

# Training & Test Lung Operation Manual



4717 Talon Court SE  
Grand Rapids, MI 49512 USA  
(800) 530-9939 or (616) 554-9696  
Fax: (616) 554-3067  
[mii@michiganinstruments.com](mailto:mii@michiganinstruments.com)  
[www.michiganinstruments.com](http://www.michiganinstruments.com)

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## Introduction

The Michigan Instruments' Training and Test Lung (TTL) is a dynamic lung simulator commonly used to evaluate and demonstrate mechanical ventilation and phenomena. Simulation of pulmonary pathologies and the evaluation of ventilators are also among the many uses of the device.

This manual provides the instructions to describe the mechanical function of the following lung models and provides the information necessary to utilize and maintain the instrument. The model number is represented by the first 3 letters in the prefix of the serial number (which can be found on the back panel).

Analog (non-instrumented) models are:

AIN – Adult/Infant Lung      DAN – Dual Adult Lung      SLN – Single Lung (Adult)

Instrumented (electronic interface installed using PneuView®3 software) models are:

AI3 – Adult/Infant Lung      DA3 – Dual Adult Lung      SL3 – Single Lung (Adult)

Instructions for the PneuView3 (PV3) software are covered in a separate document.

This is not a technical service manual and does not contain the documentation and directions required to fully service a TTL. Please contact Michigan Instruments directly if service or assistance is required. The Michigan Instruments' Service Department can be reached at (800) 530-9939 x343.

## Cautions

- **CAUTION** Operate all TTL units within their specified limits. Over-inflation of the bellows or excessive pressure within the system may cause damage to the bellows and gauges.
- **CAUTION** Damage can be done to a TTL during shipping if the unit is improperly packaged. Refer to the Maintenance and Service section for proper shipping instructions.
- **CAUTION** Do not sterilize the TTL. Some internal components are not compatible with sterilization techniques.
- **CAUTION** Do not adjust the compliance setting during use. Changing the compliance setting while ventilating the lung may cause damage to the unit.
- **CAUTION** Do not use a DC Power Supply with power ratings other than what is provided with the unit. Replacement power supplies are available from the manufacturer.
- **CAUTION** Connect the DC Power Supply directly to a standard mains power jack. Use an appropriate and properly approved adaptor or connecting cord from the power supply to the mains. Do not bypass or use any unapproved adaptor to connect to the mains.
- **CAUTION** Do not plug an O<sub>2</sub> Sensor into the O<sub>2</sub> Sensor port with power ratings other than what is provided with the unit. Replacement O<sub>2</sub> Sensor s are available from the manufacturer.

## Specifications

Tidal Volume Capacity:	2.0 L/lung 200 mL/lung	(Adult) (Infant)
Residual Lung Volume:	1.02 L/lung 70 mL/lung	(Adult) (Infant)
Lung Compliance:	.01 to .10 L/cmH <sub>2</sub> O Accuracy $\pm$ 3% (at calibration volumes) .001 to .010 L/cmH <sub>2</sub> O Accuracy $\pm$ 5% (at calibration volumes)	(Adult) (Infant)
Airway Resistance:	Rp5, Rp10, Rp20 or Rp50 cmH <sub>2</sub> O/sec Rp50, Rp100, Rp200 or Rp500 cmH <sub>2</sub> O/sec Accuracy $\pm$ 5% (at calibration flows)	(Adult) (Infant)
Unit Measurements: (in use ) (in case w/accessory case)	AIN/AI3 or DAN/DA3 Models (in ) (cm) (19 W x 24.5 L x 13.8 H) (48.3 W x 62.2 L x 35 H) (21 W x 28.5 L x 12 H) (53.3 W x 72.4 L x 30.5 H) SLN/SL3 Models (in ) (cm) (9.8 W x 24.5 L x 13.8 H) (24.9 W x 62.2 L x 35 H) (12.5 W x 28.5 L x 12 H) (31.8 W x 72.4 L x 30.5 H)	
Unit Weight (lb / (kg)):	Model (unit only) (in optional case w/accessories)	
	AIN 32 / (14.5) 40.1 / (18.19)	
	AI3 33 / (15) 42.1 / (19.1)	
	DAN 35.5 / (16.1) 43.6 / (19.8)	
	DA3 36.5 / (16.6) 45.6 / (20.7)	
	SLN 17.8 / (8.1) 24.7 / (11.2)	
	SL3 18.5 / (8.4) 26.4 / (12)	
Environmental:		
Temperature:	Operating: 32 to 104° (F) 0 to 40° (C) Storage: -4 to 167° (F) -20 to 75° (C)	
Humidity:	20 to 90%	
(AI3/DA3/PV3 only) Power Requirements:	12V DC 15W 1.25A (100 to 240V AC power supply included )	
Data Transfer:	USB 2.0	
O <sub>2</sub> Sensor Port:	8.0 to 12.0 mV	

## Description

The TTL is a unique, versatile instrument that provides simulation of the structures and mechanics of the human pulmonary system. Through the use of elastomer lung compartments, it accurately reflects typical adult and infant residual lung capacity. A simple but comprehensive set of controls provide the user with the ability to adjust the airway resistance and lung compliance of the TTL with ease. These adjustments allow for the simulation of both healthy and diseased lungs.

### The TTL in Action

When in use, the TTL allows for accurate simulation of the pulmonary system. Gas is inserted into the bellows of the TTL through a simulated airway by means of a ventilator, resuscitation bag, etc. This causes the vertical expansion of the lungs, and a corresponding rise of the top plate. Gauges on the front of the unit provide measurement of intra-lung pressures in the system as well as the airway pressure. The TTL can be further adjusted by means of the compliance spring(s) located on the side(s) of the device.

The compliance springs are easily set by means of the compliance scale marked on the top plate. The TTL has been designed to ensure that the compliance values are accurate. The resistance of the simulated pulmonary system is adjusted by means of a fixed-orifice flow restrictor. These are interchangeable in the simulated airway.

