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ANAIS - PROCEEDINGS

EXPERIMENTAL DETERMINATION OF SINGLE AND TWO-PHASE FLOW PRESSURE DROP ACROSS A PWR CORE DEGRADED BY ACCIDENT

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ABSTRACT

The present paper deals with the experimental determination of pressure drop across a four-cusped vertical channel. This geometry represents, ideally, the blockage condition in a typical pressurized water reactor with core degraded by accident. Experiments were performed for both single and two-phase flow. Water was utilized for the single-phase measurements whilst simultaneous flow of air and water simulated the steam-water flow.

Observation of the prevailing two-phase flow regime was carried out, so that its mechanism could be fully understood. The averaged void fraction was also measured, by the gamma-ray attenuation technique. A wide range of water and air mass flow rates was covered, so that all flow conditions, possible to exist in a reactor with LOCA, could be investigated. New correlations for pressure drop are proposed.

1. INTRODUCTION

During LOCA there is a short period, between the initial blowdown and the quenching of the fuel rods by the ECCS, during which the fuel cladding may be exposed to very high temperatures. This causes an excessive increase in the rod internal pressure, leading to swelling and even rupture of the fuel cladding. The result is that the reactor becomes partially blocked. This blockage can axially extend to several diameters, forming elongated channels, the flow characteristics of which are of crucial importance to the effectiveness of the emergency cooling system.

Results from multirod burst tests (Fig.1a), carried out by Kawasaki et al [1], suggest that the four-cusp geometry (Fig.1b) is representative of the degraded core of a PWR channel.

Despite the evidence that flow of steam and water is more than likely to occur in the reactor core following a LOCA, a review in the literature shows that nothing has yet been published on two-phase flow in four-cusped channels. In this respect, a research programme on the thermohydraylics of degraded PWR cores has been initiated at PUC-RJ. First studies on the effects of boiling and two-phase flow on this particular geometry have already been produced [2,3,4]. The present paper concerns with the experimental determination of pressure drop for both single and two-phase flow.

2. EXPERIMENTAL APPARATUS

To simulate the simultaneous flow of water and steam an adiabatic air-water system was employed. The effects of heat transfer (nucleate and bulk boiling) are discussed in reference [4].

The general arrangement of the experimental apparatus is shown in Figure 2. Basically it consists of a test section (TS), a mixing chamber (MC), liquid separators (LS), the compressed air line (CP,PR), water pump (WP) and water resevoir (WR). The U-tube manometer (UM) and the pressure distributor (PD) provide the pressure drop instrumentation with flow rates being monitored by orifice plates (OP). The void fraction measurement set-up (GD,GE) is also shown.

3. RESULTS

A total number of 52 runs were performed with air (1 atm) and water velocities ranging from 0.30 to 22.05 m/s, and from 0.30 to 15.35 m/s, respectively. Single-phase measurements were performed with water flowing alone.

Figure 3 shows the results obtained for the single-phase turbulent friction factor as a function of the Reynolds number. Data on pressure drop for two-phase flow was correlated by the Lockhart-Martinelli method. Figure 4 shows the experimental pressure frop plotted in terms of the usual parameters, ϕ_g and X_{tt}. It can be observed that the original Lockhart-Martinelli curve, for circular tubes, still applies for the new geometry, provided the correspondent hydraulic diameter is employed.

4. BIBLIOGRAFIA

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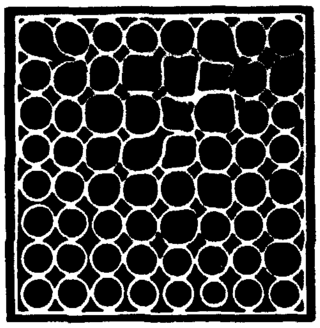
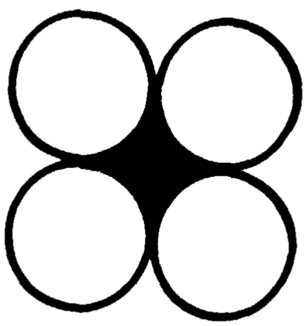


(a)



(b)

