TurboGen[TM]
Gas Turbine Electrical Generation System
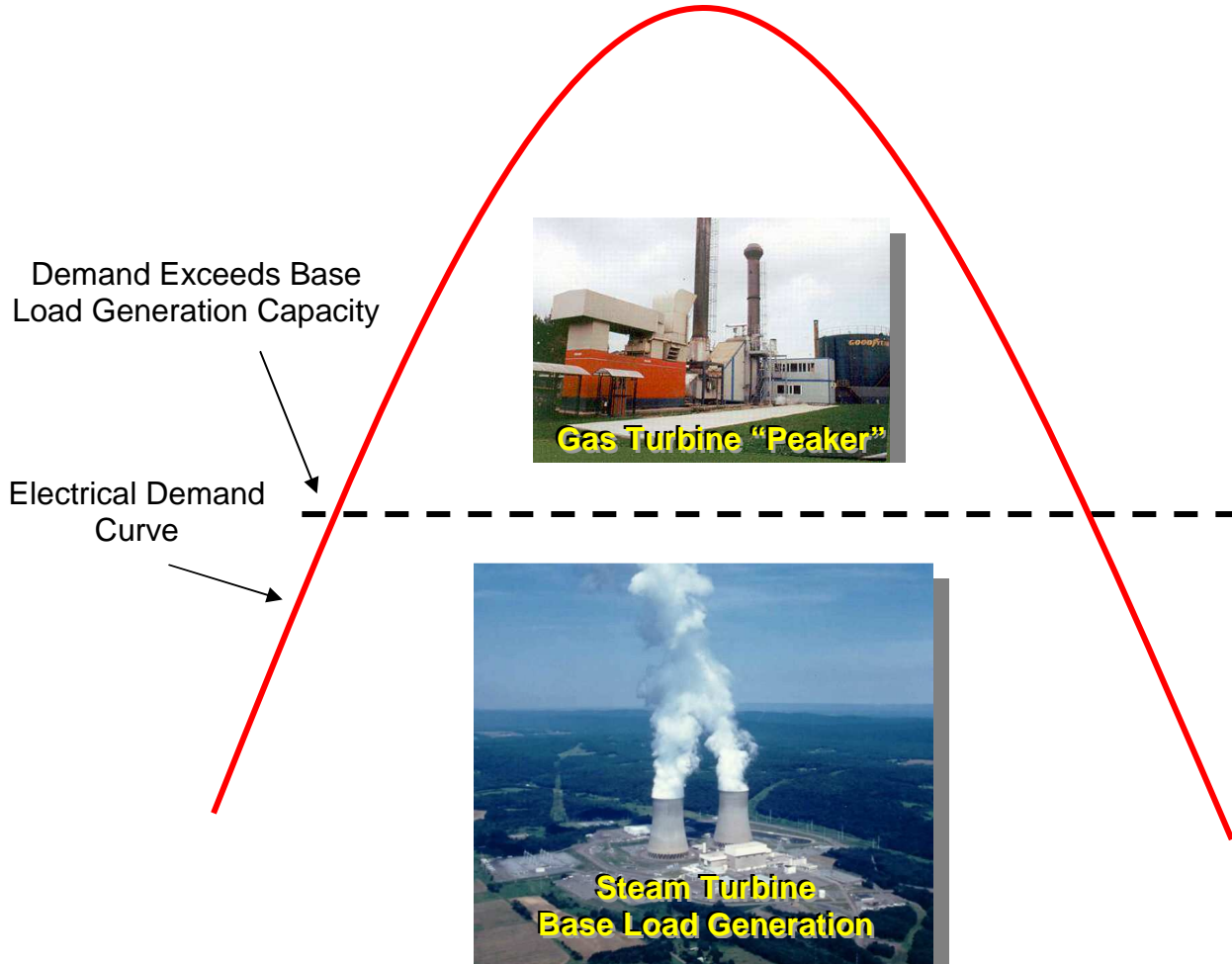## Sample Lab Experiment Procedure

Lab Session #1: System Overview and Operation

Purpose: To gain an understanding of the TurboGen[TM] Gas Turbine Electrical Generation System as a whole and details of engine and generator sensors and controls making up the system. This will prepare for operation of the system.
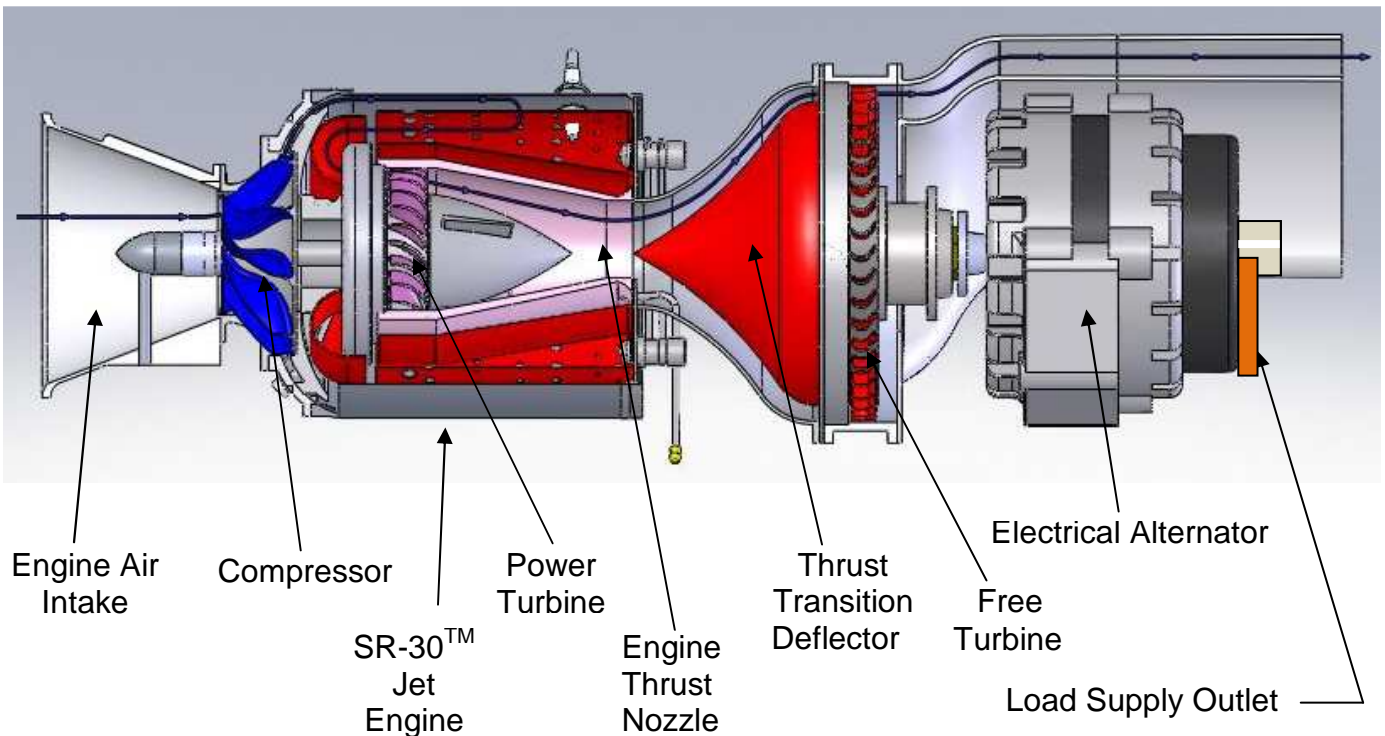
TurboGen^{TM} is a jet engine powered electrical generation system.

