HYDROGEN COMBUSTION AND CONTROL ANALYSIS ASSUMPTIONS

prepared for

AMERICAN ELECTRIC POWER SERVICE CORPORATION

March 15, 1985

by

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

HYDROGEN COMBUSTION AND CONTROL ANALYSIS ASSUMPTIONS

Introduction

The Nuclear Regulatory Commission (NRC) requires that reactor containments be able to accommodate, without loss of containment integrity or degradation of vital equipment, the hydrogen that may be generated during severe reactor accidents. As a result, certain containment designs are required to include hydrogen control systems capable of accommodating an amount of hydrogen equivalent to that generated from the reaction of seventy-five percent of the cladding in the active fuel region with steam. The hydrogen generated from such a reaction has been judged to bound the amounts of hydrogen likely to be generated in severe accidents in which core degradation is arrested prior to complete core meltdown.

In response to the above NRC requirements the American Electric Power Service Corporation (AEP) has provided the Distributed Ignition System (DIS) for the D. C. Cook Nuclear Power Plants and performed considerable analyses to demonstrate conformance with the above requirements for postulated containment hydrogen combustion events. Continuing concerns have been raised by the NRC staff with regard to the effectiveness of the hydrogen combustion and control program. These concerns appear to be based on: differences between the D. C. Cook plants and other ice condenser containments previously considered by the NRC, results of NRC sponsored analyses on the effect of hydrogen burns in ice condenser containments for accident scenarios different than those considered by AEP, and recent experimental observations on hydrogen combustion behavior. AEP has proposed a specific program of analyses to address NRC's concerns and provide the basis for closure of the licensing process for the D. C. Cook hydrogen combustion and control program.

This letter report addresses two aspects of the proposed program: the selection of the accident sequences to be treated in further analyses, and the MARCH modeling assumptions to be used for these analyses.

Accident Sequence Selection

In-vessel hydrogen generation and release to the containment will be evaluated for a variety of accident scenarios. Since the total extent of hydrogen generation has been been specified in the NRC requirements (i. e., the equivalent of seventy-five percent metal-water reaction), the key outstanding issues relate to the rates of hydrogen release to the containment and the quantities of steam that would be associated with the hydrogen.

The accident sequences that have been selected for analysis have been chosen in order to cover a broad range of primary system pressure responses. This spectrum of responses yields a variety of hydrogen release rates to the containment as well as a variety of hydrogen-to-steam ratios. This approach is fully consistent with the intent of the NRC requirements. A probabilistic risk assessment has not been performed for the D. C. Cook plant, thus there is not a direct basis for identifying potentially risk-dominant or most likely severe accident sequences; nor is there a requirement in the NRC regulations for such a basis. However, some consideration has been given to sequence probabilities as determined in PRAs for similar plants. The three types of accident events selected and described below are representative of the important phenomena related to the evaluation of the effectiveness of the hydrogen control system.

The specific accident sequences selected for detailed evaluation are:

- TMLU-a high pressure scenario with loss of feedwater and emergency coolant injection leading to the boiloff of the primary coolant through the pressurizer relief valve,
- S2D-a small-break loss-of-coolant-accident with failure of emergency cooling injection where the primary system pressure is at an intermediate level during the core overheating period, and
- S1D-an intermediate-break loss-of-coolant-accident without emergency cooling injection in which the primary system is depressurized essentially to the containment level prior to the onset of core degradation.

While specific accident sequences have been identified for this analysis, clearly they should be viewed as representing a large variety of possible accident events.

A transient-initiated event with failures of the power conversion, auxiliary feedwater, and emergency coolant injection systems (TMLU) is representative of a variety of postulated transient events that are basically characterized by loss of heat removal and makeup to the primary system, with release of hydrogen and steam at high pressure through the pressurizer relief valve. These types of sequences have been found among the more probable in several PWR PRA's.

The small-break loss-of-coolant-accident with failure of emergency core cooling (S2D) has been identified as being among the more probable degraded core cooling accident events in PRA's for several PWR designs, including Sequoyah. This has been the reason for the choice of this sequence in earlier analyses. From a phenomenological viewpoint, this sequence is also representative of a number of transient-initiated events with failure of the emergency core cooling injection system and sticking open of the pressurizer relief valve.

The intermediate size break loss-of-coolant-accident with failure of emergency core cooling injection (S1D) is representative of a variety of situations in which the primary system is essentially depressurized before the onset of core overheating; these would include intermediate and large break sequences with failures of emergency core cooling injection or recirculation. Sequences initiated by larger pipe breaks (S1 and A) are believed to be less probable than those initiated by small breaks (S2).