Fig.1. (a) A PWR degraded core and, (b) the four-cusp geometry

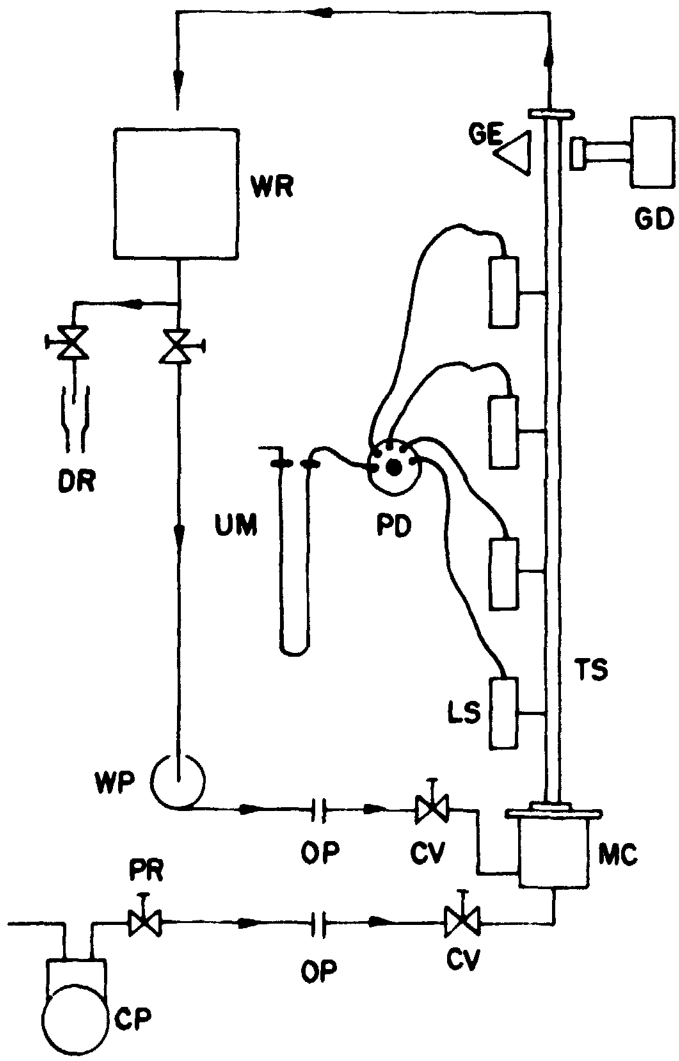


Fig.2. Experimental set-up

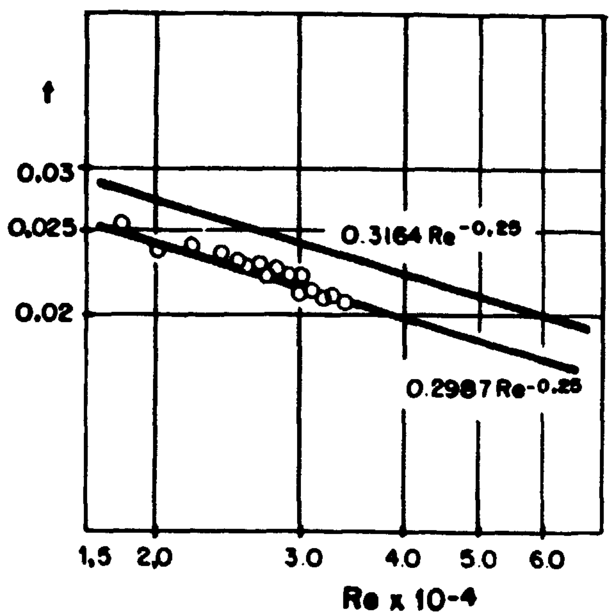
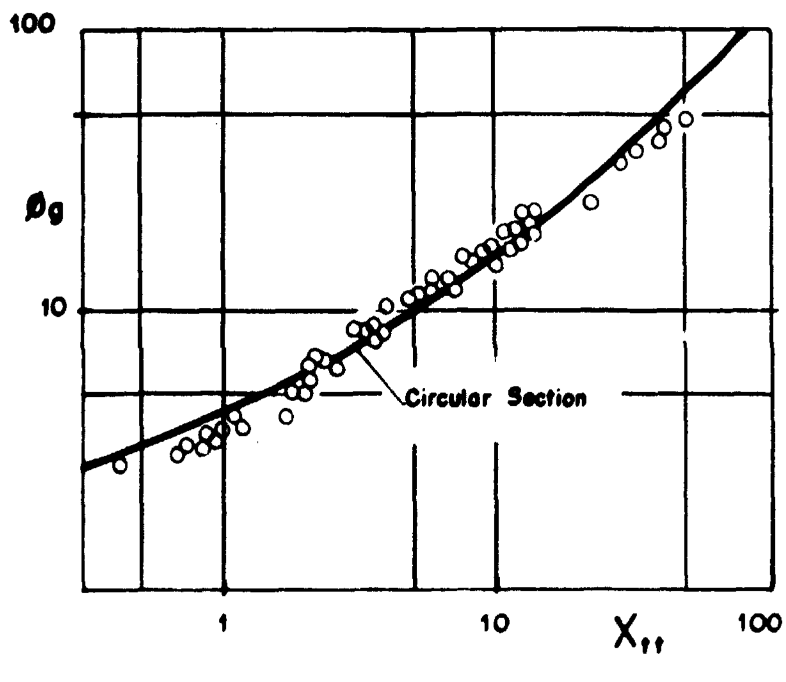


Fig.3. Single-phase pressure drop



$$\phi_g = \left[\frac{(dp/dz)_{TP}}{(dp/dz)_g}\right]^{1/2}$$

$$X_{tt} = \left[\frac{(dp/dz)_\ell}{(dp/dz)_g}\right]^{1/2}$$

Fig.4. Two-phase pressure drop