

# Mini-Lab Gas Turbine Power System™ Sample Lab Experiment Manual

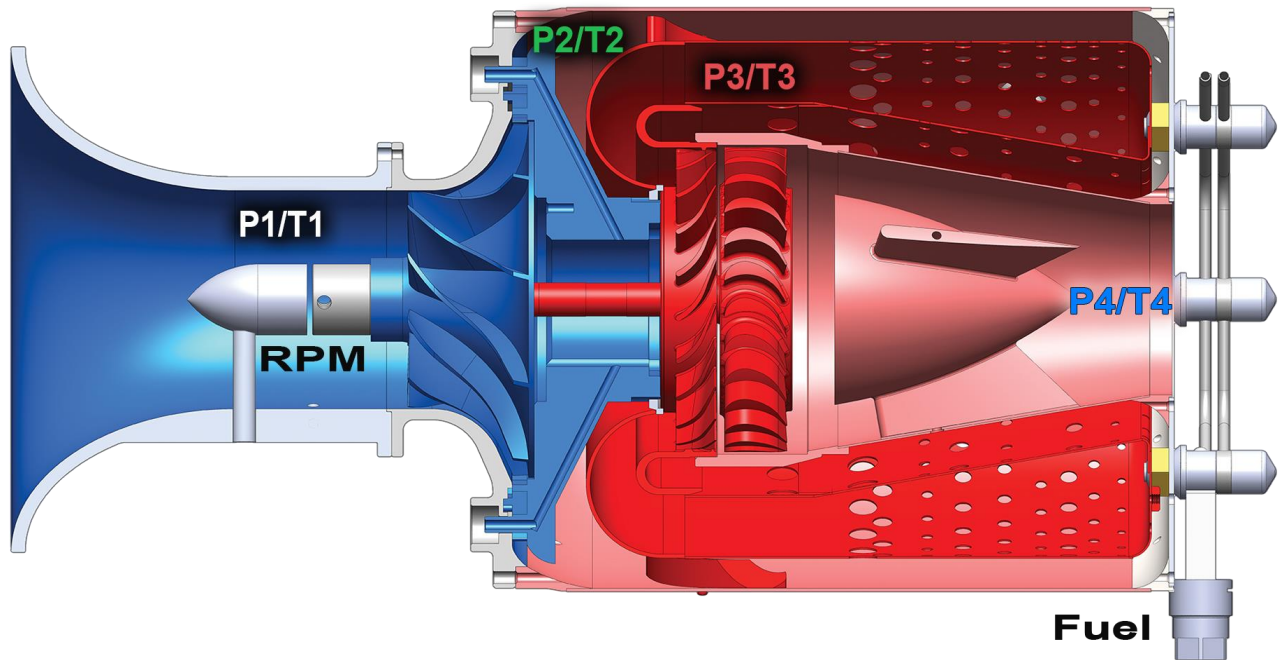
## **Lab Session #1: System Overview and Operation**

**Purpose:** To gain an understanding of the Mini-Lab™ Gas Turbine Power System as a whole and details of engine sensors and controls making up the system. This will prepare you for operation of the system.



**Note:** Sample lab does not replace Mini-Lab™ Gas Turbine Power System Operator's Manual. Please refer to manual for detailed system operational and safety instructions.

## SR-30 Gas Turbine Cutaway Engine Sensor Locations



**RPM Tachometer Generator:** (Displayed on Panel as RPM and Data Acquisition Screen).

**P1:** Compressor Inlet Pressure (Displayed on Data Acquisition Screen)

**T1:** Compressor Inlet Temperature (Displayed on Data Acquisition Screen)

**P2:** Compressor Exit Temperature (Displayed on Data Acquisition Screen)

**T2:** Compressor Exit Temperature (Displayed on Data Acquisition Screen)

**P3:** Turbine Inlet Pressure (Displayed on Panel and Data Acquisition Screen)

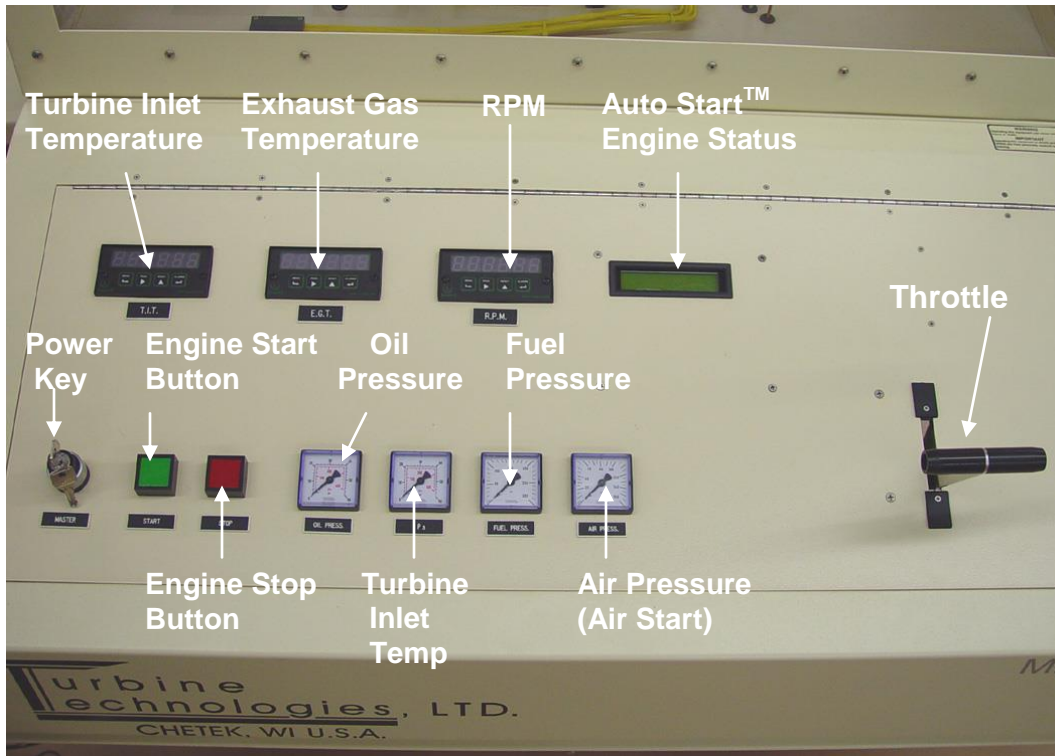
**T3:** Turbine Inlet Temperature (Displayed on Panel as TIT and Data Acquisition Screen)

**P4:** Turbine Exit Pressure (Displayed on Data Acquisition Screen)

**T4:** Turbine Exit Temperature (Displayed on Data Acquisition Screen)

**Fuel Pressure:** (Displayed on Panel)

## Mini-Lab™ Gas Turbine Power System Control Panel



## Data Acquisition Computer



Connects to unit's data acquisition system via USB port. Displays and captures data for operation and analysis.

**In preparation for system operation and data analysis, please answer the following questions:**

Determine the fuel you are using to power your system. \_\_\_\_\_

What is the energy content per unit volume of fuel? \_\_\_\_\_

What is the fuel's density per unit volume? \_\_\_\_\_

**Barometric Pressure**

What is the present barometric pressure in your area?

Why would barometric pressure be important when planning to operate the Gas Turbine System?

What will be your reliable source for accurate barometric pressure readings?

