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Summary

The PRESTO computer code is designed to analyze the performance of regenerative, superheated steam turbine cycles at valves-wide-open design flow. The code can model conventional steam cycles as well as cycles including such special features as process steam extractions and inductions and feedwater heating by external heat sources. New convenience features and extensions to the special features have been incorporated into the PRESTO code. This extended version is named PRESTO II to distinguish it from the original PRESTO code, which has been disseminated to the public through COSMIC since October 1979. The new features are detailed in this report. They include the capability to calculate the valves-wide-open design point performance in a single run; the capability to specify the cycle heat input definition so that useful heat rates are obtained when there are process steam extractions; the capability to size the cycle on the basis of the amount of heat it is required to absorb or the shaft power it is required to produce; and the provision for additional possible locations for steam extractions and inductions and for feedwater heating by external heat sources. Detailed examples are included to illustrate the use of both the original and the new special features.

Introduction

The PRESTO computer code, as described in reference 1, was written to analyze the performance of regenerative, superheated steam cycles at valves-wide-open design flow. The PRESTO code can analyze conventional steam cycles and steam cycles that include such special features as steam induction, steam extraction, and feedwater heating by external heat sources. These features are often desired to improve the overall system efficiency of an advanced energy conversion system in which the steam cycle is combined with a high-temperature topping cycle or integrated with an advanced heat source.

The PRESTO code uses a documented General Electric method (ref. 2) as the basis for its logic and functional relations in calculating steam turbine performance. Additional details on the method used are also discussed in reference 3. The PRESTO code uses the 1967 ASME formulation for steam and water properties and includes all the necessary subroutines for calculating those properties. The code output provides all the information normally shown on a heat balance diagram.

This report describes new features that have been added to PRESTO. The version of PRESTO incorporating these new features has been designated PRESTO II. The new features provide added convenience for users or additional analysis capability. The new features that provide added convenience are

(1) An option to specify the automatic calculation of valves-wide-open (VWO) design flow performance
(2) An option to specify one's own steam-cycle heat input definition to be used in the heat rate calculations or to choose from among several heat input definitions available within the code

The new features that provide added analysis capability are

(1) An option to specify the shaft power required from the cycle or the total amount of heat required to be added to the cycle. (Previously only the required electric power generation or the required steam generator flow could be specified.)
(2) An option to specify the extraction or induction of steam before the high-pressure turbine throttle
(3) An option to specify process steam extractions along the turbine expansion lines
(4) An option to specify an external heat input between the condenser and the lowest pressure feedwater heater

All these new features are discussed in detail in this report.

This report also gives examples that illustrate the use of the special features of PRESTO II. The examples cover both the original special features discussed in reference 1 and the new special features discussed in this report. Also included are examples that illustrate the use of PRESTO II for parametric analysis.

Before the new features and applications of PRESTO II are discussed, information needed for data input is presented in the following section.

The PRESTO II code that includes the new features discussed in this report is available from COSMIC, 112 Barrow Hall, the University of Georgia, Athens, Georgia 30602, telephone (404) 542-3265.

Data Input

All the input data to the program can now be read in through a single namelist, NAME. The original version of PRESTO, described in reference 1, read in some of the input variables associated with special features through a second namelist, NAME2. These variables, as given in reference 1, can still be read in through namelist NAME2 according to the procedure given in reference 1 if desired. The second namelist was retained to make PRESTO II operable in the manner described in reference 1, but the use of this form of input is no longer necessary.

Essential information about the input variables necessary to run the code is given in table I. The input variables listed include those associated with the new features to be described herein. The table includes the input variable names, their definitions and default values, sign conventions, and dimensions.

All but 13 of the input variables are supplied with default values through a BLOCK DATA routine. The 13 variables that have no default values are listed in table II. The user may supply PRESTO II with a different set of input variable default values by providing a new BLOCK DATA routine that includes these default values. This may be especially desirable when conducting parametric analyses of several turbine cycles. The BLOCK DATA routine included with PRESTO II, listed in table III, shows the required COMMON statements.

Those input variables associated with the special features described in section 3 of reference 1 and the new features described in this report are shown schematically in figure 1. This figure indicates where these variables come into play in a typical steam turbine cycle. Reference 1 gives a more extended description of many of the input variables listed in table I.

New PRESTO Features

Automatic Calculation of Valves-Wide-Open Design Flow Performance

The original PRESTO code, as described in reference 1, requires resetting the estimated throttle flow (QT) and the design throttle flow (QTD), and then rerunning a case to get a final performance result at the VWO design flow (sections 4.4.6 and 4.4.44 of ref. 1).

The PRESTO II code can provide the VWO performance in a single run. For this purpose a new input parameter, NDSGN, with a default value of 1 is added to the code. With NDSGN equal to 1 a VWO design point is calculated automatically. This is accomplished by having the design throttle flow reset to the actual throttle flow at every iteration. The generator capability (GC) is also reset at every iteration so that it will be in the proper relation to the electric power generated (WRATE). The automatic VWO design point option may be used with any of the convergence options described herein. If NDSGN is set equal to zero, PRESTO II will operate in the manner described in reference 1.

External Heat Addition Calculation

PRESTO calculates the heat rates given in table IV. For each of the two possible boiler feed pump drives, heat rates are calculated with and without accounting for the power to drive the boiler feed pump. Each heat rate involves a value for the total external heat added to the cycle. The total heat added for a conventional steam cycle can be defined unambiguously as the sum of the heat added at the boiler plus the heat added at the reheater or reheaters. If, however, there are steam (or feedwater) inductions and extractions, what constitutes the total external heat addition is not clear. If a quantity of steam or water is removed from the main flow stream at one point of the cycle and returned at a higher enthalpy at another point of the cycle, the effect is a positive contribution to the external heat added. If, however, the quantity of steam or water is returned to the cycle at a lower enthalpy, the effect is one of heat removal from the cycle. The original version of PRESTO does not distinguish between these two possibilities and treats the latter case as a negative contribution to the heat added to the cycle. In this latter case the heat rates no longer express a clear relation between the thermal energy added to the cycle and the power produced. If a distinction can be made between the two situations described above and only the positive contributions to the external heat addition are included in the heat rate calculations, more meaningful values for the heat rates are obtained. In addition, as is described in the next section, the cycle may be required to absorb a specified amount of heat from an external source or sources. In this situation it also often necessary to distinguish between positive and negative heat additions.

It is therefore desirable to be able to calculate the heat added to the cycle so that it includes only positive contributions. However, it is not possible to uniquely determine the positive contribution to the heat addition given only an arbitrary combination of extractions and inductions. (More information is required to do so—the connections between the extractions and inductions must be specified and no attempt has been made to incorporate such a feature into the program). For this reason the calculation of the external heat addition has been moved to a subroutine, EXTRHT, which can easily be adapted to any particular situation. The subroutine included with PRESTO II (table V) includes, in addition to the original calculation, another heat addition calculation. This additional calculation, described below, is designed for a particular application. Other applications may require the user to add other calculation procedures to the subroutine.

The additional calculation procedure included disregards all steam or water extractions except QFWEXT in determining the heat added to the cycle. The flow QFWEXT has been retained because it can be used for modeling an external heat source in parallel with one or several regenerative feedwater heaters. A quantity of water, say QFWEXT(i) = $-$Q (with enthalpy HFWEXT(i)), may be removed (extracted) from the feedwater stream and then returned to the feedwater stream at a higher enthalpy, HFWEXT(j) = H and QFWEXT(j) = Q. The heat added, Q(H − HFWEXT(i)), involves the water extraction QFWEXT(i). (HFWEXT(i) is calculated by the program; i,j,Q, and H must be specified; see ref. 1). If, however, the flow extracted as QFWEXT(i) is returned to the condenser (j = 13), for example, at an enthalpy lower than HFWEXT(i), the result would be heat removal from the cycle. Then some other calculation procedure must be supplied if only positive contributions to the heat addition are desired. Similar situations may arise with other extractions, and the user must add additional calculation procedures to the subroutine EXTRHT to handle these situations.

The variable NEXTRN, entered through namelist NAME, selects the desired heat addition calculation. A value of zero for NEXTRN selects the original PRESTO calculation that includes both positive and negative contributions to the external heat added. A value of 1 for NEXTRN selects the optional calculation described above. The user may add additional calculation procedures that are selected by other values of NEXTRN. The default value of NEXTRN is zero.

Options to Specify Required Shaft Power or Available External Heat Input

The shaft power required from the cycle or the total external heat available to be added to the cycle can now be specified as inputs. These new options are in addition to the previous options of specifying the required electric power generation or the required steam generator flow as discussed in sections 4.4.43 and 4.4.49 of reference 1. The option to be used is selected by specifying a value greater than zero for the appropriate variable entered through namelist NAME.

Variable	Specified input parameter
QGEN > 0	steam generator flow, specified by QGEN, lb/hr
WRATE > 0	generator output, specified by WRATE, MW
EXTRNL > 0	thermal input to the cycle, specified by EXTRNL, MW
WSHAFT > 0	shaft power, specified by WSHAFT, MW

Only one of the variables QGEN, EXTRNL, or WSHAFT should be different from zero. The default value of all three of these variables is zero. All three must be zero if the required electric power generation is specified by WRATE. Specifying WRATE when one of QGEN, EXTRNL, or WSHFT is greater than zero is optional. In this case the value supplied for WRATE will be used as an initial estimate. A good initial estimate of WRATE can improve the rate of convergence to the final solution.

Extraction or Induction of Steam at the High-Pressure-Turbine Throttle

A specified quantity of steam can now be extracted or inducted at the high-pressure-turbine throttle. In either case the steam is assumed to be at throttle conditions. The amount of steam extracted or inducted is specified in pounds per hour by the new variable QTB. If QTB is greater than zero, the steam is added; if it is less than zero, the steam is removed. The capability of removing steam at this point is useful for modeling cycles that have parallel turbine trains but a common steam generator. The bottoming cycles of magnetohydrodynamic (MHD) power systems are often of this type: Separate sets of steam turbines are used to drive an electrical generator and an oxidizer compressor for the MHD topping cycle. An example of this is given in the next main section.

When steam is added at the throttle, it may be considered to be raised by some external process, or it may be considered to be raised in a parallel steam generator that takes condensate from a common condenser and raises it to throttle conditions. In the latter case the boiler feed pump power required for this additional steam can be included in the cycle calculations by specifying the new parameter NPARA = 1 (default is NPARA = 0; that is, the additional pump power is not included). The same boiler feed pump pressure increase that is specified for the main feedwater stream will be used.

Extraction of Process Steam Along Turbine Expansion Lines

Specified quantities of process steam can be extracted through the turbine shell at any point along the turbine expansion lines (except in the governing stage). The point at which steam is extracted is specified by the extraction pressure. The extraction pressures are given in pounds per square inch absolute by the new input variable PPEXT. Because this variable is of dimension 12, up to 12 such extractions are allowed. The extractions must be given in order of decreasing pressure, beginning with PPEXT(1). The extraction flow at each value of PPEXT is specified by the corresponding value of the new input variable QPEXT (in lb/hr). The extraction enthalpies are calculated by the program.

External Heat Input Between Condenser and Lowest Pressure Regenerative Feedwater Heater

An external heat source can now be added in series between the condenser and the lowest pressure regenerative feedwater heater. This was not possible in the original version of PRESTO. The amount of heat added is specified in Btu per hour by EXTSER (NF + 1), where NF is the total number of regenerative feedwater heaters (fig. 1). This option may only be used if NF ≤ 11.

Applications of PRESTO II

This section illustrates the use of PRESTO II in the analysis of various cycles. Examples are given that illustrate the use of the special features described above and in reference 1. Examples illustrating the use of PRESTO II for parametric analysis are also given.

Example Use of Special Features of PRESTO II Code

The discussion in this section focuses on the use of the special features including the new features introduced in the previous main section and shown in figure 1. Because of the emphasis on the special features, none of the examples in this section except example 3 include leakage calculations. A table that shows the input data and a separate table that shows the overall performance results are given for each example. Additional results calculated by PRESTO II are presented on the heat balance diagram included for each example cycle. Leakage calculations are included in example 3, and a complete output listing is included for this example.

Example 1: Steam bottoming cycle for a gas turbine–steam turbine combined cycle.—This example illustrates the use of PRESTO II to calculate the performance of cycles that include steam extractions and feedwater heating by an external heat source in parallel with regenerative feedwater heaters. Figure 2 shows a gas turbine–steam turbine combined cycle with an integrated coal gasifier. In this example the topping cycle, including the gasifier and fuel gas cleanup system, was defined first. The amount of heat that can be recovered in the heat recovery steam generator (HRSG) and the hot gas cooler was then determined for the selected throttle steam conditions and for a specified HRSG pinch point temperature difference. The throttle steam flow was then determined from this total heat available for the bottoming cycle and from the selected throttle and final feedwater conditions. The PRESTO II code was then run with a value for QGEN equal to this known throttle flow, and the generator electrical output and the other quantities shown in the heat balance diagram (fig. 2(b)) were calculated.

The special features used in this example are those for the two steam extractions and for feedwater heating by an external heat source. Part of the high-pressure-turbine exhaust is extracted and is used in the gasifier. This steam extraction is specified by QPROSS(1) = −50 000 in the input data shown in table VI(a). A part of the intermediate-pressure-turbine exhaust, indicated by QPROSS(2) = −83 000 in the input data, is extracted and used in the fuel gas cleanup process. The heat available from cooling the compressed air between the main and booster air compressors is used for feedwater heating as shown in figure 2. This feedwater heating is specified by QFWEXT(3) for the extraction after feedwater heater 3 and by HECOND(1) and QECOND(1) for the return to the deaerator (DA). The enthalpy HECOND(1) is the enthalpy of saturated water at the deaerator pressure. Enthalpies of the extraction flows are not specified, because the code will use the calculated enthalpy of the steam or water at the extraction points. When steam is added, as in the case of QECOND(1), the enthalpy value, HECOND(1), must be specified. Table VI(b) presents the overall performance results of this example.

Example 2: Gas turbine–steam turbine combined cycle with a dual-pressure heat recovery steam generator (HRSG).—The steam turbine cycle configuration for this example is shown in figure 3(a). Steam is generated at two pressures in the HRSG to recover as much waste heat in the gas turbine exhaust as possible between the exhaust temperature and an acceptable stack temperature limit. For a given topping cycle and the selected bottoming cycle, the cycle parameters shown in the figure are either selected parameters or parameters derived from known values. The steam generated at 865 psia is sent to the high-pressure-steam-turbine section. Steam is also generated at a lower pressure of 147 psia. About 64 percent of the low-pressure steam is inducted at the turbine crossover point to produce additional power in the low-pressure-steam-turbine section. The rest of the low-pressure steam is returned to the deaerator after heating the high-pressure feedwater entering the HRSG. Two boiler feed pumps (BFP) are required to provide the dual pressure.

Input data for the cycle are listed in table VII(a). The feedwater leaving the deaerator for the low-pressure BFP is treated as an extracted feedwater stream between the deaerator and the high-pressure BFP, as shown in figure 3(a), and is specified in the input data by QFWEXT(1) = −230 000 (table VII(a)). The part of the low-pressure steam that is inducted at the crossover point to generate more power is specified by QPROSS(1). The rest of the low-pressure steam is returned to the deaerator after heating the high-pressure feedwater. This return to the deaerator is given by QECOND(1) and HECOND(1), as shown in table VII(a).

