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A User's Guide for MERGE

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ABSTRACT

The MERGE code acts as the interface between the MARCH-2 code, which is used to determine overall accident progression, and the TRAP-MELT code, which is used to evaluate reactor coolant system fission product transport and deposition. MERGE uses MARCH-calculated core exit flows and temperatures to perform a detailed gas-to-structures heat transfer analysis for the control volumes in the flow path through the reactor coolant system and converts these results into a form required as input to TRAP-MELT. MERGE can treat up to nine control volumes, containing up to five structures each. Required inputs include descriptions of the control volumes and their flow connections, as well as initial conditions.

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I. INTRODUCTION

At the time of the writing of the MERGE code, existing computer codes which describe the thermal-hydraulic behavior of a core meltdown accident were not capable of analyzing the flow and temperatures in the volumes of the reactor coolant system downstream of the core in the pathway for release to the containment. In the state-of-the-art report on fission product behavior, NUREG-0772(1), which was undertaken by the NRC in 1981, analyses indicated that in at least some accident sequences the retention of fission products in the reactor coolant system could be significant. In order to support the performance of more realistic analyses of fission product retention with the TRAP-MELT code, an effort was undertaken to write a simple stand-alone code, MERGE, which could be used to predict gas temperature, surface temperature, and flow within the RCS based upon the conditions of gases leaving the core as predicted by the MARCH code. In parallel an effort is being undertaken to provide a distributed reactor coolant system model for the MARCH code which is eventually expected to replace the MERGE code in usage.

Before running MERGE, it is first necessary to perform a MARCH calculation. The output of MERGE is then used as input to the TRAP-MELT code.

The user of MERGE should be aware of some of the approximations and limitations of the code. In the MERGE analysis, it is assumed that the flow of gases in the upper plenum is one-dimensional. In reality, it would be expected that circulation patterns would be established in this region due to the strong temperature gradients. Whether a more detailed analysis is required for this region must be determined based on the results of sensitivity studies with the TRAP-MELT code. The need for verification experiments must also be evaluated.

II. GENERAL CODE DESCRIPTION

MERGE is an interface code which utilizes data generated by MARCH 2(2) to calculate thermal-hydraulic data for input to TRAP-MELT(3). The code employs MARCH output parameters to perform a gas-to-structures heat transfer analysis for control volumes in the core exit gas flow path and converts its calculations into a form acceptable as input to TRAP-MELT. A MARCH output data file (TAPE20) containing the parameters necessary for the heat transfer analysis is attached to the MERGE code. This file can contain MARCH data at several thousand timesteps with each timestep identified by a timestep index. The TRAP-MELT code, however, presently accepts only a maximum of 20 times at which parameters change. To some extent, the MERGE code reduces the MARCH output data from TAPE20 since MERGE calculations begin at a user-specified time index. Further data reduction can be performed by using the numerical averaging routine supplied in the MERGE code.

For most applications, two MERGE runs are performed to process the MARCH TAPE20 output data file. Parameters required for the gas-to-structures heat transfer analysis are stored at each timestep on the file and include maximum, average, and core exit gas temperatures; primary system pressure; fraction of core melted; and steam and hydrogen mass flow rates from the core. A user-specified output print index is used to list these parameters. Using the list as guidance, a maximum of 19 MARCH timestep indexes can be selected for use as limits of a maximum of 20 intervals of averaging for the MARCH data. These numbers are selected such that they adequately represent the MARCH TAPE20 output data, and thus the MERGE output data, over the intervals of interest. The gas-to-structures heat transfer analysis performed by the MERGE code can be broken into three major sections. First, a fluid dynamics analysis is performed to predict gas flow rates, gas temperatures, gas compositions, gas enthalpies, and partial pressures within the reactor coolant system. Second, a heat transfer analysis based on results of the fluid dynamics analysis is performed to obtain heat transfer coefficients which are used to determine temperatures of structures within control volumes of the RCS. Third, an optional fission product heating analysis based on results of a TRAP-MELT analysis using MERGE calculations* is performed to include structural heating caused by fission products which are airborne in the control volumes or deposited on structures within the control volumes.

The MERGE gas-to-structures heat transfer analysis calculates data for a maximum of nine control volumes with each volume containing a maximum of five structures. In the analysis, the core is always the first control volume, while the last volume is included to account for escape from the primary system. Required geometric input data for each control volume and its structures in the core exit gas flow path include heat transfer and flow areas, hydraulic diameters, lengths, wall thicknesses and mass-specific heat products. Control volume height, gas temperature and volume, and its number of structures are also input along with initial wall temperatures of control volumes and structures.

An additional required input is the percentage of total flow entering each volume. The percentage of flow entering each volume may be altered at any time by setting a flag to indicate a change in flow. If a control volume flag is set to change (e.g., FLAG2 = .TRUE.), the time at which the change occurs (FTIME(2)) and the new flow percentage for the volume (FF(2)) are required inputs.

A control volume flow matrix is input to show the path of the gas from source volume J to control volume I. A value of 1 or 0 is assigned to each matrix member to indicate flow/no flow from J to I. Each row and column in the matrix is summed and the values are used as limits for the number of flow paths to/from each control volume. Thus, the matrix setup allows for easy handling of multiple flow paths.

Figure 1 is a diagram showing the sequential flow of the calculations in the MERGE code. It should be noted that the calculations begin at a user-specified start with data averaging from core melt to failure of the reactor pressure vessel. A description of each subroutine in the code is given below.

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* These calculations would result from a previous MERGE analysis using no fission product heating.

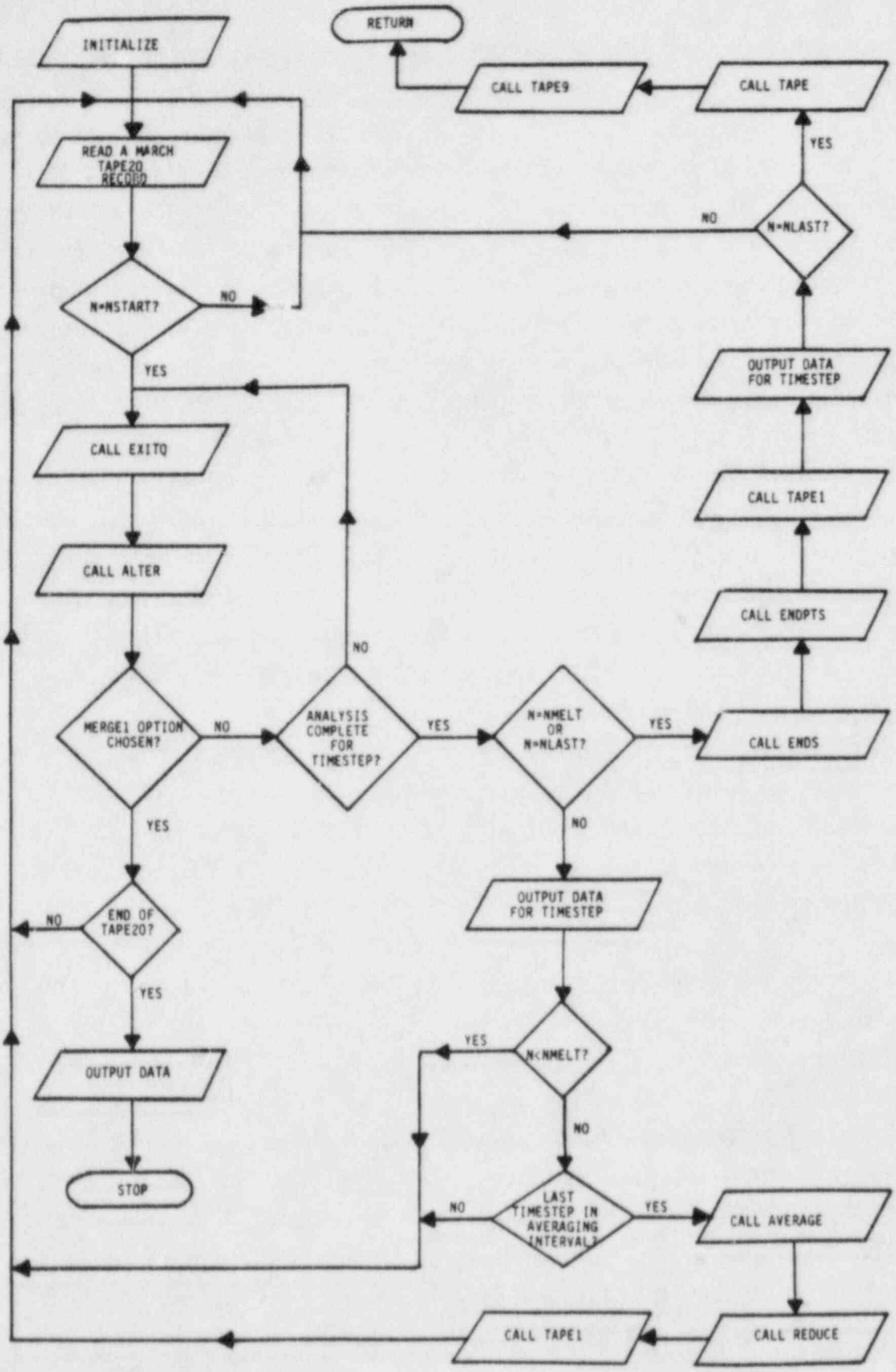

FIGURE 1. FLOW DIAGRAM OF THE MERGE CODE

Subroutine EXITQ

In the MERGE code, the subroutine EXITQ and its associated subroutines analyze the thermal-hydraulic processes. EXITQ is the main subroutine for the gas-to-structures heat transfer analysis and is the largest subroutine in the code.

