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出國報告（出國類別：其他）

赴大陸參加 2014 年國際熱傳會議出國報告

服務機關：核能研究所
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摘　要

本次 **2014** 年國際熱傳研討會(**2014 International Heat Transfer Symposium**)由華北電力大學與英國諾丁漢大學合作於 **2014** 年 **5** 月 **6-9** 日在北京舉辦。華北電力大學能源動力與機械工程學院院長徐進良教授與英國諾丁漢大學 **Prof. Yuying Yan** 為大會共同主持人。此次會議共 **286** 篇論文，研討主題範圍廣泛，包括：**(1)** 微奈米尺度熱傳**(2)** 能源動力系統中傳熱問題**(3)**可再生能源利用中的傳熱問題**(4)** 能量轉換與傳遞相關的其他傳熱問題等，與本所在工業節能之研究主題密切相關，有幸受邀於研討會中發表研發成果論文，並擔任第三場次 **Renewable Energy** 之主持人。本次會議論文經大會科學委員會委員審稿，將擇優推薦至 **Applied Thermal Engineering, International Journal of Multiphase Flow, Journal of Bionic Engineering and Chinese Science Bulletin** 四大 **SCI** 期刊，本人亦有幸擔任審查委員之一。本次發表逆流熱虹吸儲熱裝置與太陽儲能發電裝置兩篇文章，逆流熱虹吸裝置乃建立太陽熱能自主向下長距離傳輸機制，不需額外增設泵浦動力，可自主向下於淺層地源蓄熱或應用於空調節能等；兩相虹吸熱電產生器裝置，則可將不穩定的熱源轉換為高度穩定的溫度，並且持續長時間發電，在會議中引發熱烈討論發表。本次會議透過與來自世界各地的專家學者在節能與傳熱領域的交流，汲取經驗，對本組未來的工作必有相當助益。

目　　　次

一、目　的

赴大陸地區參加 2014 年國際熱傳研討會(2014 International Heat Transfer Symposium)並發表逆流熱虹吸與熱電產生器研發成果論文。本次 2014 年國際熱傳研討會由華北電力大學能源動力與機械工程學院院長徐進良教授擬跟英國諾丁漢大學 Prof. Yuying Yan 合作，於 2014 年 5 月 6-9 日在北京舉辦，與會國際學者眾多，學習並與相關領域之專家學者經驗交流，並建立未來合作關係，以回饋本組在節能領域之應用開發。

本次亦在會前拜訪中國航太科技集團公司第十一研究院第一研究所研究員曲偉，與其深談熱管與節能領域的應用。

二、過　程

本次公差自 102 年 5 月 3 日起至 10 日止共計 8 天，相關重點工作內容如下：

月/日(星期)	工作內容重點
5/3 (六)	中正機場－北京（去程）
5/4 (日)	拜訪中國航太科技集團公司第十一研究院第一研究所研究員曲偉
5/5 (一)	參加 2014 年國際熱傳研討會
5/6 (二)	參加 2014 年國際熱傳研討會
5/7 (三)	參加 2014 年國際熱傳研討會、擔任 Session 3 Renewable 場次主持人、發表兩篇會議論文
5/8 (四)	參加 2014 年國際熱傳研討會
5/9 (五)	參加 2014 年國際熱傳研討會、參觀華北電力大學徐進良院長之熱傳實驗室
5/10 (六)	北京－中正機場（返程）

三、心　得

本次代表核能研究所參加由北京華北電力大學與英國諾丁漢大學共同舉辦的 2014 年國際熱傳會議(International Heat Transfer Symposium 2014)，本次會議收稿 400 餘件，節錄 280 篇彙整成會議論文，由於篇數繁多，會議論文僅印刷摘要，詳細論文以電子檔方式提供給與會的專家學者,其中會議有 7 篇邀請演講與 28 篇 Keynotes。會議討論主題有 Electronic cooling, Heat exchanger, Renewable energy, Microfluidics, Droplet dynamics, Nanofluids, Bubble dynamics, Waste heat utilization, Air-conditioning, Power Plant, Pipeline and heat pump, Supercritical fluids, Chemical reactions, Bioengineering, Molten salt and phase change material, Numerical technique, Nuclear energy, Porous media and thermal radiation, Thermal conduction, Heat pipe, Aerodynamics and astronautics, Thermal radiation, Jet flow 23 個主題。本人有幸受邀擔任 Session 3 Renewable Energy 的主持人，並對投稿文章進行評分，優秀文章將被推薦至四大期刊系統:

Applied Thermal Engineering (special issue)

International Journal of Multiphase Flow (selected papers);

Journal of Bionic Engineering (special issue)

Chinese Science Bulletin (special issues)

本次會議與大會主席華北電力大學能源動力與機械工程學院院長徐進良教授、副主席英國 Prof. Yuying Yan 與國際知名熱流專家 Prof. Satish Kandlikar 長談，亦接觸到許多來自台灣這個領域的教授，徐進良教授表示核能研究所發表的文章在能源應用領域相當有幫助，與其研究亦有關聯性，他會好好的研讀本人發表的文章，更歡迎日後有機會可以帶相關研究人員前往他的實驗室參觀交流，本次會議收錄篇幅眾多，與會專家學者都非常盡興的交流對談，帶給我許多新的思維，更奠定未來國際交流、合作開發的基礎。

本次會議議程如下表一所示:

表一、Preliminary executive program of IHTS 2014

May 6 (Tuesday)	10:00-24:00	Registration		Lobby
	17:45-19:30	Reception		Coffee House
May 7 (Wednesday)	7:30-8:30	Registration		Lobby
	8:30-9:10	Opening ceremony		Beijing Hall
	9:10-9:30	Photo-taking		Hotel Entrance
	9:30-10:05	Plenary 1: Pool boiling on multiscale surface features by Prof. Satish Kandlikar; Chaired by Prof. Yuying Yan		Beijing Hall
	10:05-10:30	*Coffee break*		Outside Beijing Hall
	10:30-11:05	Plenary 2: Size effects on thermophysical properties of nanomaterials by Prof. Xing Zhang; Chaired by Prof. Yuying Yan		Beijing Hall
	11:05-11:40	Plenary 3: Micro to macroscale phase change heat transfer by the phase separation concept by Prof. Jinliang Xu; Chaired by Prof. Yuying Yan		Beijing Hall
	11:40-11:50	Introduction of Mechanical Engineering: Fluids and Thermal Journal in Elsevier, by Ms. Betty Chang		Beijing Hall
	11:50-13:00	*Lunch*		Coffee House
	13:00-15:20	Session 1	Electronic cooling I	Beijing Hall A
		Session 2	Heat exchanger I	Beijing Hall B
		Session 3	Renewable energy I	Beijing Hall C
		Session 4	Microfluidics I	Kunming Hall
		Session 5	Droplet dynamics	Nanjing Hall
		Session 6	Nanofluids	Chongqing Hall
		Session 7	Bubble dynamics	Hangzhou Hall
	15:20-15:40	*Coffee break*		Outside Beijing Hall
	15:40-17:40	Session 8	Electronic cooling II	Beijing Hall A
		Session 9	Heat exchanger II	Beijing Hall B
		Session 10	Renewable energy II	Beijing Hall C
		Session 11	Microfluidics II	Kunming Hall
		Session 12	Waste heat utilization	Nanjing Hall
		Session 13	Air-conditioning	Chongqing Hall
		Session 14	Power Plant	Hangzhou Hall
	18:00-20:00	*Welcome Banquet*		Coffee House
May 8 (Thursday)	8:30-9:10	Plenary 4: Fundamental investigation of droplets evaporation: experiments and theory by Prof. Khellil Sefiane; Chair: pending		Beijing Hall
	9:10-9:50	Plenary 5: Study on heat transfer enhancement of refrigerant phase change exchangers by Prof. Wenquan Tao; Chair: pending		Beijing Hall
	9:50-10:10	*Coffee break*		Beijing Hall
	10:10-10:50	Plenary 6: Microfluidics and lab-on-chip technology by Prof. Dongqing Li; Chair: pending		Outside Beijing Hall
	10:50-11:30	Plenary 7: Natural solutions help improve heat transfer by Prof. Yuying Yan; Chair: pending		Beijing Hall
	11:30-13:00	*Lunch*		Coffee House
	13:00-15:20	Session 15	Pipeline and heat pump	Beijing Hall A
		Session 16	Supercritical fluids	Beijing Hall B
		Session 17	Chemical reactions	Beijing Hall C
		Session 18	Bioengineering	Kunming Hall

		Session 19	Molten salt and phase change material	Nanjing Hall
		Session 20	Numerical technique	Chongqing Hall
		Session 21	Nuclear energy I	Hangzhou Hall
	15:20-15:40	*Coffee break*		Outside Beijing Hall
	15:40-17:40	Session 22	Porous media and thermal radiation	Beijing Hall A
		Session 23	Thermal conduction	Beijing Hall B
		Session 24	Heat pipe	Beijing Hall C
		Session 25	Aerodynamics and astronautics	Kunming Hall
		Session 26	Thermal radiation	Nanjing Hall
		Session 27	Jet flow	Chongqing Hall
		Session 28	Nuclear energy II	Hangzhou Hall
	18:00-20:00	*Dinner*		Coffee House
May 9 (Friday)	8:30-17:30	*Lab tour and farewell*		

本人擔任第三場次新能源議題之主持人，排定時程如下表二所示，會議進行過程同時對 11 篇文章進行評論，評論優秀的文章，可進一步被推薦至四大期刊系統:。

表二、會議主持場次與發表文章

Session 3: Renewable energy I; Beijing Hall C, Chairs: Prof. Jinjia Wei and Prof. Mengchang Tsai			
Wednesday, May 7, 2014			
Time	**Paper No.**	**Authors**	**Title of the presentation**
13:00-13:20	**Keynote 3**	**B. Yu**	**Fast thermal simulation of a heated crude oil pipeline with a BFC-based POD reduced-order model**
13:20-13:32	IHTS140024	J. J. Wei, L. Zhang	Thermal performance of a molten salt cavity receiver
13:32-13:44	IHTS140025	H. P. Chen, R .Ma, X.L. Li, et al.	Research on thermoelectric properties of concentrating PV / T cogeneration system
13:44-13:56	IHTS140066	Y. Lu, Y. Tian, H. W. Lu, et al.	Study of solar heating biogas fermentation system with a phase change thermal storage device
13:56-14:08	IHTS140117	J. F. Lu, T. Yu, J. Ding	Nonuniform heat transfer performances of molten salt thermocline storage system
14:08-14:20	IHTS140118	J. F. Lu, J. Ding, J. P. Yang	Enhanced heat transfer performances of molten salt receiver with spirally grooved pipe
14:20-14:32	IHTS140171	Z. Z. Zhao, Y. F. Gao	Introduction to solar energy application in building
14:32-14:44	IHTS140286	L. Xiang, Y. Lin, P. Hao, et al.	Thermal analysis of a flat heat pipe receiver in solar power tower plant
14:44-14:56	IHTS140287	M. C. Tsai, S. W. Kang, H. Y. Li, et al.	Experimental study of constant pressure two phase thermosyphon with a thermoelectric generator
14:56-15:08	IHTS140288	M. C. Tsai, S. W. Kang, H. Y. Li, et al.	Experimental study of cyclical two-phase reverse loop thermosyphon
15:08-15:20	IHTS140402	S. F. Wang, Q. B. He, S. F. Wang	Experimental investigation on the efficiency of flat-plate solar collectors with nanofluids

本人在會議中發表兩篇在核研所物理組研發之成果，發表篇名與編號分別為 IHTS140287/ Experimental Study of Constant Pressure Two Phase Thermosyphon with a Thermoelectric Generator，與 IHTS140288/ Experimental Study of Cyclical Two-Phase Reverse Loop Thermosyphon，會議中兩篇文章皆引起熱烈的討論，會議主席華北電力大學能源動力與機械工程學院 徐進良院長 更表示，核能研究所發展的熱導裝置，跟其研究方向有很大的關聯性，非常有前瞻性，很適合應用在工業節能的領域，相關著作如附件 2、附件 3 所示。

在會前，本人利用假日提早出發，於北京市先行拜訪中國航太科技集團公司第十一研究院第一研究所研究員曲偉，因高溫熱管在大陸國家發展較早，因此藉由本次機會與曲博士請益高溫熱管在節能應用領域的研究。

2014 國際傳熱研討會由徐進良教授及英國諾丁漢大學閻玉英教授共同作為該研討會主席。於 5 月 7 日上午開幕。華北電力大學校長劉吉臻，大陸科技部基礎司司長彭以祺，大陸自然科學基金委工程三處處長劉濤，西安交通大學院士陶文銓，華北電力大學副校長楊勇平，美國羅切斯特理工學院教授 Satish Kandlikar，國際多相流雜誌編輯、英國愛丁堡大學教授 Khellil Sefiane，國際微納流控雜誌原主編、加拿大微納流體首席教授 Dongqing Li、中國工程熱物理學會傳熱傳質分會主任張興及來自 16 個國家和地區的近 400 名專家學者參加開幕式。開幕式由徐進良主持。

劉吉臻校長在致辭中代表學校對到會的各位領導及專家表示熱烈歡迎。他指出，近年來，華北電力大學在科技部、大陸國家自然科學基金委及國內外學者的支持下，在重點平臺建設、基礎研究及國際合作交流等領域都取得了一系列新的突破與進展，在建設新能源電力系統國家重點實驗室、火力發電國家工程技術研究中心等國家級平臺的同時，先後主持了火力發電節能、鍋爐煙氣餘熱利用及新能源電力系統 3 項國家 973 計畫。同時，華北電力大學不斷推進國際化進程，與美、英、法、德、俄、日等 120 余家國際知名大學和研究機構開展了實質性交流與合作。

劉吉臻指出，當前，能源與環境問題面臨著新的挑戰，傳熱作為能源動力系統的基本過程之一，傳熱部件性能的優劣直接影響系統效率、安全性及可靠性。同時，國際學術前沿也需要將熱物理學科和材料學科、化學學科進行交叉。本次國際傳熱研討會圍繞能源動力系統節能、新能源利用系統、核能利用系統中的傳熱問題進行深入研討和交流，是非常必要和及時的。他感謝海內外專家學者對我校的學科建設、教學、科研、國際合作等方面工作的支援，希望進一步加強與我校工程熱物理學科的交流與合作。

彭以祺司長在致辭中代表中國科技部對會議的召開表示祝賀。他指出，中國是以化石能源為主的國家，在全球面臨能源危機和環境問題的今天，節能減排及開發利用新能源具有重要意義。在美國，有 1/3 的能源來自核能、1/3 來自再生能源、1/3 來自化石能源，而中國在

發展的過程，過於偏重石化能源。中國科技部 973 專案面向國家重大需求及國際學科前沿，對能源動力系統節能進行許多分項研究，如由華北電力大學徐進良教授主持的“鍋爐低溫煙氣餘熱深度利用的基礎研究”計畫針對電站鍋爐和工業鍋爐餘熱利用，就是其中的代表。他指出，本次會議的召開，是專家學者交流探討研究成果與心得、從不同層面展示研究成果的平臺，也是一次檢驗我國科學家研究成果和水準的良好契機，這也為進一步拓展我國科學家的學術思路和視野、進一步開展能源領域的國際合作，創造了條件。

劉濤主任代表自然科學基金委對會議的召開表示祝賀。他指出，能源和能源利用效率是世界各國共同關注的領域，有效解決能源短缺問題、提升環境品質，需要科學家們開展前沿研究，開展傳熱領域的前沿性研究具有重要意義。此次會議的召開，進一步促進國內外專家學者在傳熱領域的交流與合作。

清華大學張興教授指出，能源短缺和環境問題是當前人類社會亟待解決的問題，通過此次會議的召開，有助於推動傳熱等相關學科基礎科學問題的重視。他指出，清華大學與華北電力大學在能源動力領域有著長期的合作關係，在合作過程中取得了顯著成績，期待通過此次會議進一步促進兩校之間、以及中外高校之間的交流與合作。

閻玉英教授在致辭中代表英國諾丁漢大學對會議的舉辦表示祝賀，並對到場的海內外專家學者表示感謝。他介紹了諾丁漢大學，諾丁漢大學是英國重點大學，也是世界著名能源方面的高等教育學校，分別在中國寧波和馬來西亞吉隆玻設有分校。本次會議是華北電力大學與諾丁漢大學的合作成果之一。16 個國家和地區的近 400 名能源領域的專家學者參加了會議，7 篇 Plenary speeches，14 篇 Keynote speeches，以及 286 篇 Oral presentations，總計 307 篇論文在國際熱傳會議被發表，部分會議論文將推薦到 Applied Thermal Engineering, International Journal of Multiphase Flow, Journal of Bonics Engineering 等國際知名雜誌。

本人很榮幸受邀主持的第三場次新能源議題，會中受益良多，在論文發表的過程，許多學者在新能源科技中發表了驚人的成果，可以做為本所發展重要的參考方向。發表論文中有數篇與核研所發展息息相關值得關注的，有太陽能傳熱、太陽能儲熱、奈米鍍膜、熱傳遞姓能增強、熱管技術與模擬等，本人提出以下數篇論文於本文中分享，如:

1. 來自英國的學者 David A. McNeil，發表 The effect of substrate on boiling data on mini-pin-fin heat sinks，研究特別指出微型針柱對沸騰研究的影響，實驗利用 5 毫米厚 50mm 正方的鋁質底板，於其上直列排列為 2 毫米的間距，1 毫米的橫截面和 1 毫米的高度的散熱銅柱。利用流體 R113 和水在常壓下測試沸騰的數據。研究指出對於沸騰流動的水的數據具有一些限制效應，R113 的數據則沒有。這些分析表明，施加均勻的熱流到散熱器在固–液界面不會導致均勻的熱通量。實驗亦對鋁壁的厚度和熱導率的影響進行了探討，建立時將發生在一個沸騰流的均勻的熱通量。這個研究對核研所未來在設計沸騰傳熱增強結構時，提供一個很好的參考數據。

2. 美國加州南卡大學的 Dr. Chen Li 發表 Toward Sophisticated Controls of Flow Boiling in Microchannels at Micro/Nanoscale，流動沸騰(flow boiling)是一種最有效的熱傳遞方式，並廣泛應用在能源轉換，熱管理和流體控制。通過汽化潛熱，展現超高傳熱係數與超高熱通量，這可以大大降低泵浦功率，在微型沸騰的裝置中具有很大的潛力。然而，在微型流動沸騰中卻有幾個嚴格的限制，如 bubble confinements, viscosity and surface tension force-dominated flows。這些限制會導致不可預知的流動模式的轉換，往往引起嚴重的流動沸騰不穩定性和抑制蒸發和對流。這個研究利用三種新型微/奈米熱流體來解決的微通道中流動沸騰的問題。本技術直接針對氣泡動力學、流場結構和流況管理，做設計與分析，這三種新方法都可以大大提高熱傳係數，增大最高熱傳量與強化沸騰的穩定性，更樣重要的是，可以大大降低管路的壓力降，實屬很好傳熱的設計參考依據。

3. 來自葡萄牙 University of Lisbon 的教授 A. S. Moita 發表 Heat and Mass Transfer at interfaces between solid surfaces and Non-Newtonian Fluids，對特殊的非牛頓型流體做分析，非牛頓液滴的動態行為可以顯著不同於牛頓型流體。許多實際應用需要的液滴/壁相互作用來建立精確的模型，儘管液滴動力學進行研究了一個多世紀，大多數研究能在牛頓流體中進行。對非牛頓流體液滴中的基本的特性知識是相對要少得多。了解這些基礎知識對未來創新系統工作中流體的採用是很重要的依據。例如，利用非牛頓液滴小區的印刷方法，可以將類似的噴墨印刷的技術搭配流體，可建立活細胞組織，神經細胞上，進而發展各種可能的器官。在不同的研究背景下，非牛頓流體有很大的發展潛力。