The above sequence selection does not include consideration of events associated with loss of power situations. According to the subject regulations, "... the incremental risk reduction associated with provision of the igniter system backup power supply did not warrant the additional cost at these particular facilities. Provision of a backup power supply is not required by the rule."

In order to test and demonstrate the effectiveness of the hydrogen control system, the containment safety features, consisting of the ice condenser, sprays, air return fans, and hydrogen igniters, will be assumed to be operating in all the scenarios to be evaluated.

MARCH Modeling Assumptions

The hydrogen source term analyses to be performed as the basis for demonstrating adequacy of the D. C. Cook hydrogen control system will be conducted with the MARCH 2 code.* The following describes the approach and modeling options to be utilized for this purpose.

The NRC requirements for hydrogen control apply to severe accident events in which core degradation is arrested prior to complete core meltdown. Thus, the MARCH modeling of core heatup and degradation will be restricted to the in-vessel aspects, and not be concerned with such phenomena as core slumping into the vessel head, vessel penetration by the core debris, corium-concrete interactions, etc. The MARCH analyses will treat the release to and subsequent behavior of the hydrogen in the containment. More detailed analyses of containment response will be performed with the CLASIX code, using the hydrogen and steam source terms generated by MARCH as input.

Each of the previously identified accident sequences will be terminated by assuming the restoration of emergency core coolant injection at some time after the onset of core damage such that seventy-five percent of the cladding in the active fuel region reacts to generate hydrogen. The time of ECCS restoration will be determined parametrically to develop the requisite hydrogen generation; the rates of coolant injection utilized will be consistent with the plant design and specific accident conditions being considered. It must be recognized that while analytically realizable, the achievement of seventy-five percent reaction of the cladding while maintaining a coolable geometry may not be physically realistic. Thus, at least some of the computed parameters may not be consistent with recoverable scenarios.

For these analyses the MARCH input related to the physical description of the plant and performance of engineered safety features will be based on parameters specific to the D. C. Cook plant. Details of the modeling options to be utilized are discussed below.

---

*R. O. Wooton, et. al., "MARCH 2 (Meltdown Accident Response Characteristics) Code Description and User's Manual, NUREG/CR-3988, September, 1984.

Primary System

The primary system description, coolant inventory, and initial operating conditions are based on actual values for the D. C. Cook plant.

The core will be represented by ten radial regions and twenty-four axial zones. An equilibrium power distribution will be assumed. Fuel rod and other core details will be specific to D. C. Cook.

Primary system thermal-hydraulic analyses, including core heatup, will be based on the use of the best steam property correlations and the more detailed heat transfer models and correlations available in MARCH. The description of the rate of hydrogen generation from Zircaloy oxidation will be based on Urbanic-Heidrick reaction rate constants, steam availability, and include consideration of hydrogen blanketing. For purposes of these analyses the effective melting point of the fuel will be assumed to be that of the uranium dioxide, with cladding oxidation allowed to continue up to that temperature. Fuel slumping into the bottom head of the reactor vessel will not be considered since that is outside the scope of the hydrogen control requirements. For purposes of possible energy redistribution within the core, MARCH meltdown model "A" will be utilized; the latter assumes that when a molten region forms in the core it grows preferentially downward in such a manner that the temperature of the molten region tends to stay at the melting temperature of the core.

Core cooling upon restoration of ECCS operation will be based on the formation of debris beds in the previously molten regions. The Lipinski debris bed model will be utilized. Metal-water reaction during core quenching will be taken into account. The performance of the ECCS will reflect the D. C. Cook design and use pump performance curves to determine injection rates into the reactor vessel. The levels of operability correspond to the expected or most likely number of pumps operating.

Containment

The D. C. Cook containment is being modeled as a four compartment system comprised of the lower compartment, the accumulator rooms, the upper plenum of the ice condenser, and the upper compartment. It will be recalled

that in the context of the MARCH code, modeling the ice condenser is treated as being in the junction between two compartments, in the present case between the lower compartment and the upper plenum of the ice condenser. The free volume of the ice condenser is included in that of the lower compartment. The heat transfer performance characteristics of the ice condenser are based on the experimental data derived in the course of the development of this concept; these have been previously described in the D. C. Cook FSAR.

The containment sprays are included in the modeling of the responses of the lower and upper compartments of the containment; the latter sprays would be activated after the ice has been depleted. This is an aspect in which the D. C. Cook plant differs from the other ice condenser containments, with the other plants having the sprays only in the upper compartment. The spray flow rates utilized in the analyses will correspond to the expected or most likely levels of operation. The switchover from the injection to the recirculation mode of operation will be taken into account based on the depletion of the refueling water storage tank inventory.

