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TRANSIENT TEMPERATURE AND PRESSURE IN THE REACTOR ROOM DURING A CORE MELTDOWN ACCIDENT

INTRODUCTION

A solid adsorption noble gas confinement system has been proposed for the SRP reactors, to contain the gaseous fission products released during a fuel melting accident. The noble gases are to be removed from the reactor room ventilation exhaust system. For efficient design of the adsorption system, it is desirable to minimize the ventilation exhaust flow rate. The gauge pressure in the reactor room must be maintained below twelve inches of water to insure the integrity of the water seal in the D&E canal. The numerical model described in this document predicts the transient temperature and pressure in the reactor room during a 100% fuel melting accident.

The purpose of this numerical model is to determine the optimum ventilation exhaust flow rate for the reactor room. The influence of steam produced in the reactor vessel, on the reactor room pressure, is included in the model. A parametric study of the affect of various steam mass flow rates is included in this document. The affect of steam on the conditions in the reactor room is significant at modest flow rates.

DISCUSSION

The purpose of this computer program is to optimize the reactor room ventilation exhaust for containment of gaseous fission products during a meltdown accident. Gaseous fission products are released in a fuel melting accident. These gases are convected from the reactor vessel to the reactor room above by heated air and steam. The gaseous fission products are contained by adsorption from the reactor room ventilation exhaust system. The gauge pressure in the reactor room must be maintained below 12 inches of water, in order to prevent the escape of some of the radioactive gas through the D&E canal. A peak pressure of 12 inches of water is the criteria for minimizing the ventilation exhaust volume flow rate.

The transient temperature and pressure in the reactor room is calculated by numerical integration of the First Law of Thermodynamics. The reactor room is treated as a control volume. A schematic of the reactor room, with the appropriate mass flows that cross the control surface, is shown in Figure (1). The energy sources are the decay heat of the gaseous fission products and the steam produced in the reactor vessel. Cooling water is sprayed into the reactor room, and the water that does not evaporate is withdrawn from the control volume. The mass flow rate of the water spray is assumed to be 2 kg/s. This is greater than the peak evaporation rate, approximately 1.5 kg/s, while the heating of the nonevaporated water does not require an unrealistic amount of power. The ventilation supply air passes through a damper that closes when the reactor room pressure exceeds -.1 inches of water. The volume flow rate of the ventilation exhaust is constant with respect to time and an independent variable in this model. The initial condition is a saturated air/water vapor mixture at 24°C.

The atmosphere inside of the reactor room is assumed to be a saturated mixture of ideal gases, air and water vapor. The reactor room is assumed to undergo an equilibrium process and the form of the First Law of Thermodynamics governing this process is that for uniform flow and uniform state, reference (1):

$$\dot{Q} + \sum_{in} (\dot{m}h) = \sum_{out} (\dot{m}h) + \frac{d}{dt}(mu) \qquad (1)$$

An expression for the instantaneous time rate of change of temperature is derived in appendix A:

$$\frac{dT}{dt} = \frac{\dot{Q} + \dot{m}_i (h_i - u) + \dot{m}_s (h_s - h_L) + \dot{m}_{st} (h_{st} - h_L) - \dot{m}_o RT + (\dot{m}_{vi} - \dot{m}_{vo}) (h_L - u)}{m\frac{du}{dT} - (h_L - u)\, \frac{dm_{H2O}}{dT}} \qquad (2)$$

Equation (2) is integrated numerically:

$$T^{n+1} = T^n + \left(\frac{dT}{dt}\right) \Delta t \qquad (3)$$

The pressure in the reactor room is evaluated by summing the two partial pressures of air and water vapor.

$$P = P_{air} + P_{H_2O} \tag{4}$$

These two partial pressures can be evaluated directly from their respective equations of state, using the updated temperature. The temperature and pressure in the reactor room are evaluated in a marching technique starting at time zero, the start of the fuel melting accident.

In this problem, the gaseous fission products are modeled by an internal heat generation term. Their masses are neglected. The radioactive gases are introduced into the reactor room according to the curve in Figure (2). Five percent of the gaseous fission products is introduced at the onset of the accident. This amount remains constant for 113 seconds, and from 113 seconds to 201 seconds the balance of the gaseous fission products is ramped in linearly, (reference 2). The equilibrium assumption implies uniform mixing of the gaseous fissions products. This assumption is utilized in modifying the internal heat generation term to account of that portion of the fission products that is withdrawn from the reactor room by the ventilation exhaust system.

In the event of a core meltdown accident, the reactor core will generate approximately 100 MW. This power could potentially generate 44 kg/s of steam. It is unreasonable to postulate that all of the core heat would go to generating steam, but a steam production rate in the neighborhood of 1 kg/s is plausible. Steam production would commence at the start of a meltdown accident, since the normal operating conditions of the reactor are close to the saturation point for the circulating water. In this model, the steam production rate is constant with respect to time, and it is an independent variable. There is a need to identify a reasonable steam production rate for a fuel melting reactor accident. Modest steam production rates significantly influence the temperature and pressure excursions of the reactor room.

This numerical model has been programmed in compiled BASIC for an IBM PC. The program is in the process of being translated into FORTRAN for the mainframe computer. The BASIC version is presented in appendix (B) along with the instructions on its utilization and a list of variables.

RESULTS

The primary energy source in this model is the decay heat of the gaseous fission products. The power output of the total mass of these gases decreases exponentially with time. In the model, this power output is modified by the manner in which the fission products are introduced into the reactor room, Figure (2), and the withdrawal of fission products through the ventilation exhaust system. The transient heat generation rate of the fission products present in the reactor room is shown in Figure (3). The power peaks at 201 seconds after the onset of the accident. At this time, all of the gaseous fission products have been released into the reactor room. Thereafter the power level decreases due to radioactive decay and withdrawal of some of the fission products through the ventilation exhaust system. The case shown in Figure (3) is for a ventilation exhaust volume flow rate of 9000 CFM.

Figure (4) shows the transient pressure in the reactor room, as a function of the mass flow rate of steam. The ventilation exhaust flow rate is 7500 CFM in all cases. This flow rate is sufficient to maintain the reactor room pressure below 12 inches of water when steam is not produced by the reactor. At an exhaust flow rate of 7500 CFM, the peak pressure in the reactor room quickly becomes unacceptable as steam is introduced. Figure (5) shows the minimum ventilation exhaust volume flow rate sufficient to maintain the reactor room pressure below 12 inches of water, as a function of steam production rates. Each kg/s of steam production increases the minimum acceptable ventilation exhaust flow rate by approximately 3000 CFM.

The transient temperature in the reactor room is shown in Figure (6), for two values of steam production by the reactor. The volume flow rate of the ventilation exhaust is the minimum value that maintains the reactor room pressure below 12 inches of water. In both cases, the temperature is increasing after 30 minutes. The temperature rises rapidly at the onset of the accident and tends to level off as the decay heat generation rate decreases. The cooling mechanism is evaporation of the water spray. This evaporation rate is a function of the time rate of change of temperature. As long as the temperature is rising, the evaporation rate is positive, and its effect is beneficial. When the temperature starts to decrease water vapor will condense, releasing the latent heat, and the water spray will no longer have a beneficial effect on the temperature in the reactor room.

