

國立交通大學

機械工程學系

碩士論文

FC-72 在水平矩形流道中流過一微小加熱面暫態流動

沸騰熱傳及氣泡特性研究



**Transient Flow Boiling Heat Transfer of FC-72 and
Associated Bubble Characteristics over a Small
Heated Plate in a Horizontal Rectangular Channel**

研究生：楊政陞

指導教授：林清發 博士

中華民國九十六年六月

FC-72 在水平矩形流道中流過一微小加熱面暫態流動
沸騰熱傳及氣泡特性研究

Transient Flow Boiling Heat Transfer of FC-72 and Associated Bubble
Characteristics over a Small Heated Plate in a Horizontal Rectangular
Channel

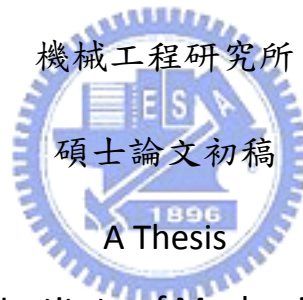
研究生：楊政陞

Student : Zheng-ShengYang

指導教授：林清發

Advisor : Tsing-Fa Lin

國立交通大學



Submitted to Institute of Mechanical Engineering

Collage of Engineering

National Chiao Tung University

In Partial Fulfillment of the Requirements

For the degree of

Master of Science

In

Mechanical Engineering

June 2007

Hsinchu, Taiwan, Republic of China

中華民國九十六年六月

國立交通大學

論文口試委員會審定書

本校 機械工程 學系碩士班 楊政陞 君

所提論文(中文) FC-72 在水平矩形流道中流過一微小加熱面暫態流動沸

騰熱傳及氣泡特性研究

(英文) Transient Flow Boiling Heat Transfer of FC-72 and Associated

Bubble Characteristics over a Small Heated Plate in a Horizontal

Rectangular Channel

合於碩士資格水準、業經本委員會評審認可。

口試委員：何清波

洪英維

潘欽

指導教授：林清發

系主任：

吳

教授

中華民國 96 年 6 月 8 日

誌謝

幕然回首兩年前的此時，對於離家到新竹交大求學的我而言，心中真是充滿了既期待又害怕的複雜心情。來到交大這充滿學術研究氣息的生活，讓我覺得在此讀書做研究是一種享受。然而，一想到即將要離開這可愛的校園，不禁令人懷念起在此的點點滴滴。

能獲得碩士學位，首先很榮幸能接受林清發教授的指導，從文獻資料的蒐集、實驗系統的構思設計到最後物理觀念的闡述分析，都令我受益匪淺。而老師對我們在研究上嚴謹的要求，更深深地影響到我日後的處事態度。而能夠順利地完成我的碩士論文，要感謝實驗室許多臥虎藏龍的博士班：張文瑞、郭威伸、賴祐民、陳尚緯、謝汎鈞及陳建安學長們的幫忙及指導。同學陳奎銘、李凱文、廖峻樟、黃宇歆的互相砥礪幫忙，當然也少不了一群為實驗室注入活力、帶來歡樂的學弟妹們：林永龍、王壹龍、李浚圩及駱長志的幫忙。得之於人者太多，在此一同向所有幫助過我的人致謝。

即將踏出交大校門成為社會新鮮人的我，回首來時路，很慶幸並沒辜負當初父母對我的期望；在今年能如期獲得碩士學位。我想今天若我有任何些微的成就，父母對我的教養及支持鼓勵，是我能一路走來的原動力，僅將我的榮耀獻予我摯愛的家人。

楊政陞
2007/6 於風城交大

FC-72 在水平矩形流道中流過一微小加熱面暫態流動沸騰熱傳及氣泡特性研究

研究生: 楊政陞

指導教授: 林清發 博士

國立交通大學機械工程學系

摘要

本實驗是要探討雙相流冷媒循環系統針對介電冷卻液 FC-72 在截面為寬 20 毫米、高 5 毫米之水平矩形流道(水力直徑為 8 毫米)中進行，隨時間週期振盪的流量如何影響暫態強制對流沸騰熱傳以及相關的氣泡特徵，加熱銅塊埋至於測試段之底板中央其尺寸為直徑 10 毫米。值得注意的是冷卻液流量隨時間振盪(振盪的形狀接近三角波)，是如何影響暫態流動沸騰將會被詳細的探討。在實驗參數範圍上，介電液 FC-72 平均質量通率從 300 到 400 kg/m²s 而且流量的振盪振幅為 0%、5%、10%，流量的振盪周期為 10 秒到 30 秒。除此之外，FC-72 於測試段入口處次冷度從 0 到 10 °C、銅塊的加熱通量從 0.1 到 10 W/cm² 而系統壓力為常壓。

由實驗結果發現介電冷卻液的振盪振幅和週期對時間平均的 FC-72 暫態的飽和態和次冷態流動沸騰熱傳特徵沒有明顯的影響，類似穩態的流動沸騰。無論如何，在熱通量高於起始成核沸騰的熱通量 FC-72 的暫態飽和態和次冷態流動沸騰對熱傳係數、氣泡脫離直徑、氣泡脫離頻率、成核址密度都有顯著的振盪影響。除此之外，在高熱通量下和振盪振幅比較大的情況下對熱傳係數、氣泡脫離直徑、氣泡脫離頻率、成核址密度都會造成更強烈的振盪情況發生，但振盪週期的影響並不明顯。因此，當流量隨時間增加的情況下，氣泡脫離的尺寸和成核址密度都會下降，但氣泡脫離頻率會增加。當流量隨時間遞減的情況下，會產生相反的趨勢。並且也發現入口處次冷度的增加會使得沸騰的熱傳係數振盪更劇烈。

FC-72 在水平矩形流道中流過一微小加熱面暫態流動沸騰熱傳及氣泡特性研究

研究生：楊政陞

指導教授：林清發 博士

國立交通大學機械工程學系

摘要

本實驗是要探討雙相流冷媒循環系統針對介電冷卻液 FC-72 在截面為寬 20 毫米、高 5 毫米之水平矩形流道(水力直徑為 8 毫米)中進行，隨時間週期振盪的流量如何影響暫態強制對流沸騰熱傳以及相關的氣泡特徵，加熱銅塊埋至於測試段之底板中央其尺寸為直徑 10 毫米。值得注意的是冷卻液流量隨時間振盪(振盪的形狀接近三角波)，是如何影響暫態流動沸騰將會被詳細的探討。在實驗參數範圍上，介電液 FC-72 平均質量通率從 300 到 400 kg/m²s 而且流量的振盪振幅為 0%、5%、10%，流量的振盪周期為 10 秒到 30 秒。除此之外，FC-72 於測試段入口處次冷度從 0 到 10 °C、銅塊的加熱通量從 0.1 到 10 W/cm² 而系統壓力為常壓。

