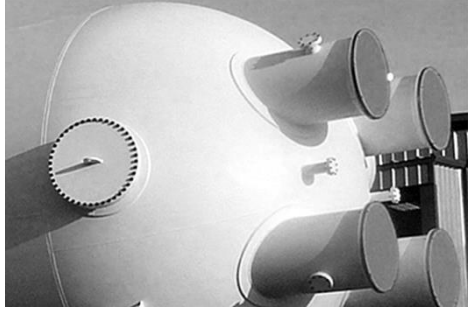
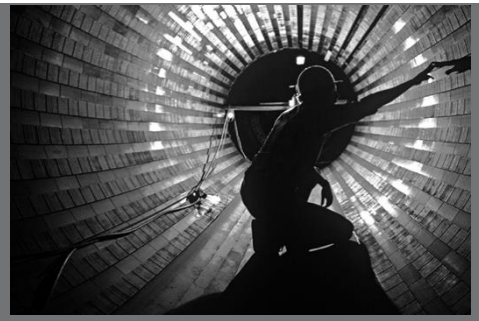
CURTISS-WRIGHT



Developing and Validating Load and Heat Rate Correction Curves Using PEPSE



Greg Alder

CURTISS-WRIGHT

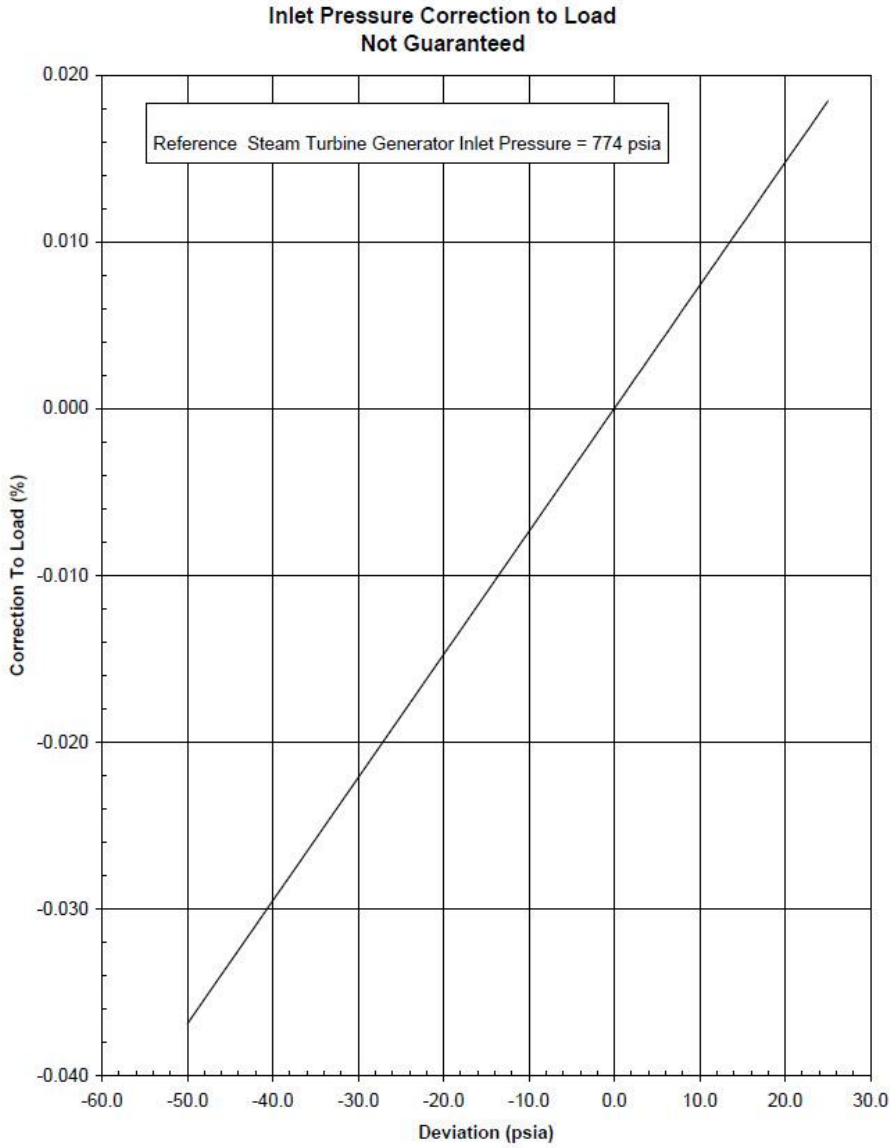
Background

- **Load and Heat Rate Correction Curves**
  - Important to a thermal performance program
    - Thermal performance reports
    - Assist in accounting for lost generation and heat rate
    - PTC 6 turbine warranty testing

Load and Heat Rate Correction Curves

- **Turbine vendors typically provide updated thermal kits, heat balance diagrams and correction curves in conjunction with uprates and major plant modifications.**
- **Validation of these curves is often critical to ensure the utility is obtaining the best representation of corrected generation.**
- **Correction curves used for periodic thermal performance reporting, PMAX controllable losses and lost generation accounting.**
  - Actual values (i.e. throttle pressure, condenser back pressure, etc.) are compared to design or best achievable targets.
  - Deviation between actual and target values are entered into the correction curves.
  - Results from the curves are used to calculate corrected generation and heat rate and subsequently lost generation and heat rate.

Sample Load Correction Curve



Curve Validation

- **Vendor load and heat rate correction curve issues**
  - "Boiler plate" curve provided
  - Error in the curve resulting from incorrect assumptions
  - Curve not provided by the vendor
    - Not used in warranty testing
- **Independent creation of correction curves can be performed using PEPSE**
  - to validate the vendor provided load correction curves
  - to generate a desired curve not provided by vendor

Curve Validation Methods - Software

- **Detailed PEPSE model of the generating unit is developed**
  - Model is “Load Generalized” to operate from VWO down to low load (25-50%) to generate multivariate curves often provided by vendors (i.e. condenser back pressure load correction curve)
- **Model is benchmarked against the vendor provided heat balance diagrams to ensure accuracy and repeatability**
- **Curves are generated using the completed model**
  - Conventionally using the software or
  - Using spreadsheet interface to the modeling software

