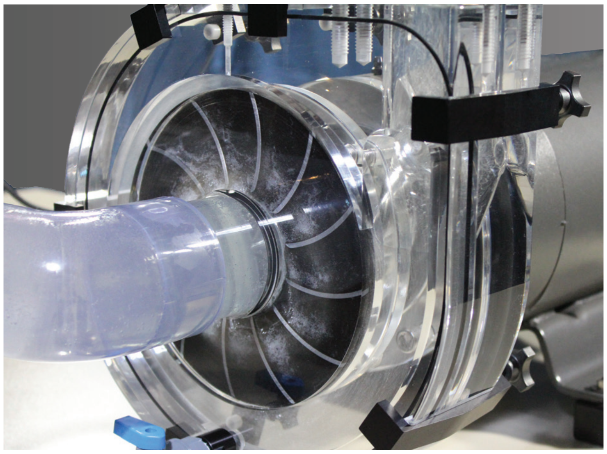
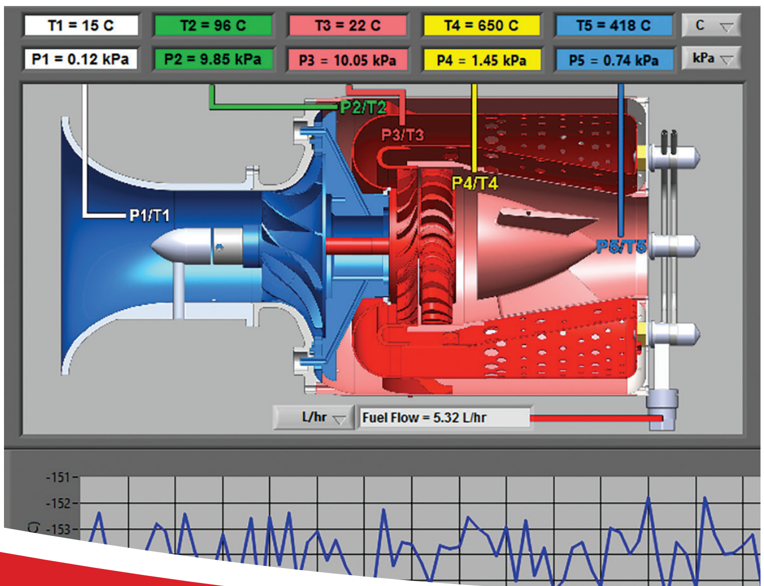
Educational Laboratory Equipment





Turbine Technologies, LTD.

2015 Product Catalog

Wind Turbine Power System

*Wind*Lab™

Warranty 2 Year Warranty

Product Summary

- Programmable, Variable Speed Wind Source
- Adjustable Pitch Hub Accepts Custom Blades for Comparative Testing
- Three-Phase Electrical Generator with Adjustable Rotor Core Excitation
- Individual Phase Adjustable Resistive Loading
- National Instruments™ Data Acquisition System Configured With LabVIEW™
- Shipped Ready to Operate

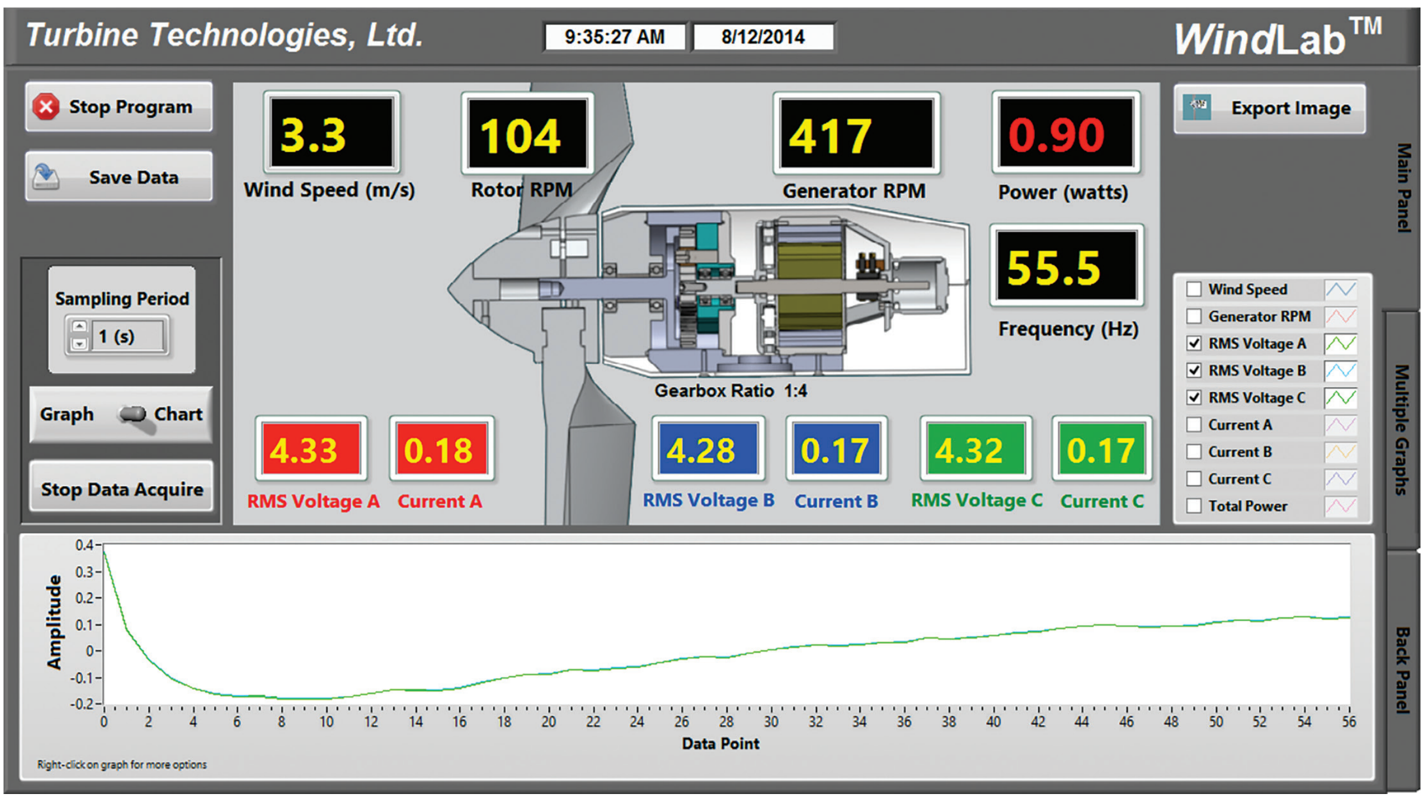
Wind Turbine Power System

Students will learn: Fundamentals of wind turbine operation and three phase electrical power generation.

Description

The system features a programmable wind fan and wind tunnel enclosure. The wind is ducted through a straightener vane to remove fan induced air rotation, providing a real-world wind flow pattern. The one meter diameter wind turbine features a three blade configuration with manual pitch adjustment. Blades can be easily changed for comparative testing.

A USB connected National Instruments™ data acquisition system is fully integrated and pre-calibrated. Sensors measure system parameters for a LabVIEW™ virtual instrument on the provided laptop computer. This system displays real time data and has interactive operator control. Run data can be recorded for playback or follow-on analysis. The data acquisition software is user configurable and all source code is open.



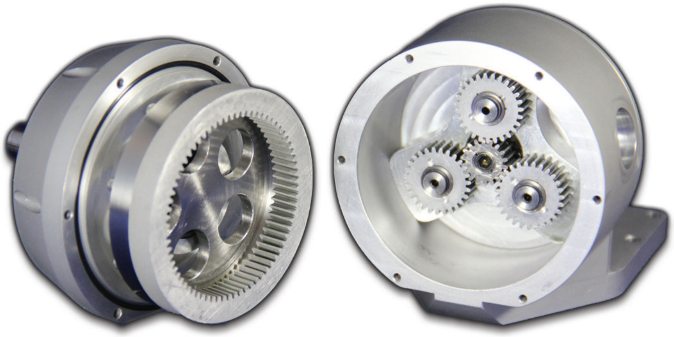
Data Acquisition System Included

WindLab™

2 Year Warranty

The turbine rotor shaft drives a precision machined alloy planetary gear box, which multiplies turbine rotor shaft RPM by 4. The three phase generator features an adjustable range, DC excited, eight pole rotor and an eight pole, three phase stator. The generator gondola nacelle features a built in “cutaway” section to allow the generator to be viewed during operation. Three rheostats can be collectively set with even resistance values to provide balanced load across all phases, or unevenly set to demonstrate uneven loading characteristics on an electrical generation system.

All components are mounted on a portable chassis allowing the entire system to be conveniently moved for use and storage. Visible metal surfaces are stainless steel or anodized aluminum. The steel chassis is powder coated for durability. A comprehensive Operator’s Manual details all aspects of system operation. Summary operating checklists allow rapid mastery of system operation. Safety instructions address all operating conditions.



Details

Dimensions
- WindLab™: 67L x 45W x 76H inches
  - (170L x 114W x 193H cm)
- As Shipped: 70L x 48W x 79H inches
  - (178L x 122W x 201H cm)

Weight
- WindLab™: 712 lbs (323 kg)
- As Shipped: 792 lbs (359 kg)

Operating Conditions / Limitations
- Wind Fan: Limited to 8.2 Amp Electrical Current Draw
  - (fuse protected)
- Generator: 7.5 Volts, 0.25 Amp, 3.25 Watts
  - (Limited for Safety)

Operating Requirements
- Typical Laboratory or Classroom Setting Power:
  - 208V single-phase 50/60Hz fused at 15 amp

Instrumentation
- Data Acquisition System:
  - National Instruments™ Hardware
  - Windows ® Laptop Computer
    - (all Software Loaded and Pre-calibrated)
  - Single Cable USB to PC Connection
  - Custom Virtual Instrument Display
    - (Configurable Data Output)
- Installed Data Acquisition Sensors / Channels:
  - Wind Speed
  - Wind Turbine Rotor RPM
  - Generator RPM
  - Generator Frequency
  - Generator Voltage for Each Phase
  - Current Draw for Each Phase
  - Total Power Output
- Control Panel Mounted Displays/Controls:
  - Wind Speed
  - Turbine RPM
  - Voltage (3 total, one for each phase)
  - Current (3 total, one for each phase)
  - Load Rheostats (3 total, one for each phase)

Wind Turbine Power System

Experimental Opportunities

WindLab™ enables students and researchers to readily conduct in-depth experimentation and analysis of wind turbine electric power generation.

