

CONTENTS

Host Chapter, Officers, and Conferences and Expositions Committee	xiii
State of Society Address, Sheila J. Hayter, 2018–2019 ASHRAE President	xiv
Technical Program	xx

CONFERENCE PAPERS

AT-19-C001	HAMT Extension for EnergyPlus Encompasses Moisture Sources due to Air Leakage Florian Antretter, Member ASHRAE; Simon Pallin, PhD, Member ASHRAE	3
AT-19-C002	Accuracy of a Crude Approach to Urban Multi-Scale Building Energy Models Compared to 15-min Electricity Use Eric Garrison; Joshua New, PhD, Member ASHRAE; Mark Adams, Member ASHRAE	11
AT-19-C003	Challenges of Creating a Verifiable Building Energy Model J. Ligade, Student Member ASHRAE; D. Sebastian, Member ASHRAE; A. Razban, PhD, PE, Member ASHRAE	20
AT-19-C004	Economic Feasibility of Combined Cooling, Heating and Power Systems Hyeunguk Ahn, Student Member ASHRAE; James D. Freihaut, PhD, Member ASHRAE; Donghyun Rim, PhD, Associate Member ASHRAE	29
AT-19-C005	Field Demonstration of an Automated Building Commissioning Tool Hayden Reeve, PhD, Member ASHRAE; Buyun (Jason) Jing; Zhengang Zhu; Rohan Chabukswar, PhD; Anarta Ghosh, PhD; Yun Li	37
AT-19-C006	Optimization of Condenser Water Loop Control in Hot and Humid Climates Lei Wang, PhD, PE, Member ASHRAE; Yasuko Sakurai, D.Eng, Member ASHRAE; Steven J. Bowman	47
AT-19-C007	Surface Condensation Control for Concrete Core Systems utilizing Model Predictive Control Deok-Oh Woo, Student Member ASHRAE	55
AT-19-C008	Applying TABS to a Publishing Company Headquarters Using Integrated Design Kosuke Sato, PhD, Member ASHRAE; Eri Kataoka; Susumu Horikawa, Member ASHRAE; Shin-ichi Tanabe, PhD, Fellow ASHRAE; Jun Shinoda, Student Member ASHRAE	64
AT-19-C009	Hybrid GEOTABS: System Concept, Individual Modules, and Interfaces Dolaana Khovalg, PhD, Associate Member ASHRAE; Ongun B. Kazanci, PhD, Associate Member ASHRAE; Gerald Parnis; Jiří Cigler, PhD; Bjarne W. Olesen, PhD, Fellow ASHRAE	72
AT-19-C010	Computational Fluid Dynamics (CFD) Modeling Indoor Chemical Reactions under Varied Lighting and HVAC Operation Conditions Youngbo Won, Student Member ASHRAE; Donghyun Rim, PhD, Associate Member ASHRAE	80
AT-19-C011	Model-based and Data-driven Anomaly Detection for Heating and Cooling Demands in Office Buildings Araz Ashouri, PhD, Associate Member ASHRAE; Yitian (Vera) Hu; H. Burak Gunay, PhD, Associate Member ASHRAE; Guy R. Newsham, PhD; Weiming Shen, PhD	87
AT-19-C012	Optimizing Building Performance using Stochastic Occupant Models Mohamed Ouf, PhD, Member ASHRAE; William O'Brien, PhD, Associate Member ASHRAE; H. Burak Gunay, PhD, Member ASHRAE	96

