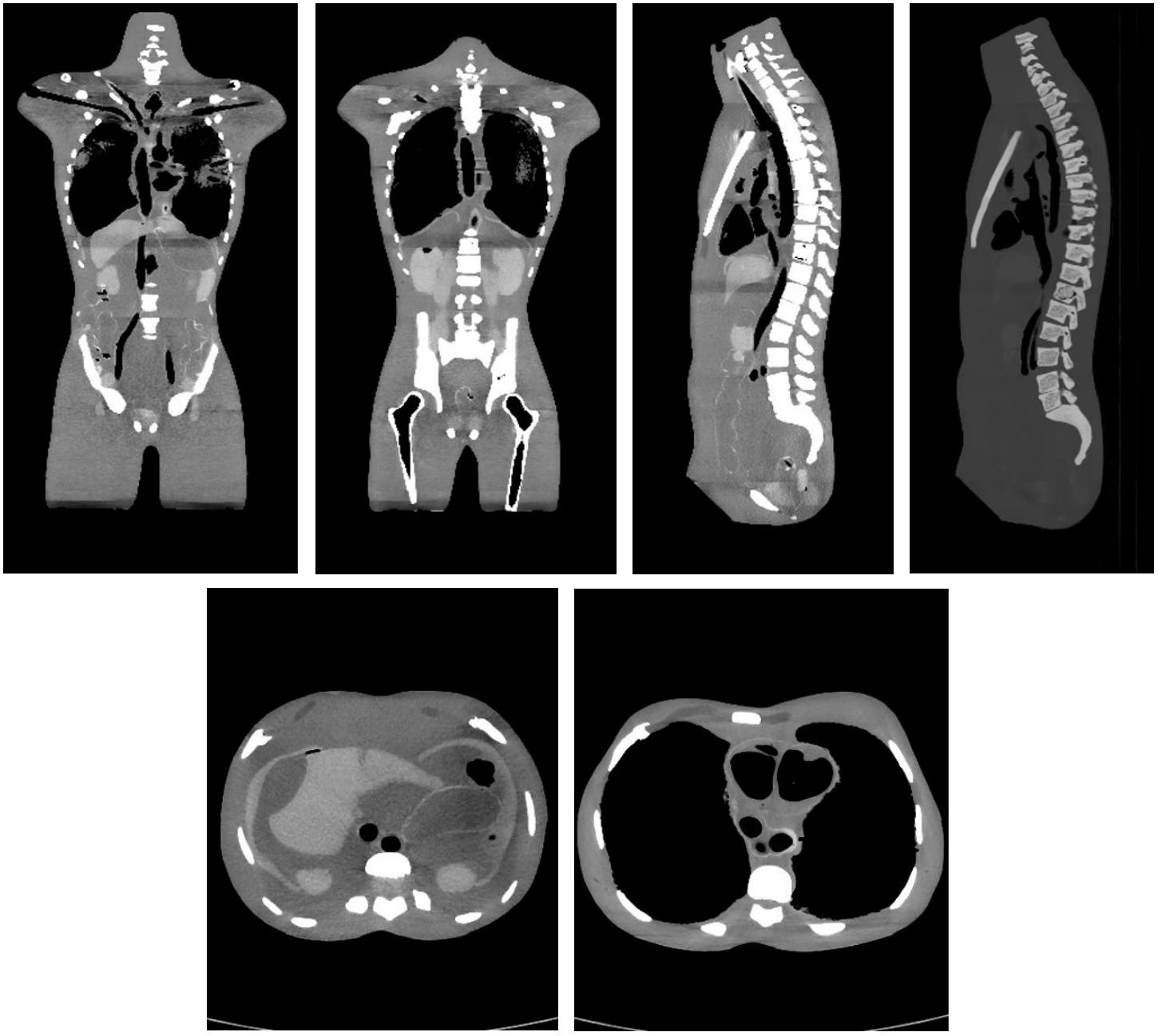
✓ Scanning the Phantom

- The phantom is fabricated based on the anatomy of a real human heart, and it can be scanned in supine, prone, and Fowler's positions; more importantly, scanning can be performed from multiple directions.
- For ultrasound applications, this phantom can be scanned either with or without the ultrasonic gel
- For MRI or X-Ray CT applications, the artificial heart can be filled with any common contrast agents.

✓ Filling the phantom with blood mimicking fluid or water

- The phantom can be filled with most types of blood-mimicking fluids using a big syringe or water pump. If there is a concern that a chosen blood mimicking fluid may cause damage to the phantom, it is recommended to do a small test on the side of the soft tissue material. The chosen liquid should be left on the phantom for at least a few hours. If there is no visible effect on the surface of the phantom, it is safe to assume that the phantom is resistant to the tested chemical, and hence it is safe to use it to fill out the entire heart.