**System Operation**

**Purpose:** Conduct pre-start, start-up, operation, data gathering and shut down of Mini-Lab™ Gas Turbine Power System.

**Procedure:**

Utilize **Mini-Lab™ Operators Manual** and follow **Section 4.2 Expanded Normal Procedures** to perform system pre-start, start-up, operation, data acquisition and shut down.

Utilize the data acquisition system to capture the operational values from startup to shut down (**covered in Section 4.2.3 Data Collection and also covered in detail on the next page of this sample lab**).

## DATA COLLECTION

Recording and using your data properly is an important part of successfully completing the lab.

***NOTE:*** *The following steps assume the use of the standard MiniLab Software and default settings as supplied with the MiniLab. Use of non-default setting or other software may necessitate alternative methods or procedures for data collection. Consult the LabView/National Instruments software specific information as required.*

From Windows, OPEN the MiniLab Software by double-clicking on the MiniLab 1.2 shortcut icon located on the Windows Desktop. MiniLab 1.2 will start with the *Main Display/Control* and *Channel Configuration Window* displayed.



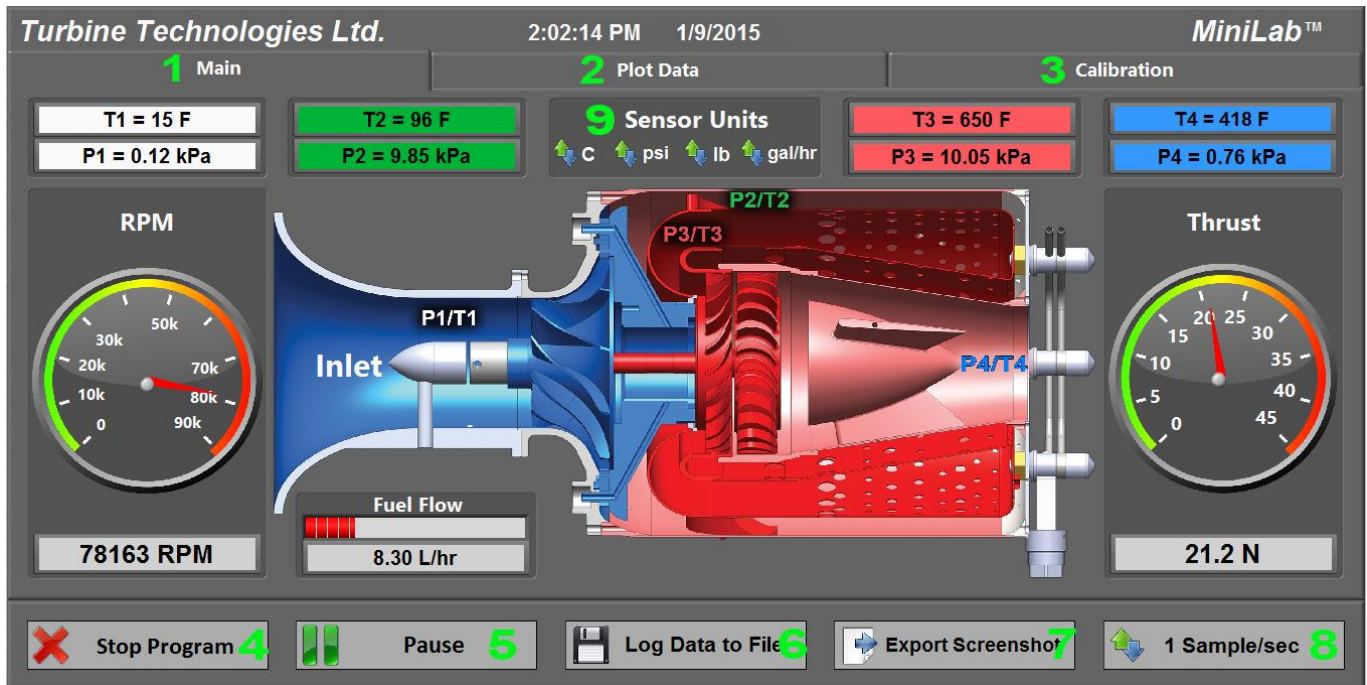
MiniLab Launch Icon

**NOTE: The computer must be connected to the MiniLab USB port prior to opening the MiniLab software.**

The MiniLab configuration software is dependent upon the specific DAQ Module serial number as installed in the MiniLab and will not function properly if the DAQ Module cannot be found. If this was done incorrectly, exit the program, attach the USB cable and start over. When the software is launched, a NI-MAX (Measurement & Automation Explorer) hardware configuration automatically sets the channels and scales of the **NI DAQ 6218** device.

### TO PERFORM THE FOLLOWING FUNCTIONS:

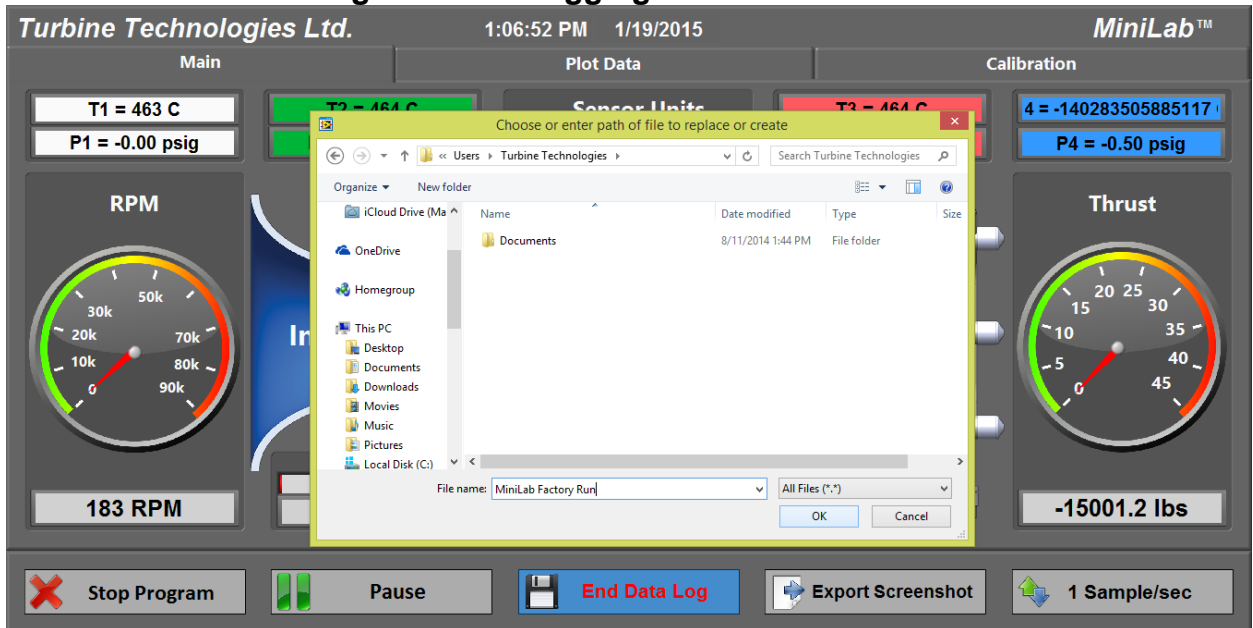
- **Virtual Instrument Panel Software Controls overview are on page 5**
- **Logging Data to File is shown on Page 6**
- **Displaying Plot Feature is shown on Page 6**



