CHAPTER I
INTRODUCTION

Nowadays, nuclear energy plays an important role for everyone, especially in major cities, as energy consumption is increased from the population that keeps rising every year. Many countries, like Germany, Japan, and South Korea, build a lot of nuclear power plants which generate electricity in response to the demand for energy and at the same time address environmental problems (Norgate *et al.*, 2013; Sovacool, 2008). Nuclear power is a clean technology that can generate electricity and does not release any greenhouse gases such as CO_2 which are the main causes of global warming (Environmental News Service, ENS, 2005).

In the latter half of the twentieth century, the CANada Deuterium Uranium or CANDU reactor was invented in Canada. It is a nuclear generating system which uses deuterium-oxide or heavy water as the coolant and the moderator and natural uranium as the fuel. It has been used in many countries as well as Canada, such as Argentina, Korea, India, Pakistan, the Peoples Republic of China, and Romania (Steed, 2006). One of the problems of the CANDU reactor has been corrosion of the feeder pipes caused by Flow Accelerated Corrosion (FAC) (Lister *et al.*, 1998). FAC causes a high rate of wall thinning (metal loss) of the carbon steel feeder pipes which contain heavy water coolant by the reaction between water and carbon steel at high temperature, resulting in deterioration of the feeder pipe (Burrill and Cheluget, 1998; Chung, 2010; Lister *et al*., 2007; Lister *et al.*, 1997; Lister *et al*., 2001; Yuan *et al*., 2008). As a result of FAC, hydrogen atoms are produced electrochemically as iron is lost into the solution. These hydrogen atoms diffuse into the metallic lattice of carbon steel, and then permeate through the metal. Subsequently, they combine to form hydrogen molecules at the outer surface of the pipes, which could be measured (Pisarev *et al.*, 2001; Stone, 1981). Therefore, from the rate of hydrogen diffusion through the pipes, which is measurable, the wall thinning rate can be obtained.

There are several techniques to monitor corrosion rates. One of the corrosion rate measurements is by the Hydrogen Effusion Probe (HEP), which has been developed by the Centre for Nuclear Energy Research (CNER). It is a device that can be used to measure the pipe thinning rate by measuring the quantity of

hydrogen produced by the corrosion reaction at the inner surface of pipes; it effuses through the pipe wall and accumulates in a chamber on the outside of the pipe wall, resulting in a pressure rise. The rate of pressure increase measured by the HEP is proportional to the corrosion and can be used to calculate the rate of metal loss. The current HEP uses a silver cup, which has very low hydrogen permeability and hydrogen diffusivity, as the chamber for the collection of the hydrogen gas. Consequently, a vacuum pump is necessary in order to operate the corrosion monitoring system (Kongvarhodom, 2014). Hence, it is inconvenient and expensive for the industry.

Among all of the industrial materials, stainless steel and carbon steel are the most used. Both of them have fairly high hydrogen permeability and diffusivity (although that of stainless steel is two orders of magnitude lower than that of carbon steel at 300°C), which means that it is conceivable to make the cups by these material for operation in the corrosion monitoring system without the requirement of a vacuum pump (Hadam and Zakroczymski, 2009; Marchi *et al.*, 2007). Furthermore, they are common metals - easy to find and inexpensive.

The purpose of this work is to develop the model of hydrogen accumulation inside the carbon steel and stainless steel cups which are designed for monitoring corrosion of carbon steel. A model of hydrogen pressure build-up inside the cups and a mathematical computation of diffusion were developed from Sievert's Law to be capable of accurately predicting the plateau pressure inside the cups. The effect of size, wall thickness of cups, and the changing to different cup materials, stainless steel and carbon steel, on the hydrogen accumulation inside the cups were investigated to aid future designs of HEP also.