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G-189A ANALYTICAL SIMULATION OF THE INTEGRATED WASTE MANAGEMENT-WATER SYSTEM USING RADIOISOTOPES FOR THERMAL ENERGY

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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G–189A ANALYTICAL SIMULATION OF THE INTEGRATED WASTE MANAGEMENT–WATER SYSTEM USING RADIOISOTOPES FOR THERMAL ENERGY

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FOREWORD

The G-189A analytical simulation of the Integrated Waste Management-Water System Using Radioisotopes for Thermal Energy (RITE) was developed by the Biotechnology and Space Sciences Department, Engineering Division, of McDonnell Douglas Astronautics Company (MDAC), Huntington Beach, California, under Contract NAS8-28982. The simulation was prepared for the NASA Marshall Space Flight Center (MSFC) under the technical direction of Mr. S. E. Clonts of the Propulsion and Thermodynamics Division, Science and Engineering Directorate.

The study was supervised by K. H. Houghton, M.D., Chief Biotechnology and Space Sciences, and R. S. Barker, Chief, Environmental Engineering ECLS Section, MDAC. J. V. Coggi was the Study Manager for McDonnell Douglas. The study development and report preparation were done under the direction of J. V. Coggi with major assistance from: A. V. Loscutoff and R. S. Barker.

The authors wish to acknowledge the cooperation and support given to this program by R. W. Murray and J. D. Schelkopf of the General Electric Valley Forge Spacecraft Center.

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Section 1.0

INTRODUCTION AND SUMMARY

An analytical simulation of the RITE-Integrated Waste Management and Water Recovery System using Radioisotopes for Thermal Energy has been prepared for the NASA-Manned Space Flight Center (MSFC). The RITE system (Reference 1 and 2) is the most advanced concept water-waste management system currently under development and has undergone extended duration testing in 1973. It has the capability of disposing of nearly all spacecraft wastes including feces and trash and of recovering water from usual waste water sources: urine, condensate, wash water, etc. All of the process heat normally used in the system is produced from low penalty radioisotope heat sources.

The analytical simulation has been developed with the G189A computer program (References 3 and 4). The objective of the simulation was to obtain an analytical simulation which can be used to a.) evaluate the current RITE system steady state and transient performance during normal operating conditions and also during off normal operating conditions including failure modes and b.) evaluate the effects of variations in component design parameters and vehicle interface parameters on system performance.

The programmed simulation was implemented so that data for the following general categories of system steady state and transient operating conditions were obtained:

A. Steady state performance for design point and off design operating conditions. The simulation includes steady state mass and energy balances which enabled the following quantities to be determined:

    1. Water recovery efficiency; water output and loss rates
    2. Required gaseous expendables: O_2 and N_2
    3. Heating and cooling requirements
    4. Power requirements

B. Transient performance for design point and off design operating conditions. Time line data for nominal and some off nominal events for the following activities were imposed on the simulation: micturation events, trash processing, defecations, and wash water processing. Some of the more significant transient output data obtained for these cases included:

1. Heat block cyclic temperature variations.
2. Evaporator controller performance
3. Incinerator cyclic temperature excursions
4. Condenser and evaporator flow, pressure and temperature cyclic variations.

C. Transient performance for failure mode conditions. Failure of the low temperature heating loop, the cooling loop, and the incinerator vent valving in different modes were investigated. Emergency equipment heat transfer capabilities were evaluated. The significant transient data obtained here were the transient fluid and radioisotope capsule temperatures.

D. Steady state performance with variations in component design parameters and vehicle interface parameters. Key parameters which affect RITE performance are condenser vapor pressure and evaporator temperature level. These have been investigated by varying the evaporator heating fluid supply temperature and the flow area of the orifice in the steam outlet circuit for the condenser. Other parameters which were varied in this investigation include the condenser cooling fluid supply temperature level and the overall conductances (UA) of the evaporator and condenser.

This report describes the subject analytical simulation effort in the following sections. Section 2, Technical Discussion, contains descriptions of the RITE system and its operation, the G189A computer program emphasizing features required in the simulation of the RITE system, the study approach, summarized simulation results, and applications for the prepared RITE simulation. Section 3, the Computer Model Description, discusses the organization of the analytical simulation model of the RITE system and describes the modeling logic for the subsystems and individual components in the subsystems. Section 4, the Computer Model Correlation section describes the correlation of G.E. component test data and G189A program modeling data for the pyrolysis units, the air sterilizer, the heat pipe, the heat block, the low temperature isotope heater, the evaporator, and the condenser. Section 5, the Characteristics of the RITE System, describes the steady state or 24-hour average performance data for the various subsystems, some nominal transient conditions, and the operational envelope for the system. RITE Simulation Design Applications, Section 6, discusses the effects on system performance due to variations in component data from the design point values for the following: low temperature heating loop inlet temperature to evaporator, condenser vapor pressure, coolant inlet temperature to the condenser, and overall conductances, UA, from the heat transport fluid to the process liquid for the condenser and the evaporator. Section 7, Failure Mode Analysis, describes system transient performance subsequent to various failures in the low temperature heating loop, the cooling loop, and the incinerator vent valving.

Section 2

TECHNICAL DISCUSSION

2.1 RITE System Descritions and Operations

The RITE system is the most advanced concept water-waste management system under development by NASA and the AEC. It has the capability of recovering water from all spacecraft waste materials including feces and can also shred and process trash. It goes one step further than other systems by automatically pumping the brine-sludge residue from the water recovery unit to an incinerator that reduces the solid waste to an innocuous ash. All of the process heat used in the system is produced from radioisotpe thermal energy (RITE) sources. A schematic of the system is shown in Figure 2.1. System specified performance data are given in Table 2.1.

Figure 2.2 shows input material rates for the system and nominal time-line data for material processing by various components in the system. The feces are conveyed into the blender via an air flow of approximately 40 CFM. Here the feces are mixed with the warm wash water and the resulting slurry is pumped along with the transport air to the evaporator.

The urinal also uses an air flow to convey the urine into a liquid gas separator. The separator centrifugally separates the phases with the air going directly to the suction blower and the urine metered into the evaporator. For urine addition, it is not necessary to repressurize the evaporator as is the case for commode and shredder operation. This permits uninterrupted evaporator operation for the frequent micturitions. After urinal use, it is automatically flushed.

Trash is manually placed into the shredder as required for later processing when the commode is used. The plastic and paper trash and garbage are shredded and mixed with water and pumped into the evaporator. Coincident operation of the trash shredder and commode permits fewer interruptions of the evaporation process.

Wash water from the galley, shower and clothes washer are also periodically added to the evaporator as required to keep the evaporator water level above minimum.

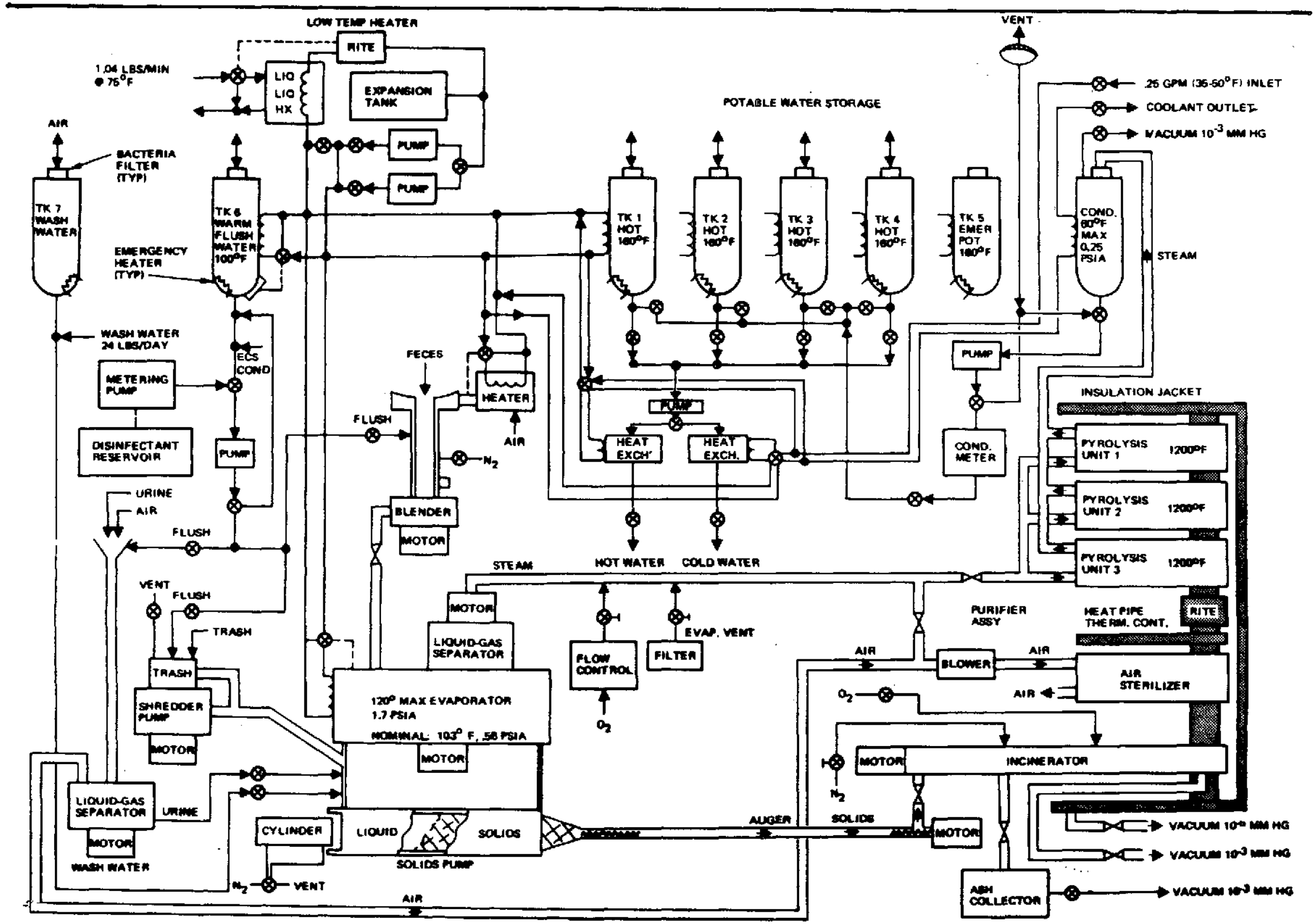


Figure 2.1 Integrated Waste Management-Water System Using Radioisotopes for Thermal Energy

Table 2.1

SUMMARY OF RITE SYSTEM DESIGN POINT AVERAGE PERFORMANCE

Water Recovery Rate	2.3 lb/hr
Water Input Rate	2.38 lb/hr
Water Loss to Incinerator	.05 lb/hr
Water Loss to Condenser Vent	.03 lb/hr
System Conversion Efficiency	9.68%
Total Heat Input Rate	6550 Btu/hr
Heat from LTHL	5280 Btu/hr
Heat from High Temperature Isotope	1270 Btu/hr
Heat Loss to Condenser Cooling Loop	2456 Btu/hr
Heat Loss to Cabin Atmosphere	3768 Btu/hr
Heat Loss to Vent Gases and Water	326 Btu/hr
Electrical Energy Requirements	30 watts-hrs/day
Evaporator Wall/Vapor Temperature	115/105°F
Expendable Oxygen Usage Rate	.043 lb/hr
Expendable Nitrogen Usage Rate	.003 lb/hr

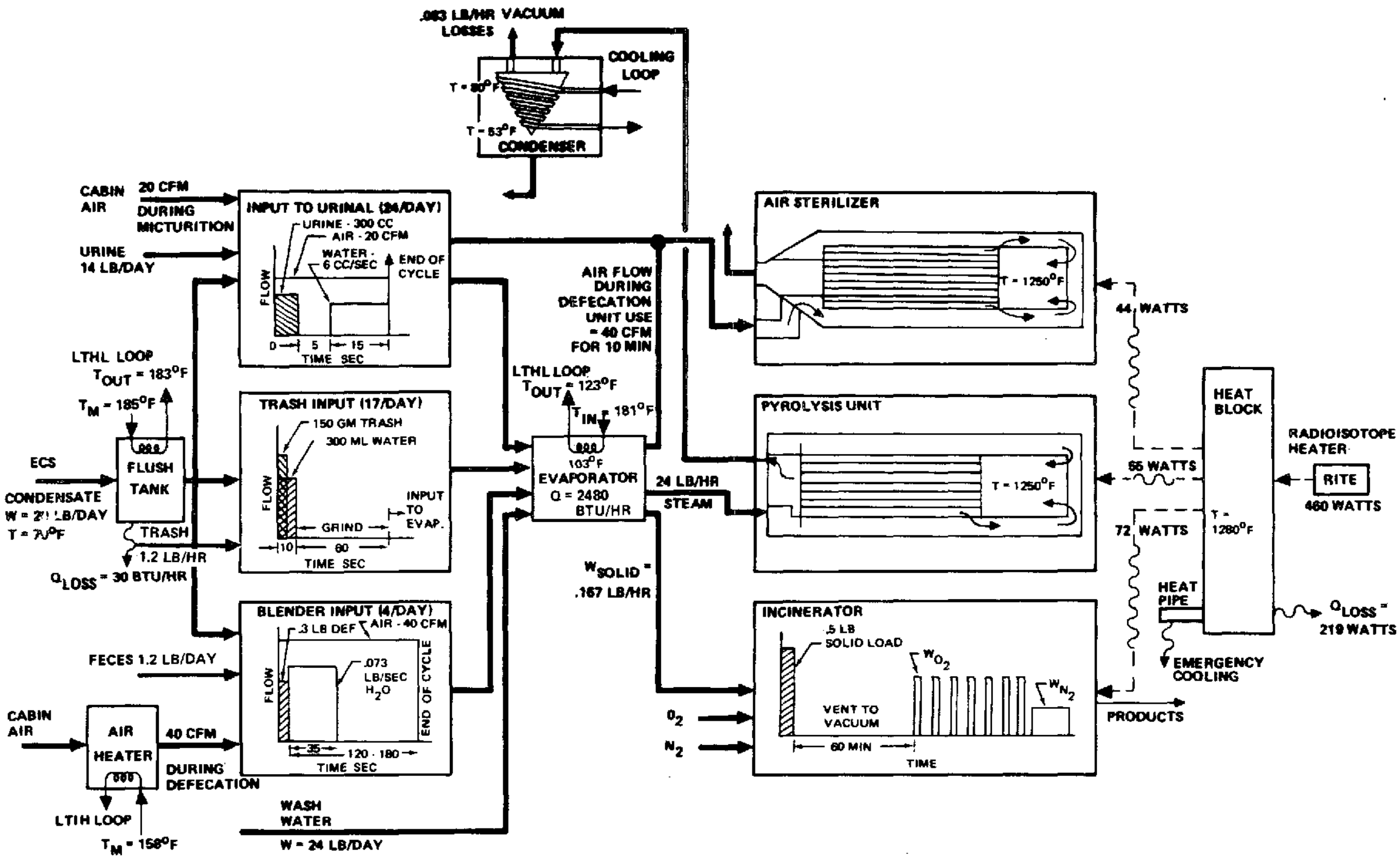


Figure 2.2 Rite System Operation

The evaporator receives all the wastes and provides solid/liquid separation and initial water purification by distillating the wastes at a reduced temperature and pressure of 105°F and 1.1 psia. The reduced temperature boiling minimizes volitization of impurities. The evaporator has two phase separators. A low speed impeller (100 RPM) creates an aritifical gravity field for nuclear boiling in zero gravity. The high speed impeller (2000 RPM) acts as a secondary phase separator to assure that liquid is not carried over with the steam or air flow.

The transport air flow used to convey the wastes into the collection devices and then into the evaporator, is created by a suction blower which then forces the air thru the air sterilizer before it is returned to the cabin. The air sterilizer provides sufficient retention time for the air at high temperatures to assure that all microorganisms are killed. A recuperative heat exchanger in the sterilizer uses most of the thermal energy in the exiting flow to heat the incoming air.

Three catalytic oxidizers are connected in parallel to process the steam from the evaporator. The three units are nested around the single heat source. Each oxidizer contains ruthenium catalyst on alumina pellets. The incoming steam at 120°F is preheated by the exiting steam and is finally heated to 1200°F in the catalyst zone. The impurities in the water vapor are oxidized and are vented from the condenser when the steam is condensed. The steam exits the catalytic oxidizers at approximately 300°F.

The steam passes from the pyrolysis units to the condenser. The steam is condensed between 75°F and 85°F and between .5 psia and .7 psia in the condenser. This pressure is less than evaporator pressure and forces the steam flow through the system. Gases in the steam flow (that are not eliminated in the pyrolysis units) are vented to space vacuum from the condenser.

The low speed impeller in the evaporator also circulates the waste liquid thru the solids pump. The solids pump consists of a filter, solids compression piston and auger. The solids separated during the distillation process are circulated thru the filter with the larger particles being retained as the liquid returns to the evaporator. Periodically, the solids collected in the filter are compressed to remove excess liquid. When the filter is filled with solids, the piston forces the solids into the auger where they are pumped into the incinerator. The incinerator consists of a motor driven shuttle in a sealed cylinder. The solids are pumped by the auger into the shuttle positioned at the cool end of the cylinder. After being filled, the shuttle is moved into the high temperature zone where the solids are initially dried and then thermally decomposed. Finally, oxygen is added and the remaining solids are incinerated and the gases vented. Incineration follows thermal decomposition to minimize the amount of oxygen required to dispose of the solids. After incineration, the shuttle is returned to the cool end and the remaining ashes are blown by use of a nitrogen purge into a filter for collection. The ash is approximately 1% of the initial solid waste input weight.

The purified water is pumped out of the condenser periodically. It passes through conductivity and pH sensors to a set of potable water storage tanks. The tanks are filled in rotation, and tested for chemical and microbiological purity prior to use.

The low-temperature RITE heater provides heat for the evaporator and the water storage tanks. The tanks are heated (160°F) to prevent microbial growth. The flush water tank is heated to 100°F and disinfectant is automatically added to this water to maintain sterility.

The system is automatically controlled to function in a fail-safe manner. Alarms warn of any failures that have occurred. If any component in the system ceases to function, components that supply effluent to it are automatically shut down.

Overheat of the RITE heaters is prevented by discharging surplus heat to compartment air. The high-temperature RITE heater discharges surplus heat through a heat pipe to the compartment air. The low temperature RITE heater is protected from overheat by a separate liquid loop and a heat exchanger which is interfaced with the low-temperature fluid loop. Excessive heater temperature (190°F) activates this loop.

2.2 G189A Program Descriptions

The G189A Generalized Environmental/Thermal Control and Life Support Systems (ETC/LSS) Computer Program (References 3 and 4) was selected for use in modelling the RITE system. It provides an extremely versatile and useful analytical tool for support of ETC/LS system development work beginning with preliminary design and proceeding through hardware design, system integration and test, and actual flight. A G189A simulation is useful in determining total system steady state and transient performance, establishing test conditions, and performing failure mode analyses.

The RITE system is simulated with the program by describing the equipment in terms of individual "components" which are connected by gaseous or liquid flow streams. Each particular type of component is simulated by an individual component subroutine contained within the G189A program. A component corresponds to all or part of a physical part; such as a tee, heat exchanger, etc.; or to a complete subsystem or process; such as incineration, pyrolysis, etc. The individual components of the simulation are arbitrarily assigned successive integer numbers which are used to define the component flow stream interconnections and to specify the computational sequence of the individual components. The interconnection and sequence data are specified by the user and may be easily changed. The computational sequence generally follows a path corresponding to the system flow stream paths.

The G189A component subroutines perform heat transfer, chemical reaction, and mass and energy balances for both steady state and transient operating conditions. System pressure drop versus fan or pump pressure rise balances can also be performed if desired. Examples of energy balances are: (1) the summation of heat rejection from the heat block balanced with the total heat generated by the high temperature isotope and (2) the summation of condenser heat loads balanced with the heat rejected to the cooling loop. Examples of mass balances include the balancing of water vapor and CO_2 generation rates from the evaporator against oxygen supply rates, pyrolysis rates, and condenser removal rates.

The G189A program is essentially comprised of seven sections: (1) a main subroutine or Master Control Block (MCB); (2) and Input Editor; (3) two user coded subroutines, GPØLY1 and GPØLY2, for implementing additional computational logic; (4) a set of ETC/LSS component subroutines; (5) a pressure drop analysis subroutine; (6) a set of utility subroutines; and (7) a SD-4060 plotting package.

Figure 2.3 presents a block diagram of the G189A program logic. The program operations and their sequence are determined by the Master Control Block (MCB), also known as subroutine ECLST. The operations performed by the MCB are indicated in the center block of Figure 2.3.

All component data and table data are dynamically loaded, at execution time, into a large single array which is predimensioned in the main program. The G189A program allocates storage within this single array as the simulation data are input and at completion the number of unused storage locations are printed. If the simulation data overflows the array execution is halted and a note to that effect is printed. This feature allows computer core storage requirements to be adjusted to each simulation and may result in cost savings and decreased turn-around time when operating on multi-processing or time sharing computer systems.

Another capability provided by the G189A program is the use of a flow code option. Table 2.2 specifies the type of flow data computed and stored within the program for each of the five basic flow code options (0-4). Addressing provisions for 100 flow code options (0-99) are provided within

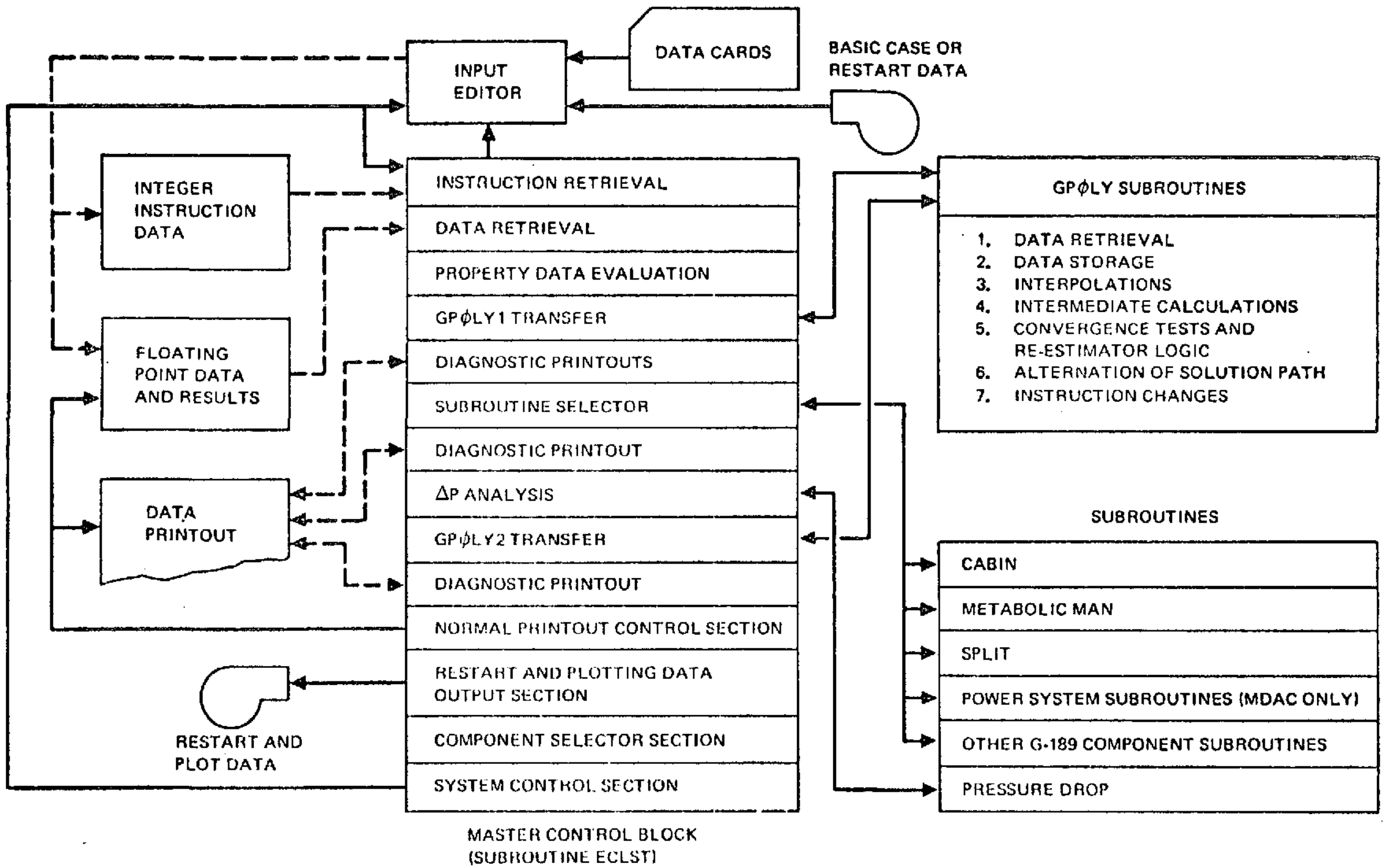


FIGURE 2.3 G-189A PROGRAM LOGIC

Table 2.2

G189A FLOW CODE OPTIONS

	Flow: Flow Code =	Liquid 0	Gaseous 1	Gaseous 2	Gaseous 3	Liquid 4
1.	Total Flow					
2.	Temperature					
3.	Upstream Duct Outlet Pressure					
4.	Component Outlet Pressure					
5.	Noncondensables Flow					
6.	Condensable Vapor Flow					
7.	Condensable Entrained Liquid Flow					
8.	Noncondensables Specific Heat					
9.	Noncondensables Molecular Weight					
10.	Oxygen Flow					
11.	Diluent Flow					
12.	Carbon Dioxide Flow					
13.	Trace Contaminants Flow					
14.	Special Flow No. 1					
15.	Special Flow No. 2					
16.	Special Flow No. 3					
17.	Special Flow No. 4					
18.	Special Flow No. 5					
19.	Special Flow No. 6					

the program. The basic liquid flow code option of zero requires the minimum amount of data storage locations (4) and contains total flow, temperature, and pressure data. A liquid flow code option of four reserves nine storage locations and allows the total flow to be subdivided into five constituent flows (Special Flow Nos. 2-6). These special flow constituents may be selected from up to 99 different species whose thermophysical property data are defined by the user. Three gaseous flow code options (1-3) are available.

The basic gaseous flow code option of one requires nine data storage locations and subdivides the total flow into noncondensables, condensable vapor, and condensable liquid flows. The gaseous flow codes of two and three further subdivide the noncondensables flow into fixed constituents and special flow constituents, these options are useful in tracking particular constituent flows within the advanced recovery systems such as carbon dioxide, hydrogen, methane, etc.

The G189A thermodynamic and mass balance equations are based on real gas mixtures and the thermodynamic properties (specific heat, molecular weight, viscosity, and thermal conductivity) of the total flow stream are computed from the input constituent property data and the calculated constituent flows. All component and table data are input using a standardized set of data card formats which provide ample room for comments. This feature allows the user to document all input data and, if desired, all component output data for an ETC/LSS simulation thereby providing a self-documenting set of input data which are always in agreement with the simulation.

2.3 Study Approach

The study approach is outlined in Table 2.3. As indicated the system was considered to be comprised of individual groups or "loops" of components which interface with each other and with boundary conditions. Schematics which are often called Component Definition Diagrams were prepared for these loops. These diagrams indicate assigned component numbers, assigned component subroutines, flow connections, and boundary

TABLE 2.3

RITE SIMULATION STUDY ORGANIZATION

TASK REQUIREMENT	ORGANIZATION	PROGRAM NEW SUBROUTINES	CORRELATION	SUBSYSTEM SIMULATION	SYSTEM SIMULATION	APPLICATIONS
COMPONENT WORK EFFORT	G-189A SCHEMATICS MASS & HEAT BALANCE	EVAPORATOR CONDENSER INCINERATOR HEAT PIPE	PYROLYSIS AIR STERILIZER HEAT PIPE EVAPORATOR CONDENSER INCINERATOR HEAT BLOCK	AIR LOOP VAPOR LOOP SOLID WASTE LOOP, COOLING LOOP, FLUSH WATER LOOP LTHL, POTABLE WATER LOOP	SYSTEM	STEADY STATE TRANSIENT
TO NASA COR	G-189 SCHEMATICS HEAT IN MASS BALANCE	SUBROUTINE DOCUMENTATION	CORRELATION DESCRIPTION, DATA DECKS	COMPUTER RESULTS DATA DECKS	COMPUTER RESULTS DATA DECK	ANALYTICAL RESULTS COMPARISON WITH 180 DAY RUN DATA
DATA REQUIREMENTS (G.E.)	SYSTEM DESCRIPTION		CONDENSER/ EVAPORATION OPERATION AT 2 PRESSURES	CORRECTED MASS @ HEAT BALANCE, CONTROL LOGIC	BASELINE 180 DAY RUN OPERATION DESCRIPTION	180 DAY RUN DATA

conditions. This procedure, along with developing system familiarization, resulted in the determination of the need for four new component subroutines and the need for modifications to one existing subroutine. The new subroutines are those for simulating the RITE evaporator (subroutine EVAP), condenser (subroutine CNDNSR), incinerator (subroutine INCIN) and heat pipe (subroutine HTPIP). The modified subroutine is used in simulating the water tanks (subroutine TANKG). The use of heating fluid coils on the RITE water tank walls necessitated that the modelling capability for this feature be added to subroutine TANKG.

As noted in Table 2.3 the individual loops are as follows: air loop, vapor loop, solid waste loop, cooling loop, low temperature heating loop, flush water loop and potable water loop. Once the loop of components were specified the next task was to obtain the parameter data for the individual components in the loops and to prepare the corresponding input data for the G189A program. The procedure for obtaining these data was as follows.

Plotted data showing the results from steady state and transient tests for some individual system components were provied by General Electric. The G189A program models for these components were correlated with the test data by adjusting such quantities as heat transfer coefficients and thermal masses so that computed temperatures closely agreed with the corresponding test data. In cases where component test data for use in determining component parameters were not available or values for the parameters themselves could not be provided by General Electric, two additional means for arriving at values for these parameters were undertaken. The first was to perform engineering calculations aimed at obtaining reasonable estimates for the parameters. The other means was to obtain computer runs for predicting performance of individual loops. Comparing test data for loop performance, such as supply and return temperatures at a given flow rate, with the corresponding analytical data often indicated the accuracy of parameter data for components in the loop. Simulations for the loops noted in Table 2.3 were run on the computer. Modifications in component data were made until satisfactory loop performance was achieved. When the loop simulations were considered

To be satisfactory they were combined into the total system simulation. The total system simulation has been used to a) evaluate the current RITE system steady state and transient performance during normal operating conditions and during off-normal operating conditions including failure modes and b) evaluate the effects of variations in component design parameters and vehicle interface parameters on system performance.

2.4 Summary of Computed Results

Computed data have been obtained for steady state and transient operational conditions. Steady state simulation cases have been run in order to determine design point and off design operating conditions. Steady state or 24-hour average design point operating conditions are summarized in Table 2.1. Off design point operating conditions have been used in preparing the performance maps for Sections 5 and 6. Section 6 contains plotted data obtained for investigations of the effects of variations in boundary conditions and component heat transfer characteristics on system performance.

One of the more significant results of these investigations is that for a LTHL supply temperature of 180°F to the evaporator the optimum water recovery rate decreases from 2.3 lb/hr to 2.13 lb/hr as the condenser coolant inlet temperature is increased from 35°F to 50°F. The condenser pressure level for optimum water recovery varies from 0.63 psia to 0.8 psia for the cases. The importance of condenser pressure level is explained and demonstrated in Section 5.3. Briefly, for condenser pressure levels lower than the optimum, condensation rates and therefore recovery efficiency are reduced due to the small temperature difference between the condenser wall temperature and the saturation temperature of the vapor. For condenser pressure levels higher than the optimum, evaporation rates are reduced with correspondingly reduced recovery rates due to the higher back pressure which restricts output flow.

In investigating changes from the design point values in evaporator and condenser overall conductances (UA) between heat transport fluid and process liquid the following improvements in system performance were determined: increasing the evaporator UA from 92.6 Btu/hr °F to 150 Btu/hr °F increased the water recovery rate from 2.3 lb/hr to 2.42 lb/hr while increasing the condenser UA from 117 Btu/hr °F to 150 Btu/hr °F increased the water recovery rate from 2.3 lb/hr to only 2.32 lb/hr.

Transient cases have been run in determining the dynamic performance of the system with nominal timelines for micturition, defacation, and incineration activities. The plotted transient results are given in Section 5. The above step function type time line activities cause damped temperature responses in system components such as the evaporator, heat block, and incinerator.

Transient failure mode data are presented in Section 7 for failures in the cooling loop, in the incinerator vent valving, and in the low temperature heating loop.

Transient evaporator and condenser temperatures for a failed cooling loop show the condenser wall temperature rising from 75°F and stabilizing at about 100°F with a corresponding slight increase in evaporator temperature. During these conditions the condenser recovery rate decreases to zero and the evaporator vapor output decreases to a low value due to the increased back pressure from the condenser.

The incinerator vent failure results in an increase in incinerator temperature from about 1150°F to about 1460°F due to the prolonged oxidation of solids within the evaporator. The isotope capsule temperature is only slightly perturbed during this condition due to the large thermal mass of the heat block and the components mounted in the heat block.

The failure of the LTHL were postulated to occur with loss of coolant flow, loss of coolant from the loop due to leakage, failure of the evaporator bypass valve or draining of liquid from the evaporator, and loss of water from the low temperature isotope shield tank with various types of simultaneous failures in the LTHL. Loss of coolant flow results in an increase in coolant temperature from 150°F to about 300°F with corresponding slight changes in isotope and shield tank temperatures. Loss of coolant from the loop, however, results in an increase in isotope capsule temperature from 900°F to over 1000°F in about 23 minutes with the temperature still rising. This is due to the fact that with the loss of the conductive path through the fluid in the isotope capsule cooling jacket heat transfer between the isotope capsule and the tank is now mainly by radiation and is assumed to be much less than when the fluid is present in the isotope capsule cooling jacket.

Loss of heat removal from the LTHL due to either failure of the evaporator bypass valve in the full bypass position or due to draining the evaporator liquid is protected by the emergency heat exchanger loop. It was found that an emergency heat exchanger UA $>$ 50.0 Btu/hr °F is required to adequately control the coolant temperature to below 190°F.

With loss of water from the isotope shield tank and with the evaporator bypass valve failed in the full bypass condition, the plotted results show that the emergency heat exchanger loop maintains the coolant outlet temperature at 210°F and the isotope capsule at about 995°F. Of course with these conditions along with a loss of the emergency heat exchanger loop, the coolant and isotope capsule temperatures rather quickly rise to excessive levels.

With the exception of the LTHL failures, failures in the system would only interupt RITE operation until repair is accomplished and, at least in the short run, would not endanger the health of the crew. Failures in the LTHL could result in the loss of isotope cooling which could lead to loss of capsule integrity and the escape of radioactive particles. Therefore, a secondary, passive, emergency cooling mode should be an integral part of the isotope design.

2.5 Applications for Prepared RITE Simulation

The prepared analytical simulation of the RITE system can be used to accomplish several different objectives. These objectives are of course related to the future research and development activities which the RITE system and derivative systems will experience. A partial list of possible future RITE activities along with corresponding applications for the prepared simulation is as follows:

A. Improvements in Present System's Performance

Further G189A simulation investigations of component design changes could lead to additional insight concerning component modifications directed toward improving system performance. For example, better thermal insulation characteristics for components in the low temperature heating loop would reduce the present large heat loss to the environment from this loop.

B. Changes in System Boundary Conditions Commensurate with Future Spacecraft Characteristics.

Investigations of system performance with revised liquid and solid waste material processing quantities and time lines, available coolant flow and temperature level, cabin atmosphere temperature, pressure, and composition, etc., appropriate to future spacecraft characteristics will determine the suitability of the RITE system to these environmental and operational characteristics.

C. Scaling of RITE System Equipment

Investigations of system performance with scaled component characteristics as a result of changes in boundary conditions and/or accommodated crew size will determine optimal component characteristics. Examples of these are: required overall UA for heat transport to fluid or environment, volume, pumping power, weight, heating and cooling requirements and expendables required. This type of investigation could be directed toward establishing an experimental RITE configuration for a Sortie Lab. experiment.

D. Integration with Other Systems or Subsystems

Revising the present simulation to provide modeling for components from integrated systems or subsystems as a result of revised boundary conditions or other reasons would lead to a system simulation capable of supporting the design and development of the integrated system. For example, imposing a large wash water requirement on the system due to inclusion of a shower in the system might lead to integrating a multifiltration assembly with the RRITE system.

Section 3

COMPUTER MODEL DESCRIPTION

The RITE system computer model is comprised of eight main subsystems. The subsystems and their function are defined below:

1. Low Temperature Heating Loop - Supplies heating fluid (water) to the evaporator, potable water storage tanks, flush water tank, hot water heater, and the air heater.

2. Flush Water Loop - Collects Environmental Control System (ECS) condensate input. Provides flush water for the urinal, blender and the trash shredder.

3. Air Loop - Provides drying air flow for the urinal. Sterilizes exhaust air in the air purifier.

4. Solid Waste Loop - Provides solid, liquid and gaseous inputs to the evaporator. Incinerates solids and then collects resultant ash in the ash collector.

5. Vapor Loop - Evaporates water vapor from the evaporator solid-liquid slurry. The vapor is purified in three catalytic burners and is then condensed in the condenser.

6. Cooling Loop - Provides cooling flow to the condenser and the water cooler.

7. Potable Water Loop - Collects and stores water from the condenser. Distributes hot and cold water as required by users.

8. High Temperature Heat Source - Provides high temperature heat to the incinerator pyrolysis units and the air sterilizer.

3.1 Computer Model Organization

The G-189A RITE simulation model was divided into the corresponding eight subsystem loops. Each loop was developed independently prior to being integrated into a total system. The component numbers for each loop were assigned as shown below.

	Subsystem	Component Numbers
1	Cooling Loop	1 - 19
2	Air Loop	20 - 39
3	Flush Water Loop	40 - 59
4	Potable Water Storage	60 - 99
5	Low Temperature Heating Loop	100 - 179
6	Heat Block	180 - 199
7	Solid Waste Loop	200 - 219
8	Water Pyrolysis	220 - 239

The calculation begins at component 100, the radioisotope heater of the low temperature heating loop. In the first part of this loop the heating fluid is distributed to all user loads. The calculation then transfers to the flush water loop where flush water is provided for the urinal, shredder and blender as required. The calculation then transfers to the air loop. Urine, flush water and air enter this loop in accordance to the micturation schedule noted in Section 5. After liquids are separated and directed to the evaporator, the remaining air is blown by the fan to the air sterilizer and then back to the cabin.

Calculation control then shifts to the solid waste loop. In the solid waste loop the air, solids, and flush water requirements for the blender and trash shredder are collected and directed to the evaporator. The input schedules are defined by table data and are shown in Section 5. In the evaporator water vapor is generated and the solids are directed to the incinerator.

The calculation then shifts to the vapor loop. In this loop the gases given off by the evaporator are oxidized in the pyrolysis beds and the water vapor is condensed in the condenser.

The order of solution then continues with the supply portion of the cooling loop. The coolant loop provides coolant for the condenser and the water cooler. The next operation involves the potable water storage loop. In this loop the water is collected from the condenser, stored, and then heated or cooled and dispensed upon demand. The calculation then returns to the cooling loop where the coolant is collected and returned to the source.

A heat balance is then performed on the heat block and the heat pipe. Finally the calculation returns to the low temperature heating loop. Here the fluid is collected from the heated equipment and returned to the isotope heater, component 100. The system is then ready to perform another pass.

The logic used to control the operation of each of the above loops is discussed in detail in the subsequent sections. The G-189A schematics of the loop are key elements in the description of the computer model. Therefore, a review is given first of the information contained in these diagrams.

3.2 Computer Model Documentation

The description of the computer model for each of the subsystems includes a G-189A block diagram schematic of the system. An example of the applications of a G-189A schematic is shown in Figure 3.1. Each block in the diagram corresponds to a major component of the subsystem. The block contains the computer component number, the component name and the name of the subroutine used to simulate that component. The circled numbers define the system flow splits and tees. The solid arrows connecting the component define the source of primary and secondary flow. Primary and secondary flow are noted by a P and S respectively. Also noted in the Figure is the flow code definition and a list of the constituents comprising that flow code. The solid-dash lines connecting the components define the component order of solution.

The subsequent writeup defines the operation of the loop and technical data for each component. Control for each component is defined by the GPOLY1 and GPOLY2 subroutines. The GPOLY1 and GPOLY2 logic for each component is defined side by side with the corresponding listing. Generally, these component descriptions do not include the detailed numerical data. Numerical values of the input data may be found in Appendix B (Input Data Card Listing).

The system G-189A schematic is shown in Figure 3.2. The system was divided into eight subsystems and the description of the computer model for each of these subsystems follows:

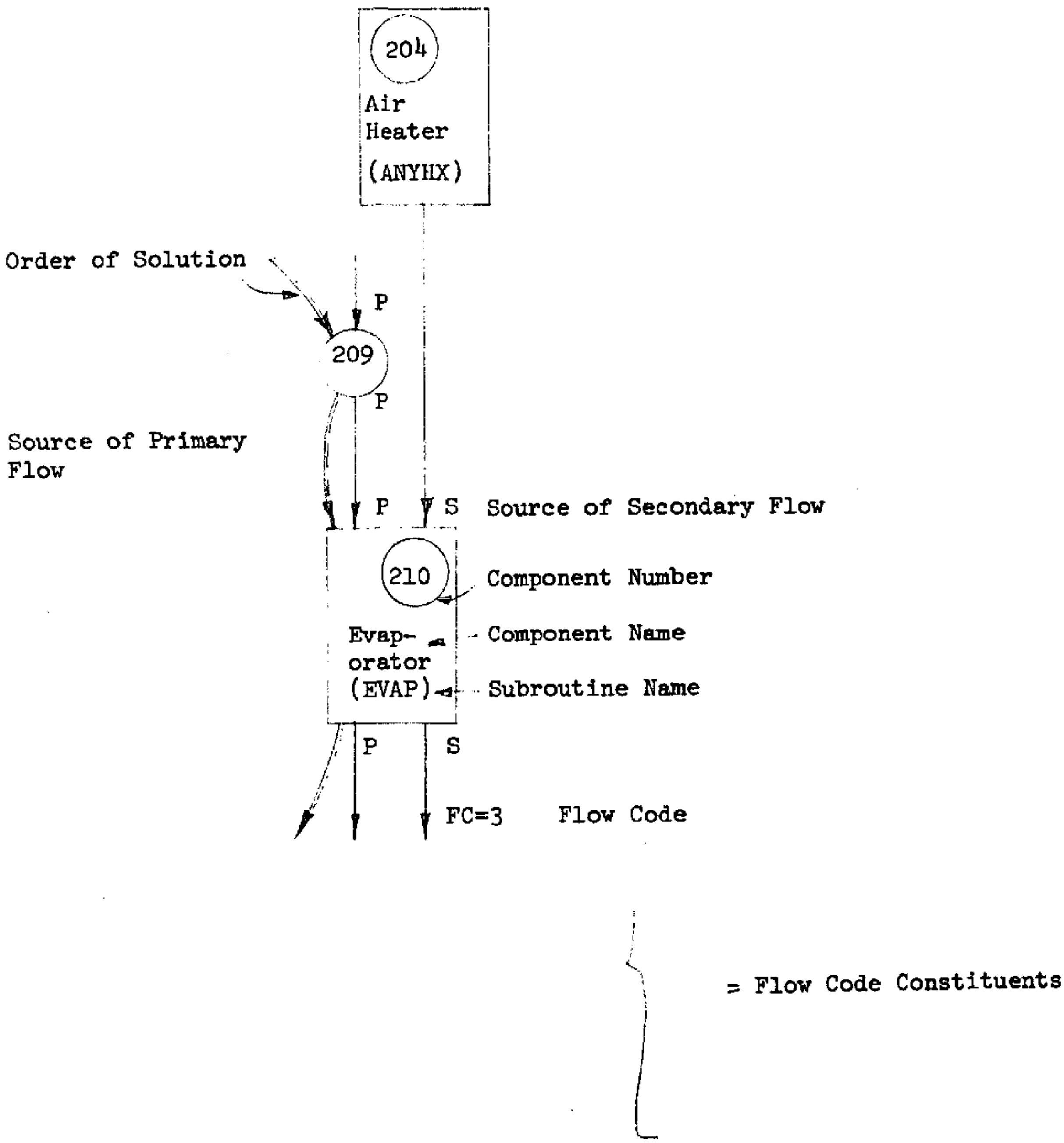


Figure 3.1 G-189 Schematic Representation

FOLDOUT FRAME 1

FOLDOUT FRAME 2

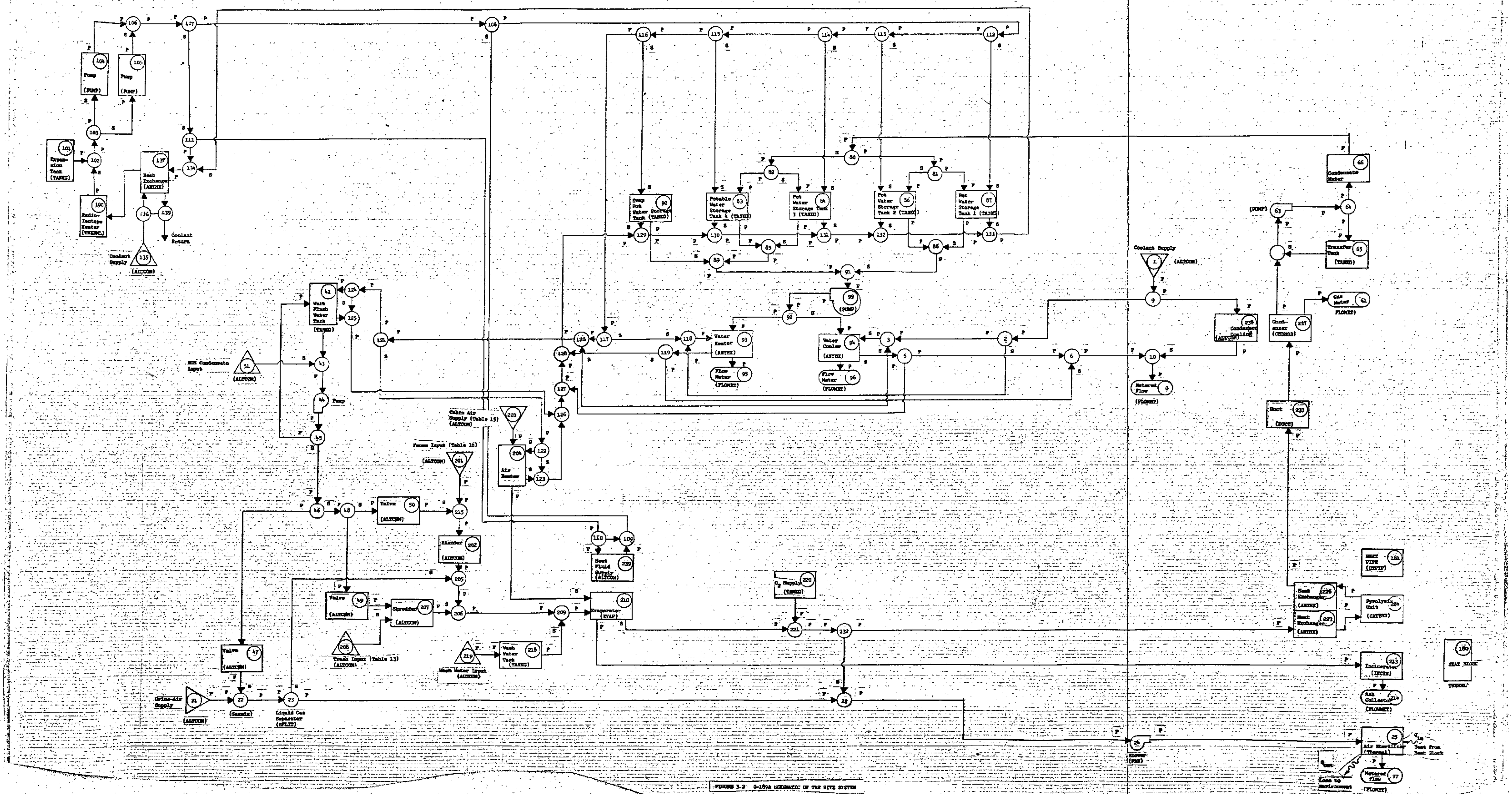


FIGURE 3.2 G-189A SCHEMATIC OF THE SITE SYSTEM

3.2.1 Low Temperature Heating Loop

The schematic of the Low Temperature Heating Loop (LTHL) is shown in Figure 3.3. The loop provides heat for the evaporator, five potable water storage tanks, water and air heaters, and the flush water tank. The coolant is heated in the isotope heater, component 100, and is then pumped by one of two pumps (104, 105) to the user components. Only one pump is used at any one time. The other pump is switched on upon failure of the first. Flow splits 108, 112, 113, 114, 115, 116, 117, 120, and 121 distribute heating fluid to the evaporator, the five storage tanks, the water heater, air heater and the warm flush water tank. Components 126, 127, 128, 129, 130, 131, 132, 133, and 134, simulated by subroutine FLØMIX, collect return flow from these components and return the flow to the radioisotope heater.

Prior to the return to the heater, the fluid flows through an emergency heat exchanger, component 137. The heat exchanger is activated when loss of cooling in the loop drives the fluid temperature at the exit of the isotope heater higher than 190°F. The coolant supply, component 135, provides coolant flow to the by-pass temperature control system, components 136 and 139. When the radioisotope coolant outlet temperature reaches 190°F, the coolant flow is directed by flow split 136 to the heat exchanger.

Components 109 and 110 form a by-pass control loop to regulate the evaporator vapor outlet temperatures. When the vapor temperature reaches 105°F the heating fluid is bypassed around the evaporator. Flow to the evaporator is re-established when the vapor temperature drops to 104°F.

Components 124 and 125, form a bypass loop to control the warm flush water tank temperature to 90 $\pm$ 1°F.

Similarly, components 122 and 123, form a bypass loop around the air heater to control the outlet air temperature to 110°F.

The detail GPOLY1 and GPOLY2 control logic which perform the functions detailed above is given in Table 3.1.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

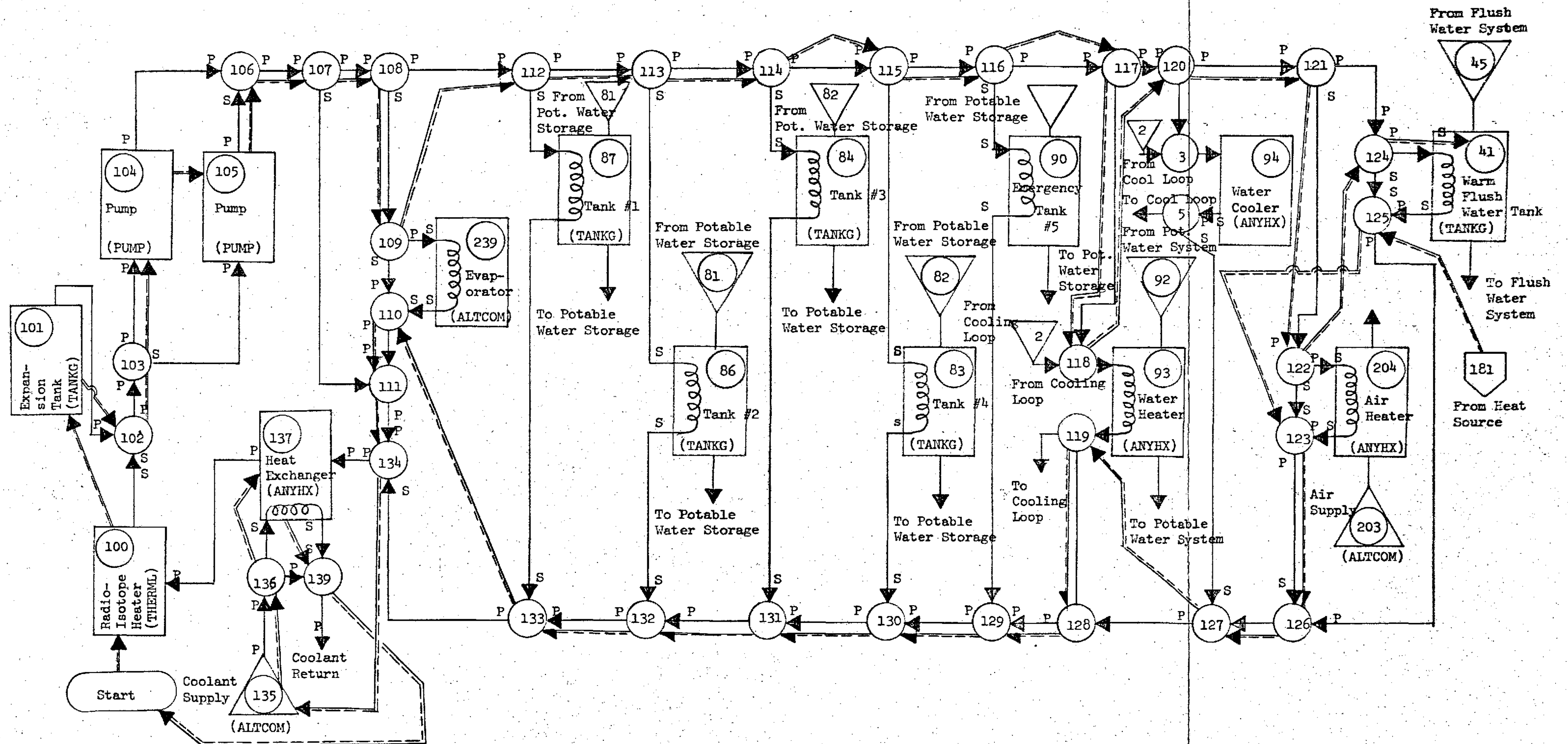


FIGURE 3.3 LOW TEMPERATURE HEATING LOOP G-189A SCHEMATIC

Table 3.1

GPOLY LOGIC FOR THE LOW TEMPERATURE HEATING LOOP

Order of Solution - START, 100, 102, 103, 104, 105, 106, 107, 108, 109, 112, 113, 114, 115, 116, 117, 118, 120, 121, 122, 124 to Flush Water Loop
From Heat Pipe, 125, 123, 126, 127, 119, 128, 129, 130, 131, 132, 133, 110, 111, 134, 136, 137, 139

Component 100, Radioisotope Heater

Subroutine: THERMAL

GPOLY1

The inlet temperature and flows are transferred to the nodal network. The inlet temperature A(2) is transferred to R(82). The inlet wC_p is entered in R(75).

Component flow and properties passed to the output R-Array

GPOLY 2

The outlet flow temperature calculated by the nodal network in R(69) is transferred to the output R-array.

```
C      GPOLY1 LOGIC FOR LOW TEMP. HEATING LOOP
C
C                                INTERFACE OF THERMAL C100 TO C139
C
       IF(N .NE. 100) GO TO 100
       NLAST=209
            R(82)=A(2)
            R(75)=CPA*A(1)
            DO 1100 J=1,19
 1100       R(J)=A(J)
  100  CONTINUE
C
C      GPOLY2 LOGIC LOW TEMPERATURE HEATING LOOP
C
       IF(N .NE. 100) GO TO 100
C                                INTERFACE OF THERMAL C100 TO C139
        R(2)=R(69)
C
  100  CONTINUE
C
```

Component 104 Coolant Loop

Subroutine: PUMP

GPOLY 2

Pump power is set proportional to flow rate. If pump 1 fails switch valve 103 to pump 2.

```
C
C      COOLANT PUMP NO.1      COMPONENT 104
C
       IF(N.NE.104)GO TO     104
       R(70)=0.0151*A(1)
  104  CONTINUE
```

Component 109, Evaporator Control Valve

Subroutine SPLIT

GPOLY1

If the evaporator outlet vapor temperature greater than 105°F bypass flow around evaporator. Reestablish evaporator flow when vapor temperature drops back to 104°F.

```
C      EVAPORATOR COOLING LIQUID CONTROL VALVE (COMPONENT 109)
C
       IF(N.NE.109) GO TO 109
       IF(STEADY)GO TO 109
       TEMPS=VV(210,2)
       IF(TEMPS.GT.105)R(65)=1.0
       IF(R(65).GT.0.0.AND.TEMPS.LT.104.)R(65)=0.0
       IF(TEMPS.LT.104.)R(65)=0.0
   109 CONTINUE
```

Component 122, Air Heater Control Valve

Subroutine SPLIT

GPOLY1

Bypass heating fluid around air heat exchanger when outlet air temperature greater than 110°F.

```
        AIR HEATER CONTROL LOGIC  COMPONENT 122

        IF(N.NE.122)GO TO 122
        AIRTEP=VV(204,2)
        R(65)=0.0
        IF(AIRTEP.GT.110.0)R(65)=1.0
   122  CONTINUE
```

Component 124, Flush Tank Control Valve

Subroutine SPLIT

GPOLY1

When tank liquid temperature greater than 96°F, bypass heating flow. Reestablish flow when temperature drops to 94°F.

```
        WARM FLUSH WATER TANK CONTROL LOGIC

        IF(N.NE.124)GO TO 124
        IF(STEADY) GO TO 124
        TTANK=VV(41,7 )
        IF(TTANK.LT.94.0)R(65)=0.0
        IF(TTANK.GT.96.0)R(65)=1.0
        IF(R(65).GT.0.0.AND.TTANK.LT.94.0)R(65)=0.0
   124  CONTINUE
```

Component 136, Emergency HX Controller

Subroutine SPLIT

GPOLY1

When the isotope heater outlet temperature reaches 190°F start coolant flow to emergency heat exchanger.

```
        LTHL  HX CONTROLLER (COMPONENT  136)

        IF(N.NE.136)GO TO 136
        RITET=VV(100,2)
        R(65)=0.0
        IF(RITET.GT.190.0)R(65)=1.0
   136  CONTINUE
```

3.2.1.1 Low Temperature Isotope Heater Nodal Network

The simulation of the low temperature heater and shield tank is accomplished using the G-189A generalized thermal analysis subroutine THERML. The low temperature heater consists of a plutonium capsule and electrical heater generating a total of 5120 BTU/hr, circumvented by a heat transfer plate which dissipates heat to the heating fluid (water at about 15.0 psi). The capsule with the heat dissipation plate are immersed in a water tank which not only acts as a radiation shield, but also serves to dissipate the heat from the radioisotope in the event the heating fluid flow stops. Figure 3.4 is a nodal model of the low-temperature heating system. It consists of a water tank, a heater exchanger through which the heat from the radioisotope is transferred to the heating fluid, and the radioisotope core.

3.2.2 Flush Water Loop

The G-189A schematic for the flush water loop is shown in Figure 3.5. The first component in the solution path of the flush loop is the warm flush water tank. The flush water requirements for the urinal, blender, and the wash shredder are given in computer input Table Data 6, 7 and 8 respectively. (Appendix B) These requirements are imposed on the tank component and the flow is pumped to the corresponding valve (components 46, 48 or 50) leading to the user load. The GPOLY logic which performs this function is listed in Table 3.2.

Makeup water is added to the tank from the ECS condensate system. A constant water flow of 0.824 lb/hr at 70°F is entered through alternate component 51.

The TANKG subroutine which simulates the warm flush water tank has been modified to include internal and external convective heating as well as being able to perform steady state heat balance. The subroutine documentation for TANKG is included in Appendix A. A mass and energy balance schematic for the tank illustrating key tank parameters is shown in Figure 3.6. The schematic should be useful in readily selecting key tank data from the program output. The schematic is valid for all the tanks included in the RITE simulation.

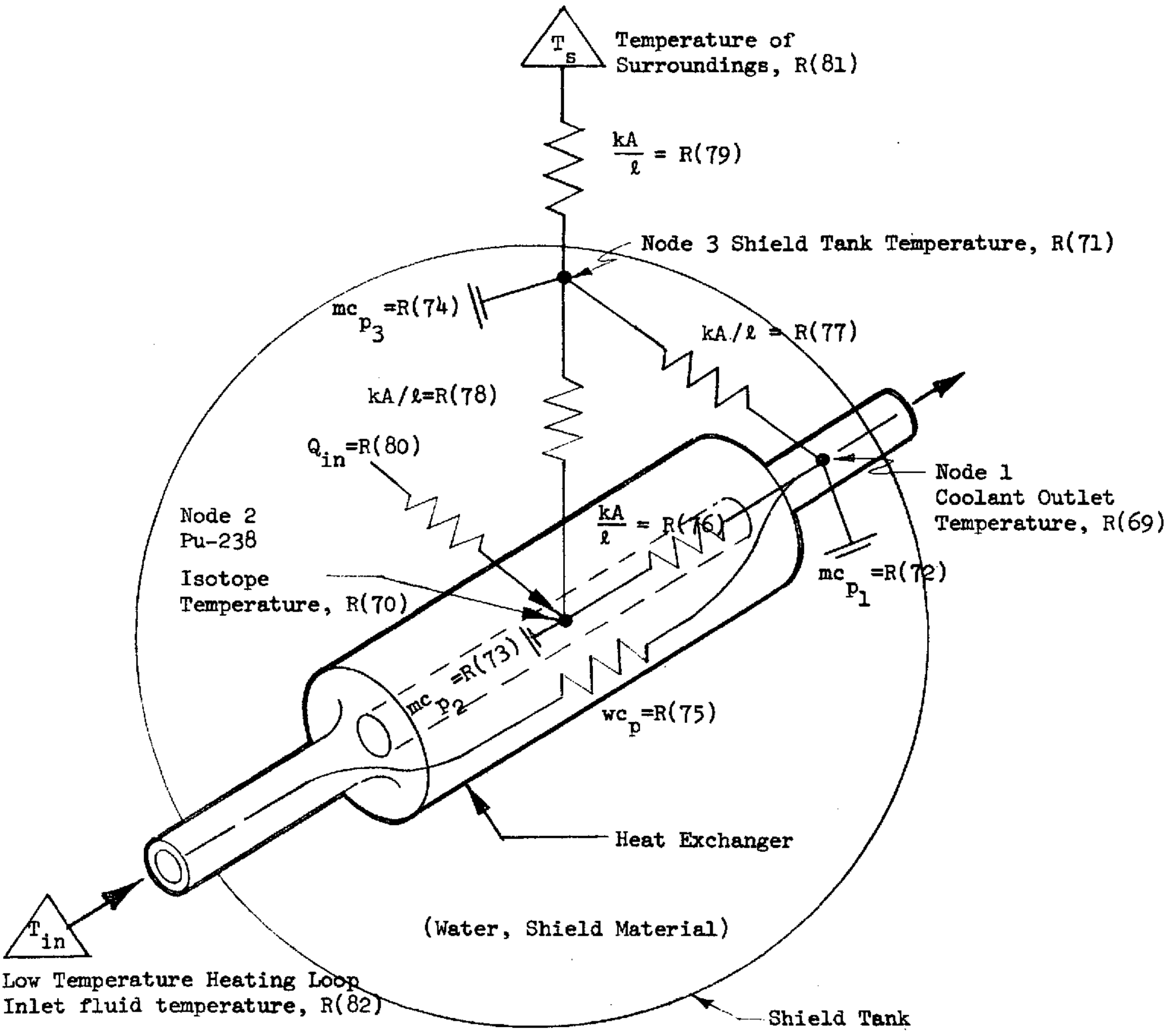


FIGURE 3.4 ISOTOPE HEATER THERMAL NODAL NETWORK

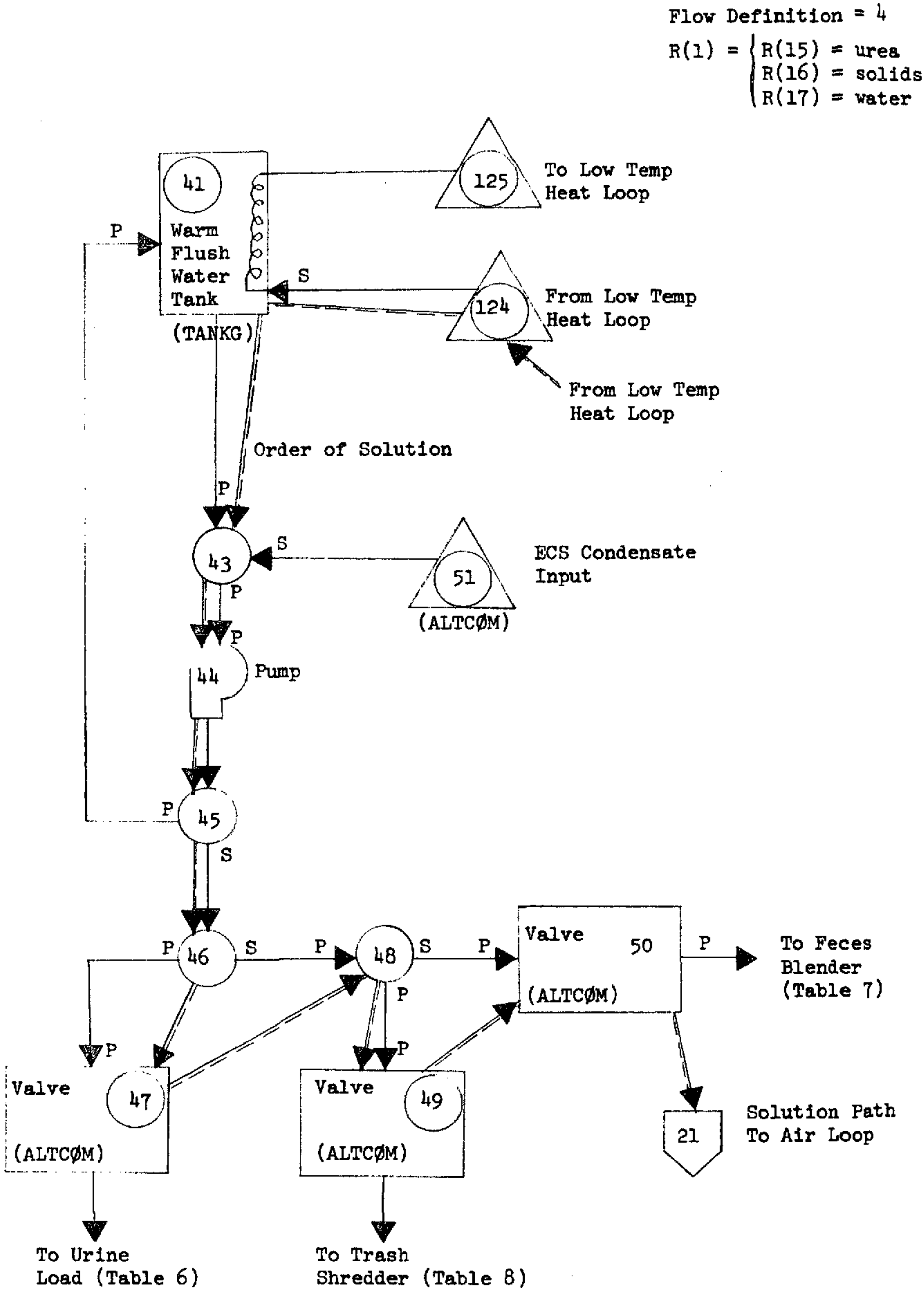


FIGURE 3.5 FLUSH WATER LOOP (FLOW CODE 4)

Table 3.2

GPOLY LOGIC FOR THE WATER LOOP

Order of Solution From Low Temperature Heating Loop, 41, 43, 44, 45, 46, 47, 48, 49, 50, to Air Loop

Component 41, Warm Flush Water Tank

Subroutine: TANKG

GPOLY1

The output of the tank is equal to the flush water requirements of the urinal, w_u, shredder, w_s, and blender, w_f. These are read from tables 6, 8 and 7 respectively (see below)

The split ratio of 45 is then calculated

$$SR = \frac{w_c}{w_c + w_u + w_s + w_f}$$

where w_c is the input condensate flow

The split ratio of 46 is then calculated

$$SR = \frac{w_s + w_f}{w_s + w_f + w_u}$$

The split ratio of 48 is then calculated

$$SR = \frac{w_f}{w_s + w_f}$$

These values are stored in their respective component data.

```
C
C     GPOLY1  LOGIC  FOR  FLUSH WATER LOOP
C
C
C
C
C     COMPONENT  41  WARM FLUSH WATER TANK
      IF(N.NE.41) GO TO 41
      WU=VALUE(6,CYCLE(3600,0,0,0),0,0)
      WS=VALUE(8,CYCLE(21000,0,0,0),0,0)
      WF=VALUE(7,CYCLE(21000,0,0,0),0,0)
      R(17)=WU+WF+WS
      R(1)=R(17)
      W51=VV(51,17)
      A(1)=W51
      A(2)=70.0
      A(17)=A(1)
      SPLT45=0.0
      IF(R(17).NE.0.0)SPLT45=R(17)/(R(17)+W51)
      CALL SV(SPLT45,45,65)
      SPLIT46=0.0
      IF(R(17).NE.0.0)SPLIT46=(WS+WF)/R(17)
      CALL SV(SPLIT46,46,65)
      SPLIT48=0.0
      IF( WS+WF.GT.0.0)SPLIT48=WF/(WS+WF)
      CALL SV(SPLIT48,48,65)
   41 CONTINUE
```

Component 44, Pump

Subroutine: PUMP

GPOLY2

Pump electrical power calculated from the following relationship:

$$P_p = 0.0527 + 0.0473\ w$$

where w is the flow rate

```
C
C     FLUSH WATER  PUMP-COMPONENT  44
C     CALCULATION OF PUMP POWER
C
      IF(N.NE.44) GO TO 44
      R(70)=0.0
      IF(R(1).GT.0.0)R(70)=0.0527+0.0473*R(1)
   44 CONTINUE
```

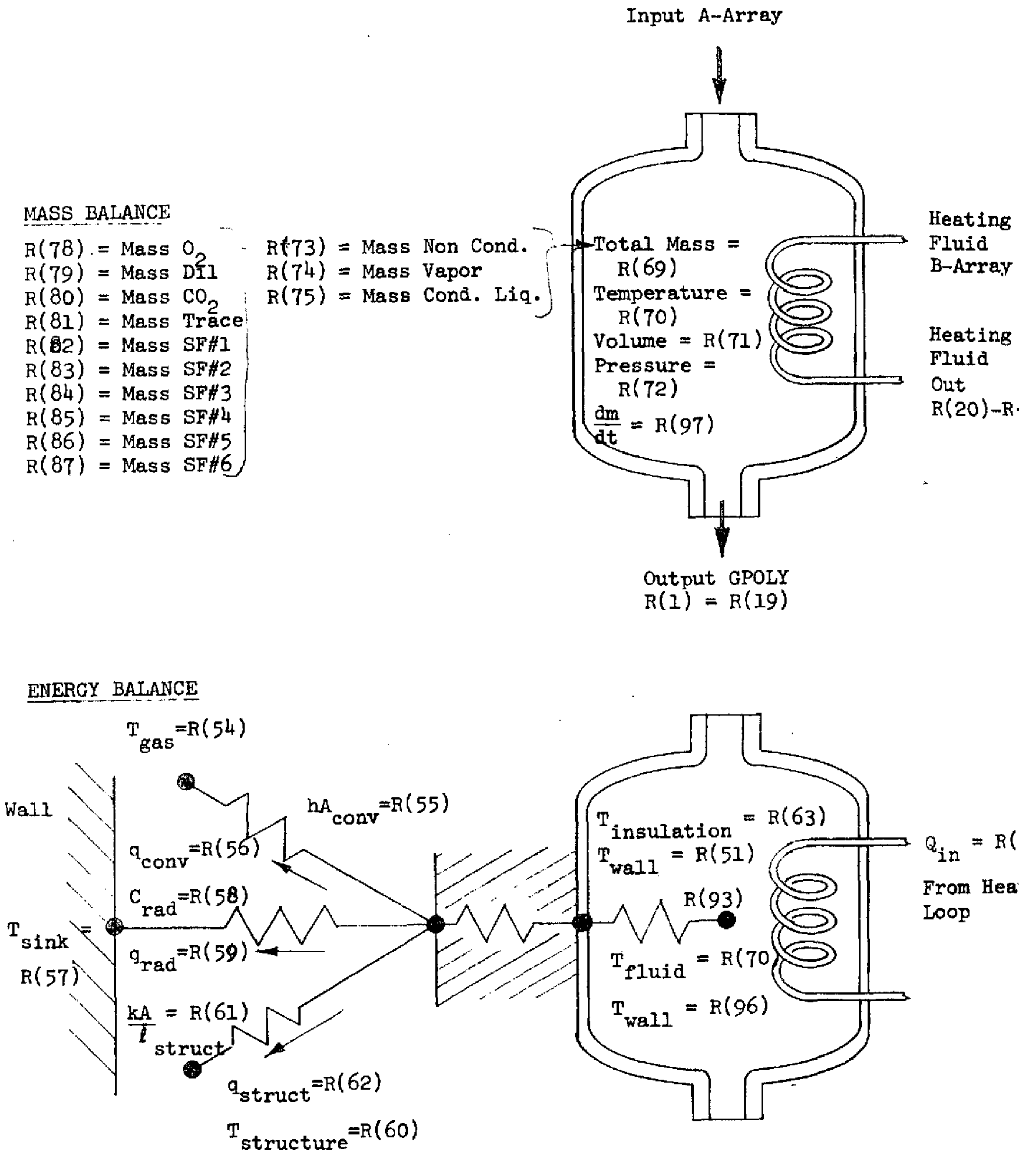


FIGURE 3.6 TANKG MASS AND ENERGY G-189 OUTPUT REPRESENTATION

3.2.3 Air Loop

The G-189A schematic for the air loop is shown in Figure 3.7. Urine and drying air enters the system through component 21, the urinal, as defined by the schedule entered in computer input Table 9 (air supply) and Table 10 (urine supply). Urinal flush water enters the loop through component 22. The combined water, urine and air flow enters the liquid-gas separator, component 23, where the liquids are separated and directed to the evaporator. The gases are blown by the fan through the air sterilizer and then returned to the cabin. The control logic for the loop is shown in Table 3.3.

3.2.3.1 Air Sterilizer Thermal Model

The air sterilizer consists of a high temperature sterilization chamber and a counterflow heat exchanger. It operates during the commode use and serves to assure that viable organisms do not escape from the WM/WS via transport air flow. A secondary function is to provide thermal control of the RITE capsule in the heat block should the heat pipe malfunction. A nodal schematic of the air sterilizer is shown in Figure 3.8.

The simulation of the air sterilizer is accomplished using the G-189 component subroutine THERML, the thermal analyzer subroutine. Subroutine THERML was used to determine heat balance and heat loss due to air sterilizer operation and to predict the overall performance of the air sterilizer.

3.2.4 Solid Waste Loop

The G-189 schematic for the solid waste loop is shown in Figure 3.9. The loop serves to direct all liquid and solid wastes into the evaporator. Component 201 is used to enter feces in accordance to the schedule entered in Computer Support Table 16 (see Appendix B). Flush water for defecation enters from the flush water loop from component 50. Trash is supplied from component 50 in accordance to the schedule noted in Computer Table 13. The corresponding trash flush water supply enters through flush loop valve component 49. A constant supply of one pound per hour wash water enters the system from component 219. All the solids and liquids are directed to the primary side of the evaporator.