### Software Controls Overview

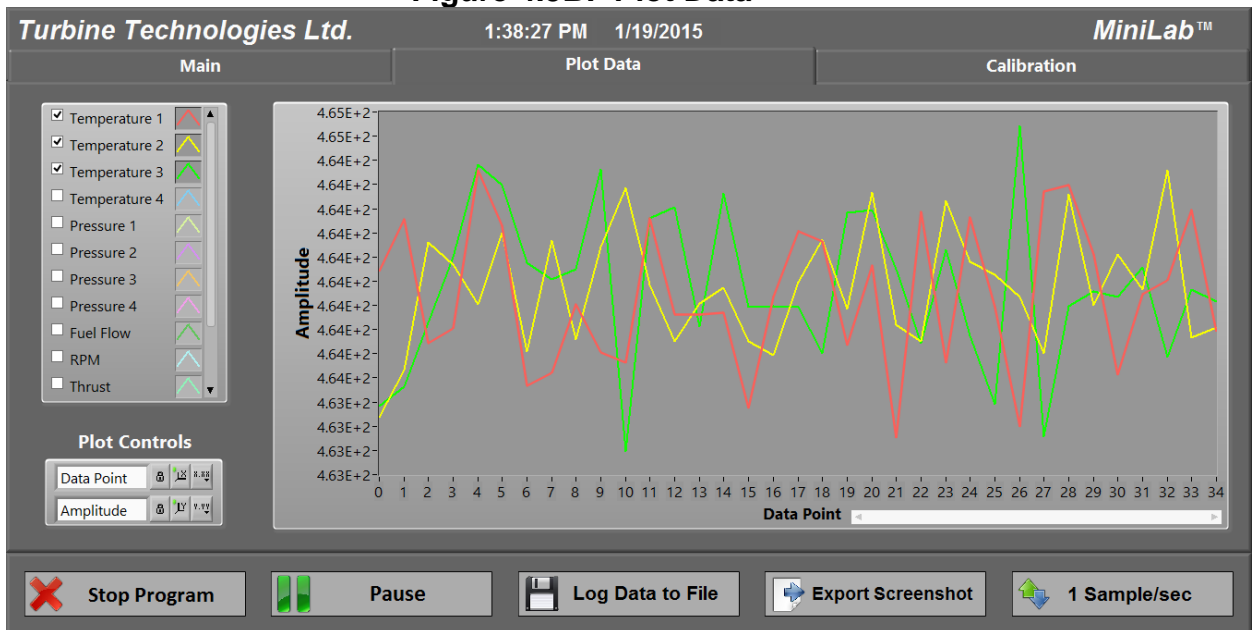
1. Click Main tab for Data Acquisition
2. Click Plot Data tab to plot any number of sensors in real-time
3. Click Calibration tab to save a calibration offset to any of the sensors
4. Click Stop Program to stop the VI
5. Click Pause to pause the VI and data logging (click Continue to resume the VI after pausing)
6. Click Log Data to File to save a text document of desired data
7. Click Export Screenshot to save an image file of the current VI screen
8. Click to change the Sampling Rate of the VI
9. Click on the arrows to change Sensor Units

**Figure 4.5A: Logging Data To File**



To log data to a file for analysis, click on the “**Log Data to File**” button and a new window will appear. Enter a file name and choose the location to save the file. Click “**OK**” to begin logging data. Click “**End Data Log**” to stop logging data.

**Figure 4.5B: Plot Data**



To plot data points, use the check boxes to select the desired sensor(s) for the data plot. You can change many different features of the plot with the Plot Controls box.

**Mini-Lab™ Gas Turbine Lab Power System Experiment Manual**  
**Lab Session #2: Mini-Lab™ Data Run Plots**

Purpose: Graphically plot Mini-Lab™ Gas Turbine Run Data in preparation for system analysis and performance calculations.

Procedure: Follow the instructions starting on the following pages of this lab session to plot system run data.

---

Plot the following, utilizing MS-Excel Spreadsheet Program:

- Compressor Inlet/Outlet Pressure vs. Time
- Compressor Inlet/Outlet Temperature vs. Time
- Turbine Inlet/Outlet Pressure vs. Time
- Turbine Inlet/Outlet Temperature vs. Time
- Exhaust Gas Temperature (EGT) vs. Time
- Fuel Flow vs. Time
- RPM vs. Time
- Thrust vs. Time
- Fuel Flow and Thrust vs. Time (on one plot)

Print out plots and order them as listed.

**Choose and mark an analysis point on each plot for the same time point.**

For this exercise, pick a spot where engine RPM is at or near its peak during the data run. This will be the basis for system performance analysis calculations.

From your plots (specific time mark) and data collected from system run, please record the following:

- Date of Run: \_\_\_\_\_
- Time: \_\_\_\_\_
- Atmospheric Pressure: \_\_\_\_\_
- Compressor Inlet Pressure: \_\_\_\_\_
- Compressor Exit Pressure: \_\_\_\_\_
- Turbine Inlet Pressure: \_\_\_\_\_
- Turbine Exit Pressure: \_\_\_\_\_
- Fuel Flow: \_\_\_\_\_
- RPM: \_\_\_\_\_
- Thrust: \_\_\_\_\_
- Compressor Inlet Temperature: \_\_\_\_\_
- Compressor Exit Temperature: \_\_\_\_\_
- Turbine Inlet Temperature: \_\_\_\_\_
- Turbine Exit Temperature: \_\_\_\_\_

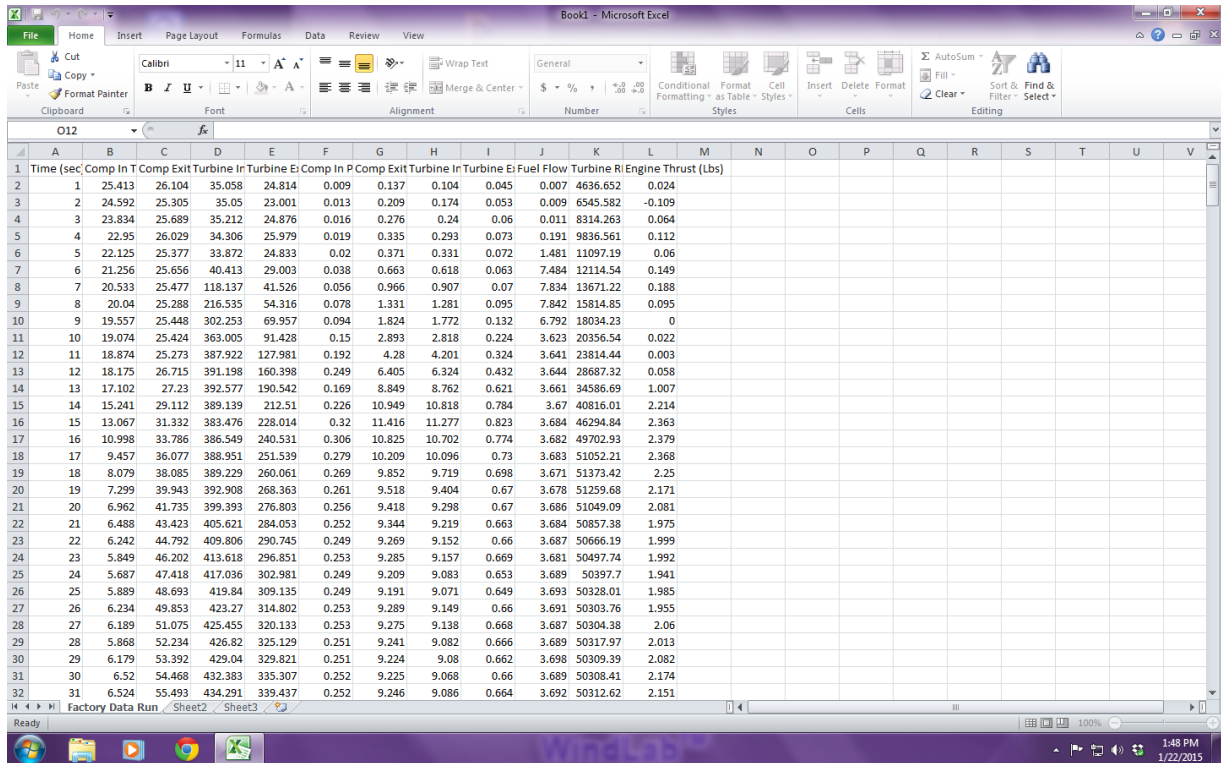


## Importing Acquisition Data into MS-Excel Spreadsheet

A convenient way to analyze MiniLab performance data is to graph the data points using MS-Excel Spreadsheet. To do this, the ASCII data captured during the lab data acquisition must be imported into Excel.