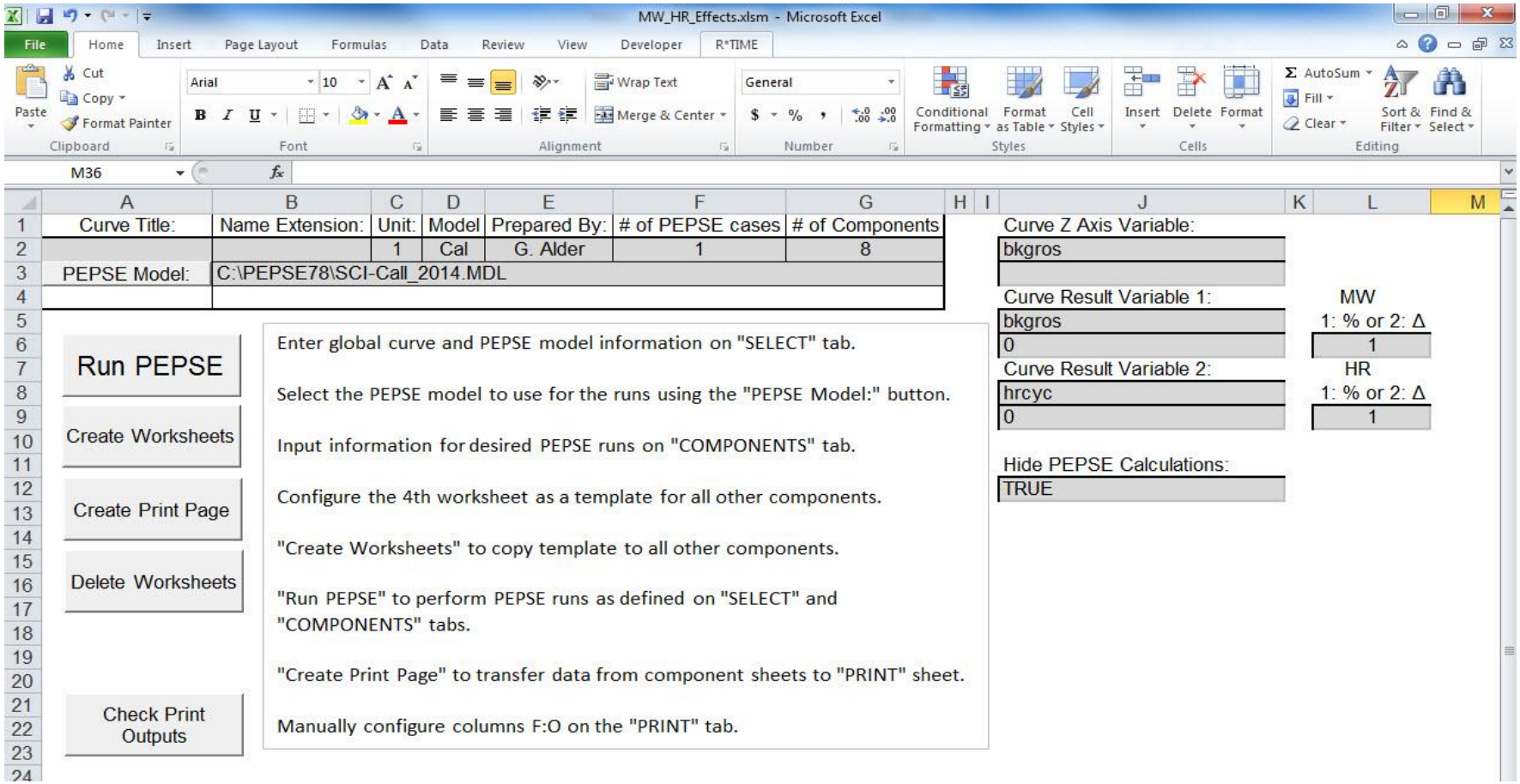
PEPSE - Methods to Generate Curves

- **One result at a Time**
  - Enter a value (i.e. throttle pressure), observe resulting generation, repeat
  - Very time consuming, potential for user entry errors
- **Stacked Case Study**
  - Time consuming to setup studies for a set of curves
- **Sensitivity Study**
  - Fast and convenient
  - Has curve export feature
  - Uses PEPSE “Save Case” feature, potential to have issues with results
- **Excel to PEPSE Automation Link – Historical Approach**
  - Typically done one curve at a time.
  - Convenient but can be time consuming to generate a set of curves

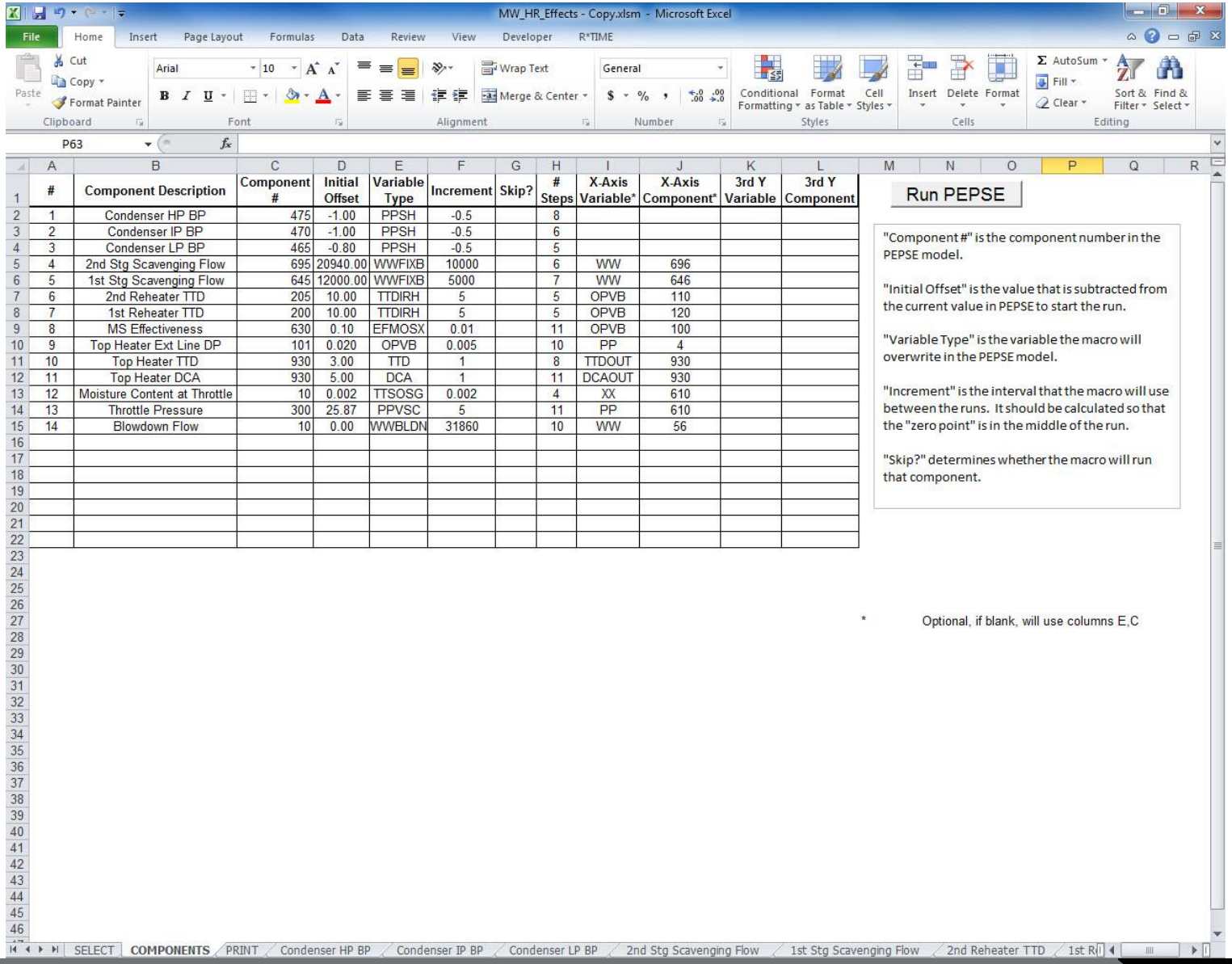
Newer Method to Validate Correction Curves

