CHAPTER I
INTRODUCTION

As the world's population keeps rising, especially in major cities, the demand for energy consumption also increases. Nuclear energy has become one of the expanding energy sources in many countries. Moreover, nuclear power generates clean electricity because it does not release greenhouse gases such as CO_2, SO_2 and NO_X that contribute to environmental problems such as smog, acid rain and global warming. In the late 1950s and 1960s, Canada developed the technology for a nuclear generating system, called CANDU reactor. The acronym CANDU stands for "CANada Deuterium Uranium". This is reference to its deuterium-oxide (heavy water) moderator and its use of natural uranium fuel. Although this type of nuclear reactor originated in Canada, it has been sold and used in many countries such as the Republic of Korea, Romania, Argentina, the People's Republic of China, India and Pakistan.

A problem of the CANDU reactor is a high feeder wall thinning rate of carbon steel pipes which contain the heavy water coolant of CANDU reactors which removes heat from the reactor during its continuous operations. It is caused by Flow-Accelerated Corrosion (FAC) inside the carbon steel pipes exposed to high temperature water and wet steam, resulting in degradation of the feeder pipes.

Under operating conditions, water reacts with the outermost layers of carbon steel, forming a protective oxide film on the steel surface, mainly magnetite (Fe_3O_4), which reduces the corrosion rate of the steel. Hydrogen atoms are produced electrochemically as iron is lost into solution as a result of FAC. The atomic hydrogen enters the metallic lattice interstitially and permeates throughout the metal and combines to form hydrogen gas at the outer surface of the pipes. Therefore, the rate of FAC-generated hydrogen diffusing through the pipe wall should be proportional to the FAC rate on the wall inside the pipes.

There are several techniques to monitor such corrosion rates. One of the corrosion rate monitors is using a Feeder On-line Thickness Monitor System (FOLTM), that is a device to measure the reduction in wall thickness through an ultrasonic signal. Nonetheless, data from the FOLTM have a low signal-to-noise ratio and respond sluggishly to local changes in thinning rate. In order to obtain a more reliable and precise corrosion rate measurement, the Center for Nuclear Energy Research (CNER) has developed the Hydrogen Effusion Probe (HEP) which provides an on-line, non-intrusive corrosion monitoring of the corrosion rate by the indirect measurement of the feeder wall thinning rate by measuring the quantity of hydrogen produced by the corrosion reaction at the inner surface of the pipes which effuses through the pipe wall. The rate of pressure rise measured by the HEP can be converted to a rate of metal loss due to corrosion. The on-line HEP measurement is expected to give a high signal-to-noise ratio and responds quickly to local changes in thinning rate. Furthermore, the HEP can be externally mounted so the pressure boundary will not be broken.

The purpose of this work is to better understand the fundamental principles of corrosion and transport of hydrogen through a carbon steel pipe from FAC. The coefficient of hydrogen diffusion in carbon steel pipe is a basic parameter that should be known in order to predict the response time from HEP. The conditions which affect the effusion of hydrogen through carbon steel will be investigated such as the effect of oxide film on the hydrogen effusion process, the effect of a coated catalyst on the carbon steel surface to eliminate the kinetic barrier at the surface of hydrogen diffusion.