A. S. Moita 教授在非牛頓滴/壁相互作用產生的流體動力學和傳熱機理進行了綜述。對構模型和關於參數的幾種方法進行了幾種討論和替代方法來模擬非牛頓型液滴，演說中強調的是過微非牛頓液滴和奈米增強的表面的相互作用，作分對各種噴塗、鍍膜、微奈米結構的設計與製造，在未來新穎的開創都有很大的幫助。

4. 來自英國的 Dongsheng Wen 教授，發表一篇 Nanomaterial transport for hydrocarbon exploration and production，演說中講述隨著新的合成技術，表面改質和建模能力迅速發展，奈米技術已經進入許多的傳統行業。奈米技術特別在石油和天然氣行業被廣泛的應用，從奈米結構功能表面的防污/耐磨/耐腐蝕/侵蝕的特性，可以有效改善鑽井和儲層診斷。適當設計的奈米粒子的地下勘探和石油生產也具有很大的潛力。這個演說主要正在進行的調查一種開發的奈米材料，可以利用奈米粒子偵測目標位置和/或記錄其軌跡的條件，同時通過注射奈米顆粒改善岩石潤濕性來提高石油採收率，對油/氣界面性能亦能有效的控制。這是一個正要開始發展的新領域研究，大多是在實驗室模擬與推測。在石化能源危機的年代，這個研究是值得核研關注的項目之一。

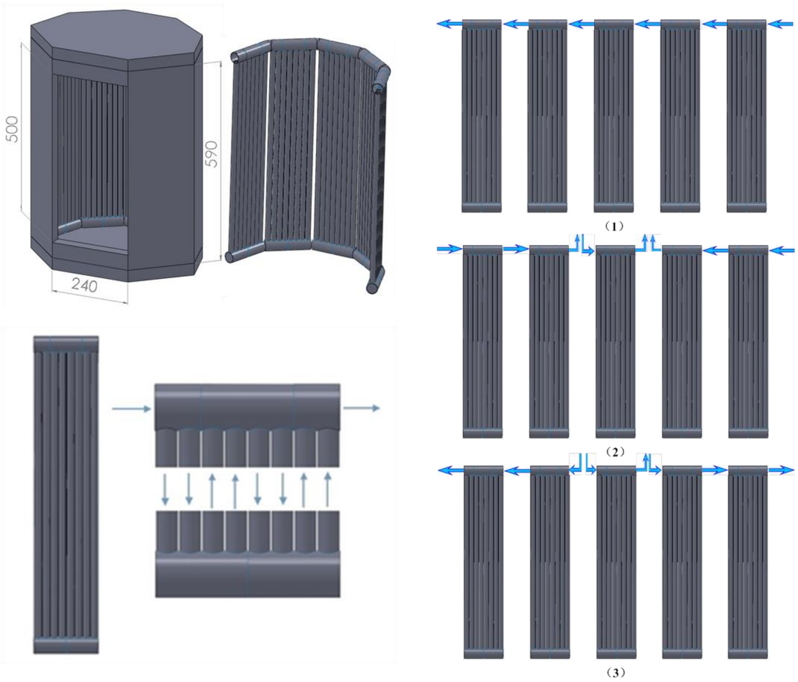
5. 來自法國的 Vishwas V. Wadekar 博士，發表 Industrial Vaporizers – Some Examples of Fascinating Research and Demanding Applications，這個研究提出在工業沸騰的領域，提出各式工業用於製造蒸汽的方法與目的的各類鍋爐、再沸器和蒸發器。儘管大多數的熱交換器都是使用管狀的流路，但是是在工業過程中也有一些特別使用非圓形的通道。非圓形通道的熱交換器比管狀熱交換器具有更小的液壓直徑。一般管狀換熱器中，管的直徑可以從直徑 50 至 150 毫米不等，非圓形通道擁有較小的直徑(15～30 毫米)。這種水力直徑為非圓形的通道可以製造 5 毫米的板式熱交換器或 2 毫米的板式鰭片熱交換器。作者也探討水力直徑對流動沸騰熱交換和壓降特性的影響，這在學術和工業的角度都是很重要議題。Vishwas V. Wadekar 博士將注意力集中在液壓直徑範圍 2 到 25 毫米的熱交換器，也就是處理工業用再沸器的範圍，採用圓形和非圓形的流動通道。說明了再沸器其獨特的功能和不同的實際應用。因為它們的高密度區域和多流能力的許多優點。經過一個有點複雜，但有趣的流體重新配置的結構，有效提供了增加的汽化所得的流動截面積。

影響汽化熱和水力特性的一個主要因素是夾帶在環形流動區域的程度，與較大的通道能夠支持更高的液體夾帶。夾帶的程度對臨界熱通量和測得接近燒乾時的壓力梯度有直接的影響。作者除了討論一些的流動沸騰壓降數據，另外提出一些有趣的研究測量例子，一系列對傳熱和兩相流壓降的實驗結果表示，最終在接近燒乾時的狀態，可以有非常高的性能產生，這在熱回收應用或高性能的熱交換器中有指標性的意義與重要性。

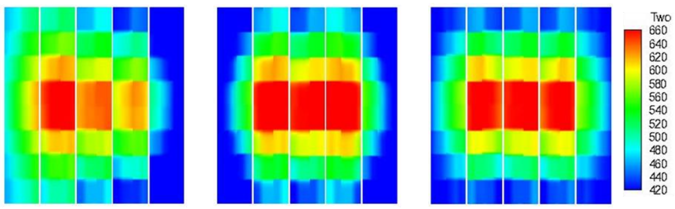
6. 來自日本的 Nagasaki University 的 Tomohiko Yamaguchi 博士，發表 Lattice Boltzmann simulation of liquid-gas two-phase flow with large density difference in complex boundary，Tomohiko Yamaguchi 博士講到熱管是一種實用並可以快速傳導熱的裝置。例如，在筆記型電腦中，可以以有效地傳導並冷卻晶片的溫度，使其工作穩定。有效的熱管理在電動車中顯得格外重要。熱管是一種有用的工具，在電動車上可以對熱源有效的管理與控制。如果我們希望提高熱管的性能，在熱管中毛細結構中的汽液二相流的模擬和知識就非常重要，因為毛細結構決定了熱管的性能。從 20 世紀 90 年代以來流體在多孔介質中的數值模擬大多利用 Lattice Boltzmann Method (LBM)的手法來模擬，因為 LBM 是流體動力學，適用於複雜邊界的結構，適合應用在多孔介質中的數值方法。而現代的 Inamuro 模型（2004 年出版）可以模擬具有大的密度差的現象，例如飽和蒸汽和液體在熱管的二相流分析。Tomohiko Yamaguchi 博士對流體在多孔介質中的數值模擬分析做了一些改進與分析，這個結果有助於推動熱管的發展與設計，對核研在熱管的開發上具有相當的助益。

7. Prof Li 等人發表 Thermal performance of a molten salt cavity receiver，文中中提到的熔鹽接收器是一種太陽熱能接收器，其中，所述熔融鹽為工作流體用來吸收集中的太陽輻射，並輸送到渦輪發電裝置。這篇研究的接收器的幾何形狀參考以在運行的美國 Sandia 國家實驗室的接收器中的熔融鹽電試驗（MSEE）為標準，研究先行計算接收器效率接近 Sandia 國家實驗室公布的實驗數據，再進一步計算自己設計的模型，如圖一所示。熔鹽接收器其熱傳性能可直接影響到整個太陽能發電系統的熱效率。透過設計熱交換吸收面管路壁上吸收的聚焦的熱能，以非常高的熱通量並通過強制對流將能量傳送到熔融鹽。由於太陽輻射熱通量並不是均勻分佈在接收器壁上，因此在研究中，學者將熔融鹽接收器的設計和它的熱性能進行了數值組合的計算模型來分析。研究的分析選擇以 3 種流動方向的

計算結果相互進行比較。分析中在第二種方法(流體向中心位子集中)具有最高的效率與最佳的均溫效果，如圖二所示，此三種模擬的模式效能都遠高於目前正在運行的裝置，熱損失都非常低，此設計在未來核研所如欲發展太陽熱能融鹽發電為一相當好的設計參考。

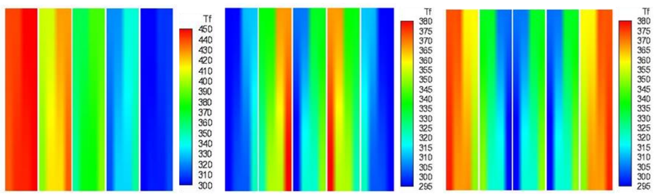


圖一、熔鹽接收器與其流動運行示意圖，含三種操作模式



（1）（2）（3）

熱交換吸收面管路壁上溫度分布



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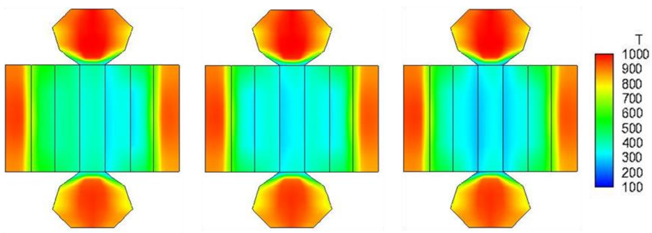
管內熔鹽流體溫度分布

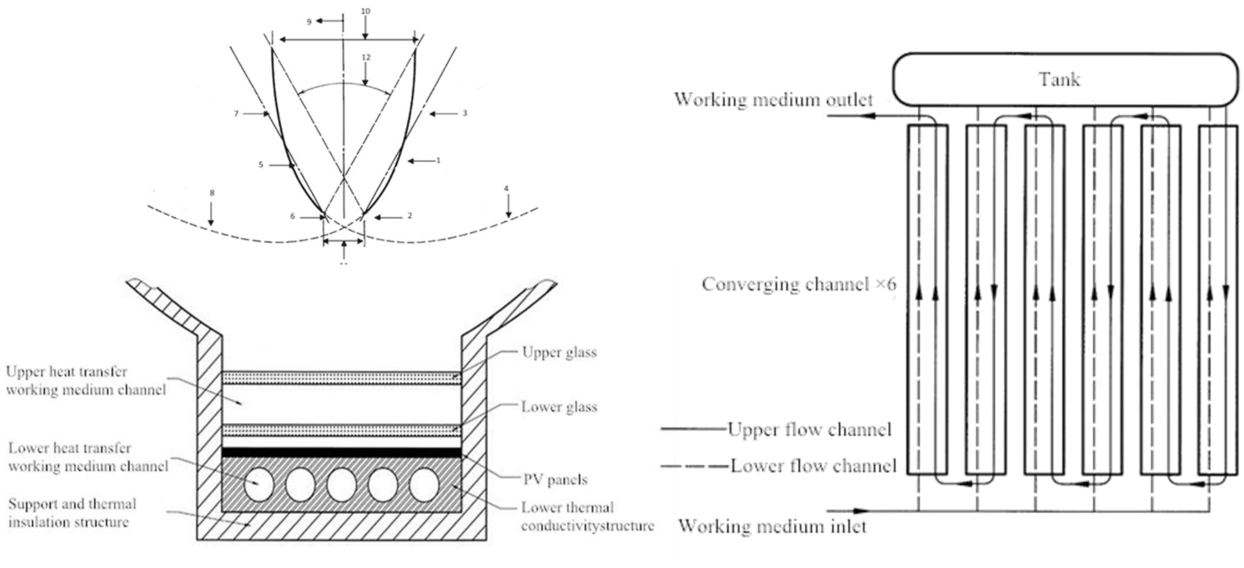


(1) (2) (3)

熔鹽接收器孔穴溫度分布

圖二、熔鹽接收器吸收面、熔鹽流體與孔穴溫度分布模擬示意圖

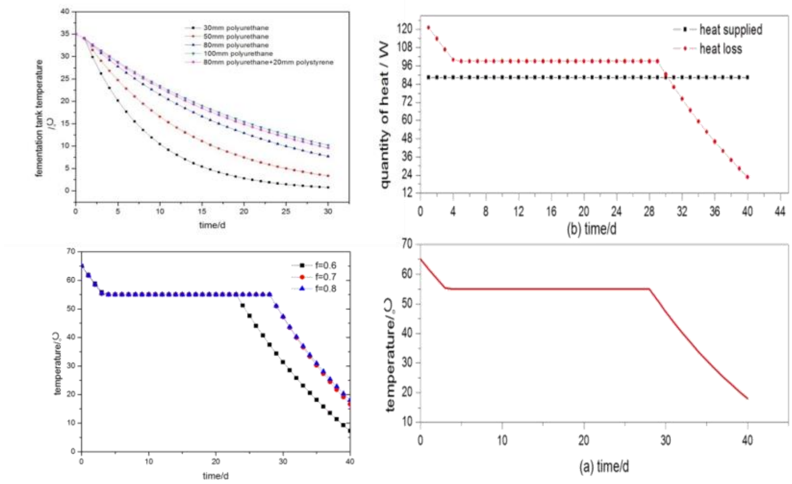
8. Prof Chen 等人發表新型的 CPC 高深度聚焦太陽能熱電共生系統，報告中提出的共生系統結合了太陽光電與熱能，使太陽能光電板在發電之餘，亦可以有熱能的輸出，而太陽能光電板上熱能的移除更有助於穩定太陽能光電的發電效率，報到提到此新型的太陽能熱電共生系統分析了熱電效率、太陽能吸收率、放射率、溫度分布和冷卻水流量。報告中講述在論文中，利用熱力分析模式建立了電效率、太陽熱效率和整體效率的分析模型。在分析中發現溫度對電效率的影響非常大，當溫升時電效率隨即下降，故增加冷卻水的流速可以穩定發電效率，研究的分析指出這個系統的能量利用效率經設計後可以高於 70 %，且熱水通過本系統所產生的溫度可以達到約 90℃的輸出，其設計示意圖如圖三所示。這個研究與本所發展 PV 太陽能、高聚光太陽能、太陽熱能等研究高度相關，像是一個整合性的研究方向，整合了高發電與高熱利用的裝置，此裝置在太陽照射下不僅能有很好的穩定電力輸出效果，也可以供應高溫的熱水，此裝置值得所內思考未來技術整合的方向。



圖三、新型的 CPC 高深度聚焦太陽能熱電共生系統

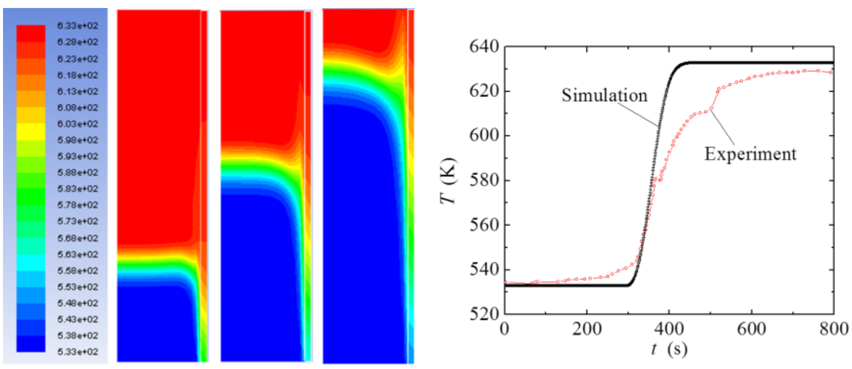
9. Prof Tian 發表太陽熱能經相變儲熱材料來加熱沼氣發酵系統，在演說中，一個太陽能加熱沼氣發酵系統的相變儲熱裝置被引入用於改善傳統沼氣技術在冬天的生產效率。此研究的理論可分成兩個部分。其中重點在分析下不同類型的保溫材料有多種厚度的一個典型的沼氣系統的厭氧發酵罐自然冷卻散熱性能。另一個部分從理論上研究自太陽熱能收

集到的熱量和相變材料儲熱之間的合理比例。數值計算熱力學結果表明，與 3 m^3 石蠟作為相變儲熱材料在太陽能保證率(solar fraction) 0.8 的情況下匹配 20 m^2 太陽能收集區域可以在中國東南部的農村地區冬季提供每天 5 立方米的沼氣系統的熱能需求。這是太陽熱能貼近民生很實際的應用面，很值得所內在熱能產業會的應用參考。



圖三、不同絕緣厚度、不同太陽能保證率與可提供熱源溫度與損失實驗與模擬數據

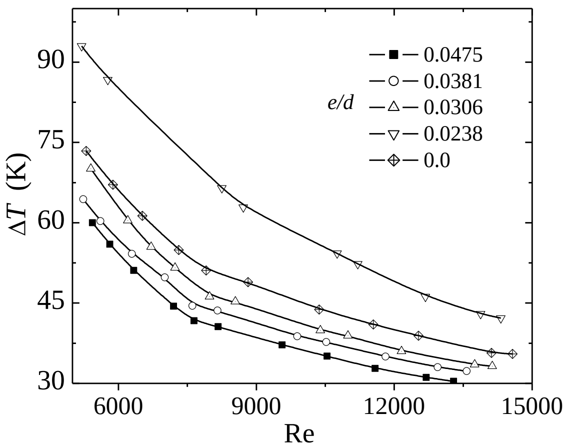
10. Prof Yu 發表在熔鹽儲熱系統中非均質熱傳性能，研究著重在熔鹽儲熱系統的行為模擬，以瞬態和二維模型來研究儲熱量充放過程，最後由實驗結果來驗證。報告中描述設計的熔鹽系統，箱邊界的自然對流，溫躍層在充熱過程中的溫度分佈是很不均勻的，並且溫躍層厚度隨從軸線到該邊界不斷增加。在溫躍層的高溫區域，溫度從軸線到該邊界逐漸減小。在溫躍層的低溫區域中，溫度從軸線到該邊界大多減小。實驗結果進一步顯示，放熱效率隨入口流速上升而降低，而放熱時間亦顯著降低。此研究對本所在儲熱的研究上，可以做為設計很好的參考依據。熔鹽溫度變化與實驗比對數據如圖四所示。



圖四、熔鹽溫度變化模擬與實驗比對數據

11. Lu 等人利用螺旋槽管強化熔鹽接收器的傳熱性能，接收器內的螺旋槽管可以有效增進熔鹽的熱對流可明顯提高熱吸收效果。吸收效率隨流速和槽的高度，而壁溫度下降。槽的高度增加，對流和輻射的熱損失都有明顯的降低，同時提高整個接收器的平均吸收效率。圖五為螺旋管不同的相對粗糙度顯現不同的溫度與雷諾數，與傳統光滑管的熱接收器相比，具有螺旋槽管接收器的所吸收的能量功率可以明顯地上升，這個研究所內在開發逆流熱虹吸、熔鹽儲熱技術等對傳熱管內部的熱增強有很好的參考價值，是未來熱能吸收利用發展的一個重要設計依據。

12. Prof Gao 描述現在能源利用的現狀，並說明太陽能開發和利用的必要性。他介紹了太陽能在建築中的應用，並指出了太陽能應用在建築的不足。它還分析了太陽能利用的發展趨勢，指出太陽能的未來發展前景，目前所內亦積極佈署開發太陽能在住商節能的應用，此篇文章不只是學術分析，對所內亦是一個鼓勵，顯示所內住商節能發展的前瞻性。



圖五為螺旋管不同的相對粗糙度顯現不同的溫度與雷諾數

本次會議因擔任新能源場次主持人，故無法廣泛涉獵每一個議題，再加上會議發表論文高達 280 篇，無法盡收眼底，實為可惜，本次報告節錄數篇在新能源值得關注的報告，當然還有許多很好的研究，收錄在會議論文當中，此論文資料對所內在熱能的開發上，能有許多實質的幫助，許多實驗的數據與模擬分析的結果也提供許多設計的參考。當然不只是國外其他研究單位的研究出色，核研所的研究在新能源的議題中亦引發熱烈的討論。這次在會議中央大學楊建裕教授與交大王啟川博士都希望在回國後，核能研究所的團隊有機會可以前往他們各自的實驗室參訪，未來在節能領域有機會可以建立一些合作與共同開發的契機。

四、建　議　事　項

1. 本次會議中 Prof. Chen 等人發表的新型的 CPC 高深度聚焦太陽能熱電共生系統，值得核研所在熱能擷取與應用研究開發上持續追蹤。
2. 英國的學者 Prof. David A. McNeil 的微型針柱沸騰研究，可有效增強核研所開發傳熱裝置的性能，可應用於本所自行開發逆流熱虹吸裝置之性能增強。
3. Prof. Lu 等人利用螺旋槽管強化熔鹽接收器的傳熱性能，亦是核研所開發熔鹽儲熱上一個重要的參考依據，值得核研所在熱能儲存設計上開發雷同的設計。
4. 法國的 Vishwas V. Wadekar 博士提出了許多工業鍋爐節能與熱交換器的設計，適合作為核研在發展工業節能上仿效的目標，應持續追蹤國外先進的設計開發。

附錄 1、

會議議程詳細資料 (Preliminary program _V1)

International Heat Transfer Symposium 2014

Beijing, China

May 6 - 9, 2014

Contents

Short description of IHTS 2014

Supported by the National Natural Science Foundation of China (NSFC), and the Royal Society of UK, Ministry of Science and Technology of the People's Republic of China, the Program of Introducing Talents of Discipline to Universities (111 Project, B12034), the International Heat Transfer Symposium is held in North China Electric Power University, Beijing, China from 6 to 9 May, 2014. The symposium aims to bring together leading academic scientists, researchers and scholars from all over the world to exchange and share their experiences and research results about heat transfer and the related applications, and discuss practical challenges encountered and solutions adopted. The following topics are covered:

Micro/Nano scale heat transfer: Targeted for the performance improvement of high power density energy saving devices/systems such as light-emitting diodes (LED) and other miniaturized systems, subtopics include single-phase, multi-phase (boiling and condensation) heat transfer in micro/nano scale, radiation heat transfer in micro/nano scale, fundamental micro/nano scale heat transfer, novel heat transfer devices, experiments and numerical simulations of micro/nano flow and heat transfer, nature-induced heat transfer phenomena and applications, etc.

