Modular modeling and control of dynamic MHD/steam power plants
by John Carrol Shovic

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Electrical Engineering
Montana State University
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Abstract:
The subject of this thesis is the description of a Modular Dynamic Modeling System written in
FORTRAN. Previous modeling work done on MHD-steam plants is described. The modular modeling
system is fully described and, as a demonstration of the validity of the modular system, the current
MHD/steam power plant model (System Model IV) has been translated to the modular system and
described. A complete FORTRAN program listing of the modular form of system model IV is
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MODULAR MODELING AND CONTROL OF DYNAMIC MHD/STEAM POWER PLANTS

by

JOHN CARROL SHOVIC

A thesis submitted in partial fulfillment of the requirements for the degree of

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in

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Approved:

Head, Major Department

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John Carrol Shovic
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ABSTRACT

The subject of this thesis is the description of a Modular Dynamic Modeling System written in FORTRAN. Previous modeling work done on MHD-steam plants is described. The modular modeling system is fully described and, as a demonstration of the validity of the modular system, the current MHD/steam power plant model (System Model IV) has been translated to the modular system and described. A complete FORTRAN program listing of the modular form of system model IV is provided.
CHAPTER I

INTRODUCTION AND REVIEW OF EARLIER WORK

This thesis describes a research activity directed towards developing a top-down-structured modular modeling system for dynamic simulation of magnetohydrodynamic (MHD) steam power plants, conventional steam plants, and other complex dynamic systems.

The major reason the modular system was developed was that the increasing complexity of Montana State University's MHD-steam plant model had brought the project to a point that changes in complexity or plant topology was a significant problem in terms of time and the manpower needed. Therefore, a need was seen for a program structure that would allow fast changes in plant topology. Thus, the modular modeling system presented in Chapter II was developed. The modular system has reduced the time for modification by an order of magnitude determined by four months experience with using and modifying the MHD-steam plant model under the modular system.

Dynamic simulations are very useful in plant parameter identification, plant parameter variation effects, plant response to disturbances, and dynamic control policy evaluation and synthesis. The model presented in this thesis was specifically developed for control policy evaluation and synthesis although it could easily be used for the other uses mentioned above.

The modular system presented here has been constructed with the primary goal of being simple to modify. No strong effort was made to
optimize the modular system with respect to either execution speed or length of compiled code.

Review of Earlier Work

The MHD-Steam plant model currently in use at Montana State University is entitled System Model IV. System models I, II, and III were developed by John Aspnes for his doctoral dissertation in 1976 at Montana State University. A further discussion of these models is pertinent here.

System Model I represented initial efforts in dynamic studies of a large-scale MHD/steam combined-cycle electrical power generating plant. The model operated on power flow variables and contained five first-order differential equations. The steam plant was characterized by a cascade of two first-order lags.

System Model II represents a logical extension of the Model I order of complexity. The heat balance and the power flow variable basis is retained. Several transport delays are added, the air preheater model is more detailed, and a new control loop to control air preheat temperature is added. System Model II contained five first-order differential equations.

System Model III is considerably more detailed than previously discussed models. The Combustor/Nozzle/Channel/Diffuser (CNCD) section is much more sophisticated, being represented by polynomial approximations
of data resulting from the solution of energy balance, state, and continuity equations for the combustor and the quasi-one dimensional MHD equations for the channel and diffuser. System Model III contained sixteen first-order differential equations.

System Model IV was developed by Daniel Goldsworthy during 1978-1980. This model contains much more detailed models of the components in the plant, including a sophisticated set of steam plant component models. The major control loops are similar to those in System Model III, although there have been changes and many minor loops added. System Model IV is still in use currently, though greatly modified. It currently contains 103 first-order differential equations.

Other MHD-steam plant models, aside from the Montana State University model, include the Gilbert/Commonwealth model and the Babcox and Wilcox Modular Modeling System (MMS) Model.

The Gilbert/Commonwealth model is a simulation of a 200-megawatt electric plant. It contains oxygen enrichment and a reheat cycle for the steam turbines. The model was prepared using IBM's CSMP-III dynamic systems computer language.

Babcox and Wilcox have developed a Modular Modeling System (MMS) for studying the dynamic characteristics of steam generation units. The MMS is very similar in concept to the system of modeling described by this thesis. The primary differences are:

1. MMS requires the use of a simulation language (Advanced Con-
tinuous Simulation Language (ACSL) developed by Mitchell and Gauthier, Inc., or EASY, developed by Boeing Computer Services) while the modular system in this thesis is coded in standard FORTRAN.

2. MMS is not as well suited toward control policy simulation synthesis and evaluation as is the modular system described in this thesis.

This thesis describes the development, synthesis, protocol, and structure of a modular modeling system for simulating dynamic MHD-steam power plants. The example in Chapter III shows how this modular system works and the listing in Appendix B shows System Model IV coded in the modular system format.
CHAPTER II
THE MODULAR MODELING FORM

The modular modeling form functions on two major levels: The system level of information flow between modules, and the functional level within modules. The first level is establishment of interconnections between modules, which defines system topology through physical variable connections. The second level is the description of function within each module. The five types of modules are described briefly below, as a general understanding of these is necessary to the description of the system information flow.

1. Supervisory Module - This module contains assignments of physical interconnections between modules, time updating procedures, demand function generation, and initialization and termination procedures for the entire model.

2. Component Modules - These modules contain the physical equations governing the modeled device and also contain the linkage needed to transfer physical information and transducer information between modules.

3. Control Module - This module contains the controller equations which generate control signals based on transducer values.

4. Data Output Module - This module contains the code needed to output variables computed by other modules to data files for plotting or other interpretation.

5. Dynamic Solution Module - This module contains the code which implements a fourth order Runge-Kutta integration algorithm.

Each of the above modules is fully described later in the system module section.
SYSTEM INFORMATION FLOW

The modular modeling form has been designed to make all information
transfers in the system to be under one of the following six forms:

1. Node (physical variable) transfer.
2. Transducer transfer.
4. State-variable derivative transfer.
5. Valve-area transfer.
6. Output-variable transfer.

Node Transfer

Node transfer is the method that component modules use to communicate
information concerning current conditions of physical variables
(pressure, enthalpy, flow rate, etc.) within component modules to adjacent
component modules. A node is defined as the physical junction between
any component module and another component module. Each component may
have as many nodes associated with it as there are other component
modules connected to it. Node transfer information flow occurs only
between component modules as diagrammed in Figure 1.

Transducer Transfer

Transducer transfer is the method of information flow between the
component modules and the control module. As the name implies, this
transfer is used to present the controller with information about current
plant conditions. Transducer transfer information flow is diagrammed in
Figure 2.
Figure 1. Node Transfer Flow

Figure 2. Transducer Transfer Flow
State-Variable Transfer

State-variable transfer is the method of information flow from the dynamic solution module to other modules that contain state variables (i.e., controller and component modules). The dynamic solution module integrates the differential equations, and then using state-variable transfer, returns results to the proper module. State-variable transfer information flow is diagrammed in Figure 3.

State-Variable Derivative Transfer

State-variable derivative transfer is the method of information flow from system modules to the dynamic solution module. The system modules calculate the numerical derivative values for the first-order differential equations, and then using this mode of transfer, send the results to the dynamic solution module. State-variable derivative transfer information flow is diagrammed in Figure 4.

Valve-Area Transfer

Valve-area transfer is the method of information flow from the control module to component modules. The control module calculates the numerical values of valve areas through algebraic or differential equations and then transfers valve areas through valve-area transfer to the appropriate component module in which the valve is located. Valve-area transfer information flow is diagrammed in Figure 5.
Figure 3. State-Variable Transfer Flow

Figure 4. State-Variable Derivative Transfer Flow
Output-Variable Transfer

The final method of information flow in the modular system is output-variable transfer. This type of transfer flow is used to send any variables of interest from any module to the data output module for outputting to data files, for plotting, or for examination. Output-variable transfer information flow is diagrammed in Figure 6.

SYSTEM MODULES

All of the modules in the modular modeling system are one of the following five types:

1. Supervisory module
2. Component modules
3. Control module
4. Data output module
5. Dynamic solution module

Each of these module types performs a specific limited function and the specifics of each are described.

Supervisory Module

The supervisory module consists of initialization, termination procedures, and physical structure linking the supervisory module in the modular modeling system is the mainline routine (program MAIN in Appendix B). The supervisory module begins with the block of COMMON statements that are common to all modules in the modular system. Following that is the model initialization section. The initialization consists of reading in the parameters concerning integration step size,
Figure 5. Valve-Area Transfer Flow

Figure 6. Output-Variable Transfer Flow
maximum time for simulation, number of integration steps between calls to data output module and ramp parameters.

These parameters are set by reading their labels (which are dummy labels, meaning they are used only for visual documentation within the data file and are not used by the program) and from an external data file (file MAINDAT.DAT in Appendix B).

Next, the plant-state data file (shown for 100% level in Appendix A) is read in. State variables are read in first, then node array initial values, AUX array initial values, and valve area initial values. Initial time is now set to zero and subroutine PLANT (see description below) is executed twice (without integrating) in order to set any algebraic variables in the system. Subroutine PLANT is executed twice due to the sequential nature of computer execution. Some early algebraic variables are dependent on values set further down in the module code, therefore, a second pass through PLANT is necessary to insure these variables are set. The sole function of the termination section is to determine whether a plant state file is to be written (ISSRUN=1) or not (ISSRUN=0). The program then terminates.

**Subroutine PLANT.** Subroutine PLANT contains the information concerning the physical connections or topology of the various component modules. It consists of a series of calls to all the component modules, and it ends with a call to the control module. An example of a particular component model call from the PLANT subroutine (given in Appendix B)
follows:

```
CALL SDCNSR0(GAS,47,46,SEED,49,MWATER,63,48,VANUM,10,
           STATE,3)
```

SDCNSR0 is a model of the lower seed condenser in a MHD-steam plant. It has gas entering and leaving at points 47,46, respectively, and has water entering and leaving at points 63,48, respectively. VANUM,10 means that valve number 10 is used in this module. STATE,3 means that SDCNSR0 contains three state-variable derivative equations.

Component Modules

The bulk of code in the modular modeling format is contained in component modules. A component module contains all the physical equations governing the particular component and also the linkage needed to transfer information to and from other modules. The description that follows will continue the example from SDCNSR0 as a particular component module from the system example in Chapter III. The form for a component module will be given in a sequential format starting with the subroutine statement at the start of the module.

The form of the subroutine statement for a component module is as follows:

```
SUBROUTINE /Name/ (/Dummy Name/, [plant location number]_1, [plant location number]_2,...
       /Dummy name/, [plant location number]_1, [plant location number]_2,...
           STATE, [number of state variables])
```
Where:

/---/ Indicate alphanumeric characters.

[---] Indicate an actual number.

/Name/ A 1-8 character subroutine name indicate the component modelled.

/Dummy name/ A descriptive name that does not pass a value but rather is used to provide description of the following plant location numbers.

[Plant location number] An integer number specifying a node number or (i.e., an inter-component module connection).

STATE Placed as the last dummy name in the component subroutine name indicating that the number of state-variables determined in module follows.

[Number of state variables] Indicates the number of state-variables determined in module.

Example:
```
SUBROUTINE SDCNSR0(MGAS,MGAS1,MGAS2,SEED,SEED1,MWATER,
                     MWATER1,MWATER2,VANUM,VANUM1,STATE,
                     STINC)
  INTEGER SEED1,VANUM1,STINC
```

This indicates model SDCNSR0 has gas flowing in from node MGAS1, flowing out from MGAS2 (note the use of dummy names as labels). Further, the module has seed being extracted from node SEED1, water flowing in from node MWATER1, and out node MWATER2. Further, a valve is present in the module (valve number VANUM1) and the module contains STINC state variables.
The next set of statements in a component module consist of the common declarations which are the same in all types of modules.

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T,THAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(3J)
COMMON /CONTROL/ VA(30), Trans(50)
COMMON /OUTPUT/ OUT(100)

Continuing, is the constant data area. Any data concerning time constants, metal constants, chamber volumes, and other physical parameters is included in this section as a data statement to keep from continually executing redundant assignment statements.

CONSTANT DATA

DATA CG8/.260E-11/
DATA CTG8/.0261/
DATA CW8/.000211/
DATA EF8/1.0/
DATA CM8/.11E85/

Following the constant data are the input node assignments. In this module section, values from the node array (node numbers as defined in the subroutine call statement) are loaded into the local subroutine variables. This section allows variable changes from other component modules to be accessed in the module. Output nodes are defined as those that are normally considered to have information flowing out from them. However, internal operation of the module usually has some
dependence on output-node conditions. Furthermore, output-nodes are influenced by other modules with which they interconnect. Therefore, output-node values are initialized at the beginning of module computations so that any changing conditions due to other modules are properly communicated. Thus, the section on 'output-node inputs' is essential.

Similar reasoning reveals a necessity for input-node outputs which
are described later in this chapter.

The next part of the component module structure is the least obvious, that of the pass-through variable section. This section is to enable changes in variables to affect components both directions from a particular component. If a variable, representing some particular parameter such as pressure is passed through node transfer, and does not appear on the left hand side of an assignment statement, then a pass-through variable assignment must be used or else changes in that parameter will not be passed through the system properly. The procedure for pass-through assignments follows:

In node input section

/Variable Name/I = input node
/Variable Name/O = output node

In pass through assignment section

/Variable Name/ = /Variable Name/I

In node output section

Output-node = /Variable name/I
Input-node = /Variable name/O

Where:

/Variable Name/ Refers to a specific local variable name (e.g. WQ6).
/Variable Name/I Refers to the same local variable name as above but with an I (for input) attached (e.g. WG6I).
/Variable Name/O  Refers to the same local variable name as above but with an O (for output) attached (e.g. WG60).

Input-node  Refers to a node transfer called an input-node, that is the node with the first subscript appearing first after a given dummy label name in a subroutine call (e.g. in a subroutine call containing MGAS,MGAS1,MGAS2, MGAS1 is referred to as the input-node and MGAS2 the output-node).

Output-node  Refers to a node transfer called an output-node.

Below is an example of a pass-through assignment. The combination of the input-node assignments, pass-through assignments, and output-node assignments together show an example of the entire procedure given above.

```
PASS THROUGH ASSIGNMENTS
WG6=WG61
```

The next part of the component module is the state-variable assignment section. This section transfers the values of the state-variables from the state-variable array to the more descriptive local module labels.

```
STATE VARIABLE ASSIGNMENTS
HG8=S(SC)
TGAV8=S(SC+1)
HM8=S(SC+2)
```
Following the state-variable assignment section is the actual code describing the device. Note that all differential equations have left hand members from the array F which corresponds one to one to the state-variable array S. An example of the simulation code is given below.

```c
LOWER SEED COND

RW10=RWHP(PW10,HW10)
TW10=TWHP(RW10,HW10)
%DRY3=AUX(24)
TW8=TMET(HM8)

RDP=SQR(RW10*(PW10-AUX(21)))

GASSYS

QG8=CG8*(TGA8**4-TM8**4)
TG7=TG1(HG7)
TG0=TG2(HG8)

F(SC)=(HG7-QG8/WG6-HG8)*WG6*CTG8
F(SC+1)=(.5*(TG7+TG8)-TGA8)*WG6*CTG8

SEED EXTRACTION

---NOT CALCUALTED---

LOWER SEED CONDENSER

BOILSYS

WW6=RDP*VA(VANUM1)

TW16=AUX(8)
IF(HW16 .LT. AUX(6)) TW16=TWHP(RW10,HW16)
QW16 = CW8*(1.-.95*%DRY3)*(TM8-.5*(TW10+TW16))**3
HW16 = HW10 + QW16/WW6

F(SC+2) = (QG8*EF8 - QW16) / CM8
```
The transducer section is used to assign local variable values to the transducer array which is accessed by the control module. An example of transducer assignment is seen below.

```
TRANS(6)=TG8
```

Next is the companion set of transfers to the input-node assignments described above, the output-node assignments. The structure of the area is the same as the input-nodes, but with the roles of input and output reversed.

```
OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

N(MGAS2,1)=0.0
N(MGAS2,2)=HG8
N(MGAS2,3)=WG61

MAIN WATER OUT

N(MWATER2,1)=PW16
N(MWATER2,2)=HW16
N(MWATER2,3)=WW6

SEED OUT

---NOT CALCULATED---

INPUT NODE OUTPUTS
```
The output variable assignment section (below) is used to assign local variables to output array elements for processing by the output module.

```
OUTPUT VARIABLE ASSIGNMENTS
OUT(23)=TGB
```

The final section in a component module is the updating of the state-variable. The subscript SC serves as a counter specifying which elements in the state and differential arrays belong to which differential equation and which local state-variable. As is shown below, there are three differential equations in a module, there are three to the state-variable counter at the end of the module. This section, along with the RETURN and END statements, conclude the description of a component module.
Control Module

The purpose of a control module is to interpret the various incoming information from the transducers to process valve dynamics, and to send out appropriate valve areas to the component module's control points. The physical layout of a control module follows. Those elements not described are similar to the corresponding elements in the component module description.

1. Subroutine statement - Example:
   SUBROUTINE CONTROL1
2. Common Assignments
3. Constant assignments
4. Transducer assignments - Assigns transducer array elements to local variables
5. Controller code - includes assignments to valve areas
6. Output variable assignments
7. State variable counter update

Variable Output Module

This module is used to output variables from other modules to data files for plotting or other interpretation. It is called periodically according to variables defined in the supervisory module (number of time steps between calls to output routine). The physical layout of the variable output module is as follows. Again, the elements not described
are similar to the corresponding elements above.

1. Subroutine statement - Example:  
2. Common Assignments  
3. Output variable assignments  
4. Write statements to data files

Dynamic Solution Module

This module numerically integrates the incoming differential equations and loads the integrated values into the corresponding elements in the state-variable array. This is done using a fourth order Runge-Kutta integration scheme using the following relations:

\[
Y_{i+1} = Y_i + \frac{h}{6} (K_1 + 2K_2 + 2K_3 + K_4), \\
K_1 = f(X_i, Y_i), \\
K_2 = f(X_i + \frac{1}{2}h, Y_i + \frac{1}{2}hK_1), \\
K_3 = f(X_i + \frac{1}{2}h, Y_i + \frac{1}{2}hK_2), \\
K_4 = f(X_i + h, Y_i + hK_3).
\]

The dynamics solution module also contains the timekeeping, the demand-function ramp-generation code and the call to the routine PLANT (which is described in the supervisory module description above). This completes the description of the modular modeling system. Any remaining questions concerning exact procedures for constructing modules can probably be answered by close examination of the example in Chapter III and the listing in Appendix B.
CHAPTER III

MODULAR MODELING SYSTEM EXAMPLE

In order to test the modular modeling system presented in Chapter III, a pre-existing dynamic simulation of an MHD-steam coupled power plant was converted to the modular form. The original simulation, titled System Model IV, was developed over a period of five years at Montana State University by J. Aspnes, D. Pierre, D. Rudberg, and D. Goldsworthy. A listing of the converted modular form of system model IV is shown in Appendix B.

Description of Example System

The example plant is the first conceptual designs for the national MHD Engineering Test Facility (ETF). It features an indirectly fired air preheater providing atmospheric air as oxidant at 3000F (1922 K). A non-reheat main steam turbine and a steam-driven oxidant compressor turbine are included, both of which are supplied from the drum-type main steam system at 1300 psia (8.63 MPa) and 950°F (783 K). Throttle conditions condenser pressure is assumed fixed. Nominal thermal input is 300 MW, including combustor coal input and air preheater fuel input. Electrical output is 108.0 MW with 51.5 MW MHD power and 56.5 MW main turbine-generator power at 100 percent of design. The complete plant model is built up from component and subsystem models, each of which is ultimately based on physical description of behavior. The steam plant is described by first-principle dynamic equations of physical laws.
Parameters and variables that appear in the actual plant (e.g. temperatures and pressures of steam and combustion air, mass flow rates, control valve areas, etc.) also appear in the dynamic model.

The state-variables of this model are principally mass flow rates, pressures, temperatures, and power extraction at pertinent points in the plant. The plant model is suitable for dynamic operation in the 50 percent to 110 percent range of rated electrical output, with principal limitations being the range coverable by the MHD power train (Figure 7) and the range of steam-water modeling.

![Diagram of MHD Power Train]

Figure 7. MHD Power Train

The MHD power train consists of a combustor, nozzle, channel, and diffuser, hence the acronym CNCD that will be used in the remainder of this thesis.

The MHD topping cycle model in the CNCD is non-dynamic because the time constants involved in the topping cycle are so much shorter than
those of the remainder that for all purposes of current use, it exhibits instantaneous response. The MHD topping cycle appears as a set of algebraic curvefits which are derived from a data base generated by other detailed, time-dependent models of specific MHD components (e.g., a pulverized-coal-fired combustor model, a chemical equilibrium routine for gas property predictions, a channel-diffuser design program, a steady-state energy routine for steam plants, and dynamic models of steam plant components). The CNCD has three flow-related inputs: oxidant flow, seed flow, and coal flow. Only oxidant flow is directly controlled during the test presented. Coal flow and seed flow are forced to maintain a .95 equivalence ratio with the oxidant flow and one percent seeding levels. Oxidant preheat is fixed at 1922 K.