AT-19-C013	Toward Machine Learning-based Prognostics for Heating Ventilation and Air-Conditioning Systems Chunsheng Yang; Weiming Shen; H. Burak Gunay; Zixiao Shi	106
AT-19-C014	Power Consumption Simulator of Data Center by using Computational Fluid Dynamics and Machine Learning Hayato Kuwahara; Ying-Feng Hsu, PhD; Kazuhiro Matsuda; Morito Matsuoka, PhD, Member ASHRAE	116
AT-19-C015	The Effect of Forced Air Warming Devices on Surgical Site Infection Abdel K. Darwich, PE, Member ASHRAE; Fatih Turan, Member ASHRAE; Suhasini Pyarasani, Member ASHRAE	124
AT-19-C016	Analysis of Displacement Ventilation for Hospital Patient Rooms Kishor Khankari, PhD, Fellow ASHRAE	133
AT-19-C017	A New Fast Fluid Dynamics Model for Data-Center Floor Plenums Wei Tian, PhD; James W. VanGilder, PE, Member ASHRAE; Xu Han, Student Member ASHRAE; Christopher M. Healey, PhD; Michael B. Condor; Wangda Zuo, PhD, Member ASHRAE	141
AT-19-C018	The Assumption of Equidistance in the Seven-point Thermal Sensation Scale and a Comparison between Categorical and Continuous Metrics Aghniaey Sama, Student Member ASHRAE; Thomas M. Lawrence, PhD, PE, Fellow ASHRAE	149
AT-19-C019	Predicting Thermal Comfort in Mixed-mode Office Building in the UK Xiaoyan Luo, Student Member ASHRAE; Mahroo Eftekhari, PhD, Member ASHRAE; Faisal Durrani, PhD; Dulhas Maliyekkal Kanhirothkandi, Associate Member ASHRAE.....	158
AT-19-C020	Maximize Thermal Comfort in Open-plan Offices by Occupant-oriented Control based on Individual Thermal Profile Wanni Zhang; Chenlu Zhang.....	167
AT-19-C021	Quantifying the Importance of Measured Metabolic Rates and Clothing Levels for Effectively Using a Predicted Mean Vote Model: A Global Sensitivity Analysis Jermy Thomas, Student Member ASHRAE; Tiffany Swenson; Amanda D. Smith, PhD, Associate Member ASHRAE	176
AT-19-C022	Photocatalytic Activity and Durability of Commercial TiO ₂ Photocatalysts for Indoor Air Purification Alireza Haghghatmamaghani, Student Member ASHRAE; Fariborz Haghghat, PhD, Fellow ASHRAE; Chang-Seo Lee, PhD, Associate Member ASHRAE.....	184
AT-19-C023	Capabilities and Limitations of Commercially Available Wireless Indoor Environment Sensors Angelos Mylonas; Ongun B. Kazanci, PhD, Associate Member ASHRAE; Rune K. Andersen, PhD; Bjarne W. Olesen, PhD, Fellow ASHRAE	193
AT-19-C024	Temporal Variations in Estimated Ventilation and Relative Performance based on Continuous CO ₂ Monitoring in Offices Tomas Novotny, Member ASHRAE; Rick Aller; Salvatore della Vecchia; Samy Clinchard; Ulla Haverinen-Shaughnessy	200