Heat transfer in energy and power systems: Targeted for the increment of the energy utilization efficiency, subtopics include flow and heat transfer issues in various heat exchangers, heat transfer enhancement, heat transfer coupling with material corrosion and chemical reactions, heat transfer for low grade energy utilization, heat transfer in chemical and nuclear reactor systems, etc.

Heat transfer in renewable energy utilizations: Targeted for the efficiency, safety and investment cost improvement, subtopics include flow and heat transfer in solar receivers, heat transfer in solar thermal-chemical reactors, various heat exchangers for renewable energy utilizations, coupled radiation and convective heat transfer, experiments and numerical simulations of heat transfer in renewable energy systems, etc.

The detailed program can be seen from the following executive program

Preliminary executive program of IHTS 2014

May 6 (Tuesday)	10:00-24:00	Registration		Lobby
	17:45-19:30	Reception		Coffee House
May 7 (Wednesday)	7:30-8:30	Registration		Lobby
	8:30-9:10	Opening ceremony		Beijing Hall
	9:10-9:30	Photo-taking		Hotel Entrance
	9:30-10:05	Plenary 1: Pool boiling on multiscale surface features by Prof. Satish Kandlikar; Chaired by Prof. Yuying Yan		Beijing Hall
	10:05-10:30	*Coffee break*		Outside Beijing Hall
	10:30-11:05	Plenary 2: Size effects on thermophysical properties of nanomaterials by Prof. Xing Zhang; Chaired by Prof. Yuying Yan		Beijing Hall
	11:05-11:40	Plenary 3: Micro to macroscale phase change heat transfer by the phase separation concept by Prof. Jinliang Xu; Chaired by Prof. Yuying Yan		Beijing Hall
	11:40-11:50	Introduction of Mechanical Engineering: Fluids and Thermal Journal in Elsevier, by Ms. Betty Chang		Beijing Hall
	11:50-13:00	*Lunch*		Coffee House
	13:00-15:20	Session 1	Electronic cooling I	Beijing Hall A
		Session 2	Heat exchanger I	Beijing Hall B
		Session 3	Renewable energy I	Beijing Hall C
		Session 4	Microfluidics I	Kunming Hall
		Session 5	Droplet dynamics	Nanjing Hall
		Session 6	Nanofluids	Chongqing Hall

		Session 7	Bubble dynamics	Hangzhou Hall
	15:20-15:40	*Coffee break*		Outside Beijing Hall
	15:40-17:40	Session 8	Electronic cooling II	Beijing Hall A
		Session 9	Heat exchanger II	Beijing Hall B
		Session 10	Renewable energy II	Beijing Hall C
		Session 11	Microfluidics II	Kunming Hall
		Session 12	Waste heat utilization	Nanjing Hall
		Session 13	Air-conditioning	Chongqing Hall
		Session 14	Power Plant	Hangzhou Hall
	18:00-20:00	*Welcome Banquet*		Coffee House
May 8 (Thursday)	8:30-9:10	Plenary 4: Fundamental investigation of droplets evaporation: experiments and theory by Prof. Khellil Sefiane; Chair: pending		Beijing Hall
	9:10-9:50	Plenary 5: Study on heat transfer enhancement of refrigerant phase change exchangers by Prof. Wenquan Tao; Chair: pending		Beijing Hall
	9:50-10:10	*Coffee break*		Beijing Hall
	10:10-10:50	Plenary 6: Microfluidics and lab-on-chip technology by Prof. Dongqing Li; Chair: pending		Outside Beijing Hall
	10:50-11:30	Plenary 7: Natural solutions help improve heat transfer by Prof. Yuying Yan; Chair: pending		Beijing Hall
	11:30-13:00	*Lunch*		Coffee House
	13:00-15:20	Session 15	Pipeline and heat pump	Beijing Hall A
		Session 16	Supercritical fluids	Beijing Hall B
		Session 17	Chemical reactions	Beijing Hall C
		Session 18	Bioengineering	Kunming Hall

		Session 19	Molten salt and phase change material	Nanjing Hall
		Session 20	Numerical technique	Chongqing Hall
		Session 21	Nuclear energy I	Hangzhou Hall
	15:20-15:40	*Coffee break*		Outside Beijing Hall
	15:40-17:40	Session 22	Porous media and thermal radiation	Beijing Hall A
		Session 23	Thermal conduction	Beijing Hall B
		Session 24	Heat pipe	Beijing Hall C
		Session 25	Aerodynamics and astronautics	Kunming Hall
		Session 26	Thermal radiation	Nanjing Hall
		Session 27	Jet flow	Chongqing Hall
		Session 28	Nuclear energy II	Hangzhou Hall
	18:00-20:00	*Dinner*		Coffee House
May 9 (Friday)	8:30-17:30	*Lab tour and farewell*		

Session 1: Electronic cooling I, Beijing Hall A, Chairs: Prof. Qiuwang Wang and Prof. Maoqiong Gong			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 1	D. A. McNeil	The effect of substrate on boiling data on mini-pin-fin heat sinks
13:20-13:32	IHTS140042	U. Pasquier, Q. W. Wang, T. Ma, et al.	CFD simulation of fluid flow distribution inside Printed Circuit Heat Exchanger headers
13:32-13:44	IHTS140064	Y. B. Li, S. C. Yao	Porous Media Modeling of Micro-channel Cooled Electronic Chips with Non-uniform Heating
13:44-13:56	IHTS140099	P. Zhang, M. Cai, X. P. Chen, et al.	Enhanced thermal performance of 100 Watt high-power LEDs array using vapor chamber-based plate
13:56-14:08	IHTS140163	T. Hirokawa, M. Murozono, Y. Shinmoto, et al.	Heat Transfer Characteristics Due to Evaporation of Shear-driven Liquid Film Flow
14:08-14:20	IHTS140175	H. K. Ma, Y. S. Li	Investigation of a D-MPMF on LED lighting Thermal Management
14:20-14:32	IHTS140206	Z. Xu, B. X. Li, Y. N. Zhang, et al.	Study of heat dissipation performance for different structural novel heat sinks
14:32-14:44	IHTS140218	Z. S. Deng, S. F. Mei, Y. X. Zhou, et al.	Capability study on hybrid mini/micro-channel heat sink based on liquid metal and water
14:44-14:56	IHTS140221	H.B. Xu, C. C. Qian, S.Q. Shao, et al.	Experimental investigation on heat transfer of spray cooling with R134a
14:56-15:08	IHTS140285	Y. Tang, X. R. Ding, Y. J. Li, et al.	The application of heat pipe heat sink for high power LED lamps
15:08-15:20	IHTS140331	M. Rajagopal, K. G	Simulation of fluid flow and heat transfer characteristics in a micro-channel heat sink

Session 2: Heat exchanger I, Beijing Hall B, Chairs: Prof. Chichuan Wang and Prof. Guihua Tang			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 2	B. Sunden	On computational opportunities in processes of relevance in energy systems
13:20-13:32	IHTS140052	C. C. Wang, K.Y. Chen, J.S. Liaw, et al.	Investigation of the semi-dimple vortex generator applicable to fin-and-tube heat exchangers
13:32-13:44	IHTS140068	G. H. Tang, Y.C. Wang	Numerical study of the acid condensation and heat transfer characteristics on H-type fin surface with dimples and longitudinal vortex generators

13:44-13:56	IHTS140071	M. C. Guo, Y. Ma, A.S. Li, et al.	Numerical simulation of steam condensation heat transfer in a direct air-cooled tube
13:56-14:08	IHTS140092	Y. T. Wu, C. Wang, B.Liu, et al.	Numerical simulation on Hitec salt mixed convection with heat wall conduction in horizontal square tube
14:08-14:20	IHTS140130	H. LI, S. Bian, T. Wu, et al.	Heat transfer characteristics of R113 refrigerant flowing through outward convex corrugated tubes
14:20-14:32	IHTS140141	B. X. Li, H. Z. Han, W. Shao.	Experimental research of heat transfer performance in a corrugated tube heat exchanger
14:32-14:44	IHTS140156	C. Y. Yang, Y. H. Lin, G. C. Li	An experimental observation of the effect of flow direction for the evaporation heat transfer in plate heat exchanger
14:44-14:56	IHTS140166	Y. F. Gao, J. J. Liu, J. W. Wu	Simulation analysis of soil' influence on heat transfer performance of direct exchange ground heat exchanger
14:56-15:08	IHTS140167	Y. Q. Feng, Y. N. Zhang, B. X. Li, et al.	Heat transfer characteristics and parametric optimization of outward convex corrugated tubes
15:08-15:20	IHTS140199	J. H. Zhang, L. Y. Zhang, T. Zhang et al.	Fouling detection in heat exchanger using a bilinear model-based parameter estimation method

Session 3: Renewable energy I; Beijing Hall C, Chairs: Prof. Jinjia Wei and Prof. Mengchang Tsai			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 3	B. Yu	Fast thermal simulation of a heated crude oil pipeline with a BFC-based POD reduced-order model
13:20-13:32	IHTS140024	J. J. Wei, L. Zhang	Thermal performance of a molten salt cavity receiver
13:32-13:44	IHTS140025	H. P. Chen, R .Ma, X.L. Li, et al.	Research on thermoelectric properties of concentrating PV / T cogeneration system
13:44-13:56	IHTS140066	Y. Lu, Y. Tian, H. W. Lu, et al.	Study of solar heating biogas fermentation system with a phase change thermal storage device
13:56-14:08	IHTS140117	J. F. Lu, T. Yu, J. Ding	Nonuniform heat transfer performances of molten salt thermocline storage system
14:08-14:20	IHTS140118	J. F. Lu, J. Ding, J. P. Yang	Enhanced heat transfer performances of molten salt receiver with spirally grooved pipe
14:20-14:32	IHTS140171	Z. Z. Zhao, Y. F. Gao	Introduction to solar energy application in building
14:32-14:44	IHTS140286	L. Xiang, Y. Lin, P. Hao, et al.	Thermal analysis of a flat heat pipe receiver in solar power tower plant
14:44-14:56	IHTS140287	M. C. Tsai, S. W. Kang, H. Y. Li, et al.	Experimental study of constant pressure two phase thermosyphon with a thermoelectric generator
14:56-15:08	IHTS140288	M. C. Tsai, S. W. Kang, H. Y. Li, et al.	Experimental study of cyclical two-phase reverse loop thermosyphon
15:08-15:20	IHTS140402	S. F. Wang, Q. B. He, S. F. Wang	Experimental investigation on the efficiency of flat-plate solar collectors with nanofluids

Session 4: Microfluidics I, Kunming Hall, Chairs: Prof. Chen Li and Prof. Xuehu Ma			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 4	C. LI	Toward sophisticated controls of flow boiling in microchannels at micro/nanoscale
13:20-13:32	IHTS140039	P. Zhang, X. Xiao, M. Li	Numerical and experimental investigation on melting characteristics of eutectic salts with free surface
13:32-13:44	IHTS140081	Y. Liu, J. Wang	Heat transfer simulation of a fresh-fuel transport cask
13:44-13:56	IHTS140110	H. Wang, X. W. Wang	Nucleate boiling on a micro wire coated with superhydrophobic micropatterns
13:56-14:08	IHTS140125	D. Zhang, L. W. Yu, B. C. Zhao, et al.	A model for bubble growth in flash boiling
14:08-14:20	IHTS140252	Y. D. Yu, Z. Yang, Y. Y. Duan	Flow resistance of fouling layer components on micro-filtration membranes
14:20-14:32	IHTS140292	Z. J. Yu, S. P. Song, Z.Liu	Convective heat transfer of water in micro-tubes with super-hydrophobic inner surface
14:32-14:44	IHTS140345	T. T. Zhang, L. Jia, Y. Jaluria	Prediction of inverted velocity profile for gas flow in nanochannel
14:44-14:56	IHTS140363	B. C. Zhang, Qi. L.LI, Y. Wang, et al.	Investigation on single phase friction factor in mini-channel
14:56-15:08	IHTS140370	Q. F. Xia, S. H. Lei, X. C. Yang	Numerical study of mixing in microchannels enhanced by vibrating stirs
15:08-15:20	IHTS140371	C. Li, F. H. Yang	Enhanced flow boiling of HFE-7000 in nano-engineered microchannels

Session 5: Droplet Dynamics, Nanjing Hall, Chairs: Prof. Fei Duan and Dr. A. S. Moita			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 5	A. S. Moita	Heat and mass transfer at interfaces between solid surfaces and Non-Newtonian Fluids
13:20-13:32	IHTS140021	B. Chen, W. M. Wang, P. Wang	Three dimensional numerical simulation of droplet passive breakup in T-shaped micro-fluidic chip using VOF method
13:32-13:44	IHTS140086	D. S. Li, Xi. Q. Qiu, Z. W. Zheng, et al.	Modelling of spray droplet evaporation within a confined space
13:44-13:56	IHTS140098	L. Liu, M. L. Mi, Y. F. Liu	Theoretical investigation of evaporation process of a bicomponent droplet during depressurization
13:56-14:08	IHTS140115	F. Duan, S. Q. Chao, B. He	Evaporation of droplet with and without laser excitation
14:08-14:20	IHTS140126	G. D. Xia, Y. F. Li, J. Wang, et al.	Droplet formation mechanism in the microchannel with different confluence angles
14:20-14:32	IHTS140181	L. J. Wei, Y. Feng, D. Z. Yuan, et al.	Experimental visualization of bubble growth and flow in thermosyphon loop with charge ratios of 90% and 95%
14:32-14:44	IHTS140183	T. T. Fu, Y. G. Ma, H. Z. Li	Breakup dynamics for droplet formation in non-Newtonian fluids in microfluidic cross-junctions

14:44-14:56	IHTS140202	X. H. Ma, R. F. Wen, Z. Lan, et al.	Droplet departure retention for dropwise condensation heat transfer at ultra-lower pressure steam
14:56-15:08	IHTS140248	Y. R. He, H. Wu, H. J. Liu, et al.	Numerical investigation on hydrodynamics in coaxial air-blast atomizers
15:08-15:20	IHTS140378	W. Z. Li, Z. Q. Yu, B. Dong, et al.	An experimental study on the spray characteristics of the air-blast atomizer

Session 6: Nanofluids I, Chongqing Hall, Chairs: Prof. A. S. Lobasov and Prof. Dongsheng Wen			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 6	D.S. Wen	Nanomaterial transport for hydrocarbon exploration and production
13:20-13:32	IHTS140049	B. Sun, D. Yang	The experimental study on the heat transfer and flow characteristics of nano-refrigerants inside a corrugated tube
13:32-13:44	IHTS140072	B. M. Sun, C. J. Sun, J. Z. Jiang	Numerical simulation of enhanced heat transfer characteristics of CuO-water nanofluid
13:44-13:56	IHTS140091	S. Y. Wu, X. Tong, D. Q. Peng, et al.	Simulation of unconstrained melting and freezing of nanoparticle-enhanced phase change material
13:56-14:08	IHTS140111	M. Wang, Y. F. Liu	A study on the preparation of Al2O3/CuO- water nanofluids
14:08-14:20	IHTS140113	S. S. Lu, X. M. Wang, K.X. Chen, et al.	Transport in carbon chains: the electron-phonon interaction effect
14:20-14:32	IHTS140134	W. N. Zhou, Y. Y. Yan, J. Zhu, et al.	LBM modelling of the effects of a magnetic field on nanofluid
14:32-14:44	IHTS140269	S. L. Dong, B. Y. Cao, Z. Y. Guo	Improved models for thermal conductivity of nanofluids
14:44-14:56	IHTS140302	L. P. Shen, H. Wang, M. Dong, et al.	Investigation on the thermal conductivity of transformer oil based alumina/aluminum nitride nanofluids
14:56-15:08	IHTS140304	A.S. Lobasov, A.V. Minakov, D.V. Guzei, et al.	Investigation of heat transfer of CuO-based nanofluids
15:08-15:20	IHTS140351	Y. R. He, Z. G. Yuan, X. Z. Wang, et al.	Rheological behavior of graphene-waternanofluid by a aew synthesis method

Session 7: Bubble Dynamics, Hangzhou Hall, Chairs: Prof. Yoshio Utaka and Prof. Jianfu Zhao			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 7	V. V. Wadekar	Industrial vaporizers – some examples of fascinating research and demanding applications
13:20-13:32	IHTS140417	Y. Utaka, T. Morokuma	Rupture of liquid film formed between approaching twin bubbles in coalescence process
13:32-13:44	IHTS140023	J. F. Zhao, L. Zhang, Z. D. Li, et al.	Influence of heater thermal capability on bubble dynamics and heat transfer in nucleate pool boiling
13:44-13:56	IHTS140028	J. Cai, B. Liu, X. L. Huai	Experimental study on heat transfer with cavitating flow in copper-based microchannels
13:56-14:08	IHTS140038	P. Zhang, H. W. Jia, X. Fu, et al.	Numerical investigation of nucleate boiling of water at a constant surface temperature
14:08-14:20	IHTS140040	G.D. Xia, X. f. Liu, Y. L. Zhai, et al.	Experimental and numerical analysis of the two-phase pressure drop and liquid distribution in single screw expander prototype
14:20-14:32	IHTS140070	B. Shen, B. J. Suroto, S. Hirabayashi, et al.	Observation of periodic bubble nucleation on a hydrophobic spot at negative surface superheats under subcooled conditions
14:32-14:44	IHTS140170	B. Liu, P. Li, T. Wang, et al.	Performance characteristics of micro-channel evaporator usingR404A as refrigerant
14:44-14:56	IHTS140271	J.G. Tang, L.C. Sun, C. Q. Yan, et al.	A Visualized study on the collapse of vapour bubbles in the field of ultrasonic
14:56-15:08	IHTS140276	Z. H. Wang, X. Meng, S. D. Wang, et al.	Experiment study of single bubble motion in a liquid metal with a strong horizontal magnetic field
15:08-15:20	IHTS140382	Y. Wang, Z. G. Wang	Heat transfer analysis of single bubble growth confined in a flat microchannel

