Heat Transfer Fluids For Concentrating Solar Power Systems

Terrafore successfully demonstrated and optimized the manufacturing of capsules containing phase-changing inorganic salts. The phase change was used to store thermal energy collected from a concentrating solar-power plant as latent heat. This latent heat, in addition to sensible heat increased the energy density (energy stored per unit weight of salt) by over 50%, thus requiring 40% less salt and over 60% less capsule container. Therefore, the cost to store high-temperature thermal energy collected in a concentrating solar power plant will be reduced by almost 40% or more, as compared to conventional two-tank, sensible-only storage systems. The cost for thermal energy storage (TES) system is expected to achieve the Sun Shot goal of $15 per kWh(t). Costs associated with poor heat-transfer in phase change materials (PCM) were also eliminated. Although thermal energy storage that relies on the latent heat of fusion of PCM improves energy density by as much as 50%, upon energy discharge the salt freezes and builds on the heat transfer surfaces. Since these salts have low thermal conductivity, large heat-transfer areas, or larger conventional heat-exchangers are needed, which increases costs. By encapsulating PCM in small capsules we have increased the heat transfer area per unit volume of salt and brought the heat transfer fluid in direct contact with the capsules. These two improvements have increased the heat transfer coefficient and boosted heat transfer. The program was successful in overcoming the phenomenon of melt expansion in the capsules, which requires the creation of open volume in the capsules or shell to allow for expansion of the molten salt on melting and is heated above its melting point to 550°C. Under contract with the Department of Energy, Terrafore Inc. and Southwest Research Institute, developed innovative method(s) to economically create the open volume or void in the capsule. One method consists of using a sacrificial polymer coating as the middle layer between the salt prill and the shell material. The selected polymer decomposes at temperatures below the melting point of the salt and forms gases which escape through the pores in the capsule shell thus leaving a void in the capsule. We have demonstrated the process with a commonly used inorganic nitrate salt in a low-cost shell material that can withstand over 10,000 high-temperature thermal cycles, or a thirty-year or greater life in a solar plant. The shell used to encapsulate the salt was demonstrated to be compatible with molten salt heat transfer fluid typically used in CSP plants to temperatures up to 600 °C. The above findings have led to the concept of a cascaded arrangement. Salts with different melting points can be encapsulated using the same recipe and contained in a packed bed by cascading the salt melting at higher melting point at the top over the salt melting at lower melting point towards the bottom of the tank. This cascaded energy storage is required to effectively transfer the sensible heat collected in heat transfer fluids between the operating temperatures and utilize the latent heat of fusion in the salts inside the capsule. Mathematical models indicate that over 90% of the salts will undergo phase change by using three salts in equal proportion. The salts are selected such that the salt at the top of the tank melts at about 15°C below the high operating-temperature, and the salt at the bottom of the tank melts 15°C above the low operating-temperature. The salt in the middle of tank melts in-between the operating temperature of the heat transfer fluid. A cascaded arrangement leads to the capture of 90% of the latent-heat of fusion of salts and their sensible heats. Thus the energy density is increased by over 50% from a sensible-only, two-tank thermal energy storage. Furthermore, the Terrafore cascaded storage method requires only one tank as opposed to the two-tanks used in sensible heat storage. Since heat is transferred from the ...

Solar Hydrogen Production: Processes, Systems and Technologies presents the most recent developments in solar-driven hydrogen generation methods. The book covers different hydrogen production routes, from renewable sources, to solar harvesting technologies. Sections focus on solar energy, presenting the main thermal and electrical technologies suitable for possible integration into solar-based hydrogen production systems and present a thorough examination of solar hydrogen technologies, ranging from solar-driven water electrolysis and solar thermal methods, to photo-catalytic and biological processes. All hydrogen-based technologies are covered, including data regarding the state-of-the art of each process in terms of costs,