This type of generation is typically used by the Electrical Power Generation Industry as supplemental or "peaking" generation. Most electricity is generated by large coal, hydro or nuclear power plants. These are known as "base load" plants and supply the majority of electricity needs (typically known as demand). On high demand days (i.e., hot day with high air conditioning use), the demand can exceed the base load supply capabilities. When this happens, peaker plants start up to generate enough electricity to make up for the base generation shortfall. The term "peaker" relates to the electrical demand curve for the day; if the curve exceeds the base generation abilities, the peakers are started to supply the "peak", and are used until demand drops enough where base supply can handle it.
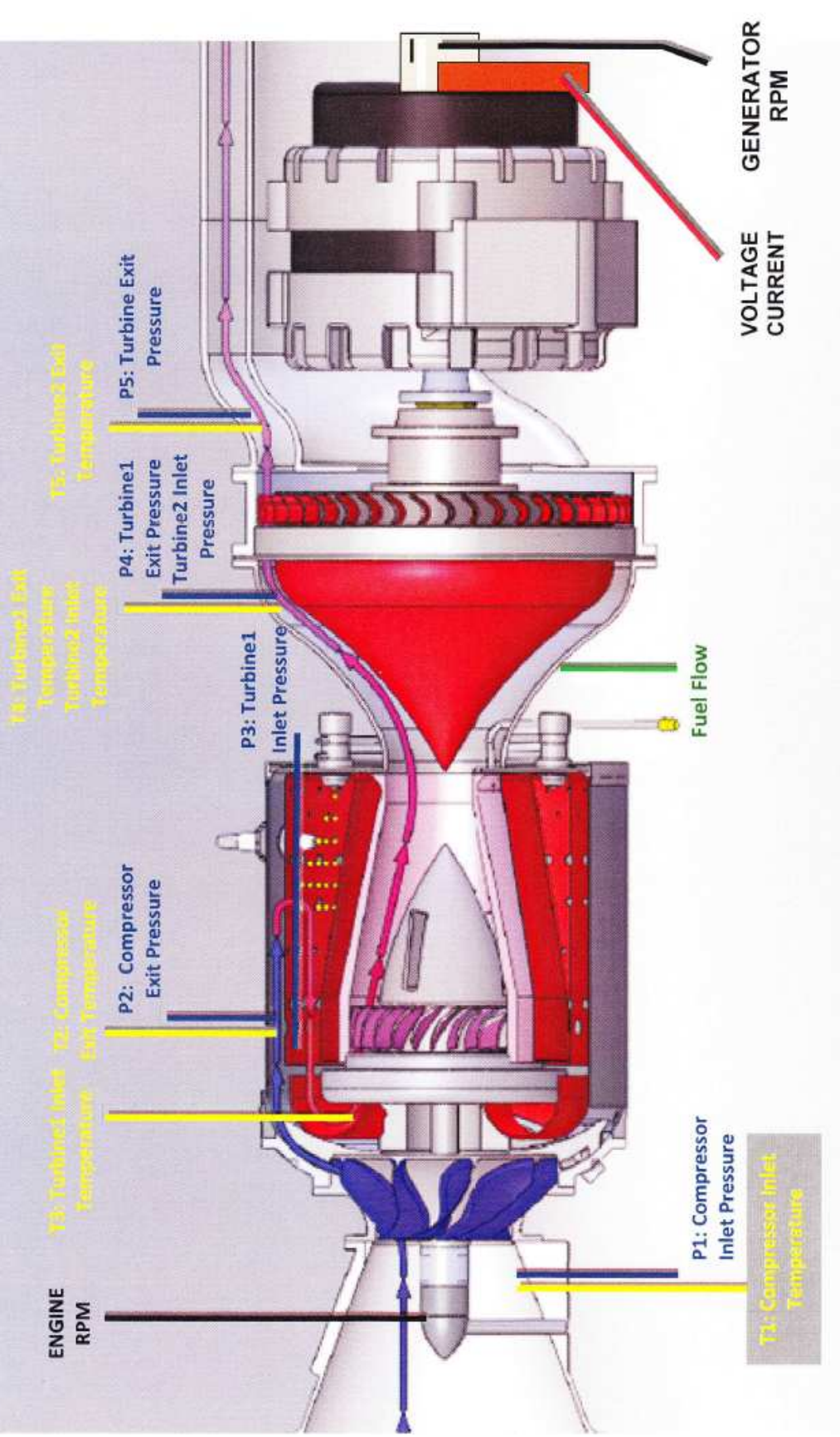
Demand Exceeds Base Load Generation Capacity

Electrical Demand Curve

Gas Turbine "Peaker"

Steam Turbine Base Load Generation

Turbine Technologies, Ltd.

How it works!

Engine Air Intake · Compressor · SR-30™ Jet Engine · Power Turbine · Engine Thrust Nozzle · Thrust Transition Deflector · Free Turbine · Electrical Alternator · Load Supply Outlet

Following the cutaway schematic; Air enters the intake of the SR-30™ Engine. It is compressed by the centrifugal compressor, mixed with fuel and combusted in the combustion chamber, creating thrust which drives the power turbine (the power turbine is connected directly to the compressor and drives it). The thrust then accelerates out the thrust nozzle. In a straight thrust engine, this would be the propelling force to move the object the engine is attached to (such as an aircraft). With TurboGen™, we direct the thrust through a thrust transition deflector, causing the thrust to drive another turbine wheel called a free turbine (not mechanically connected to engine, only thermodynamically connected). The free turbine drives an electrical alternator which generates electricity to drive an electrical load.

Strategic sensors measure operational conditions of the engine and generation system. The following shows sensor details (first for engine, then for generator).

Engine/Generator Sensor Locations

T4: Turbine3 Exit Temperature
Turbine2 Inlet Temperature

T5: Turbine2 Exit Temperature

P5: Turbine Exit Pressure

P4: Turbine1 Exit Pressure
Turbine2 Inlet Pressure

P3: Turbine1 Inlet Pressure

T3: Turbine1 Inlet Temperature

T2: Compressor Exit Temperature

P2: Compressor Exit Pressure

Fuel Flow

P1: Compressor Inlet Pressure

T1: Compressor Inlet Temperature

ENGINE RPM

GENERATOR RPM

VOLTAGE CURRENT

SR-30 Gas Turbine Engine / TG-2000 Electrical Generator
System Sensor Locations

Engine RPM Tachometer Generator: (Displayed on Panel and Data Acquisition Screen as N1 RPM).

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: Turbine1 Inlet Pressure (Displayed on Panel and Data Acquisition Screen)

T3: Turbine1 Inlet Temperature (Displayed on Panel as TIT and Data Acquisition Screen)

P4: Turbine1 Exit Pressure/Turbine2 Inlet Pressure (Displayed on Data Acquisition Screen)

T4: Turbine1 Exit Temperature/Turbine2 Inlet Temperature (Displayed on Data Acquisition Screen)

P5: Turbine2 Exit Pressure (Displayed on Data Acquisition Screen)

T5: Turbine2 Exit Temperature (Displayed on Panel as EGT and Data Acquisition Screen)

Fuel Pressure: (Displayed on Panel)

Generator RPM Tachometer Generator: (Displayed on Panel and Data Acquisition Screen as N2 RPM).

Voltage and Current: Displayed on Data Acquisition Screen as Voltage, Current and Power

TurboGen Virtual Instrument Panel

TurboGen^{TM} Power System Control Panel

OPERATIONAL CONTROLS –TurboGen Operator Panel
1. **MASTER SWITCH, KEYED:** Secured control of access and engine operation
2. **GREEN START BUTTON:** Automated Engine Start, Multiple Functions
3. **RED STOP BUTTON:** Immediate EngineStop, Multiple Functions
4. **T-HANDLED POWER LEVER:** Engine RPM/Thrust Control, Forward Increases
5. **LOAD LEVER (Blue Handle):** Controls Excitation Loading on Electric Alternator
6. **AUTOSTART LCD DISPLAY:** Real Time System Status Automatically Shuts Off Unit if Parameters Exceeded.