Session 8: Electronic cooling II, Beijing Hall A, Chairs: Prof. Xiaodong Wang			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140136	Q. Wang, B. Jiang, B. Li, et al.	Experimental investigation on EV battery internal cooling and heating by heat pipes
15:52-16:04	IHTS140315	D. X. Deng, H. He, H. R. Shao, et al.	Characterization of flow boiling performance of reentrant porous microchannels incorporating the microchannel size effects
16:04-16:16	IHTS140347	X. L. Wei, W. H. Li, X.R. Meng, et al.	Numerical simulations on heat dissipation of heat sink with different installation angles

16:16-16.28	IHTS140348	X. R. Meng, Y. Q. Li, X. L. Ma, et al.	Experimental research on the effect of the installation angle of the high-power LED heat sink
16:28-16:40	IHTS140361	L. Gong, J. Zhao, S. B. Huang, et al.	Numerical study on the effects of micro-channel heat sink layout for electronics cooling
16:40-16:52	IHTS140367	J. J. Zhou, X. L. Li	Numerical simulation for Laptop's cooling based on Icepak
16:52-17:04	IHTS140368	J. J. Zhou, M.X. Wang	Digital design and performance optimization of radiator
17:04-17:16	IHTS140375	B. J. Zhang, J.W. Zhang, J. Zhang, et al.	Numerical simulation of heat-transfer characteristics of heat pipe heat sink used for cooling electronic devices with the non-planar array structure
17:16-17:28	IHTS140416	S. L. Xu, Q. Y. Cai	Analysis and optimization of the thermal performance of multilayer microchannel heat sinks
17:28-17:40	IHTS140046	L. Yang, Y. S. Peng, Y. C. Du, et al.	Mathematical modelling of heat and mass transfer in laminar falling water film with evaporation
17:40-17:52	IHTS140168	H. J. Ban, G. H. Son	Numerical simulation of liquid film evaporation between two circular plates

Session 9: Heat exchanger II, Beijing Hall B, Chairs: Prof. Liangbi Wang			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140228	D. Li, H. B. Qi, G. Z. Wu	Influence of inner metal blinds on heat transfer characteristics of enclosed glass channel
15:52-16:04	IHTS140242	J. X. Wu, Y. F. Li, L. Wang, et al.	Research development of stationary twisted tapes inserts in heat exchangers tubes
16:04-16:16	IHTS140243	J.X. Wu, Y.F. Li, L. Wang et al.	Study on numerical simulation of twisted tape with trapezoidal notch in boiler tube
16:16-16.28	IHTS140250	J. X. Wu, X. Peng, J. F. Li	Analyses on evaluation methods of enhanced heat transfer of heat exchanger
16:28-16:40	IHTS140257	G.B. Zhou, Y. K. Zhang	Numerical simulation on heat transfer characteristic of louver - curved winglet vortex generator fins for parallel flow evaporators
16:40-16:52	IHTS140272	Q. W. Wu, J. J. Zou, J. Q. Zhang, et al.	Performance calculation of a tube bundle air-precooled heat exchanger
16:52-17:04	IHTS140317	W. S. Wang, C. Q. Su, X. Liu, et al.	Simulation and experimental study on thermal optimization of the heat exchanger for automotive exhaust-based thermoelectric generators
17:04-17:16	IHTS140366	J. J. Zhou, B. Q. Sun	Numerical simulation on heat transfer characteristics of finned tube heat exchanger
17:16-17:28	IHTS140385	L. B. Wang, Z. M. Lin, C. P. Liu	Numerical study of flow and heat transfer enhancement of circular tube bank fin heat exchanger with curved delta-winglet vortex generators
17:28-17:40	IHTS140396	X. P. Lu, D. D. Guo	Field synergy and thermodynamic coupling mechanism for convective heat transfer enhancement

Session 10: Renewable energy II, Beijing Hall C, Prof. Qibin Liu,			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140034	C.S. Cao	Modeling and solving on the solar photovoltaic cells paving optimization on buildings
15:52-16:04	IHTS140131	M. Bottarelli, Y. H. Su, C. Yousif, et al.	Numerical analysis of a novel ground-source heat exchanger coupled with phase change materials
16:04-16:16	IHTS140178	H. G. Zhang, S. S. Song,G. Y. Zhao, et al.	The simulation study for natural gas engine using miller cycle
16:16-16.28	IHTS140194	T. S. Zhang, G. Qing, G. H. Wang, et al.	Thermal integration and hydronic heat transfer from BTM to HVAC in electric vehicle
16:28-16:40	IHTS140277	C. W. Wu, Y. C. Yuan	Thermal analysis on film photovoltaic cell subjected to dual laser beam irradiation
16:40-16:52	IHTS140279	W. M. Yan, L.H. Yang, C. Y. Chang	Design of a cooling system for a switched reluctance motor
16:52-17:04	IHTS140280	W. M. Yan, Y. H. Siao, C. M. Lai	Transient characteristics of thermal energy storage in an enclosure packed with MEPCM particles
17:04-17:16	IHTS140289	J. X. Wu, J. F. Li, P. Xu, et al.	Advances in The Tube-buddle Support of The Shell and Tube Heat Exchanger Research
17:16-17:28	IHTS140299	X.Y. Han, J. Qu	CFD to predict temperature profile for scale up of a new linear concentrating photovoltaic receiver
17:28-17:40	IHTS140303	Z. G. Guo, G. Y. Deng, Y. C. Fan, et al.	Optimizing of compressed air energy storage system with ejector pressure regulating method

Session 11:Microfluidics II, Kunming Hall, Chairs: Prof. Huasheng Wang,			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140009	Y. H. Gan, J.L. Xu, Y.Y. Yan	Two-phase pressure drop of acetone due to friction in triangular silicon micro-channels at high vapor quality
15:52-16:04	IHTS140016	L. P. Zhou, Z. C. Zheng, X. Z. Du, et al.	Numerical study on marangoni convection of non-isothermal binary fluids in a closed microcavity
16:04-16:16	IHTS140074	J. J. Yan, J. S. Wang, Y. Li, et al.	Condensation heat transfer of steam on vertical micro-tubes
16:16-16.28	IHTS140077	X. M. Ye, C. X. Li	Spreading of soluble surfactant solutions with evaporation on heated interface
16:28-16:40	IHTS140102	M. C. Zhang, H. X. Liang, B. W. Chen, et al.	Numerical simulation of flow pattern and pressure pulses in direct contact condensation
16:40-16:52	IHTS140135	J. J. Hong, Y. H. Gan, P. Glover, et al.	Experimental measurement on dynamic concentrations of ferrofluid flow with NMR
16:52-17:04	IHTS140222	H. B. Xu, C. C. Qian,S. Q .Shao, et al.	Flow boiling heat transfer of R134a in a single microchannel with cavitation entrance
17:04-17:16	IHTS140403	V. Serdyukov, A. Surtaev, A. Pavlenko	Investigation of the boiling features and crisis phenomena development in subcooled falling liquid films

17:16-17:28	IHTS140420	J. Shen, D. D. Wang, Z. C. Liu, et al.	Numerical simulation on PEMFC performance—the enhancing mass transport theory
17:28-17:40	IHTS140415	Y. W. Lu, W. B. Du , X. L. Li, et al.	The study of natural convection heat transfer of molten salt under the effect of micro-convection from tank wall
17:40-17:52	IHTS140421	H. S. Wang, M. S. Kamran, Y. Li, et al.	Numerical study of a magnetic refrigerator with multi-material microchannel regenerators

Session 12: Waste Heat Utilization, Nanjing Hall, Chairs: Prof. Liang Gong			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140079	J. Q. Dong, B. Wang	Research of diesel engine waste heat ORC system
15:52-16:04	IHTS140096	Y. T. Shi, X. Y. Zhang	Engineering acid dew temperature: the limitation for flue gas heat recovery
16:04-16:16	IHTS140103	P. Liu, F. M. Jiang, J. W. Cen	Techno-economic feasibility of TFE/NMP Chemical Heat Pump for upgrading industrial waste heat
16:16-16.28	IHTS140127	T. Wu, S. Bian, H. Li, et al.	Performance optimization of heat exchanger used in Organic Rankine Cycle by genetic algorithm
16:28-16:40	IHTS140185	X. Wang, G. Q. Shu, H. Tian	Simulation and analysis of a new desalination system driven by the waste heat of charge air of internal combustion engines for ships
16:40-16:52	IHTS140203	Y. T. Wu, B. Lei, Y. W. Lu, et al.	Research on the characteristics of expander output power used for offsetting pumping work in Organic Rankine Cycles
16:52-17:04	IHTS140216	J. H. Zhang, M. M. Lin, F. Shi, et al.	Set point optimization of controlled Organic Rankine Cycle(ORC) Systems
17:04-17:16	IHTS140217	J. H. Zhang, M. F. Ren, M. Jiang, et al.	An approach to control temperature of Organic Rankine Cycle processes
17:16-17:28	IHTS140254	G. Xu, C. X. Zhang, F. F. Liang, et al.	A novel low-temperature flue gas waste heat utilization system for power plants
17:28-17:40	IHTS140335	B. Xue, X. R. Meng, X. L. Wei, et al.	Dynamic study of steam generation from low-grade waste heating a zeolite-water adsorption heat pump
17:40-17:52	IHTS140381	Y. Q. Liu, B. Zheng, R. X. Liu, et al.	Experimental investigation of heat transfer characteristics of calcined petroleum coke waste heat exchanger

Session 13: Air-conditioning, Chongqing Hall, Chairs: Prof. Wenzhong Gao			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140001	L. Z. Zhang, H. X. Fu, Q. R. Yang	Research of diesel engine waste heat ORC system
15:52-16:04	IHTS140088	C. Zhang, Y. Duan, X. H. Liu	Engineering acid dew temperature: the limitation for flue gas heat recovery

16:04-16:16	IHTS140162	Z. T. Yu, F. Y. Tian, G. F. Ye, et al.	Numerical analysis of heat transfer in a vertically-arranged sinter cooler
16:16-16.28	IHTS140180	W. Z. Gao, C. S. li, T. Liu, et al.	Simulation and analysis of a new desalination system driven by the waste heat of charge air of internal combustion engines for ships
16:28-16:40	IHTS140188	Y. B. Zhao, Q. J. Long, F. Z. Sun, et al.	Research on the characteristics of expander output power used for offsetting pumping work in Organic Rankine Cycles
16:40-16:52	IHTS140249	A.M. Omer	Compressors, condensing units, evaporators, heat exchangers, fans and testing equipment
16:52-17:04	IHTS140253	G. Xu, C. Xu，Y. Han, et al.	An approach to control temperature of Organic Rankine Cycle processes
17:04-17:16	IHTS140267	Y. L. Hu, L. J. Fang, R. X. Xue, et al.	A novel low-temperature flue gas waste heat utilization system for power plants
17:16-17:28	IHTS140344	W. K. Zhu, K. Duan, L. Wang, et al.	Dynamics simulation of heat and mass transfer for cut tobacco during multi-stage convective drying
17:28-17:40	IHTS140406	Y. L. Cui, J. Zhu, S. Riffat.	Heat transfer analysis of energy piles
17:40-17:52	IHTS140423	B. Zhou, X. Q. Qian, W. Li, et al.	Numerical study on energy consumption characteristics for different wall structures based on the intermittent energy use characteristics

Session 14: Power plant, Hangzhou Hall, Chairs: Prof. Xiaoze Du,			
Wednesday, May 7, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140075	W. Liu, J.B. Wang, Z.C. Liu	The application of exergy destruction minimization in convective heat transfer optimization
15:52-16:04	IHTS140177	M. Deodat, F. Z. Zhang, R. N. Xu, et al.	Exergy-topological analysis and optimization of a binary power plant utilizing medium-grade geothermal energy
16:04-16:16	IHTS140220	Y.Q. Zhang, G. D. Xia, Y. T. Wu, et al.	Experimental study on influence of vapor dryness on the performance of single-screw expander
16:16-16.28	IHTS140291	W. H. Wang, W. G. Pan, X. P. Wen, et al.	Exergy theory on energy consumption of pulverized power plant boiler heat exchangers
16:28-16:40	IHTS140326	Z. Zhang, H. Yan, C. F. Guan, et al.	Configuration optimization of helical blade rotors in a circular tube to enhance turbulent heat transfer using CFD modeling
16:40-16:52	IHTS140352	P. Fu, N. L. Wang, D. F. Wu, et al.	The performance study of energy-consumption benchmark state in coal-fired units with varying boundary
16:52-17:04	IHTS140353	L.F. Zhu, N. L. Wang, P. Fu, et al.	Method for determining energy-consumption benchmark in the thermal system of coal-fired units based on mixed model
17:04-17:16	IHTS140354	D. F. Wu, N. L. Wang, P. Fu, et al.	Exergetic evaluation of coal-fired power units with two different cooling technologies

17:16-17:28	IHTS140391	P. Gao, Y. P. Yang, K. Zhang, et al.	A rapid and efficient method for determination of pyrolysis temperature of mercury adsorbent
17:28-17:40	IHTS140397	F. M. Chu, N. L. Wang, F. M. Chu, et al.	Multi-factor analysis of condenser vacuum under overall working conditions

Session 15: Pipeline and heat pump, Beijing Hall A, Chairs: Prof. John Chai and Prof. Bo Yu			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 8	John Chai	Oil and gas Industry research: some challenges, selected current research activities and sample opportunities for inter-disciplinary research
13:20-13:32	IHTS140027	Y. Q. Dai, Y. H. Cheng, S. W. Guo, et al.	Numerical analysis of a novel coil wound LNG vaporizer
13:32-13:44	IHTS140031	Z. L. Liu, H. F. Wang, Y. X. Li.	Environment heating effects on the leakage rate of the long-distance gas pipelines
13:44-13:56	IHTS140050	B. Yu, J. Zhang, Y. Wang, et al.	Study on thermal characteristics of fluids in preheating commissioning for waxy crude oil pipelines
13:56-14:08	IHTS140051	B. Yu, Y. Zhao, J. F. Li.	Numerical analysis on the coupled mechanism of water, temperature and stress fields of frozen soil around a buried oil pipeline in cold regions
14:08-14:20	IHTS140192	J.W. Wu, Y. F. Gao, J. J. Liu.	Experimental study of direct expansion GSHP system
14:20-14:32	IHTS140195	Q. Gao, X. Z. Zhou, Y. Jiang, et al.	Status from GWHP to ATES in China and its facing heat transfer problems
14:32-14:44	IHTS140230	Y. K. Lv, T. Wang.	Experiment and numerical simulation of the local loss in axial guide device
14:44-14:56	IHTS140265	J. Li, G. M. He, Y. M. Liu, et al.	Numerical study on performance of a liquid natural gas (LNG) vaporizer tube with internal spiral
14:56-15:08	IHTS140329	L. Gabrielli, M. Bottarelli.	Payoff for geothermal heat pumps using shallow ground heat exchangers
15:08-15:20	IHTS140338	J. D. Ji, P. Q. Ge, D. R. Duan, et al.	Numerical simulation on the heat transfer characteristic in the horizontal spirally coiled tubes

Session 16:Supercritical fluids, Beijing Hall B, Chairs: Prof. Kun Luo and Prof. Youjun Lu			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 9	Y. J. Lu	Two-phase flow and heat transfer in supercritical water fluidized bed
13:20-13:32	IHTS140017	F. Dong, G. L. Hu, C. H. Guo.	Simulation of subcooled boiling heat transfer for internal combustion engines based on eulerianmulti-fluid approach

13:32-13:44	IHTS140036	Y. S. Bi, S. F. Wang, Y. R. Shen, et al.	Hydrodynamic analysis and calculation of metal temperature distribution in spiral water wall of subcritical tower boiler
13:44-13:56	IHTS140037	H. Meng, L. J. Tang, K. K. Xu.	Numerical studies of heat transfer enhancement of cryogenic methane flowing in ribbed cooling tubes at supercritical pressure
13:56-14:08	IHTS140140	J. X. Wu, Y. F. Li, L. Wang, et al.	Numerical simulation and development of the new enhanced heat transfer smoke pipe of the vertical gas-fired boiler
14:08-14:20	IHTS140161	M. Q. Song, T. Zhou, J. J. Li, et al.	Study on supercritical water natural circulation flow instability based on CFD
14:20-14:32	IHTS140224	X. L. Fang, T. Zhou, D. P. Lin.	Numerical simulation of the flow and deposition of fine particles in the supercritical water
14:32-14:44	IHTS140259	W. Li, X. Y. Wu, G. Q. Xu, et al.	Experimental investigation of convection heat transfer of Fe3O4-kerosene at supercritical pressures
14:44-14:56	IHTS140275	T. Zhou, D. P. Lin, J. J. Li, et al.	Research of fine particle thermophoretic deposition in SCWR
14:56-15:08	IHTS140319	Y. Y. Shen, M. Yang, K. Huang, et al.	Numerical simulation of combustion and flow, heat transfer in the ultra-supercritical tower boiler furnace
15:08-15:20	IHTS140355	H. X. Li, Q. Zhang, W. Q. Zhang, et al.	Experimental investigation and mechanism analysis on the heat transfer of supercritical pressure water in a vertically-upward internally-ribbed tube
15:20-15:32	IHTS140419	J. Chen, T. Zhou, Y. Li, et al.	Study on multi-channel transient and security features of Supercritical Water-cooled Reactor

Session 17:Chemical reactions, Beijing Hall C, Chairs: Prof. Hsiaokang Ma			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 11	K. Luo	Direct numerical simulation of turbulent multiphase reacting flows and combustion
13:20-13:32	IHTS140032	M. Xu, X. L. Huai, Y. J. Duan, et al.	Acetone hydrogenation in exothermic reactor of an isopropanol-acetone-hydrogen chemical heat pump: effect of intraparticle mass and heat transfer
13:32-13:44	IHTS140033	M. Xu, X. L. Huai, Y. J. Duan, et al.	CFD study on gas-solid heat transfer in exothermic fixed-bed reactor of an isopropanol-acetone-hydrogen chemical heat pump
13:44-13:56	IHTS140078	G. W. Zhou, W. Q. Zhong, H. C. Zhao, et al.	Heat transfer effects of spent ion exchange resin in iron ore sintering process
13:56-14:08	IHTS140164	Z. Z. Qiu, J. W. Li, R. Yao, et al.	Experiment study on combustion characteristic of liquid fuels in a capillary tube
14:08-14:20	IHTS140174	H. K. Ma, C. P. Lin, H. P. Wu, et al.	Waste heat recovery using a thermoelectric power generation system in a biomass gasifier
14:20-14:32	IHTS140189	I. Javed, S. W. Baek, H. Waheed	Auto ignition and combustion characteristics of kerosene droplets containing dilute concentrations of

			aluminum nanoparticles at elevated temperatures
14:32-14:44	IHTS140232	Y. R. He, H. J. Liu, H. Wu, et al.	Numerical simulation on denitration reaction of uranyl nitrate in a fluidized bed
14:44-14:56	IHTS140305	J. Cao, W. Q. Zhong, B. S. Jin, et al.	Calcined hydrotalcites-like compounds for the removal of HCl in simulated gases of typical compositions at high temperature
14:56-15:08	IHTS140392	Y. M. Wang, W. Z. Wang, G. Q. Shi.	Coupled Multi-stage Oxidation and Thermodynamic Process in Coal-bearing Strata under Spontaneous Combustion Condition
15:08-15:20	IHTS140414	L.J. Liu, X. F. Qi, G. X. Zhong, et al.	Effects of furnace pressure on oxygen and carbon coupled transport in an industrial directional solidification furnace

Session 18: Bioengineering, Kunming Hall, Chairs: Prof. Bin Chen			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 10	B. Chen	Heat transfer model and animal experiment in cutaneous laser surgery
13:20-13:32	IHTS140004	B. Chen, D. Li, G. X. Wang.	Mathematical prediction of cryogen spray cooling in cutaneous laser surgery using realistic boundary conditions
13:32-13:44	IHTS140015	B. Chen, Y. Zhang, G. X. Wang.	A three-dimensional geometric Monte-Carlo method for the simulations of light propagation in bio-tissue
13:44-13:56	IHTS140065	H. Qi, L. M. Ruan, Z. Z. He.	Inverse estimation of the particle size distribution using the Fruit Fly Optimization Algorithm
13:56-14:08	IHTS140089	J. Liu, S. Y. Xu, C. Jin, et al.	3D modeling of the magnetic nanoparticles enhanced radiofrequency ablation of human liver tumors based on real anatomical structures
14:08-14:20	IHTS140296	F. Xu, M. Shi, X. H. Zhang, et al.	Non-Contact Vitrification of Cell-Laden Droplet
14:20-14:32	IHTS140333	J. S. Sun, Z. G. Liu, X. F. Liu, et al.	Reference crop evapotranspiration simulated in sunlight greenhouse based on heat balance
14:32-14:44	IHTS140411	J. F. Lu, Z. S. Deng, H. Zhang, et al.	Design of a mini-fan array using thermal infrared imaging to regulate temperature inside shoes

