Short-Term Degradation Mechanisms of Piping

A. R. Morel, L. J. Reynes
Electricité de France/Septen, Villeurbanne Cedex, France

INTRODUCTION

The studies carried out by EDF as part of the Lifetime project show :

. that the evolution of the properties of the operating materials (ageing) has not yet resulted in damage but is likely to raise long term problems.

. that damage taken into account at the design stage are well controlled when loadings are clearly defined ;

. that certain damage not explicitly taken into account at the design stage may prove expensive from the maintenance point of view ;

In this paper we shall present some features of these degradation mechanisms which can act in a short time (from a few ten hours to ten thousand hours). We shall limit the subject to erosion-cavitation, vibratory fatigue and thermal fatigue due to the fact that the two other major problems : erosion-corrosion and corrosion fatigue are fully discussed in other sessions.

CAVITATION EROSION

Various cavitation erosion incidents have occurred downstream of the control valves of the Residual Heat Removal System (RRA) and the Component Cooling System (RRI) in some units of the 900MW standardized plant series.

Cavitation phenomena

Cavitation is a liquid vaporization phenomenon resulting from the negative pressure effect due to high flow velocities. As cavitation develops, it entails various harmful effects : noise, vibration, erosion of the solid surfaces near which it occurs.

Generally, three stages can be distinguished :

- a stage during which the material is marked but no material is removed
- an acceleration stage during which erosion occurs rapidly
- a constant erosion stage, during which erosion occurs at a lower level.

Assessment of cavitation

As regard cavitation, limits are difficult to determine : indeed, a certain cavitation level is accepted under steady-state or transient operating conditions.

Studies performed by EDF have shown that for the traditional PWR auxiliary systems carrying water under pressure, three criteria can be used to identify areas with risks of erosion. These are :

a) presence of cavitation : detected according to the value of THOMA coefficient (σ)

$$\sigma = \frac{P_2 - P_v}{\Delta P}$$

P_2 : absolute static pressure downstream of the section under consideration

ΔP_v : vapor pressure at the liquid temperature

P : pressure drop across the section.

When $\sigma < 5$, this results in a significant steam rate. However, the steam bubble stream so generated condenses rapidly : within 5 to 10 D, the velocity profile is sufficiently homogenized so that there are no fluid streams moving at a significant overspeed.
(D : pipe diameter).

b) the average flow velocity : According to the available data, the average flow velocity at which the erosion phenomenon occurs is 15 m/s for austenitic stainless steels. This is obviously a criterion hardly suitable for the characterization of a surface phenomenom. Therefore,it is necessary to examine conditions carefully as soon as the average flow speed exceeds 10 m/s.

c) Local disturbances : A local disturbance is easy to identify, but it is far more difficult to assess its harmful effects. Experience has shown that :

- A pipe gradual enlargment located at less than 5 D downstream of the element causing cavitation becomes a hazardous local disturbance.
- An elbow located at less than 5D downstream of a single orifice is an hazardous local disturbance.

However, the engineer's judgment in this matter is essential since the head resistance of relief valves mainly depends upon the internal design of this valve.