These features of adjustable compliance and resistance allow the TTL to accurately represent the function of both healthy and diseased lungs in ventilation procedures and simulations. The device can also be used to simulate a spontaneously breathing patient. The Oxygen sensor port on the top plate of the lung and auxiliary pressure port adjacent to the pressure gauge provide for the tie-in of related monitoring equipment.

### The TTL As Compared to Typical Patients

The TTL is designed to realistically simulate the mechanics of the pulmonary system from the upper airway through the lungs. It offers simulation capabilities and versatility and is useful for a wide variety of applications. Variable lung compliance and airway resistance allow for simulation of both healthy and diseased pulmonary conditions. Pulmonary disease is often associated with a change in lung compliance and/or airway resistance. The table below offers some typical values for healthy adult lungs. Refer to the Pathophysiology Simulation Settings section for a description of how the TTL can be used to replicate the characteristics of a diseased lung.

Compliance	0.05 to 0.10	L/cmH <sub>2</sub> O
Resistance	0.5 to 5.0	cmH <sub>2</sub> O/L/sec
Respiratory Rate	10 to 20	bpm
Tidal Volume	3 to 5	mL/kg of body weight
I:E Ratio	1 to 2	

### **The TTL As Compared to Ventilator Testing Standards**

To evaluate the performance of any mechanical ventilation device, a quantitative test lung which dynamically simulates human physiology should be utilized. Testing should take place on every ventilator before it is used in the clinical setting, and periodic testing is needed to ensure that the unit is performing in accordance with established standards as well as the manufacturer's specifications. The TTL is an ideal device for any such evaluation. Standards published by the American National Standards Institute (ANSI), the International Organization of Standardization (ISO), and the American Society for Testing and Materials (ASTM) outline minimum performance standards for such ventilators. The TTL meets or exceeds the requirements set for testing in these standards.

Standards References:

ANSI Z79.7, ISO 80601-2-12, ISO 80601-2-13, ASTM F 1100-90

## Components and Features

### The Airway

Ventilators attached to the TTL for either testing or training purposes insert air into the lung through the airway. The airway is constructed by using various connectors, adaptors and a PneuFlo® Airway Resistor included in your accessory kit (refer to the Setup and Operation section, and also the Illustrated Airway Setups section for instructions on assembling an airway). Tapered fittings on the accessories prevent leakage during use. Airway resistance in the TTL exhibits parabolic characteristics in regards to pressure change as a function of flow. This nonlinear, parabolic characteristic is similar to that seen in standard endotracheal tubes. The airway may be attached to either lung (or both in the case of a dual adult (DA) model) of the TTL depending on the ventilation scenario. An airway is used in either a dual lung or single lung simulation. Additional hoses are included in the accessory kit (DA only) to construct an airway connecting both lungs. In an Adult/Infant dual lung, either lung is used independently and not connected together.

### The Volume Scale

The volume scale allows the user to observe the approximate tidal volume of each simulated lung while the unit is in use. To ensure an accurate measurement, the sliding volume indicator on the top plate should be set according to the selected compliance. When the unit is in use, the volume scale should be in its' upright and locked position. When not in use it should be flipped down to prevent damage to the unit.

### The Compliance Scale

The compliance of each lung is independently adjusted by the position of the compliance spring. To ensure that compliance is set accurately, position the compliance spring perpendicular to the top plate during use.

### Pressure Gauges

The front plate of the TTL contains pressure gauges that will display both proximal and intra lung pressure during use. These gauges are labeled accordingly.

### Oxygen Sensor Ports

An Oxygen sensor port located on the top of each lung allows for the analysis of Oxygen (or any gas content) during ventilation. These ports may also be used to drain the device of fluids after ventilation with humidified gasses.

### Auxiliary Pressure Ports

Auxiliary pressure ports, located next to each pressure gauge, allow for monitoring pressure with third party devices. These ports are equipped with a check valve and will remain closed unless they are fitted with a miniature quick connector (included in the accessory kit).



## **PneuFlo® Resistors**

Included with the TTL are several PneuFlo resistors that allow the simulation of different airway resistances. These can be used to specify upper airway resistance in both single lung and dual lung simulations and lower airway resistance in dual lung simulations.

## **Pressure Pickoff Adaptors**

Pressure pickoff adaptors (single and dual port) are included with the TTL. These can be placed at strategic locations in the airway during setup to allow for the monitoring of pressure (by means of the proximal pressure gauge or a similar device).

## **The Lungs (Bellows)**

The TTL simulates the human pulmonary system through the use of elastomer bellows, constrained by aluminum rings to ensure that filling of the lung(s) results in a vertical rise of the top plate(s). The bellows retains a gas volume typical of a functional residual capacity for a single lung at rest. The bellows are designed to withstand normal environmental conditions and inflation to at least 120 cmH<sub>2</sub>O.

## **Lung Coupling Clip (used on the Dual Adult Only)**

The lung coupling clip is used in spontaneous breathing lung simulation. Attaching it to the TTL allows one lung chamber (typically the left) to act as a driving chamber for the other lung during testing. (NOTE: If desired, the lung coupling clip may be used on the Adult/Infant but ONLY attached to the adult lung to act as a driving chamber for the infant lung. Damage to the lung coupling clip and/or top plate may occur if used incorrectly.)

## **Y-Adaptor (Dual Adult Only)**

This adaptor, in conjunction with the hoses provided, is used to split the airway during dual lung simulation. It is not used during single lung simulation.

## **Miniature Quick Connectors**

Miniature quick connectors are included. These may be attached to the auxiliary pressure port of the TTL during ventilation to open the check valve and allow for additional ventilation analysis.

## Instructions for Lifting and Carrying

**CAUTION:** DO NOT use the rail(s) on the lower side(s) of the lung when lifting or carrying the lung. Their alignment to the top plate is critical to maintaining the proper calibration of the lung.

