RGC Ref. No.:
UGC/FDS25/E10/16
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines: *1. Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
*2. Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Study on the transient response performance of liquid desiccant dehumidifier and regenerator under the coupling effect of different control algorithm

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

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Luo Yimo/TF I	FST/THEi
Co-Investigator(s)	Dr. WANG Yuanhao Dr. WU Wing Kin Prof. YANG Hongxing	FST/THEi FST/THEi BSE/PolyU
Others	NA	

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 January 2017	NA	
Project Completion Date	31 December, 2019	9 July, 2019	25 April, 2019
Duration *(in month)*	36	30	25 April, 2019

Deadline for Submission of Completion Report	31 December, 2020	9 July, 2020	25 April, 2019

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. A dynamic model will be developed to render the predication of the transient response performance of the dehumidifier and regenerator.
2. Using the verified model in objective 1, the simulations aim to obtain the following transient response performance, such as response time, parameter distributions in the interior of the dehumidifier and regenerator, and response curves of outlet parameters.
3. The test rig will be set up using the results of objective 2. After the validation of the test rig, the experiment will be conducted to investigate the transient response performance.
4. The newly-established model will be further improved by comparing the simulation and experimental results.
5. Guidelines beneficial to the design and operation of the control system will be suggested through a comprehensive comparison and analysis.

5.2 Revised objectives

Date of approval from the RGC: NA

Reasons for the change: NA

1.

2.

3. ..

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

1) Objective 1 (100% achieved)
   A dynamic model based on CFD had been established as scheduled to investigate the transient performance of the liquid desiccant dehumidifier and regenerator. The advantage of the present novel model over other existing models is the introduce of variable time (t) to render the real-time calculation of various parameters. User defined files were compiled to the software to achieve the function of variable inlet parameters. The models for the dehumidifier and regenerator are very similar but some key parameter setting differ due to their different operating conditions.
2) Objective 2 (100% achieved)
   The simulations were conducted with the dehumidifier and regenerator under different control algorithms corresponding to variational inlet air humidity, air temperature, and so on. Besides the time-dependent outlet parameters, the interior situation of the dehumidifier and regenerator could also be investigated with the model. The indices, such as response time, delay time and adjustment time, were compared and analyzed to find the factor which had a more significant effect on the devices. The parameter distributions in the interior of the dehumidifier and regenerator could be used to find the underlying reasons for the macro phenomenon.
3) Objective 3 (100% achieved)
   As planned, the existing test rig was improved by installing some sensors with higher accuracy and control devices, making it work as an adiabatic dehumidifier, internally cooled dehumidifier, adiabatic regenerator, and an internally heated regenerator by adopting different operation modes. Therefore, it could be used to investigate the transient performance of the dehumidifier/regenerator under various circumstances. The reasonability of the test rig was then verified by the energy and mass transfer conservation principle. The data loggers were used to collect all the experimental data for convenient handling. The experimental results were compared with the simulation results to find whether there was over-estimation or under-estimation of the model.
4) Objective 4 (100% achieved)
   As mentioned, there were some discrepancies between the experimental and simulation results. The reasons of the differences had been uncovered by a careful study and analysis. It was found the biggest factor resulting in the difference might be the contact time adopted in the model. It was not easy to make a correct decision as it was the hardest part in employing the penetration mass transfer theory. In the present project, by trial and error, a relatively accurate contact time was determined and utilized for the model, making it a better predication for the performance of the devices.
5) Objective 5 (100% achieved)
   With the improved model, more cases had been simulated to find the better control methods. Based on the comprehensive study, some practical guidelines were summarized for better design and operation of the control of the dehumidifier/regenerator. Besides, the above novel model was integrated to some liquid desiccant air conditioning systems to give constructive suggestions.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. A dynamic model will be developed to render the predication of the transient response performance of the dehumidifier and regenerator	✓	100%
2. Using the verified model in objective 1, the simulations aim to obtain the following transient response performance, such as response time, parameter distributions in the interior of the dehumidifier and regenerator, and response curves of outlet parameters	✓	100%
3. The test rig will be set up using the results of objective 2. After the validation of the test rig, the experiment will be conducted to investigate the transient response performance	✓	100%
4. The newly-established model will be further improved by comparing the simulation and experimental results	✓	100%
5.Guidelines beneficial to the design and operation of the control system will be suggested through a comprehensive comparison and analysis	✓	100%