Running the PRESTO II code with these inputs results in the heat balance shown in figure 3(b). Overall performance results are presented in table VII(b). The "POWER REQUIRED BY MOTOR-DRIVEN FW PUMP" in the table represents the power required by the high-pressure BFP only, because PRESTO only calculates the BFP power for the throttle steam. The user may easily include the additional BFP power by manually calculating the power from an assumed pump and motor efficiency. The net cycle heat rate and efficiency are then corrected by using this calculated power value. None of the other results produced by PRESTO are affected by this correction. In this particular example, the results indicate that the low-pressure BFP power does not have much of an impact on the net cycle heat rate.

Example 3: Bottoming cycle for magnetohydrodynamic (MHD) system.—Figure 4(a) shows an example of an MHD-steam turbine combined cycle. In the MHD topping cycle, power is generated by passing a conducting gas through a magnetic field in the MHD generator. The heat remaining in the gas after it leaves the MHD generator as well as the heat from cooling the combustor and generator is recovered for use in a steam bottoming cycle. The bottoming cycle has two parallel turbine trains: one driving an electrical generator, and the other driving an air compressor. The bottoming cycle is required to use as the total heat input a specified amount of heat available from the topping cycle (1433.83 MW in this example) and at the same time to supply a specified amount of power to the air compressor (115.1 MW in this example).

To calculate this cycle, PRESTO II is run twice. First, the compressor-turbine cycle is run with the required shaft power specified, WSHFT = 115.1. This run is for the portion of the bottoming cycle within the dashed lines in figure 4(a). The input for this run is given in table VIII(a). The throttle flow calculated from this run is then used as input for the turbine-generator run. The input for this second run is given in table VIII(b). The steam required to drive the compressor turbine is extracted before the throttle of the high-pressure turbine by setting QTB = −767 027(lb/hr). The total heat input to the cycle is specified by setting EXTRNL = 1433.83 (MW). A portion of this heat (104.83 MW) is added between regenerative feedwater heaters 6 and 7 by setting EXTSER(7) = 357 694 640 (Btu/hr). An amount of steam (15 000 lb/hr) is extracted from the feedwater heater 5 extraction line for use in a separate process required by the MHD-steam turbine plant by setting QEXT(5) = −15 000. So that only the heat added to the bottoming cycle through heat exchange with the topping cycle will contribute toward the required amount of 1433.83 MW, NEXTRN must be set equal to 1. The heat associated with steam extractions QTB and QEXT(5) will then be disregarded in calculating the heat added to the cycle.

The complete output for the two runs of this example is given in tables VIII(c) and (d). Leakage flows have been included in this example. The overall bottoming-cycle heat rate can be calculated from the output of the two runs, as shown on the overall bottoming-cycle heat balance in figure 4(b).

Parametric Analysis by PRESTO II

In this section examples are given to illustrate the use of PRESTO II for cycle parametric analysis. As the input data for each example show, PRESTO II allows parameter variations to be easily made. All constant parameters need to be specified only once in a given computer run. Thereafter only the variable parameters need to be specified as they change their values. Cycle schematics and input data are given for each example. Performance results are presented in the form of curves of net cycle efficiency as a function of the variable parameter.

Example A: Steam extraction rate as a variable parameter.—The cycle configuration and major parameters for this example are shown in figures 5(a) and (b). Steam is extracted from the high-pressure-turbine exhaust at the rate of 0, 20, 40, and 60 percent of the throttle flow. Two high-pressure turbine exhaust pressures, 64.7 and 250 psia, are considered. The input data used in a computer run of this problem are listed in table IX. The effects of the steam extraction rate and pressure on the net cycle efficiency are shown in figure 5(c). No credit is given to the cycle efficiency for the extracted steam by setting NEXTRN = 1 as discussed previously in the section External Heat Addition Calculation.

Example B: Heat rate definition selection parameter and steam extraction rate as variable parameters.—The steam turbine cycle used for this example is identical to the one used in the previous example and shown in figure 5(a). The input data for this example are also identical to the data in table IX, except that this example does not consider the 250-psia extraction. The 64.7-psia-extraction cases were run twice, once with NEXTRN equal to zero and once with NEXTRN equal to one. This illustrates the effect on the calculated cycle heat rate, discussed in the section External Heat Addition Calculation, of the manner in which steam extractions are included in the heat rate calculation. Cycle performance results are plotted in figure 6.

Example C: Throttle temperature and pressure as variable parameters.—In this example, the throttle temperature is varied between 850° and 1050° F for three different throttle pressures (1264.7, 1464.7, and 1814.7 psia). The cycle schematic with major parameters indicated is shown in figure 7(a). Input data for a single computer run are listed in table X. Effects of the throttle conditions on cycle performance are shown in figure 7(b).

Example D: Condenser pressure as a variable parameter.—In this example, the condenser pressure is varied for three combinations of throttle pressure and temperature. The cycle schematic is identical to the one given in figure 7(a). Input data are given in table XI. Three performance curves for the three throttle conditions are shown in figure 7(c).

Concluding Remarks

The original PRESTO computer code as described in the users manual includes special features to extend its capability beyond the analysis of conventional steam turbine cycles. With these special features PRESTO has the capability to calculate the performance of the bottoming steam cycles of advanced high-temperature topping cycles and of steam turbine cycles integrated with advanced heat sources such as a coal gasifier. Some special features in addition to those originally included have been added to PRESTO, and these have been described in this report. The additional special features provide the user with added convenience or further extend the analysis capability of the code. The version of PRESTO incorporating the new features is called PRESTO II to distinguish it from the original PRESTO code. The examples included in the report have illustrated the application of PRESTO II to various cycles. In particular the examples have illustrated the use of the special features that allow PRESTO II to model a wide variety of power cycles. The examples have shown that PRESTO II is easy to use in studying either stand-alone steam turbine cycles or steam turbine cycles used as an integral part of more advanced energy conversion systems. Even though PRESTO II is not a general-purpose computer code of the building-block type, it is nevertheless very flexible in its application and requires substantially less effort to run than does a code of the building-block type. In its present form the PRESTO code can conveniently perform a valves-wide-open design flow calculation for a wide variety of cycle configurations.

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Cleveland, Ohio, June 29, 1981

References

1. Fuller, L. C.; and Stovall, T. K.: User's Manual for PRESTO—A Computer Code for the Performance of Regenerative Superheated Steam-Turbine Cycles. (ORNL-5547, Oak Ridge National Lab.; NASA Order C-10669-D.) NASA CR-159540, 1979.
2. Cannon, C. N.; Cotton, K. C.; and Spencer, R. C.: A Method for Predicting the Performance of Steam Turbine-Generators, 16,500 kW and Larger. GER-2007C, General Electric Company, Revised July 1974. (See also ASME Paper 62-WA-209, Nov. 1962.)
3. Bartlett, R. L.: Steam Turbine Performance and Economics. McGraw-Hill Book Co. Inc., 1958.

TABLE I.—INPUT VARIABLE NAMES, DIMENSIONS, DEFAULT VALUES, AND DEFINITIONS

Variable name	Dimension	Default value	Definition
BLS		30.1	Length of last-stage blades in low-pressure-turbine section, in.
CP1		171.7	Pressure at feedwater pump inlet, psia
CP2		1.30	Ratio of feedwater pump discharge pressure to high-pressure-turbine throttle pressure
EFM		0.90	Feedwater pump motor-drive efficiency
EFP		0.84	Feedwater pump isentropic efficiency
EFT		0.81	Feedwater pump turbine efficiency
EXTPAR(i)	12	12*0.0	External heat supplied in parallel with feedwater heater i, Btu/hr. Positive value means heat addition; negative value means heat removal.
EXTRNL[a]		0.0	Heat required to be absorbed by cycle, MW. Only one of the variables EXTRNL, QGEN, and WSHFT may be different from zero.
EXTSER(i)	12	12*0.0	External heat supplied downstream of heater i, Btu/hr. EXTSER(i) acts between feedwater heaters $i-1$ and i. EXTSER(1) acts between FW heater 1 and the steam generator. Same sign convention as in EXTPAR.
GC		None	Generator capability, MVA
GC2		0.0	Second-shaft generator capability, MVA
HECOND(i)	13	13*0.0	Enthalpy of external flow to i^{th} feedwater heater shell, Btu/lb; $i=1$ to 12 are for FW heaters and $i=13$ is for the condenser. If flow is being removed from the shell (negative QECOND(i)), the code will automatically set the enthalpy equal to the shell drain enthalpy. The user must specify a value of HECOND(i) if flow is added to the shell.
HEXT(i)	12	12*0.0	Enthalpy of steam added to i^{th} feedwater heater extraction steam line, Btu/lb. If steam is removed (negative QEXT(i)), HEXT(i) will automatically be set equal to the extraction steam enthalpy. If steam is added, the user must specify a value for HEXT(i).
HFWEXT(i)	12	12*0.0	Enthalpy (Btu/lb) of water added to feedwater stream by using variable QFWEXT(i). If water is removed (negative QFWEXT(i)), HFWEXT(i) will automatically be set equal to the enthalpy of the water removed. If water is added, the user must specify a value for HFWEXT(i).
HPROSS(i)		2*0.0	Enthalpy of steam inducted at turbine exhaust, Btu/lb; $i=1$ for high-pressure-turbine exhaust; $i=2$ for intermediate-pressure turbine exhaust.
ICC		0	Generator cooling method: =0, conductor cooled =1, conventionally cooled
IFPT		1	Feedwater pump drive: =0, motor driven =1, turbine driven
IMETER		0	Output format choice: =0, U.S. customary units =1, SI units
INAME2		0	Flag to read second namelist: =0, NAME2 is not read =1, NAME2 is read

[a]Variables associated with the new features described in this report.

TABLE I.—Continued.

Variable name	Dimension	Default value	Definition
IP		2	Feedwater pump location indicator: =0, after feedwater heater 1 =N, before feedwater heater N
IPEAK		0	Flag for peaking unit: =0, normal operation =1, peaking unit
IPLACE		2	Feedwater pump turbine extraction position: =1, before intermediate-pressure-turbine bowl =2, before low-pressure-turbine bowl
IRHP		3600	Rotational speed of high-pressure turbine, rpm
IRIP		3600	Rotational speed of intermediate-pressure turbine, rpm
IRLP		3600	Rotational speed of low-pressure turbine, rpm
LK		1	Flag for leakage calculation: =0, leakages will not be calculated =1, leakages will be calculated
NCASE		0	Turbine casing flag: =0, no shared casings =1, casings shared for high- and intermediate-pressure turbines =2, casings shared for high- and low-pressure turbines =3, casings shared for intermediate- and low-pressure turbines
ND(i)	12	12*0.0	Feedwater heater drain types: =0, flashed drain =1, pumped drain
NDC(i)	12	12*0.0	Flag for drain cooler: =0, no drain cooler section on feedwater heater =1, drain cooler section
NDSGN[a]		1	Specifies design point calculation: =0, calculation as per reference 1 =1, automatic valves-wide-open design point calculation
NEXTRN[a]		0	Selects cycle heat input definition to be used: =0, definition as per reference 1 =1, option definition discussed in text
NF		None	Total number of feedwater heaters
NFH		None	Number of feedwater heaters receiving extraction steam from high-pressure-turbine section
NFI		None	Number of feedwater heaters receiving extraction steam from intermediate-pressure-turbine section
NFL		None	Number of feedwater heaters receiving extraction steam from low-pressure-turbine section
NHP		1	Number of parallel high-pressure-turbine sections
NIP		1	Number of parallel intermediate-pressure-turbine sections
NLP		4	Number of parallel low-pressure-turbine sections

[a]Variables associated with the new features described in this report.

TABLE I.—Continued.

Variable name	Dimension	Default value	Definition
NLP2		0	Number of parallel low-pressure-turbine sections on second shaft of a cross-compound configuration
NOSPE		1	Flag for steam packing exhauster: =0, no steam packing exhaust =1, steam packing exhauster included
NPARA[a]		0	Flag for second boiler feed pump (applicable only if QTB>0): =0, boiler feed pump power for the stream QTB not included =1, boiler feed pump power for the stream QTB included
NRGS		1	Number of governing stage blade rows
NRH		1	Number of external reheat stages
NSHAFT		3	Number of turbine sections in series (1,2, or 3)
PBIP		633	Bowl pressure at intermediate-pressure-turbine section, psia
PBLP		177	Bowl pressure at low-pressure-turbine section, psia
PCMU		0	Feedwater makeup rate, percent
PDGS		40	Pitch diameter of governing stage, in.
PDLS		85	Pitch diameter of last stage of low-pressure-turbine section, in.
PE(i)	12	None	Extraction stage pressures (psia) for i^{th} feedwater heater
PF		0.90	Generator power factor
PT		None	Throttle steam pressure, psia
PPEXT(i)[a]	12	12*0.0	Extraction pressure of process steam extracted along turbine expansion line, psia
PXDROP(i)	2	3.,6.	Feedwater heater extraction line pressure drop, percent; i=1 is for pressure drop from turbine exhaust to feedwater heater; i=2 is for pressure drop from turbine shell opening to heater
PXLP		Dummy	Main condenser pressure, psia
PXLPI		Dummy	Main condenser pressure, in. Hg abs. A value should be specified for only one of PXLP and PXLPI
QAE		0	Steam flow to steam-jet air ejector
QCR		0	Condensate flow bypassed to steam generator
QECOND(i)	13	13*0.0	Steam or condensate return to i^{th} feedwater heater shell, lb/hr. If QECOND(i) is negative, flow is removed; if it is positive, flow is added. i=13 is for condenser. The code automatically balances mass flow by adjusting QECOND(13), when input data do not provide a mass balance.
QEXT(i)	12	12*0.0	Steam added to or removed from i^{th} feedwater heater extraction line, lb/hr. QEXT(i) is positive if steam is added to the line and negative if steam is removed from the line.
QFWEXT(i)	12	12*0.0	External feedwater flow added to (positive) or removed from (negative) main feedwater stream, lb/hr. QFWEXT(i) acts between FW heaters i−1 and i.

[a]Variables associated with the new features described in this report.

TABLE I.—Concluded.

Variable name	Dimension	Default value	Definition
QGEN		0.0	Specified steam generator outlet flow, lb/hr. Only one of the variables QGEN, EXTRNL, and WSHFT may be different from zero.
QPEXT	12	0	Extraction flow for i^{th} process steam extraction at extraction pressure PPEXT(i), lb/hr
QPROSS(i)	2	2•0.0	Steam flow extracted from or inducted at turbine exhaust; $i=1$ applies at high-pressure-turbine exhaust; $i=2$ applies at intermediate-pressure-turbine exhaust. A negative value represents an extraction flow; its enthalpy is set equal to the turbine exhaust enthalpy by the code. A positive value means that steam is inducted; and its enthalpy must be specified by the user with the variable HPROSS.
QT		None	Estimated throttle steam flow, lb/hr
QTB[a]		0.0	Steam flow added (positive) or removed (negative) before high-pressure-turbine inlet at throttle steam conditions, lb/hr
QTD		None	Design throttle steam flow, lb/hr
TDCA(i)	12	12•0.0	Drain cooler approach temperature difference of i^{th} feedwater heater, °F
TRH1		1000	Exit temperature of first-stage reheater, °F
TRH2		0.0	Exit temperature of second-stage reheater, °F
TT		None	Throttle steam temperature, °F
TTD(i)	12	12•0.0	Terminal temperature difference of i^{th} feedwater heater, °F
WRATE		None	Electrical output required or estimated, MW
WRATE2		0.0	Electrical output from second shaft of a cross-compound configuration, MW
WSHFT[a]		0.0	Shaft power required, MW. Only one of the variables WSHFT, QGEN, and EXTRNL may be different from zero.