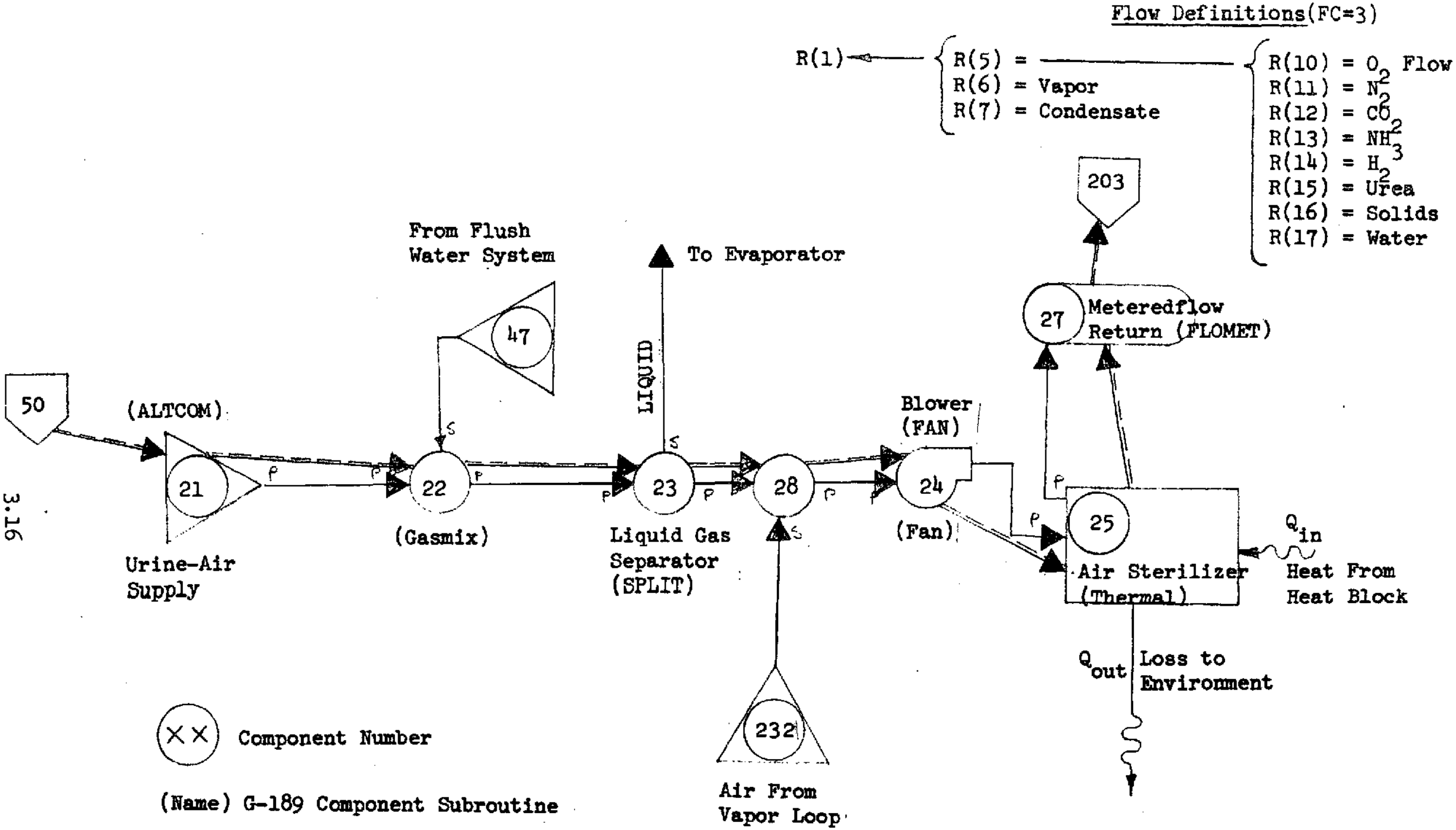


FIGURE 3.7 G-189 COMPONENT DEFINITION DIAGRAM
FOR THE AIR LOOP (FLOW CODE 3)

Table 3.3

GPOLY LOGIC FOR THE AIR LOOP

Component order of solution - From Flush Water Loop 21, 22, 23, 28, 24, 25, 27 to Solid Waste Loop

Component 21, Urine Air Supply

Subroutine: ALTCOM

GPLOY2

Air supply schedule taken from Table 9. Air is assumed to be composed of the following constituents:

Water Vapor	1.05	%
Oxygen	26.3	%
Nitrogen	72	%
Carbon Dioxide	65	%

Urine input schedule from Table 10. Urine is assumed to be composed of the following constituents:

Water	94.2%
Urea	2.8%
Urine Solids	3.0%

Urine temperature set at 98.6°F
Urine pressure set at 15 psia

```
C     COMPONENT 21  URINE AIR SUPPLY
      IF(N.NE.21) GO TO 21
C
C     STANDARD AIR INPUT=14.7 PSI     70 DEG= F
C     WATER VAPOR     1.05 PERCENT
C     OXYGEN         26.3  PERCENT
C     NITROGEN       72.0  PERCENT
C     CARB-DIOXIDE   00.65 PERCENT
      WAIR=VALUE(9,CYCLE(3600,0,0.0),0.0)
      R(6)=0.0105*WAIR
      R(10)=0.263*WAIR
      R(11)=0.72 *WAIR
      R(12)=0.0065*WAIR
C
      R(2)=98.6
C     INPUT= MICTURATION
      WUR=VALUE(10,CYCLE(3600,0,0.0),0.0)
      R(3)=15.0
      R(4)=15.0
      R(17)=0.942*WUR
      R(15)=0.028*WUR
      R(16)=0.03*WUR
   21 CONTINUE
```

Component 22 - Flush Water Supply

Subroutine: GASMIX

GPOLY1

Modification to compensate for flow code 4 of flush loop
Set flush water c_p = 1.0
Set molecular wt = 10^{10}
This is required to use a gas mix subroutine with flush water

```
C
C
C     GPOLY1  LOGIC  FOR   AIR LOOP
C
C
C
      IF(N .NE. 22) GO TO 22
C
C
         R(3)=15.
         R(4)=15.
         R(8)=1.0
         R(9)=1.0E+10
   22 CONTINUE
```

Component 24, Fan

Subroutine: FAN

GPOLY2

The pump power is calculated using the following relationship:

$P_p = 117. + 0.91\,w$

where w is the air flow

```
C     AIR LOOP FAN - COMPONENT 24 -FAN ELECTRICAL POWER
C
C
      IF(N.NE.24)GO TO 24
C
      R(72)=0.0
      IF(A(1).GT.0.0)R(72)=117.0+0.91*A(1)
   24 CONTINUE
```

Component 25, Air Sterilizer

Subroutine: THERMAL

GPOLY1

The nodal network is initiated from the R-array

The inlet temperature is set to R(116)

R(116) = A(2)

All flow in fluid nodes are set to

wc_p = A(1)*CPA

The heat block temperature which transmits heat to the sterilizer is called from heat block component 180

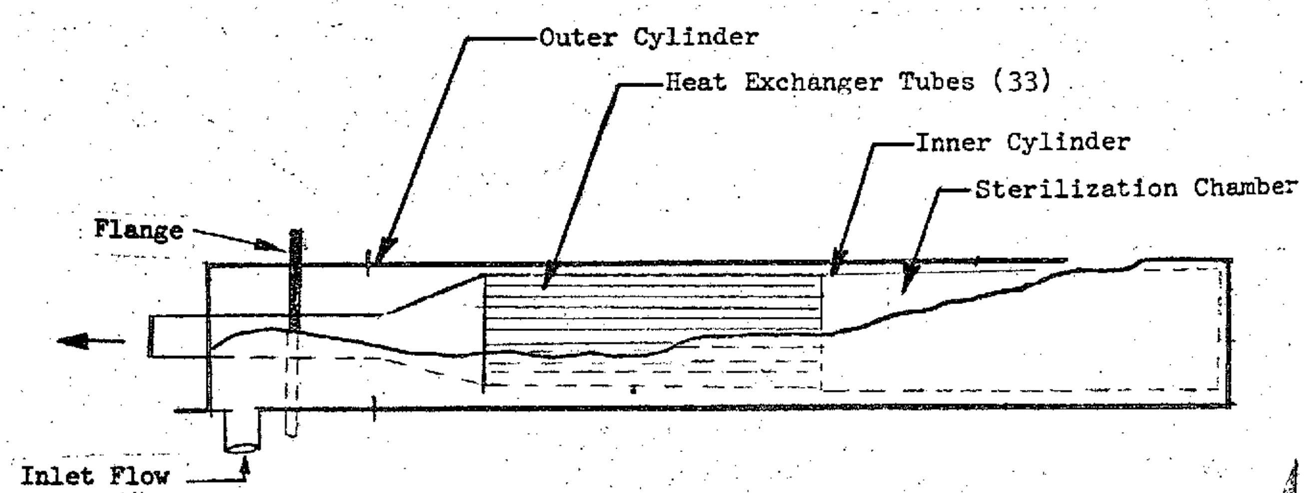
R(118) = VV(180, 76)

```
      IF(N .NE. 25) GO TO 25
C                             THE FOLLOWING CARDS INTERFACE AIR STE
C                             TO THE SYSTEM
C          FLOW CONVECTION TERMS
           DO 1025 J=1,19
 1025      R(J)=A(J)
           R(116)=A(2)
           R(106)=A(1)*CPA
           R(104)=A(1)*CPA
           R(102)=A(1)*CPA
           R(99)=A(1)*CPA
           R(96)=A(1)*CPA
           R(93)=A(1)*CPA
C          HEAT BLOCK TEMPERATURE AT NODE 6 HTNG TO AIR STERILI
           R(118)=VV(180,76)
   25 CONTINUE
```

GPOLY2

Reset outlet temperature of R-array from nodal network

```
C
      IF(N .NE. 25) GO TO 25
C                         INTERFACE COMPONENT 25 TO 27
           R(2)=R(80)
   25 CONTINUE
```



Node 1: Outer Cylinder Inlet
Node 2: Outer Cylinder Circumventing The Counterflow Hx
Node 3: Outer Cylinder In Contact With Heat Block
Node 4: Inner Cylinder Defining The Sterilization Chamber
Node 5: 33 Tubes Defining the Heat Exchanger
Node 6: Inner Tube Manifolding Flow Through Hx to the Outlet
Node 7: Air Regime Bounded by Nodes 1 and 6
Node 8: Air Regime Bounded by Nodes 2 and 5, Flow Around Hx Tubes
Node 9: Air Regime Bounded by Nodes 3 and 4
Node 10: Air Regime Defining the Air Sterilization Chamber
Node 11: Air Regime Defining the Return Flow Through Hx Tubes
Node 12: Air Regime Defining the Outlet Section of Air Sterilizer

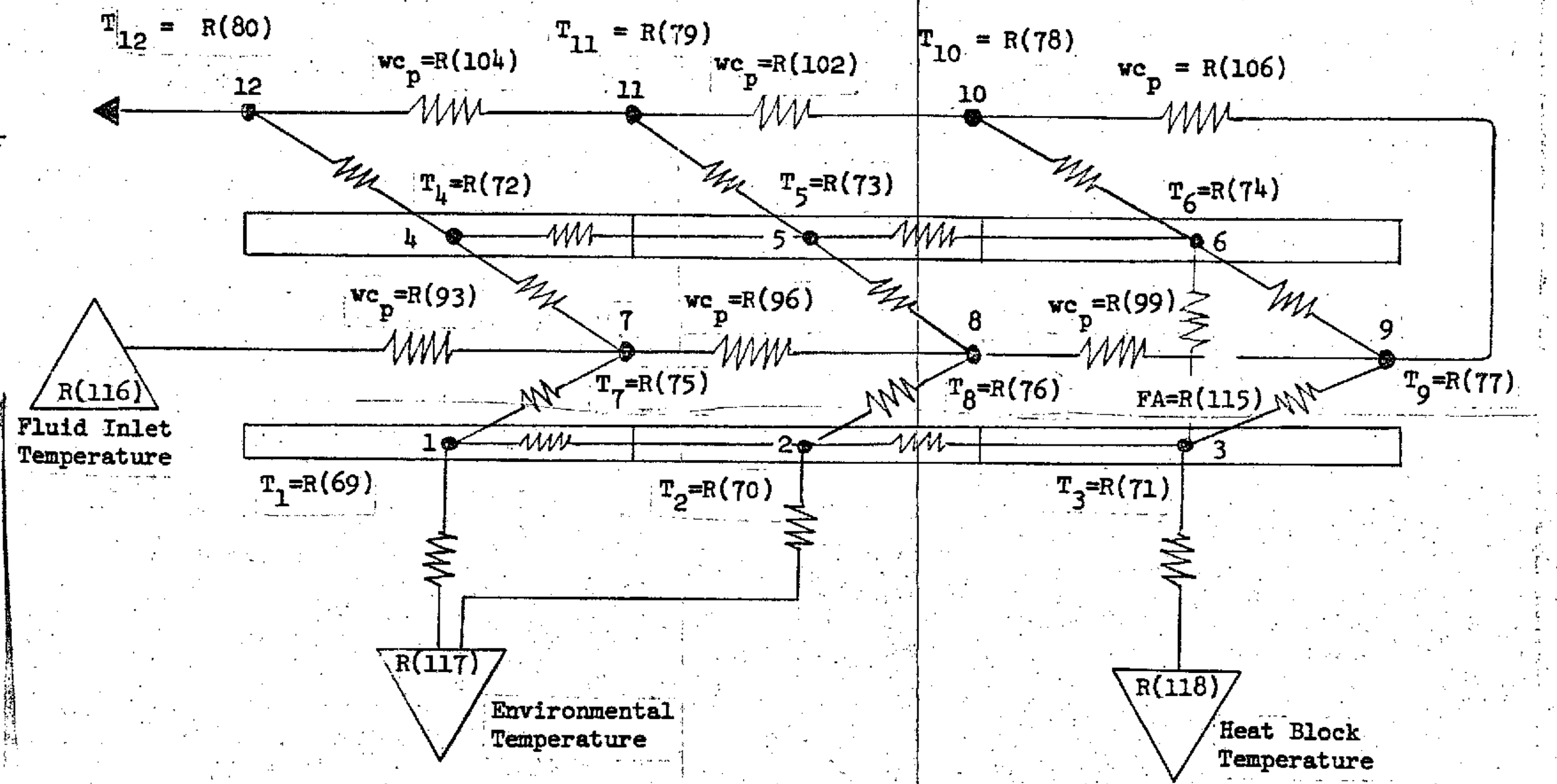


FIGURE 3.8 AIR STERILIZER SCHEMATIC DEFINING THERMAL NODES

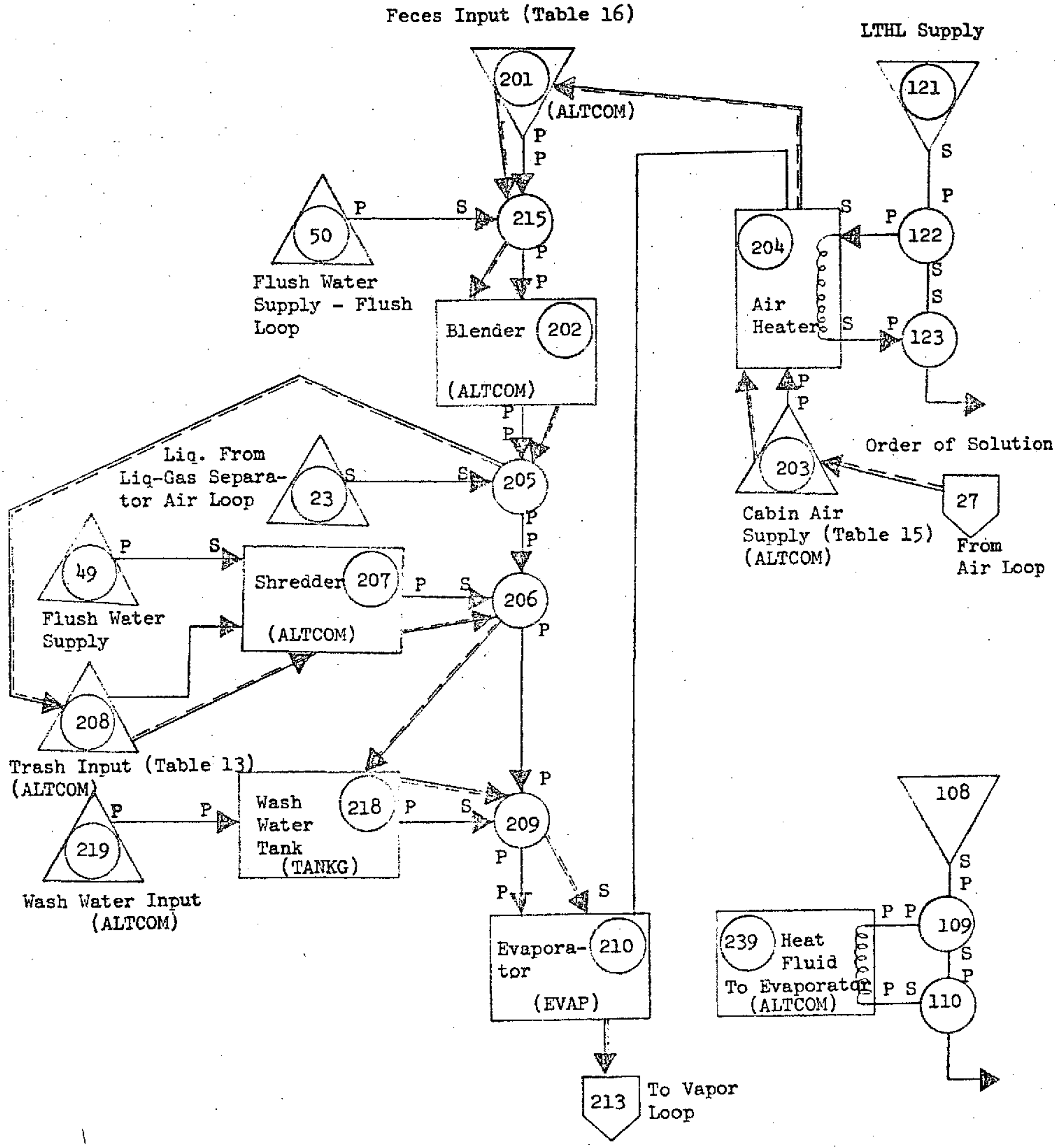


FIGURE 3.9 G-189A SCHEMATIC OF THE SOLID WASTE LOOP

Drying air for defecation enters from component 203 as scheduled by Computer Table 15. The air is heated by the low temperature heating loop prior to entering the evaporator.

The GPOLY logic for the solid waste loop is shown in detail in Table 3.4.

3.2.5 Vapor Loop

The vapor loop is comprised of those components through which the vapor stream flows, originating at the evaporator and terminating (condensing) at the condenser. The G-189A schematic of the system is shown in Figure 3.10.

All solid and gaseous inputs enter the evaporator from the solid waste loop. In the evaporator the solids are separated and directed to the incinerator. The water is evaporated and the vapor is directed to the pyrolysis units where ammonia and other products mixed with the vapor are oxidized. The neutralized vapor is then directed to the condenser where the vapor is condensed and the gaseous products of the pyrolysis reactions are vented to vacuum.

The principal problem encountered with the simulation of the vapor loop was the selection of the computational time increment during transient solution. The vapor loop requires a very small computational time increment for stability purposes because of very low evaporator and condenser contained gas weight to gas weight flow rate ratio. A scheme was implemented via GPOLY logic where a stable computing time increment smaller than the system computational time increment was computed at the beginning of the evaporator calculations and the program executed the required number of passes through the vapor loop before proceeding with the larger system time increment.to the components that follow the vapor loop. The scheme for computing the stable time increment and performing the computations for the vapor loop components is shown in Table 3.5

3.2.5.1 GPOLY Logic For Vapor Loop Components

The GPOLY logic for key vapor loop components is described below:

Table 3.4

GPOLY LOGIC FOR SOLID WASTE LOOP

Order of Solution - Start from Air Loop Component 27

203, 204, 201, 215, 202, 205, 208, 207, 206, 218, 209, Vapor Loop Component 210

Component 203, Blender Air Supply

Get total air flow from tube 15
Constituents of air are

Water vapor, R(6)	=	1.05%
Oxygen, R(10)	=	26.3 %
Nitrogen, R(11)	=	72 %
Carbon Dimxide R(12)	=	.65%

```
C      GPOLY2   LOGIC  FOR SOLID WASTE LOOP
C
C
C      COMPONENT 203   BLENDER AIR  SUPPLY
       IF(N,NE,203) GO TO 203
       WAIRB=VALUE(15,CYCLE(21000,0,0,0),0,0)
       R(6)=  0.0105*WAIRB
       R(10)= 0.263 *WAIRB
       R(11)=  0,72  *WAIRB
       R(2)=60,0
       R(12)= 0.0065*WAIRB
   203 CONTINUE
C
```

Component 201, Solids Input

Solids input into blender from Table 14.

```
C
C      COMPONENT  201--SOLIDS INPUT
       IF(N,NE,201) GO TO  201
       R(2)=98,6
       R(16)=VALUE(14,CYCLE(21000,0,0,0),0,0)
   201 CONTINUE
C
```

Component 202, Blender

The power level of the blender when in use is 372

```
C      BLENDER--COMPONENT 202    POWER CALCULATION
C      R(65) IS SET  EQUAL TO BLENDER ELECTRICAL POWER
C
       IF(N,NE,202)GO TO 202
       R(65)=0,0
       IF(A(1)                   ,GT,0,0)R(65)=372,0
   202 CONTINUE
C
```

Table 3.4

GPOLY LOGIC FOR SOLID WASTE LOOP

(continued)

Component 208, Trash Supply

Trash input is determined from Input Data Table 13.

```
C      COMPONENT  208   TRASH SUPPLY
C
       IF(N.NE.208)GO TO 208
       R(16)=VALUE(13,CYCLE(21000,0,0,0),0,0)
       R(2)=80.0
  208  CONTINUE
C
```

Component 207, Shredder

If shredder on the power level is 977 watts.

```
C
C      SHREDDER --COMPONENT 207  ELECTRICAL POWER
C
       IF(N.NE.207)GO TO 207
       R(65)=0.0
       IF(A(1).GT.0.0 .OR.R(1).GT.0.0)R(65)=977.0
  207  CONTINUE
C
```

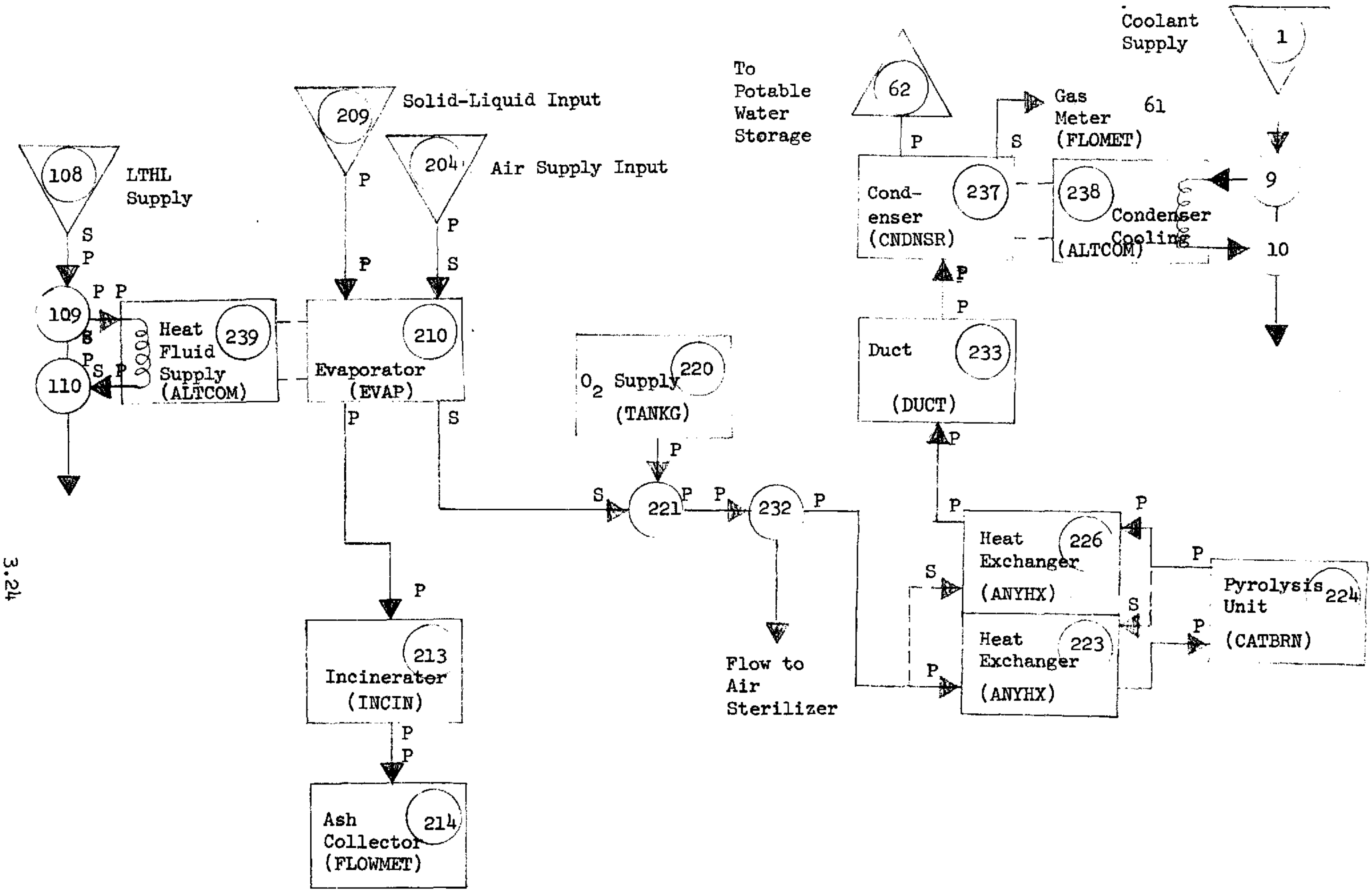


FIGURE 3.10 G-189 COMPONENT AND FLOW SCHEMATIC FOR THE VAPOR LOOP

Table 3.5

GPOLY CONTROL LOGIC FOR COMPUTING/IMPLEMENTING STABLE TIME INCREMENT (VAPOR LOOP)

Component #210 Evaporator

GPOLY Logic

At the evaporator, the system time increment is saved, DELTAT. If NCOUNT > 0, then we do not compute vapor loop time increment. If NCOUNT = 0, compute time increment, and number of passes per system pass required for the vapor loop.

TIME is incremented to maintain proper timing of system.

```
      IF(STEADY) GO TO 210
        ******  INTERNAL TIME INCREMENT  ****   (VAPOR LOOP)
 SET SMALL TIME INCREMENT FOR OUTER LOOP
      DELTAT=60.
      IF ( NCOUNT .GT. 0 ) GO TO 2103
      TIMINC=.1*VV(237,91)/R(20)*3600.
      MAXCNT =IFIX( DTIME / TIMINC ) +1
      TIMINC = DTIME/ FLOAT(MAXCNT )
      DTIME = TIMING
      WRITE(6,666) DTIME
  666 FORMAT(1X,*THE VALUE OF DTIME IS EQUAL TO * ,F9.6  ///
 2103 CONTINUE
      NCOUNT = NCOUNT + 1
      IF(NCOUNT .LE. 1) TIME=TIME-DELTAT
      TIME=TIME+TIMING
  210 CONTINUE
```

Component #237 - Condenser

GPOLY Logic

During transient saturation of the condenser a test for number of passes through vapor loop is made. If value is less than required the NEXT component to be solved is set to #210. Otherwise NCOUNT is reset to zero and system time step is reset to the original value.

```
       IF(N .NE. 237) GO TO 237
       IF(STEADY) GO TO 237

C
C        ******  INTERNAL TIME INCREMENT  ****   (VAPOR LOOP)
       IF( NCOUNT .GE. MAXCNT ) GO TO 2375
       NEXT = 210
       GO TO 2373
  2375 CONTINUE
       DTIME = DELTAT
       NCOUNT = 0
  2373 CONTINUE
       R(1)=R(69)
   237     CONTINUE
C
```

Table 3.5

GPOLY CONTROL LOGIC FOR COMPUTING/IMPLEMENTING STABLE TIME INCREMENT (VAPOR LOOP)
(Continued)

<u>Component #100 - Isotope Heater</u>
 	
<u>GPOLY Logic</u>
 	
To provide for correct time values and not to impede the system initialization process, the evaporator is made the last component once system starts executing.
	<pre>C
	      IF(N .NE. 100) GO TO 1[illegible]0
	      NLAST=209</pre>

Component 210 - Evaporator

A subroutine capable of simulating the evaporator in the General Electric RITE system was not available in the G-189A program library. Therefore a new routine, EVAP, was written. The subroutine documentation, which is contained in Appendix A, includes schematics, mathematical modelling, and operational procedures.

The EVAP subroutine flow chart is shown in Figure 3.11. The subroutine performs mass and thermal balances for either steady state or transient operation. EVAP includes the capability of separating (filtering) and storing wet solids in a reservoir so as to allow their subsequent removal from the system by a solids pump. In addition the subroutine simulates biochemical reactions that occurs within the evaporator. Due to the complex nature of the mass balance in the evaporator a mss balance schematic is included (Figure 3.12) which is helpful in reading the computer output.

The General Electric Summary Report, Reference 1, modified and reproduced as Table 5-2 of this report was used as the reference for predicting the chemical reactions. The weight flowrate of gases was not given; therefore a prediction was made that the vent flowrates would be according to the following assumptions:

1. Flow rates of product gases out of the condenser were assumed to be in the same weight proportion as reported in the G.E. vent analysis. Chemical reactions in the system were predicted based on these resultant vent gas constituents.

2. Two principal non-condensable gases generated in the evaporator are CO_2 and NH_3. They are genereated from the biochemical decomposition of urea and from ammonium carbonate/bicarbonate during vaporization of the liquid.

3. Half of the urea is removed from the evaporator by the solids filter while the other half biochemically decomposes to yield NH_3 and CO_2.

4. The amounts of CO_2, H_2, O_2, NO_2, NO and N_2 vented are based on the amount of NH_3 generated.

The GPOLY logic which was implemented to simulate the chemical reactions in the pyrolysis unit and to predice the amount of O_2 required to meet the vent requirements is presented in Table 3.6.

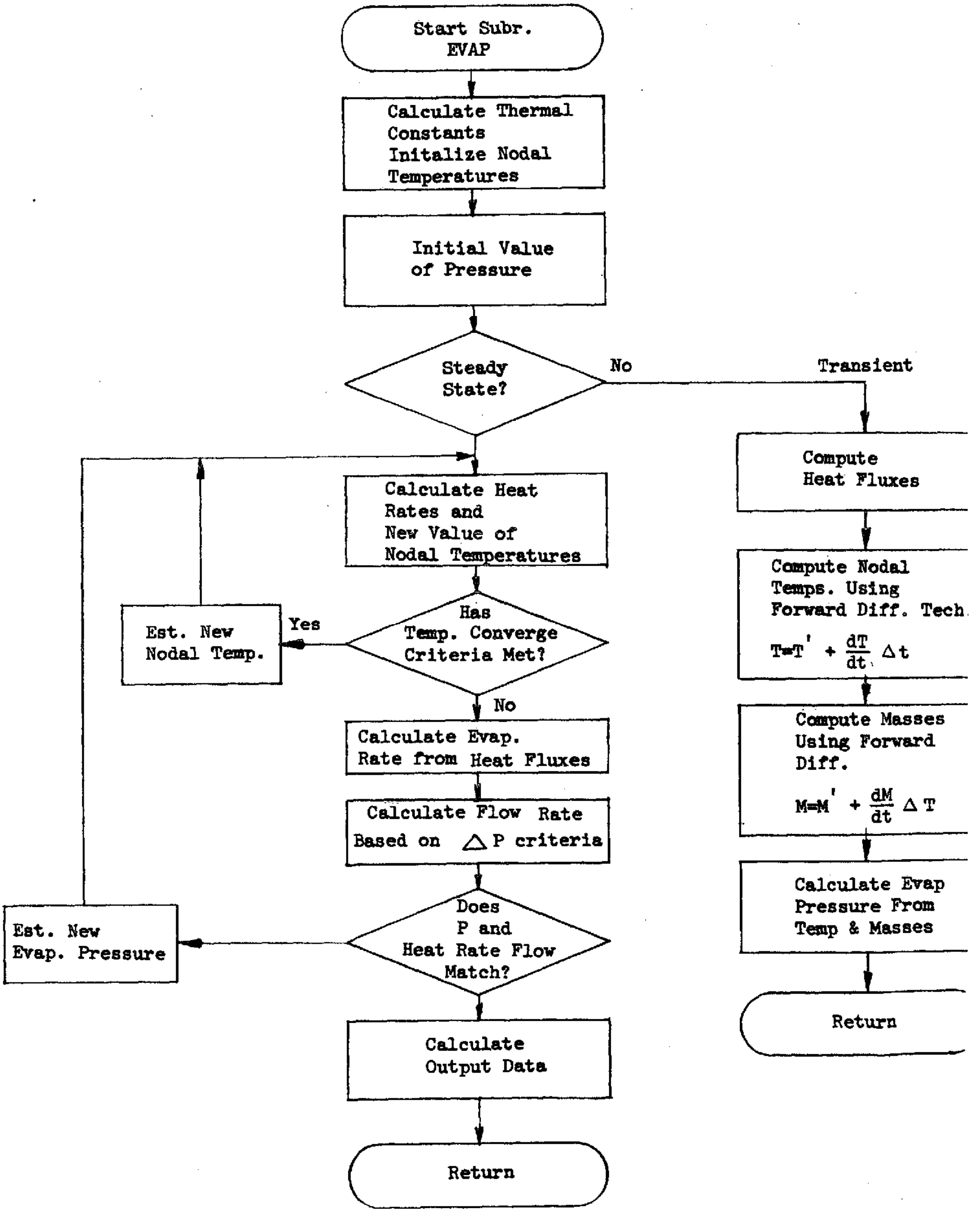


FIGURE 3.11 EVAP SUBROUTINE FLOW CHART

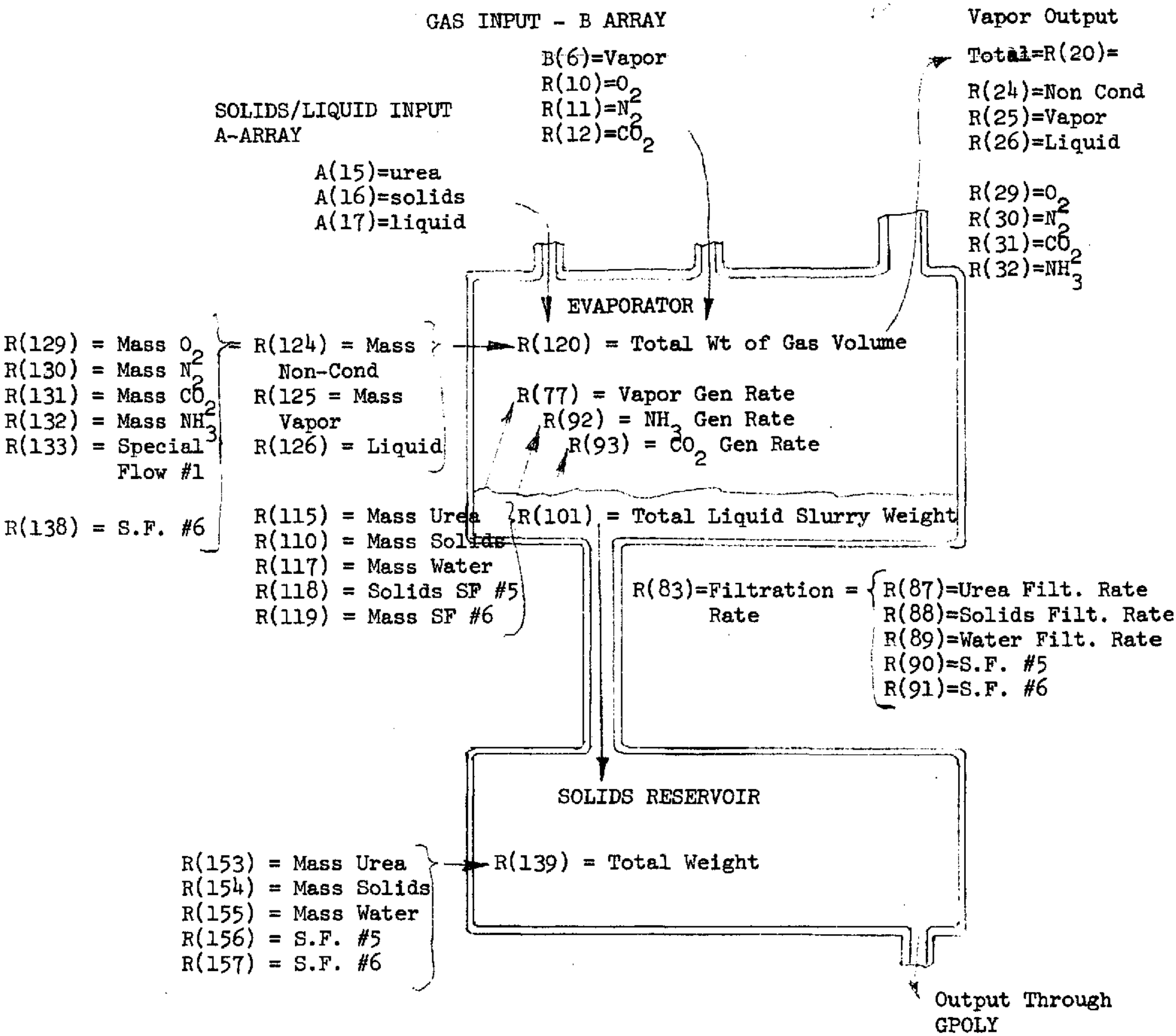


FIGURE 3.12 MASS BALANCE IN THE EVAPORATOR

TABLE 3.6 GPOLY LOGIC TO ATTAIN MASS BALANCE IN VAPOR LOOP

Order of Solution - From Solids Loop - 210, 221, 232, 223, 224, 226, 233, 237, 213, 214, to Potable Water Storage Loop

Component #221-TEE

GPOLY1 Logic

The primary flow which defines the O_2 flow injected into gas stream is defined as

$$w_{O_2} = .7651 * w_{NH_3}$$

where w_{NH_3} is NH_3 flow.

Remaining code updates the storage tanks, weight and pressure.

```
      IF(H .NE. 221) GO TO 221
            A(1)=B(13)*.7651
            A(5)=A(1)
            A(10)=A(1)
            A(2)=70.
            WO2TNK=VV(221,69)
            A(8)=.22
            A(9)=32.
            WO2TNK=WO2TNK-A(1)*DTIME
            A(3)=WO2TNK*1545./32*530./144.
            A(4)=A(3)
      CALL SV(WO2TNK,220,69)
      CALL SV(WO2TNK,220,77)
      CALL SV(WO2TNK,220,78)

      CALL SV(WO2TNK,220,69)
      CALL SV(A(3),220,3)
      CALL SV(A(3),220,4)
      CALL SV(A(3),220,72)
  221 CONTINUE
C
```

Component #224 - Pyrolysis Unit

GPOLY1 Logic

H_2 and N_2 is formed from disassociation NH_3. NH_3 flow is set to zero.

In the Bosch reaction the amount of carbon formed is function of CO_2 generated. The reaction coefficient .98491 was derived from vent analysis presented in Reference 1.

```
C                 PYROLYZE      NH3 = 1/2 N2  +  3/2 H2
      A(14)=A(13)*1.5*(WTH(14)/WTMTC)
      A(11)=A(13)*0.5*(WTHNIL/WTMTC)
      A(13)=0.
C
C           SIMULATE BOSCH REACTION  2H2+CO2=C+2H2O
C
      CRBNDR=A(12)*12./44.*.984191
      A(14)=A(14)-.98421*A(12)*4./44.
      A(12)=.015909*A(12)
  224 CONTINUE
```

Table 3.6

GPOLY LOGIC TO ATTAIN MASS BALANCE IN VAPOR LOOP

(continued)

Component #244-Pyrolysis Unit

GPOLY2 Logic

Test to see if there is sufficient N_2 to generate NO_x gases. The value of the reaction coefficient was derived from vent gas analysis.

```
C
      IF(N .NE. 224) GO TO 224
C                   PREDICT AMOUNT NOX GENERATE IN THE PYROI
C                   SPECIAL FLOW 2  (A(15))=NO2
C                   SPECIA  FLOW 3  (A(16))=NO
      IF(A(11) .LT. 0.06*A(10))GO TO 2241
            A(15)=.00294 *A(10)*46./32.
      IF(R(11) .LT.  0.06*R(10)) GO TO 2241
          R(15)=.0032*R(10)*46./32.
          R(16)=.0032*R(10)*30./16.
          R(11)=R(11)-R(15)*14./46.-R(16)*14./30.
          R(10)=R(10)-R(15)*32./46.-R(16)*16./30.

 2241           CONTINUE
  224     CONTINUE
```

Component 220 Tee-Oxygen Supply

Component 220 supplies the oxygen required to generate the mass flows defined in Section 5. The oxygen is assumed to be available from a tank and the weight of the oxygen in the tank is continually updated.

Component 224 Pyrolysis Units

The mass balances for the pyrolysis reactions are implemented in the pyrolysis unit GPOLY1 and GPOLY2 logic. In GPOLY1 the disassociation of ammonia and the Bosch reaction are simulated. In GPOLY2 the oxidation of nitrogen to form NO and NO_2 are simulated. The logic is described in detail in Table 3.6.

Component 237 Condenser

A new subroutine, CNDNR, was written to simulate the RITE system condenser. The subroutine documentation includes a system schematic, mass and heat balance modeling and a description of the operation of the subroutine. The CNDNSR subroutine flow chart is shown in Figure 3.13.

The subroutine is capable of simulating condensing of water vapor entering the condenser, and venting of gases to vacuum. The condensate is removed by GPOLY logic. Due to the complex nature of the routine a mass balance schematic is included in Figure 3.14 to help identify key output parameters.

Component 213 Incinerator

The solid products removed by the solids filter are transferred to the incinerator for disposition. The waste products are processed by vacuum drying, chemical decomposition at high temperature, and venting of resultant gases. The incinerator is loaded in a batch process. The vent to vacuum is opened and the solids are dried. The vent to vacuum is closed and a

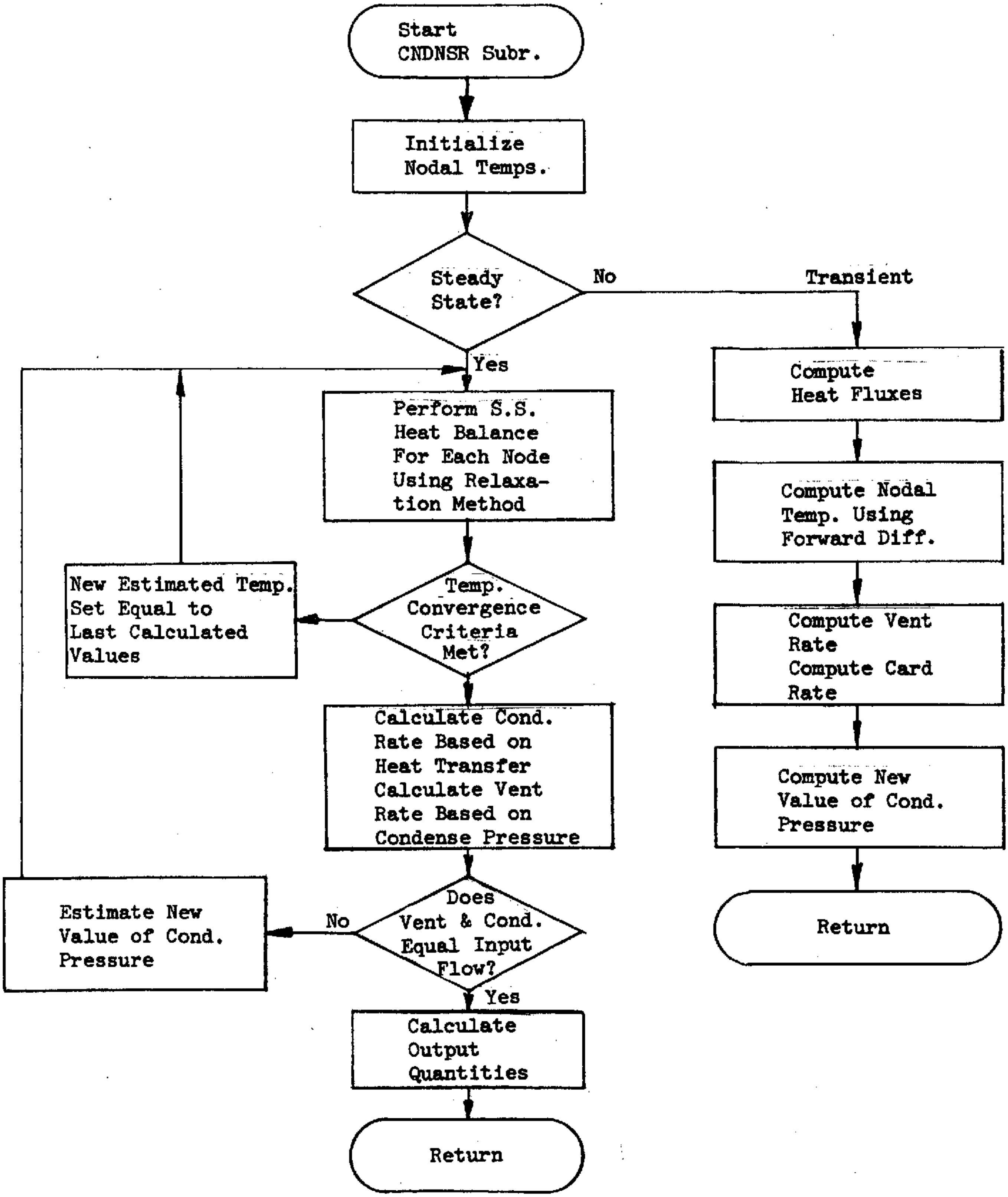
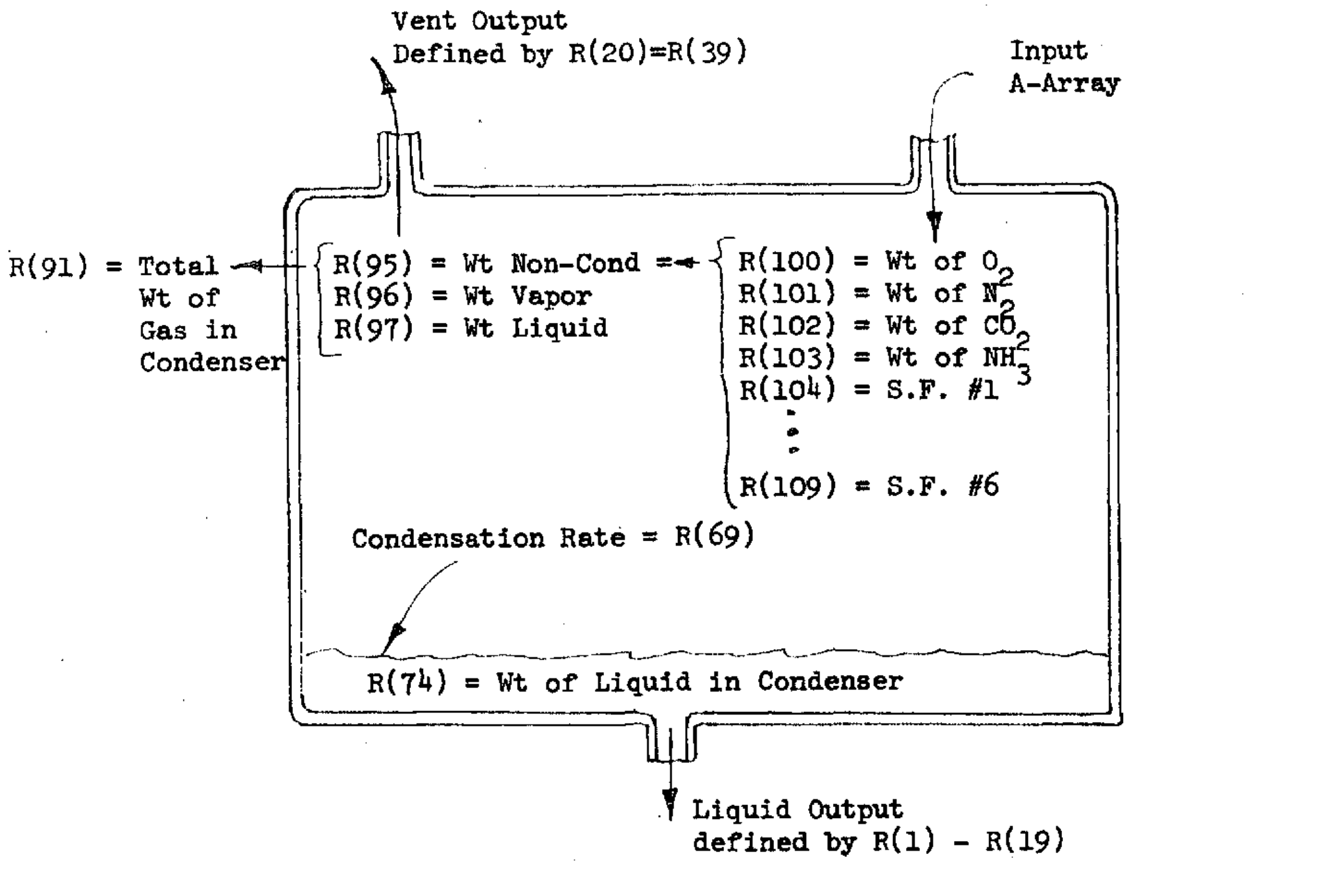
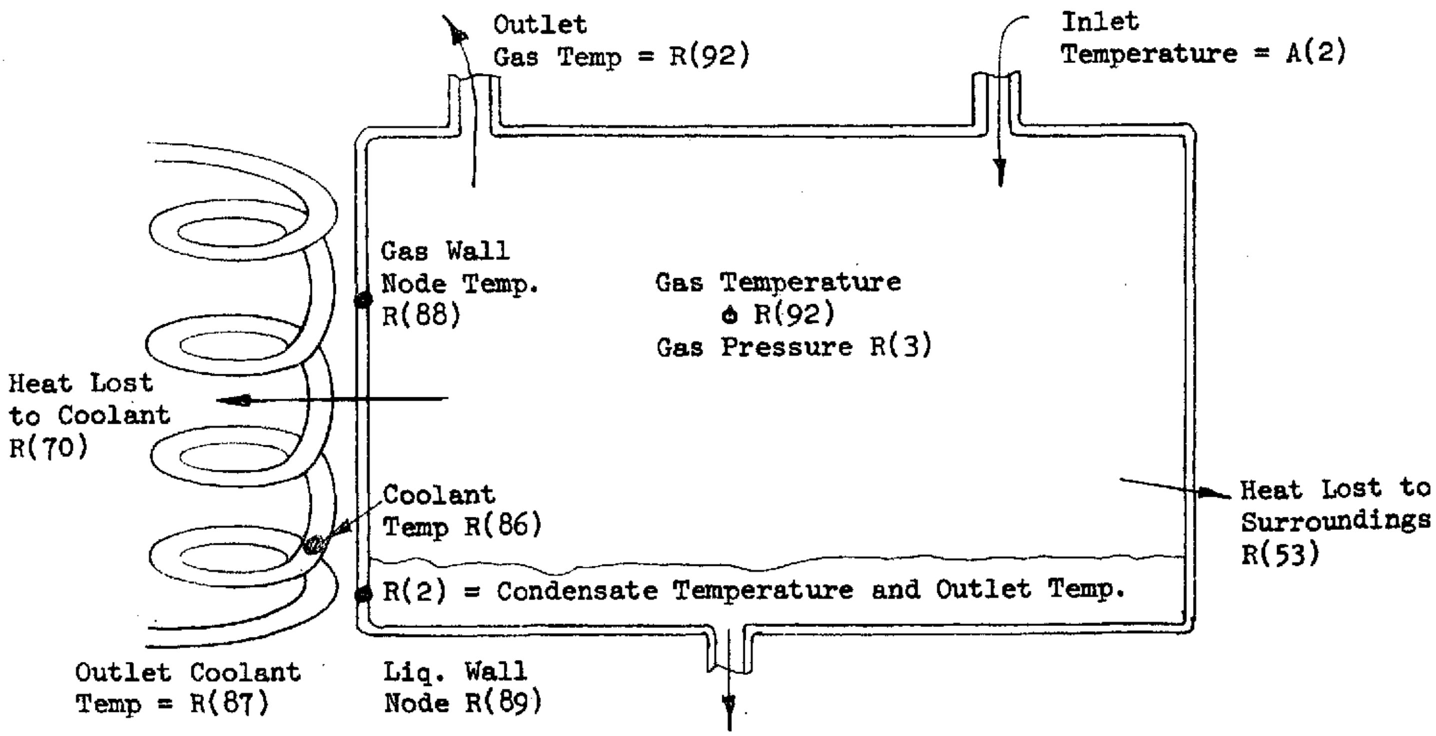


FIGURE 3.13 CNDNSR SUBROUTINE FLOW CHART



CONDENSER MASS BALANCE



CONDENSER ENERGY BALANCE

FIGURE 3.14 CONDENSER SUBROUTINE G-189 OUTPUT REPRESENTATION small amount of oxygen is introduced with the solids and the oxidation reaction proceeds. The product gases are then vented to vacuum. The oxygen cycle is repeated until all the solids are incinerated. At the end of the cycle, the remaining ash is blown out by a nitrogen purge. Approximately 0.5 pounds of solids are processed per batch. The cycle duration is approximately three hours.

A G-189A library subroutine for the incinerator was not available. Therefore a new subroutine INCIN was written. The subroutine documentation, which includes a complete description of the cycle including mass and thermal balances is provided in Appendix A.

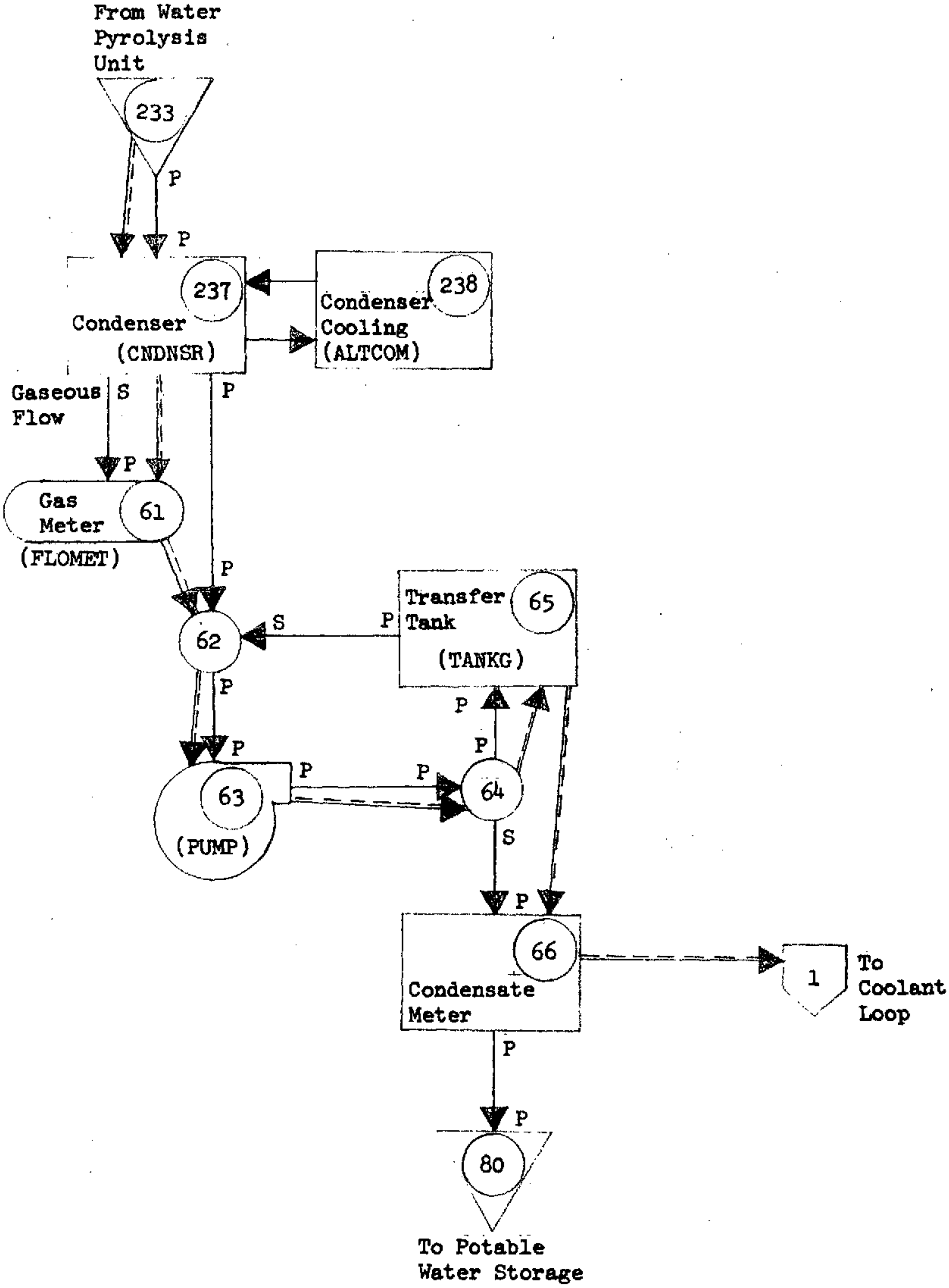
The subroutine requires a heat source temperature for waste processing. The corresponding heat block nodal temperature is entered into the subroutine through GPOLY1. The GPOLY1 logic is noted in Table 3.6.

3.2.6 Potable Water Storage Loop

The G189A schematic for the potable water storage loop is shown in Figures 3.15 and 3.16. The potable water system collects condensate water from the condenser and stores it in four potable water storage tanks. A fifth tank, initially full, is available for emergency use, however this tank cannot be filled from the condenser.

When the condenser reaches the 15 percent level, the transfer pump, component 63, draws half of the condenser condensate and stores it in an intermediate transfer tank, component 65. The condenser outlet is then closed and the same pump is then used to transfer the water in the transfer tank to the potable water tanks.

The tanks are drained upon demand as specified in Table 16 (see Appendix B); the cold water demand, and Table 17, hot water demand. Currently the tanks are drained in order of 4, 3, 2, 1. The GPOLY logic for the potable water storage loop is shown in Table 3.7.



3.15 G-189A SCHEMATIC OF THE CONDENSATE COLLECTION LOOP

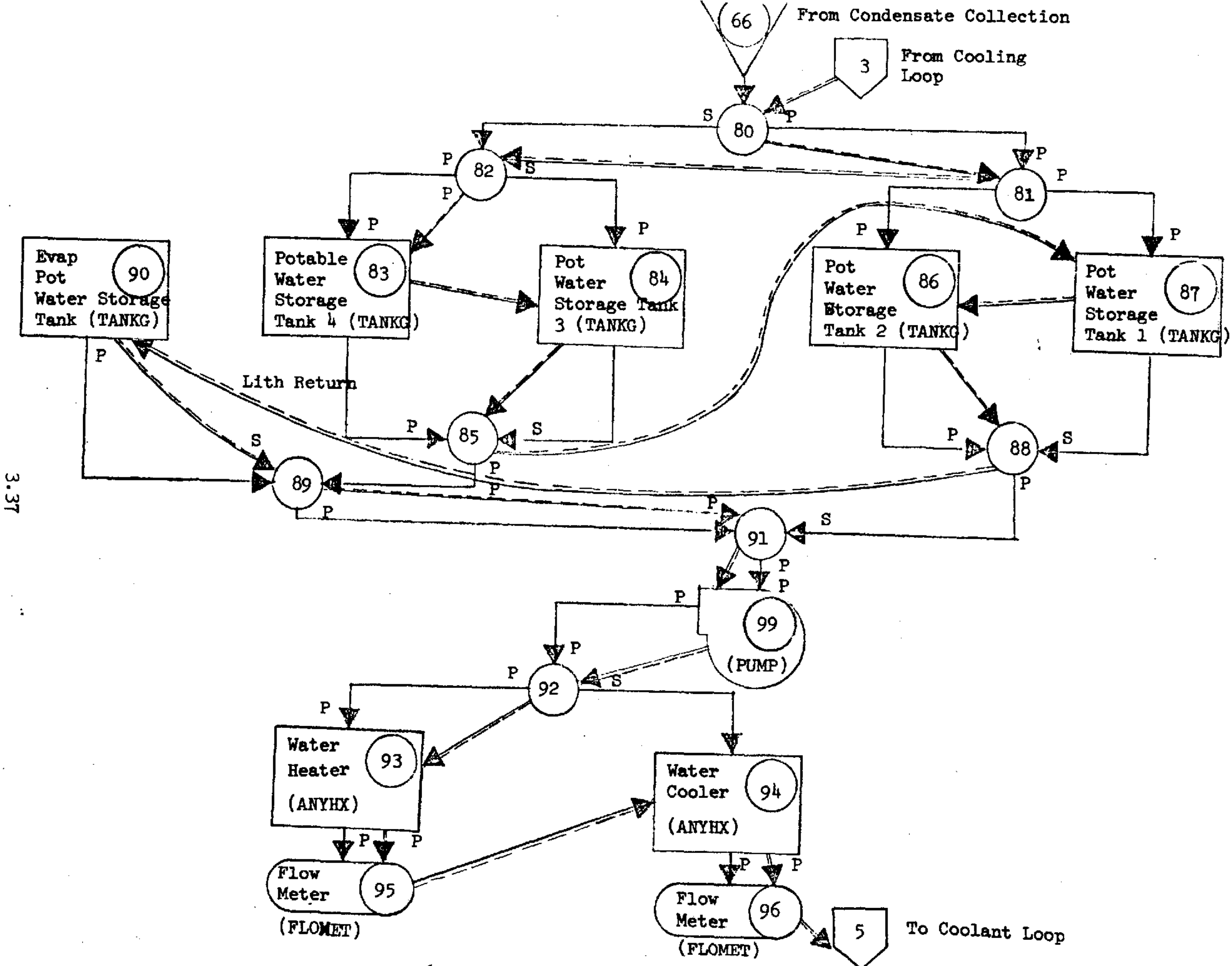


FIGURE 3.16 G-189A SCHEMATIC OF THE POTABLE WATER LOOP

Table 3.7

GPOLY CONTROL LOGIC FOR POTABLE WATER STORAGE LOOP

Order of Solution - Start from component 3 from cooling loop. 80, 81, 82, 83, 84, 85, 87, 86, 88, 90, 89, 91, 99, 92, 93, 95, 94, 96. Return to cooling loop.

<u>Filling of Potable Water Storage Tank</u>

<u>Component 80</u> Flow split to tanks

GPOLY1

If tanks 83 and 84 are full bypass flow to component 81.

If not full flow to component 82

<u>Component 81</u> Flow split to tanks 1 and 2

GPOLY1

Flow to tank 86 if not full otherwise flow to tank 87

<u>Component 82</u> Flow split to tanks 3 and 4

GPOLY1

If tank 83 full bypass flow to tank 84

<u>Draining of Potable Water Storage Tanks</u>

<u>Component 83</u> - Tank No. 4

GPOLY2

Outlet flow is the sum of cold water flow (tube 16) and hot water flow (tube 17). If there is enough water in tank 83 drain that tank.

```
C     GPOLY1 LOGIC  FOR POTABLE WATER STORAGE LOOP
C
C     THE POTABLE WATER TANKS WILL BE FILLED IN THIS ORDER 83,84,87
C
C     COMPONENT SPLIT 80 -- SPLIT TO TWO TANK GROUPS
C
      IF(N.NE.80)GO TO 80
      R(65)=1.0
      A(1)=100.0
      A(2)=100.0
      IF(VV(83,69).GT.41.50-A(1)*DTIME/3600.0.AND.VV(84,69).GT.41.5
     1)*DTIME/3600.0)R(65)=0.0
   80 CONTINUE
C
C
C     COMPONENT  SPLIT 81=SPLIT TO TANKS  86 AND 87
C
      IF(N.NE.81)GO TO 81
      R(65)=0.0
      IF(VV(86,69).LT.41.50-A(1)*DTIME/3600.0)R(65)=1.0
   81 CONTINUE
C
C
C     COMPONENT 82  SPLIT TO TANKS 83 AND 84
C
      IF(N.NE.82)GO TO 82
      R(65)=0.0
      IF(VV(83,69).GT.41.50-A(1)*DTIME/3600.0)R(65)=1.0
   82 CONTINUE
C
C     GPOLY2  LOGIC FOR POTABLE WATER STORAGE LOOP
C
C     COMPONENT  83  TANK NO. 1
C
      IF(N.NE.83)GO TO 83
      R(1)=0
      WTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
```

<u>Component 84</u> - Tank No. 3

GPOLY2

If tank 83 full, drain tank 84 if there is adequate water.

<u>Component 87</u> - Tank No. 1

GPOLY2

If tank 83 and 84 drained, use tank 87 if there is adequate water supply.

<u>Component 86</u> - Tank No. 2

GPOLY2

If previous tanks empty, drain tank 86 if there is adequate water supply

<u>Component 90</u> - Emergency Tank

GPOLY2

If no other tanks available use emergency tank.

```
C
C      COMPONENT  84  TANK NO. 2
C
       IF(N,NE.84)GO TO 84
       R(1)=0,0
       WTOT=VALUE(16,TIME,0,0)*VALUE(17,TIME,0,0)
       IF((VV(83,1),LE,0,0),AND,(WTOT,GT,0,0),AND,(R(69),GT,WTOT*DTIME/
      13600,0)) R(1)=WTOT
    84 CONTINUE
C
C      COMPONENT  87  TANK NO. 3
       IF(N,NE.87)GO TO 87
C
       R(1)=0,0
       WTOT=VALUE(16,TIME,0,0)*VALUE(17,TIME,0,0)
       IF((VV(85,1),LE,0,0),AND,(WTOT,GT,0,0),AND,(R(69),GT,WTOT*DTIME/
      13600,0)) R(1)=WTOT
    87 CONTINUE
C
C      COMPONENT  86  TANK NO. 4

       IF(N,NE.86)GO TO 86
       R(1)=0,0
       WTOT=VALUE(16,TIME,0,0)*VALUE(17,TIME,0,0)
       IF((WTOT,GT,0,0),AND,(VV(85,1),LE,0,0),AND,(VV(87,1),LE,0,0),AND,
      1(R(69),GT,WTOT*DTIME/3600,0))  R(1)=WTOT
    86 CONTINUE
C
C      COMPONENT  90 EMERGENCY TANK
C
       IF(N,NE.90) GO TO 90
       R(1)=0,0
       WTOT=VALUE(16,TIME,0,0)*VALUE(17,TIME,0,0)
       IF(WTOT.GT,0,0,AND,VV(85,1),LE,0,0,AND,VV(88,1),LE,0,0)R(1)=WTOT
    90 CONTINUE
       RETURN
       END
```

3.2.7 Cooling Loop

The G189A schematic of the cooling loop is shown in Figure 3.17. The loop provides cooling liquid for the condenser and the water cooler. A constant supply of ethylene glycol coolant (280 lb/hr, 350°F) is provided by component 1. Ninety-five percent of the fluid is directed to the cooler in order to kill any growth in bacteria which may have formed in the water cooler while it was operating at the lower temperatures. The switch in coolant direction is directed by data in Table 11 (See Appendix B), the water cooler supply requirements table. When the table indicates a hot water requirement the GPOLY logic directs the cooling flow to the secondary side of component 2. Alternately, the heating fluid is directed to the water cooler, which then serves to supply heated water to component 94. The GPOLY logic required to accomplish the change in roles is described in Table 3.8.

3.2.8 High Temperature Heat Source

The high temperature heat source consists of a heat block and a heat pipe for emergency heat rejection. The heat block provides heat for the pyrolysis units, incinerator and the air sterilizer. The inert gas controllable heat pipe is imbeded in the heat block to provide emergency cooling when the temperature reaches 1300°F. The heat pipe has the capability of rejecting 100 to 800 Btu/hr within the temperature range of 1300 to 1380°F. The component definition diagram for the high temperature heat source is shown in Figure 3.18.

Component 180 Heat Block

The heat block serves to distribute thermal energy from the radioisotope to the various components including the heat pipe, pyrolysis units, incinerator, and air sterilizer. The heat block assembly, simulated by subroutine THERML, is comprised of three principal components, the radio-isotope heater, the heat block, and the insulation jacket. The radioisotope heater located in the middle of the heat block generates the thermal

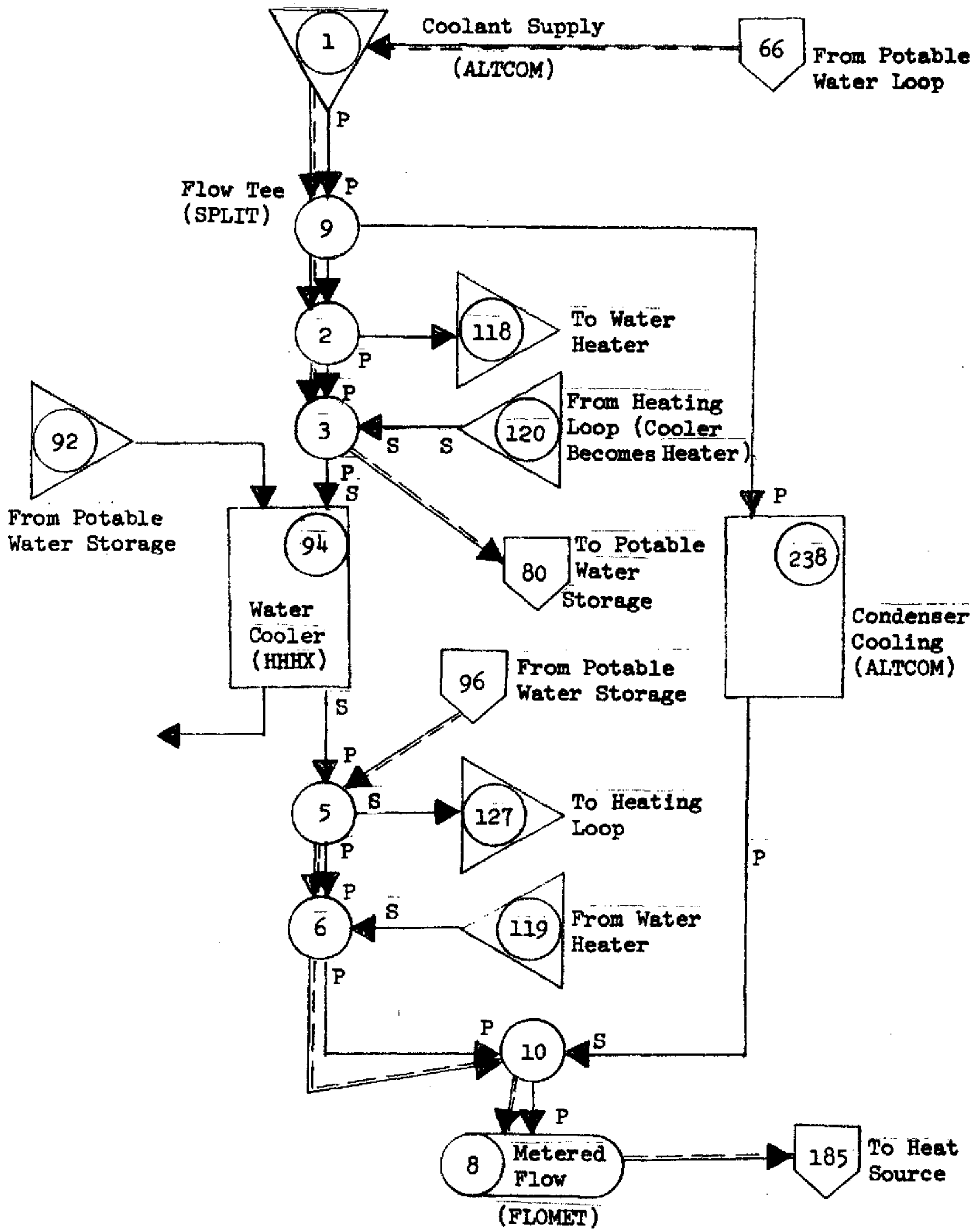


Figure 3.17 G-189 Schematic of the Cooling Loop

Table 3.8

GPOLY LOGIC FOR THE COOLING LOOP

Order of Solution: 1, 9, 2, 3, to Potable Water Storage, from Potable Water Storage to 5, 6, 10, 8

Component 2, Tee to Water Heater

Subroutine: SPLIT

GPOLY1

Table 11 is read to determine quantity and type of water flow for component 94.

If chilled water is required from component 94 the coolant flow is directed to that component. If warm water is required from component 94, coolant flow is bypassed to component 118 and then to component 93, the other heat exchanger which now serves as the water cooler. When component 94 serves as the water heater, heating fluid flow is directed to component 3, and to the heat exchanger from the low temperature heating loop at component 120.

The heating fluid is returned to the low temperature heating loop by diverting flow at component 5 to the secondary side. This leads to the heating loop.

```
C       GPOLY1 LOGIC  FOR COOLING LOOP
C
C       COMPONENT 2   FLOW SPLIT TO WATER HEATER
        IF(N.NE.2)GO TO 2
        IF(WCOOL.GE.0.0)GO TO 2000
        R(65)=0.0
        IF(WCOOL.GT.0.0) GO TO 2000
        R(65)=1.0
        CALL SV(1.0,5,65)
        GO TO 2



2000 CALL SV(0.0,5,65)
   2 CONTINUE
```

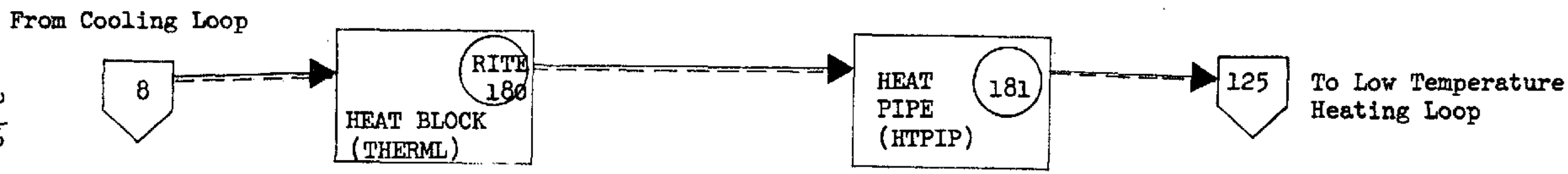


FIGURE 3.18 G-189A SCHEMATIC OF THE HIGH TEMPERATURE HEAT SOURCE LOOP

energy required for the incineration, air sterilization, and pyrolysis processes. The insulation jacket, a double walled vessel with the evacuated space between the walls containing high temperature multifoil insulation, contains the heat block and other purifier components and serves the function of minimizing heat loss from the purifier assembly to the environment. The heat block in the purifier assembly provides heat conduction to the purifier components and also serves as the positioning and holding fixture for the components within the insulation jacket.

A schematic of the heat block, showing the relative locations of the components is shown in Figure 3.19. The corresponding nodal network is shown in Figure 3.20.

Heat transfer from the heat block is calculated for the individual components. The heat loss values are then entered into the nodal network prior to calculation of the resultant nodal temperatures. The GPOLY logic required to perform this operation is shown in Table 3.9.

Component 181 Heat Pipe

An inert gas controllable heat pipe is used as an emergency heat rejection system for the high temperature isotope for a wide range of heat loads. The evaporator section of the heat pipe is imbeded into the heat block. If the temperature of the heat block reaches to a predetermined value, corresponding to the phase change pressure of the sodium vapor working fluid, heat is absorbed, and a phase change from liquid to vapor takes place. Due to the rise in temperature, pressure increases; this causes vapor to flow to the condenser region of the pipe where the process is reversed and heat is rejected. Very small temperature drops are coupled with the transfer of large quantities of heat in the phase change from liquid to vapor to liquid. This property provides the capabity for transporting large quantities of thermal energy in a near-isothermal system. Following condensation, the cycle is completed with the return of the liquid to the vaporator region.

