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August 15, 1983

Mel Silberberg
U.S. Nuclear Regulatory Commission
6915 Eastern Ave. 113033
Silver Spring, MD 20910

Dear Mr. Silberberg:

I regret that I was unable to attend the peer review during July; however, I have reviewed many of the reports sent to me for that meeting. The results of my review are enclosed and it focuses on the thermal-hydraulic aspects of the mathematical models used for the analysis. I would like to call your attention to the comment regarding the potential for fission product deposition in the multiple primary system loops and steam generators of a PWR. The current approach in MERGE and TRAP-MELT does not seem to consider this when representing the primary system as a few control volumes connected in series. From a broader point of view the reports do not convey a strong technical basis for a best estimate analysis. There are numerous assumptions stated without justification and many qualifications of the analytical tools. I recognize the difficulties here but feel that a better job could be done to tighten up the technical basis of the analysis. The results are giving a source term reduced somewhat from WASH-1400 but not by an order of magnitude. With all the uncertainties and qualifications as currently stated, is it possible to make a case for a source term reduced from that of WASH-1400?

I expect that you or others may wish to discuss these comments with me. Please feel free to call.

Sincerely,

Donald S. Rowe

Donald S. Rowe

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Enclosure

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Comments by D. S. Rowe

Draft Report: Description and State of Verification of the ORIGEN2 Code.

General Comments

My comments on this report are quite general and editorial. The opening remarks on page 1 are very vague refering to the code as a "very flexible reactor physics code." The report needs a specific statement up front such as: ORIGEN2 calculates the radionuclide composition in the core, etc.

Page 4 refers to Reference (2) and then states that most of the calculations are trivial. I really don't think this is the case and the writeup should summarize the computational methods in a way to be informative to the reader who doesn't know anything about ORIGEN2.

Coupling to Other Codes

The specific applications of MARCH2 and its associated codes indicate that MARCH2 does "overall thermal hydraulics." MARCH2 appears to do much more including calculations involving containment, core-concrete interaction and primary system such that there appears to be overlap with MERGE, TRAP-MELT, etc. A report section specifically devoted to this topic would be useful.

Editorial Comment

Section III is nearly the entire report. Some breakup could help the overall organization of the report.

More illustrations are needed to show phenomena being modelled. The text is heavy reading.

SPECIFIC COMMENTS

Pages 4 - 5

The core nodal treatment could be stated in somewhat more general terms. Each nodal volume contains volume fractions for fuel, cladding, water (or steam), channel boxes, control rods, etc, based on the overall dimensions of the core and its components.

Page 5

Increasing the thickness of the cladding to include the Zircaloy of the channel boxes needs further justification or model revision. The reaction of Zircaloy and steam depends on the exposed surface area. It would seem that putting the channel box and control blade mass into a thicker cladding would underestimate the rate of reaction with steam.

Page 6

The modeling of the primary system as a single cylindrical volume needs more explanation and justification. What happens to the steam generators, piping, pump, etc? How are the steam generations included as heat sinks (or sources)?

Comments by D. S. Rowe

Draft Report. Status of Validation of the MARCH2 Computer Code, July 11, 1983.

GENERAL COMMENTS

Assumptions

Many assumptions are made during the course of the discussion. While a few of them are discussed, most of them are not discussed. I realize that many assumptions are required to simplify the analytical model and the model must stand on that justification. Others can be justified from the physics and order-of-magnitude importance of the phenomena involved. Additional justification or statements regarding the assumptions would help strengthen and clarify the modeling discussion.

Control Volumes

Mass and energy balances are stated but without reference to the control volumes that they represent. Illustrations of the control volumes and the placement of variables on those volumes would help clarify how the mass and energy balances are done. Each control volume would then also have a clear relationship with its neighboring volume by the mass and energy flows at their mutual boundary. The assembly of all control volumes would represent the nodal description of the entire system.