[a]Variables associated with the new features described in this report.

TABLE II.—INPUT VARIABLES WITH

NO DEFAULT VALUES

Variable name	Definition
GC	Generator capability, MVA
NF	Total number of feedwater heaters
NFH	Number of extractions from high-pressure turbine
NFI	Number of extractions from intermediate-pressure turbine
NFL	Number of extractions from low-pressure turbine
PE	Extraction stage pressure, psia
PT	Throttle steam pressure, psia
PXLP[a]	Condenser pressure, psia
PXLPI[a]	Condenser pressure, in. Hg abs.
QT	Estimated throttle steam flow, lb/hr
QTD	Design throttle steam flow, lb/hr
TT	Throttle steam temperature, °F
WRATE	Electrical output required or estimated, MW

[a]A value must be specified for only one of the variables PXLP or PXLPI.

TABLE III.—BLOCK DATA ROUTINE CONTAINING DEFAULT VALUES OF INPUT VARIABLES

```
      BLOCK DATA
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /BLCK/ DUMMY
      COMMON/COMPND/WRATE1,WRATE2,GC1,GC2,WGEN1,WGEN2
     *,WML1,WML2,WGL1,WGL2
     *,NLP2
      COMMON/CONST/PI,XJOULE,GRAV,CPSI,ZERO,X100,IR,IW
      COMMON /CONV/ HCON, WCON, SSRCON
      COMMON/DATA/PCMU,PDLS,BLS, QTD, PDGS, PF,VERS,NHP,IRHP,
     * NIP,IRIP,NLP,IRLP,      NFH,NFI,NFL,ICC,      NRGS,NOSPE
     *,IPEAK,IPLACE
      COMMON/DATBLK/QGEN,IMETER
      COMMON /EXTHT/ EXTPAR(12), EXTSER(12),QPROSS(2),HPROSS(2),
     * QEXT(12), HEXT(12), QECOND(13),QFWEXT(12),HFWEXT(12), HECOND(13),
     * INAME2
      COMMON /FEED/ EFP, EFM, EFT, CP1, CP2
      COMMON /FPT/QFPT,PBFPT,HBFPT,PXFPT,HXFPT,IFPT
      COMMON /FWH/HAEI,HAEO,QR,
     * QEF(12), HEF(12),
     *                QD(12),QF(12),QE(12),QCR,HCR,QRO,QC,I1LP,I
      COMMON/HEAT/PE(12),HE(12)
      COMMON /IP2/ PBIP
      COMMON /LEAK/QLK(21),HLK(21),QSPE,QMC,QSSR,HSSR,PSSR,QFWH,QSSRMU,
     *HSSRMU,QSSRM1,NOLK(21),NOHEAT(3),LK,NCOL,NCASE
      COMMON /LP/QBLP,PBLP,TBLP,AMBLP,HBLP,SBLP,QXLP,PXLP,TXLP,AMXLP,
     *PXLPIO,
     1HXLP,SXLP,UEEPLP,PXLPI
      COMMON /MIS/CMTS(18),       TC,TFP,TR,HR,WRATE,GC,WML,WGL,QMU,QFP,
     1DP,WGEN,WFWP,HTRTN,HTRTG,CEFFN,CEFFG,PXDROP(2)
      COMMON /PAR1/HO(12),HI(12),QAE,HC,HFP,DHP,TI(12),TD(12),TDCA(12),
     * TTD(12),
     1HD(12),PLA,PLB,ND(12),NDC(12),IP,NF,NSHAFT
      COMMON/RH1/TRH1,TRH2,NRH
      COMMON /T/QT,PT,TT,AMT,HT
      COMMON /ADDOP/QTB,EXTRNL,EXTRN,EXTHTT,WSHFT,NDSGN,NCON,NEXTRN
     * ,NPARA
      COMMON /PROSS/PPEXT(12),HPEXT(12),QPEXT(12),NPE,NPEH,NPEI,NPEL
C
C   LERC REVISED BLOCK DATA,  7/31/80
C
      DATA     IP      /2/
      DATA     IR      /5/
      DATA     IW      /6/
      DATA     LK      /1/
      DATA     ND      /12*0/
      DATA     PF      /.9D0/
      DATA     PI      /3.141592654D0/
      DATA     AMT     /0.D0/
      DATA     BLS     /30.D0/
      DATA     CP1     /171.7D0/
      DATA     CP2     /1.3D0/
      DATA     EFM     /.90D0/
      DATA     EFP     /.84D0/
      DATA     EFT     /.81D0/
      DATA     GC2     /0.0D0/
      DATA     ICC     /0/
      DATA     NDC     /12*0/
      DATA     NHP     /1/
      DATA     NIP     /1/
      DATA     NLP     /4/
      DATA     NRH     /1/
      DATA     QAE     /0.0D0/
      DATA     QCR     /0.0D0/
      DATA     TTD     /12*0.0D0/
      DATA     CPSI    /2.03602234D0/
      DATA     GRAV    /32.1740486D0/
      DATA     HCON    /1.D-1/
      DATA     HEXT    /12*0.D0/
      DATA     IFPT    /1/
      DATA     IRHP    /3600/
      DATA     IRIP    /3600/
      DATA     IRLP    /3600/
      DATA     NLP2    /0/
      DATA     NRGS    /1/
      DATA     PBIP    /633.D0/
      DATA     PBLP    /177.D0/
      DATA     PCMU    /0.0D0/
      DATA     PDGS    /40.D0/
      DATA     PDLS    /85.D0/
      DATA     PXLP    /-5.D0/
      DATA     QGEN    /0.0D0/
      DATA     QEXT    /12*0.D0/
      DATA     TDCA    /12*0.0D0/
      DATA     TRH1    /1000.D0/
      DATA     TRH2    /0.D0/
      DATA     VERS    /' 7/31/80'/
      DATA     WCON    /1.D-6/
      DATA     X100    /100.D0/
      DATA     ZERO    /0.0D0/
      DATA     DUMMY   /0.0D0/
      DATA     IPEAK   /0/
      DATA     NCASE   /0/
      DATA     NOSPE   /1/
      DATA     PXLPI   /-5.D0/
      DATA     EXTPAR /12*0.D0/
      DATA     EXTSER /12*0.D0/
      DATA     HECOND /13*0.D0/
      DATA     HFWEXT /12*0.D0/
      DATA     HPROSS /2*0.D0/
      DATA     IMETER /0/
      DATA     INAME2 /0/
      DATA     IPLACE /2/
      DATA     NSHAFT /3/
      DATA     PXDROP /3.D0,6.D0/
      DATA     PXLPIO /-5.D0/
      DATA     QECOND /13*0.D0/
      DATA     QFWEXT /12*0.D0/
      DATA     QPROSS /2*0.D0/
      DATA     SSRCON /1.D-1/
      DATA     WRATE2 /0.0D0/
      DATA     XJOULE /778.169262D0/
      DATA     QTB     /0.0D0/
      DATA     NCON    /1/
      DATA     NDSGN   /1/
      DATA     EXTRNL /0.0D0/
      DATA     WSHFT   /0.0D0/
      DATA     NEXTRN /0/
      DATA     NPARA   /0/
      DATA     QPEXT   /12*0.0D0/
      DATA     HPEXT   /12*0.0D0/
      DATA     PPEXT   /12*0.0D0/
      END
```

TABLE IV.—HEAT RATE DEFINITIONS

Heat rate	Motor-driven boiler feed pump	Turbine-driven boiler feed pump
Gross	Heat added to cycle divided by generator electrical output	Heat added to cycle divided by sum of generator electrical output and boiler feed pump power
Net	Heat added to cycle divided by difference between generator electrical output and boiler feed pump power	Heat added to cycle divided by generator electrical output

TABLE V.—SUBROUTINE FOR HEAT INPUT CALCULATION

```
      SUBROUTINE EXTRHT
C
C    SUBROUTINE TO CALCULATE EXTERNAL HEAT INPUT OTHER THAN
C      STEAM GENERATOR AND REHEATERS
C
C    EXTERN    EXTERNAL HEAT ADDED TO CYCLE
C    NEXTRN    = 0, ORNL EXTERNAL HEAT INPUT CALCULATION
C              = 1, USER OPTION 1 FOR EXTERNAL HEAT INPUT
C
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /EXTHT/ EXTPAR(12), EXTSER(12),QPROSS(2),HPROSS(2),
     * QEXT(12), HEXT(12), QECOND(13),QFWEXT(12),HFWEXT(12), HECOND(13),
     * INAME2
      COMMON /PAR1/HO(12),HI(12),QAE,HC,HFP,DHP,TI(12),TD(12),TDCA(12),
     * TTD(12),
     1HD(12),PLA,PLB,ND(12),NDC(12),IP,NF,NSHAFT
      COMMON/RH2/PXRH1,PIRH1,PFPT,TXRH1,HXRH1,HIRH1,QRH
     * ,PXRH2,PIRH2,HXRH2,HIRH2,QRH2,TXRH2,WSHAF1,WSHAF2,WSHAFT,CONREJ,
     *EXTERN
      COMMON /T/QT,PT,TT,AMT,HT
      COMMON /ADDOP/QTB,EXTRNL,EXTRN,EXTHTT,WSHFT,NDSGN,NCON,NEXTRN
     * ,NPARA
C
      IF(NEXTRN.EQ.1) GO TO 100
C
      EXTERN=0.0D0
      DO 50 L=1,12
   50 EXTERN=EXTERN+EXTPAR(L)+EXTSER(L)+QEXT(L)*HEXT(L)+
     *QECOND(L)*HECOND(L)+QFWEXT(L)*HFWEXT(L)
      EXTERN=EXTERN+QECOND(13)*HECOND(13)+QPROSS(1)*HPROSS(1)+QPROSS(2)*
     *HPROSS(2) + QTB*HT
      GO TO 1001
C
  100 EXTERN=0.0D0
      DO 8 L=1,12
      IF(EXTPAR(L).GT.0.0D0) EXTERN = EXTERN+EXTPAR(L)
      IF(EXTSER(L).GT.0.0D0) EXTERN = EXTERN+EXTSER(L)
      EXTERN = EXTERN+QFWEXT(L)*(HFWEXT(L)-HC)
      IF(QECOND(L).GT.0.0D0) EXTERN=EXTERN+QECOND(L)*(HECOND(L)-HC)
    8 CONTINUE
      IF(QPROSS(2).GT.0.0D0) EXTERN=EXTERN+QPROSS(2)*(HPROSS(2)-HC)
      IF(QPROSS(1).GT.0.0D0) EXTERN=EXTERN+QPROSS(1)*(HPROSS(1)-HC)
      IF(QTB.GT.0.0D0) EXTERN=EXTERN+QTB*(HT-HECOND(13))
C
 1001 RETURN
      END
```

TABLE VI.—INPUT DATA AND RESULTS FOR EXAMPLE 1

(a) Input data

```
GASIFIER COMBINED CYCLE(EXAMPLE OF EXTRACTION & PARALLEL FW HEATING)
 &NAME
  BLS=14.3,
  CP1=25.,
  CP2=1.25,
  GC=85.,
  ICC=1,
  IFPT=0,
  IP=0,
  LK=0,
  NCASE=1,
  ND=1, 11*0,
  NDC=0, 2*1, 9*0,
  NF=3,
  NFH=0,
  NFI=0,
  NFL=3,
  NLP=2,
  NOSPE=0,
  PBIP=310.,
  PBLP=100.,
  PDGS=38.,
  PDLS=52.4,
  PE=26.6, 11.5, 6.4, 9*0.0,
  PT=1464.7,
  PXLPI=2.5,
  QGEN=507000.,
  QT=507000.,
  QTD=507000.,
  TDCA=0.0, 2*10., 9*0.0,
  TTD=0.0, 2*5.0, 9*0.0,
  TT=1000.,
  WRATE=72.,
  QPROSS(2)=-83000.,
  QPROSS(1)=-50000.,
  HECOND(1)=208.5,
  QECOND(1)=163000.,
  QFWEXT(3)=-163000.,
  NEXTRN=1,
 &END
```

(b) Summary of performance results

```
GASIFIER COMBINED CYCLE(EXAMPLE OF EXTRACTION & PARALLEL FW HEATING)
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE  1



TABLE I  OVERALL PERFORMANCE

NET TURBINE CYCLE HEAT RATE, BTU/KW-HR            10361.
NET TURBINE CYCLE EFFICIENCY, PER CENT               32.93

GROSS TURBINE CYCLE HEAT RATE, BTU/KW-HR          10203.
GROSS TURBINE CYCLE EFFICIENCY, PER CENT             33.44

GENERATOR OUTPUT, MWE                                 72.935
SHAFT WORK, MW                                        74.349

THERMAL INPUT TO CYCLE, MW                           218.084

POWER REQUIRED BY MOTOR-DRIVEN FW PUMP, MW             1.112
GENERATOR OUTPUT MINUS FW PUMP POWER, MWE             71.823

MECHANICAL LOSSES, KW                               471.
GENERATOR LOSSES, KW                                943.


THIS IS A DESIGN POINT PERFORMANCE CALCULATION FOR
     SPECIFIED STEAM GENERATOR FLOW RATE
```

TABLE VII.—INPUT DATA AND RESULTS FOR EXAMPLE 2

(a) Input data

```
STEAM INDUCTION/DUAL PRESSURE HRSG
 &NAME
  BLS=26.,
  CP1=20.8,
  CP2=1.2,
  GC=126.,
  ICC=1,
  IFPT=0,
  IP=0,
  LK=0,
  ND=1, 11*0,
  NDC=12*0,
  NF=2,
  NFH=0,
  NFI=0,
  NFL=2,
  NHP=1,
  NIP=0,
  NLP=2,
  NOSPE=0,
  NRH=0,
  NCASE=0,
  NSHAFT=2,
  PBLP=147.,
  PDGS=38.,
  PDLS=72.,
  PE=22.1, 6.2, 10*0.0,
  PT=865.,
  PXLPI=2.5,
  QGEN=770000.,
  QT=770000.,
  QTD=770000.,
  TDCA=12*0.0,
  TT=825.,
  TTD=0.0, 5.0, 10*0.0,
  WRATE=104.,
  HECOND(1)=329.,
  QECOND(1)=83200.,
  QFWEXT(1)=-230000.,
  HPROSS(1)=1245.6,
  QPROSS(1)=146800.,
  NEXTRN=1,
 &END
```

(b) Summary of performance results

STEAM INDUCTION/DUAL PRESSURE HRSG
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 1

TABLE I OVERALL PERFORMANCE	PRESTO results with high-pressure boiler feed pump power only	PRESTO results with low-pressure boiler feed pump power	Modified PRESTO results with both high- and low-pressure boiler feed pumps
NET TURBINE CYCLE HEAT RATE, BTU/KW-HR	10402.		[b]10406.
NET TURBINE CYCLE EFFICIENCY, PER CENT	32.80		32.80
GROSS TURBINE CYCLE HEAT RATE, BTU/KW-HR	10309.		No change
GROSS TURBINE CYCLE EFFICIENCY, PER CENT	33.10		
GENERATOR OUTPUT, MWE	106.234		
SHAFT WORK, MW	107.985		
THERMAL INPUT TO CYCLE, MW	320.973		
POWER REQUIRED BY MOTOR-DRIVEN FW PUMP, MW	0.947	[a]+0.045*	0.992
GENERATOR OUTPUT MINUS FW PUMP POWER, MWE	105.288	-0.045	105.243
MECHANICAL LOSSES, KW	442.		No change
GENERATOR LOSSES, KW	1308.		