The air return fans will be modeled as taking their suction from the upper compartment and exhausting to the accumulator rooms. The flow rate utilized corresponds to the expected or most likely level of operation. Failure of the air return fans will be modeled in later analyses, if the results of the initial MARCH and CLASIX calculations indicate fan failure is likely.

Hydrogen igniters will be modeled in each of the compartments of the containment. The specific parameters used to model igniter performance will be discussed in a subsequent section.

The structural heat sinks and containment compartmentalization utilized in the analyses are based on parameters specific to the D. C. Cook power plant.

Hydrogen Combustion Modeling

The earlier analyses conducted by AEP to demonstrate the effectiveness of the DIS for the D. C. Cook plant were based on CLASIX analyses which assumed ignition at eight volume percent hydrogen, eighty-five percent completeness of combustion, and a flame speed of six feet per second. Since the ignition criteria in all the compartments of the containment were the same,

flame propagation between compartments was not really considered in the earlier analyses.

In addition to considering additional accident sequences, the proposed program takes advantage of more recent research results. Of particular interest are the results of the Nevada large scale hydrogen burning experiments that have recently been completed. It has been observed, for example, that igniters can be effective in promoting combustion at hydrogen concentrations less than the eight volume percent previously assumed. Since the final report on that program is not yet available, the following conclusions are based on the preliminary information that has been made available to us and is subject to change.

The Nevada large scale tests involved two general types of experiments: the premixed and continuous injection experiments. The premixed tests started with fixed compositions of the atmosphere and investigated flammability limits, completeness of combustion, flame speeds, etc., under a variety of initial conditions. The results of this series of experiments largely confirm the data base previously developed in a variety of smaller scale investigations.

The continuous injection experiments are more representative of the behavior to be expected during severe reactor accidents and thus are of particular interest to the proposed program. In these tests various hydrogen-steam mixtures were continuously injected into the test vessel with a variety of igniter distributions and locations. The results of these tests are somewhat more difficult to interpret, particularly in the absence of the final report, but the following general observations can be made. In the continuous injection experiments with igniters on, hydrogen combustion is typically found to start well below the eight volume percent hydrogen concentration previously assumed. Ignition at these lower concentrations results in incomplete combustion. Operation of fans or sprays promotes atmospheric turbulence and leads to larger flame velocities as well as more complete combustion than have been observed in quiescent mixtures; the burning itself will also promote turbulence. In a number of the individual experiments combustion appears to have been terminated by the buildup of high steam concentrations rather than by the depletion of oxygen.

Based on our review of the available data from the Nevada large scale hydrogen combustion experiments, the following hydrogen combustion modeling assumptions are planned:

1) Ignition at a compartment-averaged hydrogen concentration of six volume percent, subject to the availability of oxygen (>5 v/o) and considerations of steam inerting (<55 v/o).
2) For ignition at six volume percent of hydrogen, seventy-five percent completeness of combustion will be assumed; this corresponds to the value predicted by the correlation in MARCH.
3) Flame speed will be based on the hydrogen combustion model in MARCH; for a six volume percent hydrogen concentration this model would predict a flame speed of about 17.5 ft/sec.
4) Flame propagation between compartments will be based on the MARCH model which takes into account hydrogen concentrations and orientation of connected compartments. The default values for upward, horizontal, and downward propagation are 4.1, 6, and 9 v/o hydrogen, respectively. Flame propagation between compartments will also require the definition of a characteristic distance, corresponding to the distance traversed by a complete burn in a compartment.

The above recommended hydrogen burn paramaters are inferred from the review of the available Nevada test data as well as making use of the hydrogen burn models in MARCH. (It may be noted that the hydrogen combustion models in MARCH 2 are quite similar to those in the more detailed hydrogen combustion code HECTR.) The recommended parameters are compatible for use with MARCH 2; some adjustment may be required in these parameters for compatibility with the CLASIX input requirements and modeling capabilities. The recommended parameters are subject to continuing review and change upon the availability of more definitive information.

SUPPLEMENT TO ATTACHMENT 2 TO AEP:NRC:Ø5ØØO

DETAILED INFORMATION ON AEP GRID SYSTEM

AND D.C. COOK SUBSTATION

I. The American Electric Power System.

The American Electric Power Company is a highly integrated system within the East Central Area Reliability (ECAR) region. The ECAR region is part of the large eastern United States interconnected systems which have a total generating capacity in excess of 400,000 MW. Loss of the largest generator or the largest plant will cause a generation deficiency of less than 1% of interconnected system capability and will not result in a significant system disturbance.