Aeronautical and **structural engineering students** will learn the principles of airfoil design. They can also design alternate airfoil rotor blades for comparison testing.

Control engineering students will gain valuable knowledge with the programmable wind fan that can be operated manually or programmed to automate specific wind profiles. User programmed wind scenarios can demonstrate/determine wind turbine power generation performance. The programmable wind speed capabilities can even be used to run actual wind data profiles from full-scale wind turbine sites to help determine site potential.

Electrical engineering students will especially appreciate the purpose-built three-phase electric generator on WindLab™. With adjustable resistive loading on each phase, and adjustable rotor core excitation, users can experiment with the affects of unbalanced loading at various generation speeds, while experiencing the hands-on operation of a true three-phase electric power generation system.

Mechanical engineering students will gain knowledge and experience with the on-board rotor to generator speed amplification gear box.

The integrated data acquisition system records and displays data in real time for enhanced experimentation and analysis of all aspects of the WindLab™ System.

The design of WindLab™ allows for a multitude of educational and research possibilities including;

- Basic understanding of wind turbine power generation system operation
- Aerodynamic performance studies of wind turbine blade airfoils
- Gearbox design and operation analysis
- Three phase electrical generator operation and analysis
- Electrical power production in steady state wind conditions
- Unsteady wind/gusting conditions affect on power production
- Balanced/unbalanced loading affects on wind turbine performance
- Programmable wind profiles for performance studies
- Frequency control considerations
- Experimental and data acquisition technique
- Discussion topic: Considerations for stand-alone energy storage systems
- Discussion topic: Considerations for power grid integration
- Discussion topic: Considerations for wind farm coordination
- Discussion topic: Considerations for wind turbine maintenance
- Discussion topic: Power factor for an inductive load

Custom Blades Available

Airfoil built with rapid prototype technology

RankineCycler™

Warranty 2 Year Warranty

Steam Turbine Power System

Product Summary

- ASME Certified Power Boiler and Piping
- National Instruments™ Data Acquisition System Configured with LabVIEW™
- Modern Steam Turbine Design
- Complete Thermodynamic Teaching Solution
- Shipped Ready to Operate

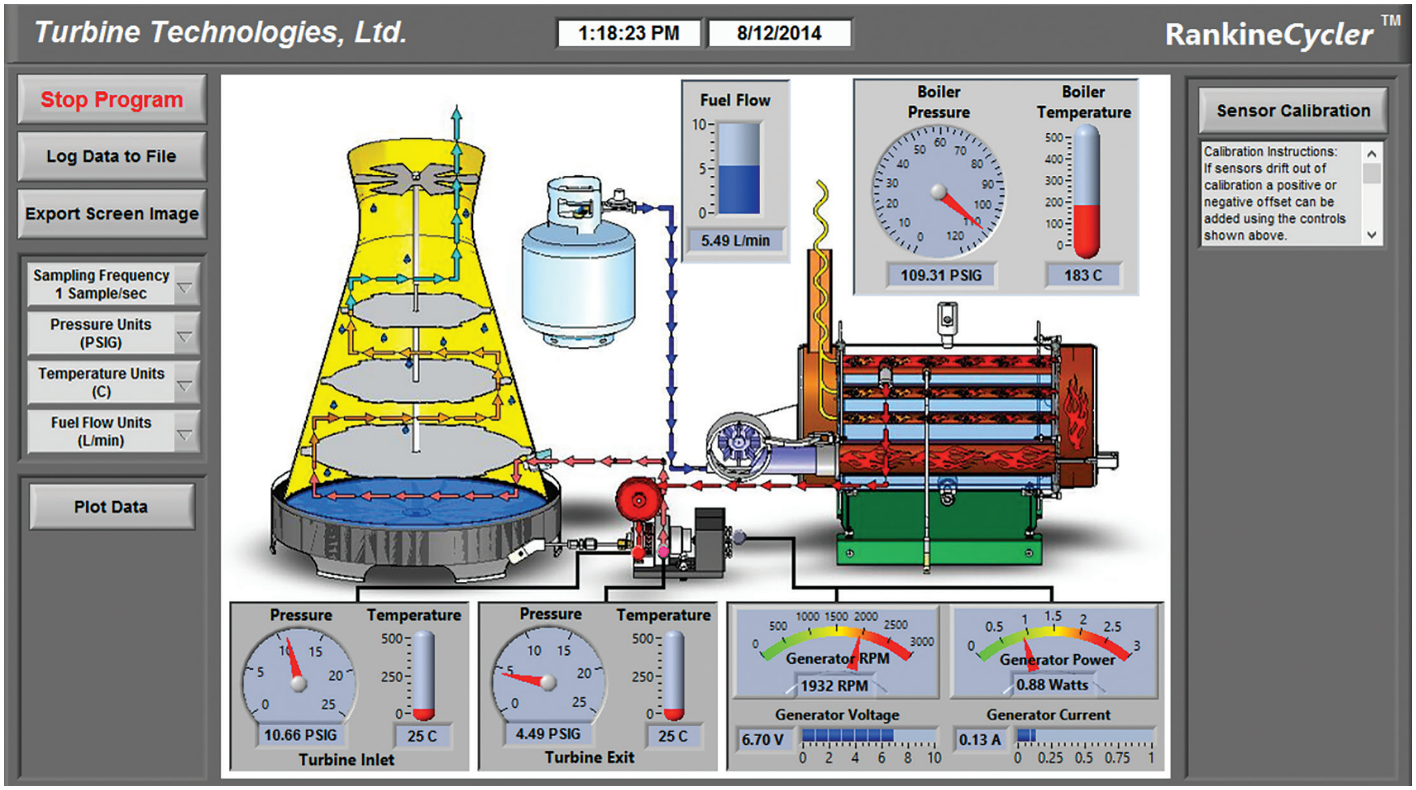
Students will learn: Fundamentals of steam turbine power generation and become familiar with the associated thermodynamic principles and efficiencies of the Rankine power cycle.

Description

The tube-type boiler is certified as a Section 1 Power Boiler ("S" Stamp) by the American Society of Mechanical Engineers (**ASME**). The boiler is also registered as a certified power boiler with the National Board of Boiler and Pressure Vessel Inspectors (NB). It features multiple safety devices for burner operation and system pressure, including:

- automatic over-pressure relief valve
- automatic low-water level cut-off sensor
- manual system blow-down valve

All components are mounted on a portable chassis allowing the entire system to be conveniently moved for use and storage. Visible metal surfaces are stainless steel or anodized aluminum. The steel chassis is powder coated for durability. A USB connected National Instruments™ data acquisition system is fully integrated and pre-calibrated. Sensors measure system parameters for a LabVIEW™ virtual instrument on the provided laptop computer. This system displays real time data and has interactive operator control. Data can be recorded for playback or analysis. Data acquisition software is user configurable and all source code is open. A sealed sight glass indicates boiler water level. A steam powered axial flow turbine drives a generator producing alternating current and rectified direct current at the output. The steam exhausts into a condenser tower where it returns to its original liquid state. A graduated beaker and boiler fill-drain system is provided for easy volume measurement. A comprehensive Operator's Manual details all aspects of system operation.



Data Acquisition System Included

RankineCycler™

2 Year Warranty

Details

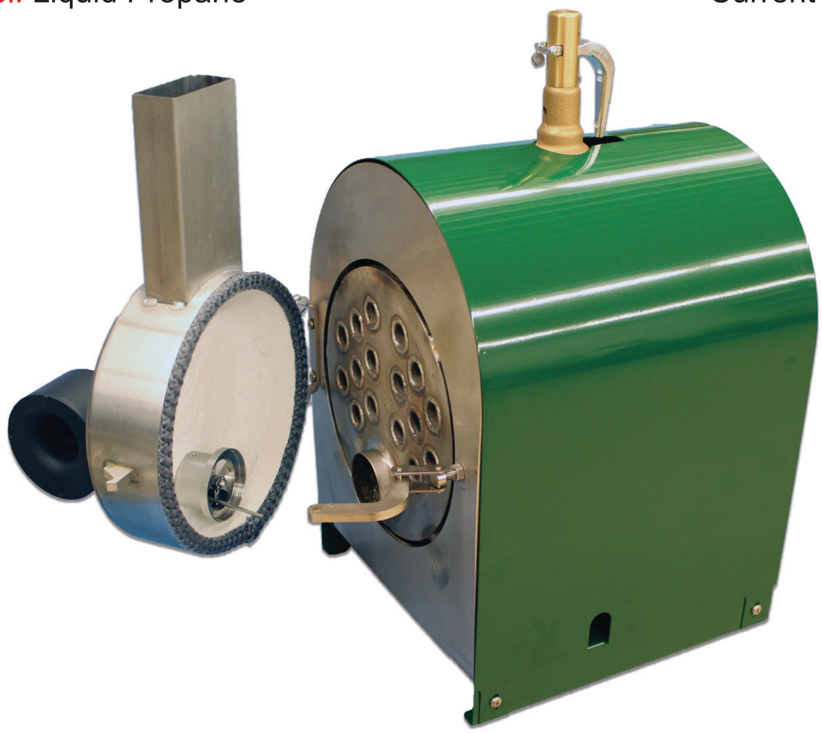
Dimensions
RankineCycler™: 58L x 30W 48H inches
(148L x 77W x 122H cm)
As Shipped: 64L x 34H x 55H inches
(163L x 86W x 140H cm)

Weight
RankineCycler™: 300 lbs (136 kg)
As Shipped: 369 lbs (168 kg)