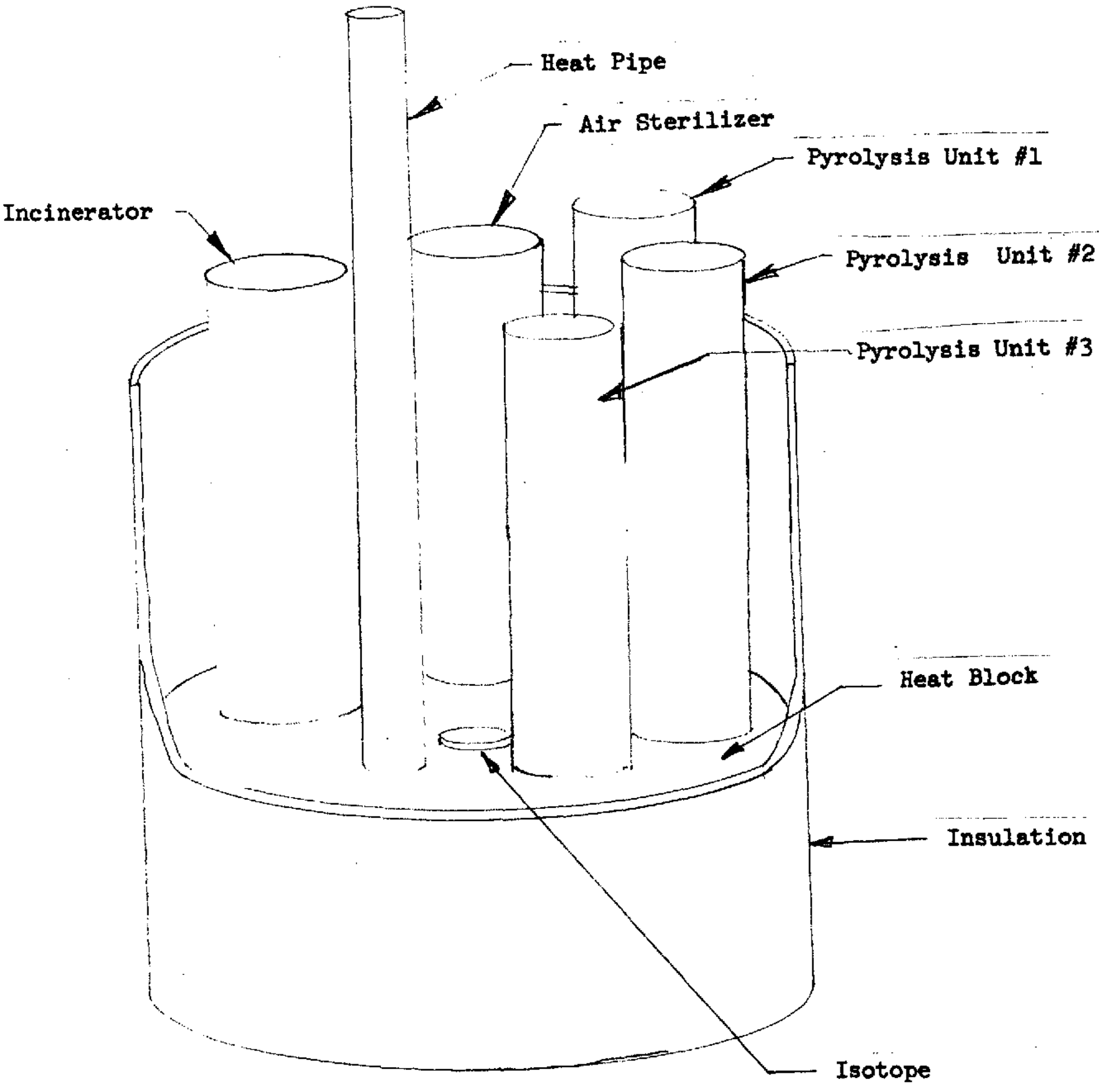


FIGURE 3.19 HEAT BLOCK MODEL

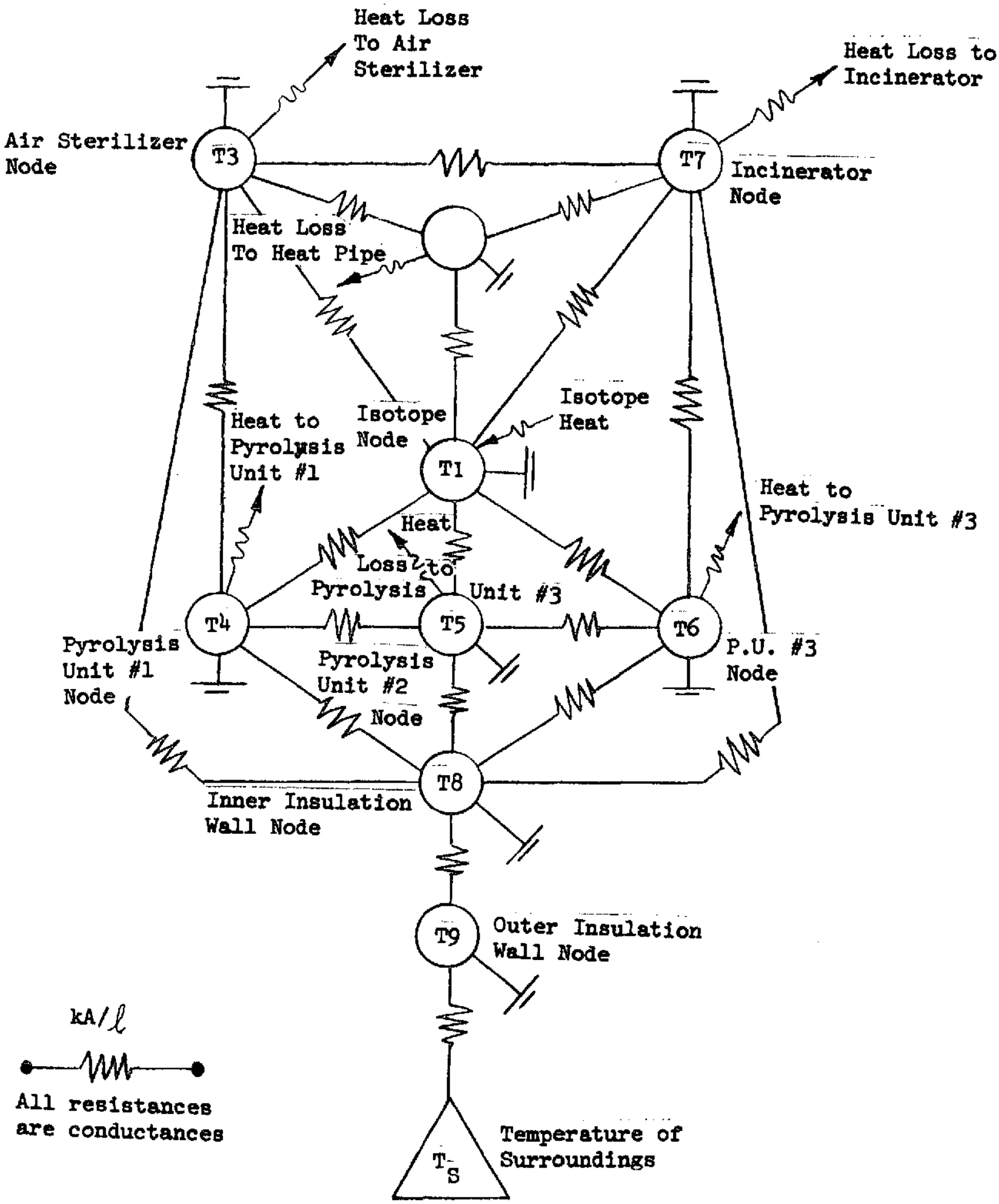


FIGURE 3.20 HEAT BLOCK NODAL NETWORK

Table 3.9

GPOLY LOGIC FOR THE HIGH TEMPERATURE HEAT SOURCE

Order of Solution - From Cooling Loop, 180, 181, to Low Temperature Heat loop

Component 180 Heat Block

GPOLY1

Enter into the heat block thermal network all heat loss terms to the heat pipe components

R(88) is heat loss to heat pipe
R(90), R(91), R(92) are the heat loss terms to the pyrolysis units
R(93) is the heat loss term to the incinerator

```
      IF(N .NE. 180) GO TO 180
C                         SET HEAT BLOCK INTERFACES
C                         HEAT LOSS TO HEAT PIPE
            R(88)=-VV(181,75)
C                         HEAT LOSS TO AIR STERILIZER
        R(89)=VV(25,93)*( VV(25,116)-VV(25,80) )-(VV(25,108)
       1VV(25,117)) -(VV(25,107)*(VV(25,70)-VV(25,117) ))
C                         HEAT LOSS TO PYROLYSIS UNIT NO1
        R(90)=-72.0
C                         HEAT LOSS TO PYROLYSIS UNIT NO2
        R(91)=R(90)
C                         HEAT LOSS TO PYROLYSIS UNIT NO3
        R(92)=R(90)
C                         HEAT LOSS TO PINCINERATOR
            R(93)=-VV(213,66)
  180 CONTINUE
```

Component 181 Heat Pipe
GPOLY1

The heat pipe interface temperature is determined from the heat block.

```
C
C
C
C
        IF(N .NE. 181) GO TO 181
C                         SET INTERFACE TEMP HEAT BLOCK TO HEAT PIPE
            R(66)= VV(180,70)
  181 CONTINUE
C
```

A G189A library heat pipe subroutine was not available, therefore, a new subroutine was written. The subroutine documentation, which includes mass and thermal balances and a discussion of subroutine operation is included in Appendix A.

Successful heat pipe subroutine operation requires that a heat source temperature, corresponding to a heat block node temperature, be made available to it. The GPOLY logic for this operation is noted in Table 3.9.

Section 4

CORRELATION OF EXPERIMENTAL AND ANALYTICAL DATA

The procedure used in correlating experimental data from tests of individual RITE system components with G189A program computed data from corresponding analytical models generally consisted of the following steps:

1. General Electric test data in Reference 1, provided in letter form, or provided informally were reviewed.

2. Component descriptive data and drawings in Reference 1 were reviewed.

3. Component heat transfer parameters were computed from the data in items 1. and 2. For example, heat exchanger overall conductances, UA, and effectivenesses were computed from experimental temperature profiles and component thermal masses were computed from dimensional, density, and specific heat data.

4. Component parameters and boundary conditions were specified as input data and computer runs were obtained.

5. Discrepancies between experimental data and computed data were reconciled in terms of modifications to the component parameter data.

6. These modifications were made and additional computer runs were obtained. This iterative process was continued until satisfactory correlation was achieved.

Discussions of the correlations for individual components and the correlative data for these components now follows.

4.1 Pyrolysis Units

The pyrolysis unit consists of a regenerative heat exchanger and a catalytic bed containing ruthenium catalyst. The unit was simulated using the ANYHX and CATBRN subroutines. The output data correlation was based on steady state heat transfer tests performed by General Electric on one pyrolysis unit. Thermocouples were attached at five locations as designated by C13, C14, B4, B5, and B6 on Figure 4.1. Figure 4.1 shows the resulting temperatures at these 5 locations for both the test and the RITE simulation. As seen from Figure 4.1 the ANYHX and CATBRN subroutines provide inlet and outlet temperatures which can be directly compared with the test data. The vapor flow as 0.807 lb/hr and the inlet temperature was 200°F.

The vapor temperature increased to 1180°F in the regenerative heat exchanger. The temperature further increased to 1240°F in the catalyst bed. The heat added in the catalyst bed was provided by the heat block. The computed outlet temperature was somewhat lower than the experimental data. This discrepancy is in the direction expected since the thermocouple was attached on the outside of the outlet pipe rather than being installed in the gas stream.

4.2 Air Sterilizer

A transient heat transfer test was performed by General Electric on the air sterilizer. The normal commode use has been assumed to require 5 minutes per event. To simulate a worst case, the sterilizer was operated for 10 minutes. This represents two successive uses. The transient test data for the thermocouples located in the sterilization chamber and at the inlets and outlets for the counterflow regenerative heat exchanger are shown on Figures 4.2 and 4.3. The test was started with no flow and the sterilization chamber at 1280°F. A constant flow of 17 Std Cfm was then imposed for the 10 minute period.

The air sterilizer was simulated using the thermal analyzer subroutine THERML. Figure 4.4 shows the thermal model for the air sterilizer. Figures 4.2 and 4.3 also show the computed temperature data corresponding to the experimental data. Thermocouples 1 and 2 on Figure 4.2 are considered to be attached to the air sterilizer structure in the vicinity of gas nodes 10 and 9, respectively.

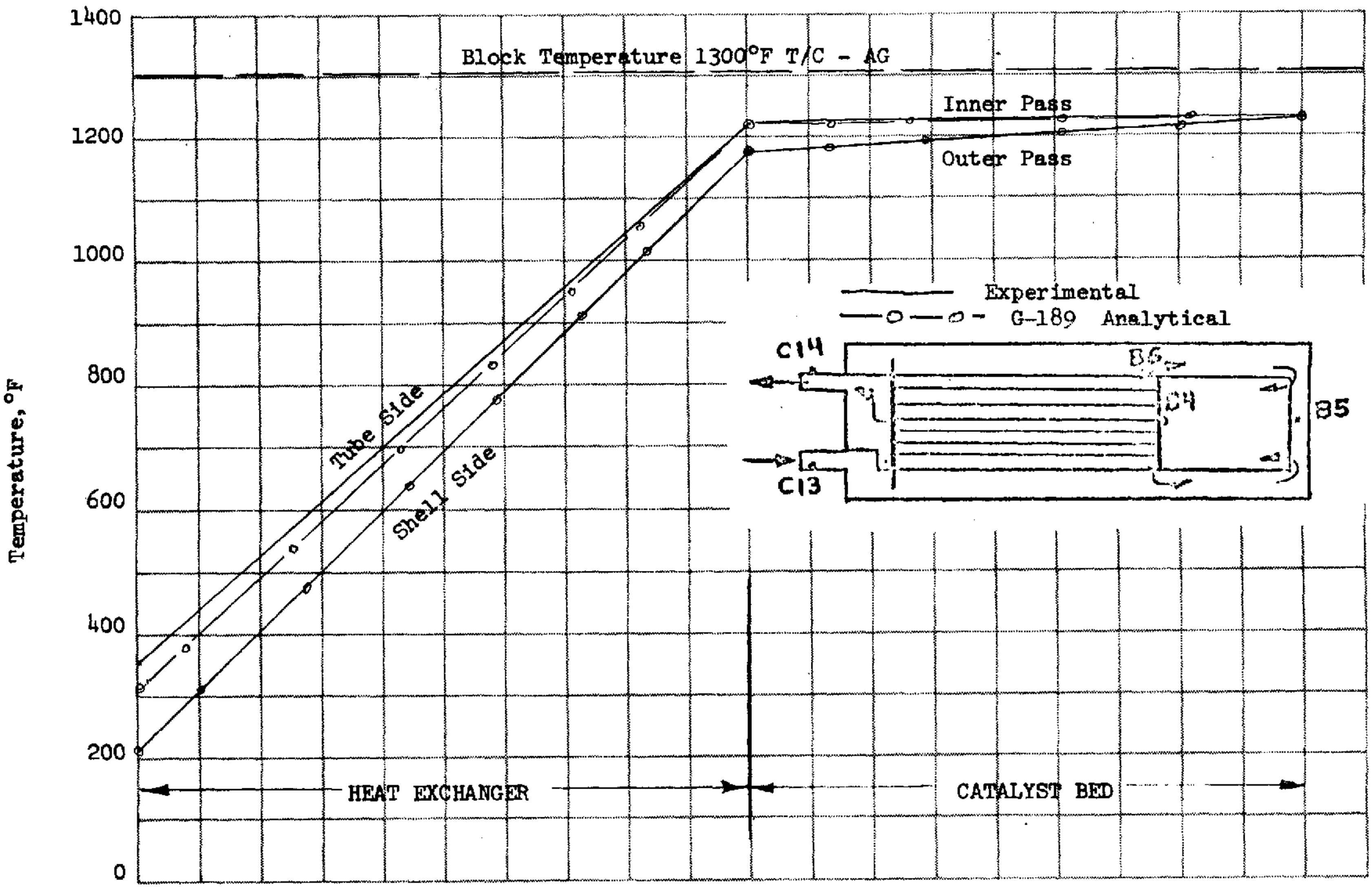


FIGURE 4.1 PYROLYSIS UNIT TEMPERATURE PROFILE

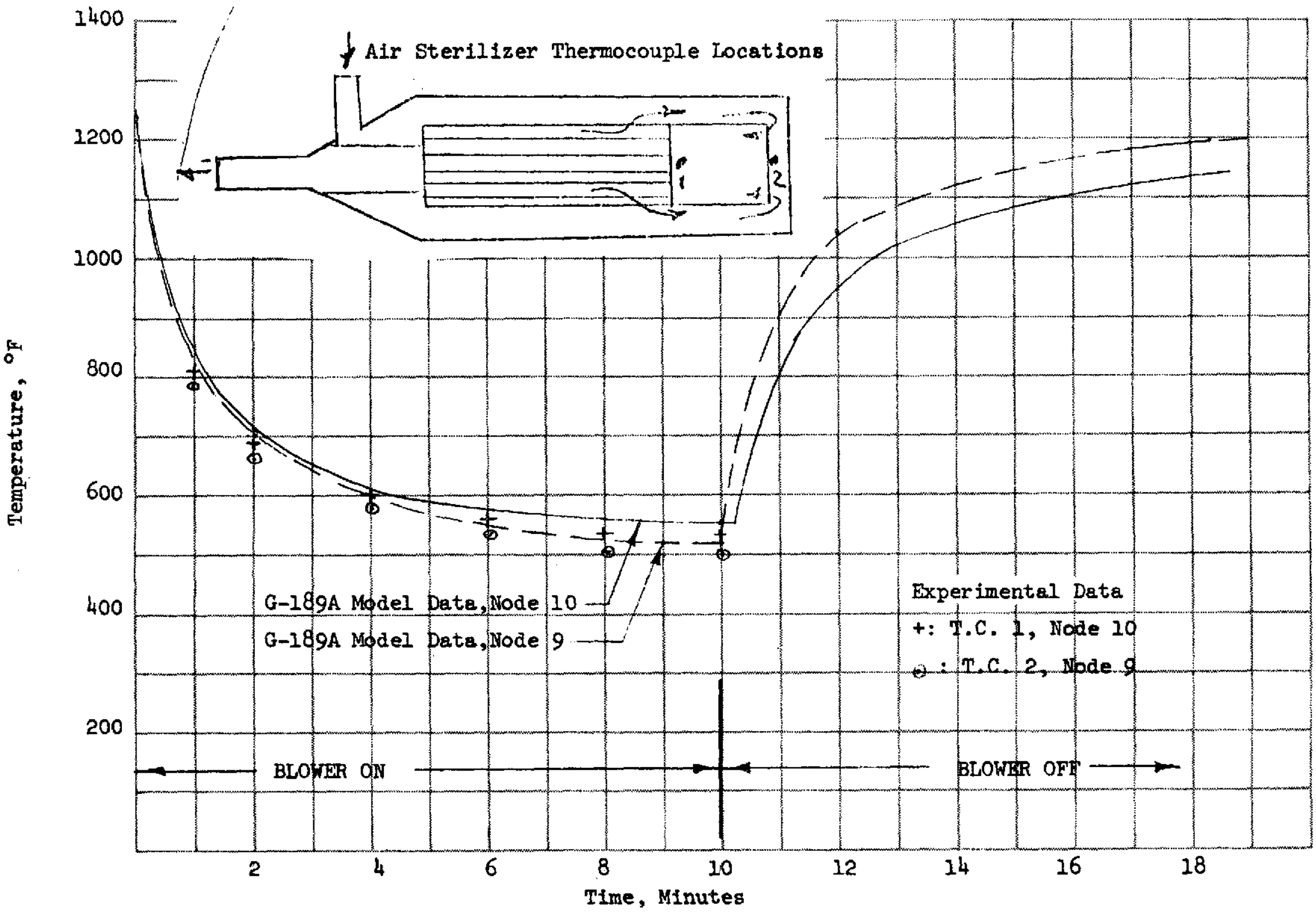


FIGURE 4.2 TIME-TEMPERATURE DATA, G-189 MODEL/EXPERIMENTAL FOR THE AIR STERILIZER

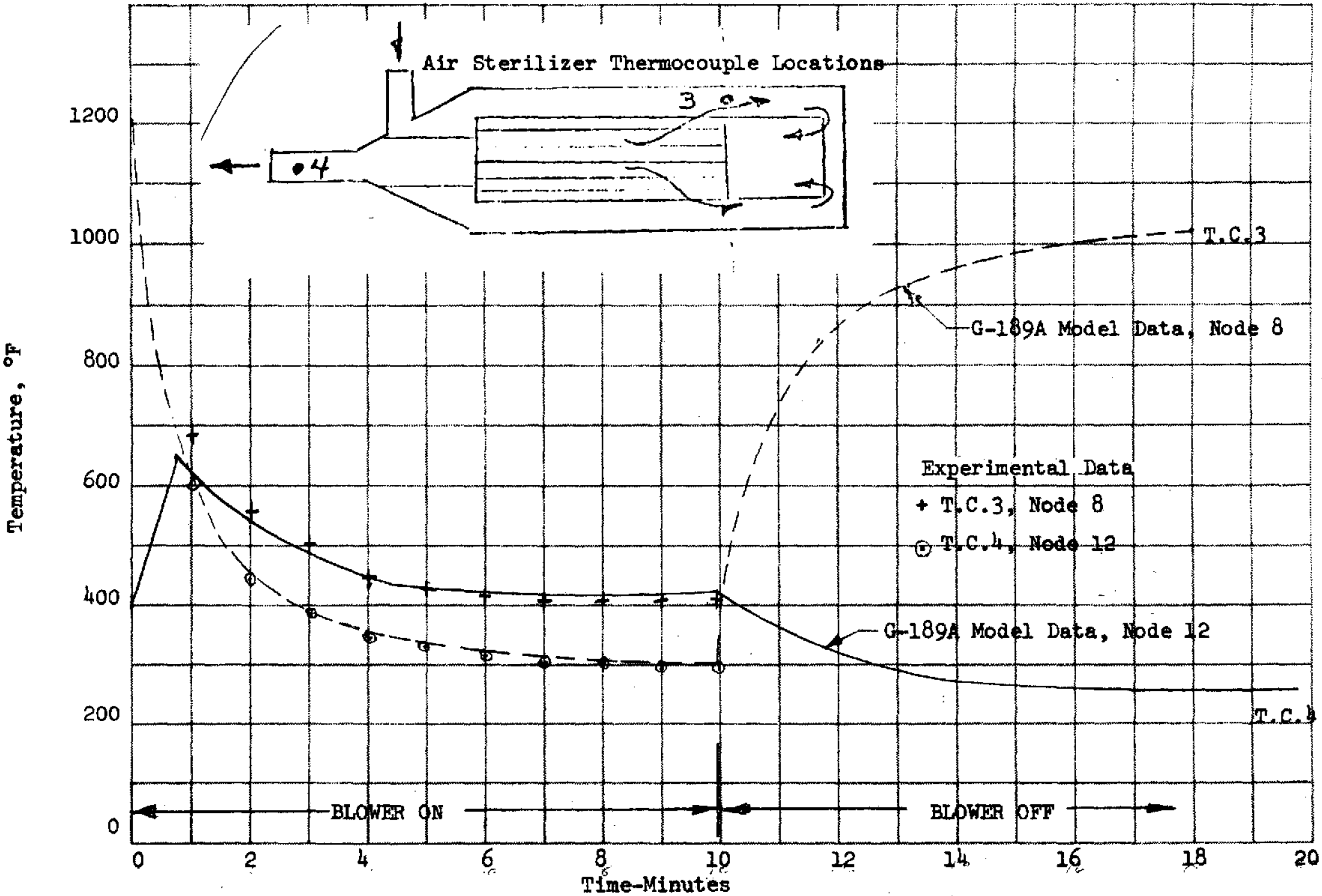


FIGURE 4.3 TIME-TEMPERATURE CURVE G-189A MODEL/EXPERIMENTAL

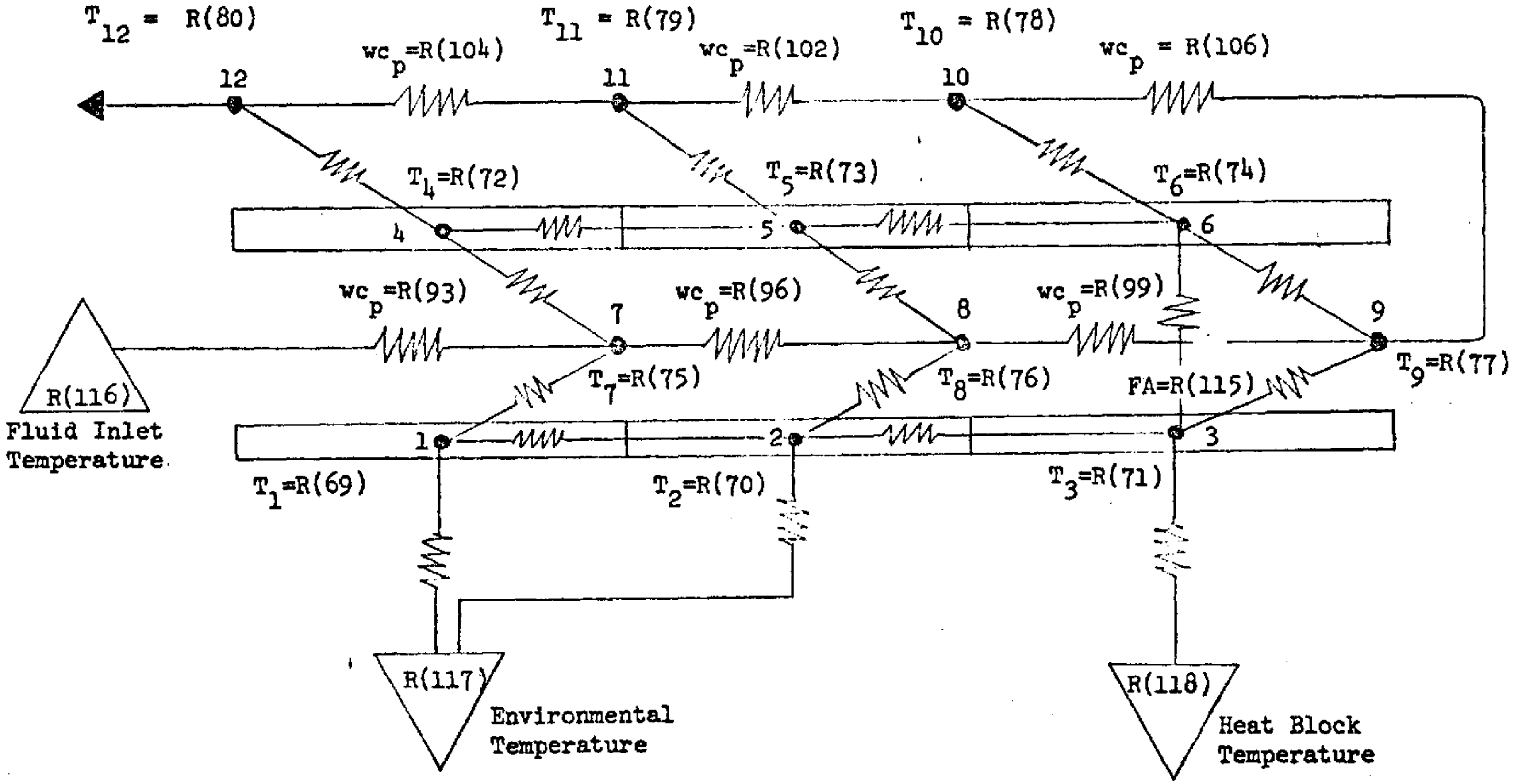


FIGURE 4.4 AIR STERILIZER THERMAL MODEL

Similarly thermocouples 3 and 4 on Figure 4.3 are related to gas nodes 8 and 12 respectively. The gas nodes should be cooler than the nearby thermocouples when the blower is on since heat is being transferred to the gas. This is seen to be the case on Figure 4.2 and 4.3 . The correlation for the case when the blower is on is considered to be satisfactory in terms of the agreement between experimental and computed temperatures and also in terms of the amount of energy removed from the heat block.

When the blower is off the amount of heat removed from the heat block is far less than when the blower is on. With the blower off heat is only conducted axially in the air sterilizer outer shell away from the heat block. The heat is then transferred from this outer shell through an insulation blanket to the local environment. This heat is far less than the amount removed by blowing air through the air sterilizer.

When the blower is off it is seen from Figure 4.2 and 4.3 the temperatures at thermocouples 1, 2, and 3 rise rather rapidly due to their close proximity to the heat block. Thermocouple 4 shows the cooling effect of the ambient environment.

The gas nodes in the thermal model do not have respresentative temperatures for the nearby thermocouples when the blower is off. During these conditions gas nodes 7, 8, and 9 go to steady state at the average temperature for the two metal nodes which each are thermally connected to. Gas nodes 10, 11, and 12 go to the temperature of the surface that each is connected to. Thermal gradients in the metal nodes in this thermal model are quite severe due to the large difference in boundary heating/cooling conditions within the heat block and due to ambient conditions. Therefore to accurately predict individual temperatures, at individual thermocouples with the blower off would require many more metal nodes than used here and would require more detailed information concerning the construction of the air sterilizer and the locations of the thermocouples than has been provided.

The important point is that with the blower on a good correlation has been achieved and that with the blower off the air sterilizer does not contribute significantly to the energy balance for the heat block and the detailed modelling required to obtain good temperature correlations is not justified.

4.3 Heat Pipe

Steady state performance data for the heat pipe have been provided by General Electric. The two data points relating heat rejection rate and heat pipe temperature are shown on Figure 4.5. Thermophysical property data were specified for the heat pipe subroutine (subroutine HTPIP) used to simulate this component. These included dimensional data, heat pipe axial thermal conductance, condensible fluid and inert gas thermodynamic data, and external thermal conductance coefficients for the evaporator and condenser sections of the heat pipe. The heat pipe axial thermal conductance and external conductance coefficients were varied so as to achieve the correlation with test data shown in Figure 4.5. The heat pipe data is included in the RITE simulation Input Data of Appendix B.

Figure 4.5 clearly illustrates the three operational modes of the heat pipe. The control range of the heat pipe encompasses a temperature range of 1303 to 1380°F. In this range the heat rejection rate varies between 100 BTU/hr and 790 Btu/hr. Below 1303°F the heat pipe behaves like a fin and heat is rejected by conduction along the pipe and natural convection to the air. At temperatures greater than 1380°F, the condenser section of the heat pipe is at a maximum area and increased heat rejection rate is possible only by increasing the total heat pipe temperature.

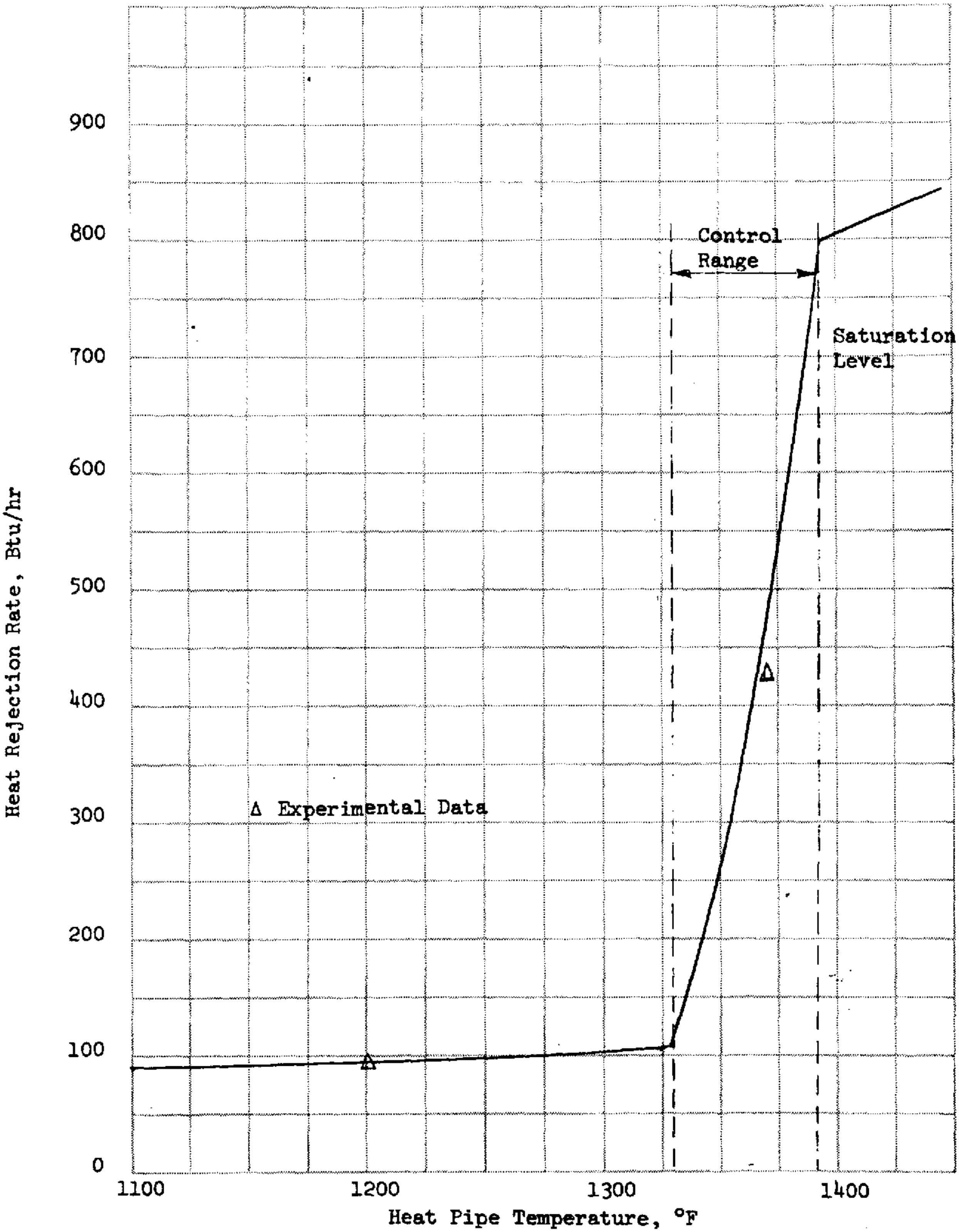


FIGURE 4.5 HEAT REJECTION RATE VS. SOURCE TEMPERATURE

4.4 Heat Block

The heat block was simulated using the thermal analyzer subroutine THERML. Transient heating curves for the heat block were obtained by General Electric. (Reference 1) Different input power levels to the electrical heater mounted in the heat block were supplied. Figure 4.6 shows experimental data and the computed data obtained from the G189A program model for the heat block for a heating condition. Temperature variations within the heat block are quite small; indicative of good heat transfer by conduction within the heat block. Figure 4.7 shows the nodal network for the heat block. The thermal mass for the heat block was basically distributed at nodes which interface with the components which are installed in the heat block: pyrolysis units, air sterilizer, heater, incinerator, and heat pipe. The thermal conductances which interconnect these nodes have large values. This is in keeping with the good conduction heat paths provided in the heat block. Each temperature profile shown on Figure 4.6 is therefore essentially the temperature throughout the heat block in the vicinities of the installed components. The computed temperature profile was obtained for 420 watts heater power rather than for the experimental power levels since that is essentially the power level that is currently used. Because of the consistency of the experimental and computed data, it was considered that the correlation was adequately demonstrated without obtaining computed data for either or both of the experimental power levels.

4.5 Low Temperature Isotope Heater, Evaporator, and Condenser

Experimental data used in the correlation studies for these components were obtained during the 180 day test of the complete RITE system. As such the data are representative of normal operating conditions for the system. The computed data from the G189A program models for the components were generated by setting boundary value data and then obtaining steady state computer runs for the individual components. In the case of the evaporator and condenser the two components were coupled for these computer runs by the flow of steam from the evaporator to the pyrolysis units and then to the condenser.

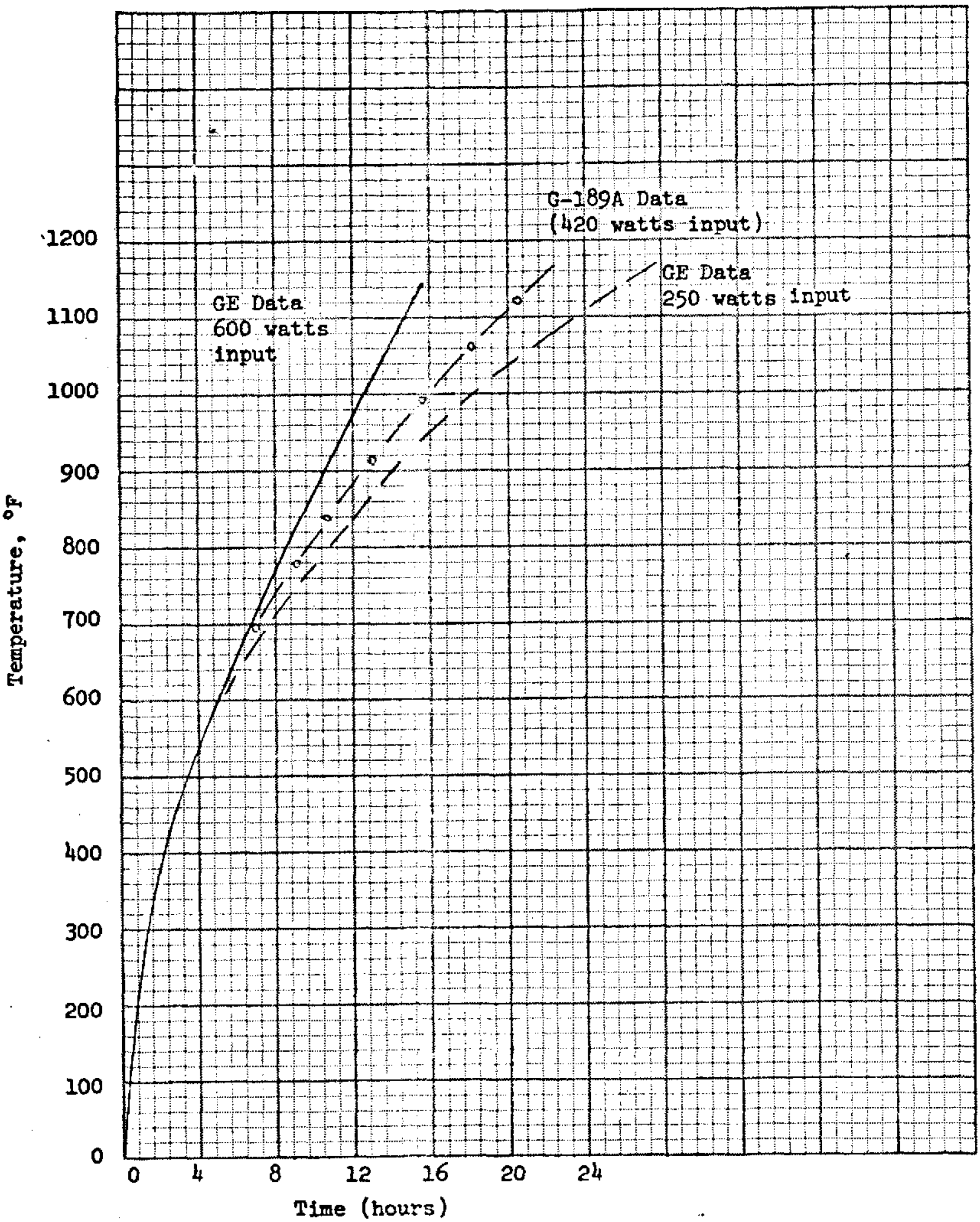


FIGURE 4.6 HEAT BLOCK HEATING PROFILE CORRELATION

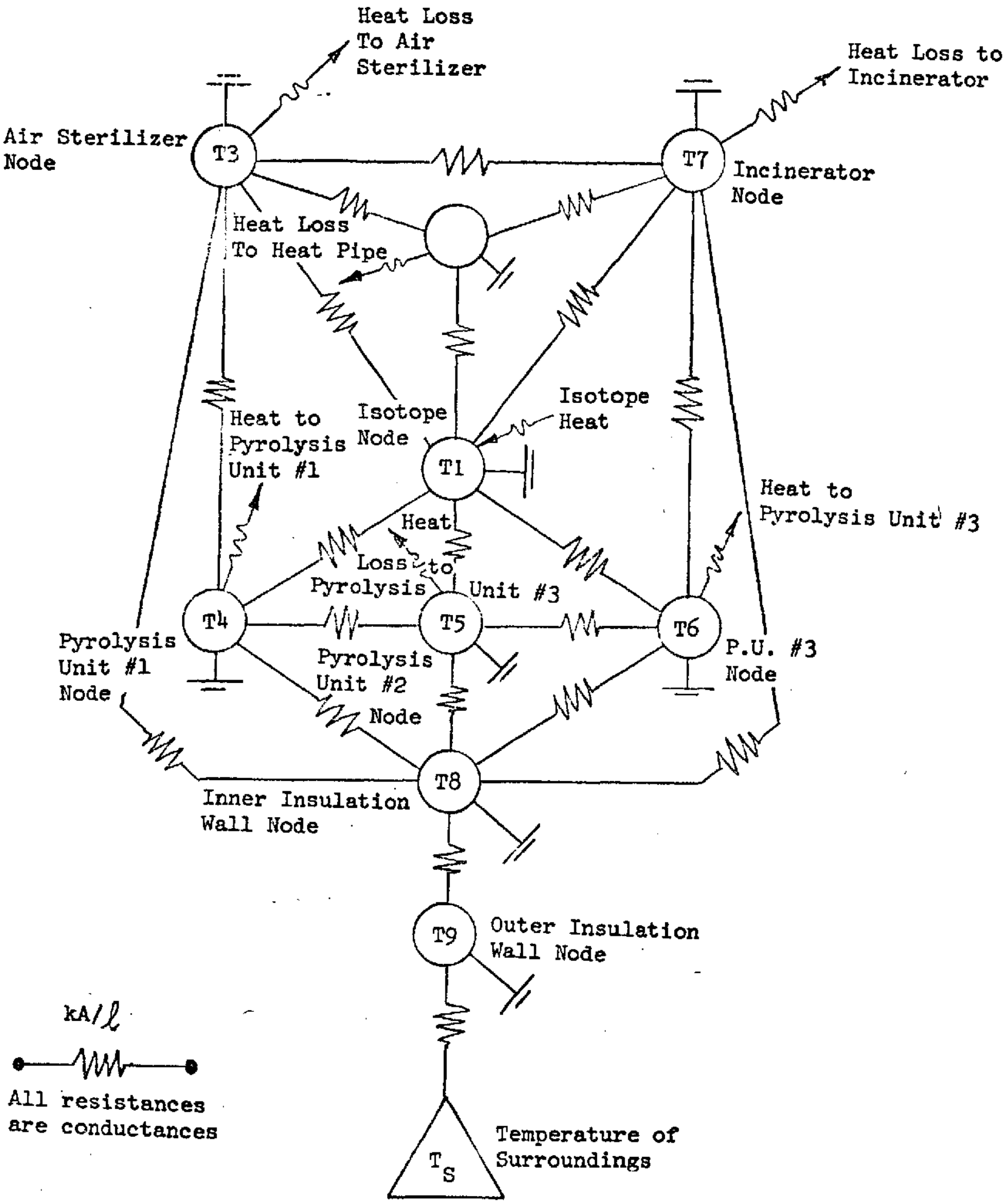


FIGURE 4.7 HEAT BLOCK NODAL NETWORK

The boundary conditions specified were the heating or cooling fluid temperatures and flow rates at the component inlets. The comparative data from the 180 day test and the computer runs are presented in Table 4.1 . It is seen that there is generally good agreement between the experimental data and the computed data. The computed condenser steam inlet temperature is seen to be about 10°F less than the experimental value. This is due to modelling the duct supplying the steam to the condenser such that excessive heat transfer from the ducted steam to the environment occurs. This simulation detail is considered to be relatively unimportant in the total simulation and has only recently been corrected.

The steam temperature into the condenser is higher than the steam temperature out of the evaporator due to the heat added in the pyrolysis units. Likewise the increase in steam flow into the condenser compared to the steam flow out of the evaporator is due to water generation in the pyrolysis units.

The analytical modeling and the data correlation performed on the key RITE system components provide assurance that the model is able to predict component performance for the operating condition to be studied. These components can now be combined with remaining components of their loop and loop performance can be investigated. Finally, the analytical models for each of the loops are combined for complete RITE system operation.

Table 4.1

CORRELATIONS FROM COMPLETE SYSTEM OPERATION

Note: N/A = Not Available

Low Temperature Isotope Heater	GE Data	G-189 Data
Power level (Btu/hr)	5120	5120
Isotope Temperature (°F)	640	640
Inlet Fluid Temperature (°F)	179	179
Outlet Fluid Temperature (°F)	185	185.11

Evaporator		
Heating fluid inlet temperature, °F	181.	181.2
Heating fluid outlet temperature, °F	123	123.03
Wall temperature, °F	116	115.55
Liquid temperature, °F	105	105.63
Gaseous outlet temperature, °F	105	105.6
Evaporation rate, lb/hr	2.3	2.36
NH_3 generation rate, lb/hr x 10^{-3}	N/A	4.62
CO_2 generation rate, lb/hr x 10^{-3}	N/A	5.98
Heat loss to surroundings	N/A	115.55
Pressure, psia	1.016	1.12

Condenser		
Coolant inlet temperature, °F	32	35
Coolant outlet temperature, °F	47	48.3
Steam into condenser temperature, °F	127	126.7
Steam into condenser flow, lb/hr	2.3	2.367
Condensation rate, lb/hr	2.277	2.332
Efficiency, water recovery, %	98+	98+
Steam vented, lb/hr	.023	.035
Condensate wall temperature	75-82	75.4
Condensate temperature	N/A	55.6
Condenser pressure	N/A	.63

Section 5

CHARACTERISTICS OF THE RITE SYSTEM

The results of the G189-A simulation of the RITE system for the nominal RITE 180-day test conditions are presented in this section.

First, the simulation system performance averaged over a 24-hour period is denoted and compared with General Electric 180-day test data. Performance data are presented for each of the RITE subsystems. The transient effects caused by periodic micturition and defecation are then discussed. Finally the operational envelope of the RITE is developed. The operational envelope yields the potential performance of the RITE system when operated at various off-design conditions.

5.1 RITE System Performance Characteristics

A computer run was made to simulate the nominal RITE operational conditions as reported in the General Electric RITE 180-day endurance test. The performance data for each of the system components was averaged over a 24-hour period. The results are presented in terms of mass and energy balance diagrams for each of the subsystems and detail component data are presented in table form.

5.1.1 Low Temperature Heating Loop

The low temperature heating loop supplies heating fluid (water) to the evaporator, water storage tanks, flush water tank, hot water heater and the air heater. The energy and mass balance diagram for the loop are shown in Figure 5.1. Detail component data are then given in Table 5.1 along with comparative GE test results when available.

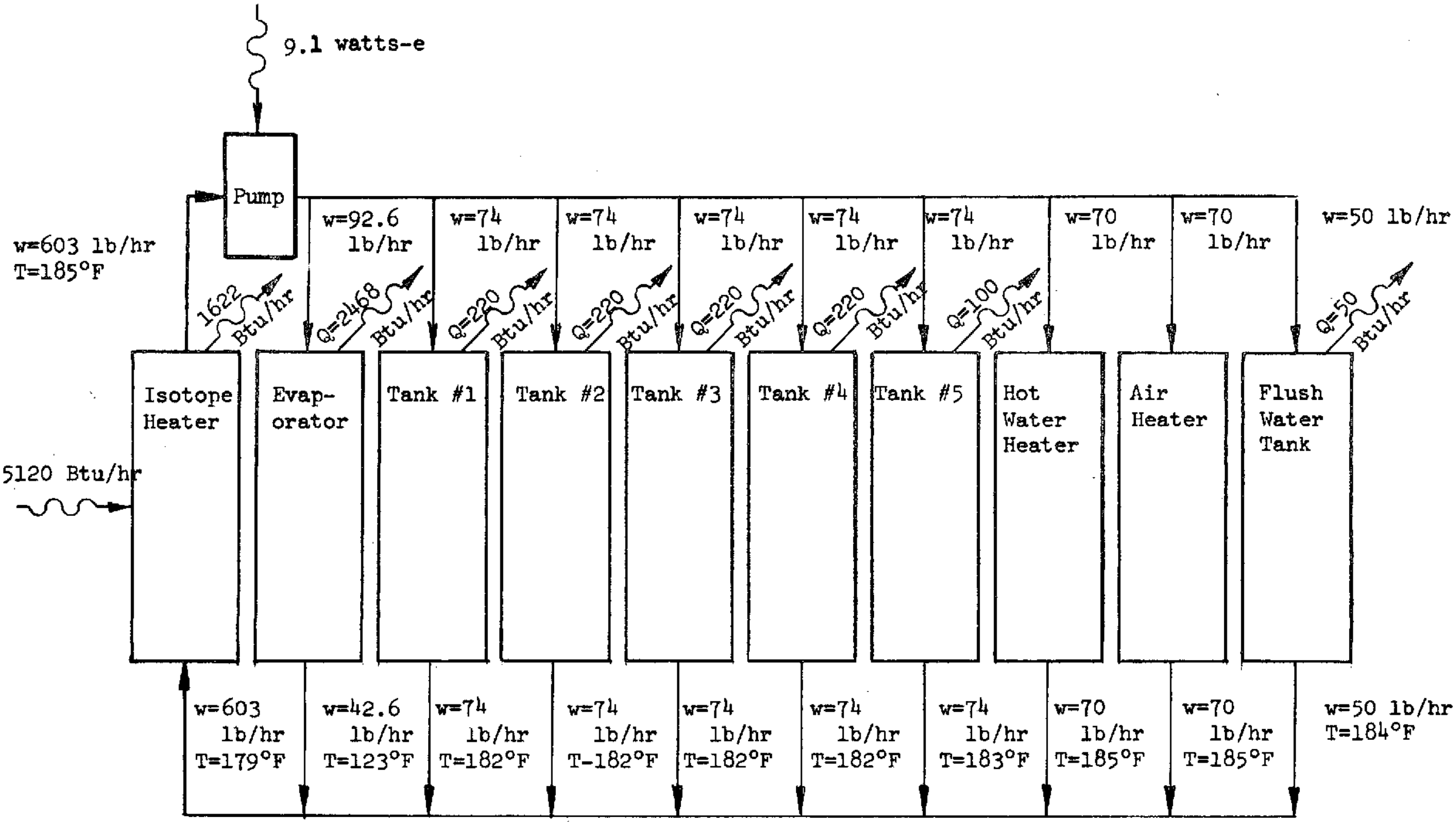


FIGURE 5.1 MASS AND HEAT BALANCE FOR LOW TEMPERATURE HEATING LOOP

TABLE 5.1

RITE SYSTEM CHARACTERISITCS

NOTE: N/A = Not Available

LOW TEMPERATURE HEATING LOOP

Component Number	Component	G-189A Data	G.E. Test Data
100	Radioisotope Heater		
	Heater Power Level	5120.0	5120.0
	Isotope Temperature (°F)	640.0	640.0
	Outlet Fluid Temperature (°F)	185.11	185.0
	Heat loss to tank and environment (Btu/hr)	1760.0	N/A
	Flow Rate (lb/hr)	603.0	N/A
104,105	Pumps		
	Type	Centrifugal Series 400 Dynapump	
	Pump Power (watts)	9.1	N/A
108	Split to Evaporator		
	Flowrate (lb/hr)	42.6	N/A
109, 110	Evaporator Liquid Control Valve		
	Control Temperature	Evaporator Steam Outlet	
	Bypass on Temperature (°F)	105	105
	Bypass off Temperature (°F)	104	104
	Coolant Outlet Temperature (°F)	123.3	123
112, 113, 114, 115, 116	Splits to Potable Water Storage Tanks		
	Flowrate to Each Tank (lb/hr)	74.08	N/A
	Average Outlet Temperatures (°F)	182	N/A
117	Split to Water Heater		
	Flowrate (lb/hr)	70.0	N/A
121	Split to Air Heater		
	Flowrate (lb/hr)	70.0	N/A

C-2

TABLE 5.1 (cont)

Component Number	Component	G-189A Data	G.E. Test Data
124	<u>Warm Flush Water Tank Controller</u>		
	Flowrate (lb/hr)	50	N/A
	Control Temperature (°F)	Tank fluid	
	Bypass - on (°F)	96	96
	Bypass - off (°F)	94	94
	Outlet Temperature (°F)	184	N/A
135	Emergency Coolant Supply		
	Flowrate (lb/hr)	60	N/A
	Temperature (°F)	80	80
136,139	Emergency Heat Exchanger Controller		
	Control Temperature	Isotope Coolant Outlet	
	Flow-on Temperature (°F)	190	190
137	<u>Emergency Heat Exchanger</u>		
	Flowrate (lb/hr)	603	N/A
	Effective UA (Btu/hr-°F)	16.0	N/A
	Outlet Temperature (°F)	179	179
41	<u>Flush Water Tank</u>		
	Tank Capacity (lb)	40.0	40.0
	Heat Exchanger UA (Btu/hr-°F)	3.0	N/A
	LTHL Inlet Temperature (°F)	185	N/A
	LTHL Outlet Temperature (°F)	184	N/A
	Tank Outlet Temperature (°F)	98	N/A
44	<u>Pump</u>		
	Type	Centrifugal	
	Pump Power (watts)	1.04	N/A
51	<u>Condensate Water Supply Tee</u>		
	Flowrate (lb/hr)	.834	N/A
	Temperature (°F)	70.04	N/A

TABLE 5.1 (cont)

AIR LOOP (CONDITIONS FOR MICTURITION)

Component Number	Component	G-189A Data	G.E.Test Data
21	Urine - Air Supply		
	Urea Flow Rate (lb/hr)	.392	N/A
	Urine Solids Flow Rate (lb/hr)	.42	N/A
	Urine Water Flow Rate (lb/hr)	13.2	N/A
	Urine Temperature (°F)	98.6	N/A
22	Flush Water Supply Tee		
	Water Flow (lb/hr)	20.0	N/A
	Water Temperature (°F)	98.0	N/A
24	Air Blower		
	Type	AMETEC Model No. E-4698-1F 15 v. 60 cy.	N/A
	Fan Power (watts)	167.98	N/A
	Flowrate (lb/hr)	56.0	N/A
25	Air Sterilizer		
	Flowrate (lb/hr)	56.0	N/A
	Inlet Temperature (°F)	98.6	N/A
	Outlet Temperature (°F)	362.8	N/A
	Heat Input (Btu/hr)	3674.0	N/A
	Heat lost to Environment (Btu/hr)	94.5	N/A

VAPOR LOOP

Component Number	Component	G-189A Data	G.E.Test Data
210	Evaporator		
	Heating fluid inlet temperature (°F)	181.2	181.
	Heating fluid outlet temperature (°F)	123.03	123
	Wall temperature (°F)	115.55	116
	Liquid temperature (°F)	105.63	105
	Gaseous outlet temperature (°F)	105.6	105
	Evaporation rate (lb/hr)	2.3615	2.3
	NH_3 generation rate (lb/hr $X10^{-3}$)	4.62	N/A
	CO_2 generation rate (lb/hr-$X10^{-3}$)	5.98	N/A
	Heat loss to surroundings (Btu/hr)	115.55	N/A
	Pressure (psia)	1.085	1.016

TABLE 5.1 (continued)

Component Number	Component	G-189A Data	G.E. Test Data
223, 224 226	Pyrolysis Units (includes integrated heat excnanger)		
	Inlet temperature	105.63	125
	Outlet temperature	172.3	N/A
	NO_2 flowing out (lb/hr-X10^{-6})	5.96	N/A
	NO flowing out (lb/hr-X10^{-6})	7.77	N/A
	CO_2 flowing out (lb/hr-X10^{-5})	9.45	N/A
	H_2 flowing out (lb/hr-X10^{-8})	1.12	N/A
	O_2 flowing out (lb/hr-X10^{-3})	1.29	N/A
	N_2 flowing out (lb/hr-X10^{-3})	3.8	N/A
	Heat transferred from heat block (Btu/hr)	206	N/A
	Pyrolysis unit temperature (°F)	1259.7	1200
237	Condenser		
	Coolant inlet temperature °F	35	32
	Coolant outlet temperature °F	48.3	47
	Steam into condenser temperature °F	126.7	127
	Steam into condenser flow lb/hr	2.3615	2.3
	Condensation rate lb/hr	2.3354	2.277
	Efficiency, water recovery %	99	99
	Steam vented lb/hr	.0261	.023
	Condensate wall temperature	75.4	75-82
	Condensate temperature	55.6	N/A
	Condenser pressure	.63	N/A
COOLING LOOP			
1	Coolant Supply		
	Flowrate (lb/hr)	280.0	280.0
	Coolant temperature (°F)	32.0	32.0
94	Water Cooler		
	Coolant flowrate (lb/hr)	21.28	N/A
	Coolant input temperature (°F)	35.0	N/A
238	Condenser Cooling		
	Flowrate (lb/hr)	258	258.72
	Inlet Temperature (°F)	35°F	35.0
	Outlet Temperature (°F)	48	48.0
10	Return Flow Tee		
	Flowrate (lb/hr)	280	N/A
	Temperature (°F)	47	N/A

TABLE 5.1 (continued)

POTABLE WATER STORAGE SYSTEM

Component Number	Component	G-189A Data	G.E. Test Data
83, 84, 86, 87, 90	Storage Tanks		
	Average Inlet Flow (lb/hr)	224	N/A
	Inlet Flow Temperature (°F)	55	N/A
	Tank Capacity (gal)	5	5
	Liquid Temperature (°F)	150.25	N/A
	Tank Wall Temperature (°F)	148.15	145.0
	Heat Loss to Environment (Btu/hr)	200.0	N/A
	Heating Fluid Inlet Flow (lb/hr)	70.08	N/A
	Heating Fluid Inlet Temperature (°F)	185.	N/A
	Heat Fluid Exit Temp. (°F)	182.41	N/A
	Heat Input (Btu/hr)	200.0	N/A
99	Pump		
	Average Inlet Flow (lb/hr)	2.24	N/A
	Pump Power (watt)	1.07	N/A

Approximately 5120 Btu/hr enter the loop through the isotope and electrical heaters. The evaporator requires 2468 Btu/hr; 220 Btu/hr are required by each of the potable water storage tanks; approximately another 100 Btu/hr are required by the flush tank and water and air heaters. The specific heat consumption rate of the tanks and air heater depend on the fill and drain schedule for the operational mode in use at the time. The results noted in the Figure represent 24-hour averaged values during nominal 180-day test conditions. The remaining heat is lost to the cabin environment from heat leaks in the lines, tanks, evaporator walls, and to the isotope shield tank.

5.1.2 Flush Water Loop

The mass and energy balance diagram for the flush water loop is shown in Figure 5.2. The loop delivers flush water upon demand to the urinal, trash shredder and the blender. The flush water flow rates are given in the figure. Water for the flush water loop is collected from the Environmental Control System condensate and stored in the warm flush water tank. The water is heated to 98°F by internal tank coils through which LTHL fluid is pumped. Temperature control is accomplished by a heating fluid bypass controller.

5.1.3 Air Loop

The air loop directs flush water and drying air to the urinal during micturition. The micturition schedule is shown in Figure 5.6. The liquids are separated and directed to the evaporator while the exhaust air is sterilized in the air sterilizer. As the air passes through the sterilizer over 3600 Btu/hr are removed from the heat block. The air returns to the cabin at a temperature of over 360°F. The air loop mass and energy balance is shown in Figure 5.3.

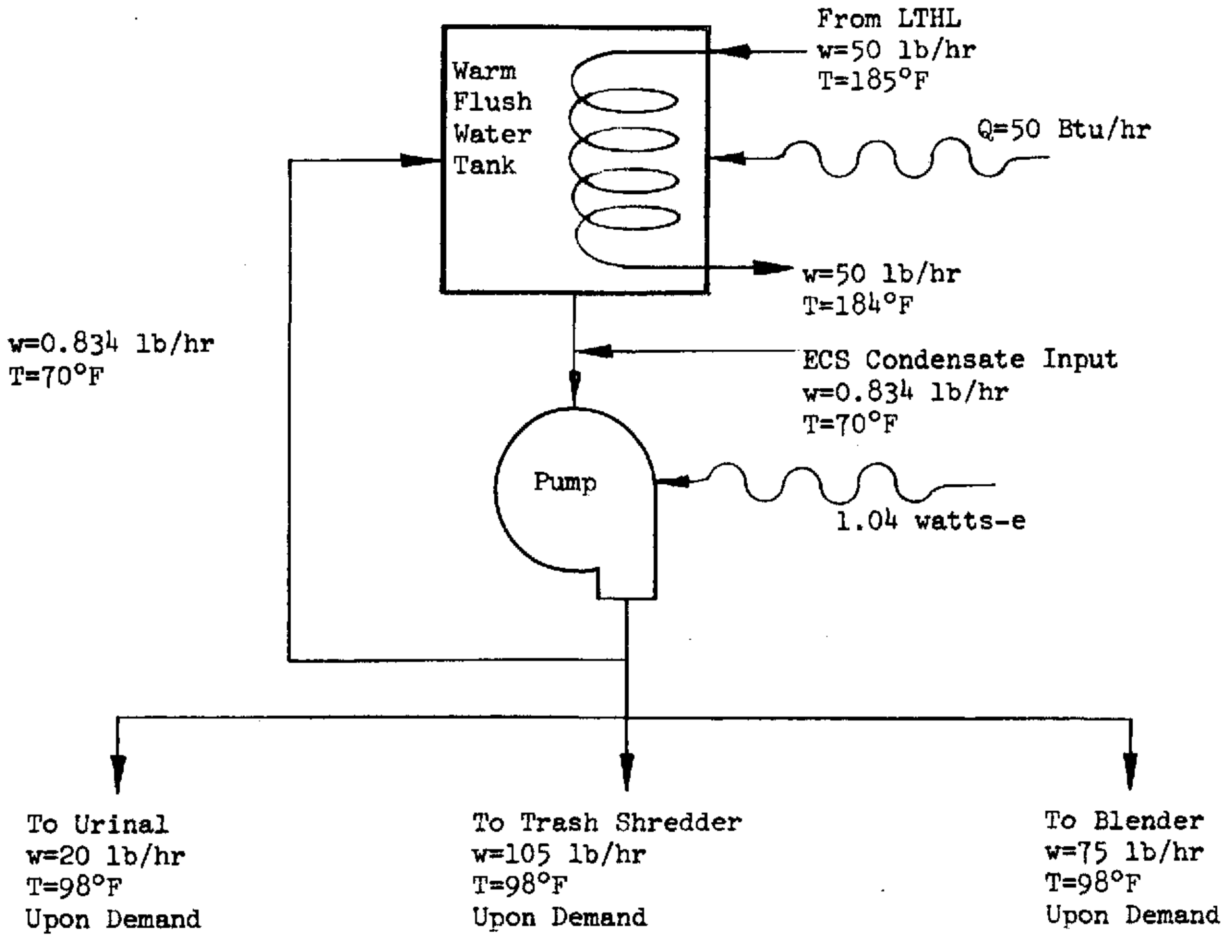


FIGURE 5.2 MASS AND HEAT BALANCE FOR FLUSH WATER LOOP

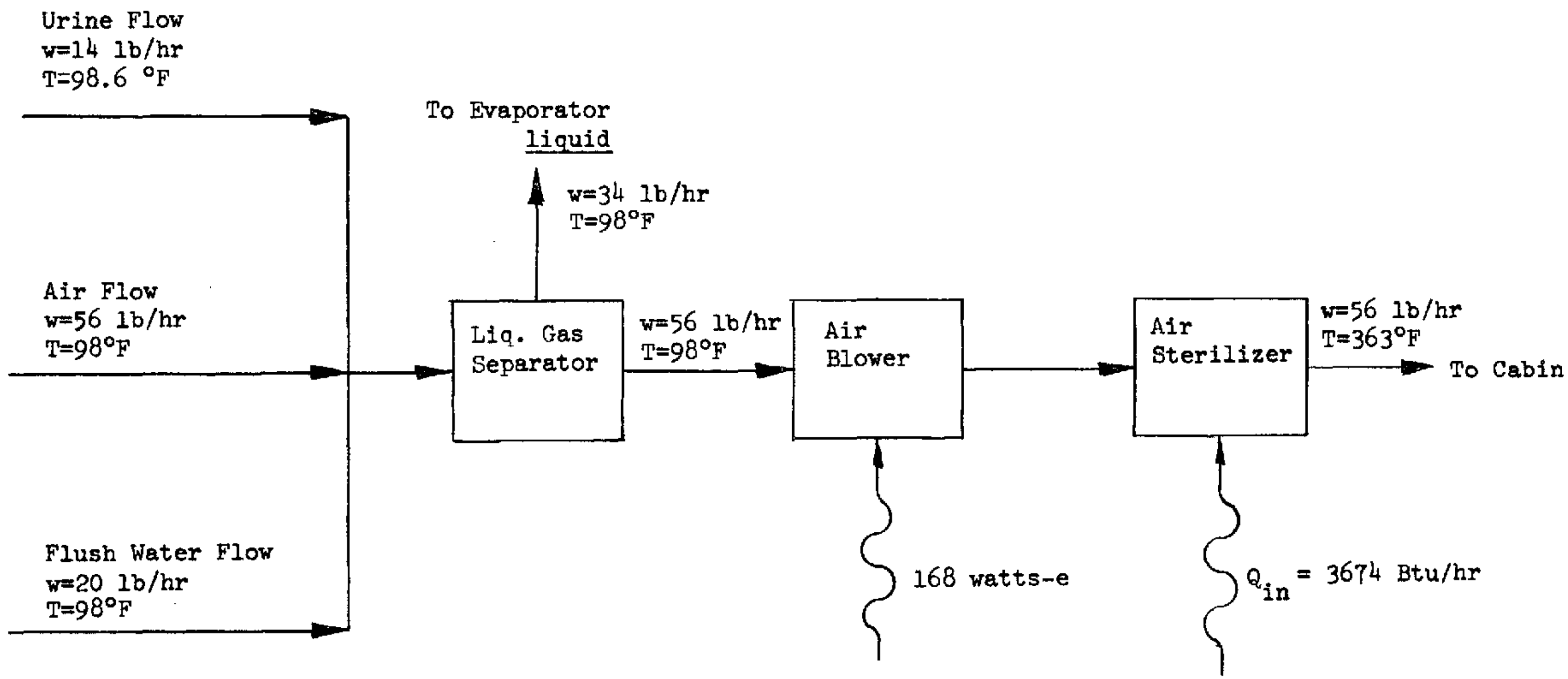


FIGURE 5.3 AIR LOOP MASS AND HEAT BALANCE DURING MICTURITION

5.1.4 Vapor Loop

The vapor loop purifies the waste water to potable water by an evaporation/condensation phase change process. The loop is comprised of five principal components, the evaporator, the three pyrolysis units and the condenser. The evaporator collects all the solid wastes and water, removes the solids by filtration and evaporates the water. The energy used in evaporating the liquid is transferred from the heating fluid supplied by the LTHL. The pyrolysis units neutralize any gases generated in the evaporator by oxidation at high temperature. The vapor flow is condensed in the condenser and the gasses are vented to vacuum.

The mass and heat balance for the vapor loop is shown in Figure 5.4. Over 96% potable water recovery is achieved. The sources of water loss are the condenser vent and water absorbed by the solids and removed by the solids pump to the incinerator. A chemical analysis of the gas reaction processes occurring in the vapor loop was attempted in order to reproduce the identical gas mass ratio reported by G.E. in their condenser vent gas analysis. The types and mass ratios of the output vent gases were reported by G.E. in Reference 1 and are repeated in Table 5.2. In order to reproduce the gas mass properties reported by G.E. it was postulated that there had most likely been a Bosch reaction in the pyrolysis unit. In this reaction hydrogen combines with carbon dioxide yielding carbon and water vapor. The possibility exists that the carbon is deposited in the catalyst and after a period of time reduces the effectiveness of the pyrolysis units. Due to the importance of water conservation and the complex nature of the processes taking place in this loop the mass balance will be discussed in detail. The chemical reactions and the resulting product generation rates taking place in the vapor loop are shown in detail in Figure 5.5.

5.1.4.1 Flow Input to the Vapor Loop

The vapor loop collects and processes wastes for a four-man crew for a 180-day simulated spacecraft mission. The quantities of solid and liquid wastes processed per day are summarized below:

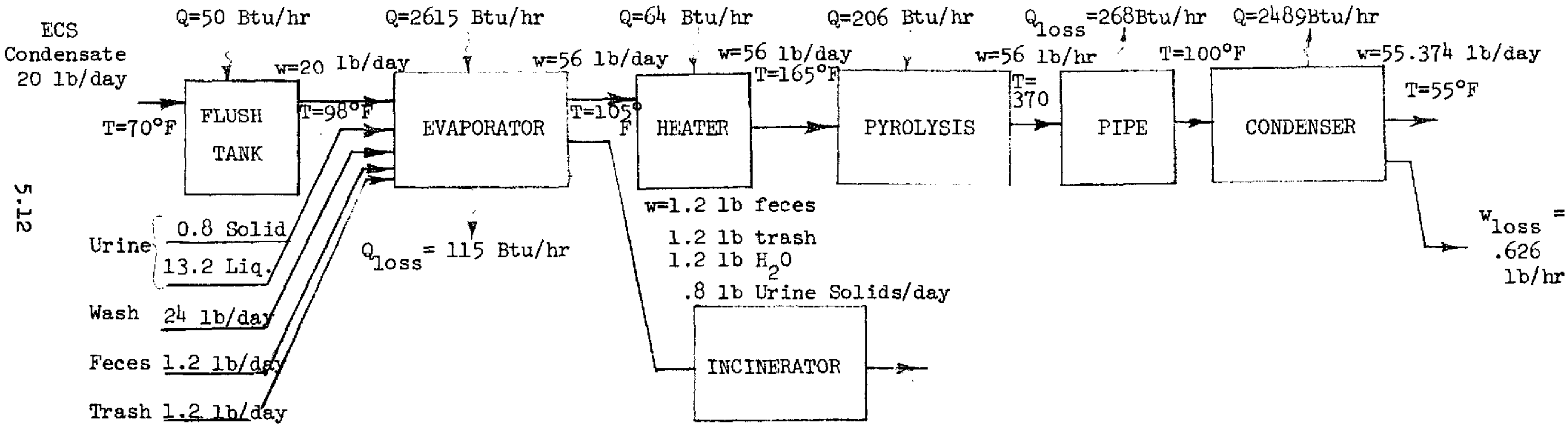


Figure 5.4 MASS AND HEAT BALANCE FOR THE VAPOR LOOP

Table 5.2

PYROLYSIS VENT GAS ANALYSIS

Note: Data are from Reference 1

COMPONENTS	PERCENT (WATER FREE)	PERCENT (LESS WATER AND ARGON)	FLOW RATES CONDENSER VENT (lb/hr)
O_2	12.2	12.6	$6.456*10^{-4}$
N_2	81.9	84.6	$3.7941*10^{-3}$
CO_2	1.3	1.34	$9.46*10^{-5}$
NO	.5	.53	$1.9854*10^{-5}$
NO_2	.2	.2	$1.52*10^{-5}$
H_2	.7	.73	$2.3*10^{-6}$
Ar	3.2		

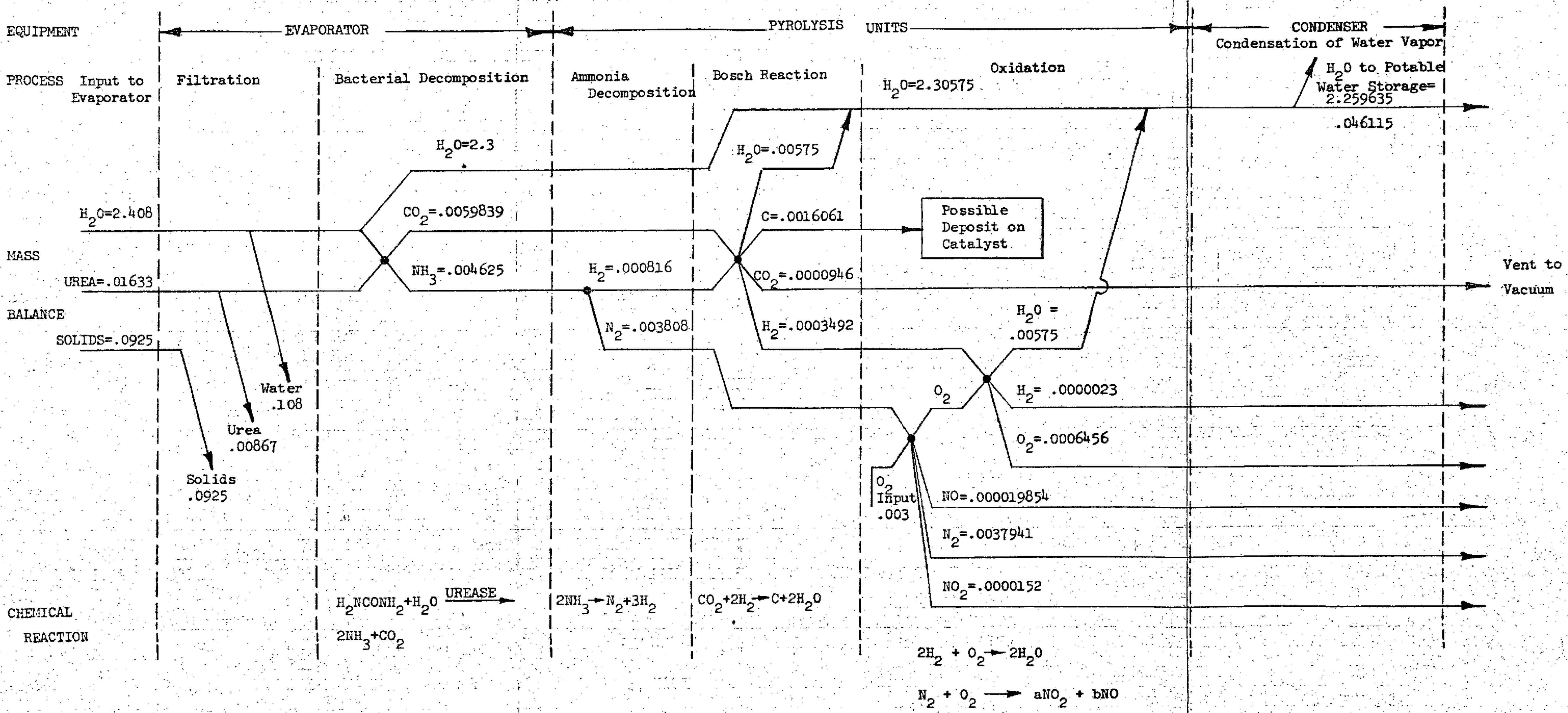


FIGURE 5.5 RITE SYSTEM CHEMICAL REACTIONS AND MASS BALANCE (ALL FLOW RATES IN LB/HR)

(a) Feces: 1.2 pounds per day for 4 defecations

(b) Urine: 14.0 pounds per day from approximately 24 micturitions.

(c) Respiration and Perspiration: 20.0 pounds per day at a continuous flow rate from the environmental control system.

(d) Wash Water: 24.0 pounds per day.

(e) Trash: 1.2 pounds per day - food, packets, wipes, and paper.

The wastes enter the evaporator from the solids loop and the air loop. The time sequence in which these products are input to the evaporator is shown in Figures 5.6 to 5.8 for the urine, feces, and trash input respectively. Micturition occurs once per hour and the solids input occur an average of once per six hours.

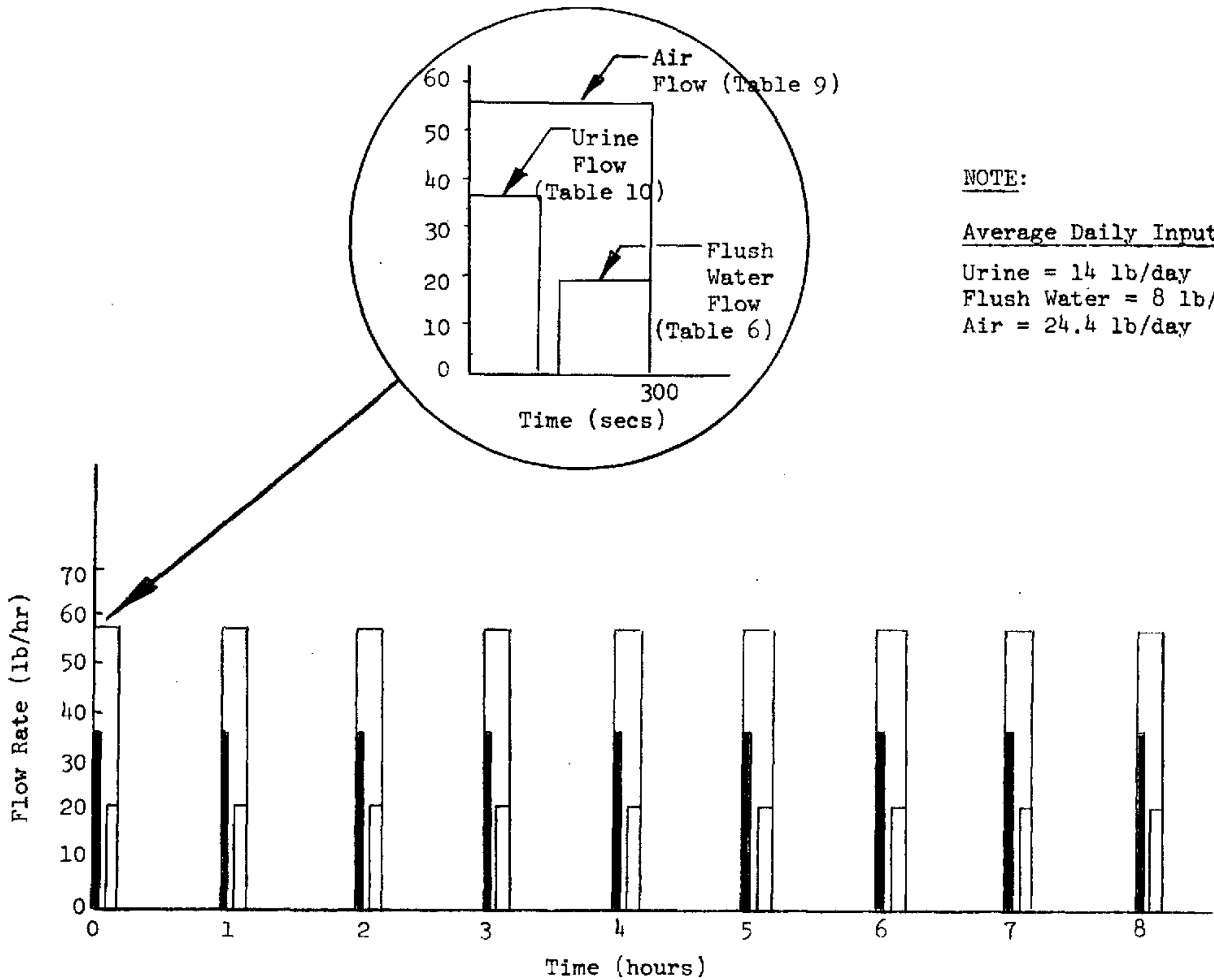
5.1.4.2 Evaporator Operation

The evaporator collects all solids and liquids that constitute waste, centrifugally separates the solids from the liquid, and evaporates the liquid. Some of the urea solids in the evaporator decomposes into ammonia and carbon dioxide and are vented with the water vapor.

Filtration

The pumping action of the impeller in the evaporator provides the means for the circulation of the liquid slurry thru an external perforated metal filter. The waste solids collect in the filter. When the filter (defined as the solids reservoir) fills with solids, the solids pump moves the solids to the incinerator. The filtration rate of the solids is proportional to solids concentration in the mixture.