American Electric Power serves customers located in seven states through an interconnected transmission system and associated power generating stations. The current generating capability of the AEP system is in excess of 22,000 MW.

II. Cook Plant Substation.

The 345 kV substation connects the Unit 1 generator to two lines from the Consumers Power Palisades Station, two lines from Twin Branch Station, one line from Olive Station and one line from Robinson Park Station. In addition, the 345 kV station is connected to the 765 kV station through Transformer #4, a 1500 MVA autotransformer.

The 765 kV station connects Unit 2 to the line from Dumont Station and to the primary winding of Transformer #4.

The 34.5 kV tertiary winding of Transformer #4 is one of the two sources of power to the 34.5 kV bus. The 34.5 kV bus can be energized from this source if Transformer #4 is energized from either the 345 kV or the 765 kV winding. The second source of power is Transformer #5 which is connected to the opposite 345 kV bus from the 345 kV connection of Transformer #4. Either of these two sources to the 34.5 kV bus is capable of supplying all of the required auxiliary power for both units. Only one source is connected to the 34.5 kV bus at one time.

III. Summary.

The transmission network can sustain the loss of any unit or plant without distress. The loss of either or both units at D.C. Cook Plant does not result in a degraded grid condition or cause, by itself, the loss of offsite power to the unit auxiliary power systems.

The maximum frequency decay rate using a worst case scenario is 2.5 Hz per second. The lowest frequency for this event is approximately 58.5 Hz.

Generator faults could possibly cause a loss of offsite power to the reactor coolant pumps at the time of trip. This trip would be caused by a malfunction of the generator and would not be caused by a reactor initiated event. This occurrence is bounded by the loss of non-emergency ac power to the station auxiliaries event.

Reactor initiated trips will result in at least 30 seconds of reactor coolant pump motor operation before the electric power system is transferred to the preferred offsite power.

No mechanism can be found which will directly cause a grid system failure or an auxiliary power system failure from an event initiated by operation of the reactor outside of acceptable limits.

ATTACHMENT 3 TO AEP:NRC: Ø5ØØO

MARCH 2 CODE INPUT DECK

D. C. COOK NUCLEAR PLANT

REFERENCE: NUREG/CR - 3988

BMI - 2115

* * * INPUT FOR NAMELIST NLMAR * * *

AEP:NRC:Ø5ØØO

COMPUTATION EXIT CONTROLS

ICHECK= 2 CPSTP = 5.000E+03 IS = 10 PRST = 1.000E+03 TRST = 5.000E+03

MARCH FLAGS

IBLDI =	0	IBLDP =	1	IBRK =	0	ICBRK =	0	ICE =	1	ICKV =	0
IECCXX=	2	IFPSM =	2	IFPSV =	2	IPDTL =	7	ISPRA =	1	ITRAN =	1
IU =	0	IYPL =	0	NINTRL=	10	NPAIRL=	0				

TIME DATA

ATIME = 0. DTINTL= 2.000E-02 TAP = 5.000E+05

INPUT WAS IN AMERICAN ENGINEERING UNITS
PRINTED OUTPUT IS IN AMERICAN ENGINEERING UNITS
CORRAL OUTPUT IS IN AMERICAN ENGINEERING UNITS

UNIT NUMBERS OF INPUT/OUTPUT FILES

INPUT FILE (INFILE)	5	OUTPUT FILE (OUTPUT)	6
DEFAULT INPUT FILE (DEFAULT)	2	SUMMARY TABLE OUTPUT (SUMRY)	12
BLOWDOWN INPUT FILE (BLODWN)	4	ERROR TEXT FILE (ERRMSG)	
BOIL PLOT FILE (BOILPT)	0	MACE PLOT FILE (MACEPT)	0
CORRAL OUTPUT (CORRAL)	0	CORSOR OUTPUT (CORSOR)	0
MASS FLOW OUTPUT (FLOWS)	0	MERGE OUTPUT (MERGE)	0

* * * INPUT FOR NAMELIST NLINTL * * *

(NONE)