Figure (7) shows the effect of the ventilation exhaust on the mass of gaseous fission products. The ratio of the mass of fission products present to the mass at 201 seconds is plotted versus elapsed time of the accident. The total mass of gaseous fission products is assumed to be inserted into the reactor room during the first 201 seconds. Thereafter, the mass of fission products decreases due to the ventilation exhaust system. Approximately 50% of the gaseous fission products are removed during the first half-hour of the meltdown accident. This mass ratio does not take into account the decrease in mass of the radioactive gas due to decay. This factor is included in the heat generation rate term shown in Figure (3).

CONCLUSIONS

The most important conclusion to be drawn from this study is that steam generation must be considered in the design of an adsorption noble gas containment system. The minimum acceptable reactor room ventilation exhaust flow rate is strongly influenced by the steam production rate during a meltdown accident. It is not implausible that sufficient water would be recirculating and spraying in the reactor vessel to support a steam production rate of one kg/s. This represents a dedication of two percent of the molten core decay heat to the generation of steam. The amount of water available for steam generation should be estimated for the various accident scenarios, and also estimates should be made of the duration of time during which the steam is generated. The pressure pulse in the reactor room occurs during the first ten minutes of the accident. The influence of steam is greatest during this period.

Though the minimum acceptable ventilation exhaust volume flow rate goes up significantly with the increased generation rate of steam, the flow rate that the noble gas adsorption system must handle does not scale up linearly. The air is dehumidified prior to going through the adsorption column. This process will remove the increased amount of water vapor due to the generation of steam in the reactor.

The automatic damper in the ventilation supply duct is designed to close when the reactor room gauge pressure exceeds -.05 inches of water. Its purpose is to insure that the pressure level in the reactor room remains below atmospheric, so air leaks into rather than out of the space. It is recommended that this damper be closed and remain closed during a meltdown accident. The cycle time of this damper is approximately five to ten seconds. This slow response is insufficient to handle the quick pressure changes that occur during a meltdown accident. The result of not closing this damper during a fuel melting accident would be periodic pressure surges with backflow of contaminated air into the ventilation supply system.

The ventilation supply air has an adverse affect on the peak pressure during the first ten minutes of an accident. The flow rate is insufficient to have a significant beneficial impact on the temperature in the reactor room due to mixing, but the added mass does aggravate the pressure surge that occurs during the first ten minutes of the accident. The pressure peaks and begins to decrease while the temperature continues to rise. This is due to a net reduction in mass of the atmosphere in the reactor room. While the adverse affect of the ventilation supply on the peak pressure may not be major, the backflow of contaminated air into the ventilation supply is serious and defeats the purpose of the noble gas containment system.

The program documented in this report covers the first thirty minutes of a meltdown accident. The reactor room pressure peaks during this time period, but the temperature does not. A FORTRAN version of the program is being written that will extend the real time duration to eight hours. Extending the duration of the problem will allow determination of the time dependence of the mass of fission products remaining in the reactor room. The magnitude of the heat generation rate, due to the fission products, determines the time dependence of the temperature solution. The temperature cannot decrease as long as the decay heat term is significant. The beneficial effect of the water spray is reduced when the evaporation rate of the water drops to zero and condensation commences. This occurs as the time rate of change of temperature levels off and becomes negative. Without an effective cooling mechanism, the temperature of the reactor room cannot decrease significantly as long as the heat input from the gaseous fission products is important. The temperature in the reactor room is strongly influenced by the steam generation rate in the reactor vessel. Since a core meltdown accident occurs due to interruption of the cooling water circulation, steam production by the molten core cannot proceed indefinitely. This is a second argument for a specific accident scenario, from the view point of the time dependence of steam production.

MAS:dwb

REFERENCES

1. G. J. Van Wylen and R. E. Sonntag, "Fundamentals of Classical Thermodynamics," John Wiley & Sons, 1978.

2. personal communication between Jim Smith and Stan Petry, March 12, 1984.

3. J. H. Keenan and F. G. Keyes, "Thermodynamic Properties of Steam," John Wiley & Sons, 1936.

SYMBOLS

C_R - concentration ratio of radioactive gases

C_V - constant volume specific heat

h - enthalpy (subscripts are the same as those for the mass flow rates)

