

CONTENTS

Host Chapter, Officers, and Conferences and Expositions Committee	xiii
State of the Society Address, Charles E. Gullledge III, 2020–2021 ASHRAE President	xiv
Technical Program	xviii

CONFERENCE PAPERS

VC-21-C001	A Tool for Modeling Energy and Resilience for Community-Scale Networks of Buildings and District Systems Michael P. O’Keefe; Peter Ellis, Member ASHRAE; Alexander Zhivov, PhD, Fellow/Life Member ASHRAE; Richard J. Liesen, PhD, Member ASHRAE; Anthony Latino, Member ASHRAE; Michael P. Case, PhD, Affiliate Member ASHRAE	3
VC-21-C002	A Text-Mining Framework to Provide Insights into the Maintenance Performance of Buildings Pedram Nojedehi, Student Member ASHRAE; H. Burak Gunay, PhD, Associate Member ASHRAE; William O’Brien, PhD, Associate Member ASHRAE	12
VC-21-C003	BIM-Based Life-Cycle Design and Commissioning in a Smart Office Building Shiro Tsukami, Member ASHRAE; Hirotaka Kubo, Associate Member ASHRAE; Iwao Hasegawa, Member ASHRAE; Masayuki Ichinose, PhD, Member ASHRAE	21
VC-21-C004	Estimation of Infiltration in Commercial Buildings Based on Existing CO ₂ Sensors: An Inverse Approach Zijun Xiong, Student Member ASHRAE; H. Burak Gunay, PhD, Associate Member ASHRAE; Cynthia Cruickshank, PhD, Associate Member ASHRAE; Adam Wills, PhD, Associate Member ASHRAE	30
VC-21-C005	Deep Reinforcement Learning for Energy Cost Optimization in Building HVAC Systems Zhanhong Jiang; Michael J. Risbeck; Vish Ramamurti; Sugumar Murugesan; Jaime Amores; Young M. Lee, Member ASHRAE; Kirk H. Drees, Member ASHRAE	38
VC-21-C006	Simulation Comparison of Different Cooling Tower Control Strategies Birajan Bhandari, Associate Member ASHRAE	48
VC-21-C007	Use of Domestic Water Consumption as Proxy for Occupancy Level in Building Cooling Energy Model Hongxiang Fu, Student Member ASHRAE; Shinwoo Lee, Student Member ASHRAE; Juan-Carlos Baltazar, PhD, PE, Member ASHRAE; David E. Claridge, PhD, PE, Fellow Member ASHRAE	57
VC-21-C008	Investigating the Thermal Performance of Canadian Houses Using Smart Thermostat Data Aya Doma, Student Member ASHRAE; Mohamed Ouf, PhD, P.Eng, Associate Member ASHRAE; Guy Newsham, PhD; Heather Knudsen, P.Eng	64
VC-21-C009	Multizone Air Handler Controls Retrofit for Energy Efficiency Eileen T. Westervelt, PE, Member ASHRAE; Christopher M. Battisti, PE, Member ASHRAE; Brianna K. Morton; David M. Schwenk	73
VC-21-C010	Technical Evaluation of a Retrofitted MVHR System: Design and In-Use Performance Adam O’Donovan, BEng, PhD, Associate Member ASHRAE; Micheál Cantillon Murphy, BEng, MEd, Student Member ASHRAE; Eméline Charles, BEng; Nazar Baker, BEng, PhD; Paul D. O’Sullivan, BEng, MSc, CEng, PhD	81
VC-21-C011	Characteristics of Residential Occupancy Profiles for Different Income Groups in the United States Debrudra Mitra, Student Member ASHRAE; Yiyi Chu, Student Member ASHRAE; Kristen Cetin, PhD, PE, Member ASHRAE; Chien-Fei Chen, PhD	91
VC-21-C012	Cooling Energy Consumption Analysis and Potential Cost Savings in a Residential Unit in the Midwest Region in the US Maher Shehadi, PhD, Member ASHRAE	100