efficiency, measured parameters, experimental analyses, and demonstration projects. In the last part of the book, the role of hydrogen in the integration of renewable sources in electric grids, transportation sector, and end-user applications is assessed, considering their current status and future perspectives. The book includes performance data, tables, models and references to available standards. It is thus a key-resource for engineering researchers and scientists, in both academic and industrial contexts, involved in designing, planning and developing solar hydrogen systems. Offers a comprehensive overview of conventional and advanced solar hydrogen technologies, including simulation models, cost figures, R&D projects, demonstration projects, test standards, and safety and handling issues Encompasses, in a single volume, information on solar energy and hydrogen systems Includes detailed economic data on each technology for feasibility assessment of different systems
Binary and Ternary mixtures of Molten Salt Nitrates are ideal candidates for future concentrating solar power (CSP) plant heat transfer fluids (HTFs) because of their high operating temperature limits resulting in greater Rankine efficiency. The inclusion of these HTFs into CSP plants is expected to revolutionize the industry by allowing for energy and cost savings that are attractive to potential plant developers and investors. It is vital for plant designers to have access to fully characterized thermo-physical properties of the intended HTFs, with thermal conductivity, viscosity, and specific heat capacity being the most crucial. Existing literature has not fully elucidated the thermo-

physical properties of binary and ternary molten salt nitrates through their operating temperature range. This work presents the viscosity of eutectic ternary and binary compositions of molten alkali salt nitrates (Li-NO3, K-NO3, and Na-NO3) up to 550°C. A device to measure the thermal conductivity of these salts with accuracy at elevated temperatures was designed and built as no commercial offerings are able to withstand the corrosive nature of molten salt at high temperatures. The device is shown to accurately measure the thermal conductivity of water at room temperature. The present work is a step towards fully characterizing the thermo-physical properties of the aforementioned molten salts.

ORNL and subcontractor Cool Energy completed an investigation of higher-temperature, organic thermal fluids for solar thermal applications. Although static thermal tests showed promising results for 1-phenylnaphthalene, loop testing at temperatures to 450 C showed that the material isomerized at a slow rate. In a loop with a temperature high enough to drive the isomerization, the higher melting point byproducts tended to condense onto cooler surfaces. So, as experienced in loop operation, eventually the internal channels of cooler components such as the waste heat rejection exchanger may become coated or clogged and loop performance will decrease. Thus, pure 1-phenylnaphthalene does not appear to be a fluid that would have a sufficiently long lifetime (years to decades) to be used in a loop at the increased temperatures of interest. Hence a decision was made not to test the ORNL fluid in the loop at Cool Energy Inc. Instead, Cool Energy tested and modeled power conversion from a moderate-temperature solar loop using coupled Stirling engines. Cool Energy analyzed data collected on third and fourth generation SolarHeart Stirling engines operating on a rooftop solar field with a lower temperature (Marlotherm) heat transfer fluid. The operating efficiencies of the Stirling engines were determined at multiple, typical solar conditions, based on data from actual cycle operation. Results highlighted the advantages of inherent thermal energy storage in the power conversion system. Concentrating solar power (CSP) may be an alternative to generating electricity from fossil fuels; however, greater thermodynamic efficiency is needed to improve the economics of CSP operation. One way of achieving improved efficiency is to operate the CSP loop at higher temperatures than the current maximum of about 400 C. ORNL has been investigating a synthetic polyaromatic oil for use in a trough type CSP collector, to temperatures up to 500 C. The oil was chosen because of its thermal stability and calculated low vapor and critical pressures. The oil has been synthesized using a Suzuki coupling mechanism and has been tested in static heating experiments. Analysis has been conducted on the oil after heating and suggests that there may be some isomerization taking place at 450 C, but the fluid appears to remain stable above that temperature. Tests were conducted over one week and further tests are planned to investigate stabilities after heating for months and in flow configurations. Thermochemical data and thermophysical predictions indicate that substituted

polyaromatic hydrocarbons may be useful for applications that run at higher temperatures than possible with commercial fluids such as Therminol-VP1.
This broad-based book covers the three major areas of Chemical Engineering. Most of the books in the market involve one of the individual areas, namely, Fluid Mechanics, Heat Transfer or Mass Transfer, rather than all the three. This book presents this material in a single source. This avoids the user having to refer to a number of books to obtain information. Most published books covering all the three areas in a single source emphasize theory rather than practical issues. This book is written with emphasis on practice with brief theoretical concepts in the form of questions and answers, not adopting stereo-typed question-answer approach practiced in certain books in the market, bridging the two areas of theory and practice with respect to the core areas of chemical engineering. Most parts of the book are easily understandable by those who are not experts in the field. Fluid Mechanics chapters include basics on non-Newtonian systems which, for instance find importance in polymer and food processing, flow through piping, flow measurement, pumps, mixing technology and fluidization and two phase flow. For example it covers types of pumps and valves, membranes and areas of their use, different equipment commonly used in chemical industry and their merits and drawbacks. Heat Transfer chapters cover the basics involved in conduction, convection and radiation, with emphasis on insulation, heat exchangers, evaporators, condensers, reboilers and fired heaters. Design methods, performance, operational issues and