由實驗結果發現介電冷卻液的振盪振幅和週期對時間平均的 FC-72 暫態的飽和態和次冷態流動沸騰熱傳特徵沒有明顯的影響，類似穩態的流動沸騰。無論如何，在熱通量高於起始成核沸騰的熱通量 FC-72 的暫態飽和態和次冷態流動沸騰對熱傳係數、氣泡脫離直徑、氣泡脫離頻率、成核址密度都有顯著的振盪影響。除此之外，在高熱通量下和振盪振幅比較大的情況下對熱傳係數、氣泡脫離直徑、氣泡脫離頻率、成核址密度都會造成更強烈的振盪情況發生，但振盪週期的影響並不明顯。因此，當流量隨時間增加的情況下，氣泡脫離的尺寸和成核址密度都會下降，但氣泡脫離頻率會增加。當流量隨時間遞減的情況下，會產生相反的趨勢。並且也發現入口處次冷度的增加會使得沸騰的熱傳係數振盪更劇烈。

**Transient Flow Boiling Heat Transfer of FC-72 and Associated
Bubble Characteristics over a Small Heated Plate in a Horizontal
Rectangular Channel**

Student : Zheng-Sheng Yang

Advisor : Prof. Tsing-Fa Lin

Institute of Mechanical Engineering

National Chiao Tung University

ABSTRACT

This study intends to explore how a time periodic coolant flow rate affects the transient forced convective boiling heat transfer and associated bubble characteristics of FC-72 over a small heated circular copper plate flush mounted on the bottom of a horizontal rectangular channel with a cross section of 20 mm in width and 5 mm in height. The diameter of the copper plate is 10 mm. More specifically, the effects of the coolant flow rate oscillation in the form of nearly triangular wave on the transient flow boiling will be examined in detail. In the experiment the time-average coolant mass flux \bar{G} is varied from 300 to 400 kg/m²s and the amplitude of the coolant mass flux oscillation is fixed at 0%, 5% and 10% of \bar{G} . The period of the coolant mass flux oscillation varies from 10s to 30s. Besides, the liquid subcooling at the inlet of the channel ranges from 0°C to 10°C and the heat flux imposed on the heated plate varies from 0.1 to 10 W/cm².

The experimental results show that the time-average data of the FC-72 transient saturated and subcooled flow boiling heat transfer characteristics are not affected to a significant degree by the amplitude and period of the coolant mass flux oscillation. In fact, they resemble these for the stable flow boiling. However, in the transient

saturated and subcooled flow boiling of FC-72 significant temporal oscillations in the boiling heat transfer coefficient, bubble departure diameter and frequency, and active nucleation site density appear for the imposed heat flux slightly higher than that for ONB. They oscillate at the same frequency as the mass flux oscillation. Besides, at a higher imposed heat flux and for a larger amplitude of the mass flux oscillation stronger oscillations in $h_{2\phi}$, d_p , f and N_{ac} are noted. But they are only slightly affected by the period of the mass flux oscillation. Furthermore, in the time duration in which the mass flux rises with time both the size of the departing bubbles and active nucleation site density decrease, but the bubble departure frequency increases. The opposite processes occur for a sink of mass flux with time. We also note that an increases in the inlet liquid subcooling causes stronger oscillations in the boiling heat transfer coefficient.



TABLE OF CONTENTS

ABSTRACT	i
TABLE OF CONTENTS	iii
LIST OF TABLE	iv
LIST OF FIGURE	v
CHAPTER 1 INTRODUCTION	1
1.1 Motive of the Present Study	1
1.2 Literature Review	2
1.2.1 Stable Single-Phase and Convective Boiling Heat Transfer	2
1.2.2 Unstable Convective Boiling Heat Transfer	4
1.2.3 Bubble Characteristics	6
1.3 Objective of This Study	7
CHAPTER 2 EXPERIMENTAL APPARATUS AND PROCEDURES	11
2.1 Degassing Unit	11
2.2 Coolant Loop	12
2.3 Test Section	13
2.4 Hot-water Loop	14
2.5 Cold-water Loop	15
2.6 DC Power Supply	15
2.7 Data Acquisition	15
2.8 Optical Measurement Technique	16
2.9 Experimental Procedures	16
2.10 Experimental Parameters	17

CHAPTER 3 DATA REDUCTION	27
3.1 Single Phase Heat Transfer	27
3.2 Two Phase Flow Boiling Heat Transfer	28
3.3 Uncertainty Analysis	29
CHAPTER 4 TRANSIENT SATURATED FLOW BOILING OF FC-72 OVER A SMALL HEATED COPPER PLATE	31
4.1 Single-phase Liquid Convective Heat Transfer	31
4.2 Stable and Time-average Saturated Flow Boiling Curves and Heat Transfer Coefficient	32
4.3 Transient Flow Boiling Heat Transfer Characteristics	34
4.4 Transient Bubble Characteristics in Saturated Flow Boiling	36
4.5 Correlation Equations	39
CHAPTER 5 TRANSIENT SUBCOOLED FLOW BOILING OF FC-72 OVER A SMALL HEATED COPPER PLATE	152
5.1 Stable and Time-average Subcooled Flow Boiling Curves and Heat Transfer Coefficient	153
5.2 Transient Subcooled Flow Boiling Heat Transfer Characteristics	155
5.3 Transient Bubble Characteristics in Subcooled Flow Boiling	157
5.4 Correlation Equations	161
CHAPTER 6 CONCLUDING REMARKS	387
REFERENCES	389

LIST OF TABLES

Table 1.1	Thermodynamic properties for FC-72 -----	9
Table 1.2	Some single-phase convection heat transfer correlations for electronic cooling -----	10
Table 2.1	Experimental parameters-----	18
Table 2.2	Thermodynamic and transport properties of the dielectric refrigerant FC-72 list-----	19
Table 3.1	Summary of the uncertainty analysis-----	30
Table 4.1	Relative amplitudes of heated surface temperature and heat transfer coefficient oscillations in transient oscillatory saturated flow boiling for various imposed heat fluxes and the amplitude and period of the coolant mass flux oscillation-----	43
Table 5.1	Relative amplitudes of heated surface temperature and heat transfer coefficient oscillations in transient oscillatory subcooled flow boiling $\Delta T_{\text{sub}} = 5^{\circ}\text{C}$ for various imposed heat fluxes and the amplitude and period of the coolant mass flux oscillation -----	164
Table 5.2	Relative amplitudes of heated surface temperature and heat transfer coefficient oscillations in transient oscillatory subcooled flow boiling at $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ for various imposed heat fluxes and the amplitude and period of the coolant mass flux oscillation -----	165

LIST OF FIGURES

Experiment Apparatus

Fig 2.1	Schematic diagram of experimental apparatus -----	20
Fig 2.2	Three-dimensional plots of test section along with inlet and outlet sections -----	21
Fig 2.3	Three-dimensional plots illustrating the test section in the rectangular flow-channel -----	22
Fig 2.4	Three-dimensional pictures showing (a) hollow cylindrical Teflon block and (b) cylindrical Teflon bolt -----	23
Fig 2.5	Locations of thermocouples -----	24
Fig 2.6	Schematics of the silicon chip module -----	25
Fig 2.7	Locations of the thermocouple of the inside of the polyethylene insulation -----	26