Fluid Dynamics Analysis

The approach used in solving for the hydraulic conditions in each volume involves an explicit finite difference solution to the flow equations. Conditions within each volume are obtained by moving consecutively from volume to volume downstream of the core. In each case the givens for a particular volume are the initial gas temperature, mass, ratio of hydrogen to steam, and rate of heat addition to structures. Also known from the MARCH calculation are the total pressure, the temperature of the gases leaving the core, the ratio of hydrogen to steam of these gases, and the mass flow rate. For each volume, the unknown variable is the flow rate out of the volume. The equations that must be solved are conservation of mass and conservation of energy. It is also assumed that the hydrogen and steam in a volume has the same temperature and that each obeys an appropriate equation of state. Conservatism of momentum is not imposed since it is assumed that at a particular timestep, all volumes have the total pressure predicted by the MARCH code. These equations can then be solved iteratively by varying the outlet flow until the total pressure is equal to the input MARCH pressure while satisfying the conservation equations and the equations of state. In practice, this approach was found to be time consuming. Instead, an approximate method is used in MERGE to estimate the flow out of the volume assuming that the gases act as an ideal gas over the timestep. This allows an analytic solution for the flow out of the volume given by:

$$W_n = \frac{H_n^0 + W_{n-1}\Delta t(h_{n-1} + 460\ C_0 - C_1) - \frac{C_0 P V_n}{R} + M_{totn}(460\ C_0 - C_1) - Q + (P - P_0)V_n}{(h_n + 460\ C_0 - C_1)\ \Delta T}$$

where

W_n = flow out of volume n,

W_{n-1} = flow out of volume n-1,

H_n^0 = total enthalpy of gases in volume n at beginning of timestep,

h_n = specific enthalpy of gases in volume n,

h_{n-1} = specific enthalpy of gases in volume n-1,

M_{totn} = total mass of gases in volume n,

Δt = timestep,

P = pressure,

P_0 = pressure of gases in volume n at beginning of timestep,

V_n = gas volume in control volume n,

Q = heat transferred between volume gas and wall,

and it is assumed that

$$h_n = C_0 T + C_1 \quad ,$$

where

T = temperature in F, and

C_0, C_1 = coefficients recalculated at each timestep based on the equations of state for steam and hydrogen.

Given the estimated value for the outflow, the gases are then required to satisfy realistic equations of state for steam and hydrogen. The result of the approximation is to yield a slightly different value of the pressure at the end of the timestep than the MARCH calculated value. Because of the crudeness of the one-volume solution that led to the MARCH calculated pressure, this discrepancy is considered minor.

It should be noted that this subroutine also regulates control volume flow throughout by dividing the MARCH timestep into subintervals in order to prevent the total evacuation of the mass in a volume within a timestep. Initially, the subinterval timesteps are determined by first examining each control volume to obtain the one having the least gas volume; second, treating the mixture exiting the top of the core as an ideal gas to determine an approximate volumetric flow rate; and third, subdividing the MARCH timestep until the volumetric flow rate times the subinterval time is less than or equal to 5 percent of the volume having the least gas volume. Subsequent subinterval timesteps are determined by first calculating the change in mass of hydrogen and steam in each control volume in the core exit gas flow path; second, calculating the change in total energy in each control volume; and third, subdividing the MARCH timestep until either the mass change or total energy change per subinterval timestep of each volume is less than or equal to a user-specified maximum. Furthermore, the heat transfer analysis is completed for each control volume over the MARCH timestep, and thus all subintervals, before proceeding to the analysis for the next control volume at the same MARCH timestep.

The Newton-Raphson(4) method of iteration is then employed to solve for control volume steam temperature, pressure, and enthalpy. The following three simultaneous equations are used:

$$HST = (HH - H2M*HH2)/STMM \quad , \qquad (a)$$

$$T = f(PSTM, HST) \quad , \text{ and} \qquad (b)^{(5)}$$

$$\nu = f(PSTM, HST) \quad , \qquad (c)^{(6)}$$

where

HST = specific enthalpy of steam in the control volume, BTU/lbm,

T = temperature of steam in the control volume, F,

ν = specific volume of steam in the control volume, ft^3/lbm,

PSTM = partial pressure of steam in the control volumes, psia,

HH2 = specific enthalpy of hydrogen in the control volume, BTU/lbm,

HH = total enthalpy of the steam-hydrogen mixture in the control volume, BTU,

H2M = mass of hydrogen in the control volume, lbm, and

STMM = mass of steam in the control volume, lbm.

The method uses initial guesses of steam temperature, pressure, and enthalpy to calculate new values of each. This iterative process continues until values are found to satisfy the three equations.

Heat Transfer Analysis

Once solutions to the simultaneous equations have been found, a heat balance between the gas and each structure within the control volume is performed. The heat is transferred from the steam-hydrogen mixture exiting the top of the core to each control volume through an internally calculated heat transfer coefficient.

In determining the heat transfer coefficient between the gas and structure, the Reynolds number is first calculated and depending on whether the flow is in the laminar or turbulent regime the coefficient is calculated as:

Laminar

$$h_c = \frac{k_m}{d} Nu_d \quad , \text{BTU/hr/ft}^2\text{/F} \text{ , and} \qquad (d)^{(7)}$$

Turbulent

$$h_c = 0.0144 \, C_{pm} \frac{G^{0.8}}{d^{0.2}} \quad , \text{BTU/hr/ft}^2\text{/F} \quad , \qquad (e)^{(8)}$$

where

k_m = thermal conductivity of the gas mixture, BTU/hr/ft^2/F,

$$Nu_d = 3.66 + \frac{0.0668(d/L)Re_d Pr}{1 + 0.04[(d/L)Re_d Pr]^{2/3}} \quad , \text{(Reference 7)}$$

d = hydraulic diameter, ft,

C_{pm} = specific heat of the gas mixture, BTU/lb/F, and

G = mass velocity, lb/hr/ft^2 .

A natural convection coefficient is also calculated depending on the Rayleigh number regime:

for $\overline{X} < 10^9$

$$h_c = 0.59 \frac{k}{L} \underline{\overline{X}}^{0.25} \quad \text{, BTU/hr/ft /F} \quad \text{, and} \qquad (f)^{(7)}$$

for $\overline{X} \geq 10^9$

$$h_c = 0.10 \frac{k}{L} \underline{\overline{X}}^{0.33} \quad \text{, BTU/hr/ft}^2\text{/F} \quad , \qquad (g)^{(7)}$$

where

k_m = thermal conductivity of the gas mixture, BTU/hr/ft^2/F,

L = length, ft, and

$\underline{\overline{X}}$ = Rayleigh number.

The larger of the natural and forced convection coefficients is used in the analysis.

The first control volume above the core also receives radiation heat transfer from the top of the core. The inlet gas temperature for this volume is the gas temperature exiting the top of the core. For other volumes, the inlet temperature is the gas temperature at the outlet of the previous volume.

Fission Products' Analysis

The fission product decay heat source term is calculated in the MERGE code by using the American Nuclear Society (ANS) standard decay power curve$^{(9)}$. To determine the distribution of the decay heat among the fission products, the reactor core was assumed to be composed of equal amounts of fuel with burnups of 11,000, 22,000, and 33,000 MWd/MT. The ORIGEN$^{(10)}$code was then used to calculate the decay heat emitted by the fission products in each of the eight WASH-1400$^{(11)}$ fission product groups at various times after reactor shutdown. The results are expressed as percentages of the total for tabular input to MERGE.

The TRAP-MELT code provides the fractions of the core inventories of the WASH-1400 groups which are deposited on structures at various times after beginning of core melt. For a gaseous fission product group, this fraction is an estimate of the rate of heat deposition in a structure as compared to the rate of heat emission by the entire inventory of the group. Results are input to MERGE in tabular form.

