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Buildings and Thermal Systems Science

NREL's Buildings and Thermal Systems Center published 19 journal and magazine articles during fiscal year 2016 highlighting recent research in building energy efficiency and concentrating solar power. For information about these or other NREL articles or reports, please contact me or the author(s). NREL acknowledges the U.S. Department of Energy for the funding support that made this research possible.

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Buildings

Automatic Building Information Model Query Generation, *Journal of Information Technology in Construction*

Energy-efficient building design and construction calls for extensive collaboration between different subfields of the Architecture, Engineering, and Construction community. Using a Building Information Modeling (BIM) data hub to host and integrate building models is a promising solution to address information-sharing challenges in building design and construction engineering. However, the partial model query mechanism of current BIM data hub collaboration models has several limitations. To address this problem, this study proposes a general and effective approach to generate query code based on a Model View Definition.

Development of Building Energy Asset Rating Using Stock Modelling in the USA, *Journal of Building Performance Simulation*

The U.S. Building Energy Asset Score helps building stakeholders quickly gain insight into the efficiency of building systems (envelope, electrical, and mechanical systems). A robust, easy-to-understand 10-point scoring system was developed to facilitate an unbiased comparison of similar building types across the country. This paper discusses the methodology used to perform several hundred thousands of building simulation runs and develop the scoring system.

Field Measurement of Moisture-Buffering Model Inputs for Residential Buildings, *Energy and Buildings*

Moisture adsorption and desorption in building materials impact indoor humidity. This effect should be included in building-energy simulations, particularly when humidity is being investigated or controlled. Several models can calculate this moisture-buffering effect, but accurate ones require model inputs that are not always known to the user of the building-energy simulation. This research developed an empirical method to extract whole-house model inputs for the effective moisture penetration depth model.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

An Introduction to Optimal Power Flow: Theory, Formulation, and Examples, *IIE Transactions*

This article provides an introduction to the set of optimization problems in electric power systems engineering known collectively as Optimal Power Flow (OPF) from an operations research perspective; it describes a complete and concise basis of knowledge for beginning OPF research. Topics covered include power systems modeling, the power flow equations, typical OPF formulations, and common OPF extensions.

Ten Questions Concerning Integrating Smart Buildings into the Smart Grid, *Building and Environment*

Recent advances in information and communications technology have initiated development of a smart electrical grid and smart buildings. Buildings consume a large portion of the total electricity production worldwide, and to fully develop a smart grid they must be integrated with that grid. This publication helps clarify key points about this integration.

Experimental Verification of an Energy Consumption Signal Tool for Operational Decision Support in an Office Building, *Automation in Construction*

This paper demonstrates an energy signal tool to assess the system-level and whole-building energy use of an office building in downtown Denver, Colorado. The energy signal tool uses a traffic light visualization to alert a building operator to energy use that is substantially different from expected. Practical discussion of the application is provided in this paper, along with additional findings from further investigating the significant difference between expected and actual energy consumption.

Thermal Systems/Concentrating Solar Power

A General Method to Analyze the Thermal Performance of Multi-Cavity Concentrating Solar Power Receivers, *Solar Energy*

Concentrating solar power (CSP) with thermal energy storage has the potential to provide grid-scale, on-demand, dispatchable renewable energy. As higher solar receiver output temperatures are necessary for higher thermal cycle efficiency, current CSP research is focused on high outlet temperature and high efficiency receivers. The objective of this study is to provide a simplified model to analyze the thermal efficiency of multi-cavity CSP receivers.

Simulations of Heat Transfer to Solid Particles Flowing Through an Array of Heated Tubes, *Solar Energy*

A novel solar receiver that uses solid particles as a heat-transfer fluid is being developed at NREL for use in CSP plants. The prototype considered in this paper contains arrays of hexagonal heat-transfer tubes that particles flow between. Discrete element method simulations were completed for a laboratory-scale solar receiver for different geometric configurations, hexagon apex angles, particle sizes, and mass flow rates.

Castable Cements to Prevent Corrosion of Metals in Molten Salts, *Solar Energy Materials and Solar Cells*

NREL is working to improve energy storage technologies to increase the efficiency of CSP and reduce costs. NREL has recommended some molten chlorides and molten carbonates as heat-transfer fluids and thermal energy storage candidates for high-temperature applications because of their cost, high thermal stability, and relatively high heat capacity. However, these salts are highly corrosive and can degrade piping and containment materials. This paper proposes the use of castable ceramic cements to protect containment materials from the attack of molten salts at high temperatures.

Corrosion of Alloys in a Chloride Molten Salt (NaCl-LiCl) for Solar Thermal Technologies, *Solar Energy Materials and Solar Cells*

Next-generation solar power conversion systems in CSP applications require high-temperature advanced fluids in the range of 600°–800°C. Current commercial CSP plants use molten nitrate salt mixtures, which decompose at higher temperatures, as the heat-transfer fluid and the thermal energy storage media. Molten chloride salts are candidates for CSP applications because of their high decomposition temperatures and good thermal properties, but they can be corrosive to common alloys used in vessels, heat exchangers, and piping at elevated temperatures. This article presents the results of the corrosion evaluations of several alloys in eutectic 34.42 wt% NaCl - 65.58 wt% LiCl at 650°–700°C in nitrogen atmosphere.

