Simulation of Air-Cooled Organic Rankine Cycle Geothermal Power Plant Performance

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SUMMARY

This document describes simulations that were developed at the Idaho National Laboratory for the determination of plant design specifications and performance characteristic at both design and off-design ambient and resource conditions. The plant design simulation yields optimized design point operating conditions, equipment specifications, and net power output. When these equipment and design point specifications are imported to the plant rating simulation, the performance of the plant can be simulated for the specified ambient and resource conditions. Results from the plant rating simulations may be used to evaluate net power generation during a specified time period having defined ambient and resource conditions.

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ACRONYMS

ACC	air-cooled condenser
GF	geofluid or geothermal fluid
LMTD	log mean temperature difference
MITA	minimum temperature approach
ORC	organic Rankine cycle
WF	working fluid

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1. Introduction

Geothermal energy is a renewable energy source that provides reliable base load power generation. Geothermal power may be generated using various power conversion technologies, although flash and binary power plant technologies are the most common. In flash plants, steam produced by a geothermal resource is directly utilized to generate power by driving a turbine-generator prior to being condensed at sub-atmospheric pressures and reinjected to the reservoir; a portion of the condensed geofluid is often used as makeup water for the power plant evaporative cooling system, which may have the long term consequence of reservoir geofluid depletion. Air-cooled organic Rankine cycle, or binary, power plants use an intermediate working fluid that is vaporized using heat from the geofluid and condensed by rejecting heat in an air-cooled condenser. Use of hydrocarbon based refrigerant working fluids with normal boiling points lower than that of water results in the ability to generate power from lower temperature resources than flash plants. Additionally, use of dry cooling results in reduction or elimination of reservoir makeup water requirements.

This document describes Aspen Plus simulations that were developed at the Idaho National Laboratory for the determination of plant design specifications and performance characteristic at both design and off-design ambient and resource conditions. The plant design simulation yields optimized design point operating conditions, equipment specifications, and net power output. When these equipment and design point specifications are imported to the plant rating simulation, the performance of the plant can be simulated for the specified ambient and resource conditions. Results from the plant rating simulations may be used to evaluate net power generation during a specified time period having defined ambient and resource conditions.

Aspen Plus is an industry-standard process modeling software tool with extensive component physical property databases, property methods, and unit operation models. The software allows the user to model and simulate various thermal, hydraulic, mechanical, and chemical processes and/or operations. A process flowsheet is constructed of 'blocks' that model the desired unit operations and 'streams' that determine the flow of material and energy throughout the process. Aspen Plus permits manipulation and control of the process through flowsheet controls including 'design specifications,' 'calculator blocks,' and 'transfer blocks.' The software also includes tools for performing sensitivity analysis of the process to changes in a specified process variable, as well as optimization of an objective function by varying specified process variables. Aspen Plus Version 2006 (Build 20.0.3.4127) [1], run under Windows XP SP3 on computer ID 421716 was used for all modeling calculations described in this document.

2. Power Cycle Description

The basic plant design evaluated is an air-cooled organic Rankine cycle. A simple schematic for the plant is shown in Figure 1. In this plant configuration, the energy from the geothermal fluid is used to preheat, vaporize and superheat a pressurized secondary working fluid. The high pressure working fluid vapor is subsequently expanded in a turbine that drives an electrical generator. The low pressure working fluid vapor exiting the turbine is condensed in an air cooler and pumped back to the geothermal heat exchangers. The cycle can be operated such that the turbine inlet conditions are either sub- or supercritical; the simulations described in this document can be used to evaluate either condition. Supercritical cycles enable greater cycle efficiency at the expense of increased capital costs.

Figure 1. Air-cooled organic Rankine cycle

A recuperated plant design incorporates an additional heat exchanger that transfers heat from the turbine outlet stream to the pump outlet stream; the working fluid flows through both sides of the heat exchanger. A schematic of a binary cycle with recuperation is shown in Figure 2. Recuperation allows the recovery of superheat in the turbine exhaust for use in heating the high pressure condensate. The simulations described in this document can be run either with or without a recuperation heat exchanger.

Figure 2. Air-cooled organic Rankine cycle with recuperation

3. Plant Design Simulations

Plant design simulations were constructed using multiple Aspen Plus unit operation (or block) models. Multistream heat exchanger blocks are used to model the preheater, vaporizer, air-cooled condenser, as well as an optional recuperator. Compressor/turbine blocks are used to model the working fluid turbine as well as the condenser fan. A pump block is used to model the pump and a valve block is implemented to model the control valve. Frictional pressure losses throughout the model are accounted for by setting fixed pressure drops in heater blocks. A flow diagram of the process configuration is shown in Figure 3.

Figure 3. Air-cooled binary plant design simulation process flow diagram

The Peng-Robinson property method is used as the simulation base property method and is utilized for calculation of working fluid properties. The REFPROP and GERG2008 property methods, which are available in Aspen Plus V7.0 and V7.2 respectively, also provide accurate calculation of organic Rankine cycle working fluid properties for operating conditions typical of air-cooled binary geothermal power plants. Each simulation block defaults to the base property method unless overridden at the individual block level.

The STEAMNBS property method (International Association for the Properties of Steam formulation 1984) is used to calculate geothermal fluid properties and the IDEAL property method is used to calculate air properties. The STEAMNBS and IDEAL property methods are specified at the individual block level. Multistream heat exchanger blocks such as the preheater, vaporizer, recuperator, and air-cooled condenser allow use of different property methods for the hot and cold sides. Thus, the hot sides of the preheater and vaporizer blocks utilize the STEAMNBS property method while the cold side of the air-cooled condenser utilizes the IDEAL property method.

3.1 Resource and Ambient Conditions

The design resource and ambient conditions are user specified values. The design ambient temperature and pressure is set in stream AIRI. The global ambient pressure is set in the Setup | Specifications variable browser sheet and should be used to set the design ambient pressure if gauge units are to be used for inputs related to the air-cooled condenser. Hourly data for analysis and selection of the design ambient temperature can be obtained from the University of Utah MesoWest web site [2] for individual weather stations located throughout the United States. Median ambient temperature is a commonly used design value. For more general analyses, average annual temperatures for each US state are included in Appendix III. Although an initial estimate of the air mass flow rate is required, the optimal design air flow rate is calculated by the plant design simulation.

The design resource temperature and flow rate are both user specified values. Although an initial estimate of the brine pressure is required, design spec PGF-DS calculates the brine pressure corresponding to 50°F of subcooling relative to the user-specified brine inlet temperature. The brine subcooling may be adjusted by changing the subcooling specification in heater block PGF.

3.2 Working Fluids

The plant design simulation includes several common working fluids. Table 1 provides basic information about the general properties of each of these fluids. These fluids are specified in comp-group WF to aid in simulation convergence. The working fluid composition is set in the control valve inlet stream CVI, which is also the simulation tear stream. Working fluid selection impacts plant design and each set of design conditions and parameters will have a specific working fluid composition that maximizes net power generation. The engineered refrigerants are generally more expensive to procure than the hydrocarbon based fluids, sometimes by an order of magnitude or more per unit fluid mass. For power plants with large working fluid inventory, this has the potential to be a significant fraction of the overall plant cost.

Table 1. Plant design simulation working fluids

fluid	chemical formula	molecular weight (lbm/lbmol)	critical temp (°F)	critical pressure (psia)	normal boiling point (°F)
propane	CH ₃ CH ₂ CH ₃	44.1	206.1	616.6	-43.8
n-butane	CH ₃ -2(CH ₂)-CH ₃	58.1	305.6	550.6	31.1
isobutane	CH(CH ₃) ₃	58.1	274.4	526.3	10.9
n-pentane	CH ₃ -3(CH ₂)-CH ₃	72.1	385.8	488.8	96.9
isopentane	(CH ₃) ₂ CHCH ₂ CH ₃	72.1	369.0	489.9	82.1
R-134a 1,1,1,2-tetrafluoroethane	CF ₃ CH ₂ F	102.0	213.9	588.8	-14.9
R-245fa 1,1,1,3,3-pentafluoropropane	CF ₃ CH ₂ CHF ₂	134.1	309.2	529.5	59.3

3.3 Design Parameters

The plant design simulation calculates optimized equipment specifications, process conditions, and net power generation that correspond to a set of user-specified input design parameters. These design parameters include the heater (preheater and vaporizer), condenser, and recuperator minimum temperature approach (MITA) values; condenser working fluid subcooling; turbine, pump, and fan efficiencies; and frictional pressure losses in all relevant blocks and process piping.

The minimum temperature approach values are dependent variables that must be set by one or more independent variables that exist within the process simulation. The minimum temperature approach design values are obtained by using Aspen Plus design specs that manipulate the appropriate independent variables required to drive the minimum temperature approach values to the design conditions. Table 2 details the minimum temperature approach design values as well as the variables manipulated by the Aspen Plus design specs and/or optimization blocks to achieve the design specifications.

Table 2. Minimum temperature approach design values

Heat Exchanger Block	MITA(°F)	Constraint/Design Spec	manipulated variable(s)
Preheater/Vaporizer*	10	TAHX constraint (WNET optimization block)	working fluid flow rate; air flow rate; pump outlet pressure; vaporizer hot side outlet temperature
Condenser	15	TACND-DS design spec	turbine exhaust pressure
Recuperator	10	TARCP-DS design spec	recuperator hot side duty

* Single constraint is used for obtaining specified preheater/vaporizer MITA. MITA is determined by using the result from the block with lowest calculated value.

The condenser subcooling, rotational equipment efficiencies, and block and piping frictional pressure losses are set directly within the corresponding Aspen Plus simulation blocks. The default equipment and piping design frictional pressure losses are detailed in Table 3 and the default design efficiencies are detailed in Table 4. The default level of condenser working fluid subcooling is 2°F.

Table 3. Design frictional pressure losses

Unit Operation/Process Piping Section	ΔP_{design} (psia)
Control Valve	2
Preheater and Boiler combined pressure drop	38
Recuperator vapor side (shell side)	1
Recuperator liquid side (tube side)	5
Condenser working fluid side	1
Condenser air side	calculated
Pump to control valve piping	5
Control valve to preheater piping	5
Boiler to turbine piping	3
Turbine to condenser piping	1

Table 3 lists the condenser air side design pressure drop value as “calculated”. This value is calculated because neither the air flow rate, condenser size, or air temperature rise are fixed in the model. As a consequence it is unrealistic to use a fixed static pressure drop across the condenser tube bundle. To relate the air pressure drop to the condenser size and air flow, the following relationship was used in design spec DPAIR-DS.

$$\Delta P = \Delta P_D \cdot \frac{\rho}{\rho_D} \cdot \left(\frac{Q}{Q_D} \cdot \frac{UA_D}{UA} \right)^2$$

Where

ΔP = pressure drop (default design pressure drop = 0.260 in-H₂O)

ρ = air density

Q = volumetric flow rate

UA = product of overall heat transfer coefficient U and heat exchanger area A

subscript “D” indicates design condition

In this relationship, the parameters with the D subscript were taken from the design specification sheet for an air-cooled condenser in an operating binary plant. The UA term is the product of overall heat transfer coefficient and heat exchange area; if not quoted, it can be calculated by dividing the specified heat exchange duty by the effective log mean temperature difference (LMTD). The simulation calculation assumes that the U value remains constant so that the ratio of the Q/UA ’s is effectively the ratio of the air velocities for the condenser. The simulation pressure drop is then the reference pressure drop times the square of this air velocity ratio and the air density ratio. This pressure drop correlation therefore scales similarly to the Darcy-Weisbach (ρV^2) pressure loss relation. It is recognized that the overall heat transfer coefficient U will not remain constant and will vary with air velocity, however use of the identified correlation is more representative than assuming a constant air-side pressure drop.

Table 4. Design efficiency values

Simulation block	$\eta_{\text{fluid}} (\%)$	$\eta_{\text{mechanical}} (\%)$
Turbine	83	94
Pump	80	98
Fan	55	90

3.4 Net Power Optimization

Following specification of the aforementioned plant design values, the simulation net power output is maximized by implementing the Aspen Plus optimization feature. The WNET optimization block is configured to vary the working fluid mass flow rate, air flow rate, pump pressure, and vaporizer outlet temperature to maximize the net power objective function:

$$\dot{W}_{\text{net}} = \dot{W}_{\text{trb}} - \dot{W}_{\text{pmp}} - \dot{W}_{\text{fan}}$$

Where

$\dot{W}_{\text{trb}}$ = turbine power

$\dot{W}_{\text{pmp}}$ = pump power

$\dot{W}_{\text{fan}}$ = fan power

The plant design simulation includes design constraints that may be deactivated at the user's discretion.

3.4.1 Geofluid Exit Temperature Constraint

The geothermal fluid exit temperature constraint limits the temperature change of the geothermal fluid in the preheater and vaporizer. This constraint is common when using hydrothermal resources to preclude the precipitation of dissolved solids in the preheater. Typically it is imposed to prevent the precipitation of amorphous silica, which is introduced into the geofluid via dissolution of quartz in the hydrothermal reservoir. The solubility of both quartz and amorphous silica increase with the fluid temperature, hence as the resource temperature increases so does the minimum temperature needed to prevent silica precipitation. Based upon solubility equations for both quartz and amorphous silica [1], a correlation was developed that predict the temperature constraint based upon the production fluid temperature. This calculation is included in the simulation as the TGFEXLIM calculator block. The TGFEXLIM optimization constraint uses the calculation results to limit the plant design to process conditions that should minimize precipitation of amorphous silica.

3.4.2 Dry Turbine Expansion Constraint

The dry turbine expansion constraint requires that no portion of the turbine expansion occurs within the two-phase region. This requirement is commonly used by operators of commercial binary plants to prevent damage to turbine internals exposed to vapor having entrained droplets, as well as the adverse impact that 'wet' expansions have on turbine efficiency. Though there has been work that indicates this constraint is overly conservative [2], the dry turbine expansion constraint is active in the default simulation configuration.

To assure that the turbine expansion remains dry, a minimum constraint is placed on the entropy of the vapor entering the turbine. This constraint is illustrated in Figure 4.

Figure 4. Inlet temperature constraint on vapor entering turbine

For those fluids having retrograde dew point curves like isobutane, for saturation conditions up to the maximum dew point entropy (dashed line in figure on the left) a minimum level of superheat (1°F) is imposed on the vapor entering the turbine. For saturation conditions above the maximum dew point entropy, as well as for supercritical pressures, the minimum turbine inlet temperature is established by the maximum dew point entropy. For fluids like propane where the dew point entropy increases with a decreasing temperature (figure on the right), the minimum turbine inlet entropy is established by the dew point entropy at the exhaust pressure (dashed line in right figure). The imposition of these constraints on the entropy (or superheat) of the vapor entering the turbine assures that the resulting expansion occurs outside of the two-phase region (to the right of the dashed lines in both of the above figures).

3.4.3 Maximum and Minimum Working Fluid System Pressure Constraints

The WNET optimization block includes two separate constraints for specifying the minimum and maximum working fluid system pressure. In the default plant design simulation configuration, both of these constraints are disabled as a result of the limits on the working fluid system pressure being limited by the upper and lower bounds set for WNET optimization block pump pressure and TACND-DS design spec turbine exhaust pressure, respectively. In the event the simulation is reconfigured such that the working fluid pressure is no longer bounded by these simulation objects, the PMIN and PMAX constraints described below may be activated.

WNET optimization block constraint PMIN prevents the pressure in the condensate stream from falling below the specified pressure. Typically, this constraint would be implemented to prevent the working fluid pressure from being condensed at a vacuum to eliminate the possibility of noncondensable gases (air) leaking into the working fluid system. The minimum system pressure may alternatively be limited by adjusting the lower bound of the turbine exhaust pressure in the TACND-DS design spec (downstream piping and condenser pressure losses must be accounted for).

WNET optimization block constraint PMAX places an upper limit of 1,200 psi on the working fluid system pressure. This pressure constraint is less than the maximum pressure rating for an ANSI 600 pound flange at 200°C . Operation at higher pressures is not considered to be likely because of the additional cost for system components when these pressures are used (costs increase not necessary as a result of higher component pressures, but also due to the increased pump and turbine-generator sizes). The maximum system pressure may alternatively be limited by adjusting the upper bound of the pump pressure variable in the WNET optimization block.

3.5 Summary of Design Spec, Calculator, and Optimization Block Functionality

design spec	vary	purpose
DPAIR-DS	condenser air side pressure drop	set condenser air side pressure drop according to change in ratio of actual to design product of air density and square of air velocity
PGF-DS	geofluid inlet pressure	set geofluid inlet pressure such that specified geofluid temperature is 50°F below saturation temperature
SPRHX-DS	preheater cold side heat duty	adjust preheater outlet conditions to match entropy target set in SPRHX-C calculator
TACND-DS	turbine exhaust pressure	set condenser minimum temperature approach to specified design value (default 15°F)
TARCP-DS	recuperator hot side duty	set recuperator minimum temperature approach to specified design value (default 10°F)

calculator	purpose
PSUBCR-C	specify pressure for bubble point calculation used in determining preheater outlet entropy specification for SPRHX-DS design spec
PTHRT-C	calculate pressure at throat of turbine nozzles assuming isentropic working fluid expansion
RESULTS	consolidate, format, and output relevant simulation results to simulation terminal, history file, and report file
SETVAR	consolidated input interface for setting design spec and optimization bounds
SPRHX-C	select preheater outlet entropy specification for SPRHX-DS design spec depending on whether working fluid vaporization occurs under subcritical or supercritical conditions
STRBMIN	calculate minimum dew point entropy depending on working fluid characteristics (standard or retrograde dew point curve)
TGFEXLIM	calculate minimum geofluid exit temperature value for TGFEXLIM constraint in WNET optimization block
TVAP-C	set vaporizer outlet temperature equal to dew point temperature (subcritical process) or critical point temperature (supercritical process) plus ΔT value specified by WNET optimization block

optimization block	vary	purpose
SDWPTMAX	block SDPMX pressure	determine maximum dew point entropy pressure
WNET	working fluid flow rate; air flow rate; pump outlet pressure; vaporizer hot side outlet temperature	maximize net power (turbine power – pump power – fan power)

constraint	purpose
PMAX	limit maximum working fluid pressure as specified by user
PMIN	limit minimum working fluid pressure to prevent entry of noncondensable gas into cycle
STRBIN	specify minimum turbine inlet entropy calculated in STRBMIN calculator block to ensure dry turbine expansion
TAHX	set minimum temperature approach value occurring in preheater/vaporizer blocks (default 10°F)
TGFEXLIM	specify minimum geofluid exit temperature calculated in TGFEXLIM calculator block

4. Plant Rating Simulations

The plant design simulations previously described provide the basis for equipment sizing and performance specifications. The plant performance data associated with these plant design simulations correspond to a single operating point that is tied to the ambient and resource design conditions. Changes to the ambient temperature or resource temperature and/or flow rate force the plant to operate at off-design conditions, which impacts plant performance. The plant rating simulation provides the capability to simulate the performance of a selected plant design at off-design ambient and resource conditions. A flow diagram of the process configuration is shown in Figure 5.

Figure 5. Air-cooled binary plant rating simulation process flow diagram

For a given set of off-design conditions, the plant rating simulations determine maximal net power output by optimizing plant operating parameters analogous to those that would be controlled by the operator of an actual geothermal plant. These operating parameters include the working fluid mass flow rate, control valve pressure drop, and air mass flow rate. The plant operating point determined by these variables could be replicated by a geothermal plant operator by manipulating the control valve position, turbine vane position, and condenser fan operation (turning fans on or off).

The plant rating simulations account for the changes in heat transfer and thermodynamic properties, and equipment performance that were deemed to be the major factors affecting off-design plant performance. The principles and calculations used to determine off-design plant performance are described below.

4.1 Pump and Fan Curves

Results from the plant design simulations include the design operating point for each of the process components. The operating characteristics of the pump will vary significantly at conditions differing from the design point. The performance of the pump at off-design conditions is described by a pump curve that specifies head and efficiency as a function of volumetric flow rate. Therefore, each plant rating simulation requires a pump curve to calculate pump performance at plant operating conditions differing from the design point.

The shape of these pump curves was determined using the spec sheet for the working fluid pumps in an operating commercial binary plant. A normalized pump curve, with the design point flow rate

corresponding to an x-axis value of unity and the design point head and efficiency values occupying the corresponding unity positions on the dual y-axis plot, was generated by curve fitting the pump curve for the commercial plant. The plant rating simulation pump curve was then generated from this normalized pump curve by using the pump operating point from the plant design simulation as the design condition. The normalized pump curve is shown in Figure 6. The pump specifications are imported from the SETVAR calculator block and the normalized pump curve is generated in calculator PMPCURVE. The normalized pump curve is then imported into the PUMP block where the option to “use performance curve to determine discharge conditions” is selected.

Figure 6. Normalized pump curve (head and efficiency vs. volumetric flow)

The fan curve is calculated in a similar manner: A normalized fan curve was derived from a fan curve representative of a geothermal air-cooled binary plant condenser fan. The fan design operating point is imported from the plant design simulation results via the SETVAR calculator. The plant rating simulation fan curve is generated in the FANCURVE calculator and scaled according to the percentage of fans operating, which is set by the WNET optimization block. The fan curve is exported to the FAN block where the “use performance curve to determine discharge conditions” option is selected. Pressure drop in the condenser is determined using the DPAIR-C calculator block. The MAIR design spec varies the air mass flow rate until the fan exit pressure is equal to the condenser air side inlet pressure.

4.2 Turbine

The method used to characterize operation of the turbine quantifies how the turbine reacts as the operating conditions both into and out of the turbine deviate from those for which it was designed. The two parameters quantified by this methodology are the effects on the flow rate of the working fluid through the turbine and on the turbine efficiency. For this analysis it is assumed that the turbine is a single stage, reaction turbine with variable nozzle geometry. A similar approach would have been used for an impulse turbine.

The working fluid flow through a turbine is choked, i.e., the vapor flow through the throat of the turbine nozzles is at the sonic velocity. For a constant throat area, the working fluid flow varies with both the density of the vapor at the throat and the sonic velocity. The vapor density varies directly with the pressure and indirectly with temperature, and if the operator would like to decrease flow through the

turbine, it is necessary to increase the temperature or decrease pressure. Decreasing the turbine inlet pressure will decrease the necessary pump head and increase the flow produced by the pump. In order to operate a turbine at ‘off-design’ conditions, it becomes necessary to throttle flow either leaving the pump or entering the turbine, both of which increase cycle thermodynamic irreversibilities and lower plant performance. Operation at off-design conditions is inevitable as the ambient and resource conditions deviate from the plant’s design values.

As indicated, flow through the turbine is a function of both the sonic velocity and the fluid density at the throat of the turbine nozzle. One method of defining the throat conditions is to identify the pressure where the mass flux (flow/area, or velocity times density) is a maximum for an isentropic expansion from a given inlet condition. In this approach the velocity, V , is defined as

$$V = (2 \cdot \Delta h_{isentropic})^{0.5}$$

where $\Delta h_{isentropic}$ is the isentropic enthalpy change from the inlet to a given pressure [3].

As the pressure is reduced from the turbine inlet condition, the velocity increases and the density (at this pressure and the entropy at the turbine inlet) decreases. At some reduced pressure, the product of this velocity and density goes through a maximum. This maximum defines operation at the throat of the turbine nozzle.

The plant rating model uses the following relationship [4] to compute the pressure at the throat of the turbine nozzle:

$$P^* = 0.67 \cdot P_{trb,in} \cdot \left(\frac{P_{trb,in}}{P_{crit}} \right)^{0.2} \cdot \left(\frac{T_{trb,in}}{T_{crit}} \right)^{-1}$$

Where

P = absolute pressure

T = absolute temperature

superscript “*” denotes turbine nozzle throat conditions

subscript “crit” denotes critical condition.

Using this relationship to define the throat pressure, the enthalpy change and density can be defined for an isentropic expansion from the design turbine inlet condition and used to determine the mass flux. With the design flow rate established, this relationship allows the total turbine nozzle cross sectional area to be determined. Once the throat area is known, the mass flow rate can then be calculated for turbine inlet conditions other than design.

The plant rating simulation assumes the turbine has variable nozzle geometry, which allows the throat area to be changed. This provides an additional degree of freedom in maximizing plant performance. It is assumed that the turbine is oversized such that the turbine nozzles are partially closed at the design condition. The over design factor is a user defined parameter that can be changed in the plant rating simulation by altering the ODFTRB variable in the SETVAR calculator block. The default value is set at 25%, i.e. the turbine nozzles are in the 80% open position at design conditions. This provision allows additional flexibility in optimizing performance at the off-design condition, and is used in some commercial plant turbine designs.

The use of variable nozzle geometry reduces the efficiency of the turbine when operation requires a level of throttling that deviates from the optimal. Using similar information from different sources [3] and [4], a correlation was developed that related the change in turbine efficiency to the change in throat area resulting from manipulating the nozzle geometry.

To characterize the effect of varying inlet and exhaust conditions on turbine performance, information in reference [3] was used to relate the turbine efficiency to a velocity ratio for a reaction turbine. The velocity ratio is the ratio of the tip speed to the spouting velocity, which is the velocity one would have if the potential energy defined by an isentropic expansion (enthalpy change) were converted to kinetic energy (velocity).

At off-design conditions, these relationships establish the flow the turbine is able to accommodate and the effect of those conditions on the turbine's efficiency, both in terms of changes in the inlet and exhaust conditions as well as any throttling needed to adjust the flow to match the desired inlet pressure. The correlations are included in the plant rating model in the form of the TRB1-C calculator, which computes overall turbine efficiency as a function of the variables described above. The EFFTRB design spec adjusts turbine performance to match that calculated by the TRB1-C calculator block.