Given a time after reactor shutdown, MERGE calculates the total rate of heat emission by the core and interpolates between times on group distribution of the heat emission and on fractional amounts of group heating rates transferred to each structure. The result is the rate of fission product heating of the structure.

A flow diagram showing the calculations in subroutine EXITQ is given in Figure 2. It should also be noted that for a control volume with an inlet gas-wall temperature difference of five degrees or less, the calculations are skipped. Thus, the outlet gas and wall temperatures of the control volume remain unchanged and outlet flow rate is equated to inlet flow rate.

Subroutine ALTER

Subroutine ALTER saves control volume thermal-hydraulic data as a function of timestep index N. It also serves to redefine output parameters for total mass flow rates less than 10^{-10} lb/sec. For any timestep index if the flow meets this criterion: (1) total, hydrogen, and steam mass flow rates are set to zero, and (2) control volume inlet, outlet, and wall temperatures remain unchanged.

Subroutine AVERAGE

Subroutine AVERAGE uses a numerical averaging routine to compute interval values of the input data from the MARCH code. It uses TAPE20 parameters and the preselected intervals to generate 18 intervals of data. The routine also prints these interval values and stores them on the MERGE output file labelled TAPE5.

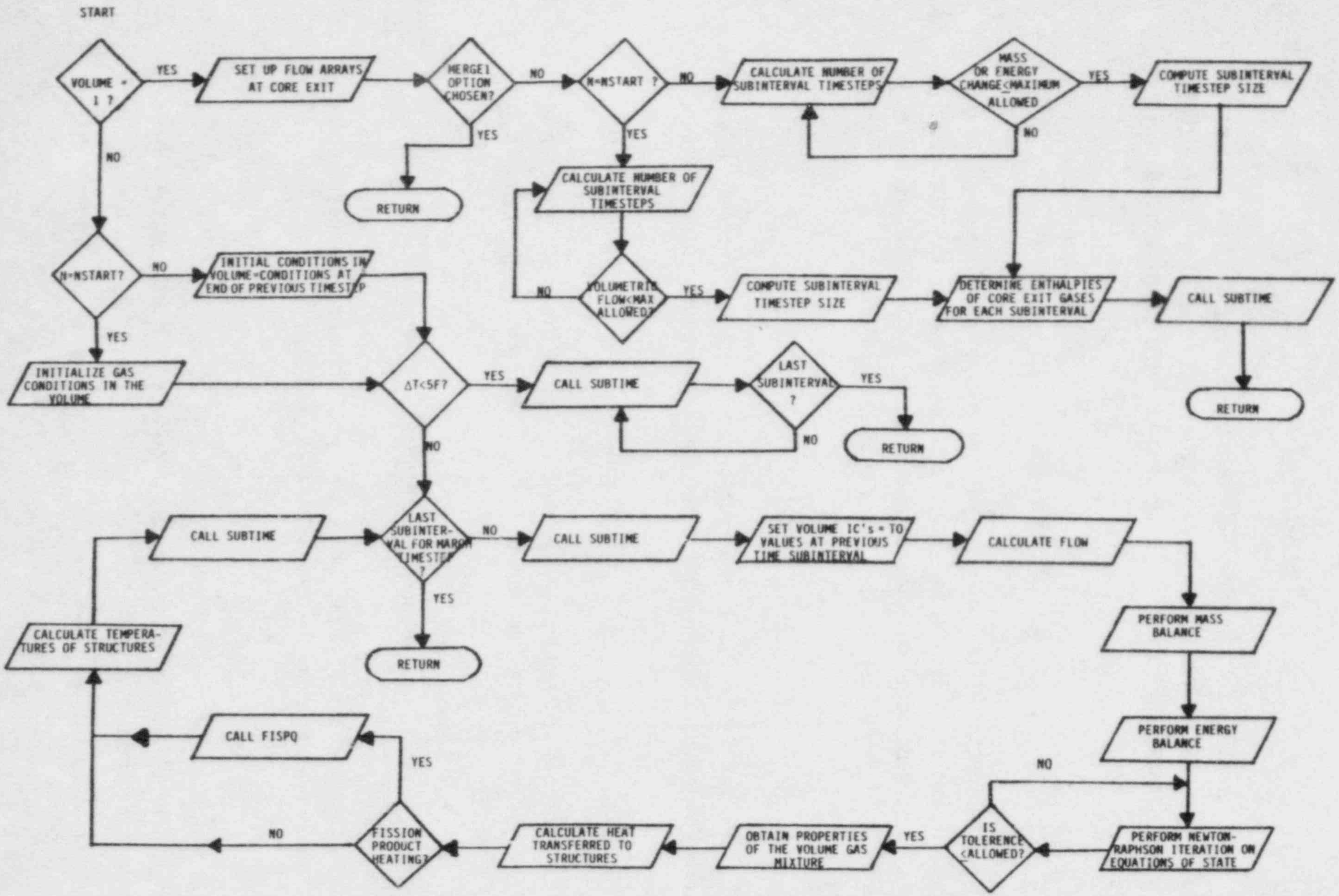

FIGURE 2. FLOW DIAGRAM OF CALCULATIONS IN SUBROUTINE EXITQ

Subroutine ENDS

Subroutine ENDS is the routine used to store the start and end values of the MARCH TAPE20 input data in the first (NMELT) and final (NLAST) intervals. It also prints these values and stores them on MERGE output file TAPE5.

Subroutine REDUCE

Subroutine REDUCE uses a numerical averaging routine to compute interval values of control vlume output data required for the TRAP-MELT analysis. It uses control volume output data and the preselected intervals to generate 18 intervals of data for each control volume.

Subroutine ENDPTS

Subroutine ENDPTS is the routine used to obtain interval values of control volume data for the first and final intervals.

Subroutine ANSQ

Subroutine ANSQ calculates the American Nuclear Society standard (ANS5.1-1979) decay heat fraction as a function of time after shutdown and time at power.

Subroutine FISPQ

Subroutine FISPQ calculates heatup of primary system structures due to decay heat of stored volatile fission products.

Subroutine TAPE

Subroutine TAPE writes the 20 intervals of MERGE control volume output data on the output file labelled TAPE2. The file is cataloged for later use in the TRAP-MELT code.

Subroutine TAPE1

Subroutine TAPE1 prints the interval values of MERGE output data of each control volume at the end of each interval calculation.

Subroutine TAPE9

Subroutine TAPE9 writes the interval values of the gas temperature of each control volume on an output file labelled TAPE9. The temperatures of control volume structures are also written to the file. The file is saved and later plotted.

Subroutine ENTHAL

Subroutine ENTHAL uses an empirical equation to express hydrogen specific heat; and thus, the specific enthalpy of hydrogen as a function of temperature(12). The relationship may be adequately approximated throughout the range of temperatures from 80 F to 5840 F with a maximum error of 0.60%. The subroutine additionally uses empirical equations to express specific enthalpy of saturated liquid or saturated vapor as a function of pressure.(13) The relationships may be adequately approximated through the range of pressures from 1.1 psia to the critical pressure of 3208.2 psia (PCRIT).

Subroutine ENTH

Subroutine ENTH calculates the enthalpy of superheated steam. The subroutine uses the empirical relationship(5) of steam temperature as a function of pressure and enthalpy.

Subroutine TEMP

Subroutine TEMP approximates the temperature of the steam as a function of pressure and specific enthalpy. The empirical relationship(5) employed in the subroutine is valid for pressure less than 3208.2 psia and specific enthalpy equal to or greater than saturated vapor enthalpy at pressure.

Subroutine SPVOL

Subroutine SPVOL approximates the specific volume of steam as a function of pressure and specific enthalpy(6). The critical pressure value is 3208.2 psia and the specific enthalpy boundary is enthalpy greater than or equal to saturated vapor enthalpy at pressure.

Subroutine PART

Subroutine PART calculates the partial derivatives of temperature and specific volume with respect to both steam pressure and enthalpy for use in the Newton-Raphson iterative calculations. The subroutine differentiates the empirical relationships previously established for temperature and specific volume.

Subroutine SUBTIME

Subroutine SUBTIME stores time subinterval MERGE control volume source parameters for later use as inputs to the receiver volumes at corresponding time intervals.

Subroutine HRSTM

Subroutine HRSTM calculates steam emissivity by using the product of steam partial pressure and control volume hydraulic diameter in conjunction with a plot of gas emissivity versus gas temperature given in McAdam's Figure 4-15(8). The resulting emissivity is used to calculate a radiant heat transfer coefficient between the control volume gas and wall surfaces.