DIGITAL and ANALOG OPERATOR DISPLAY: Direct visual indication of the following:
7. **Digital Turbine Inlet Temperature (TIT)**
8. **Digital Engine Rotational Speed (RPM)**
9. **Digital Generator Turbine Rotational Speed (RPM)**
10. **Analog Oil Pressure**
11. **Analog Engine Pressure (P3)**
12. **Analog Fuel Pressure**
13. **Analog Starting Air Pressure**
14. **Generator Overspeed Warning Light**

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

Determine the fuel you are using to power your system. _JET A_

What is the energy content per unit volume of fuel? _18,610 BTU/lb, 43.28 MJ/kg_

What is the fuel's density per unit volume? _6.76 lb/gal, 0.81 kg/l_

Barometric Pressure

What is the present barometric pressure in your area?

TODAY IT IS 30.02 IN. HG = 0.101373 MPa = 14.7 PSI

Why would barometric pressure be important when planning to operate the Gas Turbine System? _ALL PRESSURE READINGS ARE GAGE PRESSURE._
THERMODYNAMIC PROPERTY TABLE DATA IS BASED ON
ABSOLUTE PRESSURE: $P_{ABS} = P_{ATM} + P_{GAGE}$

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

ONE SOURCE IS: WWW.WUNDERGROUND.COM (CHECK "CURRENT CONDITIONS")

System Operation

Purpose: Conduct pre-start, start-up, operation, data gathering and shut down of TurboGen™ Gas Turbine Electrical Generation System.

Procedure:
Utilize **TurboGen™ 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).**

Run Engine throttle up to full speed with Load Lever in pinned position (Fixed Excitation Current).

Optional: After full run-up in pinned position, unpin Load Lever and slowly bring it forward (increasing Excitation Current) and then slowly pushing it back (decreasing Excitation Current). A variety of speeds and operating load condition scenarios can be run during this time.

<mark>**WARNING!! CHECK OPERATOR'S MANUAL FOR LOAD LEVER/GENERATOR OVER-SPEED CAUTIONS!**</mark>

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 TurboGen Software and default settings as supplied with the TurboGen. 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 TurboGen Software by double-clicking on the TurboGen 1.0 shortcut icon located on the Windows Desktop. TurboGen 1.0 will start with the *Main Display/Control* and *Channel Configuration Window* displayed.
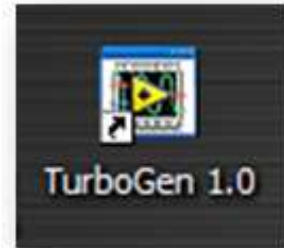
TurboGen Launch Icon

NOTE: The computer must be connected to the TurboGen USB port prior to opening the TurboGen software.
The TurboGen configuration software is dependent upon the specific DAQ Module serial number as installed in the TurboGen 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.

To verify that the software is communicating with the DAQ Module, open **Measurement and Automation** from desktop. In menu tree, click on **Devices and Interfaces**, then, click on **NI DAQ 6218.** This provides and verifies the proper serial number for the on board DAQ system and also verifies that a proper connection to that device is being made.
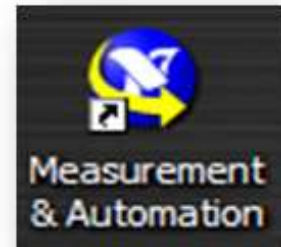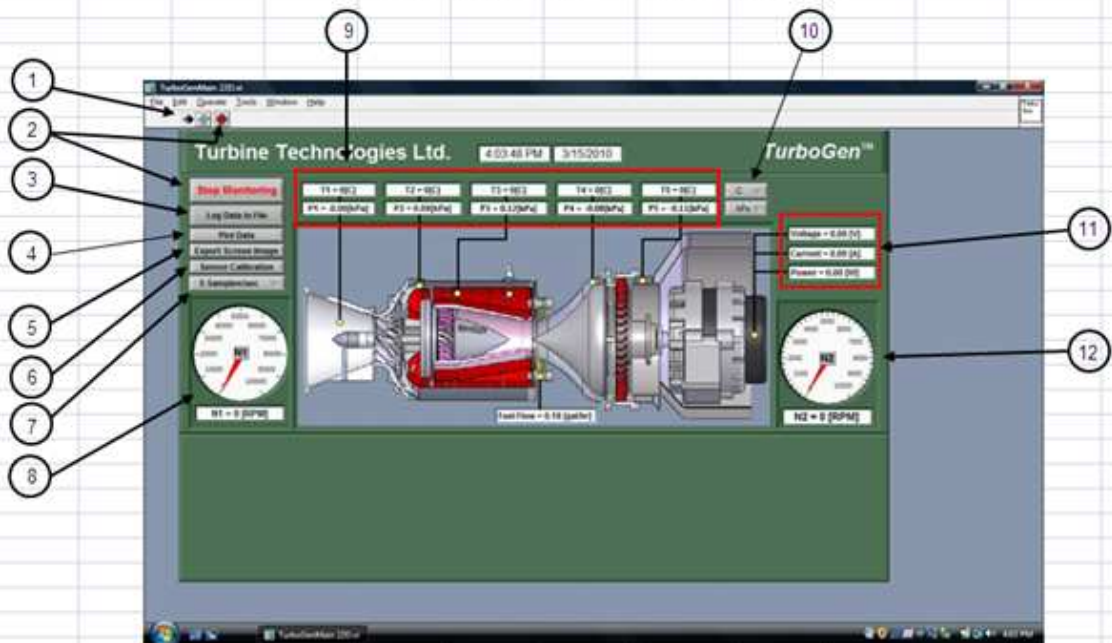
Measurement and Automation
Launch Icon

TO PERFORM THE FOLLOWING FUNCTIONS:

- **Virtual Instrument Panel Software Controls overview are on page 9**
- **Logging Data to File is shown on Page 10**
- **Displaying Plot Feature is shown on Page 10**

Overview of the Software Controls

1 Click this arrow to Monitor data
2 Click button or stop sign to stop monitoring data.
3 Click to log data to a file.
4 Toggles real time data plot on and off
5 Saves screen shot of all the data at any period of time.
6 Allows reset of any sensor to it's "0" point
7 Select sampling rate from 0.1 to 5 samples per second.
8 Displays real time Gas Turbine RPM

9 Real time Temperatures and pressures display.
10 °C to °F and Psig to kPa toggle.
11 Displays real time generator power output.
12 Displays real time free Turbine/Generator RPM.

Logging Data to a File and Displaying the Plot Feature

To log data to a file for later viewing and analysis, click "**Log Data to File**" button and this window will appear. Enter a file name and click "**OK**" and the file will be saved in "C:\desktop\ **My Documents\TurboGen**". Click on it again to stop saving data.

Click on "**Plot Data**" and the following screen appears along with all the options for formatting the graph. Data will be plotted at the selected sample rate(#6). The options are sensor selection, line style, background color and auto scaling for both X and Y axis.
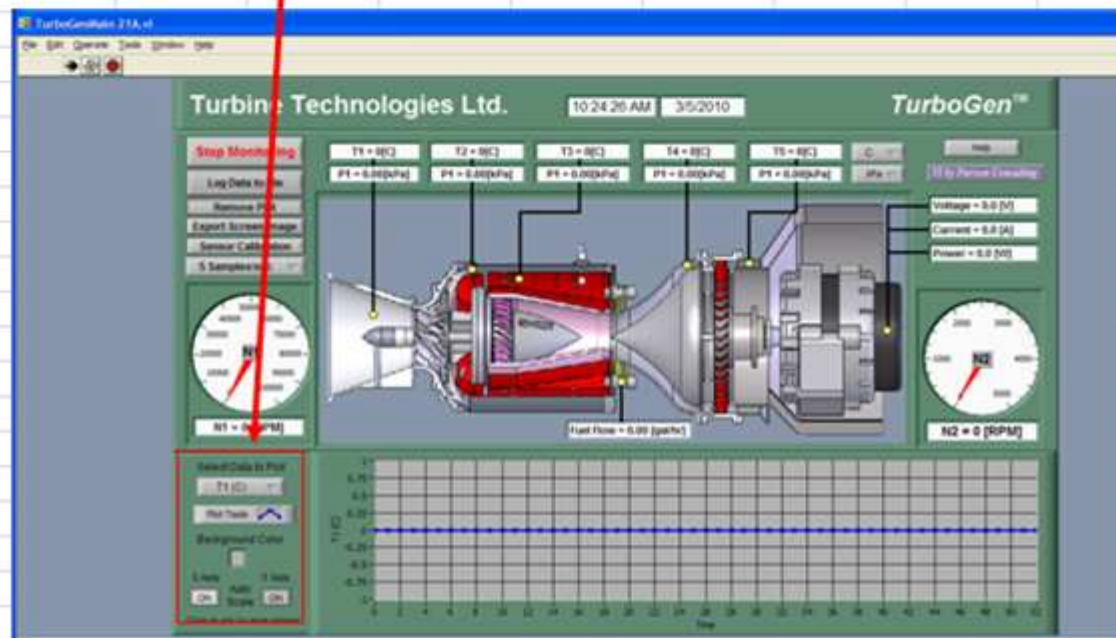
TurboGen^{TM} Gas Turbine Electrical Generation System Experiment Manual