4.3 Heat Exchangers

Changes to the fluid mass flow rates and properties will affect the heat transfer occurring in each of the heat exchangers. Heat exchanger duty is a function of the temperature difference between the hot and cold sides of the heat exchanger; the overall heat transfer coefficient, which is a function of heat exchanger geometry, fluid properties, and flow regime; as well as heat transfer area.

Heat exchanger geometry and area are constant by definition in the plant rating simulations. However, changes to fluid flow rates will affect the fluid flow regime, equipment operating pressures, and temperature differences throughout each heat exchanger; which in turn will affect fluid physical properties. Changes in the fluid flow regime were assumed to have a greater effect on the overall heat transfer coefficient than changes in fluid properties (viscosity, density, heat capacity, and thermal conductivity).

Table 5. Heat transfer coefficient correction factors

Heat Exchanger	Hot Side				Cold Side			
	Geometry	Fluid	Governing heat transfer correlation	Correlation Reynolds Number exponent	Geometry	Fluid	Governing heat transfer correlation	Correlation Reynolds Number exponent
Preheater	Tube	GF	Sieder-Tate	0.8	Shell	WF	Donohue	0.6
Boiler	Tube	GF	Sieder-Tate	0.8	Shell	WF	Donohue	0.6
Condenser	Tube	WF	Boyko and Kruzhilin	0.8	Fin	Air	Zukauskas	0.6
Recuperator	Shell	WF (vap)	Donohue	0.6	Tube	WF (liq)	Sieder-Tate	0.8

The Sieder and Tate [5], Donohue [6], Boyko and Kruzhilin [7], and Zukauskas [8] heat transfer correlations are used to determine the dependence of the heat transfer coefficients on fluid mass flow rates. A correction to the UA of each heat exchanger was derived to account for changes in fluid mass flow rates:

$$UA = UA_D \cdot \left[1 + R_{hot} \cdot \left(\left(\frac{\dot{m}_{hot}}{\dot{m}_{hot,D}} \right)^{exp_{hot}} - 1 \right) + R_{cold} \cdot \left(\left(\frac{\dot{m}_{cold}}{\dot{m}_{cold,D}} \right)^{exp_{cold}} - 1 \right) \right]$$

Where

UA = product of overall heat transfer coefficient and heat exchange area

R = heat transfer resistance associated with specified side of heat exchanger, proportional to reciprocal of specified heat transfer coefficient

$\dot{m}$ = mass flow rate

exp = exponent of Reynolds number in governing heat transfer correlations listed in Table 5

subscript “D” denotes design condition value

subscripts “hot” and “cold” denote hot and cold side of heat exchanger, respectively

In order to set the plant rating simulation UA equal to the value calculated using the above mass flow rate correction equation, one independent variable dependent on the UA of each heat exchanger is manipulated. These variables are described in Table 6.

Table 6. Plant rating simulation heat exchanger manipulated variables

Heat Exchanger Block	Design Spec	Variable manipulated to achieve corrected UA
Preheater	UAPRHX	Preheater cold side duty
Vaporizer	UAVAP	Vaporizer cold side duty
Condenser	UACOND	Turbine outlet pressure
Recuperator	UARECP	Recuperator cold side duty

4.4 Frictional losses

In addition to affecting pump performance and heat transfer processes, changes in the fluid mass flow rates also affect the magnitude of frictional losses in individual unit operations as well as in process piping. The plant rating simulation frictional losses are determined by applying the Aspen Plus pressure drop correlation parameter calculation [11]:

$$\Delta P = kW^2 \frac{(1/\rho_{in} + 1/\rho_{out})}{2}$$

Where

k = pressure-drop correlation parameter [m^{-4}], k is always specified in SI units]

W = mass flow rate

ρ_{in} = inlet density

ρ_{out} = outlet density

The pressure drop correlation is a native calculation performed by Aspen Plus heater blocks, and is the primary reason heater block are used for pressure drop specification and calculation in the plant design and rating simulations, respectively. The pressure drop correlation is based on pV^2 pressure loss and the area needed to convert the flow rate to velocity is incorporated into k. The pressure drop correlation parameters calculated for each unit operation and piping section in the plant design simulation

are exported to the corresponding plant rating simulation blocks using the SETVAR calculator. Each heater block designated for pressure drop calculations using the pressure-drop correlation parameter is configured with an adiabatic heat transfer specification to compute pressure drop as a function of fluid flow rate.

4.5 Net Power Optimization

Following import of equipment specifications and design operating point data from a selected plant design simulation, the Aspen Plus optimization feature is used to maximize the plant rating simulation net power output for the specified off design ambient and resource conditions. The plant rating simulation WNET optimization block is configured to vary the working fluid mass flow rate, control valve pressure drop, and operating percentage of air-cooled condenser fans to maximize an identical net power objective function as used in the plant design simulations:

$$\dot{W}_{net} = \dot{W}_{trb} - \dot{W}_{pmp} - \dot{W}_{fan}$$

Where

$\dot{W}_{trb}$ = turbine power

$\dot{W}_{pmp}$ = pump power

$\dot{W}_{fan}$ = fan power

The plant design simulation includes design constraints that may be deactivated at the user's discretion. The minimum geofluid exit temperature (TGFEXLIM), dry turbine expansion (STRBIN), and minimum working fluid pressure (PMIN) constraints are identical in terms of computations and implementation to the corresponding plant design simulation constraints. The WMAX constraint limits maximum turbine generator output to a user specified value to prevent exceeding the rated capacity. The VANPOS constraint prevents the plant rating simulation from selecting plant operating points with mass flux through the turbine nozzle greater than what could be achieved with the turbine vanes in the fully open position.

4.6 Summary of Design Spec, Calculator, and Optimization Block Functionality

design spec	vary	purpose
EFFTRB	turbine specified isentropic efficiency	adjust turbine specified isentropic efficiency to match off-design condition value calculated by TRB1-C calculator
MAIR	air mass flow rate	adjust air mass flow rate to account for off-design condition condenser air side pressure drop and fan performance such that condenser inlet pressure matches fan exit pressure
PGF-DS	geofluid inlet pressure	set geofluid inlet pressure such that specified geofluid temperature is 50°F below saturation temperature
UACOND	turbine outlet pressure	adjust turbine outlet pressure to match condenser UA adjusted for off-design process conditions
UAPRHX	preheater cold side duty	adjust preheater cold side duty to match preheater UA adjusted for off-design process conditions
UARECP	recuperator cold side duty	adjust recuperator cold side duty to match recuperator UA adjusted for off-design process conditions
UAVAP	vaporizer cold side duty	adjust vaporizer cold side duty to match vaporizer UA adjusted for off-design process conditions

calculator	purpose
COMP	transfers working fluid composition specified in PMPE tear stream to blocks used for calculating working fluid reference state, maximum dewpoint entropy, working fluid T-S 2-phase envelope geometry (standard vs. retrograde), and design turbine nozzle throat conditions
DPAIR-C	calculates condenser air-side pressure drop as function of air density and flow rate
FANCURVE	generates fan curve using pump design point data imported from SETVAR calculator
PMPCURVE	generates pump curve using pump design point data imported from SETVAR calculator
PTHRT	calculate pressure at throat of turbine nozzles assuming isentropic working fluid expansion
PTHRTD	calculate pressure at throat of turbine nozzles at plant design conditions assuming isentropic working fluid expansion
RESULTS	consolidate, format, and output relevant simulation results to simulation terminal, history file, and report file
SETRECP	diverts working fluid flow to or around recuperator based on RECP flag in SETVAR calculator (recuperator bypassed when RECP = 0, recuperator used when RECP = 1)
SETVAR	consolidated input interface for importing plant design simulation results and setting design spec and optimization bounds
STRBMIN	calculate minimum dew point entropy depending on working fluid characteristics (standard or retrograde dew point curve)
TGFEXLIM	calculate minimum geofluid exit temperature value for TGFEXLIM constraint in WNET optimization block
TRB1-C	calculates turbine isentropic efficiency as function of vane position and turbine spouting velocity

optimization block	vary	purpose
SDWPTMAX	block SDPMX pressure	determine maximum dew point entropy pressure
WNET	working fluid flow rate; control valve pressure drop; percent of condenser fans operating	maximize net power (turbine power – pump power – fan power)

constraint	purpose
PMIN	limit minimum working fluid pressure to prevent entry of noncondensable gas into cycle
STRBIN	specify minimum turbine inlet entropy calculated in STRBMIN calculator block to ensure dry turbine expansion
TGFEXLIM	specify minimum geofluid exit temperature calculated in TGFEXLIM calculator block
VANEPOS	limit calculated plant performance to operating points that can be accommodated by the range of possible turbine nozzle vane positions ($\leq 100\%$ open)
WMAX	limit turbine generator output to prevent exceeding rated capacity

5. Works Cited

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Appendix I

Aspen Plus 2006 Plant Design Simulation Input File

IN-UNITS ENG

DEF-STREAMS CONVEN ALL

DIAGNOSTICS

HISTORY SIM-LEVEL=2 PROP-LEVEL=2 STREAM-LEVEL=2 CONV-LEVEL=2
TERMINAL SIM-LEVEL=2 CONV-LEVEL=2 PROP-LEVEL=2 &
STREAM-LEVEL=2

SIM-OPTIONS

DESCRIPTION "

GENERAL SIMULATION WITH ENGLISH UNITS : F, PSI, LB/HR,
LBMOL/HR, BTU/HR, CUFT/HR. PROPERTY METHOD: NONE FLOW BASIS
FOR INPUT: MOLE STREAM REPORT COMPOSITION: MOLE FLOW
"

DATABANKS PURE20 / AQUEOUS / SOLIDS / INORGANIC / &
NOASPENPCD

PROP-SOURCES PURE20 / AQUEOUS / SOLIDS / INORGANIC

COMPONENTS

C3H8 C3H8 /
N-C4H10 C4H10-1 /
I-C4H10 C4H10-2 /
N-C5H12 C5H12-1 /
I-C5H12 C5H12-2 /
R134A C2H2F4 /
R245FA C3H3F5-D1 /
H2O H2O /
AIR AIR

COMP-GROUP WF SUBSTREAM=MIXED COMPS=R245FA

FLOWSHEET

BLOCK PUMP IN=CONDE OUT=PMPE
BLOCK CV IN=CVI OUT=CVE
BLOCK VAP IN=GFIN HX-COLD OUT=HXE HX-HOT
BLOCK TRB IN=TURBIA OUT=TURBE
BLOCK COND IN=CONDI CNDAIRI OUT=CONDE CNDAIRE
BLOCK FAN IN=CNDAIRE OUT=AIRE
BLOCK DPL2 IN=CVE OUT=L3
BLOCK DPL1 IN=L2 OUT=CVI
BLOCK DPV1 IN=HXE OUT=TURBI
BLOCK DPV2 IN=V2 OUT=V3
BLOCK SDPMX IN=WFREF OUT=SDPMX
BLOCK REFSTATE IN=GFEX OUT=GF0
BLOCK RECP IN=SHELLI TUBEI OUT=SHELLE TUBEE
BLOCK VDUPL IN=TURBE OUT=V1
BLOCK VSELECT IN=SHELLE V1 OUT=V2
BLOCK LDUPL IN=PMPE OUT=L1
BLOCK LSELECT IN=TUBEE L1 OUT=L2
BLOCK TRBDUPL IN=TURBI OUT=TURBIA TURBIB TURBIC
BLOCK DPCN IN=V3 OUT=CONDI
BLOCK DPHX IN=L3 OUT=L4
BLOCK DPRV IN=RV1 OUT=SHELLI
BLOCK DPRL IN=RL1 OUT=TUBEI
BLOCK DPAIR IN=AIRI OUT=CNDAIRI
BLOCK TRBX IN=TURBIB OUT=TRBTHRT
BLOCK TDECR IN=SDPMX OUT=TDECR
BLOCK WFREF IN=WF OUT=WFREF
BLOCK TRBSMIN IN=TURBIC OUT=SMIN
BLOCK PRHX IN=HX-HOT HXI OUT=HX-COLD GFEX
BLOCK PTRBUB IN=TDECR OUT=PTRBUB
BLOCK PTRBLB IN=PTRBUB OUT=PTRBLB
BLOCK TDEW IN=TBUB OUT=TDEW
BLOCK TBUB IN=HXI1 OUT=TBUB
BLOCK SPRHX IN=TDEW OUT=SPRTGT
BLOCK HXIDUPL IN=L4 OUT=HXI1 HXI
BLOCK PGFIN IN=GF OUT=GFIN

PROPERTIES PENG-ROB
PROPERTIES STEAMNBS
PROPERTIES IDEAL

PROP-DATA PRKBV-1

IN-UNITS ENG

PROP-LIST PRKBV

BPVAL C3H8 I-C5H12 .01110 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 C3H8 .01110 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 I-C4H10 -.00780 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C4H10 C3H8 -.00780 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 N-C4H10 .00330 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 C3H8 .00330 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 I-C4H10 -.00040 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C4H10 N-C4H10 -.00040 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 N-C5H12 .02670 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 C3H8 .02670 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 N-C5H12 .01740 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 N-C4H10 .01740 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 I-C5H12 0.0 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 N-C5H12 0.0 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 I-C5H12 .002920 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 N-C4H10 .002920 0.0 0.0 -459.66999230 &
1340.3299930

PROP-SET PBUB PBUB SUBSTREAM=MIXED

PROP-SET PCMX PCMX SUBSTREAM=MIXED

PROP-SET TBUB TBUB SUBSTREAM=MIXED

PROP-SET TCMX TCMX SUBSTREAM=MIXED

PROP-SET TDEW TDEW SUBSTREAM=MIXED

STREAM AIRI

SUBSTREAM MIXED TEMP=50 PRES=14.6959488 MASS-FLOW=29199525
MASS-FRAC AIR 1

STREAM GF

SUBSTREAM MIXED TEMP=392 PRES=500 MASS-FLOW=1000000
MASS-FRAC H2O 1

STREAM L2

SUBSTREAM MIXED TEMP=89.9144358 PRES=870.615145 &
MASS-FLOW=1840466.65
MASS-FRAC R245FA 1

STREAM RL1

SUBSTREAM MIXED TEMP=93.3844427 PRES=717.287447 &
MASS-FLOW=3250459.25
MASS-FRAC I-C4H10 1

STREAM RV1

SUBSTREAM MIXED TEMP=129.806464 PRES=63.7993169 &
MASS-FLOW=3250459.25
MASS-FRAC I-C4H10 1

STREAM SHELLE
 SUBSTREAM MIXED TEMP=103.394785 PRES=62.7993169
 MASS-FLOW I-C4H10 3250459.25

STREAM TUBEE
 SUBSTREAM MIXED TEMP=113.022878 PRES=712.287447
 MASS-FLOW I-C4H10 3250459.25

STREAM WF
 SUBSTREAM MIXED TEMP=32 PRES=14.69595 MASS-FLOW=1839889.44
 MASS-FRAC R245FA 1

BLOCK DPAIR HEATER
 PARAM PRES=-0.0095065785 DUTY=0.0
 PROPERTIES IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPCN HEATER
 PARAM PRES=-1.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPHX HEATER
 PARAM PRES=-38.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPL1 HEATER
 PARAM PRES=-5.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPL2 HEATER
 PARAM PRES=-5.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPRL HEATER
 PARAM PRES=-5.0 DUTY=0.0

BLOCK DPRV HEATER
 PARAM PRES=-1.0 DUTY=0.0

BLOCK DPV1 HEATER
 PARAM PRES=-3.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK DPV2 HEATER
 PARAM PRES=-1.0 DUTY=0.0
 PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES

BLOCK PGFIN HEATER
 PARAM PRES=389.088064 DELT=0.
 PROPERTIES STEAMNBS

BLOCK PTRBLB HEATER
 PARAM TEMP=50.0 VFRAC=0.0

BLOCK PTRBUB HEATER
 PARAM TEMP=150.0 VFRAC=0.0

BLOCK REFSTATE HEATER
 PARAM TEMP=50.0 PRES=14.6959488 NPHASE=1 PHASE=L
 PROPERTIES STEAMNBS FREE-WATER=STEAM-TA SOLU-WATER=3 &
 TRUE-COMPS=YES
 BLOCK-OPTION FREE-WATER=NO

BLOCK SDPMX HEATER
 PARAM PRES=323.831426 VFRAC=1.0 TOL=1.0000E-08


```

BLOCK SPRHX HEATER
  PARAM TEMP=309.290002 PRES=527.937365

BLOCK TBUB HEATER
  PARAM PRES=526.937365 VFRAC=0.0

BLOCK TDECR HEATER
  PARAM VFRAC=1.0 DELT=-10.0

BLOCK TDEW HEATER
  PARAM PRES=0.0 VFRAC=1.0

BLOCK TRBSMIN HEATER
  PARAM TEMP=262.467361 PRES=323.831426

BLOCK WFREF HEATER
  PARAM TEMP=32. PRES=14.69595

BLOCK COND MHEATX
  HOT-SIDE IN=CONDI OUT=CONDE DEGSUB=2.0 FREE-WATER=NO
  COLD-SIDE IN=CNDAIRI OUT=CND Aire FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES
  STREAM-PROPE CND AIRI IDEAL

BLOCK PRHX MHEATX
  HOT-SIDE IN=HX-HOT OUT=GFEX FREE-WATER=NO
  COLD-SIDE IN=HXI OUT=HX-COLD DUTY=186134115 FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES
  STREAM-PROPE HX-HOT STEAMNBS FREE-WATER=STEAM-TA &
  SOLU-WATER=3 TRUE-COMPS=YES

BLOCK RECP MHEATX
  HOT-SIDE IN=SHELLI OUT=SHELLE DUTY=-37387972.5 &
  FREE-WATER=NO
  COLD-SIDE IN=TUBEI OUT=TUBEE FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES

BLOCK VAP MHEATX
  HOT-SIDE IN=GFIN OUT=HX-HOT FREE-WATER=NO
  COLD-SIDE IN=HX-COLD OUT=HXE TEMP=379.26083 FREE-WATER=NO
  PARAM NPOINT=25 ADAPTIVE-GRI=YES
  STREAM-PROPE GFIN STEAMNBS FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK PUMP PUMP
  PARAM PRES=870.615145 EFF=.80 DEFF=.980

BLOCK FAN COMPR
  PARAM TYPE=ISENTROPIC PRES=14.6959488 SEFF=.550 MEFF=.90
  PROPERTIES IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK TRB COMPR
  PARAM TYPE=ISENTROPIC PRES=27.9789871 SEFF=.830 MEFF=.940 &
  MODEL-TYPE=TURBINE

BLOCK TRBX COMPR
  PARAM TYPE=ISENTROPIC PRES=548.210395 SEFF=1.0 MEFF=1.0 &
  MODEL-TYPE=TURBINE

BLOCK HXIDUPL DUPL

BLOCK LDUPL DUPL

BLOCK TRBDUPL DUPL

BLOCK VDUPL DUPL

BLOCK LSELECT SELECTOR
  PARAM STREAM=L1

```

```

BLOCK VSELECT SELECTOR
  PARAM STREAM=V1

BLOCK CV VALVE
  PARAM P-DROP=2.0
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
    TRUE-COMPS=YES

;set condenser air side pressure drop according to change in ratio of actual
;design product of air density and square of air velocity

;

;

;

; "DPAIR-DS design spec"

DESIGN-SPEC DPAIR-DS
F   REAL K
  DEFINE MAIR STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE RHOAIR STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
  DEFINE UA BLOCK-VAR BLOCK=COND VARIABLE=UA SENTENCE=RESULTS
  DEFINE DPPSI BLOCK-VAR BLOCK=DPAIR VARIABLE=PRES &
    SENTENCE=PARAM
  DEFINE PAIRI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE PCNDAI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
C DESIGN DATA FROM SPEC SHEET OF COMMERCIAL POWER PLANT
C WITH 5 ROW 2 PASS AIR-COOLED CONDENSER
F
C   CONDENSER SPEC SHEET VOLUMETRIC AIR FLOW RATE [ACFM]
C   FLOWD = AIR QTY PER FAN [ACFM] * UNITS * FANS/UNIT
F   FLOWD = 135062.*40.*3.
F
C   CONDENSER DESIGN UA
C   UAD = DUTY/LMTD [BTU/HR-F]
F   UAD = 3.65E+08/22.7
F
C   CONDENSER DESIGN DENSITY [LB/CUFT]
F   RHOD = 0.05993608
F
C   CONDENSER DESIGN PRESSURE DROP
C   DPD = 0.260 [IN H2O]
F   DPD = -0.260
F
C   PRESSURE DROP PARAMETER
F   K = DPD/(RHOD*(FLOWD/UAD)**2)
F
C   SIMULATION VOLUMETRIC AIR FLOW RATE [ACFM]
F   FLOW = MAIR/(RHOAIR*60.)
F
F   DP = K*RHOAIR*(FLOW/UA)**2
F   DPPSI = DP * 3.612E-02
F
C   WRITE(NTerm,100) DP
C 100 FORMAT('COND AIR SIDE DELTA P ', F6.3 , ' IN-H2O')
F
C   WRITE(NTerm,101) K
C 101 FORMAT('PRESSURE DROP PARAMETER ', E10.3)
  SPEC "PCNDAI-PAIRI" TO "DPPSI"
  TOL-SPEC "1.0E-05"
  VARY BLOCK-VAR BLOCK=DPAIR VARIABLE=PRES SENTENCE=PARAM
  LIMITS "-0.1" "-0.001"

;set geofluid inlet pressure such that specified geofluid temperature is 50°
;below saturation temperature
;

```

```

; "PGF-DS design spec"
DESIGN-SPEC PGF-DS
  DEFINE TGF STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE TBUB STREAM-PROP STREAM=GFIN PROPERTY=TBUB
  SPEC "TBUB-TGF" TO "50."
  TOL-SPEC "0.001"
  VARY BLOCK-VAR BLOCK=PGFIN VARIABLE=PRES SENTENCE=PARAM
  LIMITS "20" "1000"

;adjust preheater outlet conditions to match entropy target set in SPRHX-C c
; "SPRHX-DS design spec"
DESIGN-SPEC SPRHX-DS
  DEFINE SHXCOLD STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE SPRTGT STREAM-VAR STREAM=SPRTGT SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE QPRHLB PARAMETER 54
  DEFINE QPRHUB PARAMETER 55
  SPEC "SHXCOLD" TO "SPRTGT"
  TOL-SPEC "1.0E-04"
  VARY BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY SENTENCE=COLD-SIDE &
    ID1=HXI
  LIMITS "QPRHLB" "QPRHUB"

;set condenser minimum temperature approach to specified design value (defau
; "TACND-DS design spec"
DESIGN-SPEC TACND-DS
  DEFINE TACOND BLOCK-VAR BLOCK=COND VARIABLE=MITA &
    SENTENCE=RESULTS
  DEFINE PTRBLB PARAMETER 58
  DEFINE PTRBUB PARAMETER 59
  SPEC "TACOND" TO "15"
  TOL-SPEC "0.001"
  VARY BLOCK-VAR BLOCK=TRB VARIABLE=PRES SENTENCE=PARAM
  LIMITS "PTRBLB" "PTRBUB"

;set recuperator minimum temperature approach to specified design value (def
; "TARCP-DS design spec"
DESIGN-SPEC TARCP-DS
  DEFINE TARECP BLOCK-VAR BLOCK=RECP VARIABLE=MITA &
    SENTENCE=RESULTS
  DEFINE QRCPLB PARAMETER 60
  DEFINE QRC PUB PARAMETER 61
  SPEC "TARECP" TO "10"
  TOL-SPEC "0.001"
  VARY BLOCK-VAR BLOCK=RECP VARIABLE=DUTY SENTENCE=HOT-SIDE &
    ID1=SHELLI
  LIMITS "QRCPLB" "QRC PUB"

EO-CONV-OPTI

;specify pressure for bubble point calculation used in determining preheater
;outlet entropy specification for SPRHX-DS design spec

;

; "PSUBCR-C calculator"
CALCULATOR PSUBCR-C
  DEFINE PHXI STREAM-VAR STREAM=L4 SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE PCMX STREAM-PROP STREAM=L4 PROPERTY=PCMX
  DEFINE PSUBCR BLOCK-VAR BLOCK=TBUB VARIABLE=PRES &
    SENTENCE=PARAM
F   IF (PHXI .LT. PCMX) THEN
F   PSUBCR = 0.
F   ELSE