When lifting or carrying the TTL, observe the following:

Always use both hands and grasp opposing sides (or front/back) when lifting and carrying the TTL.

When lifting the TTL, first apply pressure using the palms of the hands against the side surfaces then tilt the TTL and rotate the palms to position the fingers under the base to support it.

Before setting down the TTL, always check that the surface is level and has sufficient support and area to allow all four rubber feet on the bottom to be in contact with the surface.

When setting down the TTL, always set one side (or front/back) on the surface to support the TTL while rotating the palms to clear the fingers from under the base before gently setting it down.

Removing the TTL from the optional storage case:

1. Place the unit on a level surface with the zipper on the top flap oriented upwards.
2. Loosen the Velcro enclosure on the handle to release the two handle straps.
3. Open the zipper and lay the top flap to the side.
4. Remove the accessory case and any supplied documentation and set to the side.
5. If provided, use the lift strap to pull the TTL upwards to get a hand under the front and release the lift strap. Otherwise, reach into the sides of the case, with both hands, approximately 6-8" from the front. Press the palms of the hands against the sides and pull upwards to rotate the palms to position the fingers under the base then bring the front of the unit out of the case enough to get a hand under it. While holding the side of the unit with one hand, bring the other hand under the front then release the grasp on the side.
6. Grasp in the center by placing the fingers under the base and palm against the front. With the free hand, place it to the center back of the unit and with both hands slide the unit forward slightly in order to be able to grasp the back of the unit. Apply pressure with the palm against the back plate to lift the back upwards in order to rotate the palm and place the fingers under the base.
7. Lift the unit clear of the storage case and set it on a level surface.

Placing the TTL into the optional storage case:

1. Place all accessories into the accessory case, zip close and place to the side.
2. Set the storage case next to the unit and unzip the top flap and lay it to the side. Orient the case to the TTL so that the side with the 2 cut-out slots is on the right.
3. Using the slots in the case as a guide, move the compliance spring(s) to align with the centers of the slots and secure the compliance springs.
4. If not already down, place the volume scale plate(s) in their lowered, latched position.
5. If provided, position the lift strap down the center of the case with the loop end hanging outside of the case. Lift and place the TTL into the storage case by holding it at approximately a 30° angle with the front down. Lower the TTL into the case placing the front near the lower foam block in the bottom of the case.
6. Gently push the TTL forward so the front is against the lower foam block.
7. Gently lower the back into the storage case.
8. Ensure the volume scale plate(s) are lowered and locked in position.
9. If provided, tuck the lift strap between the fabric and foam support wall at the front of the case to store it.
9. Place the accessory pouch on top of the TTL in the space provided (align between foam blocks on top flap). Close the top flap and zipper on the case.
10. Gather the two handle straps together and secure with the Velcro enclosure.

## Setup and Operation

### To Begin Setup

1. Place the TTL on a level working surface.
2. Raise the volume scale plate(s) to the upright and locked position.
3. All parts needed to construct the airway are located within the TTL accessory case.

### Single-Adult Lung or Infant-Lung Airway Setup

(See pages 25 & 26 for illustrations)

1. Select one PneuFlo resistor to simulate total airway resistance and connect it to the 15mm airway adaptor.
2. Connect the other end of the 15mm airway adaptor to the lung inlet port.
3. Attach a single-outlet pressure pickoff adaptor to the proximal end of the PneuFlo resistor, and using the 1/8" hose, connect this adaptor to the proximal pressure input port.

### Dual-Lung Airway Setup

(See page 27 for illustration)

1. Select one PneuFlo resistor to simulate upper airway resistance and two resistors to simulate lower airway resistance according to the test that you wish to perform.
2. Connect the selected upper airway resistor to the Y-adaptor.
3. Connect one end of each hose assembly to the Y-adaptor and the other ends to the selected lower airway resistors.
4. Attach a single-outlet pressure pickoff adaptor to the proximal end of the upper airway resistor, and using the 1/8" hose, connect this adaptor to the proximal pressure input port.
5. Attach a 15mm airway adaptor to each lung inlet port.
6. Connect the free end of the lower airway resistors to the 15mm airway adaptors.

### To Set Lung Compliance

1. Loosen the knob on the compliance spring.
2. Grasp the compliance spring and slide the mechanism until the pointer is positioned over the desired setting.
3. Ensure that the spring hangs perpendicular to the lung top plate.
4. Lock in place by tightening the knob.

### To Measure Oxygen Concentration

1. Remove the oxygen port cover.
2. Place an appropriate oxygen sensor into the port.
3. Connect the oxygen sensor to the desired test instrument. (In the case of a PneuView equipped unit, the O<sub>2</sub> jack on the back plate can be used).

## Spontaneous Breath Simulation

A Dual Adult TTL can be set up for spontaneous breath simulation. See the following instructions for the appropriate assembly of spontaneous breath simulation.

1. Set up the TTL for single-lung ventilation (described above). *The right lung will serve as the spontaneously breathing lung.*
2. Set an appropriate compliance (right lung) and resistance (right lung) for the conditions to be simulated.
3. Attach the Lung Coupling Clip to the top plate of the left lung. A dimple is provided on the left lung to align the knob to. The extension on the lung coupling clip is positioned under the right lung top plate. The left lung will be the “driving chamber” which will serve as the musculature of the spontaneously breathing (right) lung.
4. Attach a hose assembly to the inlet port of the driving chamber. Set the compliance spring of the driving chamber to 0.03.
5. Ventilate the driving chamber with the appropriate rate, volume, waveform, etc. for spontaneous breathing.

As the driving chamber fills, the Lung Coupling Clip will lift the top plate of the spontaneous breathing lung. This will create a negative pressure in that lung during inspiration and allow passive exhalation, as seen in normal spontaneous breathing.