- **Excel to PEPSE Automation Link – Updated Approach**
  - Visual Basic used to generate the complete set of curves at one time
    - User:
      - Enters PEPSE model name and directory
      - Puts in a list of desired load and/or heat rate correction curves
      - Presses a button to setup the curve templates
      - Executes PEPSE and generates the curve set

Setup Tab – Enter Model Information



Curves Tab – Enter Desired Curves



#	Component Description	Component #	Initial Offset	Variable Type	Increment	Skip?	# Steps	X-Axis Variable*	X-Axis Component*	3rd Y Variable	3rd Y Component
1	Condenser HP BP	475	-1.00	PPSH	-0.5		8				
2	Condenser IP BP	470	-1.00	PPSH	-0.5		6				
3	Condenser LP BP	465	-0.80	PPSH	-0.5		5				
4	2nd Stg Scavenging Flow	695	20940.00	WWFIXB	10000		6	WW	696		
5	1st Stg Scavenging Flow	645	12000.00	WWFIXB	5000		7	WW	646		
6	2nd Reheater TTD	205	10.00	TTDIRH	5		5	OPVB	110		
7	1st Reheater TTD	200	10.00	TTDIRH	5		5	OPVB	120		
8	MS Effectiveness	630	0.10	EFMOSX	0.01		11	OPVB	100		
9	Top Heater Ext Line DP	101	0.020	OPVB	0.005		10	PP	4		
10	Top Heater TTD	930	3.00	TTD	1		8	TTDOUT	930		
11	Top Heater DCA	930	5.00	DCA	1		11	DCAOUT	930		
12	Moisture Content at Throttle	10	0.002	TTSOSG	0.002		4	XX	610		
13	Throttle Pressure	300	25.87	PPVSC	5		11	PP	610		
14	Blowdown Flow	10	0.00	WWBLDN	31860		10	WW	56		

Run PEPSE

"Component #" is the component number in the PEPSE model.

"Initial Offset" is the value that is subtracted from the current value in PEPSE to start the run.

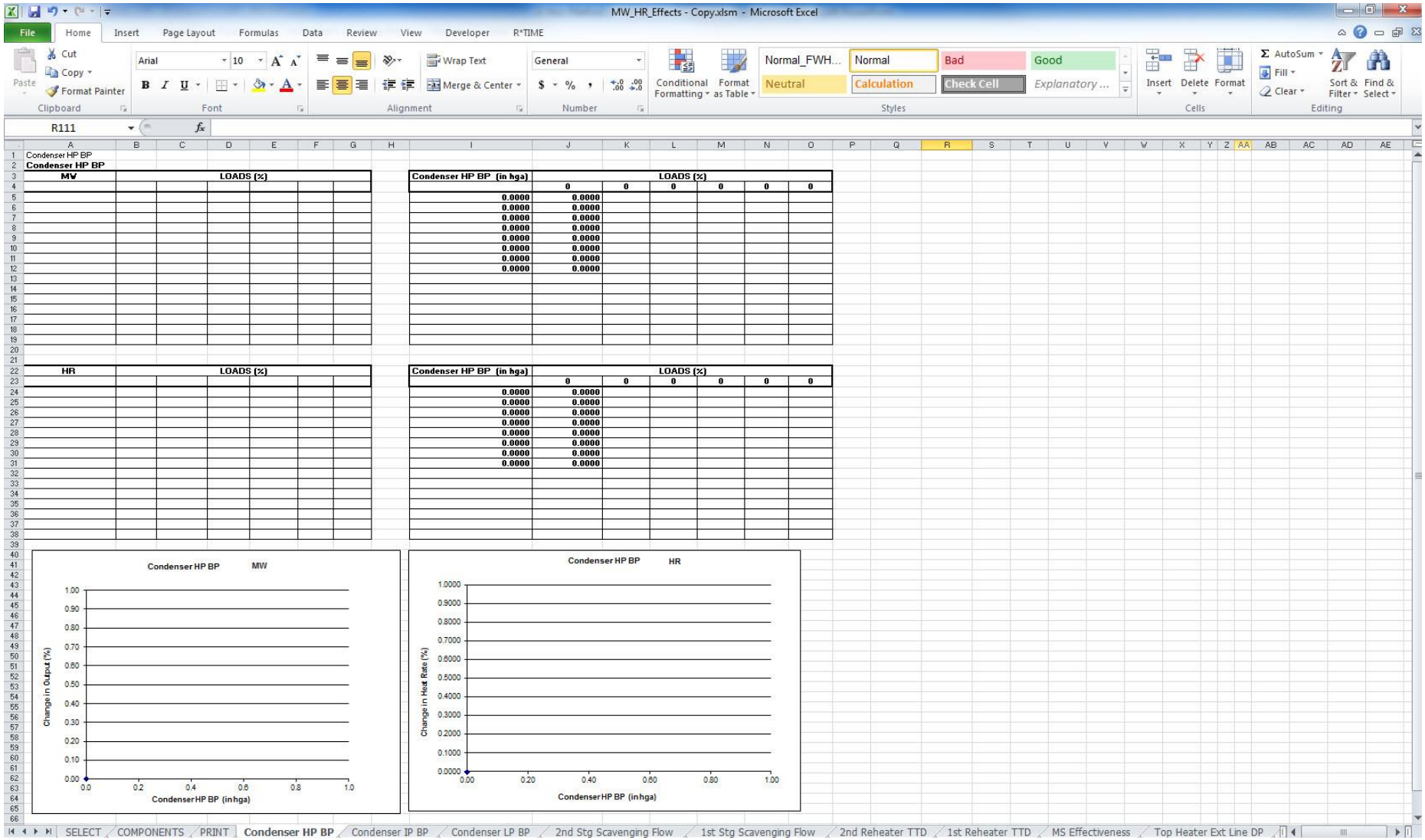
"Variable Type" is the variable the macro will overwrite in the PEPSE model.