The physical arrangement of the steam generating plant is shown in Figure 8, which displays the assumed locations of all significant steam
generator components. The gas-side heat transfer equations for these units are:

\[ Q_{\text{SECSH}} = 0.00141(\bar{T}_{\text{gas}} - \bar{T}_{\text{met}})W_{\text{gas}}^{0.6} + 0.561 \times 10^{-12}(\bar{T}_{\text{gas}}^4 - \bar{T}_{\text{met}}^4) \]

for the secondary superheater, and

\[ Q_{\text{RB}} = 3.53 \times 10^{-12}(\bar{T}_{\text{gas}}^4 - \bar{T}_{\text{met}}^4) \]
\[ Q_{\text{LTAH}} = 0.00390(\bar{T}_{\text{gas}} - \bar{T}_{\text{met}})W_{\text{gas}}^{0.6} \]
\[ Q_{\text{PRISH}} = 0.0102(\bar{T}_{\text{gas}} - \bar{T}_{\text{met}})W_{\text{gas}}^{0.6} \]
\[ Q_{\text{ECON}} = 0.0160(\bar{T}_{\text{gas}} - \bar{T}_{\text{met}})W_{\text{gas}}^{0.6} \]

for the radiant boiler, low-temperature air heater, primary superheater, and economizer, respectively.

\( \bar{T}_{\text{water}} \), \( \bar{T}_{\text{gas}} \), and \( \bar{T}_{\text{met}} \) are the average water temperatures, average gas temperatures, and average metal temperatures (°K) appropriate to each unit, while \( W_{\text{gas}} \) is gas flow in Kg/sec.

Steam/water-side heat transfer is given by the equations

\[ Q_{\text{SECSH}} = 0.00645(\bar{T}_{\text{met}} = \bar{T}_{\text{steam}})W_{\text{steam}}^{0.8} \]
\[ Q_{\text{WB}} = 1.25 \times 10^{-3}(1.0 - 0.95X_{\text{RB}})(\bar{T}_{\text{met}} - \bar{T}_{\text{water}})^3 \]
\[ Q_{\text{LTAH}} = 0.0118(\bar{T}_{\text{met}} - \bar{T}_{\text{air}})W_{\text{air}}^{0.8} \]
\[ Q_{\text{PRISH}} = 0.0221(\bar{T}_{\text{met}} - \bar{T}_{\text{steam}})W_{\text{steam}}^{0.8} \]
Where $X_{RB}$ is the steam fraction in the radiant boiler and the other symbols are self-explanatory. The coefficients of equations 1-8 incorporate emissivity, average film transfer coefficients, surface area and shape factor. Additional equations contain information on metal mass, metal specific heat, steam/water/air volume and enthalpy-temperature relations. Other heat transfer equations are found in System Model IV but the above are representative of these.

The gas path, shown in Figure 9 is the path of the combustion gas, starting at the combustor and terminating at the stack. No gas path pressure drops are calculated. Typical times in the gas stream are 60-120 msec combustor residence time and 20 msec total channel diffuser passage time. All other gas stream components are either first-principle models or are represented by time lag expressions to simulate complex-
ities beyond the scope of the problem, (e.g., characteristic mixing times for merging of turbulent gas flows). Figures 10 and 11 show the steam-water path and the air path, both with controller points shown.

Figure 10. Steam-Water Path with Control Points

Figure 11. Air Path with Control Points
Controller Structure

While an MHD-steam plant is very similar to a conventional fossil-fired steam plant, certain fundamental aspects of control possibilities and problems set them apart. The principal differences are:

- The firing rate produces immediate power through enthalpy extraction in the MHD channel, a feature not existing in conventional plants.

- Firing power is required in the form of steam to operate the air compressor drive turbine. This is about 22 to 25 percent of total steam generation in steady-state.

- Burner tilts for balancing superheat and steam generation heat transfer are absent, leaving gas recycling as the major possibility for such control.

The main flow paths and flow control points are shown in Figures 9, 10, and 11. The two most important control points (in terms of their overall effect on the plant) are the main turbine governor valve (C₃) and the air compressor turbine governor valve (C₄).

Other control points are no less significant in their effect on proper plant operation but either they have invariant set points or the range of control policies that can be applied to them is restricted. Control points such as spray attemperator, secondary air injection, and waterwall circulation are less significant in operating impact (producing secondary effects on stability) in comparison to the main turbine valve and the aircompressor valve.

Considering the needs of plant responsiveness and plant integrity, the two most important variables are net plant power output (QE₄) and
main steam pressure \( (PS_g) \). Therefore, control signals that actuate the turbine governor valves will be formed from these physical variables. The need to meet power demands is clear, especially if the plant is part of a power grid. The identification of main steam pressure as the principal integrity measure is based on the fact that without adequate steam pressure, system functions shut down. With the remainder of the plant controls operating in normal closed-loop manners (e.g., spray attemperator fixing upper limit on steam temperature, boiler feed pump control setting drum level, etc.), the simplified main control loops appear as in Figure 12.

Figure 12. Main Turbine Valve and Air Compressor Turbine Valve Control Structure, MHD-Leading when \( H_2 \) and \( H_3 \) non-zero; \( H_1 = H_4 = 0 \). MHD-Following when \( H_1 \) and \( H_4 \) non-zero; \( H_2 = H_3 = 0 \). Feed-forward may be present in either mode.
The power reference input is megawatt demand \((Q_{\text{ref}})\) and the controlled output is combined MHD-steam megawatt production \((Q_{\text{out}})\). \(P_{\text{ref}}\) is the throttle steam pressure reference, and \(P_{\text{out}}\) is the actual throttle pressure. Thus, the major loop is from \(Q_{\text{ref}}\) to \(Q_{\text{out}}\) and returning through the upper feedback path, while another loop is from \(P_{\text{ref}}\) to \(P_{\text{out}}\) and return. Plant dynamics are represented by \(G\) in which \(G_1\) and \(G_2\) embody the effects of main turbine valve area on power production and throttle pressure, respectively, while \(G_3\) and \(G_4\) represent the effects of air compressor turbine valve area on power production and throttle pressure.

Proportional-integral-derivative (PID) controllers are placed in cascade between the error signal and the pertinent turbine valve and are represented by \(H_j\), \(j = 1, 2, 3, 4\). In general form,

\[
H_j = K_j + \frac{K_{j2}}{s} + \frac{K_{j3}s}{s+a_h}.
\]

Two basic control modes are defined by the manner in which the main turbine valve and the air compressor are modulated. Figure 12 shows that three signals are used for such control: power demand \((Q_{\text{ref}})\), power error \((Q_{\text{ref}} - Q_{\text{out}})\), and throttle pressure error \((P_{\text{ref}} - P_{\text{out}})\). If power error is the signal controlling air compressor turbine valve area and throttle pressure error is the signal controlling main turbine valve area, the mode of control is labeled 'MHD-Leading', since the MHD power train leads the steam bottoming plant by responding immediately.
to power generation error, leaving the steam plant to respond more slowly to changes in throttle steam pressure. It is similar in response to conventional turbine-following control--stable with slow settling of response. Referring to Figure 12, \( H_2 \) and \( H_3 \) controllers are providing the control signals for valve actuation, while \( H_1 = H_4 = 0 \).

When the controlling signals are interchanged, i.e., when throttle pressure error controls air compressor valve area and power demand error controls main turbine valve area, the mode of control is labeled 'MHD-following'. The steam plant leads in response to the power demand, thereby dropping the throttle pressure and creating an increased firing rate signal which the air compressor governor valve (and hence the MHD power train) follows. This control is similar to conventional boiler following control--rapid response from the steam plant, higher overshoots, and tendencies toward instability.

Either control strategy may be augmented by feedforward control asserted by the power demand. When feedforward is applied, either or both turbine governor valves are driven rapidly to their nominal steady-state values corresponding to the new demand point. Controllers \( FF_1 \) and \( FF_2 \) of Figure 12 provide this action.

Results

These two control modes (MHD-leading and MHD-following) were applied to the modular system and the results compared to the original
system model IV results and seen to be very nearly the same, differing only in the least significant numerical digits. The small differences are readily attributable to a slightly different starting point at time zero. Figures 13 and 14 show graphically the response of several major plant parameters to a ramp in the reference demand (curve 1 in the upper graph in both figures).

Figure 13 shows the response of the plant under 'MHD-Leading' control. Note the slow response of the combined plant output (curve 4 in the upper graph in both figures) versus the same output under 'MHD-Following' control in Figure 14.
Figure 13. MHD-Leading Control
Figure 14. MHD-Following Control
CHAPTER IV
DISCUSSION AND CONCLUSIONS

The purpose of this investigation was to develop a top-down-structured modular modeling system for dynamic simulation of magneto-hydrodynamic (MHD) steam power plants. To accomplish this, a modular modeling methodology and form was devised. The modular form functions on two major levels: the system level of information flow between modules and the functional level within modules. The first level is the establishment of system topology through defining of interconnection between modules. The second level is the description of function within each module. The system level of information flow in the modular system has been designed to make all information transfers in the system to be under one of the following six forms:

1. Node (physical variable) transfer.
2. Transducer transfer.
4. State-variable derivative transfer.
5. Valve-area transfer.
6. Output-variable transfer.

All of the system modules in the modular modeling system are one of the following five types:

1. Supervisory module.
2. Component modules.
3. Control module.
4. Data output module.
5. Dynamic solution module.

Each of these modules performs a specific limited function and the specifics of each were described in Chapter II.
The modular system was designed with the primary goal of the system being easy to make modifications to the simulation in use at the time. The Goldsworthy program 6 used previously to the modular system was extremely difficult to modify due to the structure of the program itself. The main difficulties were:

1. The separation of a single component into several different subprograms. Thus any change in a component, such as resizing the component, required a search of several subprograms, compounding the chance of error.

2. The vast majority of the variables in the Goldsworthy model were global variables, thus a change in one variable had to be traced through the entire model to insure that all the changes were found.

3. Any changes in the number of differential equations in the model required changes in several subprograms, as each differential equation and state-variables was assigned a specific number not under program control.

4. The Goldsworthy system was not readily adaptable for use in modeling other systems due to its lack of top-down structure.

The modular modeling system was designed as an answer to the above problems. The solution to each of the problems enumerated above is listed below using the corresponding numbers.

1. All the equations concerning the physical behavior of a given component are placed in one separate program module (a component module). This allows changes in a given component to be isolated in a single subroutine thus reducing the chance for error.

2. All variables in the main section of component module subroutine can be assigned unique local names which have no effect with naming variables on other modules. This allows greater user readability of program code.
3. The modular system allows adding differential equations within the model anywhere without requiring any changes elsewhere in the system. This is accomplished by using the counter sc as described in Chapter II.

4. The modular system in its present form can be used to simulate many first-order dynamic systems by modifying the various component and control modules to suit the system to be modeled.

The modular system has been operational since April 1981 and in the many major changes in the model since then a time savings of an order of magnitude have been realized in modification and correction time. A direct comparison with Goldsworthy's model was not done due to the extreme difficulty in modifying the model so the above estimate is taken from experience and engineering judgment.

It was mentioned in the introduction that no attempt was made to optimize the modular system with respect to execution speed or compiled machine code size. Any degradation in execution speed was simply to be accepted (a degradation factor of two to three was expected). During comparison tests run on a VAX 11-780 at Montana State University, the modular system required from 1.4 to 1.6 the execution time of the Goldsworthy system. Due to the high cost of personnel in comparison to computer time, this is a very acceptable price to pay for the increased efficiency in modification. Note here however, that if a given dynamic model were complete and no further modifications were expected, it might be worthwhile to translate the model to a faster system if it were to be run many times
with no modification. There are several areas outside the scope of this thesis that warrant further investigation. The system developed in this thesis should be compared analytically with other methods of simulating comparable sized dynamic systems. This would give a better indication of the modular systems performance in relation to similar systems.

Another area that has not been investigated is whether the optimum integration algorithm for this type of modular structure is being used (a fourth order Runge-Kutta is currently in use). Comparisons between types of integration algorithms (Adams-Bashforth, Adams-Moulton, etc.) could speed system execution time with some possible loss in accuracy.
Bibliography
Bibliography


Appendix A

Plant State Initial Valves for 100% Level
This Appendix contains the Plant-state data file that the modular version of System Model IV reads in to start a run at a known point. The file contains the following variables, given in order of actual appearance in the file:

1. State-variable array.
2. Node array with the node number first.
3. The AUX array of auxiliary variables.
4. The valve-area array.

Lengths of these arrays and exact formats can be found in program MAIN in Appendix B.
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RS2
32.804829
X(46)
105.363890
HM11
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WS11
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OV23
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OV7
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KW7
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HG5
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WG2
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2024.121948
HG4
1.897676
HH4
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HG13
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Hg7     1.285344
HM7     0.164393
RS4     27.534605
X(40)    93.69166
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HW5     1.156476
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Appendix B

Modular Form of System Model IV FORTRAN Program Listing.
MAINLINE COMMAND FILE

WRITE SYSSOUTPUT "<*> MAIN LINE COMMAND FILE "<*>"

WRITE SYSSOUTPUT "<*> MODULAR SYSTEM TEST "<*>"

I/O ASSIGNS

DEBUG OUTPUT

ASSIGN SYSSOUTPUT FOR015

COMMAND FILE DATA INPUT

ASSIGN MAINDAT.DAT FOR018

DOCUMENTATION OUTPUT

ASSIGN SYSSOUTPUT FOR011

PLOT DATA FILES

ASSIGN PLOT2.DAT FOR020
ASSIGN PLOT3.DAT FOR030
ASSIGN PLOT4.DAT FOR040
ASSIGN PLOT5.DAT FOR050
ASSIGN PLOT6.DAT FOR060
ASSIGN PLOT7.DAT FOR070

STeady STATE DATA FILE

ASSIGN SS70.DAT FOR090

STeady STATE TEXT FILE

ASSIGN TEXT.DAT FOR095

LINK STATEMENTS

WRITE SYSSOUTPUT "<*> LINKING PLANT "<*>"

LINK/DEBUG MAIN,PLANT/LIBRARY

WRITE SYSSOUTPUT "<*> MAINLINE RUNNING "<*>"

SRUN MAIN

GO

EXIT

SPLOT ALL

WRITE SYSSOUTPUT "<*> MAINLINE COMPLETED "<*>"

SPURGE *.DAT
COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRAN(60)
COMMON /OUTPUT/ OUT(100)

DIMENSION RUNGE-KUTTA
DIMENSION SF(250),SS(250),ITEXT(32),IDUMTXT(32)

START OF INITIALIZATION BOOKKEEPING

CONTROL VARIABLES

T TIME
DT SIZE OF TIME STEP FOR INTEGRATION ROUTINE
TMAX TIME LIMIT OF SIMULATION
IFREQ NUMBER OF TIME STEPS BETWEEN CALLS TO OUTPUT SUB.
TCH TIME OF CHANGE TO NEW DT
DTT VALUE OF DT AFTER TCH
IFREQT VALUE OF IFREQ AFTER TCH
STARTDEM STARTING MW DEMAND
ENDDEM ENDING MW DEMAND
STARTTIME START TIME FOR RAMP
ENDTIME END TIME FOR RAMP

ISSRUN IF 0 -- NOT A STEADY STATE RUN (I.E. SS DATA NOT WRITTEN TO SS FILE AT END OF RUN)

IF 1 -- STEADY STATE RUN (I.E. SS DATA WRITTEN TO SS FILE AT END OF RUN)
*** READ IN TMAX,DT,IFREQ,TCH,DTT,IFREQ,STARTDEM,ENDDEM,STARTTIME,ENDTIME,ISSRUN

*** ALSO PRINT THEM OUT FOR DOCUMENTATION PURPOSES

NOTE: (IDUMTXT(I),I=1,32) IS A DUMMY VARIABLE TO ALLOW LABELING IN THE DATA FILE

READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,101) TMAX
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,98) TMAX
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,101) DT
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,98) DT
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,102) IFREQ
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,97) IFREQ
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,101) TCH
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,99) TCH
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,101) DT
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,99) DT
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,102) IFREQ
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,97) IFREQ
READ(10,100) (IDUMTXT(I),I=1,32)
READ(10,101) STARTDEM
WRITE (11,99) (IDUMTXT(I),I=1,32)
WRITE (11,98) STARTDEM
READ(10,100) (IDUMTXT(I),I=1,32)
READ(I0,101) ENDDEM
WRITE(11,99) (IDUMTXT(I),I=1,32)
WRITE(11,90) ENDDEM
READ(I0,100) (IDUMTXT(I),I=1,32)
READ(I0,101) STARTTIME
WRITE(11,99) (IDUMTXT(I),I=1,32)
WRITE(11,90) STARTTIME
READ(I0,103) (IDUMTXT(I),I=1,32)
READ(I0,101) ENDTIME
WRITE(11,99) (IDUMTXT(I),I=1,32)
WRITE(11,90) ENDTIME
READ(I0,100) (IDUMTXT(I),I=1,32)
READ(I0,102) ISSRUN
WRITE(11,99) (IDUMTXT(I),I=1,32)
WRITE(11,97) ISSRUN

FORMAT STATEMENTS
97 FORMAT(1X,15)
99 FORMAT(1X,32A1)
98 FORMAT(1X,F12.6)
100 FORMAT(32A1)
101 FORMAT(F12.6)
102 FORMAT(15)

CALCULATE RAMP SLOPE
SLOPE=(ENDDEM-STARTDEM)/(ENDTIME-STARTTIME)

SET NDIFF TO ABOVE THE MAXIMUM NUMBER OF DIFFERENTIAL EQUATIONS IN MODEL
NDIFF=100

SET NODES TO ABOVE THE MAXIMUM NUMBER OF NODES IN PLANT
NODES=100

READ SS DATA FILE
READ TITLE OF SS FILE FIRST
READ(90,100) (ITEXT(I),I=1,32)

DUMP LABEL TO TEXT FILE
WRITE(95,100) (ITEXT(I),I=1,32)

DO 2000 J=1,NDIFF
READ DUMMY LABEL FIRST
READ(90,100) (ITEXT(I),I=1,32)

DUMP LABEL TO TEXT FILE
WRITE(95,100) (ITEXT(I),I=1,32)

NOW READ STATE VARIABLE VALUE
READ(90,101) S(J)
2000 CONTINUE

************
INITIALIZE NODE ARRAY TO ZERO
************

DO 3000 I=1,200
DO 3000 J=1,3
N(I,J)=0.0
3000

READ INITIAL NODE VALUES FROM SS DATA FILE

DO 3500 I=1,NODES
READ(90,105) IGUMMY,N(I,J),J=1,3)
105

READ IN AUX ARRAY INITIAL VALUES
NOTE: IN LATER VERSIONS THIS WILL BE ELIMINATED

DO 4500 I=1,30
READ(90,106) AUX(1)
106

FORMAT(F15.6)
READ IN INITIAL VALVE AREAS
FROM SS DATA FILE

DO 6000 I=1,30
6000 READ(9W,106) VA(I)

SET TRANSDUCER EQUAL TO MW DEMAND
TRANS(I)=QE1

STORE TIME IN TEMPORARY VARIABLE
TT=T
STORE IFREQ IN TEMPORARY VARIABLE
ITFREQ=IFREQ
SET IFREQ=1 FOR ONE ITERATION
IFREQ=1
CALL APPROPRIATE PLANT TWICE
CALL PLANT
CALL PLANT
RESTORE IFREQ POINT
IFREQ=ITFREQ

RESTORE TIME VALUE
T=TT
CALL OUTPUT

END BOOKKEEPING INITIALIZATION

START OF DYNAMIC SOLUTION MODULE

START OF MAIN LOOP

\[ DTBY2 = DT \times 0.5 \]
\[ DTBY6 = DT / 6 \]
CONTINUE

DO 1000 ISYS = 1, IFREQ

\[ \text{IF}(T \text{.} \text{GT} \text{.} \text{STARTTIME} . \text{AND} . T \text{.} \text{LT} \text{.} \text{ENDTIME}) \text{QE1=} \text{STARTDEM}+ \]
\[ \text{SLOPE}=(T-\text{STARTTIME}) \]

SET TRANSDUCER
\[ \text{TRANS}(1) = \text{QE1} \]

