Notes for the Pre-Retrofit Template for Co-Gen Systems:

1 In order to operate, the steam boiler requires positive steam flow rate, an input control signal greater than zero, and an inlet steam enthalpy less than the desired steam enthalpy. The boiler model adds energy to the steam flow, elevating its temperature and enthalpy in the process. The boiler model utilizes a combination of external and internal controls to keep the boiler outlet enthalpy at or below the desired outlet enthalpy (in other words the device may be capacity limited but will never exceed the user-provided setpoint values). The available capacity at the current timestep is found by multiplying the rated capacity (a parameter) by the input control signal (an input set to a constant value of 1 for this example). For this example, the steam boiler attempts to make 50 degree C superheated steam at 1 MPa.

2 In this example, a simple forcing function is used to control the condensate pump, but there are many possible control options in TRNSYS. Users may choose from one of several controller models (proportional, PID, differential controller, time-delayed controller etc) or instead use the power of EQUATIONs to generate a control signal (typically a value from 0 to 1). EQUATIONs can be based on the outputs from one or more models in the simulation. Refer to section 2.7 of the TRNSYS reference set for more information on EQUATIONs.

3 The repeat period of a forcing function is based on the last value of time specified in the function. Daily repeating functions should be completely specified through hour 24.

4 Layers can be used inside the studio to help the user visualize what's happening in the projects. Layers containing models and links may be turned on and off throughout the simulation process. Use the View menu in the studio to control which layers are currently being displayed.

5 Use different line styles to help identify the function of the connection. While you may always remember, it makes it much easier for another user to visualize the system. It's usually easier to change the linestyles after all the connections are made; otherwise you may forget to make the connections (the stdio does not change the color of the linesafter connections are made for non-standard line types and colors).

6 At least one component model in <u>each</u> flow loop must definitively set the flow rate for that loop. In most simulations, this is the function of the pump model. In some circumstances, the flow rate can be set by another component. For example a load-following steam turbine (a device which meets an electrical load by varying the steam flow rate) or a heat recovery steam generator operating in the “Make as much as possible” mode are examples of other devices that can set the flow rate. In these cases, a pump model which does not set the flow rate, but instead just calculates the pump power can be used. The condensate pump will generate an error and the simulation will stop if two-phase or superheat steam is provided at the inlet. The pump model calculates the required pump power and heat transfer to the fluid and ambient by imposing the overall pump and motor efficiencies on the theoretical pump power (incompressible fluid v * dP).

7 Make sure and check the component order before running your simulations. Besides a likely increase in speed, many convergence problems can be avoided by simply changing the order. The best order seems to correspond to the natural flow of information via pipes and wires of the real system. The component order can be modified using the control cards under the assembly menu.

8 Before running the simulation, and usually before any of the models are connected, the user should set the values for the control cards. The control cards set the simulation start and stop times, the timestep, the convergence tolerances and many other simulation-specific values.

9 After every simulation, the TRNSYS list file should be checked for warnings and/or errors that were found. The list file can be accessed from a small button on the left side of the studio or through the Calculate menu of the studio.

10 Every input that is left unconnected in a project will assume it’s specified initial value for the duration of the simulation; so be sure and set the initial values carefully.

11 Common variables can be set using simple EQUATION cards and then the variable name may be used as a parameter in any model in the project. In this example the pump flow rate, a parameter of the main pump model, is set using an equation. You’ll have to set the variable type of the parameter to “string” and then type in the name of the variable.

12 In this example, the heating loads to be met by the system are read from a user-supplied external data file; although there are many ways to introduce a heating load to the system. Refer to the sample projects "Template_BuildingLoads.tpf" and "Template_ConvertingLoadsToTemperatures.tpf" for more information on the different methods. Care should be taken when reading in the building loads as this is one of the more common errors found in simulations. Choose the data reader mode carefully; there are numerous options for reading in external files dealing with whether the data file has a line of initial values and whether the program should "skip" into the data file to find the correct place to start reading. Pay careful attention to the type of data that you have (instantaneous or average values), the conversion factors, the number of header lines, and whether or not you want the program to interpolate between data points. The data files that you create should be at even time intervals which must be integer multiples of the time step. The data should be arranged so that one row contains data for one time interval. The outputs from the model correspond to the column containing the data (for example if the ambient temperature is in column 2, the 2nd output from the model will contain the ambient temperature. The outputs from the model are <u>average</u> values over the timestep, not instantaneous values. The data will repeat after the last line of the data file has been read. Hint: Early on in the project use an online plotter to check the outputs from the data file and make sure that they are correct. In this example, the external data file contains the time of the day and the heating load in kJ/h.

13 One of the best ways to avoid problems when creating a complicated project is to run the simulation, with an online plotter watching the variables, after each component has been added to the system.

14 In this example, the pressure reducing valve modulates the pressure from its elevated condition leaving the boiler (1 MPa) to 500 kPa which is required by the load. The reduction in pressure is assumed to occur adiabatically.