* * * INPUT FOR NAMELIST NLSLAB * * *

NUMBER OF SLABS 15 NUMBER OF MATERIALS 2

MATERIAL PROPERTIES

NAME	CONCRETE	STEEL
DENSITY	150.	490.
HEAT CAPACITY	.152	.115
THERMAL CONDUCTIVITY	.800	26.0

SLAB PROPERTIES

NAME	IVL	IVR	NNO1	NNO2	MAT1	MAT2	AREA	HIF	DTDX
DELCHS1	1	1	5	9	2	1	1.211E+04	100.	0.
LCHS1	2	2	10	0	1	1	9.018E+04	0.	0.
LCHS2	2	2	5	0	2	2	1.889E+04	0.	0.
LCHS3	2	2	3	0	2	2	1.101E+05	0.	0.
LCHS4	2	2	3	0	2	2	2.543E+04	0.	0.
LCHS5	2	2	6	0	2	2	3.439E+03	0.	0.
LCHS6	2	2	3	0	2	2	9.470E+03	0.	0.
ICCHS1	3	3	5	0	2	2	5.692E+03	0.	0.
ICCHS2	3	3	10	0	2	2	3.892E+03	0.	0.
UCHS1	4	4	5	9	2	1	3.413E+04	100.	0.
UCHS2	4	4	11	0	1	1	2.933E+04	0.	0.
UCHS3	4	4	3	0	2	2	630.	0.	0.
UCHS4	4	4	3	0	2	2	3.781E+04	0.	0.
UCHS5	4	4	3	5	2	1	378.	100.	0.
ICCHS3	3	3	3	0	2	2	1.806E+05	0.	0.

NODE COORDINATES MEASURED FROM LEFT BOUNDARY OF EACH SLAB

DELCHS1	0.	5.000E-03	1.000E-02	2.350E-02	4.690E-02	.100	.200	.400	.600	.800
	1.00	1.25	1.50	2.05						
LCHS1	0.	1.000E-02	2.000E-02	4.000E-02	8.000E-02	.160	.320	.640	.960	1.40
LCHS2	0.	1.000E-02	2.000E-02	4.000E-02	6.850E-02					
LCHS3	0.	1.140E-02	2.280E-02							
LCHS4	0.	4.240E-03	8.480E-03							
LCHS5	0.	1.000E-02	2.000E-02	4.000E-02	8.000E-02	.156				
LCHS6	0.	1.805E-02	3.610E-02							
ICCHS1	0.	1.000E-02	2.000E-02	4.000E-02	6.250E-02					
ICCHS2	0.	1.000E-02	2.000E-02	3.000E-02	5.000E-02	.100	.250	.500	.750	1.00
UCHS1	0.	5.000E-03	1.000E-02	2.350E-02	4.690E-02	.100	.200	.400	.600	.800
	1.00	1.25	1.50	2.05						
UCHS2	0.	1.000E-02	2.000E-02	3.000E-02	5.000E-02	.100	.250	.500	.735	.970
	1.47									
UCHS3	0.	2.600E-03	5.200E-03							
UCHS4	0.	5.850E-03	1.169E-02							
UCHS5	0.	1.825E-02	3.650E-02	.102	.167	.182	.197	.203		
ICCHS3	0.	3.300E-03	6.600E-03							

INITIAL TEMPERATURES

DELCHS1	120.	120.	120.	120.	120.	120.	120.	120.	120.	120.
	120.	120.	120.	120.						
					[illegible]	[illegible]	[illegible]	120.	120.	120.

LCHS2	120.	120.	120.	120.	120.					
LCHS3	120.	120.	120.							
LCHS4	120.	120.	120.							
LCHS5	120.	120.	120.	120.	120.	120.				
LCHS6	120.	120.	120.							
ICCHS1	100.	100.	100.	100.	100.					
ICCHS2	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
UCHS1	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
	100.	100.	100.	100.						
UCHS2	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
	100.									
UCHS3	100.	100.	100.							
UCHS4	100.	100.	100.							
UCHS5	100.	100.	100.	100.	100.	100.	100.	100.		
ICCHS3	20.0	20.0	20.0							

TEMPERATURES OF NODES 1 15 36 99 60 ARE SAVED

* * * INPUT FOR NAMELIST NLECC * * *

	UPPER HEAD INJECTION TANK	ACCUMULATOR	BORATED WATER STORAGE TANK
INITIAL PRESSURE	0.	636.	- - - - -
INITIAL MASS OF WATER	0.	2.350E+05	2.901E+06
INITIAL WATER TEMP.	100.	100.	100.

FRACTIONAL VALUE OF RWSTM TO START ECC RECIRCULATION = -1.00

FRACTIONAL VALUE OF RWSTM TO STOP INJECTION AND START SPRAY RECIRCULATION = .334

MINIMUM SUBCOOLING TO PREVENT RECIRCULATION PUMP CAVITATION = -100.