CALL PLANT

RUNGE-KUTTA

90 GO TO (150, 200, 300, 400), IRUNG

150 TMP = T
DO 122 J = 1, NDIFF
\[ SS(J) = S(J) \]
\[ SF(J) = F(J) \]
122 S(J) = SS(J) + DTBY2*F(J)
T = T + DTBY2
IRUNG=2
GO TO 5
C
200 DO 233 J=1,NDIFF
SF(J) = SF(J) + 2.*F(J)
233 S(J) = SS(J) + DTBY2*F(J)
IRUNG=3
GO TO 5
C
300 DO 344 J=1,NDIFF
SF(J) = SF(J) + 2.*F(J)
344 S(J) = SS(J) + DT*F(J)
T = T + DTBY2
IRUNG=4
GO TO 5
C
400 DO 455 J=1,NDIFF
455 S(J) = SS(J) + (SF(J) + F(J))*DTBY6
IRUNG=1
T = TMP + DT
C
1000 CONTINUE
C
******END OF DYNAMIC SOLUTION******
C
OUTPUT VARIABLES
CALL OUTPUTB
C
CHECK FOR TIME TO CHANGE PARAMETERS
IF(T.LT.TCH) GOTO 60
DT=DTT
IF(REO=IFREOT
DTBY2=DTA5
DTBY6=DT6.
60 IF(T.LT.TMAX) GOTO 50
C
BEGIN BOOKKEEPING CLEAN UP
C
CHECK FOR SS RUN
IF(ISSRUN.NE.1) GOTO 199
WRITE TO SS DATA FILE

REWIND 90
REWIND 95

READ(95,100) (ITEXT(I),I=1,32)
WRITE(90,100) (ITEXT(I),I=1,32)

DO 4000 J=1,NDIFF
READ(95,100) (ITEXT(I),I=1,32)
WRITE(90,100) (ITEXT(I),I=1,32)

WRITE(90,101) S(J)
CONTINUE

WRITE TO NODE ARRAY

DO 5000 I=1,NODES
WRITE(90,105) I,(N(I,J),J=1,3)

WRITE TO AUX ARRAY

DO 5500 I=1,30
WRITE(90,106) AUX(I)

WRITE TO VALVE ARRAY

DO 6500 I=1,30
WRITE(90,106) VA(I)

END OF MAINLINE

CALL EXIT
END
SUBROUTINE PLANT

SPECIFIES THE NODE LINKAGES BETWEEN SUBROUTINES

MODULAR MODEL OF SM4

JOHN SHOVIC 3/18/81

SUBROUTINE PLANT

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SH4/ AUX(3B)
COMMON /CONTROL/ VA(3B),TRANS(6B)
COMMON /OUTPUT/ OUT(10B)

MODULAR FORM OF SYSTEM MODEL 4 BY DAN GOLDSWORTHY

RESET CURRENT STATE VARIABLE COUNTER

SC=1

PLANT CALLS

CALL SUPHT(MGAS,43,5B,MWATER,44,34,STATE,4)
CALL DSTR(MWATER,8,18,SBP,19,2B,VANUM,7,STATE,4)
CALL CNCD0(COAL,2,MGAS,1,11,SEED,3,CHNWTR,7,8,NOZWTR,5,6,CMBWTR,4,5,DIFWTR,9,10,VANUM,8,8,8,8,STATE,4)
CALL GASINJ0(MGAS,12,13,SGAS,14,VANUM,13,STATE,1)
CALL RADBOL0(MGAS,11,12,MWATER,15,6B,VANUM,9,STATE,4)
CALL COALDY0(MGAS,21,22,GBP,23,STATE,1)
CALL GASCMP0(MGAS,24,25,SHFTPWR,26,STATE,1)
CALL GASCMP1(MGAS,23,73,SHFTPWR,74,STATE,8)
CALL WTRPMP0(MWATER,18,4B,SHFTPWR,27,STATE,1)
CALL VTRMP1(MWATER,20,7,SHFTPWR,29,VANUM,12,STATE,0)
CALL VTRMP2(MWATER,30,31,SHFTPWR,32,STATE,0)
CALL GASINJ1(MGAS,13,33,SGAS,73,VANUM,14,STATE,2)
CALL SPRATM0(MWATER,34,35,HSRSPRAY,72,VANUM,2,STATE,0)
CALL MТUBO(MWATER,36,37,SHFTPWR,39,BP,38,28,VANUM,3,STATE,0)
CALL MТUB1(MWATER,65,60,SHFTPWR,26,VANUM,4,STATE,0)
CALL MТUB2(MWATER,66,69,SHFTPWR,27,VANUM,5,STATE,0)
CALL LTAH07(MGAS,42,43,MAIR,25,41,STATE,3)
CALL ECOH07(MGAS,50,21,MWATER,54,55,STATE,3)
CALL FURTIN0(MGAS,46,42,MWATER,64,58,VANUM,11,STATE,3)
CALL SDCN0(MGAS,47,46,SEED,49,MWATER,63,48,VANUM,18,STATE,3)
CALL SSHUSC0(MGAS,33,47,SHWATER,35,53,SCWATER,48,59,STATE,7)
CALL SDHIN0(MWATER,47,50,MAIR,52,48,STATE,3)
CALL MТAH07(MGAS,41,1,MAIR,51,52,STATE,0)
CALL WMLSS0(MWATER,53,67,STATE,0)
CALL WMLSS1(MWATER,71,54,STATE,1)
CALL WMLSS2(MWATER,55,45,STATE,1)
CALL WMLSS3(MWATER,56,4,STATE,1)
CALL WMLSS4(MWATER,6,57,STATE,1)
CALL DIV0(LINEIN,58,59,60,18,LINEOUT,61,STATE,0)
CALL DIV1(LINEIN,31,LINEOUT,9,15,63,64,STATE,0)
CALL DIV2(LINEIN,67,LINEOUT,36,65,66,STATE,0)
CALL DIV3(LINEIN,37,68,69,LINEOUT,78,STATE,0)
CALL DIV4(LINEIN,48,LINEOUT,71,72,STATE,0)
CALL CONTROL1
RETURN
END
**SUBROUTINE CONTROL I**
CONPIFF CONTROLLER MODULAR FORM OF SM4
JOHN C. SHOVIC 4/24/81

**SUBROUTINE CONTROL I**

**GENERAL CONTROL ROUTINE ----- JUNE, 1980**

DOUBLE PID CONTROLLERS ON MAIN TURB VALVE AND AIR COMP VALVE

SUBROUTINE TO DO CONTROL CALCULATIONS AND PROVIDE VALVE SETTINGS
RUDBERG JAN 1980

ANTI-WINDUP MODIFIED BY J EVANS 8/8/80

**COMMON ASSIGNMENTS**

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(169)

**DIMENSION CC(80),CTC(30),Y(60)**

**BLOCK DATA FOR CONTROL CONSTANTS**

--- CONTROL DATA ---

DATA CC/ 1.0, 4*0.8, 4.42, 0.1, 6.5,
S 0.001, 2.5E-04, 0., 0.17, 1.276, 0.1, 1.68, 0053,
S 0.015, 0.015, 0.0, 0.3, 0.1, 0.03, 0.0053,
S 0.016, 1.0, 0.5, 1.0, 0.8, 0.2, 0.91, 3.2E-05, 1.0,
S 0.6, 8.5, 0.01, 0.13, 6.5, 1.0, 1.8,
S 0.1, 2.74, 0.146, 0.002, 0.1, 0.14, 0.14, 3.62,
S 11.7, 3.92, 2.09, 4.6, 14.6, 4.7, 2.6, -1.0,
$S \ 0.5, 0.002, 0., 1.0, 1.0, 3*0., 16*0./$

DATA CTC/ 1.0, 2.0, 5.0, 3.333, 3.333, 2.0, 0.1, 3.333,
3.333, 1.0, 18.0, 6.0, 1.0, 2.0, 2.0, 5.0,
4*0.0, 4*0.2, 2*2.0, 4*0./

OTHER CONSTANT DATA

DATA CIN11/8.963/  
DATA CIN12/794./  
DATA CIN13/1358./  
DATA CIN14/2./  
DATA CIN15/400./

DATA CIN35/625./  
DATA CIN36/625./  
DATA CIN37/625./  
DATA CIN38/625./

CONTROL CONSTANT CONSTANTS

CC(57)=.5  
CC(60)=.002  
CC(9)=.005  
CC(10)=.00025

CONSTANTS FOR MHD FOLLOWING

CC(1)=100.0  
CC(2)=8.02  
CC(3)=.00005  
CC(4)=8.0  
CC(25)=.036  
CC(61)=1.8  
CC(62)=.5  
CC(63)=.002  
CC(64)=8.0  
DISABLE H2,H3

CC(56)=8.0  
CC(60)=8.0
TRANSDUCER ASSIGNMENTS

MV REFERENCE
OE1=TRANS(1)
T-G OUTPUT
OE2=TRANS(2)
MHD OUTPUT
OE3=TRANS(3)
TEMP AT PRI SUPERHEATER
TS2=TRANS(4)
TEMP. GAS AT SEC AIR INJ
TG5=TRANS(5)
TEMP GAS AT LOWER SEED CONDENSER
TG6=TRANS(6)
FEED WATER MASS FLOW INTO DRUM
W1=TRANS(7)
INPUT TO PRIM SUPERHEATER
WS1=TRANS(8)
LEVEL OF WATER IN DST
AUX2=TRANS(9)
TEMP OF WATER IN DST
TW24=TRANS(10)
TEMP METAL IN DIFFUSER
TM3=TRANS(11)
TEMP METAL IN RAD BOILER
TM4=TRANS(12)
TEMP METAL IN UPPER SEED CONDENSER
TM7=TRANS(13)
TEMP METAL AT SEC FURNACE
TM9=TRANS(14)
PRESSURE OF STEAM AT PRI SUPERHEATER
STATE VARIABLE ASSIGNMENTS

Y(1) = S(SC)  
Y(3) = S(SC+1)  
Y(4) = S(SC+2)  
Y(5) = S(SC+3)  
Y(7) = S(SC+4)  
Y(8) = S(SC+5)  
Y(10) = S(SC+6)  
Y(11) = S(SC+7)  
Y(12) = S(SC+8)  
Y(14) = S(SC+9)  
Y(15) = S(SC+10)  
Y(16) = S(SC+11)  
Y(17) = S(SC+12)  
Y(19) = S(SC+13)  
Y(20) = S(SC+14)  
Y(21) = S(SC+15)  
Y(22) = S(SC+16)  
Y(24) = S(SC+17)  
Y(25) = S(SC+18)  
Y(26) = S(SC+19)  
Y(27) = S(SC+20)  
Y(30) = S(SC+21)  
Y(31) = S(SC+22)  
Y(32) = S(SC+23)  
Y(34) = S(SC+24)  
Y(35) = S(SC+25)  
Y(37) = S(SC+26)  
Y(42) = S(SC+27)  
Y(43) = S(SC+28)  
Y(44) = S(SC+29)  
Y(45) = S(SC+30)  
Y(46) = S(SC+31)  
Y(49) = S(SC+32)  
Y(53) = S(SC+33)  
Y(54) = S(SC+34)
CONTROL EQUATIONS

ERROR SIGNALS

POWER GENERATION ERROR
OE4 = OE2 + OE3

THROTTLE PRESSURE ERROR
PS6 = CIN1 - PS5

MAIN TURBINE VALVE CONTROL AND DYNAMICS

PID CONTROLLER H1 (VMAIN = F(QE5))

ER = CC(1) * QE5

Y(2) = CC(2) * ER
F(SC+1) = CC(3) * ER + CC(56) * CC(58) * (CIN1 - PS5)
YD = CC(4) * CTC(2) * ER - Y(4)
F(SC+2) = CTC(2) * YD
Y(46) = Y(2) + Y(3) + YD

PID CONTROLLER H2 (VMAIN = F(PS6))

ER = CC(56) * PS6

Y(47) = CC(57) * ER
YD = CC(59) * CTC(25) * ER - Y(49)
F(SC+32) = CTC(25) * YD
Y(50) = Y(47) + YD

ANTI-WINDUP MODIFIED 4/7/81 (TO INCLUDE HIGH & LOW CASES)

IF (F(SC+1) .GT. B) .AND. (Y(6) .GE. CC(8) / CC(6)) F(SC+1) = B
IF (F(SC+31) .GT. B) .AND. (Y(6) .GE. CC(8) / CC(6)) F(SC+31) = B
IF (F(SC+1) .LT. B) .AND. (Y(6) .LE. B) F(SC+1) = B
IF (F(SC+31) .LT. B) .AND. (Y(6) .LE. B) F(SC+31) = B

VALVE FEEDFORWARD AND COMBINATION WITH PID CONTROLLERS

F(SC+3) = (CC(5) * CTC(3) * OE1 - Y(6)) * CTC(3)
Y(6) = Y(46) + Y(50) + ((OE1 / 100) * 3.1 + 1.12) / 4.1895

TURBINE VALVE SERVO DYNAMICS

F(SC+4) = (Y(6) - Y(7)) * CTC(4)
F(SC+5) = (CC(6) * Y(7) - Y(8)) * CTC(5)
TURBINE VALVE MAGNITUDE AND RATE LIMITING

IF(ABS(F(SC+5)).GT.CC(7)) F(SC+5)=SIGN(1.,F(SC+5))*CC(7)
IF(Y(8).GT.CC(8)) Y(8)=CC(8)
IF(Y(8).LT.0.0) Y(8)=0.0
VA(3)=Y(8)

AIR COMPRESSOR TURBINE VALVE CONTROL AND DYNAMICS

PID CONTROLLER H3 (VAC=F(QE5))

ER=CC(6)*QE5

Y(9)=CC(9)*ER
F(SC+6)=CC(10)*ER+CC(61)*CC(63)*(CIN11-PS5)
YD=CC(11)*CTC(6)*ER-Y(11)
F(SC+7)=CTC(6)*YD
Y(51)=Y(9)+Y(10)+YD

PID CONTROLLER H4 (VAC=F(PS6))

ER=CC(61)*PS6

Y(52)=CC(62)*ER
YD=CC(64)*CTC(26)*ER-Y(54)
F(SC+34)=CTC(26)*YD
Y(55)=Y(52)+YD

ANTI-WINDUP MODIFIED 4/5/81

(INCLUDES BOTH HIGH AND LOW CASES)
IF((F(SC+6).GT.0.0).AND.(Y(13).GE.CC(15)/CC(13)))F(SC+6)=0.0
IF((F(SC+33).LT.0.0).AND.(Y(13).LE.0.0)) F(SC+33)=0.0

VALVE FEEDFORWARD AND COMBINATION WITH PID CONTROLLER

F(SC+6)=CC(12)*CTC(7)*QE1-Y(12)*CTC(7)
Y(13)=Y(51)+Y(55)+((QE1/100.)*0.61+.6442)/1.2595

DUAL MODE CONTROLLER FOR MHD CHANNEL OUTPUT LIMITING

CMAX=188.0
IF(QE3.LT.CMAX) GO TO 48
YN=(QE3-CMAX)*0.815
Y(13)=Y(13)-YN
DUAL MODE CONTROLLER USING SWITCHING INTEGRATOR INPUT SIGNALS

CONTINUE

TURBINE VALVE SERVO DYNAMICS

\[ F(\text{SC}+6) = -0.4 \times YN \]

\[ F(\text{SC}+9) = (Y(13) - Y(14)) \times CTC(8) \]
\[ F(\text{SC}+10) = (CC(13) \times Y(14) - Y(15)) \times CTC(9) \]

TURBINE VALVE MAGNITUDE AND RATE LIMITING

\[ \text{IF} (|F(SC+9)| > CC(14)) \quad F(SC+9) = \text{SIGN}(1, F(SC+9)) \times CC(14) \]
\[ \text{IF} (Y(15) > CC(15)) \quad Y(15) = CC(15) \]
\[ \text{IF} (Y(15) < 0.0) \quad Y(15) = 0.0 \]
\[ V4(4) = Y(15) \]

SPRAY ATTEMPTERATOR CONTROL

INPUT STEAM TEMPERATURE FEEDFORWARD

\[ F(SC+1) = (CC(16) \times CTC(10) \times T2(2) - Y(16)) \times CTC(10) \]

OUTPUT STEAM TEMPERATURE PI CONTROLLER

\[ F(SC+12) = CC(18) \times (TS5 - CIN12) \]

ANTI-WINDUP MODIFIED 8/8/88

(INCLUDES HIGH AND LOW CASES) 4-7-81

\[ \text{IF} ((F(SC+12) > 0.0) \land (Y(18) \geq CC(22)/CC(19)) \quad F(SC+12) = 0.0 \]
\[ \text{IF} ((F(SC+12) < 0) \land (Y(18) \leq 0) \quad F(SC+12) = 0 \]

SUMMING OF FEEDFORWARD AND PI CONTROL

\[ Y(18) = CC(16) \times CTC(10) \times T2(2) - Y(16) + CC(17) \times (TS5 - CIN12) + Y(17) \]

ATTEMPTERATOR VALVE SERVO DYNAMICS

\[ F(SC+13) = (Y(19) - Y(19)) \times CTC(11) \]
\[ F(SC+14) = (CC(19) \times Y(19) - Y(20)) \times CTC(12) \]

ATTEMPTERATOR VALVE MAGNITUDE AND RATE LIMITING

\[ \text{IF} (|F(SC+14)| > CC(21)) \quad F(SC+14) = \text{SIGN}(1, F(SC+14)) \times CC(21) \]
\[ \text{IF} (Y(20) > CC(22)) \quad Y(20) = CC(22) \]
\[ \text{IF} (Y(20) < 0.0) \quad Y(20) = 0.0 \]
VA(2) = Y(20)

COMBUSTION GAS RECYCLE CONTROL

INPUT GAS TEMPERATURE FEEDFORWARD

\[ F(SC+15) = (CC(23) \times CTC(13) \times TS2 - Y(21)) \times CTC(13) \]

OUTPUT STEAM TEMPERATURE PI CONTROLLER

\[ F(SC+16) = CC(25) \times (-TS5 + CIN12 - 3.0) \]

ANTI-WINDUP MODIFIED 0/0/00

(INCLUDES HIGH AND LOW CASES) 4-7-81

\[ IF((F(SC+16).GT.0.0).AND.(Y(23).GE.CC(28)/CC(26))) F(SC+16)=0.0 \]
\[ IF((F(SC+16).LT.0) .AND. (Y(23) .LE. 0 ) ) ) F(SC+16)=0 \]

SUMMING OF FEEDFORWARD AND PI CONTROL

\[ Y(23) = CC(23) \times CTC(13) \times TS2 - Y(21) + CC(24) \times (-TS5 + CIN12) + Y(22) \]

GAS RECYCLE VALVE SERVO DYNAMICS

\[ F(SC+17) = (Y(23) - Y(24)) \times CTC(14) \]
\[ F(SC+18) = (CC(26) \times Y(24) - Y(25)) \times CTC(15) \]

GAS RECYCLE VALVE RATE AND MAGNITUDE LIMITING

\[ IF(ABS(F(SC+18)).GT.CC(27)) F(SC+18)=SIGN(1.,F(SC+18)) \times CC(27) \]
\[ IF(Y(25).GT.CC(20)) Y(25)=CC(20) \]
\[ IF(Y(25).LT.0.0) Y(25)=0.0 \]

VA(14) = Y(25)

BOILER FEED PUMP TURBINE VALVE CONTROL

THROTTLE STEAM PRESSURE FEEDFORWARD

\[ F(SC+19) = (CC(29) \times CTC(16) \times PS5 - Y(26)) \times CTC(16) \]

FLOWRATE DIFFERENCE PI CONTROL

\[ F(SC+20) = CC(31) \times (WV1 - WS1) \]

ANTI-WINDUP MODIFIED 0/0/00

(INCLUDES BOTH HIGH AND LOW CASES) 4-7-81

\[ IF((F(SC+20).GT.0.0).AND.(Y(29).GE.CC(37)/CC(35))) F(SC+20)=0.0 \]
\[ IF((F(SC+20).LT.0) .AND. (Y(29) .LE. 0 )) ) F(SC+20)=0 \]

DRUM LEVEL PROPORTIONAL CONTROL WITH DEADBAND

\[ Y(28) = 0.0 \]
IF(AUX4.GT.CC(32)) Y(20)=CC(34)*AUX4 - CC(32)
IF(AUX4 .LT. CC(33)) Y(20)=CC(34)*AUX4 - CC(33)

NEGATIVE SUMMING OF CONTROL SIGNALS
Y(29)=Y(2G) -CC(29)*CTC(1G)*PSS -CC(39)*WV1-WS1
\[
\theta = (Y(27) + Y(20))
\]

CONTROL VALVE SERVO DYNAMICS
F(SC+21)=(Y(29) - Y(30))*CTC(17)
F(SC+22)=(CC(35)*Y(30) - Y(31))*CTC(18)

BOILER FEEDPUHP TURBINE VALVE RATE AND MAGNITUDE LIMITING
IF(ABS(F(SC+22)).GT.CC(3G)) F(SC+22)=SIGN(1.,F(SC+22))*CC(3G)
IF(Y(31).GT.CC(37)) Y(31)=CC(37)
IF(Y(31).LT. 0.0) Y(31)=0.0
VA(5)=Y(31)

CONDENSATE FEEDPUMP VALVE CONTROL

DST LEVEL PI CONTROL
F(SC+23)=(CC(39)*CIN14 - AUX2)
Y(33)=Y(32) + CC(30)*CIN14 - AUX2

ANTI-WINDUP MODIFIED 8/8/8
INCLUDES BOTH HIGH AND LOW CASES 4-7-81
IF((F(SC+23).GT.0.0).AND.(YOG).GE.CC(47) )F(SC+23)=0.0
IF((F(SC+23).LT.0).AND.(YOG).LE.0) )F(SC+23)=0.0

CONTROL VALVE SERVO DYNAMICS
F(SC+24)=(CC(40)*Y(33) - Y(34))*CTC(19)

CFP CONTROL VALVE RATE AND MAGNITUDE LIMITING
IF(ABS(F(SC+24)).GT.CC(41)) F(SC+24)=SIGN(1.,F(SC+24))*CC(41)
IF(Y(34).GT.CC(42)) Y(34)=CC(42)
IF(Y(34).LT. 0.0) Y(34)=0.0
VA(12)=Y(34)

BLEED POINT #2 VALVE CONTROL

DST TEMPERATURE PI CONTROL
F(SC+25)=(CC(44)*CIN15 - TW24)
Y(36)=Y(35) + CC(43)*CIN15 - TW24

ANTI-WINDUP MODIFIED 8/8/8
IF((F(SC+25).GT.0.0).AND.(Y(36).GE.CC(47) )F(SC+25)=0.0
IF((F(SC+25).LT.0).AND.(Y(36).LE.0) )F(SC+25)=0.0
CONTROL VALVE SERVO DYNAMICS

F(SC+2G)=(CC(45)*Y(36) - Y(37)) * CTC(20)

VALVE RATE AND MAGNITUDE LIMITING

IF(ABS(F(SC+2G).GT.CC(46)) F(SC+2G)=SIGN(1.,F(SC+2G))*CC(46)
IF(Y(37).GT.CC(47)) Y(37)=CC(47)
IF(Y(37).LT.0.) Y(37)=0.
VA(7)=Y(37)

WATERWALL WATER VALVE CONTROL

METAL TEMPERATURE ERROR

Y(38)=2.*TH3/CIN35 - 1.
Y(39)=2.*TH4/CIN36 - 1.
Y(40)=2.*TH7/CIN37 - 1.
Y(41)=2.*TH9/CIN38 - 1.