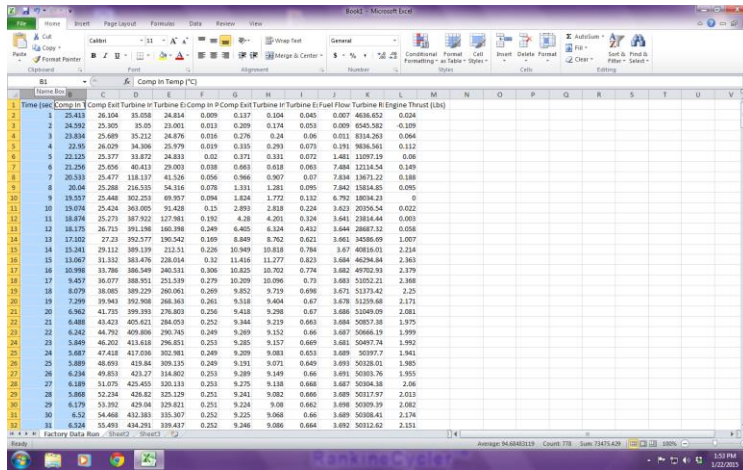
**Open: Double-Click the data file saved from the VI**  
**Click: Open With and select Microsoft Excel**

Your data will now be in spreadsheet form in MS Excel.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Time (sec)	Comp In T	Comp Exit Turbine In	Turbine In	Turbine E	Comp In P	Comp Exit Turbine E	Fuel Flow	Turbine R	Engine Thrust (Lbs)			
2	1	25.413	26.104	35.058	24.814	0.009	0.137	0.104	0.045	0.007	4636.652	0.024	
3	2	24.592	25.305	35.05	23.001	0.013	0.209	0.174	0.053	0.009	6545.582	-0.109	
4	3	23.834	25.689	35.212	24.876	0.016	0.276	0.24	0.06	0.011	8314.263	0.064	
5	4	22.95	26.029	34.306	25.979	0.019	0.335	0.293	0.073	0.191	9836.561	0.112	
6	5	22.125	25.377	33.872	24.833	0.02	0.371	0.331	0.072	1.481	11097.19	0.06	
7	6	21.256	25.656	40.413	29.003	0.038	0.663	0.618	0.063	7.484	12114.54	0.149	
8	7	20.533	25.477	118.137	41.526	0.056	0.966	0.907	0.07	7.834	13671.22	0.188	
9	8	20.04	25.288	216.535	54.316	0.078	1.331	1.281	0.095	7.842	15814.85	0.095	
10	9	19.557	25.448	302.253	69.957	0.094	1.824	1.772	0.132	6.792	18034.23	0	
11	10	19.074	25.424	363.005	91.428	0.15	2.893	2.818	0.224	3.623	20356.54	0.022	
12	11	18.874	25.273	387.922	127.981	0.192	4.28	4.201	0.324	3.641	23814.44	0.003	
13	12	18.175	26.715	391.198	160.398	0.249	6.405	6.324	0.432	3.644	28687.32	0.058	
14	13	17.102	27.23	392.577	190.542	0.169	8.849	8.762	0.621	3.661	34586.69	1.007	
15	14	15.241	29.112	389.139	212.51	0.226	10.949	10.818	0.784	3.67	40816.01	2.214	
16	15	13.067	31.332	383.476	228.014	0.32	11.416	11.277	0.823	3.684	46294.84	2.363	
17	16	10.998	33.786	386.549	240.531	0.306	10.825	10.702	0.774	3.682	49702.93	2.379	
18	17	9.457	36.077	388.951	251.539	0.279	10.209	10.096	0.73	3.683	51052.21	2.368	
19	18	8.079	38.085	389.229	260.061	0.269	9.852	9.719	0.698	3.671	51373.42	2.25	
20	19	7.299	39.943	392.908	268.363	0.261	9.518	9.404	0.67	3.678	51259.68	2.171	
21	20	6.962	41.735	399.393	276.803	0.256	9.418	9.298	0.67	3.686	51049.09	2.081	
22	21	6.488	43.423	405.621	284.053	0.252	9.344	9.219	0.663	3.684	50857.38	1.975	
23	22	6.242	44.792	409.806	290.745	0.249	9.269	9.152	0.66	3.687	50666.19	1.999	
24	23	5.849	46.202	413.618	296.851	0.253	9.285	9.157	0.669	3.681	50497.74	1.992	
25	24	5.687	47.418	417.036	302.981	0.249	9.209	9.083	0.653	3.689	50397.7	1.941	
26	25	5.889	48.693	419.84	309.135	0.249	9.191	9.071	0.649	3.693	50328.01	1.985	
27	26	6.234	49.853	423.27	314.802	0.253	9.289	9.149	0.66	3.691	50303.76	1.955	
28	27	6.189	51.075	425.455	320.133	0.253	9.275	9.138	0.668	3.687	50304.38	2.06	
29	28	5.868	52.234	426.82	325.129	0.251	9.241	9.082	0.666	3.689	50317.97	2.013	
30	29	6.179	53.392	429.04	329.821	0.251	9.224	9.08	0.662	3.698	50309.39	2.082	
31	30	6.52	54.468	432.383	335.307	0.252	9.225	9.068	0.66	3.689	50308.41	2.174	
32	31	6.524	55.493	434.291	339.437	0.252	9.246	9.086	0.664	3.692	50312.62	2.151	

# Graphing Data using MS-Excel Spreadsheet Graphing Function



Highlight columns of data desired for graph. For this example, the Time and Compressor Inlet column data will be plotted.