m - mass

m_R - instantaneous mass of fission products

m_{Ro} - total mass of fission products

$\dot{m}_{evap}$ - evaporation rate of water spray

$\dot{m}_i$ - mass flow rate in

$\dot{m}_L$ - mass flow rate of liquid out

$\dot{m}_o$ - mass flow rate out

$\dot{m}_s$ - mass flow rate of water spray

$\dot{m}_{st}$ - mass flow rate of steam

$\dot{m}_{vi}$ - mass flow rate of water vapor in

$\dot{m}_{vo}$ - mass flow rate of water vapor out

M - molecular weight

P - pressure

$\dot{Q}$ - heat generation rate

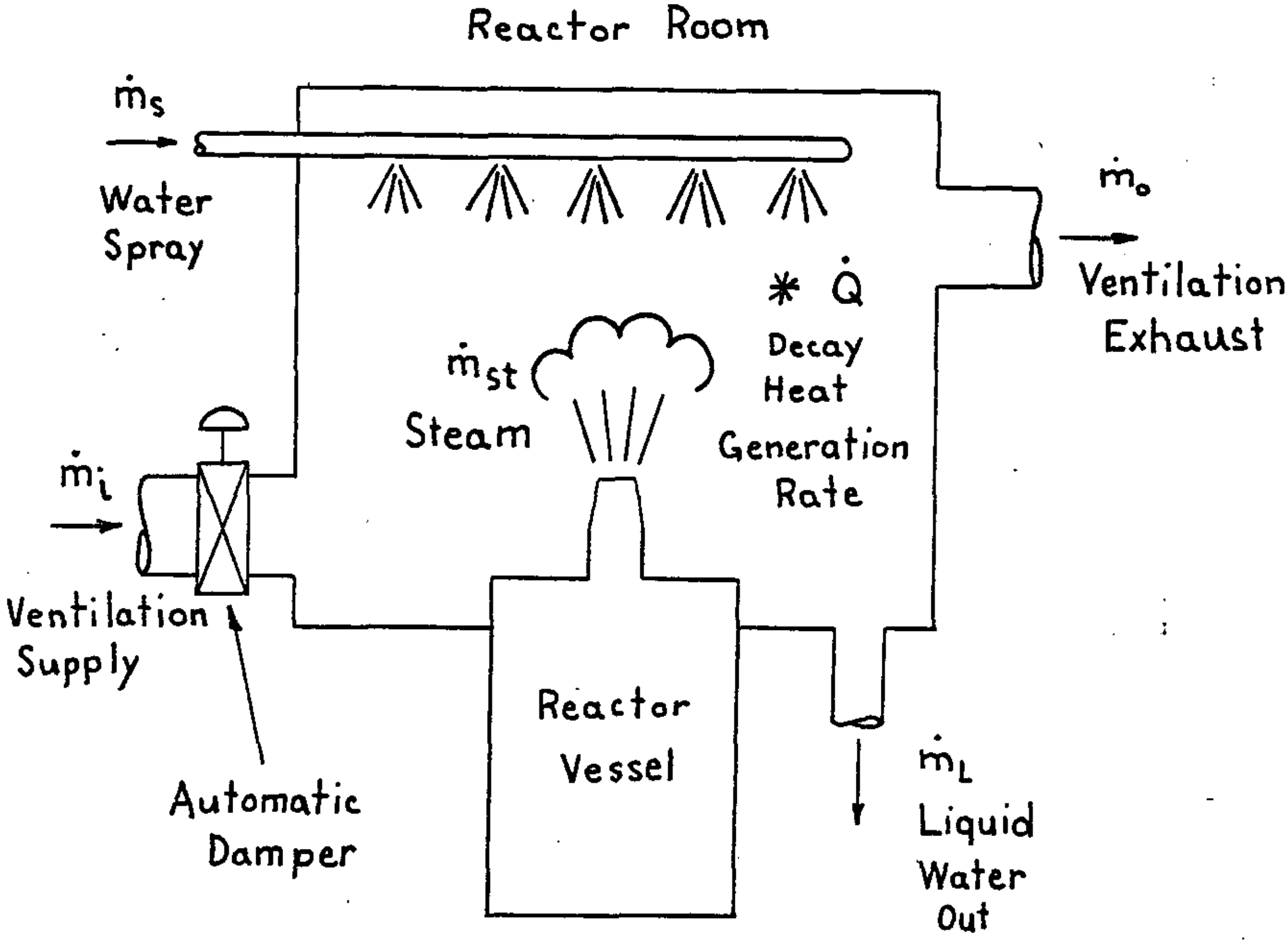
R - gas constant

t - time

T - temperature

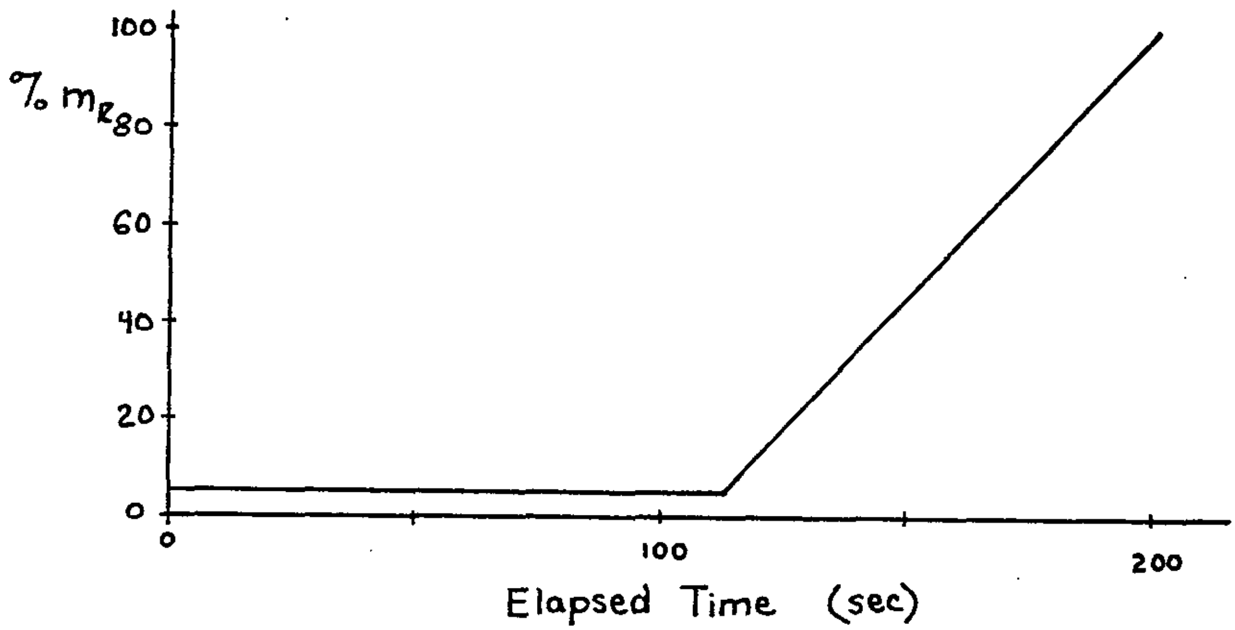
u - internal energy

V - volume of reactor room



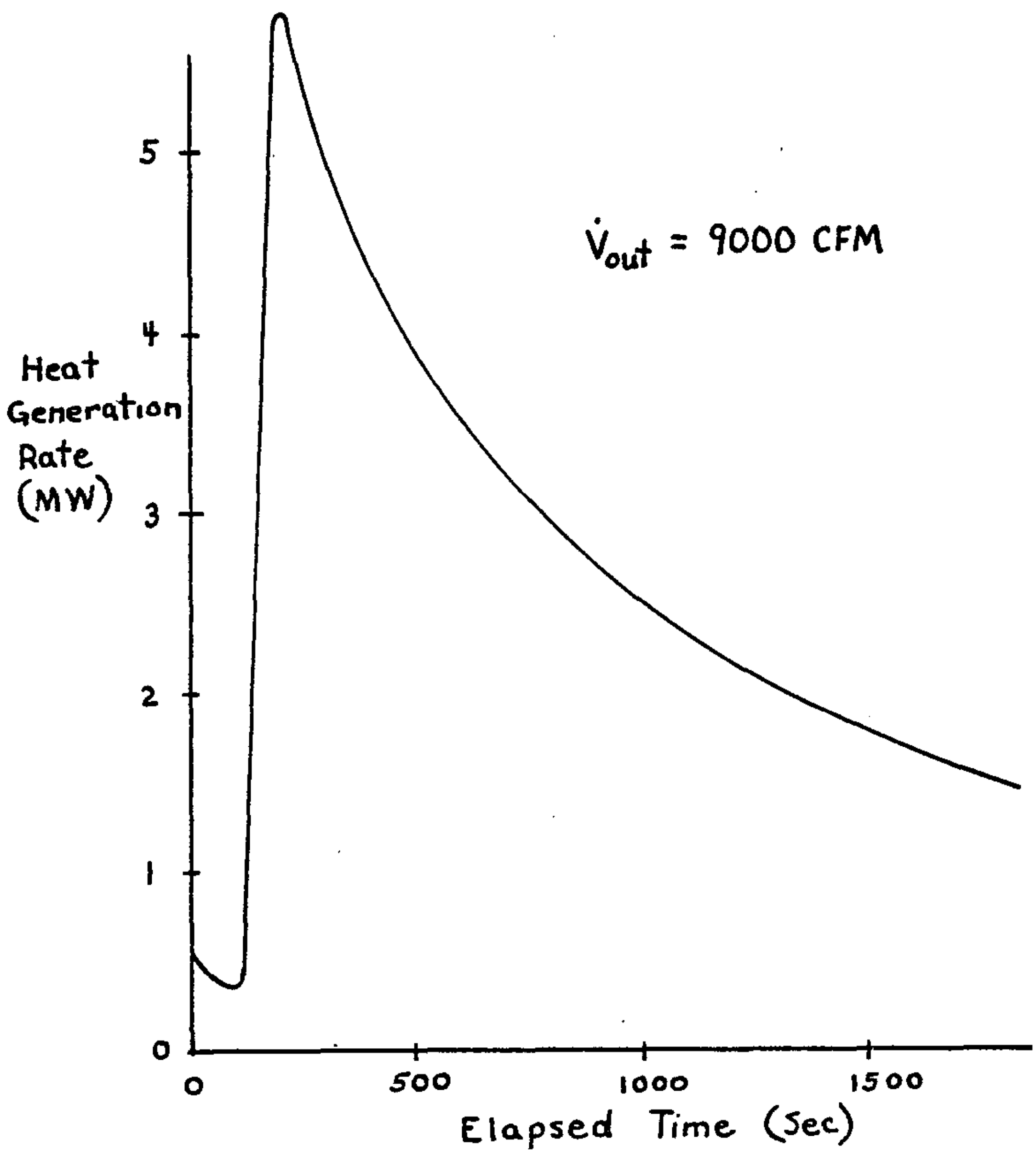
Reactor Room Schematic for a Meltdown Accident