```

```

F      PSUBCR = PCMX - 1.
F      ENDIF
      READ-VARS PHXI PCMX
      WRITE-VARS PSUBCR

;calculate pressure at throat of turbine nozzles assuming isentropic working
; "PTHRT-C calculator"

CALCULATOR PTHRT-C
      DEFINE PTRBIN STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
      VARIABLE=PRES
      DEFINE TTRBIN STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE PCMX STREAM-PROP STREAM=TURBI PROPERTY=PCMX
      DEFINE TCMX STREAM-PROP STREAM=TURBI PROPERTY=TCMX
      DEFINE PTHRT BLOCK-VAR BLOCK=TRBX VARIABLE=PRES &
      SENTENCE=PARAM
F      TTR = TTRBIN + 459.67
F      TCR = TCMX + 459.67
F      PTHRT = 0.67 * PTRBIN * (PTRBIN/PCMX)**0.2 * (TTR/TCR)**-1
      READ-VARS PTRBIN TTRBIN PCMX TCMX
      WRITE-VARS PTHRT

;consolidate, format, and output relevant simulation results to simulation
;terminal, history file, and report file

;

; "RESULTS calculator"

CALCULATOR RESULTS
F      INTEGER AMWF(51),APTRB(51),APPMP(51),AMAIR(51),ATVAP(51)
      DEFINE XC3 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=C3H8
      DEFINE XNC4 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=N-C4H10
      DEFINE XIC4 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=I-C4H10
      DEFINE XNC5 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=N-C5H12
      DEFINE XIC5 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=I-C5H12
      DEFINE XR134 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=R134A
      DEFINE XR245 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
      COMPONENT=R245FA
      DEFINE TAIRI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE TGF STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE MGF STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
      VARIABLE=MASS-FLOW
      DEFINE QPRH BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY &
      SENTENCE=RESULTS
      DEFINE UAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=UA &
      SENTENCE=RESULTS
      DEFINE LTDPRH BLOCK-VAR BLOCK=PRHX VARIABLE=LMTD &
      SENTENCE=RESULTS
      DEFINE MTAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=MITA &
      SENTENCE=RESULTS
      DEFINE TWPRIH STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE TWPRIH STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE TGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE TGPRIH STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
      VARIABLE=TEMP
      DEFINE QVAP BLOCK-VAR BLOCK=VAP VARIABLE=DUTY &
      SENTENCE=RESULTS
      DEFINE UAVAP BLOCK-VAR BLOCK=VAP VARIABLE=UA &
      SENTENCE=RESULTS

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DEFINE LTDVAP BLOCK-VAR BLOCK=VAP VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTAVAP BLOCK-VAR BLOCK=VAP VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE SMXDEC STREAM-VAR STREAM=TDECR SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE PSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE TTRBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PTRBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE TTRBE STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PTRBE BLOCK-VAR BLOCK=TRB VARIABLE=OUT-PRES-CAL &
    SENTENCE=RESULTS
DEFINE VANPOS PARAMETER 201
DEFINE TDTRBI STREAM-PROP STREAM=TURBI PROPERTY=TDEW
DEFINE SDP STREAM-VAR STREAM=SMIN SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE STRBIA STREAM-VAR STREAM=TURBIA SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE SRCPHE STREAM-VAR STREAM=SHELLE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE SV2 STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE QRCP BLOCK-VAR BLOCK=RECP VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UARCP BLOCK-VAR BLOCK=RECP VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDRCP BLOCK-VAR BLOCK=RECP VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTARCP BLOCK-VAR BLOCK=RECP VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TRCPhi STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPHE STREAM-VAR STREAM=SHELLE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPCI STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPCE STREAM-VAR STREAM=TUBEE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TDWRHI STREAM-PROP STREAM=SHELLI PROPERTY=TDEW
DEFINE TDWRHE STREAM-PROP STREAM=SHELLE PROPERTY=TDEW
DEFINE TBBRCI STREAM-PROP STREAM=TUBEI PROPERTY=TBUB
DEFINE TBBRCE STREAM-PROP STREAM=TUBEE PROPERTY=TBUB
DEFINE QCND BLOCK-VAR BLOCK=COND VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UACND BLOCK-VAR BLOCK=COND VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDCND BLOCK-VAR BLOCK=COND VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTACND BLOCK-VAR BLOCK=COND VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TWCNDI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TWCNDE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TDCNDI STREAM-PROP STREAM=V3 PROPERTY=TDEW
DEFINE TBCNDE STREAM-PROP STREAM=CONDE PROPERTY=TBUB
DEFINE TAIRE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE MAIR STREAM-VAR STREAM=CND Aire SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
DEFINE RHOAIR STREAM-VAR STREAM=CND Aire SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE FANVOL PARAMETER 31
DEFINE PCTFAN PARAMETER 200

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DEFINE PAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE PAE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE DPPSI BLOCK-VAR BLOCK=DPAIR VARIABLE=PRES &
  SENTENCE=PARAM
DEFINE PPM PARAMETER 900
DEFINE TGFLIM PARAMETER 901
DEFINE WFAN BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
  SENTENCE=RESULTS
DEFINE WPUMP BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
  SENTENCE=RESULTS
DEFINE WTRB BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
  SENTENCE=RESULTS
DEFINE EFFTRB BLOCK-VAR BLOCK=TRB VARIABLE=SEFF &
  SENTENCE=RESULTS
DEFINE EFFD PARAMETER 42
DEFINE EFFPMP BLOCK-VAR BLOCK=PUMP VARIABLE=CALCULATED-E &
  SENTENCE=RESULTS
DEFINE EFFFAN BLOCK-VAR BLOCK=FAN VARIABLE=SEFF &
  SENTENCE=RESULTS
DEFINE MWFLB PARAMETER 52
DEFINE MWFUB PARAMETER 53
DEFINE MWF STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
  VARIABLE=MASS-FLOW
DEFINE CVDPLB PARAMETER 70
DEFINE CVD PUB PARAMETER 71
DEFINE CVDP BLOCK-VAR BLOCK=CV VARIABLE=P-DROP-R &
  SENTENCE=RESULTS
DEFINE MAIRLB PARAMETER 50
DEFINE MAIRUB PARAMETER 51
DEFINE PTRBLB PARAMETER 58
DEFINE PTRBUB PARAMETER 59
DEFINE PPMLB PARAMETER 48
DEFINE PMPUB PARAMETER 49
DEFINE PMP STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE TVAPLB PARAMETER 56
DEFINE TVAPUB PARAMETER 57
DEFINE TPARAM PARAMETER 500
F    WRITE(NTERM,50) TAIRI,TGF,MGF
F    WRITE(NRPT,50) TAIRI,TGF,MGF
F    WRITE(NHSTRY,50) TAIRI,TGF,MGF
F 50 FORMAT(//////3X,'SIMULATION RESULTS'
F    $/5X,'INLET AIR TEMPERATURE',T53,F7.1,1X,'°F'
F    $/5X,'INLET BRINE TEMPERATURE',T53,F7.1,1X,'°F'
F    $/5X,'BRINE FLOW RATE',T50,F10.1,1X,'LB/HR')
F
F    WRITE(NTERM,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F    $XIC5*100,XR134*100,XR245*100
F    WRITE(NRPT,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F    $XIC5*100,XR134*100,XR245*100
F    WRITE(NHSTRY,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F    $XIC5*100,XR134*100,XR245*100
F 60 FORMAT(/3X,'WORKING FLUID COMPOSITION',
F    $/5X,'MASS FRAC C3',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC NC4',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC IC4',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC NC5',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC IC5',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC R134A',T55,F5.1,1X,'WT%'
F    $/5X,'MASS FRAC R245FA',T55,F5.1,1X,'WT%')
F
F    WRITE(NTERM,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F    $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F    WRITE(NRPT,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F    $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F    WRITE(NHSTRY,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F    $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F 80 FORMAT(/3X,'PREHEATER RESULTS',
F    $/5X,'PREHEATER DUTY',T50,E10.3,1X,'BTU/HR'
F    $/5X,'PREHEATER UA',T50,E10.3,1X,'BTU/HR-R'

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F    $/5X, 'PREHEATER LMTD', T53, F7.1, 1X, '°F'
F    $/5X, 'PREHEATER MITA', T53, F7.1, 1X, '°F'
F    $/5X, 'WF INLET/EXIT T', T46, F6.1, ' / ', F6.1, 1X, '°F'
F    $/5X, 'BRINE INLET/EXIT T', T46, F6.1, ' / ', F6.1, 1X, '°F')
F
F    WRITE(NTERM, 90) QVAP, UAVAP, LTDVAP, MTAVAP,
F    $TWPRHE, TWVAPE, TGF, TGPRHI
F    WRITE(NRPT, 90) QVAP, UAVAP, LTDVAP, MTAVAP,
F    $TWPRHE, TWVAPE, TGF, TGPRHI
F    WRITE(NHSTRY, 90) QVAP, UAVAP, LTDVAP, MTAVAP,
F    $TWPRHE, TWVAPE, TGF, TGPRHI
F 90 FORMAT(/3X, 'VAPORIZER RESULTS',
F    $/5X, 'VAPORIZER DUTY', T50, E10.3, 1X, 'BTU/HR'
F    $/5X, 'VAPORIZER UA', T50, E10.3, 1X, 'BTU/HR-R'
F    $/5X, 'VAPORIZER LMTD', T53, F7.1, 1X, '°F'
F    $/5X, 'VAPORIZER MITA', T53, F7.1, 1X, '°F'
F    $/5X, 'WF INLET/EXIT T', T46, F6.1, ' / ', F6.1, 1X, '°F'
F    $/5X, 'BRINE INLET/EXIT T', T46, F6.1, ' / ', F6.1, 1X, '°F')
F
F    IF (SDPMX.GT.SMXDEC) THEN
F    WRITE(NTERM, 100) PSDPMX, SDP, STRBIA
F    WRITE(NRPT, 100) PSDPMX, SDP, STRBIA
F    WRITE(NHSTRY, 100) PSDPMX, SDP, STRBIA
F    ELSE
F    WRITE(NTERM, 101)
F    WRITE(NRPT, 101)
F    WRITE(NHSTRY, 101)
F    ENDIF
F
F 100 FORMAT(/3X, 'TURBINE RESULTS',
F    $/5X, 'RETROGRADE WORKING FLUID DEWPOINT CURVE'
F    $/5X, 'MAX DEW POINT ENTROPY PRESSURE', T53, F7.1, 1X, 'PSIA'
F    $/5X, 'MINIMUM TURBINE INLET ENTROPY', T53, F7.3, 1X, 'BTU/LB-R'
F    $/5X, 'TURBINE INLET ENTROPY', T53, F7.3, 1X, 'BTU/LB-R')
F
F 101 FORMAT(/3X, 'TURBINE RESULTS',
F    $/5X, 'STANDARD WORKING FLUID DEWPOINT CURVE')
F
F    WRITE(NTERM, 102) TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F    WRITE(NRPT, 102) TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F    WRITE(NHSTRY, 102) TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F 102 FORMAT(5X, 'TURBINE INLET TEMPERATURE', T53, F7.1, 1X, '°F'
F    $/5X, 'TURBINE INLET PRESSURE', T53, F7.1, 1X, 'PSIA'
F    $/5X, 'TURBINE INLET SUPERHEAT', T53, F7.1, 1X, '°F'
F    $/5X, 'TURBINE OUTLET TEMPERATURE', T53, F7.1, 1X, '°F'
F    $/5X, 'TURBINE OUTLET PRESSURE', T53, F7.1, 1X, 'PSIA'
F    $/5X, 'TURBINE NOZZLE VANE POSITION', T53, F7.1, 1X, '%')
F
F    IF (SRCPHE.EQ.SV2) THEN
F    WRITE(NTERM, 110) QRCF, UARCF, LTDRCP, MTARCF,
F    $TRCPHI-TDWRHI, TRCPHE-TDWRHE, TBBRCI-TRCPCI, TBBRCE-TRCPCE
F    WRITE(NRPT, 110) QRCF, UARCF, LTDRCP, MTARCF,
F    $TRCPHI-TDWRHI, TRCPHE-TDWRHE, TBBRCI-TRCPCI, TBBRCE-TRCPCE
F    WRITE(NHSTRY, 110) QRCF, UARCF, LTDRCP, MTARCF,
F    $TRCPHI-TDWRHI, TRCPHE-TDWRHE, TBBRCI-TRCPCI, TBBRCE-TRCPCE
F    ENDIF
F 110 FORMAT(/3X, 'RECUPERATOR RESULTS'
F    $/5X, 'RECUPERATOR DUTY', T50, E10.3, 1X, 'BTU/HR'
F    $/5X, 'RECUPERATOR UA', T50, E10.3, 1X, 'BTU/HR-R'
F    $/5X, 'RECUPERATOR LMTD', T53, F7.1, 1X, '°F'
F    $/5X, 'RECUPERATOR MITA', T53, F7.1, 1X, '°F'
F    $/5X, 'HOT SIDE INLET/EXIT SUPERHEAT', T46, F6.1, ' / ', F6.1, 1X, '°F'
F    $/5X, 'COLD SIDE INLET/EXIT SUBCOOLING', T46, F6.1, ' / ', F6.1, 1X, '°F')
F
F    WRITE(NTERM, 120) QCND, UACND, LTDCND, MTACND,
F    $TWCNDI, TWCNDE, TAIRI, TAIRE, TWCNDI-TDCNDI, TBCNDE-TWCNDE,
F    $PCTFAN*100, (PAI-PAE)/3.612E-02
F    WRITE(NRPT, 120) QCND, UACND, LTDCND, MTACND,
F    $TWCNDI, TWCNDE, TAIRI, TAIRE, TWCNDI-TDCNDI, TBCNDE-TWCNDE,
F    $PCTFAN*100, (PAI-PAE)/3.612E-02
F    WRITE(NHSTRY, 120) QCND, UACND, LTDCND, MTACND,
F    $TWCNDI, TWCNDE, TAIRI, TAIRE, TWCNDI-TDCNDI, TBCNDE-TWCNDE,

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F      $PCTFAN*100,(PAI-PAE)/3.612E-02
F 120 FORMAT(/,3X,'AIR-COOLED CONDENSER RESULTS'
F      $/5X,'CONDENSER DUTY',T50,E10.3,1X,'BTU/HR'
F      $/5X,'CONDENSER UA',T50,E10.3,1X,'BTU/HR-R'
F      $/5X,'CONDENSER LMTD',T53,F7.1,1X,'°F'
F      $/5X,'CONDENSER MITA',T53,F7.1,1X,'°F'
F      $/5X,'WF INLET/EXIT T',T46,F6.1,'/',F6.1,1X,'°F'
F      $/5X,'AIR INLET/EXIT T',T46,F6.1,'/',F6.1,1X,'°F'
F      $/5X,'INLET SUPERHEAT',T53,F7.1,1X,'°F'
F      $/5X,'EXIT SUBCOOLING',T53,F7.1,1X,'°F'
F      $/5X,'CONDENSER FANS OPERATING',T53,F7.1,1X,'%
F      $/5X,'COND AIR SIDE DELTA P',T53,F7.3,1X,'IN-H2O')
F
F      WRITE(NTERM,130)PPM,TGFLIM,TGPRHE
F      WRITE(NRPT,130)PPM,TGFLIM,TGPRHE
F      WRITE(NHSTRY,130)PPM,TGFLIM,TGPRHE
F 130 FORMAT(/,3X,'GEOTHERMAL FLUID RESULTS',
F      $/,5X,'SIO2 DISSOLVED IN GEOTHERMAL FLUID',T53,F7.1,1X,'PPM',
F      $/,5X,'GEOTHERMAL FLUID OUTLET T LIMIT',T53,F7.1,1X,'°F',
F      $/,5X,'GEOTHERMAL FLUID OUTLET T',T53,F7.1,1X,'°F')
F
F      WRITE(NTERM,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F      WRITE(NRPT,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F      WRITE(NHSTRY,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F 140 FORMAT(/,3X,'POWER SUMMARY',
F      $/,5X,'TURBINE POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'PUMP POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'FAN POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'NET POWER',T40,F7.1,' HP / ',F7.1,' KW')
F
F      WRITE(NTERM,150)EFFTRB*100,EFFPMP*100,EFFFAN*100
F      WRITE(NRPT,150)EFFTRB*100,EFFPMP*100,EFFFAN*100
F      WRITE(NHSTRY,150)EFFTRB*100,EFFPMP*100,EFFFAN*100
F 150 FORMAT(/,3X,'EFFICIENCIES',
F      $/,5X,'TURBINE EFFICIENCY',T56,F4.1,1X,'% ',
F      $/,5X,'PUMP EFFICIENCY',T56,F4.1,1X,'% ',
F      $/,5X,'FAN EFFICIENCY',T56,F4.1,1X,'%')
F
F      M = 50
F      N = M + 1
F
F      WRITE(NTERM,300)
F      WRITE(NRPT,300)
F      WRITE(NHSTRY,300)
F 300 FORMAT(/,3X,'OPTIMIZATION VARIABLE RANGES')
F
F      DO 301 I = 1, N
F      AMWF(I) = 10
F 301 CONTINUE
F      FMWF = (((MWF-MWFLB)/(MWFUB-MWFLB))*M)+1
F      AMWF(FMWF) = 1
F      WRITE(NTERM,302) AMWF,MWFLB,MWFUB
F      WRITE(NRPT,302) AMWF,MWFLB,MWFUB
F      WRITE(NHSTRY,302) AMWF,MWFLB,MWFUB
F 302 FORMAT(/,5X,'MWF',4X,51I1,/,5X,E9.3,40X,E9.3)
F
F      DO 303 I = 1, N
F      APTRB(I) = 10
F 303 CONTINUE
F      FPTRB = (((PTRBE-PTRBLB)/(PTRBUB-PTRBLB))*M)+1
F      APTRB(FPTRB) = 1
F      WRITE(NTERM,304) APTRB,PTRBLB,PTRBUB
F      WRITE(NRPT,304) APTRB,PTRBLB,PTRBUB
F      WRITE(NHSTRY,304) APTRB,PTRBLB,PTRBUB
F 304 FORMAT(/,5X,'PTRBE',2X,51I1,/,9X,F5.1,44X,F5.1)
F
F      DO 305 I = 1, N
F      APPMP(I) = 10
F 305 CONTINUE

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F      FPPMP = (((PPMP-PPMPLB)/(PPMPUB-PPMPLB))*M)+1
F      APPMP(FPPMP) = 1
F      WRITE(NTERM,306) APPMP,PPMPLB,PPMPUB
F      WRITE(NRPT,306) APPMP,PPMPLB,PPMPUB
F      WRITE(NHSTRY,306) APPMP,PPMPLB,PPMPUB
F 306  FORMAT(/,5X,'PPMP',3X,5I11/,9X,F5.1,43X,F6.1)
F
F      DO 307 I = 1, N
F      AMAIR(I) = 10
F 307  CONTINUE
F      FMAIR = (((MAIR-MAIRLB)/(MAIRUB-MAIRLB))*M)+1
F      AMAIR(FMAIR) = 1
F      WRITE(NTERM,308) AMAIR,MAIRLB,MAIRUB
F      WRITE(NRPT,308) AMAIR,MAIRLB,MAIRUB
F      WRITE(NHSTRY,308) AMAIR,MAIRLB,MAIRUB
F 308  FORMAT(/,5X,'MAIR',3X,5I11/,5X,E9.3,40X,E9.3)
F
F      DO 309 I = 1, N
F      ATVAP(I) = 10
F 309  CONTINUE
F      FTVAP = (((TPARAM-TVAPLB)/(TVAPUB-TVAPLB))*M)+1
F      ATVAP(FTVAP) = 1
F      WRITE(NTERM,310) ATVAP,TVAPLB,TVAPUB
F      WRITE(NRPT,310) ATVAP,TVAPLB,TVAPUB
F      WRITE(NHSTRY,310) ATVAP,TVAPLB,TVAPUB
F 310  FORMAT(/,5X,'TVAP',3X,5I11/,9X,F5.1,43X,F6.1,/)
      READ-VARS VANPOS DPPSI PPM TGFLIM WFAN WTRB WPUMP EFFTRB &
      EFFPMP MWFLB MWFUB MWF PTRBE MAIR RHOAIR FANVOL &
      EFFFAN PCTFAN SDP SDPMX PSDPMX SMXDEC STRBIA PTRBI &
      TAIRI TGF MGF TTRBI TTRBE QPRH UAPRH LTDPRH MTAPRH &
      TGPRHE TGPRHI TWPRHE TWPRHI QVAP UAVAP LTDVAP MTAVAP &
      TWVAPE TDTRBI PAI PAE QCND UACND MTACND TWCNDI TWCNDE &
      TAIRE LTDCND TDCNDI TBCNDE PTRBLB PTRBUB PPMPLB PPMPUB &
      PPMP TVAPLB TVAPUB TPARAM MAIRLB MAIRUB XC3 XNC4 XIC4 &
      XNC5 XIC5 XR134 XR245 SV2 SRCPHE QRCPLB UARCP LTDRCPL &
      MTARCP TRCPHI TRCPHE TDWRHI TBBRCI TBBRCE TRCPCI &
      TRCPCE TDWRHE CVDPLB CVD PUB CVDP EFFD

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;consolidated input interface for setting design spec and optimization bound
; "SETVAR calculator"

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CALCULATOR SETVAR
      DEFINE PMIN STREAM-VAR STREAM=PTRBLB SUBSTREAM=MIXED &
      VARIABLE=PRES
      DEFINE PMAX STREAM-VAR STREAM=PTRBUB SUBSTREAM=MIXED &
      VARIABLE=PRES
      DEFINE VANPOS PARAMETER 201
      DEFINE PCTFAN PARAMETER 200
      DEFINE PPMPLB PARAMETER 48
      DEFINE PPMPUB PARAMETER 49
      DEFINE MAIRLB PARAMETER 50
      DEFINE MAIRUB PARAMETER 51
      DEFINE MWFLB PARAMETER 52
      DEFINE MWFUB PARAMETER 53
      DEFINE QPRHLB PARAMETER 54
      DEFINE QPRHUB PARAMETER 55
      DEFINE TVAPLB PARAMETER 56
      DEFINE TVAPUB PARAMETER 57
      DEFINE PTRBLB PARAMETER 58
      DEFINE PTRBUB PARAMETER 59
      DEFINE QRCPLB PARAMETER 60
      DEFINE QRC PUB PARAMETER 61
C DESIGN TURBINE VANE POSITION AND PCT COND FANS OPERATING
F      VANPOS = 0.8
F      PCTFAN = 1.0
F
C PUMP OUTLET PRESSURE OPTIMIZATION BOUNDS
F      PPMPLB = 250
F      PPMPUB = 1200
F
C AIR MASS FLOW RATE BOUNDS
F      MAIRLB = 2.0E07

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F      MAIRUB = 2.0E08
F
C WORKING FLUID MASS FLOW RATE OPTIMIZATION BOUNDS
F      MWFLB = 500000
F      MWFUB = 3000000
F
C PREHEATER DUTY OPTIMIZATION BOUNDS
F      QPRHLB = 1.0E00
F      QPRHUB = 1.0E09
F
C VAPORIZER TEMPERATURE OPTIMIZATION BOUNDS
F      TVAPLB = 1.
F      TVAPUB = 200.
F
C TURBINE OUTLET PRESSURE OPTIMIZATION BOUNDS
F      PTRBLB = PMIN + 2.
F      PTRBUB = PMAX + 2.
F
C RECUPERATOR DUTY OPTIMIZATION BOUNDS
F      QRCPLB = -2.0E08
F      QRCPUB = -1.
      READ-VARS PMIN PMAX
      WRITE-VARS VANPOS PCTFAN MWFLB MWFUB PTRBLB PTRBUB PPMLB &
        PMPUB TVAPLB TVAPUB MAIRLB MAIRUB QPRHLB QPRHUB &
        QRCPLB QRCPUB

;select preheater outlet entropy specification for SPRHX-DS design spec
;depending on whether working fluid vaporization occurs under subcritical or
;supercritical conditions

;

; "SPRHX-C calculator"

CALCULATOR SPRHX-C
  DEFINE PHXI STREAM-VAR STREAM=L4 SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE PCMX STREAM-PROP STREAM=L4 PROPERTY=PCMX
  DEFINE TCMX STREAM-PROP STREAM=L4 PROPERTY=TCMX
  DEFINE TBUB STREAM-VAR STREAM=TBUB SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE TEMP BLOCK-VAR BLOCK=SPRHX VARIABLE=TEMP &
    SENTENCE=PARAM
  DEFINE PRES BLOCK-VAR BLOCK=SPRHX VARIABLE=PRES &
    SENTENCE=PARAM
F      IF (PHXI .LT. PCMX) THEN
F        TEMP = TBUB - 1.
F        PRES = 0.
F      ELSE
F        TEMP = TCMX
F        PRES = PCMX
F      ENDIF
      READ-VARS PHXI PCMX TBUB TCMX
      WRITE-VARS TEMP PRES

;calculate minimum dew point entropy depending on working fluid characterist
;(standard or retrograde dew point curve)

; "STRBMIN calculator"

CALCULATOR STRBMIN
  DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE SMXDEC STREAM-VAR STREAM=TDECR SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE PTURBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE TTURBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE PSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE TSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &

```

```

        VARIABLE=TEMP
        DEFINE PCMX STREAM-PROP STREAM=TURBI PROPERTY=PCMX
        DEFINE PBUB STREAM-PROP STREAM=WFREF PROPERTY=PBUB
        DEFINE PRES BLOCK-VAR BLOCK=TRBSMIN VARIABLE=PRES &
        SENTENCE=PARAM
        DEFINE TEMP BLOCK-VAR BLOCK=TRBSMIN VARIABLE=TEMP &
        SENTENCE=PARAM
F      IF (SDPMX.GT.SMXDEC) THEN
C      RETROGRADE WORKING FLUID DEWPOINT CURVE
F      IF (PTURBI.GT.PSDPMX) THEN
F          PRES = PSDPMX
F          TEMP = TSDPMX + 1.
F      ELSE
F          PRES = PBUB
F          TEMP = 32.
F      ENDIF
F      ELSE
C      STANDARD WORKING FLUID DEWPOINT CURVE
F      IF (PTURBI.GT.PCMX) THEN
F          PRES = PBUB
F          TEMP = 32.
F      ELSE
F          PRES = PBUB
F          TEMP = 32.
F      ENDIF
F      ENDIF
        READ-VARS PSDPMX PTURBI SDPMX SMXDEC PCMX TSDPMX TTURBI &
        PBUB
        WRITE-VARS PRES TEMP

;calculate minimum geofluid exit temperature value for TGFEXLIM constraint i
;WNET optimization block

;

; "TGFEXLIM calculator"

CALCULATOR TGFEXLIM
F      REAL GFTINC,B4,B3,B2,B1,B0,PPM,C4,C3,C2,C1,C0,GFTEXC,GFTEXF
        DEFINE TGFIN STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
        VARIABLE=TEMP
        DEFINE PPM PARAMETER 900
        DEFINE TGFLIM PARAMETER 901
C      TEMPERATURE LIMIT LEAVING PLANT
C      RESOURCE TEMPERATURE IN DEGREES CELSIUS
F      TGFINC = (TGFIN-32.)*(5./9.)
F
C      SI IN SOLUTION CORRELATION COEFFICIENTS
F      B4 = -1.334837E-07
F      B3 = 7.06584462E-05
F      B2 = -3.6294799613E-03
F      B1 = 3.672417729236E-01
F      B0 = 4.2059443514950
F
F      PPM = B4*TGFINC**4 + B3*TGFINC**3 + B2*TGFINC**2 + B1*TGFINC + B0
F
C      TEMPERATURE LIMIT CORRELATION COEFFICIENTS
F      C4 = 2.49634E-11
F      C3 = -4.25191E-09
F      C2 = -1.19669E-04
F      C1 = 3.07616E-01
F      C0 = 2.94394E-01
F
F      TGFEXC = C4*PPM**4 + C3*PPM**3 + C2*PPM**2 + C1*PPM + C0
F      TGFLIM = (9./5.)*TGFEXC + 32.
F
C      WRITE(NHSTRY,*)'SIO2 IN SOLUTION, PPM = ', PPM
C      WRITE(NHSTRY,*)'BRINE OUTLET T LIMIT, F = ', TGFLIM
        READ-VARS TGFIN
        WRITE-VARS PPM TGFLIM

;set vaporizer outlet temperature equal to dew point temperature (subcritica

```

```
;process) or critical point temperature (supercritical process) plus delta T
;value specified by WNET optimization block
```

```
;
```

```
;
```

```
; "TVAP-C calculator"
```

```
CALCULATOR TVAP-C
  DEFINE TPARAM PARAMETER 500
  DEFINE PCMX STREAM-PROP STREAM=HXI PROPERTY=PCMX
  DEFINE TCMX STREAM-PROP STREAM=HXI PROPERTY=TCMX
  DEFINE THXCLD STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE PHXI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE TDEW STREAM-VAR STREAM=TDEW SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE TVAP BLOCK-VAR BLOCK=VAP VARIABLE=TEMP &
    SENTENCE=COLD-SIDE ID1=HX-COLD
F    IF (PHXI .GE. PCMX) THEN
F      TVAP = THXCLD + TPARAM
F    ELSE
F      TVAP = TDEW + TPARAM
F    ENDIF
  READ-VARS TPARAM TCMX TDEW PCMX PHXI THXCLD
  WRITE-VARS TVAP
```

```
TRANSFER PGF0-T
  SET BLOCK-VAR BLOCK=REFSTATE VARIABLE=PRES SENTENCE=PARAM
  EQUAL-TO STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
```

```
TRANSFER TGF0-T
  SET BLOCK-VAR BLOCK=REFSTATE VARIABLE=TEMP SENTENCE=PARAM
  EQUAL-TO STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=TEMP
```

```
TRANSFER WFCOMP
  SET STREAM-FLOWS WF
  EQUAL-TO STREAM-FLOWS L2
  EXECUTE FIRST
```

```
SENSITIVITY SFTK
  PARAM WIDE=NO HIGH-PRECISI=YES BASE-CASE=NO
  DEFINE MG STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE MA STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE MW STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE QACN BLOCK-VAR BLOCK=COND VARIABLE=DUTY &
    SENTENCE=RESULTS
  DEFINE UAACN BLOCK-VAR BLOCK=COND VARIABLE=UA &
    SENTENCE=RESULTS
  DEFINE LTDACN BLOCK-VAR BLOCK=COND VARIABLE=LMTD &
    SENTENCE=RESULTS
  DEFINE MTAACN BLOCK-VAR BLOCK=COND VARIABLE=MITA &
    SENTENCE=RESULTS
  DEFINE MWACN STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE WFAN BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
    SENTENCE=RESULTS
  DEFINE WISFAN BLOCK-VAR BLOCK=FAN VARIABLE=ISEN-POWER &
    SENTENCE=RESULTS
  DEFINE VOLFAN BLOCK-VAR BLOCK=FAN VARIABLE=VFLOW-IN &
    SENTENCE=RESULTS
  DEFINE MEFFAN BLOCK-VAR BLOCK=FAN VARIABLE=MEFF &
    SENTENCE=RESULTS
  DEFINE SEFFAN BLOCK-VAR BLOCK=FAN VARIABLE=SEFF &
    SENTENCE=RESULTS
```

```

DEFINE PCTFAN PARAMETER 200
DEFINE QPRH BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDPRH BLOCK-VAR BLOCK=PRHX VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE QVAP BLOCK-VAR BLOCK=VAP VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UAVAP BLOCK-VAR BLOCK=VAP VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDVAP BLOCK-VAR BLOCK=VAP VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTAVAP BLOCK-VAR BLOCK=VAP VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE WPMP BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE EFFPMP BLOCK-VAR BLOCK=PUMP VARIABLE=CALCULATED-E &
    SENTENCE=RESULTS
DEFINE DPPMP BLOCK-VAR BLOCK=PUMP VARIABLE=DELP-CALC &
    SENTENCE=RESULTS
DEFINE WTR1 BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE WISTR1 BLOCK-VAR BLOCK=TRB VARIABLE=ISEN-POWER &
    SENTENCE=RESULTS
DEFINE EFFTR1 BLOCK-VAR BLOCK=TRB VARIABLE=SEFF &
    SENTENCE=RESULTS
DEFINE VPTR1 PARAMETER 201
DEFINE DPCVL BLOCK-VAR BLOCK=CV VARIABLE=P-DROP-R &
    SENTENCE=RESULTS
DEFINE QRCF BLOCK-VAR BLOCK=RECF VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UARCF BLOCK-VAR BLOCK=RECF VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDRCF BLOCK-VAR BLOCK=RECF VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTARCF BLOCK-VAR BLOCK=RECF VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE PCVI STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PL2 STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PL3 STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PCVE STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PHXI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PTURBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PHXE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PV3 STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PV2 STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PCONDI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PSHELLI STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PRV1 STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PTUBEI STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PRL1 STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PCNDAI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PAIRI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=PRES

```

```

DEFINE PDPL1 BLOCK-VAR BLOCK=DPL1 VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPL2 BLOCK-VAR BLOCK=DPL2 VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPHX BLOCK-VAR BLOCK=DPHX VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPV1 BLOCK-VAR BLOCK=DPV1 VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPV2 BLOCK-VAR BLOCK=DPV2 VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPCN BLOCK-VAR BLOCK=DPCN VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPR1 BLOCK-VAR BLOCK=DPRL VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPRV BLOCK-VAR BLOCK=DPRV VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
DEFINE PDPAIR BLOCK-VAR BLOCK=DPAIR VARIABLE=DPP-CALC &
    SENTENCE=RESULTS
F      DPL1 = PCVI - PL2
F      DPL2 = PL3 - PCVE
F      DPHX = PHXI - PL3
F      DPV1 = PTURBI - PHXE
F      DPV2 = PV3 - PV2
F      DPCN = PCONDI - PV3
F      DPRV = PSHELI - PRV1
F      DPRL = PTUBEI - PRL1
F      DPAIR = PCNDAI - PAIRI
F
F      QPRH = -QPRH
F      QVAP = -QVAP
F      QACN = -QACN
TABULATE 1 "MG"
TABULATE 2 "MA"
TABULATE 3 "MW"
TABULATE 4 "QACN"
TABULATE 5 "UAACN"
TABULATE 6 "LTDACN"
TABULATE 7 "MTAACN"
TABULATE 8 "MWACN"
TABULATE 9 "WFAN"
TABULATE 10 "WISFAN"
TABULATE 11 "VOLFAN"
TABULATE 12 "MEFFAN"
TABULATE 13 "SEFFAN"
TABULATE 14 "PCTFAN"
TABULATE 15 "QPRH"
TABULATE 16 "UAPRH"
TABULATE 17 "LTDPRH"
TABULATE 18 "MTAPRH"
TABULATE 19 "QVAP"
TABULATE 20 "UAVAP"
TABULATE 21 "LTDVAP"
TABULATE 22 "MTAVAP"
TABULATE 23 "WPMP"
TABULATE 24 "EFFPMP"
TABULATE 25 "DPPMP"
TABULATE 26 "WTR1"
TABULATE 27 "WISTR1"
TABULATE 28 "EFFTR1"
TABULATE 29 "VPTR1"
TABULATE 30 "DPCVL"
TABULATE 31 "QRCP"
TABULATE 32 "UARCP"
TABULATE 33 "LTDRCP"
TABULATE 34 "MTARCP"
TABULATE 35 "PCVI"
TABULATE 36 "PL2"
TABULATE 37 "PL3"
TABULATE 38 "PCVE"
TABULATE 39 "PHXI"
TABULATE 40 "PTURBI"
TABULATE 41 "PHXE"

```

```

TABULATE 42 "PV3"
TABULATE 43 "PV2"
TABULATE 44 "PCONDI"
TABULATE 45 "PSHELI"
TABULATE 46 "PRV1"
TABULATE 47 "PTUBEI"
TABULATE 48 "PRL1"
TABULATE 49 "PCNDAI"
TABULATE 50 "PAIRI"
TABULATE 51 "PDPL1"
TABULATE 52 "PDPL2"
TABULATE 53 "PDPHX"
TABULATE 54 "PDPV1"
TABULATE 55 "PDPV2"
TABULATE 56 "PDPCN"
TABULATE 57 "PDPR1"
TABULATE 58 "PDPRV"
TABULATE 59 "PDPAIR"
TABULATE 60 "DPL1"
TABULATE 61 "DPL2"
TABULATE 62 "DPHX"
TABULATE 63 "DPV1"
TABULATE 64 "DPV2"
TABULATE 65 "DPCN"
TABULATE 66 "DPRV"
TABULATE 67 "DPRL"
TABULATE 68 "DPAIR"
VARY STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED VARIABLE=TEMP
RANGE LIST=50.

;limit maximum working fluid pressure as specified by user
; "PMAX constraint"

CONSTRAINT PMAX
  DEFINE PPMPE STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
    VARIABLE=PRES
  SPEC "PPMPE" LE "1200"
  TOL-SPEC "0.01"

;limit minimum working fluid pressure to prevent entry of noncondensable gas
; "PMIN constraint"

CONSTRAINT PMIN
  DEFINE PCONDE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=PRES
  SPEC "PCONDE" GE "14.7"
  TOL-SPEC "0.01"

;specify minimum turbine inlet entropy calculated in STRBMIN calculator bloc
;ensure dry turbine expansion

;

; "STRBIN constraint"

CONSTRAINT STRBIN
  DEFINE STRBI STREAM-VAR STREAM=TURBIA SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE SMIN STREAM-VAR STREAM=SMIN SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  SPEC "STRBI" GE "SMIN"
  TOL-SPEC "1.E-08"

;set minimum temperature approach value occurring in preheater/vaporizer blo
;(default 10°F)

;

; "TAHX constraint"

CONSTRAINT TAHX

```

```

        DEFINE TAPRHX BLOCK-VAR BLOCK=PRHX VARIABLE=MITA &
            SENTENCE=RESULTS
        DEFINE TAVAP BLOCK-VAR BLOCK=VAP VARIABLE=MITA &
            SENTENCE=RESULTS
C      TAHX = MIN(TAPRHX,TAVAP)
F      IF (TAPRHX .LT. TAVAP) THEN
F      TAHX = TAPRHX
F      ELSE
F      TAHX = TAVAP
F      ENDIF
        SPEC "TAHX" EQ "10."
        TOL-SPEC "0.01"

;specify minimum geofluid exit temperature calculated in TGFEXLIM calculator
; "TGFEXLIM constraint"

CONSTRAINT TGFEXLIM
        DEFINE TGFLIM PARAMETER 901
        DEFINE TGFEX STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
            VARIABLE=TEMP
        SPEC "TGFEX" GE "TGFLIM"
        TOL-SPEC "0.1"

;determine maximum dew point entropy pressure

; "SDWPTMAX optimization block"

OPTIMIZATION SDWPTMAX
        DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
            VARIABLE=MASS-ENTROPY
        DEFINE PCMX STREAM-PROP STREAM=WF PROPERTY=PCMX
        MAXIMIZE "SDPMX"
        VARY BLOCK-VAR BLOCK=SDPMX VARIABLE=PRES SENTENCE=PARAM
        LIMITS "50" "PCMX"

;maximize net power (turbine power - pump power - fan power)

; "WNET optimization block"

OPTIMIZATION WNET
        DEFINE TRBPWR BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
            SENTENCE=RESULTS
        DEFINE FANPWR BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
            SENTENCE=RESULTS
        DEFINE PMPPWR BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
            SENTENCE=RESULTS
        DEFINE PPMPPLB PARAMETER 48
        DEFINE PPMPUB PARAMETER 49
        DEFINE MAIRLB PARAMETER 50
        DEFINE MAIRUB PARAMETER 51
        DEFINE MWFLB PARAMETER 52
        DEFINE MWFUB PARAMETER 53
        DEFINE QPRHLB PARAMETER 54
        DEFINE QPRHUB PARAMETER 55
        DEFINE TVAPLB PARAMETER 56
        DEFINE TVAPUB PARAMETER 57
        MINIMIZE "TRBPWR+FANPWR+PMPPWR"
        CONSTRAINTS STRBIN / TAHX / TGFEXLIM / PMAX / PMIN
        VARY STREAM-VAR STREAM=L2 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
        LIMITS "MWFLB" "MWFUB"
        VARY STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
            VARIABLE=MASS-FLOW
        LIMITS "MAIRLB" "MAIRUB"
        VARY BLOCK-VAR BLOCK=PUMP VARIABLE=PRES SENTENCE=PARAM
        LIMITS "PPMPPLB" "PPMPUB"
        VARY PARAMETER 500
        LIMITS "TVAPLB" "TVAPUB"

CONV-OPTIONS
        SQP MAXIT=60 TOL=.00010 MAXLSPASS=6 NLIMIT=6 &
            OPT-METHOD=BIEGLER DERIVATIVE=CENTRAL CONST-ITER=4

```



```

TEAR
  TEAR L2 COMPS=WF

CONVERGENCE SDWPTMAX SQP
  OPTIMIZE OPTID=SDWPTMAX
  PARAM MAXIT=100 TOL=1.0000E-08

CONVERGENCE WNET SQP
  OPTIMIZE OPTID=WNET
  TEAR L2 COMPS=WF

SEQUENCE SEQ-1 DPV1 TRBDUPL PTHRT-C TRBX STRBMIN TRBSMIN

STREAM-REPOR NOMOLEFLOW MASSFLOW MASSFRAC
;
;
;
;
;
;
;
;

```

Appendix II

Aspen Plus 2006 Plant Rating Simulation Input File

```

IN-UNITS ENG

DEF-STREAMS CONVEN ALL

DIAGNOSTICS
  HISTORY SIM-LEVEL=2 PROP-LEVEL=2 STREAM-LEVEL=2 CONV-LEVEL=2
  TERMINAL SIM-LEVEL=2 CONV-LEVEL=2 PROP-LEVEL=2 &
  STREAM-LEVEL=2

SIM-OPTIONS

DESCRIPTION "
  GENERAL SIMULATION WITH ENGLISH UNITS : F, PSI, LB/HR,
  LBMOL/HR, BTU/HR, CUFT/HR.
"

DATABANKS PURE20 / AQUEOUS / SOLIDS / INORGANIC / &
  NOASPENPCD

PROP-SOURCES PURE20 / AQUEOUS / SOLIDS / INORGANIC

COMPONENTS
  C3H8 C3H8 /
  N-C4H10 C4H10-1 /
  I-C4H10 C4H10-2 /
  N-C5H12 C5H12-1 /
  I-C5H12 C5H12-2 /
  N-C6H14 C6H14-1 /
  I-C6H14 C6H14-2 /
  R134A C2H2F4 /
  R245FA C3H3F5-D1 /
  H2O H2O /
  AIR AIR

COMP-GROUP WF SUBSTREAM=MIXED COMPS=R245FA

FLOWSHEET
  HIERARCHY RCPLSPLT
  CONNECT $C-8 IN=PMPE OUT=RCPLSPLT.PMPE
  CONNECT $C-9 IN=RCPLSPLT.L1 OUT=L1
  CONNECT $C-7 IN=RCPLSPLT.RL1 OUT=RL1
  HIERARCHY RCPVSPLT
  CONNECT $C-11 IN=TURBE OUT=RCPVSPLT.TURBE
  CONNECT $C-10 IN=RCPVSPLT.V1 OUT=V1
  CONNECT $C-12 IN=RCPVSPLT.RV1 OUT=RV1
  BLOCK PUMP IN=CONDE OUT=PMPE
  BLOCK CV IN=CVI OUT=CVE
  BLOCK VAP IN=GFIN HX-COLD OUT=HXE HX-HOT
  BLOCK TRB IN=TURBIA OUT=TURBE
  BLOCK COND IN=CONDI CNDAIRI OUT=CONDE CNDAIRE
  BLOCK FAN IN=CNDAIRE OUT=AIRE
  BLOCK DPL2 IN=CVE OUT=L3
  BLOCK DPL1 IN=L2 OUT=CVI
  BLOCK DPV1 IN=HXE OUT=TURBI
  BLOCK DPV2 IN=V2 OUT=V3
  BLOCK REFSTATE IN=GFEX OUT=GF0
  BLOCK RECP IN=SHELLI TUBEI OUT=SHELLE TUBEE
  BLOCK VSELECT IN=SHELLE V1 OUT=V2
  BLOCK LSELECT IN=TUBEE L1 OUT=L2
  BLOCK TRBDUPL IN=TURBI OUT=TURBIA TURBIB TURBIC
  BLOCK DPCN IN=V3 OUT=CONDI
  BLOCK DPHX IN=L3 OUT=HXI
  BLOCK CNDAIR IN=AIRID OUT=FANID
  BLOCK DPRL IN=RL1 OUT=TUBEI
  BLOCK DPRV IN=RV1 OUT=SHELLI
  BLOCK DPAIR IN=AIRI OUT=CNDAIRI
  BLOCK TRBX IN=TURBIB OUT=TURBX
  BLOCK TRB1XD IN=TURBID OUT=TURBXD
  BLOCK TDECR IN=SDPMX OUT=TDECR
  BLOCK SDPMX IN=WFREF OUT=SDPMX
  BLOCK TRBSMIN IN=TURBIC OUT=SMIN
  BLOCK PRHX IN=HXI HX-HOT OUT=GFEX HX-COLD