Subroutine INTERP

Subroutine INTERP is a routine also written and supplied by Sandia. It is used in conjunction with subroutines PROP and FISPQ and performs required properties' interpolation.

III. INPUT GUIDE TO MERGE

The MERGE code reads the results of the MARCH 2 code calculations from storage device TAPE20. The job control cards must identify this device for it contains the pertinent data for the heat transfer analysis. Four input cards (1, 1A, 2, and 3) are required if a list of the MARCH code calculations (TAPE20) is required.* If calculations are to be performed, several additional input cards are needed. It should be noted that input to the code is unformatted. (Input data decks for an example (S2HF) run are given in Appendix A.) The MERGE data cards follow.

Card 1: MERGE1, MERGE2

MERGE1 = .TRUE., list MERGE input parameters from the MARCH 2 code calculations.

MERGE1 = .FALSE., do not list MERGE input parameters.

MERGE2 = .TRUE., perform gas-to-structures heat transfer analysis.

MERGE2 = .FALSE., do not perform gas-to-structures heat transfer analysis.

Card 1A: NSTEP

NSTEP(a) = an incrementation parameter used to control listing of MERGE input data, e.g., NSTEP = 2 would allow listing of every other record (beginning with the first) from the MARCH 2 output data sets.

(a) Only required if MERGE1 = .TRUE., i.e., if a listing of the data sets from MARCH is desired.

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* If listing only, Card 1 should read as follows: .TRUE., .FALSE.
If calculations are to be performed, Card 1 should read: .FALSE., .TRUE.

Card 2: NSTART, NUNCV, NMELT, NPRT, NPSTP, NLAST

NSTART = MARCH timestep index at which analysis begins.

NUNCV = MARCH timestep index at which core uncovery begins.

NMELT = MARCH timestep index at which the start of core melt begins.

NPRT = MARCH timestep index to start detailed printout (Default: 10000).

NPSTP = MARCH timestep index to stop detailed printout (Default: 10000).

NLAST = last averaging interval completed, used to restart analysis (Default: 0).

Card 3: IVOL, ISG, ITRAN, ACUR

IVOL(b) = number of control volumes.

ISG(c) = steam generator control volume number.

ITRAN(c) = 0, large pipe break.
= 1, transients and small pipe breaks.
= 2, transients (ECCS recirculation inoperable).

ACUR = maximum fractional change allowed in any volume mass or energy per MERGE timestep.

(b) To account for escape from the primary system, a control volume is included to represent the containment. The value input for IVOL does not include the core which is control volume 1.

(c) For a BWR, ISG = 0; for a PWR with a large pipe break, the steam generator structure temperature is reduced to the saturation temperature of the steam generator secondary.

The following data cards relate to volumes above the core and in the exit gas stream (I = 1 identifies the core).

Card 4(d): TT(I), GG(I), VOL(I), LL(I), HGT(I), ISTR(I), CM1(I), DELX(I), AH1(I), DD1(I), AR1(I); I=2, IVOL+1

TT(I) = initial control volume wall surface temperature, F.

GG(I) = initial control volume gas temperature, F.

VOL(I) = gas volume for the control volume, ft^3.

LL(I) = length of control volume, ft.

HGT(I) = vertical height of control volume, ft.

ISTR(I) = number of structures within a control volume.

CM1(I)(e) = product of mass and specific heat of a control volume, BTU/F.

DELX(I) = wall thickness of a control volume, ft.

AH1(I) = heat transfer area of a control volume, ft^2.

DD1(I) = flow hydraulic diameter, ft.

AR1(I) = flow area of a control volume, ft^2.

(d) Use one card for each control volume.

(e) For the steam generator, CM1 should include water in the secondary.

Card 5(f): TTS(I,M) CM(I,M), AH(I,M), DD(I,M), AR(I,M), LL1(I,M), DELX1(I,M); I=2, IVOL+1; M=1, ISTR(I)

TTS(I,M) = initial structure wall temperature in a control volume, F.

CM(I,M) = product of mass and specific head of a structure in a control volume, BTU/F

AH(I,M) = heat transfer area of a structure in a control volume, ft^2.

DD(I,M) = flow hydraulic diameter for a structure in a control volume, ft.

LL1(I,M) = length for a structure in a control volume, ft.

DELX1(I,M) = wall thickness of structure, ft.

(f) Only required if ISTR(I) is greater than 1. Must input one card for each structure in the control volume.

Card 6(g): [TOTM1(I), H2M(I), W(I); I=2, IVOL+1]; PSTART (Default: IVOL*0.,0.)

TOTM1(I) = gas mass in volume I, lbm.

H2M(I) = hydrogen mass in volume I, lbm.

W(I) = mass flow rate from volume I, lbm.

PSTART = primary system pressure, psia.

(g) If a restart of MERGE is required, input values are those at last completed MERGE interval.

Card 7: NCV(I,J); I=1, IVOL+1; J=1, IVOL

NCV(I,J) = 0, no flow from source volume J to control volume I.
= 1, flow from source volume J to control volume I.

Card 8: FF(I+1); I=1, IVOL

FF(I+1) = the percentage of total source flow rate entering control volume I+1.

Card 9(h): FLAG2, FLAG3, FLAG4, FLAG5, etc.

FLAG2 = .TRUE., a change occurs in the percentage of total mass flow rate from the source volume to control volume 2.
= .FALSE., no change occurs in the percentage of total mass flow rate from the source volume to control volume 2.

(h) Use one flag indicator for each control volume, e.g, for five control volumes, input FLAG2 - FLAG6. Similar definitions as above would be used for FLAG3 through FLAG6. The flag indicators should be separated by commas, e.g., the following would be input for no change in flow for five control volumes: .FALSE., .FALSE., .FALSE., .FALSE., .FALSE.

Card 10a(i): FTIME(I); I=2, IVOL+1

FTIME(I) = the time at which the change in percentage of total mass flow rate from the source volume to control volume I occurs (e.g., if FLAG2 = .TRUE., then FTIME(2) would be input to the code).

Card 10b(i): FF2(I); I=2, IVOL+1

FF2(I) = the new value of the percentage of total source flow rate entering control volume I at time FTIME(I). [Only input to the code if the flag indicator for volume I is .TRUE.].

(i) Use one card for 10a and one card for 10b for each control volume in which a change occurs.

Card 11: NINT

NINT = the number of intervals for data averaging (maximum = 18).

Card 12: INT(N); N=1, NINT+1

INT(N) = endpoints to be used for the intervals of the numerical averaging technique; a maximum of 19 is permitted. These limits must be expressed in terms of MARCH TAPE20 timestep indexes.

Card 13a: NBDPT (Default: 0)

NBDPT = number of non-converging MARCH TAPE20 data points.

If NBDPT ≠ 0, input the following:

Card 13b: NBPT(I), I=1, NBDPT

NBPT(I) = timestep index of each non-converging MARCH TAPE20 data point.

Card 13c: STMBD(I); I=1, NBDPT

STMBD(I) = steam flow rate for each non-converging MARCH TAPE20 data point, lbm/min.

Card 13d: H2BD(I); I=1, NBDPT

H2BD(I) = hydrogen flow rate for each non-converging MARCH TAPE20 data point, lbm/min.

Card 13e: PRESBD(I); I=1, NBDPT

PRESBD(I) = primary system pressure for each non-converging MARCH TAPE20 data point, psia.

Card 13f: TGASBD(I); I=1, NBDPT

TGASBD(I) = core exit gas temperature for each non-converging MARCH TAPE20 data point, F.

Card 14a: HSUMT, QZERO, TAP (Defaults: 0., 0., 0.)

HSUMT = total release of hydrogen gas, lbm.

QZERO = reactor power, BTU/hr.

TAP = time at power, min.

If QZERO ≠ 0, and
TAP ≠ 0, input the following:

Card 14b: NTIM, NGP, NTFP

NTIM = number of times at which fission product group distributions are input.

NGP = number of fission product groups.

NTFP = number of times at which fission product deposition percentages are input.

Card 14c: TDK(I); I=1, NTIM

TDK(I) = times at which fission product group distributions are input.

Card 14d: [QFCT(J,I); J=1, NGP], I=1, NTIM

QFCT(J,I) = fission product group deposition percentages for each fission product group distribution.

Card 14e: TFP(I); I=1, NTFP

TFP(I) = times at which fission product deposition percentages are input.

Card 14f: [XMFP(I,J,K); K=1, NGP]; J=1, NTFP; I=2, IVOL

XMFP(I,J,K) = fraction of inventory of each group releasing its heat (QFCT) to each volume at each time TFP.