Session 19:Molten salt and phase change material, Nanjing Hall, Chairs: Prof. Zuankai Wang and Xun Zhu			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 12	Z.K. Wang	Biomimetic surfaces for enhanced phase change phenomena
13:20-13:32	IHTS140018	A. Ghosh.	Applications of weld pool dynamics and gaussian distribution in submerged arc welding
13:32-13:44	IHTS140083	L. J. Guo, P. Xiao, X. M. Zhang.	Investigations on heat transfer characteristic of molten salt flow in helical annular duct
13:44-13:56	IHTS140084	X. Zhu, F. F. Zhang, Y. D. Ding, et al.	Marangoni flow in falling film of ionic liquid-MEA solution on vertically free and confined plates
13:56-14:08	IHTS140097	J. M. Zhou, Y. Li, W. Peng.	The application of transformation method to dynamic measurement of thermal conductivity for Phase Change Materials
14:08-14:20	IHTS140101	X. Zhu, H. Zhang, Y. Tan, et al.	Analogue experiment on centrifugal granulation in the waste heat recovery system for molten slag combining centrifugal granulation and fluidized bed
14:20-14:32	IHTS140137	M. Alsaady, R. Fu, B. Li, et al.	Thermo-physical properties and thermo-magnetic convection of ferrofluid
14:32-14:44	IHTS140143	W. Li, H. X. Li, G. Q. Li, et al.	Numerical-theoretical analysis of cooling tower fouling in internal helically ribbed tubes
14:44-14:56	IHTS140211	H.N. Zhang, S. Q. Shao, H. B. Xu, et al.	Optimization of three-fluid heat exchangers with phase change based on entransy theory
14:56-15:08	IHTS140237	Z.Q. Sun, S. W. Li, Y. Chen.	The melting of phase change material in a cylinder shell with hierarchical heat sink array
15:08-15:20	IHTS140321	G.G. Lin, C. D. Ho, Y. H. Liao.	Heat Transfer in a double-pass parallel-plate device with hybrid boundary condition for the power-law fluid

Session 20: Numerical technique, Chongqing Hall, Chairs: Prof. Yuting Wu			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	Keynote 13	T. Yamaguchi	Lattice Boltzmann simulation of liquid-gas two-phase flow with large density difference in complex boundary
13:20-13:32	IHTS140169	Y. T. Wu, R. P. Zhi, W. Wang, et al.	Influences of the meshing depth coefficient on a main rotor in single screw compressors
13:32-13:44	IHTS140056	H. M. Cui, F. Xu.	3D transient natural convection flows in a triangular cavity
13:44-13:56	IHTS140080	Y. Shi, Y. W. Yap, J. E. Sader.	A linearized Lattice Boltzmann model for micro- and nanoscale thermal flows
13:56-14:08	IHTS140214	D.M. Mo, Y. R. Li, Y. P. Hu.	Application of the implicitly restarted Arnoldi iteration method in flow stability of two-layer system
14:08-14:20	IHTS140261	J. Z. Zhang, L. Tan, X. M. Tan.	Numerical investigation of heat transfer characteristics on a vertical surface with resonating cantilever beam

14:20-14:32	IHTS140300	M. H. Xu, Y. L. Liu, D. X. Liu.	A modification of simple algorithm for incompressible fluid flow
14:32-14:44	IHTS140313	H. Wang, Z. Qian, F. J. Chen.	The development of a 3D/1D transient heat transfer model
14:44-14:56	IHTS140323	G. L. Zhang, M. Yang, F. Karimi.	The numerical simulation of fluid cross from one-cylinder and contrastive analysis of the experimental data
14:56-15:08	IHTS140359	J. Zhang, F. J. Gao, G. D. Jin, et al.	A double-Gaussian FDF model for scalar mixing at sub-grid scales
15:08-15:20	IHTS140364	H. W. Zhao, Y. C. Shao.	A study of particle swarm algorithm based on Multiple Particle Swarm Coevolutionary for multi-objective optimization problem

Session 21:Nuclear energy I ,Hangzhou Hall, Chairs: Prof. Daogang Lu and Zhiguo Qu			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
13:00-13:20	IHTS140069	W. Bai, W. F. Ni, Y. H. Yang.	Heat transfer research of corium by finite element method
13:20-13:32	IHTS140121	W. Q. Zhou, F. L. Niu, J. C. Cai, et al.	The study of mixing and thermal stratification in passive containment
13:32-13:44	IHTS140124	X. Huang, X. F. Lv, L. Chen.	Study on hydrogen risk under severe accident in AP1000 nuclear power plant
13:44-13:56	IHTS140142	H. B. Qi, F. L. Niu, Y. Yu, et al.	The feasibility analysis of underground nuclear power plant based on multiple criteria decision analysis technology
13:56-14:08	IHTS140148	X. B. Li, M. C. Zhang, W. T. Wu, et al.	Numerical investigation on coolant temperature fluctuating in the upper plenum of PWR under different outlet conditions
14:08-14:20	IHTS140149	X. B. Li, M. C. Zhang, W. T. Wu, et al.	Scaling analysis on heat transfer characteristics of residual heat removal exchanger
14:20-14:32	IHTS140200	Y. H. Zhang, D. G. Lu, Z. Du, et al.	Numerical simulation and experimental investigation on two phase natural convection in IRWST of the AP1000 reactor
14:32-14:44	IHTS140204	Y. G. Zhao, F. L. Niu, D. X. Zhang.	Natural convection and oxygen transfer of liquid lead-bismuth eutectic in cylindrical container
14:44-14:56	IHTS140205	C. Guo, D. G. Lu, Q. Cao, et al.	Preliminary development on thermal-hydraulic analysis code for the spent fuel rod under the condition of spray cooling
14:56-15:08	IHTS140215	Y. Liu, D. G. Lu, Y. Yu.	Thermal – hydraulic performance analysis for AP1000 passive residual heat removal system

Session 22: Porous media, Beijing Hall A, Chairs: Prof. Changying Zhao and Prof. Leping Zhou			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140043	Z. G. Qu, A. Li.	Numerical study of film condensation on a metallic foams sintered plate with considering convection and super-cooling effects
15:52-16:04	IHTS140095	C. Y. Zhao, Z. G. Xu.	Nanoparticle deposition effect on pool boiling heat transfer of metal foams
16:04-16:16	IHTS140157	Z.Q. Chen, J. Shi, Q. Ma.	Study on freezing behavior of phase change materials in ice ball with metal foam
16:16-16.28	IHTS140212	Y. P. Chen, C. Q. Chen.	Natural convection of air in fractal porous medium
16:28-16:40	IHTS140247	C.F. Ma, X. Z. Meng, W. B. Kang, et al.	The experimental investigation on thermal characteristics of high porosity metal foams in convective heat transfer
16:40-16:52	IHTS140262	J.Z. Zhang, B. B. Wu.	Numerical study on mixed convective heat transfer inside vertical anisotropic porous annuli locally heated from Inner cylinder
16:52-17:04	IHTS140263	B. Bourdon. R. Rioboo, P. Di Marco., et al.	Wettability influence on the solid superheat at the onset of pool boiling on nanometrically smooth surfaces
17:04-17:16	IHTS140295	S. S. Feng, M. Shi, D. M. Liu, et al.	Unidirectional Freezing of Phase Change Materials Saturated in Open-Celled Metal Foams
17:16-17:28	IHTS140325	L. Zhang, H. Xu, Y. Sun, et al.	Visualization research on flow boiling from microporous surface in mini-/microchannels
17:28-17:40	IHTS140407	L. Zhang, H. Xu, Y. L. Dai, et al.	Influence of surface orientation on the onset of nucleate boiling heat transfer from microporous surface

Session 23: Thermal conduction, Beijing Hall B, chairs: pending			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140002	K. Long, J. Jia.	Hierarchical topology optimization for heat conduction
15:52-16:04	IHTS140010	H. Q. Xie, Z. H. Wu, Y. B. Zhai.	Enhanced thermoelectric figure of merit in Zn0.9Co0.1O alloy with conducting polymer nanoinclusions
16:04-16:16	IHTS140060	S.C. Yu, D. Nanto, J. S. Hwang, et al.	Critical exponents of small doped Germanium in La0.7Ca0.3Mn1-xGexO3 (x = 0.05 and x = 0.07)
16:16-16.28	IHTS140133	H. Q. Xie, J. F. Wang.	Simulation of thermal transfer across carbon nanotube/Cu interfaces
16:28-16:40	IHTS140184	S. C. Yu, D. Nanto, J. S. Hwang, et al.	Temperature span of magnetocaloric effect in tiny Nb-doped La0.7Ca0.3Mn1-xNbxO3 (x = 0, 0.002 and 0.01)

16:40-16:52	IHTS140241	Y. F. Chen, C. H. Cheng	Topology Optimization of Conduction Path in Laminated Metals Composite Materials by Volume-of-Solid Method
16:52-17:04	IHTS140244	L. Wang, Y. R. He, H. R. Li, et al.	Investigation of thermal conductivity and viscosity of water based ZnO nanofluid
17:04-17:16	IHTS140251	L. T. Wang, Z. Yang, Y. Y. Duan.	A Multiscale Thermal Network Analysis of CNT Arrays for Lithium-ion Battery Electrode Application
17:16-17:28	IHTS140258	L. Gui, B. Niu.	Study of liquid metal based membrane with anisotropic thermal conductivity
17:28-17:40	IHTS140342	B. Liu, Z. Y. Wei, J. K. Yang, et al.	Thermal conductivity of Molybdenum Disulphide (MoS2) Sheets: a molecular dynamics study
17:40-17:52	IHTS140346	S. M. Lin, K. D. Bi, B. Liu, et al.	Investigation of the thermal conductivity of boron-nitride nanostructures using molecular dynamics simulations
17:52-18:04	IHTS140410	M. R. Wang, X. D. Shan.	Non-Fourier heat conduction in nanomaterials based on thermon gas model

Session 24:Heat Pipe, Beijing Hall C, chairs: pending			
Thursday, May 8, 2014			
Time	Paper No.	Authors	Title of the presentation
15:40-15:52	IHTS140012	J. Li, L.C. Lv.	Influence of parallel condensers on performance of a compact loop heat pipe
15:52-16:04	IHTS140044	Z. G. Qu, F. Xu, Z. Liu, et al.	Experimental study of liquid wicking into filter papers for lateral flow assays
16:04-16:16	IHTS140067	Y. Tang, H. Li, B. Zhou, et al.	Effect of working fluid on heat transfer performance of the anti-gravity loop-shaped heat pipe
16:16-16.28	IHTS140085	H. Z. Xian, W. J. Xu, W. Q. Shi, et al.	Visualization experiment of oscillating heat pipe under pulse heating
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16:16-16.28	IHTS140310	Z.H. Hu, M. Yang, L. L. Wang, et al.	Heat transfer based fault diagnosis for heat exchanger of aircraft environmental control system
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16:04-16:16	IHTS140062	H. L. Huang, J. Zhu.	Heat transfer performance of solar absorber under non-uniform heat load
16:16-16.28	IHTS140229	D. Li, H. B. Qi, G. Z. Guo.	Laminar natural convection with surface radiation in air filled horizontal optical cell
16:28-16:40	IHTS140281	G. Liu, X. J. Tang, C. Wang, et al.	Development of 65 kW micro-channels thermal management system for high power laser
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16:28-16:40	IHTS140318	L. P. Pang.	Experiments on two-phase flow distribution in a manifold with two-turret injection
16:40-16:52	IHTS140328	Y. W. Lv, J. Z. Zhang, Y, Shan.	A numerical investigation of the sparkJet flow in single-shot mode
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17:16-17:28	IHTS140425	Q.W. Wang, B. Wu, Y. T. Yin, et al.	Mean pressure distributions around circular cylinder under flow in the branch of a T pipe junction
17:28-17:40	IHTS140427	W. Zhang, S. X. Wang, C. Q. Wang, et al.	Mixed Convective Heat Transfer to CO2 at Supercritical Pressures Flowing Vertically Upward inside a Uniform Heated Helically Coiled Tube.

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4. Appendix

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附錄 2 發表論文 I _ Paper No_IHTS140287

題名:

Experimental Study of a Constant Pressure Two-Phase Thermosyphon with a Thermoelectric Generator

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Experimental Study of a Constant Pressure Two-Phase Thermosyphon with a Thermoelectric Generator

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Abstract

With the goal of maintaining secondary electricity generation by a Peltier generator for a long period of time, our research team built a thermoelectric generator with a static vapor temperature control unit, called a thermoelectric generator unit (TGU). We used a two-phase thermosyphon and a wastegate valve to create constant pressure and a constant saturated temperature. The Peltier generator converts any temperature differences into electric voltage on the TGU. Experimental tests were conducted in active and passive modes. We also calculated the maximum heat transfer rate and the boiling heat transfer coefficient of the TGU charging with 20 % liquid water, and conducted preliminary passive mode tests on a 3.7 m^2 solar energy stove on a cloudy day. In the active mode, we used concentrating solar power (CSP) technologies to directly heat the TGU. The active modes used thermal energy storage combined with the CSP system to sustain electricity generation for a long period of time. Experimental results show that the TGU can support a highly uniform temperature on its upper plate and generate electricity over a long period of time using unstable thermal energy. A molten salt pool bath can store a huge amount of thermal power and is a very good buffer of unstable solar power. A fibreglass insulation cover significantly decreases the loss of heat from the surface of the pool bath. Therefore, the TGU equipment shows very good capability for maintaining a constant temperature, stable electronic generation over a long period of time, and low energy loss; thus offers a low-cost portable equipment option in the green energy field.

1 Introduction

Today, the primary energy sources for the world's daily needs are fossil fuels such as coal, petroleum, and natural gas. Not only are these finite resources but they also release gaseous or liquid pollutants during processing. Because solar energy is an inexhaustible, clean, and safe source of energy, it has received much attention as one of the most promising candidates for replacing conventional fuels for electricity generation. Recently, there has been rapid development worldwide in basic technologies and market strategies for concentrating solar power (CSP) technologies, including the parabolic trough, the power tower, and the dish/engine. But renewable sources have the disadvantage that their supply is not consistent and are largely dependent on the weather conditions.

Thermal energy storage (TES) involves the temporary storage of high- or low- temperature thermal energy for later use. It is an excellent candidate for offsetting the mismatch between thermal energy availability and demand. For example, storage of solar energy may be used for overnight heating. TES systems have the following advantages: they increase generation capacity, enable better operation of cogeneration plants, shift energy purchases to low cost periods, increase system reliability, and may be integrated with other functions [1]. TES options for CSP plants are classified into three types: sensible, latent, and thermochemical storage. The only TES type that currently operates with multiple hours of storage is the sensible, two-tank, molten salt system, which has demonstrated reliable operation at a commercial scale [2]. Li et al. presented energy and exergy analyses of a new small CSP plant at the Asia-Pacific Power and Energy Engineering Conference [3]. Laubscher and Dobson presented a sodium-charged heat pipe heat exchanger design for processing primary and secondary reactor coolant streams in a high-temperature nuclear reactor [4-5].

Following these design ideas, our research team built a thermoelectric generator (TEG) with a static vapor temperature control unit, called a thermoelectric generator unit (TGU), to sustain secondary electricity generation by a Peltier generator over a long period of time. A TEG can convert temperature differences into electric voltage using CSP technologies directly (active mode) or with a TES combined with a CSP system (passive mode) for long-term electricity generation, as shown in Figure 1. A detailed schematic of the TGU is shown in Figure 2. The TGU consists of an enclosure containing a working fluid, the lower half of which is charged with liquid and the upper half with vapor. With this enclosure design, latent heat is transferred with essentially no resistance to flow or pressure loss, similar to a closed two-phase thermosyphon-type (natural circulation) heat pipe. In the TGU, the vapor condenses on the top wall inside the chamber, and the heat is removed by natural convection outside the chamber by gravity, flowing back into the liquid pool.

With this design, the vapor uniformity inside the pressure container and the wastegate's valve pressure release, making it possible for the cover plate to maintain approximately the same temperature. The hot and cold temperatures of the thermoelectric generator (TEG) are controlled by the static vapor pressure and the heat sink. There is a special trap hole at the bottom of the TGU to trap the CSP high-power energy during the active mode, and also to increase the connecting surface in the passive mode.

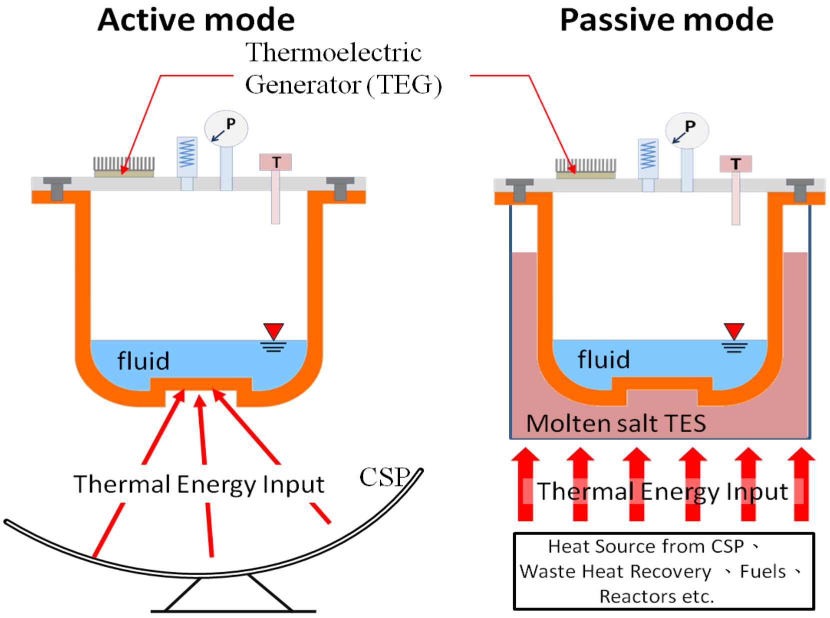

Figure 1: Active and Passive Modes of the TGU

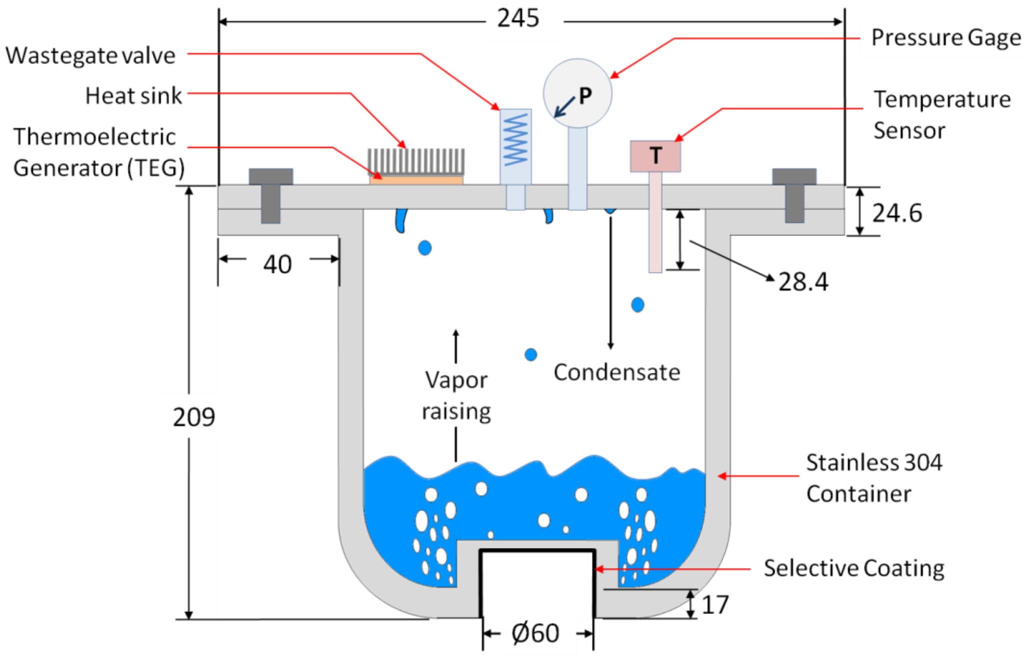

Figure 2: Sectional View of the TGU

2 Background Theory

2.1 Liquid and Vapor Weight

During vaporization, a substance exists as part liquid and part vapor. To analyze this substance, we must determine its proportions of liquid and vapor. The key property of the mixtures is steam quality (x) analysis of thermodynamics, we can determine the ratio of a vapor mass to the total mass of a mixture as in equation (1) [6]. Consider a tank that contains a saturated liquid–vapor mixture. The volume occupied by saturated liquid is V_f, and the volume occupied by saturated vapor is V_g.

$$x = \frac{m_{vapor}}{m_{total}} = \frac{V_{avg} - V_f}{V_{fg}},$$

$$\text{where } m_{total} = m_{liquid} + m_{vapor}, \; V_{avg} = V_f + xV_{fg}, V_{fg} = V_g - V_f \quad (1)$$

Assuming the liquid is fixed at 700 ml, at approximately 20% filling ratio in the TGU, the mass ratio can be calculated from the specific volume of the saturated pressure table [6]. We can determine the vapor weight, liquid weight, and the maximum available heat transfer rate as shown in Figure 3. The maximum available heat transfer rate is calculated by the Zuber equation for the peak flux in a saturated pool boiling. Equations are described in more detail in section 2.2. From Figure 3, we selected an effective saturated pressure of the wastegate valve (3.71 kg/m^2) for the saturated temperature (140 ℃) in the TGU and 3.7 m^2 in the CSP (assuming 1000 W/m^2 of solar power) for long term use.

