

**DEVELOPMENT OF A NEUTRON DEVICE TO MEASURE  
STEAM QUALITY AT A HIGH PRESSURE**



Ms. Bhurisa Thitakamol

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for the Degree of Master of Science  
The Petroleum and Petrochemical College, Chulalongkorn University  
in Academic Partnership with  
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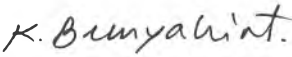
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Prof. Frank R. Steward


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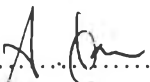
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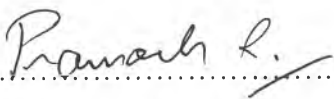
  
..... College Director  
(Assoc. Prof. Kunchana Bunyakiat)

**Thesis Committee:**

  
.....  
(Assoc. Prof. Thirasak Rirksomboon )

  
.....  
(Prof. Frank R. Steward)

  
.....  
(Prof. Somchai Osuwan)

  
.....  
(Asst Prof. Pramoch Rangsunvigit)

## ABSTRACT

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Steam quality, measured as the void fraction in a two-phase, steam-water flow in an autoclave, was investigated by the fast neutron scattering technique. This technique based on the slowing-down of neutrons, resulting from the thermalization of fast neutrons, is proportional to the number of hydrogen nuclei in the liquid. A Monte Carlo simulation demonstrated that linearity between void fraction and neutron count rate (detector response) could be achieved using the instrument geometry; viz.  $^{252}\text{Cf}$  as isotropic neutron source, helium detector and half-inch stainless steel pipe. Before the steam-water system was studied, a static experiment using Lucite rods and a nitrogen-water experiment in which nitrogen was bubbled through water in a plexiglas tube were performed to confirm the Monte Carlo result. A simplified calibration method was used to estimate the void fraction obtained from experiment; the estimated value varied linearly with the actual value of the void fraction. At high pressure and temperature, the density of water was found to be proportional to neutron count rate. The measurement of steam quality calculated from the parameters of the autoclave operation was detected by a neutron scatterometer. It was found that the neutron count rate decreased as steam quality increased as predicted.

## บทคัดย่อ

ภุริสา คิฐกมล : การพัฒนาเครื่องมือนิวตรอนในการวัดสตีมควอลิตี้ในระบบความดันสูง (Development of a Neutron Device to Measure Steam Quality at a High Pressure) อ. ที่ปรึกษา ศ. แฟรงค์ อาร์ สจิวต์ (Prof. Frank R. Steward) และ รศ.ดร. ชีรศักดิ์ ฤกษ์สมบูรณ์ 93 หน้า ISBN 974-17-2276-1

สตีมควอลิตี้หรืออัตราส่วนที่ว่างของของไหลที่ประกอบด้วยไอน้ำและน้ำที่ไหลภายในท่อสามารถวัดได้โดยการใช้วิธีฟาสต์นิวตรอนสเคทเทอร์ริง หลักการของการวัดคืออนุภาคนิวตรอนจะสูญเสียพลังงานเมื่อชนกับอนุภาคของไฮโดรเจนในน้ำ ดังนั้นจำนวนของอนุภาคนิวตรอนที่สูญเสียพลังงานนั้นเป็นสัดส่วนกับปริมาณของน้ำ การจำลองโดยใช้วิธีมอนติคาร์โลแสดงให้เห็นว่ามีความสัมพันธ์เชิงเส้นระหว่างอัตราส่วนที่ว่างกับอัตราการนับของนิวตรอน (ค่าการตอบสนองของเครื่องตรวจวัดนิวตรอน) เมื่อระบบใช้แคลิฟอร์เนียม-252 เป็นแหล่งกำเนิดนิวตรอน เครื่องตรวจวัดนิวตรอนชนิดฮีเลียมและท่อสแตนเลสสตีลขนาดครึ่งนิ้ว ผลการทดลองที่ได้จากการทดลองแบบสแตติกที่ใช้ลูโซท์ในการแทนที่ปริมาณน้ำในท่อและการทดลองของระบบในโตรเจนกับน้ำซึ่งในโตรเจนถูกทำให้เป็นฟองไหลเข้าในน้ำที่อยู่ในท่อพีซีกล้ำสียันย่นผลที่ได้จากการจำลองโดยใช้วิธีมอนติคาร์โลก่อนที่จะทำการทดลองในระบบที่ประกอบด้วยไอน้ำและน้ำ วิธีการสอบเทียบจะใช้ในการประมาณค่าอัตราส่วนที่ว่างที่ได้จากการทดลองซึ่งพบว่าค่าที่ได้จากการประมาณนั้นแปรผันอย่างเป็นเชิงเส้นกับค่าจริงของอัตราส่วนที่ว่าง สำหรับที่ความดันสูงและอุณหภูมิสูง ความหนาแน่นของน้ำพบว่าเป็นสัดส่วนกับอัตราการนับของนิวตรอน ในการวัดค่าสตีมควอลิตี้ซึ่งคำนวณได้จากค่าพารามิเตอร์ที่มาจากการทำงานของอโตเคฟสามารถทำได้โดยการใช้อุปกรณ์นิวตรอนสเคทเทอร์ริง พบว่าอัตราการนับของนิวตรอนลดลงเมื่อสตีมควอลิตี้ลดลง

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## LIST OF SYMBOLS

$N(1)$	Detector count rate corresponding to the test section containing vapor or full of liquid
$N(0)$	Detector count rate corresponding to the test section containing water or full of vapor
$N(\varepsilon)$	Detector count rate corresponding to the test section containing steam-water mixture
$N(\rho)$	Detector count rate corresponding to the test section with actual liquid fraction steam-water mixture
$R(1)$	Neutron count rate corresponding to a full-of-water test section
$R(\rho)$	Neutron count rate corresponding to an empty test section
$R(\rho)$	Neutron count rate corresponding to a known Lucite fraction test section
$\hat{\varepsilon}$	Estimated void fraction
$E_{th}$	Thermal energy of the neutron
$T$	Temperature of the medium
$k$	Boltzmann's constant
$N$	Number of radioactive nuclei
$E$	Neutron energy (eV)
$T$	Constant value of 1.3 MeV
$\rho$	Density of mixture ( $\text{g/cm}^3$ )
$\rho_L$	Density of liquid phase ( $\text{g/cm}^3$ )
$\rho_g$	Density of vapor phase ( $\text{g/cm}^3$ )
$\alpha$	Void fraction
$\hat{\rho}$	Lucite fraction or estimated liquid fraction
$m$	Mass flow rate (g/s)
$u$	Velocity of saturated water (m/s)
$g$	Gravitational force ( $\text{m/s}^2$ )

$Q$	Heat added in the system (J/s)
$W_s$	Shaft work (J/s)
$x$	Steam quality
$\Delta h$	Enthalpy change of saturated water before and after passing through the autoclave (J/g)
$h_1$	Enthalpy of saturated water at the entrance of autoclave (J/g)
$h_2$	Enthalpy of saturated water at the exit of autoclave (J/g)
$h_f$	Enthalpy of saturated water at saturated temperature (J/g)
$h_g$	Enthalpy of saturated vapor at saturated temperature (J/g)