THIS IS A DESIGN POINT PERFORMANCE CALCULATION FOR
SPECIFIED STEAM GENERATOR FLOW RATE

[a]Based on 20-percent pressure loss, 84-percent pump efficiency, and 90-percent motor efficiency.

[b]Based on the data in fig. 3(b) and low- and high-pressure pump power:

$$\frac{770\,000\,(1410.7 - 202.1) + 83\,200\,(329 - 198.3) + 146\,800\,(1245 - 198.5)}{106.234 - (0.947 + 0.045)} = 10\,406$$

TABLE VIII.—INPUT DATA AND OUTPUT FOR EXAMPLE 3

(a) Compressor-turbine cycle input data

```
MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
 &NAME
  BLS = 33.5,
  CP1 = 2.0,
  CP2 = 1.25,
  ICC = 1,
  IFPT = 0,
  IP = 0,
  NCASE = 2,
  NEXTRN = 1,
  NF = 0,
  NFH = 0,
  NFI = 0,
  NFL = 0,
  NHP = 1,
  NIP = 0,
  NLP = 1,
  NOSPE = 0,
  NRH = 0,
  NSHAFT = 2,
  PBIP = 0.0,
  PBLP = 176.,
  PDLS = 90.5,
  PE = 12*0.0,
  PT = 2414.7,
  PXLPI = 2.0,
  QT = 750000.,
  QTD = 750000.,
  TT = 1004.7,
  WRATE = 113.0,
  WSHFT = 115.1,
 &END
```

(b) Generator-turbine cycle input data

```
MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
 &NAME
  BLS = 30.,
  CP1 = 167.2,
  CP2 = 1.25,
  EXTSER = 6*0.0, 357.69464D6, 5*0.0,
  EXTRNL = 1433.83,
  IP = 4,
  NCASE =0,
  ND = 4*0, 1, 0, 1, 5*0,
  NDC = 4*1, 0, 1, 6*0,
  NEXTRN = 1,
  NF = 7,
  NFH = 3,
  NFI = 2,
  NFL = 2,
  NHP = 1,
  NIP = 1,
  NLP = 4,
  NOSPE = 0,
  NSHAFT = 3,
  PBIP = 459.0,
  PBLP = 176.0,
  PDLS = 85.0,
  PE = 1414., 940., 0.0, 378., 0.0, 89., 4.15, 5*0.0,
  PT = 2414.7,
  PXLPI = 2.0,
  QEXT = 4*0.0, -15000.0, 7*0.0,
  QT = 3683000.0,
  QTD = 3683000.0,
  QTB = -767027.,
  TDCA = 4*10.0, 0.0, 10.0, 6*0.0,
  TT = 1004.7,
  TTD = 2*0.0, 2*5.0, 0.0, 5.0, 4.0, 5*0.0,
  WRATE = 496.522,
 &END
```

TABLE VIII.—Continued.

(c) Compressor-turbine cycle output

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

INPUT DATA

THROTTLE STEAM TEMPERATURE	1004.7	F		
THROTTLE STEAM PRESSURE	2414.7	PSIA		
ESTIMATED THROTTLE STEAM FLOW	750000.	LB/HR		
ESTIMATED DESIGN THROTTLE FLOW	750000.	LB/HR		
FW MAKE-UP RATE (TO CONDENSER HOTWELL)	0.0	PER CENT		
CONDENSATE BY-PASSED TO STEAM GENERATOR	0.	LB/HR		
ESTIMATED GENERATOR RATED CAPABILITY	125.556	MVA		
GENERATOR POWER FACTOR	0.90			
TOTAL ESTIMATED ELECTRICAL OUTPUT	113.000	MWE		
REQUIRED SHAFT POWER	115.100	MW		
CONVENTIONALLY-COOLED GENERATOR, ICC= 1				
ROTATIONAL SPEED OF TURBINE-GENERATOR	3600	RPM		
1-ROW GOVERNING STAGE				
PITCH DIAMETER OF GOVERNING STAGE	40.00	IN.		
NO. OF TURBINE SECTIONS IN SERIES	2			
NUMBER OF PARALLEL HP SECTIONS	1			
NUMBER OF PARALLEL LP SECTIONS	1			
BOWL PRESSURE LP SECTION	176.0	PSIA		
EXHAUST PRESSURE LP SECTION	0.98231	PSIA	=	2.00 IN. HGA
PITCH DIAMETER OF LAST STAGE LP SECTION	90.50	IN.		
LENGTH OF LAST STAGE BUCKETS LP SECTION	33.50	IN.		
FEEDWATER PUMP ISENTROPIC EFFICIENCY	0.8400			
FEEDWATER PUMP DRIVE MOTOR EFFICIENCY	0.9000			
PRESSURE AT FWP INLET	2.00	PSIA		
RATIO OF FWP DISCHARGE PRESSURE TO HP THROTTLE PRESSURE	1.25			
FW PUMP IS MOTOR DRIVEN, IFPT= 0				
NUMBER OF STAGES OF REHEAT	0			
TOTAL NO. OF FW HEATERS	0			
NO. OF FW HEATERS HP SECTION	0			
NO. OF FW HEATERS LP SECTION	0			
EXTRACTION LINE PRESSURE DROP AT TURBINE EXHAUST	3.0	PER CENT		
EXTRACTION LINE PRESSURE DROP ALL OTHERS	6.0	PER CENT		

THERE IS NO STEAM JET AIR EJECTOR, QAE = 0.

VALVE STEM AND PACKING LEAKAGES WILL BE CALCULATED, LK= 1

THERE IS NO STEAM PACKING EXHAUSTER, NOSPE= 0

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 1

TABLE I OVERALL PERFORMANCE

NET TURBINE CYCLE HEAT RATE, BTU/KW-HR	9599.
NET TURBINE CYCLE EFFICIENCY, PER CENT	35.55
GROSS TURBINE CYCLE HEAT RATE, BTU/KW-HR	9371.
GROSS TURBINE CYCLE EFFICIENCY, PER CENT	36.41
GENERATOR OUTPUT, MWE	113.252
SHAFT WORK, MW	115.100
THERMAL INPUT TO CYCLE, MW	311.026
POWER REQUIRED BY MOTOR-DRIVEN FW PUMP, MW	2.694
GENERATOR OUTPUT MINUS FW PUMP POWER, MWE	110.558
MECHANICAL LOSSES, KW	464.
GENERATOR LOSSES, KW	1384.

THIS IS A DESIGN POINT PERFORMANCE CALCULATION FOR
SPECIFIED SHAFT POWER OUTPUT

TABLE VIII.—Continued.

(c) Continued

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 2

TABLE II TURBINE EXPANSION LINE

	STEAM FLOW LB/HR	PRESSURE PSIA	TEMPERATURE F	MOISTURE FRACTION	ENTHALPY BTU/LB	ENTROPY BTU/LB-F
TURBINE THROTTLE	767027.	2414.7	1004.7	0.0000	1463.5	
GOVERNING STAGE BOWL	763556.	2342.3	1001.1	0.0000	1463.5	1.5374
GOVERNING STAGE ELEP AND UEEP	763556.	1869.4	934.1	0.0000	1436.6	1.5407
HP SECTION BOWL	740223.	1869.4	934.1	0.0000	1436.6	1.5407
HP SECTION ELEP	740223.	176.0	408.4	0.0000	1219.6	1.5834
LP SECTION BOWL	759955.	176.0	419.6	0.00	1226.3	1.5910
LP SECTION ELEP	759955.	0.98231	101.1	0.1647	934.9	1.6753
LP SECTION UEEP		0.98231			947.9	
EXHAUST LOSS					20.0	

TABLE III THERE IS NO STEAM JET AIR EJECTOR

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE
PRESTO, VERSION 7/31/80

CALCULATED RESULTS, PAGE 3

TABLE IV THERE ARE NO FW HEATERS

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 4

TABLE V CONDENSER

CONDENSER PRESSURE, PSIA	0.98231	=	2.00	IN. HGA
CONDENSATE FLOW, LB/HR	767027.			
CONDENSATE TEMPERATURE, F	101.1			
CONDENSATE ENTHALPY, BTU/LB	69.1			
CONDENSER DUTY, BTU/HR	658649460.			

TABLE VI CONDENSATE AND FEEDWATER

FW FLOW TO FW PUMP, LB/HR	767027.
FW TEMPERATURE TO FW PUMP, F	101.1
FW ENTHALPY TO FW PUMP, BTU/LB	69.1
FW ENTHALPY RISE ACROSS FW PUMP, BTU/LB	10.8
FW PRESSURE INCREASE ACROSS FW PUMP, PSI	3016.
FW FLOW TO STEAM GENERATOR, LB/HR	767027.
FW TEMPERATURE TO STEAM GENERATOR, F	104.1
FW ENTHALPY TO STEAM GENERATOR, BTU/LB	79.9
MAKE-UP TO CONDENSER HOTWELL, LB/HR	0.
STEAM FLOW FROM STEAM GENERATOR, LB/HR	767027.
STEAM ENTHALPY FROM STEAM GENERATOR, BTU/LB	1463.5

TABLE VIII.—Continued.

(c) Concluded

MHD-STEAM BOTTOM CYCLE EXAMPLE, COMPRESSOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 5

TABLE VII VALVE STEM AND SHAFT LEAKAGES

STEAM SEAL REGULATOR	
FLOW TO SSR, LB/HR	7071.
ENTHALPY AT SSR, BTU/LB	1339.3
FLOW FROM SSR TO MAIN CONDENSER, LB/HR	7071.
FLOW FROM SSR TO STEAM PACKING EXHAUSTER, LB/HR	0.
MAKE-UP FROM THROTTLE STEAM, LB/HR	0.
ENTHALPY OF MAKE-UP STEAM, BTU/LB	0.0
THROTTLE VALVE STEM	
LEAK NO. 19(DRAINS TO SSR), LB/HR	3438.
ENTHALPY LEAK NO. 19, BTU/LB	1463.5
LEAK NO. 20(DRAINS TO SSR), LB/HR	32.
ENTHALPY LEAK NO. 20, BTU/LB	1463.5
HP TURBINE SECTION, BOWL	
LEAK NO. 1(DRAINS TO THE LP TURBINE BOWL.),LB/HR	23333.
ENTHALPY LEAK NO. 1, BTU/LB	1436.6
HP TURBINE SECTION, SHELL	
LEAK NO. 6(DRAINS TO SSR), LB/HR	828.
ENTHALPY LEAK NO. 6, BTU/LB	1219.6
LEAK NO. 7(DRAINS TO SSR), LB/HR	2773.
ENTHALPY LEAK NO. 7, BTU/LB	1219.6

(d) Generator-turbine cycle output

MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

INPUT DATA

THROTTLE STEAM TEMPERATURE	1004.7	F			
THROTTLE STEAM PRESSURE	2414.7	PSIA			
ESTIMATED THROTTLE STEAM FLOW	3683000.	LB/HR			
ESTIMATED DESIGN THROTTLE FLOW	3683000.	LB/HR			
FW MAKE-UP RATE (TO CONDENSER HOTWELL)	0.0	PER CENT			
CONDENSATE BY-PASSED TO STEAM GENERATOR	0.	LB/HR			
ESTIMATED GENERATOR RATED CAPABILITY	551.691	MVA			
GENERATOR POWER FACTOR	0.90				
TOTAL ESTIMATED ELECTRICAL OUTPUT	496.522	MWE			
REQUIRED THERMAL INPUT TO CYCLE	1433.830	MWT			
CONDUCTOR-COOLED GENERATOR, ICC= 0					
ROTATIONAL SPEED OF TURBINE-GENERATOR	3600	RPM			
1-ROW GOVERNING STAGE					
PITCH DIAMETER OF GOVERNING STAGE	40.00	IN.			
NO. OF TURBINE SECTIONS IN SERIES	3				
NUMBER OF PARALLEL HP SECTIONS	1				
NUMBER OF PARALLEL IP SECTIONS	1				
NUMBER OF PARALLEL LP SECTIONS	4				
BOWL PRESSURE IP SECTION	459.0	PSIA			
BOWL PRESSURE LP SECTION	176.0	PSIA			
EXHAUST PRESSURE LP SECTION	0.98231	PSIA	=	2.00	IN. HGA
PITCH DIAMETER OF LAST STAGE LP SECTION	85.00	IN.			
LENGTH OF LAST STAGE BUCKETS LP SECTION	30.00	IN.			
FEEDWATER PUMP ISENTROPIC EFFICIENCY	0.8400				
FEEDWATER PUMP TURBINE EFFICIENCY	0.8100				
PRESSURE AT FWP INLET	167.20	PSIA			
RATIO OF FWP DISCHARGE PRESSURE TO HP THROTTLE PRESSURE	1.25				
FWP TURBINE EXTRACTION BEFORE LP BOWL					
FW PUMP IS LOCATED BEFORE FW HEATER NO. 4, IP= 4					
FW PUMP IS TURBINE DRIVEN, IFPT= 1					

TABLE VIII.—Continued.

(d) Continued

```
NUMBER OF STAGES OF REHEAT                                   1
FIRST REHEAT TEMPERATURE                                  1000.0        F

TOTAL NO. OF FW HEATERS                                      7
NO. OF FW HEATERS HP SECTION                                 3
NO. OF FW HEATERS IP SECTION                                 2
NO. OF FW HEATERS LP SECTION                                 2

EXTRACTION LINE PRESSURE DROP AT TURBINE EXHAUST             3.0        PER CENT
EXTRACTION LINE PRESSURE DROP ALL OTHERS                     6.0        PER CENT

FW HEATER NO.  1

  EXTRACTION STAGE PRESSURE                               1414.0        PSIA
  TERMINAL TEMPERATURE DIFFERENCE                            0.0        F
  DRAIN IS FLASHED, ND( 1)= 0
  THERE IS A DRAIN COOLER SECTION, NDC( 1)= 1
  DRAIN COOLER APPROACH TEMPERATURE DIFFERENCE              10.0        F

FW HEATER NO.  2

  EXTRACTION STAGE PRESSURE                                940.0        PSIA
  TERMINAL TEMPERATURE DIFFERENCE                            0.0        F
  DRAIN IS FLASHED, ND( 2)= 0
  THERE IS A DRAIN COOLER SECTION, NDC( 2)= 1
  DRAIN COOLER APPROACH TEMPERATURE DIFFERENCE              10.0        F

FW HEATER NO.  3

  EXTRACTION STEAM FROM TURBINE EXHAUST
  TERMINAL TEMPERATURE DIFFERENCE                            5.0        F
  DRAIN IS FLASHED, ND( 3)= 0
  THERE IS A DRAIN COOLER SECTION, NDC( 3)= 1
  DRAIN COOLER APPROACH TEMPERATURE DIFFERENCE              10.0        F

FW HEATER NO.  4

  EXTRACTION STAGE PRESSURE                                378.0        PSIA
  TERMINAL TEMPERATURE DIFFERENCE                            5.0        F
  DRAIN IS FLASHED, ND( 4)= 0
  THERE IS A DRAIN COOLER SECTION, NDC( 4)= 1
  DRAIN COOLER APPROACH TEMPERATURE DIFFERENCE              10.0        F

FW HEATER NO.  5

  EXTRACTION STEAM FROM TURBINE EXHAUST
  TERMINAL TEMPERATURE DIFFERENCE                            0.0        F
  DRAIN IS PUMPED, ND( 5)= 1
  THERE IS NO DRAIN COOLER SECTION, NDC( 5)= 0

FW HEATER NO.  6

  EXTRACTION STAGE PRESSURE                                 89.0        PSIA
  TERMINAL TEMPERATURE DIFFERENCE                            5.0        F
  DRAIN IS FLASHED, ND( 6)= 0
  THERE IS A DRAIN COOLER SECTION, NDC( 6)= 1
  DRAIN COOLER APPROACH TEMPERATURE DIFFERENCE              10.0        F

FW HEATER NO.  7

  EXTRACTION STAGE PRESSURE                                  4.2        PSIA
  TERMINAL TEMPERATURE DIFFERENCE                            4.0        F
  DRAIN IS PUMPED, ND( 7)= 1
  THERE IS NO DRAIN COOLER SECTION, NDC( 7)= 0

THERE IS NO STEAM JET AIR EJECTOR, QAE =         0.

VALVE STEM AND PACKING LEAKAGES WILL BE CALCULATED, LK= 1

THERE IS NO STEAM PACKING EXHAUSTER, NOSPE= 0
```

TABLE VIII.—Continued.