PROPORTIONAL CONTROL AND VALVE DYNAMICS

DO 50 I=1,4
I2=I + 41
F(SC+2G+1)=(Y(I+37)*CC(I+47) - Y(I2))*CTC(I+20)

VALVE MAGNITUDE LIMITING

IF( Y(I2).GT.CC(I+51)) Y(I2)=CC(I+51)
IF( Y(I2).LT.0.) Y(I2)=0.
VA(I+7)=Y(I2)

50 CONTINUE

OUTPUT VARIABLE ASSIGNMENTS

OUT(1)=QE1
OUT(7)=VA(3)
OUT(9)=VA(4)

UPDATE STATE VARIABLE COUNTER

CONTROL CURRENTLY HAS 35 DIFFERENTIAL EQUATIONS

SC=SC+35

RETURN
END
SUBROUTINE OUTPUTS

OUTPUTS SELECTED VARIABLES TO FILES MODULAR FORM OF SM4

JOHN SHOVIC 3/17/81

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,MAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(30)
COMMON /OUTPUT/ OUT(100)

OUTPUT VARIABLE ASSIGNMENTS

OE1=OUT(1)
OE2=OUT(2)
OE3=OUT(3)
PS5=OUT(6)
VA3=OUT(7)
WS5=OUT(8)
VA4=OUT(9)
VS6=OUT(10)
TS1=OUT(11)
TS2=OUT(12)
TS3=OUT(13)
TS5=OUT(14)
WJ2=OUT(15)
PS1=OUT(16)
WS1=OUT(17)
WJ1=OUT(18)
AUX4=OUT(19)
XDRYS=OUT(20)
TG3=OUT(21)
TG4=OUT(22)
TG8=OUT(23)
WG1=OUT(24)
WG4=OUT(25)
WAS=OUT(26)
TA5=OUT(27)
AUX11=OUT(20)
TG1=OUT(29)
AUX14=OUT(39)

C QE4=QE2+QE3
C WRITE(20,500) T,OE1,OE2,OE3,OE4
C WRITE(30,500) T,PS5,VA3,WS5,VA4,WS6
C WRITE(40,500) T,TS1,TS2,TS3,TS5,WS2
C WRITE(50,500) T,PS1,WS1,WS1,AUX4,XDRYS
C WRITE(60,500) T,TG3,TG4,TG0,WS1,WS4

PCMB = AUX14 = 9.0692
WRITE(70,500) T,WS5,TAS,AUX11,TG1,PCMB

FORMAT FOR FILES

FORMAT(6E12.5)

RETURN
END
CURVE FITS FOR MODULAR SYSTEM
JOHN SHOVIC 2/10/01

FUNCTION TG1(H)
TG1=224.66+H*(1861.44-H*111.217)
RETURN
END

FUNCTION TG2(H)
TG2=382.3816+H*(908.0559-H*72.16902)
RETURN
END

FUNCTION PHEAD(W)
PHEAD =1.16176+W*(.330227-W*.4962121)
RETURN
END

FUNCTION TAIR(H)
TAIR =297.0248+H*(1003.543-H*88.19658)
RETURN
END

FUNCTION TMET(H)
TMET =298.599+H*(2177.29+H*(-1364.76+H*126.76))
RETURN
END

FUNCTION PEFF(V, O)
PEFF =-.10706+W*(.33403-W*1.67027) +
FUNCTION TWLP(H)
TWLP = 271.3844 + H*(248.6686 - H*15.3777)
RETURN
END

FUNCTION TWHP(R, H)
TWHP = 40.32403 + R*(.4294405 - R*.3950163E-03) +
S H*(210.5729 - H*3.722737 + R*.0929735E-02)
RETURN
END

FUNCTION RWHP(P, H)
RWHP = 1003.10 + P*(-.2701534 + P*.02420779) +
S H*(-47.39872 - H*127.2869 + P*.3999056)
RETURN
END

FUNCTION TSTM(R, H)
TSTM = -199.90 + R*(11.82 - R*.21803) +
S H*(31.280 + H*70.547 - R*2.449)
RETURN
END

FUNCTION PSTM(R, H)
PSTM = .74266 + R*(-.41792 - R*.98E-05) +
S H*(-.61224 + H*.13253 + R*.21908)
RETURN
END

FUNCTION HWSAT(P)
HWSAT = .3076013 + P*(.05062874 - P*.001717417)
RETURN
END

FUNCTION HSSAT(P)
HSSAT = 2.772041 + P*(.71263 - P*.001648333)
RETURN
END

FUNCTION TSAT(P)
TSAT = 433.57770 + P*(125.58754 - P*.020923)
RETURN
END

FUNCTION RSTM(P, H)
RSTM = 283.93 + P*(15.445 + P*.06487) +
S H*(-106.069 + H*38.034 - P*.02097)
RETURN
END

FUNCTION HSTRB(PL)
HSTRB = 2.2927 + PL*(.156546 + PL*.06384555)
RETURN
END

FUNCTION TSTRB(H)
TSTRB = 1241.655 + H*(-966.638 + H*244.8964)
RETURN
END

FUNCTION EFTRB(W)
EFTRB = .5 + W*(1. - .5*W)
RETURN
END
SUBROUTINE SUPHTF

SUBROUTINE SUPHTF(M GAS, MGAS1, MGAS2, M WATER, MWATER1, MWATER2, STATE, STINC)

INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CF15/13.73/
DATA CV11/.0221/
DATA CV17/.07/
DATA CM11/.685/
DATA CG11/.01018/
DATA CTG11/.0522/
DATA EF11/.99/

INPUT NODE ASSIGNMENTS

MAIN GAS INPUT
PG10=N(MGAS1,1)
NOTE: PG10 NOT CALCULATED
HG10=N(MGAS1,2)
WG71=N(MGAS1,3)

MAIN WATER(STEAM) INPUT
PS1=N(MWATER1,1)
HS1 = N(MWATER1,2)
WS1 = N(MWATER1,3)

OUTPUT NODE INPUTS

MAIN GAS OUT

PG11 = N(MGAS2,1)
NOTE: PG11 NOT CALCULATED
HG11 = N(MGAS2,2)
WG70 = N(MGAS2,3)

MAIN WATER(STEAM) OUT

PS2 = N(MWATER2,1)
HS2 = N(MWATER2,2)
WS2 = N(MWATER2,3)

PASS THROUGH ASSIGNMENTS

WG7 = W7

STATE VARIABLE ASSIGNMENTS

TGAV11 = S(SC)
RS2 = S(SC+1)
HS2 = S(SC+2)/S(SC+1)
HM11 = S(SC+3)

PRIMARY SUPERHEATER

TM11 = TMET(HM11)
WG7 = W7**.6
OG11 = CG11*(TGAV11 – TM11)*WG7
HG11 = HG10-CG11/W7
TG10 = TG2(HG10)
TG11 = TG2(HG11)

F(SC) = -.5*(TG10+TG11)-TGAV11)*WG7*CTG11

TS1 = TSTM(AUX(2B),HS1)
TS2 = TSTM(RS2, HS2)
PS2 = PSTM(RS2, HS2)
RS1 = AUX(20)

WS1 = CF15 + SORT(RS1 * (PS1 - PS2))
Q52 = CW11 = (TH11 - 0.5*(TS1 + TS2)) = WS2**0.8

F(SC-1) = (WS1 - WS2) / CV17
F(SC-2) = (WS1 * HS1 + Q52 - WS2 - HS2) / CV17
F(SC-3) = (QG11 * EF11 - Q52) / CM11

TRANSDUCERS
TRANS(4) = TS2
TRANS(15) = PS2
TRANS(8) = WS1

OUTPUT NODE ASSIGNMENTS

MAIN WATER (STEAM) OUT
N(MWATER2,1) = PS2
N(MWATER2,2) = HS2
N(MWATER2,3) = WS2

MAIN GAS OUT
N(MGAS2,1) = 0.0
N(MGAS2,2) = HG11
N(MGAS2,3) = WG7I

INPUT NODE OUTPUTS

MAIN WATER (STEAM) IN
N(MWATER1,1) = PS1
N(MWATER1,2) = HS1
N(MWATER1,3) = WS1

MAIN GAS IN
N(MGAS1,1) = 0.0
N(MGAS1,2) = HG11
N(MGAS1,3) = WG70

OUTPUT VARIABLE ASSIGNMENTS
C

OUT(12)=TS2
OUT(17)=WS1

UPDATE CURRENT STATE VARIABLE COUNTER
SUPHT# CURRENTLY HAS 4 STATE VARIABLES
SC=SC+4

RETURN
END
SUBROUTINE DST0
MODULAR FORM OF SM
JOHN SHOVIC 2/19/81

SUBROUTINE OST0(MWATER, MWATER1, MWATER2, SBP, SBP1, SBP2,
VANUM, VANUM1, STATE, STINC)
INTEGER SBP1, SBP2, VANUM, VANUM1, STATE, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(3,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM*/ AUX(30)
COMMON /CONTROL/ VAST(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CTW1/3.0/
DATA CTW3/1.5/
DATA CIN3/2345/

INPUT NODE ASSIGNMENTS

MAIN WATER INPUT

PW23=N(MWATER1,1)
HW23=N(MWATER1,2)
WW9=N(MWATER1,3)

STEAM BLEED IN POINT 1

PW25=N(SBP1,1)
HW25=N(SBP1,2)
WS18=N(SBP1,3)

STEAM BLEED IN POINT 2
PS11 = N(SBP2,1)
HS11 = N(SBP2,2)
WS11 = N(SBP2,3)

OUTPUT NODE INPUTS

MAIN WATER OUT

PW24 = N(MWATER2,1)
HW24 = N(MWATER2,2)
WW1 = N(MWATER2,3)

STATE VARIABLE ASSIGNMENTS

WS11 = S(SC)
AUX1 = S(SC + 1)
HW24 = S(SC + 2)

BLEED PT 1

HW25 = AUX23

RS11 ASSUMED CONSTANT

RS11 = 3.2468

BLEED PT 2

F(SC) = (SQRT(RS11*(PS11 - PW24))*VA(VANUM1) - WS11)*CTW3

DEAERATOR & STORAGC TANK

AUX2 = CIN3 * AUX1
TW24 = TWLP(HW24)

PW24, RW24 ASSUMED CONSTANT

RW24 = 931.000

PW24 = .3103
AUX23 = PW24
F(SC1) = (WW9 + WS18 + WS11 - WW1)/RW24
F(SC2) = (WW9*HW23 + WS18*HW25 + WS11*HS11 -
& WW1*HW24/* (RW24* AUX(1))

TRANSDUCERS

TRANS(9)=AUX(2)
TRANS(10)=TW24

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT
N(MWATER2,1)=PW24
N(MWATER2,2)=HW24
N(MWATER2,3)=WW1

INPUT NODE OUTPUTS

MAIN WATER INPUT
N(MWATER1,1)=PW23
N(MWATER1,2)=HW23
N(MWATER1,3)=WW9

STEAM BLEED IN POINT 1
N(SBP1,1)=PV23
N(SBP1,2)=HW25
N(SBP1,3)=WS10

STEAM BLEED IN POINT 2
N(SBP2,1)=PS11
N(SBP2,2)=HS11
N(SBP2,3)=WS11

UPDATE CURRENT STATE VARIABLE COUNTER
DSTG CURRENTLY HAS 4 STATE VARIABLES

SC=SC+3
RETURN
END
**SUBROUTINE CNCDZ**

MODULAR MODEL FORM OF SM4 CNCDZ

COMPLETED 2/17/81

CURVE FIT FOR CONSTANT LOAD CURRENT BY CHENG HUY JULY 1980

IMPLEMENTED 7-22-80 BY SHOVIC AND EVANS

SUBROUTINE FOR INPUT OUTPUT EQUATIONS DESCRIBING OPERATION OF

COMBUSTOR, NOZZLE, CHANNEL AND DIFFUSER(CNCD)

MODIFIED BY JE 8-6-80 INCLUDES COMB HEAT TRANSFER

**SUBROUTINE CNCDZ(COAL,COAL1,MGAS, MGAS1, MGAS2, SEED, SEED1, CHNWTR, CHNWTR1, CHNWTR2, NOZWTTR, NOZWTTR1, NOZWTTR2, CHNWTR, CHNWTR1, CHNWTR2, DIFWTR, DIFWTR1, DIFWTR2, VANUM, VANUM1, VANUM2, VANUM3, VANUM4, STATE, STINC)

**INTEGER COAL1, SEED1, CHNWTR1, CHNWTR2, NOZWTTR, NOZWTTR1, NOZWTTR2, CHNWTR, CHNWTR1, CHNWTR2, DIFWTR, DIFWTR1, DIFWTR2, VANUM, VANUM1, VANUM2, VANUM3, VANUM4, STINC

**COMMON ASSIGNMENTS**

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFRQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

**CONSTANT DATA**

DATA CV3/0.400E-03/
DATA CIN1/1.645/
DATA CIN2/0.1294/
DATA CTG1/3.00/
DATA CF7/3.071E-01/
DATA CTO7/3.0/
DATA CM3/1.885/
DATA EF1/0.98/
DATA EF2/0.96/
DATA EF3/0.98/
DATA CIN4/1.366/
DATA CIN5/1.150/
NODE ASSIGNMENTS

COAL INPUTS

AS AUX ARRAY IS ELIMINATED THIS WILL BE ACTIVATED
AUX11=I(N(COAL1,3)

MAIN GAS INPUTS

PA5=I(N(MGAS1,1))
HA5=I(N(MGAS1,2))
WA5=I(N(MGAS1,3))

SEED INPUTS

THIS WILL BE ACTIVATED AS THE AUX ARRAY IS ELIMINATED
AUX12=I(N(SEED1,3))

CHANNEL WATER INPUTS

INPUTS

PW22=I(N(CHNWTR1,1))
HW22=I(N(CHNWTR1,2))
WW21=I(N(CHNWTR1,3))

NOZZLE WATER

INPUTS

PW7=I(N(NOZWTR1,1))
HW7=I(N(NOZWTR1,2))
WW1=I(N(NOZWTR1,3))

COMBUSTOR WATER INPUTS

PW6=I(N(CMBWTR1,1))
HW6=I(N(CMBWTR1,2))
WW11=I(N(CMBWTR1,3))

DIFFUSER WATER INPUTS

PW10=I(N(DIFWTR1,1))
HW10=I(N(DIFWTR1,2))
WW4=I(N(DIFWTR1,3))
OUTPUT NODE INPUTS

MAIN GAS OUTPUTS

PG3=N(MGAS2,1)
HG3=N(MGAS2,2)
WG1=N(MGAS2,3)

CHANNEL WATER OUTPUTS

PW23=N(CHNWTR2,1)
HW23=N(CHNWTR2,2)
WW20=N(CHNWTR2,3)

NOZZLE WATER OUTPUTS

PW7=N(NOZWTR2,1)
HW7=N(NOZWTR2,2)
WW10=N(NOZWTR2,3)

COMBUSTOR WATER OUTPUTS

PW17=N(CMBWTR2,1)
HW17=N(CMBWTR2,2)
WW1=N(CMBWTR2,3)

DIFFUSER WATER OUTPUTS

PW11=N(DIFWTR2,1)
HW11=N(DIFWTR2,2)
WW4=N(DIFWTR2,3)

PASS THROUGH ASSIGNMENTS

WW9=WW91
WW1=WW11
WW4=WW4

STATE VARIABLE ASSIGNMENTS

QW23=S(SC)


\[
\begin{align*}
QW7 &= S(SC+1) \\
HW7 &= S(SC+2) \\
HM3 &= S(SC+3) \\
PW23 &\text{ ASSUMED CONSTANT} \\
PW23 &= 1.034 \\
\text{VARIABLES:} & \\
& \text{COAL FLOW RATE: } AUX(11) \text{ KG/S} \\
& \text{COMBUSTOR STOICHIOMETRY: } AUX(13) \\
& \text{COMBUSTOR PRESSURE: } AUX(14) \text{ MPA, } PCMB: \text{ ATM} \\
& \text{AIR FLOW RATE: } WA5 \text{ KG/S} \\
& \text{AIR PREHEAT: } TA5 \text{ K} \\
& \text{NET MHD ELECT. POWER: } QE3 \text{ MW} \\
\text{AIR PREHEAT } TA5 &\text{ ASSUMED CONSTANT AT 1922.0 K} \\
TA5 &= 1922.0 \\
\text{COAL AND SEED FLOW RATES} & \\
& AUX(11) = CIN24*WA5 \\
& AUX(12) = CIN25*AUX(11) \\
\text{COMBINED FLOWS} & \\
& WG1 = WA5*AUX(12)+0.866*AUX(11) \\
\text{SEED AND STOICHIOMETRY} & \\
& \text{SEEDXX} = AUX(12)/(1.0*WG1) \\
& AUX(13) = 0.13*WA5/AUX(11) \\
\text{COMBUSTOR PRESSURE AND TEMPERATURE} & \\
& PCMB = 0.44623+0.467312D-1*WA5-0.191608D-3 \\
& WA5 = 0.5262D-6*WA5*WA5*WA5*AUX(14) = PCMB\times0.101325 \\
& TGX1 = 1991.2-71.8*AUX(13)+21.6*PCMB-3930.0*SEEDXX \\
& +0.35*TA5+7.16*\text{AUX}(11) \\
\text{NET MHD POWER OUTPUT} & \\
& QE3 = -6.55108+0.375122*WA5+0.07885D-2*WA5 \\
& \text{WALL HEAT LOSSES} & \\
& QNOZ = -0.968193-0.4826D-1*WA5+0.375292D-3 \\
& \text{CALCULATION BASED ON 6% LOSS OF THERMAL INPUT} & \\
\end{align*}
\]
\[ QG_1 = QNOZ \times 16.7656 \]

\[ QG_2 = 9.93793 - .87991 BD - 2 \times WA5 + .299713D - 3 \]

\[ S = WA5 \times WA5 + .94214D - 6 \times WA5 \times WA5 \]

\[ QG_3 = 11.9266 + .186144 \times WA5 - .1651D - 2 \]

\[ S = WA5 \times WA5 + .891456D - 5 \times WA5 \times WA5 \times WA5 \]

**GAS ENTHALPY LEAVING DIFFUSER**

\[ HG_3 = 1.92052 + .147609D - 1 \times WA5 - .133045D - 3 \]

\[ S = WA5 \times WA5 + .87444D - 6 \times WA5 \times WA5 \times WA5 \]

**FEEDWATER SYSTEM**

**CHANNEL COOLING**

\[ HW_23 = HW_22 + QW_23/WW_9 \]

\[ TW_23 = TWHP(HW_23) \]

\[ F(SC) = (QG_2 \times E^2 - QW_23) \times CTG_2 \]

**UNITS AND LINES OF FEEDWATER PATH**

**COMBUSTOR**

**DENSITIES AND PRESSURES**

**IN COMBUSTOR**

\[ RW_6 = RWHP(PW_6, HW_6) \]

\[ PS_7 = PW_6 - CF_7 \times (HW_6 \times WW_1)/RW_6 \]

\[ RW_7 = RWHP(PW_6, HW_7) \]

\[ TW_7 = TWHP(RW_7, HW_7) \]

\[ F(SC+1) = (QG_1 \times EF_1 - QW_7) \times CTG_1 \]