VC-21-C013	Evaluation of Energy Consumption and Efficiency in a Historical Residential Home Before and After Building Renovations Jonathan P. Ore, Student Member ASHRAE; Davide Ziviani, PhD, Member ASHRAE; Eckhard A. Groll, Dr. Eng., Fellow ASHRAE	110
VC-21-C014	Residential Occupant-Dependent Appliance Power and Time-Of-Use Estimation for Grid Demand Response Applications Niraj Kunwar, PhD, Student Member ASHRAE; Soham Vanage, Student Member ASHRAE; Kristen Cetin, PhD, PE, Member ASHRAE	118
VC-21-C015	A Modularized Urban Scale Building Energy Modeling Framework Designed with an Open Mind Xuechen Lei, PhD, Associate Member ASHRAE; Yunyang Ye, PhD, Associate Member ASHRAE; Jeremy Lerond, Associate Member ASHRAE; Jian Zhang, PhD, Member ASHRAE.....	126
VC-21-C016	Modeling Modern, Residential, Combined Space and Water Heating Systems Using EnergyPlus Aleksandr Fridlyand, PhD, Associate Member ASHRAE; Alejandro Baez Guada, Associate Member ASHRAE; Tim Kingston, Associate Member ASHRAE; Paul Glanville, PE, Associate Member ASHRAE	135
VC-21-C017	Applying ASHRAE Standard 100 to Real-World Building Data Jamie Kono, PE, Associate Member ASHRAE; Noriaki Kono.....	143
VC-21-C018	WITHDRAWN	
VC-21-C019	Implementation of Occupant-Based Control in Typical Academic Buildings Yiyi Chu, Student Member ASHRAE; Debrudra Mitra, Student Member ASHRAE; Kristen Cetin, PhD, PE, Member ASHRAE	152
VC-21-C020	An Investigation on the Impact of Retrofitting the Envelope of a Typical Small Office Building with PCM on the Building Energy Consumption in Different Zones of the U.S. Amin Hosseini, Student Member ASHRAE; Pouya Ammari Azar; Kim Yang-Seon, PhD, Member ASHRAE	161
VC-21-C021	Dynamic Thermal Performance of the BIPV Facades Mohammad Rahiminejad; Alexandre L.M. Pâris; Dolaana Khovalyg, PhD, Associate Member ASHRAE	170
VC-21-C022	Evaluating a 1MW Solar PV/Natural Gas Microgrid for Firm On-Peak Power and Resiliency: A Detailed Look at Cost and Performance James Leidel, Member ASHRAE	179
VC-21-C023	Impact of the Ventilated Cavity on the Thermal Performance of Traditional Wall Structures Mohammad Rahiminejad; Dolaana Khovalyg, PhD, Associate Member ASHRAE.....	187
VC-21-C024	Comparison of Three Different Ventilation Approaches for an Open Office Space Regarding Pathogen Distribution and Thermal Comfort by CFD Oliver Höfert, PhD; Maciej Danielak, PhD, Associate Member ASHRAE	196
VC-21-C025	Effects of Indoor Airflow and Ventilation Strategy on the Airborne Virus Transmission Gen Pei, Student Member ASHRAE; Donghyun Rim, PhD, Associate Member ASHRAE; Mary Isabella Taylor, Student Member ASHRAE.....	206
VC-21-C026	Investigating Air Distribution Designs for DOAS Systems to Reduce Cross-Contamination in Open Offices Sama Aghniaey, Member ASHRAE; John G. Williams, Member ASHRAE; Steven D. Chaitow; Luis Rivera, Member ASHRAE	216
VC-21-C027	Using Dilution Factor to Characterize Aerosol Risk Management in Emergency Scenarios Travis R. English, PE, Member ASHRAE.....	225