As shown in Fig. 5.5, half of the urea that flows into the evaporator and all of the remaining solids that constitute the influent are assumed to be removed by the filter. For each pound of solids removed, approximately 1.17 pounds of water is also removed from the reservoir through filtration. This



NOTE:

Average Daily Input

Urine = 14 lb/day
Flush Water = 8 lb/day
Air = 24.4 lb/day

FIGURE 5.6 URINAL INPUT FLOW CYCLE

Average Daily Input:	Solids	=	1.2 lb/day
	Flush Water	=	5 lb/day
	Air	=	8.7 lb/day

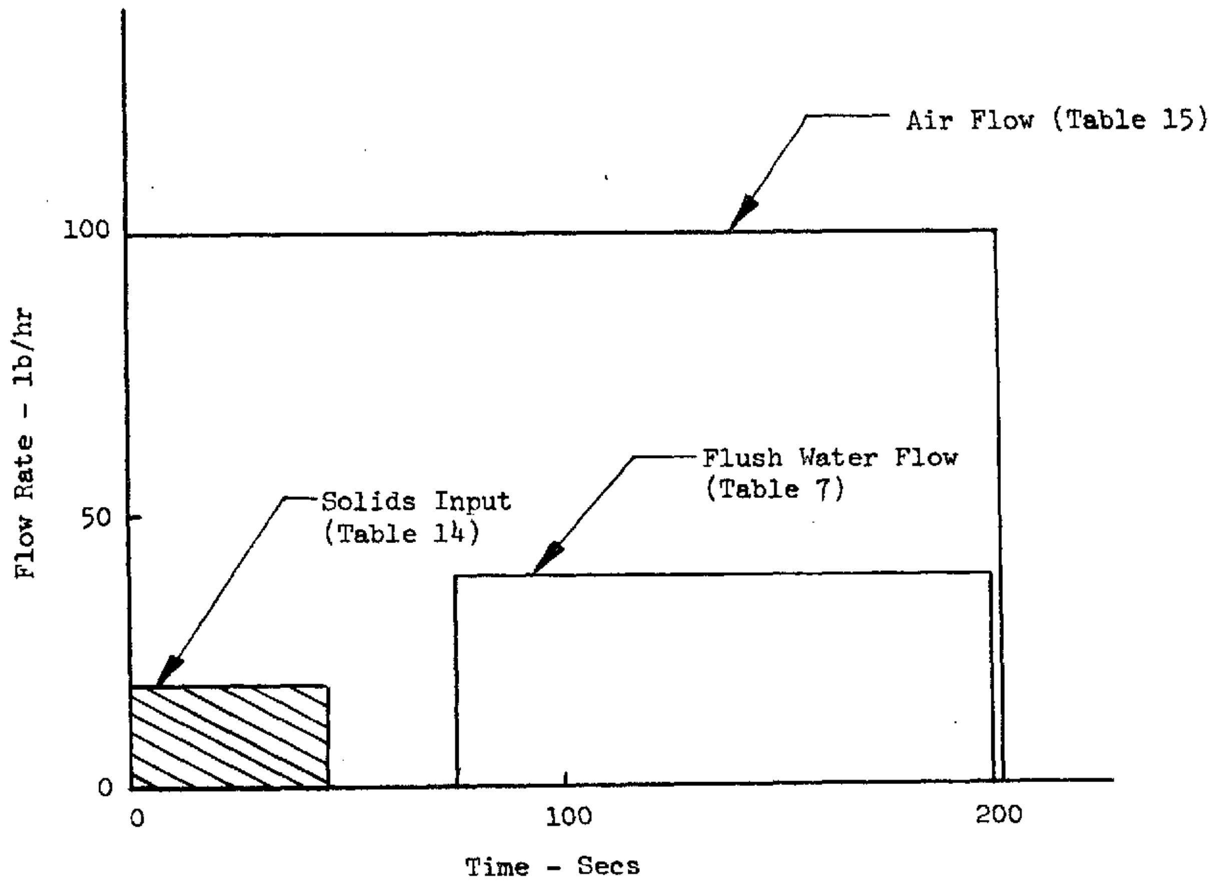


FIGURE 5.7 BLENDER INPUT CYCLE (one/6 hrs)

(Average Daily Input: Trash = 1.2 lb/day
Flush Water = 7 lb/day)

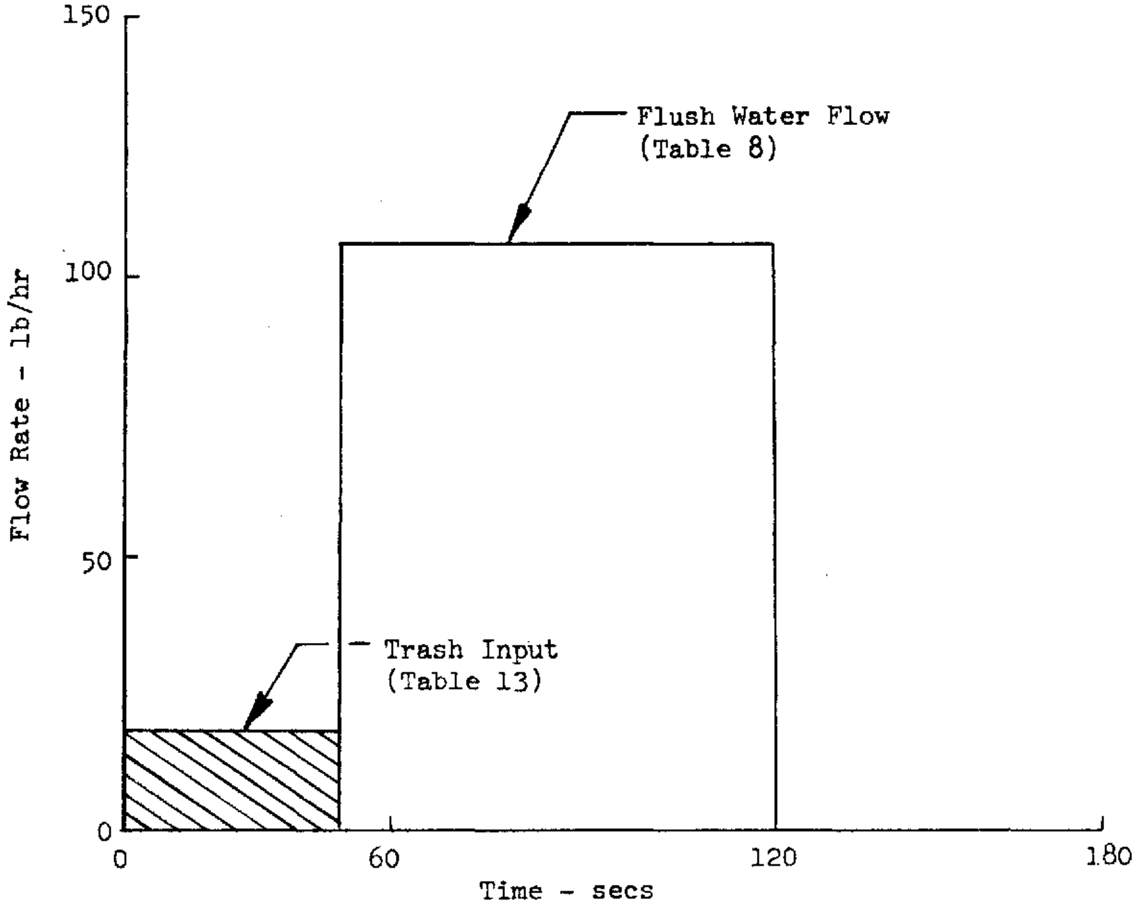


FIGURE 5.8 TRASH INPUT CYCLE (ONE/6 hrs)

water is added to the total solids in the reservoir and is also transferred to the incinerator. This represents a serious water loss to the system. A detailed discussion of the filtration process is included in the EVAP subroutine writeup.

Decomposition of Urea

The remaining urea is assumed to decompose biochemically/chemically generating NH_3 and CO_2. Urine contains a certain amount ($\sim$ 50 mg/ℓ) of ammonium carbonate/bicarbonate which will liberate ammonia and carbon dioxide when it is vaporized. In addition, urea which is the principal component of urine ($\sim$ 28000 mg/ℓ) may decompose thermally when the temperature is above 150°F to yield NH_3 and CO_2. Urea also decomposes in the presence of the enzyme urease which is provided from bacteria derived from the feces. Once the bacteria is introduced it will multiply while decomposing most of the urea within 12 to 48 hours. Since no germicidal chemicals are added to the evaporator it is assumed that biochemical decomposition of urea will occur. The urea decomposes to NH_3 and CO_2 according to the following reaction.

$$H_2NCONH_2 + H_2O \xrightarrow{\text{UREASE}} 2NH_3 + CO_2$$

Since the bacterial decomposition of urea was assumed to be at 0.008167 lb/hr, the ammonia generation rate was 0.004625 lb/hr and the carbon dioxide generation rate was 0.00594 lb/hr.

Vaporization of Water

The nominal design point steady state vaporization of water is 2.3 lb/hr at a vapor temperature of 105°F and vapor pressure of 1.1 psia. The Corresponding wall temperature is 115°F. A detail discussion of the evaporation heat transfer characteristics is included in the EVAP subroutine writeup.

5.1.4.3 Pyrolysis Unit

The pyrolysis units initially disassociate the ammonia to yield nitrogen and hydrogen

$$2NH_3 \longrightarrow N_2 + 3H_2$$

The product generation rates are given in Figure 5.5.

Oxygen is added to the vapor stream, upstream of the pyrolysis units, to oxidize the hydrogen to prevent ammonia from reforming. The oxygen flow to the vapor loop is determined by measuring the pH of the condensate in the condenser, where a basic solution would require an increase in O_2 flow to the vapor stream while an acidic solution would result in the decrease of O_2 flow to the vapor stream. The philosophy supporting the forementioned approach for O_2 flow control is that excess O_2 generates excess NO_X gasses in the pyrolysis units yielding an acidic condensate while insufficient O_2 in the vapor stream causes nitrogen and hydrogen to reform causing the condensate to be basic. A balance of ammonia and nitrates/ nitrites yields a neutral solution; but, possibly an unacceptable solution due to a high level of nitrate/nitrite salts in the condensate. The water analysis results presented in Reference 1, indicate the existance of nitrate/nitrite salts in the product and the possibility of a problem in this area.

The presence of hydrogen, carbon dioxide, high temperature ($\sim$1250°F), and a catalyst in the pyrolysis unit yields an ideal condition for a BOSCH reaction. In the BOSCH process, carbon dioxide is hydrogenated to water and carbon according to the reaction

$$CO_2 + 2H_2 \longrightarrow C + 2\ H_2O + \text{heat}$$

The water is recovered in the condenser while the carbon is unaccounted for. It is assumed that the carbon is deposited in the pyrolysis units, thus degrading the operation of the pyrolysis units. The rate of carbon deposition may be derived from the difference between CO_2 generated in the evaporator and the CO_2 vent rated from the condenser.

The remaining hydrogen (99.95%) that is not reacted in the BOSCH process is reacted with oxygen to generate more water as follows:

$$2\ H_2 + O_2 \longrightarrow 2\ H_2O + \text{Heat}$$

The excess oxygen reacts with nitrogen to form NO and NO_2 gasses as follows:

$$2\ N_2 + 3\ O_2 \longrightarrow 2\ NO_2 + 2\ NO$$

The product generation rates for all these processes are noted in Figure 5.5.

5.1.4.4 Condenser

The condenser is the final component in the vapor loop. There the non-condensable gases are vented and the vapor is condensed. The condensation rate in the condenser was calculated to be 2.260 lb/hr and since the original water input to the system was 2.357 lb/hr the overall conversion efficiency is 96 percent.

5.1.5 Cooling Loop

The cooling loop provides the coolant flow to the condenser and the water cooler. Approximately 2489 Btu/hr is added at the condenser increasing the coolant temperature from 35°F to 47°F. The loop schematic is shown in Figure 5.9.

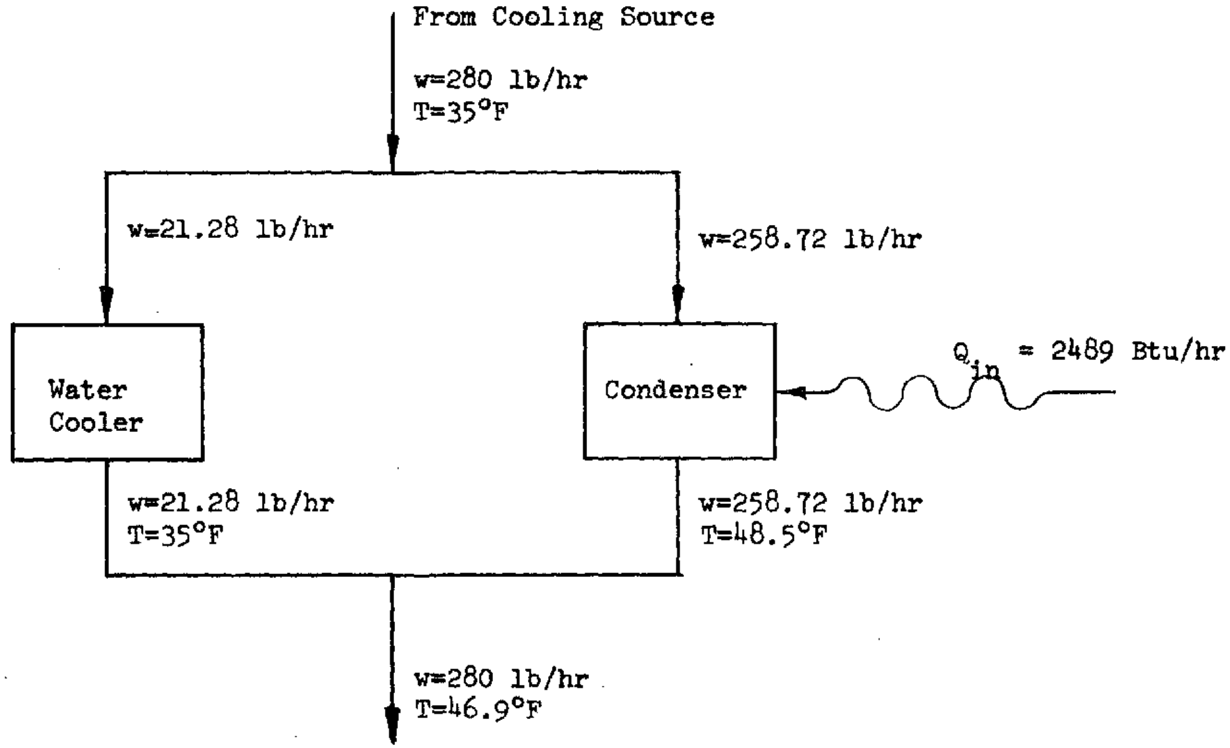


FIGURE 5.9 MASS AND HEAT BALANCE FOR THE COOLING LOOP

5.1.6 Potable Water Loop

The potable water loop collects and stores purified water from the condenser. The system also distributes hot and cold water as required by users. A heat balance for a typical tank is shown in Figure 5-10. Approximately 210 Btu/hr are used to heat the water.

5.2 Transient Behavior

The G-189A model of the RITE system has been used to predict the performance for several transient events which occur during normal RITE operation. These events are micturition, defecation and incineration.

5.2.1 Micturition

During micturition a slug of urine and flush water mixture suddenly enters the evaporator. The input schedule is shown in Figure 5.6. Urine is assumed to enter the evaporator at a body temperature of 98.6°F. The flush water is heated to 99 $\pm$ 1°F in the flush tank prior to use. Urinal drying air is then blown through the air loop to the air sterilizer and returned to the cabin.

The response of the evaporator to the sudden entry of liquid is shown in Figures 5.11 and 5.12. The input liquid drops the average temperature of the slurry approximately 2°F. Since some of the heat is diverted into heating the liquid the evaporation rate drops from 2.3 lbs/hr to a minimum of 2.15 lb/hr. The pressure in the evaporator drops to the saturation pressure at that temperature. Since the temperature of the input liquid is close to that of the liquid in the evaporator the transient effects are minimal and disappear rapidly once the input flows cease.

The response of the heat block to the sudden surge of urinal air is shown in Figure 5.13. The temperature of the heat block node associated with the air sterilizer drops rapidly. The remaining nodes show only a small temperature drop due to the large thermal capacity of the heat block. This indicates that the operation of the incinerator and pyrolysis units are not jeopardized while the air sterilizer is being used.

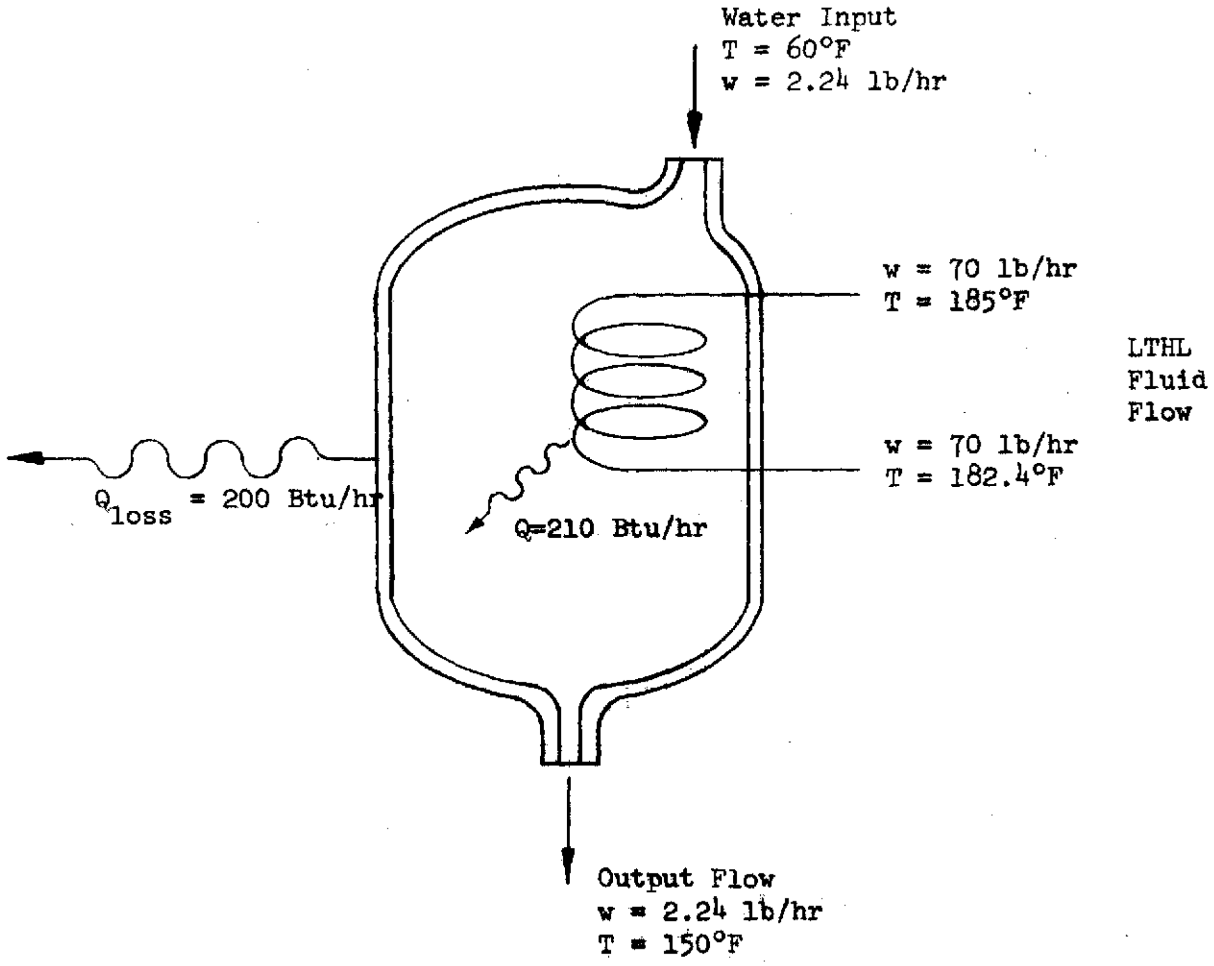


FIGURE 5.10 TYPICAL POTABLE WATER STORAGE TANK

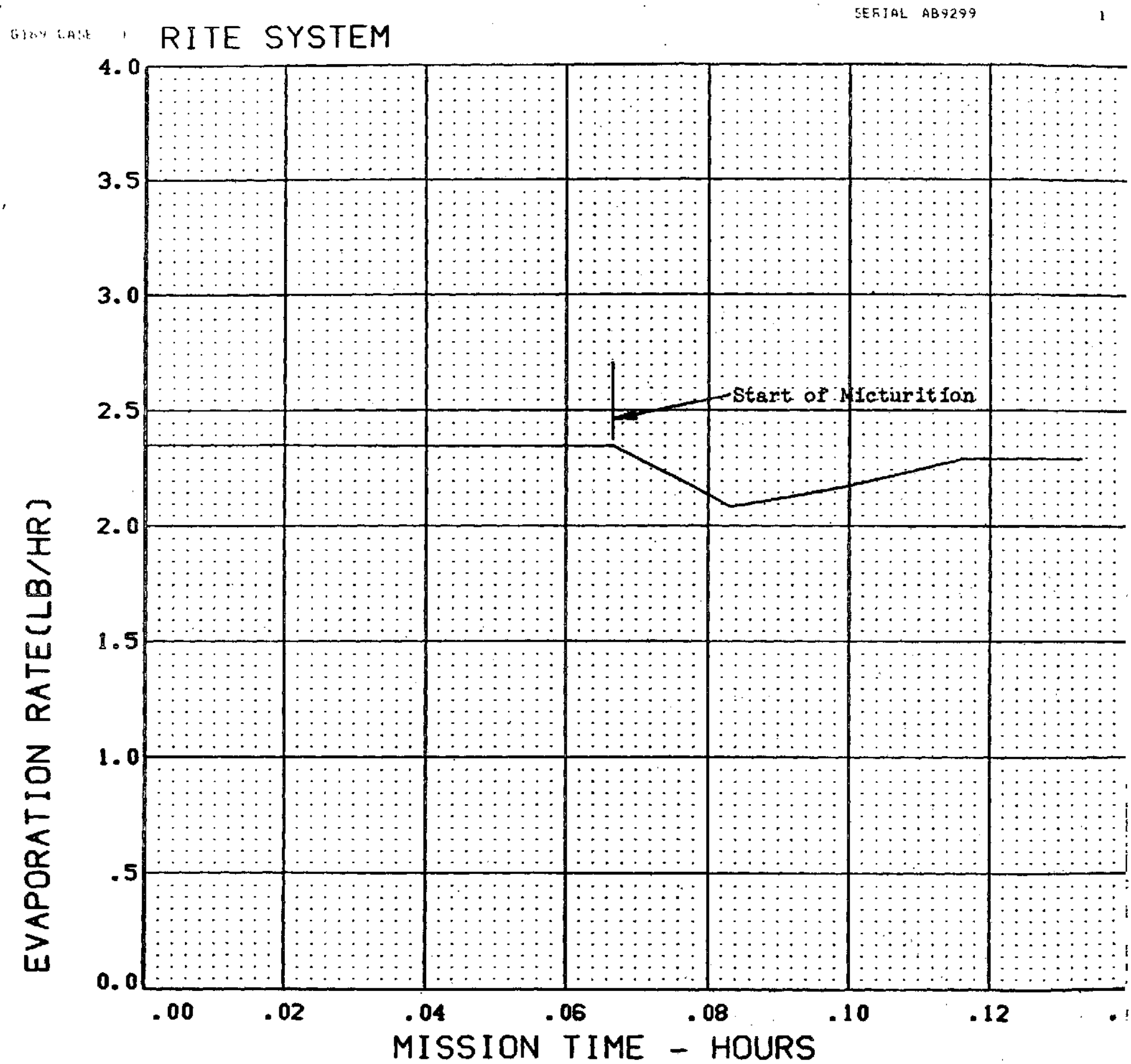


FIGURE 5.11 EVAPORATOR EVAPORATION RATE DURING MICTURITION

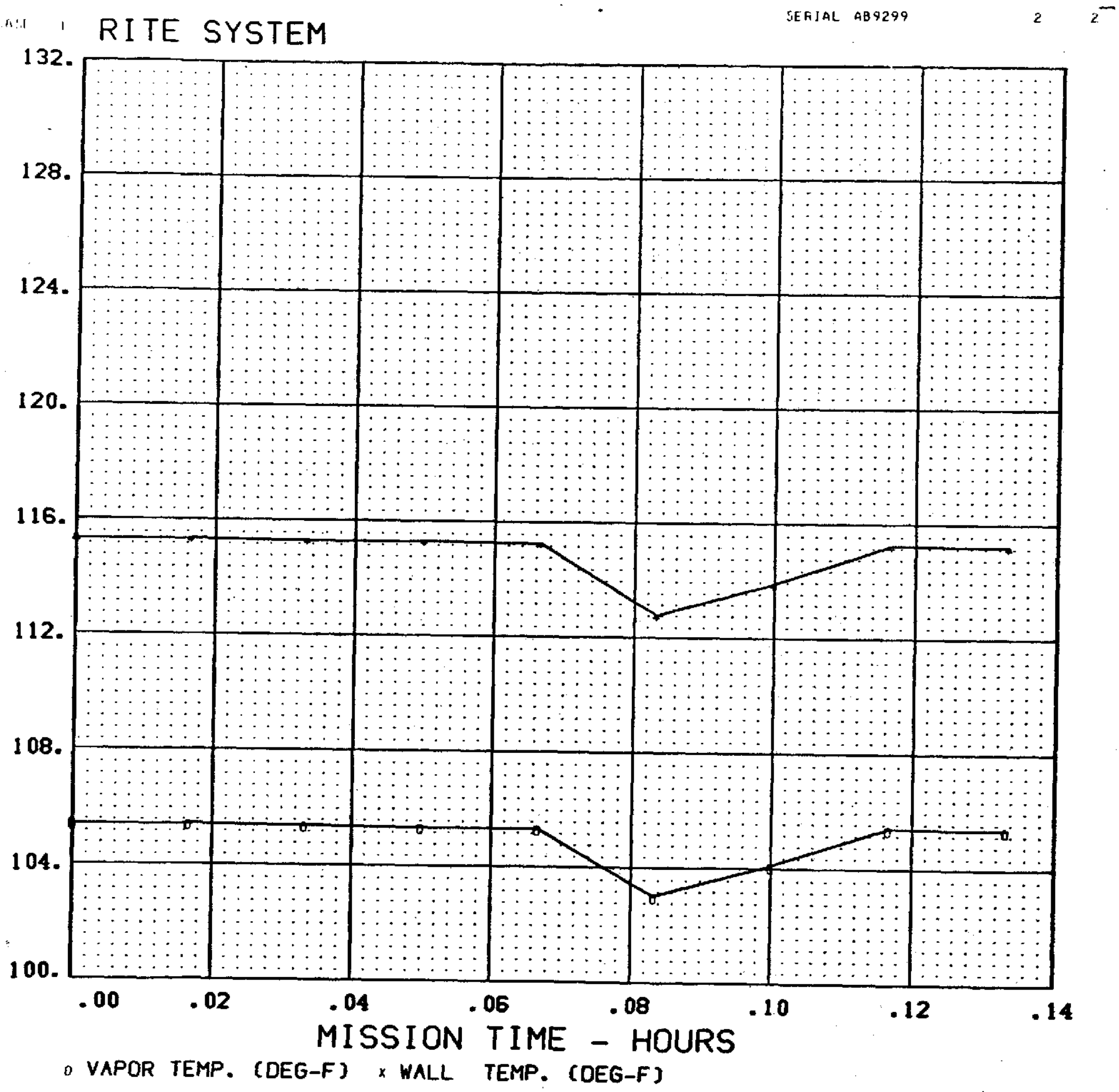


FIGURE 5.12 EVAPORATOR TEMPERATURE RESPONSE TO MICTURITION

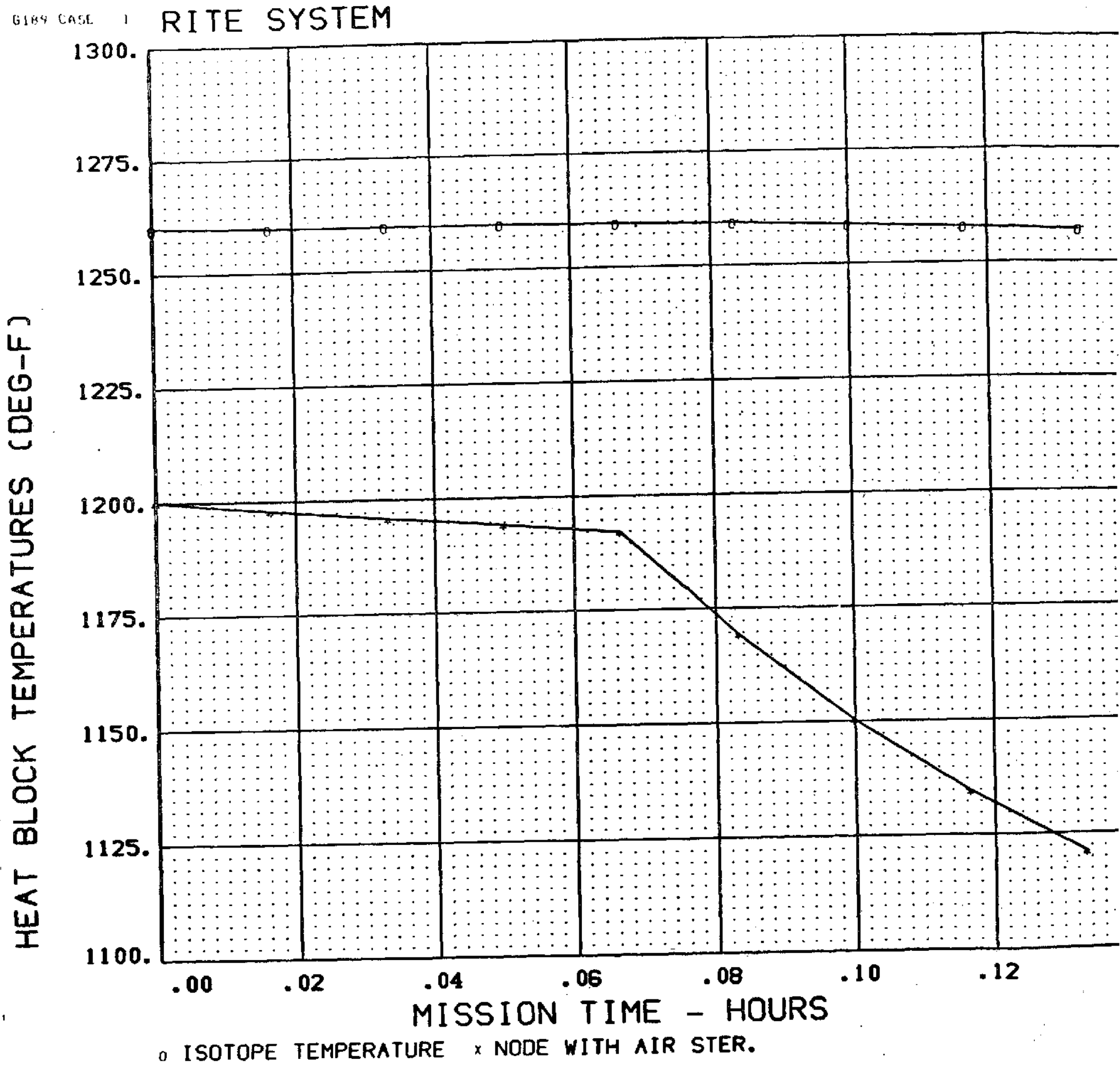


FIGURE 5.13 HEAT BLOCK TEMPERATURE RESPONSE TO MICTURITION

5.2.2 Defecation

During defecation, the normal low pressure operation of the evaporator is interrupted. The evaporator is exposed to cabin atmosphere and the output line is diverted to the air loop. Feces and flush water enter the evaporator through the blender. A stream of drying air is then blown from the blender, through the evaporator to the air loop and returned via the air sterilizer back to the cabin. During this time any liquid which is vaporized is lost to the cabin with the air stream. The vapor will then most likely be collected by the cabin's environmental control system and returned to the evaporator by way of the flush water loop.

The response of the RITE system to the disturbance caused by defecation is shown in Figures 5.14 and 5.15. The water recovery rate drops to zero since all vaporized liquid is returned to the cabin.

The evaporator temperature increases to 106°F since at the higher pressure boiling does not occur and the heat from the LTHL is used to heat the fluid. The temperature increase of the evaporator is limited to 105°F by the LTHL bypass controller which bypasses fluid around the evaporator when this temperature is reached.

The temperature response of the air sterilizer due to the sudden influx of the air ($\sim$37 cfm) is shown in Figure 5.16.

5.2.3 Incineration

The liquid-solid slurry in the evaporator is continuously being pumped through a circular metal screen filter. The solids remain behind and the liquid is returned to the evaporator. Periodically, an air driven piston compresses the solid concentrate inside the filter. The compressed solids are a sixty-forty mixture of solids and liquid. When the filter is full (0.5 lbs) the solids concentrate is transferred mechanically to the incinerator.

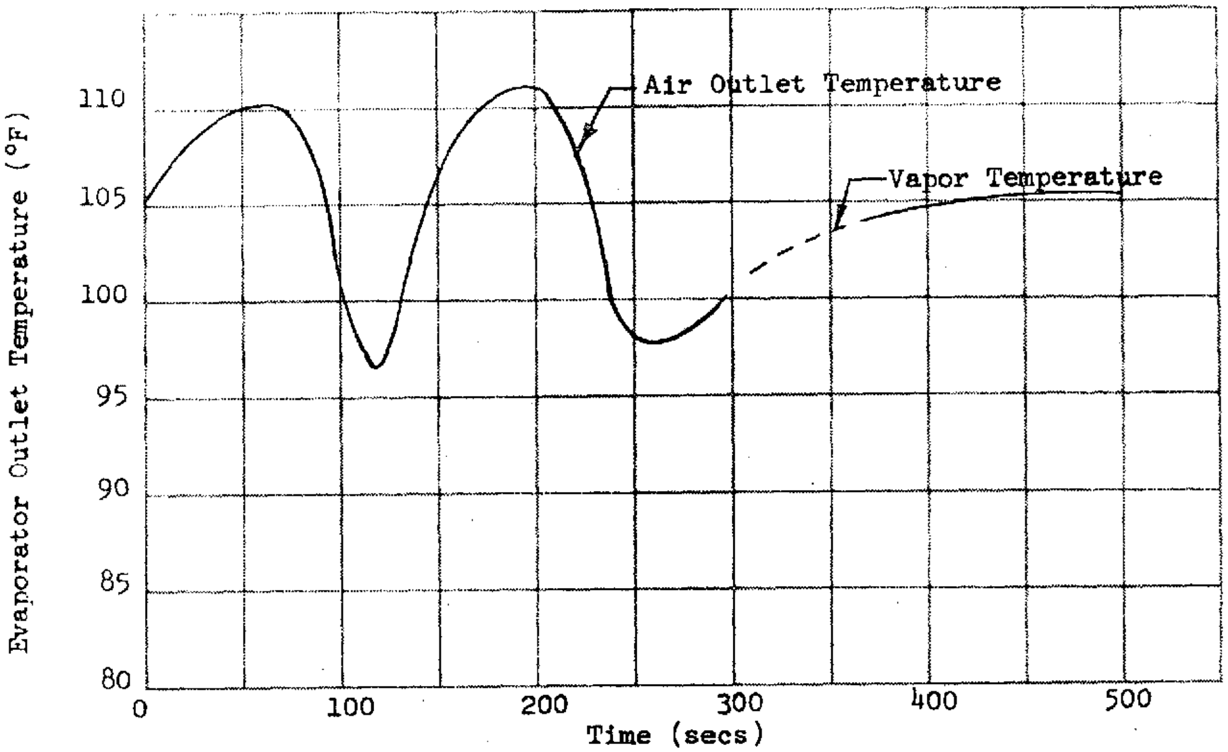


FIGURE 5.14 EVAPORATOR TEMPERATURE RESPONSE TO DEFECATION

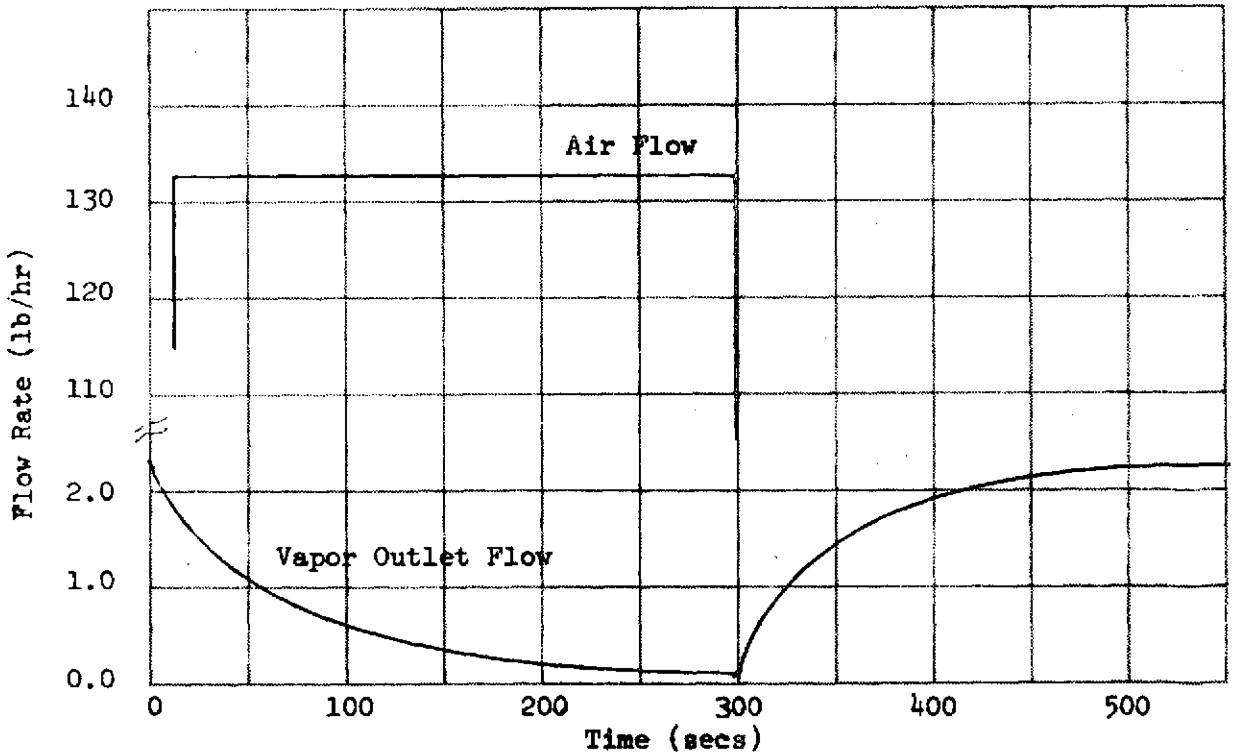


FIGURE 5.15 FLOW RATES IN EVAPORATOR DURING DEFECATION

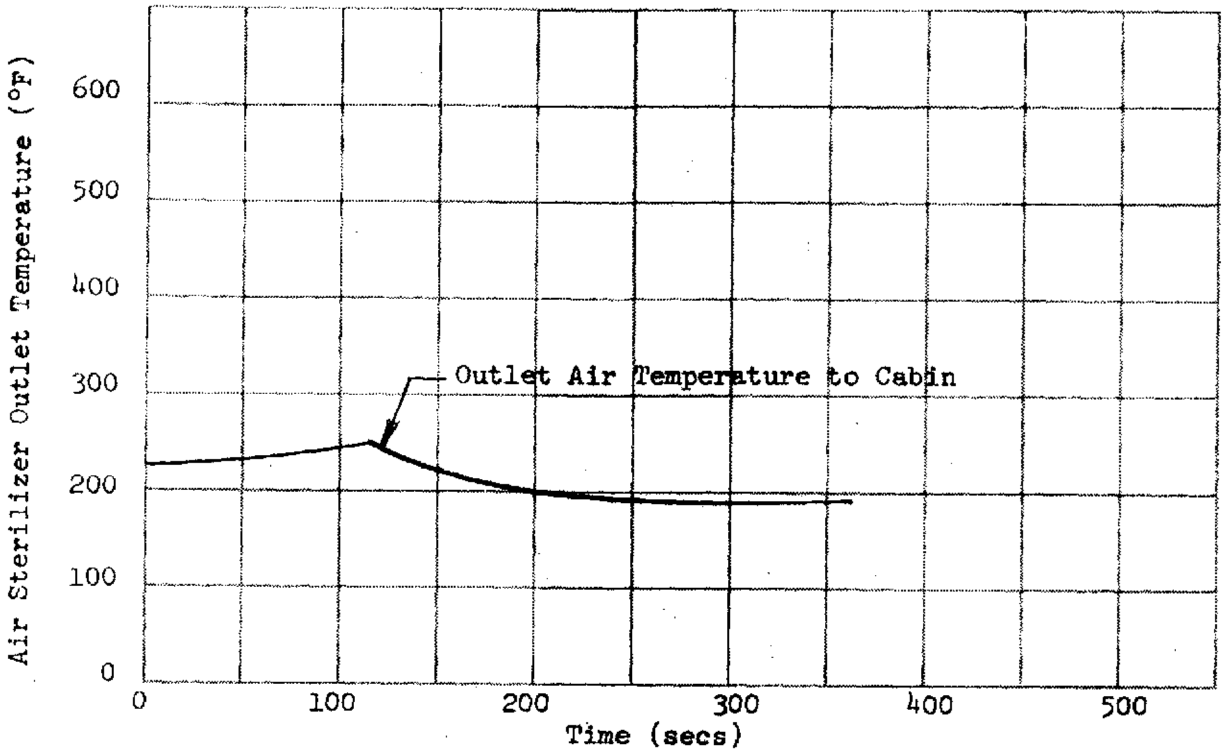


FIGURE 5.16 TEMPERATURE RESPONSE OF THE AIR STERILIZER DUE TO DEFECATION AIR

The solid waste is processed by vacuum drying, chemical decomposition at high temperature, and venting of resultant gasses. The temperature of the vented wastes of the incinerator are plotted in Figure 5.17.

During vacuum drying, heat from the heat block is used to evaporate the liquid. The vapor then flows to space through the open vent. Approximately 95% of the liquid is removed in the two hour drying period.

In the next step the vent to vacuum is closed and a small amount of oxygen is introduced with the solids and the oxidation reaction proceeds. Since the reactions are exothermic, there is a sudden rise in temperature. The chemical reactions are described in detail in the INCIN subroutine documentation contained in Appendix A. The product gasses are then vented to vacuum. The oxygen cycle is repeated until all the solids are incinerated. Approximately fourteen cycles are needed for full incineration. At the end of the cycle, the remaining ash is blown out by a nitrogen purge and stored in an ash collector. The volume of the remaining ash is only 1% of the original solid waste volume.

5.3 RITE System Operational Envelope

The RITE system operational envelope as generated by G-189A computer simulation is shown in Figure 5.18. The figure shows the variation in performance of the current RITE configuration as the boundary conditions, evaporator heat source temperature and condenser back pressure, are varied. The data shows excellent correlation with the General Electric 180-day run operating test point.

For any condenser pressure, increasing the LTHL fluid temperature increases water recovery rate until a vapor flow and temperature is reached which is beyond the condensation capacity of the condenser. The condenser removes only the sensible heat of the steam and the vapor escapes through the vent. The recovery rate rapidly drops to zero.

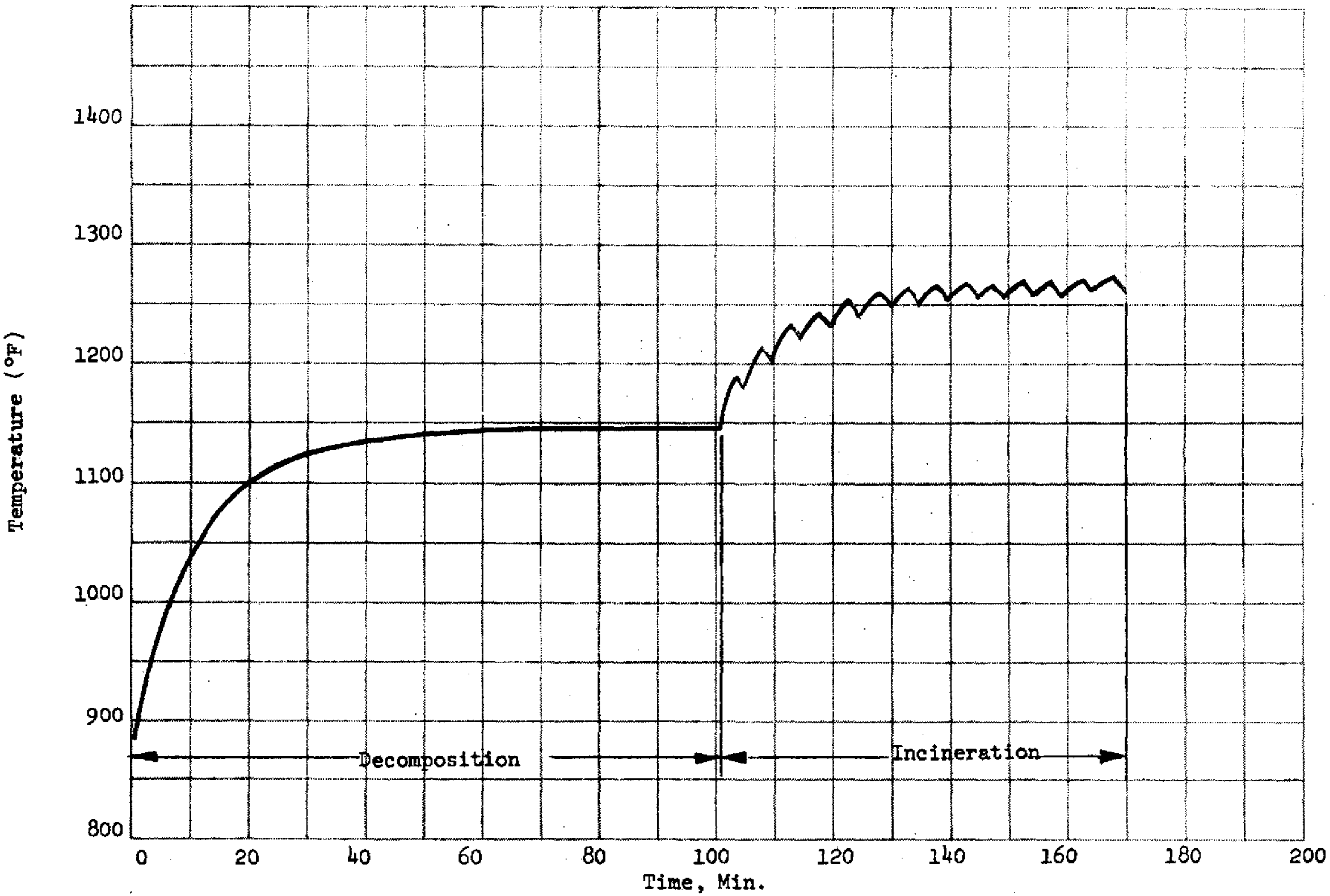


FIGURE 5.17 INCINERATOR TEMPERATURE CYCLE

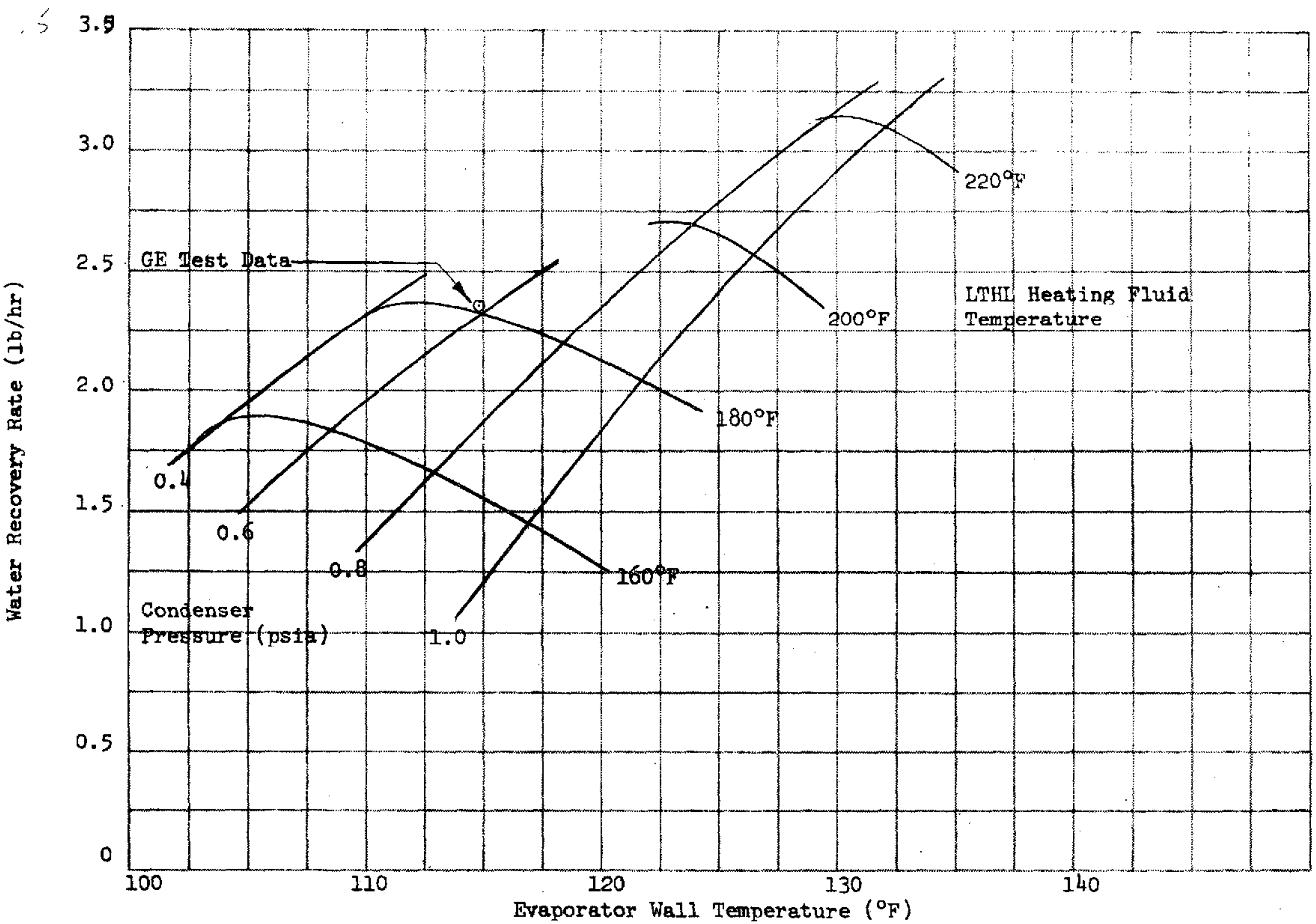


FIGURE 5.18 RITE SYSTEM OPERATIONAL ENVELOPE
(CONDENSER COOLANT TEMPERATURE 35°F)

The performance of the RITE system as the condenser back pressure is varied with constant LTHL temperature is shown in Figures 5.19 and 5.20. The 180°F LTHL evaporator inlet temperature corresponds to the General Electric operating point. A peak condensation or recovery rate is reached at a condenser pressure of 0.63 psia. Below this pressure the saturation temperature of the liquid approaches the temperature of the condenser wall and therefore the condensation rate falls. The vapor then escapes out the vent which results in a low conversion efficiency. Increasing the condenser back pressure increases the condensation efficiency; however, the pressure head driving force from the evaporator to the condenser is reduced resulting in a lower evaporator output. A tradeoff must therefore be made between recovery efficiency and total recovery rate. The results indicate that General Electric has selected as its operating point the peak recovery rate and a recovery efficiency greater than 98%.

The evaporator heat input requirements corresponding to the water generation rates of Figure 5.18 are shown in Figure 5.21. The G.E. instrumentation does not yield evaporator heat requirements; however, the heat load generated by the G189A corresponding to the G.E. operating point is noted in the figure. The 2500 Btu/hr used by the evaporator is less than half of the 5120 Btu/hr available in the isotope. Assuming that 900 Btu/hr are used to heat the water tanks, there is a heat loss to the environment of approximately 1500 Btu/hr in the low temperature heating loop. If this heat loss were reduced, the system water recovery rate of 2.3 lb/hr could be improved by a factor of 1-1/2 or more. Alternately, if only 2.3 lb/hr were required, the isotope inventory could be reduced from 1500 watts to 1060 watts.

Figures 5.22 and 5.23 show evaporator vapor temperature and pressure as a function of evaporator wall temperatures. The G.E. test point is 105°F vapor temperature at 1.1 psia vapor pressure.

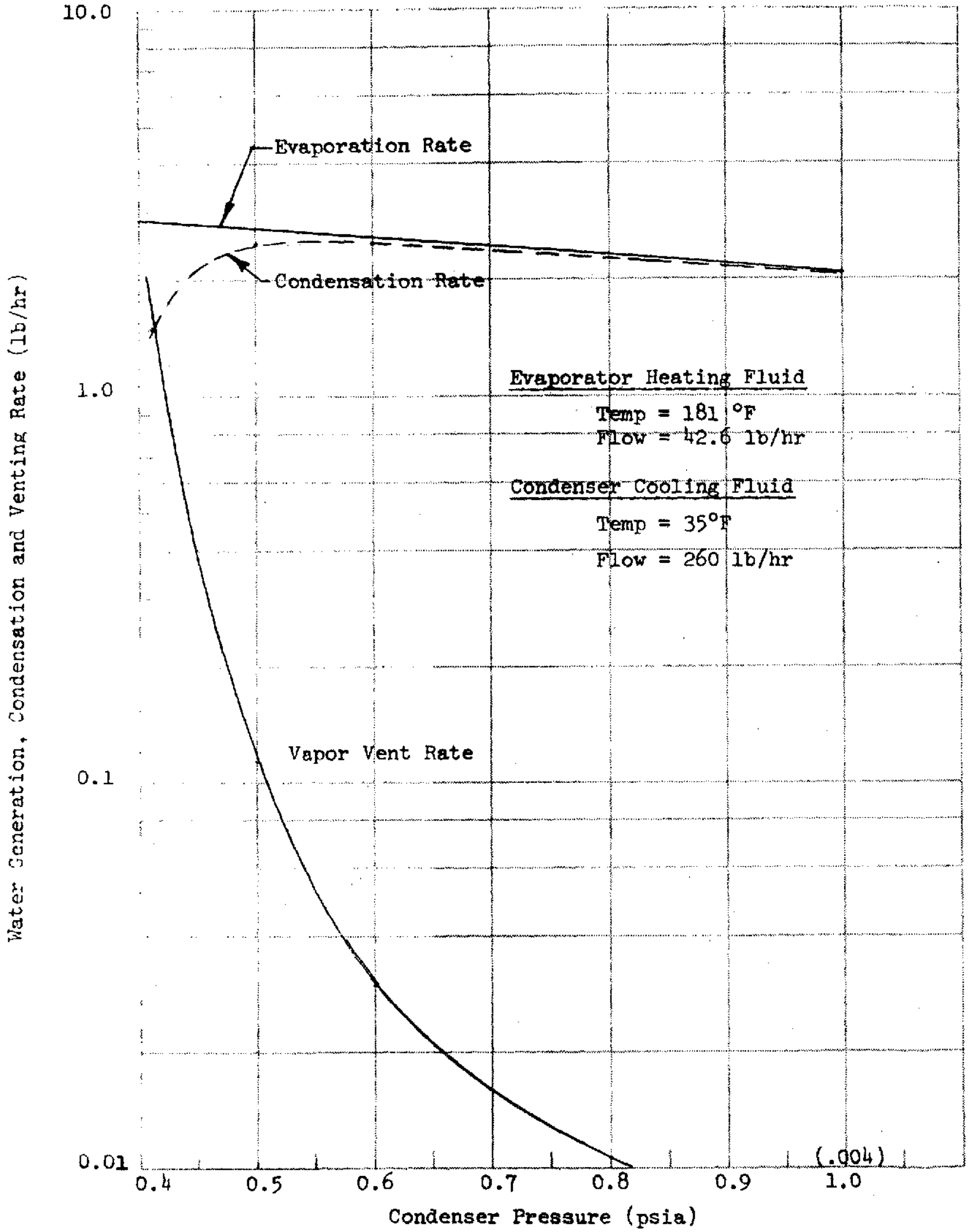


FIGURE 5.19 EVAPORATOR AND CONDENSER PERFORMANCE EVALUATION
(at G.E. Operating Point of 181°F LTHL Temperature)

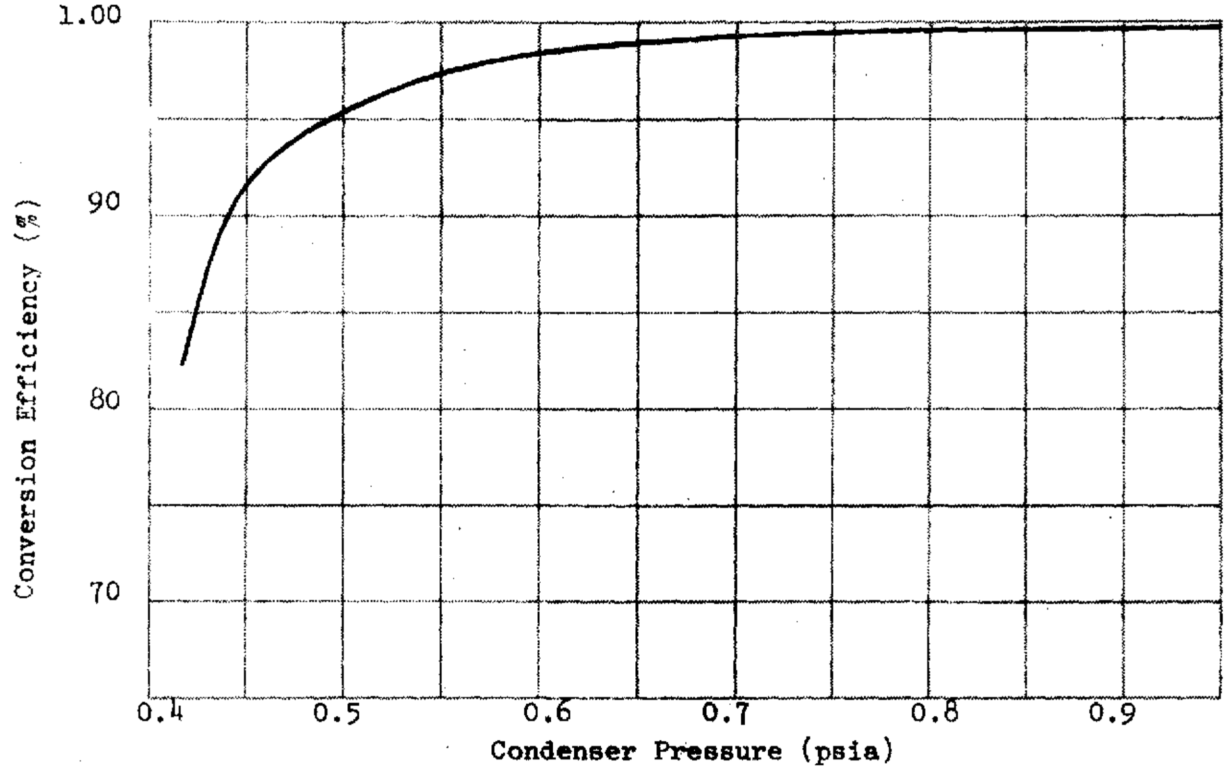


FIGURE 5.20 RITE SYSTEM WATER PURIFICATION EFFICIENCY

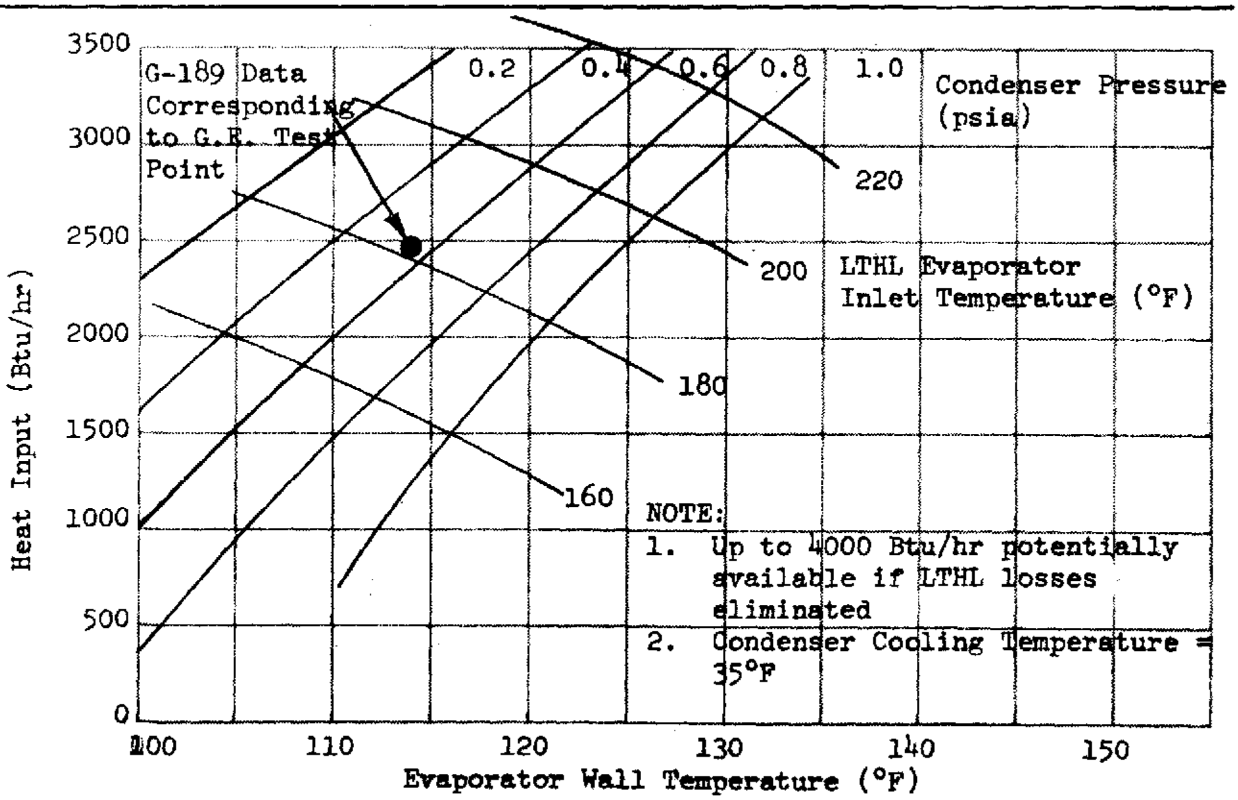


FIGURE 5.21 HEAT INPUT TO EVAPORATOR

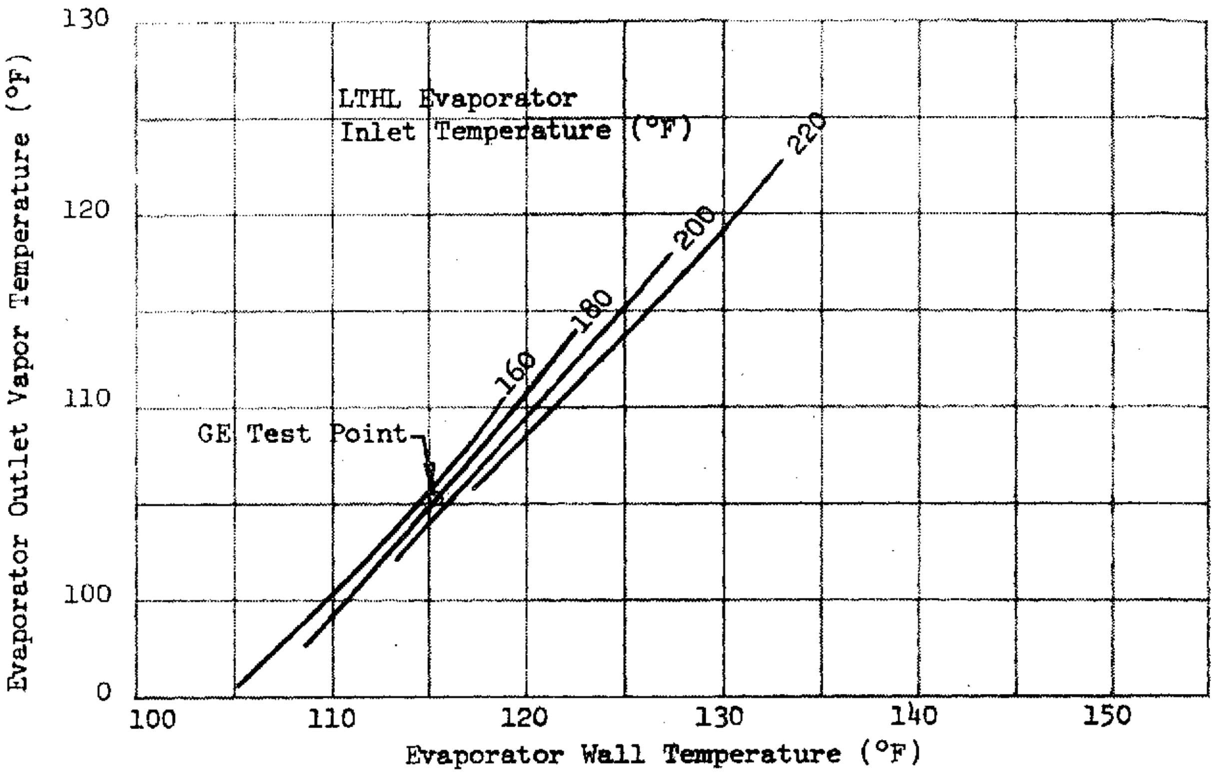


FIGURE 5.22 EVAPORATOR OUTLET TEMPERATURE AS A FUNCTION OF WALL TEMPERATURE

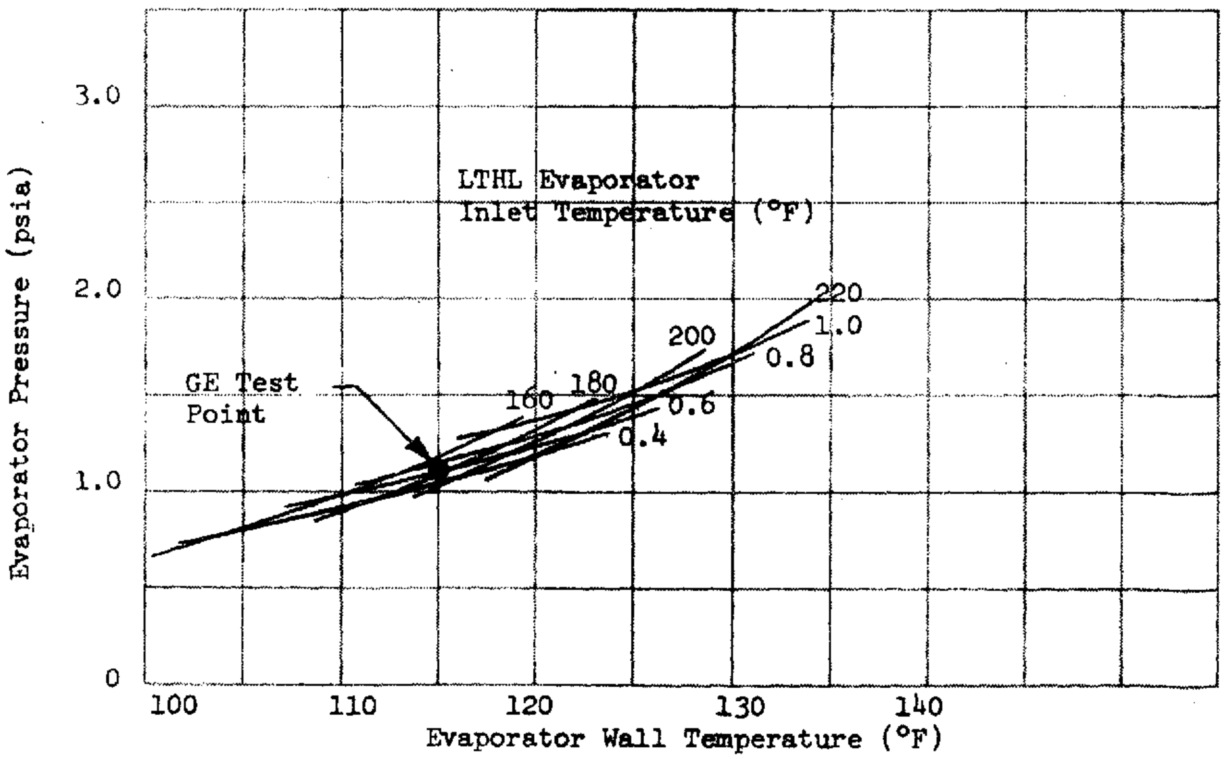


FIGURE 5.23 EVAPORATOR PRESSURE AS A FUNCTION OF WALL TEMPERATURE

Section 6

RITE Simulation Design Applications

Once the basic configuration of the system under study has been simulated by use of the G-189A Program, the simulation can be used in support of both detail component design, system design and system integration. Examples of G-189 program RITE simulation applications to RITE system design analyses and investigations are listed below:

1. Effect of Vehicle Equipment Limitations on RITE Performance
    a. Available vehicle radiator coolant temperature level and heat load capability.
    b. Amount and temperature level of heat available
    c. Electrical power limitations
    d. Oxygen supply limitation
    e. Size and dimensional limitations for RITE
2. Effect of component design on RITE Performance
    a. Effect of RITE component operating temperature levels
    b. Thermal effectiveness of evaporator
    c. Thermal effectiveness of condenser
    d. Size and efficiency of other components
3. System Integration
    a. Effect of venting gases to cabin
    b. Heat loss to cabin
    c. Nuclear safety
    d. Timeline for crew activities in water/waste management events
    e. Mission life
    f. Controls and instrumentation

Analysis of each of these problems is beyond the scope of this study. Therefore, to illustrate the simulation design potential, the effects of available coolant temperature on system effectiveness and the study of potential design changes in the evaporator and condenser were chosen for study.

6.1 Condenser Coolant Inlet Temperature

The radiator outlet coolant temperatures available to the subsystems aboard advanced manned vehicles such as Space Shuttle and Sortie Lab will generally range from 40°F to over 100°F. The current RITE system is operating at a coolant temperature of 32°F which is clearly optimistic. Since other subsystems such as the batteries will make demands for the lower coolant temperatures, it is possible that the lowest coolant temperature available to the RITE would be in the 50 to 60°F range.

Figures 6.1, 6.2, and 6.3 detail the operational envelope of the RITE system for coolant temperatures of 35, 40 and 50°F. The system output is plotted as functions of evaporator wall temperature, evaporator heating fluid (LTHL heating fluid) inlet temperature and condenser pressure.

For all coolant temperatures, increasing the LTHL temperature with constant condenser pressure improved the system output, until a condensation limit is reached. At a coolant temperature of 50°F and the LTHL temperature of 220°F, the resultant vapor output temperature of the evaporator was too high for the condenser to be operational and as a result all the vapor was lost through the vent.

The system output at the baseline LTHL temperature of 180°F was cross-plotted in Figure 6.4 to show clearly the effect of condenser coolant temperature. As the condenser temperature increases the partial pressure of water required for condensation increase and therefore the total pressure of the condenser must increase. Increased condenser pressure, however, limits evaporator output due to a higher pressure drop or flow resistance in the vapor loop. Therefore, the optimum output of the system as the condenser temperature is increased from 35 to 40 to 50°F drops from 2.3, to 2.2 and to 2.13 lb/hr. Table 6.1 shows the key system parameters for the three condenser temperatures for the same condenser total pressure of 0.63 psia. In each case the evaporator output is the same, however, the ability of the condenser to condense the flow, which is defined as the system efficiency, drops as condenser temperature increases. Finally, at 50°F the condenser wall temperature of 83.2°F and the corresponding water partial pressure of 0.58 psi is too high for effective condensation.

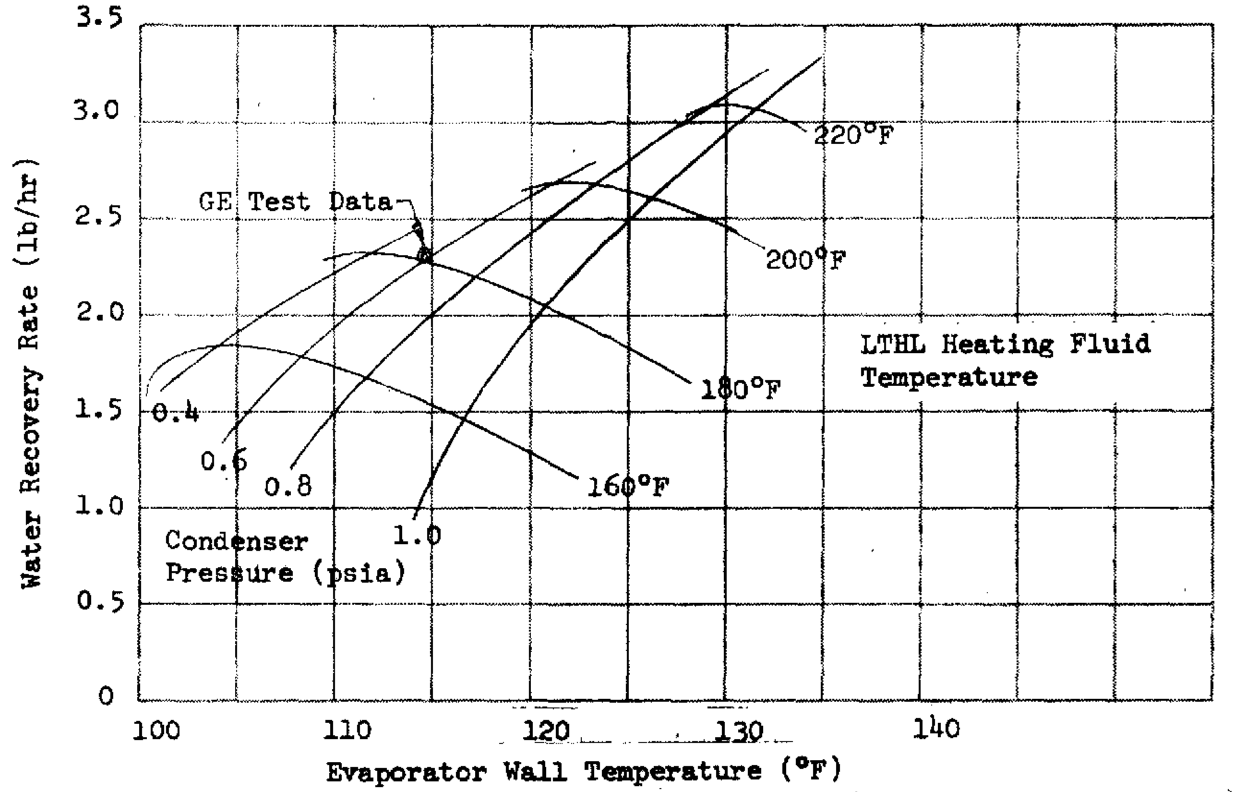


FIGURE 6.1 RITE SYSTEM OPERATIONAL ENVELOPE CONDENSER COOLANT TEMPERATURE 35°F

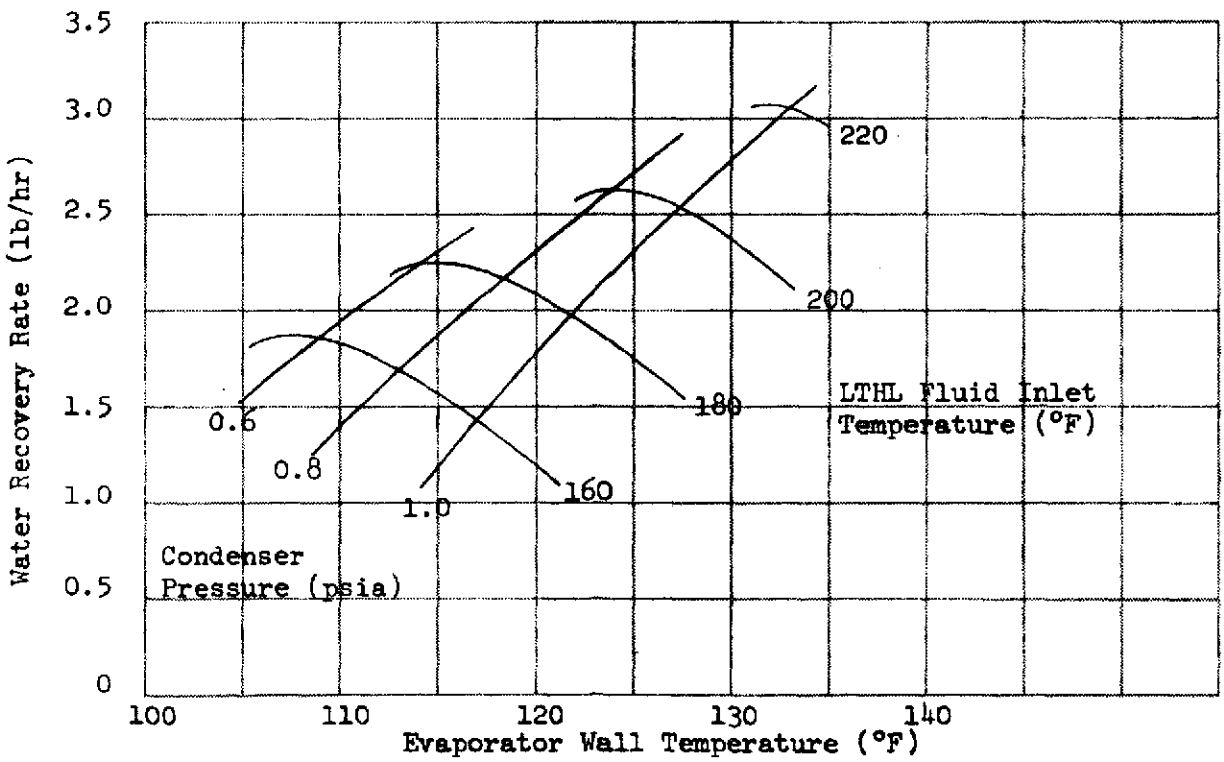


FIGURE 6.2 RITE OPERATIONAL ENVELOPE WITH CONDENSER COOLANT TEMPERATURE EQUAL TO 40°F

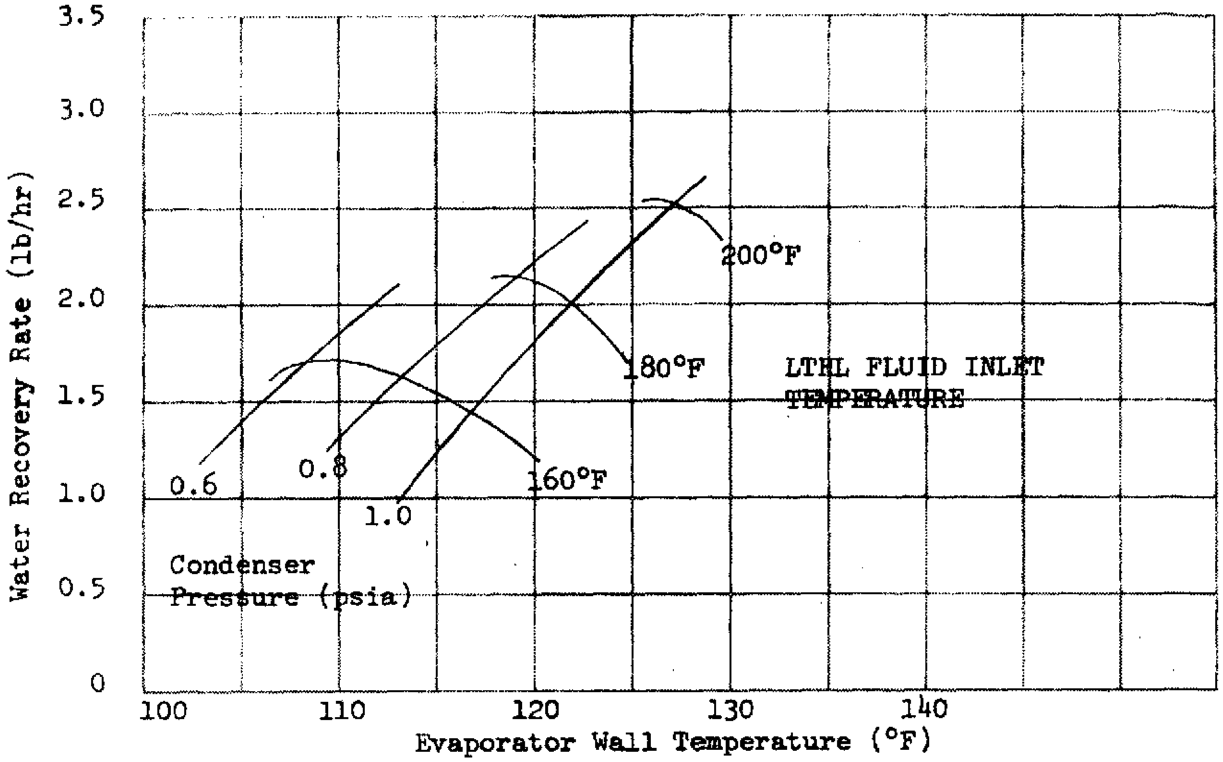


FIGURE 6.3 RITE OPERATIONAL ENVELOPE WITH RADIATOR COOLANT TEMPERATURE EQUAL TO 50°F

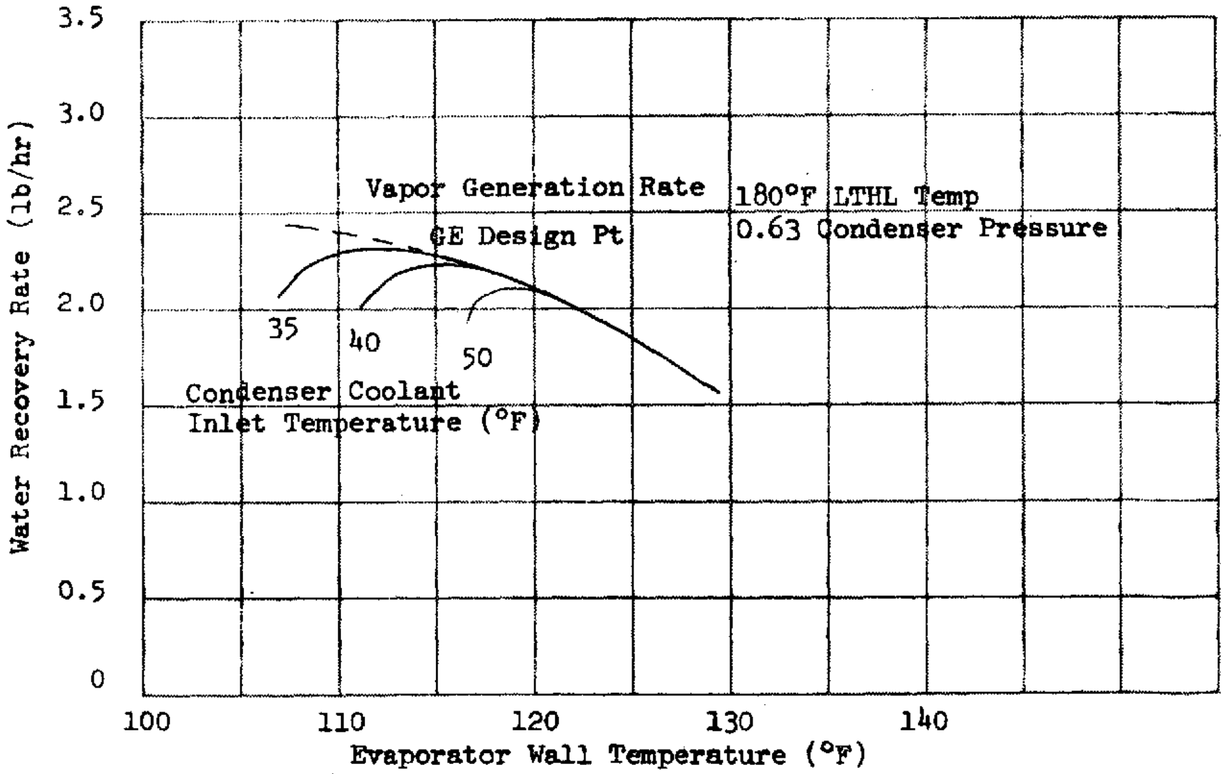


FIGURE 6.4 WATER RECOVERY RATE AS A FUNCTION OF CONDENSER COOLANT TEMPERATURE

TABLE 6.1

KEY SYSTEM PARAMETERS FOR RADIATOR COOLANT TEMPERATURES

OF 35, 40 and 50°F

Condenser Temperature (°F)	35**	40	50
System Output (lb/hr)	2.301	2.207	0
System Efficiency*			
$\left(\frac{\text{condensation rate}}{\text{evaporator rate}}\right)$	$\frac{2.301}{2.3297} = .9877$	$\frac{2.207}{2.3297} = .947$	$\frac{0}{2.3297} = 0$
Condenser Wall Temperature (°F)	77.629	80.76	83.3
Condenser Total Pressure (psia)	0.63	0.63	0.63
Partial Pressure of Water Vapor (psia)	0.46	0.51	0.58
Evaporator Vapor Temp. (°F)	104.39	104.39	104.39
Evaporator Pressure (psia)	1.085	1.085	1.085
Evaporator Heat Input (Btu/hr)	2412	2412	2412

* Efficiency as defined here does not include water losses to the incinerator.