15 This example utilizes a de-aerating (DA) heater; a device used to elevate the temperature of the steam condensate to near its saturation temperature. In this project, a version of the de-aerating heater has been chosen which calculates the amount of high-temperature steam which is needed to temper the low temperature steam to within 5 C of the steam saturation temperature (other versions of the DA heater exist where the outlet condition floats with the amount of high-temperature steam addition). As this model calculates the amount of steam required, we need to make sure that this amount is also provided to the DA heater or convergence problems may arise. Refer to note 16 for details on the diverting valves. The inlet steam flow rate to the model is only used for convergence checking. The model restricts high-temperature steam flow if the inlet steam condition is already above the desired condition or if the high-temperature steam has a lower enthalpy than the low-temperature steam inlet.

16 Using EQUATIONs in a project is a commonly-used and extremely powerful tool. In this example, we are using an EQUATION component to calculate the required flow rate to the DA heater based on the flow rate from the boiler and the required flow rate into the DA heater. The outputs from this EQUATIONs component are used as an input to the diverting valve and also as a variable in another EQUATIONs component. EQUATIONs may be as simple as defining a constant (A=5) or may be more complicated; utilizing outputs from components in the project, previously-defined variables, and algebraic and Boolean expressions. There are restrictions on the naming of variables, the type of linear equations that can be solved (the equations A=5+B and B=A-3 would generate an error), and the format of the equation. Refer to the programmers guide for more details on using EQUATIONs.

17 While the temperature, pressure, and enthalpy of the steam are passed from component to component in TRNSYS, only the pressure and enthalpy are used to set the state of the steam for any component.

18 Make sure and carefully read the detailed description of each model you are considering using in the project. The proforma for each model contains all the assumptions, limitations, and a description on how the model is intended to operate.

19 This EQUATION component calculates the diverting valve fractions for the process steam load and the building heating load streams. The controls are configured such that the DA heater load is first met followed by the building heating load. Any additional steam that is available after these two loads have been met is directed to a process steam load. The diverting fractions for the steam heating load stream are calculated based on the current boiler outlet conditions (enthalpy and flow rate), and the desired steam outlet condition from the heating load.

20 The diverting valve directs an inlet steam flow to multiple outlet ports. The pressure, temperature, and enthalpy at each outlet are set to the inlet values. The flow rate at each outlet port is calculated by multiplying the input fraction for that port (an INPUT) by the inlet flow rate. The sum of the input fractions should be one.

21 In this example, city water from the local water utility is used to desuperheat the steam entering the process heat load. The mains temperature could be specified in several different ways (constant value, from an EQUATION, from a forcing function etc.). We utilized a weather reader model that incorporates a mains water temperature profile based on measured weather data.

22 A desuperheater model is used in this project to reduce the temperature of the inlet steam to just 2 degrees above the saturation temperature. City water is used as the heat sink fluid and the flow rate is set to a very large number. In this way the water flow rate does not restrict the heat transfer. If the outlet water temperature from the desuperheater was being used elsewhere in the system (as the make-up water for the process steam flow for example), a method of reasonably setting or modulating the water flow rate would be required. A counterflow desuperheater is used in this project with a pinchpoint temperature difference approach. Other calculation methods (effectiveness) and configurations (parallel flow) are also available.

23 The steam heating load for the project is read from an external data file and imposed on the steam flow using this model. The user must specify the outlet pressure from the steam load. The user may also provide a lower limit on the steam outlet temperature; effectively capping the heat transfer to a reasonable value. This situation may arise if a large steam heating load is imposed on a small steam flow rate; causing the theoretically calculated steam outlet temperature to be well below zero. The model reports the steam load that it was able to meet (and not meet) at each timestep and this value should be compared to the steam load to ensure that the system is behaving properly. In this example, the steam flow rate to the load is calculated in an earlier EQUATION based on the inlet steam conditions and the desired outlet steam enthalpy.

24 In this system, a process heat load is modeled using this component. The user must specify an outlet pressure and enthalpy from the load (set to constant values in this case but either could have been specified using EQUATION's, external files etc.) and the fraction of condensate that is returned. This component is especially useful in circumstances where a variable steam flow is doing as much heating as possible given the inlet conditions. The model reports the heating load that was met by the steam flow. This component could also have been used instead of the component in note 23.

25 The enthalpy of the steam (required as one of the steam state properties by all models in this library) is calculated by this model based on the mains water temperature and the pressure. This component model is part of the standard TRNSYS package and is found in the "Physical Phenomena / Thermodynamic Properties" folder in the direct access tool.

26 This component pumps city water back into the steam heating system in order to make-up for the steam condensate lost in the process heating load. This version of the pump model pressurizes a steam flow to a user-specified condition but does not set the steam flow rate. The steam flow rate has been set by the process load model while the temperature and enthalpy have been dictated by the current mains water temperature.

27 The steam mixing valve allows multiple steam flows to be mixed together and the resultant outlet condition calculated. The enthalpy for the outlet stream is calculated from an energy balance on the device; where the device is assumed to be perfectly insulated. The outlet pressure from the device is set to the minimum pressure of all active flow streams (those with a positive flow rate). All flows entering above this minimum pressure will adiabatically expand to the minimum pressure. The outlet flow rate from the device is simply the sum of all the inlet flow rates.

28 Use Online plotters throughout the simulation process!! They are the most powerful debugging tool you have at your disposal. Up to 5 plotters may be used for a total of 100 variables. They can be connected like any other model, or they may be specified using the Output Manager from the Assembly menu in the studio.