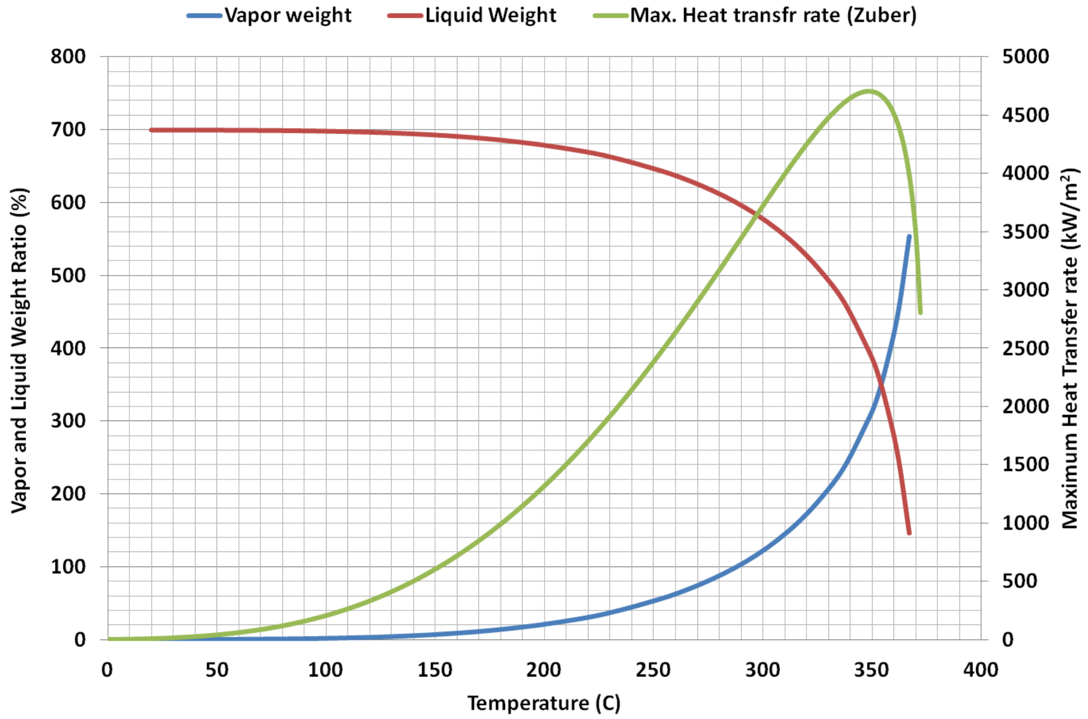

Figure 3: Vapor and Liquid Mass Ratios [Primary Axis] and the Maximum Heat Transfer Rate of the TGU [Secondary Axis] Variations Over Temperature

2.2 Boiling Heat Transfer Coefficient

Zuber et al. (1962) [7] defined the Zuber equation for the peak flux (in W/m^2) in saturated pool boiling as

$$q"_{max.Z} = \frac{\pi}{24}\rho_v^{1/2} h_{fg}\left[\sigma g(\rho_l - \rho_v) g_c\right]^{1/4} \tag{2}$$

An experimental equation for different fluids by Vachon et al. (1968) [8] is

$$\frac{c_l \Delta T_x}{h_{fg} Pr_l^n} = C_{sf}\left[\frac{q"}{\mu_l h_{fg}}\sqrt{\frac{g_c \sigma}{g(\rho_l - \rho_v)}}\right]^{0.33} \tag{3}$$

Where the number n of water is 1.0. C_{sf} is the empirical constant that depends on the nature of the heating surface fluid combination and whose numerical value varies from system to system. The C_{sf} for water on mechanical polished stainless steel is 0.0132. This equation can be used to predict the average temperature on the TGU container surface. Stephan and Abdelsalam (1980) [9] formulated a correlation containing four groups of variables using regression technology for water, refrigerants, organics, and cryogens as

$$\frac{h_b d_{bub}}{k_l} = 0.0546\left[\left(\frac{\rho_v}{\rho_l}\right)^{0.5}\left(\frac{q d_{bub}}{k_l T_{sat}}\right)\right]^{0.67}\left[\frac{h_{fg} d_{bub}}{\alpha_l^2}\right]^{2.48}\left[\frac{\rho_l - \rho_v}{\rho_l}\right]^{-4.33} \tag{4}$$

Where d_{bub} is the bubble departure diameter, given by

$$d_{bub} = 0.0146(\beta)\left[\frac{2\sigma}{g(\rho_l - \rho_v)}\right] \tag{5}$$

Where β is the contact angle that may be assigned a fixed value of 35 °, irrespective of the fluid. Gorenflo (1993) [10] proposed a fluid-specific correlation that included the effect of surface roughness and reduced pressure and that contains a working fluid specific and a reference heat transfer coefficient αo (water is 5600 W/m^2K), given by

$$h_b = \alpha_o F_{PF} \left(\frac{\dot{q}}{\dot{q_o}}\right)^{nf} \left(\frac{R_p}{r_{po}}\right)^{0.133} \quad (6)$$

Where the pressure correction factor for water FPF is given by

$$F_{PF} = 1.73\,Pr^{0.27} + \left(6.1 + \frac{0.68}{1 - p_r}\right) \quad \text{and } nf = 0.9 - 0.3Pr^{0.15} \quad (7)$$

The surface roughness (R_p) is set at 0.4 μm when unknown. q_o is at a fixed reference value of 20,000 W/m^2. This correlation is applicable for reduced pressure ranges from 0.0005 to 0.95.

The Kutateladze et al. (1961, 1966) [11,12] correlation is applicable to a wide range of conditions (fluid-type, heater geometry, and surface roughness) and is given by

$$Nu = \frac{h_b l_*}{k_l} = 0.44 \left(\frac{1 \times 10^{-4} \dot{q} P}{g h_{fg} \rho_v \mu_l} \frac{\rho_l}{(\rho_l - \rho_v)}\right) Pr^{0.35} \quad (8)$$

3 Experiment Setup

A schematic of the tested apparatus is shown in Figure 4. The prototype was made of a stainless-304 container and cover cap. The total height of the TGU was 209 mm with a thickness of 17 mm. A pressure gauge, a 3 kg/cm^2 wastegate valve, and the TEG module were installed on the top of the tested TGU. A K-type thermocouple was inserted in the chamber and was used to measure the vapor temperature. We used a first-class gas stove as a heater to simulate high-power CSP energy. A hole through the firebrick center creates focused thermal energy at the bottom of the TGU. The experimental test apparatus can separate the active mode, which simulates CSP focused thermal energy directly. The passive mode, which put use a TES molten salts pool bath to be an outer pot under the TGU.

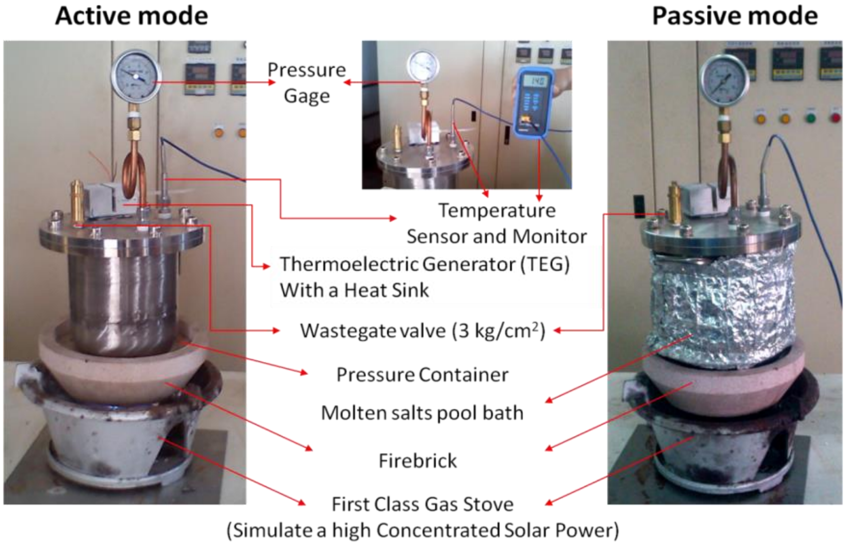

Figure 4: Specific TEG Units Testing for Active and Passive Modes

4 Experiment Results and Discussion

In this experiment, we first filled the TGU with 700 mL of liquid water, and then heated it with the gas stove. We observed that when the vapor temperature reached 138 ℃, the wastegate valve started to release noncondensable gases. After 30 min, the static pressure remained at 3 kg/cm^2, and the vapor temperature was 140 ± 1 ℃. From the pressure gradient, we calculated the wastegate valve release to be 0.3 g of liquid water each time. This means that the maximum work time was 35 h with a 20 % charging rate for a continuum of thermal energy input. The active and passive modes experimental results and calculation of the boiling heat transfer coefficient as follow.

4.1 Experimental Results of the Active Mode

Figure 5 compares the saturated pressure with the vapor temperature in the active mode of the experiment. From this figure, we can see a pressure rising trend matches the ideal curve exactly. A spring tube pressure gauge has a more simple structure and a lower price, but its sensitivity is not good enough, yielding approximately a 10 ℃ gradient from the ideal curve line. The vapor temperature and gauge pressure variations with respect to time are shown in Figure 6. From this figure, we can see that after 27 min both the pressure and vapor temperature approach a steady state. The reaction time of the vapor temperature was more sensitive than that of the pressure.

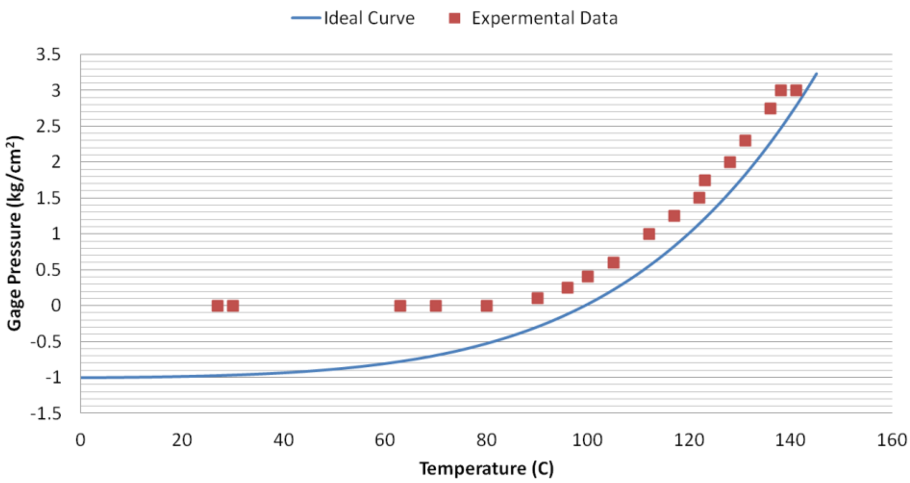

Figure 5: Static Pressure Variations with Vapor Temperature at a 700 ml Filling Rate

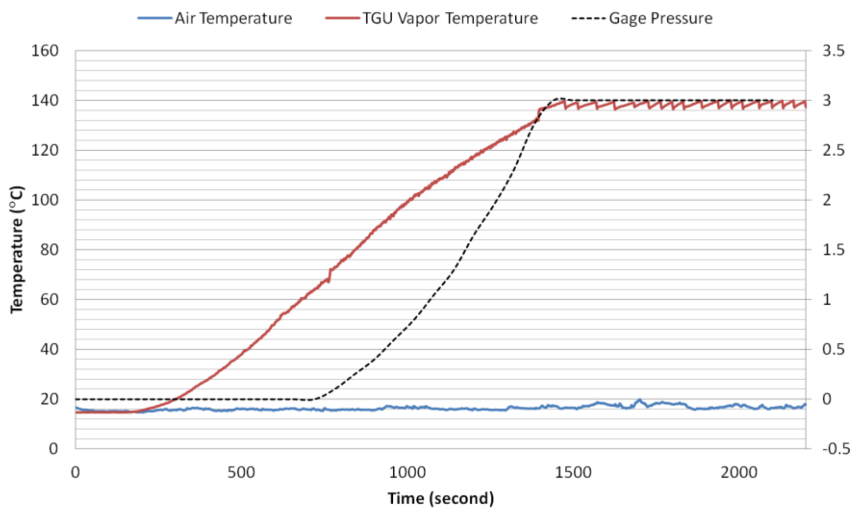

Figure 6: Vapor Temperature and Gauge Pressure Variations with Respect to Time

4.2 Experimental Results of the Passive Mode

We used 4000 g of a molten eutectic mixture of salt with 60 % $NaNO_3$ and 40 % KNO_3. Once the gas heater had fully melted the salt, we then put the TGU onto it. Results show that the TGU can support 3.5 V for more than half an hour. Figure 7 shows the preliminary test results observed on July 24, 2013, a cloudy day. A 3.7 m^2 solar energy stove was used as the heater. The TGU started heating at 10:00, with a power input between 1314 and 1359 W/m^2. After 16 min, the pressure started to rise. From 18 to 24 min, a cloud covered the sun, and the power decreased to 416.8 W/m^2, but the pressure kept rising from 1.3 to 1.75 kg/m^2. The molten salt pool bath was a very good buffer for absorbing the unstable solar power, and the fiberglass insulation cover decreased the amount of heat loss from the surface of the pool bath. After 24 min, the sun light returned at 1416 W/m^2 of power. After 47 min, the TGU began to release vapor pressure and transferred thermal energy into steady electricity.

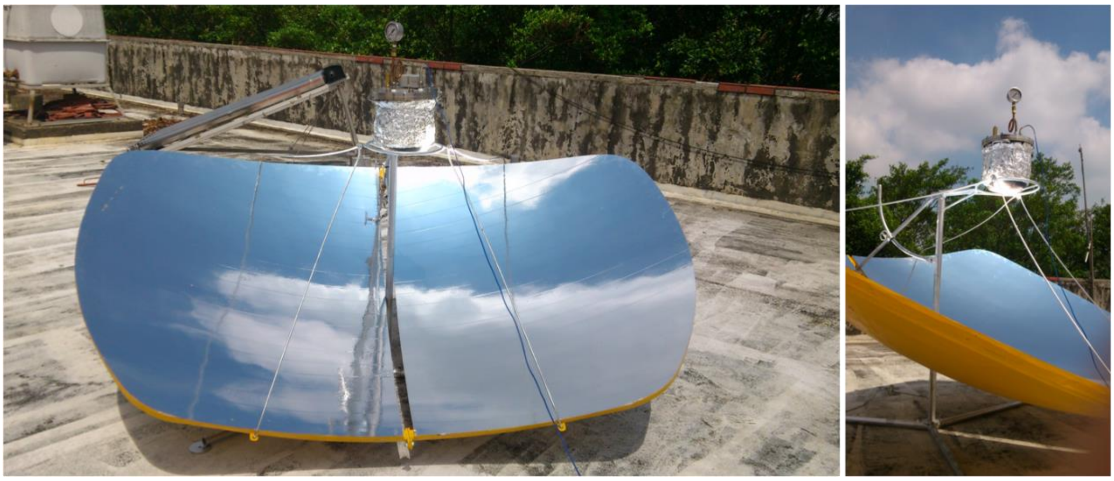

Figure 7: Passive Mode TGU Heated by a 3.7 m^2 Solar Energy Stove

4.3 Boiling Heat Transfer Rate and Coefficient

In the experimental results, when the stable vapor temperature was 140 ℃, we determined that the average temperature of the TGU container surface, which was immersed in the molten salt liquid, should be lower than 150.38 ℃. The heat flux was calculated from Zuber equation as the equation (2). The properties reference the Appendix 2 of a heat transfer textbook [13]. Then the heat transfer coefficient inside the TGU can be predicted to 224,706 W/m^2K by Fourier's law. Figure 8 shows the relationship of the prediction of the Zuber heat flux, and the boiling heat transfer coefficient as by Stephan and Abdelsalam, Gorenflo, and Kutateladze et al. The prediction results show that the TGU can support a very high heat flux with a high boiling heat transfer coefficient inside. This means that the TGU can support a highly uniform temperature on the upper plate, generating long term electricity using the thermal energy.

