CRITICAL CONTROL VALVES AND THEIR RELIABILTY DURING SEISMIC EVENTS

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Abstract

The revitalization of nuclear industry in world comes with increasing safety concerns and regulations. This paper focuses on the study of reliability of controlling valves regulating the cooling water flow around a nuclear core. The cooling process of a nuclear core is of high importance when considering nuclear power plant safety. The main concern for the valve's construction and operation is its survivability and continued functioning at all times. The main purpose of this paper is to enable the nuclear industries in Canada to gain an overview of the valve design and its capability in withstanding unforeseen condition such as seismic events.

1. Introduction

The rapidly increasing need for cleaner and more efficient energy in the world has created a blooming season for nuclear industry in Canada and around the world. The increased demand and fast growing activities in nuclear world comes in the era of evolving modern technologies; Technologies that have increase the performance, reliability and naturally expectations from many different industries including nuclear industry.

As in any industry, safety is a vital factor in a nuclear power plant. In order to enhance safety, all the parts involved in the processes must be reliable to ensure the safety of a whole power plant.

Valves are used in numerous industries and are designed for specific applications depending on various factors such as flow velocity, pressure and temperature. In addition, they are operated by different methods.

2. Valves and Controlling Operation

Basically, valves are categorized into the following design types: gate, poppet, plug, globe, check, butterfly, diaphragm, ball and needle. Their operation could be facilitated manually or by use of solenoid and hydraulic or pneumatic actuators.

In the nuclear industry, a variety of these valves are used and operated with different methods depending on its performance requirements and safety issues.

For instance, a ball valve is a valve that opens by turning a handle attached to a ball inside the valve. The ball has a hole through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. A butterfly valve is similar in operation to a ball valve. A flat circular plate is positioned in the center of the pipe. The plate has a rod through it connected to an actuator on the outside of the valve. Rotating the actuator turns the plate either parallel or perpendicular to the flow. Unlike a ball valve, the plate is always present within the flow, therefore a pressure drop is always induced in the flow regardless of valve position.

Valves are usually controlled manually by use of a handle attached to it. However, in more sensitive cases, valves can also be controlled by devices called actuators attached to the stem. They can be electromechanical actuators such as an electric motor or solenoid, pneumatic actuators which are controlled by air pressure, or hydraulic actuators which are controlled by the pressure of a liquid such as oil or water.

3. Valve Quality Testing

In order to ensure valves have ability to function continuously and survive unexpected conditions, they need to be tested to meet safety requirements designated for them. Based on safety regulations, one of the tests needed for valves to pass to be eligible to be used in sensitive areas at a nuclear plant is to examine its resistance to destruction or malfunction during earthquakes and seismic waves caused by a volcano eruption.

Advanced software applications, including finite element analysis, computational fluid dynamics and three dimensional solid modeling, help engineers design valves that can meet the most demanding performance requirements during severe conditions. However, physical testing is absolutely required for a valve to meet with safety standards in the nuclear industry.

Valves undergo the stringent, code-prescribed nondestructive testing regimen before they are used in power plants. In addition, for more sensitive applications such as cooling control valve, they go through destructive testing in order to prove the performance of the valves.

A seismic simulation test is needed to see if a valve can survive an earthquake or other possible vibrations. Moreover, they need to be completely functional during and after such events.

The test program is consisted of hot and cold cycling, biaxial resonant searches, biaxial random multifrequency testing with design nozzle loads applied, and cold cycling tests performed during seismic simulation. Uniaxial strain gauges are mounted on the stem, crotch and other critical areas of the valve and strain data are recorded. Data acquired is used to prove if valve possesses sufficient functional and structural integrity to withstand a seismic event of prescribed magnitude or not.

In addition, a series of experiments are preformed to ensure that actuator functions properly during a seismic event. The Nuclear Regulatory Commission requires that the actuator to be able to close the valve in a "worst case" design/operation condition. The flow interruption test with saturated steam is designed to demonstrate that the valve will close under extreme accident conditions and to demonstrate resistance of the valve to pressure entrapment, thermal binding and seismic loading.

4. References

[1] Furness, Harry. (1994). *Digital Communications Provides...* **Control Engineering**, January, 21–25.

[2] Spear, Mike. (1993). *Fieldbus Faces Up To First Trials* **Process Engineering**, March, p22.

[3] A. Zahara (1978). **Introduction to Valves**, April, 45-51.

[4] C. Zhang (1992). **Gate Valves and their Applications**, January, 4-5.