IV. DESCRIPTION OF MERGE OUTPUT

The output of the MERGE code includes both printed and stored data at user-specified intervals. The results of MERGE calculations, along with several MARCH TAPE20 parameters, for each MARCH timestep are printed in tabular form. Printed output also includes the control volume flow matrix, control volume geometry, and initial conditions. Storage devices (TAPE2, TAPE5, and TAPE9) are used to save numerically-averaged data records for input to the TRAP-MELT code and for plotting purposes. In addition, the averaged data records are printed at the end of the user-specified intervals. Sample output printouts are identified and given in Appendix B. The output is for a small pipe break case in a BWR assuming vapor suppression failure.

The essential output of MERGE consists of numerically-averaged records of control volume temperatures (gas and structures), pressures, and mass flow rates over time for each control volume. The code stores the averaged thermal-hydraulic data of each control volume in the accident sequence on output data file TAPE2. The data in order of storage is as follows:

NINT = number of data intervals.

TPARM(K) = time of data output (sec); K=1, NINT.

FLOP(K,I,5) = total mass flow rate exiting control volume I (lb/sec); K=1, NINT.

NINT = as previously defined.

TPARM(K) = as previously defined.

PRESOUT(K) = control volume pressure (psia); K=1, NINT.

NINT = as previously defined.

TPARM(K) = as previously defined.

FLOP(K,I,6) = control volume gas temperature (F); K=1, NINT.

NINT = as previously defined.

TPARM(K) = as previously defined.

FLOP(K,I,L) = structure temperature in control volume I (F); K=1, NINT, L=6+M (where M = the structure number).

The above data is stored on TAPE2 for each control volume in the primary system and is used as input to the TRAP-MELT computer code.

Additionally, the code stores on output file TAPE5 numerically-averaged MARCH TAPE20 data. A description of each parameter stored on TAPE5 is given below. It should be noted that the described parameters are in order of their storage on the file.

N = timestep index number.

TIME = accident time from start of core melt, min.

TRMAX = maximum core temperature, F.

TCORE = average core temperature, F.

TSAT = primary system saturation temperature, F.

TGEX = core exit gas temperature, F.

PRES = primary system pressure, psia.

STMEXC = core exit steam flow rate, lbm/min.

H2EXC = core exit hydrogen flow rate, lbm/min.

DTMN = time differential, min.

FCM = fraction of core melted.

HSAT = primary system saturation enthalpy, BTU/lbm.

TMAXSG = maximum temperature in steam generator secondary, F.

HFGSG = heat of vaporization in steam generator secondary, BTU/lbm.

WTRSG = weight of water in steam generator secondary, lbm.

RADT = heat radiated to grid plate above core, BTU/hr.

Several of these parameters from the MARCH TAPE20 output data file can be listed at user-specified intervals if the MERGE1 option is selected.

Finally, the code stores on output storage device TAPE9 time-temperature profiles of control volume gas and of structures in each volume. The file is saved and is later plotted. Data storage on TAPE9 is as follows:

K = data set number.

TMAR(K) = time (sec) at which data is output.

FLOP(K,I,6) = temperature of gas in control volume I for data set K.

FLOP(K,I,L) = structure temperature in control volume I (F), where L=6+M and M = the structure number.

It should be noted that the times of data storage on all output storage devices refer to the MARCH time of TAPE20 unless otherwise specified.

V. SUMMARY

The MERGE code performs a gas-to-structures heat transfer analysis for all connected volumes in the flow path of the superheated gas exiting the top of the core. The code predicts key thermal and flow conditions for structures in connected volumes by processing conditions predicted by the MARCH 2 code for the flow out of the reactor core through these connected volumes.

An option in the code allows calculation of structural heating due to airborne or deposited fission products in the volumes. The code performs these calculations from a user-specified start to pressure vessel failure. Output from the code is used as input to the TRAP-MELT code to describe radionuclide behavior. The code is written in FORTRAN and its input and output data are in the British system of units.

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(9) "American National Standard for Decay Heat Power in Light Water Reactors", ANSI/ANS-5.1-1979 (August 29, 1979).

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(12) Van Wylen, G. J., and Sonntag, R. E., Fundamentals of Classical Thermodynamics, Second Edition, John Wiley and Sons, Inc., New York (1973).

(13) McFadden, J. H., et al, "RETRAN-02 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 1: Equations and Numerics", EPRI NP-1850, Equations III.1-4 through III.1-9, pp III-3, -4 (May, 1981).

(14) Sandia National Laboratories, Private Communication from Eric Haskin (1982).

APPENDIX A

APPENDIX A

TABLE A-1. SAMPLE INPUT DATA FOR MERGE

BCL CONTROL CARDS

```
KELLY,AC=A1234,5678,T300
ATTACH,TAPE20,TAPE20,ID=S2HF.(a)
REQUEST,TAPE2,PF.(b)
REQUEST,TAPE5,PF.(b)
REQUEST,TAPE9,PF.(b)
ATTACH,X,MRLGO,ID=KELLY.(c)
X(PL=10000)
CATALOG,TAPE2,TAPE2,ID=S2HF.(b)
CATALOG,TAPE5,TAPE5,ID=S2HF.(b)
CATALOG,TAPE9,TAPE9,ID=S2HF.(b)
*EOR
```

SAMPLE INPUT DATA DECKS

OPTION 1: LIST TAPE20 DATA

```
.TRUE.,.FALSE.,
1
1,301,508,2*10000,0
9,0,1,0.
```

OPTION 2: PERFORM ANALYSIS

```
.FALSE.,.TRUE.,
2*301,508,2*10000,0
2*4,1,0.02
2*580.,1000.,2*12.5,4,5*1.0
2*580.,100.,2*15.0,1,1.E4,0.5,750.0,2.5,5.0
2*525.,850.,2*80.0,1,5.E5,5.E-3,2.E5,7.5E-2,10.0
2*580.,3*1.0,1,5*1.0
```

TABLE A-1. (Continued)

SAMPLE INPUT DATA DECKS (Continued)

```
580.,1000.,7500.,5.E-2,50.0,2.0,5.E-3
580.,7500.,4500.,0.5,75.0,12.5,5.E-2
580.,600.,100.,12.5,75.0,3.0,2.5E-1
580.,7500.,250.,12.5,75.0,8.0,1.0
13*0.
0,1,5*0,1,5*0,1,5*0,1
4*1.
.FALSE.,.FALSE.,.FALSE.,.FALSE.
18
508,526,544,562,580,598,616,634,652,670,688
706,724,742,759,776,793,810,827
0
3*0.
```

(a) MARCH output data file containing parameters necessary for the heat transfer analysis.

(b) Not required for MERGE Option 1; must be included if MERGE output files are to be retrieved.

(c) Binary file created from MERGE source code.

