**United States Nuclear Regulatory Commission Official Hearing Exhibit**

**In the Matter of:** Entergy Nuclear Operations, Inc.
(Indian Point Nuclear Generating Units 2 and 3)

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**EXCERPT**

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# Thermal Analysis of Pressurized Water Reactors

**AN AEC MONOGRAPH**

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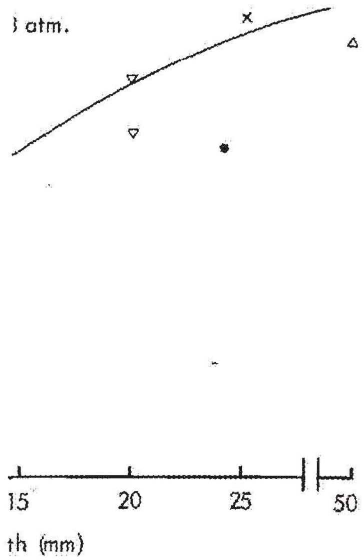

essure.
*roc. 3rd Intern. Heat Trans. Conf.*,
5 to 20 mm)
Report, No. HW-77594, 1963.

*ng. Prog. Symp. Series*, 61, No. 59,
mm)
*rgia Nucleare*, **13**, 7, 1966.
ength = 50 mm)

has plotted the back pressures vs
ata as shown in Fig. 3.13, and this
pressure is smaller in a shorter
n time for the liquid to flash. For
ves a back pressure of one atmo-
y experimental observations.

a pressure wave reaches a rigid
of equal magnitude and sign; that
as a rarefaction wave and a com-
ve. When a wave reaches an open
ted as a wave of equal magnitude

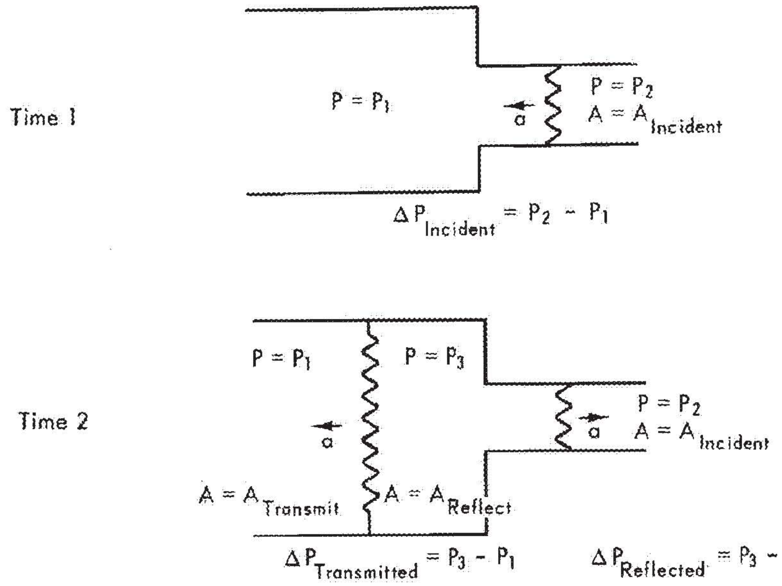

Fig. 3.14 Transmission and reflection of acoustic wave at area change.

but of opposite sign. When a wave encounters a change in area, a portion of the wave is transmitted in the original direction of travel, and a portion is reflected back. It may be shown[65] that the amplitude of the transmitted wave is given by

$$\frac{\Delta P_{\text{transmitted}}}{\Delta P_{\text{incident}}} = \frac{2A_{\text{incident}}}{A_{\text{incident}} + A_{\text{transmission}}} , \qquad (3\text{-}91)$$

and the ratio of reflected $\Delta P$ to the incident $\Delta P$ is

$$\frac{\Delta P_{\text{reflected}}}{\Delta P_{\text{incident}}} = \frac{A_{\text{incident}} - A_{\text{reflection}}}{A_{\text{incident}} + A_{\text{reflection}}} . \qquad (3\text{-}92)$$

This behavior is illustrated in Fig. 3.14.