FIGURE 1



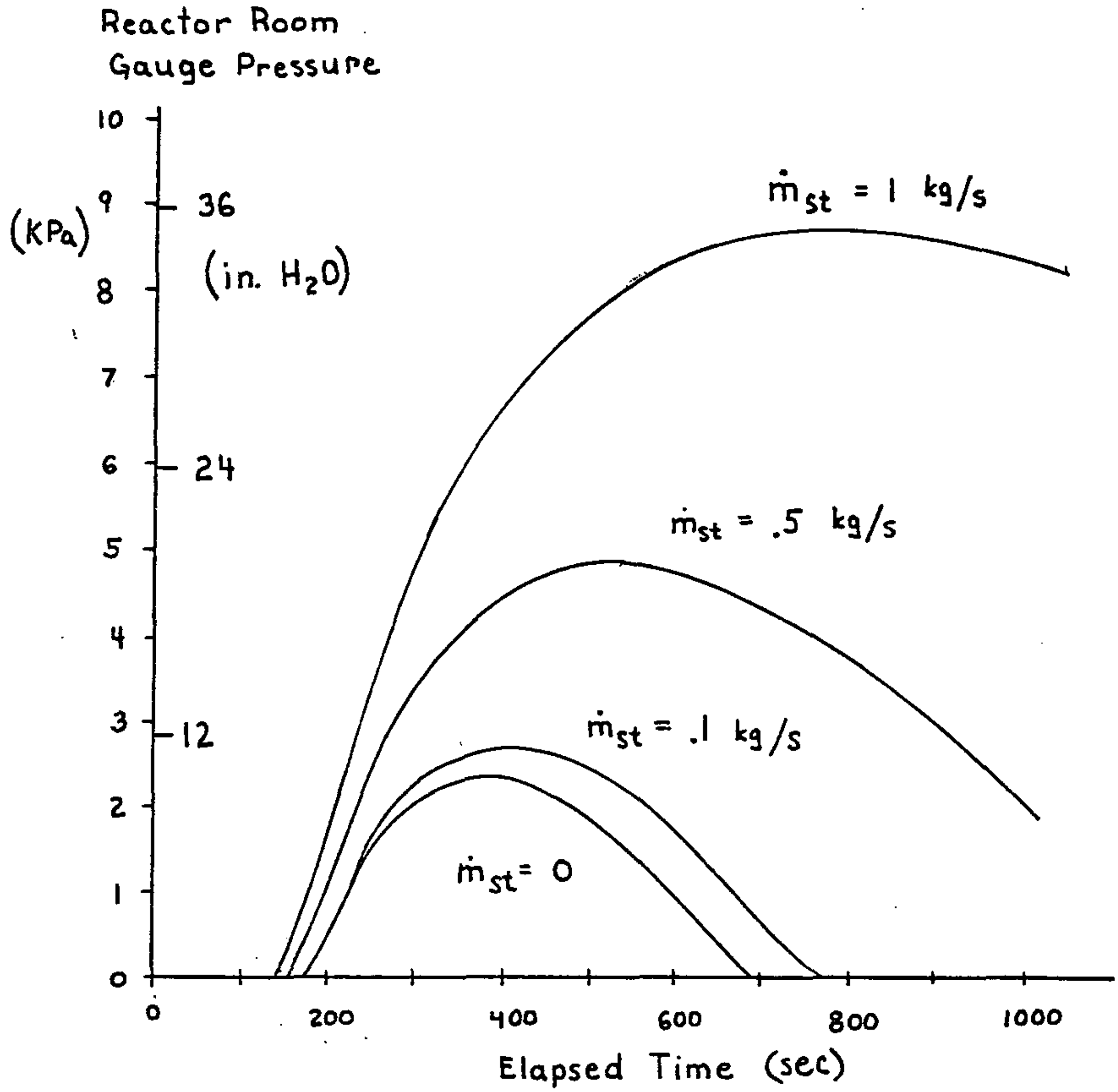
Percentage of Released Gaseous Fission Products Present in the Reactor Room