***NOTE: A resistor is not used in the airway of the driving chamber as the altered flow rate produced can interfere with the natural rise and fall of the top plate of the spontaneous breathing lung.***

***NOTE: It is recommended that a Michigan Instruments Breath Simulation Module (BSM) be used during spontaneous breath simulation. Additional information on the BSM as well as brochures and product quotes are available on our website. If a BSM is used, refer to the BSM manual for specific setup instructions for the device.***

***NOTE: The spontaneous breathing setup is used in several applications including the evaluation of spontaneous breathing ventilator modes and work of breathing studies.***

### Care for the TTL After Ventilation With Humidified Gasses

The airway and lung(s) of the TTL are constructed of noncorrosive materials. Typical humidification agents such as sterile water and normal saline solution will not damage the instrument. Excess moisture should be drained after use with humidified gasses. Any accumulated fluid can be drained through the oxygen sensor port located on the top plate by carefully inverting the unit with the sensor port caps removed. After the fluids are drained, replace the sensor port caps and ventilate the TTL with dry gas until no condensation remains.

## Applications

The TTL is an ideal instrument for a variety of applications including:

- Performance Testing of Ventilators and Associated Instruments
- Classroom Instruction on Mechanical Ventilation Equipment, Techniques, and Phenomena
- Pulmonary Research
- Product Demonstrations and Evaluations
- Product Development and Quality Control

It is beyond the scope of this manual to offer examples of all of the applications for this system, as new ones are continually being discovered and developed by TTL users. The following are a few of the most common tests for which the TTL is ideally suited. While these simple evaluations are by no means the only useful functions that the TTL provides, they are the basis on which the instrument was designed and provide an excellent starting point for any user.

### Equipment Testing

The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) states that “All equipment shall be calibrated and operated according to the manufacturer's specifications, and shall be periodically inspected and maintained according to an established schedule as part of the hospital's preventive maintenance program.”

The TTL is designed to allow performance testing of ventilators intended for use on human patients.

*Use Case:* Following a routine test protocol to create a table for documentation of test results.

#### *Procedure:*

1. Set up the TTL for single lung ventilation.
2. Attach the patient connection of the ventilator's breathing circuit to the proximal airway of the TTL.
3. Set the ventilator in accordance with your test protocol.
4. Record the observed pressure, volume, FIO<sub>2</sub>, timing and flow measurements.
5. Repeat steps 1-4 for as many tests as necessary.
6. Record the results of each test, comparing the ventilator settings to the measured values.

## Classroom Instruction

The TTL can be of great assistance in the classroom. The adjustable lung compliance and airway resistance allows the instructor (or student) to demonstrate or investigate a wide variety of ventilation phenomena. The relationships between pressure, volume, and flow are more easily understood when displayed using the TTL. There are few things more valuable in an academic environment than hands-on and visual experience. The TTL offers a look into the inner workings of the human pulmonary system that students would not otherwise have.

**Use Case:** Pulmonary Simulation (using a Single Adult or Infant lung)

**Procedure:**

1. Set up the TTL for ventilation.
2. Set lung compliance to 0.05 (Adult) .005 (Infant) L/cmH<sub>2</sub>O.
3. Set total airway resistance to Rp5 (Adult) Rp50 (Infant).
4. Using a ventilator or resuscitation bag, ventilate the TTL at a rate of 12 bpm and tidal volume of approximately 0.80 L (Adult) 80 mL (Infant).
5. Note the tidal volume delivered to the lung.
6. Note the pressure generated in the lung and simulated airway.
7. Change the compliance of the lung to 0.03 (Adult) .003 (Infant), then 0.02 (Adult) .002 (Infant), and finally 0.01 (Adult) .001 (Infant), and note the differing lung volume and pressure with each change.

**Use Case:** Decreasing Lung Compliance with Worsening Disease Process

**Procedure:**

1. Set up the Dual Adult TTL for ventilation.
2. Set each lung compliance to 0.05 L/cmH<sub>2</sub>O.
3. Set total airway resistance to Rp5.
4. Using a ventilator or resuscitation bag, ventilate the TTL at a rate of 12 bpm and tidal volume of approximately 0.80 L.
5. Note the tidal volume delivered to each lung.
6. Note the pressure generated in the lungs and simulated airway.
7. Change the compliance of the right lung to 0.03, then 0.02, and finally 0.01, and note the differing lung volumes and pressures with each change.

**Use Case:** Demonstration of Inadvertent (Auto) PEEP

**Procedure:**

1. Set up the Dual Adult TTL for a dual lung ventilation.
2. Place Rp5 resistors in the right and left lower airways and an Rp20 resistor at the proximal airway (comparable to the resistance of a #6.0 endotracheal tube).
3. Set the compliance at 0.04 L/cmH<sub>2</sub>O on both the right and left lung.
4. Ventilate the TTL at a rate of 26 bpm and a tidal volume of 1.0 L with a baseline (PEEP) of zero.
5. Note the inadvertent PEEP in both proximal airway and right lung pressures caused by the increased airway resistance. Also note the difference in the baseline pressure of the proximal airway and right lung.

**Other Common Applications**

- Performing in-hospital ventilator training sessions
- Troubleshooting ventilator malfunctions
- Checking ventilator systems for leaks
- Performing routine ventilator performance testing
- Testing the fail-safe features of a mechanical ventilator
- Demonstrating the changes in functional residual capacity caused by PEEP and CPAP
- Demonstrating the difference in cycling and limiting mechanisms in mechanical ventilators
- Demonstrating the difference between airway pressure and intra-lung pressures
- Evaluating new mechanical ventilators and ventilation monitoring equipment
- Identifying optimal ventilator settings for particular patients and conditions
- Performing work of breathing studies
- Evaluating the performance of high and low flow oxygen delivery systems
- And many more

## Maintenance and Service

TTLs are designed to provide years of trouble-free service. Every unit is calibrated and thoroughly checked before leaving the factory. The compliance springs operate within only a small fraction of their potential range and exhibit no significant change in their performance characteristics after years of use. Likewise, the PneuFlo resistors and all accessories are designed for consistent, repeatable, long-term performance.