**ENTHALPIES ALONG FEEDWATER LINE**

\[ F(SC+2) = ((HW_6 - HW_7) \times WW_1 + QW_7)/(CV_7 \times RW_7) \]

**BOILING (WATERWALL) SYSTEM CALCULATIONS**

**DIFFUSER**

**GAS TEMP AT DIFFUSER**

\[ TG_3 = TG_1(HG_3) \]
RW10 = RWHP(PW10, HW10)
TW10 = THWP(RW10, HW10)
RDP = SMDP(RW10, PW10-AUX(21))
WW4 = RDP * VA(VANUM4)

TW11 = AUX(8)
DW111 = (AUX(7) - AUX(6))
XDRY1 = (HW11 - AUX(6)) * DW111
IF(HW11 < AUX(6)) XDRY1 = 0.8
IF(HW11 > AUX(6)) TW11 = THWP(RW1B, HW11)

TM3 = THETHC3
GW1 = CW2 * (1 - 0.95 * XDRY1) * (TM3 - 0.5 * (TW1B + TW11)) / 3

HW11 = HW1B + GW1 / WW4

F(SC+3) = (OG3 * EF3 - OW11) / CM3

TRANSUCERS
TRANS(3) = QE3
TRANS(11) = TM3

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUTPUTS

N(MGAS2,1) = PG3
N(MGAS2,2) = HG3
N(MGAS2,3) = WC1

CHANNEL WATER OUTPUTS

N(CHNWTRZ1,1) = PW23
N(CHNWTRZ2,1) = PW23
N(CHNWTRZ2,3) = WW91

NOZZLE WATER OUTPUTS

N(NOZWTRZ1,1) = PW7
N(NOZWTRZ2,1) = PW7
N(NOZWTRZ2,3) = WW11

COMBUSTOR WATER OUTPUTS

N(CMBWTRZ1,1) = PW7
N(CMBWTRZ2,1) = HW7
N(CMBWTRZ2,3) = WW1

DIFFUSER WATER OUTPUTS
\[ \begin{align*} 
N(DIFWTR2,1) & = 0.0 \\
N(DIFWTR2,2) & = HW11 \\
N(DIFWTR2,3) & = WW4 \\
\end{align*} \]

**INPUT NODE OUTPUTS**

**COAL INPUTS**

AS AUX ARRAY IS ELIMINATED THIS WILL BE ACTIVATED
\[ N(COAL1,1) = AUX11 \]

**MAIN GAS INPUTS**

\[ \begin{align*} 
N(MGAS1,1) & = PA5 \\
N(MGAS1,2) & = HA5 \\
N(MGAS1,3) & = WA5 \\
\end{align*} \]

**SEED INPUTS**

THIS WILL BE ACTIVATED AS AUX ARRAY IS ELIMINATED
\[ N(SEED1,3) = AUX12 \]

**CHANNEL WATER INPUTS**

\[ \begin{align*} 
N(CHNWTR1,1) & = PW22 \\
N(CHNWTR1,2) & = HW22 \\
N(CHNWTR1,3) & = WW90 \\
\end{align*} \]

**NOZZLE WATER INPUTS**

\[ \begin{align*} 
N(NOZWTR1,1) & = PW7 \\
N(NOZWTR1,2) & = HW7 \\
N(NOZWTR1,3) & = WW1 \\
\end{align*} \]

**COMBUSTOR WATER INPUTS**

\[ \begin{align*} 
N(CMBWTR1,1) & = PW6 \\
N(CMBWTR1,2) & = HW6 \\
N(CMBWTR1,3) & = WW10 \\
\end{align*} \]

**DIFFUSER WATER INPUTS**

\[ \begin{align*} 
N(DIFWTR1,1) & = PW18 \\
N(DIFWTR1,2) & = HW18 \\
N(DIFWTR1,3) & = WW4 \\
\end{align*} \]
OUTPUT VARIABLE ASSIGNMENTS

OUT(3) = QE3
OUT(21) = TG3
OUT(24) = WC1
OUT(28) = AUX(11)
OUT(29) = TGX1
OUT(30) = AUX(14)

UPDATE CURRENT STATE VARIABLE COUNTER

CNCD10 CURRENTLY HAS 4 DIFFERENTIAL EQUATIONS
SC = SC + 4

RETURN
END
SUBROUTINE GASINJ0

MODULAR FORM OF SM4

JOHN SHOVIC 2/28/81

SUBROUTINE GASINJ0(MGAS, MGAS1, MGAS2, SGAS, SGAS1, VANUM, VANUM1, STATE, STINC)

INTEGER SGAS1, VANUM1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(30)
COMMON /OUTPUT/ OUT(180)

CONSTANT DATA

DATA CTG5/6./

INPUT NODE ASSIGNMENTS

MAIN GAS
NOTE : PG4 NOT CALCULATED
PG4=N(MGAS1,1)
HG4=N(MGAS1,2)
WG2=N(MGAS1,3)

SECONDARY AIR INPUT
PAS=N(SGAS1,1)
HAS=N(SGAS1,2)
WAS=N(SGAS1,3)

OUTPUT NODE INPUT

MAIN GAS OUTPUT
PG5=N(MGAS2, 1)
HG5=N(MGAS2, 2)
WG3=N(MGAS2, 3)

STATE VARIABLE ASSIGNMENTS

HG5=S(SC)

PA6 ASSUMED CONSTANT
PA6=0.0

SECONDARY AIR

HA6=.4150
TAG=TAIR(HA6)
WAG=.9232*(AUX(10)-AUX(9))*WG2
WG3=WG2+WA6
TG5=TAG(HG5)

F(SC)=(((HG4+.1689)*WG2+HA6+WA6)/WG3-HG5)*CTG5

TRANSUDERS

TRANS(5)=TG5

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUTPUT
N(MGAS2,1)=0.0
N(MGAS2,2)=HG5
N(MGAS2,3)=WG3

INPUT NODE OUTPUT

MAIN GAS INPUT
N(MGAS1,1)=0.0
N(MGAS1,2)=HG4
N(MGAS1,3)=WG2
N(SGAS1,1)=PA6
N(SGAS1,2)=HA6
N(SGAS1,3)=WA6

UPDATE CURRENT STATE VARIABLE COUNTER

GASINJ30 CURRENTLY HAS 1 DIFFERENTIAL EQUATION
SC=SC+1

RETURN
END
SUBROUTINE RADBOLB

MODULAR FORM OF SM4

JOHN SIHOVIC 2/10/81

******************************************************************************

SUBROUTINE RADBOLB(MGAS1,MGAS2,MWATER,MWATER1,MWATER2,
                   VANUM1,VANUM2,STATE,STINC)

INTEGER VANUM1,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL M(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,THAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SHA/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CTG1/3./
DATA CTG4/.017/
DATA CV4/.00125/
DATA CM4/.9E05/
DATA EF4/.96/
DATA CG4/.359E-11/

INPUT NODE ASSIGNMENTS

MAIN GAS INPUT

PG3=N(MGAS1,1)
NOTE:PG3 IS NOT CALCULATED
HG3=N(MGAS1,2)
WG1=N(MGAS1,3)
WATER INPUT

\[ PW10 = N(M\text{WATER1}, 1) \]
\[ HW10 = N(M\text{WATER1}, 2) \]
\[ WW5 = N(M\text{WATER1}, 3) \]

OUTPUT NODE INPUTS

MAIN GAS

\[ PG4 = N(M\text{GAS2}, 1) \]
\[ HG4 = N(M\text{GAS2}, 2) \]
\[ WG4 = N(M\text{GAS2}, 3) \]

WATER OUTPUT

\[ PW12 = N(M\text{WATER2}, 1) \]
\[ HW12 = N(M\text{WATER2}, 2) \]
\[ WW5 = N(M\text{WATER2}, 3) \]

STATE VARIABLE ASSIGNMENTS

\[ WG2 = S(SC) \]
\[ TGAV4 = S(SC+1) \]
\[ HG4 = S(SC+2) \]
\[ HM4 = S(SC+3) \]

PW12 ASSUMED CONSTANT

\[ PW12 = 0.0 \]

RADIANT BOILER GAS SYSTEM

\[ TG3 = TG1(HG3) \]
\[ TG4 = TG1(HG4) \]
\[ TM4 = \text{THET}(HG4) \]
\[ OG4 = CG4*(TGAV4**4-TM4**4) \]
\[ F(SC) = (WG1-WG2)*CTG1 \]
\[ F(SC+1) = 1.5*(TG3-TG4)-TGAV4)*WG2*CTG4 \]
\[ F(SC+2) = (HG3-QG4/WG2-HG4)*WG2*CTG4 \]

RADIANT BOILER STEAM SYSTEM

\[ RW10 = RWHP(PW10, HW10) \]
\[ TW10 = TWHP(RW10, HW10) \]
\[ RDP = \text{SCRT}(RW10*(PW10-AUX(21))) \]
WS = RDP*VA(VARUN1)
TW12 = AUX(0)
DHWS1 = 1./(AUX(7)-AUX(6))
XDRY2 = (HW12 - AUX(6)) * DHWS1
IF (HW12.LT.AUX(6)) TW12 = THWP(RW18, HW12)
IF (HW12.LT.AUX(6)) XDRY2 = 0.0
QV12 = CV4*(1.-95*XDRY2)*(TM4-.5*(TW10+TW12))**3
HW12 = HW10 + QV12/WS

C 68 F(SC+3) = (OG4 * EF4 - OV12) / CM4

TRANSUCERS
TRANS(12) = TM4

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUTPUT

N(MGAS2,1)=I 0.0
N(MGAS2,2)=HG4
N(MGAS2,3)=WG2

WATER OUTPUT

N(MWATER2,1)=PW12
N(MWATER2,2)=HW12
N(MWATER2,3)=WS

INPUT NODE OUTPUTS

MAIN GAS INPUT

N(MGAS1,1)=I 0.0
N(MGAS1,2)=HG3
N(MGAS1,3)=WG1

MAIN WATER INPUT

N(MWATER1,1)=PW10
N(MWATER1,2)=HW10
N(MWATER1,3)=WS

OUTPUT VARIABLE ASSIGNMENTS

OUT(22) = TG4

UPDATE CURRENT STATE VARIABLE COUNTER
RADDLOB CURRENTLY HAS 4 STATE VARIABLES
SC = SC+4

RETURN
END
SUBROUTINE COALDY$F
MODULAR FORM OF SM4
JOHN SHOVIC 2/20/81

SUBROUTINE COALDY$(MGAS, MGAS1, MGAS2, GBP, GBP1, STATE, STINC)
INTEGER GBP1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TM, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CTG13/.006/

INPUT NODE ASSIGNMENTS

MAIN GAS INPUTS

PG12=N(MGAS1, 1)
NOTE: PG12 NOT CALCULATED
HG12=N(MGAS1, 2)
WG71=N(MGAS1, 3)

OUTPUT NODE INPUTS

MAIN GAS OUTPUT

PG13=N(MGAS2, 1)
HG13=N(MGAS2, 2)
WG70=N(MGAS2, 3)

GAS BLEED OUTPUT
C
PG14=N(GBP1,1)
NOTE: PG14 NOT CALCULATED
HG14=N(GBP1,2)
WG4=N(GBP1,3)

PASS THROUGH ASSIGNMENTS
WG7=WG7I

STATE VARIABLE ASSIGNMENT
HG13=S(SC)

COAL DRYING
TG13=TG2(HG13)
F(SC)*=((0.76*AUX(11))/WG7-HG13)*CTG13

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUTPUTS
N(MGAS2,1)=0.8
N(MGAS2,2)=HG13
N(MGAS2,3)=WG7I

GAS BLEED OUT
N(GBP1,1)=0.8
N(GBP1,2)=HG14
N(GBP1,3)=WG4

INPUT NODE OUTPUT

MAIN GAS INPUTS
N(MGAS1,1)=0.8
N(MGAS1,2)=HG12
N(MGAS1,3)=WG70

UPDATE CURRENT STATE VARIABLE COUNTER
COALDYYB CURRENTLY HAS ON STATE VARIABLE
SC=SC+1

RETURN
END
SUBROUTINE GASCMP0
MAIN AIR COMPRESSOR MOD FORM OF SM4
JOHN SHOVIC 2/20/81

SUBROUTINE GASCMP0(MGAS,MGAS1,MGAS2,SHFTPWR,SHFTPWR1,STATE,STINC)
INTEGER SHFTPWR1,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CIN19,.05385/
DATA CTW6/.2/

INPUT NODE ASSIGNMENT

MAIN GAS IN
PA1=N(MGAS1,1)
HA1=N(MGAS1,2)
WA1=N(MGAS1,3)

SHAFT POWER IN

THIS STATEMENT WILL BE ACTIVATE AS AUX IS ELIMINATED
AUXT7=N(SHFTPWR1,1)
OUTPUT NODE INPUTS

MAIN GAS OUT

PA2=N(MGAS2,1)
HA2=N(MGAS2,2)
WAS=N(MGAS2,3)

STATE VARIABLE ASSIGNMENT

WAS=S(SC)

COMPRESSOR

PA1=0.1818
PA2=0.6558

QSHN = AUX(17) * CIN19
QEFF = 0.3 + QSHN * (1.4 - 0.7*QSHN)
WA2 = AUX(17) * 4.2 * QEFF
QA2 = AUX(17)
HA2 = HA1 + QA2 / WAS
TA2 = TAIR(HA2)
F(SC) = (WA2 - WAS) * CTW6

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUTPUT (COMPRESSOR OUTPUT)

N(MGAS2,1)=PA2
N(MGAS2,2)=HA2
N(MGAS2,3)=WAS

INPUT NODE OUTPUT

MAIN GAS INPUT

N(MGAS1,1)=PA1
N(MGAS1,2)=HA1
N(MGAS1,3)=WA1

SHAFT POWER IN

THIS WILL BE ACTIVATED AS THE AUX ARRAY IS ELIMINATED
N(SHFTPWR1,1)=AUX17

OUTPUT VARIABLE ASSIGNMENTS

OUT(26)=WAS

UPDATE CURRENT STATE VARIABLE COUNTER
GASCHM CURRENTLY HAS 1 STATE VARIABLE
SC=SC+1
RETURN
END
SUBROUTINE GASCMP1
GAS RECYCLE COMPRESSOR MODULAR FORM OF SM4
JOHN SHOVIC 3/5/81

SUBROUTINE GASCMP1(MGAS,MGAS1,MGAS2,SHFTPWR,SHFTPWR1,STATE,STINC)
INTEGER STINC,SHFTPWR1

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

MAIN GAS IN

PG13=N(MGAS1,1)
NOTE: PG13 NOT CALCULATED
HG13=N(MGAS1,2)
WG41=N(MGAS1,3)

SHAFT POWER IN

NO SHAFT POWER CALCULATED

OUTPUT NODE INPUTS
MAIN GAS OUT

PG14=N(MGAS2.1)
NOTE: PG14 NOT CALCULATED
HG14=N(MGAS2.2)
WG40=N(MGAS2.3)

PASS THROUGH ASSIGNMENTS

WG4=WG4I

STATE VARIABLE ASSIGNMENT

NONE

GAS RECYCLE COMPRESSOR

HG14=HG13

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

N(MGAS2.1)=0.0
N(MGAS2.2)=HG14
N(MGAS2.3)=WG4I

INPUT NODE OUTPUTS

MAIN GAS IN

N(MGAS1.1)=0.0
N(MGAS1.2)=HG13
N(MGAS1.3)=WG40

SHAFT POWER IN

NO SHAFT POWER CALCULATED

UPDATE CURRENT STATE VARIABLE COUNTER
GASCMPI CURRENTLY HAS 8 STATE VARIABLES

RETURN
END
SUBROUTINE WTRPM0
BOILER FEED PUMP MODULAR FORM OF SM4
JOHN SHOVIC 3/6/81

SUBROUTINE WTRPM0(MWATER, MWATER1, MWATER2, SHFTPWR, SHFTPWR1, STATE, STINC)
  INTEGER SHFTPWR1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, THMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CIN4/.0111/
DATA CINS/.7902/
DATA CF1/2.505/
DATA CTW4/1.5/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PW24=N(MWATER1,1)
HW24=N(MWATER1,2)
WW1=N(MWATER1,3)

SHAFT POWER IN

AUX16=N(SHFTPWR1,1)
NOTE: THIS WILL BE ACTIVATED AS AUX ARRAY IS ELIMINTATED
OUTPUT NODE INPUTS

MAIN WATER OUT

PW1=N(MWATER2,1)
HW1=N(MWATER2,2)
WW1=N(MWATER2,3)

STATE VARIABLE ASSIGNMENT

WW1=S(SC)

BOILER FEED PUMP

RW1 ASSUMED CONSTANT

RW1=936.2004

AUX(21) IS PW9 (DRUM WATER PRESSURE)

PW9=AUX(21)

DHBFP = AUX(16)*PEFF(WW1*CIN4, AUX(16)*CIN5) / WW1
PW1 = PW24 + DHBFP = RW1 * 1.8147
HW1 = HW24 + DHBFP

F(SC) = (SQRT(RW1*(PW1 - PW9)) * CF1 - WW1) * CTW4

TRANSUDERS

TRANS(7)=WW1

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2,1)=PW1
N(MWATER2,2)=HW1
N(MWATER2,3)=WW1

INPUT NODE OUTPUTS
MAIN WATER IN

N(MWATER1,1)=PW24
N(MWATER1,2)=HW24
N(MWATER1,3)=WW1

SHAFT POWER IN

N(SHFTPWR1,1)=AUX16

NOTE: THIS WILL BE ACTIVATED AS AUX ARRAY IS REMOVED

OUTPUT VARIABLE ASSIGNMENTS

OUT(18)=WW1

UPDATE CURRENT STATE VARIABLE COUNTER
WTRPMP&B CURRENTLY HAS 1 STATE VARIABLE
SC=SC+1

RETURN
END
SUBROUTINE WTRPMI

CPF PUMP MODULAR FORM OF SM4
JOHN SHOVIC 3/9/81

SUBROUTINE WTRPMI(MWATER,MWATER1,MWATER2,SHFTPWR,
* SHFPWR1,VANUM,VANUM1,STATE,
* STINC)
INTEGER SHFTPWR1,VANUM1,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(30)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
DATA CIN1/1.645/
DATA CIN2/.01294/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PWZ0=N(MWATER1,1)
HW20=N(MWATER1,2)
WW9=N(MWATER1,3)

SHAFT POWER IN
NONE CALCULATED
OUTPUT NODE INPUTS

MAIN WATER OUT
PW22=N(MWATER2,1)
HW22=N(MWATER2,2)
WW9=N(MWATER2,3)

STATE VARIABLE ASSIGNMENTS
---NONE---

CFP PUMP

RW21,PW22,HW22,HW21 IS ASSUMED CONSTANT
RW21=989.000
HW21=.1962
HW22=.1962
PW22=1.5170

AUX ASSIGNMENTS
PW24=AUX(22)

PW21=PW20*CIN1*PHEAD(WW9*CIN2)
WW9=SQRT(RW21*(PW21-PW24))*VA(VANUM1)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT
N(MWATER2,1)=PW22
N(MWATER2,2)=HW22
N(MWATER2,3)=WW9

INPUT NODE OUTPUTS

MAIN WATER IN
N(MWATER1,1)=PW20
\begin{verbatim}
N(MWATER1, 2)=W20
N(MWATER1, 3)=W9

SHAFTPOWER IN
NONE

UPDATE STATE VARIABLE COUNTER
WTRPMP1 CURRENTLY HAS NO STATE VARIABLES

RETURN
END
\end{verbatim}
SUBROUTINE VTRPMP2
CIRCULATION PUMP MOLAR FORM OF SM4
JOHN SHOVIC 3/9/01

SUBROUTINE WTRPMP2(MVATER, MWATER1, MWATER2, SHFTPWR, SHFTPWR1, STATE, STINC)
INTEGER SHFTPWR1, STINC

COMMON ASSIGNMENTS
INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRENTSTATE/ SC
COMMON /NODES/ N
COMMON /S114/ AUX(38)
COMMON /CONTROL/ VA(38), TRANS(58)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
DATA CIN0/1.038/  
DATA CIN9/1.751E-02/

INPUT NODE ASSIGNMENTS
MAIN WATER IN
PW9=N(MWATER1,1)
HW9=N(MWATER1,2)
WW31=N(MWATER1,3)

SHAFT POWER IN
NONE CALCULATED

OUTPUT NODE INPUTS
MAIN WATER OUT
PW10 = N(MWATER2,1)  
HW10 = N(MWATER2,2)  
WW30 = N(MWATER2,3)

PASS THROUGH ASSIGNMENTS

WW3 = WW3I

STATE VARIABLE ASSIGNMENTS

---NONE---

CIRCULATION PUMP

PW10 = PW9 + CIN8 + PHEAD(WW3 + CIN9)  
HW10 = HW9  
RW10 = RWHP(PW10, HW10)  
AUX(25) = RW10  
TW10 = TWHP(RW10, HW10)