** Current system design point.

If in future systems the available coolant temperature is 50°F or higher, the vapor pressure and, therefore, the total pressure in the condenser, and the evaporator LTHL temperature level must all be increased in order to achieve a system with a specified output of 2.3 lbs./hr.

6.2 Component Design

The key parameters which control the effectiveness of the system components are the component operating temperatures, pressures and thermal effectiveness. The effect of varying these parameters for the key system components, the evaporator and condenser, will be investigated in this section.

6.2.1 Evaporator

The computed system output for overall thermal conductance, UA, values at the design point value of 92.6 Btu/hr °F and for 75 and 150 Btu/hr-°F are shown in Figures 6.5, 6.6 and 6.7. Increasing the effectiveness of the evaporator has the result of increasing the average wall temperature to a point closer to the LTHL heating fluid inlet temperature. The increased temperature improves the heat transfer to the evaporator bulk liquid and increases the evaporator pressure. The higher pressure in turn provides a larger driving force to improve vapor throughput.

The output of the RITE system as a function of evaporator UA for the current design conditions is summarized in Table 6.2. Increasing UA from 92.6 Btu/hr°F, the design point, to 150 BTU/hr °F results in an increase in wall temperature from 114.38°F to 116.19°F and an increase in water output from 2.3 lb/hr to 2.42 lb/hr.

The evaporator effectiveness can be improved by increasing the overall thermal conductance, UA, between the heating fluid and the vapor. This can be accomplished by placing the fluid tubes on the inside in direct contact with the liquid rather than on the outside wall of the evaporator. Other possibilities include increasing the number of tubes, use of better conducting materials such as copper, modifying structural dimensions, or increasing evaporator size.

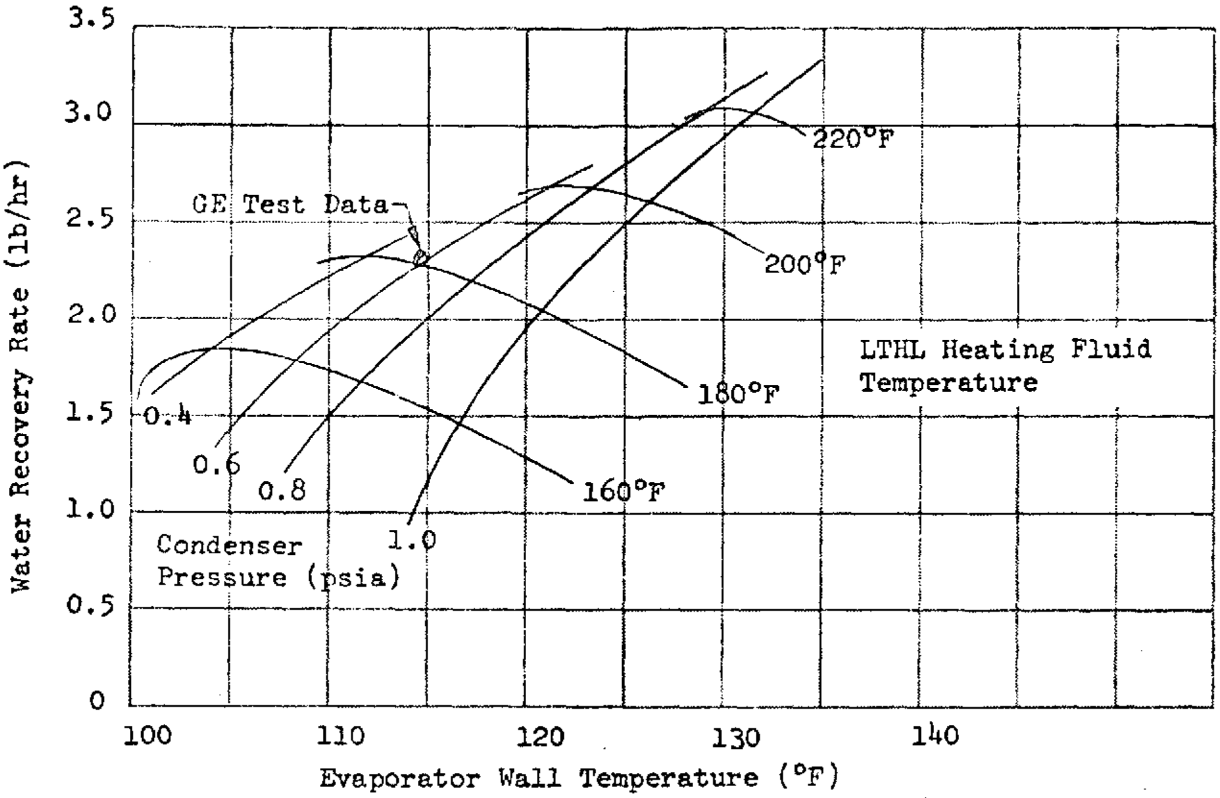


FIGURE 6.5 RITE OPERATIONAL ENVELOPE WITH EVAPORATOR
UA = 92.6 Btu/hr-°F

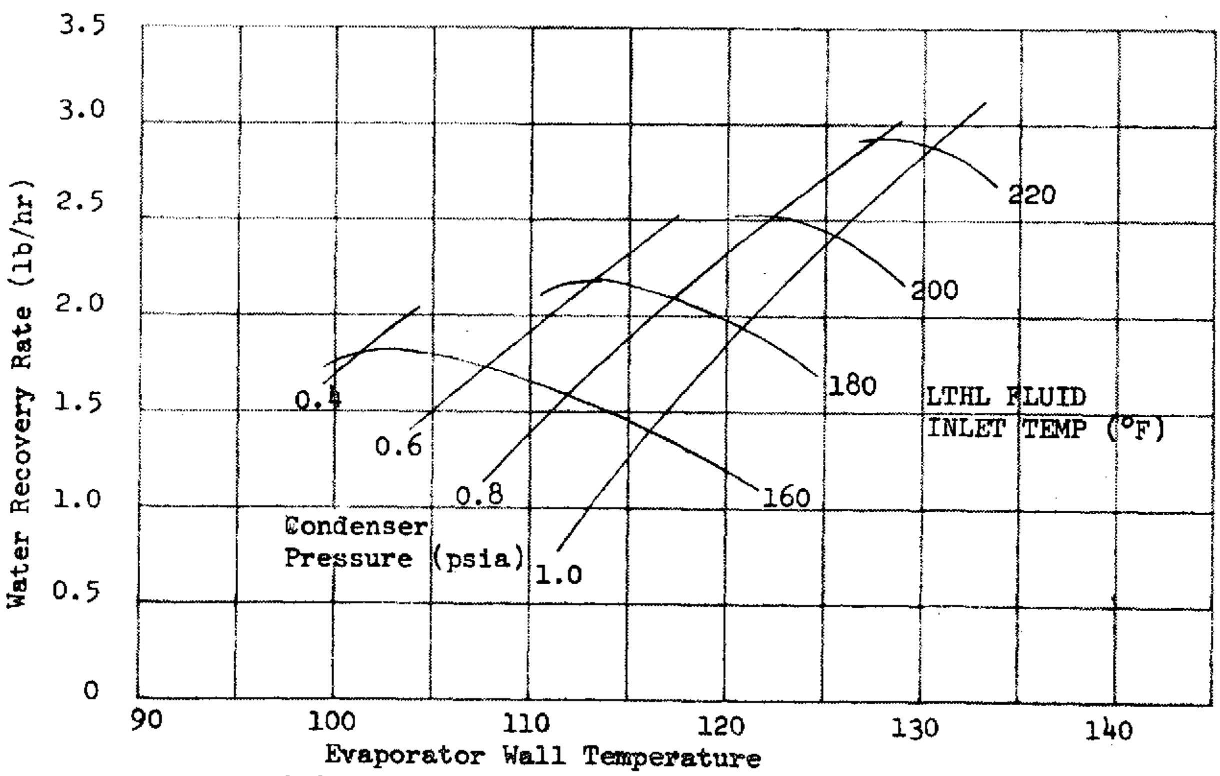


Figure 6.6 RITE OPERATIONAL ENVELOPE WITH EVAPORATOR
UA=75 Btu/hr-°F

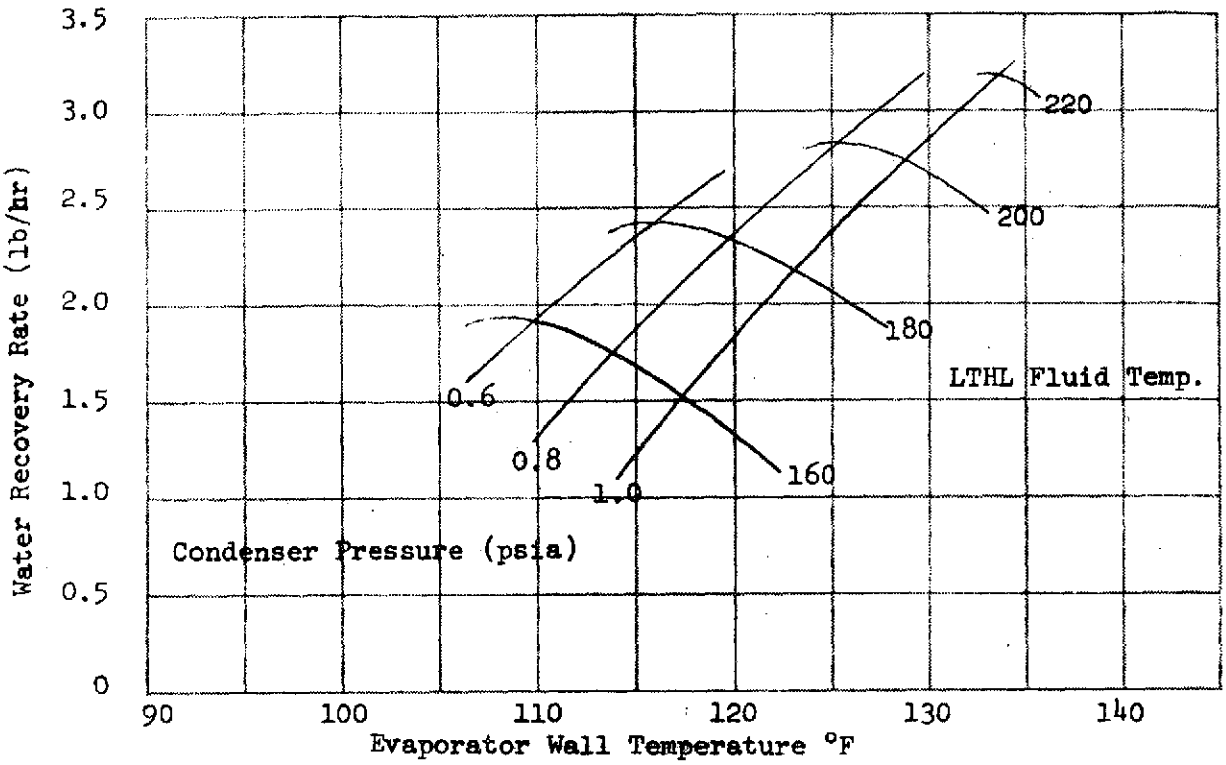


FIGURE 6.7 RITE OPERATIONAL ENVELOPE WITH EVAPORATOR
UA=150 Btu/hr-°F

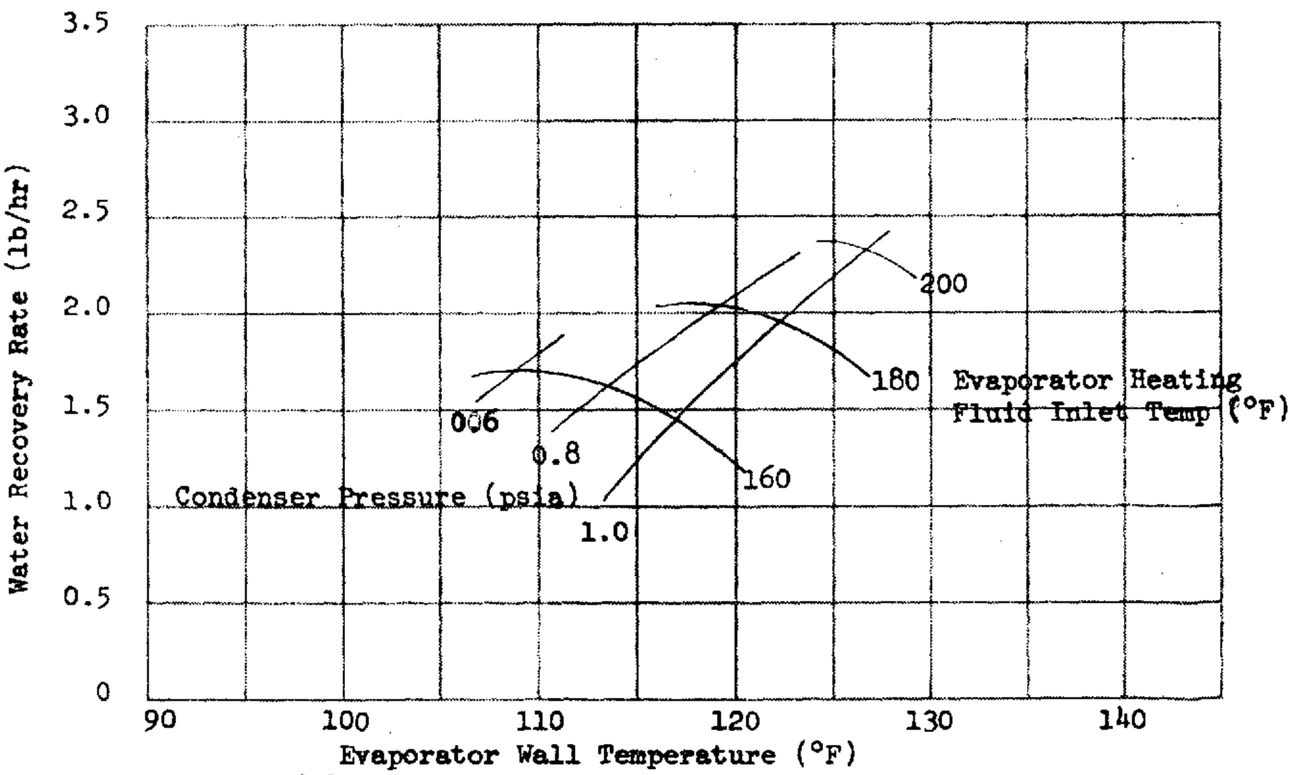


FIGURE 6.8 RITE OPERATIONAL ENVELOPE WITH CONDENSER
UA-75 Btu/hr-°F

TABLE 6.2

SYSTEM OUTPUT FOR EVAPORATOR UA'S OF 75, 92.6

AND 150 BTU/HR °F

Evaporator UA (But/hr °F)	75	92.6**	150
System Output (lb/hr)	2.2342	2.301	2.4235
System Efficiency* $\left(\frac{\text{condensation rate}}{\text{evaporation rate}}\right)$	$\frac{2.2342}{2.238} = .998$	$\frac{2.301}{2.3297} = .9877$	$\frac{2.435}{2.4707} = .9856$
Condenser Total Pressure (psia)	0.63	0.63	0.63
Evaporator Vapor Temp. (°F)	103.62	104.39	106.19
Evaporator Pressure (psia)	1.0606	1.085	1.1433
Evaporator Heat Rate (Btu/hr)	2314	2412	2556

* Efficiency does not include water loss to the incinerator

** Current design point

6.2.2 Condenser

The operational envelope for the RITE system with condenser UAs of 117, 150, and 75 Btu/hr°F are shown in Figures 6.8, 6.9 and 6.10. Improving condenser effectiveness has a similar effect as does decreasing the condenser coolant inlet temperature. A lower wall temperature results in a lower partial pressure for water and therefore a greater condensation rate. Table 6.3 shows the system output for the three UAs at the system design point. Increasing UA beyond the design point of 117 results in a small improvement in efficiency. Decreasing the UA to 75 Btu/hr-°F results in a wall temperature of 83°F and therefore a partial pressure of water vapor higher than that required for condensation.

Improved condenser thermal design can be achieved using techniques similar to those suggested for the evaporator.

6.3 Design Study Summary

The recent prototype RITE 180-day operation has verified the basic RITE design principles. The RITE system simulation was used to test the application of these principles to various spacecraft applications and under various spacecraft restraints. The design section has shown that the current RITE configuration is able to accommodate water recovery requirements of up to 3.0 lb/hr by increasing LTHL temperatures to 220°F. Higher recovery rates can be achieved by increasing the UA of the condenser and the evaporator.

The available condenser coolant temperatures effect the system efficiency by reducing the condensation rate. Most spacecraft radiator coolant temperatures are in the range of 40°F to 60°F. At these temperatures the recovery rate drops 10 percent from the value at the prototype operating temperature of 32°F.

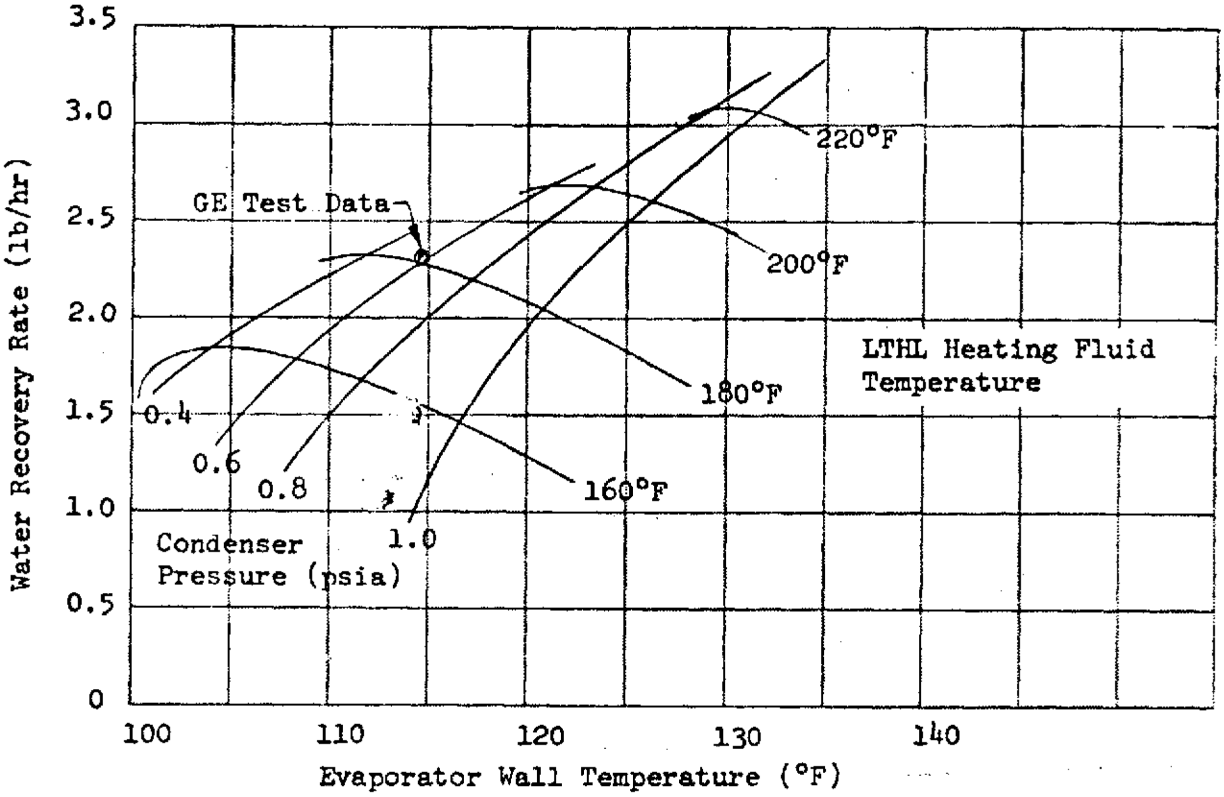


FIGURE 6.9 RITE OPERATIONAL ENVELOPE WITH CONDENSER
UA = 117.0 Btu/hr-°F

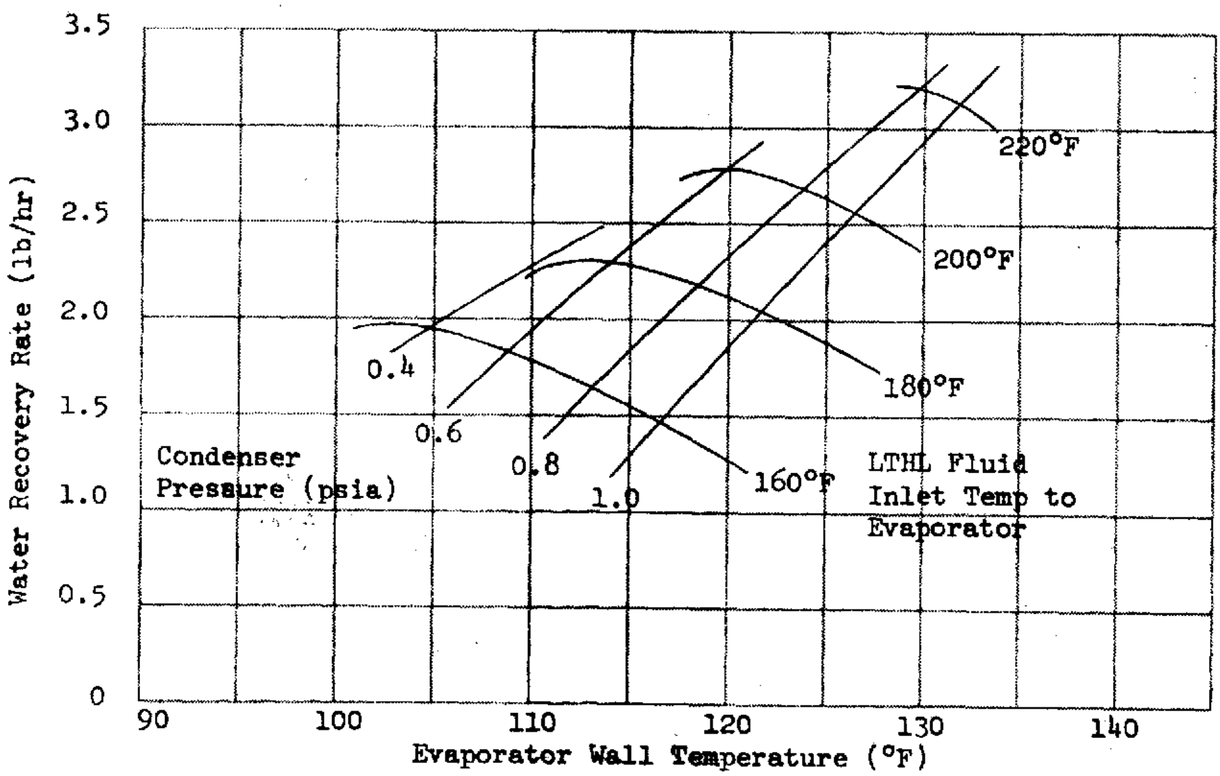


FIGURE 6.10 RITE System Operational Envelope with Condenser
UA=150 Btu/hr-°F

TABLE 6.3

KEY SYSTEM PARAMETERS FOR CONDENSER UA'S OF

75, 117 AND 150 Btu/hr °F

Condenser UA (Btu/hr °F)	75	117**	150
System Output (lb/hr)	0	2.301	2.3175
System Efficiency*	0	2.301	2.3175
$\left(\frac{\text{condensation rate}}{\text{evaporation rate}}\right)$	$\frac{0}{2.3297} = 0.0$	$\frac{2.301}{2.3297} = .9877$	$\frac{2.3175}{2.3297} = .995$
Condenser wall temperature, (°F)	83	77.63	70.36
Condenser total pressure (psia)	0.63	0.63	0.63
Condenser coolant temperature (°F)	35	35	35

* Efficiency does not include losses to the incinerator

** Current system design point

Section 7

FAILURE MODE ANALYSES

One of the more productive applications of the G-189A RITE simulation is to predict the RITE response to proposed system failures. The failure modes analyzed can be divided into two categories. In the first category are failures which would only result in reduced system efficiency or at worst system shutdown. The second type of failures have potential impact on the integrity of the nuclear isotopes and therefore would threaten the safety of the crew.

Example of the first type of failures include: leakage in the vapor, flush water or potable water loop; pump failures; leakage or loss of flow in coolant loop, and solids transfer equipment failures. These failures can most likely be repaired in orbit, by resupply, or at worst would result in premature ending of the mission.

Failures that impact the low temperature nuclear isotope include all failures which effect the operation of the low temperature heating loop. Failures which effect the high temperature isotope capsule include cooling failure or a failure which would continuously add heat to the capsule. The isotope cooling failure could be the result of the loss of the heat pipe. Continuous heating of the isotope could result if oxidation of solids in the incinerator was to occur without periodic venting of the product gasses.

The failures simulated and discussed in this section are the cooling loop failure, the incinerator continuous oxidation failure, and the low temperature heating loop failure.

7.1 Cooling Loop Failure

Cooling loop failure could be the result of a loss of flow due to a pump or controller failure, or a loss of coolant from the loop. Each of these failures would result in the loss of condensing capability in the condenser. The water vapor generated in the evaporator would then be lost to space through the vent unless the system was shut down.

The response of the system to the cooling loop failure is summarized in Figures 7.1 and 7.2. The temperature of the condenser wall rises until it approaches the temperature of the incoming vapor. The higher wall temperature results in a loss of condensing capability and the water recovery rate rapidly drops to zero. The incoming vapor is lost to space through the vent. The evaporator vapor generation rate drops since the vapor accumulated in the condenser builds up the condenser pressure and therefore limits the pressure driving force from the evaporator to the condenser. The evaporator would tend to increase in temperature and pressure, however, the low temperature heating loop controller bypasses the heating fluid at a vapor temperature of 105°F and therefore limits the pressure to the corresponding saturation pressure of 1.1 psia.

The net result of the cooling failure is that the water recovery capability of the system is lost. Unless the system is shut down the evaporator low signal will automatically feed water to the evaporator from the wash water system. The water would be evaporated and then lost to the condenser vent. When the system is shut down the evaporator cooling load is transferred to the emergency heat exchanger keeping the LTHL in thermal equilibrium. Heat from the LTHL can be added to the evaporator and water recovery may proceed once the condenser problem is repaired.

7.2 Incinerator Vent Valve Failure

The most serious incinerator failure mode identified to date is the failure of the cycle to switch from the oxidation mode to the vent mode. This failure

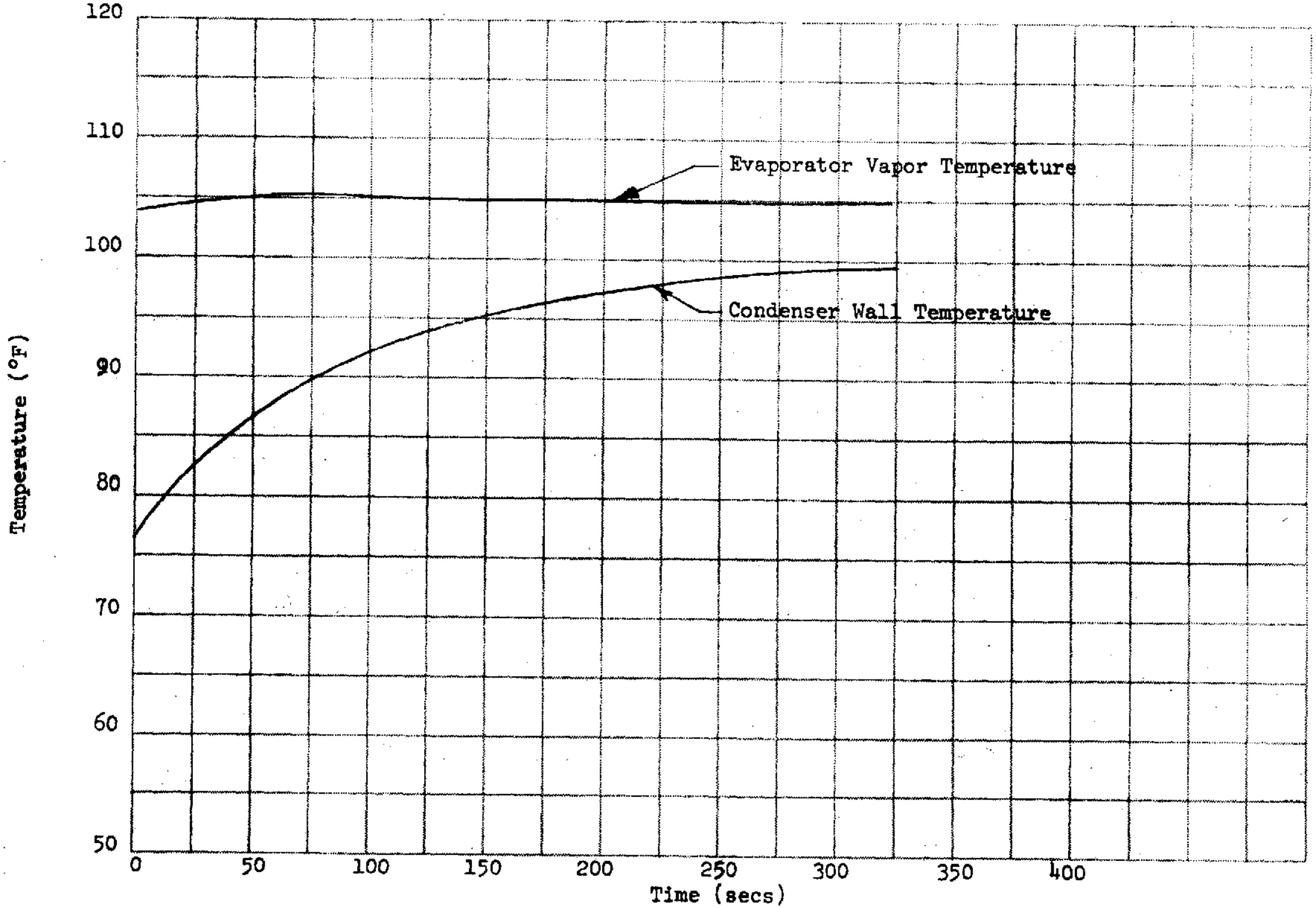


FIGURE 7.1 TEMPERATURE RESPONSE TO LOSS-OF-COOLING ACCIDENT

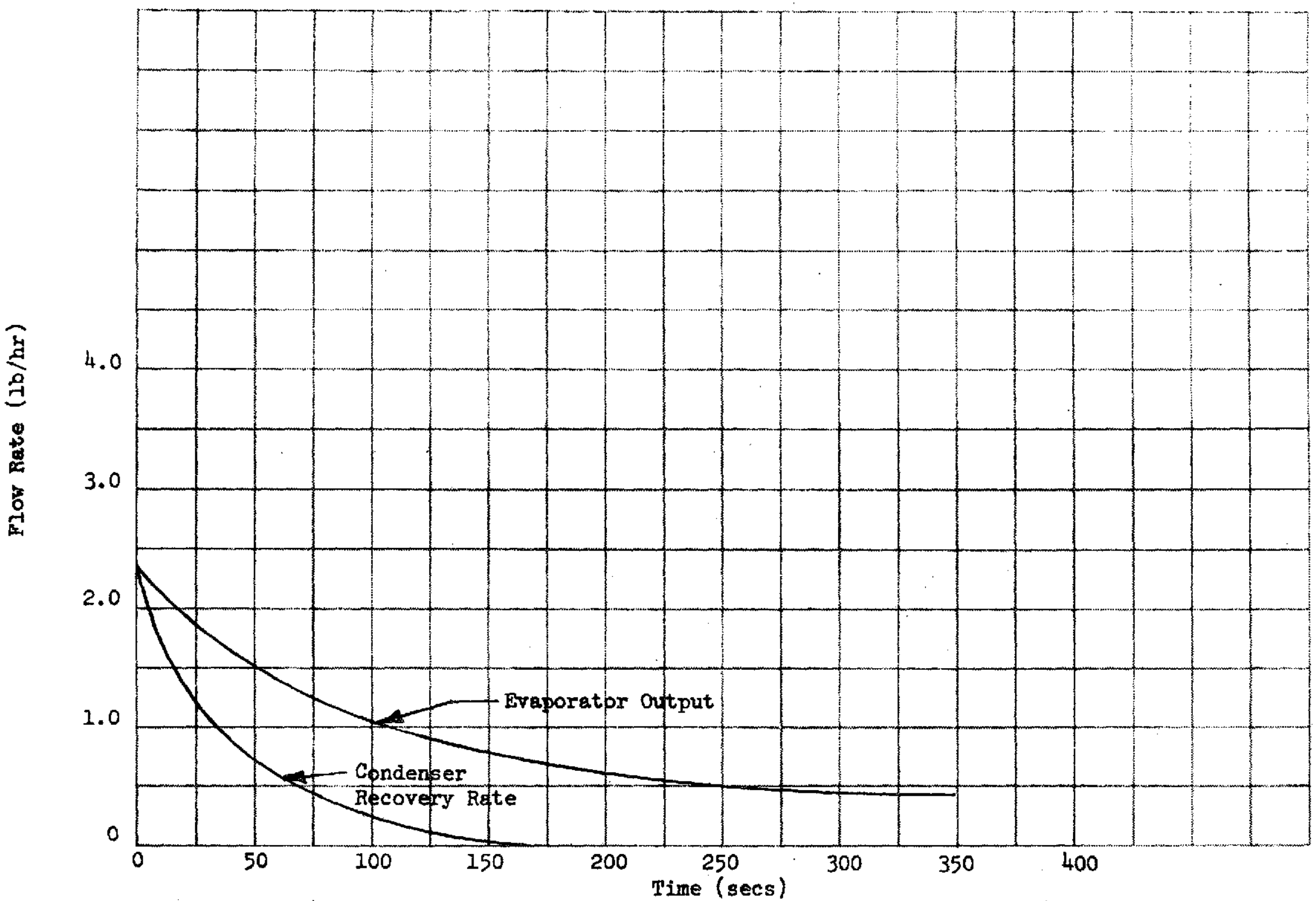


FIGURE 7.2 CONDENSER AND EVAPORATOR FLOW RATES AS A RESULT OF LOSS-OF-COOLING ACCIDENT

could occur if the vent valve to vacuum failed to open. Oxygen would continue to react with the solids and generate approximately 1100 Btu/hr. The possibility exists that this heat input would increase the temperature of the isotope in the heat block beyond its design point. Failure of the isotope capsule would then release the extremely toxic Pu-238 isotope to the cabin atmosphere.

The temperature response of the incinerator and the heat block as a result of the vent failure is shown in Figure 7.3. The temperature of the incinerator reaches only 1450°F before all solids in the shuttle load are burned. This is only 150°F higher than its normal operating point. The temperature rise is limited since heat generated by the chemical reaction is readily absorbed by the heat block. The isotope and heat block temperatures drop as they give up heat to the incinerator in the drying cycle. When the failure occurs the heat block absorbs the excess heat to return to its normal operating point sooner than normal. All the solids are burned and the heat generation rate drops to zero at the end of the oxidation cycle.

The increment of heat imposed on the heat block as a result of the vent failure is absorbed by its thermal mass and is in turn rejected to the environment by the heat pipe. The isotope capsule design point temperature is not exceeded.

7.3 Low Temperature Heating Loop Failure Analyses

Failure analysis of the Low Temperature Heating Loop (LTHL) is especially important due to potential nuclear hazards posed by the isotope heat source. A complete nuclear safety analysis from ground handling, launch and recovery would be required before approval is given for use of the nuclear capsule in a space system. The thermal analysis by the G-189A program of the LTHL is a preliminary effort to identify potential failures and corresponding effects prior to application design development.

The LTHL provides heat to the evaporator, potable water storage tanks, flush water tank, and the water heater. The heat source, a 1500 watt Pu-238 isotope, is enclosed in a large diameter water tank which serves as a

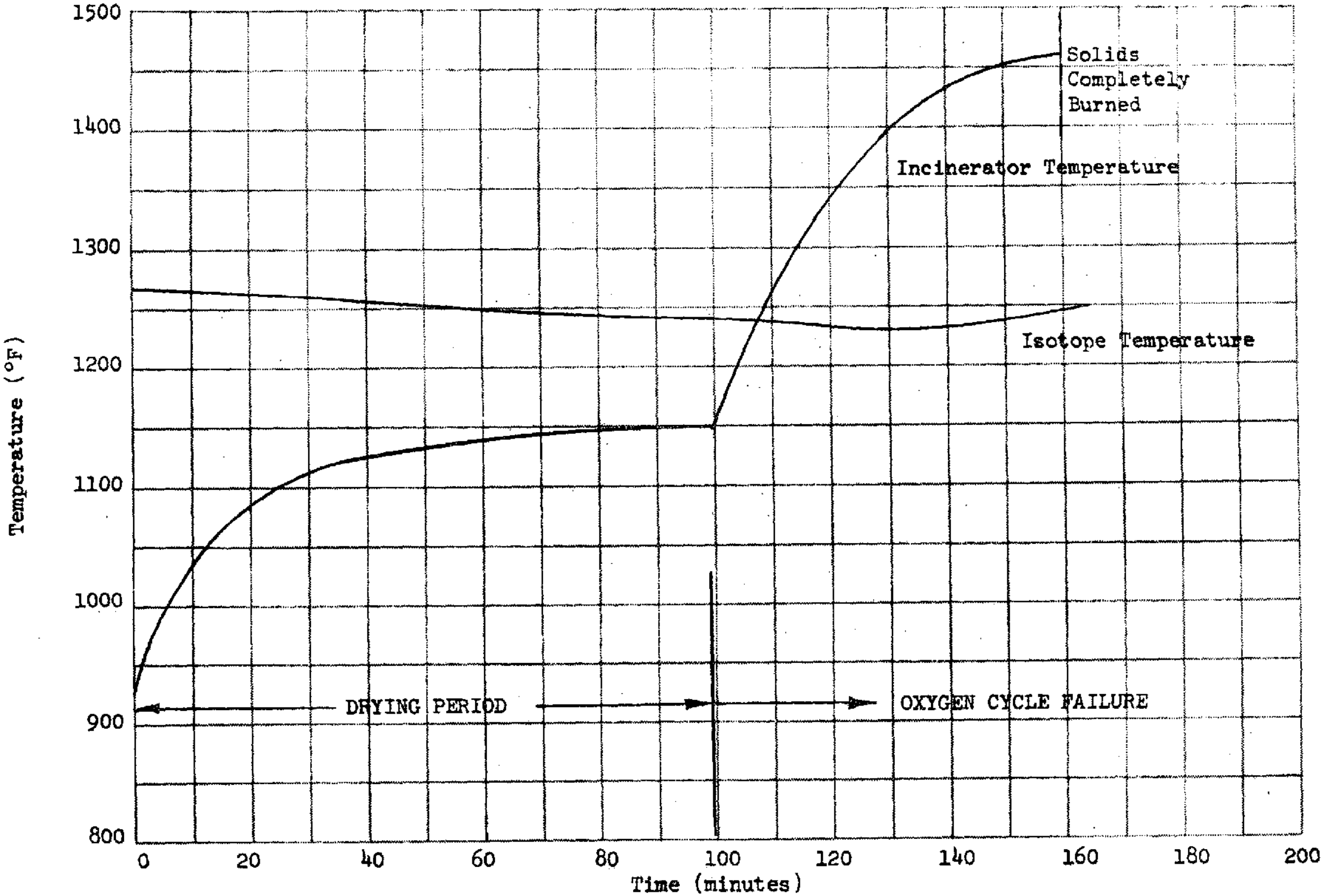


FIGURE 7.3 TEMPERATURE RESPONSE TO THE INCINERATOR OXYGEN CYCLE FAILURE

nuclear shield. The water tank, which will be discussed later, also serves to dampen isotope temperature excursions as a result of any system failures. Out of the total 5120 Btu/hr generated by the isotope approximately 2700 is used by the evaporator, 900 Btu/hr is used to heat the tanks and 1500 Btu/hr is lost through line losses and through the shielding tank wall.

Emergency cooling for the isotope is provided through an on line liquid-liquid heat exchanger located in the LTHL just upstream from the isotope heat source. A water coolant loop, with bypass control around the heat exchanger, provides the coolant supply. The bypass controller senses the LTHL fluid temperature at the heat source exit and at 190°F will direct flow to the emergency heat exchanger.

The potential failures identified for the LTHL are listed below:

1. Loss of coolant flow due to pump loss or line blockage.
2. Loss of coolant due to leakage.
3. Loss of evaporator heat removal (bypass on or evaporator drained).
4. Emergency coolant supply failure (pump or bypass valve) in conjunction with any of the above failures.
5. Shield tank drained in conjunction with evaporator or coolant supply failure.

The results of the loss of coolant flow and loss of coolant due to leakage are shown in Figure 7.4. When coolant remains in the isotope heater a conduction path is provided to the shield tank and then to the outside environment. Due to the large thermal capacity of the tank little change in temperature is recorded for the isotope and tank. When a loss of coolant occurs the conduction path to the tank is reduced and heat transfer is mainly by radiation. Temperature of the isotope then begins to rise rapidly raising the possibility of a nuclear accident.

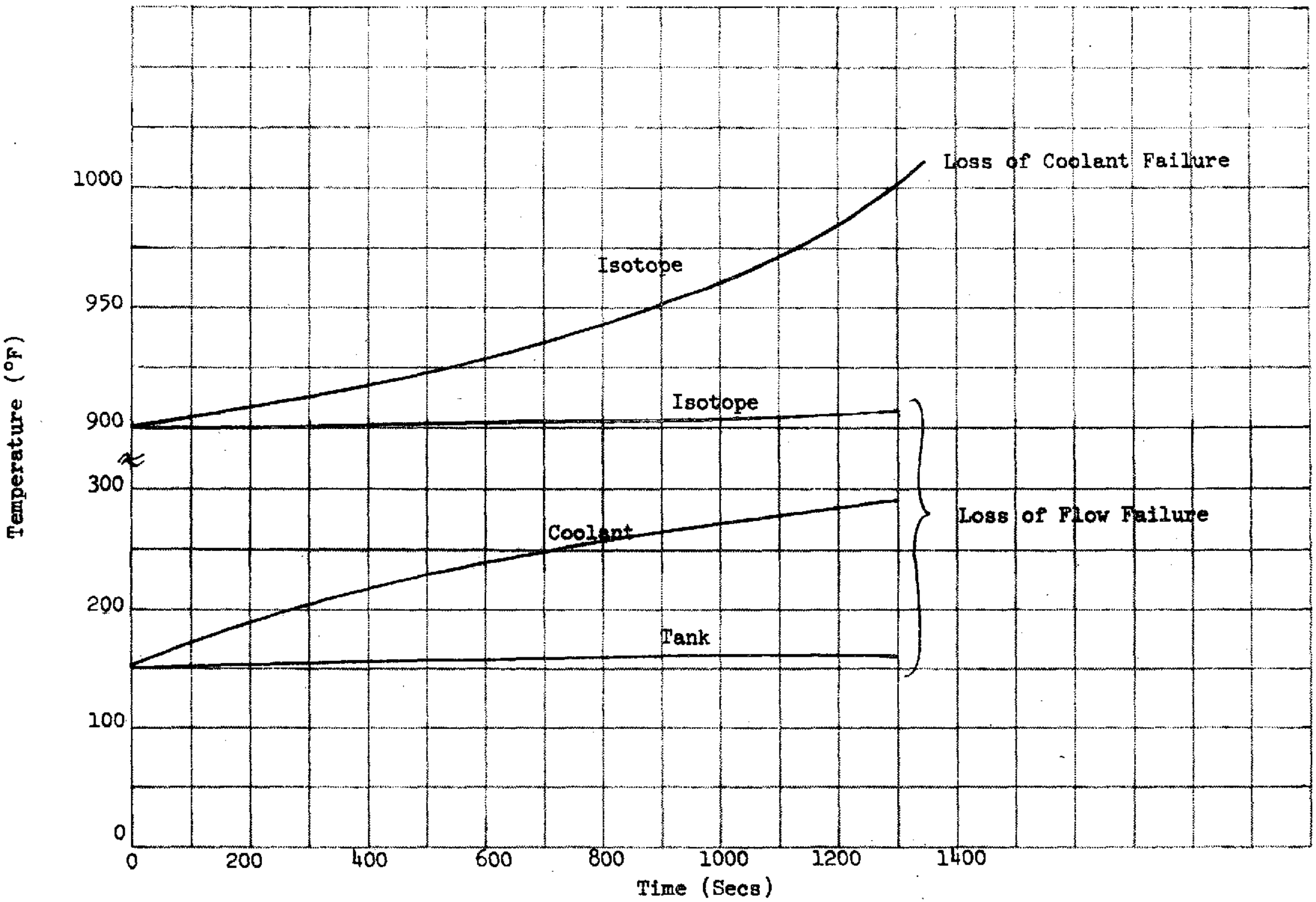


FIGURE 7.4 TEMPERATURE RESPONSE TO LOSS-OF-FLOW AND LOSS-OF-COOLANT FAILURES

Loss of evaporator heat removal capability can be caused by controller failure in the bypass mode or draining of the evaporator liquid. The result of this type failure on the LTHL is shown in Figure 7.5. Due to lack of definitive emergency heat exchanger thermal data, hand calculations were made that indicated that the heat exchanger UA was the 15-60 Btu/hr °F range. Three runs were made in this range to test LTHL coolant response. At time = 0 an evaporator bypass failure was assumed and in 220 seconds the LTHL coolant temperature reached the 190°F limit which triggered the emergency coolant heat exchanger flow. For UA less than 50 Btu/hr °F, the emergency heat exchanger did not stabilize the LTHL temperatures at less than 190°F. The increase of coolant temperature and therefore pressure could result in loop valve or fitting leakage which in turn would precipitate the loss of coolant failure described above. At a UA of 50 Btu/hr °F the temperature cycles within the range of 189 to 198°F. Therefore, it is recommended that the emergency heat exchanger UA should be specified to be greater than 50 Btu/hr-°F.

The next set of computer runs were made with the assumption that the shield tank was drained. For applications in space a clean isotope would be used and the shield tank would not be required. An evaporator bypass failure (in the full bypass position) was additionally imposed and the results are shown in Figure 7.6. The emergency cooling system was able to control LTHL coolant temperature to 210°F and the isotope temperature rose from 990 to 995°F. When a loss of emergency flow failure was run in conjunction with a drained shield tank and a filed evaporator bypass valve (in the full bypass position), the lack of thermal capacity in the shield tank water results in a rapid increase in coolant and isotope temperature. The data shown in Figure 7.6 indicate a coolant temperature greater than 350 degrees within 20 minutes. The corresponding saturation pressures of greater than 150 psi at these temperatures could result in loop leakage.

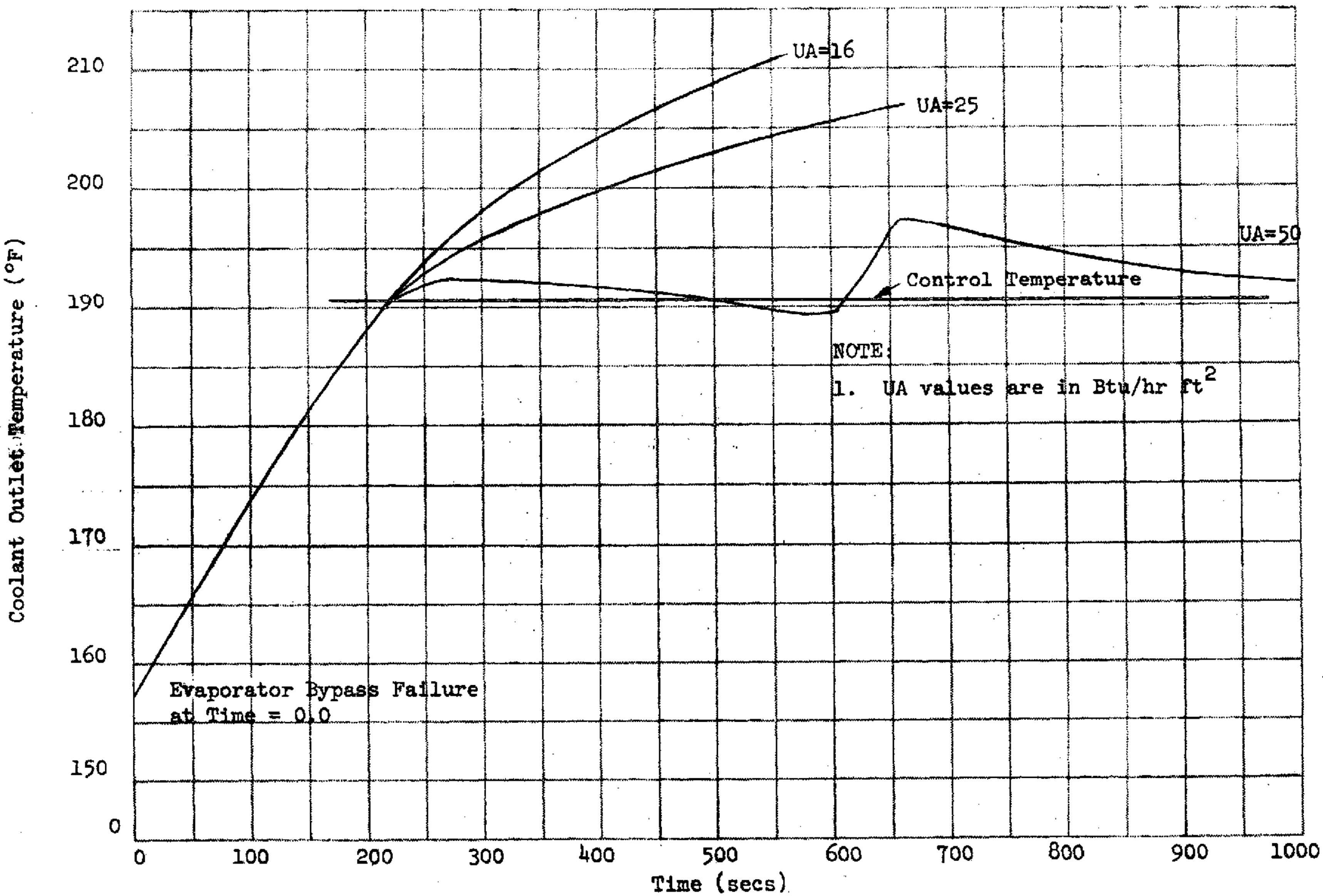


FIGURE 7.5 EVAPORATOR BYPASS FAILURE –
ISOTOPE COOLANT OUTLET TEMPERATURES WITH VARIOUS EMERGENCY HEAT EXCHANGER UA VALUES

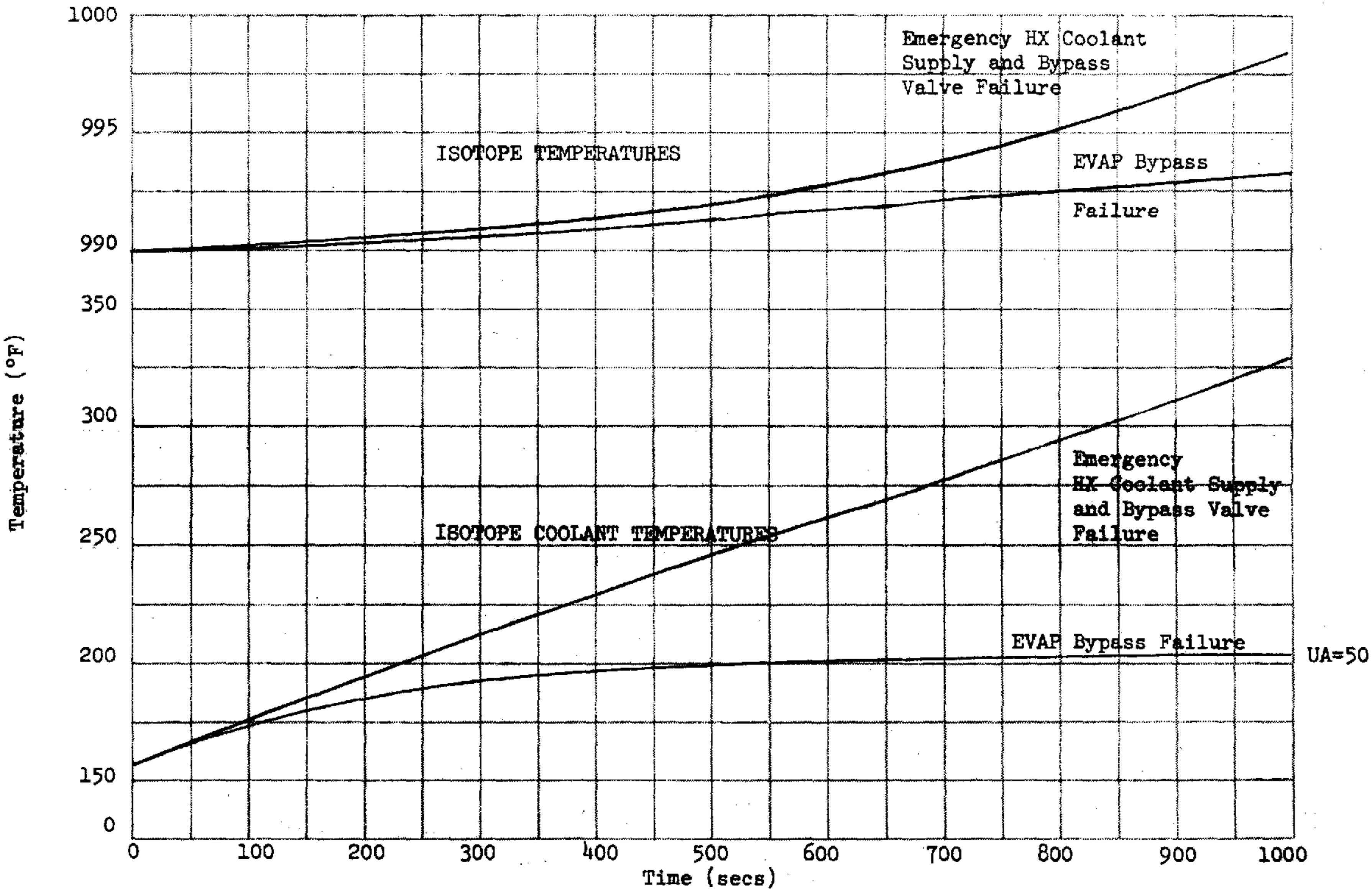


FIGURE 7.6 EFFECTS OF EVAPORATOR BYPASS AND EMERGENCY HEAT EXCHANGER COOLANT SUPPLY FAILURES ON ISOTOPE AND ISOTOPE COOLANT TEMPERATURES (SHIELD TANK DRAINED)

The preliminary failure analysis discussed above indicates that, with the exception of the LTHL, the RITE system can compensate for the failure modes discussed. To eliminate the possibility of a nuclear accident, the LTHL pumps should be made failure independent, and a secondary, static, emergency cooling mode should be provided for the isotope.

Section 8

REFERENCES

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2. Murray, R. W., Shivers, R. W., Ingelfinger, A. L., and Metzger, C. A. Integrated Waste Management - Water System Using Radioisotopes for Thermal Energy. ASME Paper 71-Av-4, Presented to the SAE/ASME/AIAA Life Support and Environmental Control Conference, July 1971.

3. Barker, R. S., Blakely, R. L., Hamill, T. D., and Nicol, S. W. G189A Generalized Environmental/Thermal Control and Life Support Systems Computer Program. McDonnell Douglas Astronautics Company, Western Division, Report MDAC-G2444, September 1971.

4. Vaughan, R. L., Barker, R. S., and Stephens, H. M. Generalized Environmental Control and Life Support System Fortran Programs. McDonnell Douglas Astronautics Company, Western Division, Report SM-49403, Volumes I through III, May 1966.

Appendix A

SUBROUTINE DOCUMENTATION

EVAPO

CNDNSR

INCIN

HTPIP

TANKG

EVAP

Component Subroutine No. 59 - Evaporator for Waste Management/Water Recovery System

1. Subroutine Description

This subroutine simulates an evaporator such as the one used in the RITE Waste Management/Water Recovery System developed by General Electric at Valley Forge, Pennsylvania. See Reference 1. The evaporator collects all solids and liquids that constitute waste, centrifugally separates the solids from the liquid, and evaporates the liquid. The vaporized liquid (steam) in the RITE system is ducted through a purifier assembly and into a condenser where pure water is recovered.

The evaporator accepts both primary and secondary flows. The primary inlet and outlet flows define the liquid and solid flow through the evaporator and use flow codes 0 or 4. The secondary inlet and outlet flows define the gaseous flow through the evaporator and employ flow codes 2 or 3. Heating to the evaporator is provided by either electrical heaters attached to the evaporator wall, or by heating fluid flowing through the tubes encircling the evaporator, or by both. The evaporator component schematic is shown in Figure 1.

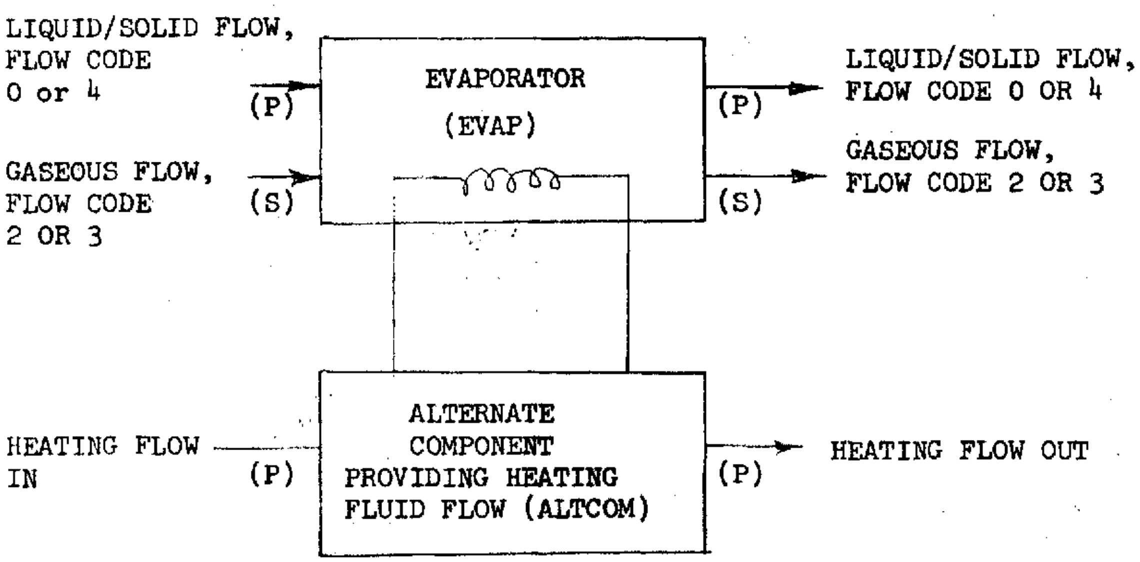


FIGURE 1. COMPONENT SCHEMATIC OF THE EVAPORATOR

The evaporator subroutine performs mass and thermal balances for either steady state or transient operation. It includes the capability of separating (filtering) and storing wet solids in a reservoir so as to allow their subsequent removal from the system by a solids pump. In addition, the subroutine may simulate, as an option, a biochemical reaction that may occur within the evaporator. This simulation includes the decomposition of urea, defined by primary inlet/outlet special flow #2, R(15), into two gaseous components, ammonia, secondary flow trace contaminant, R(32), and carbon dioxide, R(31). The evaporator schematic is shown in Figure 2.

2.0 SUBROUTINE DATA

2.1 General Notes

1. The primary inlet and outlet flows define the liquid/solid flows through the evaporator.
2. The secondary inlet and outlet flows define the gaseous flows through the evaporator.
3. The phase separator is assumed to be 100% effective and zero entrained liquid flow is assumed in the evaporator secondary loop.
4. The solids filtration rate, removing the solids from the evaporator to the solids reservoir, is a product of the solids concentration in the evaporator and an input value defined as the filtration rate. If the solids reservoir attains a maximum value (input value) the filtration process ceases and an appropriate flag is set.
5. The biochemical reaction rate in the evaporator is a product of weight of the decomposing solid (always special flow #2 on the primary side) in the evaporator and the decomposition constant. The products of the decomposition are carbon dioxide R(31) and ammonia which is provided in the trace contaminant location, R(32), for the secondary outlet flow.
6. The initial weights of liquids and solids in the evaporator must be input; if the removal rate of the solids is not equal to the solids influent or the water removal/vaporization rates do not equal the water inlet flow rate, appropriate flags are set.

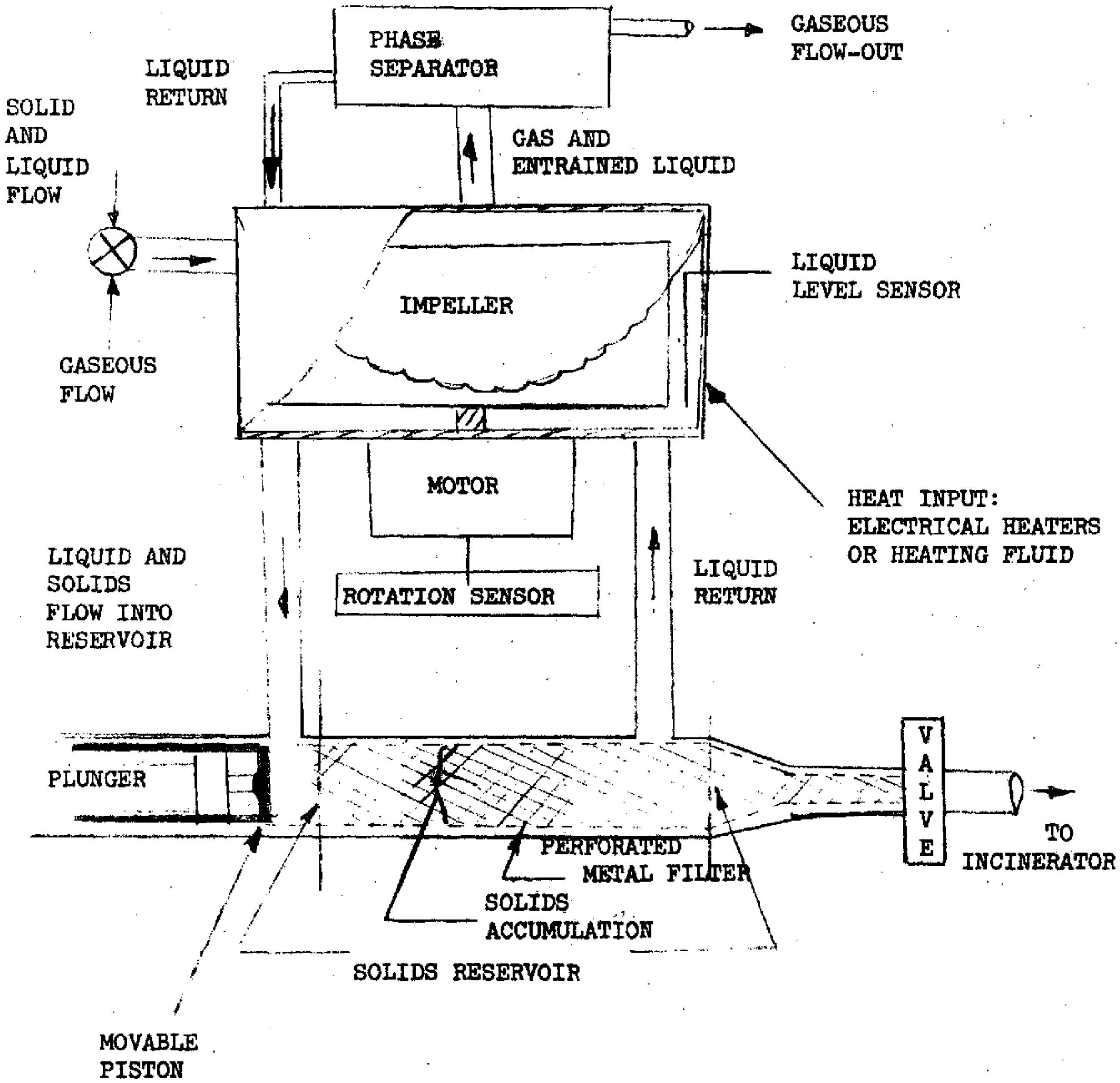


FIGURE 2 EVAPORATOR SCHEMATIC

7. The primary side special flows 2 and 4 have specific uses where:

   Special Flow #2 is defined as urea when bacterial decomposition is considered.

   Special Flow 4 is defined as water

2.2 Instruction Options

NSTR(1): Heating fluid availability
- = 0 Heating fluid is available
- = 1 Heating fluid is not available

NSTR(2): Not used

NSTR(3): Not used

NSTR(4): Operating pressure node
- = 0 Low pressure operating mode
- = 1 High pressure operating mode

2.3 Heat Loss V-Array Data

Reference Location	Description	Data Type
51	Temperature of evaporator wall (°F)	I(R)
52	Effective thermal conductance from evaporator wall to surroundings (Btu/hr-°F)	0
53	Total heat loss to surroundings (Btu/hr) R(53) = R(56) + R(59) + R(62)	0
54	Ambient gas temperature (°F)	I(0)
55	Thermal conductance between surface of insulation and ambient gas (Btu/hr-°F)	I(0)
56	Convective heat loss to ambient gas (Btu/hr)	0
57	Ambient wall temperature (°F)	I(0)
58	Thermal radiation, ℱA, factor from surface of insulation to ambient wall (ft^2)	I(0)
59	Radiative heat loss to ambient wall (Btu/hr)	0
60	Structure temperature (°F)	I(0)

Reference Location	Description	Data Type
61	Conductance (kA/x) between evaporator wall and structure (Btu/hr-°F)	I(0)
62	Conductance heat loss to structure (Btu/hr)	0
63	Insulation surface temperature, (°F)	0
64	Conductance (kA/x) between evaporator wall and outer surface of insulation, (Btu/hr-°F) (If R(64) = 0, there is no insulation)	I(0)

2.4 Steady State K-Array Data

Reference Location	Description	Data Type
16	Packed failure flag data 6 5 4 3 2 1	0

Individual digits are set to one for a failed condition and set to zero for a passing condition.

Digit Position	Condition
1	The solid reservoir has been filled, the filtration process has been stopped.
2	The solids filtration and decomposition rate does not correspond to the solids inlet rate in steady state.
3	The liquid removal and vaporization rate does not equal the liquid inlet rate in steady state.
4	Liquid level in the evaporator is above the maximum specified.
5	Liquid level in the evaporator is below the minimum allowable.
6	Not used

Reference Location	Description	Data Type
17	Component number of the alternate component providing the heating fluid flow	I(R) if NSTR(1)=0
18	Table number defining the heat flux, q/A, between the fluid in the evaporator and the evaporator wall as a function of temperature differential between fluid and wall and liquid pressure	

2.5 Steady State V-Array Data

Reference Location	Description	Data Type
65	Effective conductance between the evaporator wall and the heating fluid (Btu/hr-°F)	I(R) if NSTR(1)=0
66	Electrical heat input into the evaporator wall (Btu/hr)	I(O)
67	Internal height of the evaporator (ft)	I(R)
68	Internal diameter of the evaporator (ft)	I(R)
69	Effective height of the liquid slurry in the evaporator (ft)	O
70	Minimum liquid level allowable for normal operation (ft)	I(R)
71	Maximum liquid level allowable for normal operation (ft)	I(R)
72	Heat lost in vaporization of water to air flowing through the evaporator (Btu/hr)	O
73	Total effective gas space in the evaporator (ft^3)	O
74	Heat flow from evaporator wall to liquid (Btu/hr)	O
75	Heat flux, q/A, from wall to liquid (Btu/hr-ft^2)	O*
76	Gas space in the evaporator that is not subject to liquid filling (ft^3)	I(R)
77	Vaporization rate of water (lb/hr)	O
78	Bacterial/thermal decomposition factor for urea/ammonia carbonate-bicarbonate in the evaporator (1/hr)	I(O)
79	Decomposition rate of urea (lb/hr) (Alway special flow #2 of the inlet primary flow)	O
80	Liquid used in thermal/biochemical decomposition reaction (lb/hr) removed from special flow #4 of the inlet primary flow	O
81	Ratio of liquid to solid in the solids reservoir (decimal)	I(R)
82	Filtration factor of the liquid/solid filter (lb/hr)	I(R)
83	Removal rate of solids from the liquid/solid stream by the filter (lb/hr)	O

* Value is interpolated from Table Data specified in Table number 18.

Reference Location	Description	Data Type
84	In the high pressure mode, the fraction of liquid that is expected to vaporize to the air flowing through the evaporator as compared to maximum, assuming fully saturated air leaving the evaporator (decimal).	I(0)
85	The liquid/solid reservoir capacity (lb) (If not input then R(83) will be always zero.)	I(0)
86	Liquid lost due to filtration (special flow #4 in inlet primary flow) (lb/hr)	0
87	Urea (special flow #2 in inlet primary flow) removal rate to solid reservoir (lb/hr)	0
88	Remaining solids (special flow #3 in inlet primary flow) removal rate to solid reservoir (lb/hr)	0
89	Water (special flow #4 in inlet primary flow) removal rate to solid reservoir (lb/hr) (same as R(86))	0
90	Special flow #5, primary inlet flow constituent, removed to the solid reservoir (lb/hr)	0
91	Special flow #6, primary inlet flow constituent removed to the solid reservoir (lb/hr)	0
92	NH_3, (located in the trace contaminant address, R(32) in secondar outlet flow) generation rate in the evaporator (lb/hr)	0
93	CO_2, R(31), generation rate due to thermal/biochemical decomposition of urea in the evaporator (lb/hr)	0
94	Steady state convergence criterion for prediction of temperature (per cent)	0
95	Power required to drive the impeller (watts)	I(0)
96	Conductance between wall and liquid in evaporator (Btu/hr-°F)	I(0)
97	Not used	
98	Not used	
99	Effective orifice area between the evaporator and the source of downstream pressure (used only in the low pressure mode) (ft^2)	I(R)
100	Downstream pressure, generally the condenser pressure, where the vaporized liquid is flowing (psia)	I(R)

Reference Location	Description	Data Type

The V-array locations 101 through 119 are a 19 member set of data defining the liquid slurry in the evaporator. These data must be initialized because the evaporator will not run dry.

101	Total weight of liquid slurry in the condenser (lbs)	I(R), 0
102	Temperature of the liquid slurry in the condenser (°F)	I(R), 0
103	Pressure of liquid slurry in the evaporator (psia)	I(R), 0
104	Pressure of liquid slurry in the evaporator (psia)	I(R), 0
105-114	Not used	
115	Weight of urea in the evaporator. Urine in primary inlet/outlet flow is special flow #2 (lbs)	I(R), 0
116	Weight of solid defined by primary inlet/outlet special flow #3 in the evaporator (lbs)	I(R), 0
117	Weight of water, defined by primary inlet/outlet special flow #4 in the evaporator (lbs)	I(R), 0
118	Weight of solids component defined by primary inlet/outlet special flow #5 in the evaporator (lbs)	I(R), 0
119	Weight of solid component defined by primary inlet/outlet special flow #6 in the evaporator (lbs)	I(R), 0

The V-Array locations 120 through 138 are a 19 member set of data defining the initial gas mixture in the evaporator. If the run is executed for a transient case only, the initial values must be input. In steady state, values are computed which initialize the parameters for a subsequent transient run.

120	Total weight of gas in the evaporator (lbs)	I(0), 0
121	Temperature of the gas in the evaporator (°F)	I(0), 0
122, 123	Pressure of the gas in the evaporator (psia)	I(0), 0
124	Weight of non-condensables in the evaporator (lbs)	I(0), 0
125	Weight of condensable gas (vapor) in the evaporator (lbs)	I(0), 0
126	Weight of entrained liquid (always zero) in the evaporator (lbs)	I(0), 0
127	Effective capacitance of non-condensable gas in the evaporator (Btu/lb-°F)	I(0), 0

Reference Location	Description	Data Type
128	Molecular weight of non-condensable gas in the evaporator (lb/lb-mole)	I(O), O
129	Weight of O_2 in the evaporator (lbs)	I(O), O
130	Weight of diluent, N_2, in the evaporator (lbs)	I(O), O
131	Weight of CO_2 in the evaporator (lbs)	
132	Weight of trace contaminant, NH_3, in the evaporator (lbs)	I(O), O
133	Weight of special flow #2 in evaporator (lbs)	I(O), O
134	Weight of special flow #2 in evaporator (lbs)	I(O), O
135	Weight of special flow #2 in evaporator (lbs)	I(O), O
136	Weight of special flow #4 in evaporator (lbs)	I(O), O
137	Weight of special flow #5 in evaporator (lbs)	I(O), O
138	Weight of special flow #6 in evaporator (lbs)	I(O), O

The V-array locations 139 through 157 are a 19 member set of data defining the liquid/solid mixture in the solid reservoir.