(d) Continued

MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 1

TABLE I OVERALL PERFORMANCE

NET TURBINE CYCLE HEAT RATE, BTU/KW-HR	10239.
NET TURBINE CYCLE EFFICIENCY, PER CENT	33.32
GROSS TURBINE CYCLE HEAT RATE, BTU/KW-HR	9929.
GROSS TURBINE CYCLE EFFICIENCY, PER CENT	34.37
GENERATOR OUTPUT, MWE	477.823
SHAFT WORK, MW	486.342
THERMAL INPUT TO CYCLE, MW	1433.830
POWER REQUIRED BY TURBINE-DRIVEN FW PUMP, MW	14.934
GENERATOR OUTPUT PLUS FW PUMP POWER, MW	492.758
MECHANICAL LOSSES, KW	1958.
GENERATOR LOSSES, KW	6561.

THIS IS A DESIGN POINT PERFORMANCE CALCULATION FOR
SPECIFIED EXTERNAL HEAT INPUT TO CYCLE

MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 2

TABLE II TURBINE EXPANSION LINE

	STEAM FLOW LB/HR	PRESSURE PSIA	TEMPERATURE F	MOISTURE FRACTION	ENTHALPY BTU/LB	ENTROPY BTU/LB-F
TURBINE THROTTLE	3691298.	2414.7	1004.7	0.0000	1463.5	--
GOVERNING STAGE BOWL	3686439.	2342.3	1001.1	0.0000	1463.5	1.5374
GOVERNING STAGE ELEP AND UEEP	3686439.	1869.4	934.2	0.0000	1436.7	1.5407
HP SECTION BOWL	3651978.	1869.4	934.2	0.0000	1436.7	1.5407
HP SECTION ELEP	2989142.	520.4	611.6	0.0000	1304.6	1.5605
1ST STAGE REHEATER INLET	2845923.	520.4			1305.7	
1ST STAGE REHEATER OUTLET	2845923.	468.4	1000.0		1521.3	
IP SECTION BOWL	2832470.	459.0	999.5	0.0000	1521.3	1.7470
IP SECTION ELEP	2656556.	176.0	754.1	0.0000	1403.1	1.7620
LP SECTION BOWL	2309301.	176.0	754.1	0.00	1403.1	1.7620
LP SECTION ELEP	2059598.	0.98231	101.1	0.0840	1018.5	1.8244
LP SECTION UEEP		0.98231			1030.7	
EXHAUST LOSS					16.1	

TABLE III THERE IS NO STEAM JET AIR EJECTOR

TABLE VIII.—Continued.

(d) Continued

MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 3

TABLE IV FW HEATERS

FW HEATER NO.	1	2	3	4	5	6
FW FLOW, LB/HR	4458325.	4458325.	4458325.	4458325.	3286832.	3286832.
FW TEMPERATURE OUT, F	580.3	529.8	463.0	428.2	368.8	310.2
FW ENTHALPY OUT, BTU/LB	584.0	522.0	446.2	408.4	341.6	280.2
FW TEMPERATURE IN, F	529.8	463.0	428.2	375.7	310.1	256.4
FW ENTHALPY IN, BTU/LB	522.0	446.2	408.4	353.0	280.2	225.1
EXTRACTION STAGE PRESSURE, PSIA	1414.0	940.0	520.4	378.0	176.0	89.0
EXTRACTION STEAM FLOW, LB/HR	318069.	344767.	155702.	175914.	188113.	136191.
EXTRACTION STEAM ENTHALPY, BTU/LB	1405.6	1362.5	1304.6	1495.8	1403.1	1330.1
SHELL PRESSURE, PSIA	1329.2	883.6	504.8	355.3	170.7	83.7
SHELL TEMPERATURE, F	580.3	529.8	468.0	433.2	368.8	315.2
SHELL DRAIN FLOW, LB/HR	318069.	662836.	822466.	998380.	1171493.	163000.
SHELL DRAIN TEMPERATURE, F	539.8	473.0	438.2	385.7	368.8	266.4
SHELL DRAIN ENTHALPY, BTU/LB	536.5	456.4	417.0	359.7	341.6	235.3
HEATER DUTY, BTU/HR	276433972.3	337870612.9	168443340.2	246975970.1	201812331.4	181067513.2

FW HEATER NO.	7
FW FLOW, LB/HR	3002007.
FW TEMPERATURE OUT, F	147.9
FW ENTHALPY OUT, BTU/LB	115.9
FW TEMPERATURE IN, F	101.1
FW ENTHALPY IN, BTU/LB	69.1
EXTRACTION STAGE PRESSURE, PSIA	4.2
EXTRACTION STEAM FLOW, LB/HR	113512.
EXTRACTION STEAM ENTHALPY, BTU/LB	1096.4
SHELL PRESSURE, PSIA	3.9
SHELL TEMPERATURE, F	151.9
SHELL DRAIN FLOW, LB/HR	284825.
SHELL DRAIN TEMPERATURE, F	151.9
SHELL DRAIN ENTHALPY, BTU/LB	119.9
HEATER DUTY, BTU/HR	140365852.8

MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE 4

TABLE IV-A EXTERNAL HEAT ADDITION (REMOVAL)

TOTAL EXTERNAL HEAT ADDED OTHER THAN AT STEAM GENERATOR OR REHEATERS	357694640.	BTU/HR
STEAM REMOVED FROM THE NO 5 FEEDHEATER EXTRACTION LINE, QEXT =	-15000.	LB/HR
EXTERNAL HEAT ADDITION AFTER FW HEATER NO 7 EXTSER=	357694640.	BTU/HR
CONDENSATE RETURNED TO THE CONDENSER, QECOND =	782027.	LB/HR
AT AN ENTHALPY OF HECOND =	69.1	BTU/LB
STEAM REMOVED BEFORE HP TURBINE THROTTLE, QTB =	-767027.	LB/HR

TABLE VIII.—Concluded.

(d) Concluded

```
MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE  5



TABLE V      CONDENSER

CONDENSER PRESSURE, PSIA                   0.98231       =          2.00      IN. HGA
CONDENSATE FLOW, LB/HR                  3002007.
CONDENSATE TEMPERATURE, F                  101.1
CONDENSATE ENTHALPY, BTU/LB                 69.1
CONDENSER DUTY, BTU/HR               2064235387.



TABLE VI  CONDENSATE AND FEEDWATER

FW FLOW TO FW PUMP, LB/HR                                      4458325.
FW TEMPERATURE TO FW PUMP, F                                      368.7
FW ENTHALPY TO FW PUMP, BTU/LB                                    341.6
FW ENTHALPY RISE ACROSS FW PUMP, BTU/LB                            11.4
FW PRESSURE INCREASE ACROSS FW PUMP, PSI                          2851.

FW FLOW TO STEAM GENERATOR, LB/HR                              4458325.
FW TEMPERATURE TO STEAM GENERATOR, F                              580.3
FW ENTHALPY TO STEAM GENERATOR, BTU/LB                            584.0

MAKE-UP TO CONDENSER HOTWELL, LB/HR                                  0.

STEAM FLOW FROM STEAM GENERATOR, LB/HR                         4458325.
STEAM ENTHALPY FROM STEAM GENERATOR, BTU/LB                      1463.5

THROTTLE STEAM FLOW FW PUMP TURBINE, LB/HR                      155182.
THROTTLE PRESSURE FW PUMP TURBINE, PSIA                           170.7
THROTTLE ENTHALPY FW PUMP TURBINE, BTU/LB                        1403.1
EXHAUST PRESSURE FW PUMP TURBINE, PSIA                              1.22789     =        2.50    IN. HGA
EXHAUST ENTHALPY FW PUMP TURBINE, BTU/LB                         1074.7


MHD-STEAM BOTTOM CYCLE EXAMPLE, GENERATOR TURBINE
STEAM TURBINE CYCLE HEAT BALANCE

CALCULATED RESULTS, PAGE  6



TABLE VII VALVE STEM AND SHAFT LEAKAGES

STEAM SEAL REGULATOR
  FLOW TO SSR, LB/HR                                       13512.
  ENTHALPY AT SSR, BTU/LB                                   1408.9
  FLOW FROM SSR TO MAIN CONDENSER, LB/HR                    5200.
  FLOW FROM SSR TO STEAM PACKING EXHAUSTER, LB/HR             0.
  FLOW FROM SSR TO FW HEATER NO.  7, LB/HR                  8312.
  MAKE-UP FROM THROTTLE STEAM, LB/HR                          0.
  ENTHALPY OF MAKE-UP STEAM, BTU/LB                           0.0

THROTTLE VALVE STEM

  LEAK NO. 19(DRAINS TO FW HEATER NO.  3), LB/ HR           3928.
  ENTHALPY LEAK NO. 19, BTU/LB                              1463.5

  LEAK NO. 20(DRAINS TO SSR), LB/HR                          931.
  ENTHALPY LEAK NO. 20, BTU/LB                              1463.5

HP TURBINE SECTION, BOWL

  LEAK NO.  1(DRAINS TO SHELL OF THIS TURBINE SECTION.)   24953.
  ENTHALPY LEAK NO.  1, BTU/LB                              1436.7

  LEAK NO.  3(DRAINS TO FW HEATER NO.  6), LB/ HR           6913.
  ENTHALPY LEAK NO.  3, BTU/LB                              1436.7

  LEAK NO.  4(DRAINS TO SSR), LB/HR                         2595.
  ENTHALPY LEAK NO.  4, BTU/LB                              1436.7

HP TURBINE SECTION, SHELL

  LEAK NO.  6(DRAINS TO FW HEATER NO.  6), LB/ HR           8882.
  ENTHALPY LEAK NO.  6, BTU/LB                              1304.6

  LEAK NO.  7(DRAINS TO SSR), LB/HR                         3589.
  ENTHALPY LEAK NO.  7, BTU/LB                              1304.6

IP TURBINE SECTION, BOWL

  LEAK NO.  8(DRAINS TO FW HEATER NO.  6), LB/ HR          11015.
  ENTHALPY LEAK NO.  8, BTU/LB                              1521.3

  LEAK NO.  9(DRAINS TO SSR), LB/HR                         2438.
  ENTHALPY LEAK NO.  9, BTU/LB                              1521.3

IP TURBINE SECTION, SHELL

  LEAK NO. 12(DRAINS TO SSR), LB/HR                         3960.
  ENTHALPY LEAK NO. 12, BTU/LB                              1403.1
```

TABLE IX.—INPUT DATA FOR EXAMPLE A

```
EXTRACTION RATE AS A VARIABLE PARAMETER
 &NAME
  BLS=20.,
  CP1=71.6,
  CP2=1.25,
  EFP=.8,
  GC=89.5,
  ICC=1,
  IFPT=0,
  IP=2,
  LK=0,
  ND=2*0, 1, 9*0,
  NDC=2*1, 0, 2*1, 7*0,
  NF=5,
  NFH=3,
  NFI=0,
  NFL=2,
  NHP=1,
  NIP=0,
  NLP=2,
  NOSPE=0,
  NRGS=1,
  NRH=0,
  NCASE=0,
  NSHAFT=2,
  PBLP=64.7,
  PDGS=38.,
  PDLS=60.,
  PE=393.5,  193.8, 77.0, 36.5, 11.4, 7*0.0,
  PT=1464.7,
  PXDROP=3., 7.,
  PXLPI=3.0,
  QAE=800.,
  QGEN=679200.,
  QT=678400.,
  QTD=678400.,
  TDCA=2*10., 0.0, 2*10., 7*0.0,
  TT=1000.,
  TTD=-4.0, 5.0, 0.0, 2*5.0, 7*0.0,
  WRATE=80.5,
  NEXTRN=1,
 &END
20% STEAM EXTRACTION AT 64.7 PSIA
 &NAME QPROSS(1)=-135680.  &END
40% STEAM EXTRACTION AT 64.7 PSIA
 &NAME QPROSS(1)=-271360.  &END
60% STEAM EXTRACTION AT 64.7 PSIA
 &NAME QPROSS(1)=-407040. &END
80% STEAM EXTRACTION AT 64.7 PSIA
 &NAME QPROSS(1)=-542720.  &END
0% STEAM EXTRACTION AT 250 PSIA
 &NAME
  PBLP=250.,
  NFH=1,
  NFL=4,
  QPROSS(1)=0.0,
 &END
20% STEAM EXTRACTION AT 250 PSIA
 &NAME QPROSS(1)=-135680.  &END
40% STEAM EXTRACTION AT 250 PSIA
 &NAME QPROSS(1)=-271360.  &END
60% STEAM EXTRACTION AT 250 PSIA
 &NAME QPROSS(1)=-407040.   &END
80% STEAM EXTRACTION AT 250 PSIA
 &NAME QPROSS(1)=-542720.  &END
```