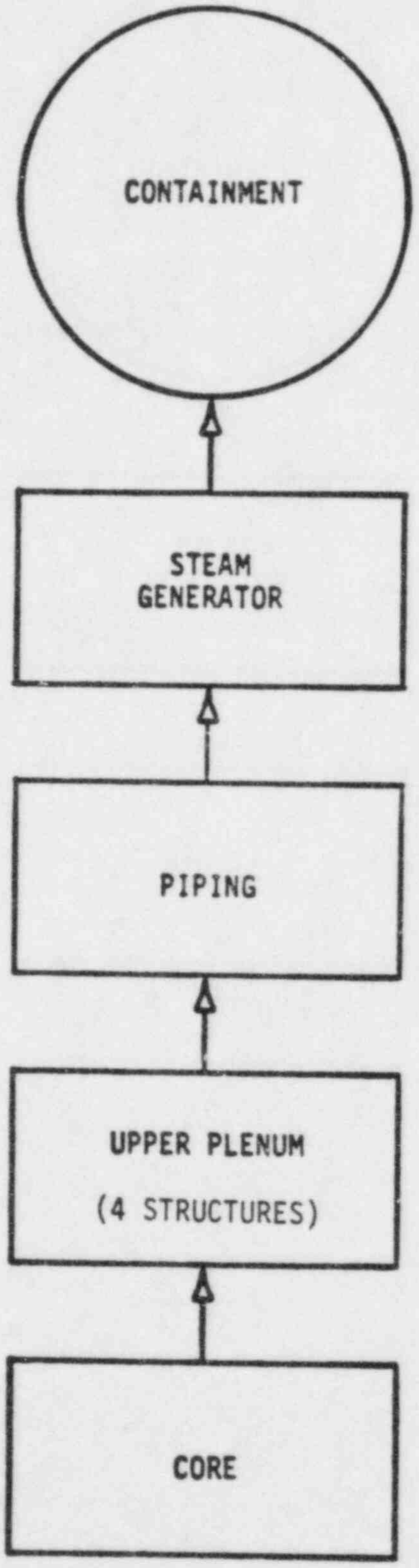

FIGURE A-1. SCHEMATIC OF MERGE CONTROL VOLUMES FOR SEQUOYAH S_2HF SEQUENCE

APPENDIX B

TABLE B-1. SAMPLE OUTPUT PRINTOUT FROM THE MERGE CODE

```
         NCV(I,J) ARE

                  0       0       0       0
                  1       0       0       0
                  0       1       0       0
                  0       0       1       0
                  0       0       0       1

 CONTROL VOLUME 1 IS THE CORE


   CONTROL VOLUME          2
 GAS VOLUME  (FT3)                            =  .100E+04
 GAS TEMPERATURE  (F)                         =  .580E+03
 NUMBER OF STRUCTURES                         =         4

 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .100E+04
 HEAT TRANSFER AREA  (FT2)                    =  .750E+04
 EQUIVALENT DIAMETER  (FT)                    =  .500E+01
 FLOW AREA  (FT2)                             =  .500E+02
 STRUCTURE LENGTH  (FT)                       =  .200E+01
 STRUCTURE THICKNESS  (FT)                    =  .500E-02


 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .750E+04
 HEAT TRANSFER AREA  (FT2)                    =  .450E+04
 EQUIVALENT DIAMETER  (FT)                    =  .500E+00
 FLOW AREA  (FT2)                             =  .750E+02
 STRUCTURE LENGTH  (FT)                       =  .125E+02
 STRUCTURE THICKNESS  (FT)                    =  .500E-01


 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .600E+03
 HEAT TRANSFER AREA  (FT2)                    =  .100E+03
 EQUIVALENT DIAMETER  (FT)                    =  .125E+02
 FLOW AREA  (FT2)                             =  .750E+02
 STRUCTURE LENGTH  (FT)                       =  .300E+01
 STRUCTURE THICKNESS  (FT)                    =  .250E+00


 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .750E+04
 HEAT TRANSFER AREA  (FT2)                    =  .250E+03
 EQUIVALENT DIAMETER  (FT)                    =  .125E+02
 FLOW AREA  (FT2)                             =  .750E+02
 STRUCTURE LENGTH  (FT)                       =  .800E+01
 STRUCTURE THICKNESS  (FT)                    =  .100E+01
```

```
   CONTROL VOLUME          3
 GAS VOLUME  (FT3)                            =  .100E+03
 GAS TEMPERATURE  (F)                         =  .580E+03
 NUMBER OF STRUCTURES                         =         1

 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .100E+05
 HEAT TRANSFER AREA  (FT2)                    =  .750E+03
 EQUIVALENT DIAMETER  (FT)                    =  .250E+01
 FLOW AREA  (FT2)                             =  .500E+01
 STRUCTURE LENGTH  (FT)                       =  .150E+02
 STRUCTURE THICKNESS  (FT)                    =  .500E+00


   CONTROL VOLUME          4
 GAS VOLUME  (FT3)                            =  .850E+03
 GAS TEMPERATURE  (F)                         =  .525E+03
 NUMBER OF STRUCTURES                         =         1

 STRUCTURE TEMPERATURE  (F)                   =  .525E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .500E+06
 HEAT TRANSFER AREA  (FT2)                    =  .200E+06
 EQUIVALENT DIAMETER  (FT)                    =  .750E-01
 FLOW AREA  (FT2)                             =  .100E+02
 STRUCTURE LENGTH  (FT)                       =  .800E+02
 STRUCTURE THICKNESS  (FT)                    =  .500E-02


   CONTROL VOLUME          5
 GAS VOLUME  (FT3)                            =  .100E+01
 GAS TEMPERATURE  (F)                         =  .580E+03
 NUMBER OF STRUCTURES                         =         1

 STRUCTURE TEMPERATURE  (F)                   =  .580E+03
 MASS X SPECIFIC HEAT  (BTU/F)                =  .100E+01
 HEAT TRANSFER AREA  (FT2)                    =  .100E+01
 EQUIVALENT DIAMETER  (FT)                    =  .100E+01
 FLOW AREA  (FT2)                             =  .100E+01
 STRUCTURE LENGTH  (FT)                       =  .100E+01
 STRUCTURE THICKNESS  (FT)                    =  .100E+01


 CORE UNCOVERY OCCURS AT MARCH CYCLE NUMBER        301
 CORE MELT BEGINS AT MARCH CYCLE NUMBER            508

 ACUR =       .020
```

TABLE B-2. SAMPLE OUTPUT OF THE RESULTS OF THE MERGE CALCULATIONS USING MARCH TAPE20 PARAMETERS

```
                THE DATA SET NUMBER =     1          THE MERGE CYCLE NUMBER =     1          THE TIME = 11770.926SEC

                                                     THE MARCH CYCLE NUMBER =  508    THE MARCH TIME =    196.182MIN

                THE NUMBER OF MERGE TIME INTERVALS =               48

                THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)                 THE AVERAGE CORE TEMPERATURE =    1906.00 (F)

                THE FRACTION OF CORE MELTED =   .998E-03                      THE PRIMARY SYSTEM PRESSURE =    591.12 (PSIA)

                THE HYDROGEN MASS FLOW RATE =   .100E+01 (LB/SEC)             THE TOTAL MASS FLOW RATE =   .723E+01 (LB/SEC)

                 INLET        OUTLET       VOLUME       STRUCTURE      FLOW        HYDROGEN      TOTAL        HYDROGEN       TOTAL
  VOLUME        GAS TEMP     GAS TEMP     PRESSURE        TEMP        FACTOR      MASS FLOW    MASS FLOW        MASS          MASS


    2          .2014E+04    .7684E+03    .5927E+03    .6000E+03    .1000E+01    .3372E+00    .2088E+02    .1209E+02    .7485E+03
    2                                                 .5819E+03
    2                                                 .5809E+03
    2                                                 .5802E+03
    3          .7684E+03    .7030E+03    .5927E+03    .3804E+03    .1000E+01    .2741E+00    .2222E+02    .1015E+01    .8227E+02
    4          .7030E+03    .5267E+03    .5916E+03    .5251E+03    .1000E+01    .4821E-01    .2482E+02    .1884E+01    .9700E+03
    5          .5267E+03   0.            .5911E+03    .5800E+03    .1000E+01    .4821E-01    .2482E+02   0.            0.
THE AVERAGING INTERVAL =          1          THE TIME =  .117709E+05
TAPE 5 VARIABLES ARE
 .413E+04  .191E+04  .485E+03  .201E+04  .591E+03  .374E+03  .600E+02  .250E+00  .998E-03  .120E+04
 .556E+03  .632E+03  .308E+06  .264E+06


THE AVERAGING INTERVAL IS NUMBER      1
THE AVERAGE TIME IS    .117709E+05 SECONDS

                FLOP( 1, 1, 5) =    .723E+01
                PRESOUT( 1) =    .591E+03
                FLOP( 1, 1, 6) =    .201E+04
                FLOP( 1, 1, 7) =    .191E+04

                FLOP( 1, 2, 5) =    .209E+02
                PRESOUT( 1) =    .591E+03
                FLOP( 1, 2, 6) =    .768E+03
                FLOP( 1, 2, 7) =    .600E+03
                FLOP( 1, 2, 8) =    .582E+03
                FLOP( 1, 2, 9) =    .581E+03
                FLOP( 1, 2,10) =    .580E+03

                FLOP( 1, 3, 5) =    .222E+02
                PRESOUT( 1) =    .591E+03
                FLOP( 1, 3, 6) =    .703E+03
                FLOP( 1, 3, 7) =    .580E+03

                FLOP( 1, 4, 5) =    .248E+02
                PRESOUT( 1) =    .591E+03
                FLOP( 1, 4, 6) =    .527E+03
                FLOP( 1, 4, 7) =    .525E+03

                FLOP( 1, 5, 5) =    .248E+02
                PRESOUT( 1) =    .591E+03
                FLOP( 1, 5, 6) =  0.
                FLOP( 1, 5, 7) =    .580E+03
```