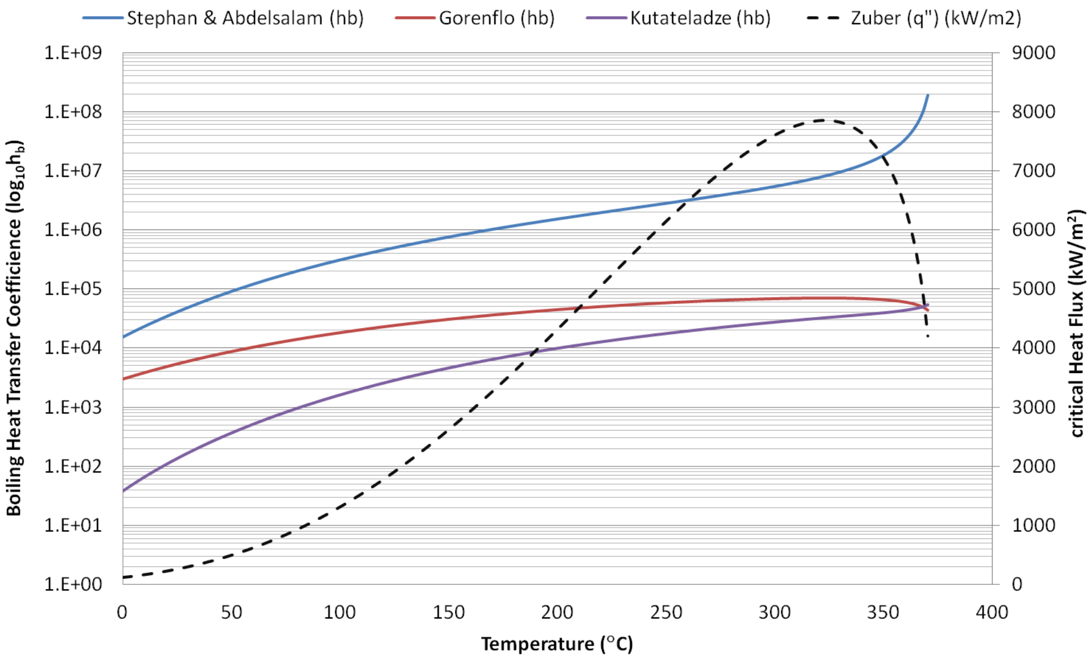

Figure 8: Relationship of the Boiling Heat Transfer Coefficient and Heat Flux Prediction

5 Conclusion

In this research, we studied a constant pressure two-phase thermosyphon using a TGU in active and passive modes. Experimental results indicate that temperature can be accurately maintained at 140 ± 1 ℃ using a 3 kg/cm^2 wastegate valve. The TGU can store thermal energy in a 4000 g molten salt pool bath and support 3.5 V for more than half an hour in the passive mode. Preliminary passive mode tests on a 3.7 m^2 solar energy stove on a cloudy day were successful. The molten salts pool bath can absorb the unstable thermal energy and transfer it into stable electric power for a long period of time. The maximum heat transfer rate and boiling heat transfer coefficient of the TGU equipment, charging with 20 % liquid water, were calculated and predicted according to Zuber, Stephan and Abdelsalam, Gorenflo, and Kutateladze et al. We conclude that the experimental TGU can support a highly uniform temperature on its upper plate and generate long-term electric power using unstable thermal energy. The molten salt pool bath serves as a very good buffer for absorbing the unstable solar power, and the fiber glass insulation cover decreases heat loss from the surface of the pool bath. The TGU passive mode may be used as a long-term small electronic generator for any kind of thermal energy, and especially for TES of solar energy combined with CSP system technologies.

Nomenclature

x	Ratio of the mass of vapor to the total mass	P_{rl}	Prandtl number of the saturated liquid, $c_p\mu_l$ / k
m_{liquid}	Mass of liquid, kg	μ_l	Viscosity of the liquid, kg/s·m
m_{vapor}	Mass of vapor, kg	C_{sf}	Empirical (Rohsenow) constant
m_{total}	Total mass of vapor and liquid,, kg	h_b	Boiling heat transfer coefficient, W/m^2k
V_g	Volume occupied by saturated vapor, m^3/kg	d_{bub}	Bubble departure diameter, m
V_f	Volume occupied by saturated liquid, m^3/kg	k_l	Thermal conductivity of the liquid, W/mk
V_{fg}	Difference in volume occupied by saturated liquid and saturated vapor, m^3/kg	T_{sat}	Saturated temperature, K
V_{avg}	Average volume occupied by saturated vapor and V_{fg}, m^3/kg	α_l	Liquid diffusivity, m^2/s, $k_l / \rho_l c_{pl}$
c_l	Specific heat of a saturated liquid, J/kg	β	Contact angle
q''	Heat flux, W/m^2	α_o	Reference heat transfer coefficient
$q''_{max.Z}$	Peak heat flux by the Zuber equation	$\dot{q}$	Heat flux, W/m^2
h_{fg}	Latent heat of vaporization, J/kg	$\dot{q}_o$	Outside Heat flux, W/m^2
g	Gravitational acceleration, m/s^2	R_p	Surface roughness, μm
ρ_l	Density of the saturated liquid, kg/m^3	r_{po}	Radius
ρ_v	Density of the saturated vapor, kg/m^3	F_{PF}	Correction factor
σ	Surface tension of the liquid-to-vapor interface, N/m	n_f	Gorenflo coefficient
Nu	Nusselt number, dimensionless heat transfer coefficient, hL/k	$l*$	Dimensionless factor for pool boiling, $l* = \left[\frac{\sigma}{g(\rho_l - \rho_g)}\right]^{0.5}$

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附錄 3 發表論文 II _ Paper No_IHTS140288

題名:

Experimental Study of a Cyclical Two-Phase Reverse Loop Thermosyphon

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Experimental Study of a Cyclical Two-Phase Reverse Loop Thermosyphon

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Abstract

In this study, we created a two-phase reverse-loop thermosyphon (RLT) for effectively moving the thermal energy downward to a thermal storage tank. This downward heat transfer some papers call it a top-heat-type heat transport loop. The two-phase RLT is a passive device, much like a non-wick heat pipe, driven by thermal energy and having extremely high thermal conductivity. The experimental cyclical two-phase RLT consists of a working liquid circulation loop with heat transfer in the downward direction, opposite from the direction of natural convection. The process transfer thermal energy by the pressure differences in the saturated vapor, which then transfer the heated liquid or vapor downwards. The heated portion is 1.5 m higher than the cooled portion, and we use a 95% concentration of methanol liquid with different fill ratios as the working fluid inside the heat exchanger loop. Experimental results show the effects of different filled ratios on the heat transfer speed and temperature description.

1 Introduction

Heat transfer is a challenge ideally achieved with high intensity across long distances with small temperature differences. In many terrestrial applications, heat transfer requirements are best satisfied by flow loops in which a fluid’s heat is transferred by a circulation exchanger between the heating zone (heat source) and cooling zone (condenser). The heat transfer circulation exchanger may be spontaneous or driven by electronic pumps.

However, system reliability is greater when circulation is spontaneous. After the natural earthquake disaster on March 11, 2011, a tsunami then caused a serious nuclear reactor meltdown in Fukushima, Japan. The problem was due to the loss of electrical power to the nuclear reactor’s active cooling system. At 10th International heat pipe symposium, Mochizuki et al. presented several designs for spontaneous heat pipe heat exchangers, which could replace the traditional cooling system used by nuclear power plants [1].

The conventional thermosyphon in a closed system, also referred to as a “bottom-heat-type” thermosyphon, depends on the natural upward movement of hot liquids and the downward movement of cold liquids. According to Faghri, the abovementioned thermosyphon has been widely applied because of its high efficiency, reliability, simplicity and cost effectiveness, where it is necessary to transport heat from lower to higher positions [2]. Kang et al. demonstrated a very high thermal performance of a loop thermosyphon by using methanol and water as the working fluid [3]. A boiling-enhanced structure and different charging rates were analyzed in that study. The two types of traditional thermalsyphons two-phase single and loop are shown in Figure 1. However, the weakest point in the two-phase single and loop thermalsyphons is that these devices usually work only when the heat source is situated below the heat sink. Ensuring spontaneous downward heat transfer is difficult, but the devices have the potential to be very useful for solar heating system, thermal storage, waste recovery, geothermal energy exploitation, warm water storage, and solar refrigeration fields.

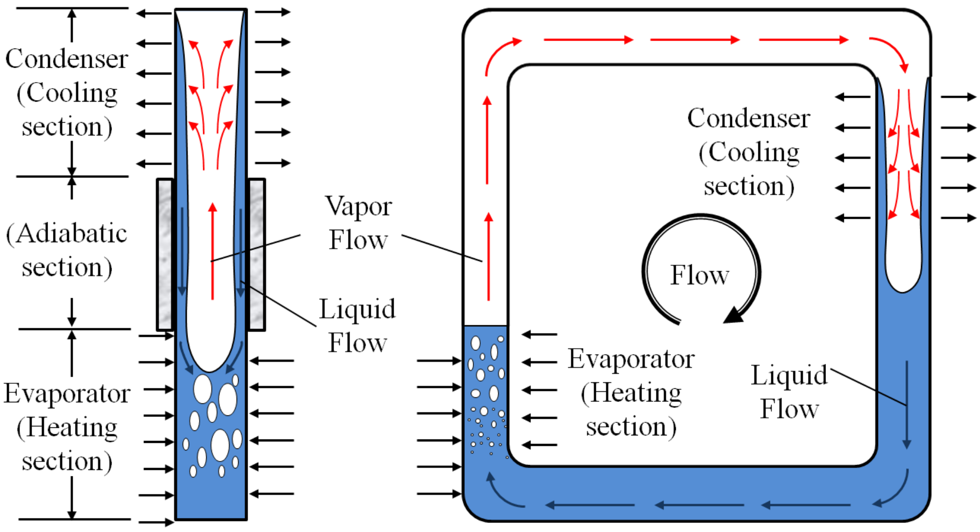

Figure 1: Traditional Two-Phase Single and Loop Thermalsyphons

There are far fewer publications on spontaneous downward heat transfer than on the topic of heat pipes, loop heat pipes, and thermosyphons. Roberts has reviewed 10 different technical solutions, but only one of which is widely in use [4]. Dobriansky and Yohanis described a reverse thermosyphon action consisting of a self-acting and self-controlled liquid circulation loop with heat transfer in a downward direction [5]. Dobriansky took the next step forward by reviewing self-acting circulation loop concepts for downward heat transfer in the field of energy conversion and management [6]. Dobriansky regarding many possible methods for designing effective devices to transfer heat download, yet achievable. The purpose of this paper is to establish and build a cyclical two-phase reverse loop thermosyphon device for long distance downward heat transfer application.

Figure 2 shows a simple reverse flow method design in a cyclical two-phase loop thermosyphon. A bubble lifts evaporator on the top of the heating section transfer latent heat to the loop condenser through the recuperator (preheater). Figure 3 shows the pretest of a simple two-phase reverse-loop thermalsyphon. This experiment used a pencil torch to burn a bended-loop thermalsyphon charged with 60% methanol liquid at 95% concentration. The device worked successfully and the flow reversal results are shown as the infrared image. The next step forward by the designing, testing, and the performance calculation for long distance cyclical two-phase reverse-loop thermosyphon was presented in this paper.

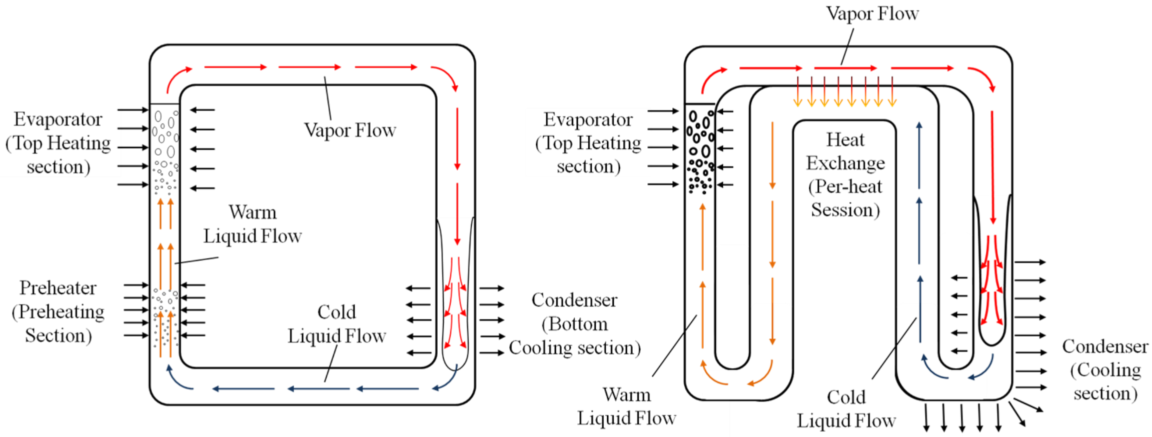

Figure 2: Reverse flow design in two-phase loop thermalsyphon

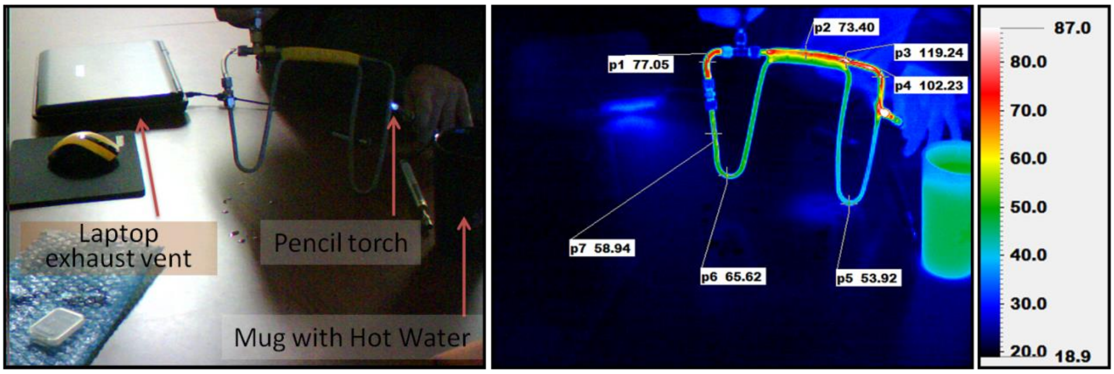

Figure 3: Pre-Test of a Simple Two-Phase Reverse Loop Thermalsyphon

2 Experimental Apparatus and Procedure

2.1 Fabrication of A Cyclical Two-Phase Reverse-Loop Thermosyphon

Ippohshi et al. conducted considerable research on top-heated two-phase reverse-loop thermosyphon (RLT) apparatus [7-8]. Reference to their experimental apparatus, we fabricated the cyclical two-phase RLT apparatus shown in Figure 4. This RLT apparatus consisted of an evaporator, a condenser, a reservoir (preheater), and pipes connecting each of the components. The heat transport height was 1500 mm from the evaporator to the bottom of the cooling coil. The total height of apparatus was 1650 mm. The evaporator was prepared from a copper slug (72 mm diameter), in which 10 holes (13 mm diameter) were drilled for the placement of 10 electronic iron heater coils totaling electronic resistance are 70 ohm. Straight through the center, the slug was connected with ½″ copper tubing with a wall thickness of 1 mm. The reservoir (0.08 L) consisted of a 3½″ stainless steel tube with a height of 200 mm and 2 caps (50 mm in height). A single stainless steel tube goes through the reservoir to exchange thermal energy from vapor and preheat the working fluid. The condenser is a heat exchanger prepared by coiling a ½″ copper 620 mm long and with wall thickness of 1 mm. The working fluid was 95% concentration methanol liquid inside the RLT loop. A water pool and a thermostatic bath were used for storage and condensation of the RLT loop in the condenser, respectively.

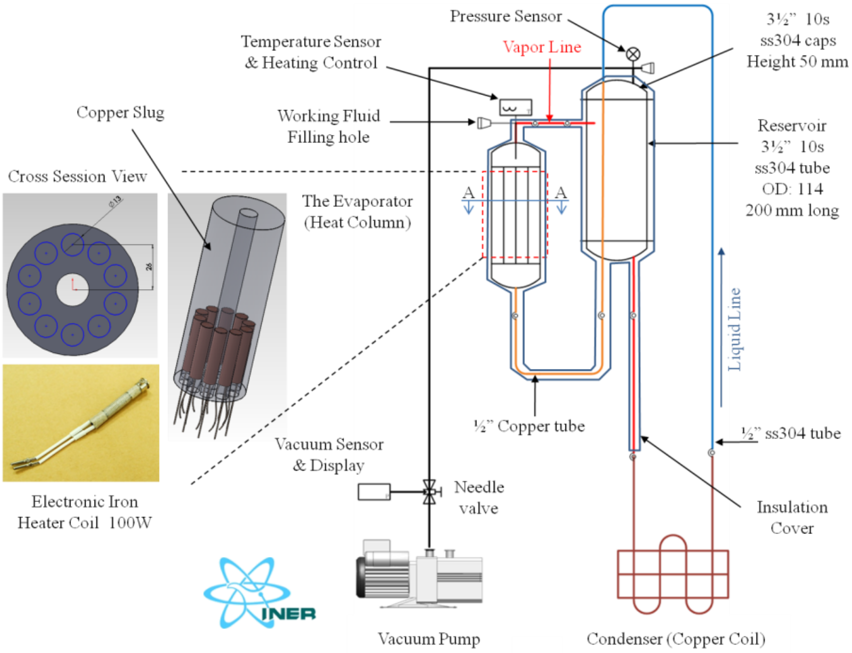

Figure 4: Schematic and Equipment of Two-Phase Reverse Loop Thermosyphon

2.2 Experimental Setup and Methods

A photograph and the temperature measurement points of the two-phase RLT apparatus are shown in Figure 5. Type-T thermocouples (Omega® - TT-T-040) were installed as shown in the figure, and all temperatures outputs were connected to a data logger and continuously logged. The temperature measurement uncertainty was ± 0.1 ℃. To guarantee thermal insulation, insulated fiberglass foam ($k < 0.04$ W / mk) was used to cover the evaporator, reservoir, and the entire liquid-descending pipe line.

In our tests, we investigated 16 different working fluid filling ratios in the two-phase RLT. One-third of the condensing coil immerses in a pool bath fill with 2 L liquid water. The experiment use AC Power and a digital power regulator to supply to supply the evaporator with a steady 660 W of heating power. The water absorbs and stores thermal energy as latent heat in pool bath.

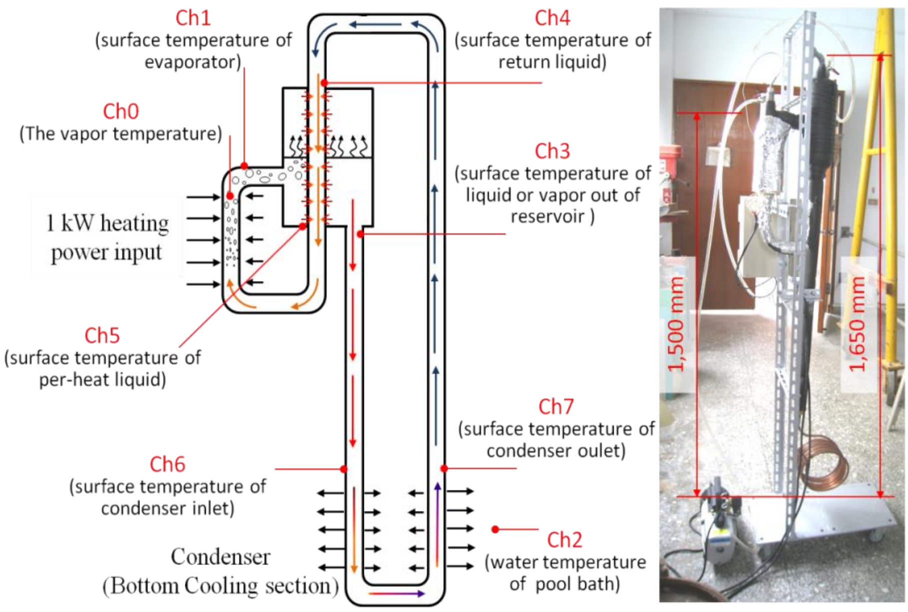

Figure 5: Measurement Points and Photograph of The Two-Phase RLT

3 Results and Discussion

In our tests, we determined the optimal filling ratios for 16 different working fluid charging rates. We also measured the temperature during the heating and cooling process of the two-phase RLT apparatus, and observed the liquid flow direction during the heating "on" and turn "off" modes.

3.1 Temperature variation with time

Figure 6 shows the temperature variations over time with 660 W of heat input and a 60% filling rate (900 mL). The heating region can be separated into two steps of 2350 each. The first step is liquid flow region, when the heat transfers in a reverse flow down to the condenser. During this step, the temperature increase is fast and steady. The second step is the bubble flow, when the heat transfers in a bubble flow down to the condenser. During this step, the temperature amplitude oscillates in the evaporator (Ch0 & Ch1) and condenser (Ch6 & Ch7). The oscillation amplitude of Ch6 is approximately 1.5 ℃, and that of Ch0 is approximately 1 ℃, whereas the others are lower than 1 ℃. The rising ramp slope of the average vapor temperature (Ch0) and condenser inlet temperature (Ch6) in the bubble flow region are approximately same. The parallel trend line distance between temperatures Ch0 and Ch6 in the bubble flow region is approximately 9 ℃. The temperature trend of the condenser outlet (Ch7) is linear, i.e., the thermal energy store in the water pool bath is stable. After the power shut-down, the reservoir becomes the heater of two-phase RLT apparatus. Figure 6 shows that the apparatus reverts to natural convection, where the bubble flows through Ch5 and Ch4, the temperature increase quickly. In contrast, the Ch6 temperature declines rapidly because of the sudden loss of reverse drive pressure. Temperature Ch5 has the "shaking appearance" in the thermodynamic equilibration process between the evaporator and the reservoir. The flow direction during the heating "on" and "shut-off" modes are shown in Figure 7.