TABLE X.—INPUT DATA FOR EXAMPLE C

```
THROTTLE TEMPERATURE AS A VARIABLE PARAMETER
 &NAME
  BLS=20.,
  CP1=71.6,
  CP2=1.25,
  EFP=.8,
  GC=89.5,
  ICC=1,
  IFPT=0,
  IP=2,
  LK=0,
  ND=2*0, 1, 9*0,
  NDC=2*1, 0, 2*1, 7*0,
  NF=5,
  NFH=3,
  NFI=0,
  NFL=2,
  NHP=1,
  NIP=0,
  NLP=2,
  NOSPE=0,
  NRGS=1,
  NRH=0,
  NCASE=0,
  NSHAFT=2,
  PBLP=64.7,
  PDGS=38.,
  PDLS=60.,
  PE=393.5,  193.8, 77.0, 36.5, 11.4, 7*0.0,
  PT=1264.7,
  PXDROP=3., 7.,
  PXLPI=3.0,
  QAE=800.,
  QGEN=679200.,
  QT=678400.,
  QTD=678400.,
  TDCA=2*10., 0.0, 2*10., 7*0.0,
  TT=850.,
  TTD=-4.0, 5.0, 0.0, 2*5.0, 7*0.0,
  WRATE=80.5,
  NEXTRN=1,
 &END
900 F AND 1264.7 PSIA THROTTLE
 &NAME TT=900.  &END
950 F AND 1264.7 PSIA THROTTLE
 &NAME TT=950.  &END
1000 F AND 1264.7 PSIA THROTTLE
 &NAME TT=1000.  &END
1050 F  AND 1264.7 PSIA THROTTLE
 &NAME TT=1050.  &END
850 F AND 1464.7 PSIA THROTTLE
 &NAME PT=1464.7, TT=850.  &END
900 F AND 1464.7 PSIA THROTTLE
 &NAME TT=900.  &END
950 F AND 1464.7 PSIA THROTTLE
 &NAME TT=950.  &END
1000F AND 1464.7 PSIA THROTTLE
 &NAME TT=1000.  &END
1050 F AND 1464.7 PSIA THROTTLE
 &NAME TT=1050.  &END
850 F AND 1814.7 PSIA THROTTLE
 &NAME PT=1814.7, TT=850.  &END
900 F AND 1814.7 PSIA THROTTLE
 &NAME TT=900.  &END
950 F AND 1814.7 PSIA THROTTLE
 &NAME TT=950.  &END
1000 F AND 1814.7 PSIA THROTTLE
 &NAME TT=1000.  &END
1050 F AND 1814.7 PSIA THROTTLE
 &NAME TT=1050.  &END
```

TABLE XI.—INPUT DATA FOR EXAMPLE D

```
CONDENSER PRESSURE AS A VARIABLE PARAMETER
 &NAME
  BLS=20.,
  CP1=71.6,
  CP2=1.25,
  EFP=.8,
  GC=89.5,
  ICC=1,
  IFPT=0,
  IP=2,
  LK=0,
  ND=2*0, 1, 9*0,
  NDC=2*1, 0, 2*1, 7*0,
  NF=5,
  NFH=3,
  NFI=0,
  NFL=2,
  NHP=1,
  NIP=0,
  NLP=2,
  NOSPE=0,
  NRGS=1,
  NRH=0,
  NCASE=0,
  NSHAFT=2,
  PBLP=64.7,
  PDGS=38.,
  PDLS=60.,
  PE=393.5,  193.8, 77.0, 36.5, 11.4, 7*0.0,
  PT=1264.7,
  PXDROP=3., 7.,
  PXLPI=1.0,
  QAE=800.,
  QGEN=679200.,
  QT=678400.,
  QTD=678400.,
  TDCA=2*10., 0.0, 2*10., 7*0.0,
  TT=950.,
  TTD=-4.0, 5.0, 0.0, 2*5.0, 7*0.0,
  WRATE=80.5,
  NEXTRN=1,
 &END
1264.7/950/2 IN
 &NAME PXLPI=2.0  &END
1264.7/950/3 IN
 &NAME PXLPI=3.0   &END
1264.7/950/4 IN
 &NAME PXLPI=4.0  &END
1464.7/1000/1 IN
 &NAME PT=1464.7, TT=1000., PXLPI=1.0  &END
1464.7/1000/2 IN
 &NAME PXLPI=2.0  &END
1464.7/1000/3 IN
 &NAME PXLPI=3.0  &END
1464.7/1000/4 IN
 &NAME PXLPI=4.0  &END
1814.7/1000/1 IN
 &NAME PT=1814.7, PXLPI=1.0  &END
1814.7/1000/2 IN
 &NAME PXLPI=2.0  &END
1814.7/1000/3 IN
 &NAME PXLPI=3.0  &END
1814.7/1000/4 IN
 &NAME PXLPI=4.0   &END
```

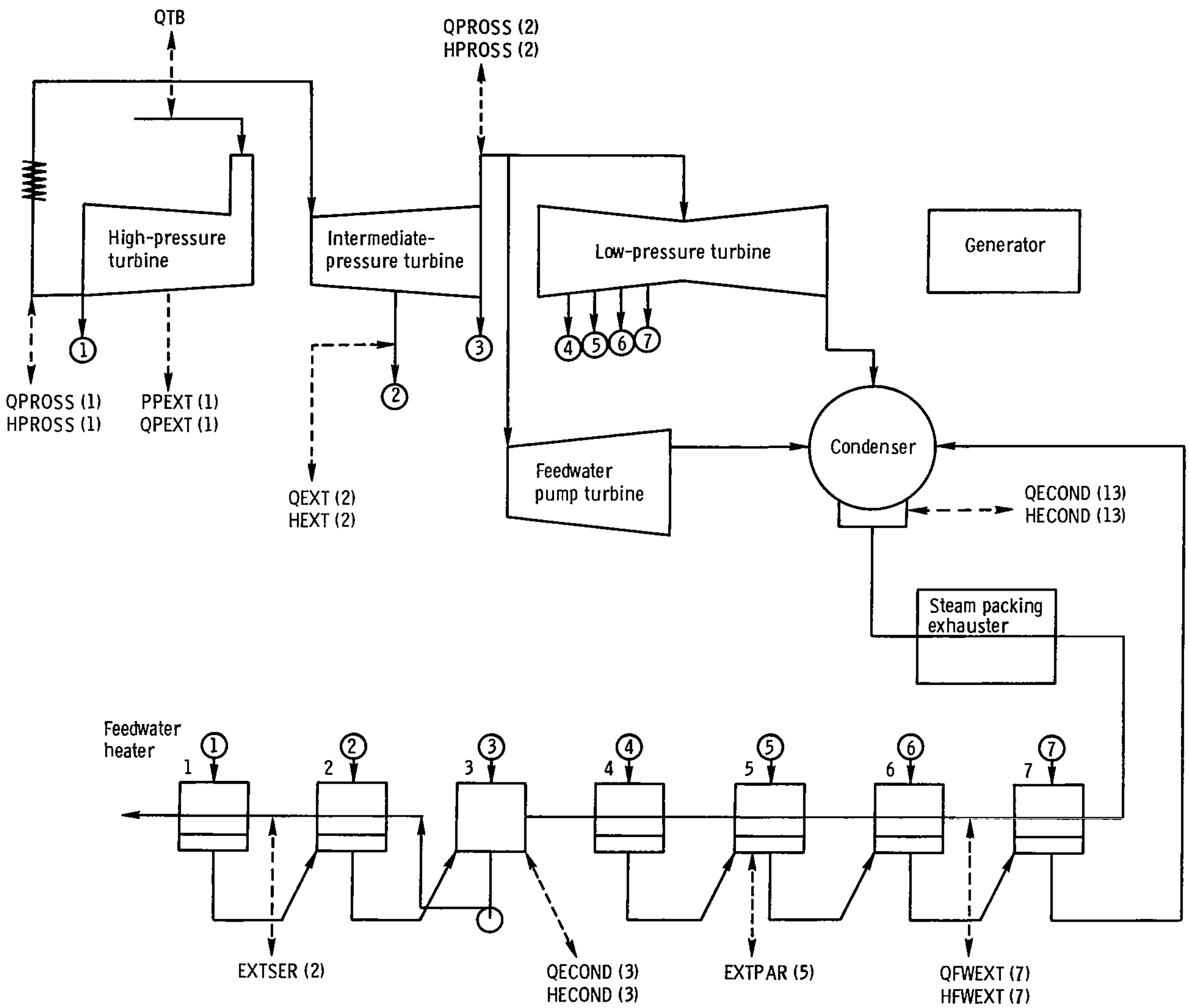
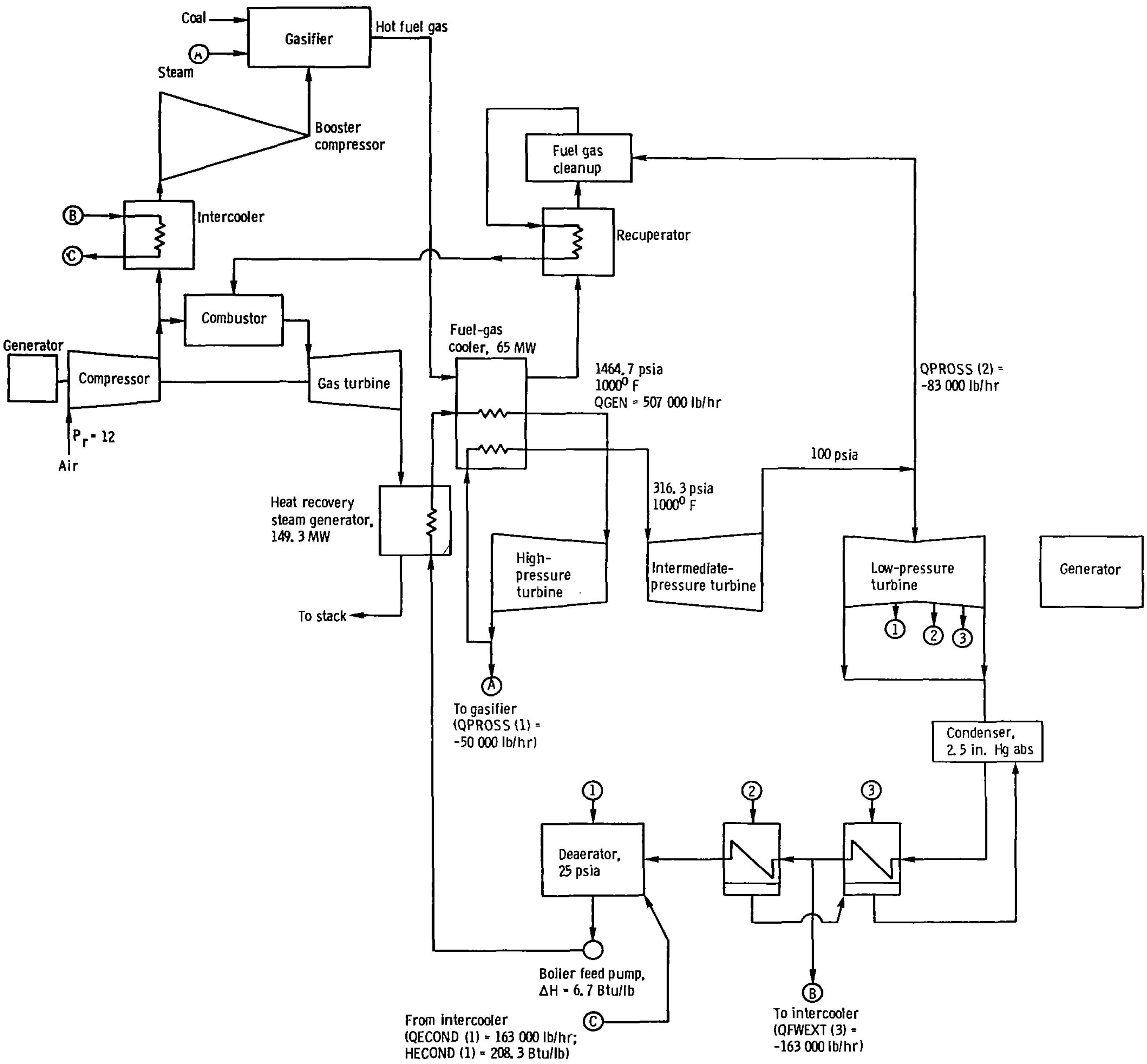
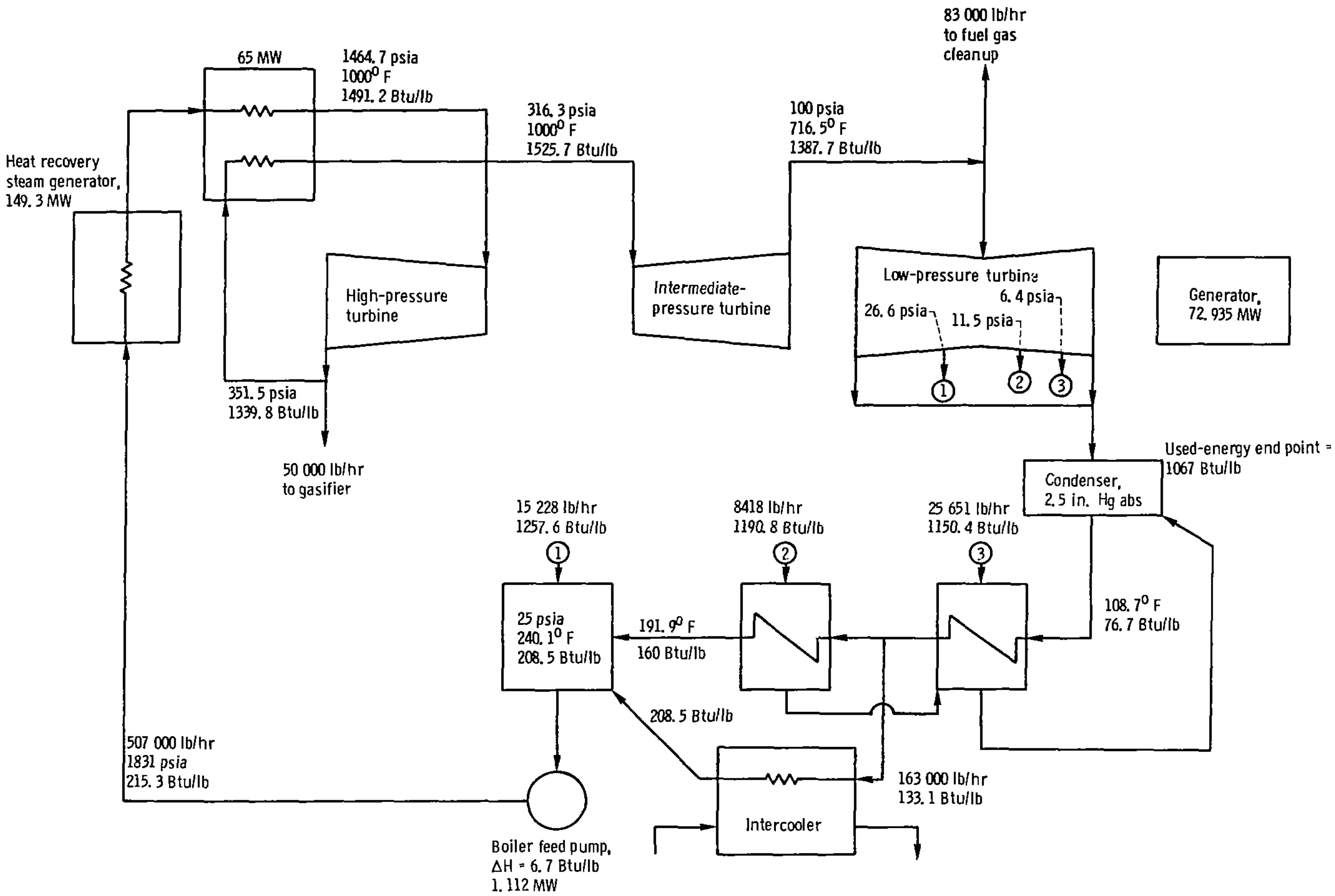


Figure 1. - Input variables for special features of PRESTO II.



(a) Gas turbine - steam turbine combined cycle with integrated gasifier.