AUX(27) = HW10

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2,1) = PW10  
N(MWATER2,2) = HW10  
N(MWATER2,3) = WW3I

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1,1) = PW9  
N(MWATER1,2) = HW9  
N(MWATER1,3) = WW30

SHAFT POWER

NONE CALCULATED

UPDATE STATE VARIABLE COUNTER

WTRPIHP2 CURRENTLY HAS NO STATE VARIABLES

RETURN

END
SUBROUTINE GASINJ1
RECYCLED GAS INJECTION MODULAR FORM OF SM4
JOHN SHOVIC 3/9/61

* SUBROUTINE GASINJ1(MGAS,MGAS1,MGAS2,SGAS,SGAS1,
  VANUM,VANUM1,STATE,STINC)
  INTEGER SGAS1,VANUM1,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,THMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CIN21/5.9/
DATA CIN22/.0556/
DATA CIN23/.207/
DATA CTG6/6.1/
DATA CTG14/3.1/

INPUT NODE ASSIGNMENTS

MAIN GAS IN

PG5=N(MGAS1,1)
HG5=N(MGAS1,2)
WG3=N(MGAS1,3)

RECYCLED GAS INJECT

PG14=N(SGAS1,1)
HG14 = N(SGAS1,2)
WG4 = N(SGAS1,3)

OUTPUT NODE INPUTS

MAIN GAS OUTPUTS

PG6 = N(MGAS2,1)
HG6 = N(MGAS2,2)
WG5 = N(MGAS2,3)

STATE VARIABLE ASSIGNMENTS

HG6 = S(SC)
WG4 = S(SC+1)

GAS RECYCLE INJECTION

TG5 = TG1(HG5)
TG6 = TG1(HG6)
WG5 = WG3 + WG4

F(SC) = (HG5*WG3 + HG14*WG4)/WG5 - HG6)*CTG6
F(SC+1) = (VA(VANUM1)*CIN21*SORT(PHEAD(WG4*CIN22)*
CIN23-AUX(15)) - WG4)*CTG14

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

N(MGAS2,1) = PG6
N(MGAS2,2) = HG6
N(MGAS2,3) = WG5

INPUT NODE OUTPUTS

MAIN GAS IN

N(MGAS1,1) = PG5
N(MGAS1,2) = HG5
N(MGAS1,3) = WG3
RECYCLED GAS INJECTION

N(SGAS1,1)=PG14
N(SGAS1,2)=HG14
N(SGAS1,3)=WG4

OUTPUT VARIABLE ASSIGNMENTS

OUT(25)=WG4

UPDATE STATE VARIABLE COUNTER
GASINJ1 CURRENTLY HAS 2 STATE VARIABLES
SC=SC+2
RETURN
END
SUBROUTINE SRRATM
SPRAY ATTEMPERATOR MODULAR FORM OF SM4
JOHN SHOVIC 3/9/01

SUBROUTINE SPRATM(MWATER, MWATER1, MWATER2, MSPRAY, MSPRAY1, VANUM, VANUM1, STATE, STINC)
INTEGER VANUM1, STINC

COMMON ASSIGNMENTS
INTEGER SC
REAL N(200, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CUPRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(180)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS
MAIN WATER IN

PS2=N(MWATER1, 1)
HS2=N(MWATER1, 2)
WS2=N(MWATER1, 3)

MAIN SPRAY IN

PW1=N(MSPRAY1, 1)
HW1=N(MSPRAY1, 2)
WW2=N(MSPRAY1, 3)

OUTPUT NODE INPUTS
C

N(MSPRAY1,1)=PW1
N(MSPRAY1,2)=HW1
N(MSPRAY1,3)=W2

OUTPUT VARIABLE ASSIGNMENTS

OUT(13)=TS3
OUT(15)=W2

UPDATE STATE VARIABLE COUNTER
SPRATMØ CURRENTLY HAS NO STATE VARIABLES

RETURN
END
SUBROUTINE MTURB

MAIN TURBINE-GENERATOR MODULAR MODEL OF SM4

JOHN SHOVIC 3/9/81

SUBROUTINE MTURB(MWATER, MWATER1, MWATER2, SHFTPWR, SHFTPWR1, BP1, BP2, VANUM, VANUM1, STATE, STINC)

INTEGER SHFTPWR1, BP1, BP2, VANUM1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(38)
COMMON /CONTROL/ VA(38), TRANS(58)
COMMON /OUTPUT/ OUT(168)

CONSTANT DATA

DATA CIN16/.502/
DATA CIN17/.8782/
DATA CIN10/.0145/

INPUT NODE ASSIGNMENTS

MAIN STEAM IN

PSS=N(MWATER1, 1)
HSS=N(MWATER1, 2)
WSS=N(MWATER1, 3)

OUTPUT NODE INPUTS
MAIN STEAM OUT

PS12=N(MWATER2,1)
HS12=N(MWATER2,2)
NOTE FLOW RATE OUT NOT CALCULATED

SHAFT POWER OUT

NOT SENT OUT

BLEED POINT 1

PS10=N(BP1,1)
HS10=N(BP1,2)
WS10=N(BP1,3)

BLEED POINT 2

PS11=N(BP2,1)
HS11=N(BP2,2)
WS11=N(BP2,3)

STATE VARIABLE ASSIGNMENTS

---NONE---

MAIN TURBINE-GENERATOR

PS12, HS12 ASSUMED CONSTANTS

PS12=.0103
HS12=2.3170

RS5=RS3M(P55,HS5)
RDP=SOR(RS5*(PS5-PS12))

BLEED POINTS

PS10 = CIN16 = P55
PS11 = CIN17 = P55
HS10 = HSTRB( ALOG10( PS10*145.))
HS11 = HSTRB( ALOG10( PS11*145.))

TS10 = TSTRB(HS10)
TS11 = TSTRB(HS11)
OUTPUT POWER

WS5 = VA(VANUM1) * RDP

PWR = WS5*HS5 - WS18*HS18 - WS11*HS11 +

EFT = (WS18 + WS11 - WS5)*HS12

EFT = .09 * EFTRB( WS5*CIN18 )

OE2 = PWR * EFT

TRANSDUCERS

TRANS(2)=OE2

OUTPUT NODE ASSIGNMENTS

MAIN STEAM OUT

N(MWATER2,1)=PS12
N(MWATER2,2)=HS12

NOTE: MASS FLOW OUT NOT CALCULATED
N(MWATER2,3)=0.0

BLEED POINT 1

N(BP1,1)=PS10
N(BP1,2)=HS10
N(BP1,3)=WS10

BLEED POINT 2

N(BP2,1)=PS11
N(BP2,2)=HS11
N(BP2,3)=WS11

SHAFT POWER OUT

NOT SENT OUT

INPUT NODE OUTPUTS

MAIN STEAM IN

N(MWATER1,1)=PS5
N(MWATER1,2)=HS5
N(MWATER1,3)=WS5
OUTPUT VARIABLE ASSIGNMENTS

OUT(2)=OE2
OUT(8)=WS5

UPDATE STATE VARIABLE COUNTER
CURRENTLY MTURB0 HAS NO STATE VARIABLE

RETURN
END
SUBROUTINE MTURB1
AIR COMPRESSOR MODULAR FORM OF SM4
JOHN SHOVIC 3/9/81

SUBROUTINE MTURB1(MWATER,MWATER1,MWATER2,SHFTPWR,
SHFTPWR1,VANUM,VANUM1,STATE,
STINC)
INTEGER SHFTPWR1,VANUM1,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CIN28/.05/

INPUT NODE ASSIGNMENTS

MAIN STEAM IN

PS5=N(MWATER1,1)
HS5=N(MWATER1,2)
WS5=N(MWATER1,3)

OUTPUT NODE INPUTS

MAIN STEAM OUT

PS12=N(MWATER1,1)
HS12=N(MWATER1,2)
NOTE: MASS FLOW OUT NOT CALCULATED
SHAFT POWER OUT
AUX17=H(SHFTPWR1,1)
NOTE: THIS WILL BE ACTIVATED AS AUX IS ELIMINATED

STATE VARIABLE ASSIGNMENTS
---NONE---

AIR COMPRESSOR TURBINE

PS12,HS12 ASSUMED CONSTANT
PS12=.8193
HS12=2.3170

RS5=RSTM(PS5,HS5)
RDP=SQRT(RS5*(PS5-PS12))
DH=HS5-HS12

WS6 = VA(VANUM1) * RDP
EFT = .85 * EFTRB( WS6*CIN20 )
AUX(17)= DH * WS6 * EFT

OUTPUT NODE ASSIGNMENTS

MAIN STEAM OUT

N(MWATER2,1)=PS12
N(MWATER2,2)=HS12
N(MWATER2,3)=0.0

SHAFT POWER OUT

N(SHFTPWR1,1)=AUX17
NOTE: THIS WILL BE ACTIVATED AS AUX IS ELIMINATED
INPUT NODE OUTPUTS

N(MWATER1,1)=PS5
N(MWATER1,2)=HS5
N(MWATER1,3)=WS6

OUTPUT VARIABLE ASSIGNMENTS

OUT(10)=WS6

STATE VARIABLE ASSIGNMENTS
CURRENTLY MTURBI HAS NO STATE VARIABLES

RETURN
END
SUBROUTINE MTURB2
BOILER FEED PUMP TURBINE MOULAR FORM OF SM4
JOHN SHOVIC 3/9/81

SUBROUTINE MTURB2(MWATER, MWATER1, MWATER2, SHFTPWR,
* SHFTPWR1, VANUM, VANUM1, STATE,
* STINC)
INTEGER SHFTPWR1, VANUM1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(60)
COMMON /OUTPUT/ OUT(180)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

MAIN STEAM IN

PSS=N(MWATER1,1)
HSS=N(MWATER1,2)
WS7=N(MWATER1,3)

OUTPUT NODE INPUTS

MAIN STEAM OUT
PS12 = N(MWATER2,1)
HS12 = N(MWATER2,2)
NOTE: FLOW OUT IS NOT CALCULATED

SHAFT POWER OUT

AUX16 = N(SHFTPWR1,1)
NOTE: THIS WILL BE ACTIVATED AS AUX IS REMOVED

STATE VARIABLE ASSIGNMENTS

---NONE---

BOILER FEED PUMP TURBINE

PS12, HS12 ASSUMED CONSTANTS
PS12 = 0.0103
HS12 = 2.317ø

RSS = RSTM(PS5,HS5)
RDP = SQRT(RSS*(PS5-PS12))
DH = HS5-HS12

WS7 = VA(VANUM1) * RDP
AUX(16) = 0.05 * DH * WS7

OUTPUT NODE ASSIGNMENTS

MAIN STEAM OUT

N(MWATER2,1) = PS12
N(MWATER2,2) = HS12
N(MWATER2,3) = 0.0

SHAFT POWER OUT

N(SHFTPWR1,1) = AUX16
NOTE: THIS WILL BE ACTIVATED AS AUX IS ELIMINATED
INPUT NODE OUTPUTS

MAIN STEAM IN

N(MWATER1,1)=PS5
N(MWATER1,2)=HS5
N(MWATER1,3)=WS7

STATE VARIABLE ASSIGNMENTS

CURRENTLY MTURB2 HAS NO STATE VARIABLES

RETURN
END
SUBROUTINE LTAH
LOW TEMPERATURE AIR HEATER MODULAR FORM OF SM4
JOHN SHOVIC 3/9/81

* SUBROUTINE LTAH(MGAS1,MGAS2,MAIR,MAIR2,STATE,STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL H(Z30,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CG10/.003903/
DATA CTG10/.0522/
DATA CV19/1.11/
DATA CV19/5.8/
DATA EF10/.98/
DATA CM10/1.4E05/

INPUT NODE ASSIGNMENTS

MAIN GAS IN
PG9=N(MGAS1,1)
HG9=N(MGAS1,2)
WG71=N(MGAS1,3)

MAIN AIR IN
PA2=N(MAIR1,1)
HA2 = N(MAIR1,2)
WA51 = N(MAIR1,3)

OUTPUT NODE INPUTS

MAIN GAS OUT
PG10 = N(MGAS2,1)
HG10 = N(MGAS2,2)
WG70 = N(MGAS2,3)

MAIN AIR OUT
PA3 = N(MAIR2,1)
HA3 = N(MAIR2,2)
WA50 = N(MAIR2,3)

PASS THROUGH ASSIGNMENTS
WG7 = WG7I
WA5 = WA5I

STATE VARIABLE ASSIGNMENTS
TGAV10 = S(SC)
HA3 = S(SC+1)
HM10 = S(SC+2)

LOW TEMPERATURE AIR HEATER
RA3, PG10, PA3 ASSUMED CONSTANT
PG10 = 0.8
PA3 = 6210
RA3 = 3.0000

GAS SYSTEM
TA2 = TAIR(HA2)
TM10 = TEMT(HM10)
TG9 = TG2(HG9)
WGT7 = W7**.6

QG10 = CG10*(TGAV10 - TH10)*WGT7
HG10 = HG9 - QG10/W7
TG10 = TQ2(HG10)
F(SC) = (.5*(TG9+TG10) - TGAV10)*W7*CTG

AIR SYSTEM

TA3 = TAIR(HA3)
QA3 = CW18*(TM10 - .5*(TA2 + TA3)) = W2**.8
F(SC+1) = ((HA2-HA3)*W5 + QA3) / (CV19*RA3)
F(SC+2) = (QG18 * EF18 - QA3) / CM10

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

N(MGAS2,1)=PG10
N(MGAS2,2)=HG10
N(MGAS2,3)=WG71

MAIN AIR OUT

N(MAIR2,1)=PA2
N(MAIR2,2)=HA2
N(MAIR2,3)=WA51

INPUT NODE OUTPUTS

MAIN GAS IN

N(MGAS1,1)=PG9
N(MGAS1,2)=HG9
N(MGAS1,3)=WG70

MAIN AIR IN

N(MAIR1,1)=PA2
N(MAIR1,2)=HA2
N(MAIR1,3)=WA50
SUBROUTINE ECON
ECONOMIZER MODULAR FORM OF SM4
JOHN SHOVIC 3/10/81

* SUBROUTINE ECON(MGAS, MGAS1, MGAS2, MWATER, MWATER1, MWATER2, STATE, STINC)
  INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CGI 2/.016/
DATA CTG12/.0261/
DATA CW12/.0416/
DATA CV3/33.1/
DATA CF3/.44E-01/
DATA EF12/.98/
DATA CM12/1.5E05/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PW2=N(MWATER1,1)
HW2=N(MWATER1,2)
WWI=N(MWATER1,3)
MAIN GAS IN

PG11=N(MGAS1,1)
HG11=N(MGAS1,2)
WG71=N(MGAS1,3)

OUTPUT NODE INPUTS

MAIN WATER OUTPUT

PW3=N(MWATER2,1)
HW3=N(MWATER2,2)
WW10=N(MWATER2,3)

MAIN GAS OUTPUT

PG12=N(MGAS2,1)
HG12=N(MGAS2,2)
WG70=N(MGAS2,3)

PASS THROUGH ASSIGNMENTS

WG7=WG71
WW1=WW11

STATE VARIABLE ASSIGNMENTS

TGAV12=S(SC)
HM12=S(SC+1)
HW3=S(SC+2)

ECONOMIZER

WW2=WW1*2
RW2=RWHP(PV2,HW2)
PW3=PV2-CF3*WW2/RW2
RW3=RWHP(PW3,HW3)
TG11=TG2(TG11)
TM12=TMET(TM12)
TW2=TWH(RW2,HW2)
C

WG7=WG7**.6
G(12=CG12*(TGAV12-TG12)*WG7
HG12=HG11-QG12/WG7
TG12=TG21(HG12)

F(SC)=.5*(TG11+TG12)-TGAV12)*WG7*CTG12

2B

TW3 = TWHP(RW3,HW3)

Q(W3 = CW12 * (TM12 -.5*(TW3+TW2)) * WW1**.8

F(SC+1) = (OG12 = EF12 - QW3) / CM12

5B

F(SC+2) = ((HW2-HW3)*WW1 + QW3) / (CW3*RW3)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2,1)=PW3
N(MWATER2,2)=HW3
N(MWATER2,3)=WW11

MAIN GAS OUT

N(MGAS2,1)=PG12
N(MGAS2,2)=HG12
N(MGAS2,3)=WG71

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1,1)=PW2
N(MWATER1,2)=HW2
N(MWATER1,3)=WW10

MAIN GAS IN

N(MGAS1,1)=PG11
N(MGAS1,2)=HG11
N(MGAS1,3)=WG70

UPDATE CURRENT STATE VARIABLE COUNTER

ECONO CURRENTLY HAS 3 STATE VARIABLES

SC=SC+3

RETURN
END
SUBROUTINE FURNCE01
SECONDARY FURNACE MOLAR FORM OF SM4
JOHN SHOVIC 3/11/01

SUBROUTINE FURNCE01(MGAS, MGAS1, MGAS2, MWATER, 
  MWATER1, MWATER2, VANUM, 
  VANUM1, STATE, STINC)
  INTEGER VANUM, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CG9/.544E-11/
DATA CTG3/.2 /
DATA CTG9/.0251/
DATA CW9/.000314/
DATA CN9/.0005/
DATA EF9/.98/

INPUT NODE ASSIGNMENTS

MAIN GAS IN

PGG=N(MGAS1,1)
HGB=N(MGAS1,2)
WGG=N(MGAS1,3)

MAIN WATER IN
PW18=N(MWATER1,1)
HW16=N(MWATER1,2)
WV7=N(MWATER1,3)

OUTPUT NODE INPUTS

MAIN GAS OUT

PG9=N(MGAS2,1)
HG9=N(MGAS2,2)
WG7=N(MGAS2,3)

MAIN WATER OUT

PWM=M(MWATER2,1)
HW14=N(MWATER2,2)
WW7=N(MWATER2,3)

STATE VARIABLE ASSIGNMENTS

WG7=S(SC)
TGAV9=S(SC+1)
HM9=S(SC+2)

SECONDARY FURNACE

GASSYS

TM9=TMET(HM9)
QG9=CG9*(TGA9**4-TM9**4)
HG9=HG9-QG9/WG7
TG8=TG2(HG8)
TG9=HG2(TG9)
F(SC)=(WG6-WG7)*CTG3
F(SC+1)=(.5*(TG8+TG9)-TGA9)*WG7*CTG9

TW14=AUX(8)
DHWSI = 1/(AUX(7) - AUX(6))
RW10 = RWHP(PW10, HW10)
TW10 = TVHP(RW10, HW10)
RDP = SQRT(RW10*(PW10 - AUX(21)))
WW7 = RDP * VA(VANUM1)

TW14 = AUX(9)
IF(HW14 .LT. AUX(6)) TW14 = TWHP(RW10, HW14)
QW14 = C99*(1. - .95*XDRY4)*(TM9 - .5*(TW10 + TW14))**3
HW14 = HW10 + QW14/WW7

XDRY4 = (HW14 - AUX(6)) * DHWSI
IF(HW14 .GE. AUX(6)) GO TO 89
XDRY4 = 0.
S9 F(SC+2) = (QG9 * EF9 - QW14) / CM9

TRANSUCERS
TRANS(14) = TH9

OUTPUT NODE ASSIGNMENTS
MAIN GAS OUTPUT
N(MGAS2, 1) = 8.8
N(MGAS2, 2) = HG9
N(MGAS2, 3) = WG7

MAIN WATER OUTPUT
N(MWATER2, 1) = 8.8
N(MWATER2, 2) = HW14
N(MWATER2, 3) = WW7

INPUT NODE OUTPUTS
MAIN GAS INPUT
N(MGAS1, 1) = 8.8
N(MGAS1, 2) = HG8
N(MGAS1, 3) = WG6
MAIN WATER INPUT

N(MWATER1,1)=PW1\$0
N(MWATER1,2)=HW1\$0
N(MWATER1,3)=WW7

UPDATE STATE VARIABLE COUNTER

FURNCE6 CURRENTLY HAS 3 STATE VARIABLES
SC=SC+3
RETURN
END
SUBROUTINE SDCNSR0
LOWER SEED CONDENSER MODULAR FORM OF SM4
JOHN SHovic 3/12/81

SUBROUTINE SDCNSR0(MGAS, MGAS1, MGAS2, SEED, SEED1, MWATER, MWATER1, MWATER2, VANUM, VANUM1, STATE, STINC)
INTEGER SEED1, VANUM1, STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(20V,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, Tmax, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CGB/.260E-11/
DATA CTGB/.0261/
DATA CWB/.00211/
DATA EF0/1.0/
DATA CBM/.11E05/

INPUT NODE ASSIGNMENTS

MAIN GAS

PG7=N(MGAS1,1)
HG7=N(MGAS1,2)
WG61=N(MGAS1,3)

MAIN WATER IN
PW10=N(MWATER1,1)  
HW10=N(MWATER1,2)  
WG6=N(MWATER1,3)  

OUTPUT NODE INPUTS  

MAIN GAS OUT  
PG0=N(MGAS2,1)  
HG0=N(MGAS2,2)  
WG0=N(MGAS2,3)  