VC-21-C028	A Comparison of Sensing Type and Control Complexity Techniques for Personalized Thermal Comfort Hejja Zhang, Student Member ASHRAE; Michael Kim, Student Member ASHRAE; Xiaoqi Liu, Student Member ASHRAE; Athanasios Tzempelikos, PhD, Member ASHRAE.....	234
VC-21-C029	Dynamic Mesh Analyses of Thermal Comfort of Passengers and IAQ in Wide Body Aircraft Cabins Hassan Kotb, PE; Essam E. Khalil, PhD, PE, Fellow ASHRAE	243
VC-21-C030	Numerical Investigation on the Effect of Stadium Outer Geometry on Cooling Load Esmail M. Bialy, PhD; Saud Ghani	251
VC-21-C031	Avoiding Adverse Air Quality in Hyperscale Data Centers Due to Re-entrainment of Diesel Exhaust Brad C. Cochran, PE, Member ASHRAE	259
VC-21-C032	Effective and Efficient Ventilation for a Healthy Work Environment during Aircraft Painting James S. Bennett, PhD, Member ASHRAE	267
VC-21-C033	Review of the Effects of Indoor Air Quality on Occupants Mary Taylor, Student Member ASHRAE; Donghyun Rim, PhD, Associate Member ASHRAE....	276
VC-21-C034	A Combined Study Of Heat Transfer And Temperature Distribution Inside Heated Double-Wall Infant Incubator Using CFD Hesham Safwat Osman, PhD, Fellow ASHRAE; Ahmed Y. ELHaddad, Student Member ASHRAE	284
VC-21-C035	CFD Analysis of Enclosed Parking Garage Ventilation Kishor Khankari, PhD, Fellow ASHRAE	292
VC-21-C036	CFD Investigation of the Optimal Ventilation System for a Single-Family Room Neonatal Intensive Care Unit Hesham Safwat Osman, PhD, Member ASHRAE; Ahmed M.R. Elbaz, PhD; Ahmed Hosam Antar, Student Member ASHRAE	300
VC-21-C037	Investigation of a Novel Ejector-Based R-290 Refrigeration Cycle Architecture Junyan Ren, Student Member ASHRAE; Riley B. Barta, Student Member ASHRAE; David Ladd; Davide Ziviani, PhD, Member ASHRAE; Eckhard A. Groll, Dr. Ing., Fellow ASHRAE.....	309
VC-21-C038	Model Predictive Control Performance Assessment of Absorption Refrigeration Cycles Utilizing Different Working Fluids Alexios-Spyridon Kyriakides, PhD; Thomas Prousalis; Athanasios I. Papadopoulos, PhD; Ibrahim Hassan, PhD; Panos Seferlis, PhD	318
VC-21-C039	Measuring Oil Retention in Unitary Split System Gas Lines Vatsal M. Shah, Student Member ASHRAE; James E. Braun, PhD, Fellow ASHRAE; Eckhard A. Groll, PhD, Fellow ASHRAE	327
VC-21-C040	Systematic Assessment of Working Fluid Mixtures for Absorption Refrigeration Based on Process and Sustainability Indicators Alexios-Spyridon Kyriakides, PhD; Athanasios I. Papadopoulos, PhD; Vassilis Champilomatis; Alexandros Giannakakis; Vergis Kousidis; Mirko Stijepovic, PhD; Ibrahim Hassan, PhD; Panos Seferlis, PhD	337
VC-21-C041	Fire Propagation in Rail Environments Emil Persson, Affiliate Member ASHRAE; Xinhe (Lily) Liu, Affiliate Member ASHRAE	346
VC-21-C042	Using Normalized Net Energy Savings to Effectively Size Membrane-Based Energy Recovery Ventilation Systems Sancheyan Pushparajah; Patrick Ryan; Krzysztof Kobus, PhD, Member ASHRAE; Jonathan Maisonneuve, PhD, Associate Member ASHRAE	355

VC-21-C043	Demonstrating an Integrated Thermal Heat Pump System for Hot Water and Air-Conditioning at Full Service Restaurants Paul Glanville, PE, Member ASHRAE; Isaac Mahderekal, PE, PhD, Member ASHRAE; Michael Mensinger, Jr., Luke Bingham; Chris Keinath, PhD, Member ASHRAE	363