6. Research Outcome

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

Major findings are listed as follows,

1) The influences of various parameters on the response performance of the devices were investigated with simulation. The conclusions are: (a) Air outlet humidity and air outlet temperature showed almost the same sensitivity to the change of air inlet humidity; (b) The response time of the dehumidifier to the increase of air velocity was much shorter than that to the change of air temperature and humidity; (c) For the dehumidifier with an adverse current configuration, there was not any lag for both outlet parameters after the change of solution parameters. More information could be referred to the conference paper titled with "Study on the Transient Performance of a Liquid Desiccant Dehumidifier under Changing Boundary Conditions" in Part C.
2) The film shrinkage was introduced to the mathematical models of dehumidification/regeneration and validated by the experimental data. Results showed that the wetting ratio predicted by the model matched well with the measured one with the relative difference of 3.4%. Besides, the dehumidification/regeneration performance obtained by the model in terms of absolute moisture changes was also in line with the experimental ones with the MARD of 6.05%/4.2%. More information could be referred to the journal paper titled with "Thermal properties study and performance investigation of potassium formate solution in a falling film dehumidifier/regenerator" in Part C.
3) Regarding the unsteady properties of the components, a novel dynamic model was developed for a liquid desiccant air conditioning system. In the model, the variable t (time) was involved in the governing equations for each component. Then, the system was tailored to an office building with the capacity of eight people in Hong Kong. The tendency of various parameters was presented and the results showed that there was delay or even some discrepancies between the tendency of input and output parameters. This further reflects that the influence of the former state on the following running of the system could not be ignored. Therefore, the novel model could be a reliable tool to predicate the system operation and provide useful information for better control of the system as well. More information could be referred to the journal paper titled with "Development and application of a dynamic model for a solar assisted liquid desiccant air conditioning system" in Part C.
4) The transient model was applied for the dehumidifier/regenerator in a desiccant enhanced evaporative cooling air conditioning system. It indicates that the thermal energy input to the regenerator plays a key role in system performance. The RIEC performance not so largely depends on the outdoor air conditions because of the pre-treatment process by LDD. Both the moisture removal rate and cooling capacity improve with the increase of solar collector area. The LDD-RIEC A/C system saves 47% energy consumption compared with the MVCR system in Hong Kong summer days. More information could be referred to the conference paper titled with "Energy Performance of Solar Assisted Desiccant Enhanced Evaporative Cooling Air conditioning System" in Part C.

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

Based on the present project, some research directions could be developed in future.

1) The simulation method could be applied to investigate the dynamic performance of other heat and mass transfer devices, such as condenser, indirect evaporative cooler, and so on.

2) It is potential to integrate the developed model to air conditioning systems for accurate predication, and therefore more in-depth investigation of the transient performance of various systems can be expected.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

Compared to the traditional air conditioner, the control system of liquid desiccant air-conditioning system is more complicated. Its inadequate control scheme has prevented its popularization. To guarantee an effective and stable operation of the liquid desiccant air-conditioning system, it is important that the transient response performance of the dehumidifier and regenerator should be predicted accurately. However, this is difficult because there are very few studies on their dynamic operation and transient response performance. Because of the absence of accurate predictions, appropriate guidelines for the control system design and operation cannot be put forward. Therefore, this project had established reliable dynamic models for the dehumidifier and regenerator to investigate their transient response performance numerically and experimentally. The developed model had been used to carry out a comprehensive analysis of the effect of various factors and different conditions. Measures to optimize the control system design and operation were put forward. Practical guidelines for the design and operation of the control system were presented for engineering applications, especially for some popular air conditioning systems.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the 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) *(denote the correspond-ing 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)*	Acknowl-edged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2018				Xiaohui She, Yonggao Yin, Yimo Luo, Brett Lindeman, Dan Zhong, Xiaosong Zhang*	Experimental study of a novel subcooling method based on liquid desiccant dehumidification for vapor-compression refrigeration systems. *Applied Thermal Engineering* 130 (2018) 1460–1471.	2018	No	Yes	Yes
2018				Dan Zhong, Tao Wen, Xiaohui She, Yi Chen, Meng Wang, Hongxing Yang, Yimo Luo*	Development and application of a dynamic model for a solar assisted liquid desiccant air conditioning system. *Science and Technology for the Built Environment*, (2018) 0, 1–11	NA	Yes	Yes	Yes
2019				Tao Wen, Meng Wang, Yi Chen, Weifeng He, Yimo Luo*	Thermal properties study and performance investigation of potassium formate solution in a falling film dehumidifier/regenerator. International *Journal of Heat and Mass Transfer* 134 (2019) 131–142	NA	Yes	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 conference abstract)

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 RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
June/2018/ Edinburgh, Scotland, UK	Study on the Transient Performance of a Liquid Desiccant Dehumidifier under Changing Boundary Conditions	The Economy, Sustainable Development and Energy International Conference (ESDEIC)	No	Yes	Yes	Yes
Oct/2017/ Shandong, China	Energy Performance of Solar Assisted Desiccant Enhanced Evaporative Cooling Air Conditioning System	International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC)	Yes	No	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

Yes. 1) During project execution, the researchers had a deep experience in the significance of understanding the dynamic heat and mass transfer in various devices. The knowledge was conveyed to students with more explanation in the chapter of transient heat and mass transfer in the BSE core module “Heat & Mass Transfer”. 2) The comprehensive investigation of various models deepened researchers' understanding of their development. It facilitated the researchers to introduce the history of relevant rules or laws in the class, which played a positive role in consolidating the basic knowledge of students. 3) By attending international conferences, the advanced knowledge and news in BSE were shared by the researchers, especially beneficial for supervising final year research projects.

11. 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
NA			

12. Other Impact
(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

1)During project execution, a research group at Southeast University in Nanjing led by Prof. Zhang was found doing very good works in related areas and having excellent facilities. Therefore, except for Prof. Yang at PolyU mentioned in the proposal, PI also tried to contact Prof. Zhang and finally established a good collaboration with him.
2)The teaching was enhanced by introducing updated technologies acquired through conducting the project. Besides, the mechanism study made the researchers give a much clearer derivation of various fundamental formulas.

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	3	2	0	0	Type	No.
					NA	0

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
NA	