```

```

BLOCK PGFIN IN=GF OUT=GFIN

PROPERTIES PENG-ROB
PROPERTIES STEAMNBS
PROPERTIES IDEAL

PROP-DATA PRKBV-1
IN-UNITS ENG
PROP-LIST PRKBV
BPVAL C3H8 N-C4H10 .00330 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 C3H8 .00330 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 I-C4H10 -.00780 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C4H10 C3H8 -.00780 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 I-C4H10 -.00040 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C4H10 N-C4H10 -.00040 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 N-C6H14 .00070 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C6H14 C3H8 .00070 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 N-C6H14 -.00560 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C6H14 N-C4H10 -.00560 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 I-C5H12 .01110 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 C3H8 .01110 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL C3H8 N-C5H12 .02670 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 C3H8 .02670 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 N-C5H12 .01740 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 N-C4H10 .01740 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C5H12 I-C5H12 0.0 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 N-C5H12 0.0 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL N-C4H10 I-C5H12 .002920 0.0 0.0 -459.66999230 &
1340.3299930
BPVAL I-C5H12 N-C4H10 .002920 0.0 0.0 -459.66999230 &
1340.3299930

PROP-SET PBUB PBUB SUBSTREAM=MIXED

PROP-SET PCMX PCMX SUBSTREAM=MIXED

PROP-SET TBUB TBUB SUBSTREAM=MIXED

PROP-SET TCMX TCMX SUBSTREAM=MIXED

PROP-SET TDEW TDEW SUBSTREAM=MIXED

STREAM AIRI
SUBSTREAM MIXED TEMP=50 PRES=14.6959488 MASS-FLOW=29209507.7
MASS-FRAC AIR 1

STREAM AIRID
SUBSTREAM MIXED TEMP=50 PRES=14.6959488 MASS-FLOW=29200739.5
MASS-FRAC AIR 1

STREAM GF
SUBSTREAM MIXED TEMP=392 PRES=500 MASS-FLOW=1000000
MASS-FRAC H2O 1

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STREAM L2
  SUBSTREAM MIXED TEMP=89.9378315 PRES=875.469481 &
  MASS-FLOW=1842999.13
  MASS-FRAC R245FA 1

STREAM PMPE
  SUBSTREAM MIXED TEMP=89.9667098 PRES=875.411922 &
  MASS-FLOW=1842999.13
  MASS-FRAC R245FA 1

STREAM TURBID
  SUBSTREAM MIXED TEMP=378.966173 PRES=817.617148 &
  MASS-FLOW=2984851.1
  MASS-FRAC R245FA 1

STREAM WREF
  SUBSTREAM MIXED TEMP=32 PRES=14.69595 MASS-FLOW=2984851.1
  MASS-FRAC R245FA 1

BLOCK CNDAIR HEATER
  PARAM TEMP=76.8539877 PRES=14.6864416
  PROPERTIES IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPAIR HEATER
  PARAM PRES=-0.0095129099 DUTY=0.0
  PROPERTIES IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPCN HEATER
  PARAM DUTY=0.0 DPPARM=1.10376924
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPHX HEATER
  PARAM DUTY=0.0 DPPARM=6430.2829
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPL1 HEATER
  PARAM DUTY=0.0 DPPARM=846.173339
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPL2 HEATER
  PARAM DUTY=0.0 DPPARM=846.152651
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPRL HEATER
  PARAM DUTY=0.0 DPPARM=0

BLOCK DPRV HEATER
  PARAM DUTY=0.0 DPPARM=0

BLOCK DPV1 HEATER
  PARAM DUTY=0.0 DPPARM=152.117491
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK DPV2 HEATER
  PARAM DUTY=0.0 DPPARM=1.14676763
  PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES

BLOCK PGFIN HEATER
  PARAM PRES=389.087843 DELT=0.
  PROPERTIES STEAMNBS

BLOCK REFSTATE HEATER
  PARAM TEMP=50.0 PRES=14.6959488 NPHASE=1 PHASE=L
  PROPERTIES STEAMNBS FREE-WATER=STEAM-TA SOLU-WATER=3 &

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      TRUE-COMPS=YES
      BLOCK-OPTION FREE-WATER=NO

BLOCK SDPMX HEATER
  PARAM PRES=326.229484 VFRAC=1.0 TOL=1.0000E-08

BLOCK TDECR HEATER
  PARAM VFRAC=1.0 DELT=-10.0

BLOCK TRBSMIN HEATER
  PARAM TEMP=263.148691 PRES=326.229484

BLOCK COND MHEATX
  HOT-SIDE IN=CONDI OUT=CONDE DEGSUB=2.0 FREE-WATER=NO
  COLD-SIDE IN=CNDAIRI OUT=CNDaire FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES DTCORR2=10.0
  STREAM-PROPE CNDaire IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
    TRUE-COMPS=YES

BLOCK PRHX MHEATX
  COLD-SIDE IN=HXI OUT=HX-COLD DUTY=186529866 FREE-WATER=NO
  HOT-SIDE IN=HX-HOT OUT=GFEX FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES DTCORR=.20 DTCORR2=200.0
  STREAM-PROPE HX-HOT STEAMNBS FREE-WATER=STEAM-TA &
    SOLU-WATER=3 TRUE-COMPS=YES

BLOCK RECP MHEATX
  HOT-SIDE IN=SHELLI OUT=SHELLE FREE-WATER=NO
  COLD-SIDE IN=TUBEI OUT=TUBEE DUTY=27820.9169 FREE-WATER=NO
  PARAM NPOINT=50

BLOCK VAP MHEATX
  HOT-SIDE IN=GFIN OUT=HX-HOT FREE-WATER=NO
  COLD-SIDE IN=HX-COLD OUT=HXE DUTY=38614165.8 FREE-WATER=NO
  PARAM NPOINT=50 ADAPTIVE-GRI=YES DTCORR=.20 DTCORR2=200.0
  STREAM-PROPE GFIN STEAMNBS FREE-WATER=STEAM-TA SOLU-WATER=3 &
    TRUE-COMPS=YES

HIERARCHY RCPLSPLT

DEF-STREAMS CONVEN ALL

SOLVE
  PARAM METHOD=SM
  RUN-MODE MODE=SIM

FLOWSHEET
  BLOCK LDUPL IN=PMPE OUT=L1 PMPEB
  BLOCK LFEED IN=PMPEB NULL OUT=RL1

PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES
  PROPERTIES STEAMNBS
  PROPERTIES IDEAL

STREAM NULL
  SUBSTREAM MIXED TEMP=50 PRES=800
  MASS-FLOW R245FA 10000

BLOCK LDUPL DUPL

BLOCK LFEED SELECTOR
  PARAM STREAM=PMPEB

ENDHIERARCHY RCPLSPLT
HIERARCHY RCPVSPLT

DEF-STREAMS CONVEN ALL

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SOLVE
  PARAM METHOD=SM
  RUN-MODE MODE=SIM

FLOWSHEET
  BLOCK VDUPL IN=TURBE OUT=V1 TURBEB
  BLOCK VFEED IN=TURBEB NULL OUT=RV1

PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
  TRUE-COMPS=YES
  PROPERTIES STEAMNBS
  PROPERTIES IDEAL

STREAM NULL
  SUBSTREAM MIXED TEMP=200 PRES=50
  MASS-FLOW R245FA 10000

BLOCK VDUPL DUPL

BLOCK VFEED SELECTOR
  PARAM STREAM=TURBEB

ENDHIERARCHY RCPVSPLT

BLOCK PUMP PUMP
  PARAM
  PERFOR-PARAM NCURVES=1 H-FLOW-VAR=VOL-FLOW H-FLOW-UNIT= &
    "gal/min" HEAD-UNITS="FT-LBF/LB" HEAD-NPOINT=16 &
    EF-FLOW-VAR="VOL-FLOW" EF-FLOW-UNIT="gal/min" &
    EFF-NPOINT=16 HR-FLOW-VAR=VOL-FLOW HR-FLOW-UNIT="cuft/hr"
  HEAD-TABLE 1 1 1987.20322 276.655333 / 1 2 1958.49475 &
    553.310667 / 1 3 1930.73295 829.966 / 1 4 &
    1899.20958 1106.62133 / 1 5 1860.0809 1383.27667 / 1 &
    6 1810.36764 1659.932 / 1 7 1747.95502 1936.58733 / &
    1 8 1671.59275 2213.24267 / 1 9 1580.89501 2489.898 / &
    1 10 1476.34048 2766.55333 / 1 11 1359.27233 &
    3043.20867 / 1 12 1231.89821 3319.864 / 1 13 &
    1097.29023 3596.51933 / 1 14 959.385025 3873.17467 / &
    1 15 822.983692 4149.83 / 1 16 693.75182 4426.48534
  EFF-TABLE 1 1 .182460474 276.655333 / 1 2 .327887825 &
    553.310667 / 1 3 .450664317 829.966 / 1 4 &
    .552267620 1106.62133 / 1 5 .634175404 1383.27667 / &
    1 6 .697865339 1659.932 / 1 7 .744815096 1936.58733 / &
    1 8 .776502345 2213.24267 / 1 9 .794404755 2489.898 / &
    1 10 .799999997 2766.55333 / 1 11 .794765741 &
    3043.20867 / 1 12 .780179658 3319.864 / 1 13 &
    .757719416 3596.51933 / 1 14 .728862688 3873.17467 / &
    1 15 .695087142 4149.83 / 1 16 .657870450 4426.48534

BLOCK FAN COMPR
  PARAM TYPE=ISENTROPIC MEFF=.90
  PERFOR-PARAM NCURVES=1 H-FLOW-VAR=VOL-FLOW H-FLOW-UNIT= &
    "cuft/hr" HEAD-UNITS="FT-LBF/LB" HEAD-NPOINT=16 &
    EF-FLOW-VAR="VOL-FLOW" EF-FLOW-UNIT="cuft/hr" &
    EFF-NPOINT=16 CURVE-FORMAT=TABLE
  HEAD-TABLE 1 1 27.1719738 39529786.7 / 1 2 27.0181669 &
    79059573.4 / 1 3 26.6532491 118589360 / 1 4 &
    26.0888316 158119147 / 1 5 25.331502 197648934 / 1 &
    6 24.3828252 237178720 / 1 7 23.2393427 276708507 / &
    1 8 21.8925731 316238294 / 1 9 20.3290119 355768080 / &
    1 10 18.5301315 395297867 / 1 11 16.4723811 &
    434827654 / 1 12 14.1271869 474357440 / 1 13 &
    11.460952 513887227 / 1 14 8.43505651 553417014 / 1 &
    15 5.00585726 592946800 / 1 16 1.1246881 632476587
  EFF-TABLE 1 1 .088590827 39529786.7 / 1 2 .167976393 &
    79059573.4 / 1 3 .243682869 118589360 / 1 4 &
    .314274375 158119147 / 1 5 .378315032 197648934 / 1 &
    6 .434368959 237178720 / 1 7 .481000275 276708507 / &
    1 8 .516773101 316238294 / 1 9 .540251556 355768080 / &
    1 10 .549999761 395297867 / 1 11 .544581834 &
    434827654 / 1 12 .522561897 474357440 / 1 13 &
    .482504068 513887227 / 1 14 .422972468 553417014 / 1 &

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15 .342531217 592946800 / 1 16 .239744433 632476587
PROPERTIES IDEAL FREE-WATER=STEAM-TA SOLU-WATER=3 &
TRUE-COMPS=YES

BLOCK TRB COMPR
PARAM TYPE=ISENTROPIC PRES=27.9927387 SEFF=0.829899312 &
MEFF=.940 NPHASE=2 MODEL-TYPE=TURBINE
BLOCK-OPTION FREE-WATER=NO

BLOCK TRB1XD COMPR
PARAM TYPE=ISENTROPIC PRES=548.211916 SEFF=1.0 MEFF=1.0 &
MODEL-TYPE=TURBINE

BLOCK TRBX COMPR
PARAM TYPE=ISENTROPIC PRES=551.931542 SEFF=1.0 MEFF=1.0 &
MODEL-TYPE=TURBINE

BLOCK TRBDUPL DUPL

BLOCK LSELECT SELECTOR
PARAM STREAM=L1

BLOCK VSELECT SELECTOR
PARAM STREAM=V1

BLOCK CV VALVE
PARAM P-DROP=2.0
PROPERTIES PENG-ROB FREE-WATER=STEAM-TA SOLU-WATER=3 &
TRUE-COMPS=YES

;adjust turbine specified isentropic efficiency to match off-design conditio
;value calculated by TRB1-C calculator
;
; "EFFTRB design spec"

DESIGN-SPEC EFFTRB
DEFINE SEFF BLOCK-VAR BLOCK=TRB VARIABLE=SEFF &
SENTENCE=PARAM
DEFINE EFF PARAMETER 202
SPEC "SEFF" TO "EFF"
TOL-SPEC "0.0001"
VARY BLOCK-VAR BLOCK=TRB VARIABLE=SEFF SENTENCE=PARAM
LIMITS "0.25" "0.9"

;adjust air mass flow rate to account for off-design condition condenser air
;side pressure drop and fan performance such that condenser inlet pressure
;matches fan exit pressure
;
; "MAIR design spec"

DESIGN-SPEC MAIR
DEFINE PAIRI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE PAIRE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE PCTFAN PARAMETER 200
DEFINE MALB PARAMETER 50
DEFINE MAUB PARAMETER 51
SPEC "PAIRE" TO "PAIRI"
TOL-SPEC "1.0E-4"
VARY STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
VARIABLE=MASS-FLOW
LIMITS "PCTFAN*MALB" "PCTFAN*MAUB"

;set geofluid inlet pressure such that specified geofluid temperature is 50°
;below saturation temperature
;
; "PGF-DS design spec"

DESIGN-SPEC PGF-DS
DEFINE TGF STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
VARIABLE=TEMP

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        DEFINE TBUB STREAM-PROP STREAM=GFIN PROPERTY=TBUB
        SPEC "TBUB-TGF" TO "50."
        TOL-SPEC "0.001"
        VARY BLOCK-VAR BLOCK=PGFIN VARIABLE=PRES SENTENCE=PARAM
        LIMITS "20" "1000"

;adjust turbine outlet pressure to match condenser UA adjusted for off-design
;process conditions
;
; "UACOND design spec"

DESIGN-SPEC UACOND
F    REAL ACF, MA100, CF, UAC, UCF
    DEFINE UADCND PARAMETER 14
    DEFINE UACOND BLOCK-VAR BLOCK=COND VARIABLE=UA &
        SENTENCE=RESULTS
    DEFINE MWFCND PARAMETER 81
    DEFINE MWF STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
    DEFINE MAD STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
    DEFINE MAIR STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
    DEFINE PCTFAN PARAMETER 200
    DEFINE CNDTOL PARAMETER 20
    DEFINE RPCNDI PARAMETER 23
    DEFINE RPCNDO PARAMETER 24
    DEFINE PTRBLB PARAMETER 58
    DEFINE PTRBUB PARAMETER 59
C    DESIGN CONDENSER UA UADCND [BTU/HR-R]
C    DESIGN WF FLOW RATE MWFCND [LB/HR]
C    DESIGN AIR FLOW RATE MAD [LB/HR]
C    INSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPCNDI
C    OUTSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPCNDO
F
C    CORRECTION FACTOR TO A AS AFFECTED BY NUMBER OF CONDENSER
C    FANS OPERATING (FANS MAY BE SHUT DOWN AT LOW AMBIENT TEMPS)
F    ACF = PCTFAN
F
C    NORMALIZED AIR MASS FLOW RATE
F    MA100 = MAIR/PCTFAN
F
C    CORRECTION FACTOR TO U AS AFFECTED BY FLUID FLOW RATES
F    UCF = 1+RPCNDO*((MA100/MAD)**0.6-1)+RPCNDI*((MWF/MWFCND)**0.8-1)
F    UAC = UCF*ACF*UADCND
    SPEC "UACOND" TO "UAC"
    TOL-SPEC "CNDTOL"
    VARY BLOCK-VAR BLOCK=TRB VARIABLE=PRES SENTENCE=PARAM
    LIMITS "PTRBLB" "PTRBUB"

;adjust preheater cold side duty to match preheater UA adjusted for off-design
;process conditions
;
; "UAPRHX design spec"

DESIGN-SPEC UAPRHX
F    REAL CF,UA1
    DEFINE UADPRH PARAMETER 11
    DEFINE UAPRHX BLOCK-VAR BLOCK=PRHX VARIABLE=UA &
        SENTENCE=RESULTS
    DEFINE MGFD PARAMETER 1
    DEFINE FLOG STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
    DEFINE MWFD PARAMETER 2
    DEFINE FLOW STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
    DEFINE PRHTOL PARAMETER 17
    DEFINE RPHXI PARAMETER 21
    DEFINE RPHXO PARAMETER 22
    DEFINE QPRHLB PARAMETER 54
    DEFINE QPRHUB PARAMETER 55
C    DESIGN PREHEATER UA UADPRH [BTU/HR-R]

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C DESIGN WF FLOW RATE MWFD [LB/HR]
C DESIGN GF FLOW RATE MGFD [LB/HR]
C INSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPHXI
C OUTSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPHXO
F
C CORRECTION FACTOR TO U AS AFFECTED BY FLUID FLOW RATES
F   CF=1+RPHXI*((FLOG/MGFD)**0.8-1)+RPHXO*((FLOW/MWFD)**0.6-1)
F   UA1=CF*UADPRH
      SPEC "UAPRHX" TO "UA1"
      TOL-SPEC "PRHTOL"
      VARY BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY SENTENCE=COLD-SIDE &
          ID1=HXI
      LIMITS "QPRHLB" "QPRHUB"

;adjust recuperator cold side duty to match recuperator UA adjusted for off-
;design process conditions
;
; "UARECP design spec"

DESIGN-SPEC UARECP
F   REAL CF,UAR
      DEFINE UADRCP PARAMETER 13
      DEFINE UARECP BLOCK-VAR BLOCK=RECP VARIABLE=UA &
          SENTENCE=RESULTS
      DEFINE MWFD PARAMETER 2
      DEFINE MWF STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
          VARIABLE=MASS-FLOW
      DEFINE RCPTOL PARAMETER 19
      DEFINE RPRCPI PARAMETER 25
      DEFINE RPRCPO PARAMETER 26
      DEFINE QRCPLB PARAMETER 72
      DEFINE QRC PUB PARAMETER 73
C DESIGN RECUPERATOR UA UADRCP [BTU/HR-R]
C DESIGN WORKING FLUID FLOW RATE MWFD [LB/HR]
C INSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPRCPI
C OUTSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPRCPO
F
C CORRECTION FACTOR TO U AS AFFECTED BY FLUID FLOW RATES
F   CF=1+RPRCPO*((MWF/MWFD)**0.6-1)+RPRCPI*((MWF/MWFD)**0.8-1)
F   UAR=CF*UADRCP
      SPEC "UARECP" TO "UAR"
      TOL-SPEC "RCPTOL"
      VARY BLOCK-VAR BLOCK=RECP VARIABLE=DUTY SENTENCE=COLD-SIDE &
          ID1=TUBEI
      LIMITS "QRCPLB" "QRC PUB"

;adjust vaporizer cold side duty to match vaporizer UA adjusted for off-desi
;process conditions
;
; "UAVAP design spec"

DESIGN-SPEC UAVAP
F   REAL CF,UAV
      DEFINE UADVAP PARAMETER 12
      DEFINE UAVAP BLOCK-VAR BLOCK=VAP VARIABLE=UA &
          SENTENCE=RESULTS
      DEFINE MGFD PARAMETER 1
      DEFINE FLOG STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
          VARIABLE=MASS-FLOW
      DEFINE MWFD PARAMETER 2
      DEFINE FLOW STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
          VARIABLE=MASS-FLOW
      DEFINE VAPTOL PARAMETER 18
      DEFINE RPHXI PARAMETER 21
      DEFINE RPHXO PARAMETER 22
      DEFINE QVAPLB PARAMETER 56
      DEFINE QVAPUB PARAMETER 57
C DESIGN VAPORIZER UA UADVAP [BTU/HR-R]
C DESIGN WF FLOW RATE MWFD [LB/HR]
C DESIGN GF FLOW RATE MGFD [LB/HR]
C INSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPHXI
C OUTSIDE FLUID HEAT TRANSFER RESISTANCE PERCENTAGE RPHXO

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F
C CORRECTION FACTOR TO U AS AFFECTED BY FLUID FLOW RATES
F   CF=1+RPHXI*((FLOG/MGFD)**0.8-1)+RPHXO*((FLOW/MWFD)**0.6-1)
F   UAV=CF*UADVAP
   SPEC "UAVAP" TO "UAV"
   TOL-SPEC "VAPTOL"
   VARY BLOCK-VAR BLOCK=VAP VARIABLE=DUTY SENTENCE=COLD-SIDE &
       ID1=HX-COLD
   LIMITS "QVAPLB" "QVAPUB"

EO-CONV-OPTI

;calculates condenser air-side pressure drop as function of air density and
; "DPAIR-C calculator"

CALCULATOR DPAIR-C
  DEFINE MAD STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE RHOAD STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
  DEFINE MAIR STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE RHOACI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
  DEFINE PCTFAN PARAMETER 200
  DEFINE PAIRID STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE PFANID STREAM-VAR STREAM=FANID SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE DPPSI BLOCK-VAR BLOCK=DPAIR VARIABLE=PRES &
    SENTENCE=PARAM
F   MA100 = MAIR/PCTFAN
F
F   QA100 = MA100/(RHOACI*60.)
F   QAD = MAD/(RHOAD*60.)
F
F   DPD = PFANID-PAIRID
F
C   DARCY-WEISBACH PRESSURE LOSS EQUATION
C   DP = FD*L/D*(RHO*V**2)/2
F   DPPSI = DPD*(RHOACI/RHOAD)*(QA100/QAD)**2
F
C   DPH20 = DPPSI/3.612E-02
  READ-VARS PAIRID PFANID RHOACI MAIR MAD RHOAD PCTFAN
  WRITE-VARS DPPSI

;generates fan curve using pump design point data imported from SETVAR calcu
; "FANCURVE calculator"

CALCULATOR FANCURVE
F   REAL FAN(16,4)
  DEFINE PCTFAN PARAMETER 200
  DEFINE PCTEXP PARAMETER 902
  DEFINE FANVOL PARAMETER 31
  DEFINE HFD PARAMETER 32
  DEFINE EFD PARAMETER 33
  DEFINE HQ1 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=1
  DEFINE HQ2 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=2
  DEFINE HQ3 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=3
  DEFINE HQ4 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=4
  DEFINE HQ5 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=5
  DEFINE HQ6 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=6
  DEFINE HQ7 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=7
  DEFINE HQ8 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=8

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DEFINE HQ9 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=9
DEFINE HQ10 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=10
DEFINE HQ11 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=11
DEFINE HQ12 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=12
DEFINE HQ13 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=13
DEFINE HQ14 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=14
DEFINE HQ15 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=15
DEFINE HQ16 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=HEAD-TABLE ID1=1 ID2=16
DEFINE EFQ1 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=1
DEFINE EFQ2 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=2
DEFINE EFQ3 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=3
DEFINE EFQ4 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=4
DEFINE EFQ5 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=5
DEFINE EFQ6 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=6
DEFINE EFQ7 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=7
DEFINE EFQ8 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=8
DEFINE EFQ9 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=9
DEFINE EFQ10 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=10
DEFINE EFQ11 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=11
DEFINE EFQ12 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=12
DEFINE EFQ13 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=13
DEFINE EFQ14 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=14
DEFINE EFQ15 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=15
DEFINE EFQ16 BLOCK-VAR BLOCK=FAN VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=16
DEFINE H1 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=1
DEFINE H2 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=2
DEFINE H3 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=3
DEFINE H4 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=4
DEFINE H5 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=5
DEFINE H6 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=6
DEFINE H7 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=7
DEFINE H8 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=8
DEFINE H9 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=9
DEFINE H10 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=10
DEFINE H11 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=11
DEFINE H12 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=12

```

```

DEFINE H13 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
  SENTENCE=HEAD-TABLE ID1=1 ID2=13
DEFINE H14 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
  SENTENCE=HEAD-TABLE ID1=1 ID2=14
DEFINE H15 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
  SENTENCE=HEAD-TABLE ID1=1 ID2=15
DEFINE H16 BLOCK-VAR BLOCK=FAN VARIABLE=HEAD &
  SENTENCE=HEAD-TABLE ID1=1 ID2=16
DEFINE EFF1 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=1
DEFINE EFF2 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=2
DEFINE EFF3 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=3
DEFINE EFF4 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=4
DEFINE EFF5 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=5
DEFINE EFF6 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=6
DEFINE EFF7 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=7
DEFINE EFF8 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=8
DEFINE EFF9 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=9
DEFINE EFF10 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=10
DEFINE EFF11 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=11
DEFINE EFF12 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=12
DEFINE EFF13 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=13
DEFINE EFF14 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=14
DEFINE EFF15 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=15
DEFINE EFF16 BLOCK-VAR BLOCK=FAN VARIABLE=EFFICIENCY &
  SENTENCE=EFF-TABLE ID1=1 ID2=16
F      PCTEXP = PCTFAN
F
C NORMALIZED FAN CURVE COEFFICIENTS OBTAINED FROM HUDSON PRODUCTS
C CORPORATION - THE BASICS OF AXIAL FLOW FANS WEB DOCUMENT
C SECOND TERM IN C0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      C4 = -0.1129487
F      C3 = 0.217381433
F      C2 = -0.67183349
F      C1 = 0.105023863
F      C0 = 1.45468792 + 0.00768898
F
C NORMALIZED FAN EFFICIENCY CURVE COEFFICIENTS
C SECOND TERM IN E0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      E3 = -0.435115203
F      E2 = -0.073393565
F      E1 = 1.495850057
F      E0 = 0.001793276 + 0.010865
F
C APPARENT FAN ACTUAL VOLUMETRIC FLOW RATE (ACFH)
F      QAPP = PCTFAN*FANVOL*60.
F
F      NROW = 16
F      NCOL = 4
F
F      DO 10 I = 1,NROW
F          FAN(I,1) = I/10.
F          FAN(I,2) = QAPP*FAN(I,1)
F          FAN(I,3) = HFD*(C0 + C1*FAN(I,1) + C2*FAN(I,1)**2
F      $      + C3*FAN(I,1)**3 + C4*FAN(I,1)**4)
F          FAN(I,4) = EFD*(E0 + E1*FAN(I,1) + E2*FAN(I,1)**2

```

```

F      $      + E3*FAN(I,1)**3)
F 10 CONTINUE
F
F      HQ1 = FAN(1,2)
F      HQ2 = FAN(2,2)
F      HQ3 = FAN(3,2)
F      HQ4 = FAN(4,2)
F      HQ5 = FAN(5,2)
F      HQ6 = FAN(6,2)
F      HQ7 = FAN(7,2)
F      HQ8 = FAN(8,2)
F      HQ9 = FAN(9,2)
F      HQ10 = FAN(10,2)
F      HQ11 = FAN(11,2)
F      HQ12 = FAN(12,2)
F      HQ13 = FAN(13,2)
F      HQ14 = FAN(14,2)
F      HQ15 = FAN(15,2)
F      HQ16 = FAN(16,2)
F
F      EFQ1 = HQ1
F      EFQ2 = HQ2
F      EFQ3 = HQ3
F      EFQ4 = HQ4
F      EFQ5 = HQ5
F      EFQ6 = HQ6
F      EFQ7 = HQ7
F      EFQ8 = HQ8
F      EFQ9 = HQ9
F      EFQ10 = HQ10
F      EFQ11 = HQ11
F      EFQ12 = HQ12
F      EFQ13 = HQ13
F      EFQ14 = HQ14
F      EFQ15 = HQ15
F      EFQ16 = HQ16
F
F      H1 = FAN(1,3)
F      H2 = FAN(2,3)
F      H3 = FAN(3,3)
F      H4 = FAN(4,3)
F      H5 = FAN(5,3)
F      H6 = FAN(6,3)
F      H7 = FAN(7,3)
F      H8 = FAN(8,3)
F      H9 = FAN(9,3)
F      H10 = FAN(10,3)
F      H11 = FAN(11,3)
F      H12 = FAN(12,3)
F      H13 = FAN(13,3)
F      H14 = FAN(14,3)
F      H15 = FAN(15,3)
F      H16 = FAN(16,3)
F
F      EFF1 = FAN(1,4)
F      EFF2 = FAN(2,4)
F      EFF3 = FAN(3,4)
F      EFF4 = FAN(4,4)
F      EFF5 = FAN(5,4)
F      EFF6 = FAN(6,4)
F      EFF7 = FAN(7,4)
F      EFF8 = FAN(8,4)
F      EFF9 = FAN(9,4)
F      EFF10 = FAN(10,4)
F      EFF11 = FAN(11,4)
F      EFF12 = FAN(12,4)
F      EFF13 = FAN(13,4)
F      EFF14 = FAN(14,4)
F      EFF15 = FAN(15,4)
F      EFF16 = FAN(16,4)
F
READ-VARS FANVOL HFD EFD PCTFAN
WRITE-VARS HQ1 HQ2 HQ3 HQ4 HQ5 HQ6 HQ7 HQ8 HQ9 HQ10 &

```

```

HQ11 HQ12 HQ13 HQ14 EFQ1 EFQ2 EFQ3 EFQ4 EFQ5 EFQ6 &
EFQ7 EFQ8 EFQ9 EFQ10 EFQ11 EFQ12 EFQ13 EFQ14 HQ15 &
HQ16 EFQ15 EFQ16 H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 &
H11 H12 H13 H14 H15 H16 EFF1 EFF2 EFF3 EFF4 EFF5 &
EFF6 EFF7 EFF8 EFF9 EFF10 EFF11 EFF12 EFF13 EFF14 &
EFF15 EFF16 PCTEXP

```

```

;generates pump curve using pump design point data imported from SETVAR calc
; "PMPCURVE calculator"

```

```

CALCULATOR PMPCURVE
F   REAL PUMP(16,4)
    DEFINE QPD PARAMETER 34
    DEFINE HPD PARAMETER 35
    DEFINE EPD PARAMETER 36
    DEFINE HQ1 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=1
    DEFINE HQ2 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=2
    DEFINE HQ3 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=3
    DEFINE HQ4 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=4
    DEFINE HQ5 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=5
    DEFINE HQ6 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=6
    DEFINE HQ7 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=7
    DEFINE HQ8 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=8
    DEFINE HQ9 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=9
    DEFINE HQ10 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=10
    DEFINE HQ11 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=11
    DEFINE HQ12 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=12
    DEFINE HQ13 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=13
    DEFINE HQ14 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=14
    DEFINE HQ15 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=15
    DEFINE HQ16 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=HEAD-TABLE ID1=1 ID2=16
    DEFINE EFQ1 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=1
    DEFINE EFQ2 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=2
    DEFINE EFQ3 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=3
    DEFINE EFQ4 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=4
    DEFINE EFQ5 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=5
    DEFINE EFQ6 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=6
    DEFINE EFQ7 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=7
    DEFINE EFQ8 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=8
    DEFINE EFQ9 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=9
    DEFINE EFQ10 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=10
    DEFINE EFQ11 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=11
    DEFINE EFQ12 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
        SENTENCE=EFF-TABLE ID1=1 ID2=12
    DEFINE EFQ13 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &

```

```

    SENTENCE=EFF-TABLE ID1=1 ID2=13
DEFINE EFQ14 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=14
DEFINE EFQ15 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=15
DEFINE EFQ16 BLOCK-VAR BLOCK=PUMP VARIABLE=FLOW &
    SENTENCE=EFF-TABLE ID1=1 ID2=16
DEFINE H1 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=1
DEFINE H2 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=2
DEFINE H3 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=3
DEFINE H4 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=4
DEFINE H5 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=5
DEFINE H6 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=6
DEFINE H7 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=7
DEFINE H8 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=8
DEFINE H9 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=9
DEFINE H10 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=10
DEFINE H11 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=11
DEFINE H12 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=12
DEFINE H13 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=13
DEFINE H14 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=14
DEFINE H15 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=15
DEFINE H16 BLOCK-VAR BLOCK=PUMP VARIABLE=HEAD &
    SENTENCE=HEAD-TABLE ID1=1 ID2=16
DEFINE EFF1 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=1
DEFINE EFF2 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=2
DEFINE EFF3 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=3
DEFINE EFF4 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=4
DEFINE EFF5 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=5
DEFINE EFF6 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=6
DEFINE EFF7 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=7
DEFINE EFF8 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=8
DEFINE EFF9 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=9
DEFINE EFF10 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=10
DEFINE EFF11 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=11
DEFINE EFF12 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=12
DEFINE EFF13 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=13
DEFINE EFF14 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=14
DEFINE EFF15 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=15
DEFINE EFF16 BLOCK-VAR BLOCK=PUMP VARIABLE=EFFICIENCY &
    SENTENCE=EFF-TABLE ID1=1 ID2=16
C NORMALIZED PUMP CURVE COEFFICIENTS OBTAINED FROM COMMERCIAL