VC-21-C044	Investigation of Heat Transfer Correlation Comparisons in a Commercial Round-Tube Plate-Fin Condenser Timothy Fair, Student Member ASHRAE; Robert Bedard, PhD, Associate Member ASHRAE; Anthony Bowman, PhD, Associate Member ASHRAE; Hyunjae Park, PhD	371
VC-21-C045	New Method to Simultaneously Measure Local Heat Transfer Coefficient and Visualize Flow Regimes During Evaporation in the Plate Heat Exchanger: Validation and Accuracy Abdel-Rahman Farraj, Student Member ASHRAE; Pega Hrnjak, PhD, Fellow ASHRAE	381
VC-21-C046	Challenges with the New ASHRAE 90.1 Performance Rating Method Jagan Pillai, PE, Member ASHRAE; Shivani Shah, Member ASHRAE; Devanshi Dadia, Member ASHRAE; Jennifer Chalos, Member ASHRAE	391
VC-21-C047	Creating an Energy Model of an Entire University Campus—Part 1: Preliminary Assessment of Building Modeling Techniques Vahid Ahmadi Kalkhorani, Student Member ASHRAE; Jordan D. Clark, PhD, Member ASHRAE.....	400
VC-21-C048	Advanced Zonal Infiltration Measurement Method for Multifamily Buildings: A Novel Test Procedure to Determine Air Leakage Through External and Internal Surfaces Tharanga Jayarathne, Student Member ASHRAE; Michael A. Browne, Associate Member ASHRAE; Michael Gevelber, PhD, Member ASHRAE	409
VC-21-C049	The Technical Basis of Building Performance Standards Jim Edelson, Associate Member ASHRAE; Kim Cheslak	418
VC-21-C050	Fire Detection and Ventilation Response in Rail Tunnels Andre Calado, Member ASHRAE.....	426
VC-21-C051	Global Environmental Stimuli and Human-Building Interaction in Open Space Offices: A Swiss Case Study Verena M. Barthelmes, PhD; Caroline Karmann, PhD; Viviana Gonzalez Serrano; Arnab Chatterjee; Marilyne Andersen, PhD; Jan Wienold, PhD; Dusan Licina, PhD, Associate Member ASHRAE; Dolaana Khovalyg, PhD, Associate Member ASHRAE	434
VC-21-C052	Investigating Occupant Behaviour to Inform Terminal Devices' Control in Mixed-Mode Ventilation Buildings Weihao Liu, Student Member ASHRAE; H. Burak Gunay, PhD, Associate Member ASHRAE; Mohamed Ouf, PhD, Associate Member ASHRAE	443
VC-21-C053	Harmonic Mitigation Strategies in Variable Frequency Drive Applications Ian Wallace.....	452
VC-21-C054	WITHDRAWN	
VC-21-C055	Gaseous By-Products Generated from UV-PCO Process—A Review Jing Wu, Student Member ASHRAE; Anu Stella Mathews, PhD, Member ASHRAE; Lexuan Zhong, PhD, Member ASHRAE.....	460
VC-21-C056	Assessment of Mini-Split Heat Pump Performance with Non-Condensable Gas in Line-Set Aaron Tam, Member ASHRAE; Ronald Domitrovic, Member ASHRAE; Harshal Upadhye.....	469
VC-21-C057	Development of a Continuous Heating Technology for Air Source Heat Pumps Naofumi Takenaka, Kazuya Watanabe, Takeshi Hatomura, Shohei Ishimura, Shinichi Wakamoto.....	478

VC-21-C058	Experimental Evaluation of Frost Development on Tube-Fin Heat Exchangers: Fin Types, Fin Densities, (Super)Hydrophobic and Icephobic Coatings Song Li; Daniel Bacellar, Member ASHRAE; Cara Martin, Member ASHRAE; Colin Lee, Member ASHRAE; Sara Beaini, PhD, Member ASHRAE; James Leverette, Member ASHRAE	487