maintenance problems are highlighted. Topics such as heat pipes, heat pumps, heat tracing, steam traps, refrigeration, cooling of electronic devices, NOx control find place in the book. Mass transfer chapters cover basics such as diffusion, theories, analogies, mass transfer coefficients and mass transfer with chemical reaction, equipment such as tray and packed columns, column internals including structural packings, design, operational and installation issues, drums and separators are discussed in good detail. Absorption, distillation, extraction and leaching with applications and design methods, including emerging practices involving Divided Wall and Petluk column arrangements, multicomponent separations, supercritical solvent extraction find place in the book.

In recent years, due to rising energy costs as well as an increased awareness of the environmental effects of greenhouse gas emissions produced through traditional forms of energy production, there is great interest in developing alternative sources of energy. One of the most viable alternative energy sources is solar energy. In particular, concentrating solar power (CSP) technologies have been identified as an option for meeting utility needs in the U.S. Southwest. These systems are required to produce electricity not only during periods of high solar radiation but also during times of reduced radiation due to cloud cover, and even extend production to periods during the night. In order to achieve this goal, CSP plants must incorporate a thermal energy storage (TES) system from which energy can be sourced when needed. Besides the integration of a TES sub-system, another area where CSP technologies can be improved is in the development and use of heat transfer fluids (HTF) that can remain stable at temperatures up to and in excess of 1112F (600C). This research explores the use of concrete as a TES storage medium for CSP technologies, specifically, parabolic trough power plants. Concrete is relatively inexpensive and the costs/ kWhthermal of energy based on the concretes used in this research could be less than $1. Researchers using concrete as a TES storage medium have achieved maximum operating temperatures of 752F (400C) with a 6-hour storage capacity. The operating temperature limit of 752F (400C) is dictated by the limitations of the concrete when exposed to elevated temperatures and by the stability of the heat transfer fluid at these temperatures. By exposing various concrete types to different heating regimens and subsequently measuring their thermo-mechanical properties, this research has identified concrete that can withstand temperatures up to 1112F (600C) for deployment as a TES medium. The benefits derived from using concretes that are resistant to higher temperatures are an increase in the operating efficiency of the CSP plant, an increase in the number of storage hours and a significant reduction in both the storage cost and the unit cost of solar generated electricity.

Concentrating Solar Thermal TechnologiesAnalysis and Optimisation by CFD ModellingSpringer

Binary and ternary mixtures of molten salt nitrates ($LiNO_3$ -$NaNO_3$ and KNO_3) are ideal candidates as large scale phase change thermal energy storage materials and as heat transfer fluids for concentrating solar power systems. They have higher specific heat capacities and wider operating temperature ranges (150-600 C) compared to the silicon based oils which are currently used in parabolic trough type plants. For design considerations related to power plant and equipment, it is critically important to know the thermo-physical properties of molten salt nitrates; as thermal conductivity being one of the most important. In this regard, the measurements of thermal conductivity of molten salt nitrates are of interest in the present study."

After decades of research and development, concentrating solar thermal (CST) power plants (also known as concentrating solar power (CSP) and as Solar Thermal Electricity or STE systems) are now starting to be widely commercialized. Indeed, the IEA predicts that by 2050, with sufficient support over ten percent of global electricity could be produced by concentrating solar thermal power plants. However, CSP plants are just but one of the many possible applications of CST systems. Advances in Concentrating Solar Thermal Research and Technology provides detailed information on the latest advances in CST systems research and technology. It promotes a deep understanding of the challenges the different CST technologies are confronted with, of the research that is taking place worldwide to address those challenges, and of the impact that the innovation that this research is fostering could have on the emergence of new CST components and concepts. It is anticipated that these developments will substantially increase the cost-competiveness of commercial CST solutions and reshape the technological landscape of both CST technologies and the CST industry. After an introductory chapter, the next three parts of the book focus on key CST plant components, from mirrors and receivers to thermal storage. The final two parts of the book address operation and control and innovative CST system concepts. Contains authoritative reviews of CST research taking place around the world Discusses the impact this research is fostering on the emergence of new CST components and concepts that will substantially increase the cost-competitiveness of CST power Covers both major CST plant components and system-wide issues