Lab Session #2: TurboGen^{TM} Data Run Plots

<u>Purpose</u>: Graphically plot TurboGen^{TM} Run Data in preparation for system analysis and performance calculations.

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

_____

<u>Plot the following, utilizing MS-Excel Spreadsheet Program:</u>
- Compressor Inlet/Outlet Pressure vs. Time
- Compressor Inlet/Outlet Temperature vs. Time
- Turbine1 (N1) Inlet/Outlet Pressure vs. Time
- Turbine1 (N1) Inlet/Outlet Temperature vs. Time
- Turbine 2 (N2)Inlet/Outlet Pressure vs. Time
- Turbine 2 (N2) Inlet/Outlet Temperature vs. Time
- Fuel Flow vs. Time
- Engine RPM vs. Time
- Generator RPM vs. Time
- Generator Voltage vs. Time
- Generator Current vs. Time
- Generator Power vs. Time

Print out plots and order them as listed.

Choose and mark an <u>analysis point</u> 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: _3/15/10_
- Time: _11:20 AM CST_ (306.2 = PARTICULAR ANALYSIS POINT)
- Atmospheric Pressure: _14.7 PSI_
- Compressor Inlet Pressure: _0.02 psig, 14.72 psia, 0.104 MPa_
- Compressor Exit Pressure: _7.24 psig, 21.94 psia, 0.156 MPa_
- Turbine1 Inlet Pressure: _7.42 psig, 22.12 psia, 0.157 MPa_
- Turbine1 Exit Pressure: _0.41 psig, 15.11 psia, 0.107 MPa_   Same {
- Turbine2 Inlet Pressure: _0.41 psig, 15.11 psia, 0.107 MPa_
- Turbine2 Exit Pressure: _0.50 psig, 15.20 psia, 0.108 MPa_
- Fuel Flow: _2.71 GPH, 10.26 L/hr_
- Engine RPM: _47,222_
- Compressor Inlet Temperature: _20.4°C, 293°K, 68.7°F, 528.4°R_
- Compressor Exit Temperature: _145.14°C, 418°K, 293.2°F, 752.9°R_

- Turbine1 Inlet Temperature: _532.9 °C, 805 °k_
- Turbine1 Exit Temperature: _488.48 °C, 761 °k_
- Turbine2 Inlet Temperature: _488.48 °C, 761 °k_
- Turbine2 Exit Temperature: _540.16 °C, 813 °k_
- Turbine2 RPM: _9,597 RPM_
- Generator Voltage: _13.57 V_
- Generator Current: _28.43 A_

Importing Acquisition Data into MS-Excel Spreadsheet

A convenient way to analyze TurboGen 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: MS-Excel on computer desktop
Click: File
Click: Open
Click: C-Drive
Click: Program Files
Click: TurboGen
Click: "All Files" under "Files of Type"
Click: Next (In Text Import Window, Step 1 of 3)
Click: Next (In Text Import Window, Step 2 of 3)
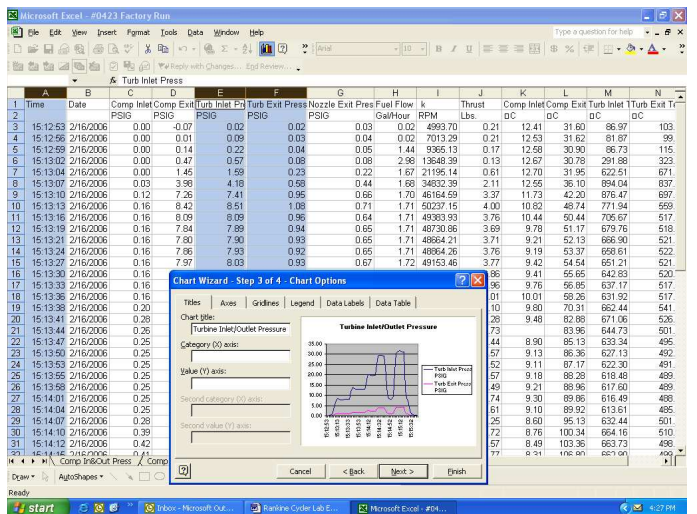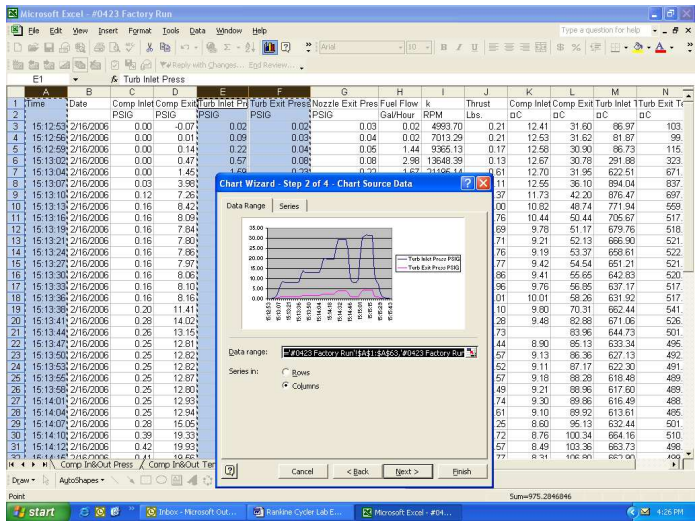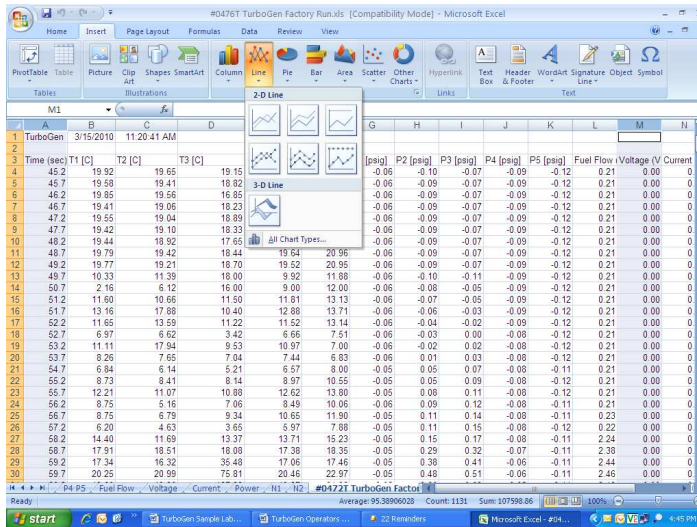**Click: Next (In Text Import Window, Step 3 of 3)**