Reference Location	Description	Data Type
139	Total weight of solids in solid reservoir (lbs)	O
140	Temperature of solids in solid reservoir (°F)	O
141, 142	Pressure in solid reservoir	O
143, 152	Not used	
153	Weight of urine in solids reservoir (lbs)	O
154	Weight of solid, defined by primary inlet/outlet special flow #3 in the solids reservoir (lbs)	O
155	Weight of water, defined by primary inlet/outlet special flow #4 in the solids reservoir (lbs)	O
156	Weight of solid, defined by primary inlet/outlet special flow #5 in the solids reservoir (lbs)	O
157	Weight of solid, defined by primary inlet/outlet special flow #6 in the solids reservoir (lbs)	O

2.6 Transient V-Array Data

Reference Location	Description	Data Type
158	Thermal capacitance of evaporator shell (Btu/°F)	I(R)
159	Thermal capacitance of liquid in the evaporator (Btu/°F)	O

3.0 ANALYTICAL MODEL DESCRIPTION

Subroutine EVAP was designed to model an evaporator such as that which is an integral part of the Waste Management/Water Recovery system (RITE system) developed by General Electric at Valley Forge. Consequently, the model includes the simulation of solid filtering capabilities and biochemical/thermal decomposition of urea in addition to the mass and energy balance during steady state and transient analyses of the evaporator.

3.1 Thermal Balance

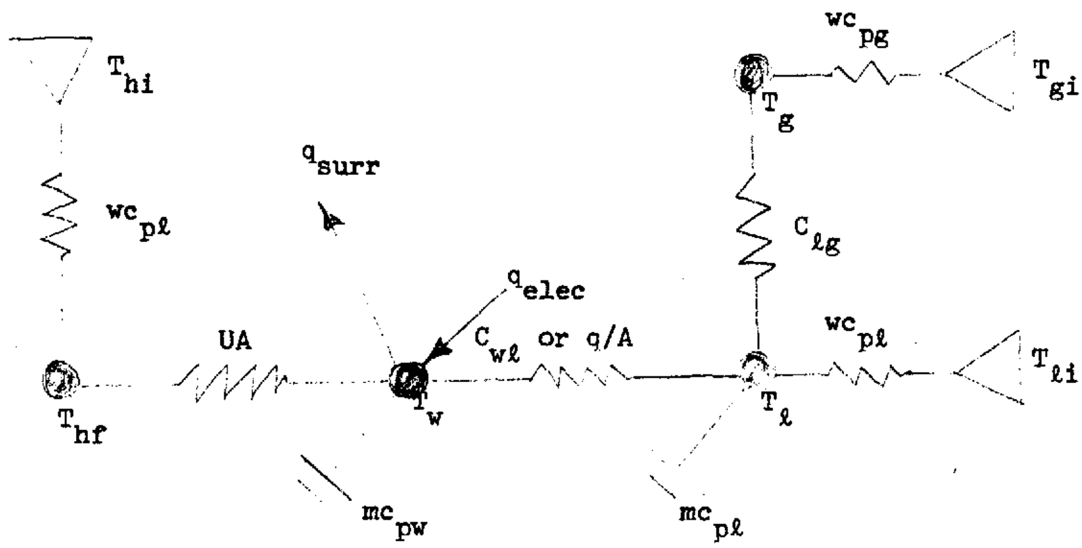
The energy balance for the fluid within the evaporator is developed by defining two modes of operation; hereafter, referred to as the high pressure mode and the low pressure mode. In the high pressure mode, the value of NSTR(4) is set to 1 and the following assumptions are made:

1. A relatively high gaseous flow prevails through the evaporator.
2. The pressure in the evaporator is equal to the inlet pressure of the gas stream.
3. The air stream leaving the evaporator may either be fully saturated; that is; air temperature equals the dew point temperature of the air, or it may vaporize relatively small amounts of liquid from the evaporator as it flows through it.

In the low pressure mode, the value of NSTR(4) is set to 0 and the following assumptions are made for the thermal analysis.

1. The gas temperature is equal to the liquid temperature.
2. The liquid temperature is equal to the boiling temperature, a function of the evaporator pressure.

The nodal thermal model developed for the energy balance of evaparator is shown below:



where:

T_{hi}	=	Heating fluid inlet temperature (°F)
$wc_{p,hf}$	=	Heating fluid flow conductance (Btu/hr-°F)
T_{hf}	=	Heating fluid outlet temperature (°F)
UA	=	R(65) = Effective thermal conductance between heating fluid and evaporator wall (Btu/hr-°F)
T_w	=	R(51) = Evaporator tank wall temperature (°F)
q_{elec}	=	R(66) = Electrical heat input (Btu/hr)
q_{surr}	=	R(53) = Heat lost to the surroundings (Btu/hr)
$C_{w\ell}$	=	R(75) = Heat conductance wall to liquid (Btu/hr-°F)
T_ℓ	=	R(2) = Temperature of the liquid in the evaporator (°F)
$mc_{p\ell}$	=	R(159) = Thermal capacitance of the liquid slurry in the evaporator (Btu/°F)
mc_{pw}	=	R(158) = Thermal capacitance of the evaporator shell (Btu/°F)
$wc_{p\ell}$	=	Fluid flow conductance of liquid slurry flowing into the evaporator (Btu/hr-°F)

T_g = R(21) = Temperature of the gas leaving the evaporator (°F)

wc_{pg} = B(1)*CPB = Flow conductance of gas flowing through the evaporator (Btu/hr-°F)

$T_{\ell i}$ = A(2) = Temperature of the liquid flowing into the evaporator (°F)

T_{gi} = B(2) = Temperature of the gas flowing through the evaporator (°F)

$C_{\ell g}$ = Thermal conductance between liquid and gas flowing through the system (Btu/hr-°F)

Steady State

The steady state analysis in the high pressure mode has a provision for the vaporization of liquid into the air that is flowing through the evaporator. This is accomplished by predicting the saturation vapor pressure of air flowing through the evaporator and the amount of vaporized liquid that is required to attain saturation. The mathematical development of this portion of the model is presented below.

Saturation vapor pressure leaving the evaporator is derived from air temperature using the function PSAT.

$$p_{H_2O,\ s} = \text{PSAT}\ (T_{gi}) \tag{1}$$

$$w_{H_2O,\ s} = \frac{p_{H_2O}}{p_t} * \frac{18.0}{M_g} * w_g \tag{2}$$

$$w_{vapr} = K_v * (w_{H_2O,\ s} - w_{H_2O,\ i}) \tag{3}$$

where:

p_{H_2O} = Saturation pressure of vapor (psia)

w_g = Total gaseous flow through the system (lb/hr)

$w_{H_2O,\ s}$ = Assuming saturation vapor flow leaving evaporator (lb/hr)

$w_{H_2O,\ i}$ = Vapor flow into the evaporator (lb/hr)

w_{vapr} = Vaporization rate of liquid (lb/hr)

K_v = Vaporization fraction of liquid factor (between 0. and 1.)

P_t = Total pressure of gas in evaporator (psi)

M_g = Molecular weight of gas entering evaporator (lb/lb-mole

The thermal balance in the high pressure mode is accomplished by predicting heat flow to the wall from the heating fluid, heat flow from the wall to surroundings and to the liquid in the evaporator and cooling of the liquid due to evaporation of water into the gas stream. The nodal heat balance equations are given below:

Heating Fluid Node, T_{hf}

Heat lost by fluid = Heat transfer to wall

$$wc_{p\ell}\ (T_{hi} - T_{hf}) = wc_{p\ell}\ (1 - e^{-(UA/wc_{p\ell})})\ (T_w - T_{hi})$$

Evaporator Wall Node, T_w

Heat transfer from heating fluid + Electrical heat input =
Heat lost to surroundings + Heat transfer to slurry

$$wC_{p\ell}\ (1 - e^{(-UA/wc_{p\ell})})\ (T_w - T_{hi}) + q_{elec} = q_{surr} + C_{w\ell}\ (T_w - T_\ell)$$

Liquid Node, T_ℓ

Heat transfer from wall = Heat transfer to entering liquid + Heat transfer to gas

$$C_{w\ell}\ (T_w - T_\ell) = wc_{p\ell}\ (T_\ell - T_{\ell i}) + C_{\ell g}\ (T_\ell - T_g)$$

Gas Node, T_g

Heat transfer from liquid = Heat gain by gas flow

$$C_{\ell g}(T_\ell - T_g) = wc_{pg}\ (T_g - T_{gi})$$

The steady state heat balance is assumed accomplished when the individual heat balances for the heating fluid node, the wall node, and the liquid node are approximately numerically correct, meeting the steady state convergence criteria.

The steady state thermal analysis in the low pressure mode is accomplished in a similar fashion to that for the high pressure mode except that the heat flux from the wall to the liquid is predicted from an input table. The table relates the boiling heat transfer rates to the temperature differential between the wall and the liquid and the evaporator pressure. The nodal equations for the low pressure mode reduce to the following:

Heating Fluid Node, T_{hf}

Heat lost by fluid = Heat transfer to wall

$$wc_{p\ell}\ (T_{hi} - T_{hf}) = wc_{p\ell}\ (1 - e^{(-UA/wc_{p\ell})})\ (T_w - T_{hi})$$

Evaporator Wall Node, T_w

Heat transfer from heating loop + Electrical Heat Input = Heat lost to surroundings + Heat transfer to liquid

$$wc_{p\ell} \left(1 - e^{(-UA/wc_{p\ell})}\right) (T_w - T_{hi}) + q_{elec} = q_{surr} + q/A\ (T_w - T_\ell)$$

Liquid Node, T_ℓ

Heat transfer from wall = Heat transfer to input liquid + Heat for evaporation

$$q/A\ (T_w - T_\ell) = wc_{p\ell}\ (T_\ell - T_{\ell i}) + w_v\ h_{fg}$$

Since the temperature of the liquid is set equal to the dew point temperature corresponding to the evaporator pressure level, the heat balance is computed for only the heating fluid and wall nodes. The evaporator pressure is computed from the pressure drop between the evaporator and the downstream pressure, R(100). In this calculation, the vapor flow rate is equal to the current evaporation rate, R(77), and the flow resistance is due to the effective orifice area, R(99).

Transient

The transient thermal analysis of the evaporator is accomplished using the forward difference techniques for the nodes that include thermal capacitance. These nodes are the wall node (capacitance input in R(158)) and the liquid node. The liquid node's thermal capacitance is calculated from the amount of liquid in the evaporator and its specific heat. The value is stored in R(159).

The critical time step is computed for each node to insure against computationa instability. The minimum critical time step is compared with the system time step; if the value of the minimum critical time step is below the system time step then the subroutine time step is set eual to the minimum critical time step. Each time the subroutine is called, successive time step passes are performed in the subroutine until the system time step is achieved. The critical time step is defined as:

$$\Delta t_c = \frac{\text{node capacitance}}{\Sigma \text{ conductances}}$$

Mass Balance

The mass balance of the evaporator system, besides accounting for the amount of gases, liquids, and solids flowing through the system also has the capabilities of computing the biochemical/thermal decomposition of urea into NH_3 and CO_2 and the removal of solids from the evaporator to the solid reservoir by the solids filter.

Urine contains a certain amount of ammonium carbonate/bicarbonate which will liberate 500 mg/ℓ of carbon dioxide when it is vaporized. In addition, urea which is the principal solute in urine ($\sim$ 28000 mg/ℓ) may decompose thermally when the temperature is above 150°F to yield NH_3 and CO_2. Urea also decomposes in the presence of the enzyme urease which is produced by bacteria contained in the feces. Once the bacteria is introduced they will multiply while decomposing most of the urea within 12 to 48 hours. Since no germicidal chemicals are added to the evaporator it is assumed that biochemical decomposition of urea will occur. The urea decomposes to NH_3 and CO_2 according to the following reaction:

$$H_2NCONH_2 + H_2O \xrightarrow{\text{UREASE}} 2NH_3 + CO_2$$

The reaction is modeled as follows:

$$w_{ag} = K_R * \frac{M_{ag}}{M_{ur}} * m_{ur} * 2 \tag{5}$$

$$w_{CO_2g} = K_R * \frac{M_{CO_2}}{M_{ur}} * m_{ur} \tag{6}$$

$$w_{urd} = \frac{M_{ur}}{(M_{H_2O} + M_{ur})} * (w_{ag} + w_{CO_2g}) \tag{7}$$

$$w_{H_2Ou} = \frac{M_{H_2O}}{(M_{H_2O} + M_{ur})} * (w_{ag} + w_{CO_2g}) \tag{8}$$

where:

w_{ag} = NH_3 generation rate (lb/hr)

w_{CO_2g} = CO_2 generation rate (lb/hr)

w_{urd} = Urea decomposition rate (lb/hr)

w_{H_2Ou} = Water used in decomposition of urea (lb/hr)

M_{ag} = Molecular weight of ammonia (lb/lb-mole)

M_{ur} = Molecular weight of the urea (lb/lb-mole)

M_{CO_2} = Molecular weight of CO_2 (lb/lb-mole)

m_{ur} = Weight of urea in evaporator (lbs)

K_R = Decomposition factor (1/hr)

Subroutine EVAP models the solids filtering capability of the evaporator. In the evaporator the pumping action of the impeller circulates the liquid slurry thru an external perforated metal filter. The waste solids collect in the filter. When the filter (defined as the solids reservoir) fills with solids, a means through GPOLY logic is provided to remove the solids from the solids reservoir. The mathematical development of the process is presented below:

$$m_{st} = \Sigma\ m_j \tag{9}$$

$$CONC_s = m_{st}/m_t \tag{10}$$

$$w_{sfr} = CONC_s * K_F \tag{11}$$

$$w_\ell = w_{sfr}\ K_{PL} \tag{12}$$

$$w_j = \frac{m_j}{m_{st}} * (w_{sfr}) \tag{13}$$

where:

m_{st} = Total weight of solids in the evaporator (lbs)

m_j = Weight of individual solid component in evaporator (lbs)

m_t = Total weight of liquid slurry in the evaporator (lbs)

$CONC_s$ = Concentration of solids in evaporator (decimal)

w_{sfr} = Solids filtering rate (lb/hr)

K_F = Filtration constant (lb/hr)

w_ℓ = Liquid filtration rate by filter (lb/hr)

K_{PL} = Ratio of liquid to solid in solids reservoir (decimal)

w_j = Removal rate of individual components from evaporator to solids reservoir (lb/hr)

The transient mass balance is accomplished by maintaining flows in and out of the evaporator, accounting for urea that may have biochemically reacted, solids and liquid that may be filtered out, and the liquid that is vaporized. The flow stability (the critical time step) for the low pressure node flow exiting the evaporator and flowing into downstream components must be determined by GPOLY logic within the EVAP subroutine. In this mode the evaporator pressure and flow is a function of the downstream (e.g., condenser) pressure. The mass balance for all components in the evaporator may be represented by the following general equation.

$$m' = m + (\pm w_{reac} + w_{in} - w_f - w_o) * \Delta t \qquad (14)$$

where,

$\pm w_{reac}$ = Rate of generation of component in evaporator (lb/hr)

w_{in} = Inlet flow of component (lb/hr)

w_f = Outlet flow to solids filter (lb/hr)

w_o = Outlet flow to vapor loop (lb/hr)

m, m' = Old and new values for mass of constituent in evaporator (lb)

4.0 LOWER LEVEL SUBROUTINES AND FUNCTIONS REQUIRED

HF
HG
ESTIM
QSURR
PSAT (T)
TSAT (P)

PROP

FLOARY

FLØWØR

LV

SV

5.0 REFERENCES

1. Schelkopf, J. D., Witt, F. J., Murray, R. W.; Summary Report, Integrated Waste Management - Water System Using Radioisotopes for Thermal Energy, General Electric Report No. NYO-4104-1, September 8, 1970.

2. Putnam, D. F., Chemical Aspects of Urine Distillation, American Society of Mechanical Engineers, Paper No. 65-AV-24, March 1965.

3. Barker, R. S., et. al., G-189A Generalized Environmental/Thermal Control and Life Support Systems Computer Program, MDAC G2444, September, 1971.

CNDNSR

Component Subroutine No. 60 - Condenser

1. Subroutine Description

This subroutine simulates a condenser such as that used by a Waste Management/ Water Recovery system, specifically the RITE system that has been developed by General Electric at Valley Forge, Pennsylvania. See Reference 1. The condenser is used to condense the water vapor discharged by the pyrolysis units and to store the condensate prior to its transfer to the collection tanks. The condenser component schematic is shown below.

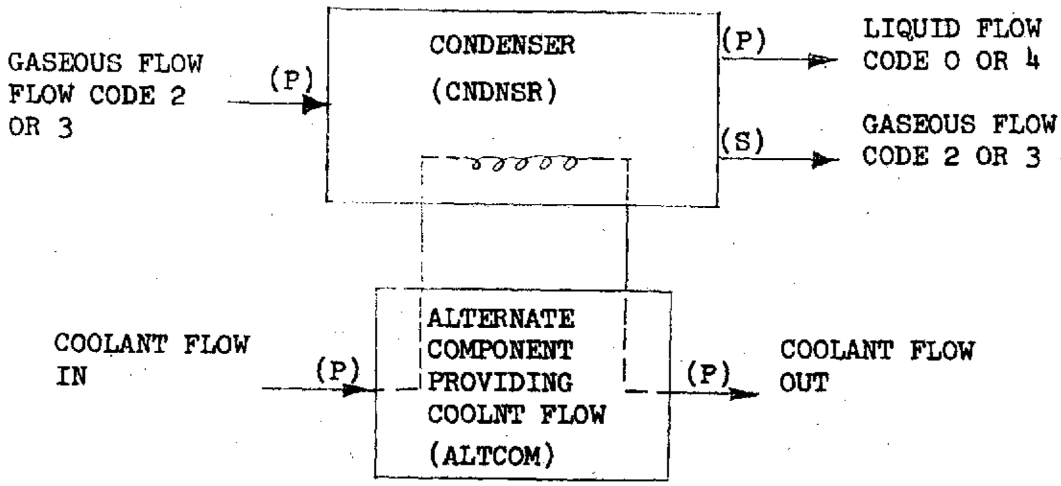


FIGURE 1. COMPONENT SCHEMATIC OF THE CONDENSER

An engineering sketch of the condenser is shown in Figure 2. Water vapor and inert gases enter at the top of the condenser. The sensible and latent heat of the vapor is removed at the top part of the condenser wall. Cooling is provided by an alternate component providing the coolant flow through the tubes attached to the condenser. The non-condensable gases remain in the condenser until vented to vacuum as secondary flow. The condenser is

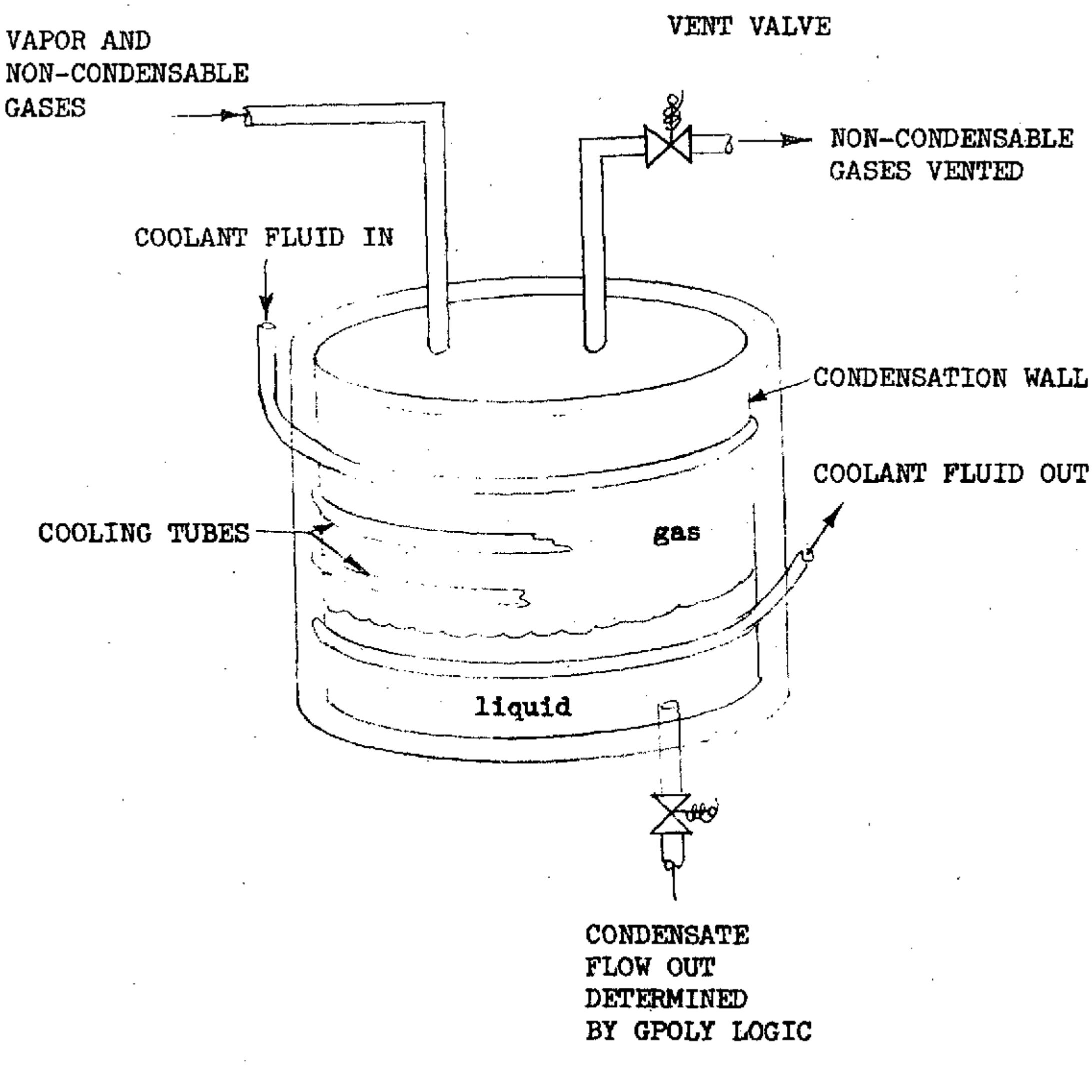


FIGURE 2. CONDENSER UNIT

designed to retain the condensate at the bottom either by the force of gravity or by capillary action in a zero-g environment. The condensate may be removed as primary flow by an external command through GPOLY1 logic.

2.0 Subroutine Data

2.1 General Notes

1. The primary inlet flow must be gaseous; that is, use flow codes 2 or 3.
2. There is no secondary inlet flow.
3. The primary outlet flow is liquid using flow code 0 or 4 and the rate is determined by GPOLY1 logic.
4. The secondary outlet flow is gaseous and is computed by the subroutine.
5. The R-Array data R(91) through R(109) are a 19-member set of variables defining the gas mixture in the condenser. Initial values are computed during steady state analysis to satisfy the steady state criteria. It is recommended that a steady state run be made prior to transient analysis in order to initialize these variables.

2.2 Instruction Options

NSTR(1) Type of Condenser
- = 0 Cylindrical condenser
- = 1 Conical condenser

NSTR(2) Criteria used for steady state mass balance
- = 0 Fraction of vent gas defined by R(79) is used in obtaining the mass balance in steady state.
- = 1 The total pressure in evaporator is defined and used as basis in obtaining mass balance

2.3 Steady State K-Array Data

Reference Location	Description	Data Type
16	Component number of alternate component	I(R)

2.4 Steady State/Transient V-Array Data

Reference Location	Description	Data Type
	(See Figure 2 for Thermal Network)	
65	Total heat flux through the condenser wall (Btu/hr)	0
66	Effective orifice area of the valve used in venting gases out of the condenser (ft^2). The orifice is sized during steady state conditions according to the NSTR(2) criterion, inlet conditions, condensing rate, and downstream pressure R(67). During transient conditions the area can be adjusted by GPOLY logic to simulate vent valve operation.	
67	Downstream pressure to which the gases are venting (psia)	I(0)
68	Dew point temperature of gases in condenser (°F)	0
69	Water condensation rate in the condenser (lb/hr)	0
70	Heat loss to wall due to latent heat of condensation (Btu/hr)	0
71	Internal radius of condenser (ft)	I(R)
72	Internal height of condenser (ft)	I(R)
73	Height of the liquid level in the condenser (ft)	0
74	Mass of liquid in the condenser, (lbs) (an initial value may be specified)	I(0), 0
75	Effective thermal conductance between condenser wall and the coolant in the tubing which is attached to the condenser wall (Btu/hr-°F)	I(R)
76	Steady state convergence tolerance (decimal)	I(R)
77	Condenser total lumped thermal capacitance (Btu/°F)	I(R)
78	Condensate lumped thermal capacitance (Btu/°F)	0
79	Molar fraction of vent gas that is condensable vapor (decimal)	I(R) when NSTR(2) =
80	Conductance (KA/ℓ_1) between the two condenser wall nodes (Btu/hr-°F)	I(R)
81	Effecitve total conductance between the condenser wall and the surroundings (Btu/hr-°F)	I(R)

2.4 Steady State/Transient V-Array Data (continued)

Reference Location	Description	Data Type
82	Effective temperature of the surroundings (°F)	I(R)
83	Heat transfer convection coefficient between the gas and the wall and liquid nodes; the sensible heat transfer coefficient (Btu/hr-°F)	I(R)
84	Conductance (KA/ℓ_2) between the wall node and the condensate node, (Btu/hr-°F)	0
85	Heat transfer coefficient due to condensation of vapor on the condenser wall (Btu/hr-°F-Ft^2)	0
86	Coolant outlet temperature at coolant node 1 (°F)	0
87	Coolant outlet temperature at coolant node 2, (°F)	0
88	Condenser wall node 1 temperature (°F)	0
89	Condenser wall node 2 temperature (°F)	0

The V-array locations 91 through 109 are a 19-member set of data defining the gas mixture in the condenser. If the run is executed for a transient case only, the initial values must be input. If a steady state case is executed, the values are computed by the subroutine and are not required to be input.

91	Total weight of gas in condenser, (lbs)	I(O), O
92	Temperature of the gas in condenser, (°F)	I(O), O
93, 94	Pressure of the gas in condenser, (psia)	I(O), O
95	Weight of non-condensables in condenser, (lbs)	I(O), O
96	Weight of condensable vapor in condenser, (lbs)	I(O), O
97	Weight of contained liquid (always zero), (lbs)	I(O), O
98	Effective capacitance of non-condensable gas, (Btu/lb-°F)	I(O), O
99	Molecular weight of non-condensable gas, (lb/lb mole)	I(O), O
100	Weight of O_2 in the condenser, (lbs)	I(O), O
101	Weight of N_2 in the condenser, (lbs)	I(O), O
102	Weight of CO_2 in the condenser, (lbs)	I(O), O
103	Weight of NH_3 in the condenser, (lbs)	I(O), O
104	Weight of special flow #1 in the condenser, (lbs)	I(O), O

Reference Location	Description	Data Type
105	Weight of special flow #2 in the condenser, (lbs)	I(0), 0
106	Weight of special flow #3 in the condenser, (lbs)	I(0), 0
107	Weight of special flow #4 in the condenser, (lbs)	I(0), 0
108	Weight of special flow #5 in the condenser, (lbs)	I(0), 0
109	Weight of special flow #6 in the condenser, (lbs)	I(0), 0

3.0 Analytical Model Description

The modeling of the condenser by this subroutine includes both mass and thermal balances. Figure 3 is a schematic of the condenser thermal network. Thermal parameters for the condenser are shown. The mass flow constituents entering the condenser (from the pyrolysis units in the RITE system) include liquid water, water vapor, carbon dioxide, oxygen, nitrogen, and other non-condensable gases. The condensate is assumed to be stored in the condenser until pumped from the condenser by an external command, determined by GPOLY1 logic. The non-condensable gases and vapor that is not condensed are considered to be either contained in the condenser or vented to vacuum by opening the vent valve.

3.1 Thermal Balance

The energy balance of the water condenser is accomplished by a formulated 6-node thermal network with the wall nodes defined by the liquid level of the condensate. The lumped parameter thermal network is shown in Figure 3 below

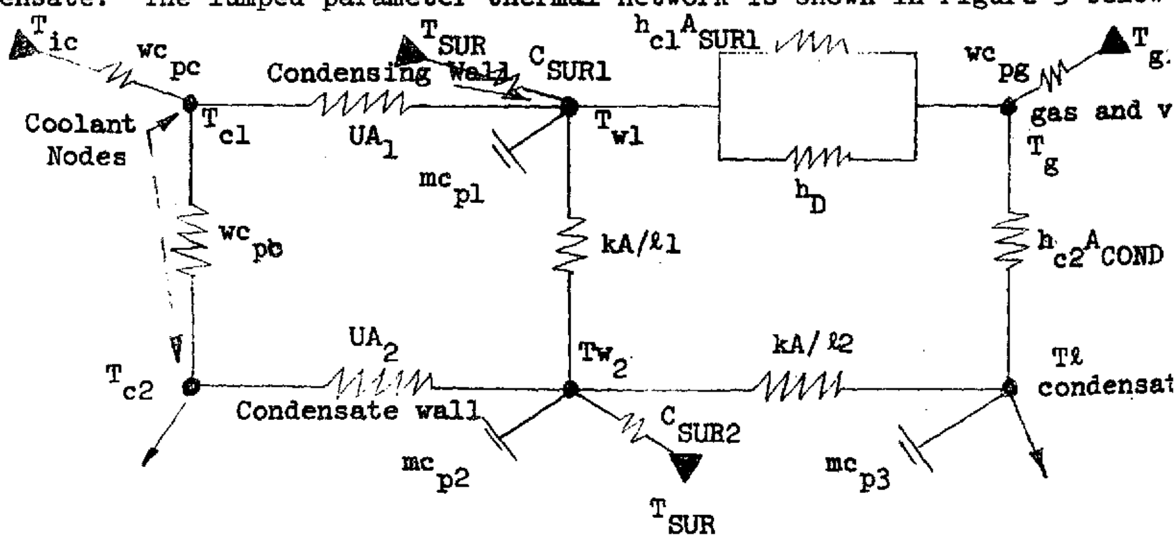


FIGURE 3. CONDENSER NODAL NETWORK

where:

T_{ic} = Inlet temperature of the coolant, (°F)

T_{c1} = R(86) = Temperature of coolant at node 1, (°F)

T_{c2} = R(87) = Temperature of coolant at node 2, (°F)

T_{w1} = R(88) = Temperature of wall node 1, (°F)

T_{w2} = R(89) = Temperature of wall node 2, (°F)

T_g = R(21) = Temperature of gas in the condenser, (°F)

T_ℓ = R(2) = Temperature of the condensate in the condenser, (°F)

T_{gi} = A(2) = Temperature of the gas flowing in, (°F)

wc_{pc} = Fluid flow conductance, coolant flow, (Btu/hr-°F)

wc_{pg} = Fluid flow conductance gaseous inlet flow, (Btu/hr-°F)

T_{SUR} = Effective temperature of the surroundings, (°F)

C_{SUR1} = Effective conductance to the surroundings, wall node 1 to surroundings, (Btu/hr-°F)

C_{SUR2} = Effective conductance to the surroundings, wall node 2 to surroundings, (Btu/hr-°F)

UA_1 = Effective thermal conductance between wall node 1 and coolant node 1, (Btu/hr-°F)

UA_2 = Effective thermal conductance between wall node 2 and coolant node 2, (Btu/hr-°F)

KA/ℓ_1 = R(80) = Conductance between wall node 1, and wall node 2, (Btu/hr-°F)

KA/ℓ_2 = R(84) = Conductance between wall node and liquid node, (Btu/hr-°F)

hc_1 = R(83) = Convective heat transfer coefficient between wall node and gas node, (Btu/hr-Ft^2-°F)

h_D = Heat transfer coefficient, diffusion, for condensation of vapor on the condenser wall, (Btu/hr-°F-Ft^2)

mc_{p1} = Thermal capacitance of wall node 1, (Btu/°F)

mc_{p2} = Thermal capacitance of wall node 2, (Btu/°F)

mc_{p3} = R(78) = Thermal capacitance of liquid in the condenser, (Btu/°F)

A_{SUR1} = Surface area of node 1 (ft^2)

A_{COND} = Surface area of condensate (ft^2)

Steady State

A steady state heat balance is performed about each node.

1. Coolant node associated with condensation wall, T_{c1}

Heat gained by the coolant = Heat transfer from condenser wall node

$$wc_{pc}(T_{c1} - T_{ic}) = wc_{pc}(1 - e^{-(uA_1/wc_{pc})})(T_{w1} - T_{ic}) \tag{1}$$

2. Coolant Node associated with condensate storage wall node, T_{c2}

Heat gained by the coolant = Heat transfer from wall, T_{c2}

$$wc_{pc}(T_{c2} - T_{c1}) = wc_{pc}(1 - e^{-(uA_2/wc_{pc})})(T_{w2} - T_{c1}) \tag{2}$$

3. Wall node associated with condensing portion of wall, T_{w1}

Heat lost to coolant + Heat lost to surrounding + Heat lost to lower wall = Sensible heat gained from gas node + Heat of condensation

$$wc_{pc}(1 - e^{-(uA_1/wc_{pc})})(T_{w1} - T_{ic}) + C_{SUR1}(T_{w1} - T_{SUR})$$
$$+ kA/\ell_1 (T_{w1} - T_{w2}) = h_{c1}A_{SUR1} (T_g - T_{w1}) + h_D A_{SUR1} (T_v - T_{w1}) \tag{3}$$

where T_v = TSAT (Vapor Pressure)

4. Wall node associated with condensate storage part of wall, T_{w2}

Heat lost to coolant + Heat lost to surroundings = Heat transfer from upper wall + Heat gained from condensate

$$wc_{pc}(1 - e^{-(uA_2/wc_{pc})})(T_{w2} - T_{c2}) + C_{SUR2}(T_{w2} - T_{SUR}) =$$
$$kA/\ell_1 (T_{w1} - T_{w2}) + kA/\ell_2 (T_\ell - T_{w2}) \tag{4}$$

5. Gas/Vapor Node, T_g

Heat lost by incoming gas vapor = Heat lost by condensation + Sensible heat loss = Connection heat lost to condensate

$$WC_{pg}(T_{gi} - T_g) = h_{c1}A_{SUR1} (T_g - T_{w1}) + h_D A_{SUR1} (T_v - T_{w1}) \tag{5}$$
$$+ h_{c2} A_{COND} (T_g - T_\ell)$$

6. Condensate Node, T_e

Heat gained from gas = Heat lost to wall

$$h_{c2}\, A_{COND}\, (T_g - T_\ell) = kA/_{\ell 2}\, (T_\ell - T_{w2}) \tag{6}$$

The energy balance of the thermal network in steady state is accomplished using the Gauss-Seidel iteration method. The heat balance equations are modified to yield six equations for the nodal temperatures.

$$T_{c1} = T_{ic} + C_1 * (T_{w1} - T_{ic}) \tag{7}$$

$$\text{where:}\quad C_1 = 1. - e^{-(uA_1/wc_{pc})} \tag{7a}$$

$$T_{c2} = T_{c1} + C_4 * (T_{w2} - T_{c1}) \tag{8}$$

$$\text{where:}\quad C_4 = 1. - e^{-(uA_2/wc_{pc})} \tag{8a}$$

$$T_{w1} = \frac{T_{ic}\, C_2 + \frac{KA}{\ell_1}\, T_{w2} + h_{c1}A_{SUR1}\, T_g + h_D A_{SUR1}\, T_v + (C_{SUR1}\, T_{SUR})}{C_2 + \frac{KA}{\ell_1} + h_{c1}A_{SUR1} + h_D A_{SUR1} + C_{SUR1}} \tag{3}$$

$$\text{where:}\quad C_2 = wc_{pc} * C_1 \tag{9a}$$

$$T_{w2} = \frac{C_3\, T_{c1} + \frac{KA}{\ell_1}\, T_{w1} + \frac{KA}{2}\, T_\ell + C_{SUR2}\, T_{SUR}}{C_3 + \frac{KA}{\ell_1} + \frac{KA}{2} + C_{SUR2}} \tag{10}$$

$$\text{where:}\quad C_3 = C_4 * wc_{pc} \tag{10a}$$

$$T_g = \frac{h_{c1}A_{SUR1}\, T_{w1} + h_{c2}A_{COND}\, T_\ell + wc_{pg}\, T_{gi}}{hc_1 + hc_2 + wc_{pg}} \tag{11}$$

$$T_\ell = (h_{c2}A_{COND}\, T_g + \frac{KA}{\ell_2}\, T_{w2})/(h_{c2}A_{COND} + \frac{KA}{\ell_2}) \tag{12}$$

After the new temperatures for the six nodes are computed, they are tested against previously computed temperatures, if all the values are within the convergence criterion, an input value, the thermal balance on the condenser is assumed to be attained for the given condenser vapor pressure. At each iterative pass the vapor pressure is determined from the function PSAT for the current vapor temperature.

Mass Balance

The mass balance of the condenser is attained by making the following assumptions:

1) The constituency of the gases venting out of the condenser is the same as the constituency of gases in the condenser.

2) The total non-condensable flow and the constituency of non-condensable flow does not change between inlet and outlet.

From the condensing wall temperature, T_{wl}, and the dew point temperature, T_v, of the gas in the condenser, we compute the condensation rate, w_{cond}.

$$w_{cond} = h_D * (T_v - T_{wl})/h_{fg} \qquad (13)$$

where: h_{fg} = heat of vaporization, (Btu/lb)

Since the condensation rate cannot exceed the vapor inlet flow, a test is made to insure that the condensation rate is not greater than the vapor inlet flow. If vapor inlet flow is less than the condensation rate, then the partial pressure of vapor, pp_{H_2O}, is decreased and a new heat balance is computed using the new, T_v, saturation temperature of the gas.

The vented flow rate is derived from the partial pressure of vapor, pp_{H_2O}, in the condenser and the volumetric percentage of water vapor, V_{ratio} = R(79), is vented with non-condensable gases by first predicting the total pressure in the condenser.

Total pressure:

$$p_t = pp_{H_2O}/V_{ratio} \tag{14}$$

The molecular weight of gas vented is derived from the following relationship

$$M_t = \frac{M_c * pp_{H_2O} + M_{nc} * (p_t - pp_{H_2O})}{p_t} \tag{15}$$

where:

M_t = Average molecular weight of gas in the condenser (same as vented gas) (lbs/lb mole)

M_c = Molecular weight of condensable gas (water vapor) (lbs/lb mole)

M_{nc} = Molecular weight of the non-condensable gas in the condenser, the value is equal to the molecular weight of non-condensable gas at inlet (lbs/lb mole)

The total flow vented is computed from the following relationship:

$$w_t = w_{nc} * \left(\frac{p_t}{p_t - pp_{H_2O}}\right) * \left(\frac{M_t}{M_{nc}}\right) \tag{16}$$

where:

w_t = Total flow vented, (lb/hr)

w_{nc} = Total non-condensable gas vented, (lb/hr)

w_c = Total condensable gas (vapor) vented, (lb/hr)

From total flow and non-condensable we compute the vapor flow vented:

$$w_c = w_t - w_{nc} \tag{17}$$

The vapor flow vented out of the condenser should equal the vapor flowing in less the condensation rate. If the vapor flow vented out is higher than the vapor flowing in less condensation rate, we assume that there was insufficient condensation and we increase the partial pressure of vapor to induce a higher condensation rate. If the vapor flow vented is lower than the difference between vapor flowing in less condensation rate, we decrease the pp_{H_2O} to decrease the condensation rates. In both cases a new steady state thermal balance is computed for the new T_v term.

If the vapor flow vented approximately equals the difference between vapor flow in less condensation rate, we assume a mass balance has been achieved. With the steady state flow computed, we determine the initial values for the gas components in the condenser by first computing the total weight of gas in the condenser and then the individual components.

$$m_t = (V * p_t * M_t)/(1545. * (T + 460.)) \qquad (18)$$

where:

m_t = Weight of gas in the condenser, (lbs)

V = Gaseous volume in the condenser, (Ft^3)

T = Temperature of gas in the condenser, (°F)

M_t = Molecular weight of gas in the condenser (lbs/lb-mole)

$$w_i = (m_i/m_t) * w_t \qquad (19)$$

where:

m_i = Weight of constituent i in the condenser, (lbs)

w_i = Flow rate of constituent i vented (lbs/hr)

With the temperature, pressure, and weight of individual components calculated for the gas in the condenser, we compute the effective orifice area of the vent, A_v, that would yield the specified flow rate computed above. The value is derived using the choked flow formula as follows:

$$A_v = \frac{\left(\frac{w_t}{3600. * P_t}\right) \sqrt{\frac{1545.}{M_t} (T + 460)}}{\sqrt{r * g_c * (\frac{2}{r+1})^{(r+1)/(r-1)}}} \qquad (20)$$

where:

A_v = Effective orifice area of the vent, (ft^2)

g_c = 32.174 proportionality constant (lb_m/lb_f sec^2)

r = Ratio of specific heats (dimensionless)

Transient Analysis

The nodal temperatures suring transient analysis are computed through the use of forward difference techniques for nodes that include capacitance values, namely the two wall nodes, and the liquid condensate node. The two coolant nodes and the gas node are assumed to have negligible capacitance values. The temperatures for the two liquid coolant nodes and the gas node are computed from the following:

$$T_{c1} = T_{ic} + (T_{w1} - T_{ic}) * C_1 \qquad (21)$$

$$T_{c2} = T_{c1} + (T_{w2} - T_{c1}) * C_4 \qquad (22)$$

$$T_g = (h_{c1}A_{SUR1}\ T_{w1} + h_{c2}\ A_{COND}\ T_\ell + wc_{pg}\ T_{gi})/(h_{c1}A_{SUR1} + h_{c2}A_{COND} + wc_{pg}) \qquad (23)$$

From which we compute heat flux from all nodes to coolant nodes

$$Q_{out1} = C_2 * (T_{w1} - T_{ic}) \tag{24}$$

$$Q_{out2} = C_3 * (T_{w2} - T_{c1}) \tag{25}$$

where:

Q_{out1} = Heat flow from wall node 1 to coolant node 1, (Btu/hr)

Q_{out2} = Heat flow from wall node 2 to coolant node 2, (Btu/hr)

The total heat flows into the wall nodes are computed as follows:

$$Q_{tw1} = -Q_{out1} + C_{SUR1} * (T_{SUR} - T_{w1}) + \frac{KA}{\ell_1} * (T_{w2} - T_{w1}) + h_D A_{SUR1} * (T_v - T_{w1}) + h_{c1} A_{SUR1} * (T_g - T_{w1}) \tag{26}$$

$$Q_{tw2} = -Q_{out2} + C_{SUR2} * (T_{SUR} - T_{w2}) + \frac{KA}{\ell_1} * (T_{w1} - T_{w2}) + \frac{KA}{\ell_2} * (T_\ell - T_{w2}) \tag{27}$$

where:

Q_{tw1} = Heat flux through wall node 1, (Btu/hr)

Q_{tw2} = Heat flux through wall node 2, (Btu/hr)

The heat flow into the liquid node is computed by the following:

$$Q_L = \frac{KA}{\ell_2} * (T_{w2} - T_\ell) + h_{c1} A_{COND} * (T_g - T_\ell) \tag{28}$$

New values for constituent gas masses and the total gas mass are obtained. PROP is used to obtain the molecular weight for the total gas mixture and the water vapor partial pressure and the total pressure are computed as follows:

$$m_i' = m_i + w_i * \Delta t \tag{34}$$

$$m_t = \sum_i^n m_i \tag{35}$$

$$pp_{H_2O} = m_{H_2O} * 1545. * (T+460.)/(V*18.*144.) \tag{36}$$

$$p_t = m_t * 1545.*(T+460.)/(V*m_t*144.) \tag{37}$$

where:

m_{H_2O} = Weight of vapor in the condenser (lb.)

V = Gaseous volume in the condenser (ft^3)

m_t = Total weight of gases in the condenser (lb)

4.0 Lower Level Subroutines Called

PROP
FLOWOR

5.0 References

1. Schelkopf, J. D., Witt, F. J., Murray, R. W., Summary Report, Integrated Radioisotopes for Thermal Energy, General Electric Report No. NYO-4104-1, September 8, 1970.

2. Barker, R. S., et al., G-189A Generalized Environmental/Thermal Control and Life Support Systems Computer Program, MDAC G2444, September 1971.

where:

Q_L = Heat flux through liquid node, (Btu/hr)

Before the transient temperatures are computed, the critical time step is computed for each node, and compared against the system time step; if the value of the minimum critical time step is below the system time step then the subroutine time step is set equal to the minimum critical time step. Each time the subroutine is called, successive time passes are performed in the subroutine until the system time step is achieved. The critical time step is defined as:

$$\Delta t = \frac{\text{node capacitance}}{\Sigma \text{ conductances}} \tag{29}$$

The new temperatures for the liquid and wall nodes are computed from the following:

$$T_{w1}' = T_{w1} + Q_{tw1} * \Delta t/mc_{p1} \tag{30}$$

$$T_{w2}' = T_{w2} + Q_{tw2} * \Delta t/mc_{p2} \tag{31}$$

$$T_{\ell}' = T_{\ell} + Q_L * \Delta t/mc_{p3} \tag{32}$$

Where, the prime, denotes the predicted temperatures of the wall and liquid nodes at the end of the time step.

The mass balance during transient analysis is computed by first determining the total flow of vent gas using the function FLØWØR. This function computes choked or sonic flow through an orifice.

The flow rate of individual constituents through the vent valve is determined as follows:

$$w_i = w_t * \frac{m_i}{m_t} \tag{33}$$

INCIN

Component Subroutine No. 58 - Incinerator

1.0 Subroutine Description

This subroutine simulates an incinerator in which the waste products are processed by vacuum drying, chemical decomposition at high temperature, and venting of resultant ash. Waste products such as paper and feces are loaded into the incinerator in a batch process. The vent to vacuum is opened and the solids are dried. The vent to vacuum is closed and a small amount of oxygen is introduced with the solids and the oxidation reaction proceeds. The product gasses are then vented to vacuum. The oxygen cycle is repeated until all the solids are incinerated. At the end of the cycle, the remaining ash is blown out by a nitrogen purge. The incineration cycle is summarized in Figure 1.

2.0 Subroutine Data

2.1 General Notes

1. The input is an instantaneous batch process, therefore the solid and liquid mass is input through GPOLY logic.
2. The primary outlet flow is gaseous using flow code 3.
3. There is no secondary outlet flow.
4. During steady state the incinerator is assumed to be empty.

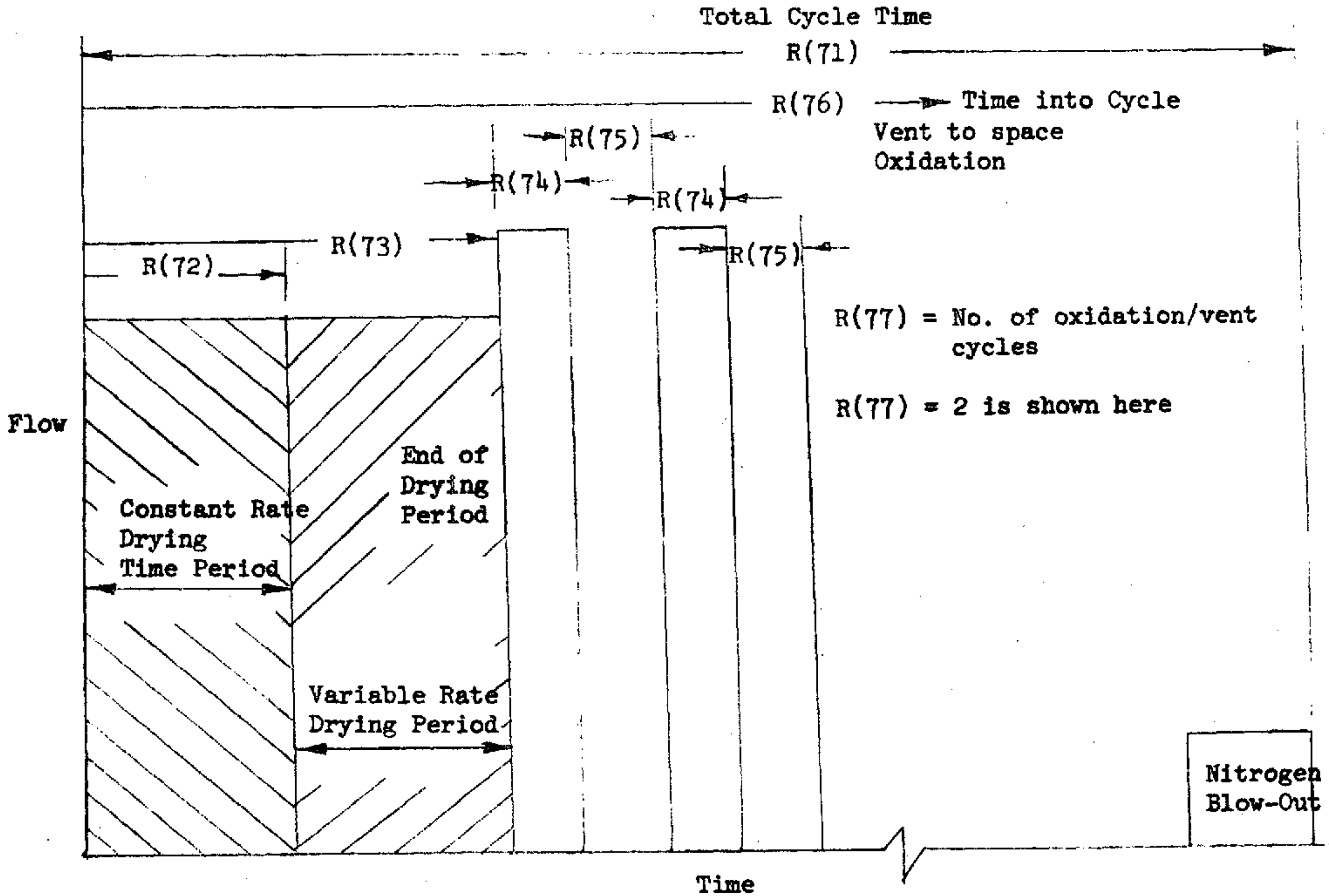
2.2 Instruction Options

2.3 Heat Loss V-Array Data

Reference Location	Description	Data Type
51	Temperature of incinerator (°F)	0
52	Effective thermal conductance from incinerator to surroundings (Btu/hr-°F)	0

C-3

INCINERATOR CYCLE DEFINITION



Reference Location	Description	Data Type
53	Total heat loss to surroundings (Btu/hr) R(53) = R(56) + R(62)	0
54	Ambient gas temperature (°F)	I (0)
55	Thermal conductance between surface of insulation and ambient gas (Btu/hr-°F)	I (0)
56	Convective heat loss to ambient gas (Btu/hr)	0
57	Ambient wall temperature (°F)	I (0)
58	Thermal radiation ℱA factor from surface of insulation to ambient wall (ft^2)	I (0)
59	Radiative heat loss to ambient wall (Btu/hr)	0
60	Structure temperature (°F)	I (0)
61	Conductance (kA/X) between incinerator and structure (Btu/hr-°F)	I (0)
62	Conductance heat loss to the structure (Btu/hr)	0
63	Insulation surface temperature (°F)	0
64	Conductance (kA/X) between incinerator and outer surface of insulation (Btu/hr-°F) (If R(64) = 0 there is no insulation)	I (0)

2.4 Steady State/Transient V-Array Data

Reference Location	Description	Data Type
65	Total heat transfer in the incinerator (Btu/hr)	0
66	Heat input by conduction from the heat source (Btu/hr)	0
67	Evaporative heat loss (Btu/hr)	0
68	Heat generated by oxidation reaction (Btu/hr)	0
69	Heat of reaction (Btu/lb-oxygen)	I (0)
70	Stability time increment (seconds)	0

R-array locations R(71) to R(77) define the incineration cycle. See Figure 1.

71	Total cycle time (seconds)	I (R)
72	Time to constant rate drying period (seconds)	I (R)
73	Time to end of drying period (seconds)	I (R)

Reference Location	Description	Data Type
74	Oxidation time period (seconds)	I(R)
75	Gas venting time period (seconds)	I(O)
76	Time into cycle (seconds)	I(O)
77	Number of oxidation vent cycles (number of cycles)	I(R)
78	Mass of water in incinerator (lb)	I(O) or GPOLY1
79	Mass of solids in incinerator (lb)	I(O) or GPOLY1
80	Critical moisture content (lb)	O
81	Mass of carbon dioxide in incinerator (lb)	O
82	Mass of nitrogen oxide in incinerator (lb)	O
83	Mass of ash in incinerator (lb)	O
84	Mass of oxygen added per oxidation cycle (lb)	I(R)
85	Mass of ash in incinerator (lb)	O
86	Mass of nitrogen used for venting (lb)	I(R)
87	Saturation pressure (psia)	O
88	Environmental pressure for venting of exhaust products (psia)	I(R)
89	Heat source temperature (°F)	I(R)
90	Mass transfer coefficient (lb/hr-ft^2-psi)	I(R)
91	Evaporation surface area (ft^2)	I(R)
92	Heat of vaporization (Btu/lb)	O
93	Thermal conductance between heat source and incinerator (Btu/hr-°F)	I(R)
94	Effective thermal capacitance of shuttle (Btu/lb-°F)	I(R)

3.0 Analytical Model Description

Constant Rate Drying Period

During the constant-rate drying periods, drying proceeds by diffusion of vapor from the saturated surface of the material to the environment. The mass transfer rate is:

$$\left(\frac{dw}{dt}\right)_c = k \; A \; (p_s - p_e)$$

where:

w = moisture contents (lbs water/lb solids)

$\left(\frac{dw}{dt}\right)_c$ = drying rate, (lbs water/lb solids/hr)

k = mass transfer coefficient, (lbs water/lb solids/(hr-ft^2-atms))

A = area of evaporation surface (ft^2)

p_s = vapor pressure of water at solids surface temperature (atms)

p_e = partial pressure of water vapor in incinerator environment (atms)

Falling Rate Period

The falling rate drying rate is proportional to the moisture contents of the solid.

$$\left(\frac{dw}{dt}\right)_f = -K \; w$$

K is a function of the constant rate as follows:

$$K = \left(\frac{dw}{dt}\right)_c \; / \; w_c$$

$\left(\frac{dw}{dt}\right)_f$ = falling drying rates (lbs water/hr)

w_c = critical moisture contents (lb water/lb dry solid)

Energy Balance

During drying heat is input to the incinerator by conduction from the isotope heat block.

$$q_i = \frac{kA}{\ell} (T_{HB} - T_i)$$

where

q_i = Heat conducted to incinerator from heat block (Btu/hr)

$\frac{kA}{\ell}$ = Thermal conductance (Btu/hr °F)

T_i = Average incinerator temperature (°F)

T_{HB} = Heat block temperature (°F)

The evaporative heat loss is given by:

$$q_e = \left(\frac{dw}{dt}\right) \cdot \Delta h_{fg}$$

where

q_e = Evaporative heat loss, Btu/hr

Δh_{fg} = latent heat of evaporation, Btu/lb

Heat is lost to the surroundings by conduction to the supporting structure, q_k, by convection to the cabin air, q_c, and by radiation to the cabin, q_r. These heat terms are calculated using subroutine QSURR. The analytical model for this is provided in subroutine QSURR's writeup. The sum of the three terms is set equal to q_{SURR}.

$$q_{SURR} = q_r + q_c + q_k$$

The temperature of the incinerator is solved using the forward difference technique.

$$T_i = T_i' + \frac{(q_i - q_{SURR} - q_e)\ \Delta t}{mc_p}$$

where

T_i = Incinerator temperature at end of time step (°F)

T_i' = Incinerator temperature at start of time step (°F)

mc_p = Effective thermal capacity of incinerator (Btu/lb °F)

The stability time increment is computed as follows:

$$\Delta t_{stab} = \frac{\Sigma mc_p}{\Sigma c_i}$$

where

Σmc_p = Total heat capacitance of incinerator (Btu/°F)

Σc_i = Sum of conductances to incinerator (Btu/hr °F)

Δt_{stab} = Stability time increment (hrs)

If the stability time increment is less than the system time increment, then the number of internal passes is set so as to accommodate the stability time increment.

Incineration

Incineration occurs in the incinerator shuttle when oxygen is introduced in the presence of isotope heat. Typical constituents of dried incinerator solids are listed in Table 1.

TABLE 1

CONSTITUENTS OF INCINERATOR SOLIDS

Constituent	% of Total Weight	Chemical Symbol
Bacteria	30	$(CH_2)_x NH_3$ COOH
Indigested protein	2-3	$(CH_2)_x NH_3$ COOH
Fat	10-20	$C_{12} H_{16} O$
Ruffage	30	$C H_2O$
Inorganic Materials	20-30	Various

The oxidation reactions for each of these constituents are listed below along with the heats of reaction.

Bacteria and Protein

$$2CH_2NH_3\,COOH + 7O_2 \longrightarrow 4CO_2 + 2NO_2 + 6H_2O$$

$\Delta h = -5680$ Btu/lb oxygen

Fat

$$2\,C_{12}H_{16}O \;+\; 31O_2 \longrightarrow 24\,CO_2 + 16H_2O$$

$\Delta h = -5900$ Btu/lb oxygen

Ruffage

$$CH_2\,O + O_2 \longrightarrow CO_2 + H_2O$$

$\Delta h = -6360$ Btu/lb oxygen

For a typical incinerator load, 1.89 pounds of oxygen is required for each pound of solids incinerated. The average heat of reaction is 5650 Btu/lb.

The heat generated by the reaction is determined from the first law of thermodynamics.

$$q = E_2 - E_1$$

where

E_2 = internal energy of the products (Btu/lb)

E_1 = internal energy of the reactants (Btu/lb)

This equation can be written as:

$$q = \Sigma\, m_p\, c_{v,p}\,(T_2-T_B) - \Sigma\, m_R\, c_{v,R}\,(T_B-T_1) - \Delta h$$

where

T_2 = Product temperature (°F)

T_1 = Initial reactants temperature (°F)

T_B = 68°F, Reference temperature of reaction for Δh (°F)

m_p = Mass of reactants (lb)

m_R = Mass of reactants (lb)

The temperature of the incinerator then becomes

$$T_i = T'_i \ (\frac{q_i + q - q_{SURR}}{mc_p}) \ \Delta t$$

At the end of the reaction, the product gasses are vented to the environment.

4.0 Lower Level Subroutines Called

PSAT

QSURR

HTPIP

Component Subroutine No. 38 - Heat Pipe

1.0 Subroutine Description

This subroutine simulates an inert gas controllable heat pipe that may be used for temperature control of a near-isothermal system for a wide range of heat loads. As shown in the heat pipe schematic, Figure 1, heat is absorbed in the evaporator region and a phase change from liquid to vapor takes place. The vapor flows to the condenser region of the pipe where the process is reversed, vapor is condensed, and heat is rejected. This provides the capacity for transporting large quantities of thermal energy in a near-isothermal system.

2.0 Subroutine Data

2.1 General Notes

1. The source temperature is generally input via GPOLY logic.

2.2 Steady State K-Array Data

Reference Location	Description	Data Type
16	Table number for boiling temperature of the heat transport medium as a function of pressure.	I(R)

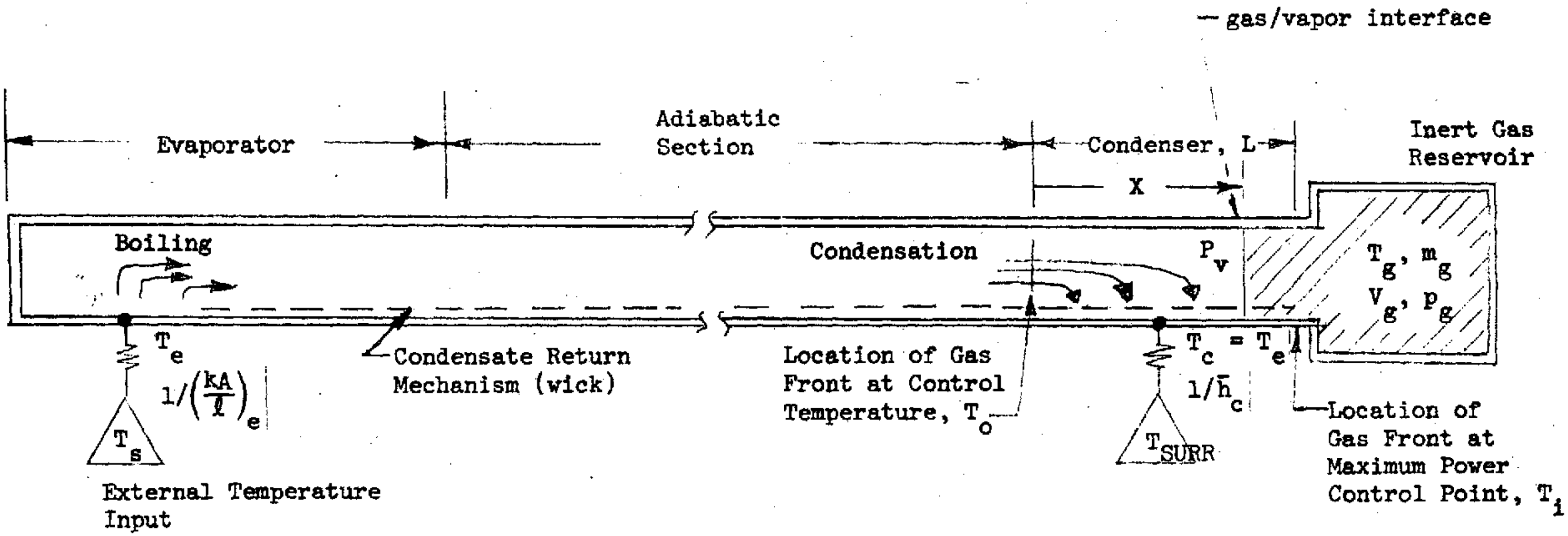
2.3 Steady State V-Array Data

Reference Location	Description	Data Type
65	Heat pipe control temperature (°F)	I(R)
66	Temperature of source from which heat is rejected (°F) (Input via GPOLY1 logic)	I(R)
67	Conductance (kA/ℓ) between the heat source and the heat pipe (Btu/hr-°F)	I(R)

FIGURE 1 - SCHEMATIC OF INERT GAS CONTROLLABLE HEAT PIPE

NOTE:

See Section 3.0 for definition of symbols



2.3 Steady State V-Array Data

Reference Location	Description	Data Type
68	Heat pipe diameter (ft)	I(R)
69	Length of the condensing region of the heat pipe (ft)	I(R)
70	Mass of the inert gas in the heat pipe (lb)	I(R)
71	Gas constant of the inert gas used (ft-lb/lb-°R)	I(R)
72	Heat pipe temperature at the cold end of heat pipe (°F) (Average temperature of gas).	I(R)
73	Volume of inert gas reservoir of heat pipe, (ft^3)	I(R)
74	Heat pipe internal pressure (psfa)	O
75	Heat rejected by the heat pipe (Btu/hr)	O
76	Heat transfer coefficient between surface of heat pipe and ambient gas (Btu/hr-ft^2-°F)	I(R)
77	Ambient temperature (°F)	I(R)
78	Temperature of the heat pipe in the evaporation region, (°F)	O
79	Not Used	
80	Convection heat transfer coefficient between surface of heat, pipe and ambient gas (Btu/hr-ft^2-°F)	I(R)
81	Thermal conductivity of heat pipe material (Btu/hr-ft-°F)	I(R)
82	Heat pipe thickness (ft)	I(R)

3.0 Analytical Model Description

The mathematical model simulating the inert gas controllable heat pipe is simplified by making the following assumptions:

1. The inert gas obeys the ideal gas law.
2. An infinitely sharp interface exists between the inert gas and vapor.
3. Steady state conditions exist.

There are three modes of heat rejection rate by the heat pipe considered in this analysis. The first is when the source temperature is below the control temperature (boiling temperature) of the heat transport medium in the evaporator. The heat pipe in this case is treated as a fin of finite length protruding from a heat source. The heat-flow rate from the heat pipe to the surroundings can then be expressed by the following relationship.

$$\dot{q}_{HP} = \sqrt{PhkA}\ (T_S - T)\tanh\left(\sqrt{\frac{hP}{kA}}\ L\right) \tag{1}$$

where:

$\dot{q}_{HP}$ = Heat flow from the heat pipe $(\frac{Btu}{hr})$

P = Perimeter of heat pipe (ft)

k = Pipe conductance $(\frac{Btu}{hr\text{-}^{o}F\text{-}Ft})$

A = Gross sectional area of heat pipe (ft^2)

T_S = Temperature of heat source (^{o}F)

T = Temperature of surroundings (^{o}F)

L = Pipe length (ft)

h = Corrective heat transfer coefficient between heat pipe condenser and the cooling medium ($Btu/hr\text{-}ft^2\text{-}^{o}F$)

The second mode of heat transfer through the heat pipe occurs when the source temperature exceeds the lower temperature level of the control temperature band. Increasing the evaporator power level increases the vapor pressure by moving the interface further down the pipe exposing more condenser area and decreasing the amount of volume available for the inert gas. This process is shown schematically in Figure 1. The algorithm adopted for the solution of heat flow through a heat pipe for this mode of heat transfer is as follows:

1. The evaporator temperature is first assumed to equal the heat pipe control temperature; from which, heat flow to the heat pipe from the heat source is computed.

$$q_{HP} = \left(\frac{kA}{\ell}\right)_e (T_s - T_e) \qquad (2)$$

where

$\left(\frac{kA}{\ell}\right)_e$ = Thermal conductance between heat pipe and heat source $\left(\frac{Btu}{hr\text{-}^\circ F}\right)$

T_e = Temperature of the evaporator ($^\circ$F)

T_s = Temperature of the source ($^\circ$F)

2. From the initial heat flow computation, q_{HP}, the condenser area, specifically the length of the condensing region of the heat pipe is computed.

$$X = q_{HP} \Big/ \left(\pi D \bar{h}_c \; (T_e - T_{SURR})\right) \qquad (3)$$

where

X = Length of effective condensing region of heat pipe (ft.)

D = Diameter of heat pipe (ft.)

$\bar{h}_c$ = Convective heat transfer coefficient $\left(\frac{Btu}{hr\text{-}^\circ F\text{-}ft^2}\right)$

3. The pressure of the inert gas is computed using the ideal gas law

$$p_g = m_g R_g T_g / (V_g + \pi D(L-X)) \qquad (4)$$

where

V_g = Volume of inert gas reservoir (ft^3)

m_g = Mass of inert gas in reservoir (lb.)

R_g = Inert gas constant $\left(\frac{ft\text{-}lb}{lb\text{-}^{\circ}F}\right)$

T_g = Temperature of inert gas (equals temperature of surrounding) ($^{\circ}F$)

p_g = Heat pipe pressure (psfa)

A new value for evaporator boiling temperature is determined from the input table data relating evaporator boiling temperature to pressure.

4. The new value for X, the length of the condensing region of the heat pipe, is compared against the last computed value and if the differe exceeds 1%, steps 1, 2, and 3 are repeated until the two values becom approximately equal.

The third mode of heat flux through the heat pipe occurs when the power reject requirements exceed the limitations of the pipe. That is, when the condensing region of the pipe encompasses the entire surface allowable. The procedure used in determining the heat flux is as follows:

The evaporator temperature is first computed from the predicted pressure of the heat pipe.

$$p_g = m_g R_g T_g / V_g \qquad (5)$$

$$T_e = f(p_g) \text{ (Table data)} \qquad (6)$$

where

p_g = Heat pipe pressure (psfa)

Initial heat flux is computed from the initial estimate for evaporator temperature, T_e.

$$q_{HP} = h_c \, \pi DL(T_e - T_{SURR}) \tag{7}$$

A new value for T_e is computed from the predicted heat flux and source temperature

$$T_e = T_s - q_{HP}/(kA/\ell) \tag{8}$$

where

T_s = Temperature of the source (°F)

kA/ℓ = Thermal conductance between source and heat pipe (Btu/hr-°F)

and then heat flux is recomputed using equation (7).

4.0 Lower Level Subroutines and Functions Required

None.

5.0 References

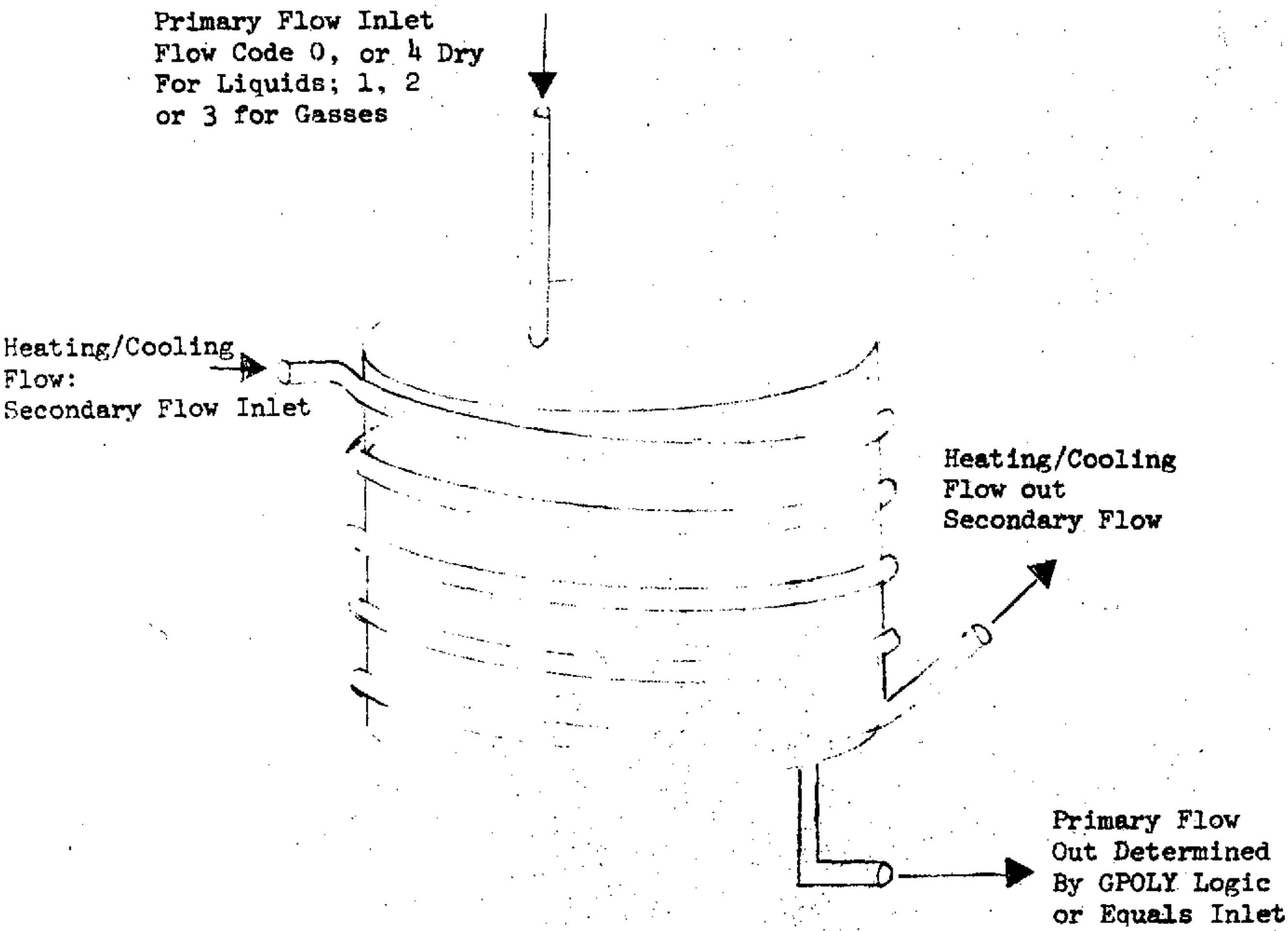
1. Kreith, F., Principles of Heat Transfer, International Textbook Company, Scranton, Pennsylvania, 1958.

TANKG

Component Subroutine No. 30 - Storage Tank

1.0 Subroutine Description

This subroutine simulates a storage tank fitted with one inlet and one outlet on the primary side that accepts either liquid or gas flow. (Flow codes 0 or 4 for liquids; flow codes 1, 2, or 3 for gasses). In addition, the tank can include the capability of transferring heat from or to the tank by means of fluid flowing through coils or other heat transfer devices which may either be attached to the tank wall or be immersed in the fluid in the tank. The heating/cooling fluid comprises the secondary inlet and outlet flows of the tank. The schematic of the tank is shown below:



The routine performs mass and thermal balances for either steady state or transient operation. It is capable of running adiabatic gas ventings and fillings as special cases. The tank is comprised of a tank shell, an optional layer of insulation, and the tank fluid. Two electrical heaters, one connected to the tank wall and the other immersed in the fluid, are provided for thermal control.

The tank exchanges heat with the environment according to the thermal model shown in Figure 2, which is a typical model for many G189A components.

2.0 Subroutine Data

2.1 General Notes

The inlet and outlet streams of principal concern are usually the primary flows. The secondary flow is used only as a heat transport medium which may be provided for thermal control of the tank. In some problems there may be no primary source component for the tank. For example, the tank may be a storage vessel with only a primary flow outlet capability. Even if there is no primary source component, the user must enter the correct flow code and special flow types on the KBAS card for the primary flow of the tank. The secondary flow data may be excluded if the heat addition/rejection capability in the tank is not provided. If the heating/cooling capability is included, the appropriate data must be entered in the KBAS and NSTR cards for the tank.

In most problems, the user will input data which specifies the initial total mass and composition inside the tank. The very nature of a tank (or storage device) is such that there is usually no relation between the flow out of the tank and the flow in. Inlet and exit flows are, in general, totally independent

The user, therefore, will set the outlet flow from the tank equal to a desired value in a GPØLY1 statement in most simulations. Only the total flow need be specified; the individual constituent flows will be determined by the routine from the known concentrations in the tank. The outlet flow could be keyed to demand schedules, evaluated from orifice equations, or determined by control logic.

2.2 Instruction Options

NSTR(1): Calculation of outlet flow during Steady State

= 0 In steady state calculations the outlet flow is set equal to the inlet flow despite any coding in GPØLY1. In transient, the GPØLY1 coding will be executed.

= 1 The outlet flow is determined by a GPØLY1 statement or the previous value if no GPØLY1 statement changes it.

NSTR(2): Steady State Heat Balance

= 0 In steady state, tank fluid temperature is equal to temperature of inflowing stream.

= 1 The tank fluid temperature is specified in R(68) and the heating or cooling load required to offset ambient heat losses and fluid expansion is calculated for steady state operation.

= 2 The tank fluid temperature is calculated by iteration on the steady state heat balance.

NSTR(3): Transient Heat Balance

= 0 Skip the transient heat balance and proceed according to NSTR(2)

= 1 Perform transient heat balance.

NSTR(4): Initial Mass or Volume in Tank.

= 0 Volume, pressure, and temperature are taken as correct in input data. Initial mass calculated by program.

= 1 Mass, pressure, and temperature are taken as correct input data. Volume calculated and used in transient runs.

NSTR(5): The provision for heat rejection/addition through use of secondary flow as heat transport medium.

= 0 No provision for heat rejection/addition through use of secondary flow as heat transport medium exists.

= 1 The heating/cooling device for thermal control of the tank is attached to the tank wall.

= 2 The heating/cooling device for thermal control of the tank is immersed in the tank.