Saturated Flow Boiling

Fig 4.1	Comparison of the present steady single-phase liquid convection heat transfer data with the correlation of Gersey and Mudawar (1992) for (a) $h_{1\phi}$ vs. G and (b) Nu_L vs. Re_L -----	44
Fig 4.2	Time-average flow boiling curves for various coolant mass fluxes for stable saturated flow boiling (a) and transient saturated flow boiling for $t_p=10$ sec (b), 20 sec (c) and 30 sec (d)-----	45
Fig 4.3	Time-average flow boiling curves for various coolant mass fluxes for transient saturated flow boiling at $t_p=10$ sec (a), 20 sec (b) and 30 sec (c) -----	47
Fig 4.4	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for stable saturated flow boiling (a) and transient saturated flow boiling at $t_p=10$ sec (b), 20 sec (c) and 30 sec (d)-----	49
Fig 4.5	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for transient saturated flow boiling at $t_p=10$ sec (a), 20 sec (b) and 30 sec (c)-----	51
Fig 4.6	Time variations of the copper plate temperature in stable saturated flow boiling for various imposed heat fluxes at (a) $G=300$ kg/m ² s and (b) $G=400$ kg/m ² s -----	53
Fig 4.7	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=2.84$ w/cm ² at $G=300$ kg/m ² s) -----	54
Fig 4.8	Time variations of (a) imposed coolant mass flux and (b) copper plate	

	temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 10$ sec. ($\bar{q}_{ONB} = 3.09$ w/cm ² at $G = 400$ kg/m ² s) -----	55
Fig 4.9	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p = 20$ sec. ($\bar{q}_{ONB} = 2.62$ w/cm ² at $G = 300$ kg/m ² s) -----	56
Fig 4.10	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 20$ sec. ($\bar{q}_{ONB} = 3.05$ w/cm ² at $G = 400$ kg/m ² s) -----	57
Fig 4.11	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p = 30$ sec. ($\bar{q}_{ONB} = 3.02$ w/cm ² at $G = 300$ kg/m ² s) -----	58
Fig 4.12	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 30$ sec. ($\bar{q}_{ONB} = 3.47$ w/cm ² at $G = 400$ kg/m ² s) -----	59
Fig 4.13	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p = 10$ sec. ($\bar{q}_{ONB} = 2.70$ w/cm ² at $G = 300$ kg/m ² s) -----	60
Fig 4.14	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p = 10$ sec. ($\bar{q}_{ONB} = 3.15$ w/cm ² at $G = 400$ kg/m ² s) -----	61
Fig 4.15	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p = 20$ sec. ($\bar{q}_{ONB} = 2.19$ w/cm ² at $G = 300$ kg/m ² s) -----	62
Fig 4.16	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p = 20$ sec. ($\bar{q}_{ONB} = 3.06$ w/cm ² at $G = 400$ kg/m ² s) -----	63
Fig 4.17	Time variations of (a) imposed coolant mass flux and (b) copper plate	

temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m²s with $t_p=30$ sec. ($\bar{q}_{ONB}=2.17$ w/cm² at $G=300$ kg/m²s) ----- 64

Fig 4.18 Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m²s with $t_p=30$ sec. ($\bar{q}_{ONB}=3.02$ w/cm² at $G=400$ kg/m²s) ----- 65

Fig 4.19 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m²s with $t_p=10$ sec----- 66

Fig 4.20 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m²s with $t_p=10$ sec----- 67

Fig 4.21 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m²s with $t_p=20$ sec----- 68

Fig 4.22 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m²s with $t_p=20$ sec----- 69

Fig 4.23 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m²s with $t_p=30$ sec----- 70

Fig 4.24 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m²s with $t_p=30$ sec----- 71

Fig 4.25 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m²s with $t_p=10$ sec ----- 72

Fig 4.26 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m²s with $t_p=10$ sec ----- 73

Fig 4.27 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m²s with $t_p=20$ sec ----- 74

Fig 4.28 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m²s with $t_p=20$ sec ----- 75

Fig 4.29 Time variations of (a) imposed coolant mass flux and (b) flow boiling heat

	transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	76
Fig 4.30	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory saturated flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	77
Fig 4.31	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=4.01$ W/cm ² and (b) $q=8.25$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec-----	78
Fig 4.32	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.98$ W/cm ² and (b) $q=8.26$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=10$ sec-----	79
Fig 4.33	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.93$ W/cm ² and (b) $q=8.24$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=20$ sec-----	80
Fig 4.34	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.96$ W/cm ² and (b) $q=8.23$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=20$ sec-----	81
Fig 4.35	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.93$ W/cm ² and (b) $q=8.21$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=30$ sec-----	82
Fig 4.36	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.47$ W/cm ² and (b) $q=8.20$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=30$ sec-----	83
Fig 4.37	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=4.04$ W/cm ² and (b) $q=8.17$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	84
Fig 4.38	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=4.01$ W/cm ² and (b) $q=8.20$ W/cm ² for $G=400\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	85
Fig 4.39	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.41$ W/cm ² and (b) $q=8.21$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	86
Fig 4.40	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.95$ W/cm ² and (b) $q=8.22$ W/cm ² for $G=400\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	87
Fig 4.41	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.39$ W/cm ² and (b) $q=8.18$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	88

Fig 4.42	Time variations of coolant mass flux and inlet pressure in transient oscillatory saturated flow boiling for various imposed heat fluxes at (a) $q=3.95 \text{ W/cm}^2$ and (b) $q=8.20 \text{ W/cm}^2$ for $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=30 \text{ sec}$ -----	89
Fig 4.43	Photos of stable saturated boiling flow at certain time instants for various imposed heat fluxes for (a) $G=300 \text{ kg/m}^2\text{s}$ and (b) $G=400 \text{ kg/m}^2\text{s}$ -----	90
Fig 4.44	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	91
Fig 4.45	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	92
Fig 4.46	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	93
Fig 4.47	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.0 \text{ W/cm}^2$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	94
Fig 4.48	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	95
Fig 4.49	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	96
Fig 4.50	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	97
Fig 4.51	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.0 \text{ W/cm}^2$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	98
Fig 4.52	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	99
Fig 4.53	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	100
Fig 4.54	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	101