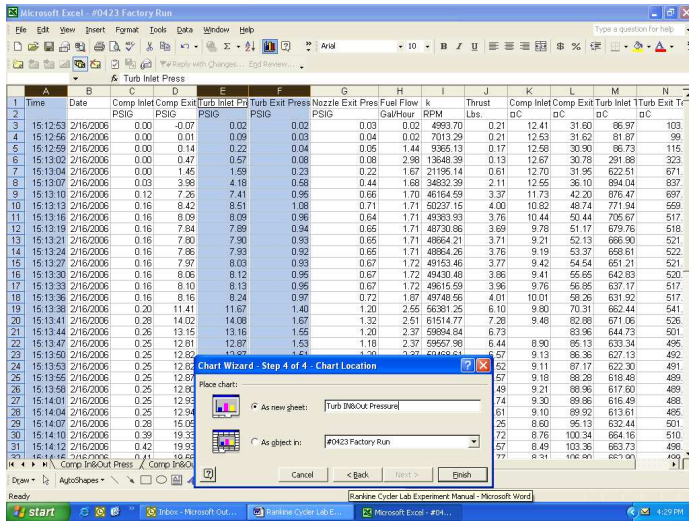Your data will now be in spreadsheet form.
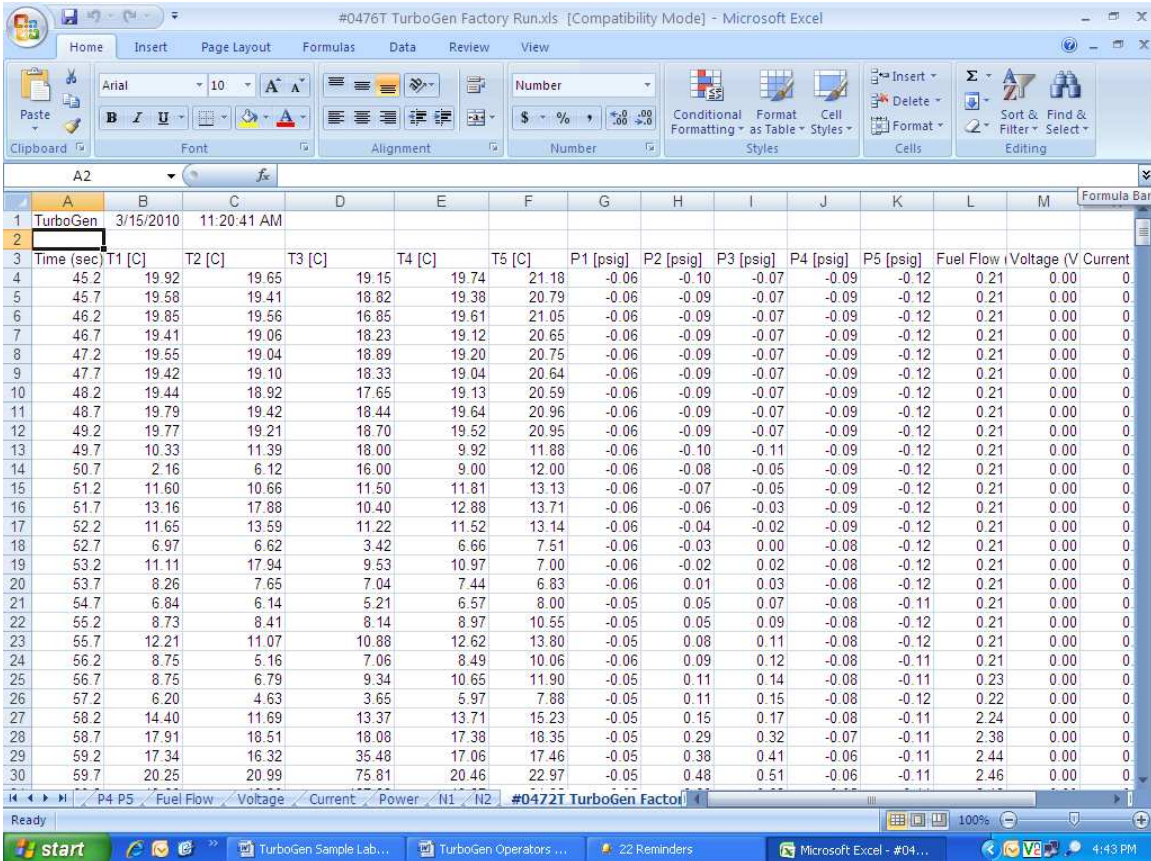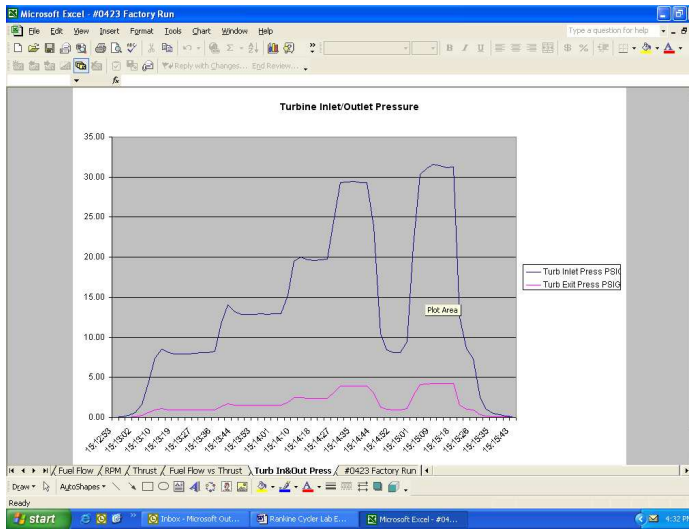
Graphing Data using MS-Excel Spreadsheet Graphing Function (Example)
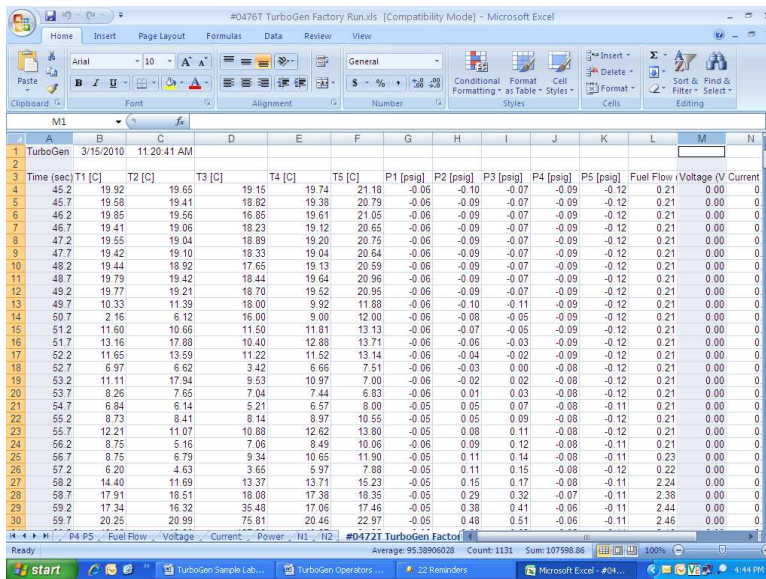
Highlight columns of data desired for graph. For this example, the Time and Voltage column data will be plotted.

Insert
Chart Type: Line
Chart Sub Type: Line (first one)
Next

Accept data range listed by choosing: Next

Choose Graph Options and Labels

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Turbine Technologies, Ltd.