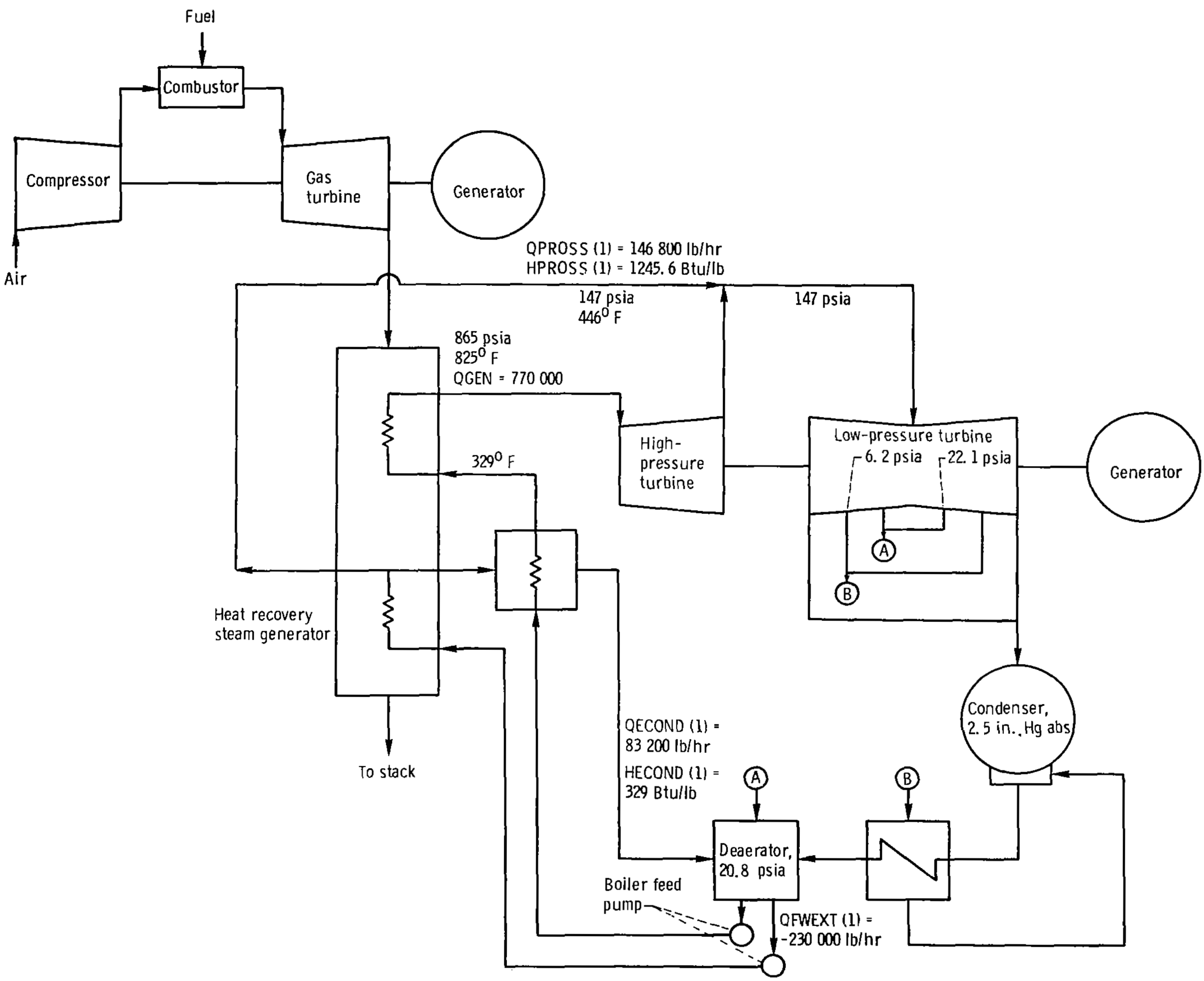
Figure 2. - Example 1.



$$\text{Net heat rate} = \frac{507\,000\,(1491.2 - 215.3) + 457\,000\,(1525.7 - 1339.8) + 163\,000\,(208 - 133.1)}{72\,935 - 1112} = 10\,361 \text{ Btu/kW-hr}$$

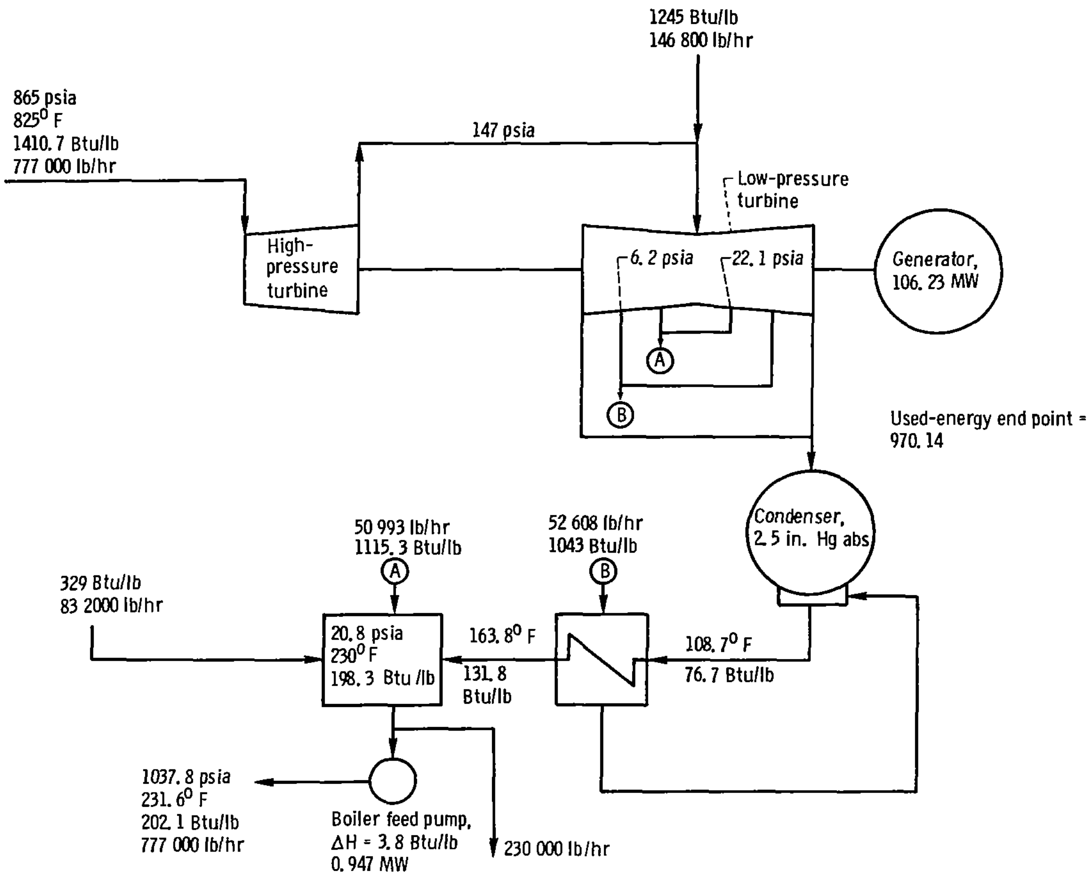
(b) Heat balance.

Figure 2. - Concluded.



(a) Gas turbine - steam turbine combined cycle with dual-pressure heat recovery steam generator.

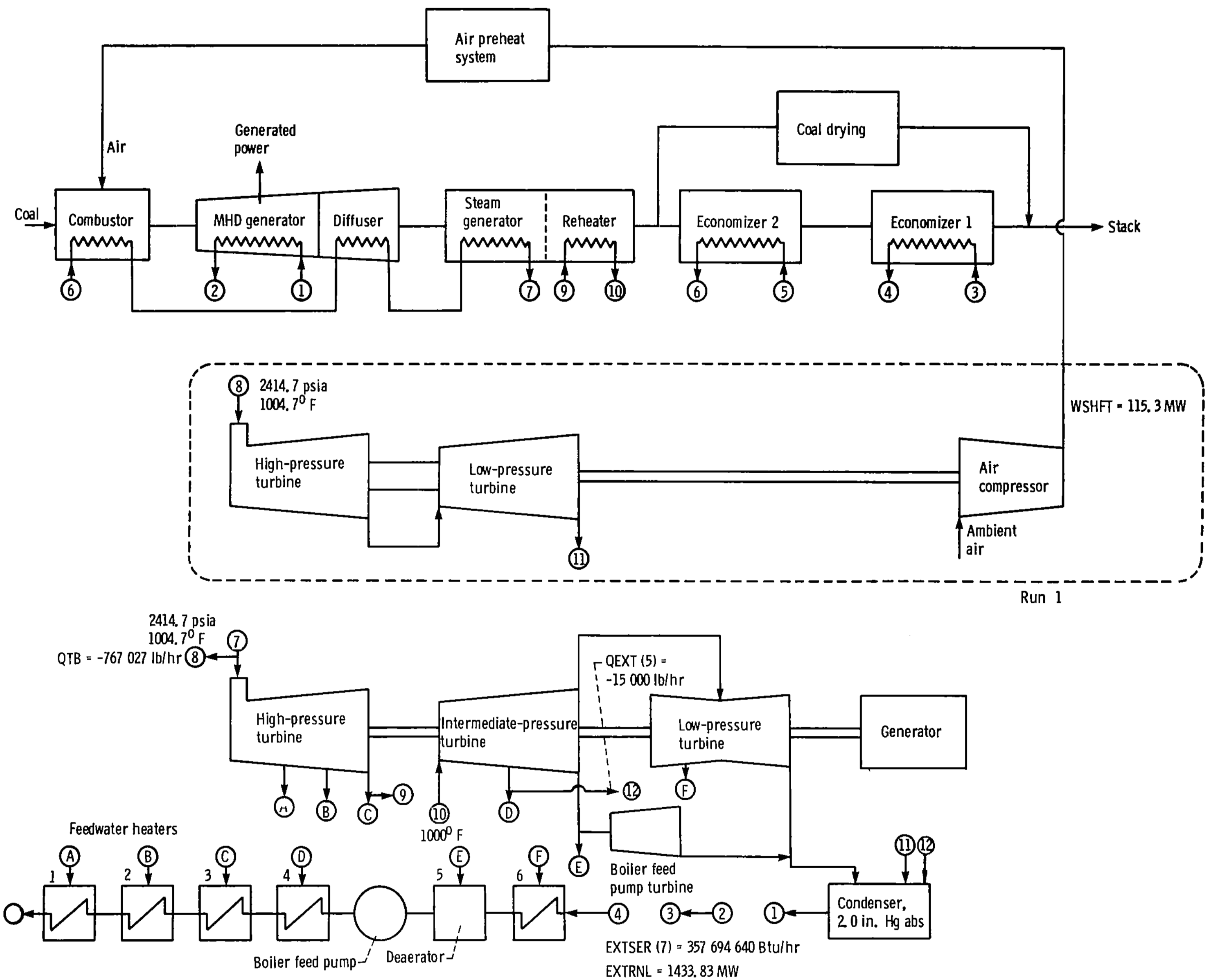
Figure 3. - Example 2.



$$\text{Gross heat rate} = \frac{770\,000\,(1410.7 - 202.1) + 83\,200\,(329 - 198.3) + 146\,800\,(1245 - 198.5)}{106\,234} = 10\,309\ \text{Btu/kW-hr}$$

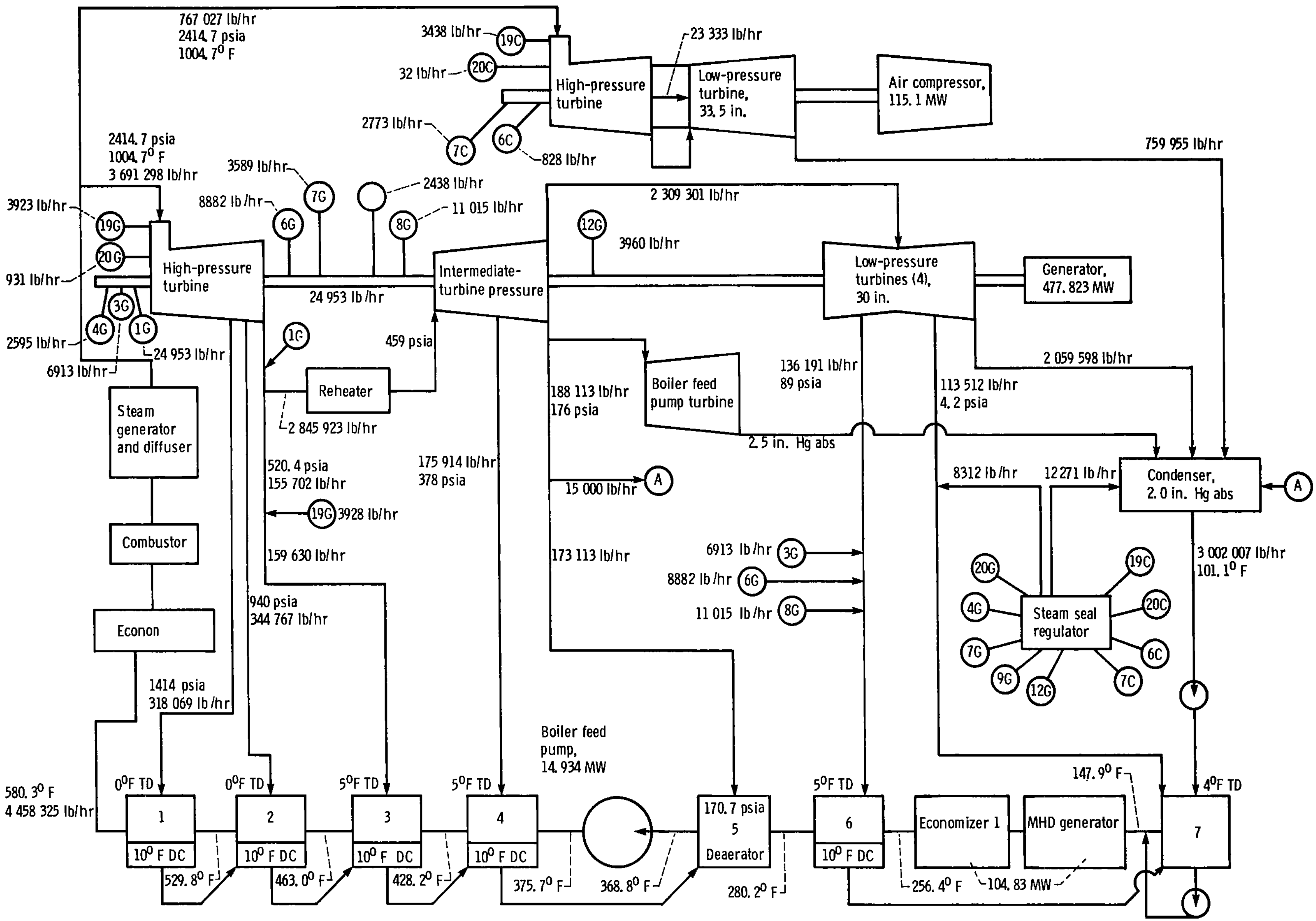
(b) Heat balance.

Figure 3. - Concluded.



(a) Magnetohydrodynamic - steam combined cycle.