Adjustable Inputs

MARCH2 contains a significant number of adjustable inputs. This can be useful for a parametric analysis but is not very satisfactory for a "best estimate" calculation unless a set of default inputs are selected. If this is not done it is conceivable that a variety of answers could be obtained by "tuning" the inputs. Inputs to MARCH2 need to be clearly identified if they are causing sensitivity in the results.

Page 7

The impact of the restriction to series connected containment volumes needs to be explained. Are there situations where convection loops could exist between compartments that would affect the transport of fission products? I believe that such loops could be included in MARCH2 with a modest effort and without limiting the code's time step.

Page 12

While mass and energy balances are discussed in this section, it is not entirely clear that a global mass and energy balance exists for the system. Does MARCH2 do a global balance at each time step to assure mass and energy conservation?

An illustration of the primary system nodalization is needed to show the various features of what is modelled.

Page 17

Equation (3.10) does not appear to be an energy balance. Is this supposed to be

$$W_{TOT}\, CP_L \, \frac{T_{POOL}^{n+1} - T_{POOL}^{n}}{-\Delta t} = Q_{TOT}$$

where n and n+1 are old on new time respectively. Are there energy flow terms missing. I would prefer to see balance equations in the above form (with flow terms) because they have a closer analog to the differential equations. They are also easily related to control volumes.

Page 30

The assumption of uniform radial temperature in fuel and cladding should be discussed and justified here.

Page 40

None of the meltdown models consider the situation of the cladding (or structure) melting before the UO_2. Is this more realistic than an average core melt? What technical basis do we have to justify the approaches assumed?

Page 43

See comment for page five regarding metal-water reactions.

Page 47

What is technical basis for forming spheres with UO_2 on the inside and zirconium on the outside? What is the impact of choosing the various fraction options? Can we justify any of them?

Page 56

It is not clear what is averaged and what is a single quantity. Is T_{SLB} an average?

Page 57

Is Equation (3.119) three equations for the unknowns T_2, T_s' and Q? If so, then state as three equations and three unknowns.

Page 58

Where are Equations (7.1) and 7.2)?

Page 59

An illustration of the control volume(s) for the bottom head and debris energy balance would help clarify the heat transfer processes. Is radiation or convection from the top of the debris sufficient to slow (or stop) the melting of the vessel bottom? How about convection through the debris bed?

Page 68

Can the omission of debris entrainment, cavity sweep out, etc, be justified? What velocities exist in the reactor cavity?

Page 88

Within the structure MARCH2, the numerical solution for containment flows and pressures could be modified with modest effort to remove the "series" restriction and allow "loops." This could be done without imposing time step limitations on the calculation.

Page 100

The variable g should be g_c, the gravitational constant.

Page 115

Reference for Le Chatelier.

Page 118

Some typical time for flame spread would be useful to the reader.

Page 126

Why not include this core radiation heat transfer discussion with that starting on page 29.

Page 128

The core barrel is heated by the outer two radial core nodes. How is this done in the axial direction where the core has many axial nodes and the core barrel is a single node.

Page 129

Is axial conduction in the fuel rods really necessary?

Page 143

I agree with many of the items brought out in III D. Some of these points could be brought out earlier in connection with the development of the models.

Page 144

The potential for two-sided oxidation would appear to real as the core begins to slump and relocate. The ratio of the surface area to volume of zirconium would seem to be an important parameter.

Page 147

Natural convection flows and associated fission product transport could be significant within containment compartments even if the results of MARCH2 show long periods of stagnation. This would require a multi-dimensional containment analysis that can consider the coupled thermal response of the structure and hydraulics of the compartment.

Page 148

Results of MARCH calculations compared to PBF tests should be included.

Comments by D. S. Rowe

Partial Report: Radionuclide Release Under Specific LWR Accident Conditions--Volume II, BWR, MARKI Design.

SPECIFIC COMMENTS

Page 3-2

A brief statement pointing out that the letters refer to WASH-1400 accident sequences would help the first time reader.

Page 5-1

The statement at the bottom of the page is not very positive. I suggest that statements be made regarding how MARCH2 represents the system and what it calculates. It can then be qualified regarding its uncertainties. It's the best we've got at this point inspite of its shortcomings.