MINIMUM SUMP MASS TO AVOID RECIRCULATION PUMP CAVITATION = 100.

ECC PUMP DATA

NPUMP = 3

PUMP	HIGH PRESSURE SHUTOFF (P)	LOW PRESSURE SHUTOFF (PLO)	START TIME (TM)	STOP TIME (STP)	FLOW RATE (VEC)
1	1.432E+03	0.	1.000E+10	1.000E+10	-174.
2	2.729E+03	0.	1.000E+10	1.000E+10	-147.
3	177.	0.	1.000E+10	1.000E+10	-1.390E+03

* * * INPUT FOR NAMELIST NLHX * * *

AEP:NRC:Ø5ØØO

HEAT EXCHANGER INPUT DATA AT RATED CONDITIONS

	CAPACITY	PRIMARY FLOW RATE	SECONDARY FLOW RATE	PRIMARY INLET TEMP.	SECONDARY INLET TEMP.
ECC HX	4.110E+07	2.467E+04	4.125E+04	140.	95.0
CS HX	1.079E+08	2.647E+04	2.712E+04	168.	76.0

* * * INPUT FOR NAMELIST NLCOOL * * *

CONTAINMENT BUILDING COOLER DATA

THE COOLER IS IN VOLUME NO 0
THE COOLER STARTS AT TIME = 1.000E+10
AT RATED CONDITIONS
Q = 0.
VP = 0.
VS = 0.
TP = 0.
TS = 0.
CVAP = .693

THERE IS NO ADDITIONAL FAN COOLER

* * * INPUT FOR NAMELIST NLMACE * * *

CONTAINMENT FLAGS

IBETA = 0 IBURN = 1 ICECUR= 3 IDRY = 1 IVENT = 0 IWET = 2
JRPV1 = 2 JRPV3 = 2 NCAV = -2 NCUB = 4 NRPV1 = 2 NRPV2 = 2
NSMP = 2 NSMP2 = 2

CONTAINMENT MODELS AND TIME DATA

DTO = 5.000E-02 DTPNT = 10.0 DTS = 1.000E+06 AVBRK = 0. CVBRK = 0. FALL = .800
HMAXX = 280. PO = 14.7 TVNT1 = 1.000E+10 TVNT2 = 1.000E+10 VCAV = 1.690E+04 VFLR = 5.996E+03

PRESSURE SUPPPESSION DATA

DCF = 100. DCFICE= 100. TICE = 20.0 TPOOL = 0. TSTM = 105. TWTR = 190.
TWTR2 = 130. WICE = 2.370E+06 WPOOL = 0.

SAFEGUARDS CONTROL

FSPRA = 0. STPECC= 1.000E+10 STPSPR= 1.000E+10 WVMAKS= 0. WVMAX = 5.220E+05

BURN FLAGS

IBURN = 1 IBURNJ= 1 IBURNL= 2 IBURNM= 0
IGNITE= 1 1 1 1

BURN DATA

CMON = .150 CMHI = .167 CMHZ = .138 CMLO = 3.000E-03 CMON = .148 CMUP = .125
CMXX = .148 H2ON = 9.000E-02 H2HI = .100 H2HZ = 6.000E-02 H2LO = 0. H2ON = 6.000E-02
H2UP = 4.100E-02 H2VO = 353. H2VX = 1.163E+04 H2XX = 8.000E-02 HIG = .550 HIOXY = 5.000E-02
H2DIST=13.0 58.0 13.0 57.6

COMPARTMENT INITIAL CONDITIONS

NUMBER	VOLUME	FLOOR AREA	HUMIDITY	TEMP	WCOD	WCMO	WHYD	WNTR	WOXY
1	1.162E+05	4.166E+03	.150	120.	-3.320E-04	0.	-4.990E-07	-.790	-.210
2	3.353E+05	5.809E+03	.150	120.	-3.320E-04	0.	-4.990E-07	-.790	-.210
3	3.653E+04	3.525E+03	.150	130.	-3.320E-04	0.	-4.990E-07	-.790	-.210
4	7.468E+05	1.039E+04	.150	100.	-3.320E-04	0.	-4.990E-07	-.790	-.210

CONTAINMENT EVENTS

EVENT NO.	NS	NC	NT	C1	C2	C3	C4
1	2	2	1	17.6	314.	80.0	2.297E-03
2	2	1	8	17.6	7.800E+04	4.00	0.