```



```

C BINARY PLANT PUMP SPEC SHEET
F
C SECOND TERM IN C0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      C4 = 0.243983138
F      C3 = -0.77550408
F      C2 = 0.436368046
F      C1 = -0.274741859
F      C0 = 1.366690213 + 0.00320454
F
C NORMALIZED PUMP EFFICIENCY CURVE COEFFICIENTS
C SECOND TERM IN E0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      E3 = 0.307847951
F      E2 = -1.600387471
F      E1 = 2.276408774
F      E0 = 0.013634832 + 0.00249591
F
F      NROW = 16
F      NCOL = 4
F
F      DO 10 I = 1,NROW
F          PUMP(I,1) = I/10.
F          PUMP(I,2) = QPD*PUMP(I,1)
F          PUMP(I,3) = HPD*(C0 + C1*PUMP(I,1) + C2*PUMP(I,1)**2
F      $      + C3*PUMP(I,1)**3 + C4*PUMP(I,1)**4)
F          PUMP(I,4) = EPD*(E0 + E1*PUMP(I,1) + E2*PUMP(I,1)**2
F      $      + E3*PUMP(I,1)**3)
F 10 CONTINUE
F
F      DO 20 I = 1,NROW
F          WRITE(NTerm,100) PUMP(I,1),PUMP(I,2),PUMP(I,3),PUMP(I,4)
F 20 CONTINUE
F 100 FORMAT (2X, F3.1, 2X, F7.1, 2X, F7.1, 2X, F5.3)
F
F      HQ1 = PUMP(1,2)
F      HQ2 = PUMP(2,2)
F      HQ3 = PUMP(3,2)
F      HQ4 = PUMP(4,2)
F      HQ5 = PUMP(5,2)
F      HQ6 = PUMP(6,2)
F      HQ7 = PUMP(7,2)
F      HQ8 = PUMP(8,2)
F      HQ9 = PUMP(9,2)
F      HQ10 = PUMP(10,2)
F      HQ11 = PUMP(11,2)
F      HQ12 = PUMP(12,2)
F      HQ13 = PUMP(13,2)
F      HQ14 = PUMP(14,2)
F      HQ15 = PUMP(15,2)
F      HQ16 = PUMP(16,2)
F
F      EFQ1 = HQ1
F      EFQ2 = HQ2
F      EFQ3 = HQ3
F      EFQ4 = HQ4
F      EFQ5 = HQ5
F      EFQ6 = HQ6
F      EFQ7 = HQ7
F      EFQ8 = HQ8
F      EFQ9 = HQ9
F      EFQ10 = HQ10
F      EFQ11 = HQ11
F      EFQ12 = HQ12
F      EFQ13 = HQ13
F      EFQ14 = HQ14
F      EFQ15 = HQ15
F      EFQ16 = HQ16
F
F      H1 = PUMP(1,3)
F      H2 = PUMP(2,3)
F      H3 = PUMP(3,3)

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```

F      H4 = PUMP(4,3)
F      H5 = PUMP(5,3)
F      H6 = PUMP(6,3)
F      H7 = PUMP(7,3)
F      H8 = PUMP(8,3)
F      H9 = PUMP(9,3)
F      H10 = PUMP(10,3)
F      H11 = PUMP(11,3)
F      H12 = PUMP(12,3)
F      H13 = PUMP(13,3)
F      H14 = PUMP(14,3)
F      H15 = PUMP(15,3)
F      H16 = PUMP(16,3)
F
F      EFF1 = PUMP(1,4)
F      EFF2 = PUMP(2,4)
F      EFF3 = PUMP(3,4)
F      EFF4 = PUMP(4,4)
F      EFF5 = PUMP(5,4)
F      EFF6 = PUMP(6,4)
F      EFF7 = PUMP(7,4)
F      EFF8 = PUMP(8,4)
F      EFF9 = PUMP(9,4)
F      EFF10 = PUMP(10,4)
F      EFF11 = PUMP(11,4)
F      EFF12 = PUMP(12,4)
F      EFF13 = PUMP(13,4)
F      EFF14 = PUMP(14,4)
F      EFF15 = PUMP(15,4)
F      EFF16 = PUMP(16,4)
READ-VARS QPD HPD EPD
WRITE-VARS HQ1 HQ2 HQ3 HQ4 HQ5 HQ6 HQ7 HQ8 HQ9 HQ10 &
            HQ11 HQ12 HQ13 HQ14 HQ15 HQ16 EFQ1 EFQ2 EFQ3 EFQ4 &
            EFQ5 EFQ6 EFQ7 EFQ8 EFQ9 EFQ10 EFQ11 EFQ12 EFQ13 &
            EFQ14 EFQ15 EFQ16 H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 &
            H11 H12 H13 H14 H15 H16 EFF1 EFF2 EFF3 EFF4 EFF5 &
            EFF6 EFF7 EFF8 EFF9 EFF10 EFF11 EFF12 EFF13 EFF14 &
            EFF15 EFF16
;calculate pressure at throat of turbine nozzles assuming isentropic working
; "PTHRT calculator"

CALCULATOR PTHRT
F      REAL TTR,TCR,PTHRT
      DEFINE PTRBIN STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
            VARIABLE=PRES
      DEFINE TTRBIN STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
            VARIABLE=TEMP
      DEFINE PCMX STREAM-PROP STREAM=TURBI PROPERTY=PCMX
      DEFINE TCMX STREAM-PROP STREAM=TURBI PROPERTY=TCMX
      DEFINE PTHRT BLOCK-VAR BLOCK=TRBX VARIABLE=PRES &
            SENTENCE=PARAM
F      TTR = TTRBIN + 459.67
F      TCR = TCMX + 459.67
F      PTHRT = 0.67 * PTRBIN * (PTRBIN/PCMX)**0.2 * (TTR/TCR)**-1.
      READ-VARS PTRBIN TTRBIN PCMX TCMX
      WRITE-VARS PTHRT

;calculate pressure at throat of turbine nozzles at plant design conditions
;assuming isentropic working fluid expansion
;
; "PTHRTD calculator"

CALCULATOR PTHRTD
F      REAL TTR,TCR,PTHRT
      DEFINE PTRBIN STREAM-VAR STREAM=TURBID SUBSTREAM=MIXED &
            VARIABLE=PRES
      DEFINE TTRBIN STREAM-VAR STREAM=TURBID SUBSTREAM=MIXED &
            VARIABLE=TEMP
      DEFINE PCMX STREAM-PROP STREAM=TURBID PROPERTY=PCMX
      DEFINE TCMX STREAM-PROP STREAM=TURBID PROPERTY=TCMX
      DEFINE PTHRT BLOCK-VAR BLOCK=TRB1XD VARIABLE=PRES &

```

```

        SENTENCE=PARAM
F      TTR = TTRBIN + 459.67
F      TCR = TCMX + 459.67
F      PTHRT = 0.67 * PTRBIN * (PTRBIN/PCMX)**0.2 * (TTR/TCR)**-1.
      READ-VARS PTRBIN TTRBIN PCMX TCMX
      WRITE-VARS PTHRT

;consolidate, format, and output relevant simulation results to simulation
;terminal, history file, and report file
;
; "RESULTS calculator"

CALCULATOR RESULTS
F      INTEGER AMWF(51),ACVDP(51),AMAIR(51)
      DEFINE XC3 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=C3H8
      DEFINE XNC4 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=N-C4H10
      DEFINE XIC4 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=I-C4H10
      DEFINE XNC5 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=N-C5H12
      DEFINE XIC5 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=I-C5H12
      DEFINE XR134 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=R134A
      DEFINE XR245 MASS-FRAC STREAM=CVI SUBSTREAM=MIXED &
        COMPONENT=R245FA
      DEFINE TAIRI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE TGFIN STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE MGF STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
      DEFINE QPRH BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY &
        SENTENCE=RESULTS
      DEFINE UAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=UA &
        SENTENCE=RESULTS
      DEFINE LTDPRH BLOCK-VAR BLOCK=PRHX VARIABLE=LMTD &
        SENTENCE=RESULTS
      DEFINE MTAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=MITA &
        SENTENCE=RESULTS
      DEFINE TWPRIH STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE TWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE TGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE TGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE QVAP BLOCK-VAR BLOCK=VAP VARIABLE=DUTY &
        SENTENCE=RESULTS
      DEFINE UAVAP BLOCK-VAR BLOCK=VAP VARIABLE=UA &
        SENTENCE=RESULTS
      DEFINE LTDVAP BLOCK-VAR BLOCK=VAP VARIABLE=LMTD &
        SENTENCE=RESULTS
      DEFINE MTAVAP BLOCK-VAR BLOCK=VAP VARIABLE=MITA &
        SENTENCE=RESULTS
      DEFINE TWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTROPY
      DEFINE SMXDEC STREAM-VAR STREAM=TDECR SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTROPY
      DEFINE PSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
        VARIABLE=PRES
      DEFINE TTRBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=TEMP
      DEFINE PTRBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=PRES
      DEFINE TTRBE STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
        VARIABLE=TEMP

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DEFINE PTRBE BLOCK-VAR BLOCK=TRB VARIABLE=OUT-PRES-CAL &
    SENTENCE=RESULTS
DEFINE VANPOS PARAMETER 201
DEFINE TDTRBI STREAM-PROP STREAM=TURBI PROPERTY=TDEW
DEFINE SDP STREAM-VAR STREAM=SMIN SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE STRBIA STREAM-VAR STREAM=TURBIA SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE SRCPHE STREAM-VAR STREAM=SHELLE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE SV2 STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE QRCP BLOCK-VAR BLOCK=RECP VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UARCP BLOCK-VAR BLOCK=RECP VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDRCP BLOCK-VAR BLOCK=RECP VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTARCP BLOCK-VAR BLOCK=RECP VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TRCPHI STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPHE STREAM-VAR STREAM=SHELLE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPCI STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TRCPCE STREAM-VAR STREAM=TUBEE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TDWRHI STREAM-PROP STREAM=SHELLI PROPERTY=TDEW
DEFINE TDWRHE STREAM-PROP STREAM=SHELLE PROPERTY=TDEW
DEFINE TBBRCI STREAM-PROP STREAM=TUBEI PROPERTY=TBUB
DEFINE TBBRCE STREAM-PROP STREAM=TUBEE PROPERTY=TBUB
DEFINE QCND BLOCK-VAR BLOCK=COND VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UACND BLOCK-VAR BLOCK=COND VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTDCND BLOCK-VAR BLOCK=COND VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTACND BLOCK-VAR BLOCK=COND VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TWCNDI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TWCNDE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE TDCNDI STREAM-PROP STREAM=V3 PROPERTY=TDEW
DEFINE TBCNDE STREAM-PROP STREAM=CONDE PROPERTY=TBUB
DEFINE TAIRE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE MAIR STREAM-VAR STREAM=CND Aire SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
DEFINE RHOAIR STREAM-VAR STREAM=CND Aire SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE FANVOL PARAMETER 31
DEFINE PCTFAN PARAMETER 200
DEFINE PAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE PAE STREAM-VAR STREAM=CND Aire SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE DPPSI BLOCK-VAR BLOCK=DPAIR VARIABLE=PRES &
    SENTENCE=PARAM
DEFINE PPM PARAMETER 900
DEFINE TGFLIM PARAMETER 901
DEFINE WFAN BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE WPUMP BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE WTRB BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE EFFTRB BLOCK-VAR BLOCK=TRB VARIABLE=SEFF &
    SENTENCE=RESULTS
DEFINE EFFD PARAMETER 42
DEFINE EFFPMP BLOCK-VAR BLOCK=PUMP VARIABLE=CALCULATED-E &

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      SENTENCE=RESULTS
      DEFINE EFFFAN BLOCK-VAR BLOCK=FAN VARIABLE=SEFF &
      SENTENCE=RESULTS
      DEFINE MWFLB PARAMETER 52
      DEFINE MWFUB PARAMETER 53
      DEFINE MWF STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
      VARIABLE=MASS-FLOW
      DEFINE CVDPLB PARAMETER 70
      DEFINE CVD PUB PARAMETER 71
      DEFINE CVD BLOCK-VAR BLOCK=CV VARIABLE=P-DROP-R &
      SENTENCE=RESULTS
      DEFINE MAIRLB PARAMETER 50
      DEFINE MAIRUB PARAMETER 51
      DEFINE PTRBLB PARAMETER 58
      DEFINE PTRBUB PARAMETER 59
      DEFINE PPMLB PARAMETER 48
      DEFINE PPM PUB PARAMETER 49
      DEFINE PMP STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
      VARIABLE=PRES
      DEFINE TVAPLB PARAMETER 56
      DEFINE TVAPUB PARAMETER 57
      DEFINE TPARAM PARAMETER 500
F      WRITE(NTERM,50) TAIRI,TGFIN,MGF
F      WRITE(NRPT,50) TAIRI,TGFIN,MGF
F      WRITE(NHSTRY,50) TAIRI,TGFIN,MGF
F 50 FORMAT(//////3X,'SIMULATION RESULTS'
F      $/5X,'INLET AIR TEMPERATURE',T53,F7.1,1X,'°F'
F      $/5X,'INLET BRINE TEMPERATURE',T53,F7.1,1X,'°F'
F      $/5X,'BRINE FLOW RATE',T50,F10.1,1X,'LB/HR')
F
F      WRITE(NTERM,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F      $XIC5*100,XR134*100,XR245*100
F      WRITE(NRPT,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F      $XIC5*100,XR134*100,XR245*100
F      WRITE(NHSTRY,60)XC3*100,XNC4*100,XIC4*100,XNC5*100,
F      $XIC5*100,XR134*100,XR245*100
F 60 FORMAT(/3X,'WORKING FLUID COMPOSITION',
F      $/5X,'MASS FRAC C3',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC NC4',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC IC4',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC NC5',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC IC5',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC R134A',T55,F5.1,1X,'WT%'
F      $/5X,'MASS FRAC R245FA',T55,F5.1,1X,'WT%')
F
F      WRITE(NTERM,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F      $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F      WRITE(NRPT,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F      $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F      WRITE(NHSTRY,80) QPRH,UAPRH,LTDPRH,MTAPRH,
F      $TWPRHI,TWPRHE,TGPRHI,TGPRHE
F 80 FORMAT(/3X,'PREHEATER RESULTS',
F      $/5X,'PREHEATER DUTY',T50,E10.3,1X,'BTU/HR'
F      $/5X,'PREHEATER UA',T50,E10.3,1X,'BTU/HR-R'
F      $/5X,'PREHEATER LMTD',T53,F7.1,1X,'°F'
F      $/5X,'PREHEATER MITA',T53,F7.1,1X,'°F'
F      $/5X,'WF INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F'
F      $/5X,'BRINE INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F')
F
F      WRITE(NTERM,90) QVAP,UAVAP,LTDVAP,MTAVAP,
F      $TWPRHE,TWVAPE,TGFIN,TGPRHI
F      WRITE(NRPT,90) QVAP,UAVAP,LTDVAP,MTAVAP,
F      $TWPRHE,TWVAPE,TGFIN,TGPRHI
F      WRITE(NHSTRY,90) QVAP,UAVAP,LTDVAP,MTAVAP,
F      $TWPRHE,TWVAPE,TGFIN,TGPRHI
F 90 FORMAT(/3X,'VAPORIZER RESULTS',
F      $/5X,'VAPORIZER DUTY',T50,E10.3,1X,'BTU/HR'
F      $/5X,'VAPORIZER UA',T50,E10.3,1X,'BTU/HR-R'
F      $/5X,'VAPORIZER LMTD',T53,F7.1,1X,'°F'
F      $/5X,'VAPORIZER MITA',T53,F7.1,1X,'°F'
F      $/5X,'WF INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F'
F      $/5X,'BRINE INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F')

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F
F      IF (SDPMX.GT.SMXDEC) THEN
F        WRITE(NTERM,100)PSDPMX,SDP,STRBIA
F        WRITE(NRPT,100)PSDPMX,SDP,STRBIA
F        WRITE(NHSTRY,100)PSDPMX,SDP,STRBIA
F      ELSE
F        WRITE(NTERM,101)
F        WRITE(NRPT,101)
F        WRITE(NHSTRY,101)
F      ENDIF
F
F 100 FORMAT(/3X,'TURBINE RESULTS',
F    $/5X,'RETROGRADE WORKING FLUID DEWPOINT CURVE'
F    $/5X,'MAX DEW POINT ENTROPY PRESSURE',T53,F7.1,1X,'PSIA'
F    $/5X,'MINIMUM TURBINE INLET ENTROPY',T53,F7.3,1X,'BTU/LB-R'
F    $/5X,'TURBINE INLET ENTROPY',T53,F7.3,1X,'BTU/LB-R')
F
F 101 FORMAT(/3X,'TURBINE RESULTS',
F    $/5X,'STANDARD WORKING FLUID DEWPOINT CURVE')
F
F      WRITE(NTERM,102)TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F      WRITE(NRPT,102)TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F      WRITE(NHSTRY,102)TTRBI, PTRBI, TTRBI-TDTRBI, TTRBE, PTRBE, VANPOS*100
F 102 FORMAT(5X,'TURBINE INLET TEMPERATURE',T53,F7.1,1X,'°F'
F    $/5X,'TURBINE INLET PRESSURE',T53,F7.1,1X,'PSIA'
F    $/5X,'TURBINE INLET SUPERHEAT',T53,F7.1,1X,'°F'
F    $/5X,'TURBINE OUTLET TEMPERATURE',T53,F7.1,1X,'°F'
F    $/5X,'TURBINE OUTLET PRESSURE',T53,F7.1,1X,'PSIA'
F    $/5X,'TURBINE NOZZLE VANE POSITION',T53,F7.1,1X,'%')
F
F      IF (SRCPHE.EQ.SV2) THEN
F        WRITE(NTERM,110)QRCF,UARCF,LTDRCF,MTARCF,
F        $TRCPHI-TDWRHI,TRCPHE-TDWRHE,TBBRCI-TRCPCI,TBBRCE-TRCPCE
F        WRITE(NRPT,110)QRCF,UARCF,LTDRCF,MTARCF,
F        $TRCPHI-TDWRHI,TRCPHE-TDWRHE,TBBRCI-TRCPCI,TBBRCE-TRCPCE
F        WRITE(NHSTRY,110)QRCF,UARCF,LTDRCF,MTARCF,
F        $TRCPHI-TDWRHI,TRCPHE-TDWRHE,TBBRCI-TRCPCI,TBBRCE-TRCPCE
F      ENDIF
F 110 FORMAT(/3X,'RECUPERATOR RESULTS'
F    $/5X,'RECUPERATOR DUTY',T50,E10.3,1X,'BTU/HR'
F    $/5X,'RECUPERATOR UA',T50,E10.3,1X,'BTU/HR-R'
F    $/5X,'RECUPERATOR LMTD',T53,F7.1,1X,'°F'
F    $/5X,'RECUPERATOR MITA',T53,F7.1,1X,'°F'
F    $/5X,'HOT SIDE INLET/EXIT SUPERHEAT',T46,F6.1,' / ',F6.1,1X,'°F'
F    $/5X,'COLD SIDE INLET/EXIT SUBCOOLING',T46,F6.1,' / ',F6.1,1X,'°F')
F
F      WRITE(NTERM,120) QCND,UACND,LTDCND,MTACND,
F      $TWCNDI,TWCNDE,TAIRI,TAIRE,TWCNDI-TDCNDI,TBCNDE-TWCNDE,
F      $PCTFAN*100,(PAI-PAE)/3.612E-02
F      WRITE(NRPT,120) QCND,UACND,LTDCND,MTACND,
F      $TWCNDI,TWCNDE,TAIRI,TAIRE,TWCNDI-TDCNDI,TBCNDE-TWCNDE,
F      $PCTFAN*100,(PAI-PAE)/3.612E-02
F      WRITE(NHSTRY,120) QCND,UACND,LTDCND,MTACND,
F      $TWCNDI,TWCNDE,TAIRI,TAIRE,TWCNDI-TDCNDI,TBCNDE-TWCNDE,
F      $PCTFAN*100,(PAI-PAE)/3.612E-02
F 120 FORMAT(/,3X,'AIR-COOLED CONDENSER RESULTS'
F    $/5X,'CONDENSER DUTY',T50,E10.3,1X,'BTU/HR'
F    $/5X,'CONDENSER UA',T50,E10.3,1X,'BTU/HR-R'
F    $/5X,'CONDENSER LMTD',T53,F7.1,1X,'°F'
F    $/5X,'CONDENSER MITA',T53,F7.1,1X,'°F'
F    $/5X,'WF INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F'
F    $/5X,'AIR INLET/EXIT T',T46,F6.1,' / ',F6.1,1X,'°F'
F    $/5X,'INLET SUPERHEAT',T53,F7.1,1X,'°F'
F    $/5X,'EXIT SUBCOOLING',T53,F7.1,1X,'°F'
F    $/5X,'CONDENSER FANS OPERATING',T53,F7.1,1X,'% '
F    $/5X,'COND AIR SIDE DELTA P',T53,F7.3,1X,'IN-H2O')
F
F      WRITE(NTERM,130)PPM,TGFLIM,TGPRHE
F      WRITE(NRPT,130)PPM,TGFLIM,TGPRHE
F      WRITE(NHSTRY,130)PPM,TGFLIM,TGPRHE
F 130 FORMAT(/,3X,'GEOTHERMAL FLUID RESULTS',
F    $/5X,'SIO2 DISSOLVED IN GEOTHERMAL FLUID',T53,F7.1,1X,'PPM',

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F      $/,5X,'GEOTHERMAL FLUID OUTLET T LIMIT',T53,F7.1,1X,'°F',
F      $/,5X,'GEOTHERMAL FLUID OUTLET T',T53,F7.1,1X,'°F')
F
F      WRITE(NTERM,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F      WRITE(NRPT,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F      WRITE(NHSTRY,140)-WTRB,-WTRB*0.7457,-WPUMP,-WPUMP*0.7457,
F      $-WFAN,-WFAN*0.7457,-WTRB-WPUMP-WFAN,(-WTRB-WPUMP-WFAN)*0.7457
F 140 FORMAT(/,3X,'POWER SUMMARY',
F      $/,5X,'TURBINE POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'PUMP POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'FAN POWER',T40,F7.1,' HP / ',F7.1,' KW',
F      $/,5X,'NET POWER',T40,F7.1,' HP / ',F7.1,' KW')
F
F      WRITE(NTERM,150)EFFTRB*100,EFFD*100,EFFPMP*100,EFFFAN*100
F      WRITE(NRPT,150)EFFTRB*100,EFFD*100,EFFPMP*100,EFFFAN*100
F      WRITE(NHSTRY,150)EFFTRB*100,EFFD*100,EFFPMP*100,EFFFAN*100
F 150 FORMAT(/,3X,'EFFICIENCIES',T49,' SIM / DES',
F      $/,5X,'TURBINE EFFICIENCY',T49,F4.1,' / ',F4.1,1X,'% ',
F      $/,5X,'PUMP EFFICIENCY',T49,F4.1,' / 80.0 %',
F      $/,5X,'FAN EFFICIENCY',T49,F4.1,' / 55.0 %')
F
F      M = 50
F      N = M + 1
F
F      WRITE(NTERM,200)
F      WRITE(NRPT,200)
F      WRITE(NHSTRY,200)
F 200 FORMAT(/,3X,'OPTIMIZATION VARIABLE RANGES')
F
F      DO 201 I = 1, N
F      AMWF(I) = 10
F 201 CONTINUE
F      FMWF = (((MWF-MWFLB)/(MWFUB-MWFLB))*M)+1
F      AMWF(FMWF) = 1
F      WRITE(NTERM,202) AMWF,MWFLB,MWFUB
F      WRITE(NRPT,202) AMWF,MWFLB,MWFUB
F      WRITE(NHSTRY,202) AMWF,MWFLB,MWFUB
F 202 FORMAT(/,5X,'MWF',4X,51I1,/,5X,E9.3,40X,E9.3)
F
F      DO 203 I = 1, N
F      ACVDP(I) = 10
F 203 CONTINUE
F      FCVDP = (((CVDPLB)/(CVDPLB-CVDPLB))*M)+1
F      ACVDP(FCVDP) = 1
F      WRITE(NTERM,204) ACVDP,CVDPLB,CVDPLB
F      WRITE(NRPT,204) ACVDP,CVDPLB,CVDPLB
F      WRITE(NHSTRY,204) ACVDP,CVDPLB,CVDPLB
F 204 FORMAT(/,5X,'CVDPLB',3X,51I1,/,9X,F5.1,44X,F5.1)
F
F      DO 205 I = 1, N
F      AMAIR(I) = 10
F 205 CONTINUE
F      FMAIR = (((MAIR-MAIRLB)/(MAIRUB-MAIRLB))*M)+1
F      AMAIR(FMAIR) = 1
F      WRITE(NTERM,206) AMAIR,MAIRLB,MAIRUB
F      WRITE(NRPT,206) AMAIR,MAIRLB,MAIRUB
F      WRITE(NHSTRY,206) AMAIR,MAIRLB,MAIRUB
F 206 FORMAT(/,5X,'MAIR',3X,51I1,/,5X,E9.3,40X,E9.3)
F
F      WRITE(NTERM,207)
F      WRITE(NRPT,207)
F      WRITE(NHSTRY,207)
F 207 FORMAT(////)
F      READ-VARS VANPOS DPPSI PPM TGFLIM WFAN WTRB WPUMP EFFTRB &
F      EFFPMP MWFLB MWFUB MWF PTRBE MAIR RHOAIR FANVOL &
F      EFFFAN PCTFAN SDP SDPMX PSDPMX SMXDEC STRBIA PTRBI &
F      TAIRI TGFIN MGF TTRBI TTRBE QPRH UAPRH LTDPRH MTAPRH &
F      TGPRHE TGPRHI TWPRHE TWPRHI QVAP UAVAP LTDVAP MTAVAP &
F      TWPAE TDTTBI PAI PAE QCND UACND MTACND TWCNDI TWCNDE &
F      TAIRE LTDCND TDCNDI TBCNDE PTRBLB PTRBUB PPMPLB PMPUB &

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PPMP TVAPLB TVAPUB TPARAM MAIRLB MAIRUB XC3 XNC4 XIC4 &
XNC5 XIC5 XR134 XR245 SV2 SRCPHE QRCPC UARCP LTDRCP &
MTARCP TRCPHI TRCPHE TDWRHI TBBRCI TBBRCE TRCPCI &
TRCPCE TDWRHE EFFD CVDPLB CVD PUB CVD
EXECUTE AFTER BLOCK REFSTATE

;diverts working fluid flow to or around recuperator based on RECP flag in
;SETVAR calculator (recuperator bypassed when RECP = 0, recuperator used whe
;RECP = 1)
;
; "SETRECP calculator"

CALCULATOR SETRECP
  DEFINE RECP PARAMETER 101
  DEFINE RCPLFD BLOCK-VAR BLOCK="RCPLSPLT.LFEED" &
    VARIABLE=STREAM SENTENCE=PARAM
  DEFINE RCPVFD BLOCK-VAR BLOCK="RCPVSPLT.VFEED" &
    VARIABLE=STREAM SENTENCE=PARAM
  DEFINE CVFD BLOCK-VAR BLOCK=LSELECT VARIABLE=STREAM &
    SENTENCE=PARAM
  DEFINE CONDFD BLOCK-VAR BLOCK=VSELECT VARIABLE=STREAM &
    SENTENCE=PARAM
F    IF(RECP.EQ.1)THEN
F    RCPLFD = 1
F    RCPVFD = 1
F    CVFD = 1
F    CONDFD = 1
F    ELSE
F    RCPLFD = 2
F    RCPVFD = 2
F    CVFD = 2
F    CONDFD = 2
F    ENDIF
  READ-VARS RECP
  WRITE-VARS RCPLFD RCPVFD CONDFD CVFD

;consolidated input interface for importing plant design simulation results
;setting design spec and optimization bounds
;
; "SETVAR calculator"

CALCULATOR SETVAR
F    REAL MWMKUD
  DEFINE MGF D PARAMETER 1
  DEFINE MWFD PARAMETER 2
  DEFINE MAD PARAMETER 3
  DEFINE TGF STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE TTRBID STREAM-VAR STREAM=TURBID SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE PTRBID STREAM-VAR STREAM=TURBID SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE MAIRID STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  DEFINE TAIRID STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE PAIRID STREAM-VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE TFANID BLOCK-VAR BLOCK=CNDPAIR VARIABLE=TEMP &
    SENTENCE=PARAM
  DEFINE PFANID BLOCK-VAR BLOCK=CNDPAIR VARIABLE=PRES &
    SENTENCE=PARAM
  DEFINE UADPRH PARAMETER 11
  DEFINE UADVAP PARAMETER 12
  DEFINE UADRCPC PARAMETER 13
  DEFINE UADCND PARAMETER 14
  DEFINE PRHTOL PARAMETER 17
  DEFINE VAPTOL PARAMETER 18
  DEFINE RCPTOL PARAMETER 19
  DEFINE CNDTOL PARAMETER 20
  DEFINE RPHXI PARAMETER 21
  DEFINE RPHXO PARAMETER 22

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DEFINE RPCNDI PARAMETER 23
DEFINE RPCNDO PARAMETER 24
DEFINE RPRCPI PARAMETER 25
DEFINE RPRCPO PARAMETER 26
DEFINE FANVOL PARAMETER 31
DEFINE HFD PARAMETER 32
DEFINE EFD PARAMETER 33
DEFINE QPD PARAMETER 34
DEFINE HPD PARAMETER 35
DEFINE EPD PARAMETER 36
DEFINE WTRBID PARAMETER 40
DEFINE WTRBD PARAMETER 41
DEFINE EFFD PARAMETER 42
DEFINE ODFTRB PARAMETER 45
DEFINE MALB PARAMETER 50
DEFINE MAUB PARAMETER 51
DEFINE MWFLB PARAMETER 52
DEFINE MWFUB PARAMETER 53
DEFINE QPRHLB PARAMETER 54
DEFINE QPRHUB PARAMETER 55
DEFINE QVAPLB PARAMETER 56
DEFINE QVAPUB PARAMETER 57
DEFINE PTRBLB PARAMETER 58
DEFINE PTRBUB PARAMETER 59
DEFINE CVDPLB PARAMETER 70
DEFINE CVD PUB PARAMETER 71
DEFINE QRCPLB PARAMETER 72
DEFINE QRCPUB PARAMETER 73
DEFINE TXLB PARAMETER 74
DEFINE TXUB PARAMETER 75
DEFINE MWFMD PARAMETER 80
DEFINE MWFC D PARAMETER 81
DEFINE UADMKU PARAMETER 82
DEFINE MKUTOL PARAMETER 83
DEFINE MGFMD PARAMETER 84
DEFINE RECP PARAMETER 101
DEFINE MKUP PARAMETER 102
DEFINE REHEAT PARAMETER 103
DEFINE PDPL1 BLOCK-VAR BLOCK=DPL1 VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPL2 BLOCK-VAR BLOCK=DPL2 VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPV1 BLOCK-VAR BLOCK=DPV1 VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPV2 BLOCK-VAR BLOCK=DPV2 VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPHX BLOCK-VAR BLOCK=DPHX VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPCN BLOCK-VAR BLOCK=DPCN VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPR L BLOCK-VAR BLOCK=DPRL VARIABLE=DPPARM &
    SENTENCE=PARAM
DEFINE PDPRV BLOCK-VAR BLOCK=DPRV VARIABLE=DPPARM &
    SENTENCE=PARAM
C plant design simulation info
C location = generic
C working fluid = r245fa
C recuperator = FALSE
C solar thermal = FALSE
C turbine reheat = FALSE
C variable nozzle = TRUE
C T.gf,ex limit = TRUE
C P.min constraint = FALSE
C w.max constraint = FALSE
C plant design ver = 2006 MheatX
F
C Unit operation included in process? NO=0, YES=1
F RECP = 0
F CST = 0
F REHEAT = 0
F
C geothermal fluid design mass flow rate [lb/hr]

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F      MGFD = 1000000
C working fluid design mass flow rate [lb/hr]
F      MWFD = 1840462.56
C air design mass flow rate [lb/hr]
F      MAD = 29200739.5
C heat transfer fluid design mass flow rate [lb/hr]
F      MHTFD = 0
F
C preheater and heat exchanger pressure drop parameter
F      PDPHX = 6430.2829
F
C preheater design duty [BTU/hr]
F      QPRH = 186134180
C preheater design UA [BTU/hr-R]
F      UADPRH = 9008107
C preheater UA tolerance
F      PRHTOL = 1.0E-04*UADPRH
F
C vaporizer design duty [BTU/hr]
F      QVAP = 39025273.1
C vaporizer design UA [BTU/hr-R]
F      UADVAP = 3080299.61
C vaporizer UA tolerance
F      VAPTOL = 1.0E-04*UADVAP
F
C aux heat exchanger design htf mass flow rate [lb/hr]
F      MHTFD = 0
C aux heat exchanger design UA [BTU/hr-R]
F      UADCST = 0
C aux heat exchanger UA tolerance
F      CSTTOL = 1.0E-03*UADCST
F
C recuperator working fluid liquid pressure drop parameter
F      PDPRL = 0
C recuperator working fluid vapor pressure drop parameter
F      PDPRV = 0
C recuperator design UA [BTU/hr-R]
F      UADRCP = 1000
C recuperator UA tolerance
F      RCPTOL = 1.0E-03*UADRCP
F
C preheater/vaporizer, condenser, and recuperator
C inside and outside film coefficient resistance percentages
F      RPHXI = 0.14
F      RPHXO = 0.18
F      RPCNDI = 0.45
F      RPCNDO = 0.50
F      RPRCPI = 0.58
F      RPRCPO = 0.24
F
C air cooled condenser pressure drop parameters
F      PDPCN = 1.10376924
F      PDPAIR = 6.0337E-06
F
C air cooled condenser design working fluid mass flow rate [lb/hr]
F      MWFCD = 1840462.56
C air cooled condenser air side design conditions
F      MAIRID = MAD
F      TAIRID = 50
F      PAIRID = 14.6959488
C air cooled condenser design UA [BTU/hr-R]
F      UADCND = 7025131.58
C air cooled condenser UA tolerance
F      CNDTOL = 1.0E-04*UADCND
F
C fan inlet design conditions
F      TFANID = 76.8539877
F      PFANID = 14.6864416
C fan design actual volumetric flow [ACFM]
F      FANVOL = 395297867./60.
C fan design head [ft-lbf/lbm]
F      HFD = 18.5301313594733

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```

C fan design efficiency
F   EFD = 0.55
F
C pump design volumetric flow rate [gpm]
F   QPD = 2766.55333441209
C pump design head [ft-lbf/lbm]
F   HPD = 1476.3404862416
C pump design efficiency
F   EPD = 0.8
F
C turbine design conditions
F   TTRBID = 378.966173
F   PTRBID = 817.617148
C turbine design isentropic power [hp]
F   WTRBID = -19899.9438
C turbine design power [hp]
F   WTRBD = -15525.9362
C turbine design isentropic efficiency
F   EFFD = 0.83
C turbine nozzle area over design factor
F   ODFTRB = 0.25
F
C vapor and liquid flow pressure drop parameters
F   PDPV1 = 152.117491
F   PDPV2 = 1.14676763
F   PDPL1 = 846.173339
F   PDPL2 = 846.152651
F
C air mass flow rate bounds [lb/hr]
F   MALB = MAD*0.25
F   MAUB = MAD*1.5
C working fluid mass flow rate bounds [lb/hr]
F   MWFLB = MWFD*0.2
F   MWFUB = MWFD*1.5
C control valve pressure drop bounds [psia]
F   CVDPLB = 2.
F   CVD PUB = 800.
C preheater duty bounds [BTU/hr]
F   QPRHLB = 0.01*QPRH
F   QPRHUB = 2.0*QPRH
C vaporizer duty bounds [BTU/hr]
F   QVAPLB = 0.01*QVAP
F   QVAPUB = 2.0*QVAP
C turbine outlet pressure bounds [psia]
F   PTRBLB = 10
F   PTRBUB = 175
C turbine throat temperature bounds [°F]
F   TXLB = 100.
F   TXUB = TGF
C recuperator duty bounds [Btu/hr]
F   QRCPLB = 1.0E-01
F   QRC PUB = 5.0E+08
  READ-VARS TGF
  WRITE-VARS MGFMD MWFD MAD UADVAP UADPRH UADRCP UADCND &
    RPHXI RPHXO RPCNDI RPCNDO RPRCPI RPRCPO WTRBID EFFD &
    MALB MAUB MWFLB MWFUB QPRHLB QPRHUB QVAPLB QVAPUB &
    PTRBLB PTRBUB ODFTRB FANVOL TTRBID PTRBID PRHTOL &
    VAPTOL RCPTOL CNDTOL MAIRID TAIRID PAIRID TFANID &
    PFANID CVDPLB CVD PUB QRCPLB QRC PUB TXLB TXUB MWFC D &
    MWFM D UADM KU MKUTOL MGFMD MKUP REHEAT RECP HFD EFD &
    QPD HPD EPD WTRBD PDPL1 PDPL2 PDPV1 PDPV2 PD PHX &
    PDPCN PDPRL PDP RV
;calculate minimum dewpoint entropy depending on working fluid characteristi
;(standard or retrograde dewpoint curve)
;
;
; "STRBMIN calculator"

CALCULATOR STRBMIN
  DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE SMXDEC STREAM-VAR STREAM=TDECR SUBSTREAM=MIXED &

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        VARIABLE=MASS-ENTROPY
        DEFINE PTURBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=PRES
        DEFINE TTURBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=TEMP
        DEFINE TDEW STREAM-PROP STREAM=TURBI PROPERTY=TDEW
        DEFINE PSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
        VARIABLE=PRES
        DEFINE TSDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
        VARIABLE=TEMP
        DEFINE PCMX STREAM-PROP STREAM=TURBI PROPERTY=PCMX
        DEFINE PBUB STREAM-PROP STREAM=WFREF PROPERTY=PBUB
        DEFINE PRES BLOCK-VAR BLOCK=TRBSMIN VARIABLE=PRES &
        SENTENCE=PARAM
        DEFINE TEMP BLOCK-VAR BLOCK=TRBSMIN VARIABLE=TEMP &
        SENTENCE=PARAM
F      IF (SDPMX.GT.SMXDEC) THEN
C      RETROGRADE WORKING FLUID DEWPOINT CURVE
F      IF (PTURBI.GT.PSDPMX) THEN
F      PRES = PSDPMX
F      TEMP = TSDPMX + 1.
F      ELSE
F      PRES = PTURBI
F      TEMP = TDEW + 1.
F      ENDIF
F      ELSE
C      STANDARD WORKING FLUID DEWPOINT CURVE
F      IF (PTURBI.GT.PCMX) THEN
F      PRES = PBUB
F      TEMP = 32.
F      ELSE
F      PRES = PBUB
F      TEMP = 32.
F      ENDIF
F      ENDIF
F      READ-VARS PSDPMX PTURBI SDPMX SMXDEC PCMX TSDPMX TTURBI &
        PBUB TDEW
        WRITE-VARS PRES TEMP

;calculate minimum geofluid exit temperature value for TGFEXLIM constraint i
;WNET optimization block
;
; "TGFEXLIM calculator"

CALCULATOR TGFEXLIM
F      REAL GFTINC,B4,B3,B2,B1,B0,PPM,C4,C3,C2,C1,C0,GFTEXC,GFTEXF
        DEFINE TGFIN STREAM-VAR STREAM=GF SUBSTREAM=MIXED &
        VARIABLE=TEMP
        DEFINE PPM PARAMETER 900
        DEFINE TGFLIM PARAMETER 901
C      TEMPERATURE LIMIT LEAVING PLANT
C      RESOURCE TEMPERATURE IN DEGREES CELSIUS
F      TGFINC = (TGFIN-32.)*(5./9.)
F
C      SI IN SOLUTION CORRELATION COEFFICIENTS
F      B4 = -1.334837E-07
F      B3 = 7.06584462E-05
F      B2 = -3.6294799613E-03
F      B1 = 3.672417729236E-01
F      B0 = 4.2059443514950
F
F      PPM = B4*TGFINC**4 + B3*TGFINC**3 + B2*TGFINC**2 + B1*TGFINC + B0
F
C      TEMPERATURE LIMIT CORRELATION COEFFICIENTS
F      C4 = 2.49634E-11
F      C3 = -4.25191E-09
F      C2 = -1.19669E-04
F      C1 = 3.07616E-01
F      C0 = 2.94394E-01
F
F      TGFEXC = C4*PPM**4 + C3*PPM**3 + C2*PPM**2 + C1*PPM + C0
F      TGFLIM = (9./5.)*TGFEXC + 32.