Name Graph, Click as
New Sheet, Finish

Completed Turbine Inlet and
Outlet Pressure Graph

TurboGen™ Gas Turbine Electrical Generation 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
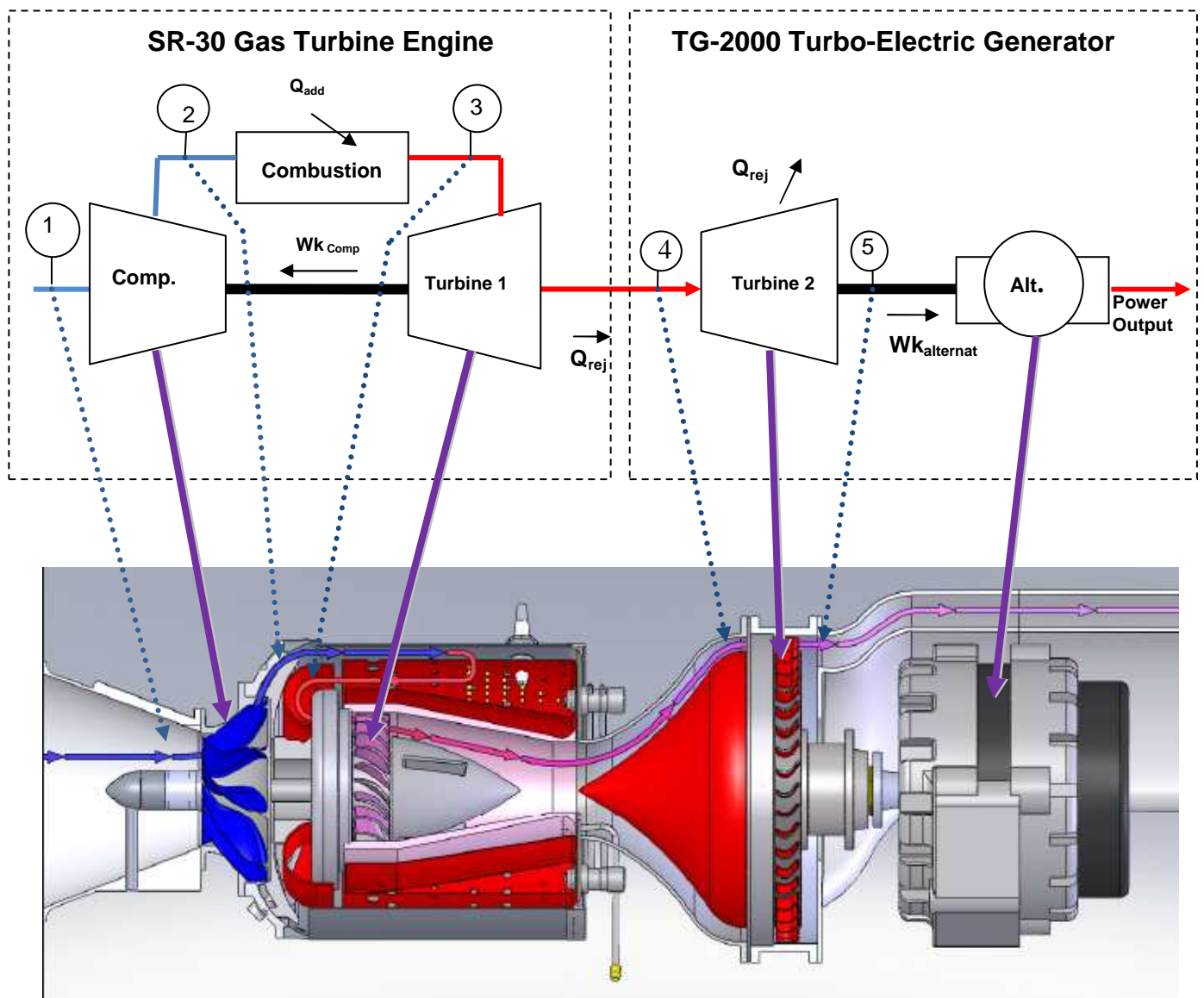
For the analysis point chosen in Lab Session #2, find the Specific Enthalpy at each Cycle Point (using air tables).

MOLECULAR MASS OF AIR
= 28.967

$H_1 =$ 8,501 kJ/kg·mol = 293 kJ/kg
3,683 BTU/lb·mol = 127 BTU/lb

$h_2 =$ 12,150 kJ/kg·mol = 419 kJ/kg
5,221 BTU/lb·mol = 180 BTU/lb

$h_3 =$ 23,980 kJ/kg·mol = 827 kJ/kg
10,305 BTU/lb·mol = 355 BTU/lb

$h_4 =$ 22,580 kJ/kg·mol = 779 kJ/kg
9,703 BTU/lb·mol = 335 BTU/lb

$h_5 =$ 24,230 kJ/kg·mol = 836 kJ/kg
10,402 BTU/lb·mol = 359 BTU/lb

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

$$wk_{comp} = h_2 - h_1 = 419 \text{ kJ/kg} - 293 \text{ kJ/kg} = \underline{126 \text{ kJ/kg}}$$
$$= 180 \text{ BTU/lb} - 127 \text{ BTU/lb} = \underline{53 \text{ BTU/lb}}$$

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

$$q_{ADD} = h_3 - h_2 = 827 \text{ kJ/kg} - 419 \text{ kJ/kg} = \underline{408 \text{ kJ/kg}}$$
$$= 355 \text{ BTU/lb} - 180 \text{ BTU/lb} = \underline{175 \text{ BTU/lb}}$$

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

$$wk_{TURB1} = h_4 - h_3 = 779 \text{ kJ/kg} - 827 \text{ kJ/kg} = \underline{-48 \text{ kJ/kg}}$$
$$= 335 \text{ BTU/lb} - 355 \text{ BTU/lb} = \underline{-20 \text{ BTU/lb}}$$

4.) Find the Specific Work done by the Power Turbine Cycle.

$$wk_{CYCLE} = wk_{TURB1} + wk_{comp} = h_3 - h_4 + h_1 - h_2$$
$$= 827 - 779 + 293 - 419 = \underline{-78 \text{ kJ/kg}}$$
$$= 355 - 335 + 127 - 180 = \underline{-33 \text{ BTU/lb}}$$

5. Find the Thermodynamic Efficiency of the Power Turbine Cycle.

$$\eta_T = \frac{wk_{CYCLE}}{q_{ADD}} \times 100 = 80 \text{ kJ/kg} / 596 \text{ kJ/kg} \times 100 = \underline{13.4\%}$$
$$= 34 \text{ BTU/lb} / 256 \text{ BTU/lb} \times 100 = \underline{13.4\%}$$

6. For Free Turbine Expansion, Find Specific Work of Free Turbine (4-5).

$$wk_{TURB2} = h_5 - h_4 = 836 \text{ kJ/kg} - 779 \text{ kJ/kg} = \underline{57 \text{ kJ/kg}}$$
$$= 359 \text{ BTU/lb} - 335 \text{ BTU/lb} = \underline{24 \text{ BTU/lb}}$$

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Lab Session #4: Engine 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

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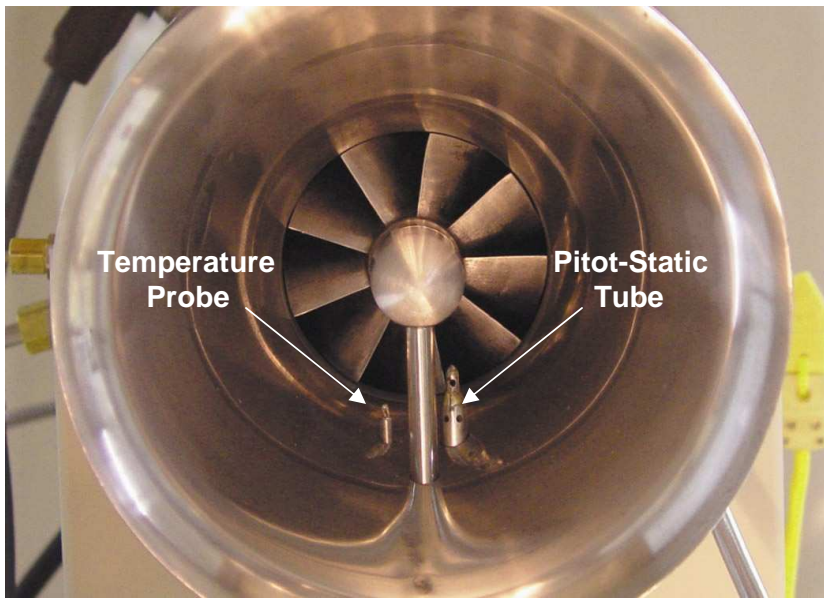
What is the **Pitot-Static Recorded Pressure** (Compressor Inlet Pressure) and **Air Density** at this location and operating condition?