TABLE B-2. (Continued)

```
              THE DATA SET NUMBER =    3         THE MERGE CYCLE NUMBER =    3         THE TIME = 11800.926SEC

                                                 THE MARCH CYCLE NUMBER =  510    THE MARCH TIME =   196.682MIN

              THE NUMBER OF MERGE TIME INTERVALS =             41

              THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)              THE AVERAGE CORE TEMPERATURE =    1974.22 (F)

              THE FRACTION OF CORE MELTED =   .198E-01                   THE PRIMARY SYSTEM PRESSURE =    586.47 (PSIA)

              THE HYDROGEN MASS FLOW RATE =   .109E+01 (LB/SEC)          THE TOTAL MASS FLOW RATE =   .691E+01 (LB/SEC)

               INLET        OUTLET        VOLUME       STRUCTURE      FLOW        HYDROGEN      TOTAL        HYDROGEN       TOTAL
 VOLUME       GAS TEMP     GAS TEMP      PRESSURE        TEMP        FACTOR      MASS FLOW    MASS FLOW         MASS          MASS


    2        .2062E+04    .9012E+03    .5877E+03    .7203E+03    .1000E+01    .6764E+00    .1183E+02    .2896E+02    .5065E+03
    2                                               .5915E+03
    2                                               .5861E+03
    2                                               .5810E+03
    3        .9012E+03    .8041E+03    .5879E+03    .5824E+03    .1000E+01    .6320E+00    .1239E+02    .2899E+01    .5682E+02
    4        .8041E+03    .5272E+03    .5874E+03    .5252E+03    .1000E+01    .2343E+00    .1692E+02    .1182E+02    .8532E+03
    5        .5272E+03   0.            .5865E+03    .5800E+03    .1000E+01    .2343E+00    .1692E+02   0.            0.
```

```
              THE DATA SET NUMBER =    8         THE MERGE CYCLE NUMBER =    8         THE TIME = 11875.926SEC

                                                 THE MARCH CYCLE NUMBER =  515    THE MARCH TIME =   197.932MIN

              THE NUMBER OF MERGE TIME INTERVALS =             12

              THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)              THE AVERAGE CORE TEMPERATURE =    2144.08 (F)

              THE FRACTION OF CORE MELTED =   .901E-01                   THE PRIMARY SYSTEM PRESSURE =    574.89 (PSIA)

              THE HYDROGEN MASS FLOW RATE =   .133E+01 (LB/SEC)          THE TOTAL MASS FLOW RATE =   .505E+01 (LB/SEC)

               INLET        OUTLET        VOLUME       STRUCTURE      FLOW        HYDROGEN      TOTAL        HYDROGEN       TOTAL
 VOLUME       GAS TEMP     GAS TEMP      PRESSURE        TEMP        FACTOR      MASS FLOW    MASS FLOW         MASS          MASS


    2        .2181E+04    .1060E+04    .5776E+03    .9918E+03    .1000E+01    .1231E+01    .7047E+01    .4683E+02    .2681E+03
    2                                               .6250E+03
    2                                               .6048E+03
    2                                               .5842E+03
    3        .1060E+04    .9119E+03    .5780E+03    .5893E+03    .1000E+01    .1231E+01    .7273E+01    .5131E+01    .3033E+02
    4        .9119E+03    .5336E+03    .5791E+03    .5256E+03    .1000E+01    .8859E+00    .1095E+02    .4260E+02    .5265E+03
    5        .5336E+03   0.            .5749E+03    .5800E+03    .1000E+01    .8859E+00    .1095E+02   0.            0.
```

TABLE B-2. (Continued)

```
          THE DATA SET NUMBER =   13        THE MERGE CYCLE NUMBER =   13        THE TIME = 11950.926SEC

                                            THE MARCH CYCLE NUMBER =  520   THE MARCH TIME =   199.182MIN

          THE NUMBER OF MERGE TIME INTERVALS =                  4

          THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)               THE AVERAGE CORE TEMPERATURE =    2320.91 (F)

          THE FRACTION OF CORE MELTED =   .177E+00                    THE PRIMARY SYSTEM PRESSURE =    563.15 (PSIA)

          THE HYDROGEN MASS FLOW RATE =   .135F+01 (LB/SEC)           THE TOTAL MASS FLOW RATE =   .501E+01 (LB/SEC)
                INLET        OUTLET        VOLUME       STRUCTURE      FLOW       HYDROGEN       TOTAL       HYDROGEN       TOTAL
 VOLUME       GAS TEMP      GAS TEMP      PRESSURE        TEMP        FACTOR      MASS FLOW    MASS FLOW        MASS         MASS


   2        .2313E+04     .1195E+04     .5651E+03     .1164E+04     .1000E+01    .1384E+01    .5524E+01    .4811E+02    .1920E+03
   2                                                  .6701E+03
   2                                                  .6307E+03
   2                                                  .5886F+03
   3        .1195E+04     .1002E+04     .5652E+03     .5984E+03     .1000E+01    .1392E+01    .5557E+01    .5449E+01    .2176E+02
   4        .1002E+04     .5509E+03     .5618E+03     .5259E+03     .1000E+01    .1272E+01    .6978E+01    .5984E+02    .3283E+03
   5        .5509E+03   0.              .5632E+03     .5800E+03     .1000E+01    .1272E+01    .6978E+01  0.           0.



          THE DATA SET NUMBER =   18        THE MERGE CYCLE NUMBER =   18        THE TIME = 12025.926SEC

                                            THE MARCH CYCLE NUMBER =  525   THE MARCH TIME =   200.432MIN

          THE NUMBER OF MERGE TIME INTERVALS =                  3

          THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)               THE AVERAGE CORE TEMPERATURE =    2505.95 (F)

          THE FRACTION OF CORE MELTED =   .256E+00                    THE PRIMARY SYSTEM PRESSURE =    551.33 (PSIA)

          THE HYDROGEN MASS FLOW RATE =   .138E+01 (LB/SEC)           THE TOTAL MASS FLOW RATE =   .486E+01 (LB/SEC)
                INLET        OUTLET        VOLUME       STRUCTURE      FLOW       HYDROGEN       TOTAL       HYDROGEN       TOTAL
 VOLUME       GAS TEMP      GAS TEMP      PRESSURE        TEMP        FACTOR      MASS FLOW    MASS FLOW        MASS         MASS


   2        .2465E+04     .1301E+04     .5523E+03     .1279E+04     .1000E+01    .1412E+01    .5083E+01    .4568E+02    .1645E+03
   2                                                  .7255E+03
   2                                                  .6636E+03
   2                                                  .5942E+03
   3        .1301E+04     .1096E+04     .5526E+03     .6096E+03     .1000E+01    .1445E+01    .5198E+01    .5177E+01    .1862E+02
   4        .1096E+04     .5820E+03     .5556E+03     .5263E+03     .1000E+01    .1504E+01    .6020E+01    .6415E+02    .2569E+03
   5        .5820E+03   0.              .5513E+03     .5800F+03     .1000E+01    .1504F+01    .6020E+01  0.           0.
```