With the exception of the replacement of lost parts and accessories, the unit is not intended to be serviced by the customer. If problems develop which cannot be easily corrected please contact the Michigan Instruments' Service Department at (800) 530-9939 x343. Michigan Instruments recommends that all units be returned to the factory every two years for recalibration and any necessary upgrades.

### Limits of Tolerance and Accuracy

Manufacturing and cost considerations mandate the use of practical tolerances on parts and components of any product, including the TTL. Major factors affecting final accuracy are compliance spring stiffness, bellows area and stiffness, scale calibration accuracy, resistor variations in inside diameter, interior wall geometry and smoothness. In the TTL, it is believed by both Michigan Instruments and its' customers that a practical balance has been achieved between cost and performance, and that the standard accuracy tolerances are quite adequate. However, the repeatability of any one unit is considerably better than the overall accuracy limits that have been specified. This permits the special calibration of individual units, and the development of "correction curves" for a particular unit, extending the accuracy of a particular TTL well beyond the standard manufacturing tolerance spread. This special calibration can be accomplished by an individual user, or special factory calibration can be ordered. The specific differences between the individual lungs, however, may result in small but discernible "tracking" differences during dynamic motion. This is likely to be most evident during exhalation at high compliance settings.

### Calibration

The accuracy of TTL volume measurements is dependent upon the proper operation of the unit (as described in this manual) and the accuracy of the compliance settings on each lung. To check the calibration of the compliance settings, use the following equipment and procedures:

Necessary Equipment: a Calibrated 1 L syringe (or another calibrated volume injector), an independent, calibrated pressure gauge, and a small flat-head screwdriver.

***NOTE: Diaphragm gauges like those used in the TTL are known to stick occasionally. Tap the gauge gently before making adjustments to ensure that this is not the case.***



## Checking Calibration: Adult Lung

1. Assemble the airway for ventilation of the lung using a dual outlet pressure pickoff adaptor instead of the standard single outlet adaptor.
2. Attach the second port of the pressure pickoff adaptor to an independent pressure gauge.
3. With the airway open to the air, ensure that the lung, airway, and independent pressure gauges are reading zero. If any of the gauges on the TTL must be zeroed, remove the plug in the gauge crystal and turn the adjusting screw until the needle of the gauge is set to zero.
4. Using the calibrated syringe, make injections of 1.0L at the compliance settings specified in the table below. The intrapulmonary (intra-lung) and proximal pressure should be within the specified limits below.

Compliance	Pressure Limits
0.10	9.7 to 10.3
0.05	19.4 to 20.6
0.01	97.0 to 103.0

## Checking Calibration: Infant Lung

1. Assemble the airway for ventilation of the infant lung using a dual outlet pressure pickoff adaptor instead of the single outlet adaptor.
2. Attach the second port of the pressure pickoff adaptor to an independent pressure gauge.
3. With the airway open to the air, ensure that the lung, airway, and independent pressure gauges are reading zero. If any of the gauges on the TTL must be zeroed, remove the plug in the gauge crystal and turn the adjusting screw until the needle of the gauge is set to zero.
4. Using a calibrated syringe, make injections of 100mL. The intrapulmonary (intra-lung) and proximal pressure should be within the specified limits listed in the table below.

Compliance Setting	Pressure Limits
0.010	9.7 to 10.3
0.005	19.4 to 20.6
0.001	97.0 to 103.0

If you find that your TTL is not properly calibrated, contact Michigan Instruments' Service Department at (800) 530-9939 x343

***NOTE: The adult lung is calibrated with 1.0L volume injections and the infant lung with 100mL injections. When using volumes other than these, the TTL may exhibit a compliance which differs from the set value due to the compressible volume in the lung.***

### **TTL Leak Test**

1. Assemble the airway for ventilation of the lung in question. Make sure all connections are secure.
2. Set the compliance spring at the 0.02 (Adult) or 0.002 (Infant) position.
3. Inject 1.0L (Adult) or 100mL (Infant) of air into the lung through the airway and note both the lung and airway pressure.
4. Hold the volume in the lung for 30 seconds and, again, read the pressure gauges. The gauges should not have dropped more than 1.0 cmH<sub>2</sub>O in 30 seconds.

If a leak exists in your system that cannot be easily fixed by tightening the airway connections, contact Michigan Instruments' Service Department at (800) 530-9939 x343

### **Warranty Agreement**

Your TTL is warranted by Michigan Instruments, Grand Rapids, Michigan to be free of defects in material and workmanship for a period of two (2) years from the date of its receipt by the end purchaser, excluding the diaphragm gauges contained therein. All repairs necessitated by malfunction of this equipment during the warranty period, when in normal use in accordance with instructions provided, will be accomplished at the Michigan Instruments factory or authorized service facility, without charge to the user other than the cost of transportation to the factory or authorized service facility. Michigan Instruments undertakes NO LIABILITY HEREUNDER FOR SPECIAL OR CONSEQUENTIAL DAMAGES, or any other expense or liability beyond the furnishing of materials and labor for the repairs covered hereby. The warranty does not cover marks and blemishes, scratches or denting which may result from normal use of this equipment, or malfunctions due to mishandling or damaging accidents. This warranty may be VOID unless the equipment to be repaired is returned in the original factory carton and protective foam plastic form. If unavailable, the protective carton and foam plastic form may be obtained from the manufacturer. If warranty registration is not performed by the purchaser, the warranty period will begin the date that the instrument was shipped from the factory.

This warranty is in lieu of all other warranties expressed or implied, and shall be void as to any products which have been repaired or altered by others, or have been subject to misuse or abuse. The buyer agrees that this written warranty constitutes the entire agreement as to warranties between the parties. Any prior or contemporaneous oral statements which have not been written into this agreement are not binding and this contract shall not be rescinded or modified except by a signed document.