"Increment" is the interval that the macro will use between the runs. It should be calculated so that the "zero point" is in the middle of the run.

"Skip?" determines whether the macro will run that component.

* Optional, if blank, will use columns E,C

Create Template Worksheets



Run PEPSE – Generates Curve Set

MW_HR_Effects1.xlsm - Microsoft Excel

Condenser HP BP

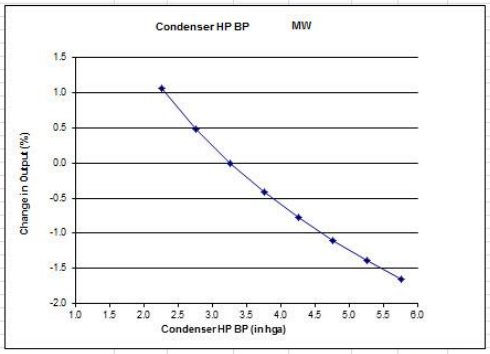
Condenser HP BP

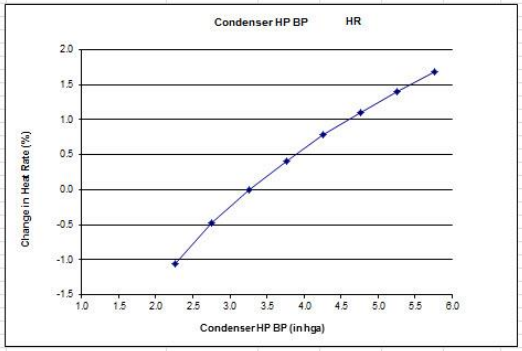
MW	LOADS (%)						
	1284.33						
2.2600	1297.99						
2.7600	1290.53						
3.2600	1284.33						
3.7600	1279.03						
4.2600	1274.40						
4.7600	1270.27						
5.2600	1266.54						
5.7600	1263.14						

Condenser HP BP (in hga)	LOADS (%)					
	1284.332	0	0	0	0	0
-1.0000	1.0636					
-0.5000	0.4826					
0.0000	0.0000					
0.5000	-0.4125					
1.0000	-0.7736					
1.5000	-1.0950					
2.0000	-1.3852					
2.5000	-1.6499					

HR	LOADS (%)						
-2.2600	9408.52						
-2.7600	9462.92						
-3.2600	9508.58						
-3.7600	9547.97						
-4.2600	9582.72						
-4.7600	9613.87						
-5.2600	9642.15						
-5.7600	9668.10						

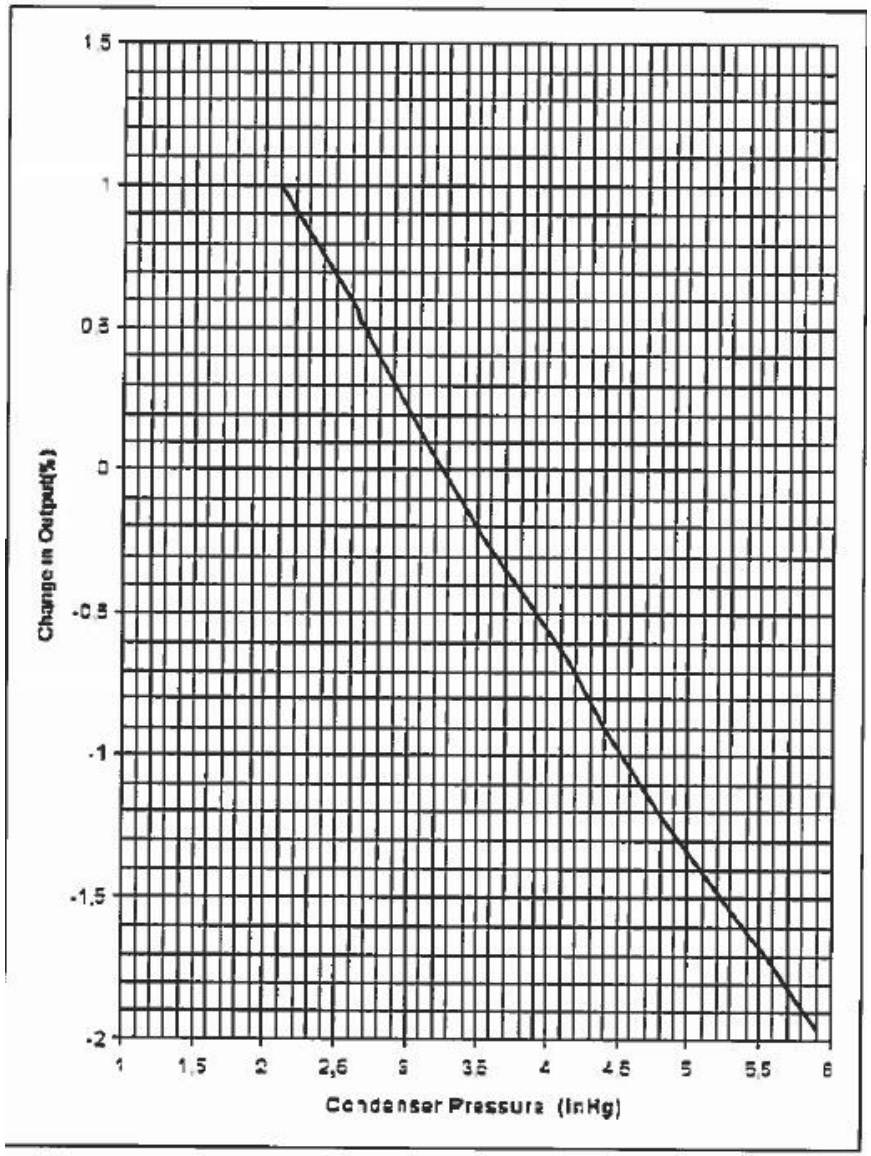
Condenser HP BP (in hga)	LOADS (%)					
	1284.332	0	0	0	0	0
1.0000	-1.0524					
0.5000	-0.4803					
0.0000	0.0000					
-0.5000	0.4143					
-1.0000	0.7797					
-1.5000	1.1072					
-2.0000	1.4047					
-2.5000	1.6776					