FIGURE 2



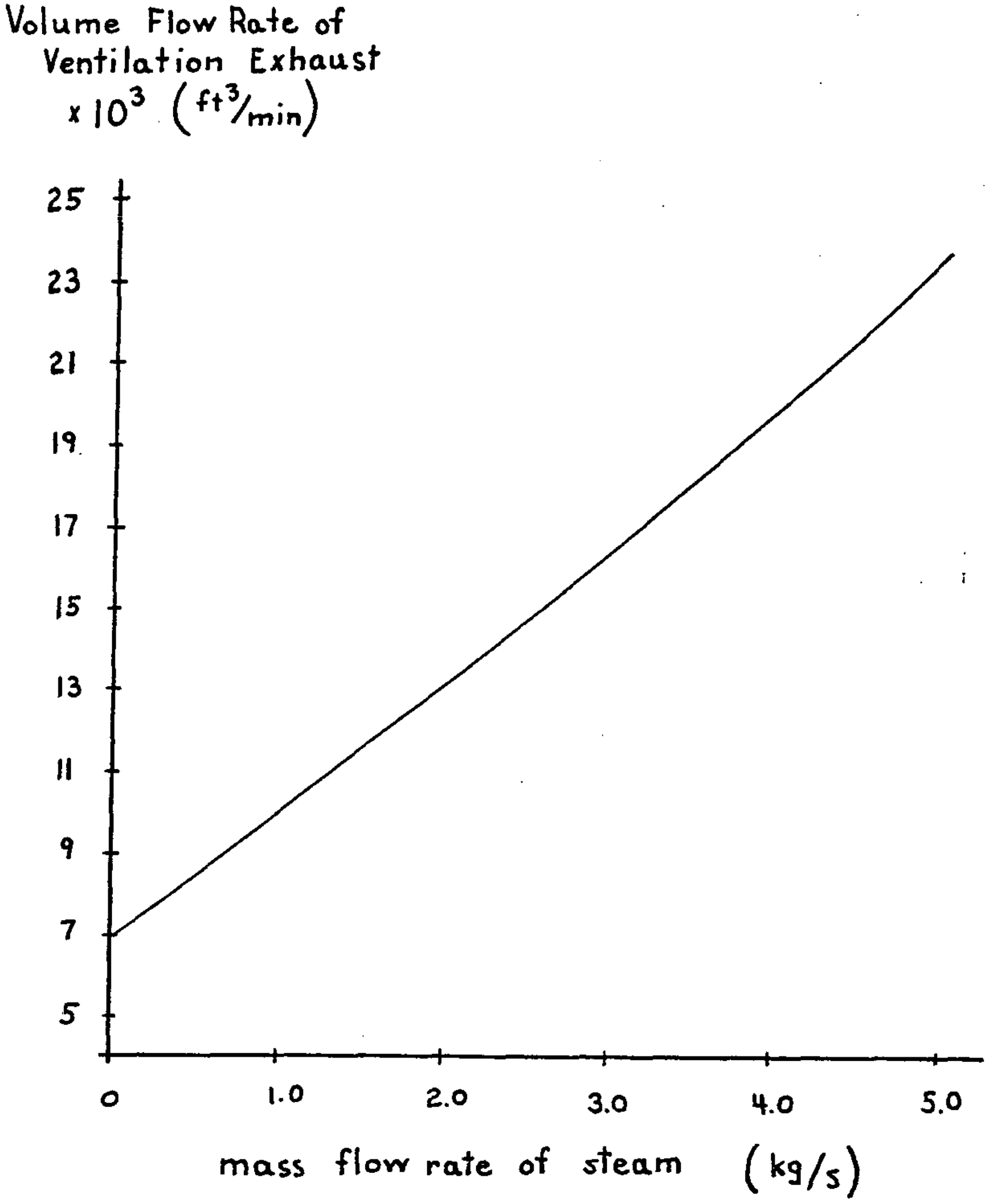
Internal Heat Generation Rate Due to Gaseous Fission Products in the Reactor Room

FIGURE 3



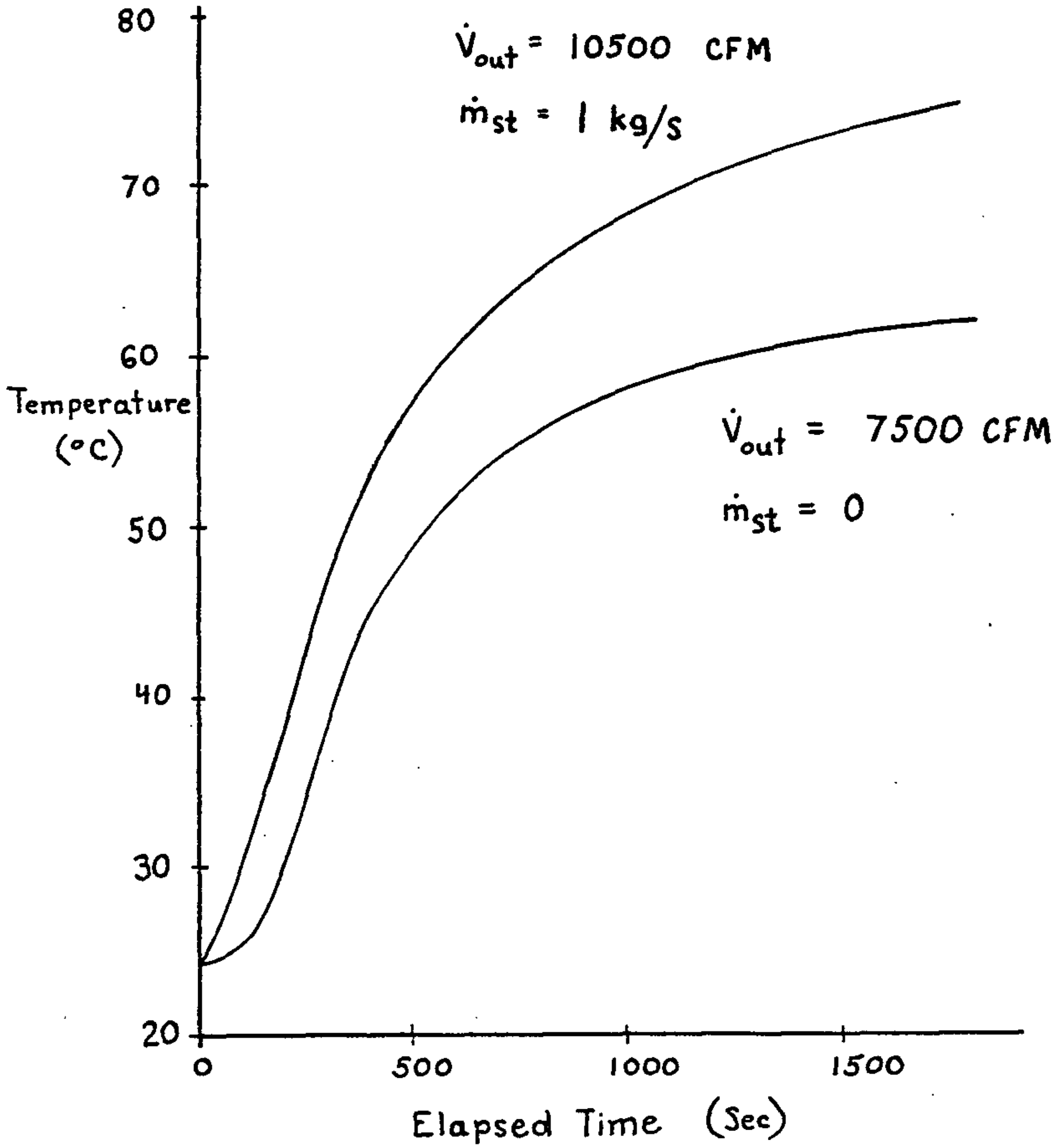
Pressure in the Reactor Room
Due to a Meltdown Accident