Fig 4.55	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.0 \text{ W/cm}^2$ at $G=400\pm 5\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	102
Fig 4.56	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	103
Fig 4.57	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	104
Fig 4.58	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	105
Fig 4.59	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9 \text{ W/cm}^2$ at $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	106
Fig 4.60	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	107
Fig 4.61	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	108
Fig 4.62	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	109
Fig 4.63	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.0 \text{ W/cm}^2$ at $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	110
Fig 4.64	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.1 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	111
Fig 4.65	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ at $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	112
Fig 4.66	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ at $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	113
Fig 4.67	Photos of transient oscillatory saturated flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.0 \text{ W/cm}^2$ at $G=400\pm 10\%$	

	kg/m ² s with oscillation t _p =30s-----	114
Fig 4.68	Mean bubble departure diameters for various coolant mass fluxes for stable saturated flow boiling (a) and various imposed heat fluxes for transient saturated flow boiling for G=300±5% kg/m ² s with t _p =10 sec (b), 20sec (c) and 30 sec (d)-----	115
Fig 4.69	Mean bubble departure diameters for various imposed heat fluxes for transient saturated flow boiling for G=300±10% kg/m ² s with t _p =10 sec (a), 20sec (b) and 30 sec (c)-----	117
Fig 4.70	Mean bubble departure diameters for various imposed heat fluxes for transient saturated flow boiling for G=400±5% kg/m ² s with t _p =10 sec (a), 20sec (b) and 30 sec (c)-----	118
Fig 4.71	Mean bubble departure diameters for various imposed heat fluxes for transient saturated flow boiling for G=400±10% kg/m ² s with t _p =10 sec (a), 20sec (b) and 30 sec (c)-----	119
Fig 4.72	Mean bubble departure diameters for various periods of the mass flux oscillation for transient saturated flow boiling for G=300±5% kg/m ² s with (a) q=6.2 W/cm ² and (b) q=7.5 W/cm ² -----	120
Fig 4.73	Mean bubble departure diameters for various periods of the mass flux oscillation for transient saturated flow boiling for G=300±10% kg/m ² s with (a) q=6.2 W/cm ² and (b) q=7.5 W/cm ² -----	121
Fig 4.74	Mean bubble departure diameters for various periods of the mass flux oscillation for transient saturated flow boiling for G=400±5% kg/m ² s with (a) q=6.2 W/cm ² and (b) q=9.0 W/cm ² -----	122
Fig 4.75	Mean bubble departure diameters for various periods of the mass flux oscillation for transient saturated flow boiling for G=400±10% kg/m ² s with (a) q=6.2 W/cm ² and (b) q=9.0 W/cm ² -----	123
Fig 4.76	Mean bubble departure diameters for various amplitudes of the mass fluxes oscillation for transient saturated flow boiling for q=6.2 W/cm ² with period=10 sec (a), 20 sec (b), and 30 sec (c)-----	124
Fig 4.77	Mean bubble departure frequencies for various coolant mass fluxes for stable saturated flow boiling (a) and various imposed heat fluxes for transient saturated flow boiling for G=300±5% kg/m ² s with t _p =10 sec (b), 20sec (c) and 30 sec (d)-----	125
Fig 4.78	Mean bubble departure frequencies for various imposed heat fluxes for transient saturated flow boiling for G=300±10% kg/m ² s with t _p =10 sec (a), 20sec (b) and 30 sec (c)-----	127
Fig 4.79	Mean bubble departure frequencies for various imposed heat fluxes for transient saturated flow boiling for G=400±5% kg/m ² s with t _p =10 sec (a),	

	20sec (b) and 30 sec (c) -----	128
Fig 4.80	Mean bubble departure frequencies for various imposed heat fluxes for transient saturated flow boiling for $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	129
Fig 4.81	Mean bubble departure frequencies for various periods of mass flux oscillation for transient saturated flow boiling for $G=300\pm 5\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=7.5$ W/cm^2 -----	130
Fig 4.82	Mean bubble departure frequencies for various periods of mass flux oscillation for transient saturated flow boiling for $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=7.5$ W/cm^2 -----	131
Fig 4.83	Mean bubble departure frequencies for various periods of mass flux oscillation for transient saturated flow boiling for $G=400\pm 5\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=9.0$ W/cm^2 -----	132
Fig 4.84	Mean bubble departure frequencies for various periods of mass flux oscillation for transient saturated flow boiling for $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=9.0$ W/cm^2 -----	133
Fig 4.85	Mean bubble departure frequencies for various amplitudes of the mass fluxes oscillation for transient saturated flow boiling for $q=6.2$ W/cm^2 with period=10 sec (a), 20 sec (b), and 30 sec (c) -----	134
Fig 4.86	Mean active nucleation site densities for various coolant mass fluxes for stable saturated flow boiling (a) and various imposed heat fluxes for transient saturated flow boiling for $G=300\pm 5\%$ $\text{kg/m}^2\text{s}$ with $t_p=10$ sec (b), 20sec (c) and 30 sec (d) -----	135
Fig 4.87	Mean active nucleation site densities for various imposed heat fluxes for transient saturated flow boiling for $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	137
Fig 4.88	Mean active nucleation site densities for various imposed heat fluxes for transient saturated flow boiling for $G=400\pm 5\%$ $\text{kg/m}^2\text{s}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	138
Fig 4.89	Mean active nucleation site densities for various imposed heat fluxes for transient saturated flow boiling for $G=400\pm 10\%$ $\text{kg/m}^2\text{s}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	139
Fig 4.90	Mean active nucleation site densities for various periods of mass flux oscillation for transient saturated flow boiling for $G=300\pm 5\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=7.5$ W/cm^2 -----	140
Fig 4.91	Mean active nucleation site densities for various periods of mass flux oscillation for transient saturated flow boiling for $G=300\pm 10\%$ $\text{kg/m}^2\text{s}$ with (a) $q=6.2$ W/cm^2 and (b) $q=7.5$ W/cm^2 -----	141

Fig 4.92	Mean active nucleation site densities for various periods of mass flux oscillation for transient saturated flow boiling for $G=400\pm 5\%$ kg/m ² s with (a) $q=6.2$ W/cm ² and (b) $q=9.0$ W/cm ² -----	142
Fig 4.93	Mean active nucleation site densities for various periods of mass flux oscillation for transient saturated flow boiling for $G=400\pm 10\%$ kg/m ² s with (a) $q=6.2$ W/cm ² and (b) $q=9.0$ W/cm ² -----	143
Fig 4.94	Mean active nucleation site densities for various amplitudes of the mass fluxes oscillation for transient saturated flow boiling for $q=6.2$ W/cm ² with period=10 sec (a), 20 sec (b), and 30 sec (c) -----	144
Fig 4.95	Comparison of the measured data for mean bubble departure diameter for saturated flow boiling of FC-72 with the proposed correlation -----	145
Fig 4.96	Comparison of the measured data for mean bubble departure diameter for transient saturated flow boiling of FC-72 with the proposed correlation -----	146
Fig 4.97	Comparison of the measured data for mean bubble departure frequency for saturated flow boiling of FC-72 with the proposed correlation -----	147
Fig 4.98	Comparison of the measured data for mean bubble departure frequency for transient saturated flow boiling of FC-72 with the proposed correlation -----	148
Fig 4.99	Comparison of the measured data for mean active nucleation site density for saturated flow boiling of FC-72 with the proposed correlation -----	149
Fig 4.100	Comparison of the measured data for mean active nucleation site density for transient saturated flow boiling of FC-72 with the proposed correlation -----	150
Fig 4.101	Comparison of the measured data for boiling heat flux for stable saturated flow boiling of FC-72 with the proposed correlation-----	151