VC-21-C059	Where are Today's Residential Heat Pump Technologies Cost-Effective? Brandon Johnson; Sreenidhi Krishnamoorthy, PhD, Associate Member ASHRAE	496
VC-21-C060	Heating Ventilation and Air Conditioning Systems Performance Optimization Using a Two-Level Optimization Approach Rand Talib, Student Member ASHRAE; Nabil Nassif, PhD, PE, Fellow ASHRAE.....	505
VC-21-C061	Condenser Water Optimization: Don't Let Perfect Be the Enemy of Good! Abdul Qayyum Mohammed, PE, Member ASHRAE; Neil Wittberg; Mohamed Tatari	514
VC-21-C062	Demonstration of Hygroscopic Cooling Towers for Reduced HVAC Water Consumption Scott Lux; Christopher Martin PhD	
VC-21-C063	Easing Transitions Between Flat Plate and Chiller Bryan Lang, PE, Member ASHRAE; Chris Jackson, PE, Member ASHRAE	531
VC-21-C064	Evaluation of Topology Optimization to Achieve Energy Savings at the Urban District Level Amy Allen, PE, Associate Member ASHRAE; Gregor Henze, PhD, PE, Member ASHRAE; Kyri Baker PhD; Gregory Pavlak, PhD, Member ASHRAE; Michael Murphy, PhD	537
VC-21-C065	Integration of High Temperature Heat Networks with Low Carbon Ambient Loop Systems Catarina Marques, PhD; Chris Dunham, MD; Phil Jones, MD; Rodrigo Matabuena; Akos Revesz, PhD; Henrique Lagoeiro; Graeme Maidment, PhD, CEng	547
VC-21-C066	Superheat Regulation and Efficiency Improvement for Refrigeration Vapor Compression Cycle	557
VC-21-C066	Mohamad Yehia Itani, PEng, Member ASHRAE	
VC-21-C066	Superheat Regulation and Efficiency Improvement for Refrigerations Vapor Compression Cycle	
VC-21-C067	Testing of a Wall Heating and Cooling System with Pipes Attached to Thermally Insulating Core Dušan Petráš, Fellow ASHRAE; Michal Krajčík; Martin Šimko; Daniel Szabó	566
VC-21-C068	Time-Lag Analysis of PCM in Floor Radiant Heating System Jin Chul Park, PhD, PE, Member ASHRAE; Seong Eun Kim; Sung Ho Chio	575
VC-21-C069	A New HVAC System for Resiliency and Ecology Utilizing Through-Wall Units on a High-Rise Office Building Hirotaka Kubo, Associate Member ASHRAE; Shiro Tsukami, Member ASHRAE; Iwao Hasegawa, Member ASHRAE; Masayuki Ichinose, PhD, Member ASHRAE	581
VC-21-C070	Displacement Ventilation System for A High-Ceiling Auditorium in Hot Climate— Design Implementation and Construction Challenges Hassan Chehade, PEng, Member ASHRAE; Mohamad Yehia Itani, PEng, Member ASHRAE; Adnan Akhdar, PEng	590
VC-21-C071	Effect of Inlet Duct Design on Fan Performance of Indoor Air Handling Units Khaled I. Alghamdi, Student Member ASHRAE; Christian K. Bach, PhD, Member ASHRAE	599
VC-21-C072	Retrofitting a Light Industrial Space with a Renewable Energy-Assisted Hydroponics Facility in a Rural Northern Canadian Community: Design Protocol Artur Udovichenko, Student Member ASHRAE; Brian Fleck, PhD, PEng, Member ASHRAE; Tim Weis, PhD, PEng, Lexuan Zhong, PhD, PEng, Member ASHRAE	607
VC-21-C073	Thermodynamic Evaluation of Solar Assisted Water Heaters Using Aluminum Oxide Nanofluid Tarashri Anand Tirtha, Student Member ASHRAE; Amir Fartaj, PhD, PE, Member ASHRAE	617