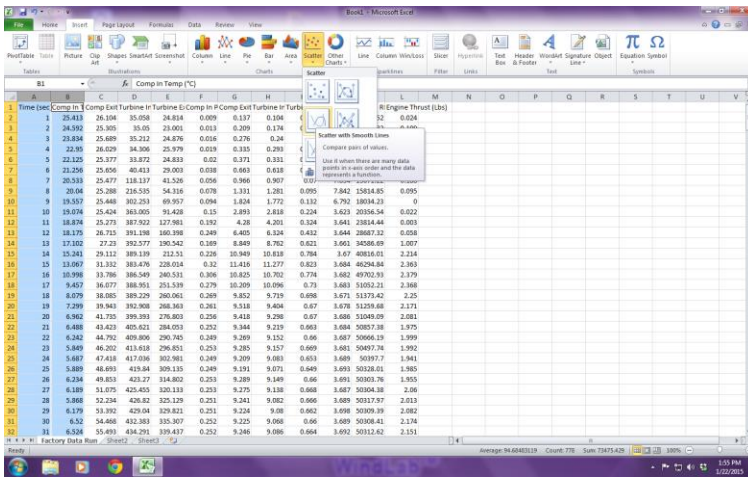
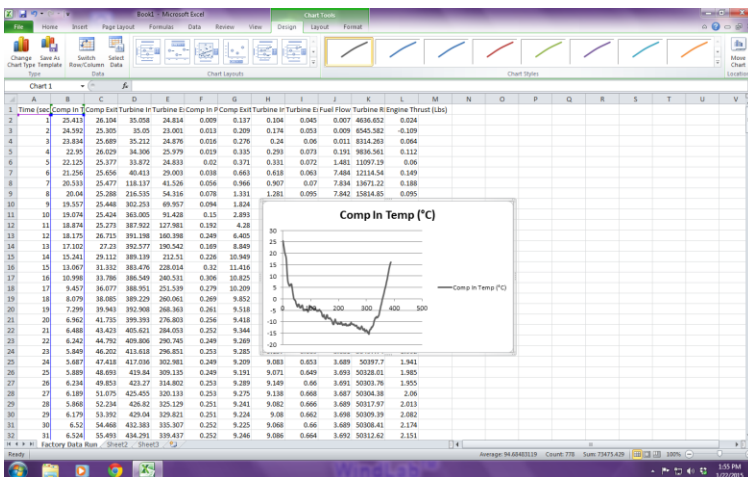
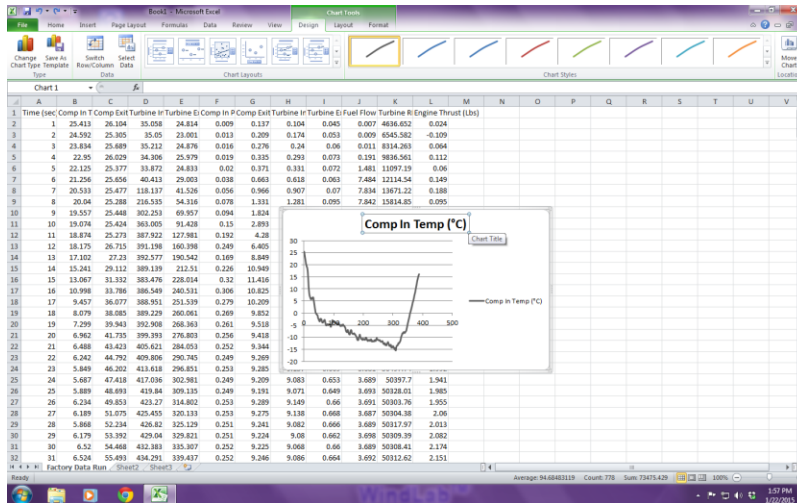