TABLE B-2. (Continued)

```
          THE DATA SET NUMBER =   19        THE MERGE CYCLE NUMBER =   19         THE TIME = 12040.926SEC

                                            THE MARCH CYCLE NUMBER =  526    THE MARCH TIME =   200.682MIN

          THE NUMBFR OF MERGE TIME INTERVALS =              7

          THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)               THE AVERAGE CORE TEMPERATURE =    2536.91 (F)

          THE FRACTION OF CORE MELTED =   .264E+00                    THE PRIMARY SYSTEM PRESSURE =     548.96 (PSIA)

          THE HYDROGEN MASS FLOW RATE =   .139E+01 (LB/SEC)           THE TOTAL MASS FLOW RATE =   .482E+01 (LB/SEC)

              INLET       OUTLET       VOLUME      STRUCTURE     FLOW        HYDROGEN       TOTAL        HYDROGEN       TOTAL
VOLUME      GAS TEMP     GAS TEMP     PRESSURE       TEMP        FACTOR      MASS FLOW    MASS FLOW          MASS          MASS


   2       .2498E+04   .1317E+04    .5493E+03    .1299E+04    .1000E+01    .1419E+01    .5041E+01    .4521E+02    .1606E+03
   2                                             .7376E+03
   2                                             .6709E+03
   2                                             .5955E+03
   3       .1317E+04   .1085E+04    .5494E+03    .6120E+03    .1000E+01    .1424E+01    .5064E+01    .5201E+01    .1849E+02
   4       .1085E+04   .5503E+03    .5503E+03    .5265E+03    .1000E+01    .1414E+01    .5490E+01    .6624E+02    .2572E+03
   5       .5503E+03   0.           .5490E+03    .5800E+03    .1000E+01    .1414E+01    .5490E+01   0.            0.
THE AVERAGING INTERVAL =          2           THE AVERAGE TIME =  .119059E+05
TAPE 5 VARIABLES ARE
 .413E+04  .222E+04  .481E+03  .224E+04  .570E+03  .256E+03  .765E+02  .250E+00  .128E+00  .120E+04
 .556E+03  .632E+03  .308E+06  .411E+06


THE AVERAGING INTERVAL IS NUMBER      2
THE AVERAGE TIME IS    .119059E+05 SECONDS

          FLOP( 2, 1, 5) =    .555E+01
          PRESOUT( 2) =    .570E+03
          FLOP( 2, 1, 6) =    .224E+04
          FLOP( 2, 1, 7) =    .222E+04

          FLOP( 2, 2, 5) =    .770E+01
          PRESOUT( 2) =    .570E+03
          FLOP( 2, 2, 6) =    .110E+04
          FLOP( 2, 2, 7) =    .103E+04
          FLOP( 2, 2, 8) =    .648E+03
          FLOP( 2, 2, 9) =    .618E+03
          FLOP( 2, 2,10) =    .586E+03

          FLOP( 2, 3, 5) =    .794E+01
          PRESOUT( 2) =    .570E+03
          FLOP( 2, 3, 6) =    .941E+03
          FLOP( 2, 3, 7) =    .594E+03

          FLOP( 2, 4, 5) =    .105E+02
          PRESOUT( 2) =    .570E+03
          FLOP( 2, 4, 6) =    .542E+03
          FLOP( 2, 4, 7) =    .526E+03

          FLOP( 2, 5, 5) =    .105E+02
          PRESOUT( 2) =    .570E+03
          FLOP( 2, 5, 6) =  0.
          FLOP( 2, 5, 7) =    .580E+03
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TABLE B-2. (Continued)

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         THE DATA SET NUMBER =    5          THE MERGE CYCLE NUMBER =   23          THE TIME = 12100.926SEC

                                             THE MARCH CYCLE NUMBER =  530    THE MARCH TIME =   201.682MIN

         THE NUMBER OF MERGE TIME INTERVALS =                 8

         THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)             THE AVERAGE CORE TEMPERATURE =    2687.78 (F)

         THE FRACTION OF CORE MELTED =   .321E+00                  THE PRIMARY SYSTEM PRESSURE =     538.40 (PSIA)

         THE HYDROGEN MASS FLOW RATE =   .141E+01 (LB/SEC)         THE TOTAL MASS FLOW RATE =   .457E+01 (LB/SEC)

               INLET       OUTLET       VOLUME      STRUCTURE      FLOW      HYDROGEN      TOTAL       HYDROGEN        TOTAL
VOLUME       GAS TEMP     GAS TEMP     PRESSURE        TEMP       FACTOR     MASS FLOW   MASS FLOW         MASS          MASS


   2        .2637E+04    .1382E+04    .5388E+03    .1367E+04    .1000E+01    .1434E+01   .4783E+01    .4359E+02    .1454E+03
   2                                               .7892E+03
   2                                               .7023E+03
   2                                               .6009E+03
   3        .1382E+04    .1128E+04    .5388E+03    .6221E+03    .1000E+01    .1438E+01   .4806E+01    .5056E+01    .1689E+02
   4        .1128E+04    .5499E+03    .5392E+03    .5269E+03    .1000E+01    .1442E+01   .5097E+01    .5681E+02    .2362E+03
   5        .5499E+03   0.            .5384E+03    .5800E+03    .1000E+01    .1442E+01   .5097E+01   0.            0.


         THE DATA SET NUMBER =   15          THE MERGE CYCLE NUMBER =   33          THE TIME = 12250.926SEC

                                             THE MARCH CYCLE NUMBER =  540    THE MARCH TIME =   204.182MIN

         THE NUMBER OF MERGE TIME INTERVALS =                21

         THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)             THE AVERAGE CORE TEMPERATURE =    3094.21 (F)

         THE FRACTION OF CORE MELTED =   .438E+00                  THE PRIMARY SYSTEM PRESSURE =     512.33 (PSIA)

         THE HYDROGEN MASS FLOW RATE =   .182E+01 (LB/SEC)         THE TOTAL MASS FLOW RATE =   .199E+01 (LB/SEC)

               INLET       OUTLET       VOLUME      STRUCTURE      FLOW      HYDROGEN      TOTAL       HYDROGEN        TOTAL
VOLUME       GAS TEMP     GAS TEMP     PRESSURE        TEMP       FACTOR     MASS FLOW   MASS FLOW         MASS          MASS


   2        .3058E+04    .1626E+04    .5133E+03    .1592E+04    .1000E+01    .1858E+01   .2375E+01    .4484E+02    .5733E+02
   2                                               .9308E+03
   2                                               .7887E+03
   2                                               .6161E+03
   3        .1626E+04    .1307E+04    .5135E+03    .6516E+03    .1000E+01    .1869E+01   .2424E+01    .5284E+01    .6850E+01
   4        .1307E+04    .5411E+03    .5145E+03    .5282E+03    .1000E+01    .1793E+01   .3439E+01    .7454E+02    .1430E+03
   5        .5411E+03   0.            .5123E+03    .5800E+03    .1000E+01    .1793E+01   .3439E+01   0.            0.
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TABLE B-2. (Continued)

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               THE DATA SET NUMBER =   19          THE MERGE CYCLE NUMBER =   37          THE TIME = 12310.926SEC

                                                   THE MARCH CYCLE NUMBER =  544    THE MARCH TIME =   205.182MIN

               THE NUMBER OF MERGE TIME INTERVALS =                 21

               THE MAXIMUM CORE TEMPERATURE =    4130.00 (F)                THE AVERAGE CORE TEMPERATURE =    3257.10 (F)

               THE FRACTION OF CORE MELTED =   .501F+00                     THE PRIMARY SYSTEM PRESSURE =    501.13 (PSIA)

               THE HYDROGEN MASS FLOW RATE =   .187F+01 (LB/SEC)            THE TOTAL MASS FLOW RATE =   .195E+01 (LB/SEC)

                  INLET        OUTLET        VOLUME       STRUCTURF       FLOW       HYDROGEN       TOTAL        HYDROGEN       TOTAL
VOLUME          GAS TEMP      GAS TEMP      PRESSURE        TEMP         FACTOR      MASS FLOW     MASS FLOW        MASS          MASS
-----------------------------------------------------------------------------------------------------------------------------------


   2          .3202E+04     .1814E+04     .5013E+03     .1764E+04     .1000E+01     .1942E+01     .2083E+01     .4109E+02     .4408E+02
   2                                                    .9814E+03
   2                                                    .8184E+03
   2                                                    .6217E+03
   3          .1814E+04     .1452E+04     .5014E+03     .6658E+03     .1000E+01     .1951E+01     .2099E+01     .4886E+01     .5255E+01
   4          .1452E+04     .5451E+03     .5024E+03     .5289E+03     .1000E+01     .1946E+01     .2532E+01     .7724E+02     .1005E+03
   5          .5451E+03   0.              .5611E+03     .5800E+03     .1000F+01     .1946E+01     .2532E+01   0.            0.
THE AVERAGING INTERVAL =           3          THE AVERAGE TIME =  .121759E+05
TAPE 5 VARIABLES ARE
 .413E+04  .289E+04  .473E+03  .285E+04  .525E+03  .109E+03  .959E+02  .250E+00  .380E+00  .120E+04
 .556E+03  .632E+03  .308E+06  .908E+06


THE AVERAGING INTERVAL IS NUMBER      3
THE AVERAGE TIME IS    .121759E+05 SECONDS

              FLOP( 3, 1, 5) =    .341E+01
              PRESOUT( 3) =    .525F+03
              FLOP( 3, 1, 6) =    .285E+04
              FLOP( 3, 1, 7) =    .289E+04

              FLOP( 3, 2, 5) =    .377E+01
              PRESOUT( 3) =    .525E+03
              FLOP( 3, 2, 6) =    .150E+04
              FLOP( 3, 2, 7) =    .148E+04
              FLOP( 3, 2, 8) =    .860E+03
              FLOP( 3, 2, 9) =    .746E+03
              FLOP( 3, 2,10) =    .604E+03

              FLOP( 3, 3, 5) =    .381E+01
              PRESOUT( 3) =    .525E+03
              FLOP( 3, 3, 6) =    .122E+04
              FLOP( 3, 3, 7) =    .637E+03

              FLOP( 3, 4, 5) =    .441E+01
              PRESOUT( 3) =    .525E+03
              FLOP( 3, 4, 6) =    .556E+03
              FLOP( 3, 4, 7) =    .528E+03

              FLOP( 3, 5, 5) =    .441E+01
              PRESOUT( 3) =    .525F+03
              FLOP( 3, 5, 6) =  0.
              FLOP( 3, 5, 7) =    .580E+03
```

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The MERGE code acts as the interface between the MARCH-2 code, which is used to determine overall accident progression, and the TRAP-MELT code, which is used to evaluate reactor coolant system fission product transport and deposition. MERGE uses MARCH-calculated core exit flows and temperatures to perform a detailed gas-to-structures heat transfer analysis for the control volumes in the flow path through the reactor coolant system and converts these results into a form required as input to TRAP-MELT. MERGE can treat up to nine control volumes, containing up to five structures each. Required inputs include descriptions of the control volumes and their flow connections, as well as initial conditions.

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