TECHNICAL PAPERS

VC-21-001	Energy Master Planning for Resilient Public Communities— Best Practices from Denmark Anders Dyrelund, Robert M. Neimeier, Hasmik Margaryan, Anders B. Møller.....	629
VC-21-002	Energy Master Planning for Resilient University Campuses— Best Practices from Austria Anna Maria Fulterer, PhD; Ingo Leusbrock, PhD; Gert Widu; Dirk Jäger.....	647
VC-21-003	Energy Master Planning for Resilient Public Communities— Best Practices from North American Universities Laxmi Rao; Juan Ontiveros, PE; Joseph Yonkoski, PE; Joshua Wauthy; Paul Holt, PEng, CEng	660
VC-21-004	Defining, Measuring and Assigning Resilience Requirements to Electric and Thermal Energy Systems Alexander M. Zhivov, PhD, Fellow/Life Member ASHRAE; Andrew Stringer; Michael D. Fox; Patrick W. Daniels; Todd J. Traver; John Benefiel.....	673
VC-21-005	Requirements for Building Thermal Conditions under Normal and Emergency Operations in Extreme Climates Alexander M. Zhivov, PhD, Fellow/Life Member ASHRAE; William Rose, Life Member ASHRAE; Raymond Patenaude, PE, CPMP, Life Member ASHRAE; W. Jon Williams, PhD.....	693
VC-21-006	Building Enclosure Testing on Alaska Military Base Projects Emmett Leffel	705
VC-21-007	Best Practices for HVAC, Plumbing, and Heat Supply in Arctic Climates Emily C. Winfield, Associate Member ASHRAE; Robin J. Rader, Member ASHRAE; Alexander M. Zhivov, PhD, Fellow/Life Member ASHRAE; Thomas A. Adams; Anders Dyrelund; Craig Fredeen, Member ASHRAE; Oddgeir Gudmundsson; Brent Goering.....	722
VC-21-008	Sizing Ducts Based on a Prescribed Friction Rate C. Kodali; S. Idem, PhD, Member ASHRAE.....	738
VC-21-009	A Simple Airflow and Power Analysis of Fan-Coil Units with Electronically Commutated Motors Dennis L. O'Neal, PhD, PE, Fellow/Life Member ASHRAE; Jessica Cramer, Student Member ASHRAE; Peng Yin, PhD, Associate Member ASHRAE	749
VC-21-010	Part-Load Airflow and Power Model of Multispeed Fan-Coil Units with Electronically Commutated Motors Dennis L. O'Neal, PhD, PE, Fellow/Life Member ASHRAE; Jessica Cramer, Student Member ASHRAE; Peng Yin, PhD, Associate Member ASHRAE.....	759
VC-21-011	Updated Database of Clothing Thermal Insulation and Vapor Permeability Values of Western Ensembles for Use in ASHRAE Standard 55, ISO 7730, and ISO 9920 (RP-1760) James W. Smallcombe, PhD; Simon Hodder, PhD; Kalev Kuklane, PhD; Magdalena Młynarczyk, PhD; Dennis Loveday, PhD, Member ASHRAE; Jakob Petersson; Amitava Halder; George Havenith, PhD	773
VC-21-012	Implementation and Evaluation of ASHRAE's Water Performance Measurement Protocols Gabrielle McMorro, Associate Member ASHRAE; Liping Wang, PhD, PE, Member ASHRAE; Xiaohui (Joe) Zhou, PhD, PE, Member ASHRAE.....	800
VC-21-013	Experimental Investigation of Induction Motor Power Factor and Efficiency Impacted by Pulse Width Modulation Power and Voltage Controls of Variable-Frequency Drives Zhitao Han, PhD; Li Ding, Student Member ASHRAE; Gang Wang, PE, PhD, Member ASHRAE	817
	Index of Papers, Volume 127, Part 1.....	829