Subcooled Flow Boiling

Fig 5.1	Time-average flow boiling curves for various coolant mass fluxes for stable subcooled flow boiling (a) and transient subcooled flow boiling at $\Delta T_{sub}=5^{\circ}\text{C}$ for $t_p=10$ sec (b), 20 sec (c) and 30 sec (d)-----	166
Fig 5.2	Time-average flow boiling curves for various coolant mass fluxes for transient subcooled flow boiling at $\Delta T_{sub}=5^{\circ}\text{C}$ for $t_p=10$ sec (a), 20 sec (b) and 30 sec (c) -----	168
Fig 5.3	Time-average flow boiling curves for various coolant mass fluxes for stable subcooled flow boiling (a) and transient subcooled flow boiling at $\Delta T_{sub}=10^{\circ}\text{C}$ for $t_p=10$ sec (b), 20 sec (c) and 30 sec (d) -----	170
Fig 5.4	Time-average flow boiling curves for various coolant mass fluxes for transient subcooled flow boiling at $\Delta T_{sub}=10^{\circ}\text{C}$ for $t_p=10$ sec (a), 20 sec (b) and 30 sec (c) -----	172
Fig 5.5	Time-average flow boiling curves for various inlet subcoolings for stable	

	subcooled flow boiling at (a) $G=300 \text{ kg/m}^2\text{s}$ and (b) $G=400 \text{ kg/m}^2\text{s}$ -----	174
Fig 5.6	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 5\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 5\% \text{ kg/m}^2\text{s}$ at $t_p=10 \text{ sec}$ -----	175
Fig 5.7	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 5\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 5\% \text{ kg/m}^2\text{s}$ at $t_p=20 \text{ sec}$ -----	176
Fig 5.8	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 5\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 5\% \text{ kg/m}^2\text{s}$ at $t_p=30 \text{ sec}$ -----	177
Fig 5.9	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 10\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 10\% \text{ kg/m}^2\text{s}$ at $t_p=10 \text{ sec}$ -----	178
Fig 5.10	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 10\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 10\% \text{ kg/m}^2\text{s}$ at $t_p=20 \text{ sec}$ -----	179
Fig 5.11	Time-average flow boiling curves for various inlet subcoolings for transient subcooled flow boiling at (a) $G=300\pm 10\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 10\% \text{ kg/m}^2\text{s}$ at $t_p=30 \text{ sec}$ -----	180
Fig 5.12	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for stable subcooled flow boiling (a) and transient subcooled flow boiling at $\Delta T_{\text{sub}} = 5^\circ\text{C}$ for $t_p=10 \text{ sec}$ (b), 20 sec (c) and 30 sec (d)-----	181
Fig 5.13	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for transient subcooled flow boiling at $\Delta T_{\text{sub}} = 5^\circ\text{C}$ for $t_p=10 \text{ sec}$ (a), 20 sec (b) and 30 sec (c) -----	183
Fig 5.14	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for stable subcooled flow boiling (a) and transient subcooled flow boiling at $\Delta T_{\text{sub}} = 10^\circ\text{C}$ for $t_p=10 \text{ sec}$ (b), 20 sec (c) and 30 sec (d) -----	185
Fig 5.15	Time-average flow boiling heat transfer coefficients for various coolant mass fluxes for transient subcooled flow boiling at $\Delta T_{\text{sub}} = 10^\circ\text{C}$ for $t_p=10 \text{ sec}$ (a), 20 sec (b) and 30 sec (c)-----	187
Fig 5.16	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300 \text{ kg/m}^2\text{s}$ and (b) $G=400 \text{ kg/m}^2\text{s}$ -----	189
Fig 5.17	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300\pm 5\% \text{ kg/m}^2\text{s}$ and (b) $G=400\pm 5\% \text{ kg/m}^2\text{s}$ at $t_p=10 \text{ sec}$ -----	190
Fig 5.18	Time-average flow boiling heat transfer coefficients for various inlet	

	subcoolings for stable subcooled flow boiling at (a) $G=300\pm 5\%$ kg/m ² s and (b) $G=400\pm 5\%$ kg/m ² s at $t_p=20$ sec -----	191
Fig 5.19	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300\pm 5\%$ kg/m ² s and (b) $G=400\pm 5\%$ kg/m ² s at $t_p=30$ sec -----	192
Fig 5.20	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300\pm 10\%$ kg/m ² s and (b) $G=400\pm 10\%$ kg/m ² s at $t_p=10$ sec -----	193
Fig 5.21	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300\pm 10\%$ kg/m ² s and (b) $G=400\pm 10\%$ kg/m ² s at $t_p=20$ sec -----	194
Fig 5.22	Time-average flow boiling heat transfer coefficients for various inlet subcoolings for stable subcooled flow boiling at (a) $G=300\pm 10\%$ kg/m ² s and (b) $G=400\pm 10\%$ kg/m ² s at $t_p=30$ sec -----	195
Fig 5.23	Time variations of the copper plate temperature in stable subcooled flow boiling for various imposed heat fluxes for $\Delta T_{sub} = 5^\circ\text{C}$ at (a) $G=300$ kg/m ² s and (b) $G=400$ kg/m ² s -----	196
Fig 5.24	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=3.59$ w/cm ² at $G=300$ kg/m ² s)-----	197
Fig 5.25	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=4.45$ w/cm ² at $G=400$ kg/m ² s)-----	198
Fig 5.26	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=3.43$ w/cm ² at $G=300$ kg/m ² s)-----	199
Fig 5.27	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=4.35$ w/cm ² at $G=400$ kg/m ² s)-----	200
Fig 5.28	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=3.40$ w/cm ² at $G=300$ kg/m ² s)-----	201

Fig 5.29	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=4.35$ w/cm ² at $G=400$ kg/m ² s)-----	202
Fig 5.30	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=3.44$ w/cm ² at $G=300$ kg/m ² s)-----	203
Fig 5.31	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=4.51$ w/cm ² at $G=400$ kg/m ² s)-----	204
Fig 5.32	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=3.34$ w/cm ² at $G=300$ kg/m ² s)-----	205
Fig 5.33	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=3.90$ w/cm ² at $G=400$ kg/m ² s)-----	206
Fig 5.34	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=3.34$ w/cm ² at $G=300$ kg/m ² s)-----	207
Fig 5.35	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=3.84$ w/cm ² at $G=400$ kg/m ² s)-----	208
Fig 5.36	Time variations of the copper plate temperature in stable subcooled flow boiling for various imposed heat fluxes for $\Delta T_{sub}=10^\circ\text{C}$ at (a) $G=300$ kg/m ² s and (b) $G=400$ kg/m ² s-----	209
Fig 5.37	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=4.33$ w/cm ² at $G=300$ kg/m ² s)-----	210
Fig 5.38	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various	

	imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=6.13$ w/cm ² at $G=400$ kg/m ² s)-----	211
Fig 5.39	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=4.28$ w/cm ² at $G=300$ kg/m ² s)-----	212
Fig 5.40	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=6.04$ w/cm ² at $G=400$ kg/m ² s)-----	213
Fig 5.41	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=4.79$ w/cm ² at $G=300$ kg/m ² s)-----	214
Fig 5.42	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=30$ sec. ($\bar{q}_{ONB}=5.96$ w/cm ² at $G=400$ kg/m ² s)-----	215
Fig 5.43	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=4.32$ w/cm ² at $G=300$ kg/m ² s)-----	216
Fig 5.44	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=10$ sec. ($\bar{q}_{ONB}=5.58$ w/cm ² at $G=400$ kg/m ² s)-----	217
Fig 5.45	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=4.30$ w/cm ² at $G=300$ kg/m ² s)-----	218
Fig 5.46	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=20$ sec. ($\bar{q}_{ONB}=5.47$ w/cm ² at $G=400$ kg/m ² s)-----	219
Fig 5.47	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various	

	imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p = 30$ sec. ($\bar{q}_{ONB} = 4.28$ w/cm ² at $G = 300$ kg/m ² s) -----	220
Fig 5.48	Time variations of (a) imposed coolant mass flux and (b) copper plate temperature in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p = 30$ sec. ($\bar{q}_{ONB} = 5.44$ w/cm ² at $G = 400$ kg/m ² s) -----	221
Fig 5.49	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p = 10$ sec-----	222
Fig 5.50	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 10$ sec-----	223
Fig 5.51	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p = 20$ sec-----	224
Fig 5.52	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 20$ sec-----	225
Fig 5.53	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p = 30$ sec-----	226
Fig 5.54	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p = 30$ sec-----	227
Fig 5.55	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p = 10$ sec -----	228
Fig 5.56	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p = 10$ sec -----	229
Fig 5.57	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p = 20$ sec -----	230
Fig 5.58	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p = 20$ sec -----	231
Fig 5.59	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various	

	imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	232
Fig 5.60	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	233
Fig 5.61	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec-----	234
Fig 5.62	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=10$ sec-----	235
Fig 5.63	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=20$ sec-----	236
Fig 5.64	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=20$ sec-----	237
Fig 5.65	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 5\%$ kg/m ² s with $t_p=30$ sec-----	238
Fig 5.66	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 5\%$ kg/m ² s with $t_p=30$ sec-----	239
Fig 5.67	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	240
Fig 5.68	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	241
Fig 5.69	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	242
Fig 5.70	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	243
Fig 5.71	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	244
Fig 5.72	Time variations of (a) imposed coolant mass flux and (b) flow boiling heat	

	transfer coefficients in transient oscillatory subcooled flow boiling for various imposed heat fluxes for $G=400\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	245
Fig 5.73	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=3.59$ W/cm ² and (b) $q=8.19$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=10$ sec -----	246
Fig 5.74	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.55$ W/cm ² and (b) $q=8.17$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=10$ sec -----	247
Fig 5.75	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.96$ W/cm ² and (b) $q=8.17$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=20$ sec -----	248
Fig 5.76	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.46$ W/cm ² and (b) $q=8.11$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=20$ sec -----	249
Fig 5.77	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.95$ W/cm ² and (b) $q=8.15$ W/cm ² for $G=300\pm 5\%$ kg/m ² s with $t_p=30$ sec -----	250
Fig 5.78	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.48$ W/cm ² and (b) $q=8.10$ W/cm ² for $G=400\pm 5\%$ kg/m ² s with $t_p=30$ sec -----	251
Fig 5.79	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.39$ W/cm ² and (b) $q=8.14$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	252
Fig 5.80	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.50$ W/cm ² and (b) $q=8.12$ W/cm ² for $G=400\pm 10\%$ kg/m ² s with $t_p=10$ sec -----	253
Fig 5.81	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.43$ W/cm ² and (b) $q=8.10$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	254
Fig 5.82	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.02$ W/cm ² and (b) $q=8.19$ W/cm ² for $G=400\pm 10\%$ kg/m ² s with $t_p=20$ sec -----	255
Fig 5.83	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.43$ W/cm ² and (b) $q=8.11$ W/cm ² for $G=300\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	256
Fig 5.84	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.88$ W/cm ² and (b) $q=8.12$ W/cm ² for $G=400\pm 10\%$ kg/m ² s with $t_p=30$ sec -----	257

Fig 5.85	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.33 \text{ W/cm}^2$ and (b) $q=8.12 \text{ W/cm}^2$ for $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=10 \text{ sec}$ -----	258
Fig 5.86	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=6.13 \text{ W/cm}^2$ and (b) $q=8.81 \text{ W/cm}^2$ for $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=10 \text{ sec}$ -----	259
Fig 5.87	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.28 \text{ W/cm}^2$ and (b) $q=8.05 \text{ W/cm}^2$ for $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=20 \text{ sec}$ -----	260
Fig 5.88	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=6.04 \text{ W/cm}^2$ and (b) $q=8.78 \text{ W/cm}^2$ for $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=20 \text{ sec}$ -----	261
Fig 5.89	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.79 \text{ W/cm}^2$ and (b) $q=8.74 \text{ W/cm}^2$ for $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=30 \text{ sec}$ -----	262
Fig 5.90	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.96 \text{ W/cm}^2$ and (b) $q=8.73 \text{ W/cm}^2$ for $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with $t_p=30 \text{ sec}$ -----	263
Fig 5.91	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.32 \text{ W/cm}^2$ and (b) $q=8.10 \text{ W/cm}^2$ for $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=10 \text{ sec}$ -----	264
Fig 5.92	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.58 \text{ W/cm}^2$ and (b) $q=8.22 \text{ W/cm}^2$ for $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=10 \text{ sec}$ -----	265
Fig 5.93	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.30 \text{ W/cm}^2$ and (b) $q=8.06 \text{ W/cm}^2$ for $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=20 \text{ sec}$ -----	266
Fig 5.94	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.47 \text{ W/cm}^2$ and (b) $q=8.08 \text{ W/cm}^2$ for $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=20 \text{ sec}$ -----	267
Fig 5.95	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=4.28 \text{ W/cm}^2$ and (b) $q=8.05 \text{ W/cm}^2$ for $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=30 \text{ sec}$ -----	268
Fig 5.96	Time variations of coolant mass flux and inlet pressure in transient oscillatory subcooled flow boiling for various imposed heat fluxes at (a) $q=5.44 \text{ W/cm}^2$ and (b) $q=8.07 \text{ W/cm}^2$ for $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with $t_p=30 \text{ sec}$ -----	269
Fig 5.97	Photos of stable subcooled boiling flow at certain time instants for various imposed heat fluxes at $\Delta T_{\text{sub}}= 5^\circ\text{C}$ for (a) $G =300 \text{ kg/m}^2\text{s}$ and (b) $G =400$	

	kg/m ² s -----	270
Fig 5.98	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.2 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	271
Fig 5.99	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	272
Fig 5.100	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	273
Fig 5.101	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	274
Fig 5.102	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	275
Fig 5.103	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	276
Fig 5.104	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	277
Fig 5.105	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	278
Fig 5.106	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	279
Fig 5.107	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	280
Fig 5.108	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	281
Fig 5.109	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.8 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	282
Fig 5.110	Photos of transient oscillatory subcooled flow boiling flow at certain time	

	instants for various imposed mass fluxes for $q=6.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	283
Fig 5.111	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	284
Fig 5.112	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	285
Fig 5.113	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.8 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	286
Fig 5.114	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.0 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	287
Fig 5.115	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	288
Fig 5.116	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	289
Fig 5.117	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	290
Fig 5.118	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	291
Fig 5.119	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=300\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	292
Fig 5.120	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	293
Fig 5.121	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 5^\circ\text{C}$ at $G=400\pm 10\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	294
Fig 5.122	Photos of stable subcooled boiling flow at certain time instants for various imposed heat fluxes at $\Delta T_{\text{sub}}= 10^\circ\text{C}$ for (a) $G =300 \text{ kg/m}^2\text{s}$ and (b) $G =400 \text{ kg/m}^2\text{s}$ -----	295