Operating Conditions / Limitations
Boiler:
Pressure 120 psi (827 kPa)
Temperature 482 F (250 C)
Generator:
15.0 Volts, 1.0 Amp
Total Load of 15.0 Watts

Operating Requirements
Power: 120V single-phase 50/60Hz
(220V upon request)
Fuel: Liquid Propane

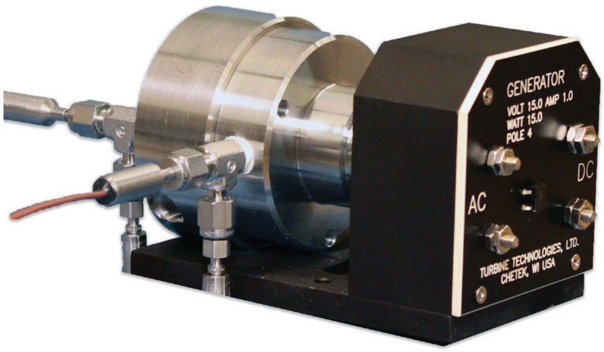
Instrumentation
Data Acquisition System:
National Instruments™ Hardware
20 Analog IN - 16 Digital IN/OUT
4 Frequency/Pulse IN Channels
Windows ® Laptop Computer
(all Software Loaded and Pre-calibrated)
Single Cable USB to PC Connection
Custom Virtual Instrument Display
(Configurable Data Output)
Installed Data Acquisition Sensors and Channels:
Boiler Temperature and Pressure
Turbine Inlet Temperature and Pressure
Turbine Exit Temperature and Pressure
Turbine RPM
Fuel Flow
Generator Voltage Output & Current Draw
Analog Data:
Boiler Pressure
Generator Voltage
Current Draw



ASME Certified Dual Pass Flame Tube Boiler

Experimental Opportunities

Numerous experimental and research opportunities are available and readily conducted with the RankineCycler™ Steam Turbine Power System. Students can learn about basic electric power generation principles. Students can also focus on learning the idealized Rankine Power Cycle and steam-water phase changes. RankineCycler™ can be used to plot many different sets of data. The sensors on the RankineCycler™ system allow students to plot:

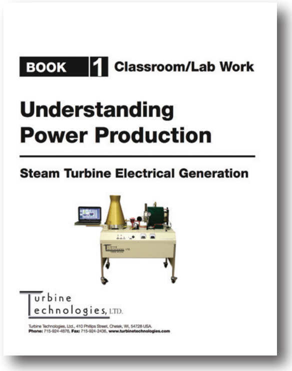


Axial Flow Steam Turbine & AC/DC Generator

- Fuel Flow vs. Time
- Boiler Temperature vs. Time
- Boiler Pressure vs. Time
- Turbine Inlet/Outlet Pressure vs. Time
- Turbine Inlet/Outlet Temperature vs. Time
- Generator DC Amps Output vs. Time
- Generator DC Voltage Output vs. Time
- Turbine RPM vs. Time

The design of RankineCycler™ allows for a multitude of educational and research possibilities including;

Full Curriculum Included



- Energy relationships and the First Law of Thermodynamics
- Cycle analysis and the Second Law of Thermodynamics
- Control volume analysis
- Entropy analysis
- Isentropic analysis and the study of turbine/nozzle efficiency
- Heat transfer analysis and the study of boiler efficiency
- Combustion processes
- Vapor power system fundamentals
- Electric power generation
- Experimental & data acquisition technique

PumpLab™

2 Year Warranty

Centrifugal Flow System

Product Summary

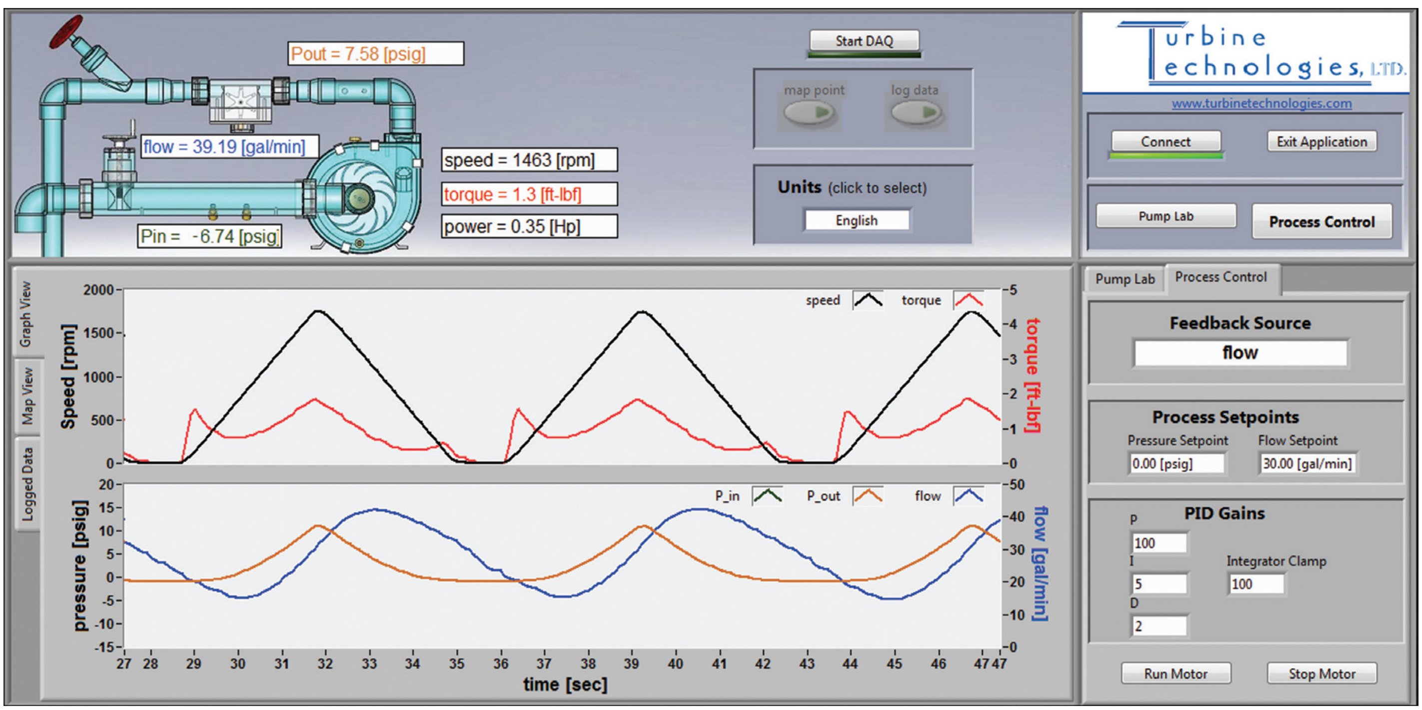
- Integrated Programmable Controller with Pressure and Flow Feedback Loops, PID Gain
- Selectable Operational Modes: Centrifugal Pumping or Process Control
- Fully Instrumented for Flow, Head, Power and Efficiency Analysis
- Integrated Digital Motor Controller Displays Pump RPM, Current and Torque Values
- LabVIEW™ Generated User Configurable Real Time Computer Data Display
- Shipped Ready to Operate

Students will learn: Aspects of incompressible fluid flow, see cavitation, and gain hands-on experience with P.I.D control.

Description

Featuring the industry's only clear view pump housing and fluid circuit; the pump housing, inlet, outlet, diffusion volute, impeller, shaft seals and drive coupling are all visible during system operation. Straight, forward, and backward curved impellers are provided and can be interchanged easily with the provided impeller puller. Pump rotation is controlled through variable frequency drive (VFD). The variable-speed feature allows experimentation into high efficiency electronic fluid flow rate control. Concepts of power management, energy conservation and cost savings in the context of pumps and pumping systems can be examined.

All components are mounted on a portable chassis allowing the entire system to be conveniently moved for use and storage. Visible metal surfaces are stainless steel or anodized aluminum. The steel chassis is powder coated for durability. System piping is high-strength PVC or acrylic. The water supply tank is integral to the unit and completely corrosion proof. Pump impellers and the provided support tools are securely stored and displayed in the integrated front cabinet. A keyed master switch is standard and provides secure control of system usage. A pump prime switch is used to conveniently operate the built in pump priming system.



Data Acquisition System Included

PumpLab™

2 Year Warranty

A USB connected digital data acquisition system is fully integrated and pre-calibrated. Sensors measure system parameters and are displayed through LabView™ generated virtual instrument panel on the provided computer. It also provides controls for system operation from the computer screen and changing from PumpLab Flow to Process Control Modes. Data can be recorded for playback or analysis. Data acquisition software is user configurable without programming. A comprehensive Operator's Manual details all aspects of system operation.