AT-19-C025	Comparing Configurations for Supply and Return Vents in Mixed Air Distribution Systems to Reduce Micro-particle Indoor Concentrations Walid Chakroun, PhD, Fellow ASHRAE; Soroor Alotabi, PhD, Member ASHRAE; Nesreen Ghaddar, PhD, Member ASHRAE; Kamel Ghali, PhD, Member ASHRAE	206
AT-19-C026	Restoring Trust: How Building Automation, Operators and Tenants Restored Indoor Environmental Conditions following Failed Improvement Measures Orvil Dillenbeck, PEng, Member ASHRAE	215
AT-19-C027	The Convergence of Standard 90.1, 62.1 and 55: Examples of Energy Efficiency Measures Chonghui Liu, PE, Member ASHRAE.....	223
AT-19-C028	Indoor Air Quality (IAQ) and Energy Efficiency D. Nirmal Ram, Fellow ASHRAE.....	231
AT-19-C029	Performance Evaluation of Active Chilled Beam in Real Office Conditions in a High-Performance Building in Heating Rohit Upadhyay, Student Member ASHRAE; Rodrigo Mora, PhD, Associate Member ASHRAE	238
AT-19-C030	Experimental and Simulation Studies on Solar-Ground Source Heat Pump System Eikichi Ono; Taizo Shimo; Masaki Shioya, PhD; Yoshiro Shiba, PhD.....	247
AT-19-C031	Modeling and Parametric Study of Large Diameter Shallow Bore Helical Ground Heat Exchanger Antash Najib, Student Member ASHRAE; Angelo Zarrella, PhD; Vinod Narayanan, PhD, Member ASHRAE; Peter Grant; Curtis Harrington, PE; Rachael Larson.....	255
AT-19-C032	Demonstration and Simulation of Gas Heat Pump-Driven Residential Combination Space and Water Heating System Performance Paul Glanville, Member ASHRAE; Aleksandr Fridlyand, Member ASHRAE; Chris Keinath, Member ASHRAE; Michael Garrabrant, Member ASHRAE	264
AT-19-C033	Human Factors of High Performance Multifamily Housing Philip Agee, Student Member ASHRAE; Andrew McCoy, PhD; Georg Reichard, PhD, Member ASHRAE; Brian Kleiner, PhD; Dong Zhao, PhD; Fredrick Paige, PhD	273
AT-19-C034	Energy Savings Estimates for Occupancy and Temperature-based Smart Ventilation Control Approaches in Single-family California Homes Jordan D. Clark, PhD, Associate Member ASHRAE; Iain S. Walker, PhD, Fellow ASHRAE; Brennan D. Less; Spencer M. Dutton, PhD; Xiwang Li, PhD; Max H. Sherman, PhD, Fellow ASHRAE	281
AT-19-C035	Next-Generation Residential Space Conditioning System for California Sara Beaini, PhD, PE, Member ASHRAE; Ammi Amarnath; Walter Hunt, Member ASHRAE; Ronald Domitrovic, PhD, Member ASHRAE; Sreenidhi Krishnamoorthy, Student Member ASHRAE; Curtis Harrington, PE; Mark Modera, PhD, PE, Fellow ASHRAE; Robert Davis, PE, Member ASHRAE; Ryohei Hinokuma; Morton Blatt, Fellow ASHRAE	289
AT-19-C036	Design of Multi Nozzles for a Portable Air Flow Meter using Numerical Simulation Sang Taek Oh, PhD, PE, Associate Member ASHRAE; Jong Jun Park, Student Member ASHRAE; Young Il Kim, PhD, PE, Member ASHRAE; Sean Hay Kim, PhD, Member ASHRAE.....	298