FIGURE 4



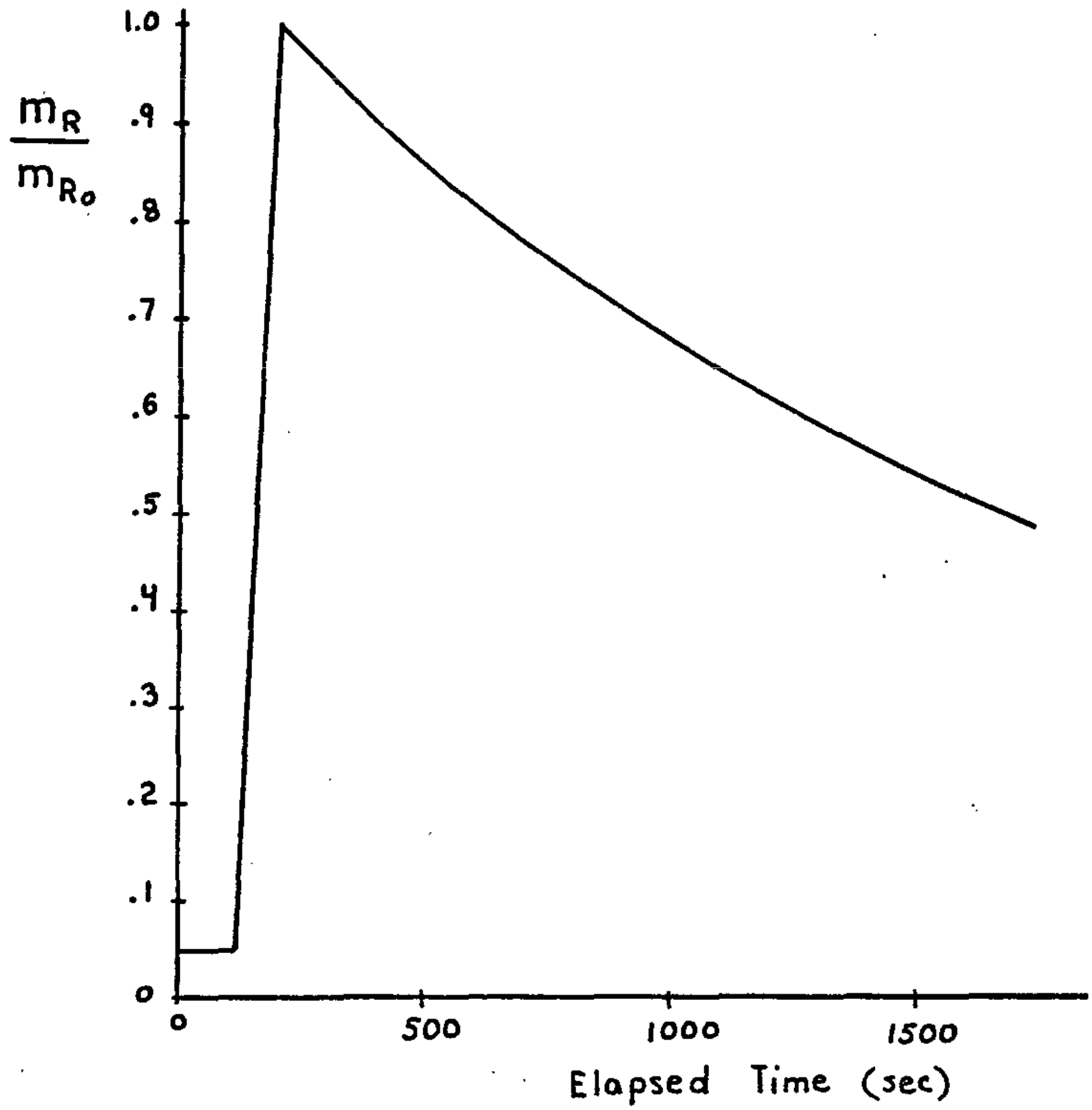
Minimum Acceptable Ventilation Exhaust as a Function of the Steam Production Rate During a Meltdown Accident

FIGURE 5



Temperature in the Reactor Room
Due to a Meltdown Accident

FIGURE 6



Ratio of the Instantaneous Mass of Fission Products to the Total Mass Released

FIGURE 7

APPENDIX A
DERIVATION OF THE EQUATIONS

The governing equations for the transient temperature and pressure in the reactor room are the continuity equation and the first law of thermodynamics for uniform flow, (reference 2):

$$\frac{dm}{dt} = \dot{m}_i + \dot{m}_s + \dot{m}_{st} - \dot{m}_o - \dot{m}_L \tag{1}$$

$$\dot{Q} + \dot{m}_i h_i + \dot{m}_s h_s + \dot{m}_{st} h_{st} = \dot{m}_o h_o + \dot{m}_L h_L + m\frac{du}{dt} + u\frac{dm}{dt} \tag{2}$$

The mass flow rate of liquid withdrawn from the reactor room can be replaced with the evaporation rate, since liquid water does not accumulate inside of the control volume

$$\dot{m}_s = \dot{m}_{evap} + \dot{m}_L \tag{3}$$

Substitution of equation (3) and the continuity equation, (1), into the first law yields the following:

$$\dot{Q} + \dot{m}_i (h_i - u) + \dot{m}_s (h_s - h_L) + \dot{m}_{st} (h_{st} - u) - \dot{m}_o (h_o - u) = m\frac{du}{dt} - \dot{m}_{evap} (h_L - u) \tag{4}$$

An expression for the evaporation rate is derived from the conservation equation for water:

$$\dot{m}_{evap} = \frac{d}{dt} (m_{H_2O}) + \dot{m}_{vo} - \dot{m}_{vi} - \dot{m}_{st} \tag{5}$$

With this substitution, an expression for the instantaneous time rate of change of temperature can be written:

$$\frac{dT}{dt} = \frac{\dot{Q} + \dot{m}_i (h_i - u) + \dot{m}_s (h_s - h_L) + \dot{m}_{st} (h_{st} - h_L) + (\dot{m}_{vi} - \dot{m}_{vo}) (h_L - u) - \dot{m}_o RT}{m\frac{du}{dT} - (h_L - u) \frac{d}{dT} (m_{H_2O})} \tag{6}$$

where:

$$\frac{du}{dT} = C_v - \frac{u}{M} \frac{dM}{dT} + \frac{u_{H_2O} M_{H_2O}}{PM} \frac{dP_{H_2O}}{dT} + \frac{u_{air} M_{air}}{PM} \frac{d}{dT} P_{air} \tag{7}$$

and

$$\frac{d}{dT} (m_{H_2O}) = \frac{m_{H_2O}}{P_{H_2O}} \frac{d}{dT} (P_{H_2O}) - \frac{m_{H_2O}}{T} \tag{8}$$

Equation (6) is integrated numerically as follows. The superscripts denote the time level.

$$T^{n+1} = T^{n} + \left(\frac{dT}{dt}\right) \Delta t \tag{9}$$

The pressure in the reactor room is updated by summing the two partial pressures of air and water vapor.