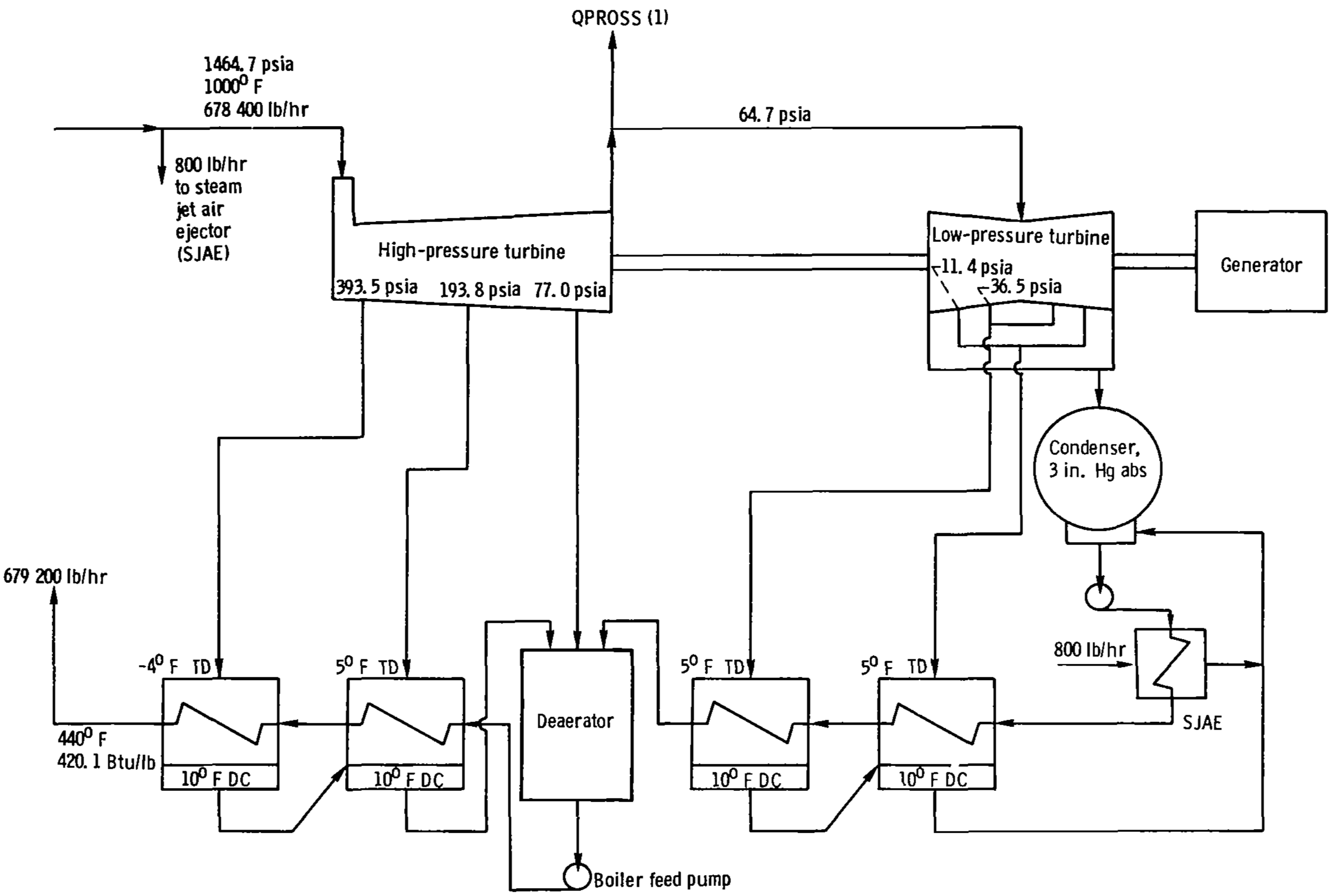
Figure 4. - Example 3.



$$\text{Net heat rate} = \frac{3413 \times 1433.83}{115.1 + 477.823} = 8253 \text{ Btu/kW-hr}$$

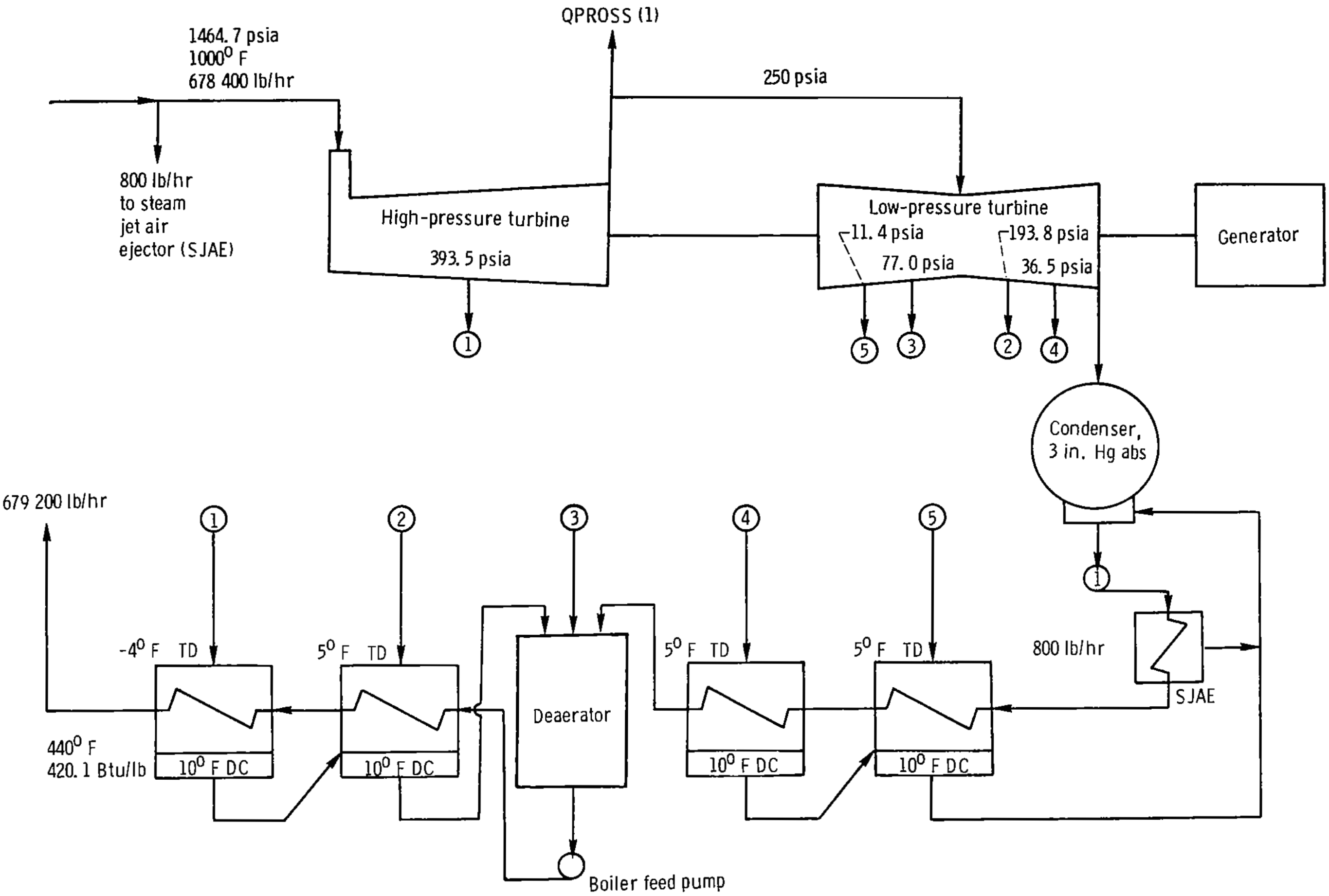
(b) Bottoming-cycle heat balance, where TD denotes terminal temperature difference and DC denotes drain cooler approach temperature difference.

Figure 4. - Concluded.

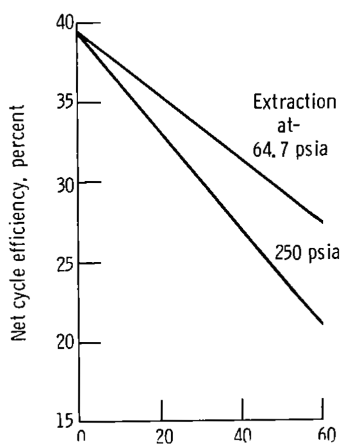


(a) Extraction at 64. 7 psia.

Figure 5. - Steam extraction rate (QPROSS (1)) as a variable parameter - example A. QPROSS (1) ranged from 0 to 60 percent of throttle flow. TD denotes terminal temperature difference and DC denotes drain cooler approach temperature difference.



(b) Extraction at 250 psia.



(c) Performance results.

Figure 5. - Concluded.

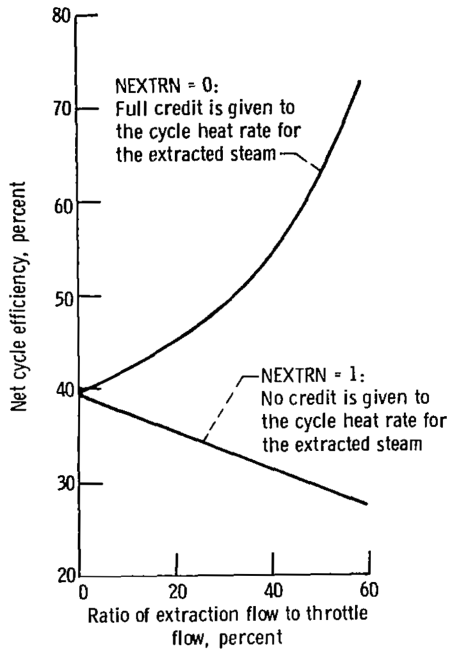
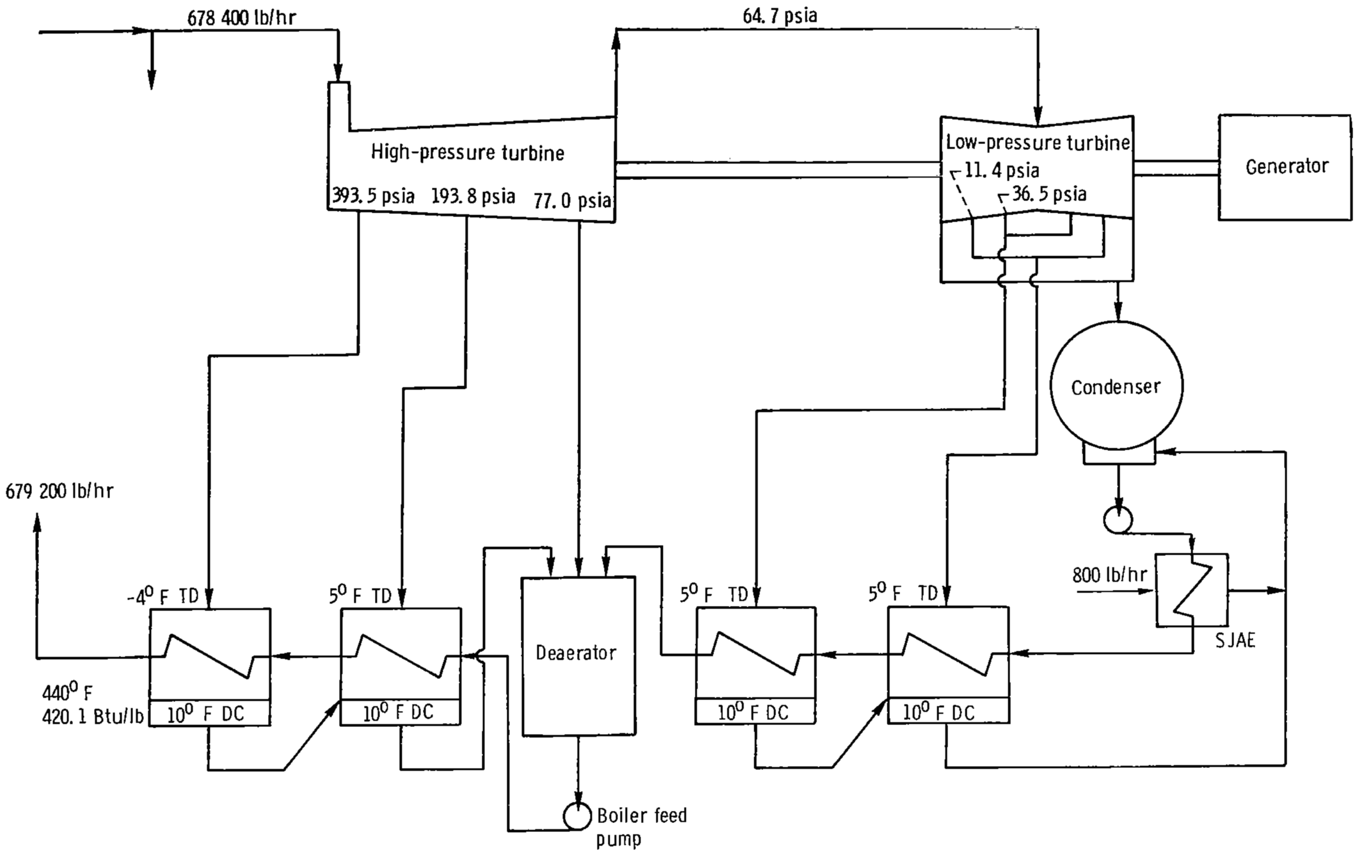
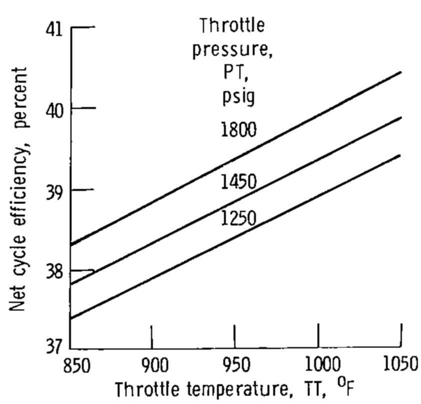


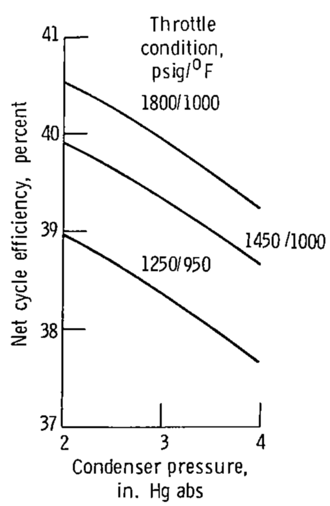
Figure 6. - Example B - net cycle efficiency with two different cycle heat input definitions.



(a) Configuration and major parameters.



(b) Performance results for condenser pressure of 3 in. Hg abs.



(c) Performance results for three throttle conditions as condenser pressure varies.

Figure 7. - Throttle temperature (TT) and pressure (PT) and condenser pressure (PXLPI) as variable parameters.

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15. Supplementary Notes

16. Abstract

The PRESTO computer code is designed to analyze the performance of regenerative, superheated steam turbine cycles at valves-wide-open design flow. The code can model conventional steam cycles as well as cycles that include such special features as process steam extraction and induction and feedwater heating by external heat sources. New convenience features and extensions to the special features have been incorporated into the PRESTO code. The new features are described, and detailed examples illustrating the use of both the original and the new special features are given. The version of PRESTO incorporating the new features has been designated PRESTO II.

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