Centrifugal Flow System

Details

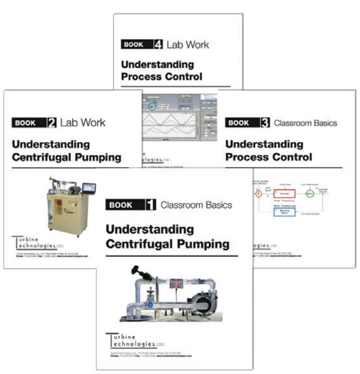
Dimensions
- PumpLab™: 48L x 29W x 74H inches
  - (122L x 74W x 188H cm)
- As Shipped: 55L x 36W x 79H inches
  - (140L x 91W x 201H cm)

Weight
- PumpLab™: 455 lbs (206 kg)
- As Shipped: 620 lbs (281 kg)

Operating Conditions / Limitations
- Main Pump and Supply Tank:
  - Maximum Flow Rate: 40 GPM (151 lpm)
  - Maximum Head: 40 ft (12 mtrs)
  - Tank Capacity: 20 Gallons (76 ltrs)
- Main Pump Motor:
  - Maximum RPM: 1725
  - Shaft Power: 3.0 HP (2.2 kW)
  - Current: 8.2 Amps
  - Frame Style: JM
- Auxiliary Prime / Drain Pump:
  - Maximum Flow Rate: 5 GPM (19 lpm)

Operating Requirements
- Typical Laboratory or Classroom Setting Power:
  - 208V single-phase 50/60Hz fused at 15 amp

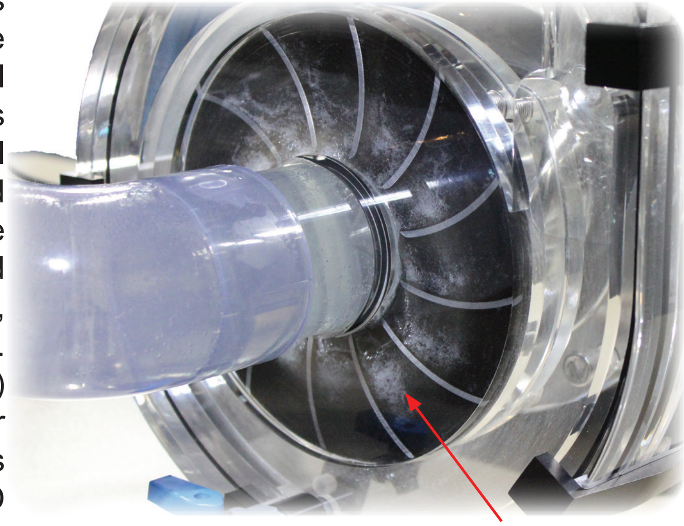
Four Part Curriculum Included



Instrumentation
- Digital: High Speed Data Acquisition System
  - Data Acquisition Software with Configurable Data Output
  - Windows ® Laptop Computer
  - Single Cable USB Connection
  - Sensors (Preinstalled and Calibrated)
    - Pump Inlet Pressure
    - Pump Exit Pressure
    - Flow Rate
    - Pump Torque
    - Pump RPM

Provided Operational Accessories
- Three Impellers
  - Straight Impeller ~ ß$_{IN}$ 90° - ß$_{OUT}$ 90°
  - Forward-Curved Impeller ~ ß$_{IN}$ 90° - ß$_{OUT}$ 115°
  - Backward-Curved Impeller ~ ß$_{IN}$ 60° - ß$_{OUT}$ 20°
    - (with splitter vanes)
  - Impeller Diameter:
    - Outer 6.500” (16.51 cm)
    - Inner 2.225” (5.65 cm)
  - Impeller Blade Height:
    - Outer 0.135” (0.34 cm)
    - Inner 0.312” (0.79 cm)
- Stroboscope ~ adjustable from 0 to 3000 fps
- Impeller Change Tool
- Prime/ Drain T-Handle
- Motor Control Keypad

Experimental Opportunities



Impeller with Visible Cavitation

Numerous experimental and research opportunities are available and readily conducted with the PumpLab™ Centrifugal Flow/Process Control System. The installed pressure and flow sensors allow basic experimentation relating to typical secondary physics and undergraduate fluid dynamics courses. Immediate access to the three common pump impeller types permits detailed analysis and experimental verification of energy, momentum and fluid machinery type problems. With the advanced variable frequency drive (VFD) system, concepts concerning efficiency and power conservation are easily explored, including process control via pressure or flow feedback loops and PID gain application. Visual vaporization bubbles help in the understanding and correlation of cavitation phenomena. Standard courses in engineering thermodynamics and fluid mechanics benefit from textbook direct examples conducted and measured in real time. Available class work and lab work curriculum enhance these capabilities. The limitations of theoretical models and the variability of experimental technique can be experienced first-hand. In addition to academics, the PumpLab™ is ideally suited for general pump and flow system familiarization as well as advanced practical studies for the technical and vocational student.

Illustrative examples of typical pump performance computations and exercises

With measured values of pump inlet and outlet pressure, flow rate, flow areas, impeller geometry, motor torque, RPM, current draw and power, determine:

- Turbo-machinery Analysis - angular momentum, Euler Turbo-machine equation, velocity polygon analysis and idealized centrifugal pump performance prediction
- Pump Characteristics - actual head, power required and efficiency at various flow rates / pump speeds
- Dimensional Analysis and Specific Speeds - determination of coefficients for pump selection, modeling and scaling problems
- Similarity and Affinity Analysis - design extrapolation and performance prediction from measured data
- Cavitation Analysis - quantifying various head values to predict, verify and measure parameters associated with the onset and propagation of cavitation phenomena
- Pump System Analysis - performance analysis at various simulated system heads for determination of pump and system operating points
- Energy Conservation - varying pump speed and system operating points to achieve cost savings
- Process Control Capabilities- utilizing pressure or flow feedback signals and PID gain response adjustments to automatically maintain process set points in the event of system disturbances or changing requirements.

TrueStructures™

2 Year Warranty

Airfoil Structures Lab

Product Summary

- Interchangeable Test Specimens Include Beam, Tube and Wing Section
- Infinitely Variable Point Loading System to Apply Bending and Torsional Moments
- Integrated Load Cell Provides Direct Indication of Actual Applied Load
- Strain Bridge Controller displays Strain Gauge Voltages and Applied Load
- Software Tool Converts Measured Voltages to Engineering Strains

Students will learn: **Practical and theoretical aspects of structural analysis. Test specimens include a strain gage equipped beam, tube, and an actual aircraft wing section.**

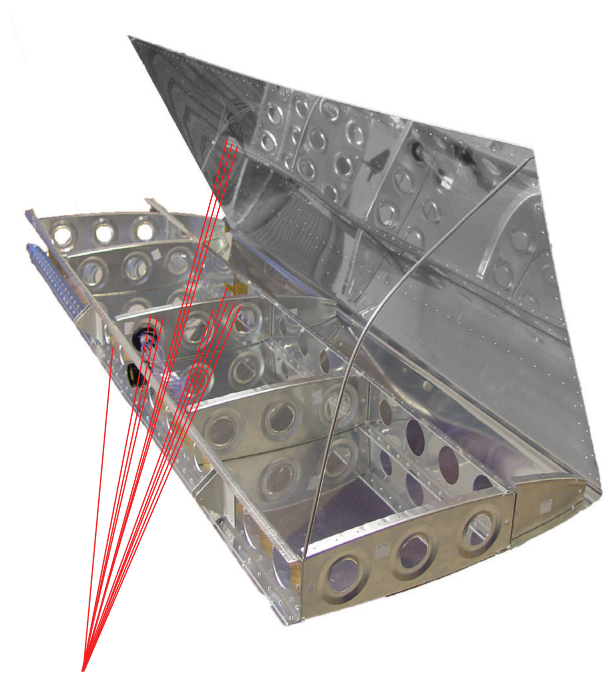
Description

TrueStructures is a complete structural analysis laboratory. Simple and complex bending, shear, and torsion are demonstrated utilizing a beam, a tube, or a complete aircraft airfoil structure. The TrueStructures Lab is ready for immediate usage upon un-crating. A powder coated main support frame is made from structural steel tubing and mounted on rolling castors for mobility. The entire lab is sized to fit through any standard interior door.

A multi-lesson laboratory procedure is provided to illustrate common usage of the TrueStructures lab. Solid models are also included to show the internal wing structure. The solid models, laboratory procedures and strain calculation program are included on CD-ROM. Industry standard linear and rosette foil strain gauges are strategically mounted on all test components to allow gathering of structural strain data under various loading conditions. The Strain Bridge Controller manages strain gauge excitation and digitally displays the selected strain voltage. Each individual strain gauge is switch-selectable. A separate digital meter displays the applied load at all times. System load and selectable strain gauge voltages are available as outputs from the Strain Bridge Controller for reading by external data acquisition or other measurement systems.

The TrueStructures Lab features an actual aircraft horizontal stabilizer. This lifting surface is typical of that found on civil and military aircraft where stressed skin construction is used. This "wing" structure is made up of an all aluminum outer skin, two span wise webbed main spars and a set of chord-wise main and nose ribs. The entire assembly is fastened together using riveted construction.

The wing's main spar is affixed in aerospace fashion to a root fitting similar to a wing-fuselage structural joint. A mechanical jackscrew mechanism applies an infinitely variable point load to the wing tip. The point load can be positioned to place the specimen in pure bending, pure torsion, or combination loading. A precision load cell is mounted at the loading point that allows a direct readout of the applied force. Multiple uni-axial and rosette strain gages are strategically mounted throughout the wing to measure the resulting strain values.



12 Strain Guages in Aircraft Horizontal Stabilizer

Airfoil Structures Lab

TrueStructures™

Details

Dimensions

TrueStructures™: 65L x 33W x 36H inches (165L x 83W x 91H cm)
As Shipped: 79L x 37W x 50H inches (200L x 94W x 127H cm)

Weight

TrueStructures™: 340 lbs (154 kg)
As Shipped: 480 lbs (218 kg)

Operating Requirements

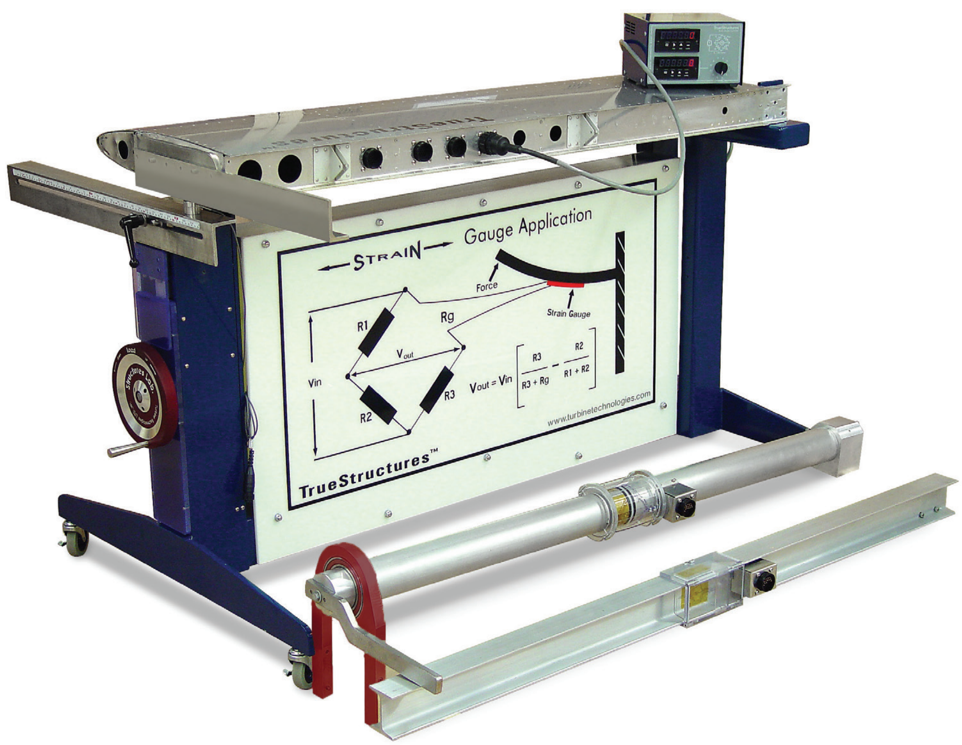
Power: 120V/220V Auto Switching Supply single-phase 50/60Hz