AT-19-C037	Effect of Mixed Super-Hydrophilic and Super-Hydrophobic Surface Coatings on Droplets Freezing and Subsequent Frost Growth During Air Forced Convection Channel Flows Lorenzo Cremaschi, PhD, Member ASHRAE; Ellyn Harges, Student Member ASHRAE; Burak Adanur, Student Member ASHRAE; Amy Strong, Student Member ASHRAE	307
AT-19-C038	Optimization of Microchannel Shape Using Analytical Models for Condensation Khoudor Keniar, Student Member ASHRAE; Srinivas Garimella, PhD, Member ASHRAE.....	315
AT-19-C039	Improving Effective Energy-Efficient Commercial Package Dedicated Outside Air Systems Located in Hot-Humid Climate Zones Charles R. Withers, Jr.; David Salyer	323
AT-19-C040	In-Situ Observations of Series and Parallel Fan Powered Terminal Units John A. Bryant, PhD, PE, Member ASHRAE; Basel Kanaan.....	332
AT-19-C041	Development and Calibration of an Online Energy Model for AHU Fan Jin Dong, PhD, Member ASHRAE; Piljae Im, PhD, Member ASHRAE; Sen Huang, PhD, Student Member ASHRAE; Yan Chen, PhD, Member ASHRAE; Jeffrey Munk, Member ASHRAE; Teja Kuruganti, PhD	341
AT-19-C042	Legionella Regulation, Cooling Tower Positivity and Water Quality in the Quebec Context Patrick Racine, PEng, Member ASHRAE; Steve Elliott; Stephen Betts	350
AT-19-C043	Method for Centrifugal Chiller Power Estimation and Prediction: Development and Verification Marcelo Acosta, PEng, Member ASHRAE; Vladimir Suslov, PhD, PEng	360
AT-19-C044	Industry/Government/Academia Partner to Achieve SCOP > 5 Hot-Climate MEPS Air-Cooled Chiller Muhammad Tauha Ali, PE, Member ASHRAE; Peter Armstrong, PE, PhD, Member ASHRAE.....	368
AT-19-C045	Effect of the Specification of Chilled and Hot Water Coil on Efficiency of Air Conditioning System with Water Thermal Storage Tomoya Kawaji, PhD, Associate Member ASHRAE; Ryuji Yanagihara, PhD; Nobuo Nakahara, Dr.Eng; Hiroshi Ninomiya, Member ASHRAE; Kazuki Nakatsuka	376
AT-19-C046	Desiccant Dehumidification Process for Energy Efficient Air Conditioning Thomas B. Cremonte, Student Member ASHRAE; Jonathan Maisonneuve, PhD, Associate Member ASHRAE	384
AT-19-C047	A Novel Heat and Mass Transfer Model for Membrane-based Ionic Liquid Desiccant Air Dehumidifier Xiaoli Liu, Student Member ASHRAE; Ming Qu, PhD, Member ASHRAE; Xiaobing Liu, PhD, Member ASHRAE; Joseph Warner, Student Member ASHRAE.....	392
AT-19-C048	Sensitivity Study of Crystallization Fouling in a Liquid-to-Air Membrane Energy Exchanger using Three Desiccant Solutions Adesola O. Olufade, PhD, Associate Member ASHRAE; Carey J. Simonson, PhD, PEng, Fellow ASHRAE	401
AT-19-C049	A Liquid-Desiccant-Based Heat Recovery System for Gas-Fired Boilers in District Heating Networks Xiaoyue Zhang; Zhen Li, PhD, Member ASHRAE	410