2.3 Heat Loss V-Array Data

Reference Location	Description	Data Type
51	Temperature of tank wall, (°F)	0
52	Effective thermal conductance from tank wall to surroundings (Btu/hr-°F)	0
53	Total heat loss to surroundings (Btu/hr) R(53) = R(56) + R(59) + R(62)	0
54	Ambient gas temperature (°F)	I(R)
55	Thermal conductance between surface of insulation and ambient gas (Btu/hr-°F)	I(R)
56	Convective heat loss to ambient gas (Btu/hr)	0
57	Ambient wall temperature (°F)	I(R)
58	Thermal radiation A factor from surface of insulation to ambient wall (ft^2)	I(R)
59	Radiative heat loss to ambient wall (Btu/hr)	0
60	Structure temperature (°F)	I(R)
61	Conductance (kA/X) between tank wall and structure (Btu/hr-°F)	I(R)
62	Conductance heat loss to the structure (Btu/hr)	0
63	Insulation surface temperature (°F)	0
64	Conductance (kA/X) between tank wall and outer surface of insulation (Btu/hr-°F) (If R(64) = 0 there is no insulation)	I(R)

2.4 Steady State V-Array Data

Reference Location	Description	Data Type
65	Fluid heating or cooling load in steady state (Btu/hr)	I(0)
66	Tank wall heating or cooling load in steady state (Btu/hr)	I(0)
67	Effective heat transfer conductance (UA) between heating/cooling fluid and the tank wall or fluid Btu/hr - (^{o}F)	I(R) if NSTR(5)>
68	Maximum weight of liquid in tank. (Full conditions (lbs.)	I(R) if Flow co 0 or 4
69	Total fluid weight in tank (lb)	I(0)
70	Fluid temperature in tank (^{o}F)	I(0)
71	Fluid volume in tank (ft^3)	I(0)
72	Fluid pressure in tank (psia)	I(0)
73	Weight of non-condensables in tank (lb)	I(0)
74	Weight of condensable vapor (lb)	I(0)
75	Weight of condensable liquid (lb)	I(0)
76	Non-condensable specific heat in tank (Btu/lb-^{o}F)	I(0)
77	Non-condensable molecular weight (lb)	I(0)
78	Weight of oxygen in tank (lb)	I(0)
79	Weight of diluent in tank (lb)	I(0)

Reference Location	Description	Data Type
80	Weight of CO_2 in tank (lb)	I(O)
81	Weight of trace contaminants in tank (lb)	I(O)
82	Weight of special flow type 1 (lb)	I(O)
83	Weight of special flow type 2 (lb)	I(O)
84	Weight of special flow type 3 (lb)	I(O)
85	Weight of special flow type 4 (lb)	I(O)
86	Weight of special flow type 5 (lb)	I(O)
87	Weight of special flow type 6 (lb)	I(O)
88	Specific heat of fluid in tank (Btu/lb-°R)	O
89	Density of fluid in tank (lb/ft^3)	O
90	Viscosity of fluid (lbm/ft-hr)	O
91	Molecular weight of fluid in tank (lb/lb-mole)	O

2.5 Transient V-Array Data

Reference Location	Description	Data Type
92	Thermal capacitance of tank shell (Btu/°F) (If zero, steady state logic will be used.)	I(R)
93	Thermal conductance between internal fluid and tank wall (Btu/hr-°F) (If R(91) = 0 process will be adiabatic.)	I(R)
94	Maximum allowable temperature change in one internal compute step to avoid instabilities in the heat balances (°F) (Typical value = 5°F)	I(R)
95.	External heat load to fluid (Btu/hr)	I(R)
96	External heat load to tank wall (Btu/hr)	I(R)
97	Rate of change of mass in tank (lb/hr)	O

2.6 Special Input Feature

It will be noticed that reference locations 69 to 87 contain information analogous to what is contained in the A or B arrays. The difference is that pounds replace pounds/hr and R(71) contains the tank volume instead of a pressure. Ordinarily the user must input data values into most of these locations in order to define the initial contents of the tank.

There is a special option (which does not depend on flagging an NSTR variable) which simplifies inputting the initial contents of the tank. The user can either (a) input the actual initial mass of each constituent, or (b) input the percent or fraction or relative amount of each constituent. The value for the total mass in the tank R(69) will be taken as correct and the mass of the individual constituents will be calculated by a scaling or normalization procedure.

3.0 Analytical Model Description

3.1 Mass Balance

The rate of change of the mass of species i within the tank is given by

$$\frac{dm_i}{dt} = w_{i,in} - w_{i,out} \tag{1}$$

3.2 Energy Balance

An energy balance for the fluid within the tank is developed in this section. In words, the conservation of energy for an open system in the absence of mechanical work is

Rate of change of internal energy = Rate of flow of enthalpy in − Rate of flow of enthalpy out + Heat added

In mathematical notation

$$\frac{dU}{dt} = \sum_{i=1}^{n} w_{i,in}\, h_{i,in} - \sum_{i=1}^{n} w_{i,out}\, h_{i,out} + q \tag{2}$$

where

U = Total internal energy of fluid in the tank (Btu)

w_i = Rate of flow of species i (lb/hr)

h_i = Specific enthalpy of species i (Btu/lb)

q = Rate of heat transfer into fluid (Btu/hr)

n = Number of species in the stream

The subscripts "in" and "out" refer to the inlet and outlet flows, respectively.

The total internal energy within the tank is given by

$$U = \sum_{i=1}^{n} m_i \; u_i \qquad (3)$$

where

m_i = Mass of species i in the tank (lb)

u_i = Specific internal energy of species i (Btu/lb)

The time derivative of U is broken into two terms as follows:

$$\frac{dU}{dt} = \sum m_i \frac{du_i}{dt} + \sum u_i \frac{d\,m_i}{dt} \qquad (4)$$

For incompressible liquids and ideal gases, the specific internal energy u_i is a function of temperature only, so that

$$\frac{d\,u_i}{dt} = \frac{d\,u_i}{dT}\frac{dT}{dt} = c_{v,i}\frac{dT}{dt} \qquad (5)$$

where

$c_{v,i}$ = The specific heat at constant volume (Btu/lb-°R)

T = Absolute temperature (°R)

Substituting for dU/dt into the energy equation, Equation 4, gives

$$\sum m_i \, c_{vi} \frac{dT}{dt} = \sum w_{i,in} \; h_{i,in} - \sum w_{i,out} \, h_{i,out} - \sum u_i \frac{dm_i}{dt} + q \qquad (6)$$

Using the relation $d\,m_i/dt = w_{i,in} - w_{i,out}$ and defining $\sum m_i \, c_{vi} = mc_v$ the balance becomes

$$(m\,c_v) \frac{dT}{dt} = \sum w_{i,in} \left[h_{i,in} - u_i \right] - \sum w_{i,out} \left[h_{i,out} - u_i \right] + q \qquad (7)$$

The specific internal energy can be written

$$u_i = h_i - p\,v_i \tag{8}$$

for ideal gases $p\,v_i = R_{gi}\,T = (c_{pi} - c_{vi})\,T$ whereas for liquids (except at high pressure) $u_i = h_i$

Thus, both gases and liquid can be handled by the same equation if we set the c_v of a liquid equal to its c_p.

Substituting for u_i into the energy balance gives

$$m\,c_v\,\frac{dT}{dt} = \sum w_{i,in}\,(h_{i,in} - h_i) + \sum w_{i,in}\,(c_{pi} - c_{vi})\,T$$

$$- \sum w_{i,out}\,(c_{pi} - c_{vi})\,T + q \tag{9}$$

but

$$h_{i,in} - h_i = \int_{T}^{T_{in}} c_{pi}\,dT = c_{pi}\,(T_{in} - T) \text{ for constant } c_{pi} \tag{10}$$

Thus, the final energy balance employed in the subroutine is

$$m\,c_v\,\frac{dT}{dt} = w_{in}\,c_{p,in}\,(T_{in} - T) + w_{in}\,(c_{p,in} - c_{v,in})\,T$$

$$- w_{out}\,(c_{p,out} - c_{v,out})\,T + q \tag{11}$$

where

m = Total mass in tank (lb)

c_v = See $c_{v,out}$

T = Absolute temperature of fluid in tank (°R)

w_{in} = Total rate of flow into tank (lb/hr)

T_{in} = Aboslute temperature of inlet stream (°R)

$c_{p,in}$ = Constant pressure specific heat of inlet stream (Btu/lb-°R)

$c_{v,in}$ = Constant volume specific heat of inlet stream (btu/lb-°R)

w_{out} = Total flow of outlet stream (lb/hr)

$c_{p,out}$ = Constant pressure specific heat of outlet stream (Btu/lb-°R)

$c_{v,out}$ = Constant volume specific heat of outlet stream (Btu/lb-°R)

q = Rate of heat transfer into fluid (Btu/hr)

Three checks on the overall energy balance are provided below:

Special Cases

1. Adiabatic venting $w_{in} = 0 \quad q = 0$

$$m \, c_v \frac{dT}{dt} = - w_{out} \, (c_p - c_v) \, T \tag{12}$$

but $w_{out} = - dm/dt$ so that

$$\frac{dT}{T} = \frac{c_p - c_v}{c_v} \frac{dm}{m} = (\gamma - 1) \frac{dm}{m} \tag{13}$$

$$\ln \frac{T_2}{T_1} = (\gamma - 1) \ln \frac{m_2}{m_1} \tag{14}$$

$$\frac{T_2}{T_1} = \frac{\rho_2}{\rho_1}^{\gamma - 1} \qquad \text{Q.E.D.} \tag{15}$$

2. Adiabatic Filling $w_{out} = 0$ $dm/dt = w_{in}$ $q = 0$

$$m\, c_v \frac{dT}{dt} = \frac{dm}{dt}\, c_p\, (T_{in} - T) + (c_p - c_v)\, T \tag{16}$$

$$= \frac{dm}{dt}\, c_v\, (\gamma\, T_{in} - T)$$

$$\frac{dT}{\gamma T_{in} - T} = \frac{dm}{m} \tag{17}$$

$$- \ell n \frac{\gamma T_{in} - T_2}{\gamma T_{in} - T_1} = \ell n \frac{m_2}{m_1} \tag{18}$$

$$\frac{T_2 - \gamma T_{in}}{T_1 - \gamma T_{in}} = \frac{m_1}{m_2} \qquad \text{Q.E.D} \tag{19}$$

3. Adiabatic draining of a liquid $c_p = c_v$ $w_{in} = 0$ $q = 0$

$$m\, c_v \frac{dT}{dt} = 0$$

which implies that the temperature of the liquid stays constant, which is correct.

The external heat flow into the fluid is comprised of two terms

$$q = UA\, (T_{tank} - T) + q_{elecf} \tag{20}$$

where

UA = Heat transfer conductance between fluid and tank wall (Btu/hr-°R)

T_{tank} = Temperature of tank wall (°F)

q_{elecf} = A heat source term that simulates an electrical heater immersed in the fluid (Btu/hr)

A thermal balance on the tank shell is also made in the subroutine, to wit:

$$(m\ c_p)\ \frac{d\ T_{tank}}{dt} = UA\ (T - T_{tank}) + q_{elect} - q_{surr} \qquad (21)$$

where

$(m\ c_p)$ = Thermal capacitance of tank shell (Btu/°F)

q_{elect} = A heat source term which simulates electrical strip heaters mounted directly on the tank (Btu/hr)

q_{surr} = Heat losses to the surroundings (Btu/hr) (calculated by a standard subroutine, QSURR)

The subroutine calculates a stable computing time based on thermal and fluid flow time constants. The stable computing time is then employed in a simple forward difference integration of the differential equations. For steady state, the thermal balance is solved by iteration.

4.0 Lower Level Subroutines and Functions Required

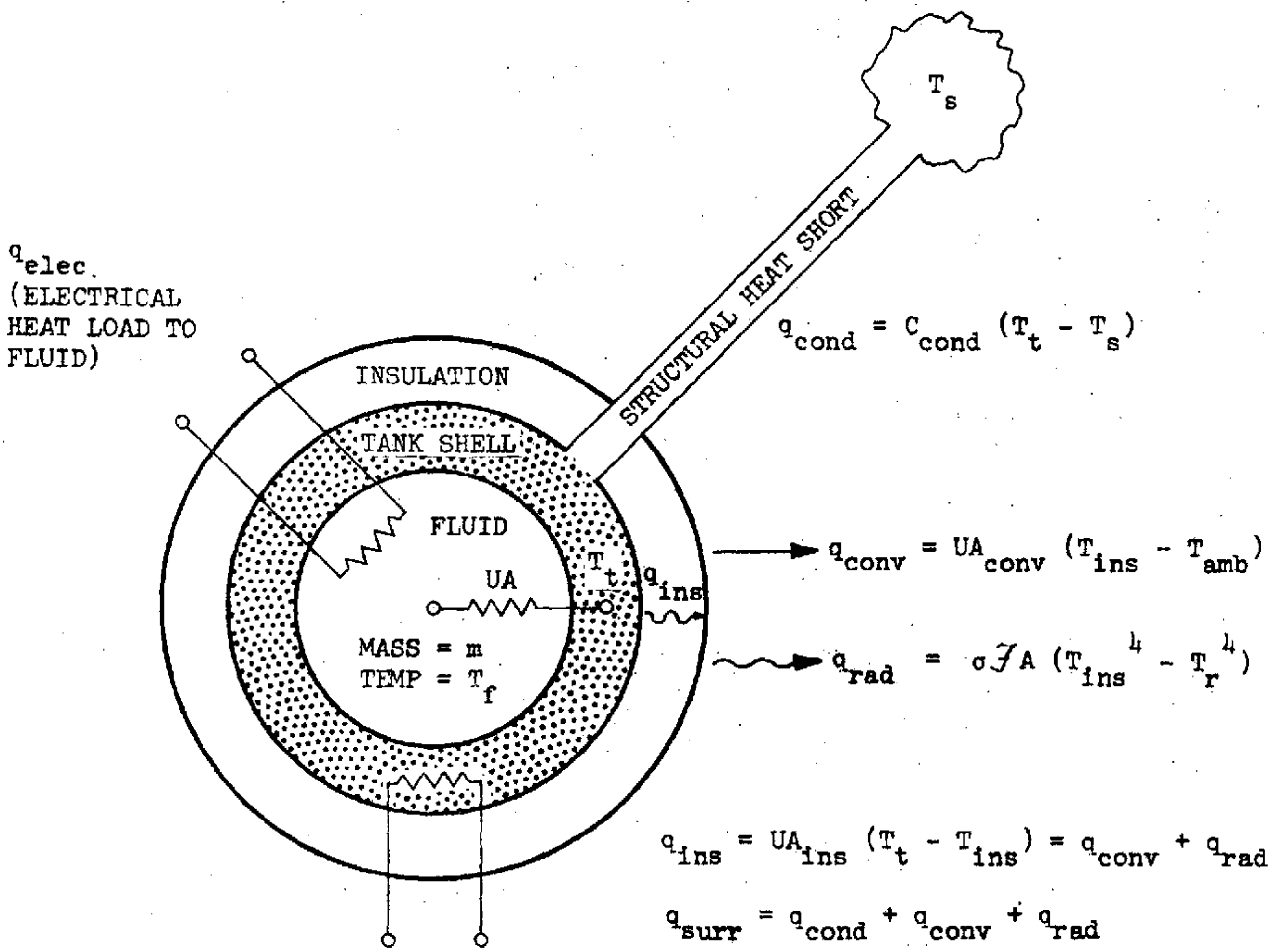
QSURR

PRØP

5.0 References

(1) The general energy balances were based on Chapter 15: Macroscopic Balances for Nonisothermal Systems from

Bird, R. B., Stewart, W. E., Lightfoot, E. N.: Transport Phenomena, John Wiley and Sons, Inc. (1960)



q_{elect} = Electrical heat load to tank case

FIGURE 1 THERMAL MODEL FOR TANK SUBROUTINE

Appendix B

INPUT DATA CARDS DESCRIPTION

The complete set of G189A input data cards required to run the RITE system simulation are listed in this Appendix. The input cards may be classified into four functional groups, they are: Case Data, K & V Component Data, Table Data and Plot Data. A complete description of each card and options available to the programmer are available in the G189 Program Manual, Reference 3.

The Case Data group contains such data as necessary to specify the overall data storage arrangement, describe the model in general and control the execution of the case. Included are such items as:

Number of components
Start time
Pressure drop flag
Steady state and/or transient run flag
Steady state or transient mode type
Maximum number of iterations allowed
Iteration tolerances
Input/output flags
Maximum/Minimum allowable values of system/component parameters

This group also contains the fluid property data (point values of heat capacity, ratio of heat capacities, viscosity, molecular weight and thermal conductivity) for each of the constituents of flow.

The K and V Component Data groups consists of all the data required to specify and describe each component. These data include the connection and option data entered in integer format and the numerical values describing the physical properties of the component entered in floating point format. The former are referred to as K array values while the latter are referred to as V array values. Some of these items are:

K Array

Component subroutine number
Primary and Secondary flow code
Primary and Secondary source flow comp. no's.
Extra storage location requirements
Table numbers for fluid property and pressure drop curves

V Array

Physical dimensions (areas, lengths, diameters, etc.)
Heat transfer conductance terms
Heat transfer source temperatures
Pressure loss coefficients

Each of the K and V array card contains a descriptive comment section which describes its function.

The Table Data group contains all the tables or curves referenced by the K and V Component Data. The form of the tables may be two dimensional (one independent variable) or three dimensional (two independent variables). These tables relate such variables as input flows as a function of time and heat transfer properties as a function of temperature.

The Plot Data group is included as the last portion of data in a case when SK-4060 graphical output is desired. As many as six variables may be plotted in one figure. The plot cards contain "self documenting" commentary feature.

```
TAPE
BASIC             1      239      139       1      YEA       NAY
CASE           RITE JOB  USING SS SOLUTION FOR CONDENSER DURING TRANS
 $CASE1
  KCHOUT=0, KPRNT=6, KPTINV(1)=1 ,MAXSLP=6, MINSS1=2 ,KRUN=1, DTIME=60.,
  TIMEMX=1200.,MAXSS1=3 ,TMAX=2000., TMIN=-450.,WTMAX=1.E4 $
 $PROP1
 CP(1)=1.,RHO(1)=62.4    ,VISC(1)= 3.6  ,WTM(1)=18.0    ,XK(1)=.325     ,
 CP(2)=.722    ,RHO(2)=67.6  ,VISC(2)=.396    ,WTM(2)=25.2     ,XK(2)=.2276 ,
 CP(3)=.175,RHO(3)=.25   ,VISC(3)= .036 ,WTM(3)=44.0    ,XK(3)=.007      ,
 CP(14)=.20    ,RHO(14)=.01144,VISC(14)=.008 ,WTM(14)=2.0    ,XK(14)=.08  ,
 CP(15)=.60    ,RHO(15)=81.744,VISC(15)=38.   ,WTM(15)=60.1   ,XK(15)=.7   ,
 CP(16)=.50    ,RHO(16)=76.0   ,VISC(16)=22.   ,WTM(16)=120.   ,XK(16)=0.2  ,
 CP(5)=.25     ,RHO(5)=.1      ,VISC(5)=.008    ,WTM(5)=46.      ,XK(5)=.08  ,
 CP(6)=.25     ,RHO(6)=.1      ,VISC(6)=.008    ,WTM(6)=30.      ,XK(6)=.08  ,
 CP(17)=1.     ,RHO(17)=62.4   ,VISC(17)=3.6   ,WTM(17)=18.     ,XK(17)=.325,
 CP(25)=.60    ,RHO(25)=81.744,VISC(25)=38.   ,WTM(25)=1.0E+9,XK(12)=.7   ,
 CP(26)=.50    ,RHO(26)=76.0   ,VISC(26)=22.   ,WTM(26)=1.0E+9,XK(26)=0.2  ,
  GAMGAS=1.4, VISGAS=0.44, WTMCON=18., WTMOIL=28., WTMTC=17.,
  CPCONL=1., CPCONV=0.44, CPCO2=0.2, CPOIL=0.25, CPOXY=0.22, CPTC=0.5,
  CPCO2 = .178,       WTMCON=18. ,     XKLIQ=.36   ,
  XKGAS=0.146 $
ID**    1      COOLANT SUPPLY
NSTR    1   -0                         NONE RORD
KBAS    1      49             0   2
VARY    1    1 280.0          COOLANT INPUT FLOW  RATE(LB/HR)
VARY    1    2 35.0           COOLANT INLET TEMPERATURE
ID**    2   -0 SPLIT TO WATER COOLER OR WATER HEATER(NORMALLY TO COOLER)
KBAS    2   -0 10            9 0   2                  0  2              3
NSTR    2   -00                        USE UNIVERSAL SPLIT RATIO FOR ALL FLOWS
ID**    3   -0 LIQMIX FROM HEATING LOOP (NORMALLY COOLANT FLOW)
KBAS    3   -0  7            2 0   2               120 0    2           80
NSTR    3   -01                        USE PRIMARY FLOW PRESS AS MIX PRESS
ID**    5   -0 SPLIT TO  HEATING  LOOP  (NORMALLY COOLANT FLOW )
KBAS    5   -0 10          -94 0   2                  0  2              6
NSTR    5   -00                        USE UNIVERSAL SPLIT RATIO FOR ALL FLOWS
ID**    6   -0 LIQMIX FROM WATER HEATER(NORMALLY COOLANT FLOW )
KBAS    6   -0  7            5 0   2               119 0    2           10
NSTR    6   -01                        USE PRIMARY FLOW PRESS AS MIX PRESS
ID**    8   -0 METERED OUTLET COOLANT FLOW
KBAS    8   -0 29  4        10 0   2                                   180
NSTR    8   -00                        METER TOTAL FLOW ONLY.
ID**    9   -0 FLOW TEE  TO PROVIDE FLOW TO WATR SUPPLY AND CONDENSER
KBAS    9   -0 10            1 0   2                                    2
NSTR    9   -00                        UNIVERSAL SPLIT RATIO
VARY    9    1 20.0           COOLANT FLO BYPASSES CONDENSER           LB/HR
VARY    9    2 35.            TEMPERATURE OF THE COOLANT               DEG-F
VARY    9    3 15.            PRESS.                                   PSI
VARY    9    4 15.            PRESS.                                   PSI
VARY    9   20 260.           COOLANT FLOWRATE THROUGH CONDENSER       LB/HR
VARY    9   21 35.            TEMPERATURE OF THE COOLANT               DEG-F
VARY    9   22 15.
VARY    9   23 15.
VARY    9   65 .924
ID**   10   -0 FLO JUNCTION ALLOW FOR RETURN FLOW FROM EITHER HX FOR H2O SUPPLI
KBAS   10   -0  7            6 0   2              -238 0    2           8
NSTR   10   -03                        USE MAX PRESS
ID**   21   -0 COMPONENT PROVIDING AIR/URINE FLOW THROUGH THE COMODE.
KBAS   21   -0 49            3  142526171819                           22
```

```
NSTR  21  -0
ID**  22  -0 COMMODE MIXING THE AIR FLOW WITH WATER.
KBAS  22  -0  6          21 3  142526171819    -47 3  142526171819    23
NSTR  22  -01                        THE MIXED FLOW PRESSURE EQUALS PRIM SOURCE
ID**  23  -0 LIQUID-GAS SEPARATOR.
KBAS  23  -0 10 12       22 3  142526171819        3  142526171819    28
NSTR  23  -01                        EACH OUTLET CONSTITUENT USES OWN SPLIT RATIO
VARY  23  73 1.0              SPIT RATIO  FOR  SF* 2  (UREA)
VARY  23  74 1.0              SPIT RATIO  FOR  SF* 3  (SOLIDS)
VARY  23  75 1.0              SPIT RATIO  FOR  SF* 4  (WATER)
ID**  24   1 AIR BLOWER 20 CFM ,STATIC PRESS=15. INCHES WATER, REQUIRING
ID**  24   2 APPROXIMATELY 120 WATTS.   SUBROUTINE FAN
KBAS  24  -0 23          28 3  14 5 6 7 8 9                           25
NSTR  24  -0003                      ADD HEAT SPECIFIED IN R(91) ONLY.
ID**  25  -0 REGENERATIVE COUNTERFLOW HEAT EXCHANGER (AIR STERILIZER).
KBAS  25  -0 37 50 35    24 3  14 5 6 7 8 9                           27
KARY  25  16          12      NUMBER  OF NODES
KARY  25  17          35      NUMBER OF HEAT TRANSFER TERMS
KARY  25  19 0000001000       STORAGE TERM,NODE NO.  1
KARY  25  20 0000002000       STORAGE TERM,NODE NO.  2
KARY  25  21 0000003000       STORAGE TERM,NODE NO.  3
KARY  25  22 0000004000       STORAGE TERM,NODE NO.  4
KARY  25  23 0000005000       STORAGE TERM,NODE NO.  5
KARY  25  24 0000006000       STORAGE TERM,NODE NO.  6
KARY  25  25 0000007000       STORAGE TERM, NODE NO.  7
KARY  25  26 0000008000       STORAGE TERM, NODE NO.  8
KARY  25  27 0000009000       STORAGE TERM, NODE NO.  9
KARY  25  28 0000010000       STORAGE TERM, NODE NO. 10
KARY  25  29 0000011000       STORAGE TERM, NODE NO. 11
KARY  25  30 0000012000       STORAGE TERM, NODE NO. 12
KARY  25  31 3000007116       FLUID CONVECTION SOURCE TO 7
KARY  25  32 5000007004       WALL TO FLUID CONVECTION  4 TO 7
KARY  25  33 4000007001       WALL TO FLUID CONVECTION  1 TO 7
KARY  25  34 2000008007       FLUID CONVECTION ,7 TO 8
KARY  25  35 5000008005       WALL TO FLUID  CONVECTION  5 TO 8
KARY  25  36 4000008002       WALL TO FLUID  CONVECTION  2 TO 8
KARY  25  37 2000009008       FLUID CONVECTION ,8  TO 9
KARY  25  38 5000009006       WALL TO FLUID  CONVECTION   6 TO 9
KARY  25  39 4000009003       WALL TO FLUID  CONVECTION   3 TO 9
KARY  25  40 2000011010       FLUID CONVECTION  10 TO 11
KARY  25  41 4000011005       WALL  TO  FLUID CONVECTION  5 TO 11
KARY  25  42 2000012011       FLUID CONVECTION  11 TO 12
KARY  25  43 4000012004       WALL TO FLUID CONVECTION   4 TO 12
KARY  25  44 2000010009       FLUID CONVECTION   9 TO 10
KARY  25  45 4000010006       WALL TO FLUID CONVECTION   6 TO 10
KARY  25  46 6000001117       CONDUCTION  SOURCE TO  1
KARY  25  47 6000002117       CONDUCTION  SOURCE TO  2
KARY  25  48 6000003118       CONDUCTION  SOURCE TO  3  HEAT FROM HEAT BLOCK
KARY  25  49 5000001002       NODE  TO NODE  CONDUCTION   1 TO  2
KARY  25  50 5000002003       NODE  TO NODE  CONDUCTION   2 TO  3
KARY  25  51 5000006005       NODE  TO NODE  CONDUCTION   6 TO  5
KARY  25  52 5000005004       NODE  TO NODE  CONDUCTION   5 TO  4
KARY  25  53 7000006003       NODE  TO NODE  RADIATTION   6 TO  3
VARY  25  65 1.00             SOLUTION  CONVERGENCE TOLERANCE  (DEG F)
VARY  25  69  220.0           TEMPERATURE   NODE  NO. 1
VARY  25  70 400.00           TEMPERATURE   NODE  NO. 2
VARY  25  71 1280.0           TEMPERATURE   NODE  NO. 3
VARY  25  72  230.0           TEMPERATURE   NODE  NO. 4
VARY  25  73 400.00           TEMPERATURE   NODE  NO. 5
```

```
VARY  25  74 1250.0        TEMPERATURE   NODE  NO. 6
VARY  25  75 1200.0        TEMPERATURE   NODE  NO. 7
VARY  25  76 200.00        TEMPERATURE   NODE  NO. 8
VARY  25  77 1200.0        TEMPERATURE   NODE  NO. 9
VARY  25  78 1200.0        TEMPERATURE   NODE  NO.10
VARY  25  79 1200.0        TEMPERATURE   NODE  NO.11
VARY  25  80 1200.0        TEMPERATURE   NODE  NO.12
VARY  25  81 0.268         CAPACITANCE  NODE   NO. 1
VARY  25  82 0.252         CAPACITANCE  NODE   NO. 2
VARY  25  83 0.126         CAPACITANCE  NODE   NO. 3
VARY  25  84 0.1078        CAPACITANCE  NODE   NO. 4
VARY  25  85 0.3895        CAPACITANCE  NODE   NO. 5
VARY  25  86 0.1100        CAPACITANCE  NODE   NO. 6
VARY  25  87 0.            CAPACITANCE  NODE  NO.  7
VARY  25  88 0.            CAPACITANCE  NODE  NO.  8
VARY  25  89 0.            CAPACITANCE  NODE  NO.  9
VARY  25  90 0.            CAPACITANCE  NODE  NO. 10
VARY  25  91 0.            CAPACITANCE  NODE  NO. 11
VARY  25  92 0.            CAPACITANCE  NODE  NO. 12
VARY  25  93 1.0           FLUID CONVECTION  SOURCE TO 7
VARY  25  94 3.31          WALL TO FLUID CONVECTION  4 TO 7
VARY  25  95 3.0           WALL TO FLUID CONVECTION  1 TO 7
VARY  25  96 1.0           FLUID CONVECTION    7 TO 8
VARY  25  97 32.           WALL  TO  FLUID CONVECTION   5 TO 8
VARY  25  98 3.0           WALL TO  FLUID CONVECTION  2 TO 8
VARY  25  99 1.0           FLUID  CONVECTION    8 TO 9
VARY  25 100 3.3
VARY  25 101 3.0
VARY  25 102 1.0           FLUID  CONVECTION     10 TO 11
VARY  25 103 32.
VARY  25 104 1.0           FLUID CONVECTION  11 TO 12
VARY  25 105 1.4           WALL TO FLUID CONVECTION   4 TO 12
VARY  25 106 1.0           FLUID CONVECTION  9 TO 10
VARY  25 107 2.3           WALL  TO  FLUID CONVECTION  6 TO 10
VARY  25 108 0.7           CONDUCTION  SOURCE  TO  1
VARY  25 109 0.7           CONDUCTION  SOURCE  TO  2
VARY  25 110 2000.         CONDUCTION  SOURCE  TO  3
VARY  25 111 0.0275        NODE TO  NODE CONDUCTION   1 TO 2
VARY  25 112 0.0275        NODE TO  NODE CONDUCTION   2 TO 3
VARY  25 113 0.1874        NODE TO  NODE CONDUCTION   6 TO 5
VARY  25 114 0.1874        NODE TO  NODE CONDUCTION   5 TO 4
VARY  25 115 .135          INLET  TEMPERATURE  (DEG F)
VARY  25 116 100.0         INLET  TEMPERATURE  (DEG F)
VARY  25 117 250.0         ENVIRONMENTAL TEMPERATURE (DEG F)
VARY  25 118 1280.0        HEAT BLOCK  TEMPERATURE  (DEG F)
ID**  27  -0 FLOWMETER TO MEASURE THE FLOW OUT OF THE AIR STERILIZER.
KBAS  27  -0 29 10      25 3  14 5 6 7 8 9                          203
NSTR  27  -00                   METER TOTAL FLOW
ID**  28  -0 FLOW JUNCTION PROVIDES MEANS OF INTRODUCING AIR FROM WATER LOOP
KBAS  28  -0  6         23 3  1425261718l9    232 3  14 5 6 7 8 9    24
NSTR  28  -02                   SECONDARY PRESSURE# MIX PRESSURE
ID**  41   1 FLUSH WATER TANK WITH INTERNAL HEAT EXCHANGER OUTLET FLOW
ID**  41   2 DETERMINED BY GPOLY LOGIC  STEADY STATE AND TRANSIENT HEAT BL
KBAS  41  -0 30         45 4  141516 11819    -124 0   1                43
NSTR  41    12012               OUTFLO=GPOLY,INTERNAL HX
VARY  41  51 100.            TANK TEMP                                  DEG-F
VARY  41  54 75.           AMBIENT GAS TEMPERATURE                      F
VARY  41  60 80.           STRUCTURE TEMP.                              F
VARY  41  61 2.77778       CONDUCTANCE BETWEEN TNK WALL/STRUCTURE     B/H-F
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VARY  41  67 .578             EFFECTIVE  UA BETWEEN  HEAT EXCHANGER TO FLUID
VARY  41  68 40.0             MAXIMUM CAPACITY  OF TANK  (LB)
VARY  41  69 30.              TOTAL FLUID WEIGHT IN TNK                   LBS
VARY  41  70 100.             FLUID TEMP IN TNK                           F
VARY  41  71 .48077           FLUID VOLUME IN TNK                         FT**3
VARY  41  72 15.              FLUID PRESS IN TNK                          PSI
VARY  41  85 30.              WEIGHT OF CONDENSABLE LIQUID                LBS
VARY  41  88 1.               SPECIFIC HEAT OF FLUIDS IN TNK              B/LB-F
VARY  41  92                  THERMAL CAPACITANCE OF TNK SELL             BTU/F
VARY  41  93 100.             CONDUCTANCE INTERVAL FLUID/TNK              B/HR-F
VARY  41  94 5.0              MAX ALLOWABLE TEMP CHANGE                   F
VARY  41  95                  EXTERNAL HT LOAD TO FLUID                   BTU/HR
VARY  41  96                  EXTERNAL HT LOAD TO SHELL                   BTU/HR
ID**  43  -0 PIPING TEE PROVIDING FOR MEANS OF STORING THE ECS CONDENSATE
KBAS  43  -0  7            41 4  141516 11819     -51 4  141516 11819     44
NSTR  43  -0
ID**  44  -0 PUMP USED FOR CIRCULATING AND PUMPING THE FLUSH WATER.
KBAS  44  -0 22            43 4  141516 11819                             45
NSTR  44  -00002                       ADD HEAT SPECIFIED NO OTHER CALCULATIONS REQRD
ID**  45  -0 VALVE DIRECTING THE FLOW TO EITHER THE TANK OR WASTE MANG SYS
KBAS  45  -0 10  5         44 4  141516 11819         4  141516 11819     46
NSTR  45  -00                          USE UNIVERSAL SPLIT RATIO ALL CONSTITUENTS
ID**  46  -0 PIPING TEE DIRECTING FLOW TO URINE SYS AND/OR SOLID PROC SYS
KBAS  46  -0 10  5        -45 4  141516 11819         4  141516 11819     47
NSTR  46  -00                          USE UNIVERSAL SPLIT RATIO ALL CONSTITUENTS
ID**  47  -0 VALVE SIMULATED BY DUMMY COMPONENT TO THE COMMODE
KBAS  47  -0 49            46 4  141516 11819                             48
NSTR  47  -00                          VALVE CONTROLLING FLOW TO COMMODE  PASS DATA
ID**  48  -0 PIPING TEE DIRECTING FLOW TO THE DEFECATION AND/OR TRASH UNIT
KBAS  48  -0 10  5        -46 4  141516 11819         4  141516171819     49
NSTR  48  -00                          USE UNIVERSAL SPLIT RATIO ALL CONSTITUENTS
ID**  49  -0 VALVE SIMULATED BY DUMMY COMPONENT TO TRASH PROCESSING UNIT.
KBAS  49  -0 49            48 4  141516 11819                             50
NSTR  49  -00                          VALVE CONTROLING FLO TO SHREDER  PASS DATA
ID**  50  -0 VALVE SIMULATED BY DUMMY COMPONENT, TO THE DEFECATION UNIT.
KBAS  50  -0 49           -48 4  141516 11819                             21
NSTR  50  -00                          VALVE CONTROLLING FLO TO CRAPPER PASS DATA
ID**  51  -0 CONDENSATE INPUT FROM ECS PRESPIRATION/RESPIRATION
KBAS  51  -0 49               4  141516 11819
NSTR  51  -00                          NONE REQRD
VARY  51   2 70.04            ECS CONDENSATE  INPUT TEMP(DEG F))
VARY  51  17 0.834            ECS CONDENSATE  INPUT FLOW (LB/HR)
ID**  61  -0 FLOW METERING OF GASSES OUTFLOWIN FROM CONENSING TNK
KBAS  61  -0 29 17        -237 3  14                                      62
NSTR  61  -01                          METER ALL CONSTITUENT FLOWS
ID**  62  -0 FLOW CONTROL VALVE SIMULATED BY LTOMIX
KBAS  62  -0 10           237 0    1                  -65 0    1          63
NSTR  62  -03                          USE PRESS FROM PRINC SOURCE
ID**  63  -0 WATER PUMP USED IN PUMPING FLOW FROM EITHER/TO WATER ACCU.
KBAS  63  -0 22            62 0    1                                      64
NSTR  63  -00002                       ADD HT SPECIFIED NO OTHER CALCS REQRD
ID**  64   1 TEE WHICH PROVIDES A MEANS OF FLOWING WATER FROM THE ACCUMULATOR
ID**  64   2 TANK OR FROM THE CONDENSING TANK
KBAS  64  -0 10            63 0    1                                      65
NSTR  64  -00                          PRIMARY SOURCE PRESSURE USED
VARY  64  65 1.0              OUMP DIRECTLY TO ROTABLE WATER UNIT
ID**  65  -0 WATER SIDE OF WATER ACCUMULATOR CYCLIC OPERATION
KBAS  65  -0 30            64 0    1                                      66
NSTR  65    12010                      OUTFLO=GPOLY,NO INTERNAL HX
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VARY  65  51 85.0            TANK TEMP                                    DEG-F
VARY  65  54 75.           AMBIENT GAS TEMPERATURE                        DEG-F
VARY  65  55 1.            THERMAL CONDUCTANCE BETWEEN SURFACE AND AMB B/HR-F
VARY  65  57 80.           AMB WALL TEMP                                  DEG-F
VARY  65  58 .22           RADIATION , FA, FACTOR                         FT**2
VARY  65  60 80.           STURCTURE TEMP                                 DEG-F
VARY  65  61 1.            CONDUCTANCE (KA/X) TANK TO STRUCTURE           B/HR-F
VARY  65  68 10.           CAPACITY OF TANK                               LBS.
VARY  65  69 10.           INITIAL WEIGHT OF TNK                          LBS.
VARY  65  70 85.           INITIAL TEMPERAT OF TNK                        F-DEG
VARY  65  71 .16           TANK VOLUME                                    FT**3
VARY  65  72 15.           TANK PRESSURE                                  PSI
VARY  65  75 10.           WEIGHT OF LIQUID IN TNK                        LB
VARY  65  88 1.             CP OF FLUID IN TANK                           B/LB-F
VARY  65  89 62.4          DENSITY OF FLUID IN TNK                        LB/FTCU
VARY  65  90 3.6           VISCOSITY OF WATER
VARY  65  91 18.           MOLECUCULAR WEIGHT OF FLUID IN TANK            LB/LB-MOLE
VARY  65  92 .5            THERMAL CAPACITANCE OF TNK SHELL               B//OI
VARY  65  94 5.0           MAX ALLOWABLE TEMP CHANGE                      F-DEG
ID**  66  -0 FLOW METER FOR MEASUREMENT OF WATER FLOW.
KBAS  66  -0 29  4       -64 0   1                                         9
NSTR  66  -00                     METER TOTAL FLOW ONLY
ID**  80  -0 TEE PROVIDING FLOW TO 2 OTHER SPLITS NO. 81 AND 82 SIMULTD BY SPLIT
KBAS  80  -0 10           66 0   1                       0  1              81
NSTR  80  -00                     UNIVERSAL SPLIT RATIO FOR AL CONSTITUENT FLOS
ID**  81  -0 TEE PROVIDING FLOW TO TNKS 1 AND 2  SIMULATED BY SPLIT
KBAS  81  -0 10           80 0   1                       0  1              82
NSTR  81  -00                     UNIVERSAL SPLIT RATIO FOR AL CONSTITUENT FLOS
ID**  82  -0 TEE PROVIDING FLOW TO TNKS 3 AND 4  SIMULATED BY SPLIT
KBAS  82  -0 10          -80 0   1                       0  1              83
NSTR  82  -00                     UNIVERSAL SPLIT RATIO FOR AL CONSTITUENT FLOS
ID**  83  -0 POTABLE STORAGE TNK 4  (TANKG)
KBAS  83  -0 30           82 0   1                 115 0   1               84
NSTR  83    12012                 OUTFLO=GPOLY,INTERNAL HX
VARY  83  51 150.            TANK TEMP                                    DEG-F
VARY  83  54 75.           AMBIENT GAS TEMP                               F
VARY  83  57 75.           AMBIENT WALL TEMP                              F
VARY  83  60 80.           STRUCTURE TEMP                                 F
VARY  83  61 3.15369       CONDUCTANCE TNK WALL/STRUCTURE                 B/HR-F
VARY  83  64 0.            CONDUCTANCE TNK WALL/INSULATION SURFACE        BTU/HR-F
VARY  83  67 6.656254      THERMAL CONDUCTANCE OF HEATING TUBES
VARY  83  68 41.5          MAXIMUM FLUID WEIGHT  IN TANK (LB)
VARY  83  69 20.0          INITIAL WEIGHT OF WATER IN TANK (LB)
VARY  83  70 150.          TEMP OF FLUID                                  F
VARY  83  71 .609          FLUID VOLUME IN TNK                            FT**3
VARY  83  72 15.           PRESS                                          PSI
VARY  83  88 1.0           SPECIFIC HEAT OF FLUID IN TNK                  BTU/LB-F
VARY  83  92 1.0           THERMAL CAPACITANCE OF TANK (BTU/DEG F)
VARY  83  93 100.          THERMAL CONDUCTANCE BETWEEN FLUID AND WALL(BTU/H-F)
VARY  83  94 5.0           MAX  ALLOWABLE TEMP. CHANGE (DEG :)
ID**  84  -0 POTABLE STORAGE TNK 3  (TANKG)
KBAS  84  -0 30          -82 0   1                 114 0   1               85
NSTR  84    12012                 OUTFLO=GPOLY,INTERNAL HX
VARY  84  51 150.            TANK TEMP                                    DEG-F
VARY  84  54 75.           AMBIENT GAS TEMP                               F
VARY  84  57 75.           AMBIENT WALL TEMP                              F
VARY  84  60 80.           STRUCTURE TEMP                                 F
VARY  84  61 3.15369       CONDUCTANCE TNK WALL/STRUCTURE                 B/HR-F
VARY  84  64 0.            CONDUCTANCE TNK WALL/INSULATION SURFACE        BTU/HR-F
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VARY   84   67 6.656254         THERMAL CONDUCTANCE OF HEATING TUBES
VARY   84   68 41.5             MAXIMUM FLUID WEIGHT  IN TANK (LB)
VARY   84   69 20.0             INITIAL WEIGHT OF WATER IN TANK (LB)
VARY   84   70 150.             TEMP OF FLUID                                   F
VARY   84   71 .609             FLUID VOLUME IN TNK                             FT**3
VARY   84   72 15.              PRESS                                           PSI
VARY   84   88 1.0              SPECIFIC HEAT OF FLUID IN TNK                   BTU/LB-F
VARY   84   92 1.0              THERMAL CAPACITANCE OF TANK (BTU/DEG F)
VARY   84   93 100.             THERMAL CONDUCTANCE BETWEEN FLUID AND WALL(BTU/H-F)
VARY   84   94 5.0              MAX  ALLOWABLE TEMP. CHANGE (DEG :)
ID**   85   -0 JUNCTION TO MERGE FLO FROM TNKS 3 AND 4  (LIQMIX)
KBAS   85   -0  7          83 0   1              -84 0    1                  87
NSTR   85   -00                      USE MIN PRESSURE AS MIXED FLO PRESS
ID**   86   -0 POTABLE STORAGE TNK 2  (TANKG)
KBAS   86   -0 30         -81 0   1              113 0    1                  88
NSTR   86     12012                  OUTFLO=GPOLY,INTERNAL HX
VARY   86   51 150.               TANK TEMP                                     DEG-F
VARY   86   54 75.              AMBIENT GAS TEMP                                F
VARY   86   57 75.              AMBIENT WALL TEMP                               F
VARY   86   60 80.              STRUCTURE TEMP                                  F
VARY   86   61 3.15369          CONDUCTANCE TNK WALL/STRUCTURE                  B/HR-F
VARY   86   64 0.               CONDUCTANCE TNK WALL/INSULATION SURFACE         BTU/HR-F
VARY   86   67 6.656254         THERMAL CONDUCTANCE OF HEATING TUBES
VARY   86   68 41.5             MAXIMUM FLUID WEIGHT  IN TANK (LB)
VARY   86   69 20.0             INITIAL WEIGHT OF WATER IN TANK (LB)
VARY   86   70 150.             TEMP OF FLUID                                   F
VARY   86   71 .609             FLUID VOLUME IN TNK                             FT**3
VARY   86   72 15.              PRESS                                           PSI
VARY   86   88 1.0              SPECIFIC HEAT OF FLUID IN TNK                   BTU/LB-F
VARY   86   92 1.0              THERMAL CAPACITANCE OF TANK (BTU/DEG F)
VARY   86   93 100.             THERMAL CONDUCTANCE BETWEEN FLUID AND WALL(BTU/H-F)
VARY   86   94 5.0              MAX  ALLOWABLE TEMP. CHANGE (DEG :)
ID**   87   -0 POTABLE STORAGE TNK 1  (TANKG)
KBAS   87   -0 30          81 0   1              112 0    1                  86
NSTR   87     12012                  OUTFLO=GPOLY,INTERNAL HX
VARY   87   51 150.               TANK TEMP                                     DEG-F
VARY   87   54 75.              AMBIENT GAS TEMP                                F
VARY   87   57 75.              AMBIENT WALL TEMP                               F
VARY   87   60 80.              STRUCTURE TEMP                                  F
VARY   87   61 3.15369          CONDUCTANCE TNK WALL/STRUCTURE                  B/HR-F
VARY   87   64 0.               CONDUCTANCE TNK WALL/INSULATION SURFACE         BTU/HR-F
VARY   87   67 6.656254         THERMAL CONDUCTANCE OF HEATING TUBES
VARY   87   68 41.5             MAXIMUM FLUID WEIGHT  IN TANK (LB)
VARY   87   69 20.0             INITIAL WEIGHT OF WATER IN TANK (LB)
VARY   87   70 150.             TEMP OF FLUID                                   F
VARY   87   71 .609             FLUID VOLUME IN TNK                             FT**3
VARY   87   72 15.              PRESS                                           PSI
VARY   87   88 1.0              SPECIFIC HEAT OF FLUID IN TNK                   BTU/LB-F
VARY   87   92 1.0              THERMAL CAPACITANCE OF TANK (BTU/DEG F)
VARY   87   93 100.             THERMAL CONDUCTANCE BETWEEN FLUID AND WALL(BTU/H-F)
VARY   87   94 5.0              MAX  ALLOWABLE TEMP. CHANGE (DEG :)
ID**   88   -0 JUNCTION TO MERGE FLO FROM TNKS 1 AND 2  (LIQMIX)
KBAS   88   -0  7          86 0   1              -87 0    1                  90
NSTR   88   -00                      USE MIN PRESSURE AS MIXED FLO PRESS
ID**   89   -0 JUNCTION PROVIDES MEANS OF UTILIZING EMERGENCY POTABLE WATER SUPPL
KBAS   89   -0  7          85 0   1              -90 0    1                  91
NSTR   89   -00                      USE MIN PRESSURE AS MIXED FLO PRESS
ID**   90   -0 EMERGENCY POTABLE STORAGE TNK (TANKG)
KBAS   90   -0 30              0   1              116 0    1                  89
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NSTR  90    12012                   OUTFLO=GPOLY,INTERNAL HX
VARY  90   51 150.                   TANK TEMP                               DEG-F
VARY  90   54 75.                  AMBIENT GAS TEMP                          F
VARY  90   57 75.                  AMBIENT WALL TEMP                         F
VARY  90   60 80.                  STRUCTURE TEMP                            F
VARY  90   61 3.15369              CONDUCTANCE TNK WALL/STRUCTURE            B/HR-F
VARY  90   64 0.                   CONDUCTANCE TNK WALL/INSULATION SURFACE   BTU/HR-F
VARY  90   67 6.656254             THERMAL CONDUCTANCE OF HEATING TUBES
VARY  90   69 41.0                 INITIAL WEIGHT OF WATER IN TANK (LB)
VARY  90   70 150.                 TEMP OF FLUID                             F
VARY  90   71 .609                 FLUID VOLUME IN TNK                       FT**3
VARY  90   72 15.                  PRESS                                     PSI
VARY  90   88 1.0                  SPECIFIC HEAT OF FLUID IN TNK             BTU/LB-F
VARY  90   92 1.0                  THERMAL CAPACITANCE OF TANK (BTU/DEG F)
VARY  90   93 100.                 THERMAL CONDUCTANCE BETWEEN FLUID AND WALL(BTU/H-F)
VARY  90   94 5.0                  MAX  ALLOWABLE TEMP. CHANGE (DEG :)
ID**  91   -0 JUNCTION PROVIDES OF MERGING ALL POTABLE WATER SUPPLY  (LIOMIX)
KBAS  91   -0  7            89 0   1               -88 0   1            99
NSTR  91   -00                      USE MIN PRESSURE AS MIXED FLO PRESS
ID**  92   -0 TEE PROVIDING FLOW TO WATER COOLER/HEATER SIMULATED BY SPLIT
KBAS  92   -0 10            91 0   1                 0  1               93
NSTR  92   -00                      UNIVERSAL SPLIT RATIO FOR AL CONSTITUENT FLOS
ID**  93   -0 WATER COOLER SIMULATED BY ANYHX
KBAS  93   -0  4            92 0   1              -118 0   1            95
NSTR  93    200020000  0000001   COUNTERFLOW, LIQ-LIQ --SS CALCULATION
VARY  93   66 12.0            OVERALL UA BTU/HR-F
ID**  94   -0 WATER HEATER SIMULATED BY ANYHX
KBAS  94   -0  4           -92 0   1                -3 0   2            96
NSTR  94    200020000  0000001   COUNTERFLOW, LIQ-LIQ --SS CALCULATION
VARY  94   66 12.0            OVERALL UA BTU/HR-F
ID**  95   -0 FLOWMETER SIMULATED BY FLOMET
KBAS  95   -0 29  4         93 0   1                                    94
NSTR  95   -00                      METER TOTAL FLO ONLY
ID**  96   -0 FLOWMETER SIMULATED BY FLOMET
KBAS  96   -0 29  4         94 0   1                                     5
NSTR  96   -00                      METER TOTAL FLO ONLY
ID**  99   -0 WATER DELIVERY PUMP
KBAS  99   -0 22            91 0   1                                    92
NSTR  99   -00002                   ADD HEAT ONLY
ID** 100   -0 LOW TEMPERATURE  RADIOISOTOPE HEATER
KBAS 100   -0 37 14  9    137 0                                        102
NSTR 100   -00                      USE CURRENT SIMULATION TIME
KARY 100   16            3     NUMBER OF NODES
KARY 100   17            9     NUMBER OF HEAT TRANSFER TERMS
KARY 100   19 0000001000       STORAGE TERM NO 1  (BTU/F)
KARY 100   20 0000002000       STORAGE TERM NO 2  (BTU/F)
KARY 100   21 0000003000       STORAGE TERM NO 3  (BTU/F)
KARY 100   22 3000001082       FLUID CONVECTION SOURCE TO NODE TERM (B/HR-F)
KARY 100   23 5000002001       CONDUCTANCE NODE 1 TO NODE 2 (B/HR-F)
KARY 100   24 5000003001       CONDUCTANCE NODE 1 TO NODE 3 (B/HR-F)
KARY 100   25 5000003002       CONDUCTANCE NODE 2 TO NODE 3 (B/HR-F)
KARY 100   26 6000003081       CONDUCTANCE NODE 3 TO SURROUNDINGS (B/HR-F)
KARY 100   27 1000002080       HEAT GENERATION TERM  BTU/HR
VARY 100   65 2.5
VARY 100   66 0.               PERIOD (NOT RQRD)
VARY 100   67 0.               INITIAL DISPLACEMENT OF INDEPENDENT VARBL  NOT RQRD
VARY 100   68                  CALCULATION TIME STEP. (SECONDS)
VARY 100   69 185.0            TEMPERATURE OF NODE 1 (DEG F)
VARY 100   70 640.0            TEMPERATURE OF NODE 2 (DEG F)
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VARY 100  71 170.27          TEMPERATURE OF NODE 3                            DEG-F
VARY 100  72 2.              CAPACITANCE NODE 1   (BTU/F)
VARY 100  73 20.             CAPACITANCE NODE 2   (BTU/F)
VARY 100  74 240.            CAPACITANCE NODE 3   (BTU/F)
VARY 100  75 603.0           FLUID CONVECTION  WCP  SOURCE TO NODE 1 (B/HR-F)
VARY 100  76 8.61            CONDUCTION NODE 1 TO NODE 2  (B/HR-F)
VARY 100  77 8.57            CONDUCTION NODE 1 TO NODE 3  (B/HR-F)
VARY 100  78 2.45            CONDUCTION NODE 2 TO NODE 3  (B/HR-F)
VARY 100  79 18.8            CONDUCTION NODE 3 TO SOURCE,SURROUNDINGS (B/HR-F)
VARY 100  80 5120.           HEAT GENERATED      (BTU/HR)
VARY 100  81 80.             EFFECTIVE TEMPERATURE OF THE SURROUNDINGS
VARY 100  82 179.0           TEMPERATURE OF INLET  STREAN (DEG F)
ID** 101  -0 EXPANSION TANK SIMULATED BY TANKS
KBAS 101  -0 30
NSTR 101    12010                   OUTFLO=GPOLY,NO INTERNAL HX
VARY 101  51 100.              TANK TEMP                                      DEG-F
VARY 101  54 75.             AMBIENT GAS TEMPERATURE                          DEG-F
VARY 101  55 .01             THERMAL CONDUCTANCE BTWN SURFACE OF INSULATION/GAS
VARY 101  57 70.             AMBIENT WALL TEMPERATURE                         DEG-F
VARY 101  58 1.2             THERMAL RADIATION FA FACTOR                      FT**2
VARY 101  60 140.            STRUCTURE TEMPERATURE                            DEG-F
VARY 101  61 .005            CONDUCTANCE KA/X TO THE STRUCTURE                B/HR-FT-F
VARY 101  64 0.              NO INSULATION
VARY 101  68 3.5             FLUID CAPACITY OF WATER ACCUMULATOR              LBS
VARY 101  69 2.0             TOTAL FLUID WEIGHT IN TNK                        LBS.
VARY 101  70 100.            FLUID TEMP. IN TNK                               F
VARY 101  71 .0320512        FLUID VOLUME IN TNK                              FT**3
VARY 101  72 15.0            FLUID PRESS IN TNK                               PSI
VARY 101  75 2.0             WEIGHT OF CONDENSABLE LIQUID                     LBS
VARY 101  88 1.0             SPECIFIC HEAT OF FLUIDS IN TNK                   B/LB-F
VARY 101  92                 THERMAL CAPACITANCE OF TNK SHELL                 BTU/F
VARY 101  93                 CONDUCTANCE BETWEEN INTERNAL FLUID TNK           BTU/HR-F
VARY 101  94 5.0             MAX ALLOWABLE TEMP CHANGE                        F
VARY 101  95                 EXTERNAL HT LOAD TO FLUID                        BTU/HR
VARY 101  96 0.              EXTERNAL HT TO SHELL                             BTU/HR
ID** 102  -0 LIQMIX FROM EXPANSION TANK
KBAS 102  -0  7           101 0   1                -100 0   1                 103
NSTR 102  -01                      MIX PRESS DEPENDENT ON PRINCIPAL SOURCE
ID** 103  -0 SPLIT TO PUMPS
KBAS 103  -0 10           102 0   1                   0   1                   104
NSTR 103  -00                      USE UNIVERSAL SPLIT RATIO FOR ALL FLOWS
ID** 104  -0 COOLANT PUMP NO. 1
KBAS 104  -0 22           103 0   1                                           105
NSTR 104  -00002                   ADD HEAT SPECIFIED NO OTHER CALCULATIONS RORD
VARY 104  85 10.             HEAT ADDED TO FLUID STREAM                       WATTS
ID** 105  -0 COOLANT PUMP NO. 2
KBAS 105  -0 22          -103 0   1                                           106
NSTR 105  -00002                   ADD HEAT SPECIFIED NO OTHER CALCULATIONS RORD
ID** 106  -0 LIQMIX FROM PUMPS
KBAS 106  -0  7           104 0   1                -105 0   1                 107
NSTR 106                           MAX PRESS OF TWO SOURCES
ID** 107  -0 SPLIT AROUND EVAPORATOR
KBAS 107  -0 10           106 0   1                   0   1                   108
NSTR 107  -00                      USE UNIVERSAL SPLIT RATIO
ID** 108  -0 SPLIT  TO EVAPORATOR
KBAS 108  -0 10           107 0   1                   0   1                   109
NSTR 108  -00                      USE UNIVERSAL SPLIT RATIO
VARY 108  65 0.07064672    SPLIT TO EVAPORATOR
ID** 109  -0 EVAPORATOR COOLING LIQUID CONTROL VALVE
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KBAS 109  -0 10         -108 0   1                    0   1             112
NSTR 109                     1    USE SS SOLUTION DURING TRANSIENT,MAX PRESS
VARY 109   1 360.          HTNG FLUID FLOWRATE                         LB/HR
VARY 109   2 157.5         HTNG FLUID TEMP.                            F
VARY 109   3 15.           HTNG FLUID PRESS                            PSI
VARY 109   4 15.           HTNG FLUID PRESS                            PSI
ID** 110  -0 LIQMIX FROM EVAPORATOR
KBAS 110  -0  7         -109 0   1             -239 0   1               111
NSTR 110  -03                     MIX PRESS DEPENDENT ON PRINCIPAL SOURCE
ID** 111  -0 LIQMIX FROM BYPASS AND EVAPORATOR
KBAS 111  -0  7          110 0   1              107 0   1               134
NSTR 111                          MAX PRESS OF TWO SOURCES
ID** 112  -0 SPLIT TO POTABLE WATER STORAGE TANK NO.1
KBAS 112  -0 10          108 0   1                    0   1             113
NSTR 112  -00                     USE UNIVERSAL SPLIT RATIO
VARY 112  65 0.1322        SPLIT TO TANK NO. 1
ID** 113  -0 SPLIT TO POTABLE WATER STORAGE TANK NO.2
KBAS 113  -0 10          112 0   1                    0   1             114
NSTR 113  -00                     USE UNIVERSAL SPLIT RATIO
VARY 113  65 0.15233       SPLIT TO TANK NO. 2
ID** 114  -0 SPLIT TO POTABLE WATER STORAGE TANK NO.3
KBAS 114  -0 10          113 0   1                    0   1             115
NSTR 114  -00                     USE UNIVERSAL SPLIT RATIO
VARY 114  65 0.1797        SPLIT TO TANK NO. 3
ID** 115  -0 SPLIT TO POTABLE WATER STORAGE TANK NO.4
KBAS 115  -0 10          114 0   1                    0   1             116
NSTR 115  -00                     USE UNIVERSAL SPLIT RATIO
VARY 115  65 0.21907       SPLIT TO TANK NO. 4
ID** 116  -0 SPLIT TO POTABLE WATER STORAGE TANK NO.5
KBAS 116  -0 10          115 0   1                    0   1             117
NSTR 116  -00                     USE UNIVERSAL SPLIT RATIO
VARY 116  65 0.2805        SPLIT TO TANK NO. 5
ID** 117  -0 SPLIT TO WATER HEATER
KBAS 117  -0 10          116 0   1                    0   1             118
NSTR 117  -00                     USE UNIVERSAL SPLIT RATIO
VARY 117  65 0.36842       SPLIT TO WATER HEATER
ID** 118  -0 BYPASS LIQMIX FROM COOLING LOOP(NORMALLY HEATING LOOP FLOW)
KBAS 118  -0  7         -117 0   1                  2 0   2             120
NSTR 118                          MAX PRESS OF TWO SOURCES
ID** 119  -0 LIQUID SPLIT TO COOLING LOOP(NORMALLY HEATING LOOP)
KBAS 119  -0 10          -93 0   1                                      128
NSTR 119  -00                     USE UNIVERSAL SPLIT RATIO
VARY 119  65 0.            ALL FLOW TO HTNG LOOP  .
ID** 120  -0 SPLIT TO WATER COOLER(NORMALLY NO HEATING FLOW)
KBAS 120  -0 10          117 0   1                    0   1             121
NSTR 120  -00                     USE UNIVERSAL SPLIT RATIO
VARY 120  65 0.0           0.0 PER CENT FLOW TO WATER COOLER
ID** 121  -0 SPLIT TO AIR HEATER AND WARM FLUSH WATER TANK
KBAS 121  -0 10          120 0   1                    0   1             122
NSTR 121  -00                     USE UNIVERSAL SPLIT RATIO
VARY 121  65 0.58333333    SPLIT TO AIR   HEATER
ID** 122  -0 LIQUID CONTROL VALVE TO AIR HEATER
KBAS 122  -0 10         -121     1                    0   1             124
NSTR 122  -00                     USE UNIVERSAL SPLIT RATIO
VARY 122  65 1.            ALL FLOW BYPASSES AIR HEATER.
ID** 123  -0 LIQMIX AT AIR HEATER
KBAS 123  -0  7         -204 0   1              122 0   1               126
NSTR 123  -03                     MIX PRESS DEPENDENT ON PRINCIPAL SOURCE
ID** 124  -0 LIQUID CONTROL VALVE TO WARM FLUSH WATER TANK
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KBAS 124  -0 10            121 0   1                        0   1              41
NSTR 124  -00                        USE UNIVERSAL SPLIT RATIO
VARY 124  65 0.                  ALL HTNG FLUID FLOWS THROUGH FLUSH WATR TNK
ID** 125  -0 LIQMIX AT MAIN FLUSH WATER TANK
KBAS 125  -0  7           -41 0   1                    124 0   1               123
NSTR 125                             MAX PRESS OF TWO SOURCES
ID** 126  -0 LIQMIX FROM AIR HEATER AND FLUSH WATER TANK
KBAS 126  -0  7            125 0   1                  -123 0   1               127
NSTR 126                             MAX PRESS OF TWO SOURCES
ID** 127  -0 LIQMIX FROM WATER COOLER(NORMALLY NO FLOW)
KBAS 127  -0  7            126 0   1                     5 0   1               119
NSTR 127                             MAX PRESS OF TWO SOURCES
ID** 128  -0 LIQMIX FROM WATER HEATER
KBAS 128  -0  7            127 0   1                  -119 0   1               129
NSTR 128                             MAX PRESS OF TWO SOURCES
ID** 129  -0 LIQMIX FROM WATER NO.5
KBAS 129  -0  7            128 0   1                    90 0   1               130
NSTR 129                             MAX PRESS OF TWO SOURCES
ID** 130  -0 LIQMIX FROM WATER NO.4
KBAS 130  -0  7            129 0   1                    83 0   1               131
NSTR 130                             MAX PRESS OF TWO SOURCES
ID** 131  -0 LIQMIX FROM WATER NO.3
KBAS 131  -0  7            130 0   1                    84 0   1               132
NSTR 131                             MAX PRESS OF TWO SOURCES
ID** 132  -0 LIQMIX FROM WATER NO.2
KBAS 132  -0  7            131 0   1                    86 0   1               133
NSTR 132                             MAX PRESS OF TWO SOURCES
ID** 133  -0 LIQMIX FROM WATER NO.1
KBAS 133  -0  7            132 0   1                    87 0   1               110
NSTR 133                             MAX PRESS OF TWO SOURCES
ID** 134  -0 LIQMIX TO HEAT EXCHANGER
KBAS 134  -0  7            111 0   1                  -133 0   1               136
NSTR 134                             MAX PRESS OF TWO SOURCES
ID** 135  -0 WATER SUPPLY
KBAS 135  -0 49                0   1
NSTR 135  -00                        DUMMY COMPONENT PROVIDE AIR THROUG HX NON ROR
VARY 135   1 60.             FLOWRATE OF CLNT TO RITE TEMP CNTRL           LB/HR
VARY 135   2 75.             TEMP OF CLNT.                                 DEG-F
VARY 135   3 14.7            PRESS                                         PSI
VARY 135   4 14.7            PRESS                                         PSI
ID** 136  -0 SPLIT FOR BYPASSING COOLANT IN TEMP CONTROL OF RADIOISOTOPE
KBAS 136  -0 10            135 0   1                        0   1              137
NSTR 136                             MAX PRESS OF TWO SOURCES
ID** 137  -0 HEAT EXCHANGER
KBAS 137  -0  4            134 0   1                    136 0   1              139
NSTR 137  -0200020000                CRUSSFLO,GAS-LIQD,UA INPUT NO SIZING.
VARY 137   1 426.            HTNG FLU LOW TEMP RITE=3.8 GPM                LB/HR
VARY 137   1 603.0           LOW TEMPERATURE LOOP  FLOW RATE (LB/HR)
VARY 137   2 179.0           LOW TEMPERATURE LOOP  TEMPERATURE(DEG F)
VARY 137   3 15.0            PRESS                                         PSI
VARY 137   4 15.0            PRESS                                         PSI
VARY 137  66 50.0            EFFECTIVE  UA
ID** 139  -0 FLOW JUNCTION PERMITS FLOW RITE TEMP CONTROL HX TO MIX
KBAS 139  -0  7            136 0   1                    137 0   1              100
NSTR 139  -01                        PRI PRESS DETERMINES MIX PRESS.
ID** 180  -0   HEAT BLOCK ASSY. SIMULATED BY SUBROUTINE THERML
ID** 180   1 HEAT BLOCK SIMULATED BY SUBROUTINE THERML
KBAS 180  -0 37 46 36                                                          181
KARY 180  16           9     NUMBER OF NODES
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KARY 180  17          36     NUMBER OF HEAT TRANSFER  TERMS
KARY 180  19 0000001000      NODE 1 HEAT STORAGE TERM FOR RADIOISOTOPE+CORE
KARY 180  20 0000002000      NODE 2 HEAT STORAGE TERM BLOCK TO HEAT PIPE
KARY 180  21 0000003000      NODE 3 HEAT STORAGE TERM BLOCK TO AIR STERILIZER
KARY 180  22 0000004000      NODE 4 HEAT STORAGE TERM BLOCK TO PYROLYSIS 1
KARY 180  23 0000005000      NODE 5 HEAT STORAGE TERM BLOCK TO PYROLYSIS 3
KARY 180  24 0000006000      NODE 6  HEAT STORAGE TERM  PYROLYSIS UNIT NO. 2
KARY 180  25 0000007000      NODE 7 HEAT STORAGE TERM BLOCK TO INCINERATOR
KARY 180  26 0000008000      NODE 8 HEAT STORAGE TERM INNER WALL
KARY 180  27 0000009000      NODE 9 HEAT STORAGE TERM INNER WALL
KARY 180  28 1000001000      HEAT GENERATION TERM      ISOTOPI
KARY 180  29 1000002000      HEAT GENERATION TERM      HEAT PIPE
KARY 180  30 1000003000      HEAT GENERATION TERM      AIR STERILIZER
KARY 180  31 1000004000      HEAT GENERATION TERM      PU 1
KARY 180  32 1000005000      HEAT GENERATION TERM      PU 2
KARY 180  33 1000006000      HEAT GENERATION TERM      PU 3
KARY 180  34 1000007000      HEAT GENERATION TERM      INCINERATOR
KARY 180  35 5000001002      CONDUCTION  NODE 1 TO NODE  2
KARY 180  36 5000001003      CONDUCTION  NODE 1 TO NODE  3
KARY 180  37 5000001004      CONDUCTION  NODE 1 TO NODE  4
KARY 180  38 5000001005      CONDUCTION  NODE 1 TO NODE  5
KARY 180  39 5000001006      CONDUCTION  NODE 1 TO NODE  6
KARY 180  40 5000001007      CONDUCTION  NODE 1 TO NODE  7
KARY 180  41 5000002003      CONDUCTION  NODE 2 TO NODE  3
KARY 180  42 5000002007      CONDUCTION  NODE 2 TO NODE  7
KARY 180  43 5000003004      CONDUCTION  NODE 3 TO NODE  4
KARY 180  44 5000003007      CONDUCTION  NODE 3 TO NODE  7
KARY 180  45 5000003008      CONDUCTION  NODE 3 TO NODE  8
KARY 180  46 5000004005      CONDUCTION  NODE 4 TO NODE  5
KARY 180  47 5000004008      CONDUCTION  NODE 4 TO NODE  8
KARY 180  48 5000005006      CONDUCTION  NODE 5 TO NODE  6
KARY 180  49 5000005008      CONDUCTION  NODE 5 TO NODE  8
KARY 180  50 5000006007      CONDUCTION  NODE 6 TO NODE  7
KARY 180  51 5000006008      CONDUCTION  NODE 6 TO NODE  8
KARY 180  52 5000007008      CONDUCTION  NODE 7 TO  NODE 8
KARY 180  53 5000008009      CONDUCTION NODE 8 TO NODE 9 TERM  IN WALL TO O WAL
KARY 180  54 6000009114      CONDUCTION  NODE  9 TO  AMBIENT TEMPERATURE
VARY 180  65 10.             SOLUTION CONVERGENCE TOLERANCE               DEG-F
VARY 180  69 1260.           TEMP NODE 1  HEAT BLOCK RADIOISOTOPE         DEG-F
VARY 180  70 1200.           TEMP NODE 2  HEAT BLOCK TO HT PIPE           DEG-F
VARY 180  71 1200.           TEMP NODE 3  HEAT BLOCK    AIR STERILIZER DEG-F
VARY 180  72 1200.           TEMP NODE 5  HEAT BLOCK    PYROLYSIS UNIT1DEG-F
VARY 180  73 1200.           TEMP NODE 5  HEAT BLOCK    PYROLYSIS UNIT2DEG-F
VARY 180  74 1200.           TEMP NODE 6  HEAT BLOCK    PYROLYSIS UNIT3DEG-F
VARY 180  75 1200.           TEMP NODE 7  HEAT BLOCK   INCINERATOR        DEG-F
VARY 180  76  810.           TEMP NODE 8  HEAT BLOCK    INNER SHELL     -F
VARY 180  77 290.0           OUTER WALL TEMPERATURE  (DEG F )
VARY 180  78 7.0             HEAT STORAGE TERM NODE 1 RADIOISOTORE REG BTU/F
VARY 180  79 5.0             HEAT STORAGE TERM NODE 2 HP REGION          BTU/F
VARY 180  80 3.0             HEAT STORAGE TERM NODE 3 AS REGION          BTU/F
VARY 180  81 3.0             HEAT STORAGE TERM NODE 4 PU1 REGION         BTU/F
VARY 180  82 3.0             HEAT STORAGE TERM NODE 5 PU2 REGION         BTU/F
VARY 180  83 3.0             HEAT STORAGE TERM NODE 6 PU3 REGION         BTU/F
VARY 180  84 4.0             HEAT STORAGE TERM NODE 7 INCIN REGION       BTU/F
VARY 180  85 4.1             HEAT STORAGE TERM NODE 8 INNER WALL         BTU/F
VARY 180  86 4.2             HEAT STORAGE TERM NODE 9 OUTSIDE WALL       BTU/F
VARY 180  87 1574.           HEAT GENERATED BY RADIOISOTOPE              BTU/HR
VARY 180  88 100.            HEAT LOST TO HP                             BTU/HR
VARY 180  89 5.              HEAT LOST TO AS                             BTU/HR
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VARY 180  90 68.             HEAT LOST TO PU1                                BTU/HR
VARY 180  91 68.             HEAT LOST TO PU2                                BTU/HR
VARY 180  92 68.             HEAT LOST TO PU3                                BTU/HR
VARY 180  93 50.             HEAT LOST TO INCIN                              BTU/HR
VARY 180  94 1.667           CONDUCTION,A/L, TERM NOD 1/NOD 2TO  HEAT PIPE
VARY 180  95 4.5             CONDUCTION,A/L, TERM NOD 1/NOD 3TO  AIR STERLIZEER
VARY 180  96 5.0             CONDUCTION,A/L, TERM NOD 1/NOD 4TO  PU 1
VARY 180  97 5.0             CONDUCTION,A/L, TERM NOD 1/NOD 5TO  PU 2
VARY 180  98 5.0             CONDUCTION,A/L, TERM NOD 1/NOD 6TO  PU 3
VARY 180  99 5.0             CONDUCTION,A/L, TERM NOD 1/NOD 7TO  INCINERATOR
VARY 180 100 .27             CONDUCTION,A/L, TERM NOD2/NOD3  HP/AS      (FT)
VARY 180 101 .25             CONDUCTION,A/L, TERM NOD2/NOD7  HP/INCIN   (FT)
VARY 180 102 .25             CONDUCTION,A/L, TERM NOD3/NOD4  AS/PU1     (FT)
VARY 180 103 .25             CONDUCTION,A/L, TERM NOD3/NOD7  AS/INCIN   (FT)
VARY 180 104 0.64            CONDUCTION,A/L, TERM NOD 3/NOD 8TO  AS TO I WALL
VARY 180 105 .25             CONDUCTION,A/L, TERM NOD4/NOD5  PU1/PU2    (FT)
VARY 180 106 0.59            CONDUCTION,A/L, TERM NOD 4/NOD 8TO  PU1 TO I WALL
VARY 180 107 .25             CONDUCTION,A/L, TERM NOD5/NOD6  PU2/PU3    (FT)
VARY 180 108 0.59            CONDUCTION,A/L, TERM NOD 5/NOD 8TO  PU2 TO I WALL
VARY 180 109 .25             CONDUCTION,A/L, TERM NOD6/NOD7  PU3/INCIN (FT)
VARY 180 110 0.59            CONDUCTION,A/L, TERM NOD 6/NOD 8TO  PU3 TO I WALL
VARY 180 111 0.64            CONDUCTION,A/L, TERM NOD 7/NOD 8TO  INCIN TO I WALL
VARY 180 112 2.3             CONDUCTION,A/L, TERM NOD 8/NOD 9TO  I WALL TO O WALL
VARY 180 113 5.7             CONDUCTION,A/L, TERM NOD 9/NODTSTO  O WALL TO  TS
VARY 180 114 80.0            EFFECTIVE TEMP OF THE SURROUNDINGS.         DEG-F
ID** 181  -0 HEAT PIPE  NEAR-ISOTHERMA HEAT REJECTION DEVICE
KBAS 181  -0 57                                                          125
KARY 181  16           1     TABLE DEFINES SODIUM BOILING TEMP VS PRESSURE
VARY 181  65 1280.           HEAT PIPE CONTROL TEMPERATURE               F
VARY 181  66 1280.           TEMP OF SOURCE FROM WHICH HEAT IS REJECTED F
VARY 181  67 38.116          CONDUCTANCE KA/L SOURCE TO HEAT PIPE        B/HR-F
VARY 181  68 0.0416          HEAT PIPE DIAMETER                          FT
VARY 181  69 .541667         LENGTH OF CONDENSING REGION OF HEAT PIPE    FT
VARY 181  70     4.4E-6      MASS OF INERT GAS IN THE HEAT PIPE          LBS
VARY 181  71 38.69           GAS CONSTANT OF INERT GAS USED              FT/ R
VARY 181  72 80.             HEAT PIPE TEMP AT COLD END OF HEAT PIPE     F
VARY 181  73   2.225E-4      VOLUME OF INERT GAS RESERVOIR HEAT PIPE
VARY 181  76  8.5            HEAT TRANSFER COEFFICIENT SURFACE/H.P.  V/HR-FTSQ-F
VARY 181  77 75.             AMBIENT TEMP                                F
VARY 181  79 1.638           NOT USED
VARY 181  80 8.5
VARY 181  81 15.8            THERMAL CONDUCTIVTY OF HEAT PIPE MATERIAL B/HR-FT-F
VARY 181  82 .002916         HEAT PIPE THICKNESS                         FT.
ID** 201  -0 DUMMY COMPONENT PROVIDING THE FECES INPUT INTO SYS
KBAS 201  -0 49                  4  141516 11819                         215
NSTR 201  -00                             NONE RQRD
ID** 202  -0 FECES BLENDER SIMULATED BY DUMMY COMPONENT
KBAS 202  -0 49            215 4  141516 11819                           205
NSTR 202  -00                             NONE RQRD
ID** 203  -0 DUMMY COMPONENT PROVIDING THE AIR FLOW TO DEFECATION UNIT
KBAS 203  -0 49                  2                                       204
NSTR 203  -00                             NONE RQRD
ID** 204  -0 AIR HEATER SIMULATED BY SUBROUTINE ANYHX.
KBAS 204  -0  4            203 2                   -122 0    1           201
NSTR 204    2                    1      AIR HEATER        STEADY CALCULATION
VARY 204  66 12.0            OVERALL  UA BTU/HR-F
ID** 205  -0 A JUNCTION PROVIDING MEANS OF INTRODUCING URINE TO EVAPORATOR
KBAS 205  -0  7            202 4  141516 11819      23 4  141516 11819   208
NSTR 205  -01                             USE PRIMARY FLO PRESS AS MIXED FLO PRESS
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ID** 206  -0 JUNCTION PROVIDE MEANS OF DUMPING WASTE FROM SHREDDER TO EVAP
KBAS 206  -0  7           205 4  141516 11819   -207 4  141516 11819   218
NSTR 206  -01                         USE PRIMARY FLO PRESS AS MIXED FLO PRESS
ID** 207  -0 TRASH SHREDDER SIMULATED BY VERSATILE SUBROUTINE ALTCOM
KBAS 207  -0  7           208 4  141516 11819    -49 4  141516 11819   206
NSTR 207  -00                         NONE RQRD
ID** 208  -0 DUMMY COMPONENT DEFINING THE TRASH INPUT
KBAS 208  -0 49               4  141516 11819                          207
NSTR 208  -00                         NONE RQRD
KBAS 209  -0  7           206 4  141516 11819   -218 4  141516 11819   210
NSTR 209  -01                         OUTFLO-DEFINED BY GPOLY SS+TRANS HT BAL
ID** 210  -0 EVAPORATOR SIMULATED BY LIQ-GAS HX WITH EVAPORATION OF WATR
KBAS 210      59          209 4    1516 11819   -204 3  14 5 6 7 8 9   221
NSTR 210                          11   USE SS SOLUTION DURING TRANSIENT
KARY 210  17          239      COMPONEN PROVIDING HTNG FLUID TO EVAPORATOR
KARY 210  18            2      TABLE RELATING NUCLEATE BOILING Q/A VS DELTMP
VARY 210  51 110.
VARY 210  52                   EFFECTIVE THERMAL CONDULTANCE WALL/SURR.  BTU/HR-F
VARY 210  53 0.                TOTAL HEAT LOSS TO SURROUNDINGS           BTU/HR
VARY 210  54 75.               AMBIENT GAS TEMPERATURE                   DEG-F
VARY 210  55 1.                CONDUCTANCE, INSULATION SURFACE/AMB. GAS  BTU/HR-F
VARY 210  56                   CONVECTIVE HEAT LOSS TO AMBIENT GAS       BTU/HR
VARY 210  57 75.               AMBIENT WALL TEMP                         DEG-F
VARY 210  58 .2                RADIATION FA FACTOR SURFACE TO AMB WALL   FTSQ
VARY 210  59                   RADIATIVE HEAT LOSS TO AMBIENT WALL       BTU/HR
VARY 210  60 85.               STRUCTURE TEMPERATURE                     DEG-F
VARY 210  61 2.5               CONDUCTANCE KA/X EVAP WALL TO STRUCTURE   BTU/HR-F
VARY 210  62                   CONDUCTANCE HEAT LOSS TO STRUCTURE        BTU/HR
VARY 210  63                   INSULATION SURFACE TEMPERATURE            DEG-F
VARY 210  64 .1                CONDUCTANCE KA/X EVAP WALL TO INSUL SURF. BTU/HR-F
VARY 210  65 92.5              EFFECTIVE CONDUCTANCE UA WALL/HTNG FLUID  B/HR-DEL-F
VARY 210  66 0.                ELECTRICAL HEAT INPUT TO THE EVAP WALL    BTU/HR
VARY 210  67 1.418             HEIGHT OF THE EVAPORATOR                  FT
VARY 210  68 1.73              DIAMETER OF THE EVAPORATOR                FT
VARY 210  69 0.                EFFECTIVE HEIGHT OF THE LIQUID SLURRY IN EVAP (FT)
VARY 210  70 .15               MINIMUM LIQUID LEVEL ALLOWABLE NORM OPRTN FT
VARY 210  71 .342              MAXIMUM LQD. LEVL ALLOWABLE NORMAL OPERATION  (FT)
VARY 210  72 0.                HEAT LOST BY VAPORIZING LQD TO AIR FLOWNG BTU/HR
VARY 210  73 0.                EFFECTIVE GAS SPACE IN THE EVAPORATOR     FT**3
VARY 210  74 0.                HEAT FLUX FROM EVAPORATOR WALL TO LIQUID  BTU/HR
VARY 210  75 0.                HEAT FLUX, Q/A, TERM BETWEEN WALL/LIQUID  B/HR-FT2
VARY 210  76 .2                GAS SPACE IN EVAP NOT SUBJECT TO LQD FILL FT**3
VARY 210  77 0.                VAPORIZATION RATE OF WATER                LB/HR
VARY 210  78 .0471489          BACTERIAL DECOMPOSITION FACTOR FOR UREA   1/HR
VARY 210  79 0.                DECOMPOSITION RATE OF UREA IN THE EVAP    LB/HR
VARY 210  80 0.                LIEQUID LOST IN DECOMPOSITION REACTION    LB/HR
VARY 210  81 1.17              RATIO OF LIQUID TO SOLID IN SOLIDS RESERVOIR
VARY 210  82 2.28              FILTRATION FACTOR OF LQD/SOLID FILTER     LB/HR
VARY 210  83 0.                FILTRATION RATE OF LIQUID SOLID COMPONENT LB/HR
VARY 210  84 .1                FRACTION VAPORIZED VS. MAX THAT CAN TO SAT AIR (DEC)
VARY 210  85 .51               SOLID RESERVOIR CAPACITY                  LB.
VARY 210  86 0.                LIQUID LOSS DUE TO FILTRATION RATE        LB/HR
VARY 210  87 0.                SOLID SP. FLO NO. 2 REMOVAL  RATE         LB/HR
VARY 210  88 0.                SOLID SP. FLO NO. 3 REMOVAL  RATE         LB/HR
VARY 210  89 0.                SOLID SP. FLO NO. 4 REMOVAL  RATE         LB/HR
VARY 210  90 0.                SOLID SP. FLO NO. 5 REMOVAL  RATE         LB/HR
VARY 210  91 0.                SOLID SP. FLO NO. 6 REMOVAL  RATE         LB/HR
VARY 210  92                   NH3 GENERATION RATE IN UREA DECOMPOSITION LB/HR
VARY 210  93                   CO2 GENERATION RATE IN UREA DECOMPOSITION LB/HR
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VARY 210  94 1.            SS CONVERGENCE CRITERIA FOR TEMP PREDICT   PER-CENT
VARY 210  95 200.          POWER REQUIRED TO DRIVE THE EVAP IMPELLER WATTS
VARY 210  96               HTNG FLUID INLET TEMPERATURE (DEG-F)
VARY 210  97               HTNG FLUID OUTLET TEMPERATURE (DEG-F)
VARY 210  98 .1064         PRESSURE DEOP COEFFICIENT FOR FLOW EVAP/CNDNSR.
VARY 210  99 .000142       EFFECTIVE ORIFICE AREA BETWEEN EVAP/DOWNSRM  (FTSQ)
VARY 210 100 1.4            DOWNSTREAM PRESS (CONDENSER)                (PSI)
VARY 210 101 26.15439      TOTAL WEIGHT OF LIQUID SLURRY IN EVAPORATOR LBS
VARY 210 102 105.          TEMPERATURE OF LIQUID/SOLID SLURRY          F-DEG
VARY 210 103 .4            PRESS.                                      PSI
VARY 210 104 .4            PRESS.                                      PSI
VARY 210 105               NOT USED
VARY 210 106               NOT USED
VARY 210 107               NOT USED
VARY 210 108               NOT USED
VARY 210 109               NOT USED
VARY 210 110               NOT USED
VARY 210 111               NOT USED
VARY 210 112               NOT USED
VARY 210 113               NOT USED
VARY 210 114 0.
VARY 210 115 .173217       AMOUNT OF UREA IN THE EVAPORATOR            LBS
VARY 210 116 .9811741      AMOUNT OF OTHER SOLIDS IN THE EVAPORATOR   LBS
VARY 210 117 25.0          AMOUNT OF LQD IN EFAP                       LBS
VARY 210 118 0.            SPECIAL FLOW NO 5                           LB
VARY 210 119 0.            SPECIAL FLOW NO 6                           LB
VARY 210 120 0.            TOTAL WEIGHT OF GAS IN EVAP SYS.            LB
VARY 210 121 102.          TEMP. OF GAS IN EVAP SYS.                   F-DEG
VARY 210 122 .4            PRESSURE GAS IN EVAP SYS                    PSI
VARY 210 123 .4            PRESS.                                      PSI
VARY 210 124 0.            WEIGHT OF NON-CONDENSABLES IN EVAP          LB
VARY 210 125 0.            WEIGHT OF VAPOR IN EVAP.                    LB
VARY 210 126 0.            WEIGHT OF ENTRAINED LIQUID (ALWAYS ZERO)    LB
VARY 210 127 .22           SPECIFIC HEAT OF NON CONDENSABLE GAS        BTU/LB-F
VARY 210 128 35.           MOLECULAR WEIGHT OF NON-CONDENSABLE GAS    LB/LB-MOLE
VARY 210 129 0.            WEIGHT OF O2 IN EVAP                        LB.
VARY 210 130 0.            WEIGHT OF N2 IN EVAP                        LB.
VARY 210 131 0.            WEIGHT OF CO2 IN EVAP                       LB.
VARY 210 132 0.            WEIGHT OF NH3 IN EVAP (TRACE CONTAMINANT) LB.
VARY 210 133 0.            WEIGHT OF SPECIAL FLOW NO 1 IN EVAP         LB.
VARY 210 134 0.            WEIGHT OF SPECIAL FLOW NO 2 IN EVAP         LB.
VARY 210 135 0.            WEIGHT OF SPECIAL FLOW NO 3 IN EVAP         LB.
VARY 210 136 0.            WEIGHT OF SPECIAL FLOW NO 4 IN EVAP         LB.
VARY 210 137 0.            WEIGHT OF SPECIAL FLOW NO 5 IN EVAP         LB.
VARY 210 138 0.            WEIFHT OF SPECIAL FLOW NO 6 IN EVAP         LB.
VARY 210 139 0.            TOTAL WEIGHT OF LIQUID/SOLID IN SOLID RES LB.
VARY 210 140               TEMPERATURE  OF LIQUID/SOLID IN SOLID RES DEG-F
VARY 210 141               PRESSURE     OF LIQUID/SOLID IN SOLID RES PSI
VARY 210 142               PRESSURE     OF LIQUID/SOLID IN SOLID RES PSI
VARY 210 143               NOT USED RC(5)
VARY 210 144               NOT USED  RC(6)
VARY 210 145               NOT USED  RC(7)
VARY 210 146               NOT USED  RC(8)
VARY 210 147 0.            NOT USED RC(9)
VARY 210 148 0.            NOT USED RC(10)
VARY 210 149 0.            NOT USED RC(11)
VARY 210 150 0.            NOT USED RC(12)
VARY 210 151 0.            NOT USED RC(13)
VARY 210 152 0.            SOLID/LIQUID COMPONENT NO 1 IN SOLID RES  LBS
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VARY 210 153 0.               SOLID/LIQUID COMPONENT NO 2 IN SOLID RES  LBS
VARY 210 154 0.               SOLID/LIQUID COMPONENT NO 3 IN SOLID RES  LBS
VARY 210 155 0.               SOLID/LIQUID COMPONENT NO 4 IN SOLID RES  LBS
VARY 210 156 0.               SOLID/LIQUID COMPONENT NO 5 IN SOLID RES  LBS
VARY 210 157 0.               SOLID/LIQUID COMPONENT NO 6 IN SOLID RES  LBS
VARY 210 158 26.4              THERML CAPACITANCE OF EVAPORATOR LESS LQD  BTU/LB-F
VARY 210 159 26.146           THERMAL CAPACITANCE OF LIQUID IN EVAP     BTU/LB-F
ID** 213   1 INCINERATOR TO ACCOMPLISH THERMAL DECOMPOSITION AND VAPORIZTN
ID** 213   2 OF 95 PER CENT OF SOLIDS TO MINIMIZE OZ RERRMNTS FOR COMBUSTN
KBAS 213  -0 58            210 4   11516                                214
NSTR 213  -0                         NONE RQRD
VARY 213   54 200.0           AMBIENT GAS TEMPERATURE DEG F
VARY 213   55 .16             THERMAL CONDUCTANCE TO GAS (BTU/HR- DEG F)
VARY 213   69 5650.0          HEAT OF REACTION   BTU/LB OXYGEN
VARY 213   71 1080.00         TOTAL CYCLE TIME, SECONDS
VARY 213   72 300.00          TIME TO CONSTANT RATE PERIOD,SECONDS
VARY 213   73 600.00          TIME TO END OF DRYING PERIOD,SECONDS
VARY 213   74 180.0           OXYDATION TIME PERIOD,SECONDS
VARY 213   75 60.0            GAS VENTING TIME PERIOD,SECONDS
VARY 213   77 2.00            NUMBER  OF OXYDATION-VENT CYCLES, N.D.
VARY 213   79 0.31            INITIAL MASS OF SOLIDS IN INCINERATOR(LB)
VARY 213   84 0.44
VARY 213   88 15.0            ENVIRONMENTAL PRESSURE,PSI
VARY 213   89 1280.0          HEAT BLOCK  TEMPERATURE,DEG F
VARY 213   90 0.0000167
VARY 213   91 2.2223          EVAPORATOR SURFACE AREA,FT2
VARY 213   92 1000.0          HEAT OF VAPORIZATION,BTU/LB
VARY 213   93 2.68            THERMAL CONDUCTANCE  FROM HEAT SOURCE TO SHUTTLE
VARY 213   94 0.4             EFFECTIVE  THERMAL CAPACITANCE OF SHUTTLE  BTU/LB-F
ID** 214  -0 ASH COLLECTOR SIMULATED BY FLOMET TO METER THE INCIN END PROD
KBAS 214     29 17         213 3  142526171819                           61
NSTR 214  -01                        METER ALL CONSTITUENTS IN INCINERATOR
ID** 215  -0 JUNCTION PROVIDES MEANS OF ADDING FLUSH WATER TO DEFCTN UNIT
KBAS 215  -0  7            201 4  141516 11819    -50 4  141516 11819   202
NSTR 215  -01                        USE PRIMARY PRESS AS MIXED FLO PRESS
ID** 218  -0 WASH  WATER TNK
KBAS 218  -0 30            219 4  141516 11819                          209
NSTR 218  -011000                    TANKG NO TRANS HT BAL INITIAL VOLUME
VARY 218   51 100.              TANK TEMP                               DEG-F
VARY 218   54 75.             AMBIENT GAS TEMP                          F
VARY 218   55 2.5             CONDUCTANCE INSUL SURFACE/AMBIENT GAS     B/HR-F
VARY 218   57 75.             AMBIENT WALL TEMP                         F
VARY 218   58                 THERMAL RADIATION FA FACTOR               FT**2
VARY 218   60 75.             STRUCTURE TEMP                            F
NSTR 218    12010                    OUTFLO=GPOLY,NO INTERNAL HX
VARY 218   61 1.5             EFFECTIVE CONDUCT BTWN TNK WALL/SURROUNDNG B/HR-F
VARY 218   64 0.              CONDUCTANCE TNK WALL/INSULATION SURFACE   BTU/HR-F
VARY 218   68 41.75           CAPACITY OF WASH WATER TANK               LBS
VARY 218   69 38.             WEIGHT FLUID IN TNK                       LB
VARY 218   70 150.            TEMP OF FLUID                             F
VARY 218   71 .609            FLUID VOLUME IN TNK                       FT**3
VARY 218   72 15.             PRESS                                     PSI
VARY 218   75 38.             WEIGHT OF CONDENSABLE LIQUID              LB
VARY 218   88 1.0             SPECIFIC HEAT OF FLUID IN TNK             BTU/LB-F
VARY 218   92 .88             THERMAL CAPACITANCE OF TNK SHELL          BTU/F
VARY 218   93 100.            CONDUCTANCE LQD TO TNK WALL
VARY 218   85 38.0            WEIGHT OF WATER IN THE WASH TANK  (LBS)
VARY 218   94 5.0             MAX ALLOWABLE TEMP CHANGE                 F
VARY 218   95                 EXTERNAL HT LOAD TO FLUID                 BTU/HR
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VARY 218  96                  EXTERNAL HT LOAD TO SHELL                        BTU/HR
ID** 219  -0 DUMMY COMPONENT PROVIDES WASH WATER FLOW TO WASH WATER TNK
KBAS 219  -0 49               4  141516 11819
NSTR 219  -0                        NON RORD
VARY 219   2 80.0             WASH WATER TEMPERATURE (DEG F)
VARY 219  17  1.              WASH WATER INPUT
ID** 220  -0 DUMMY COMPONENT PROVIDING O2 FLOW FOR COMBUSTION IN PYROLYSIS
KBAS 220  -0 30               2
NSTR 220  -01211                    DUMMY COMPONENT NO NSTRS REORD.
VARY 220   2 70.                    O2 TEMP
VARY 220   3 900.              O2 PRESS
VARY 220   4 900.              O2 PRESS
VARY 220  69 5.06462           TOTAL FLUID WEIGHT IN TANK   LBS
VARY 220  70 70                O2 TEMP  IN TANK             DEG-F
VARY 220  71 1.                FLUID VOLUME IN TANK
VARY 220  72 900.              O2 PRESSURE IN TANK          PSI
VARY 220  73 5.06462           WEIGHT OF NON-CONDENSABLES IN TANK  LBS
VARY 220  76 .22               NON-CONDENSABLE CP IN TANK
VARY 220  77 32.               NON-CONDENSABLE MOLECULAR WEIGHT IN TANK  LBS/LB-
VARY 220  78 5.06462           WEIGHT OF O2 IN TANK
VARY 220  88 .22               SPECIFIC HEAT OF FLUID IN TANK  BTU/LB-F
VARY 220  89 5.06462           DENSITY OF FLUID IN TANK LB/FT**3
VARY 220  90 .08               VISCOSITY OF FLUID IN T<ANK
VARY 220  91 32.               MOLECULAR WEIGHT OF FLUID IN TANK  LB/LB-MOLE
ID** 221  -0 TEE PROVIDES MEANS FOR INJECTING O2 INTO THE STREAM
KBAS 221      6          220 2  14               210 3  14 5 6 7 8 9   232
NSTR 221  -02                       TEE WITH SECONDARY PRESSURE USED AS MIXED PRE
ID** 223     REGENARATIVE HX COMPONENT OF THE PYROLYSIS UNIT. COMPUTES INLET FL
KBAS 223  -0  4          232 3  14 5 6 7 8 9  -224 3  14 5 6 7 8 9   224
NSTR 223  -0200010000               COUNTERFLO,NO SIZING,INPUT UA,GAS-GAS HY
VARY 223  66 21.6729          OVERALL UA                                       BTU/HR-F
ID** 224     PYROLYSIS UNIT SIMULATED BY CATBRN
KBAS 224     13  4       223 3  14 5 6 7 8 9                               226
NSTR 224  -0                        NONE REORD
KARY 224  16            2     ONE TRACE CONTAMINANT REACTING
VARY 224   1  2.6067          TOTAL FLOW
VARY 224   2 1200.            TEMPERATURE OF EXITING GAS STREAM                DEG-F
VARY 224   3 1.09             PRESS                                            PSIA
VARY 224   4 1.09             PRESS                                            PSIA
VARY 224   5 .008             TOTAL NON-CONDENSABLE FLOW                       LB/HR
VARY 224   6 2.475            CONDENSABLE VAPOR FLD                            LB/HR
VARY 224   8 .24              NON-CONDENSABLE SPECIFIC HEAT                    B/LB-F
VARY 224   9 28.              NON-CONDENSABLE MOLECULAR WEIGHT                 LB/MOL
VARY 224  11 .008             TOTAL N2 FLOW THROUGH PYROLYSIS UNIT             LB/MR
VARY 224  52                  EFFECTIVE SUMMED CONDUCTANCE                     B/HR-F
VARY 224  54 75.              AMBIENT GAS GEMP.                                F
VARY 224  55 0.               AMBIENT GAS/INSULATION UA                        B/HR-F
VARY 224  57 75.              AMBIENT WALL TEMP                                F
VARY 224  58 0.               RADIATION FACTOR                                 FT**2
VARY 224  59 0.               HT. LOSS BY RADIATION                            B/HR
VARY 224  60 1250.            STRUCTURE TEMP.                                  F
VARY 224  61 100.0            PYRO TO STRUCTURE CONDUCTANCE KA/X               B/HR-F
VARY 224  64 0.               INSULATION SURFACE/PYRO HT. TRNSFR COND.         B/HR-F
VARY 224  65 .9               REMOVAL EFFICIENCY FOR 1ST CONSTITUENT
VARY 224  66 10.              HEAT OF COMBUSTION FOR 1ST CONSTITUENT           B/LB
VARY 224  67 0.               RATIO OF CO2 PRODUCED                            BL/LB
VARY 224  68 1.5              RATIO OF H2O PRODUCED TO THE 1ST CONSTIT.        BL/LB
VARY 224  70 0.               HTR. POWER RQRD.                                 WATTS
VARY 224  71 1.               UNIT LUMPED THERMAL CAPACITANCE                  B/F
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VARY 224   72 1200.         COMPONENT INITIAL TEMP.                          F
VARY 224   73 .99996           REMOVAL EFFICIENCY OF HYDROGEN
VARY 224   74 40000.        HEAT OF COMBUSTION OF PYROLYSIS REACTION  BTU/LB
VARY 224   75 0.            RATIO OF CO2 PRODUCED                     LB/LB
VARY 224   76 9.            RATIO OF H2O PRODUCED                     LB/LB
ID** 226      REGENARATIVE HX COMP OF THE PYROLYSIS UNIT COMPUTES OUTLET FLOW
NSTR 226   -0200010000              COUNTERFLO,NO SIZING,INPUT UA,GAS-GAS HX
KBAS 226      4          224 3  14 5 6 7 8 9   -232 3  14 5 6 7 8 9   233
VARY 226   66 21.6729       OVERALL UA                                BTU/HR-F
ID** 232   -0 VALVE TO DIRECT AIR FLOW TO STERILIZER DURING DEFECATION MOVE.
KBAS 232      10         221 3  14 5 6 7 8 9        3  14 5 6 7 8 9   223
NSTR 232   -00                      UNIVERSAL SPLIT RATIO
ID** 233   -0 SIMULATION OF HT LOSS THROUGH PIPING SIMULATED BY PIPE
KBAS 233      16         226 3  14 5 6 7 8 9                          237
NSTR 233   -01                      USE STD-FWD DIFF SOLUTION
VARY 233   54 75.           AMBIENT GAS TEMPERATURE                   F
VARY 233   55 0.
VARY 233   57 75.           AMBIENT WALL TEMP                         F
VARY 233   58 0.
VARY 233   60 95.           STRUCTURE TEMP                            F
VARY 233   61 2.85          CONDUCTANCE KA/X OUTR  SURFAC/STRUCTURE   B/HR-F
VARY 233   64 5.6           CONDUCTANCE (UA) OF INSULATION            B/HR-F
VARY 233   66 5.            LENGTH OF DUCT                            FT
VARY 233   67 1.            INSIDE DIAM OF DUCT                       IN
VARY 233   68 2.5           LOCATION OF BRACKET ALONG LENGTH OF DUCT  FT
VARY 233   69 1.3           THERML CNDCTNCE GAS/DUCT WALL             B/HR-F
VARY 233   71 .1            DUCT WALL THICKNESS                       IN
VARY 233   72 488.          DUCT DENSITY                              LB/FT**3
VARY 233   73 .11           DUCT SPECIFIC HEAT
VARY 233   74 0.            MULTIPLYING FACTOR LUMPING THERML CAPACITANCE
ID** 237    1 CONDENSER SIMULATED BY G189 COMPONENT SUBROUTINE CNDNSR RECEIVES
ID** 237    2 GASEOUS FLOW AND CONDENSES OUT THE VAPOR AND VENTS THE NON-CONDENS-
ID** 237    3 ABLE GASSES THE LIQUID FLOW OUT IS DETERMINED BY GPOLY IN TRANSIENT
ID** 237    4 IN STEADDY STATE LIQUID FLOW OUT IS SET EQUAL TO CONDENSATION RATE
KBAS 237      60         233 3  14 5 6 7 8 9        3  14 5 6 7 8 9   213
NSTR 237      1                 11    PRESSURE USED AS CRITERIA USE SS DURING TRNS
KARY 237   16         238   COMPONENT NUMBER DEFINING THE COOLNT SUPPLY
KARY 237   17           5   CONDENSER DIFFUSION COEFFICIENT VS SAT PRESSURES
VARY 237    3 .63             PRESSURE                                PSI
VARY 237    4 .63             PRESSURE                                PSI
VARY 237   22 .63             PRESSURE                                PSI
VARY 237   23 .63             PRESSURE                                PSI
VARY 237   65 0.
VARY 237   66               EFFECTIVE ORIFICE AREA OF VENT VALVE      FT**2
VARY 237   67 0.01          DOWNSTREAM PRESS TO WHICH GASSES VENT     PSI
VARY 237   68                 DEW POINT TEMPERATURE OF THE GASSES     DEG-F
VARY 237   69               CONDENSER CONDENSATION RATE               LB/HR
VARY 237   70               HEAT TRANSFERRED TO WALL FROM GAS         B/HR
VARY 237   71 .29173        RADIUS    OF EVAPORATOR                   FT
VARY 237   72 1.592         HEIGHT OF EVAPORATOR                      FT
VARY 237   73               HEIGHT OF LIQUID LEVEL IN THE CONDENSER   FT
VARY 237   74 8.8           MASS OF LIQUID IN CONDENSER               LBS
VARY 237   75 117.            EFFCTV CNDCTNC (UA) CLNT FLUID/WALL     B/HR-F
VARY 237   76 0.02          CONVERGENCE TOLERANCE (TEMPERATURE)
VARY 237   77 2.0           CONDENSER LUMPD THERMAL CAPACITANCE       B/F
VARY 237   78               CONDENSATE LUMPED THERMAL CAPACITANCE     B/F
VARY 237   79 .6            FRACTION OF VENT GAS THAT IS VAPOR        (N.D.)
VARY 237   80 .0746         CONDUCTANCE.KA/L,BETWEEN TWO WALL NODES   B/HR-F
VARY 237   81 .1            CONDUCTANCE CONDENSER/SURROUNDINGS        B/HR-F
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VARY 237  82 70.            EFFECTIVE TEMP. OF SURROUNDINGS             F
VARY 237  83 1.             CONVECTIVE HEAT TRNSFR COEFF GAS/WALL       B/HR-F-F.
VARY 237  84                CONDUCTANCE,KA/L, TERM WALL/FLUID           B/HR-F
VARY 237  85 480.           HEAT TRANSFER COEFFICIENT CONDENSATION/WALL
VARY 237  86 0.             CLNT TEMP AT NODE ,TC1                      F
VARY 237  87 0.             CLNT TEMP AT NODE 2 , TC2                   F
VARY 237  88 0.             CNDNSR WALL NODE 1 TEMP, TW1                F
VARY 237  89                CONDENSER WALL NODE TEMP 2 TW2              TW2
VARY 237  90
VARY 237  91                TOTAL WEIGHT OF GAS IN THE CONDENSER        LBS
VARY 237  92                TEMP OF GAS IN THE CNDWSR                   F
VARY 237  93                PRESSURE                                    PSI
VARY 237  94                PRESSURE                                    PSI
VARY 237  95                NON-CONDENSABLE TOTAL                       LBS
VARY 237  96                VAPOR IN CNDNSR                             LBS
VARY 237  97 0.             VALUE IS ZERO SUPER SATURATION NOT ACCEPTD
VARY 237  98                SP HEAT OF N-C GASSES IN CNDNSR             B/LB-F
VARY 237  99                MOLCLR WEIGHT OF N-C GASSES IN CONSR        LB/LB-MOLE
VARY 237 100                WEIGHT OF O2  IN THE CNDNSR      O2         LB.
VARY 237 101                WEIGHT OF N2  IN THE CNDNSR      N2         LB.
VARY 237 102                WEIGHT OF CO2 IN THE CNDNSR      CO2        LB.
VARY 237 103                WEIGHT OF NH3 IN THE CNDNSR      NH3        LB.
VARY 237 104                SPECIAL FLO NO 1 WEIGHT          H2         LB.
VARY 237 105                SPECIAL FLO NO 2 WEIGHT
VARY 237 106                SPECIAL FLO NO 3 WEIGHT
VARY 237 107                SPECIAL FLO NO 4 WEIGHT
VARY 237 108                SPECIAL FLO NO 5 WEIGHT
VARY 237 109                SPECIAL FLO NO 6 WEIGHT
ID** 238   1 ALTERNATE COMPONENT PROVIDING THE COOLNT FLOW TO THE CONDENSER
KBAS 238  -0 49            -9 0   1
VARY 238   1 266.           COOLANT FLO THROUGH CONDENSER               LB/HR
VARY 238   2 35.            COOLNT TEMP.                                F
VARY 238   3 15.            PRESS.                                      PSI
VARY 238   4 15.            PRESS.                                      PSI
ID** 239   1 THE DUMMY COMPONENT PROVIDING THE HEATNG FLUID FLOW TO THE EVAPORAT
ID** 239   2 IT RECEIVES FLOW FROM COMP. 109 A VALVE
KBAS 239  -0 49           109 0   1
VARY 239   1 360.           HTNG FLUID FLOWRATE                         LB/HR
VARY 239   2 150.           HTNG FLUID TEMP                             F
VARY 239   3 15.            HTNG FLUID PRESS                            PSI
VARY 239   4 15.            HTNG FLUID PRESS                            PSI
TABL   1  10   2            7          LOG   LIN
TITL   1  20BOILING TEMPERATURE FOR SODIUM AS A FUNCTION OF PRESSURE
VALU   1 100 I      2.11       21.1        106.7      175.25      636.0      2116.
VALU   1 110 O       800.0      1000.       1200.      1300.0     1400.0      1600.
VALU   1 120 I      5731.2
VALU   1 130 D      1800.0
TABL   2  1    3            9      5     LIN   LIN   LIN
TITL   2  2 HEAT FLUX COEFFICIENT Q/A FUNCTION OF DTMP AND PRESS FOR EVAP
VALU   2 21 3I              .541       1.07        2.225      9.39       14.696
VALU   2 22 3D 1.5          1.5        4.30        8.00       17.        35.0
VALU   2 23 3D 3.0          4.2        9.0         23.0       71.0       135.0
VALU   2 24 3D 4.0          7.20       14.0        38.0       120.0      220.
VALU   2 25 3D 6.0          20.0       40.0        93.0       310.       600.
VALU   2 26 3D 8.0          58.0       120.        240.0      800.       1060.
VALU   2 27 3D 10.          165.0      310.0       620.       2100.0     4400.0
VALU   2 28 3D 12.          480.0      900.0       1060.0     60000.     88000.
VALU   2 29 3D 20.          7400.      12000.      30000.     60000.     88000.
VALU   2 30 3D 38.          42000.     102600.     155800.    300000.    372400.
```