Fig 5.123	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.7 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	296
Fig 5.124	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	297
Fig 5.125	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	298
Fig 5.126	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.6 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=10\text{s}$ -----	299
Fig 5.127	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.7 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	300
Fig 5.128	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	301
Fig 5.129	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	302
Fig 5.130	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=20\text{s}$ -----	303
Fig 5.131	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.6 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	304
Fig 5.132	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.0 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=300\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	305
Fig 5.133	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.0 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	306
Fig 5.134	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.5 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at $G=400\pm 5\% \text{ kg/m}^2\text{s}$ with oscillation $t_p=30\text{s}$ -----	307
Fig 5.135	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.7 \text{ W/cm}^2$ and $\Delta T_{\text{sub}}= 10^\circ\text{C}$ at	

	$G=300\pm 10\%$ kg/m ² s with oscillation $t_p=10$ s-----	308
Fig 5.136	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=300\pm 10\%$ kg/m ² s with oscillation $t_p=10$ s-----	309
Fig 5.137	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.2$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=10$ s-----	310
Fig 5.138	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.7$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=10$ s-----	311
Fig 5.139	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.7$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=300\pm 10\%$ kg/m ² s with oscillation $t_p=20$ s-----	312
Fig 5.140	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=300\pm 10\%$ kg/m ² s with oscillation $t_p=20$ s-----	313
Fig 5.141	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=20$ s-----	314
Fig 5.142	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=9.6$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=20$ s-----	315
Fig 5.143	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=6.7$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=300\pm 10\%$ kg/m ² s with oscillation $t_p=30$ s-----	316
Fig 5.144	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=300\pm 10\%$ kg/m ² s with oscillation $t_p=30$ s-----	317
Fig 5.145	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=30$ s-----	318
Fig 5.146	Photos of transient oscillatory subcooled flow boiling flow at certain time instants for various imposed mass fluxes for $q=8.9$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ at $G=400\pm 10\%$ kg/m ² s with oscillation $t_p=30$ s-----	319
Fig 5.147	Mean bubble departure diameters for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^\circ\text{C}$ with $t_p=10$ sec (b), 20sec (c) and 30 sec (d) -----	320

Fig 5.148	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	322
Fig 5.149	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	323
Fig 5.150	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	324
Fig 5.151	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.5$ W/cm ² -----	325
Fig 5.152	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.4$ W/cm ² -----	326
Fig 5.153	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=7.4$ W/cm ² and (b) $q=8.9$ W/cm ² -----	327
Fig 5.154	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=7.4$ W/cm ² and (b) $q=8.9$ W/cm ² -----	328
Fig 5.155	Mean bubble departure diameters for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q=7.4$ W/cm ² and $\Delta T_{sub}= 5^{\circ}\text{C}$ with period=10 sec (a), 20 sec (b), and 30 sec (c) -----	329
Fig 5.156	Mean bubble departure frequencies for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (b), 20sec (c) and 30 sec (d) -----	330
Fig 5.157	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	332
Fig 5.158	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	333
Fig 5.159	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c) -----	334
Fig 5.160	Mean bubble departure frequencies for various periods of mass flux	

	oscillation for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.4$ W/cm ² -----	335
Fig 5.161	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.4$ W/cm ² -----	336
Fig 5.162	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=7.4$ W/cm ² and (b) $q=8.9$ W/cm ² -----	337
Fig 5.163	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=7.4$ W/cm ² and (b) $q=8.9$ W/cm ² -----	338
Fig 5.164	Mean bubble departure frequencies for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q=7.4$ W/cm ² and $\Delta T_{sub}= 5^{\circ}\text{C}$ with period=10 sec (a), 20 sec (b), and 30 sec (c) -----	339
Fig 5.165	Mean active nucleation site densities for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (b), 20sec (c) and 30 sec (d) -----	340
Fig 5.166	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	342
Fig 5.167	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	343
Fig 5.168	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	344
Fig 5.169	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.4$ W/cm ² -----	345
Fig 5.170	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=6.1$ W/cm ² and (b) $q=7.4$ W/cm ² -----	346
Fig 5.171	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 5^{\circ}\text{C}$ with (a) $q=7.4$ W/cm ² and (b) $q=8.9$ W/cm ² -----	347
Fig 5.172	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and	

	$\Delta T_{\text{sub}} = 5^{\circ}\text{C}$ with (a) $q = 7.4 \text{ W/cm}^2$ and (b) $q = 8.9 \text{ W/cm}^2$ -----	348
Fig 5.173	Mean active nucleation site densities for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q = 7.4 \text{ W/cm}^2$ and $\Delta T_{\text{sub}} = 5^{\circ}\text{C}$ with period = 10 sec (a), 20 sec (b), and 30 sec (c) -----	349
Fig 5.174	Mean bubble departure diameters for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G = 300 \pm 5\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with $t_p = 10$ sec (b), 20sec (c) and 30 sec (d) -----	350
Fig 5.175	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G = 300 \pm 10\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with $t_p = 10$ sec (a), 20sec (b) and 30 sec (c) -----	352
Fig 5.176	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G = 400 \pm 5\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with $t_p = 10$ sec (a), 20sec (b) and 30 sec (c) -----	353
Fig 5.177	Mean bubble departure diameters for various imposed heat fluxes for transient subcooled flow boiling for $G = 400 \pm 10\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with $t_p = 10$ sec (a), 20sec (b) and 30 sec (c) -----	354
Fig 5.178	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G = 300 \pm 5\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with (a) $q = 6.7 \text{ W/cm}^2$ and (b) $q = 8.1 \text{ W/cm}^2$ -----	355
Fig 5.179	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G = 300 \pm 10\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with (a) $q = 6.7 \text{ W/cm}^2$ and (b) $q = 8.1 \text{ W/cm}^2$ -----	356
Fig 5.180	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G = 400 \pm 5\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with (a) $q = 8.1 \text{ W/cm}^2$ and (b) $q = 9.5 \text{ W/cm}^2$ -----	357
Fig 5.181	Mean bubble departure diameters for various period of mass flux oscillation for transient subcooled flow boiling for $G = 400 \pm 10\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with (a) $q = 8.1 \text{ W/cm}^2$ and (b) $q = 9.6 \text{ W/cm}^2$ -----	358
Fig 5.182	Mean bubble departure diameters for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q = 8.1 \text{ W/cm}^2$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with period = 10 sec (a), 20 sec (b), and 30 sec (c) -----	359
Fig 5.183	Mean bubble departure frequencies for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G = 300 \pm 5\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$ with $t_p = 10$ sec (b), 20sec (c) and 30 sec (d) -----	360
Fig 5.184	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G = 300 \pm 10\% \text{ kg/m}^2\text{s}$ and $\Delta T_{\text{sub}} = 10^{\circ}\text{C}$	