AT-19-C050	Integrated Heat Recovery System Design of a Variable Refrigerant Flow (VRF) Heat Recovery System with a Domestic Hot Water (DHW) System Dongsu Kim, Student Member ASHRAE; Jaeyoon Koh, PhD, Associate Member ASHRAE; Heejin Cho, PhD, Associate Member ASHRAE; HyunJin Nam.....	418
AT-19-C051	A Case Study of Sensitivity Analysis of the Domestic Hot Water System in Large Hotels Zhihong Pang, Student Member ASHRAE; Zheng O'Neill, PhD, PE, Member ASHRAE.....	426
AT-19-C052	Demonstrating the Benefit of Multi-Objective Optimization and Clustering for the Design of Waste Heat Recovery Systems Gabriel Legorburu, PE, Associate Member ASHRAE; Amanda D. Smith, PhD, Associate Member ASHRAE	436
AT-19-C053	Energy, Emissions and Economics (EEE) Impact Derivation and Applications for Energy Performance Calculations and Comparisons Neil Leslie, PE, Member ASHRAE; David Goldstein, PhD, Life Member ASHRAE	444
AT-19-C054	System-level Key Performance Indicators (KPIs) for Building Performance Evaluation Han Li, Associate Member ASHRAE; Tianzhen Hong, PhD, PE, Member ASHRAE; Marina Sofos, PhD, Member ASHRAE	453
AT-19-C055	Taking the (Fuel) Blinders off Energy Codes Part 2: Metrics and Mechanics in the Modern Era Jim Edelson, Member ASHRAE; Alexi Miller, PE, Member ASHRAE	461
AT-19-C056	Targeting Building Energy Efficiency Opportunities: An Open-source Analytical and Benchmarking Tool Han Li, Associate Member ASHRAE; Carolyn Szum; Sara Lisaukas, Ahmed Bekhit, PhD; Clay Nesler, Member ASHRAE; Steven C. Synder, PE, Member ASHRAE	470
AT-19-C057	Comparison of Approaches for Calculating Annualized Data Center Energy Metrics Rehan Khalid, Student Member ASHRAE; Aaron P. Wemhoff, PhD, Associate Member ASHRAE	479
AT-19-C058	Study on the Prediction Models of Temperature and Energy by using DCIM and Machine Learning to Support Optimal Management of Data Center Kosuke Sasakura; Takeshi Aoki; Takeshi Watanabe, PhD.....	488
AT-19-C059	Cooling System with Low Power Usage Effectiveness below 1.02x for Server Rooms Naoki Aizawa, Member ASHRAE.....	496
AT-19-C060	Novel Ventilation Concepts for Efficient Heating Dynamics of Vehicle Passenger Compartments Tobias Dehne; Pascal Lange; Andreas Westhoff, PhD.....	504
AT-19-C061	Numerical Investigations of Thermal Comfort inside Cruise Ships Ahmed Emad; Essam E. Khalil, Fellow ASHRAE; Gamal ElHarriry; Taher M. Aboudeif.....	512
AT-19-C062	Shape Effectiveness of HVAC Outlets on Automobile Thermal Comfort Ibrahim Reda; Essam E. Khalil, Fellow ASHRAE; Taher M. Aboudeif; Ahmed El Degwy	520
AT-19-C063	Flammable Refrigerants: Performance Comparison, Safeties and Lessons Learned Amir Jokar, PhD, PE, Member ASHRAE; Sean O'Hern, PhD, PE, Member ASHRAE; David Anderson, PhD, PE; Michael Cundy, PhD, PE; Russell Ogle, PhD, PE	528

AT-19-C064	Accelerated Life Methodology for Determining Acceptable Chemical Reactivity in HVACR Systems Steve Kujak, Member ASHRAE; Elyse Sorenson, Member ASHRAE	537
AT-19-C065	Impacts of Defrosting Air Cooling Coils Donald J. Cleland, PhD, Fellow ASHRAE; Richard J. Love, PhD, Member ASHRAE; Todd B. Jekel, PhD, PE, Member ASHRAE; Douglas T. Reindl, PhD, PE, Fellow ASHRAE	545
AT-19-C066	Improved Control of Condensers Richard J. Love, PhD, Member ASHRAE; Donald J. Cleland, PhD, Fellow ASHRAE; Todd B. Jekel, PhD, PE, Member ASHRAE; Douglas T. Reindl, PhD, PE, Fellow ASHRAE	554
AT-19-C067	Performance Evaluation of Energy-Efficient Hybrid Ventilation Systems for Office Buildings Hisaya Ishino, PhD, Member ASHRAE; Shuzo Murakami, PhD, Fellow ASHRAE; Kimiko Kohri, PhD, Member ASHRAE; Isao Makimura; Fumio Nohara, Member ASHRAE	563
AT-19-C068	Simulation Study of Infiltration Effects on Demand Controlled Ventilation System with High-variant Occupancy Schedules Siliang Lu, Student Member ASHRAE; Omer Karaguzel, PhD; Erica Cochran Hameen, PhD	571
AT-19-C069	Further Simplifying ASHRAE Standard 62.1 for Application to Existing Buildings: Comparing Informative Appendix D and Section 6.2.5.2 with Real-World Data Meghan McNulty, PE, Associate Member ASHRAE; Pamela Moua-Vargas, Associate Member ASHRAE; Barry Abramson, PE, Member ASHRAE	579
AT-19-C070	Temporal Analysis of Wind Data for Wind-Driven Ventilation Assessment James Lo, PhD, Member ASHRAE; Yun Zhang, Student Member ASHRAE; Sheng Wang, Student Member ASHRAE	588