## Factory Service Policy

This device is manufactured to very demanding quality standards. It is designed to provide years of trouble-free service if proper care is taken in its' operation. This instrument should be used and maintained as outlined in this manual. To maintain peak performance, factory service and recalibration is recommended every two years.

## What to do if Your TTL Requires Service

1. If you feel that factory service may be required, contact us to obtain an RMA number. You may also arrange for service on our website. Have the serial number of your device available, along with a description of the problem. Requests for repairs, parts, and any service related questions should be directed to the service department.
2. If your TTL must be returned to Michigan Instruments, please observe the following procedures: Use the original shipping carton and packing material. It is designed to provide maximum protection to the TTL during shipping. If the original carton is unavailable, additional cartons may be purchased from Michigan Instruments. A description of the problem(s), name and phone number of a contact person, packing slip, and returned components should be included with the unit in need of service. Ship it prepaid & insured to:

Michigan Instruments  
4717 Talon Court SE  
Grand Rapids, MI 49512  
Attn: Service Department  
RMA: XXXXX

3. Upon receipt, the unit will be evaluated and a repair estimate prepared for approval. Michigan Instruments will contact you with a repair estimate and wait for approval and/or a purchase order before repairs begin. Repairs are normally completed within two weeks of the date of approval.
4. All units returned to Michigan Instruments must be evaluated and require an evaluation fee plus any shipping charges if repairs are not authorized. This fee will not be charged to units being repaired under warranty.
5. All repairs, parts, and labor are warranted for one year. These warranties are subject to the limitations and conditions of the original warranty, and apply only to those components actually repaired, rebuilt, or replaced.
6. Terms for repair service:  
All repairs not covered by warranty are FOB Grand Rapids, MI. Warranty repairs are shipped to the customer at no charge.

***NOTE: DO NOT USE THE TTL CASE AS A SHIPPING CONTAINER. It is not designed to withstand the rough handling that may occur during shipping.***

## **Storage and Shipping**

The optional storage case for the TTL is intended to be used for storage or to hold the TTL during transportation of the instrument. The case IS NOT intended to be used solely as a shipping container. Additional protection is required when shipping the unit to protect it from damage. If the TTL must be returned to the factory for any reason, please ship it using the original shipping carton. Replacement shipping cartons are available from Michigan Instruments. Refer to the Factory Service Policy for detailed servicing instructions.

## **Securing the TTL for Transport**

1. Disassemble the airway and return all accessories to the accessory kit.
2. Remove the Lung Coupling Clip, if attached, and lower the volume scale(s).
3. Place the TTL in the storage case (if provided) following the steps described in the Instructions for Lifting and Carrying section.
4. Open the original shipping container and remove the top portion of the foam nest.
5. Place the unit on the bottom portion of the foam nest and make sure that it is seated and level.
6. Place top portion of the foam nest on the unit ensuring that the insert is flush with the carton top.
7. Close the lid.
8. Apply packaging tape to the top, bottom, and both upper side seams of the carton.

## **Shipping the TTL without using the original shipping carton**

1. Perform steps 1 through 3 in the Securing the TTL for Transport section (above).
2. Wrap in a plastic bag prior to placing the TTL in the shipping container.
3. Allow a minimum of 2" clearance on all sides for packaging material.
4. Place 2" of packing material in a sturdy corrugated carton (200 lb burst rated).
5. Center the TTL on the packing material and fill in the sides and top with packing material.
6. Apply packaging tape to top, bottom, and both side seams of the shipping carton.

## Parts and Accessories

Part Number	Description
15565	Optional Dual Lung Carry Case (DAN, AIN, DA3, AI3)
15575	Optional Single Lung Carry Case (SLN, SL3)
15525-01	Accessory Kit- Non-Instrumented (DAN*, AIN, SLN)
<i>Includes: Case, resistors, airway hoses, "Y" adaptor, resistor adaptors, lung coupling clip, pressure pickoff adaptors, and miniature quick connects.</i>	
15554	Accessory Case
13394-01	Pneuflo Resistor - Rp500 (AIN, AI3)
13394-02	Pneuflo Resistor - Rp200 (AIN, AI3)
13394-025	Pneuflo Resistor - Rp100 (AIN, AI3)
13394-03	Pneuflo Resistor - Rp50 (2/kit)
13394-04	Pneuflo Resistor - Rp20 (2/kit)
13394-045	Pneuflo Resistor - Rp10 (2/kit)
13394-05	Pneuflo Resistor - Rp5 (2/kit)
15490*	Airway Hose Assy (DAN, DA3) (2/kit)
10109-22	Hose (1/8 I.D. x 20")
11173*	"Y" Adaptor - 15mm I.D. (DAN, DA3)
15529	Adaptor - 15mm x 15mm I.D. (2/kit)
12423	Lung Coupling Clip
13197-01	Pressure Pickoff Adaptor (Single)
13197-02	Pressure Pickoff Adaptor (Double)
11254-02	Miniature Quick Connect (3/kit)
15525-02	Accessory Kit- Instrumented (DA3*, AI3, SL3)
<i>Includes all items in the Non-Instrumented case and adds: Power Transformer, Max-7 O2 Sensor, O2 sensor cable, USB cable, and software.</i>	
14739	Power Transformer – 12 Volt, 100-240 VAC
15538	Oxygen Sensor – MAX-7
15524	3.5MM Mono Cable 2ft (O2 sensor cable)
15548	USB Cable 6ft
15424	PneuView®3 Software

*\*For DAN or DA3 accessory kits, the parts listed above are included in the accessory kit provided with the TTL at time of original purchase. If ordering a replacement accessory kit for a DAN or DA3, provide the SN and include these parts on the order using the Part Number. (They are not provided in the AIN, AI3, SLN or SL3 accessory kits as they cannot be utilized).*

11523	Gauge Crystal
15521	Gauge

## Pathophysiology Simulation Settings

**Notice:** The following setups are suggestions, the physiology of healthy and diseased lungs vary from patient to patient depending on size, age, severity of disease, and many other factors. The user should not assume that the suggested settings accurately simulate any particular patient or condition.