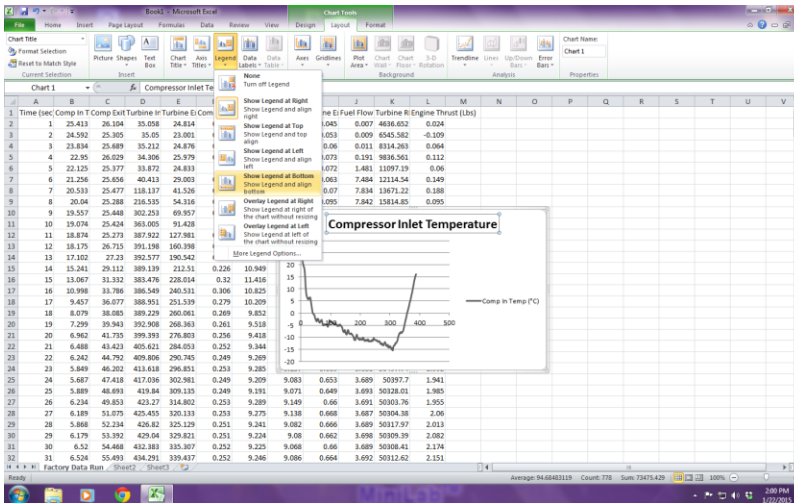
Chart Type: Line XY Scatter



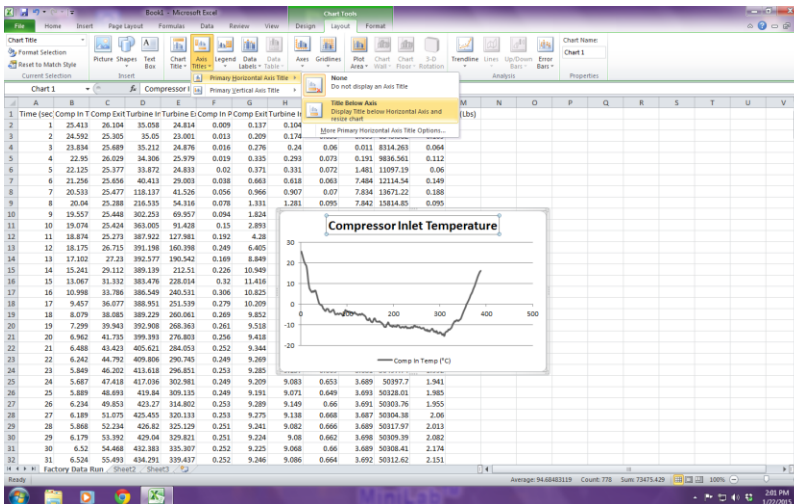
Change Color of Lines on Chart



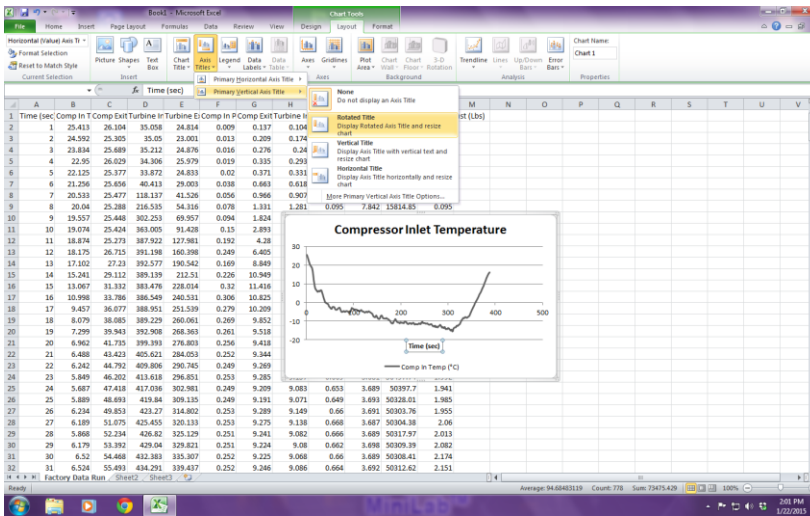
Label the Chart Title



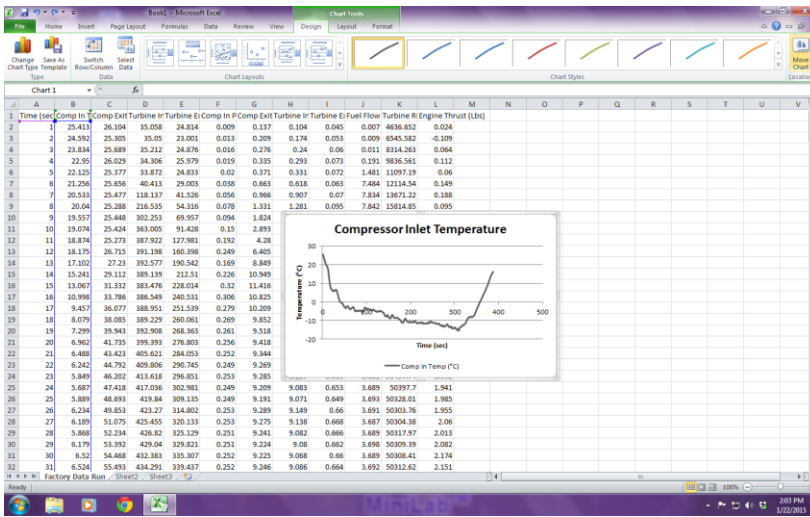
Choose your Legend Location format



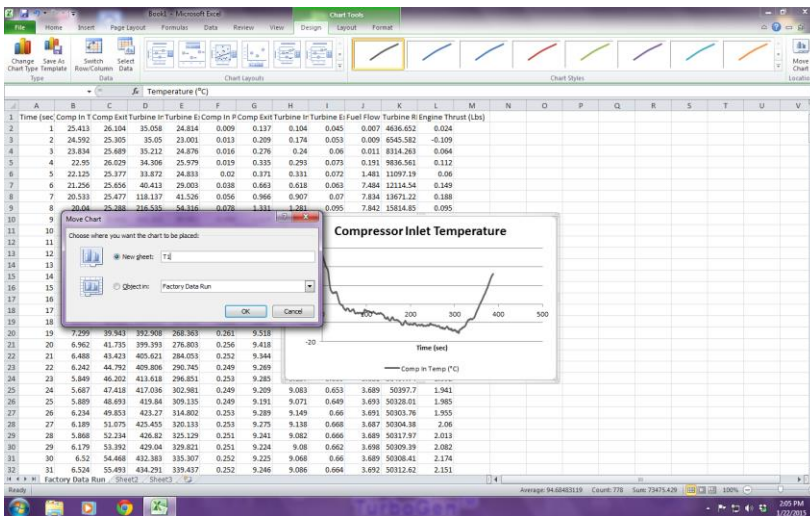
Label the X Axis



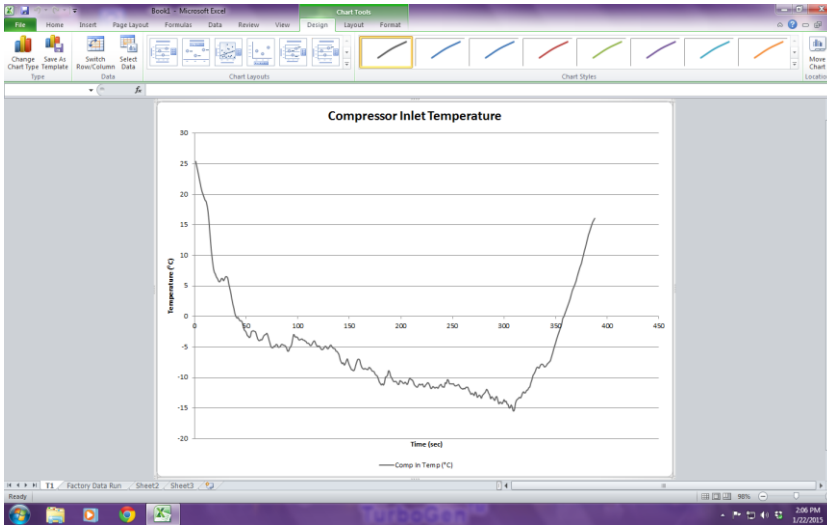
Label the Y Axis



Move Chart



Name Chart



Completed Compressor Inlet Temperature Chart

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Time (sec)	Comp In T	Comp Exit T	Turbine In T	Turbine E T	Comp In P	Comp Exit P	Turbine In P	Turbine E P	Fuel Flow	Turbine R	Engine Thrust (lbs)	
2	1	25.413	26.104	35.058	24.814	0.009	0.137	0.104	0.045	0.007	4636.652	0.024	
3	2	24.592	25.305	35.05	23.001	0.013	0.209	0.174	0.053	0.009	8545.582	-0.109	
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10	9	19.557	25.448	302.253	69.957	0.094	1.824	1.772	0.132	6.792	18034.23	0	
11	10	19.074	25.424	361.005	91.438	0.15	2.893	2.818	0.224	3.623	20556.34	0.022	
12	11	18.474	25.273	387.922	127.981	0.192	4.28	4.261	0.324	3.641	23814.44	0.003	
13	12	18.175	26.715	391.198	160.398	0.249	6.405	6.324	0.432	3.644	28687.32	0.058	
14	13	17.102	27.23	392.577	190.542	0.169	8.849	8.762	0.621	3.661	34586.69	1.007	
15	14	15.241	29.112	389.129	212.51	0.226	10.949	10.818	0.794	3.67	40816.01	2.214	
16	15	13.067	31.332	383.476	228.014	0.32	11.416	11.277	0.823	3.684	46294.84	2.363	
17	16	10.998	33.786	386.549	240.511	0.306	10.825	10.702	0.774	3.682	49702.93	2.379	
18	17	9.457	36.077	388.951	251.539	0.279	10.209	10.096	0.73	3.681	51052.21	2.388	
19	18	8.079	38.085	389.229	260.861	0.269	9.822	9.719	0.698	3.671	51272.42	2.35	
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21	20	6.962	41.735	399.393	276.803	0.256	9.433	9.298	0.67	3.686	51049.09	2.081	
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24	23	5.849	46.202	413.018	296.851	0.253	9.285	9.157	0.669	3.681	50497.74	1.992	
25	24	5.687	47.418	417.036	302.961	0.249	9.209	9.083	0.653	3.689	50397.7	1.941	
26	25	5.889	48.093	419.84	309.135	0.249	9.191	9.071	0.649	3.693	50328.61	1.955	
27	26	6.234	49.853	423.27	314.802	0.253	9.289	9.149	0.66	3.691	50303.76	1.955	
28	27	6.189	51.075	425.455	320.133	0.253	9.275	9.138	0.668	3.687	50304.38	2.06	
29	28	5.888	52.294	428.82	325.129	0.251	9.241	9.082	0.666	3.689	50317.97	2.013	
30	29	6.179	53.392	429.04	329.821	0.251	9.224	9.08	0.662	3.698	50309.59	2.082	
31	30	6.52	54.468	432.383	335.307	0.252	9.225	9.068	0.66	3.689	50308.41	2.174	
32	31	6.524	55.493	434.291	339.437	0.252	9.246	9.086	0.664	3.692	50312.62	2.151	