TECHNICAL PAPERS

AT-19-001	A Review of Prior ASHRAE Research Efforts to Characterize Noise Propagation in Ducts D.W. Herrin, Associate Member ASHRAE; Kangping Ruan, Student Member ASHRAE	599
AT-19-002	The Effect of Length on the Insertion Loss of Fiberglass-Lined Sheet Metal Ducts—Part I: Rectangular Ducts (RP-1408) Douglas Reynolds, PhD, Life Member ASHRAE; Michael Schwob, PE, Member ASHRAE	609
AT-19-003	The Effect of Length on the Insertion Loss of Fiberglass-Lined Sheet Metal Ducts—Part II: Round Ducts (RP-1408) Douglas Reynolds, PhD, Life Member ASHRAE; Michael Schwob, PE, Member ASHRAE	621
AT-19-004	A Comparison of the Annual Energy Use of Fixed- and Variable-Airflow Parallel Fan-Powered Terminal Units in a Small Office Building Di Lu; Dennis L. O'Neal, PhD, PE, Fellow/Life Member ASHRAE; Peng Yin, PhD, Associate Member ASHRAE	633
AT-19-005	Effects of System Materials toward the Breakdown of Lubricants and Low-GWP Refrigerants (RP-1774) Ngoc Dung (Rosine) Rohatgi, PhD, Member ASHRAE	648

AT-19-006	Withdrawn	
AT-19-007	Seasonal Solar Energy Storage Technologies in Buildings Uroš Stritih, PhD, Associate Member ASHRAE	668
AT-19-008	Energy Performance, Comfort, and Lessons Learned from an Institutional Building Designed for Net Zero Energy Vasken Dermardiros, Student Member ASHRAE; Andreas K. Athienitis, PhD, PE, Fellow ASHRAE; Scott Bucking, PhD, PE, Associate Member ASHRAE	682
AT-19-009	Preliminary Investigations of the Impact of Variable-Frequency Drive (VFD) Output Voltage on Motor Efficiency Gang Wang, PhD, PE, Member ASHRAE.....	696
AT-19-010	Energy Performance of an Occupancy-Based Climate Control (OBCC) Technology in Guest Rooms Hyojin Kim, PhD, Member ASHRAE; Emily Oldham, Student Member ASHRAE.....	703
AT-19-011	HVAC System Air Leakage Requirements for Deep Energy Retrofit Projects Alexander Zhivov, PhD, Life Member ASHRAE; Craig P. Wray, PEng, Member ASHRAE; Lars-Åke Mattsson; Herman Behls, PE, Fellow ASHRAE; Larry Smith, PE, Member ASHRAE.....	718
AT-19-012	Representative Layer-by-Layer Descriptions for Fenestration Systems with Specified Bulk Properties such as U-Factor and Solar Heat Gain Coefficient (RP-1588) Yu Joe Huang, BEMP, Member ASHRAE; Neal Kruis, PhD, Associate Member ASHRAE; Michael O'Keefe; Peter Lyons, PhD, Member ASHRAE; Justin Wong, Member ASHRAE.....	729
AT-19-013	Development of a Reference Building Information Model (BIM) for Thermal Model Compliance Testing—Part II: Test Cases and Analysis (RP-1468) Francisco Farias, PhD; Sandeep Kota; WoonSeong Jeong, PhD; Jong Bum Kim, PhD; Jose Luis Bermudez Alcocer, PhD, Associate Member ASHRAE; Jeff S. Haberl, PhD, BEMP, Life Member ASHRAE; Mark J. Clayton, PhD; Wei Yan, PhD	750
	Index of Technical Papers, Volume 125, Part 1	765