TRANSFER MATRIX

I	J	KT (I,J)	BK (I,J)	PRESS
1	1	NO TRANSFER		
1	2	1		20.99
1	3	NO TRANSFEP		
1	4	NO TRANSFER		
2	1	1		20.37
2	2	NO TRANSFER		

3	1	NO TRANSFER	
3	2	1	10.00
3	3	NO TRANSFER	
3	4	1	20.00
4	1	NO TRANSFER	
4	2	NO TRANSFER	
4	3	1	20.00
4	4	NO TRANSFER	

```
* * * INPUT FOR NAMELIST NLBOIL * * *

BOIL FLAGS

  IAXC   =        0   IBEDC  =        3   IBEOS  =        3   ICON   =        1   ICONV  =       20   IDECAY=        0
  IFP    =        2   IHC    =        1   IHR    =        1   IMWA   =        3   IMZ    =      100   IPRIMP=        0
  IRAD   =        2   ISAT   =        0   ISG    =        4   ISTM   =        0   ISTR   =        4   KRPSXX=        0
  MELMOD=        -1   MWDRNL=         1   NDTM   =   100000   NDZ    =       30   NDZORP=         1   NR     =    50952
  R1     =        1   R2     =       10

TIMESTEP AND OUTPUT CONTROL

  DTKXXX= 1.000E+03   DTPN   = -5.00      DTPNTB=  10.0      TPN    = 1.000E+10
  TSB    = -.250        1.00          1.00          1.00
  TSCT   = 1.000E+10    1.000E+10     1.000E+10     1.000E+10
  NRPLT  =        1             1             1             1            1            5           10
  NZPLT  =        1             7            15            22           30           15           15

CORE POWER

  ANSK   = 0.         Q235U  =  200.      QZEROX= 1.164E+10   R239U  =  .800       TDK    = 1.000E+07   TRPS   = 0.
  YB     =  4.00      YF     =  9.00

AXIAL POWER PEAKING FACTORS

  FZ     =  .411       .660       .819       .924       .994       .974       1.09       1.11       1.13       1.07
            1.15       1.16       1.17       1.15       1.17       1.18       1.18       1.17       1.11       1.17
            1.16       1.14       1.04       1.10       1.06       .996       .887       .790       .624       .398

RADIAL POWER PEAKING FACTORS

  PF     =  1.09       1.09       1.12       1.12       1.09       1.06       1.03       .838       .563       .357

FRACTION OF CORE VOLUME IN EACH RADIAL REGION

  VF     = 9.326E-02  7.254E-02  9.326E-02  .114       .135       .150       .135       .114      7.254E-02  2.073E-02

CORE PARAMETERS

  ACOR   =  51.1      ATOT   =  101.      CLAD   = 2.249E-03   D      = 3.000E-02   DC     =  11.1      DF     = 2.525E-02
  DH     = 4.256E-02  ECROS  =  .700      ELONG  =  .214       ESTRU  =  .600       EVAT   =  .950      H      =  12.0
  HW     =  350.      PITCH  = 4.133E-02  RHOCU  =  55.6       TALF1  = 1.000E+10   TALF2  = 1.000E+10  TCAV   = 1.000E+03
  VIEW   =  2.00      WBAR   = 4.337E+04  XOD    = 3.280E-06

MELTDOWN MODELS

  CONB   =  2.00      DPART  = 4.167E-02  DUO2   = 2.525E-02   FCOL   =  1.00      FDCR   = -1.00      FDROP  =  1.00
  FM     = 0.         FR     = 0.         FZMCR  =  1.00       FZOCR  =  1.00      FZOS1  = 0.         PORB   =  .400
  TCORMB= 1.000E+10   TFAIL2= 2.550E+03   TFAILB= 1.000E+10    TFAILX= 2.000E+03   TFUS   = 6.216E+03  TMELT  = 5.216E+03
  TMWOFF= 5.216E+03

PRIMARY SYSTEM

  F12    =  .445      HO     =  106.      PVSL   = 2.250E+03   QPUMP1= 0.          QPUMP2= 0.          TFEOD  =  606.
  TGOD   =  574.      TMUP1  = 1.000E+10  TMUP2  = 1.000E+10   TPUMP1= 1.000E+10   TPUMP2= 1.000E+10   VOLPX  = 1.250E+04
  VOLSX  =  720.      WATBHX= 4.652E+04   WDED   =  200.       WFE2   = 1.000E+04   WMUP1  = 0.         WMUP2  = 0.
```

* * * INPUT FOR NAMELIST NLBOIL * * * (CONTINUED)

AEP:NRC:05000

STRUCTURES ABOVE CORE

This information is considered proprietary to Westinghouse Electric Corporation, and is deliberately not included at this time.

