Sixteenth Annual Meeting Committee

AMERICAN NUCLEAR SOCIETY

Received
3/31/70

Louis J. Weidner, Jr.
Technical Program Chairman
P.O. Box 111, Terminal Annex
Room 634C, GOB
Los Angeles, California 90054, USA

18 March 1970

Mr. W. H. Rettig
Idaho Nuclear Corporation
P. O. Box 1845
Idaho Falls, Idaho 83401

LOG NO. LA 010

Dear Mr. Rettig:

I regret to inform you that the Committee has not accepted your summary.

The Program Committee feels that your summary, as submitted, does not have sufficient content to warrant its presentation. As you continue your work along this line and have additional information to present, we urge that a new summary be submitted for consideration at a later meeting. The paper is a description of a computer program, and such descriptions are normally not acceptable for presentation as papers. The results of the program for some significant situations would perhaps be acceptable. Also, references to earlier work are desirable.

Sincerely,

[signature]

Louis J. Weidner, Jr.
Technical Program Chairman

This was the first attempt to publish a paper on RELAP. (1970) It took 2 more years to get this done in 1972 See next pages.

Ken

November 6, 1972

S. O. Johnson
HDQ Annex B-8

TRANSMITTAL OF ANS SUMMARY - KVM-7-72

Attached are three copies of a summary which we submit for your consideration as a paper at the ANS Topical Meeting on Water Reactor Safety.

This paper is coauthored by myself, C. E. Slater and L. J. Ybarrondo.

This summary has not yet been cleared for publication, but it has been submitted for Company review. You will be notified shortly if approval is withheld.

Thank you for your consideration.

pj

Original signed by
K. V. Moore
Computer Science Branch

Attachments

cc: w/Attachment
B. M. Beardsley/r/R. J. Wagner
G. F. Brockett
H. D. Curet
G. E. Denning
C. E. Slater
F. H. Tingey
L. J. Ybarrondo
K. V. Moore - 2

MOMENTUM FLUX HYDRAULIC TERMS IN DECOMPRESSION CODES

K. V. Moore, C. E. Slater, L. J. Ybarrondo

Analysis of transient fluid processes in light water commercial reactors usually involves the use of a decompression code such as RELAP3[1]. Although thermodynamic nonequilibrium and nonhomogeneous processes occur during decompression, the accuracy of predictions will be partly determined by the approximations used in the solution of the fundamental fluid conservation equations. Current decompression codes such as RELAP3 solve a simplified set of conservation equations (momentum, energy, mass) for homogeneous, equilibrium flow. To achieve the simplified set of conservation equations, the momentum flux, kinetic energy, and potential energy terms are assumed negligible since their pressure head equivalence is usually small. Neglecting these terms is erroneous when the fluid velocity is near sonic velocity or when large density gradients exist. If the above terms are neglected, Bernoulli effects and momentum mixing effects occurring when two or more streams flow together (such as in a Boiling Water reactor jet pump) cannot be described correctly.

Under certain conditions, the RELAP3 code has displayed an erroneous effect in which a volume becomes completely depleted of mass. Omission of the momentum flux in the momentum equation was suspected as the cause of this problem. Therefore, development of a version of RELAP3 with momentum flux terms was initiated to study the problem. With this version of RELAP3, interesting insights have been obtained into the importance of the momentum flux term, $-\vec{\nabla} \cdot \rho\vec{v}\vec{v}$, where ρ is density and v is velocity. The production version of RELAP3 neglects this term as a simplifying expediency because, as it is argued, the contribution of momentum flux should not change significantly during a fluid transient. Several simple approximations to the $-\vec{\nabla} \cdot \rho\vec{v}\vec{v}$ term were coded, tested and rejected on the basis of physical arguments. These approximations were developed from a control volume basis and failed to sufficiently describe the physics of momentum flux changes.

A different approach based on stream tube equations was coded and found to be reasonably acceptable. This formulation of the momentum flux terms includes the effects of fluid compressibility, area changes, and stream mixing.

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[1] W. H. Rettig, G. A. Jayne, K. V. Moore, C. E. Slater, M. L. Uptmor, "RELAP3 -- A Computer Program for Reactor Blowdown Analysis", IN-1321, (June 1970)

By integrating the fluid momentum partial differential equation over a stream tube volume defined from Station 1 to Station 2 with a variable flow area A, the momentum flux term $-\vec{\nabla} \cdot \rho\vec{v}\vec{v}$ can be expressed in terms of mass flow, W, as

$$- \int_1^2 \frac{1}{A}\, d(vW).$$

This integral can be expanded as

$$- \frac{v_2 W_2}{A_2} + \frac{v_1 W_1}{A_1} + \frac{W^2}{2\rho_o}\left(\frac{1}{A_2^2} - \frac{1}{A_1^2}\right) F$$

where the first two terms represent the momentum change occurring within the tube section by transport across Boundaries 1 and 2. The third term represents the momentum change occurring across a change in flow area and includes a compressible effect defined by the F function. For incompressible flow F is unity and the three terms reduce to the familiar Bernoulli form.

The kinetic and potential energy terms were also coded in this effort by using a similar stream-tube equation. The resultant combination thus includes an approximation for all physical effects described in the fundamental fluid conservation equations.