	with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	362
Fig 5.185	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	363
Fig 5.186	Mean bubble departure frequencies for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	364
Fig 5.187	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with (a) $q=6.7$ W/cm ² and (b) $q=8.1$ W/cm ² -----	365
Fig 5.188	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with (a) $q=6.7$ W/cm ² and (b) $q=8.1$ W/cm ² -----	366
Fig 5.189	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with (a) $q=8.1$ W/cm ² and (b) $q=9.6$ W/cm ² -----	367
Fig 5.190	Mean bubble departure frequencies for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with (a) $q=8.1$ W/cm ² and (b) $q=9.6$ W/cm ² -----	368
Fig 5.191	Mean bubble departure frequencies for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^\circ\text{C}$ with period=10 sec (a), 20 sec (b), and 30 sec (c)-----	369
Fig 5.192	Mean active nucleation site densities for various coolant mass fluxes for stable subcooled flow boiling (a) and various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (b), 20sec (c) and 30 sec (d) -----	370
Fig 5.193	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	372
Fig 5.194	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	373
Fig 5.195	Mean active nucleation site densities for various imposed heat fluxes for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with $t_p=10$ sec (a), 20sec (b) and 30 sec (c)-----	374
Fig 5.196	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^\circ\text{C}$ with (a) $q=6.7$ W/cm ² and (b) $q=8.1$ W/cm ² -----	375

Fig 5.197	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=300\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^{\circ}\text{C}$ with (a) $q=6.7$ W/cm ² and (b) $q=8.1$ W/cm ² -----	376
Fig 5.198	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 5\%$ kg/m ² s and $\Delta T_{sub}= 10^{\circ}\text{C}$ with (a) $q=8.1$ W/cm ² and (b) $q=9.6$ W/cm ² -----	377
Fig 5.199	Mean active nucleation site densities for various periods of mass flux oscillation for transient subcooled flow boiling for $G=400\pm 10\%$ kg/m ² s and $\Delta T_{sub}= 10^{\circ}\text{C}$ with (a) $q=8.1$ W/cm ² and (b) $q=9.6$ W/cm ² -----	378
Fig 5.200	Mean active nucleation site densities for various amplitudes of the mass fluxes oscillation for transient subcooled flow boiling for $q=8.1$ W/cm ² and $\Delta T_{sub}= 10^{\circ}\text{C}$ with period=10 sec (a), 20 sec (b), and 30 sec (c)-----	379
Fig 5.201	Comparison of the measured data for mean bubble departure diameter for subcooled flow boiling of FC-72 with the proposed correlation-----	380
Fig 5.202	Comparison of the measured data for mean bubble departure diameter for transient subcooled flow boiling of FC-72 with the proposed correlation-----	381
Fig 5.203	Comparison of the measured data for mean bubble departure frequency for subcooled flow boiling of FC-72 with the proposed correlation-----	382
Fig 5.204	Comparison of the measured data for mean bubble departure frequency for transient subcooled flow boiling of FC-72 with the proposed correlation -----	383
Fig 5.205	Comparison of the measured data for mean active nucleation site density for subcooled flow boiling of FC-72 with the proposed correlation-----	384
Fig 5.206	Comparison of the measured data for mean active nucleation site density for transient subcooled flow boiling of FC-72 with the proposed correlation-----	385
Fig 5.207	Comparison of the measured data for boiling heat flux for stable subcooled flow boiling of FC-72 with the proposed correlation-----	386

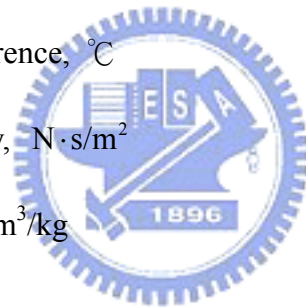
NOMENCLATURE

A	area, m ²
B	element height, m
c_p	specific heat, J/kg°C
D	hydraulic diameter of rectangular-channel, m
G	mass flux, kg/m ² s
g	acceleration due to gravity, m/s ²
H	height, m
h	heat transfer coefficient, W/m ² · K
I	measured current from DC power supply, A
i_{lv}	enthalpy of vaporization, J/kg · K
k	thermal conductivity, W/m · K
L	length, mm
\dot{m}	mass flow rate, kg/s
Ja'	Jacob number based on ΔT_{sub} , $Ja' = \frac{\rho_l \cdot C_{pl} \cdot \Delta T_{sub}}{\rho_v \cdot i_{lv}}$, dimensionless
Nu	Nusselt number, $Nu = \frac{h \cdot L}{k}$, dimensionless
P	system pressure, kPa
Pr	Prandtl number, $Pr = \frac{\mu \cdot C_p}{k}$, dimensionless
N_{ac}	Active nucleation site density, n/m ²
Q	heat transfer rate, W

q	average imposed heat flux, W/cm^2
Re	Reynolds number, $\text{Re} = \frac{G \cdot D}{\mu}$, dimensionless
S	element space between two adjacent elements, m
T	temperature, $^{\circ}\text{C}$
V	coolant FC-72 flow velocity, m/s
V	measured voltage from DC power supply, V
W	width, m

Greek Symbols

ΔT	temperature difference, $^{\circ}\text{C}$
μ	dynamic viscosity, $\text{N} \cdot \text{s}/\text{m}^2$
v	specific volume, m^3/kg
ρ	density, kg/m^3
ε	relative heat loss, dimensionless



Subscripts

ave	average
c,h	from heater surface to cooper surface
cop	copper
cs	cross-section of rectangular-channel
d	diameter

e	effective
f	fin
fin	mean bubble departure frequency
g	gas
h	hydraulic
i	at the inlet of the test section
in	at the inlet of the test section
i,o	at inlet and exit of the test section
l	all-liquid nonboiling heat transfer
lv	liquid phase to vapor phase
m	average value for the two phase mixture or between the inlet and exit
M	mica
n	net power input to the coolant FC-72
n	active nucleation site density
o	at the outlet of the test section
p	preheater
pool	pool boiling
r	coolant FC-72
s	surface
sat	saturated state for coolant FC-72
sp	single-phase convective heat transfer



sub	subcooled state for coolant FC-72
T	teflon
t	total
t-g	thermal-grease
tp	two-phase boiling heat transfer
v	vapor
w	wall
w	water
1 ϕ	single-phase
2 ϕ	two-phase