Click Data Tab to Start a New Chart

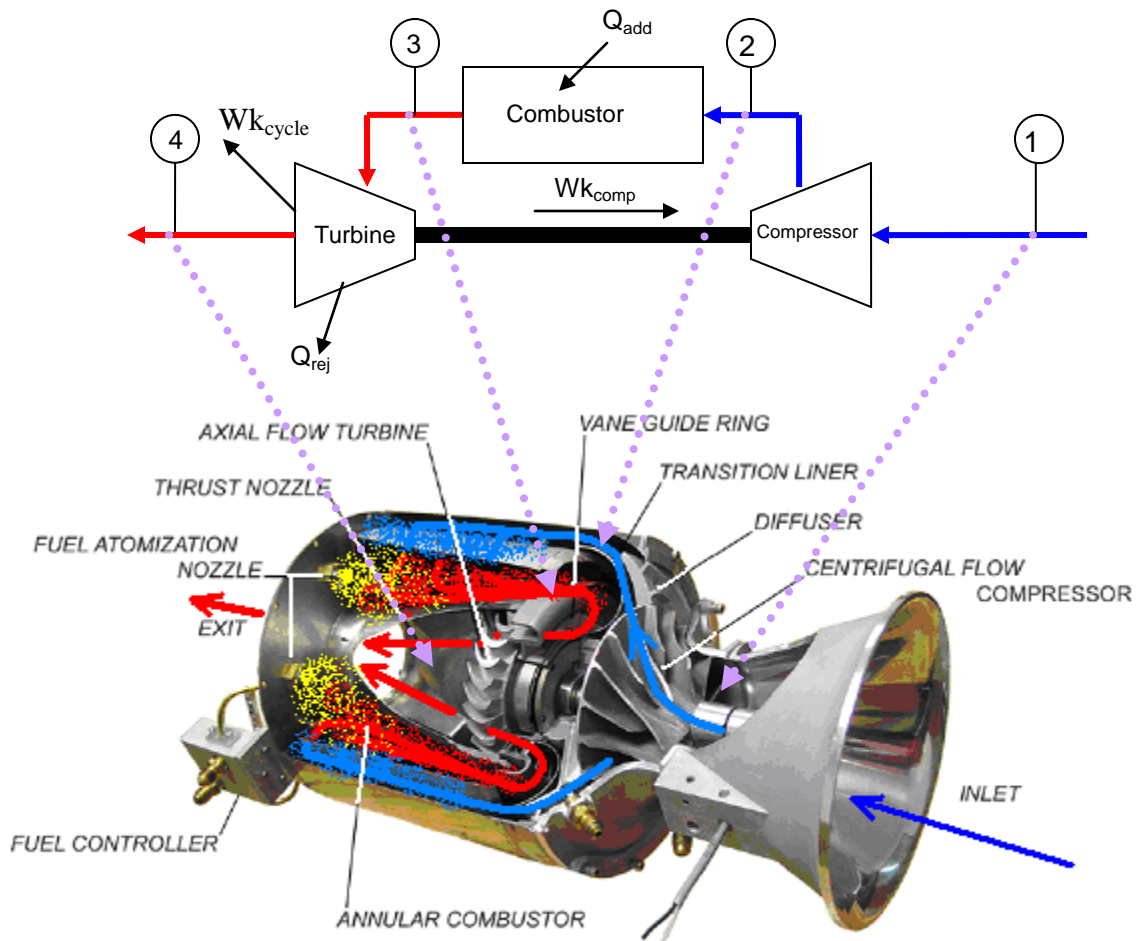
## Mini-Lab™ Gas Turbine Lab Experiment Manual

### Lab Session #3: System Analysis

**Purpose:** To perform system performance calculations using First Law Energy Conservation Equation for Steady State, Steady Flow Conditions (**SSSF**). The data for these calculations comes from the information plotted and recorded in the previous lab session

**Procedure:** Perform requested analysis and calculations.

### Schematic of Brayton Cycle for Gas Turbine and Cut Away of SR-30 Engine



**For the analysis point chosen in Lab Session #2, find the Specific Enthalpy at each Cycle Point from page 7(using air tables).**

1.) **For the Compression Stage, Find Specific Work Done by the Compressor (1-2).**

2.) **For Combustion Stage, Find Specific Energy Added by the Fuel (2-3).**

3.) **For the Turbine Expansion, Find the Specific Work of the Turbine (3-4).**

4.) **Find the Specific Work done by the Cycle .**

5. **Find the Thermodynamic Efficiency of the Cycle**

## **Mini-Lab™ Gas Turbine Power System Lab Experiment Manual**

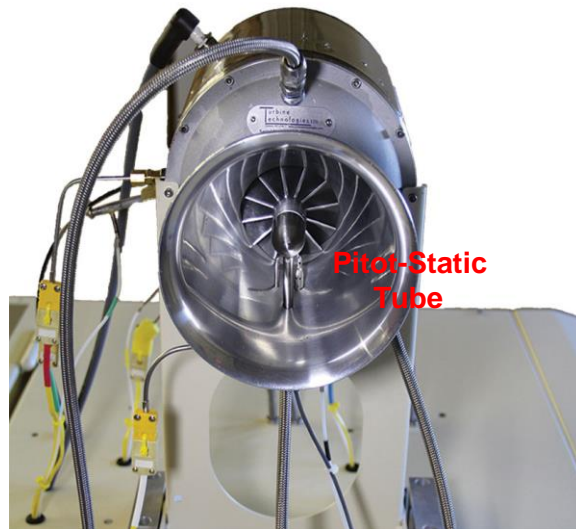
### **Lab Session #4: Performance Analysis**

**Purpose:** To perform system performance calculations of the engine at the compressor inlet and nozzle exit. The data for these calculations comes from the information recorded and plotted in a previous lab session

**Procedure:** Perform requested analysis and calculations at this location and operational point.

---

### **COMPRESSOR INLET**



What is the **Pitot-Static Recorded Pressure** (Compressor Inlet Pressure) and **Air Density** at this location and operating condition?

At pitot static location in engine intake bell, cross-sectional is:

Calculate the gas (air) **Velocity** into compressor at this operating condition.



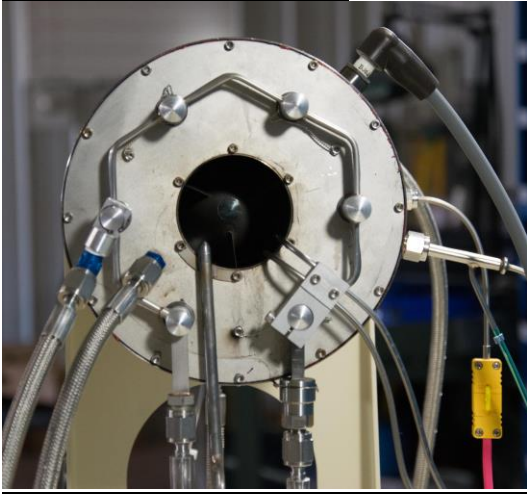
Calculate the **Volumetric Flow Rate** of air into compressor at this operating condition.

Calculate **Mass Flow Rate** of air into compressor at this operating condition.

Calculate the **Thrust** generated at this location and operating condition.

Calculate the **Mach Number** of the flow at this location and operating condition.

## **THRUST NOZZLE EXIT**



What is the **Pitot Ram Air Recorded Pressure** (Exhaust Gas Pressure) and **Air Density** at this location and operating condition?

Pitot Ram Air Recorded Pressure = 11.2 kPa

Calculate the gas (air) **Velocity** exiting the nozzle at this operating condition.

Calculate the **Volumetric Flow Rate** of air exiting the nozzle at this operating condition.

Nozzle cross-section area =  $0.0025\text{ m}^2$

Calculate **Mass Flow Rate** of air exiting the nozzle at this operating condition.

Calculate the **Thrust** generated at this location and operating condition.

Calculate the **Mach Number** of the flow at this location and operating condition.