$$P^{n+1} = P^{n+1}_{H_2O} = P^{n+1}_{air} \tag{10}$$

Since the air inside the reactor room is saturated, the partial pressure of the water vapor is the saturation pressure of steam corresponding to the air temperature. An empirical expression from the "Steam Tables" by Keenan and Keyes (reference 3) is used to calculate the saturation pressure. The partial pressure of the air is calculated from the ideal gas law:

$$P^{n+1}_{air} = \frac{m^{n+1}_{air} \, R \, T^{n+1}}{V} \tag{11}$$

where:

$$m^{n+1}_{air} = m^{n}_{air} + (\dot{m}_{air\ in} - \dot{m}_{air\ out}) \, \Delta t \tag{12}$$

The gaseous fission products, released during a fuel melting accident, are modeled as an internal heat source. The magnitude of the heat generation rate is proportional to the mass of fission products in the reactor room. At 201 seconds from the onset of the accident, all of the gaseous fission products have been released into the reactor room. Thereafter the mass of the fission products in the reactor room changes due to withdrawal of the gas by the ventilation exhaust. To account for the reduction in the decay heat generation rate caused by this change in mass, the decay heat source term is multiplied by the ratio of the mass of fission products present to the mass present at 201 sec.

$$\dot{Q} = \frac{m_R}{m_{Ro}} \dot{Q}_{m_R}(t) = h_o \, \dot{Q}_{m_R}(t) \tag{13}$$

This simplified analysis neglects the fission products withdrawn prior to 201 seconds, while they are being convected into the reactor room.

Over a single timestep, the ratio of the final mass to the initial mass is:

$$\frac{m_R^{n+1}}{m_R^n} = \frac{m_R^n - \dot{m}_R \quad t}{m_R^n} = 1 - \frac{\dot{m}_R \Delta t}{m_R^n} \qquad (14)$$

With a concentration ratio, the mass of fission products can be expressed as a function of the mass of air/water vapor in the reactor room.

$$C_R = \frac{m_R}{m} = \frac{\dot{m}_R}{\dot{m}_o} \qquad (15)$$

$$\therefore \quad \frac{m_R^{n+1}}{m_R^n} = 1 - \frac{\dot{m}_o \Delta t}{m} \qquad (16)$$

The desired ratio, of the mass of fission products to the mass at 201 sec, is the product of the ratios over each timestep.

$$\frac{m_R^{n+1}}{m_{Ro}} = \frac{m_R^1}{m_{Ro}} \frac{m_R^2}{m_R^1} \frac{m_R^3}{m_R^2} \cdots \frac{m_R^n}{m_R^{n-1}} \frac{m_R^{n+1}}{m_R^n} \qquad (17)$$

The coefficient, h_o, is determined each timestep by the following relation:

$$h_o^{n+1} = h_o^n \left(1 - \frac{\dot{m}_o \Delta t}{m}\right) \qquad (18)$$

APPENDIX B
PROGRAM LISTING

The computer program, documented in this report, is written in BASIC for an IBM PC. This appendix includes a program listing and a list of variables.

This program determines the transient temperature and pressure in the reactor room during a 100% core meltdown accident. The input variables are the volume flow rate of the ventilation exhaust, the initial temperature of the reactor room (24°C), the mass flow rate of the water spray (2 kg/s), and the mass flow rate of steam. The ventilation exhaust and steam flow rates were the two parameters that varied in this study. The program prints out the time in seconds, the temperature (°C), and the gauge pressure (KPa).

When the reactor room pressure is -.1 inches of water, the ventilation supply volume flow rate is 19600 CFM. 1000 CFM leaks into the reactor room from the actuator tower. When the gauge pressure is greater than -.1 inches of water, the damper in the ventilation supply duct closes. The leakage from the actuator tower is one way, air leaks into the reactor room but does not leak out. No effort was made to model the slow response of the real damper. Numerically, the damper is either open or shut and its state can change from one time step to another.

This program is in the process of being translated into FORTRAN and put on the IBM mainframe computer. The FORTRAN version will be improved to allow running in real time, beyond the initial thirty minutes of an accident.