```

```

F
C      WRITE(NHSTRY,*)'SIO2 IN SOLUTION, PPM = ', PPM
C      WRITE(NHSTRY,*)'BRINE OUTLET T LIMIT, F = ', TGFLIM
      READ-VARS TGFIN
      WRITE-VARS PPM TGFLIM

;calculates turbine isentropic efficiency as function of vane position and
;turbine spouting velocity
;
; "TRB1-C calculator"

CALCULATOR TRB1-C
F      REAL MAX,MAXD
      DEFINE MWFD PARAMETER 2
      DEFINE MWF STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=MASS-FLOW
      DEFINE RHOXD STREAM-VAR STREAM=TURBXD SUBSTREAM=MIXED &
        VARIABLE=MASS-DENSITY
      DEFINE RHOX STREAM-VAR STREAM=TURBX SUBSTREAM=MIXED &
        VARIABLE=MASS-DENSITY
      DEFINE WTRBID PARAMETER 40
      DEFINE WTRBI BLOCK-VAR BLOCK=TRB VARIABLE=ISEN-POWER &
        SENTENCE=RESULTS
      DEFINE HTRBID STREAM-VAR STREAM=TURBID SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTHALP
      DEFINE HTRBI STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTHALP
      DEFINE HTRBXD STREAM-VAR STREAM=TURBXD SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTHALP
      DEFINE HTRBX STREAM-VAR STREAM=TURBX SUBSTREAM=MIXED &
        VARIABLE=MASS-ENTHALP
      DEFINE EFFD PARAMETER 42
      DEFINE ODFTRB PARAMETER 45
      DEFINE VANPOS PARAMETER 201
      DEFINE EFF PARAMETER 202
C CORRELATION FOR EFFECT OF NOZZLE AREA ON EFFICIENCY
C SECOND TERM IN AR0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      AR0=-0.1882+0.002376388
F      AR1=6.1821
F      AR2=-15.333
F      AR3=21.611
F      AR4=-17.243
F      AR5=7.1836
F      AR6=-1.2149
F
C CORRELATION FOR EFFECT OF VELOCITY RATIO ON EFFICIENCY
C SECOND TERM IN VR0 DEFINITION IS ERROR CORRECTION TO
C FORCE CURVE TO PASS THROUGH VALUE OF 1.0
F      VR0=0.008536+0.00001875
F      VR1=1.545186
F      VR2=-0.11604
F      VR3=-0.4377
F
C GC = 32.174 (LBM*FT)/(LBF*S**2)
F      GC = 32.174
C 1 BTU = 778.169 FT-LBF
F      BTUCNV = 778.169
C 1 HP = 2544.433 BTU/HR
F      HPCNV = 2544.434
F
C DESIGN WORKING FLUID MASS FLOW RATE MWFD [LB/HR]
C DESIGN THROAT VELOCITY VXD=(2*GC*(DHX_ISEN))**0.5 [FT/S]
F      VXD=(2*GC*BTUCNV*(HTRBID-HTRBXD))**0.5
C DESIGN ISENTROPIC ENTHALPY CHANGE THROUGH TURBINE = DESIGN
C ISENTROPIC TURBINE POWER * 2544.433 (HP TO BTU/HR)/DESIGN
C WORKING FLUID FLOW RATE [BTU/LB]
F      DHISD=(-WTRBID*HPCNV)/MWFD
C DESIGN SPOUTING VELOCITY CO,D [FT/S]
F      COD=(2*GC*BTUCNV*DHISD)**0.5
C DESIGN THROAT DENSITY RHOXD [LB/CUFT]
C DESIGN THROAT MASS FLUX [LB/FT**2-S]

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```

F      MAXD=RHOXD*VXD
C DESIGN THROAT AREA [FT**2]
F      AXD=MWFD/(3600*MAXD)
C THROAT AREA WITH NOZZLES 100% OPEN
F      AXMAX = AXD*(1.0+ODFTRB)
F
C ISENTROPIC ENTHALPY CHANGE THROUGH TURBINE = ISENTROPIC TURBINE
C POWER * 2544.433 (HP TO BTU/HR)/WORKING FLUID FLOW RATE
F      DHIS=(-WTRBI*HPCNV)/MWF
C THROAT VELOCITY VT=(2*GC*(ISENTROPIC ENTHALPY DROP))*0.5 [FT/S]
F      VX=(2*GC*BTUCNV*(HTRBI-HTRBX))*0.5
C OFF-DESIGN SPOUTING VELOCITY CO [FT/S]
F      CO=(2*GC*BTUCNV*DHIS)**0.5
C MASS FLUX AT NOZZLE THROAT [LB/FT**2-S]
F      MAX=RHOX*VX
C NOZZLE THROAT AREA [FT**2]
F      AX=MWF/(3600*MAX)
C THROTTLING OF VANES TO ACHIEVE OPERATING FLOW RATE
F      AR=AX/AXD
F      VANPOS = AX/AXMAX
C      WRITE(NHSTRY,*)'TURBINE NOZZLE VANE POSITION = ',VANPOS
F
C RATIO OF VELOCITY RATIOS
F      VR=COD/CO
F
C EFFICIENCY CORRECTION FOR THROTTLING OF TURBINE NOZZLES
F      ERAR = AR0 + AR1*AR + AR2*AR**2 + AR3*AR**3
F      1      + AR4*AR**4 + AR5*AR**5 + AR6*AR**6
C      WRITE(NHSTRY,*)'AREA RATIO EFFICIENCY CORRECTION = ',ERAR
F
C EFFICIENCY CORRECTION FOR OFF-DESIGN PROCESS CONDITIONS
F      ERVR = VR0 + VR1*VR + VR2*VR**2 + VR3*VR**3
C      WRITE(NHSTRY,*)'OFF-DESIGN PROCESS COND EFF CORRECTION = ',ERVR
F
F      EFF = EFFD*ERAR*ERVR
READ-VARS MWFD MWF RHOXD RHOX WTRBID WTRBI HTRBID HTRBI &
      HTRBXD HTRBX EFFD ODFTRB
WRITE-VARS VANPOS EFF
EXECUTE AFTER BLOCK TRB

TRANSFER PGF0-T
SET BLOCK-VAR BLOCK=REFSTATE VARIABLE=PRES SENTENCE=PARAM
EQUAL-TO STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
VARIABLE=PRES

TRANSFER TGF0-T
SET BLOCK-VAR BLOCK=REFSTATE VARIABLE=TEMP SENTENCE=PARAM
EQUAL-TO STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
VARIABLE=TEMP

TRANSFER WFCOMP
SET STREAM-FLOWS TURBID
SET STREAM-FLOWS WFREF
EQUAL-TO STREAM-FLOWS PMPE
EXECUTE FIRST

SENSITIVITY SENS
PARAM HIGH-PRECISI=YES BASE-CASE=NO
DEFINE MG STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=MASS-FLOW
DEFINE MA STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
VARIABLE=MASS-FLOW
DEFINE MW STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=MASS-FLOW
DEFINE QACN BLOCK-VAR BLOCK=COND VARIABLE=DUTY &
SENTENCE=RESULTS
DEFINE UAACN BLOCK-VAR BLOCK=COND VARIABLE=UA &
SENTENCE=RESULTS
DEFINE LTDAACN BLOCK-VAR BLOCK=COND VARIABLE=LMTD &
SENTENCE=RESULTS
DEFINE MTAACN BLOCK-VAR BLOCK=COND VARIABLE=MITA &
SENTENCE=RESULTS

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```

DEFINE TWACNI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWACNI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWACNI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWACNI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWACNI STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWACNE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWACNE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWACNE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWACNE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWACNE STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TAACNI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PAACNI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RAACNI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HAACNI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SAACNI STREAM-VAR STREAM=CNDAIRI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TAACNE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PAACNE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RAACNE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HAACNE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SAACNE STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE MWACN STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
DEFINE PCTFAN PARAMETER 902
DEFINE WFAN BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
    SENTENCE=RESULTS
DEFINE WISFAN BLOCK-VAR BLOCK=FAN VARIABLE=ISEN-POWER &
    SENTENCE=RESULTS
DEFINE VOLFAN BLOCK-VAR BLOCK=FAN VARIABLE=VFLOW-IN &
    SENTENCE=RESULTS
DEFINE MEFFAN BLOCK-VAR BLOCK=FAN VARIABLE=MEFF &
    SENTENCE=RESULTS
DEFINE SEFFAN BLOCK-VAR BLOCK=FAN VARIABLE=SEFF &
    SENTENCE=RESULTS
DEFINE TAFANI STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PAFANI STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RAFANI STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HAFANI STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SAFANI STREAM-VAR STREAM=CNDARE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TAFANE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PAFANE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RAFANE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HAFANE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SAFANE STREAM-VAR STREAM=AIRE SUBSTREAM=MIXED &

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VARIABLE=MASS-ENTROPY
DEFINE QPRH BLOCK-VAR BLOCK=PRHX VARIABLE=DUTY &
SENTENCE=RESULTS
DEFINE UAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=UA &
SENTENCE=RESULTS
DEFINE LTDPRH BLOCK-VAR BLOCK=PRHX VARIABLE=LMTD &
SENTENCE=RESULTS
DEFINE MTAPRH BLOCK-VAR BLOCK=PRHX VARIABLE=MITA &
SENTENCE=RESULTS
DEFINE TWPRHI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWPRHI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWPRHI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWPRHI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWPRHI STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWPRHE STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SGPRHI STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SGPRHE STREAM-VAR STREAM=GFEX SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE QVAP BLOCK-VAR BLOCK=VAP VARIABLE=DUTY &
SENTENCE=RESULTS
DEFINE UAVAP BLOCK-VAR BLOCK=VAP VARIABLE=UA &
SENTENCE=RESULTS
DEFINE LTDVAP BLOCK-VAR BLOCK=VAP VARIABLE=LMTD &
SENTENCE=RESULTS
DEFINE MTAVAP BLOCK-VAR BLOCK=VAP VARIABLE=MITA &
SENTENCE=RESULTS
DEFINE TWVAPI STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWVAPI STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWVAPI STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWVAPI STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWVAPI STREAM-VAR STREAM=HX-COLD SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &

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VARIABLE=MASS-DENSITY
DEFINE HWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWVAPE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TGVAPI STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PGVAPI STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RGVAPI STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HGVAPI STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SGVAPI STREAM-VAR STREAM=GFIN SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TGVAPE STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PGVAPE STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RGVAPE STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HGVAPE STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SGVAPE STREAM-VAR STREAM=HX-HOT SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE WPMP BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
SENTENCE=RESULTS
DEFINE EFFPMP BLOCK-VAR BLOCK=PUMP VARIABLE=CALCULATED-E &
SENTENCE=RESULTS
DEFINE DPPMP BLOCK-VAR BLOCK=PUMP VARIABLE=DELP-CALC &
SENTENCE=RESULTS
DEFINE TWPMP1 STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWPMP1 STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWPMP1 STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWPMP1 STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWPMP1 STREAM-VAR STREAM=CONDE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TWPMP2 STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWPMP2 STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWPMP2 STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWPMP2 STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWPMP2 STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE WTR1 BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
SENTENCE=RESULTS
DEFINE WISTR1 BLOCK-VAR BLOCK=TRB VARIABLE=ISEN-POWER &
SENTENCE=RESULTS
DEFINE EFFTR1 BLOCK-VAR BLOCK=TRB VARIABLE=SEFF &
SENTENCE=RESULTS
DEFINE VPTR1 PARAMETER 201
DEFINE TWTR11 STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWTR11 STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
VARIABLE=PRES
DEFINE RWTR11 STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
VARIABLE=MASS-DENSITY
DEFINE HWTR11 STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
VARIABLE=MASS-ENTHALP
DEFINE SWTR11 STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
VARIABLE=MASS-ENTROPY
DEFINE TWTR1E STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
VARIABLE=TEMP
DEFINE PWTR1E STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
VARIABLE=PRES

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DEFINE RWTR1E STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWTR1E STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWTR1E STREAM-VAR STREAM=TURBE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE DPCVL BLOCK-VAR BLOCK=CV VARIABLE=P-DROP-R &
    SENTENCE=RESULTS
DEFINE TWCVL1 STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWCVL1 STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWCVL1 STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWCVL1 STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWCVL1 STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWCVL2 STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWCVL2 STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWCVL2 STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWCVL2 STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWCVL2 STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE QRCF BLOCK-VAR BLOCK=RCF VARIABLE=DUTY &
    SENTENCE=RESULTS
DEFINE UARCF BLOCK-VAR BLOCK=RCF VARIABLE=UA &
    SENTENCE=RESULTS
DEFINE LTRCF BLOCK-VAR BLOCK=RCF VARIABLE=LMTD &
    SENTENCE=RESULTS
DEFINE MTRCF BLOCK-VAR BLOCK=RCF VARIABLE=MITA &
    SENTENCE=RESULTS
DEFINE TWRCV1 STREAM-VAR STREAM=SHELL1 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWRCV1 STREAM-VAR STREAM=SHELL1 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWRCV1 STREAM-VAR STREAM=SHELL1 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWRCV1 STREAM-VAR STREAM=SHELL1 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWRCV1 STREAM-VAR STREAM=SHELL1 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWRCV2 STREAM-VAR STREAM=SHELL2 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWRCV2 STREAM-VAR STREAM=SHELL2 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWRCV2 STREAM-VAR STREAM=SHELL2 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWRCV2 STREAM-VAR STREAM=SHELL2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWRCV2 STREAM-VAR STREAM=SHELL2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWRC21 STREAM-VAR STREAM=TUBE1 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWRC21 STREAM-VAR STREAM=TUBE1 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWRC21 STREAM-VAR STREAM=TUBE1 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWRC21 STREAM-VAR STREAM=TUBE1 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWRC21 STREAM-VAR STREAM=TUBE1 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWRC22 STREAM-VAR STREAM=TUBE2 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWRC22 STREAM-VAR STREAM=TUBE2 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWRC22 STREAM-VAR STREAM=TUBE2 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY

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DEFINE HWRCL STREAM-VAR STREAM=TUBEE SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWRCL STREAM-VAR STREAM=TUBEE SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TAFAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PAFAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RAFAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HAFAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SAFAI STREAM-VAR STREAM=AIRI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TAFAE STREAM-VAR STREAM=CNDARI SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PAFAE STREAM-VAR STREAM=CNDARI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RAFAE STREAM-VAR STREAM=CNDARI SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HAFAE STREAM-VAR STREAM=CNDARI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SAFAE STREAM-VAR STREAM=CNDARI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFL1I STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFL1I STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFL1I STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFL1I STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFL1I STREAM-VAR STREAM=L2 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFL1E STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFL1E STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFL1E STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFL1E STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFL1E STREAM-VAR STREAM=CVI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFL2I STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFL2I STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFL2I STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFL2I STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFL2I STREAM-VAR STREAM=CVE SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFL2E STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFL2E STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFL2E STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFL2E STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFL2E STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFXI STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFXI STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFXI STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFXI STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP

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DEFINE SWFHXI STREAM-VAR STREAM=L3 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFHXE STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFHXE STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFHXE STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFHXE STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFHXE STREAM-VAR STREAM=HXI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFVLI STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFVLI STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFVLI STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFVLI STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFVLI STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFVLE STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFVLE STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFVLE STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFVLE STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFVLE STREAM-VAR STREAM=TURBI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFV2I STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFV2I STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFV2I STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFV2I STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFV2I STREAM-VAR STREAM=V2 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFV2E STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFV2E STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFV2E STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFV2E STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFV2E STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFCNI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFNCI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFNCI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFCNI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFCNI STREAM-VAR STREAM=V3 SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
DEFINE TWFCNE STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=TEMP
DEFINE PWFNE STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=PRES
DEFINE RWFNE STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-DENSITY
DEFINE HWFCNE STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTHALP
DEFINE SWFCNE STREAM-VAR STREAM=CONDI SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY

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DEFINE TWFR1I STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFR1I STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFR1I STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFR1I STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFR1I STREAM-VAR STREAM=RL1 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFRLE STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFRLE STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFRLE STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFRLE STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFRLE STREAM-VAR STREAM=TUBEI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFRVI STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFRVI STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFRVI STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFRVI STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFRVI STREAM-VAR STREAM=RV1 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TWFRVE STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PWFRVE STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RWFRVE STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HWFRVE STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SWFRVE STREAM-VAR STREAM=SHELLI SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
DEFINE TG0 STREAM-VAR STREAM=GF0 SUBSTREAM=MIXED &
  VARIABLE=TEMP
DEFINE PG0 STREAM-VAR STREAM=GF0 SUBSTREAM=MIXED &
  VARIABLE=PRES
DEFINE RG0 STREAM-VAR STREAM=GF0 SUBSTREAM=MIXED &
  VARIABLE=MASS-DENSITY
DEFINE HG0 STREAM-VAR STREAM=GF0 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTHALP
DEFINE SG0 STREAM-VAR STREAM=GF0 SUBSTREAM=MIXED &
  VARIABLE=MASS-ENTROPY
F      DPL1 = PWFL1I - PWFL1E
F      DPL2 = PWFL2I - PWFL2E
F      DPHX = PWFHXI - PWFHXE
F      DPV1 = PWFV1I - PWFV1E
F      DPV2 = PWFV2I - PWFV2E
F      DPCN = PWFCNI - PWFCNE
F      DPRL = PWFR1I - PWFRLE
F      DPRV = PWFRVI - PWFRVE
F      DPAIR = PAFAI - PAFAE
F
F      QACN = -QACN
F      QPRH = -QPRH
F      QVAP = -QVAP
F
TABULATE 1 "MG"
TABULATE 2 "MA"
TABULATE 3 "MW"
TABULATE 4 "QACN"
TABULATE 5 "UAACN"
TABULATE 6 "LTDACN"
TABULATE 7 "MTAACN"
TABULATE 8 "TWACNI"
TABULATE 9 "PWACNI"

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TABULATE	10	"RWACNI"
TABULATE	11	"HWACNI"
TABULATE	12	"SWACNI"
TABULATE	13	"TWACNE"
TABULATE	14	"PWACNE"
TABULATE	15	"RWACNE"
TABULATE	16	"HWACNE"
TABULATE	17	"SWACNE"
TABULATE	18	"TAACNI"
TABULATE	19	"PAACNI"
TABULATE	20	"RAACNI"
TABULATE	21	"HAACNI"
TABULATE	22	"SAACNI"
TABULATE	23	"TAACNE"
TABULATE	24	"PAACNE"
TABULATE	25	"RAACNE"
TABULATE	26	"HAACNE"
TABULATE	27	"SAACNE"
TABULATE	28	"MWACN"
TABULATE	29	"PCTFAN"
TABULATE	30	"WFAN"
TABULATE	31	"WISFAN"
TABULATE	32	"VOLFAN"
TABULATE	33	"MEFFAN"
TABULATE	34	"SEFFAN"
TABULATE	35	"TAFANI"
TABULATE	36	"PAFANI"
TABULATE	37	"RAFANI"
TABULATE	38	"HAFANI"
TABULATE	39	"SAFANI"
TABULATE	40	"TAFANE"
TABULATE	41	"PAFANE"
TABULATE	42	"RAFANE"
TABULATE	43	"HAFANE"
TABULATE	44	"SAFANE"
TABULATE	45	"QPRH"
TABULATE	46	"UAPRH"
TABULATE	47	"LTDPRH"
TABULATE	48	"MTAPRH"
TABULATE	49	"TWPRHI"
TABULATE	50	"PWPRHI"
TABULATE	51	"RWPRHI"
TABULATE	52	"HWPRHI"
TABULATE	53	"SWPRHI"
TABULATE	54	"TWPRHE"
TABULATE	55	"PWPRHE"
TABULATE	56	"RWPRHE"
TABULATE	57	"HWPRHE"
TABULATE	58	"SWPRHE"
TABULATE	59	"TGPRHI"
TABULATE	60	"PGPRHI"
TABULATE	61	"RGPRHI"
TABULATE	62	"HGPRHI"
TABULATE	63	"SGPRHI"
TABULATE	64	"TGPRHE"
TABULATE	65	"PGPRHE"
TABULATE	66	"RGPRHE"
TABULATE	67	"HGPRHE"
TABULATE	68	"SGPRHE"
TABULATE	69	"QVAP"
TABULATE	70	"UAVAP"
TABULATE	71	"LTDVAP"
TABULATE	72	"MTAVAP"
TABULATE	73	"TWVAPI"
TABULATE	74	"PWVAPI"
TABULATE	75	"RWVAPI"
TABULATE	76	"HWVAPI"
TABULATE	77	"SWVAPI"
TABULATE	78	"TWVAPE"
TABULATE	79	"PWVAPE"
TABULATE	80	"RWVAPE"
TABULATE	81	"HWVAPE"

TABULATE 82 "SWVAPE"
 TABULATE 83 "TGVAPI"
 TABULATE 84 "PGVAPI"
 TABULATE 85 "RGVAPI"
 TABULATE 86 "HGVAPI"
 TABULATE 87 "SGVAPI"
 TABULATE 88 "TGVAPE"
 TABULATE 89 "PGVAPE"
 TABULATE 90 "RGVAPE"
 TABULATE 91 "HGVAPE"
 TABULATE 92 "SGVAPE"
 TABULATE 93 "WPMP"
 TABULATE 94 "EFFPMP"
 TABULATE 95 "DPPMP"
 TABULATE 96 "TWPMPI"
 TABULATE 97 "PWPMPI"
 TABULATE 98 "RWPMPI"
 TABULATE 99 "HWPMPI"
 TABULATE 100 "SWPMPI"
 TABULATE 101 "TWPMPE"
 TABULATE 102 "PWPMPE"
 TABULATE 103 "RWPMPE"
 TABULATE 104 "HWPMPE"
 TABULATE 105 "SWPMPE"
 TABULATE 106 "WTR1"
 TABULATE 107 "WISTR1"
 TABULATE 108 "EFFTR1"
 TABULATE 109 "VPTR1"
 TABULATE 110 "TWTR1I"
 TABULATE 111 "PWTR1I"
 TABULATE 112 "RWTR1I"
 TABULATE 113 "HWTR1I"
 TABULATE 114 "SWTR1I"
 TABULATE 115 "TWTR1E"
 TABULATE 116 "PWTR1E"
 TABULATE 117 "RWTR1E"
 TABULATE 118 "HWTR1E"
 TABULATE 119 "SWTR1E"
 TABULATE 120 "DPCVL"
 TABULATE 121 "TWCVLI"
 TABULATE 122 "PWCVLI"
 TABULATE 123 "RWCVLI"
 TABULATE 124 "HWCVLI"
 TABULATE 125 "SWCVLI"
 TABULATE 126 "TWCVLE"
 TABULATE 127 "PWCVLE"
 TABULATE 128 "RWCVLE"
 TABULATE 129 "HWCVLE"
 TABULATE 130 "SWCVLE"
 TABULATE 131 "QRCP"
 TABULATE 132 "UARCP"
 TABULATE 133 "LTDRCP"
 TABULATE 134 "MTARCP"
 TABULATE 135 "TWRCVI"
 TABULATE 136 "PWRCVI"
 TABULATE 137 "RWRCVI"
 TABULATE 138 "HWRCVI"
 TABULATE 139 "SWRCVI"
 TABULATE 140 "TWRCVE"
 TABULATE 141 "PWRCVE"
 TABULATE 142 "RWRCVE"
 TABULATE 143 "HWRCVE"
 TABULATE 144 "SWRCVE"
 TABULATE 145 "TWRCLE"
 TABULATE 146 "PWRCLE"
 TABULATE 147 "RWRCLE"
 TABULATE 148 "HWRCLE"
 TABULATE 149 "SWRCLE"
 TABULATE 150 "TWRCLE"
 TABULATE 151 "PWRCLE"
 TABULATE 152 "RWRCLE"
 TABULATE 153 "HWRCLE"

TABULATE	154	"SWRCLE"
TABULATE	155	"TAFAI"
TABULATE	156	"PAFAI"
TABULATE	157	"RAFAI"
TABULATE	158	"HAFAI"
TABULATE	159	"SAFAI"
TABULATE	160	"TAFAE"
TABULATE	161	"PAFAE"
TABULATE	162	"RAFAE"
TABULATE	163	"HAFAE"
TABULATE	164	"SAFAE"
TABULATE	165	"TWFL1I"
TABULATE	166	"PWFL1I"
TABULATE	167	"RWFL1I"
TABULATE	168	"HWFL1I"
TABULATE	169	"SWFL1I"
TABULATE	170	"TWFL1E"
TABULATE	171	"PWFL1E"
TABULATE	172	"RWFL1E"
TABULATE	173	"HWFL1E"
TABULATE	174	"SWFL1E"
TABULATE	175	"TWFL2I"
TABULATE	176	"PWFL2I"
TABULATE	177	"RWFL2I"
TABULATE	178	"HWFL2I"
TABULATE	179	"SWFL2I"
TABULATE	180	"TWFL2E"
TABULATE	181	"PWFL2E"
TABULATE	182	"RWFL2E"
TABULATE	183	"HWFL2E"
TABULATE	184	"SWFL2E"
TABULATE	185	"TWFHXI"
TABULATE	186	"PWFHXI"
TABULATE	187	"RWFHXI"
TABULATE	188	"HWFHXI"
TABULATE	189	"SWFHXI"
TABULATE	190	"TWFHXE"
TABULATE	191	"PWFHXE"
TABULATE	192	"RWFHXE"
TABULATE	193	"HWFHXE"
TABULATE	194	"SWFHXE"
TABULATE	195	"TWFV1I"
TABULATE	196	"PWFV1I"
TABULATE	197	"RWFV1I"
TABULATE	198	"HWFV1I"
TABULATE	199	"SWFV1I"
TABULATE	200	"TWFV1E"
TABULATE	201	"PWFV1E"
TABULATE	202	"RWFV1E"
TABULATE	203	"HWFV1E"
TABULATE	204	"SWFV1E"
TABULATE	205	"TWFV2I"
TABULATE	206	"PWFV2I"
TABULATE	207	"RWFV2I"
TABULATE	208	"HWFV2I"
TABULATE	209	"SWFV2I"
TABULATE	210	"TWFV2E"
TABULATE	211	"PWFV2E"
TABULATE	212	"RWFV2E"
TABULATE	213	"HWFV2E"
TABULATE	214	"SWFV2E"
TABULATE	215	"TWFCNI"
TABULATE	216	"PWFCNI"
TABULATE	217	"RWFCNI"
TABULATE	218	"HWFCNI"
TABULATE	219	"SWFCNI"
TABULATE	220	"TWFCNE"
TABULATE	221	"PWFCNE"
TABULATE	222	"RWFCNE"
TABULATE	223	"HWFCNE"
TABULATE	224	"SWFCNE"
TABULATE	225	"TWFRLI"