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TABL    4  10   2              5             LIN   LIN
TITL    4  20CONDUCTANCE  OF NICKEL 600 ALLOY USED FOR HEAT BLOCK BTU/HR-FT-F
VALU    4 400 I 212.        572.        932.        1292.       1652.
VALU    4 410 D 8.          9.825       11.65       14.475      15.3
TABL    5  10   2              5             LIN   LIN
TITL    5  20HEAT TRANSFER COEFICIENT CONDENSATION OF VAPOR ON CONDENSER WALL
VALU    5 500 I 0.000       3.00        5.0         10.0        15.0        100.
VALU    5 510 D 0.00        15.0        50.         400.        1000.       1000.
TABL    6 10    2              3             LIN   STP
TITL    6 20 FLUSH WATER FLOW FOR URINAL(ONE CYCLE/HOUR)  CYCLE=3600.0
VALU    6100 2I 0.0         300.0       419.0
VALU    6110 2D 0.0         20.0        0.0
TABL    7  1    2              3             LIN   STP
TITL    7  2 FLUSH WATER FLOW  FOR BLENDER(ONE CYCLE/6 HOURS) CYCLE=21600.0
VALU    7 10 2I 0.0         1000.0      1058.
VALU    7 11 2D 0.0         75.0        0.0
TABL    8  10   2              3             LIN   STP
TITL    8  20FLUSH WATER FLOW  FOR SHREDDER (ONE CYCLE/6 HRS) CYCLE=21600.0
VALU    8 1002I 0.0         7200.0      7258.0
VALU    8 1102D 0.0         105.0       0.0
TABL    9 10    2              3             LIN   STP
TITL    9 20 AIR FLOW FOR URINAL(ONE CYCLE/HOUR)  CYCLE=3600.0
VALU    9100 2I 0.0         300.0       558.0
VALU    9110 2D 0.0         56.0        0.0
TABL   10 10    2              3             LIN   STP
TITL   10 20 URINE FLOW INPUT (ONE CYCLE/HOUR)  CYCLE=3600.0
VALU   10100 2I 0.0         300.0       358.0
VALU   10110 2D 0.0         35.0        0.0
TABL   11  10   2              4             LIN   LIN
TITL   11  20COOLANT FLOW--WATER COOLER --IF NEG.  BYPASS TO  HEATER
VALU   11 1002I 0.0         100.0       200.0       400.0
VALU   11 1102D 0.0         0.0         0.0         0.0
TABL   12  10   2              4             LIN   LIN
TITL   12  20LOW TEMP HEAT  TO HEATER-- IF NEGATIVE  BYPASS TO  COOLER
VALU   12 1002I 0.0         100.0       200.0       400.0
VALU   12 1102D 0.0         0.0         0.0         0.0
TABL   13  10   2              3             LIN   STP
TITL   13  20TRASH INPUT --COMPONENT  208  (LB/HR )
VALU   13 1002I 0.0         7200.0      7258.0
VALU   13 1102D 0.0         18.0        0.0
TABL   14  1    2              3             LIN   STP
TITL   14  2 SOLIDS INPUT --COMPONENT  201 (LB/HR)
VALU   14 10 2I 0.0         1000.0      1058.0
VALU   14 11 2D 0.0         18.0        0.0
TABL   15  1    2              3             LIN   STP
TITL   15  2 AIR FLOW FOR BLENDER --COMPONENT 203(LB/HR)
VALU   15 10 2I 0.0         1000.0      1300.0
VALU   15 11 2D 0.0         132.00      0.0
TABL   16  10   2              2             LIN   LIN
TITL   16  20WATER COOLER (COMPONENT 93) DEMAND RATE (LB/HR)
VALU   16 1002I 0.0         200.0
VALU   16 1102D 1.123       1.123
TABL   17 100   2              2             LIN   LIN
TITL   17  20WATER HEATER DEMAND RATE (COMPONENT 94) LB/HR
VALU   17 1002I 0.0         200.0
VALU   17 1102D 1.123       1.123
PLOT00                                     RITE SYSTEM
PLOT21     210  25  0.0         4.0        EVAPORATION RATE(LB/HR)
PLOT22                100.0     130.0      TEMPERATURE (DEG-F)
```

```
PLOT2     210   2                            VAPOR TEMP. (DEG-F)
PLOT2     210  51                            WALL  TEMP. (DEG-F)
PLOT22              1100.0     1300.0        HEAT BLOCK TEMPERATURES (DEG-F)
PLOT2     180  69                            ISOTOPE TEMPERATURE
PLOT2     180  71                            NODE WITH AIR STER.
PLOT25                                       AIR STERILIZER TEMPERATURES
PLOT2      25  80                            AIR OUTLET TEMP.
PLOT2      25 116                            AIR INLET  TEMP.
PLOT2      25 118                            HEAT BLOCK TEMP.
PLOT2      25  71                            OUTER CYLINDER TEMP.
PLOT2      25  74                            STERILE CHAMBER TEMP
PLOT21    213   2   700.0      1500.0        INCINERATOR  TEMPERATURE
ENDC
ENDR
```

Appendix C

OUTPUT DATA

Appendix C describes the output formats chosen to define the output of the RITE simulation. The first output format consists of the card images of all cards being input for the current simulation case. These data include the control cards (TAPE and ENDC), the case data cards (BASIC and CASE card, namelist $CASE1 data, and namelist $PRØP1 data), and modifications to the component K and V array data. Since these cards are listed in Appendix B they are not repeated here.

The second section of output is shown in Figure C-1 reflects the Input Editor's interpretation of the data entered on the BASIC card. The output includes the case title, case number, and the number of components in the simulation.

The third section of output shown in Figure C-2 contains the Fortran system output format for all the variables defined under the namelist $CASE1. If the variables were not input they contain a default value of zero. The fourth and fifth sections shown in Figure C-3 contain a similar output format of the variables contained in the fluid property namelist $PROP1.

The sixth page of output shows the beginning of the printout of the edited data after the Input edotor has sorted and merged the input data from tape and cards and arranged them in groups of cards by numerical order for the components and tables and by card type within the component or table groups. The heading "BASIC CASE DATA" is printed at the beginning and it is followed by the case title as input on the CASE card.

```
BASIC  CASE NO.     1
THE EC/LS MODEL HAS  239 COMPONENTS. THE LAST OF WHICH TO BE SOLVED IS NO.  139
THE MODEL IS    TRANSIENT, WITHOUTPRESSURE DROP DATA ALLOCATION.
```

Figure C-1. INPUT EDITOR INTERPRETATION OF BASIC CARD

$CASE1

~~DTIME = 0.6E+02,~~

KCHOUT = 0,

KPRNT = 6,

~~KPRUN = 0,~~

KPTINV = 1, 0, 0, 0,

KPUNCH = 0,

~~KRUN = 1,~~

MAXCI = 0,

MAXLP = 0,

~~MAXSLP = 6,~~

MAXSSI = 3,

MINSSI = 2,

~~NPASPD = 0,~~

PGMIN = 0.0,

PLMIN = 0.0,

~~START = 0.0,~~

TIMEMX = 0.3E+03,

TMAX = 0.2E+04,

~~TMIN = 0.45E+03,~~

WTMAX = 0.1E+05,

IUT15 = 0,

~~IPONLY = 0,~~

TPLOTS = 0.0, 0.0, 0.0, 0.0, 0.0,

TPLOTE = 0.0, 0.0, 0.0, 0.0, 0.0,

~~IFPLOT = 0,~~

ICHK = 0,

ICPLMT = 0,

~~IPPLMT = 0,~~

IPGLMT = 0,

$END

Figure C-2. NAMELIST $CASE1 DATA

```
$PROP1

 CP      =  0.1E+01,  0.722E+00,  0.17E+00,  0.0,  0.25E+00,  0.25E+00,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.2E+00,  0.6E+00,  0.5E+00,
            0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.6E+00,
            0.5E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 CPCONL  =  0.1E+01,

 CPCONV  =  0.44E+00,

 CPCO2   =  0.174E+00,

 CPDIL   =  0.25E+00,

 CPOXY   =  0.22E+00,

 CPTC    =  0.5E+00,

 GAMGAS  =  0.14E+01,

 RHO     =  0.624E+02,  0.676E+02,  0.75E+00,  0.0,  0.1E+00,  0.1E+00,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.11445E-01,  0.81744E+02,
            0.76E+02,  0.624E+02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.81744E+02,  0.76E+02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 VISC    =  0.36E+01,  0.39E+00,  0.3E-01,  0.0,  0.6E-02,  0.6E-02,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.8E-02,  0.30E+02,  0.27E+02,
            0.36E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.39E+02,
            0.32E+02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 VISGAS  =  0.44E+00,

 VISLIQ  =  0.0,

 WTM     =  0.18E+02,  0.292E+02,  0.44E+02,  0.0,  0.45E+02,  0.35E+02,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.2E+01,  0.501E+02,  0.12E+03,
            0.18E+02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.15E+10,
            0.15E+10,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 WTMCON  =  0.18E+02,

 WTMDIL  =  0.28E+02,

 WTMTC   =  0.17E+02,

 XK      =  0.325E+00,  0.2275E+00,  0.77E-02,  0.0,  0.8E-01,  0.8E-01,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.7E+00,  0.0,  0.8E-01,  0.7E+00,  0.2E+00,
            0.325E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.2E+00,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 XKGAS   =  0.146E+00,

 XKLIQ   =  0.46E+00,

 $END
```

Figure C-3. NAMELIST $PROP1 DATA

The next section of output, Figure C-4, shows the initial solution path and the component numbers not in the solution path but used for data storage.

The G189A program then automatically prints out an expanded and labelled form of the K and V array data for all components in the solution path and others which are not in the solution path but are given subroutine numbers to produce a printout. This printout, a partial output is shown in Figure C-5, is given at the beginning of the run, at the end of steady state calculations and at the end of transient calculations.

The RITE simulation is set up to print out the V-array data for each component in the solution path at every system pass. Samples of this output are shown in Figures C-6 to C-8. The definition of the V-array variable is given in the G-189 manual and in the documented input cards described in Appendix B.

An option is available in the G189A program to produce SD-4060 graphical output. The output plots are of the form of a specified V array location (component number, reference location) versus mission times. Typical output plots are shown in Section 5.

The G189A program contains many alternate output options which are available to the programmer. These options are described in detail in the G189 Manual.

INITIAL SOLUTION PATH - (USER MAY ALTER DURING RUN)

A

100, 102, 103, 104, 105, 106, 107, 108, 109, 112, 113, 114, 115, 116, 117, 118, 120, 121, 122, 124,
41, 43, 44, 45, 46, 47, 48, 49, 50, 21, 22, 23, 28, 24, 25, 27, 203, 204, 201, 215,
202, 205, 208, 207, 206, 218, 209, 210, 221, 232, 223, 224, 226, 233, 237, 213, 214, 61, 62, 63,
64, 65, 66, 9, 2, 3, 80, 81, 82, 83, 84, 85, 87, 86, 88, 90, 89, 91, 99, 92,
93, 95, 94, 96, 5, 6, 10, 8, 180, 181, 125, 123, 126, 127, 119, 128, 129, 130, 131, 132,
133, 110, 111, 134, 136, 137, 139,

ALTERNATE COMPONENTS - (COMPONENTS WHICH MAY BE INCLUDED IN SOLUTION PATH AS A RESULT OF AN INSTRUCTION CHANGE OR COMPONENTS USED FOR DATA STORAGE) - -(FLAG BY INPUTTING A SUBROUTINE NO. IN KK(I,1), THIS ALSO FORCES PRINTOUT OF DATA)- -

1, 51, 101, 135, 219, 220, 238, 239,

COMPONENT ROWS NOT SPECIFIED IN THE SOLUTION PATH OR AS AN ALTERNATE PATH OR AS DATA STORAGE

4, 7, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 26, 29, 30, 31, 32, 33, 34, 35,
36, 37, 38, 39, 40, 42, 52, 53, 54, 55, 56, 57, 58, 59, 60, 67, 68, 69, 70, 71,
72, 73, 74, 75, 76, 77, 78, 79, 97, 98, 138, 140, 141, 142, 143, 144, 145, 146, 147, 148,
149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168,
169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 182, 183, 184, 185, 186, 187, 188, 189, 190,
191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 211, 212, 216, 217, 222, 225, 227, 228, 229, 230,
231, 234, 235, 236,

Figure C-4. INITIAL SOLUTION PATH

2-TEMPERATURE	R	35.0000	0.	0.	0.				
3-DUCT OUTLET P	I	0.	0.	0.	0.	0.	0.	[illegible]	
4-COMP OUTLET P	I	0.	0.	0.	0.	0.	0.	15.0000	0.
5-NON-COND FLOW	A	0.	0.	0.	0.	0.	0.	0.	0.
6-COND VAP FLOW	R	0.	0.	0.	0.	0.	0.	0.	0.
7-COND LIQ FLOW	Y	0.	0.	0.	0.	0.	0.	0.	0.
8-N-C SP HEAT		0.	0.	0.	0.	0.	0.	0.	0.
9-N-C MOL WT	S	0.	0.	0.	0.	0.	0.	0.	0.
10-OXYGEN FLOW	I	0.	0.	0.	0.	0.	0.	0.	0.
11-DILUENT FLOW	D	0.	0.	0.	0.	0.	0.	0.	0.
12-CO2 FLOW	E	0.	0.	0.	0.	0.	0.	0.	0.
13-TRACE CT FLOW		0.	0.	0.	0.	0.	0.	0.	0.
14-SPCL FLOW 1	D	0.	0.	0.	0.	0.	0.	0.	0.
15-SPCL FLOW 2	A	0.	0.	0.	0.	0.	0.	0.	0.
16-SPCL FLOW 3	T	0.	0.	0.	0.	0.	0.	0.	0.
17-SPCL FLOW 4	A	0.	0.	0.	0.	0.	0.	0.	0.
18-SPCL FLOW 5		0.	0.	0.	0.	0.	0.	0.	0.
19-SPCL FLOW 6		0.	0.	0.	0.	0.	0.	0.	0.
20-TOTAL SEC FLOW	S	0.	0.	0.	0.	0.	0.	260.000	0.
21-TEMPERATURE	E	0.	0.	0.	0.	0.	0.	35.0000	0.
22-DUCT OUTLET P	C	0.	0.	0.	0.	0.	0.	15.0000	0.
23-COMP OUTLET P	O	0.	0.	0.	0.	0.	0.	15.0000	0.
24-NON-COND FLOW	N	0.	0.	0.	0.	0.	0.	0.	0.
25-COND VAP FLOW	D	0.	0.	0.	0.	0.	0.	0.	0.
26-COND LIQ FLOW	A	0.	0.	0.	0.	0.	0.	0.	0.
27-N-C SP HEAT	R	0.	0.	0.	0.	0.	0.	0.	0.
28-N-C MOL WT	Y	0.	0.	0.	0.	0.	0.	0.	0.
29-OXYGEN FLOW		0.	0.	0.	0.	0.	0.	0.	0.
30-DILUENT FLOW	S	0.	0.	0.	0.	0.	0.	0.	0.
31-CO2 FLOW	I	0.	0.	0.	0.	0.	0.	0.	0.
32-TRACE CT FLOW	D	0.	0.	0.	0.	0.	0.	0.	0.
33-SPCL FLOW 1	E	0.	0.	0.	0.	0.	0.	0.	0.
34-SPCL FLOW 2		0.	0.	0.	0.	0.	0.	0.	0.
35-SPCL FLOW 3	D	0.	0.	0.	0.	0.	0.	0.	0.
36-SPCL FLOW 4	A	0.	0.	0.	0.	0.	0.	0.	0.
37-SPCL FLOW 5	T	0.	0.	0.	0.	0.	0.	0.	0.
38-SPCL FLOW 6	A	0.	0.	0.	0.	0.	0.	0.	0.
39-DH, C, DP PRI	P	0.	0.	0.	0.	0.	0.	0.	0.
40-LE, N, K DUCT	R	0.	0.	0.	0.	0.	0.	0.	0.
41-FF AREA	E	0.	0.	0.	0.	0.	0.	0.	0.
42-DH, C, DP PRI	S	0.	0.	0.	0.	0.	0.	0.	0.
43-LE, N, K COMP	S	0.	0.	0.	0.	0.	0.	0.	0.
44-FF AREA		0.	0.	0.	0.	0.	0.	0.	0.
45-DH, C, DP SEC	C	0.	0.	0.	0.	0.	0.	0.	0.
46-LE, N, K DUCT	U	0.	0.	0.	0.	0.	0.	0.	0.
47-FF AREA	E	0.	0.	0.	0.	0.	0.	0.	0.
48-DH, C, DP SEC	F	0.	0.	0.	0.	0.	0.	0.	0.
49-LE, N, K COMP	F	0.	0.	0.	0.	0.	0.	0.	0.
50-FF AREA		0.	0.	0.	0.	0.	0.	0.	0.
51-COMP SOURCE TEMP		0.	0.	0.	0.	0.	0.	0.	0.
52-EFF SUMMED COND		1.	0.	0.	0.	0.	0.	0.	0.
53-COMP TOTAL LOSS		0.	0.	0.	0.	0.	0.	0.	0.
54-AMBIENT GAS TEMP		0.	0.	0.	0.	0.	0.	0.	0.
55-AMBIENT HA		0.	0.	0.	0.	0.	0.	0.	0.
56-AMB CONV Q LOSS		0.	0.	0.	0.	0.	0.	0.	0.

Figure C-8: EXPANDED K AND V ARRAY DATA

51-COMP SOURCE TEMP	0.	0.	0.	0.	0.	0.	0.	0.
52-EFF SUMMED COND	0.	0.	0.	0.	0.	0.	0.	0.
53-COMP TOTAL Q LOSS	0.	0.	0.	0.	0.	0.	0.	0.
54-AMBIENT GAS TEMP	0.	0.	0.	0.	0.	0.	0.	0.
55-AMBIENT HA	0.	0.	0.	0.	0.	0.	0.	0.
56-AMB CONV Q LOSS	0.	0.	0.	0.	0.	0.	0.	0.
57-AMB WALL TEMP	0.	0.	0.	0.	0.	0.	0.	0.
58-AMB SCRIPT(F)*A	0.	0.	0.	0.	0.	0.	0.	0.
59-AMB RAD Q LOSS	0.	0.	0.	0.	0.	0.	0.	0.
60-STRUCTURE TEMP	0.	0.	0.	0.	0.	0.	0.	0.
61-STRUCTURE KA/X	0.	0.	0.	0.	0.	0.	0.	0.
62-STRUCTURE Q LOSS	0.	0.	0.	0.	0.	0.	0.	0.
63-INSULATION TEMP	0.	0.	0.	0.	0.	0.	0.	0.
64-INSULATION KA/X	0.	0.	0.	0.	0.	0.	0.	0.

SUBROUTINE DEPENDENT V ARRAY DATA - - -

```
VR(  1, 65)= 0.        VR(  1, 66)= 0.        VR(  2, 65)= 0.        VR(  5, 65)= 0.        VR(  8, 65)= 0.
VR(  8, 66)= 0.        VR(  8, 67)= 0.        VR(  8, 68)= 0.        VR(  9, 65)=  .92400   VR(
```

COMPONENT NO. = SUBR. TYPE = KR	1 ALTCOM	2 SPLIT	3 LIQMIX	5 SPLIT	6 LIQMIX	8 FLOMET	9 SPLIT	10 LIQMIX
1-SUBR NO./EXV/EXX	49007000	10000000	7000000	10000000	7000000	29004000	10000000	7000000
2-PRI SOR/FLO CODE	0	900	200	-0400	500	1000	100	600
3-PRI SPFL TYP 1-3	20000	20000	20000	20000	20000	20000	20000	20000
4-PRI SPFL TYP 4-9	-0	-0	-0	-0	-0	-0	-0	-0
5-SEC SOR/FLO CODE	-0	0	12000	0	11900	-0	0	-23800
6-SEC SPFL TYP 1-3	-0	20000	20000	20000	20000	-0	20000	20000
7-SEC SPFL TYP 4-9	-0	-0	-0	-0	-0	-0	-0	-0
8-NEXT COMP/CABIN	-0	300000	8001000	600000	1000000	18000000	200000	800000
9-COMP INSTR 1-9	-0	0	100000000	0	110000000	0	0	300000000
10-COMP INSTR 10-18	-0	-0	-0	-0	-0	-0	-0	-0
11-NCFL/NLFC/IPASS	0	0	0	0	0	0	0	0
12-PRI VISC/DENSITY	0	0	0	0	0	0	0	0
13-PRI CP/DP/OP/UP	0	0	0	0	0	0	0	0
14-SEC VISC/DENSITY	0	0	0	0	0	0	0	0
15-SEC CP/DP/OP/UP	0	0	0	0	0	0	0	0

Figure C-5 (continued)

```
COMP NO   25  THERML     SUBR NO  17    PRI SQR     24    SEC SQR    =0            COMP PASS NO      1         TIME =      60.0 SEC
                         FAILURE FLAGS -- COMP=  0     LOOP=  0             ELAPSED TIME IN MILLISEC -- CP=   85       PP=      58
VR(  1)= 0.              VR(  2)=  310.49        VR(  3)= 0.              VR(  4)= 0.              VR(  5)= 0.              VR(  6)= 0.
VR(  7)= 0.              VR(  8)= 0.             VR(  9)= 1.              VR( 10)= 0.              VR( 11)= 0.              VR( 12)= 0.
VR( 13)= 0.              VR( 14)= 0.             VR( 15)= 0.              VR( 16)= 0.              VR( 17)= 0.              VR( 18)= 0.
VR( 19)= 0.              VR( 20)= 0.             VR( 21)= 0.              VR( 22)= 0.              VR( 23)= 0.              VR( 65)=  1.0000
VR( 66)= 0.              VR( 67)= 0.             VR( 68)=  .22556         VR( 69)=  293.73         VR( 70)=  407.91         VR( 71)=  309.95
VR( 72)=  310.49         VR( 73)=  449.35        VR( 74)=  721.23         VR( 75)=  302.52         VR( 76)=  439.40         VR( 77)=  300.15
VR( 78)=  721.23         VR( 79)=  449.35        VR( 80)=  310.49         VR( 81)=  .26000         VR( 82)=  .25200         VR( 83)=  .12500
VR( 84)=  .10780         VR( 85)=  .31950        VR( 86)=  .11000         VR( 87)= 0.              VR( 88)= 0.              VR( 89)= 0.
VR( 90)= 0.              VR( 91)= 0.             VR( 92)= 0.              VR( 93)= 0.              VR( 94)=  3.3100         VR( 95)=  3.0000
VR( 96)= 0.              VR( 97)=  32.000        VR( 98)=  3.0000         VR( 99)= 0.              VR(100)=  3.3000         VR(101)=  3.0000
VR(102)= 0.              VR(103)=  32.000        VR(104)= 0.              VR(105)=  1.4000         VR(106)= 0.              VR(107)=  2.3000
VR(108)=  .70000         VR(109)=  .70000        VR(110)=  2000.0         VR(111)= 2.75000E-02     VR(112)= 2.75000E-02     VR(113)=  .18740
VR(114)=  .18740         VR(115)=  .13500        VR(116)= 0.              VR(117)=  250.00         VR(118)=  810.00         VR(
                         CPP=  1.0000            NTPP=  13.000            RHOP=  62.400            VISCP=  3.6000           XKP=  .32500
                         CPS= 0.                 NTPS= 1.                 RHOS= 0.                 VISCS= 0.                XKS= 0.
```


Figure C-6. V-ARRAY OUTPUT FOR THE AIR STERILIZER

```
COMP NO  211  EVAP      SUBR NO  57    PRI SUR   209    SEC SUR  -204      COMP PASS NO     1      TIME =    60.0 SEC
                        FAILURE FLAGS -- COMP=  0    LOOP=  0

  A(1)= 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.
          CPA= 0.                   JTMA= 0.                  RHOA= 0.              VISCA= 0.               XKA= 0.
  B(1)= 0.          10.000      14.700      14.700      0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.
          CPB= 0.                   JTMB= 0.                  RHOB= 0.              VISCB= 0.               XKB= 0.
R(  1)= 0.          105.40      1.1174      1.1174      0.          0.          0.          0.          0.          0.
R( 11)= 0.          -0.         -0.         -0.         0.          -0.         0.          0.          0.          2.3520
R( 21)= 105.40      1.1174      1.1174      1.05994E-02 2.3514      0.          .31836      26.000      0.          0.
R( 31)= 5.97916E-03 4.62026E-03 0.          0.          0.          0.          0.          0.          0.          0.
R( 41)= 0.          0.          -0.         0.          0.          0.          0.          0.          0.          0.
R( 51)= 117.33      2.5924      79.534      75.000      1.0000      3.0757      75.000      .20000      .64995      85.000
R( 61)= 2.3000      75.827      71.176      .11000      92.500      0.          1.4180      1.7300      .17659      .15000
R( 71)= .34200      -0.         3.1146      2433.6      315.94      .20000      2.3514      4.71409E-02 8.12653E-03 2.44299E-03
R( 81)= 1.4700      2.2800      .16943      .10000      .51000      .11774      1.51001E-02 8.51335E-02 .11774      0.
R( 91)= 0.          4.62026E-03 5.77961E-03 1.0000      2473.8      180.87      122.80      .10640      1.42000E-04 .63000
R(101)= 26.154      105.40      1.1174      .40000      -0.         -0.         -0.         -0.         -0.         -0.
R(111)=-0.          -0.         -0.         0.          .17322      .95117      25.000      0.          0.          1.04011E-02
R(121)= 105.40      1.1174      .40000      9.29324E-05 1.03001E-02 0.          .22000      35.000      0.          0.
R(131)=-2.62117E-03-2.02545E-05 0.          -0.         0.          -0.         -0.         -0.         -0.         105.40
R(141)= 1.1174      -0.         -0.         -0.         -0.         -0.         0.          0.          0.          0.
R(151)= 0.          0.          0.          0.          0.          0.          0.          26.400      26.146      0.
```

Figure C-7. V-ARRAY OUTPUT FOR THE EVAPORATOR

```
COMP NO  237  CHANGE      SUBR NO  40     PRI SBR.  233     SEC SBR    0          COMP PASS NO     2      TIME =    60,0 SEC
                           FAILURE FLAGS -- COMP=  0    LOOP=  0

  A(1)=  2,3591        135,23       -1,0900      1,0000      5,12465E-03  2,3539      0,             ,24126      29,109      1,28690E-03
         3,79948E-03 9,45246E-05 0,              1,11723E-08 5,95798E-06 7,77115E-06 0,             0,          0,
               CPA=  ,43956             WTMA=  18,015                RHOA= 3,10083E-03       VISCA= 0,                      XKA= 0,
  B(1)=  0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
         0,          0,          0,          0,          0,          0,          0,          0,          0,
               CPB=  0,                 WTMB=  0,                    RHOB= 0,                VISCB= 0,                      XKB= 0,
R(  1)=  0,          56,634      ,63000      ,63000      0,          0,          0,          0,          0,          0,
R( 11)=  0,          0,          0,          0,          0,          0,          0,          0,          0,          2,40676E-02
R( 21)=  92,923      ,63000      ,63000      5,19465E-03 1,83729E-02 0,          ,24126      29,109      1,28690E-03 3,79948E-03
R( 31)=  9,45246E-05 0,          1,11723E-08 5,95783E-06 7,77115E-06 0,          0,          0,          0,          0,
R( 41)=  0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
R( 51)=  0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
R( 61)=  0,          0,          0,          0,          2479,3      3,95954E-06 1,00000E-02 81,650      2,3227      -0,
R( 71)=  ,29173      1,5920      ,59745      3,9000      117,10      2,00000E-02 2,0000      -0,         ,60000      7,46000E-02
R( 81)=  ,10000      70,000      1,0000      -0,         430,00      48,202      48,273      78,069      48,502      -,67146
R( 91)=  5,99916E-04 92,923      ,63000      ,63000      1,27773E-04 4,64943E-04 0,          ,24126      29,109      3,17035E-05
R(101)=  9,36029E-05 2,32866E-16 0,          2,75900E-10 1,46775E-07 1,91446E-07 0,          0,          0,          0,
R(111)=  0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
```

Figure C-8. V-ARRAY OUTPUT FOR THE CONDENSER

Appendix D

GPOLY SUBROUTINES

The G189A program contains two subroutines GPOLY1 and GPOLY2, to be used to add user coded Fortran logic which is peculiar to the RITE simulation. The GPOLY1 subroutine is called before component solution and the GPOLY2 subroutine is called after component solution. The subroutines are used to modify data computed by the component subroutines, to insert new logic, and to exercise control over the order and method of solution used for the system simulation.

The logic contained in the RITE simulation GPOLY subroutines is described in detail in Section 3. A complete listing of the RITE GPOLY1 and GPOLY2 subroutines follows.

```
      SUBROUTINE GPOLY1
      COMMON  /COMP/  DS(15),N,NA1,NB1,NC,NCAS,NCFL,NEXT,NEXV,NK
     1  NKEX,NKS,NKT,NLFL,NP,NPASS,NPF,NPFT(6),NQ,NS,NSF,NSPT(6
     2  NSTR(18),NSUBR,NV,NVT,Y(12)
      COMMON  /RARRAY/  IMAXR,R(1)
      COMMON  /ECLST1/  KCHOUT,KPRNT,KPTINV(4),KWIT,KWIT1,KWIT2,
     1  KWIT3,KWIT4,NUFF
      COMMON  /KANDV/ K
      COMMON  /MISC/  DTIME,GRAV,KFLSYS,KOUTPT,KPDROP,KSYPAS,KTF
     1  LPSUM(5),MAXCI,MAXLP,MAXSLP,MAXSSI,NCOMPS,NEWDT,NLAST,NF
     2  MINSSI,PGMIN,PLMIN,START,STEADY,TIME,TIMEMX,TMAX,TMIN,WT
      COMMON  /CASE/ NCASE,NRSCS
      COMMON  /PROPTY/  CP0,CP(99),CPCONL,CPCONV,CPCO2,CPDIL,CPO
     1  GAMGAS,RHO0,RHO(99),VISC0,VISC(99),VISGAS,WTM0,WTM(99),W
     2  WTMDIL,WTMTC,XK0,XK(99),XKGAS,XKLIQ,VISLIQ
      COMMON  /SOURCE/  A(19),B(19),CPA,CPB,IA1,IB1,NA,NB,NPFS,N
     1  NSFS,NSFST(6),RHOA,RHOB,VISCA,VISCB,WTMA,WTMB,XKA,XKB
      COMMON /POW/ POWER
      COMMON /VLOC/ IP,IS,IC,IQ,IV,IVT,IEX,INEXK
      LOGICAL POWER
      DIMENSION V(1),K(1)
      EQUIVALENCE (V,K)
      LOGICAL  STEADY
C
C
C
C               THIS LOGIC ALLOWS US TO GET THE CORRECT INLET FLOW
C               TEMPERATURE TO COMPONENT  10
C
      IF(N .NE. 10) GO TO 10
         R(1)=VV(9,20)
         B(2)=VV(237,87)
   10    CONTINUE
C
C                       ********** END OF COMPONENT 10  GPOLY LOG
C
C
C
C     GPOLY1 LOGIC FOR LOW TEMP, HEATING LOOP
C
C                       INTERFACE OF THERMAL C100 TO C139
C
      IF(N .NE. 100) GO TO 100
         R(82)=A(2)
         R(75)=CPA*A(1)
         DO 1100 J=1,19
 1100    R(J)=A(J)
  100 CONTINUE
C
C
C
C
C
C     EVAPORATOR COOLING LIQUID CONTROL VALVE (COMPONENT 109)
C
      IF(N.NE.109) GO TO 109
      IF(STEADY .OR.(NSTR(16) .GT. 0)) GO TO 109
```

```
      TEMPS=VV(210,2)
      IF(TEMPS.GT.105)R(65)=1,0
      IF(R(65).GT.0.0.AND.TEMPS.LT.104.)R(65)=0.0
      IF(TEMPS.LT.104.)R(65)=0.0
  09  CONTINUE
```

GPOLY1 LOGIC FOR AIR LOOP

AIR HEATER CONTROL LOGIC COMPONENT 122

```
      IF(N.NE.122)GO TO 122
      AIRTEP=VV(204,2)
      R(65)=0.0
      IF(AIRTEP.GT.110.0)R(65)=1.0
 122  CONTINUE
```

WARM FLUSH WATER TANK CONTROL LOGIC

```
      IF(N.NE.124)GO TO 124
      IF(STEADY) GO TO 124
      TTANK=VV(41,70)
      IF(TTANK.LT.94.0)R(65)=0.0
      IF(TTANK.GT.96.0)R(65)=1.0
      IF(R(65).GT.0.0.AND.TTANK.LT.94.0)R(65)=0.0
 124  CONTINUE
```

LTHL HX CONTROLLER (COMPONENT 136)

```
      IF(N.NE.136)GO TO 136
      RITET=VV(100,2)
      R(65)=0.0
      IF(RITET.GT.190.0)R(65)=1.0
 136  CONTINUE
```

```
C
C     GPOLY1  LOGIC  FOR   FLUSH WATER LOOP
C
C
C
C
C     COMPONENT  41  WARM FLUSH WATER TANK
      IF(I.NE.41) GO TO 41
      WU=VALUE(6,CYCLE(3600,0,0,0),0,0)
      WS=VALUE(8,CYCLE(21000,0,0,0),0,0)
      WF=VALUE(7,CYCLE(21000,0,0,0),0,0)
      R(17)=WU+WF+WS
      R(1)=R(17)
      W51=VV(51,17)
      A(1)=W51
      A(2)=70.0
      A(17)=A(1)
      SPLT45=0.0
      IF(R(17).NE.0.0)SPLT45=R(17)/(R(17)+W51)
      CALL SV(SPLT45,45,65)
      SPLIT46=0.0
      IF(R(17).NE.0.0)SPLIT46=(WS+WF)/R(17)
      CALL SV(SPLIT46,46,65)
      SPLIT48=0.0
      IF( WS+WF.GT.0.0)SPLIT48=WF/(WS+WF)
      CALL SV(SPLIT48,48,65)
   41 CONTINUE
C
C
C     GPOLY1  LOGIC  FOR   AIR LOOP
C
C
C
      IF(I .NE. 22) GO TO 22
C                                   THIS MOD COMPENSATES FOR FLO CODE 4
C                                   THIS MOD COMPENSATES FOR FLO CODE 4
         R(3)=15.
         R(4)=15.
         R(8)=1.0
         R(9)=1.0E+10
   22 CONTINUE
C
C
C
C
C
      IF(I .NE. 25) GO TO 25
C                               THE FOLLOWING CARDS INTERFACE AIR STERILIZR
C                               TO THE SYSTEM
C        FLOW CONVECTION TERMS
         DO 1025 J=1,19
 1025    R(J)=A(J)
         R(116)=A(2)
         R(106)=A(1)*CPA
         R(104)=A(1)*CPA
         R(102)=A(1)*CPA
         R(99)=A(1)*CPA
         R(96)=A(1)*CPA
```

```
      R(93)=A(1)*CPA
      HEAT BLOCK TEMPERATURE AT NODE 6 HTNG TO AIR STERILIZER
      R(118)=VV(180,76)
   25 CONTINUE



      SPOLY1   LOGIC  FOR SOLID WASTE LOOP

      IF (N .NE. 210) GO TO 210
      B(3)=14.7
      B(4)=14.7
      NSTR(4)=0
      IF(VALUE(15,TIME,0.0).GT.0.0)NSTR(4)=1
      CALL SV(0.0,232,65)
      IF(NSTR(4).GT.0) CALL SV(1.0,232,65)
      R(100)=VV(237,22)
  210 CONTINUE
C
C
C     SPOLY1 LOGIC FOR INCINERATOR
C
      IF(N.NE.213) GO TO 213
      R(51)=R(2)
      IF(TIME.LT.10.OR.TIME.GT.60.0) GO TO 213
      R(76)=1.0
      R(78)=0.2
      R(79)=0.31
  213 CONTINUE
      IF(N .NE. 221) GO TO 221
           A(1)=B(13)*.7651
           A(5)=A(1)
           A(10)=A(1)
           A(2)=70.
           WO2TNK=VV(220,69)
           A(8)=.22
           A(9)=32.
           WO2TNK=WO2TNK-A(1)*DTIME
           A(3)=WO2TNK*1545./32*530./144.
           A(4)=A(3)
      CALL SV(WO2TNK,220,69)
      CALL SV(WO2TNK,220,73)
      CALL SV(WO2TNK,220,78)
      CALL SV(WO2TNK,220,89)
      CALL SV(A(3),220,3)
      CALL SV(A(3),220,4)

      CALL SV(A(3),220,72)
  221 CONTINUE
C
C     BYPASS VAPOR LOOP IF  FLOW=0.0
C
C
      IF(N.NE.232) GO TO 232
      IF(VALUE(15,TIME,0.0).GT.0.0)NEXT=213
```

```
  232 CONTINUE
C
C
C
C
C
      IF(N .NE. 224) GO TO 224
C                       SET HEAT BLOCK (STRUCTURE) TEMP
      R(60)=1200.0
C              PYROLYZE      NH3 = 1/2 N2  +  3/2 H2
      A(14)=A(13)*1.5*(WTM(14)/WTMTO)
      A(11)=A(13)*0.5*(WTMPIL/WTMTO)
      A(13)=0.
C
C            SIMULATE BOSCH REACTION  2H2+CO2=C+2H2O
C
      CRBNDR=A(12)*12./44.*.984191
      A(14)=A(14)-.98491*A(12)*4./44.
      A(12)=.015809*A(12)
  224 CONTINUE
C
      IF( N  .NE.  8) GO TO 8
C                       THIS 100 BYPASSES HEAT BLOCK DURING STEADY STAT
         IF(STEADY) NEXT=101
    8    CONTINUE
C
C
C
C
C     RPOLY1 LOGIC- FOR COOLING LOOP
C
C     COMPONENT 2   FLOW SPLIT TO WATER HEATER
      IF(N.NE.2)GO TO 2
      IF(HCOOL.GE.0.0)GO TO 2000
      R(65)=0.0
      IF(HCOOL.GT.0.0) GO TO 2000
      R(65)=1.0
      CALL SV(1,0,5,65)
      GO TO 2
 2000 CALL SV(0,0,5,65)
    2 CONTINUE
C     RPOLY1   LOGIC  FOR  RITE LOOP
C
C
C
      IF(N .NE. 180) GO TO 180
C                 SET HEAT BLOCK INTERFACES
C                 HEAT LOSS TO HEAT PIPE
         R(88)=-VV(181,75)
C                 HEAT LOSS TO AIR STERILIZER
     R(89)=VV(25,93)*( VV(25,116)-VV(25,80) )-(VV(25,108)*(VV(25,65
    1VV(25,117))) -(VV(25,107)*(VV(25,70)-VV(25,117) ))
C                 HEAT LOSS TO PYROLYSIS UNIT NO1
      R(90)=-70.0
C                 HEAT LOSS TO PYROLYSIS UNIT NO2
      R(91)=R(90)
C                 HEAT LOSS TO PYROLYSIS UNIT NO3
      R(92)=R(90)
```

```
C         HEAT LOSS TO PINCINERATOR
          R(93)=-VV(213,66)
  180 CONTINUE
C
C
C
      IF(N .NE. 181) GO TO 181
C         SET INTERFACE TEMP HEAT BLOCK TO HEAT PIPE
          R(66)= VV(180,70)
  181 CONTINUE
C
C
C
C
      CONDENSER- OUTPUT=INPUT
      IF(N.NE.237)GO TO 237
C
      R(1)=R(69)
  237 CONTINUE
C
C
C
C
C     GPOLY1 LOGIC  FOR POTABLE WATER STORAGE LOOP
C
C     THE POTABLE WATER TANKS WILL BE FILLED IN THIS ORDER 83,84,87,86
C
C     COMPONENT SPLIT 80 -- SPLIT TO TWO TANK GROUPS
C
      IF(N.NE.80)GO TO 80
      R(65)=1.0
      IF(VV(83,69).GT.41.50-A(1)*DTIME/3600.0.AND.VV(84,69).GT.41.50-A(1
     1)*DTIME/3600.0)R(65)=0.0
   80 CONTINUE
C
C
C     COMPONENT  SPLIT 81-SPLIT TO TANKS  86 AND 87
C
      IF(N.NE.81)GO TO 81
      R(65)=0.0
      IF(VV(86,69).LT.41.50-A(1)*DTIME/3600.0)R(65)=1.0
   81 CONTINUE
C
C
C     COMPONENT 82  SPLIT TO TANKS 83 AND 84
C
      IF(N.NE.82)GO TO 82
      R(65)=0.0
      IF(VV(83.69).GT.41.50-A(1)*DTIME/3600.0)R(65)=1.0
   82 CONTINUE
C
C
C     COMPONENT  83  TANK NO. 1
C
      IF(N.NE.83)GO TO 83
      R(1)=0.0
      NTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
      IF(R(69).GT.NTOT*DTIME/3600.0) R(1)=NTOT
   83 CONTINUE
C
```

```
C     COMPONENT  84  TANK NO. 2
C
      IF(I.NE.84)GO TO 84
      R(1)=0.0
      WTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
      IF((VV(83,1).LE.0.0).AND.(WTOT.GT.0.0).AND.(R(69).GT.WTOT*DT
     13600.0)) R(1)=WTOT
   84 CONTINUE
C
C     COMPONENT  87  TANK NO. 3
      IF(I.NE.87)GO TO 87
C
      R(1)=0.0
      WTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
      IF((VV(85,1).LE.0.0).AND.(WTOT.GT.0.0).AND.(R(69).GT.WTOT*DT
     13600.0)) R(1)=WTOT
   87 CONTINUE
C
C     COMPONENT  86  TANK NO. 4
C
      IF(I.NE.86)GO TO 86
      R(1)=0.0
      WTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
      IF((WTOT.GT.0.0).AND.(VV(85,1).LE.0.0).AND.(VV(87,1).LE.0.0).
     1(R(69).GT.WTOT*DTIME/3600.0))  R(1)=WTOT
   86 CONTINUE
C
C     COMPONENT  90 EMERGENCY TANK
C
      IF(I.NE.90) GO TO 90
      R(1)=0.0
      WTOT=VALUE(16,TIME,0.0)+VALUE(17,TIME,0.0)
   90 CONTINUE
      IF(WTOT.GT.0.0.AND.VV(85,1).LE.0.0.AND.VV(88,1).LE.0.0)R(1)=WT
C
C COMPONENT 92  SPLIT TO WATER HEATER AND COOLER
C
      IF(I.NE.92)GO TO 92
      W93=VALUE(16,TIME,0,0)
      W94=VALUE(17,TIME,0,0)
      R(60)=W94/(W93+W94)
   92 CONTINUE
C                   THIS CARD MODIFIES THE KL8) DATA TO ALLOW VAPOR LOOP
      IF(I .NE. 137) GO TO 137
C
  137 CONTINUE
C
C
      RETURN
      END
```

```
      SUBROUTINE GPOLY2
      COMMON  /COMP/ ~~DS(15),~~ ~~NA1,NB1,NC,NCAB,~~NCFL,NEX~~T~~,NEXV,NK,
     1  NKEX,NKS,NKT,NLFL,NP,NPASS,NPF,NPFT(6),NQ,NS,NSF,NSFT(6),
     2  NSTR(18),NSJOR,NV,NVT,Y(12)
      COMMON  /RARRAY/  ~~IMAXR,R(1)~~
      COMMON  /KANDV/ K
      COMMON  /MISC/  DTIME,GRAV,KFLSYS,KOUTPT,KPDROP,KSYPAS,KTRANS,
     1  LPSUM(5),MAXCI,MAXLP,~~MAXSLP,MAXSSI~~,NCOMPS,NEWDT,NLAST,NPASPD,
     2  MINSSI,PGMIN,PLMIN,START,STEADY,TIME,TIMEMX,TMAX,TMIN,WTMAX
      COMMON  /CASE/ NCASE,IRSCS
      COMMON  /PROPTY/  CP0,CP~~(99),CPCONL~~,CPCONV,CPC02,CPDIL,CPOXY,CPTC,
     1  GAMGAS,RHO0,RHO(99),VISC0,VISC(99),VISGAS,WTM0,WTM(99),WTMCON,
     2  WTMOIL,WTMTC,XK0,XK(99),XKGAS,XKLIQ,VISLIQ
      COMMON  /SOURCE/  A(19),~~B(19),CPA,CPB,IA1,IB1~~,NA,NB,NPFS,NPFST(6),
     1  NSFS,NSFST(6),RHOA,RHOB,VISCA,VISCB,WTMA,WTMB,XKA,XKB
      COMMON /POW/ POWER
      LOGICAL POWER
      DIMENSION V(1),K(1)
      EQUIVALENCE (V,K)
      LOGICAL  STEADY
C                    *****   THIS PRINTS V-ARRAY DATA FOR EACH COMPONENT
C
C     GPOLY2 LOGIC LOW TEMPERATURE HEATING LOOP
C
      IF(I .NE. 100) GO TO 100
C                           INTERFACE OF THERMAL C100 TO C139
        R(2)=R(69)
C
  100 CONTINUE
C
C
C     COOLANT PUMP  NO.1      COMPONENT  104
C
      IF(I.NE.104)GO TO    104
      R(70)=0.0151*A(1)
  104 CONTINUE
C
C
C     THIS CHANGE  COMPENSATES FOR HEAT LOSS IN PIPE
C
C
      IF(I.NE.108) GO TO 108
      R(21)=R(21)-4.0
  108 CONTINUE
C
C
C
C
C     GPOLY 2  LOGIC FOR FLUSH WATER LOOP
C
C
C
C
C     FLUSH WATER  PUMP-COMPONENT  44
C     CALCULATION OF PUMP POWER
C
```

```
      IF(J.NE.44) GO TO 44
      R(70)=0.0
      IF(R(1).GT.0.0)R(70)=0.0527+0.0473*R(1)
   44 CONTINUE
C
C
C
C
C
C
C
C
C
C     GPOLY2  LOGIC FOR AIR LOOP
C
C     COMPONENT 21  URINE AIR SUPPLY
C
      IF(J.NE.21) GO TO 21
C
C     STANDARD AIR INPUT=14.7 PSI    70 DEG. F
C     WATER VAPOR     1.05 PERCENT
C     OXYGEN         26.3  PERCENT
C     NITROGEN       72.0  PERCENT
C     CARB.DIOXIDE   0.65 PERCENT
      WAIR=VALUE(9,CYCLE(3600.,0.0,0),0.0)
      R(6)=0.0105*WAIR
      R(10)=0.263*WAIR
      R(11)=0.72 *WAIR
      R(12)=0.0065*WAIR
C
      R(2)=29.6
C     INPUT- MICTURATION
      WUR=VALUE(10,CYCLE(3600.,0.0,0),0.0)
C
C     URINE CONSTITUANTS=94.2 PERCENT  WATER
C     URINE CONSTITUANTS=3.0
C                          2.8 PERCENT  UREA
      R(3)=15.0
      R(4)=15.0
      R(17)=0.942*WUR
      R(15)=0.028*WUR
      R(16)=0.03*WUR
   21 CONTINUE
C
C
C
C
C     AIR LOOP FAN - COMPONENT 24 -FAN ELECTRICAL POWER
C
C
      IF(J.NE.24)GO TO 24
C
      R(72)=0.0
      IF(A(1).GT.0.0)R(72)=117.0+0.91*A(1)
   24 CONTINUE
C
C
C
C
      IF(J .NE. 25) GO TO 25
C                        INTERFACE COMPONENT 25 TO 27
```

```
      R(2)=R(80)
   25 CONTINUE

      SPOLY2  LOGIC  FOR SOLID WASTE LOOP

      COMPONENT 203   BLENDER AIR  SUPPLY
      IF(N.NE.203) GO TO 203
      WAIRB=VALUE(15,CYCLE(21000,0,0,0),0,0)
      R(6)=  0.0105*WAIRB
      R(10)= 0.263 *WAIRB
      R(11)=  0.72  *WAIRB
      R(2)=80.0
      R(3)=14.7
       R(4)=14.7
      IF(WAIRB.GT.0.0)CALL SV(0,23,204,72)
      R(12)= 0.0065*WAIRB
  203 CONTINUE

      COMPONENT  201--SOLIDS INPUT
      IF(N.NE.201) GO TO  201
      R(2)=98.6
      R(3)=14.7
      R(4)=14.7
      R(16)=VALUE(14,CYCLE(21000,0,0,0),0.0)
  201 CONTINUE
C
C
C
C
C
C     BLENDER--COMPONENT 202    POWER CALCULATION
C     R(65) IS SET  EQUAL TO BLENDER ELECTRICAL POWER
C
      IF(N.NE.202)GO TO 202
      R(65)=0.0
      IF(A(1)              .GT.0.0)R(65)=372.0
  202 CONTINUE
C
C
C
C
C
C     COMPONENT  208   TRASH SUPPLY
C
      IF(N.NE.208)GO TO 208
      R(16)=VALUE(13,CYCLE(21000,0,0,0),0.0)
      R(2)=80.0
      R(3)=14.7
      R(4)=14.7
  208 CONTINUE
C
C
C
C
C
```

```
C     SHREDDER --COMPONENT 207  ELECTRICAL POWER
C
      IF(N.NE.207)GO TO 207
      R(65)=0.0
      IF(A(1).GT.0.0.OR.R(1).GT.0.0)R(65)=977.0
  207 CONTINUE
C
C
C
      IF (N  .NE. 210) GO TO 210
  210 CONTINUE
C
      IF(N .NE. 224) GO TO 224
C                   PREDICT AMOUNT NOX GENERATE IN THE PYROLYSIS UNI
C                   SPECIAL FLOW 2  (A(15))=NO2
C                   SPECIA  FLOW 3  (A(16))=NO
      IF(A(11) .LT. 0.06*A(10))GO TO 2241

                A(15)=.00294 *A(10)*46./32.
      IF(R(11) .LT.  0.06*R(10)) GO TO 2241
          R(15)=.0032*R(10)*46./32.
          R(16)=.0032*R(10)*30./16.
          R(11)=R(11)-R(15)*14./46.-R(16)*14./30.
          R(10)=R(10)-R(15)*32./46.-R(16)*16./30.
 2241           CONTINUE
  224     CONTINUE
      RETURN
      END
```