VARIABLES

CL	Cp water
CPA	Cp air
CPW	Cp water vapor
CVA	C_v air
CVW	C_v water vapor
DELT	Time Step
DEN	Density
DMLT	Temperature derivative of molecular weight
DPH	Temperature derivative of vapor pressure
HA	Enthalpy of air
HG	Enthalpy of water vapor
HL	Enthalpy of water
HO	Correction factor for decay heat
HS	Enthalpy of water spray
HST	Enthalpy of reactor steam
MAIN	Mass flow rate of air in
MAIR	Molecular weight of air
MAN	Mass of air
MAOT	Mass flow rate of air out
MI	Mass flow rate air/water vapor mixture in
MO	Mass flow rate air/water vapor mixture out
MS	Mass of air/water vapor mixture
MVAP	Molecular weight of water vapor
MVIN	Mass flow rate of water vapor in
MVO	Mass flow rate of water vapor out
P	Pressure (KPa)
PA	Partial pressure of air
PATM	Atmospheric pressure
PH	Partial pressure of water vapor
QI	Decay heat generation rate (KW)
TP	Temperature (K)
VA	Internal energy of air
VG	Internal energy of water vapor
VOL	Volume of reactor room (m^3)

```
1     REM program trp
2     REM THIS PROGRAM CALCULATES THE TRANSIENT
3     REM TEMPERATURE AND PRESSURE IN THE REACTOR ROOM
4     REM DURING A 100 % CORE MELTDOWN ACCIDENT.
5     REM
15    DEFINT I-L
16    REM
17    REM W AND T ARE ARRAYS WITH THE FISSION PRODUCTS
18    REM POWER SOURCE TERM IN WATTS.
19    REM
20     DIM T(31),W(31)
30     T6=0!
40     FOR L=1 TO 31
50     T(L)=T6
60     T6=T6+60!
70     READ W(L)
80     NEXT L
85    REM VOUT IS THE VENT. EX. VOLUME FLOW RATE.
90     PRINT "VOUT= CFM";
100    INPUT VOUT
110    LPRINT "VOUT=";VOUT;"CFM"
120    PRINT "INITIAL TEMP= DEG C";
130    INPUT TINT
140    LPRINT "INITIAL TEMP=";TINT;"DEG C"
142    PRINT "MASS FLW STM  KG/SEC";
144    INPUT MST
146    LPRINT "MST=";MST;"KG/SEC"
150    TP=TINT+273.16
151   REM MDS MUST EXCEED THE MAX VALUE OF THE
152   REM EVAPORATION RATE.  2 KG/S IS A GOOD VALUE.
153   REM
154 PRINT "spray flow rate kg/sec"
155 INPUT MDS
156 LPRINT "MDS=";MDS;"KG/SEC"
160    VDOT=VOUT*4.7195E-04
164   REM
165   REM CONSTANTS FOLLOW. UNITS ARE MKS.
166   REM
170    MAIR=28.95
180    MVAP=18.016
190    PC=22112.8
200    TC=647.27
210    A1=3.24378
220    B=5.86826E-03
230    C=1.17024E-08
240    D=2.18785E-03
250    RBAR=8.31434
260    PATM=101.3
270    CPW=1.82247
280    CVW=1.36563
290    HO=1!
```

```
300   P=101.176
310   VOL=9061.481
320   CVA=.718
330   RA=RBAR/MAIR
340   RH=RBAR/MVAP
350   X=TC-TP
360   A5=(A1+B*X+C*X^3)/(1!+D*X)
370   A6=A5*X/TP
380   PH=PC/(10!^A6)
390   CL=4.178
394  REM
395  REM DELT IS THE SIZE OF THE TIME STEP (SEC).
396  REM
400   DELT=1!
410   LPRINT
420   LPRINT "TIME SEC","TEMP C","PRESSURE KPA"
440   K=2
450   CPA=1.005
470   PA=P-PH
480   HA=CPA*(TP-273.16)+78.447
490   HG=CPW*(TP-273.15)+2501.4
500   MOLWT=MAIR+(MVAP-MAIR)*PH/P
510   HI=(PH*MVAP*HG+PA*MAIR*HA)/(P*MOLWT)
540  REM
541  REM HST IS THE ENTHALPY OF THE REACTOR STEAM.
542  REM
550   HST=2675.4
560   MAN=(PA*VOL)/(RA*TP)
570  HS=100.7
600   CT1=1132.84
610   CT2=2688.985
620   EP=-.6258
630   CT3=-74.405
640   CT4=1120.9
990  REM
991  REM THIS IS THE START OF THE COMPUTATIONAL LOOP.
992  REM
1000  FOR I=1 TO 7200!
1001  T=I*DELT
1002  FOR J=1 TO 30
1003  IF T<=T(J+1) THEN 1005
1004  GOTO 1010
1005  Y=W(J+1)-W(J)
1006  TAVG=T+(DELT/2!)
1007  A=(TAVG-T(J))/(T(J+1)-T(J))
1008  W=W(J)+(Y*A)
1009  GOTO 1110
1010  NEXT J
1012 REM
1013 REM the following statements 1020-28 calculate the decay
1014 REM heat term for  .5< time <8 hours.
1015 REM
```

```
1020  IF T >= 1800! THEN 1022
1021  GOTO 1110
1022  THR=T/3600!
1023  IF THR < 6! THEN 1026
1024  Q=CT3*(THR-6!)+CT4
1025  GOTO 1180
1026  EP1=EP*THR
1027  Q=CT1+CT2*(EXP(EP1))
1028  GOTO 1180
1110  IF T>=201 THEN 1170
1120  IF T>=113 THEN 1150
1130  Q=W*.05/1000!
1140  GOTO 1180
1150  Q=W*(.05+.95*(T-113)/88)/1000!
1160  GOTO 1180
1170  Q=W/1000
1174 REM
1175 REM Q1 IS THE DECAY HEAT POWER TERM, (KW).
1176 REM
1180  Q1=Q*HO
1190  DP=P-PATM
1194 REM
1195 REM THIS DETERMINES IF THE DAMPER IS OPEN OR SHUT.
1196 REM
1200  IF DP<-.0248 THEN 1230
1210  DP1=0!
1220  GOTO 1390
1230  DP1=1!
1390  ADP=ABS(DP)
1400  CO=SQR(ADP/.124)
1410  MAIN=11.1998*CO
1420  MVIN=.211435*CO
1430  MI=MAIN+MVIN
1431  IF DP>=0! THEN 1436
1432  MI=MI*((1000+19600*DP1)/20600)
1433  MAIN=MAIN*((1000!+19600!*DP1)/20600!)
1434  MVIN=MVIN*((1000!+19600!*DP1)/20600!)
1435  GOTO 1440
1436  MI=0!
1437  MAIN=0!
1438  MVIN=0!
1440  MOLWT=MAIR+(MVAP-MAIR)*PH/P
1460  R=RBAR/MOLWT
1470  DEN=P/(R*TP)
1480  MS=DEN*VOL
1530  MO=DEN*(VDOT)
1540  WO=.622*PH/(P-PH)
1550  MVO=WO*MO/(WO+1!)
1560  MAOT=MO/(1!+WO)
1570  MVN=(PH*VOL)/(RH*TP)
1580  MAN=MS-MVN
1600  MAN1=DELT*(MAIN-MAOT)+MAN
```

```
1610  UA=CVA*(TP-273.16)
1620  UG=CVW*(TP-273.15)+2375.54
1630  U=(PH*MVAP*UG+PA*MAIR*UA)/(P*MOLWT)
1635  CV=(PH*MVAP*CVW+PA*MAIR*CVA)/(P*MOLWT)
1640  HL=CL*(TP-298.16)+104.89
1660  X=TC-(TP+1!)
1670  A5=(A1+B*X+C*X^3)/(1!+D*X)
1680  A6=A5*X/(TP+1!)
1690  PHN=PC/(10!^A6)
1700  DPH=PHN-PH
1705  DMLT=(MVAP-MAIR)*(DPH/P)
1710  TNUM=Q1+MI*(HI-U)+MDS*(HS-HL)+MST*(HST-HL)-MO*R*TP
1712  TNUM=TNUM+(U-HL)*(MVIN-MVO)
1714 DPA=MAN*RA/VOL
1715 UHA=(MVAP*UG*DPH+MAIR*UA*DPA)/(P*MOLWT)
1720  PMT=MVN*(DPH/PH-1!/TP)
1725 UTP=CV+UHA-(U/MOLWT)*DMLT
1730  TDNM=MS*UTP-PMT*(HL-U)
1735  MDEV=PMT*TNUM/TDNM+MVO-MVIN-MST
1740  TP=TP+DELT*TNUM/TDNM
1760  X=TC-TP
1765  A5=(A1+B*X+C*X^3)/(1!+D*X)
1770  A6=A5*X/TP
1775  PH=PC/(10!^A6)
1810  PA=(MAN1*RA*TP)/VOL
1900  P=PA+PH
1910  PG=P-PATM
1920  TCG=TP-273.16
1930  IF T<=1 THEN 1980
1940  IF K=10 THEN 1970
1950  K=K+1
1960  GOTO 1990
1970  K=1
1980  LPRINT T,TCG,PG
1990  IF T>201 THEN 2010
2000  GOTO 2020
2010  HO=HO*(1!-(MO*DELT)/MS)
2020  NEXT I
3000  DATA 1.1147E7,8.1566E6,6.7751E6,6.0207E6,5.5368E6
3010  DATA 5.1876E6,4.9161E6,4.6955E6,4.5113E6,4.3547E6
3020  DATA 4.2197E6,4.1021E6,3.9987E6,3.907E6,3.825E6
3030  DATA 3.7511E6,3.684E6,3.6226E6,3.5662E6,3.514E6
3040  DATA 3.4654E6,3.4199E6,3.3771E6,3.3367E6,3.2984E6
3050  DATA 3.262E6,3.2272E6,3.1939E6,3.1619E6,3.1311E6
3060  DATA 3.1015E6
4000  END
```