Instrumentation

Strain Bridge Controller:
- Wheatstone Bridge configuration
- 12-channel display of strain voltages
- 350 Ohm dummy gauges ≈ 2.09 Gauge Factor
- Self contained 15-volt strain gauge exita-tion

Applied Load Indication:
- 0-100 lbs Button Type Load Cell
- Digital display of applied load in lbs or kg

Analog Output
- Strain Gauge: 0-10V proportional to strain voltage, channel selectable
- Applied Load: 0-10V proportional to load cell output



TrueStructures™ and System Components

Numerous experimental and research opportunities are available and readily conducted with the TrueStructures™ Aerospace Structures Lab. Basic structural analysis can be studied with the readily interchangeable simple beam and tube structures. Unlimited opportunities exist with typical structures problems as well as the real world issues associated with experiment design, fundamental transducer concepts (strain gauges) and measurement noise. Provided lab projects include strain gauge fundamentals, applied loads, component section and material properties, principal and combined stresses, beam and torsional loading, shear flow and displacement.

Strain Bridge Controller

Airfoil Structures Lab

Experimental Opportunities

- Fundamental problems associated with statics and strength of materials.
- Basic structures concepts of bending, shear and torsion.
- Advanced problems with shear flow, combined loads and fittings.
- Material shapes, section properties and their effects on structural efficiency.
- Problems with loading, deflection and the stress & strain relationship.
- Usage of strain gauges and support equipment for experimental stress determination
- Aerospace, civil and mechanical structures analysis and testing.
- Design of experiments and data acquisition technique.

MiniLab™

2 Year Warranty

Product Summary

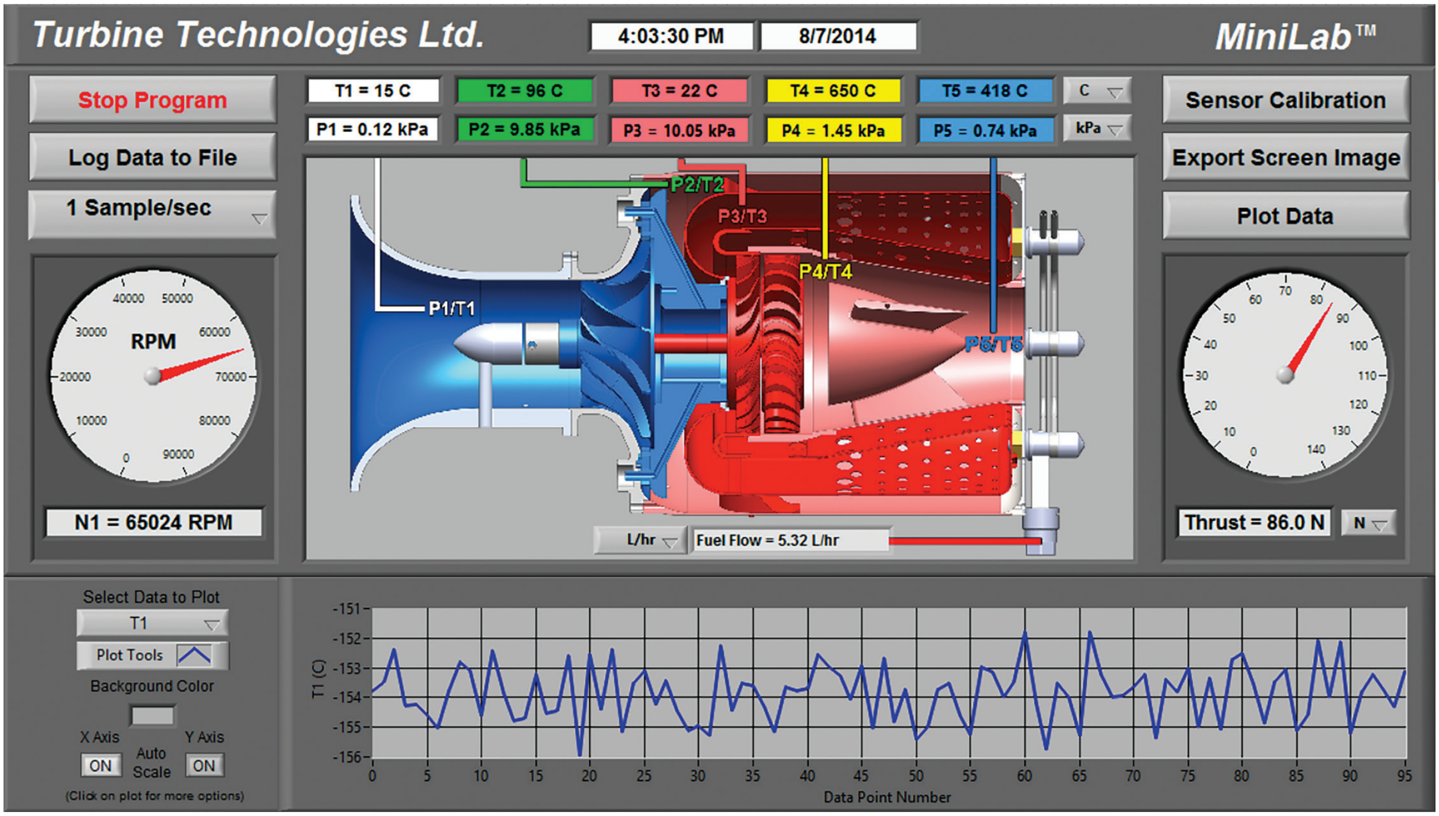
- Gas Turbine Engine Designed and Manufactured to Aerospace Standards
- Engine Operations Instrumented for Temperature and Pressure Measurement
- Gas Turbine Auto Start and Auto Shutdown System
- National Instruments™ Data Acquisition System Configured with LabVIEW™
- Includes Laboratory Procedures and Available Classroom and Lab Curriculum
- Shipped Ready to Operate

Students will learn: Fundamentals of jet engine propulsion and become familiar with the associated thermodynamic principles and efficiencies of the Brayton Cycle.

Description

A complete gas turbine power plant designed for engineering, technical and military education as well as advanced research and study. The core gas-generator is representative of all major gas turbine types and the Brayton and Gas Turbine cycles.

The SR-30™ Turbo-Jet engine is designed and manufactured by Turbine Technologies, LTD specifically for the MiniLab™ Gas Turbine Power System. The compact engine features a centrifugal flow compressor, reverse flow annular combustor and an axial flow turbine stage. Ambient air enters the engine through the bell shaped inlet. The air is then compressed, diffused and directed into the combustor can. Kerosene based fuel, introduced via six high-pressure atomization nozzles, is mixed with the compressed air and ignited. Heated combustion gas expands and accelerates through the vane guide ring causing the turbine to rotate. Useful work is extracted from this rotation as the turbine powers the compressor. The combustion gases are further accelerated through the thrust nozzle where the remaining heat energy is converted to kinetic energy in the form of jet thrust. The ejected gas returns to ambient atmospheric conditions thereby completing the thermodynamic cycle. For safety and performance reasons, no off-the-shelf, former military or surplus components are used in any portion of the engine. All components are manufactured in-house to exact specifications. Electronic controlled vacuum investment casting ensures void and impurity-free components. Individual component materials are selected based upon desired mechanical properties, durability and longevity.



Data Acquisition System Included

MiniLab™

Combustor components and the vane guide ring utilize Inconel® 718 alloy. The integral bladed disk turbine wheel is manufactured from CMR 247 Super Alloy. All material is verified to possess the desired properties specific to the application. The completed engine undergoes rigorous final operational testing and inspection.

The MiniLab™ cabinet is composed of a rigid steel chassis mounted on rolling castors for portability and ease of storage, requiring no permanent facility modifications or additions. The SR-30™ engine is securely mounted within the cabinet behind protective transparent polycarbonate shields allowing view of the engine during operation. All engine accessories including fuel and oil pumps are located in the lower portion of the cabinet. Safe and reliable air starting provides for consistent and easy engine operation without the need for additional electric starters, complicated couplings, heavy cabling, high amperage current or auxiliary batteries. All fuel atomization is accomplished within the fuel control unit and adjacent nozzles. No gaseous fuels of any type are required for starting. A wide range of kerosene based or diesel blended fuels may be used without the need for any fuel preheating or conditioning. All fuel, oil and starting air lines are aviation grade braided stainless steel.

SR30™ Inlet

All Engine Components Designed and Manufactured In-House

Industrial grade sensors measure all key engine station parameters as well as overall system variables for real time display on the provided computer. Direct engine thrust is accurately measured through a pivoting bearing arrangement utilizing a calibrated load cell, eliminating problems inherent to linear bearings with critical alignment requirements. A National Instruments™ USB connected digital data acquisition system is fully integrated and pre-calibrated. Data can be recorded for playback or analysis. The full range of sensors allows calculations of fuel flow, thrust and pressure ratio to be compared directly to measured values. A custom LabView™ generated Virtual Instrument panel displays all operating parameters in real time digital displays as well as graphically. Convenient on-screen settings buttons allow easy data display configurability.

