PREDICTION OF REACTOR PRESSURE TUBE FLOW TRANSIENTS WITH EFFECTS OF FRICTION AND HEAT ADDITION INCLUDED USING A FIXED-GRID METHOD OF CHARACTERISTICS

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SUMMARY

An important consideration in nuclear generating station design with pressurized coolant is the effect of a loss-of-coolant accident. This may result in fuel sheath failures and release of fission products, as well as a buildup of pressure in the containment.

In this paper, a method for solving pressure tube flow transient problems by means of a high speed digital computer is illustrated. The method is very accurate for the study of single phase diabatic transient flows of compressible fluids. The transient problems handled include postulated tube rupture or flow blockage. Solutions to these problems are of interest in reactor design and safety assessment.

Transient air flow behaviour in a reactor channel fed by an infinite source was computed for the case of a rapid reduction in outlet pressure or density, representing a discharge end rupture. Only subsonic flow was considered. The fixed-grid method of characteristics was used to solve the differential equations governing the flow of the fluid. This method is not only much easier to program on a digital computer, but also has an added advantage over the characteristic-tracing method. This advantage lies in the fact that the computer dependent variables are made available for all stations along the channel for fixed values of time. They are also available for fixed intervals of time at any station along the channel. The problem of inlet flow blockage was treated in the same manner.

To demonstrate the usefulness of the technique, flow properties were computed at 51 equally spaced stations along a 1.86 in (4.72 cm) diameter channel of 10 ft (3.05 m) length for fixed time intervals of 0.0001 seconds. The initial inlet air pressure was specified as 2000 psia (138 bar (a)).

It is observed that after 0.002 seconds the expansion wave has only moved about 3 ft (0.91 m) upstream. Beyond this region the flow is still undisturbed. Only after about 0.008 seconds is the entire field disturbed. When the first expansion wave reaches the inlet end, it is reflected as a compression wave and can be seen moving back downstream. It takes about 0.008 seconds further time to travel downstream to the outlet.

Mass flow rate histories at the inlet and outlet ends of the channel were studied. The inlet flow remains constant at 100 lb/ft^2 s (488 kg/m^2 s) until the arrival of first expansion wave at $t \sim 8$ milliseconds. Thereafter, the flow rate begins to increase. At the discharge end, the flow rate starts increasing at $t=0$. Finally, a new steady-state is reached at $G \sim 4120$ lb/ft^2 s (20 100 kg/m^2 s).

As a further check on the solution, the new steady-state density and entropy were compared with a steady-state solution utilizing the new mass flow rate of 4120 lb/ft^2 s, (20 100 kg/m^2 s). It was observed that the curves overlapped.

The ability of the fixed-grid method of characteristics to clearly demonstrate the interplay of the basic system parameters such as, heat addition rates, friction factor, and rates of rupture or blockage etc., is discussed in detail. While the analysis is limited to single phase flow it could with proper modifications be extended to two-phase flow.