MAIN WATER OUT  
PW16=N(MWATER2,1)  
HW16=N(MWATER2,2)  
WG6=N(MWATER2,3)  

SEED OUT  
---NOT CALCULATED---  

PASS THROUGH ASSIGNMENTS  
WG6=WG61  

STATE VARIABLE ASSIGNMENTS  
HGB=S(SC)  
TGAV0=S(SC+1)  
HMB=S(SC+2)  

LOWER SEED COND  
RW10=RWHP(PW10,HW10)  
TW10=TWHP(RW10,HW10)  
XDRY3=AUX(24)  
TMB=TMET(HMB)  
RDP=SQRTRW10*(PW10-AUX(21)))  
GASSYS
\[
\begin{align*}
QG8 &= CG8*(TGA9B**4-TMB**4) \\
TG7 &= TG1(HG7) \\
TG8 &= TG2(HG8) \\
F(SC) &= (HG7-QG8/WG6-HGB)*WG6*CTG8 \\
F(SC+1) &= (.5*(TG7+TG8)-TGA9B)*WG6*CTG8
\end{align*}
\]

SEED EXTRACTION
---NOT CALCULATED---

LOWER SEED CONDENSER

BOILSYS

\[
\begin{align*}
WG6 &= RDP*VA(VANUM1) \\
TW16 &= AUX(0) \\
\text{IF}(HW16 \text{ LT. AUX(6)) TW16=TVHP(RW10,HW16) QW16} &= CWB^*(1-.95*XR3)^*(TM8-.5*(TW10+TW16)**3 \\
HW16 &= HW18 + QW16/WG6 \\
F(SC+2) &= (QG8 = EFB - QW16) / CM8
\end{align*}
\]

TRANSDUCERS

\[
\begin{align*}
\text{TRANS}(5) &= TG8
\end{align*}
\]

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

\[
\begin{align*}
N(MGAS2,1) &= G8 \\
N(MGAS2,2) &= HG8 \\
N(MGAS2,3) &= WG61
\end{align*}
\]

MAIN WATER OUT

\[
\begin{align*}
N(MWATER2,1) &= PV16 \\
N(MWATER2,2) &= HV16 \\
N(MWATER2,3) &= WW6
\end{align*}
\]

SEED OUT
---NOT CALCULATED---

INPUT NODE OUTPUTS

MAIN GAS IN

N(MGAS1,1)=B.0
N(MGAS1,2)=HG7
N(MGAS1,3)=WGO

MAIN WATER IN

N(MWATER1,1)=FW18
N(MWATER1,2)=HW18
N(MWATER1,3)=WOG

OUTPUT VARIABLE ASSIGNMENTS

OUT(23)=TGB

UPDATE STATE VARIABLE COUNTER

SC-SC+3

RETURN

END
SUBROUTINE SSUSC2

UPPER SKEW CONDENSER--SECONDARY SUPERHEATER MODULAR
FORM OF SM4

JOHN SHOVIC 3/12/81

SUBROUTINE SSUSC2(MGAS,MGAS1,MGAS2,SHWATER,
SHWATER1,SHWATER2,SCWATER,
SCWATER1,SCWATER2,STATE,
STINC)

INTEGER SHWATER1,SHWATER2,SCWATER1,SCWATER2,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DRT,FREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(60)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CF16/28.9/
DATA CG6/.00175/
DATA CG15/.561E-12/
DATA CG7/.257E-11/
DATA CTG2/3. /
DATA CTG7/.8261/
DATA CV7/.88425/
DATA EF7/1.0/
DATA CM7/.6E05/
DATA CW6/.80646/
DATA CV10/10./
DATA EF6/.99/
DATA CM6/1.2E05/

INPUT NODE ASSIGNMENTS
MAIN GAS IN
PG6=N(MGAS1,1)
HG6=N(MGAS1,2)
WG6=N(MGAS1,3)

UPPER SEED COND WATER IN
PV16=N(SCWATER1,1)
HW16=N(SCWATER1,2)
WW61=N(SCWATER1,3)

SECONDARY SUPER HEATER WATER (STEAM) IN
PS3=N(SHwater1,1)
HS3=N(SHwater1,2)
WS3=N(SHwater1,3)

OUTPUT NODE INPUTS
MAIN GAS OUT
PG7=N(MGAS2,1)
HG7=N(MGAS2,2)
WG7=N(MGAS2,3)

SEED CONDENSER WATER OUT
PV13=N(SCWATER2,1)
HW13=N(SCWATER2,2)
WW6G=N(SCWATER2,3)

SECONDARY SUPER HEATER WATER (STEAM) OUT
PS4=N(SHwater2,1)
HS4=N(SHwater2,2)
WS4=N(SHwater2,3)

PASS THROUGH VARIABLE ASSIGNMENTS
WW6=WW61
STATE VARIABLE ASSIGNMENTS

\[ \begin{align*}
W_{G6} &= S(SC) \\
T_{GAV7} &= S(SC+1) \\
H_{G7} &= S(SC+2) \\
H_{M7} &= S(SC+3) \\
R_{S4} &= S(SC+4) \\
H_{S4} &= S(SC+5)/S(SC+4) \\
H_{M6} &= S(SC+6)
\end{align*} \]

\[ \begin{align*}
T_{W16} &= \text{AUX}(8) \\
X_{D3Y3} &= \text{AUX}(24) \\
R_{U18} &= \text{AUX}(25) \\
R_{S3} &= S\text{T}(RS3, HS3) \\
T_{S3} &= S\text{T}(RS3, HS3) \\
D_{HWS1} &= S\text{T}(\text{AUX}(7) - \text{AUX}(6)) \\
T_{M7} &= S\text{T}(HM7) \\
T_{H0} &= S\text{T}(HM6) \\
T_{G8} &= S(TG1(HG6))
\end{align*} \]

UPPER SEED CONDENSER

GASSYS

SEC SUPERHEATER-UPPER SEED COND

\[ \begin{align*}
T_{G7} &= T_{G1}(HG7) \\
Q_{G6} &= CG6\times(T_{GAV7}-TM6)\times(W6^*0.7)^*0.6 \\
&~+CG15\times(T_{GAV7}^**4-TM6^**4) \\
Q_{G7} &= CG7\times(T_{GAV7}^**4-TM7^**4) \\
F(SC) &= (W5-WG6)*CTG2 \\
F(SC+1) &= (-S*(T6+TG7)-TGA7V)*WG6*CTG7 \\
F(SC+2) &= (HG6-(QG6+QG7)/WG6-HG7)*WG6*CTG7
\end{align*} \]

BOILSYS

UPPER SEED CONDENSOR
TW13 = AUX(0)
IF (HW13 < AUX(6)) TW13 = TWHP(RW18, HW13)
QW13 = CW7*(1 - .95*XDRY3)*(TM7 - .5*(TW16 + TW13))**3
HW13 = HW16 + QW13/WW6

XDRY3 = (HW13 - AUX(6)) * DHWS1
IF (HW13 < AUX(6)) GO TO 7B
XDRY3 = 8.

7B F(SC+3) = (QM7 * EF7 - QW13) / CM7
AUX(24) = XDRY3
STMSYS

SECONDARY SUPERHEATER
AUX(26) = RS4

TS4 = TSTM(RS4, HS4)
PS4 = PSTHM(RS4, HS4)
WS3 = CF16 * SQRT(RS4 - (PS4 - PS3))
QS4 = CV6 * (TM6 - .5*(TS3 + TS4)) = WS4**.8

F(SC+4) = (WS2 - WS4) / CV18
F(SC+5) = (WS3 - HS3 + QS4 - WS4 * HS4) / CV18
F(SC+6) = (QM6 * EF6 - QS4) / CM6

TRANS(13) = TM7

OUTPUT NODE ASSIGNMENTS

MAIN GAS OUT

N(MGAS2,1) = 8.8
N(MGAS2,2) = HG7
N(MGAS2,3) = WG6

SEED CONDENSER WATER OUT

N(SCWATER2,1) = PW13
N(SCWATER2,2) = HW13
\[ N(\text{SCWATER}_2, 3) = \text{WS4} \]

SECONDARY SUPER HEATER WATER (STEAM) OUT

\[ N(\text{SHWATER}_2, 1) = \text{PS4} \]
\[ N(\text{SHWATER}_2, 2) = \text{HS4} \]
\[ N(\text{SHWATER}_2, 3) = \text{WS4} \]

INPUT NODE OUTPUTS

MAIN GAS IN

\[ N(\text{MGAS}_1, 1) = \emptyset \emptyset \]
\[ N(\text{MGAS}_1, 2) = \text{HG6} \]
\[ N(\text{MGAS}_1, 3) = \text{WG5} \]

UPPER SEED CONDENSER WATER IN

\[ N(\text{SCWATER}_1, 1) = \text{PV16} \]
\[ N(\text{SCWATER}_1, 2) = \text{HW16} \]
\[ N(\text{SCWATER}_1, 3) = \text{WV60} \]

SECONDARY SUPER HEATER WATER (STEAM) IN

\[ N(\text{SHWATER}_1, 1) = \text{PS3} \]
\[ N(\text{SHWATER}_1, 2) = \text{HS3} \]
\[ N(\text{SHWATER}_1, 3) = \text{WS3} \]

UPDATE CURRENT STATE VARIABLE COUNTER
CURRENTLY SSHUSC# HAS 7 STATE VARIABLES
\[ \text{SC} = \text{SC} + 7 \]
RETURN
END
SUBROUTINE STMDFM
STEAM DRUM MODULAR FORM OF SM4
JOHN SHOVIC 3/12/81

SUBROUTINE STMDFM(MWATER,MWATER1,MHTWTR,MHTWTR1,
*                  MHTWTR2,WCIRC,WCIRC1,STATE,
                  STINC)
INTEGER WCIRC,STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(3B)
COMMON /CONTROL/ VA(3B),TRANS(5B)
COMMON /OUTPUT/ OUT(188)

CONSTANT DATA

DATA C1N5/.BB/
DATA C1N7/28.1/
DATA C1N18/.1/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PW0=N(MWATER1,1)
HW0=N(MWATER1,2)
WWI=N(MWATER1,3)

HOT WATER IN

PW15=N(MHTWTR1,1)
HWI5 = N(MHTWTR1,2)  
W08 = N(MHTWTR1,3)  

OUTPUT NODE INPUTS  

STEAM OUT  

PS1 = N(MHTWTR2,1)  
HS1 = N(MHTWTR2,2)  
WS1 = N(MHTWTR2,3)  

CIRCULATION WATER OUT  

PW9 = N(WCIRC1,1)  
HW9 = N(WCIRC1,2)  
WW3 = N(WCIRC1,3)  

STATE VARIABLE ASSIGNMENTS  

X41 = S(SC)  
X42 = S(SC+1)  
X43 = S(SC+2)  
X44 = S(SC+3)  

STEAM DRUM  

RS1 = X42 / AUX(3)  
HS1 = X44 / X42  
TS1 = TSTM(RS1, HS1)  
PS1 = PSTM(RS1, HS1)  

PW9 = PS1  
HW9 = X43 / X41  
RW9 = RWP(PW9, HW9)  
TW9 = TWP(RW9, HW9)  

AUX(3) = X41 / RW9  
AUX(4) = AUX(3) * CIN6  
AUX(5) = CIN7 - AUX(3)  

AUX(6) = HWSAT(PW9) * 2.255  
AUX(7) = HSSAT(PS1)  
AUX(8) = TSAT(PS1)  

RECOMBINATION & DRUM DIFF EQUATIONS
DHWSI = 1/(AUX(7) - AUX(6))
TW15 = AUX(8)
XDRYS = (HW15 - AUX(6)) * DHWSI
IF(HW15 .LT. AUX(6)) XDRYS = 0.

WW10 = CW10 * (TS1 - TW9)

XD = XDRYS
F(SC) = WW1 + WW10 - XD = WW0
F(SC+1) = XD = WW0 - VS1 - WW10
F(SC+2) = WW1*HW9 * (1 - XD)*WW0*AUX(6) - WW0*HW9 + WW10*HS1
F(SC+3) = XD = WW0 = AUX(7) - (VS1 + WW10) * HS1

AUX(20) = RS1
AUX(21) = PW9

TRANSUDCERS
TRANS(16) = AUX(4)

OUTPUT NODE ASSIGNMENTS

HOT WATER OUT

N(MHTWTR2, 1) = PS1
N(MHTWTR2, 2) = HS1
N(MHTWTR2, 3) = WS1

CIRCULATION WATER OUT

N(WCIRC1, 1) = PW9
N(WCIRC1, 2) = HW9
N(WCIRC1, 3) = WW3

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1, 1) = PW8
N(MWATER1, 2) = HW8
N(MWATER1, 3) = WW1

HOT WATER IN

N(MHTWTR1, 1) = PW15
N(MHTWTR1, 2) = HW15
N(MHTWTR1, 3) = WW8
OUTPUT VARIABLE ASSIGNMENTS

OUT(11) = TS1
OUT(16) = PS1
OUT(19) = AUX(4)
OUT(20) = XDRY5

UPDATE CURRENT STATE VARIABLE COUNTER

STMOR currently has 4 state variables
SC = SC + 4
RETURN
END
SUBROUTINE FWATE#R
FEED WATER HEATER MODULAR FORM OF SM4
JOHN SHOVIC 3/12/81

SUBROUTINE FWATE#R(MFEEDW,MFEEDW1,MFEEDW2,MWATER
                  * MATER1,MWATER2,VANUM,VANUM1,
                  STATE,STINC)
INTEGER VANUM1,STINC

COMMON ASSIGNMENTS
INTEGER SC
REAL N(20,3)
COMMON /STATE/ F(25),S(25)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(35)
COMMON /CONTROL/ VA(35),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
DATA CTW1/3.
DATA CTW2/.81/
DATA CVS/8.5/
DATA CF5/.1765/

INPUT NODE ASSIGNMENTS

MAIN FEED WATER IN
PV4=N(MFEEDW1,1)
MV4=N(MFEEDW1,2)
MW1=N(MFEEDW1,3)

BP1 STEAM IN
PS18=N(MWATER1,1)
HS10 = N(MWATER1, 2)
WS10 = N(MWATER1, 3)

OUTPUT NODE INPUTS

FEED WATER OUT

PW5 = N(MFEEDW2, 1)
HW5 = N(MFEEDW2, 2)
W10 = N(MFEEDW2, 3)

CONDENSATE OUT

PW25 = N(MWATER2, 1)
HW25 = N(MWATER2, 2)
WS10 = N(MWATER2, 3)

PASS THROUGH ASSIGNMENTS

WW1 = WW11

STATE VARIABLE ASSIGNMENTS

WS10 = S(SC)
QV5 = S(SC+1)
HW5 = S(SC+2)

FEED WATER HEATER

RW4 = RWHP(PV4, HW4)
RW25 = 818.80
PW24 = AUX122

UPDATE

WWTZ = WW11*2
PV5 = PW4 - CF5*WWTZ/RW4
RW5 = RWH(PW5, HW5)

BLEED PT 1 & FEEDWATER HEATER

HW25 = HV4

F(SC) = (SORT(RW25*(PS10-PW24))*VA(VANUM1) - WS10) * CTW1
F(SC+1) = (WS10 * (HS10 - HW25) - QV5) * CTW2

ENTHALPIES ALONG FEEDWATER LINE
\[ F(\text{SC}+2) = ((\text{HW}_4-\text{HW}_5)\times\text{WW}_1 + \text{Q}_5) / (\text{CV}_S-\text{RWS}) \]

**OUTPUT NODE ASSIGNMENTS**

**FEED WATER OUT**

\[ \begin{align*}
N(M\text{FEEDW2}, 1) &= \text{PW}_5 \\
N(M\text{FEEDW2}, 2) &= \text{HW}_5 \\
N(M\text{FEEDW2}, 3) &= \text{WW}_1 \\
\end{align*} \]

**CONDENSATE OUT**

\[ \begin{align*}
N(M\text{WATER2}, 1) &= \text{PW}_{25} \\
N(M\text{WATER2}, 2) &= \text{HW}_{25} \\
N(M\text{WATER2}, 3) &= \text{WS}_{10} \\
\end{align*} \]

**INPUT NODE OUTPUTS**

**FEED WATER IN**

\[ \begin{align*}
N(M\text{FEEDW1}, 1) &= \text{PW}_4 \\
N(M\text{FEEDW1}, 2) &= \text{HW}_4 \\
N(M\text{FEEDW1}, 3) &= \text{WW}_{10} \\
\end{align*} \]

**BPI IN**

\[ \begin{align*}
N(M\text{WATER1}, 1) &= \text{PS}_{10} \\
N(M\text{WATER1}, 2) &= \text{HS}_{10} \\
N(M\text{WATER1}, 3) &= \text{WS}_{10} \\
\end{align*} \]

**UPDATE CURRENT STATE VARIABLE COUNTER**

FWHEAT# CURRENTLY CONTAINS 3 STATE VARIABLES

\[ \text{SC} = \text{SC} + 3 \]

RETURN

END
SUBROUTINE COND0
CONDENSER MODULAR FORM OF SM4
JOHN SHOVIC 3/13/81

SUBROUTINE COND0(M WATER, MWATER1, MWATER2, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(30)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

---NONE---

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PS12=N(MWATER1,1)
HS12=N(MWATER1,2)
WS12=N(MWATER1,3)

NOTE: WS12 NOT CALCULATED

OUTPUT NODE INPUTS

PW20=N(MWATER2,1)
HW20=N(MWATER2,2)
\[ WV9 = N(\text{MWATER2,3}) \]

**STATE VARIABLE ASSIGNMENTS**

---NONE---

**CONDENSER**

\[ PW20 = 0.0103 \]
\[ HW20 = 0.1946 \]

**OUTPUT NODE ASSIGNMENTS**

**MAIN WATER OUT**

\[ N(\text{MWATER2,1}) = PW20 \]
\[ N(\text{MWATER2,2}) = HW20 \]
\[ N(\text{MWATER2,3}) = WV9 \]

**INPUT NODE OUTPUTS**

\[ N(\text{MWATER1,1}) = PS12 \]
\[ N(\text{MWATER1,2}) = HS12 \]
\[ N(\text{MWATER1,3}) = WS12 \]

**UPDATE STATE VARIABLE COUNTER**

**CONDO CURRENTLY HAS NO STATE VARIABLES**

RETURN

END
SUBROUTINE HTAH
HIGH TEMPERATURE AIR HEATER MODULAR FORM OF SM4
JOHN SHOVIC 3/13/81

SUBROUTINE HTAH(MGAS1, MGAS2, MAIR1, MAIR2, STATE, STINC)
   INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

MAIN GAS IN
PA3=N(MGAS1,1)
HA3=N(MGAS1,2)
WA3=N(MGAS1,3)

MAIN AIR IN
---NOT CALCULATED---

OUTPUT NODE INPUTS

MAIN GAS OUT
PA5=N(MGAS2,1)  
HAS=N(MGAS2,2)  
WAS0=N(MGAS2,3)  

MAIN AIR OUT  

---NOT CALCULATED---  

PASS THROUGH ASSIGNMENTS  

WAS=WASI  

STATE VARIABLE ASSIGNMENTS  

---NONE---  

HIGH TEMPERATURE AIR HEATER  

PA5=.6880  
HAS=1.8750  
TAS=1922.0  

OUTPUT NODE ASSIGNMENTS  

MAIN GAS OUT  

N(MGAS2,1)=PA5  
N(MGAS2,2)=HAS  
N(MGAS2,3)=WASI  

MAIN AIR OUT  

---NOT CALCULATED---  

INPUT NODE OUTPUTS  

MAIN GAS IN  

N(MGAS1,1)=PA3  
N(MGAS1,2)=HAS
N(MGAS1,3)=WASO

MAIN AIR OUT
---NOT CALCULATED---

OUTPUT VARIABLE ASSIGNMENTS

OUT(27)=TAS

UPDATE STATE VARIABLE COUNTER
HTAHO CURRENTLY HAS 8 STATE VARIABLES

RETURN
END
SUBROUTINE WLNLSS0
TRANSPORT LINE TO TURBINES MODULAR FORM OF SM4
JOHN SHOVIC 3/13/81

SUBROUTINE WLNLSS0(MWATER,MWATER1,MWATER2,STATE,STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CF17/.939E-03/

INPUT NODE ASSIGNMENTS

MAIN STEAM IN
PS4=N(MWATER1,1)
HS4=N(MWATER1,2)
WS41=N(MWATER1,3)

OUTPUT NODE ASSIGNMENTS

PS5=N(MWATER2,1)
HS5=N(MWATER2,2)
WS40=N(MWATER2,3)

PASS THROUGH ASSIGNMENTS
WS4=WS41

STATE VARIABLE ASSIGNMENTS
---NONE---

TRANSPORT LINE TO TURBINES

TRANSPORT LINE

RS4=AUX(26)
HS5 = HS4
P55 = PS4 - CF17 * WS4**2 / RS4
RS5 = RSTM(P55, HS5)
TSS = TSTM(RS5, HS5)