Experimental Opportunities

Experimental and research opportunities include scientific, engineering, thermodynamic and environmental investigations. With a wide array of sensors, experiments relating to secondary education physics and chemistry through graduate level fuels and combustion research are readily performed. Standard courses in engineering thermodynamics and fluid mechanics benefit from textbook direct examples conducted and measured in real time. The limitations of theoretical models and the variability of experimental technique can be experienced first-hand. In addition to academics, the MiniLab™ is ideally suited for general gas turbine familiarization and jet engine operational training for aviation and military professionals; as well as alternative fuels, emissions and scaled engine testing and research.

Illustrative examples of Gas Turbine computations

With measured values of compressor inlet temperature and pressure, turbine inlet temperature and pressure, turbine exit temperature and pressure, fuel flow and inlet and exit areas, possible calculations include:

- Compressor Analysis - compressor pressure ratio, power required, rotational speed and compressor efficiency
- Turbine Analysis - work and power developed, expansion ratio and turbine efficiency
- Cycle / Brayton Type Analysis - mass flow rate, inlet and exit velocity, station temperature and pressures, combustion and thermal efficiency, specific fuel consumption and power / thrust developed
- Combustion Analysis - excess air and fuel-air ratio
- General Analysis - diffuser and nozzle performance and efficiency
- Similar performance comparison research using bio-diesel fuel formulations

Details

Dimensions
MiniLab™: 40L x 42W x 62H inches
(102L x 107W x 158H cm)
As Shipped: 48L x 48W x 69H inches
(122L x 122W x 176H cm)

Weight
MiniLab™: 570 lbs (257 kg)
As Shipped: 660 lbs (298 kg)

Operating Requirements
Master Switch, Keyed - Secured control of equipment usage
Green Start Button, Push - Initiates Engine Start, Multiple Functions
Red Stop Button, Push - Initiates Engine Shut-down,
Multiple Functions
T-Handled Power Lever - Controls Engine RPM
Integral LCD Display - Real Time System Status

Operating Requirements
Typical Laboratory Setting Power
Power: 120V single-phase 60Hz
(220V upon request)

Operating Requirements
Design Maximum Thrust: 40 lbf (178 N)
Approved Fuels: Jet A, A-1, B; JP-4, 5, 8; Kerosene, Diesel, Fuel Oil #1 or #2
Exhaust Gas Temperature: 1328˚F (720˚C)
Mass Flow: 1.1 lbs/s (0.5 kg/s)
Ignition System: Air gap, high voltage capacitor discharge type hermetically sealed ignition coil and igniter plug
Compressor Type: Single Stage Centrifugal (Radial Outflow)
Turbine Type: Single Stage Axial Flow
Design Maximum RPM: 87,000
Engine Mount: Pivot bearing support allowing direct thrust to be obtained by a load cell
Engine Compression Ratio: 3.4
Engine Pressure Ratio: 30.0
Specific Fuel Consumption: 1.2
Approved Oils: MIL-PRF-23699F-STD
Engine Diameter: 6.8 inches (17 cm)
Engine Length: 10.8 inches (27 cm)

Auto Start System
- Single green push button for engine start
- Monitors system parameters during engine operation
- Out-of-limit conditions results in safe engine shutdown
- LCD panel alerts the operator to any system faults
- Total run time and cycle counts are digitally recorded
- Single red push button safely shuts the system down

Instrumentation
Digital: High Speed Data Acquisition System
Data Acquisition Software with Configurable Data Output
Windows ® Computer for Data Display
Single Cable National Instruments™ USB to PC Connection
Sensors (Preinstalled and Calibrated)
- Compressor Inlet Temperature and Pressure (T1/P1)
- Compressor Exit Temperature and Pressure (T02/P02)
- Turbine Stage Inlet Temperature and Pressure (T03/P3)
- Turbine Stage Exit Temperature and Pressure (T04/P04)
- Thrust Nozzle Exit Temperature and Pressure (T05/P05)
- Fuel Flow
- Thrust
- Engine Rotational Speed (RPM)

Digital and Analog: As provided on the Operator Panel
- Digital Turbine Inlet Temperature (TIT)
- Digital Exhaust Gas Temperature (EGT)
- Digital Engine Rotational Speed (RPM)
- Analog Oil Pressure
- Analog Engine Pressure
- Analog Air Start Pressure

TurboGen™

2 Year Warranty

Gas Turbine Electrical System

Product Summary

- Gas Turbine Engine Designed and Manufactured to Aerospace Standards
- Three Phase Electric Generator with Adjustable Rotor Excitation
- Engine Operations Instrumented for Temperature and Pressure Measurement
- Gas Turbine Auto Start and Auto Shutdown System
- National Instruments™ Data Acquisition System Configured with LabVIEW™
- Shipped Ready to Operate

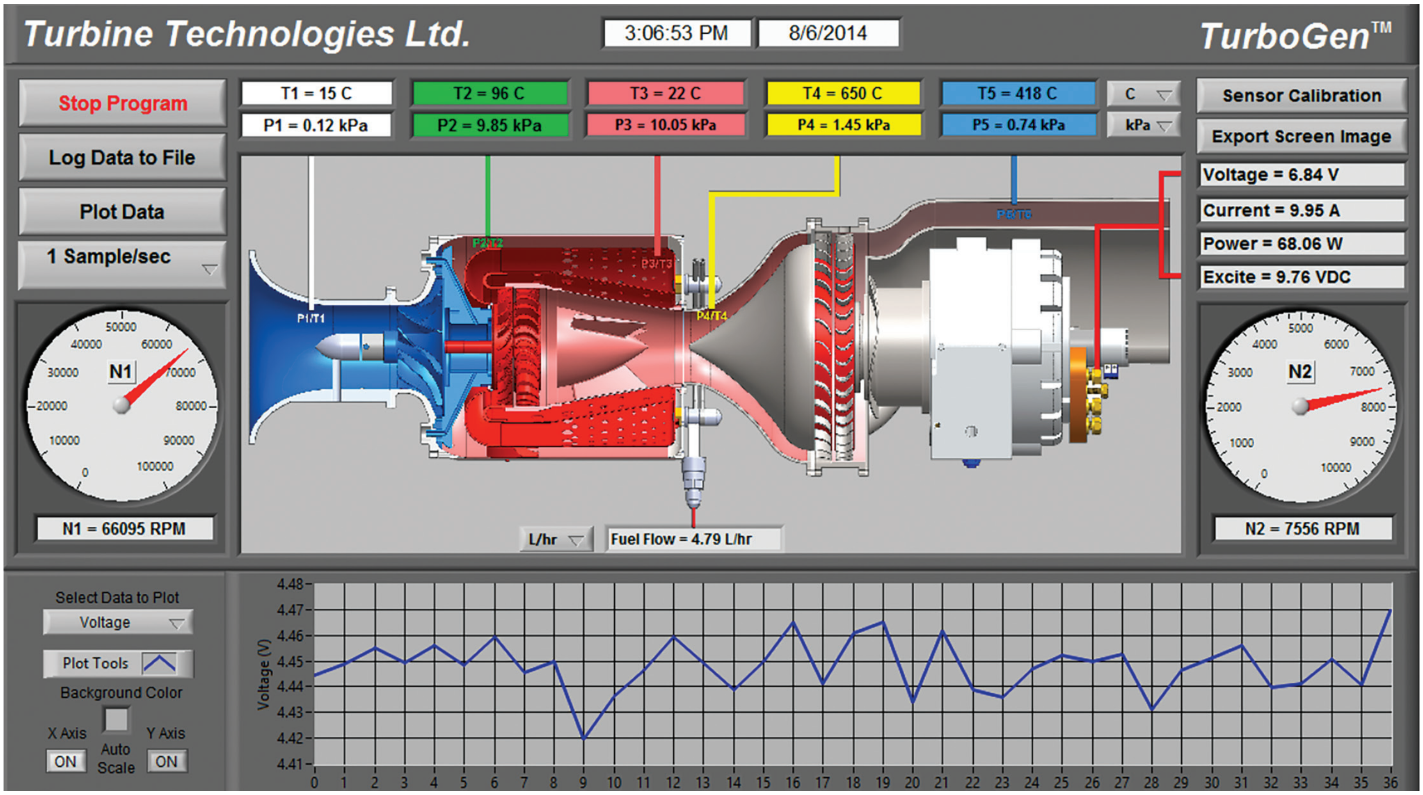
Students will learn: **Fundamentals of electrical power generation using a two-spool turboshaft engine. The system's free power turbine design allows studies involving variable loading of the onboard 3-phase generator.**

Description

The compact jet engine gasifier core is representative of all major gas turbine types and entails an axial flow turbine stage, reverse flow annular combustor and radial flow compressor stage. This allows textbook analysis of the air equivalent Brayton Cycle.

The electric power generation section features a thrust driven free power turbine directly coupled to a three phase liquid-cooled electric alternator. The generation circuit is base-loaded with an integrated fixed-value resistance module. An adjustable-rate excitation current controller allows wide-range alternator loading through the complete speed range of the generation system. The electrical power system can produce up to 14.4 volts, with a maximum rated power output of 2.1 kW. A jet thrust driven exhaust fan effectively expels heat and exhaust from the engine/generator compartment.

Fifteen sensors report directly to an installed National Instruments™ DAQ platform. LabVIEW™ displays that data on the provided laptop computer. Data is configurable for output via numerous export options which include .txt and .csv file types. A comprehensive Operator's Manual details all aspects of system operation. Safety instructions address all operating conditions.