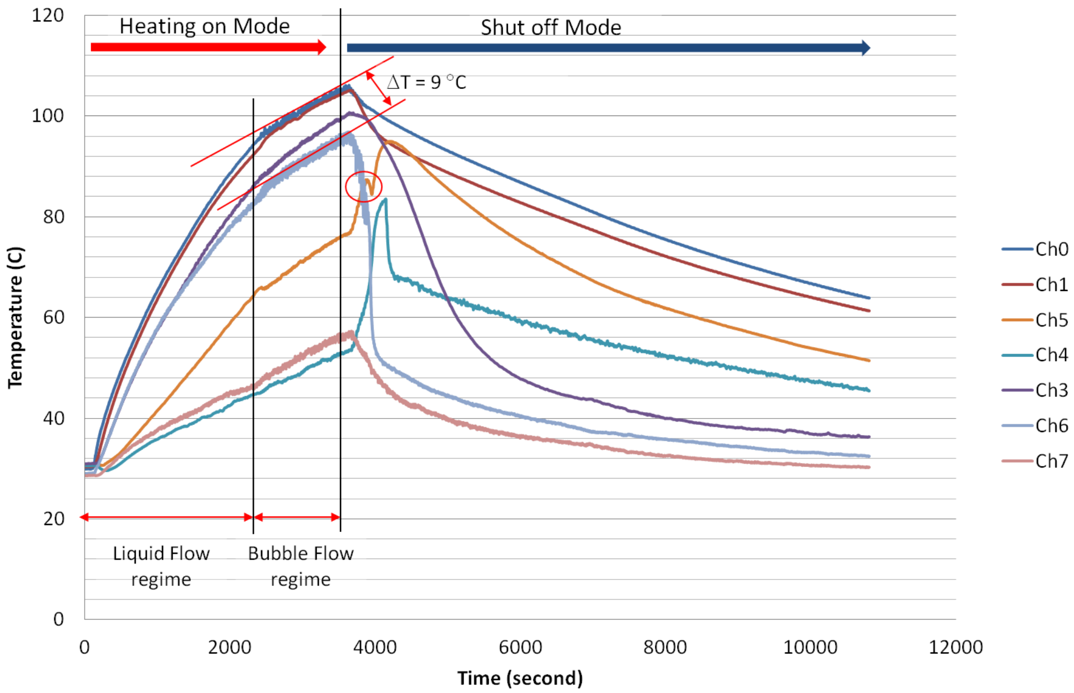

Figure 6: Temperature Variations Over Time with 660 W of Heat Input and A 900 ml Filling Rate

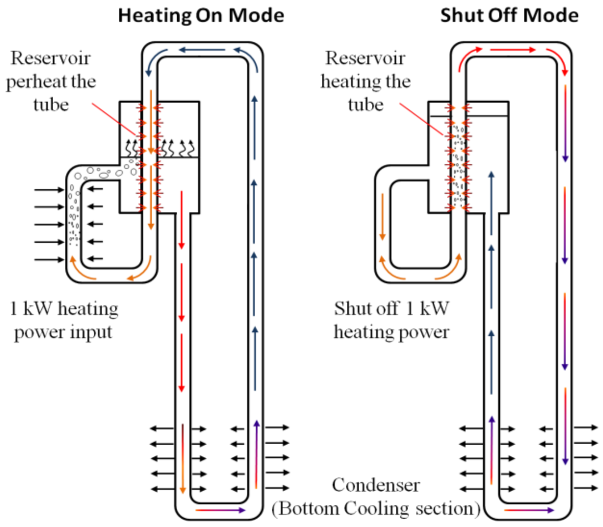

Figure 7: Flow Direction During The Heating "On" and "Shut-Off" Modes

3.2 Effect of different charging rates

The evaporator vapor temperature (Ch0) and condenser inlet wall temperature (Ch6) at all charging amounts of the working fluid with time step are illustrated in Fig. 8 and 9 respectively. Fig. 8 shows the temporal temperature distribution of the vapor temperature (Ch0) for evaporator at 6 different working fluid charges was 700 to 950 ml, which corresponded to 47 % to 63 % the original RLT inlet volume. From the figure, we can obtain that larger amounts of the working fluid require lower vapor temperature. The lowest vapor temperature was obtained at fill charge of 950 ml (the filling ratio is 63%). The temperature was uncertainties and oscillations on 1700 to 2000 second period when the RLT filled with 700, 750, 800, and 850 ml charge amounts. The temperature was oscillations later after 2400 second when the RLT fill charge of 900 and 950 ml. The uncertainties amplitude of 950 ml fill charge was much smaller than the other filling rate. Fig. 9 shows the temporal temperature distribution of condenser inlet wall temperature (Ch6) at 6 different working fluid charges. From figures, we can obtain the time which taken to start to raises up is substantially longer when the RLT filled with 700 and 750 ml charge amounts.

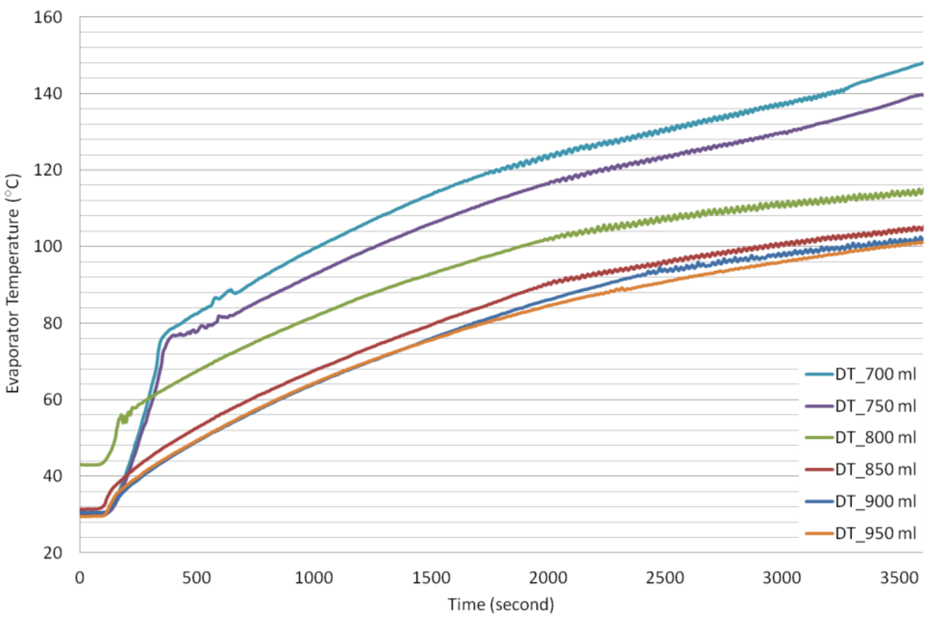

Figure 8: The Vapor Temperature of Evaporator Variations Over Time with Different Filling Rate

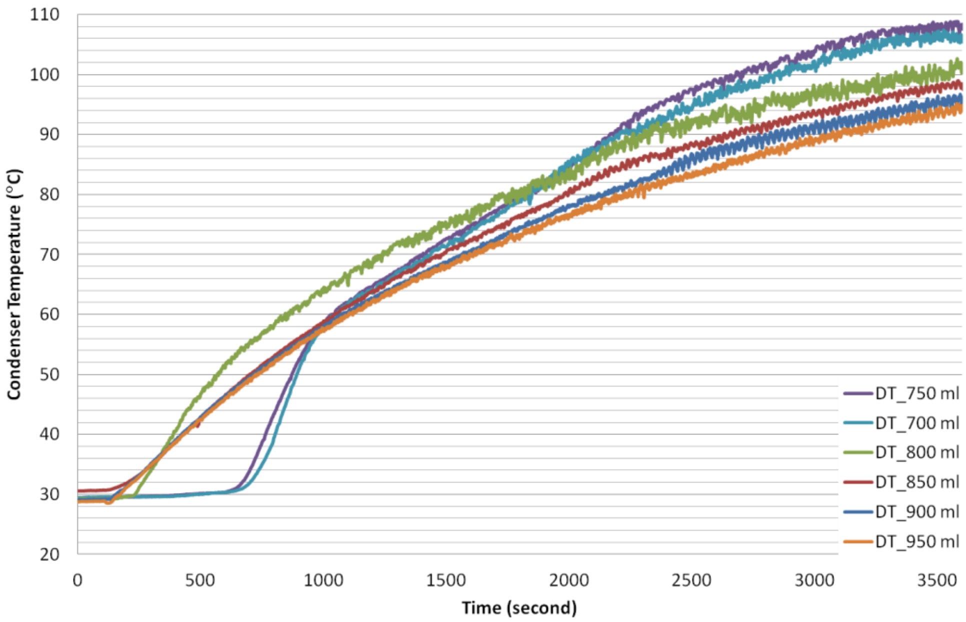

Figure 9: The Condenser Inlet Temperature Variations Over Time with Different Filling Rate

Figure 10 shows the temporal temperature distribution of the temperature difference between evaporator and condenser inlet temperature (Ch0 – Ch6). The RLT fill charges of 800 to 950 ml were much stable than fill charge of 700 and 750 ml. From the figure, we can obtain that the fill charge of 900 ml (the filling ratio is 60%) exhibits the lowest temperature difference.

Table 1 shows the characteristics of the two-phase RLT with different charging volumes. The reverse start time was the time region for reverse flow overcomes the earth gravity, and down to the condenser. This time delay since the heating started to the condenser inlet temperature began to rise named the reverse start time. The thermal resistance of the two-phase RLT in this study was calculated by equation (1), considering that the temperature difference between the vapor and the condenser inlet temperature from 660W heat input energy.

$$R_{RLT} = \frac{\mathrm{T_{vapor}} - \mathrm{T_{ci}}}{660\mathrm{W}},$$

$$= \frac{\mathrm{Ch0} - \mathrm{Ch6\ (K)}}{660\ \mathrm{(W)}} \quad (1)$$

The thermal storage in the 1 h heating process of the water pool was calculated by equation (2), with the specific volume of water at 373.13 K being 4.22 (kJ/kgK). We took 4 measurements at 4 points that were immersed in the water. Ch2 was the average temperature of the water. The experimental results show approximately a 20 K temperature increase from room temperature in the 1 h heating process.

$$Q_{storage} = \frac{\mathrm{mC_p}(\Delta \mathrm{T})}{3600}$$

$$= \frac{15(\mathrm{L}) \times 4.22 \left(\frac{\mathrm{kJ}}{\mathrm{kgK}}\right) \times 20(\mathrm{K})}{3600} \quad (2)$$

The heat loss from the storage tank was calculated by equation (3), with the heat convection coefficient assumed to be 15 (W/mK). The surface area was 0.25 m2 and average temperature difference was 14 ℃. There were 4 measured points set up on the glass surface of the water pool.

$$Q_{\text{cond.loss}} = \frac{\mathrm{h} \times \mathrm{A} \times (\Delta \mathrm{T})}{3600}$$

$$= \frac{15\left(\frac{\mathrm{W}}{\mathrm{m^2K}}\right) \times 0.25\ (\mathrm{m^2}) \times 14(\mathrm{K})}{3600} \tag{3}$$

The calculations shows that the 55% thermal energy storage in the water and 45% thermal energy storage loss in the environment.

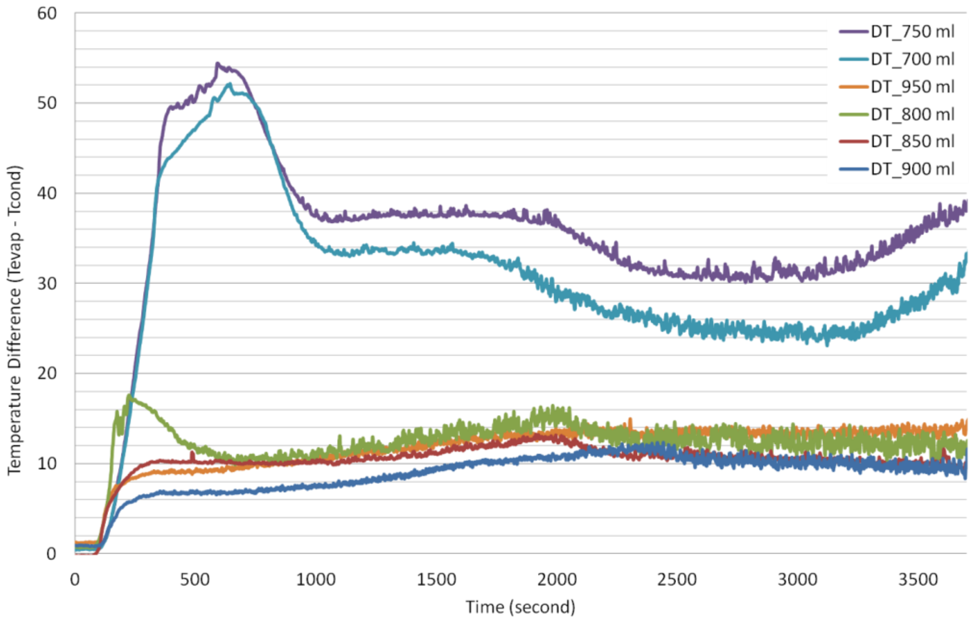

Figure 10: The Temperature Difference Between Evaporator Vapor and Condenser Inlet Temperatures Variation Over Time with Different Filling Rate

Table 1 The Characteristic of Two-Phase RLT in Different Charging Volume

Charging volume (ml) (%)	Vapor Temperature (Ch0) (℃)	Condenser Inlet Temp. (Ch6) (℃)	Reverse Start Time (Second)	Thermal Resistance (℃/W)
700 (47)	148	106	562	0.064
750 (50)	151	108	574	0.065
800 (53)	132	105	138	0.041
850 (57)	110	99	80	0.017
900 (60)	106	97	30	0.014

3.3 Sine Wave Heating Test

Sine wave heat was inputted to the two-phase RLT, at a heating frequency of 10 min “on” and 10 min “shut-off”. The resulting vapor temperature (Ch0), reservoir outlet surface temperature (Ch3), and condenser inlet surface temperature (Ch6), in Figure 11 showed that heat was conducted from the top with the sine wave to the condenser of the two-phase RLT. After a period of time, the temperature oscillation amplitude on the condenser inlet was larger than that of the evaporator and the reservoir. When the power shut-off, the condenser wave crest responded immediately, but the evaporator and reservoir had a time delay and kept accumulating thermal energy.

Fiqure 12 shows that after the power was “on” and “shut-off”, the fluid flows were alternating and fast. This phenomenon can be observed by the curve of Ch4 and Ch5. Temperature Ch5 shows characteristic shaking appearance during the thermodynamic equilibration process after thermal exchange inside the reservoir.

Tables and figures should be placed close after their first reference in the text. All figures and tables should be numbered with Arabic numerals. Table headings should be centred above the tables. Figure captions should be centred below the figures.

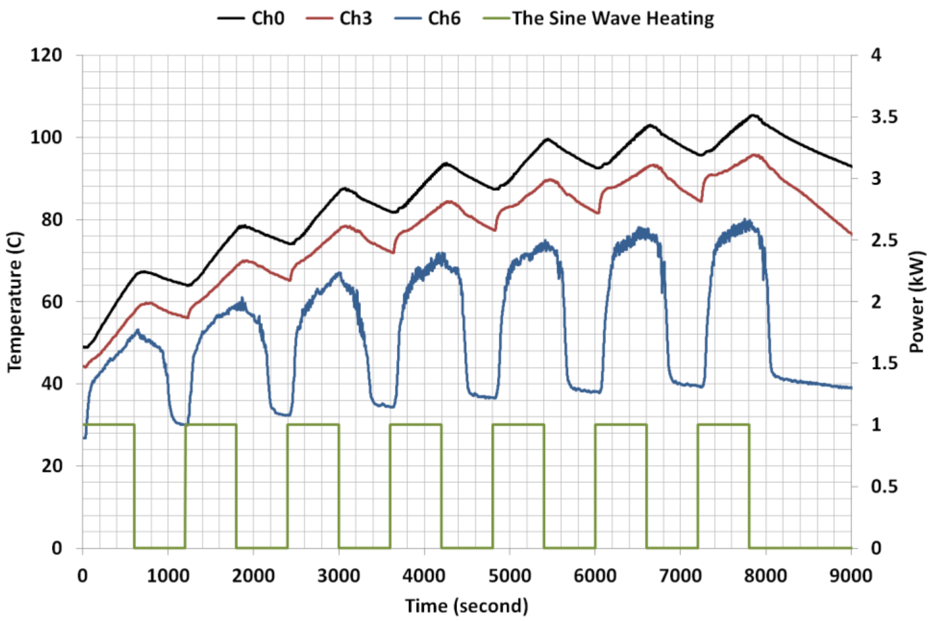

Figure 11: Three Temperature Variations Over Time in The Sine Wave Heating Process

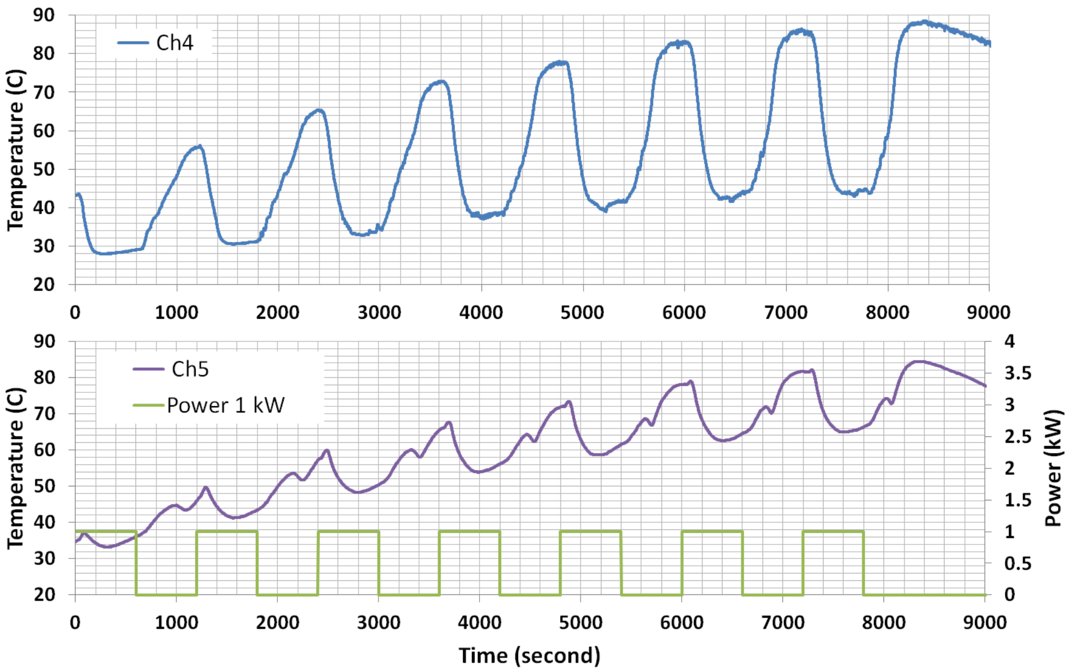

Figure 12: Alternately Reverse and Regular Flow by Ch4 And Ch5

4 Conclusion

In the experimental studies, we built a two-phase RLT (1500 mm) to successfully transfer thermal energy. Investigations were conducted regarding the operational characteristics of the two-phase RLT. Results suggest that the optimal fill ratio is 60% methanol. Given an actual heating power of 660W, the vapor temperature of the heat source was 106 ℃, and the thermal resistance was 0.014 ℃/W. There was 55% thermal energy storage in the water.

The two-phase RLT achieved high reliability, and anti-gravity capability, and showed the potential for good performance in high-power energy storage applications.

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