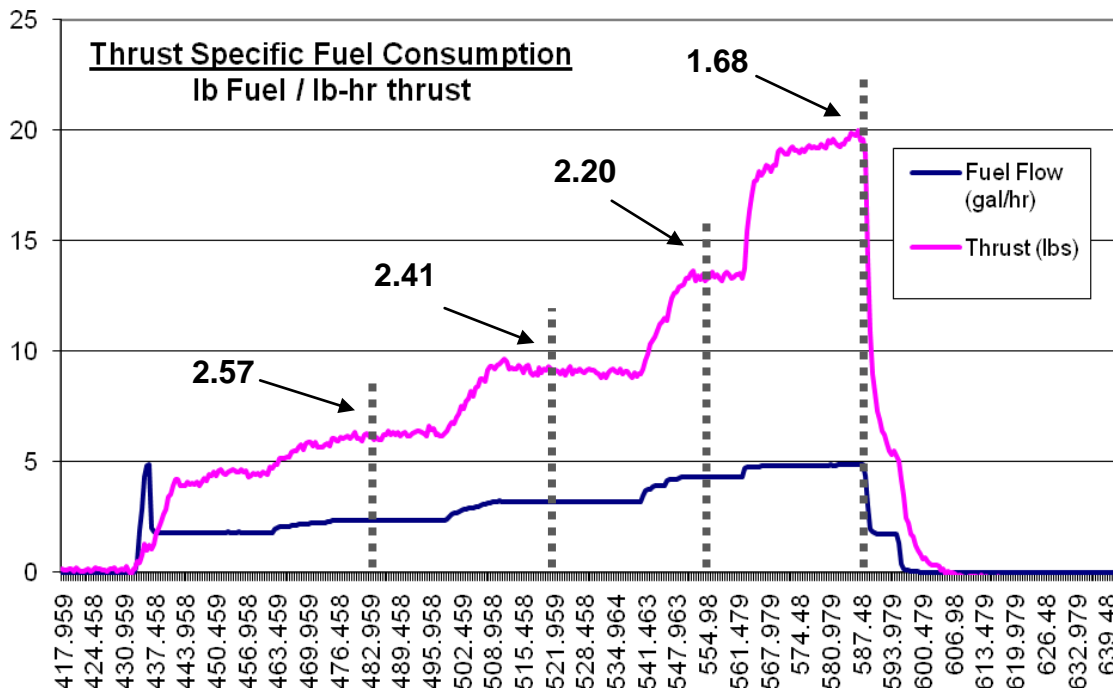
**Questions:**

Why is the calculated value of Thrust using pitot tube reading different than what is captured by system's load cell thrust measurement?

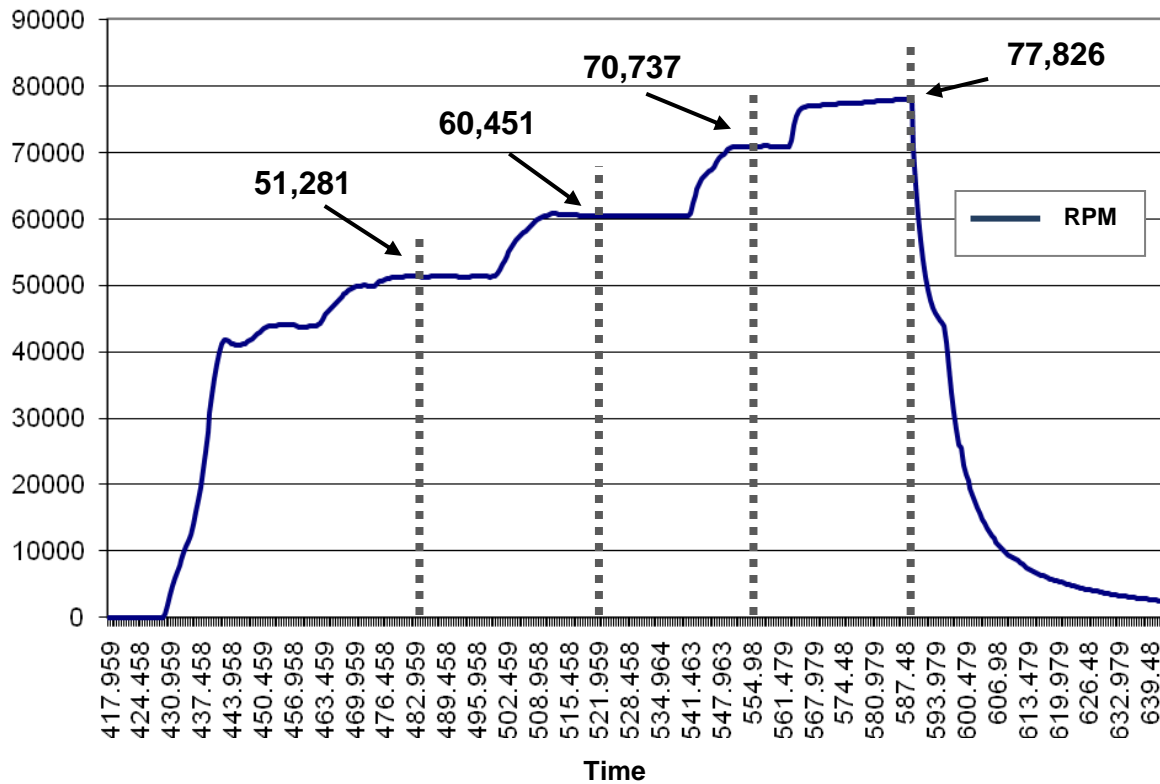
Does temperature of exhaust gases affect Mach Number?



### Fuel Flow Verses Thrust



### Engine RPM



**Mini-Lab™ Gas Turbine Lab Experiment Manual**  
**Lab Session #6: Jet Engine Propulsive Efficiency Analysis**

**Purpose:** To gain an understanding of the propulsive efficiency of a turbo-jet engine. The data for these calculations comes from the information recorded and plotted in a previous lab session

**Procedure:** Perform requested analysis and calculations that follow.

---

We have calculated our engine thrust when the unit is standing still in the lab. Now, let's turn our Mini-Lab™ Gas Turbine System into a go-kart (since your professor won't really let you do this, let's just imagine it). Let's assume we've replaced the casters with a remote steering wheel system and we took the unit out to an airport runway.

- 1.) If we fired the engine at the same maximum power setting we used in the lab and got the unit rolling 50 miles/hour (80.5 km/hr) down the runway, what is the propulsive efficiency of the unit?
  
  
  
  
  
  
  
  
  
  
- 2.) Since the unit is boxy, with a great deal of flat plate area causing drag, someone suggested attaching a sleek nose cone to the front of the vehicle. With the new nose cone, it was sent down the runway at the same power setting, reaching 100 miles/hour (161 km/hour). What is the new propulsive efficiency

- 3.) Someone suggested adding a sleek tail cone to the set-up and when it was sent down the runway in this configuration at the same power setting, it reached 150 miles/hour (241.5 km/hour). What is the new propulsive efficiency?
  
- 4.) Finally, a pair of swept wings and tail was added and the unit actually lifted off and flew at 200 miles/ hour (322 km/hour) in ground affect above the runway. What was the new propulsive efficiency?
  
- 5.) After it was all over the unit was returned to its original configuration and returned to the lab. It was fired up again and run at the same power setting that was used on the runway. What is the propulsive efficiency now?

**Questions:**

Knowing what you have learned about propulsive efficiency, which would be a better use of the same turbo-jet engine; putting it on an ultralight airplane with a maximum airframe speed of 80 miles/hour (129 km/hr) or one on an observation drone that cruises at 300 (483 km/hr) miles per hour?

What is the difference in propulsive efficiency between the two aircraft?