A key technological issue facing the success of future Concentrating Solar Thermal Power (CSP) plants is creating an economical Thermal Energy Storage (TES) system. Current TES systems use either sensible heat in fluids such as oil, or molten salts, or use thermal stratification in a dual-media consisting of a solid and a heat-transfer fluid. However, utilizing the heat of fusion in inorganic molten salt mixtures in addition to sensible heat, as in a Phase change material (PCM)-based TES, can significantly increase the energy density of storage requiring less salt and smaller containers. A major issue that is preventing the commercial use of PCM-based TES is that it is difficult to discharge the latent heat stored in the PCM melt. This is because when heat is extracted, the melt solidifies onto the heat exchanger surface decreasing the heat transfer. Even a few millimeters of thickness of solid material on heat transfer surface results in a large drop in heat transfer due to the low thermal conductivity of solid PCM. Thus, to maintain the desired heat rate, the heat exchange area must be large which increases cost. This project demonstrated that the heat transfer coefficient can be increase ten-fold by using forced convection by pumping a hyper-eutectic salt mixture over specially coated heat exchanger tubes. However, only 15% of the latent heat is used against a goal of 40% resulting in a projected cost savings of only 17% against a goal of 30%. Based on the failure mode effect analysis and experience with pumping salt at near freezing point significant care must be used during operation which can increase the operating costs. Therefore, we conclude the savings are marginal to justify using this concept for PCM-TES over a two-tank TES. The report documents the specialty coatings, the composition and morphology of hypereutectic salt mixtures and the results from the experiment conducted with the active heat exchanger along with the lessons learnt during experimentation.

This book presents the basic principles and engineering data governing the process design of indirect heat transfer fluids and systems. It focuses on the selection of systems based on common engineering criteria such as reliability and cost, and particularly on energy conservation and safety.

Increasing population and environmental pollution are the main stress on freshwater sources. On the other hand, freshwater needs of human being increase dramatically every day. From agriculture to industry and from household to recreation, we need freshwater. In the near future, saltwater and brackish water bodies may be the main source of freshwater for our planet. Desalination phenomena are now being implemented with increasing interest. The book on desalination provides a valuable scientific contribution on freshwater production from saltwater sources. In this book, necessary theoretical knowledge and experimental results of different desalination processes are presented.

Nanofluids are solid-liquid composite material consisting of solid nanoparticles suspended in liquid with enhanced thermal properties. This book introduces basic fluid mechanics, conduction and convection in fluids, along with nanomaterials for nanofluids, property characterization, and outline applications of nanofluids in solar technology, machining and other special applications. Recent experiments on nanofluids have indicated significant increase in thermal conductivity compared with liquids without nanoparticles or larger particles, strong temperature dependence of thermal conductivity, and significant increase in critical heat flux in boiling heat transfer, all of which are covered in the book. Key Features Exclusive title focusing on niche engineering applications of nanofluids Contains high technical content especially in the areas of magnetic nanofluids and dilute oxide based nanofluids Feature examples from research applications such as solar technology and heat pipes Addresses heat transfer and thermodynamic features such as efficiency and work with mathematical rigor Focused in content with precise technical definitions and treatment

This book focuses on CFD (Computational Fluid Dynamics) techniques and the recent developments and research works in thermo-mechanics applications. It is devoted to the publication of basic and applied studies broadly related to this area. The chapters present the development of numerical methods, computational techniques, and case studies in the thermo-mechanics applications. They offer the fundamental knowledge for using CFD in real thermo-mechanics applications and complex flow problems through new technical approaches. Also, they discuss the steps in the CFD process and provide benefits and issues when using the CFD analysis in understanding of complicated flow phenomena and its use in the design process. The best practices for reducing errors and uncertainties in CFD analysis are also discussed. The presented case studies and development approaches aim to provide the readers, such as engineers and PhD students, the fundamentals of CFD prior to embarking on any real simulation project. Additionally, engineers supporting or being supported by CFD analysts can benefit from this book. ?