Data Acquisition System Included

TurboGen™

2 Year Warranty

Details

Dimensions
TurboGen™: 40L x 42W x 62H inches
(102L x 107W x 158H cm)
As Shipped: 48L x 48W x 69H inches
(122L x 122W x 175H cm)

Weight
TurboGen™: 640 lbs (290 kg)
As Shipped: 715 lbs (324 kg)

Operating Requirements
Master Switch, Keyed - Secured control of equipment usage
Green Start Button, Push - Initiates Engine Start, Multiple Functions
Red Stop Button, Push - Initiates Engine Shutdown, Multiple Functions
T-Handled Power Lever - Controls Engine RPM
Integral LCD Display - Real Time System Status

Operating Requirements
Typical Laboratory Setting Power
Power: 120V single-phase 60Hz
(220V 50Hz upon request)

Operating Requirements
Design Maximum Thrust: 40 lbf (178 N)
Approved Fuels: Jet A, A-1, B; JP-4, 5, 8; Kerosene, Diesel, Fuel Oil #1 or #2
Exhaust Gas Temperature: 1328°F (720°C)
Ignition System: Air gap, high voltage capacitor discharge type hermetically sealed ignition coil and igniter plug
Compressor Type: Single Stage Centrifugal (Radial Outflow)
Turbine Type: Single Stage Axial Flow
Design Maximum RPM: 87,000
Engine Mount: Pivot bearing support allowing direct thrust to be obtained by a load cell
Engine Compression Ratio: 3.4
Engine Pressure Ratio: 30.0
Specific Fuel Consumption: 1.2
Approved Oils: MIL-PRF-23699F-STD

Generator Limits
Regulated Volts: 13.1 Volts
Maximum Current: 194 Amps
Maximum Power: 2541 Watts
Maximum RPM: 10,000

Gasifier Limits
Mass Flow: 1.1 lbs/s (0.5 kg/s)
Turbine Inlet Temp: 1328°F (720°C)

Auto Start System
- Single green push button for engine start
- Monitors system parameters during engine operation
- Out-of-limit conditions results in safe engine shutdown
- LCD panel alerts the operator to any system faults
- Total run time and cycle counts are digitally recorded
- Single red push button safely shuts the system down

Instrumentation
Digital: High Speed Data Acquisition System
Data Acquisition Software with Configurable Data Output
Windows ® Laptop Computer for Data Display
Single Cable National Instruments™ USB to PC Connection
Sensors (Preinstalled and Calibrated)
- Compressor Inlet & Exit Temperature and Pressure
- Turbine Inlet Temperature and Pressure
- Turbine Exit / Power Turbine Inlet Temperature and Pressure
- Power Turbine Exit Pressure and Temperture
- Fuel Flow
- Gasifier & Generator Rotational Speed (RPM)
- Generator Current & Power

Digital and Analog: As provided on the Operator Panel
- Digital Turbine Inlet Temperature (TIT)
- Digital Exhaust Gas Temperature (EGT)
- Digital Engine Rotational Speed (RPM)
- Analog Oil Pressure
- Analog Engine Pressure
- Analog Air Start Pressure

Gas Turbine Electrical Generation System

Experimental Opportunities

Experimental and research opportunities include scientific, engineering, thermodynamic and environmental investigations. With a wide array of sensors, experiments relating to secondary education physics and chemistry through graduate level fuels and combustion research are readily performed using an electrical generation performance benchmark. Standard courses in engineering thermodynamics, fluid mechanics and three-phase electrical power generation benefit from textbook direct examples conducted and measured in real time. The limitations of theoretical models and the variability of experimental technique can be experienced first-hand. In addition to academics, the TurboGen™ is ideally suited for general gas turbine electrical generation familiarization, jet engine driven electrical power generation operational training for diverse power generation professionals, as well as alternative fuels, emissions and scaled-jet engine power generation testing and research.

Illustrative examples of Gas Turbine computations

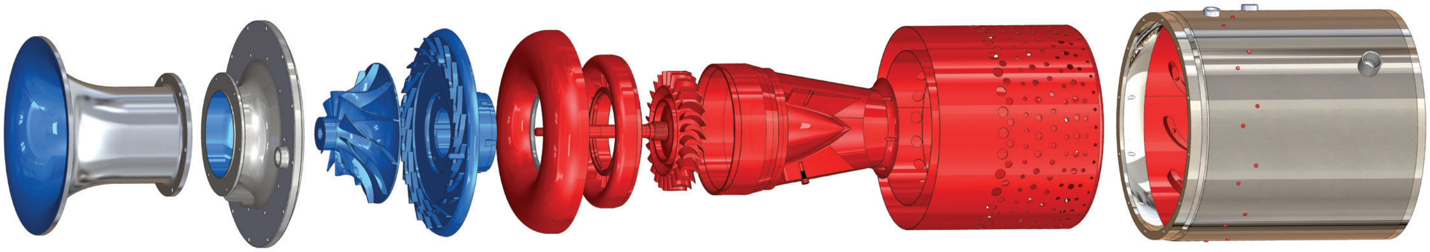
With measured values of compressor inlet temperature and pressure, turbine inlet temperature and pressure, turbine exit temperature and pressure, fuel flow and inlet and exit areas, electric power, excitation voltage, possible calculations include:

- Compressor Analysis - compressor pressure ratio, power required, rotational speed and compressor efficiency
- Turbine Analysis - work and power developed, expansion ratio and turbine efficiency
- Full Cycle/Brayton Type Analysis - mass flow rate, inlet velocity, station temperature and pressures, combustion and thermal efficiency, work output
- Combustion Analysis - excess air and fuel-air ratio
- Thermodynamic to Electric Power Conversion Ratio (specific fuel consumption)
- Similar performance comparison research using bio-diesel fuel formulations

Variable 3-Phase Generator and Resistive Load

SR-30™

Warranty 2 Year Warranty



PRODUCT SUMMARY

- Electronic solid models of all major SR-30 turbojet engine components
- Material specifications for each component with associated mechanical properties
- Supports FEA and CFD analysis
- Assists in volumetric & mass flow calculations & velocity vector diagram generation
- License includes unlimited use by faculty and enrolled students

Description

This CAD model package contains twelve electronic solid models in IGES, SLDPRT, and STL format. It facilitates basic flow analysis to include design parameters like velocity vector diagram generation and also provides geometry for import into CFD and FEA packages. Information is included regarding material properties for each component.

1. Engine inlet
2. Intake case
3. Centrifugal flow compressor
4. Bladed diffuser
5. Reverse flow annular combustor
6. Combustor straightener vanes
7. Combustor transition liner
8. Nozzle vane guide ring
9. Axial flow turbine
10. Turbine containment ring
11. Thrust nozzle cone
12. Engine outer mantle

Additionally, information is included regarding material types and properties for each component. The SR-30 engine is designed and manufactured by Turbine Technologies, Ltd. specifically for the MiniLab™ Gas Turbine Power System. A pure turbojet, the SR-30 is representative of all straight jet engines in which combustion results in an expanding gas that is sufficiently capable of producing useful work and propulsive thrust. The SR-30 engine is typical of the gas generator core found in turbofan, turboprop, and turboshaft gas turbine engines, which are typically used for aircraft and marine propulsion as well as stationary and industrial power generation.

Turbojet Engine CAD Model

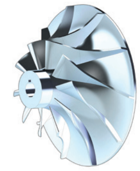
Students will Learn: Standard component geometries utilized in all commercial engines, to include axial flow stators and rotors, annular combustors and centrifugal flow rotors and diffusers. Students can then apply this knowledge in areas of flow and energy analysis, finite element analysis (FEA) and computational fluid dynamics (CFD).

Inlet Bellmouth

The inlet bellmouth (ASME Long Nozzle type) is the first engine component to encounter the gaseous working fluid (atmospheric air) necessary for the operation of a gas turbine engine. Not to be confused with the external inlet and ducting associated with a particular engine's specific installation (e.g. the aerodynamic inlet on the nose of a fighter aircraft), the engine inlet performs the final conditioning of inlet air prior to its entering the interior of the engine. The inlet bell of the SR-30 Cutaway is illustrative of a typical subsonic inlet duct in which ambient air is directly routed to the face of the compressor.

Centrifugal Flow Compressor

The compressor (rotor), along with the compressor turbine, makes up the rotating assembly of the turbojet engine. The SR-30 engine utilizes a centrifugal (radial flow) compressor, with the flow path being referenced to the rotation axis of the compressor itself. As viewed from the front, the compressor rotates in the counter-clockwise direction to properly function. Through this mechanical rotation, energy is imparted to the inlet air. The compressor, also known as an impeller, rotates upwards of 80,000 revolutions per minute. This high rotational speed takes inlet air at the impeller hub and centrifugally accelerates it in a radial direction toward the outer circumference of the impeller where it is discharged through the diffuser.

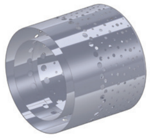


Diffuser

The diffuser (stator) works in conjunction with the compressor to further process the working fluid. The compressor discharge air is directed through the diffuser where the fluid velocity is decreased and the static pressure increased. This discharge air also undergoes a 90 degree change in direction, transitioning from a radial to axial flow. The compressor and diffuser working together comprise the compressor stage of the engine.

Annular Combustor

The SR-30 engine features an annular type combustor composed of two perforated tubes fixed in concentric relation to one another. The combustor is oriented in a reverse flow arrangement with the inlet of the combustor situated at the rear of the engine.

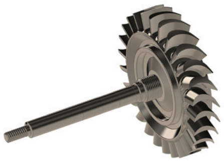


Vane Guide Ring

The vane guide ring (stator) is the first component in the turbine stage and permits the turbine to extract useful work from the combustion process. This ring consists of a shrouded series of small airfoil blades each facing into the oncoming combustion gas flow as directed by the transition liner. As the flow path narrows between the individual blades, the hot, high pressure combustion gases are accelerated to a high velocity, high energy flow. The vane guide ring further directs this accelerating gas in such a manner as to produce the most effective reaction against the turbine blades.

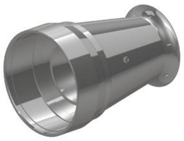
Axial Flow Turbine

The turbine (rotor) absorbs energy from the accelerating gas flow and converts it into usable mechanical power. Further acceleration of the expanding flow takes place through the turbine blades. Much like the blades of the vane guide ring, the individual turbine blades are also airfoil shaped. A combination of aerodynamic and reaction forces cause the turbine to rotate. Coupled to the compressor, the sole job of the turbine is to effect a rotation of the compressor to perpetuate the entire flow process. Only the power necessary to drive the compressor is extracted from the flow as it expands through the turbine blades. The remaining energy is available and utilized for the generation of propulsive thrust.