AT PITOT STATIC LOCATION IN ENGINE INTAKE BELL, CROSS-SECTIONAL AREA:

$$A_{BELL\ OPENING} = \pi \left(\frac{2.6''}{2}\right)^2 - \pi \left(\frac{.75''}{2}\right)^2 = 4.87\ in^2 = 0.0338\ FT^2 = 0.00311\ m^2$$

(RPM GEN HOUSING)

PITOT-STATIC RECORDED PRESSURE = 0.02 PSIG = 14.68 PSIA = 0.000138 MPa = 138 N/m²

FOR $\begin{array}{l} T = 528.4°R \\ P = 14.68\ PSIA \end{array}$ $\mathcal{N} = 385.9\ \frac{FT^3}{lb\cdot mol}$ $\rho = \frac{1}{\mathcal{N}} = \frac{(1\ lb)(28.967) \leftarrow mol.\ wt.}{385.9\ FT^3} = \underline{0.075\ lb/FT^3}$

FOR $\begin{array}{l} T = 293°K \\ P = 0.1012\ MPa \end{array}$ $\mathcal{N} = 16.96\ \frac{m^3}{kg\cdot mol}$ $\rho = \frac{1}{\mathcal{N}} = \frac{(1\ kg)(28.967)}{24.07\ m^3} = \underline{1.203\ kg/m^3}$

$\begin{array}{l} \updownarrow\ BASED\ ON \\ P_{ABS} = 14.68\ PSIA \end{array}$

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

$$V = \sqrt{\frac{2 P_{DYN}}{\rho}} = \sqrt{\frac{(2)(0.02 \ lb/in^2)(144 \ in^2/ft^2)}{(0.075 \ lb/FT^3)(s^2/32.174 \ FT)}} = \underline{49.7 \ FT/s}$$

$$= \sqrt{\frac{(2)(138 \ kg \cdot m/s^2 \cdot m^2)}{1.203 \ kg/m^3}} = \underline{15.14 \ m/s}$$

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

$$Q = AV = (4.87 \ in^2)(FT^2/144 \ in^2)(49.7 \ FT/s) = \underline{1.68 \ FT^3/s}$$
$$= (0.00311 \ m^2)(15.14 \ m/s) = \underline{0.047 \ m^3/s}$$

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

$$\dot{m} = \rho AV = \rho Q = (0.075 \ lb/FT^3)(1.68 \ FT^3/s) = \underline{0.126 \ lb_m/s}$$
$$= (1.203 \ kg/m^3)(0.047 \ m^3/s) = \underline{0.056 \ kg/s}$$

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

$$M = \frac{V}{\underset{\text{SPEED OF SOUND}}{\sqrt{g_c \left(\frac{c_p}{c_T}\right) RT}}_{AIR}} = \frac{49.7 \ FT/s}{\sqrt{\left(32.174 \ \frac{FT \cdot lb_m}{s^2 \ lb_f}\right)(1.4)\left(53.3 \ \frac{FT \cdot lb_f}{lb_m \ °R}\right)(498.67 \ °R)}} = \underline{0.045}$$

$$= \frac{15.14 \ m/s}{\sqrt{(1.4)(287 \ J/kg \ °K)(293 \ °K)}} = \underline{0.045}$$

Purpose: To determine optimal operational settings for the SR-30 Gas Turbine Engine to calculate Power Specific Fuel Consumption in the process of generating Electricity.

Procedure: Perform requested analysis and calculations that follow.

TurboGen generates electricity by thermodynamically spinning a turbine wheel, which drives an electric alternator. A basic electric schematic of the electric alternator system is shown in Figure 1.

The alternator consists of two basic components; a rotor and a stator. The rotor is an electromagnet (not permanent), so it needs **Excitation Current** for it to generate electricity. The rotor spins, creating a voltage

The rotor consists of a coil of wire wrapped around an iron core. Current through the wire coil - called "field" current - produces a magnetic field around the core. The strength of the field current determines the strength of the magnetic field. The

Figure 1: Electric Alternator

field current is D/C, or direct current. In other words, the current flows in one direction only, and is supplied to the wire coil by a set of brushes and slip rings. The magnetic field produced has, as any magnet, a north and a south pole. The rotor is driven by the alternator pulley, rotating as the engine runs, hence the name "rotor."

Surrounding the rotor is another set of coils, three in number, called the stator. The stator is fixed to the shell of the alternator, and does not turn. As the rotor turns within the stator windings, the magnetic field of the rotor sweeps through the stator windings, producing an electrical current in the windings. Because of the rotation of the rotor, an alternating current is produced. As, for example, the north pole of the magnetic field approaches one of the stator windings, there is little coupling taking place, and a weak current is produced, As the rotation continues, the magnetic field moves to the center of the winding, where maximum coupling takes place, and the induced current is at its
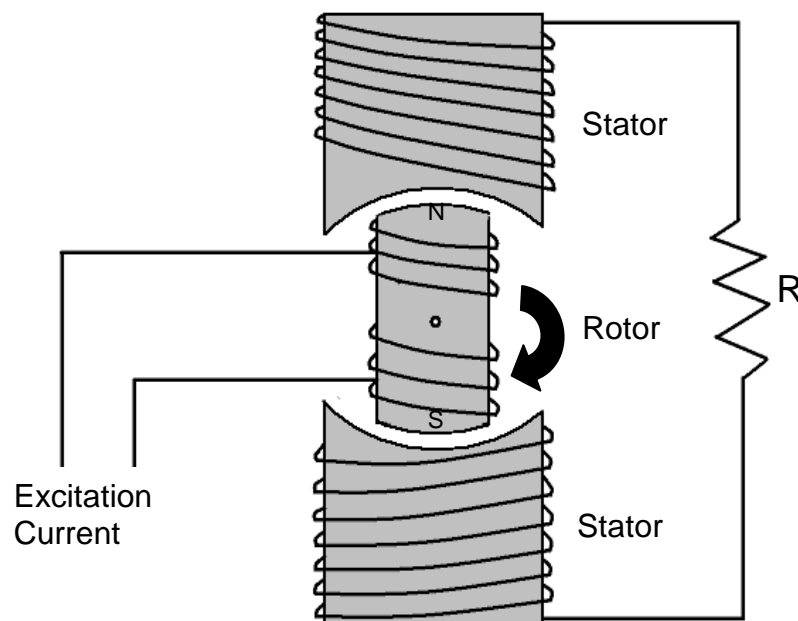
peak. As the rotation continues to the point that the magnetic field is leaving the stator winding, the induced current is small. By this time, the south pole is approaching the winding, producing a weak current in the opposite direction. As this continues, the current produced in each winding plotted against the angle of rotation of the rotor has the form shown in figure 2. The three stator windings are spaced inside the alternator 120 degrees apart, producing three separate sets, or "phases," of output voltages, spaced 120 degrees apart, as shown in figure 3.

A Resistive Load "R" completes the circuit as shown in Figure 1.

