(Revised 07/09)

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(please insert ref. above)

NSFC/RGC Joint Research Scheme
Joint Completion Report

(Please attach a copy of the completion report submitted to the NSFC by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Investigation of Heat and Mass Transfer Mechanisms in a Novel Total Heat Exchanger

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Professor NIU, Jianlei	Professor ZHANG, Lizhi
Post	Chair Professor of Building Environment and Energy	Professor
Unit / Department / Institution	BSE	Key Lab of Enhanced Heat Transfer and Energy Conservation / South China University of Technology
Co-investigator(s) *(with title)*	Dr. XIAO, Fu	Dr PEI, Li-xia

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted)*
Project Start date	01/01/2012		
Project Completion date	31/12/2014		
Duration *(in month)*	36		18-NOV-2011

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. To set up the heat and mass transfer model in a one-step fabricated asymmetric vapor permeable membrane (made from Cellulose Acetate) using the fractal theory and experiments. To intensify moisture transfer through the novel membrane by revealing the relations between its thermo-physical properties, interface characteristics, micro and meso structures and its heat and moisture transfer properties.

2. To establish friction and transport correlations in cross-corrugated triangular channels under transition flow conditions. To build mathematical models that govern the fluid flow and heat mass transfer in the structure, and find the ways to intensify its convective heat and mass transfer.

3. To build the conjugate heat and mass transfer model of the novel total heat exchanger combining the membrane with the structure. To find the ways to intensify its heat and moisture transfer, and to achieve a sensible effectiveness of 0.8 and a latent effectiveness of 0.70 at pressure head loss comparable to current designs.

5.2 Revised Objectives

Date of approval from the RGC: N/A

Reasons for the change: _____

_____

1.
2.
3. ....

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

The major finding and outcomes can be summarized in two aspects. The first one is the new chemical engineering process, by which a membrane with high moisture permeation coefficient can be prepared using a one-step approach. The membrane is porous and asymmetric, exhibiting the highly desired properties for the total heat exchanger in building applications to save ventilation energy (Li et al 2015).

The 2nd research outcome is about the assembly of the membrane as one single device/equipment used in the air-conditioning system. A balance between three conflicting demands must be considered: the energy recovered, the increased system fan energy use to overcome the pressure loss, and the material cost and space use, which is an optimization problem. Physical and mathematical models have been proposed and evaluated, firstly under the duct geometry and the flow regime where analytical and experimental correlations are available (Liu and Niu 2014). It is shown that the classical *j* and *f* factors are not good indicators for comparing the performance, and a new optimization procedure is proposed and demonstrated. For complicated airflow duct cross sections, computational fluid dynamics methods were demonstrated (Liu and Niu 2015).

Potential for further development of the research and the proposed course of action
(maximum half a page)

For different climates, the available indoor- outdoor temperature and moisture differences are different. Therefore, a climate adaptive optimization of the total heat recovery unit will be required. A generic optimization criterion needs to be established, which can guide the development of more efficient membranes using other emerging new materials such as Graphene.

7. The Layman's Summary

(describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

To save energy in air-conditioned or heated buildings, a so called total heat exchanger (THE), which enables both heat and moisture recovery from the exhaust air, is a technology option. In this project, two technical issues are addressed. The first one is to develop a technique to produce the one-step fabricated asymmetric vapor permeable membrane, which is the core component of a THE and is made from Cellulose Acetate; the 2nd technology is the optimization of the assembly of such membranes in a novel cross-corrugated triangular duct structure in comparison with traditional regular ducts.

The best ingredients for membrane making are found to be K2SO4（5wt.%）/PEG-2000（1wt.%）. Then numerical modeling analysis is undertaken to find the optimal assembly of the membranes, which involves both the conductive heat and diffuse moisture transfer in porous membranes and the flow and convection transfer in cross-corrugated ducts. A

new method for the optimal design of THE is proposed, which considers pressure loss, energy recovered, material use and space requirement, respectively considering laminar and turbulent flow conditions. The scientific findings from this project are reported in 20 SCI papers published. Five patents were granted. One monograph book in was published.

Part C: Research Output

8. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.))

The Latest Status of Publications				Author(s) *(**bold** the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*					
2015				**Li, Zhen-Xing; Zhong, TS; Niu, JL; Xiao, Fu; Zhang, LZ***	Conjugate heat and mass transfer in a total heat exchanger with cross-corrugated triangular ducts and one-step made asymmetric membranes, International Journal Of Heat And Mass Transfer ,Volume: 84, Pages: 390-400, Published: MAY 2015	No	Yes	Yes
2015				**Liu Xiaoping; Niu Jian-lei***	Effects of geometrical parameters on the thermohydraulic characteristics of periodic cross-corrugated channels, International Journal Of Heat And Mass Transfer Volume: 84 Pages: 542-549 Published: MAY 2015	No	Yes	Yes
2014				**Liu Xiaoping; Niu Jian-lei***	An optimal design analysis method for heat recovery devices in building applications, APPLIED ENERGY Volume: 129 Pages: 364-372 Published: SEP 15 2014	No	Yes	Yes

9. Recognized International conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper)*

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*
July/2014/ Hong Kong	Evaluation Of Turbulence Models For Simulating Flow And Heat Transfer In Cross-Corrugated Triangular Channels	ISIAQ flagship International conference - Indoor Air 2014, Hong Kong, July 6-12, 2014	No	Yes	Yes
July/2014/ Hong Kong	An Optimal Design Analysis Method For Heat Recovery Heat Exchangers In Building Applications	ISIAQ flagship International conference - Indoor Air 2014, Hong Kong, July 6-12, 2014	No	Yes	Yes

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

An MEng graduate from PolyU is undertaking PhD study in Norway, extending the study to the application of the membrane-based heat recovery unit to frosty, cold climates.