TRANSDUCER
TRANS(18)=TSS

OUTPUT NODE ASSIGNMENTS

MAIN STEAM OUT

N(MWATER2,1)=PS5
N(MWATER2,2)=HS5
N(MWATER2,3)=WS41

INPUT NODE OUTPUTS

MAIN STEAM IN

N(MWATER1,1)=PS4
N(MWATER1,2)=HS4
N(MWATER1,3)=WS40

OUTPUT VARIABLE ASSIGNMENTS

OUT(14)=TSS

UPDATE STATE VARIABLE COUNTER

WLNLS550 CURRENTLY HAS 0 STATE VARIABLES

RETURN
END
SUBROUTINE WLNLSSI
BFP-ECON LINE MODULAR FORM OF SM4
JOHN SHOVIC 3/13/81

SUBROUTINE WLNLSSI(MVATER, MWATER1, MWATER2, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200, 3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
DATA CV2/1.134/
DATA CF2/.3946E-02/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PW1=N(MWATER1, 1)
HW1=N(MWATER1, 2)
WW1=N(MWATER1, 3)

OUTPUT NODE INPUTS

MAIN WATER OUT

PW2=N(MWATER2, 1)
HW2=N(MWATER2, 2)
WW1O=N(MWATER2, 3)
PASS THROUGH ASSIGNMENTS

WW1 = WW11

STATE VARIABLE ASSIGNMENTS

HW2 = S(SC)

RW1 = 936.2834
QW2 = 9.8

WVT2 = WW1**2
PW2 = PW1 - CF2*WVT2/RW1
RW2 = RWHP(PW2, HW2)

F(SC) = ((HW1-HW2)*WW1+QW2)/(CV2*RW2)

TW2 = TWHP(RW2, HW2)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2,1) = PW2
N(MWATER2,2) = HW2
N(MWATER2,3) = WW11

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1,1) = PW1
N(MWATER1,2) = HW1
N(MWATER1,3) = WW10

UPDATE STATE VARIABLE COUNTER

WLQLSS1 CURRENTLY HAS 1 STATE VARIABLE

SC = SC + 1

RETURN

END
SUBROUTINE VNLSS2
ECON - FWL LINE MODULAR FORM OF SM
JOHN SHOVIC 3/13/81

SUBROUTINE VNLSS2(MWATER, MWATER1, MWATER2, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS
 INTEGER SC
 REAL N(200,3)
 COMMON /STATE/ F(250),S(250)
 COMMON /GENERAL/ T,TMAX,DT,IFREQ
 COMMON /CUK Schools/ SC
 COMMON /NODES/ N
 COMMON /N/ U/ AUX(35)
 COMMON /C/ C(35),TRANS(55)
 COMMON /OUTPUT/ OUT(180)

CONSTANT DATA
 DATA CV4/1.134/
 DATA CF4/.7079E-02/

INPUT NODE ASSIGNMENTS
 MAIN WATER IN

 PW3=N(MWATER1,1)
 HW3=N(MWATER1,2)
 WW11=N(MWATER1,3)

OUTPUT NODE INPUTS
 MAIN WATER OUT

 PW4=N(MWATER2,1)
 HW4=N(MWATER2,2)
 WW10=N(MWATER2,3)
PASS THROUGH ASSIGNMENTS

WW1 = WW11

STATE VARIABLE ASSIGNMENTS

HV4 = S(SC)

AUX(23) = HW4

QW4 = 0.0
RV3 = RWHP(PW3, HW3)

WVT2 = WW1**2
PW4 = PW3 - CF4*WVT2/RW3
RW4 = RWHP(PW4, HW4)

GW = S(SC)*((HW3-HW4)*WVT2/QW4)/(CV4*RW4)

T2/4 = TWHP(RW4, HW4)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2, 1) = PW4
N(MWATER2, 2) = HW4
N(MWATER2, 3) = WW11

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1, 1) = PW3
N(MWATER1, 2) = HW3
N(MWATER1, 3) = WW10

UPDATE STATE VARIABLE COUNTER

WLNLSSZ CURRENTLY HAS 1 STATE VARIABLE

SC = SC + 1

RETURN

END
SUBROUTINE WLNLSS3
FWH- COMBUSTOR LINE MODULAR FORM OF SM4
JOHN SHOVIC 3/13/81

SUBROUTINE WLNLSS3(MWATER, MWATER1, MWATER2, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODS/ N
COMMON /SH4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA

DATA CV6/1.890/
DATA CF6/.01017/

INPUT NODE ASSIGNMENTS

MAIN WATER IN

PW5=N(MWATER1,1)
HW5=N(MWATER1,2)
WW1I=N(MWATER1,3)

OUTPUT NODE INPUTS

MAIN WATER OUT

PW6=N(MWATER2,1)
HW6=N(MWATER2,2)
WW1O=N(MWATER2,3)
PASS THROUGH ASSIGNMENTS

WW1 = WW1

STATE VARIABLE ASSIGNMENTS

HW6 = S(SC)

OVS = 0.0

RVS = RWHP(PW5, HW5)

WWT2 = WW1 ** 2

PV6 = PV5 - CF6 * WWT2 / RV5

RW6 = RWHP(PW6, HW6)

F(SC) = ((HW5 - HW6) * WW1 + OVS) / (CV5 * RV6)

TW6 = TWHP(RW6, HW6)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2, 1) = PW6

N(MWATER2, 2) = HW6

N(MWATER2, 3) = WW1

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1, 1) = PW5

N(MWATER1, 2) = HW5

N(MWATER1, 3) = WW10

UPDATE STATE VARIABLE COUNTER

WLNLSS3 CURRENTLY HAS 1 STATE VARIABLE

SC = SC + 1

RETURN

END
**SUBROUTINE WLNLSS4**

**COMBUSTOR - DRUM LINE MODULAR FORM OF SM4**

JOHN SHOVIC 3/13/01

**SUBROUTINE WLNLSS4(MWATER,MWATER1,MWATER2,STATE,STINC)**

INTEGRAL STINC

**COMMON ASSIGNMENTS**

INTEGER SC

REAL H(250,3)

COMMON /STATE/ T(250),S(250)

COMMON /GENERAL/ T,TMAX,DT,IFREQ

COMMON /CURRSTATE/ SC

COMMON /NODES/ N

COMMON /SM*/ AUX(30)

COMMON /CONTROL/ VA(30),TRANS(50)

COMMON /OUTPUT/ OUT(100)

**CONSTANT DATA**

DATA CV8/1.890/

DATA CF8/.009016/

**INPUT NODE ASSIGNMENTS**

MAIN WATER IN

PW7= NW(MWATER1,1)

HW7= NW(MWATER1,2)

WW1= NW(MWATER1,3)

**OUTPUT NODE INPUTS**

MAIN WATER OUT

PW8= NW(MWATER2,1)

HW8= NW(MWATER2,2)

WW10= NW(MWATER2,3)
PASS THROUGH ASSIGNMENTS

WW1=WW1

STATE VARIABLE ASSIGNMENTS

HW8=SC

QW3=QW3
RW7=RWH(PW7,HW7)

WWT2=WW1=W
PW8 = PW7 - CF8*WWT2/RW7
RW8 = RWH(PW8, HW8)

F(SC) = ((HW7-HW8)*WW1+QW8)/(CVB*RW8)

TW8=TWHP(RW8,HW8)

OUTPUT NODE ASSIGNMENTS

MAIN WATER OUT

N(MWATER2,1)=PW8
N(MWATER2,2)=HW8
N(MWATER2,3)=WW11

INPUT NODE OUTPUTS

MAIN WATER IN

N(MWATER1,1)=PW7
N(MWATER1,2)=HW7
N(MWATER1,3)=WW10

UPDATE STATE VARIABLE COUNTER

WNLSS4 CURRENTLY HAS 1 STATE VARIABLE

SC=SC+1

RETURN

END
SUBROUTINE DIV0
WATER WALL RECOMBINATION
JOHN SHOVIC 3/13/81

SUBROUTINE DIV0(LINEIN, LINEIN1, LINEIN2, LINEIN3, LINEIN4,
LINEOUT, LINEOUT1, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

SECONDARY FURNACE WW INPUT

PW14 = N(LINEIN1, 1)
HW14 = N(LINEIN1, 2)
WW7 = N(LINEIN1, 3)

UPPER SEED CONDENSER WW INPUT

PW13 = N(LINEIN2, 1)
HW13 = N(LINEIN2, 2)
WW6 = N(LINEIN2, 3)
RADIANT BOILER WW INPUT

\[ \begin{align*}
p_{12} &= n(\text{LINEIN3}, 1) \\
n_{12} &= n(\text{LINEIN3}, 2) \\
w_{5} &= n(\text{LINEIN3}, 3) \\
\end{align*} \]

DIFFUSER WW INPUT

\[ \begin{align*}
p_{11} &= n(\text{LINEIN4}, 1) \\
n_{11} &= n(\text{LINEIN4}, 2) \\
w_{4} &= n(\text{LINEIN4}, 3) \\
\end{align*} \]

OUTPUT NODE INPUTS

**WW RECOMBINED FLOW OUTPUT**

\[ \begin{align*}
p_{15} &= n(\text{LINEOUTI}, 1) \\
n_{15} &= n(\text{LINEOUTI}, 2) \\
w_{8} &= n(\text{LINEOUTI}, 3) \\
\end{align*} \]

STATE VARIABLE ASSIGNMENTS

--- NONE ---

**WW RECOMBINATION**

\[ \begin{align*}
w_{8} &= w_{4} + w_{5} + w_{6} + w_{7} \\
n_{15} &= (n_{11} + n_{12} + w_{5} + w_{6} + w_{13} + w_{14} + w_{7}) / w_{8} \\
p_{15} &= 0.8 \\
\end{align*} \]

OUTPUT NODE ASSIGNMENTS

**RECOMBINED WW FLOW**

\[ \begin{align*}
n(\text{LINEOUTI}, 1) &= p_{15} \\
n(\text{LINEOUTI}, 2) &= n_{15} \\
n(\text{LINEOUTI}, 3) &= w_{8} \]
INPUT NODE OUTPUTS

SECONDARY FURNACE WW INPUT

N(LINEIN1,1)=PW14
N(LINEIN1,2)=HW14
N(LINEIN1,3)=WW7

UPPER SEED CONDENSER WW INPUT

N(LINEIN2,1)=PW13
N(LINEIN2,2)=HW13
N(LINEIN2,3)=WW6

RADIANT BOILER WW INPUT

N(LINEIN3,1)=PW12
N(LINEIN3,2)=HW12
N(LINEIN3,3)=WW6

DIFFUSER WW INPUTS

N(LINEIN4,1)=PW11
N(LINEIN4,2)=HW11
N(LINEIN4,3)=WW4

UPDATE STATE VARIABLE COUNTER

DIV0 CURRENTLY HAS 0 STATE VARIABLES

RETURN
END
SUBROUTINE DIV1
WATER WALL SPLIT
JOHN SHOVIC 3/13/81

SUBROUTINE DIV1(LINEIN,LINEIN1,LINEOUT,LINEOUT1,LINEOUT2,
LINEOUT3,LINEOUT4,STATE,STINC)
INTEGER STINC

COMMON ASSIGNMENTS
INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30),TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
DATA CTW5/1.5/

INPUT NODE ASSIGNMENTS
CIRCULATION PUMP OUTPUT
PW10I=N(LINEIN1,1)
HW10I=N(LINEIN1,2)
WW3=N(LINEIN1,3)

OUTPUT NODE INPUTS
DIFFUSER WW LINE OUTPUT

PW100 = N(LINEOUT1,1)
HV100 = N(LINEOUT1,2)
WW4 = N(LINEOUT1,3)

RADIANT BOILER WW LINE OUTPUT

PW100 = N(LINEOUT2,1)
HV100 = N(LINEOUT2,2)
WW5 = N(LINEOUT2,3)

LOWER SEED CONDENSER WW LINE OUTPUT

PW100 = N(LINEOUT3,1)
HV100 = N(LINEOUT3,2)
WW6 = N(LINEOUT3,3)

SECOND FURNACE WW LINE OUTPUT

PW100 = N(LINEOUT4,1)
HV100 = N(LINEOUT4,2)
WW7 = N(LINEOUT4,3)

PASS THROUGH ASSIGNMENTS

PW10 = PW101
HV10 = HW101

NOTE: ANY CHANGE OF PW10, HW10 DUE TO WW EFFECTS WILL NOT BE CALCULATED DUE TO THE EQUATIONS IN THIS MODULE.

STATE VARIABLE ASSIGNMENTS

WW3 = S(SC)
WWW = WW4 + WW5 + WW6 + WW7
F(SC) = (WWW - WW3) * CW5

OUTPUT NODE ASSIGNMENTS

DIFFUSER WW LINE OUTPUT
N(LINEOUT1,1)=PW10I
N(LINEOUT1,2)=HW10I
N(LINEOUT1,3)=WW4

RADIANT BOILER LINE OUTPUT

N(LINEOUT2,1)=PW10I
N(LINEOUT2,2)=HW10I
N(LINEOUT2,3)=WW5

LOWER SEED CONDENSER LINE OUTPUT

N(LINEOUT3,1)=PW10I
N(LINEOUT3,2)=HW10I
N(LINEOUT3,3)=WW6

SECONDARY FURNACE LINE OUTPUT

N(LINEOUT4,1)=PW10I
N(LINEOUT4,2)=HW10I
N(LINEOUT4,3)=WW7

INPUT NODE OUTPUTS

CIRCULATION PUMP OUTPUT INPUT

N(LINEIN1,1)=PW10O
N(LINEIN1,2)=HW10O
N(LINEIN1,3)=WW3

UPDATE STATE VARIABLE COUNTER

DIV1 CURRENTLY HAS 1 STATE VARIABLES
SC=SC+1

RETURN
END
SUBROUTINE DIV2
THROTTLE DIVERGENCE
JOHN SHOVIC 3/13/81

SUBROUTINE DIV2(LINE1, LINE11, LINEOUT, LINEOUT1, LINEOUT2,
LINEOUT3, STATE, STINC)
INTEGER STINC

COMMON ASSIGNMENTS
INTEGER SC
REAL N(200,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(38)
COMMON /CONTROL/ VA(38), TRANS(58)
COMMON /OUTPUT/ OUT(188)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

THROTTLE INPUT

PSSI=N(LINE1,1)
WS1=N(LINE1,3)

OUTPUT NODE INPUTS

MAIN TURBINE OUTPUT
P550=N(LINEOUT1,1)
H550=N(LINEOUT1,2)
W55=N(LINEOUT1,3)

AIR COMPRESSOR OUTPUT
P550=N(LINEOUT2,1)
H550=N(LINEOUT2,2)
W56=N(LINEOUT2,3)

BFP TURBINE
P550=N(LINEOUT3,1)
H550=N(LINEOUT3,2)
W57=N(LINEOUT3,3)

PASS THROUGH ASSIGNMENTS
PSS=PSBI
HSS=HSSI

NOTE: CHANGES TO PSS, HSS DUE TO DOWNSTREAM COMPONENTS ARE NOT MODELED IN THIS MODULE. FOR THESE TO HAVE A CORRECT EFFECT ONE MUST MAKE CHANGES IN THE ABOVE AND BELOW CODE.

STATE VARIABLE ASSIGNMENTS
---NONE---
WS4=WS5=WS6=WS7

TRANSUDER
TRANS(17)=PSS

OUTPUT NODE ASSIGNMENTS

MAIN TURBINE OUT
N(LINEOUT1,1)=PSSI
N(LINEOUT1,2)=HSSI
N(LINEOUT1,3)=WS5

AIR COMPRESSOR OUTPUT
N(LINEOUT2,1)=PSSI
N(LINEOUT2,2)=HSSI
N(LINEOUT2,3)=WS6

BFP TURBINE OUT

N(LINEOUT3,1)=PSSI
N(LINEOUT3,2)=HSSI
N(LINEOUT3,3)=WS7

INPUT NODE OUTPUTS

THROTTLE IN

N(LINEIN1,1)=PSS0
N(LINEIN1,2)=HSSI
N(LINEIN1,3)=WS4

OUTPUT VARIABLE ASSIGNMENTS

OUT(6)=PSS

UPDATE STATE VARIABLE COUNTER

DIV2 CURRENTLY HAS 0 STATE VARIABLES

RETURN
END
SUBROUTINE DIV3
CONDENSER RECOMBINATION
JOHN SHOVIC 3/13/81

SUBROUTINE DIV3(LINEIN,LINEIN1,LINEIN2,LINEIN3,LINEOUT,
LINEOUT1,STATE,STINC)
INTEGER STINC

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250),S(250)
COMMON /GENERAL/ T,TMAX,DT,IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SH4/ AUX(38)
COMMON /CONTROL/ VA(38),TRANS(58)
COMMON /OUTPUT/ OUT(188)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

MAIN TURBINE EXHAUST

PS12=N(LINEIN1,1)
HS12=N(LINEIN1,2)
NOTE: NO MASSFLOWS CALCULATED

AC TURBINE EXHAUST

PS12=N(LINEIN2,1)
HS12=N(LINEIN2,2)
NOTE: NO MASSFLOWS CALCULATED
BFP TURBINE EXHAUST

PS12=N(LINEIN3,1)
HS12=N(LINEIN3,2)
NOTE: NO MASS FLOWS CALCULATED

OUTPUT NODE INPUTS

CONDENSER LINE OUTPUT

PS12=N(LINEOUT1,1)
HS12=N(LINEOUT1,2)
NOTE: NO MASS FLOWS CALCULATED

STATE VARIABLE ASSIGNMENTS

---NONE---

NOTE: THE CONDENSER IS ASSUMED TO HAVE AN INFINITE VOLUME
HENCE NO CHANGES

PS12=0.0103
HS12=2.3170

OUTPUT NODE ASSIGNMENTS

CONDENSER LINE OUTPUT

N(LINEOUT1,1)=PS12
N(LINEOUT1,2)=HS12

INPUT NODE OUTPUTS

MAIN TURBINE

N(LINEIN1,1)=PS12
N(LINEIN1,2)=HS12

AC TURBINE
N(LINEIN2,1)=PS12
N(LINEIN2,2)=HS12

BFP TURBINE

N(LINEIN3,1)=PS12
N(LINEIN3,2)=HS12

UPDATE STATE VARIABLE COUNTER

DIV0 CURRENTLY HAS 0 STATE VARIABLES

RETURN
END
SUBROUTINE DIV4
ECON-SPRAY ATTEMPERATOR DIVERGENCE
JOHN SHOVIC 3/13/81

SUBROUTINE DIV4(LINEIN, LINEIN1, LINEOUT, LINEOUT1, LINEOUT2, STATE, STINC)

COMMON ASSIGNMENTS

INTEGER SC
REAL N(250,3)
COMMON /STATE/ F(250), S(250)
COMMON /GENERAL/ T, TMAX, DT, IFREQ
COMMON /CURRSTATE/ SC
COMMON /NODES/ N
COMMON /SM4/ AUX(30)
COMMON /CONTROL/ VA(30), TRANS(50)
COMMON /OUTPUT/ OUT(100)

CONSTANT DATA
---NONE---

INPUT NODE ASSIGNMENTS

INPUT FROM BFP

PW11=N(LINEIN1,1)
HW11=N(LINEIN1,2)

NOTE: NO MASS FLOW IS CALCULATED IN SM4 FOR THIS POINT
THE SPRAY ATTEMPERATOR MASS IS COMING FROM NOWHERE....
WW11=N(LINEIN1,3)

OUTPUT NODE INPUTS
ECON LINE OUTPUT

PW10=N(LINEOUT1,1)
HW10=N(LINEOUT1,2)
WW10=N(LINEOUT1,3)

SPRAY ATTEMPERATOR

PW10=N(LINEOUT2,1)
HW10=N(LINEOUT2,2)
WW2=N(LINEOUT2,3)

PASS THROUGH ASSIGNMENTS

PW1=PW1
HW1=HW1
WW1=WW1

STATE VARIABLE ASSIGNMENTS

---NONE---

NOTE: THERE IS NO CURRENT BODY TO THIS MODULE
BUT AS THE MASS FLOW PROBLEM IN SM4 IS FIXED THERE WILL BE

OUTPUT NODE ASSIGNMENTS

ECON LINE OUTPUT

N(LINEOUT1,1)=PW1
N(LINEOUT1,2)=HW1
N(LINEOUT1,3)=WW1

SPRAY ATTEMPERATOR LINE OUTPUT

N(LINEOUT2,1)=PW1
N(LINEOUT2,2)=HW1
N(LINEOUT2,3)=WW2

INPUT NODE OUTPUTS
BFP INPUT

\textbf{N(LINEIN1,1)}=PW10
\textbf{N(LINEIN1,2)}=HV10
\textbf{NOTE: SAME MASS FLOW PROBLEM}
\textbf{N(LINEIN1,3)}=WW10

\textbf{UPDATE STATE VARIABLE COUNTER}
\textbf{DIV4 CURRENTLY HAS 8 STATE VARIABLES}

\textbf{RETURN}
\textbf{END}
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