FIGURE 2: OUTPUT VOLTAGE vs DEGREES OF ROTATION

Calculat

FIGURE 3: OUTPUT VOLTAGE vs DEGREES OF ROTATION
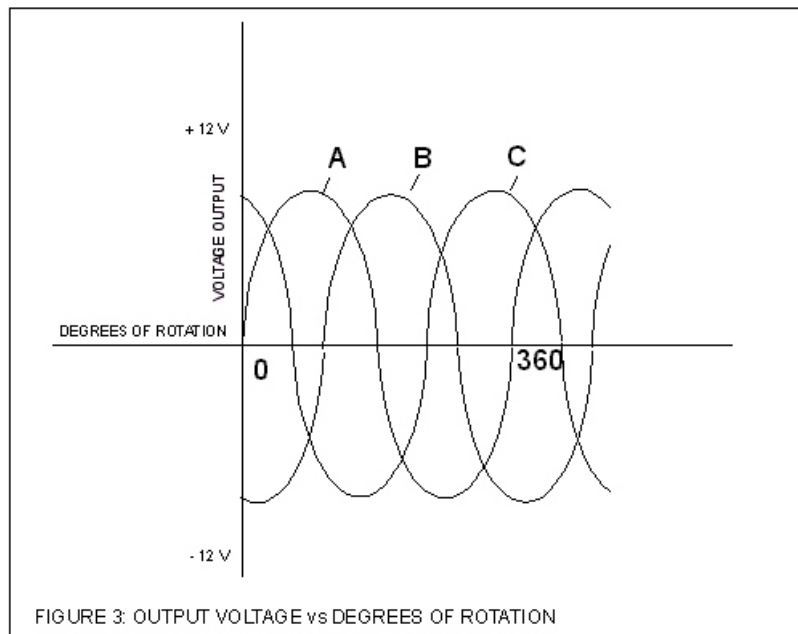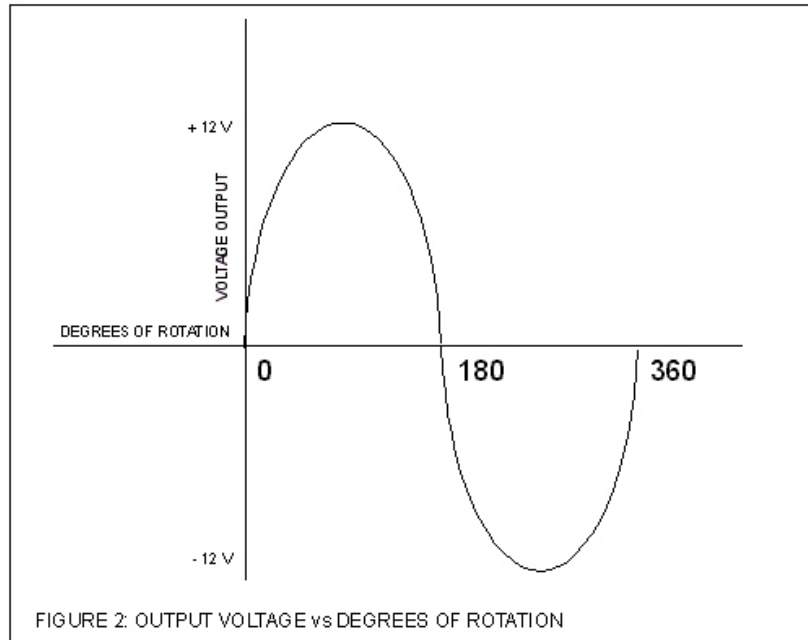
Power Specific Fuel Consumption is a measure of fuel consumption of the engine divided by the electric power produced by the generator.

When the TurboGen was run and data gathered, the optional strategy was to run the system with the Load Lever pinned (mid-range excitation current) and then unpin the lever and increase excitation to maximum current, then reduce it to minimum current. For the following analysis, a data run with all three options is used **(See plotted graphs on pages 25 - 27).** It can be seen that a pinned-only option can still be analyzed.

1. Using your operational run data plots, pull up and print the following graphs:
   - N1 RPM (Engine RPM) plotted over Time.
   - N2 RPM (Generator RPM) plotted over Time
   - Voltage over Time
   - Current over Time
   - Power over Time
   - Fuel Flow over Time

2. Plot analysis points of interest (similar to those shown on graph) for
   - Load Lever Pinned
   - Load Lever Maximum Excitation
   - Load Lever Minimum Excitation

Reasonably exact values can be extracted from your Excel data by lining up a graphical time stamp with a particular time line in the data.

3. Looking at data values while the excitation current Load Lever was in the pinned position, pick a specific time marker to view conditions: • • • • • • • • • • • • • • • •

Time Marker: *240 s*

Gas Turbine RPM (N1): *66,547 RPM*

Generator Turbine RPM (N2): *820 RPM*

Speed ratio: *81 : 1*

Fuel Flow: *6.22 GPH*

Voltage Output: *4.12 V*

Current Output: *22.3 A*

Resistance of fixed Resistive Element: R=V/I: *4.12/22.3 = 0.184 Ω*

Power Output = IV: $(22.3 A)(4.12 V) = 91.86 W$

To hold at this RPM, calculate Power Specific Fuel Consumption:

$96.6 W \times 1 HR = 96.6 \text{ watt} \cdot hr$

$PSFC = 96.6 \text{ w} \cdot h / 6.22 \text{ GPH} = 15.53 \text{ w} \cdot h / GAL$

ENERGY CONVERSION EFFICIENCY:

$15.53 \text{ w} \cdot h \times 3.414 \text{ BTU} / \text{w} \cdot h = 53 \text{ BTU}$

$6.22 \text{ GPH} \times 6.67 \text{ lb/gal} \times 18,610 \text{ BTU/lb} = 772,080$

$53 \text{ BTU} / 772,080 \text{ BTU} = \underline{0.0064\%}$

4. Let's go to a marker where excitation current Load Lever was loaded to maximum excitation current: • • • • • • • • • • • • •

Time Marker: $254 s$

Gas Turbine RPM (N1): $48,091 \text{ RPm}$

Generator Turbine RPM (N2): 736 RPm

Speed ratio: $65:1$

Fuel Flow: 2.74 GPH

Voltage Output = V: $3.11 V$

Current Output = I: $16.82 A$

Resistance of fixed Resistive Element: R=V/I: $3.11 V / 16.82 A = 0.184$

Power Output = IV: $(16.82 A)(3.11 V) = 52.3 \text{ WATTS (w)}$

To hold at this RPM, calculate Power Specific Fuel Consumption:

$52.3 W \times 1 HR = 52.3 \text{ WATT} \cdot hr (w \cdot h)$

$PSFC = 52.3 \text{ w} \cdot h / 2.74 \text{ GPH} = 19.08 \text{ w} \cdot h / gal$

ENERGY CONVERSION EFFICIENCY

$19.08 \text{ w} \cdot h \times 3.414 \text{ BTU} / \text{w} \cdot h = 65 \text{ BTU}$

$2.74 \text{ GPH} \times 6.67 \text{ lb/gal} \times 18,610 \text{ BTU/lb} = 340,112 \text{ B}$

$65 \text{ BTU} / 340,112 \text{ BTU} = \underline{0.019\%}$

5. Let's go to a marker where excitation current Load Lever was loaded to minimum excitation current: • • • • • • • • • • • • • • • • •

Time Marker: 306 S

Gas Turbine RPM (N1): 47,222 RPM

Generator Turbine RPM (N2): 9,597 RPM

Fuel Flow: 2.71 GPH

Voltage Output: 13.57 V

Current Output: 73.43 A

Resistance of fixed Resistive Element: R=V/I: 13.57/73.43 = 0.1

Power Output = IV: $(73.43 A)(13.57 V) = 996.4 W$

To hold at this RPM, calculate Power Specific Fuel Consumption:

996.4 W x 1 HR = 996.4 WATT·HR (W·h)

PSFC = 996.4 w·h / 2.71 GPH = 367 w·h/gal

ENERGY CONVERSION EFFICIENCY

(367 w·h)(3,414 BTU/w·h) = 1,252 BTU

2.71 GPH x 667 lb/gal x 18,610 BTU/lb = 336,38

1,252 BTU / 336,388 BTU = 0.37%

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N1 (RPM)

N2 (RPM)

Voltage (V)

Current (Amps)

Power (watts)

Fuel Flow (Gal/Hr)