GRIDPLATES AND BOTTOM HEAD

TEMP	HT CAP	HT AREA	THICK	YGRID
580.	5.400E+03	160.	6.250E-02	0.
580.	6.000E+03	160.	.125	-2.00
580.	8.450E+03	327.	.448	-4.00

STEAM GENERATOR

FULSG = 3.988E+04 PSG = 1.100E+03 TAFW = 100. TMAFW = 1.000E+10 TMSG1 = 1.000E+10 TMSG2 = 1.000E+10
WAFW = 7.458E+03 WCST = 4.144E+06 WTRSG = 3.988E+04 YLEG = 0. YLEG2 = 1.000E+10
TMLEG = .100E+11 .100E+11 .100E+11

BREAK AND VALVE PARAMETERS

ABRK = 0. ASRV = 0. FLD = 0. PSETX = 2.365E+03 TMYBK = 1.000E+10 TPM = 1.00
WSETX = 1.400E+04 YBRK = 16.0 YBRK2 = 1.000E+03 YSRV = 37.7

TR	AR	YBR	ABR	YSR	ASR	PSR
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00
1.000E+10	0.	-1.00	-1.00	-1.00	-1.00	-1.00

* * * INPUT FOR NAMELIST NLBWR * * *

IBWR = 0 BWR CHANNEL BOX MODEL NOT USED

```
* * * INPUT FOR NAMELIST NLHEAD * * *

      COND   = -8.00       DBH    =  14.7       E1     =  .800       E2     =  .500       FHEAD  = 0.          FOPEN  = 0.
      SIGF   = 8.000E+04   THICK  =  .500       THKF   =  10.0       TMLTXX= 4.130E+03    WFECXX= 1.916E+04    WGRIDX= 9.500E+04
      WUO2XX= 1.919E+05    WZRCXX= 4.490E+04

* * * INPUT FOR NAMELIST NLHOT * * *

   HOTDRP FLAGS

      IDBED  =        103  IHOT   =          2  MWR    =        101  NSTOP  =        500

   DEBRIS PARAMETERS

      ACAV   =  549.       CON    =  2.00       DP     = 4.167E-02    FLRMC  = 2.700E+03   PORO   =  .400       TCORM  = 1.328E+04
      TMS    = 2.600E+03   TPOOLH=  100.        TONCH  = 0.           WTR    =  100.

* * * INPUT FOR NAMELIST NLINTR * * *

   INTER FLAGS

      IGAS   =          1  IVRC   =          1  IZRFEO=           0  NEPS   =          2

   MODEL PARAMETERS

      CAYCXX= 1.385E-02    CPCXXX=  .996        DENSCX=  2.52       DPRIN  = 3.600E+03   DTXXXX=  .500        FC1XXX=  .800
      FC2XXX=  .150        FC3XXX= 1.000E-02    FC4XXX= 3.000E-02   FIOPEN=  .500        FRCW   =  1.00       HIM    =-1.000E-02
      HIO    = 1.000E-02   ROXXXX=  259.        PBPXXX=  .112       RXXXXX= 6.000E+03    TAUL   =  .500       TAUS   =  5.00
      TDC    = 1.373E+03   TF     = 7.201E+04   TIC    =  293.      TPRIN  = 0.          WALL   =  900.       ZF     = 1.000E+10

      NEPS         TIME             EPSILON
        1          0.                .500
        2          1.000E+10         .500
```

AEP:NRC:Ø5ØØO

THE OUTPUT IS IN AMERICAN ENGINEERING UNITS

TIME	MIN
TEMPERATURE	DEGREES F
MASS	LB
LENGTH	FT
AREA	FT**2
VOLUME	FT**3
ENERGY	BTU
POWER	BTU/HR
SPECIFIC ENTHALPY	BTU/LB
MASS FLOW RATE	LB/MIN
DENSITY	LB/FT**3
PRESSURE	PSI
HEAT CAPACITY	BTU/LB/F
THERMAL CONDUCTIVITY	BTU/HR/FT/F
HEAT TRANSFER COEFFICIENT	BTU/HR/FT**2/F
VOLUME FLOW RATE	FT**3/MIN

THE OUTPUT VARIABLES DEFINITIONS LIST ALSO CONTAINS THE UNITS USED FOR EACH VARIABLE IN THE OUTPUT.

SUBROUTINE INTER OUTPUT IS ALWAYS IN CM FOR LENGTH, GR FOR MASS, AND SEC FOR TIME.

30 NORMAL EXIT ECHO: END OF MARCH INPUT CHECK