In a frictionless system, the combination of forward and reflected waves would be undamped and would set up a standing wave. In any real system, the friction at the walls gradually reduces the amplitude of the waves. In a straight pipe, Lieberman and Brown[65] give the decay with time $t$ as

$$\Delta P = (\Delta P_0)\exp(-f\,u\,t/D) , \qquad (3\text{-}93)$$

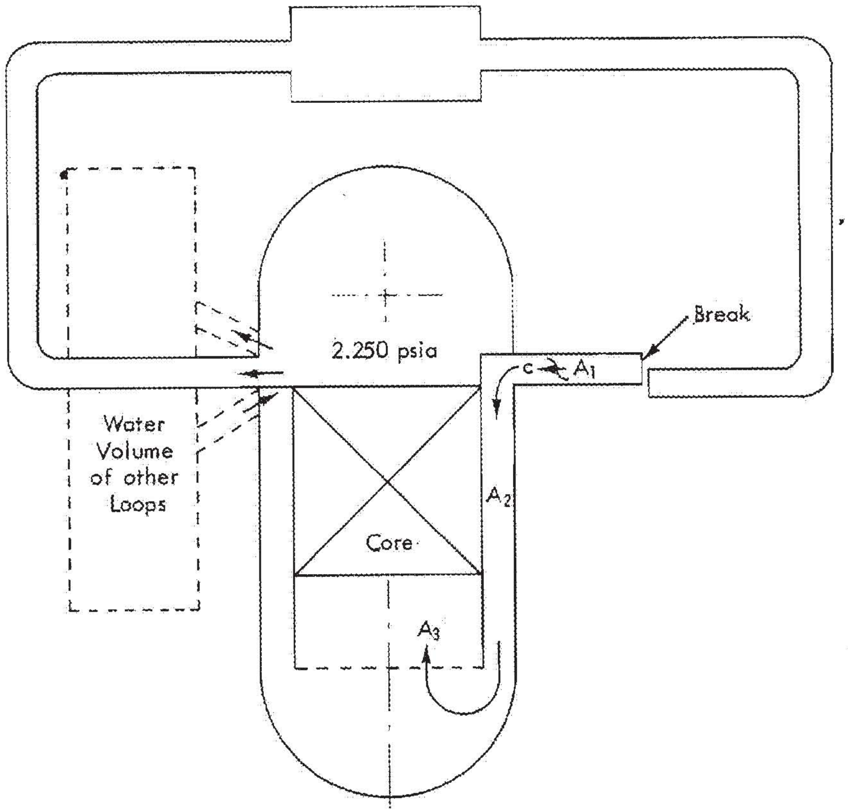

Fig. 3.15 Passage of rarefaction wave after break.
Notation $A_1$—Flow area of inlet pipe, 4.12 ft$^2$.
$A_2$—Annular area beside thermal shield, 26.4 ft$^2$.
$A_3$—Frontal area of reactor core, 92.0 ft$^2$.

where

$D$ = diameter of the pipe

$f$ = Fanning Friction Factor

$u$ = fluid velocity

$\Delta P_0 = \Delta P$ at zero time.

For a pipe diameter of 1 ft, Fanning Friction Factor of 0.005, and water velocity of 20 ft/sec, the time constant $D/fu$ is 10 sec; thus, the frictional effect is relatively small.

When a pressure wave is reflected by a body that can deflect significantly, the amplitude of the reflected wave is appreciably reduced. The reader is referred to Streeter and Wylie[66] for discussion of this

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case. In a reactor system, the pi
very little and can usually be c
deflection of any thin wall internal

The major attenuation of the ac
reactor system arises because of
sider the simplified reactor syst
break in the inlet pipe is occurrin
assumed to change in a series of sm
jump, the exit pressure has droppe
in the pipe is $\Delta P_1$, then from Eq.
shield passage is equal to

$$\Delta P_2 = \Delta P_1 \left(\frac{4.12 \times}{26.4 + 4.}\right.$$

For the reactor core, the wave fron

$$\Delta P_3 = \left(\frac{26.4 \times 2}{26.4 + 92}\right)$$

## 3-2 REACTOR VESSE

### 3-2.1 Flow in Plenums

The flow streams or vortices i
flow distribution at the core inlet.
flow coming down between the th
causes a low pressure region at the
reduce the flow in the outer assem
of a vortex with a horizontal plane
the surrounding pressure; thus, th
located above a vortex is reduced.

The most effective way to even
flow resistance at the bottom of t
equation for velocity distribution im

$$\frac{\Delta V_{\text{after screen}}}{V_{\text{avg}}} = \frac{1}{K + 1}$$

where

$$K = \frac{\Delta P}{\rho\, V_{\text{a}}^2}$$

A similar relationship can be applie
consider the situation where the