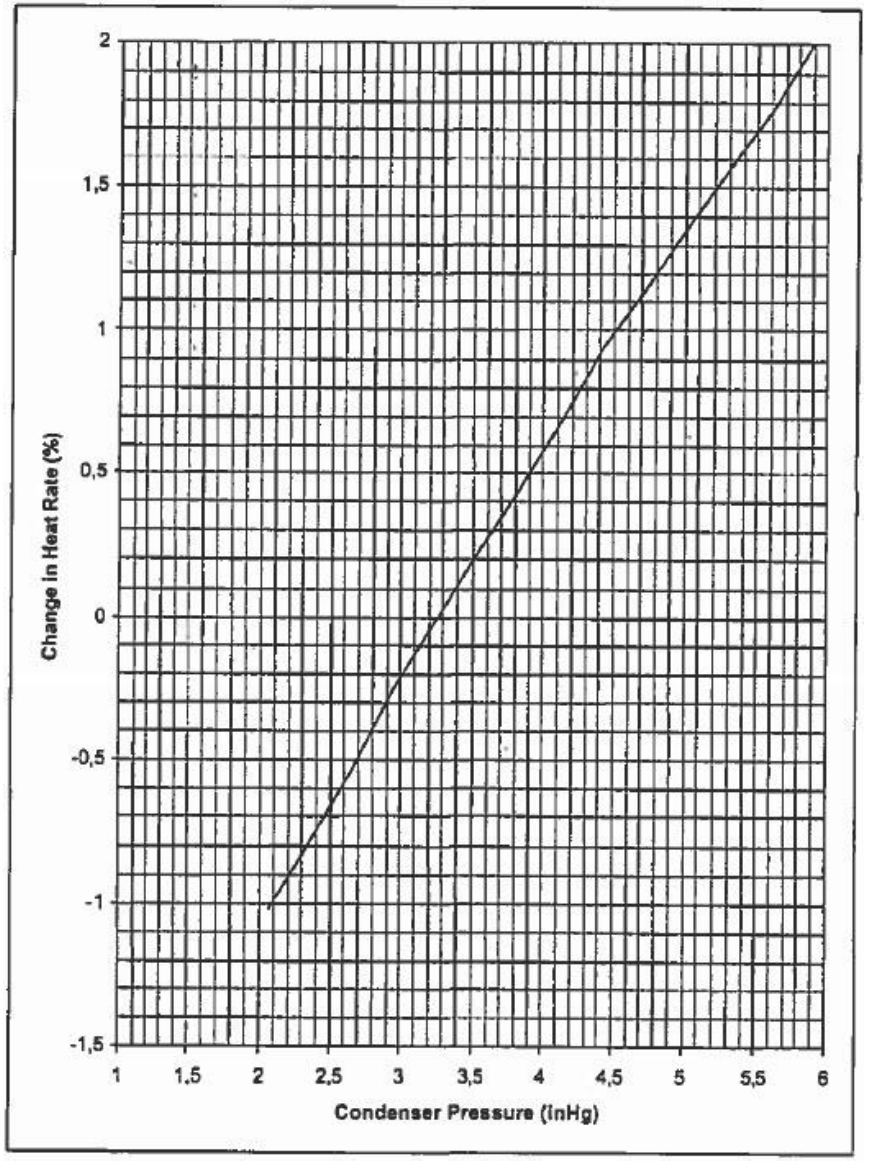




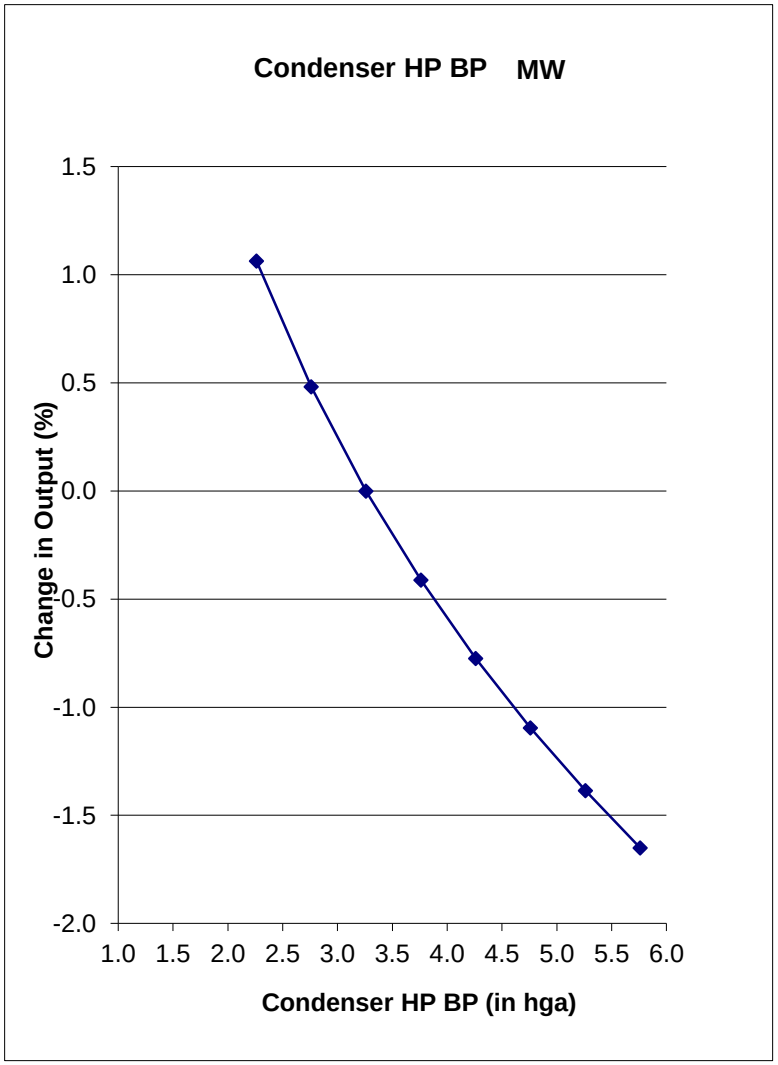
SELECT | COMPONENTS | PRINT | Condenser HP BP | Condenser IP BP | Condenser LP BP | 2nd Stg Scavenging Flow | 1st Stg Scavenging Flow | 2nd Reheater TTD | 1st Reheater TTD | MS Effectiveness | Top Heater Ext Line DP