CT Scans



*/ These scans were obtained from a customized ultrasound & X-RAY CT Torso that were captured by a CANON CT Scanner – One Aquilion (Model TSX-305A). If you have any questions related to these, please write us at *info@truephantom.com* /*

Technical Properties

Type of Tissue	Sound Velocity[m/s]	Density [g/cm^3]	Attenuation Measured at 2.25 MHz [dB/cm]	Hardness [Shore OO]	T2 [ms]	Speckles
Organs with Speckles (liver, kidneys, etc.)	1400 ± 10	0.99	1.0 ± 0.2	20	70	VARIABLE
Organs without Speckles (stomach, intestines, etc.)	1400 ± 10	0.99	1.0 ± 0.2	20	70	NO
Body Tissue	1400 ± 10	1.00	1.2 ± 0.2	30	65	NO/LOW
Tumor Feature	1400 ± 10	1.01	1.2 ± 0.2	30	65	YES
Cortical Bone	3000 ± 30	2.31	6.4 ± 0.3	N/A	N/A	N/A
Trabecular Bone	2800 ± 50	2.03	21 ± 2	N/A	N/A	N/A

Thermal Properties of Bone-Mimicking Tissue

Thermal Conductivity	Volumetric Specific Heat Capacity	Thermal Diffusivity	Thermal Resistivity	Specific Heat	Speed of Sound
0.776 W/ m K	1.040 MJ/ m^3 K	0.746 mm^2/ s	1.289 m K/ W	0.978 J/ g Deg Celsius	3070 m/s

HU Values of the Tissue Mimicking Materials

S.No.	Tissue Type	HU Value (average)
1	Body Tissue	-25
2	Trabecular Bone	800
3	Cortical Bone	1300
4	Aorta	40
5	Vena Cava	40
6	Trachea	80 (Tissue Part), -1000 (Air Filled Part)
7	Pancreas	110
8	Spleen	110

9	Kidneys	110
10	Bladder	35
11	Rectum Wall	100
12	Sigmoid Colon Wall	100
13	Heart	40
14	Liver	110
15	Gallbladder	35

Materials Used

- Soft tissue and organs: Composition of urethane-based soft resin
- Synthetic bones: Patented ceramic-reinforced epoxy-based composite material

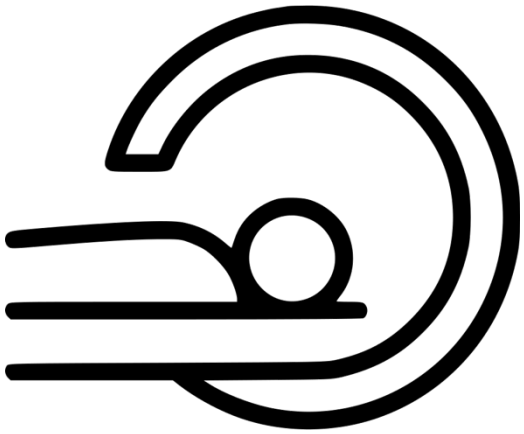
Size and Weight of the Phantom

- Phantom Size: 34 x 18 x 10 Inches, Weight: 88 Lbs (approx.)
- Heart Pump Size: 36 x 12 x 8 Inches, Weight: 88 Lbs (approx.)
- Lung Pump Size: 49 x 17 x 13 Inches, Weight: 62.5 Lbs (approx.)
- Shipment Size with Hard Carry Case: 47 x 26 x 18 Inches, Weight: 144 Lbs (approx.)
- Shipment Size of Heart Pump Package: 36 x 14 x 10 Inches, Weight: 90 Lbs (approx.)
- Shipment Size of Lung Pump Package: 36 x 14 x 10 Inches, Weight: 90 Lbs (approx.)
- Entire shipment will be placed on a wooden pallet.

Included In Order

- Adult Torso (Dynamic) Phantom
- TPS Heart Pump
- TPS Lung Pump
- User Manual/Assembly Instructions
- 2-Year Warranty & Unlimited Customer Service
- Hard Carry Case

Handling Instructions



- The phantom is fabricated based on the anatomy of the real human body. It can be scanned per the standard protocols used while positioning a real person.
- The phantom can be put on horizontal and vertical positions for scanning purposes.
- Anterior, Lateral, and Posterior techniques can also be performed.

Storage and Handling

- The phantom is made of urethane-based material and should be protected from direct exposure to any intense UV light.
- The experiments conducted on the phantom can be performed in a sunny lab, but leaving the phantom under direct sunlight for weeks or months is not recommended. If the phantom is not in use, we strongly recommend storing it in a dry and dark place or covering it with a plastic sheet/foil.

Cleaning

- The phantom is water-resistant and can be cleaned after use. It is ideal for cleaning it either with water or with soapy water.
- It is also quite resistant to chemicals, but if stronger solvents are meant to be used with the phantom, we recommend doing a small test on the bottom part of the neck or legs. The phantom should be placed on its belly, and the chosen solvent can be applied on a small, selected surface of the phantom for a few hours. If there is no visible effect on the phantom's surface, it is safe to assume that the phantom is resistant to the tested chemical, and it is safe to use it for the rest of the phantom. In other cases, avoid the solvent or contact us for alternatives.