```

TABULATE 226 "PWFRLI"
TABULATE 227 "RWFRLI"
TABULATE 228 "HWFRLI"
TABULATE 229 "SWFRLI"
TABULATE 230 "TWFRLE"
TABULATE 231 "PWFRLE"
TABULATE 232 "RWFRLE"
TABULATE 233 "HWFRLE"
TABULATE 234 "SWFRLE"
TABULATE 235 "TWFRVI"
TABULATE 236 "PWFRVI"
TABULATE 237 "RWFRVI"
TABULATE 238 "HWFRVI"
TABULATE 239 "SWFRVI"
TABULATE 240 "TWFRVE"
TABULATE 241 "PWFRVE"
TABULATE 242 "RWFRVE"
TABULATE 243 "HWFRVE"
TABULATE 244 "SWFRVE"
TABULATE 245 "TGO"
TABULATE 246 "PGO"
TABULATE 247 "RGO"
TABULATE 248 "HGO"
TABULATE 249 "SGO"
TABULATE 250 "DPL1"
TABULATE 251 "DPL2"
TABULATE 252 "DPHX"
TABULATE 253 "DPV1"
TABULATE 254 "DPV2"
TABULATE 255 "DPCN"
TABULATE 256 "DPRL"
TABULATE 257 "DPRV"
TABULATE 258 "DPAIR"
VARY STREAM=VAR STREAM=AIRI SUBSTREAM=MIXED VARIABLE=TEMP
RANGE LOWER="-22." UPPER="122." NPOINT="9"

;limit minimum working fluid pressure to prevent entry of noncondensable gas
;into cycle
;
; "PMIN constraint"

CONSTRAINT PMIN
  DEFINE PPMPI STREAM=VAR STREAM=CONDE SUBSTREAM=MIXED &
    VARIABLE=PRES
  DEFINE PAIRID STREAM=VAR STREAM=AIRID SUBSTREAM=MIXED &
    VARIABLE=PRES
  SPEC "PPMPI" GE "PAIRID"
  TOL-SPEC "0.01"

;specify minimum turbine inlet entropy calculated in STRBMIN calculator bloc
;ensure dry turbine expansion
;
; "STRBIN constraint"

CONSTRAINT STRBIN
  DEFINE STRBI STREAM=VAR STREAM=TURBIA SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE SMIN STREAM=VAR STREAM=SMIN SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  SPEC "STRBI" GE "SMIN"
  TOL-SPEC "1.E-08"

;specify minimum geofluid exit temperature calculated in TGFEXLIM calculator
; "TGFEXLIM constraint"

CONSTRAINT TGFEXLIM
  DEFINE TGFLIM PARAMETER 901
  DEFINE TGFEX STREAM=VAR STREAM=GFEX SUBSTREAM=MIXED &
    VARIABLE=TEMP
  SPEC "TGFEX" GE "TGFLIM"
  TOL-SPEC "0.1"

```

```

;limit calculated plant performance to operating points that can be accommodated
;by the range of possible turbine nozzle vane positions (less than or equal
;100% open)
;
; "VANEPOS constraint"

CONSTRAINT VANEPOS
  DEFINE VANPOS PARAMETER 201
  SPEC "VANPOS" LE "1.0"
  TOL-SPEC "0.0001"

;limit turbine generator output to prevent exceeding rated capacity
; "WMAX constraint"

CONSTRAINT WMAX
  DEFINE WTRB BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
    SENTENCE=RESULTS
  SPEC "WTRB" LE "20000"
  TOL-SPEC "0.1"

;determines maximum dew point entropy pressure
;
; "SDWPT optimization block"

OPTIMIZATION SDWPTMAX
  DEFINE SDPMX STREAM-VAR STREAM=SDPMX SUBSTREAM=MIXED &
    VARIABLE=MASS-ENTROPY
  DEFINE PCMX STREAM-PROP STREAM=WFREF PROPERTY=PCMX
  MAXIMIZE "SDPMX"
  VARY BLOCK-VAR BLOCK=SDPMX VARIABLE=PRES SENTENCE=PARAM
  LIMITS "50" "PCMX"

;maximize net power (turbine power - pump power - fan power)
; "WNET optimization block"

OPTIMIZATION WNET
  DEFINE THXE STREAM-VAR STREAM=HXE SUBSTREAM=MIXED &
    VARIABLE=TEMP
  DEFINE TRBPWR BLOCK-VAR BLOCK=TRB VARIABLE=NET-WORK &
    SENTENCE=RESULTS
  DEFINE FANPWR BLOCK-VAR BLOCK=FAN VARIABLE=NET-WORK &
    SENTENCE=RESULTS
  DEFINE PMPPWR BLOCK-VAR BLOCK=PUMP VARIABLE=NET-WORK &
    SENTENCE=RESULTS
  DEFINE MWFLB PARAMETER 52
  DEFINE MWFUB PARAMETER 53
  DEFINE CVDPLB PARAMETER 70
  DEFINE CVD PUB PARAMETER 71
  DEFINE MALB PARAMETER 50
  DEFINE MAUB PARAMETER 51
  MINIMIZE "TRBPWR+FANPWR+PMPPWR"
  CONSTRAINTS VANEPOS / STRBIN / TGFEXLIM
  VARY STREAM-VAR STREAM=PMPE SUBSTREAM=MIXED &
    VARIABLE=MASS-FLOW
  LIMITS "MWFLB" "MWFUB"
  VARY BLOCK-VAR BLOCK=CV VARIABLE=P-DROP SENTENCE=PARAM
  LIMITS "CVDPLB" "CVD PUB"
  VARY PARAMETER 200 INIT-VAL=1.0
  LIMITS "0.25" "1.0"

CONV-OPTIONS
  SECANT BRACKET=YES
  SQP MAXLSPASS=6 NLIMIT=6 OPT-METHOD=BIEGLER CONST-ITER=4 &
    DERIV-SWITCH=YES

TEAR
  TEAR L2 COMPS=WF / PMPE COMPS=WF

CONVERGENCE TEAR WEGSTEIN
  TEAR L2 COMPS=WF

CONVERGENCE SDWPTMAX SQP

```

```

OPTIMIZE OPTID=SDWPTMAX
PARAM MAXIT=100 TOL=1.0000E-08 OPT-METHOD=BIEGLER

CONVERGENCE WNET SQP
OPTIMIZE OPTID=WNET
TEAR PMPE COMPS=WF

SEQUENCE S-1 DPV1 TRBDUPL PTHRT TRBX STRBMIN TRBSMIN

STREAM-REPOR NOMOLEFLOW MASSFLOW MASSFRAC

DISABLE
    CONSTRAINT PMIN WMAX
;
;
;
;
;
;
;
;

```

Appendix III

Average Annual Temperature for Each US State

Average Annual Temperature for Each US State based on data collected by weather stations throughout each state during the years 1971 to 2000 and made available by the NOAA National Climatic Data Center of the United States [9].

State	°F	°C
Alabama	62.8	17.1
Alaska	26.6	-3.0
Arizona	60.3	15.7
Arkansas	60.4	15.8
California	59.4	15.2
Colorado	45.1	7.3
Connecticut	49.0	9.4
Delaware	55.3	12.9
Florida	70.7	21.5
Georgia	63.5	17.5
Hawaii	70.0	21.1
Idaho	44.4	6.9
Illinois	51.8	11.0
Indiana	51.7	10.9
Iowa	47.8	8.8
Kansas	54.3	12.4
Kentucky	55.6	13.1
Louisiana	66.4	19.1
Maine	41.0	5.0
Maryland	54.2	12.3
Massachusetts	47.9	8.8
Michigan	44.4	6.9
Minnesota	41.2	5.1
Mississippi	63.4	17.4
Missouri	54.5	12.5
Montana	42.7	5.9
Nebraska	48.8	9.3
Nevada	49.9	9.9
New Hampshire	43.8	6.6
New Jersey	52.7	11.5
New Mexico	53.4	11.9
New York	45.4	7.4
North Carolina	59.0	15.0
North Dakota	40.4	4.7
Ohio	50.7	10.4
Oklahoma	59.6	15.3
Oregon	48.4	9.1
Pennsylvania	48.8	9.3
Rhode Island	50.1	10.1
South Carolina	62.4	16.9
South Dakota	45.2	7.3
Tennessee	57.6	14.2
Texas	64.8	18.2
Utah	48.6	9.2
Vermont	42.9	6.1
Virginia	55.1	12.8
Washington	48.3	9.1
West Virginia	51.8	11.0
Wisconsin	43.1	6.2
Wyoming	42.0	5.6