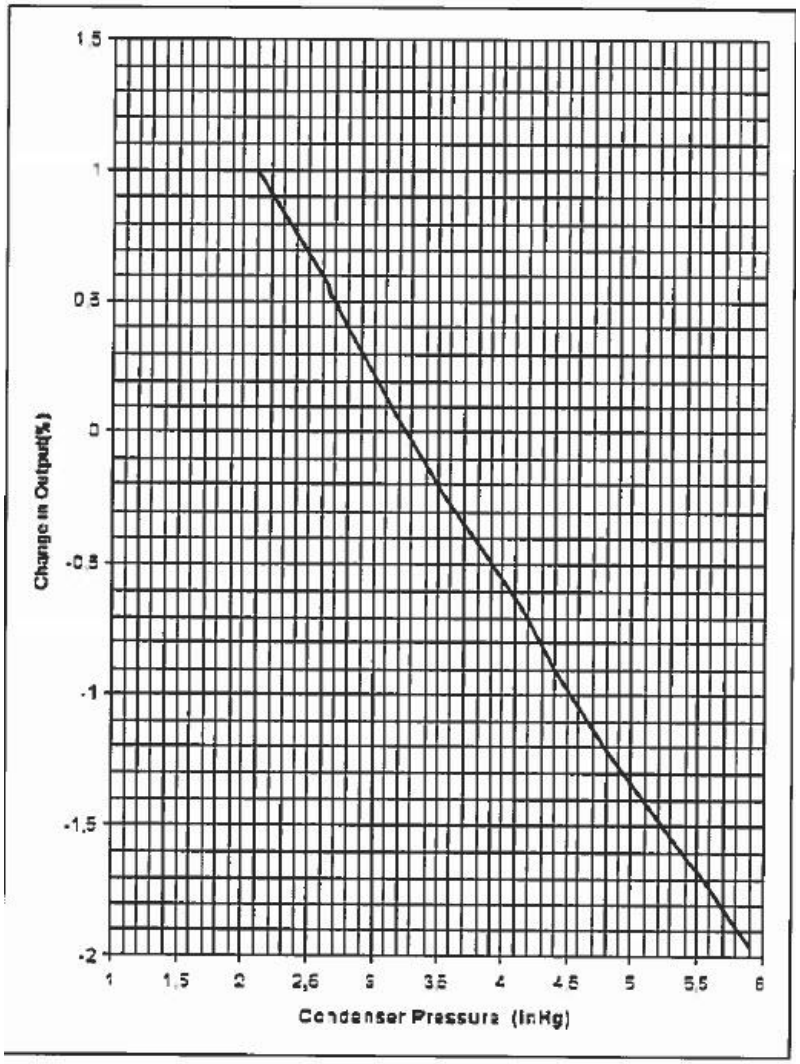
Vendor Curve Sample – Condenser Back Pressure