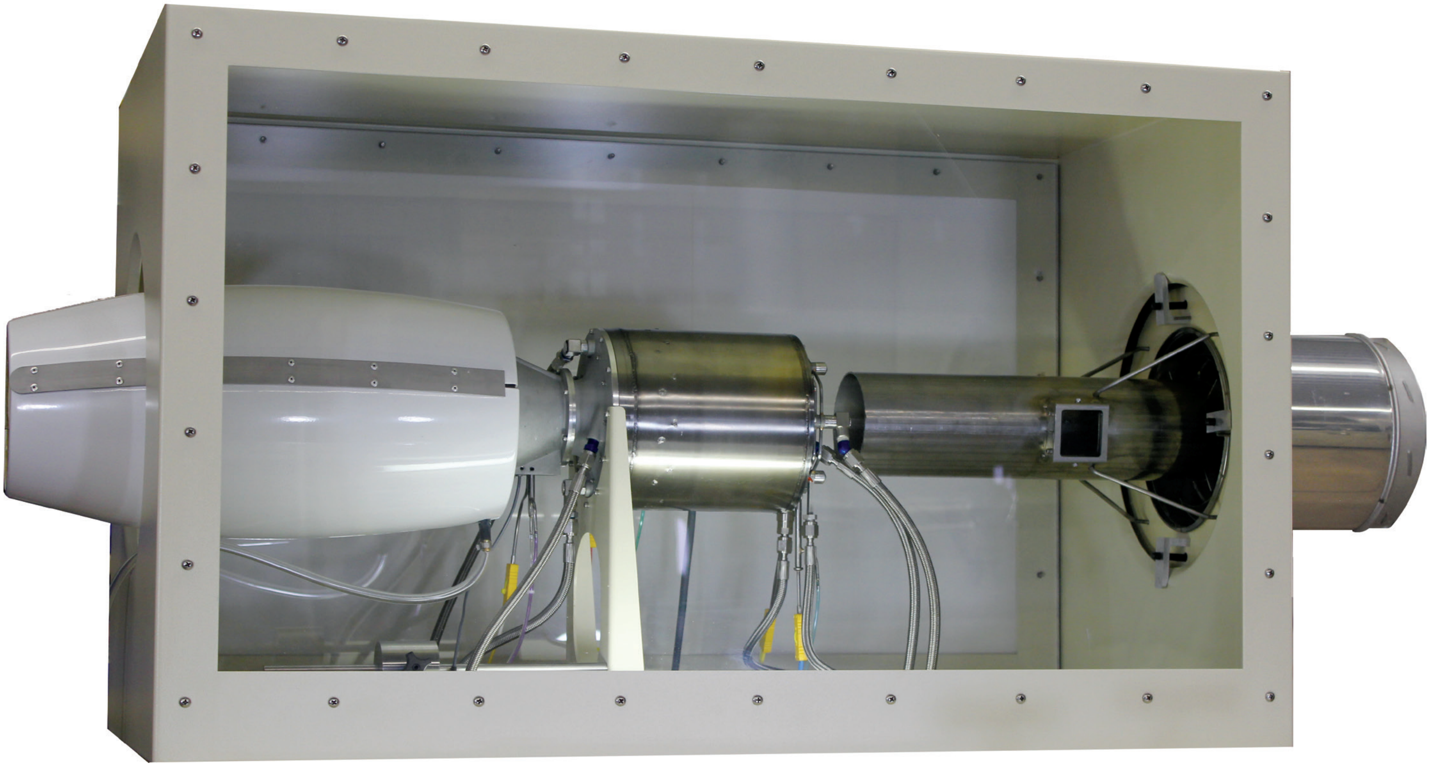
Thrust Nozzle / Exit

A convergent tube of gradually reducing cross-section, the thrust nozzle converts the remaining combustion heat energy into kinetic energy. The gas accelerates through the nozzle at high velocity resulting in propulsive thrust at the nozzle exit.



HushKit™

2 Year Warranty



Product Summary

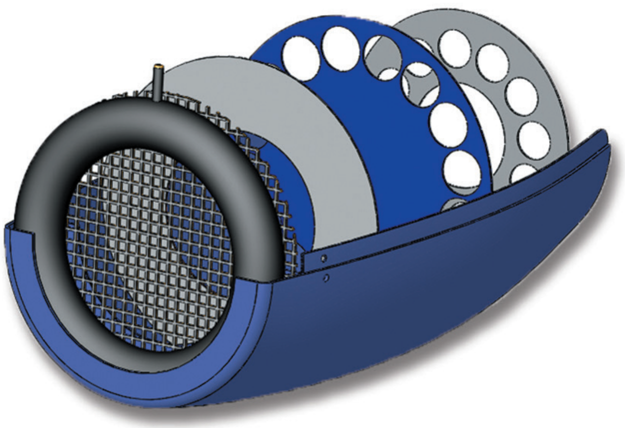
- Complete SR-30™ Gas Turbine Sound Suppressor System
- Typically Provides 84% Intake and 75% Exhaust Sound Reduction
- Stainless Steel Exhaust Suppressor Housing with Flame Plume Sight Window
- Quick Installation Requires No MiniLab™ System Modifications
- 9” Exaust Pipe for Gas Turbine Engine Ducted Installation

Description

The HushKit™ Gas Turbine Sound Suppressor System is an optional silencer assembly available for installation in the MiniLab™ Gas Turbine Power System. Designed to reduce the sound level of the SR-30™ Gas Turbine Engine, the HushKit™ is effective in both the academic and research setting and capable of retrofit to existing installations.

The HushKit™ system is composed of individual intake and exhaust suppressor units. The aircraft style nacelle shaped intake suppressor housing is designed to reduce acoustic energy associated with compressor intake flow. Molded from aerospace quality fiberglass, the intake suppressor mounts to the SR-30™ engine with a pneumatic friction seal system. The exhaust suppressor assembly is manufactured from stainless steel to maximize heat dissipation and durability. A positive pressure clamping system requires no modification of the existing MiniLab™ for installation. The suppressor exhaust ducting incorporates a glass sight window for flame plume visibility during starting operation. An acoustic expansion chamber on the end of the duct provides a convenient transition to facility specific exhaust ducting and integrates well with already existing installations. Neither the intake or exhaust suppressor assemblies interfere with engine operation.

Comprehensive installation and usage instructions are provided.



Hush Kit Internal Design

Operating Performance

Decibel (dB) Levels Without and With Suppressor System Installed in MiniLab:

	Engine Speed 50,000 RPM			Engine Speed 84,000 RPM		
Position	**3 feet**	**10 feet**	**25 feet**	**3 feet**	**10 feet**	**25 feet**
Controller Side	97/90	94/88	91/79	107/98	102/94	99/90
Intake Side	120/103	121/91	103/86	124/113	121/106	108/96
Exhaust Side	113/93	100/88	92/80	116/104	107/100	103/92

Gas Turbine Power System

Gas Turbine Electrical System

SprayView™

Warranty 2 Year Warranty

Fuel Atomization Verification

Product Summary

- Self Contained Fuel Atomization Verification System
- Clear-View Spray Observation Chamber with Spray Verification Impingement Plates
- Jet Engine Spray Manifold with Precision Variable Flow Control
- Instrumented with Fuel Delivery Pressure and Digital Fuel Flow Meters
- Integrated Fuel Spray Vacuum Capture / Drain System
- Shipped Ready to Operate

Students will learn: **Fundementals of fuel nozzle spray quality and understand numerous variables associated with requisite patterns and droplet sizes.**

Description

SprayView™ is an optional fuel spray testing system for the SR-30™ Gas Turbine Engine. It has been designed with a built-in engine spray manifold to allow MiniLab™ operators the ability to test the atomization characteristics of fuels before they are actually burned in the engine. Proper atomization is important for testing alternative fuel formulations such as bio-diesels. Improper spray patterns signify non-conforming fuel formulations and can cause engine damage.

The SprayView™ system also allows MiniLab™ operators to remove their actual SR-30™ Engine Fuel Spray Manifold and test it for proper operation. Injector nozzles can be inspected for any build-up of contaminants and can be conveniently cleaned for continued reliable performance when reinstalled on the engine.

SprayView™ features a clear view spray observation chamber allowing the operator to visually inspect the fuel spray pattern. Integrated impingement plates can be lined up under each spray nozzle to verify their spray integrity. The injected fuel is colleced in a tank, which can be conveniently drained after the tests. An integrated spray throttling system allows the operator to vary the fuel spray to determine the optimum spray atomization "cloud" for a particular fuel.

Details

Dimensions

SprayView™: 29L x 22W x 63H inches
(74L x 56W x 160H cm)
As Shipped: 35L x 28W x 69H inches
(89L x 71W x 175H cm)

Weight

SprayView™: 160 lbs (73kg)
As Shipped: 225 lbs (102kg)

Operating Panel

Digital Fuel Flow Meter
Analog Fuel Pressure Gauge
Keyed Master Switch
Test Chamber Vacuum Switch
Fuel Pump Switch

Operating Requirements

Typical Laboratory Setting Power
Power: 120V single-phase 60Hz 8 Amp
(220V 50Hz upon request)

Experimental Opportunities

SprayView™ is primarily offered as an accessory to the MiniLab™ Gas Turbine Power System. With the growing need to do more with existing equipment, the MiniLab™ Gas Turbine Power System finds itself being used by undergraduate students working to gain an understanding of the Brayton Power Cycle as well as researchers testing alternative fuel formulations for performance and emissions results. The ability to verify fuel integrity and to check an existing SR-30™ engine fuel manifold for potential fuel injector clogging contaminants are major considerations for using the SprayView™.

- Check spray pattern and integrity of various heavy fuel formulations.
- Verify proper operational integrity of in-service engine spray manifold.
- Integrating various atomization sensors such as lasers for advanced research.

Turbine Technologies, LTD.

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