### “Normal” or healthy lung characteristics

The following conditions are based on a “standard” human patient who might normally be expected to exhibit pulmonary characteristics as follows:

#### **Dual Adult Lung Simulation**

**Compliance:** *0.05 L/cmH<sub>2</sub>O in each lung (0.10 L/cmH<sub>2</sub>O total compliance)*

**Resistance:** *Upper airway: Rp5, Lower airway: None*

#### **Single Adult Lung Simulation**

**Compliance:** *0.05 L/cmH<sub>2</sub>O*

**Resistance:** *Rp5*

#### **Single Infant Lung Simulation**

**Compliance:** *0.005 L/cmH<sub>2</sub>O*

**Resistance:** *Rp20*

## Diseases affecting the Airway

### Examples: Chronic Obstructive Pulmonary Disease (COPD), Asthma and Infants with Stridor or Bronchospasm

Characterized by increased resistance to airflow, particularly in the lower airways. Depending on the severity and duration of the disease, pulmonary compliance may be slightly increased in these cases. Upper airway resistance may also be increased if the simulated patient is assumed to be intubated.

#### **Dual Adult Lung Simulation**

**Compliance:** *0.05 L/cmH<sub>2</sub>O in each lung (0.10 L/cmH<sub>2</sub>O total compliance)*

**Resistance:** *Upper airway: Rp10, Lower airway: Rp20 to each lung*

#### **Single Adult Lung Simulation**

**Compliance:** *0.08 L/cmH<sub>2</sub>O*

**Resistance:** *Rp20*

#### **Infant Lung Simulation**

**Compliance:** *0.005 L/cmH<sub>2</sub>O*

**Resistance:** *Rp50 or Rp100*

## Diseases affecting Lung Compliance

### Examples: Pulmonary Fibrosis, Pulmonary Edema and Pneumonia

Characterized by decreased pulmonary compliance (increased lung stiffness). Airway resistance is typically unaffected by the disease but may be increased in cases like pneumonia and edema when associated with increased pulmonary secretions, or if the simulation supposes the patient is intubated.

#### Dual Adult Lung Simulation

**Compliance:** *0.02 L/cmH<sub>2</sub>O in each lung (0.04 L/cmH<sub>2</sub>O total compliance)*

**Resistance:** *Upper airway: Rp5, Lower airway: Rp20 to each lung*

#### Single Adult Lung Simulation

**Compliance:** *0.02 L/cmH<sub>2</sub>O to 0.05 L/cmH<sub>2</sub>O*

**Resistance:** *Rp20*

## Acute Asthma Attack

Characterized by greatly increased airway resistance, with generally normal pulmonary compliance. Compliance will decrease, however, as the duration of the simulated attack increases.

#### Dual Adult Lung Simulation

**Compliance:** *0.05 L/cmH<sub>2</sub>O in each lung (0.10 L/cmH<sub>2</sub>O total compliance)*

**Resistance:** *Upper airway: Rp10, Lower airway: Rp50 to each lung*

#### Single Adult Lung Simulation

**Compliance:** *0.05 L/cmH<sub>2</sub>O*

**Resistance:** *Rp20 or Rp50*

## Collapsed Lung

Characterized by drastically reduced compliance in the affected lung(s), with normal airway resistance values. If the simulated cause of the collapse includes a blocked airway, use a higher resistance value for that portion of the airway (e.g., replace Rp20 with Rp50).

#### Dual Adult Lung Simulation

**Compliance:** *0.01 L/cmH<sub>2</sub>O in affected lung(s), (0.05 L/cmH<sub>2</sub>O in the normal lung)*

**Resistance:** *Upper airway: Rp5, Lower airway: Rp10 to each lung*

#### Single Adult Lung Simulation

**Compliance:** *0.03 L/cmH<sub>2</sub>O to 0.05 L/cmH<sub>2</sub>O*

**Resistance:** *Rp10*

## **Pneumothorax / Hemothorax**

Similar to the Collapsed Lung scenario, but decrease in pulmonary compliance may not be as marked.