Curve Comparison Discussion – Condenser Back Pressure

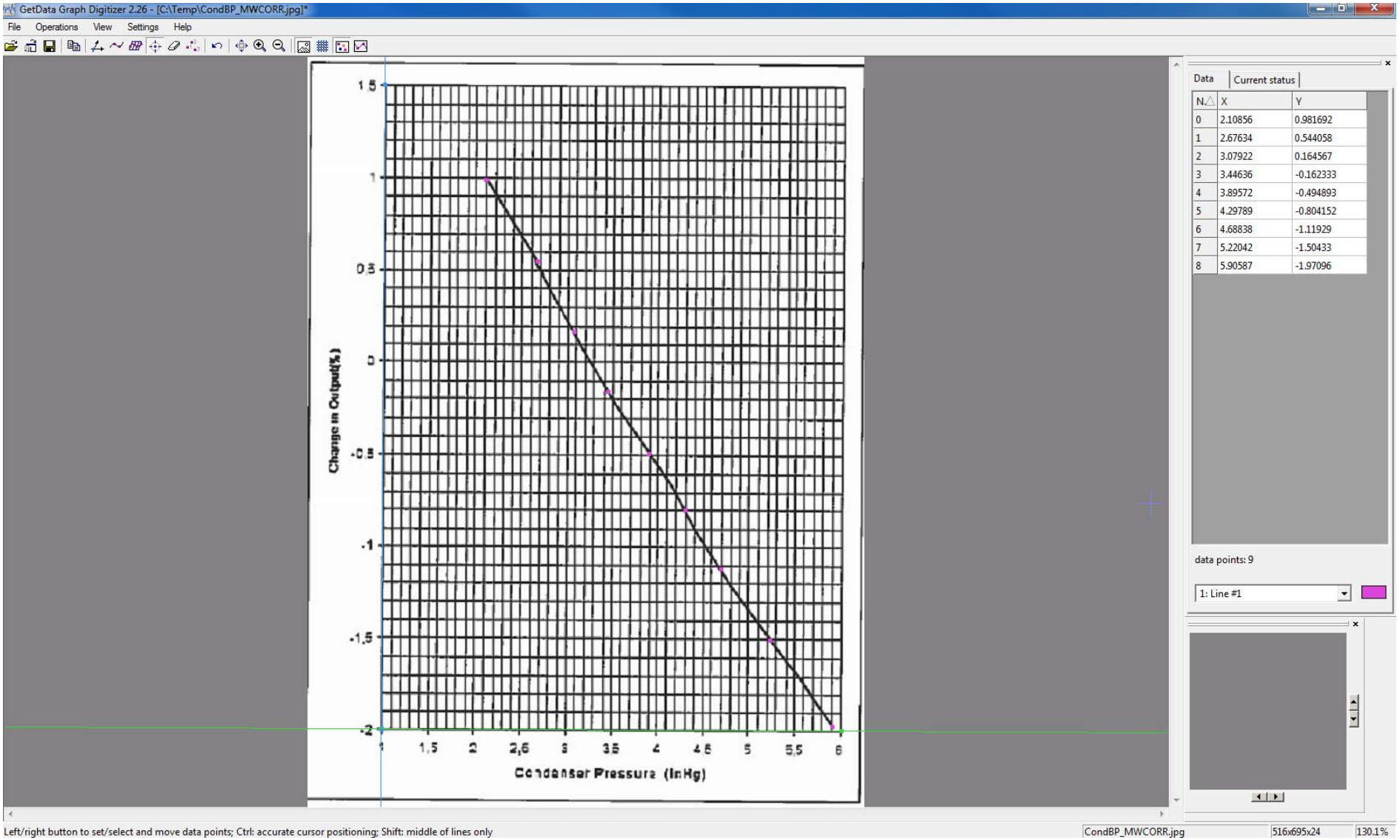




Validating Curves – Vendor Curves Placed into Excel

- **Use a curve digitizing product such as GetData Graph Digitizer**
  - Each vendor correction curve is quickly and accurately placed into Excel for comparison to the PEPSE generated curve
    - Open a graph
    - Set the scale (coordinate system)
    - Digitize (automatically or manually) and
    - Export data to Excel

Validating Curves – Digitized Load Correction Curve



Validating Curves – Curve Comparison

MW_HR_Effects.xlsm - Microsoft Excel

Condenser HP BP

MW	LOADS (%)					
	1284.33					
2.2600	1297.99					
2.7600	1290.53					
3.2600	1284.33					
3.7600	1279.03					
4.2600	1274.40					
4.7600	1270.27					
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5.7600	1263.14					

Condenser HP BP (in hga)	LOADS (%)					
	1284.332	0	0	0	0	0
-1.0000	1.0636					
-0.5000	0.4826					
0.0000	0.0000					
0.5000	-0.4125					
1.0000	-0.7736					
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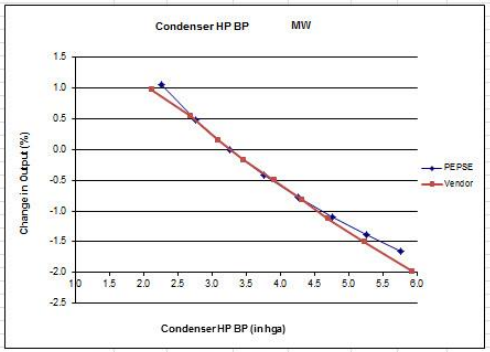
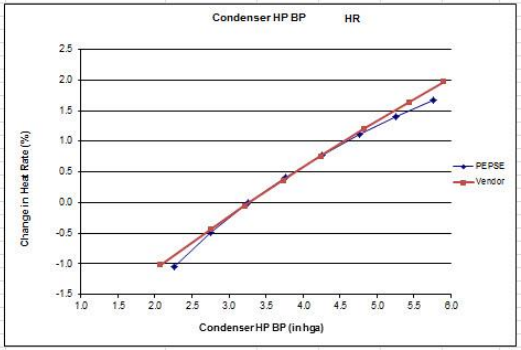
Condenser HP BP (in hga)	LOADS (%)					
	1284.332	0	0	0	0	0
1.0000	-1.0524					
0.5000	-0.4803					
0.0000	0.0000					
-0.5000	0.4143					
-1.0000	0.7797					
-1.5000	1.1072					
-2.0000	1.4047					
-2.5000	1.6776					





