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NASA TECH BRIEF

Thermally Induced Oscillations in Fluid Flow

Advanced technology in such areas as nuclear power generation and sea water desalinization demands high-efficiency working fluids. This has increased interest in thermodynamic systems designed to operate at or near the fluid's critical pressure, in order to maximize such desirable parameters as specific heat and coefficient of thermal expansion. However, experiments have shown that unstable flow conditions are frequently encountered in such systems. Oscillations of pressure, temperature, and flow velocity occur which may cause mechanical or thermal fatigue failure of various system components.

A theoretical investigation was undertaken to distinguish the various mechanisms responsible for oscillations, to derive a quantitative description of the most troublesome mechanisms, and to develop a capability to predict the occurrence of unstable flow.

Three types of thermohydraulic oscillations were identified: the first caused by rapid change of the heat transfer coefficient in the vicinity of the temperature of maximum specific heat (the transposed, or pseudocritical point); the second due to high fluid compressibility in the critical pressure region; and the third caused by local variations in flow characteristics and fluid density (pseudo-boiling) brought about by temperature changes in the fluid in contact with the vessel walls.

The first two mechanisms produce relatively high-frequency oscillations which, although bothersome, do not represent a great hazard; the third causes low frequency "chugging" oscillations which are harmful to the apparatus and furthermore, appear to be the most prevalent in systems of practical interest. The third mechanism, therefore, is discussed in detail (see Note 2), and a quantitative description is derived —a characteristic equation in the form of a third-order exponential polynomial with two time constants, expressed in terms of fluid parameters, system geometry, and operating conditions. This equation is used to obtain stability maps and criteria not previously available in the literature.

The similarity between a reduced form of this equation and one derived previously to describe "chugging" oscillations in combustion systems leads to a prediction that a servo-control mechanism, similar to that found successful in overcoming the combustion system oscillations, will also reduce "chugging" oscillations in thermodynamic systems.

Notes:

1. Information on a related investigation involving unstable flow in liquid nitrogen may be found in: NASA TSP69-10541 (N69-74548), Investigation of the Nature of Cryogenic Fluid Flow Instabilities in Heat Exchangers.

2. The following documentation may be obtained from:

   Clearinghouse for Federal Scientific and Technical Information
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.65)

   Reference:
   NASA-CR-84801 (N67-28778), An Analysis of Thermally Induced Flow Oscillations in the Near-Critical and Super-Critical Thermodynamic Region

(continued overleaf)

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: Novak Zuber of
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