### **Dual Adult Lung Simulation**

**Compliance:** *0.02 L/cmH<sub>2</sub>O in affected lung(s), (0.05 L/cmH<sub>2</sub>O in the normal lung)*

**Resistance:** *Upper airway: Rp5, Lower airway: Rp20 to each lung*

### **Single Adult Lung Simulation**

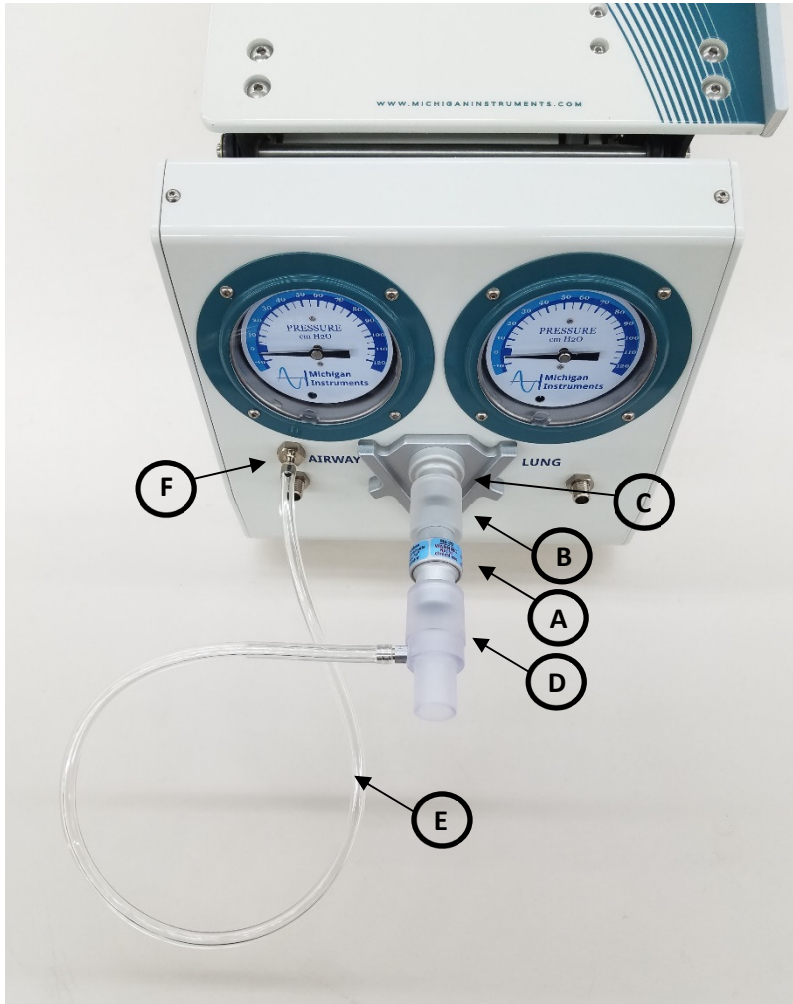
**Compliance:** *0.02 L/cmH<sub>2</sub>O to 0.05 L/cmH<sub>2</sub>O*

**Resistance:** *Rp10*



## Illustrated Airway Setups

### Single-Adult Lung Airway Setup



1. Select one PneuFlo resistor (A) to simulate total airway resistance and connect it to the 15mm airway adaptor (B).
2. Connect the other end of the 15mm airway adaptor to the lung inlet port (C).
3. Attach a single-outlet pressure pickoff adaptor (D) to the proximal end of the PneuFlo resistor, and using the 1/8" hose (E), connect this adaptor to the proximal pressure input port (F).

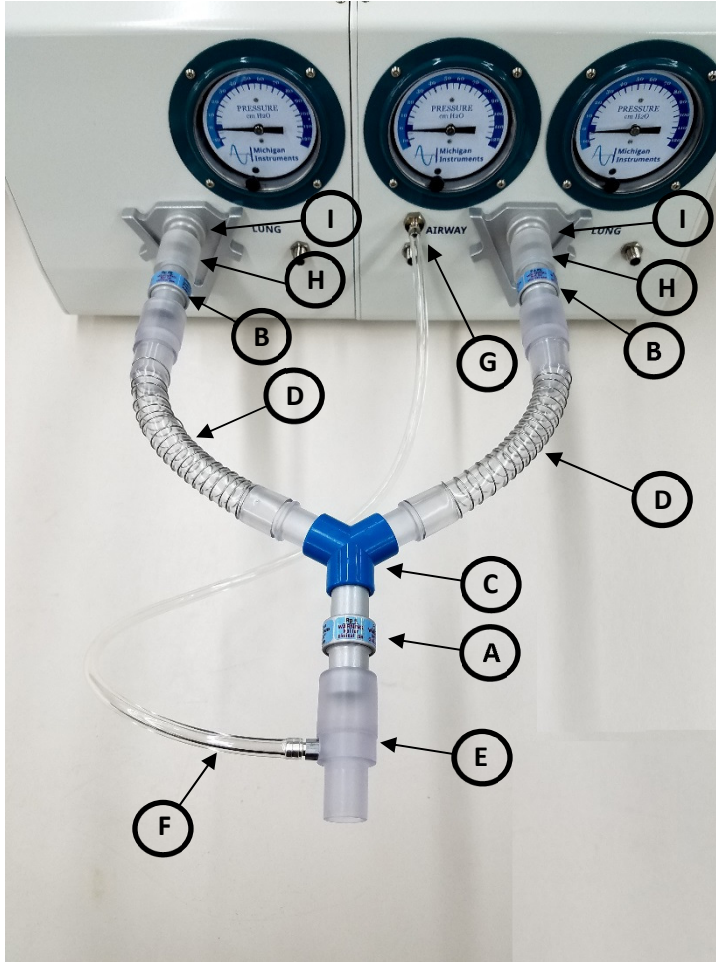
NOTE: The setup illustrated above can also be used on the adult side of an Adult/Infant model or the right lung on a dual adult lung. If using just a single lung on the dual adult model, it is advised to use the right lung. Only use the left lung on the dual lung setup when a dual lung setup is desired.

## Infant-Lung Airway Setup



1. Select one PneuFlo resistor (A) to simulate total airway resistance and connect it to the 15mm airway adaptor (B).
2. Connect the other end of the 15mm airway adaptor to the lung inlet port (C).
3. Attach a single-outlet pressure pickoff adaptor (D) to the proximal end of the PneuFlo resistor, and using the 1/8" hose (E), connect this adaptor to the proximal pressure input port (F).

## Dual-Adult Lung Setup



1. Select one PneuFlo resistor to simulate upper airway resistance (A) and two resistors to simulate lower airway resistance (B) according to the test that you wish to perform.
2. Connect the upper airway resistor to the Y-adaptor (C).
3. Connect one end of each hose assembly (D) to the Y-adaptor and the other ends to the lower airway resistors.
4. Attach a single-outlet pressure pickoff adaptor (E) to the proximal end of the upper airway resistor, and using the 1/8" hose (F), connect to the proximal pressure input port (G).
5. Attach a 15mm airway adaptor (H) to each lung inlet port (I).
6. Connect the free end of the lower airway resistors to the 15mm airway adaptors.

NOTE: Only the Dual Adult lung models are designed to use both lungs at the same time. Do not use the setup illustrated above on an Adult/Infant model.