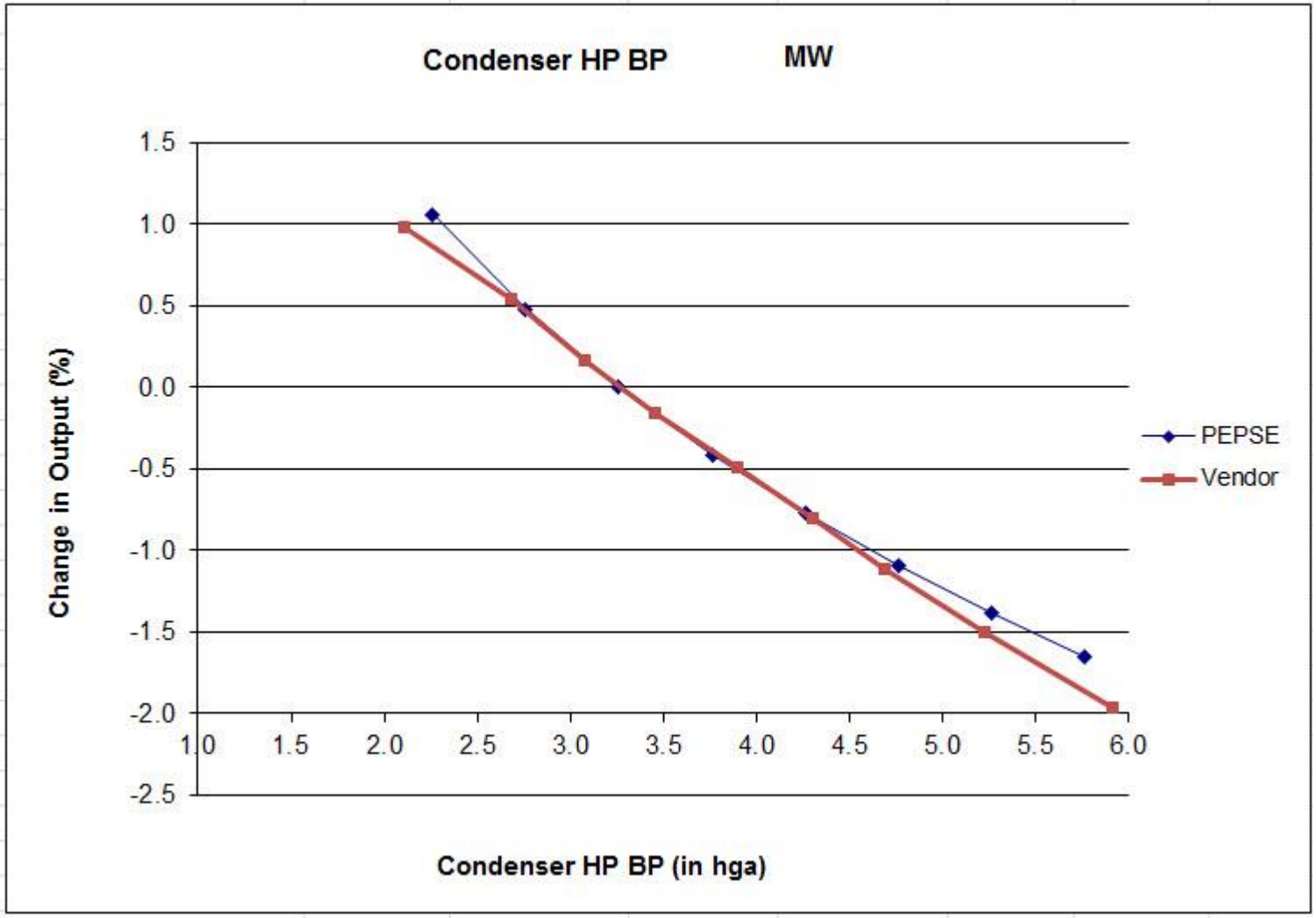
Vendor MW Correction

BP	Load Change
2.11E+00	9.82E-01
2.68E+00	5.44E-01
3.08E+00	1.65E-01
3.45E+00	-1.62E-01
3.90E+00	-4.95E-01
4.30E+00	-8.04E-01
4.69E+00	-1.12E+00
5.22E+00	-1.50E+00
5.91E+00	-1.97E+00

Vendor HR Correction

BP	HR Change
2.07E+00	-1.02E+00
2.75E+00	-4.43E-01
3.21E+00	-4.96E-02
3.74E+00	3.61E-01
4.24E+00	7.61E-01
4.83E+00	1.21E+00
5.44E+00	1.64E+00
5.90E+00	1.98E+00

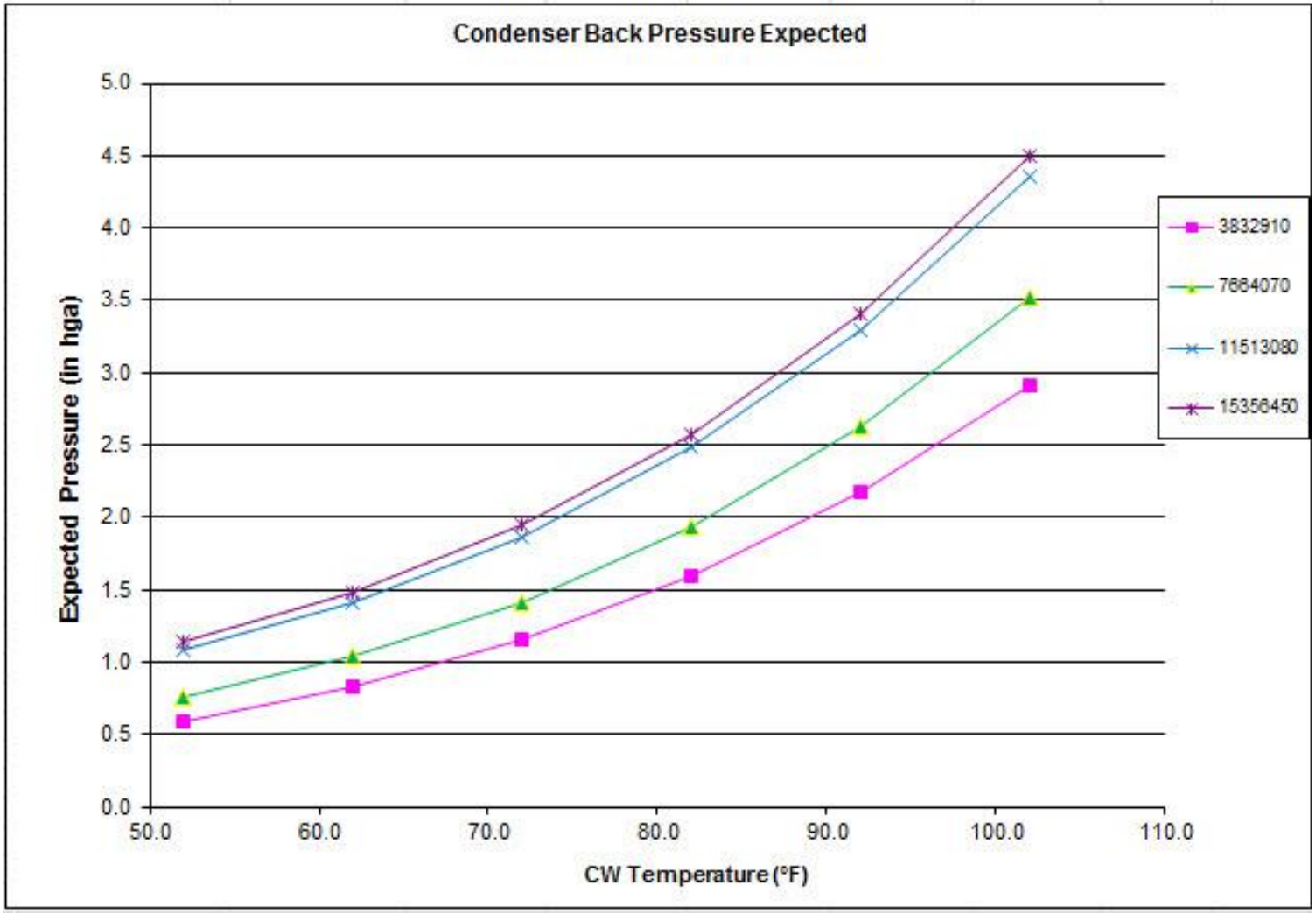
Validating Curves – Curve Comparison



Other Curves

- **This approach can also be used to generate expected target conditions**

Sample Target Curve – Expected Back Pressure



Summary

- Correction and other curves can be quickly created using PEPSE in conjunction with Excel and VB macros
- The resulting curves can be compared to vendor provided curves to determine accuracy
- Additional curves not provided by the vendor can be created for load and heat rate correction and for expected best achievable target values