Page 6-5

Figure 6.3 is not very enlightening regarding the nodal treatment in the core. The MARCH2 representation contains many control volumes for purposes of core heat up. That point needs to be brought out.

The 6 control volume treatment here may be satisfactory for calculating pressure drops, flows and wall temperature but it is probably too coarse for accuracy in the fission transport analysis because of numerical diffusion. Does the TRAP-MELT part of the analysis use this same nodal representation? If so, nodal sensitivity analysis should be considered to determine the adequacy of the nodal treatment. This need not be done on a full system calculation but it could be done as separate effects calcuation for a standalone problem.

Page 7-37

Reference to BWR1, BWR2, etc. in tables should be footnoted or accompanied by reference to WASH-1400 so as not to be confused with the GE product line designation.

Page 7-39

Reference to the hydrogen explosion destroying the reactor building is a rather dramatic statement that calls for more discussion or explanation. In the mind of the public this sounds like a reactor exploding.

Pages 7-40, 7-41

This discussion is quite a let down. Are we any better off than WASH-1400?

Page A-2

Can the operator be expected to shut off the two blowers?

Page A-6

It would be helpful to have some volume estimates for the aerosols in relationship to the capacity of the filters. The mass numbers are not very informative.

Comments by D. S. Rowe

Report: Review of MERGE Code, P. Saha, June 1983.

GENERAL COMMENTS

I generally concur with the views expressed in this report.

From a broader point of view, I don't understand why the calculations of MERGE are not done in TRAP-MELT. If the mission of MERGE is to calculate primary system flows and structure temperatures for use in TRAP-MELT then it would seem appropriate to do it within the same code. Such an integrated approach would assure a consistent control volume apparoach and allow inclusion of relocating fission product heat sources along the primary system piping.

If reevolution of fission products from surfaces is an important possibility that depends on an accurate calculation surface temperature, it would be necessary to replace the lumped parameter wall temperature model with a distributed parameter model. The extra work would be small with so few control volumes in the primary system.

The primary system is represented in MERGE as a series of control volumes; however, PWRs have multiple loops. What justification is used to exclude transport through those loops and their steam generators? If the steam generators are effective heat sinks there could be significant steam flow and condensation in the steam generators. The steam flow could carry significant aerosals and fission products into the steam generators and associated primary system piping. I believe this could be an important phenomena that has been omitted from the MERGE analysis.

Comments by D. S. Rowe

Draft Report: Status of Validation of the TRAP-MELT Computer Code, T. S. Kress and A. L. Wright.

General Comments

This report is quite good as it deals with many of the issues related to fission product transport.

TRAP-MELT is primarily concerned with the transport of mass in the primary system. It does not, however, consider the volume of material being transported or deposited. This should be addressed because it could have an important affect on the flow areas, pressure drops, surface heat transfer from pipes, etc.

The affect of heating by transported fisson products has been brought up several times and is worthy of mention again. This could be especially important regarding the reevolution of fission products caused by heating of a deposit on a structure surface.

The nodal treatment for TRAP-MELT apparently is the same as for MERGE. Those nodes (control volumes) are large and there are few of them which can lead to substantial numerical diffusion of aerosals along the flow path. I suggest that a nodal sensitivity study be done to explore the accuracy of the current nodal treatment. This could be done in a separate stand alone calculation rather than in a full system calculation.

Specific Comment:

Pg. 12 From a numerical point of view, the well mixed volume assumption leads to numerical diffusion. This will cause a smearing of nonuniform distributions of aerosals and a late calculation of last arrival of aerosals. The effect of numerical diffusion can be reduced by using more control volumes.

Pg. 16 The equation

$$\dot{M} = CQ$$

is a definition for mass flow rate and not the incompressible continuity equation.

Pg. 22 I would expect that the gravitational settling issue would be related to aerosal size. If particles are large, they would settle by gravity at some velocity and not depend on the concentration.

Pg. 29 I would like to specifically concur with the thoughts expressed concerning fission product heat sources, 2-D thermal hydraulics and resuspension of deposited aerosals.