As an example of the success of this approach, Edwards[2] experiment was modeled in which data were obtained on the decompression of a simple pressurized straight pipe (13.44' long by 2.88" I.D., initial condition of 1000 psig and 467°F). From a calculational viewpoint, these data have been very difficult to reproduce. Normal RELAP3 calculations of this experiment fail on the above mentioned mass depletion problem whereas the momentum flux version of RELAP3 produces an acceptable comparison to the Edwards data. These calculations are shown in Figures 1 and 2 for a pressure history at Station GS7 0.26 feet from the closed end of the pipe. Other comparisons to Semiscale experiments illustrate the same general type of problem as shown in Figure 1 and resolution as shown in Figure 2.

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[2] A. R. Edwards, and T. P. O'Brien, "Studies of Phenomena Connected With The Depressurization of Water Reactors", Journal of British Nuclear Society, Vol. 9, pp 125-135, (April 1970)

Basically, we conclude that the momentum flux terms are important and can significantly alter the calculated results. These facts were demonstrated in the disappearance of the mass depletion problem that was encountered in versions of the code without momentum flux terms and in the inability to predict jet pump behavior in a boiling water reactor without the momentum flux terms.

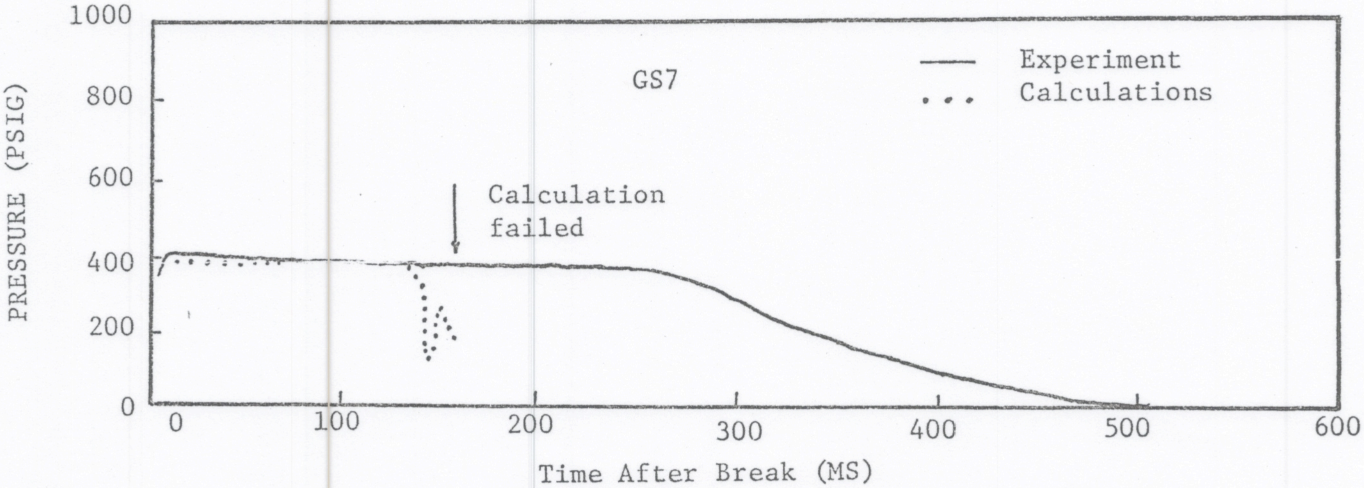

Figure 1. Comparison of Predictions Using RELAP3 without Momentum Flux Terms

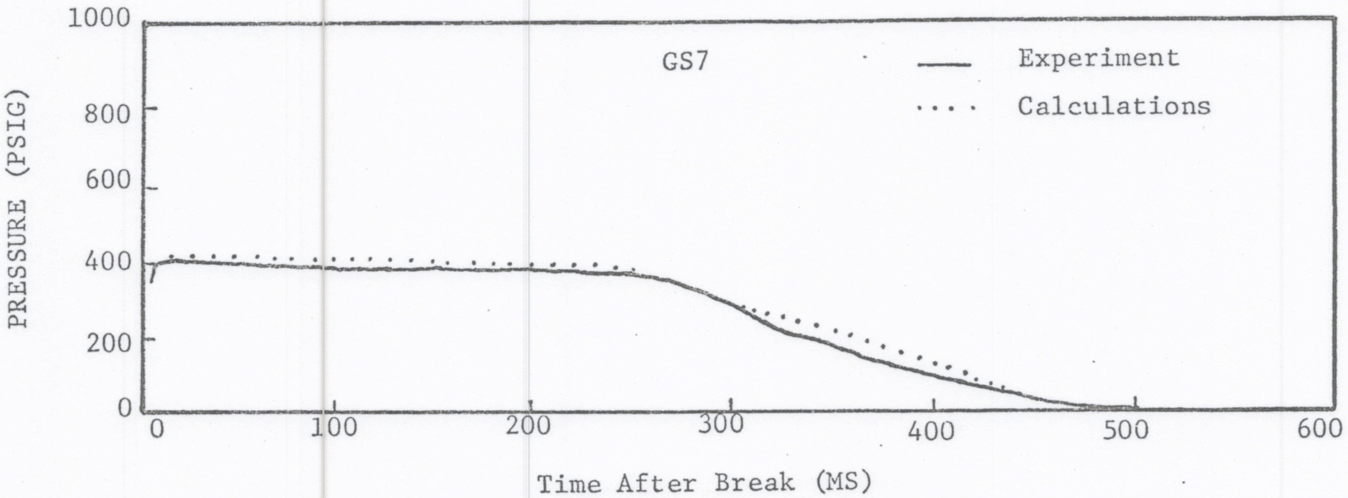

Figure 2. Comparison of Predictions Using RELAP3 with Momentum Flux Terms