Development of Soft-Sphere Contact Models for Thermal Heat Conduction in Granular Flows, *AiChE Journal*

Conductive heat transfer to flowing particles occurs when two particles (or a particle and wall) come into contact. The direct conduction between the two bodies depends on the collision dynamics. For soft-sphere discrete-particle simulations, it is computationally expensive to resolve the true collision time because doing so would require a restrictively small numerical time step. To improve the computational speed, it is common to increase the "softness" of the material to artificially increase the collision time, but doing so affects the heat transfer. In this work, two physically-based correction terms are derived to compensate for the increased contact area and time stemming from artificial particle softening.

Corrosion Evaluation of Alloys and MCrAlX Coatings in Molten Carbonates for Thermal Solar Applications, *Solar Energy Materials and Solar Cells*

Advanced components in next-generation CSP applications will require advanced heat-transfer fluids and thermal-storage materials. In particular, the supercritical CO_2 (sCO_2) Brayton power cycle has received much attention, yet is of little value without viable thermal energy storage (TES) designs. For a viable full-plant system, sCO_2 receivers require TES systems that will operate with the sCO_2 heat-transfer fluid. This study evaluates alloys and MCrAlX coatings in molten carbonates for thermal solar applications.

Thermophysical Properties of Low-Cost Lithium Nitrate Salts Produced in Northern Chile for Thermal Energy Storage, *Renewable Energy*

In recent years, lithium-containing salts have been studied for TES applications because of their excellent thermophysical properties. In solar power plants, lithium is seen as a way to improve the properties of state-of-the art molten salts used today. Lithium nitrate is a good candidate for sensible heat storage because of its ability to increase the salt mixture's working temperature range. In the present research, thermophysical property characterization of lithium nitrate containing salts, produced in Chile, has been carried out.

Durability of Polymeric Encapsulation Materials in a PMMA/Glass Concentrator Photovoltaic System, *Progress in Photovoltaics: Research and Applications*

The durability of polymeric encapsulation materials was examined using outdoor exposure at the nominal geometric concentration of 500 suns. The results for 36-month cumulative field deployment are presented for materials including: poly(ethylene-co-vinyl acetate); polyvinyl butyral; ionomer; polyethylene/polyoctene copolymer; thermoplastic polyurethane; poly(dimethylsiloxane); poly(diphenyl dimethyl siloxane); and poly(phenyl-methyl siloxane).

Solar Field Optical Characterization at Stillwater Geothermal/Solar Hybrid Plant, *Journal of Solar Energy Engineering*

For a newly constructed solar field at a geothermal power plant site, it is critical to properly characterize its performance so the prediction of thermal power generation can be derived to develop an optimum operating strategy for a hybrid system. This paper illustrates this detailed solar field optical characterization procedure and demonstrates how the results help to quantify an appropriate tracking-correction strategy to improve solar field performance.

Design of a Thermosyphon-Based Thermal Valve for Controlled High-Temperature Heat Extraction, *Applied Thermal Engineering*

Conventional CSP is a reliable alternative energy source that uses the sun's heat to drive a heat engine to produce electrical power. An advantage of CSP is its ability to store thermal energy, which is typically done by storing sensible heat in molten salts. Alternatively, thermal energy may be stored as latent heat in a phase-change material, which stores large quantities of thermal energy in an isothermal process. This paper presents the design of a thermosyphon-based device with sodium working fluid that is able to extract heat from a source as demand requires.

New Adaptive Method to Optimize the Secondary Reflector of Linear Fresnel Collectors, *Solar Energy*

The performance of linear Fresnel collectors may largely depend on the secondary-reflector profile design when small-aperture absorbers are used. Optimization of the secondary-reflector profile is an extremely challenging task because there is no established theory to ensure superior performance of derived profiles. In this work, an innovative method is proposed to optimize the secondary-reflector profile of a generic linear Fresnel configuration.

Corrosion Resistance of Alumina-Forming Alloys Against Molten Chlorides for Energy Production. I: Pre-Oxidation Treatment and Isothermal Corrosion Tests, *Solar Energy Materials and Solar Cells*

Advanced components in next-generation CSP applications will require advanced heat-transfer fluids and thermal-storage materials for integration with advanced power-conversion systems. To reach the cost target, less-expensive salts such as molten chlorides have been identified as high-temperature fluid candidates. High-strength alloys need to be identified, and their mechanical and chemical degradation must be minimized to be used in CSP applications. This paper is an investigation of the use of surface passivation using alumina-forming alloys Inconel 702, Haynes 224, and Kanthal APMT to optimize corrosion mitigation.

Corrosion Resistance of Alumina Forming Alloys Against Molten Chlorides for Energy Production. II: Electro-chemical Impedance Spectroscopy under Thermal Cycling Conditions, *Solar Energy Materials and Solar Cells*

The CSP technology needs high-temperature thermal fluids that are able to work in the range of 550°–750°C. Molten chlorides containing NaCl, KCl, $MgCl_2$, and/or $ZnCl_2$ are being considered for solar receivers and/or sensible- or latent-thermal energy storage systems. Vapor pressures of chlorides are high enough that, in combination with oxygen, gaseous compounds will produce a harsh atmosphere that is generally very aggressive to common chromia-forming alloys. Corrosion mitigation must consider a solution in which both zones (immersed in fluid and exposed to vapor phase) will be protected. This could easily be obtained using alloy surface modification approaches. Surface passivation produced after pre-oxidation treatments of alumina-forming alloys (Inconel 702, Haynes 224 and Kanthal APMT) was evaluated in molten 35.59 wt% $MgCl_2$ - 64.41 wt% KCl thermally cycled from 550°C to 700°C in flowing Ar and static zero air atmospheres.

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