Renewable energies have a major role in today's energy systems development, energy security and climate change fight. Thermal Concentrating Solar Power (CSP) has the potential to get up to 11.3% of world's electricity production with the adequate support. This type of renewable energy has proved to be price competitive and to have the advantage of integrating Thermal Energy Storage (TES). This adds the generation flexibility that other renewable energies, like wind or photovoltaics, does not have integrated.In order to continue developing this technology, solid particle CSP has been proposed. This design uses granular solid materials as Heat Transfer Fluid (HTF) and TES material in solar towers in order to be able to achieve higher operation temperatures, than current commercial CSP. Higher temperature means more efficiency in heat-to-electricity conversion, due to the use of better power generation cycles.The main objective of this thesis is to enhance relevance and provide theoretical and experimental background for solid particles to be used as TES material and HTF for CSP tower power plants, from the materials perspective, by using existent or new methodologies.During this dissertation, current scientific output and relevance were studied in two separate contributions, one for CSP and the other for TES, both by using bibliometric methods. For the CSP study, additional analyses were carried out according to the harvesting technologies (parabolic trough, solar tower, Stirling dish and linear Fresnel). For the TES study, the additional analyses were performed according to the different ways to store thermal energy (sensible, latent and thermochemical). For both analyses, most productive countries, regions, authors, journals and research communities were identified. Moreover, funding impact and cooperation between countries and authors were analyzed. For developing these bibliometric analyses, a specific methodology was implemented following Bibliometrics principles. For these purposes, two existing software programs were used for a part of the analysis, while for performing the rest of the analysis a special software was developed ad-hoc for this study.For providing background, two state-of-the-art analyses were performed in order to get current development status of solid particle CSP. The first one was oriented to the plant design itself. Several solar receivers were analyzed, as well as TES, Heat Exchanger (HEX) and conveyance systems. During the second state-of-the-art, a material driven study was carried out in order to understand the behavior expected by the particle media and to identify some of the materials proposed by the most relevant researchers in this field.Next step of this dissertation was focused on establishing the design criteria for solid particle CSP technology, from the materials science perspective. This was achieved by finding the most relevant objectives that a power plant of this kind must comply, as well as the influence of the particle media properties and parameters.Last part of this dissertation is related with two studies regarding the durability of some of the most promising solid particle materials from high temperature exposure effect perspective. The first study was focused on analyzing the effect of long

term high temperature (900 °C) in the optical, mechanical, thermal and chemical properties and parameters of the solid particle material. The second study was focused in the effect of long term thermal cycling, in which is considered that the materials should resist several thousand charge-discharge cycles remaining with acceptable operational conditions. For achieving an accelerated thermal cycling test with realistic thermal conditions, a novel device was developed to perform the thousands of thermal cycles required. Electronic, software and hardware design was developed and implemented. Current device has performed more than 20 thousand cycles for different kind of materials, analyzing the same properties and parameters as the first study.
Heat transfer enhancement has seen rapid development and widespread use in both conventional and emerging technologies. Improvement of heat transfer fluids requires a balance between experimental and numerical work in nanofluids and new refrigerants. Recognizing the uncertainties in development of new heat transfer fluids, Advances in New Heat Transfer Fluids: From Numerical to Experimental Techniques contains both theoretical and practical coverage.
Interest in capturing the energy of the sun is rising as demands for renewable energy sources increase. One area of developing research is the use of concentrating solar power (CSP), where the solar energy is concentrated by using mirrors to direct the sunlight towards a collector filled with a heat transfer fluid (HTF). The HTF transfers the collected energy into pressurized steam, which is used to generate energy. The greater

the energy collected by the HTF, the more efficent the electrical energy production is, thus the overall efficiency is controlled by the thermal fluid. Commercial HTFs such as Therminol{reg_sign} (VP-1), which is a blend of biphenyl and diphenyl oxide, have a significant vapor pressure, especially at elevated temperatures. In order for these volatile compounds to be used in CSP systems, the system either has to be engineered to prevent the phase change (i.e., volatilization and condensation) through pressurization of the system, or operate across the phase change. Over thirty years ago, a class of low-melting organic compounds were developed with negligible vapor pressure. These compounds are referred to as ionic liquids (ILs), which are organic-based compounds with discrete charges that cause a significant decrease in their vapor pressure. As a class, ILs are molten salts with a melting point below 100 C and can have a liquidus range approaching 400 C, and in several cases freezing points being below 0 C. Due to the lack of an appreciable vapor pressure, volatilization of an IL is not possible at atmospheric pressure, which would lead to a simplification of the design if used as a thermal fluid and for energy storage materials. Though the lack of a vapor pressure does not make the use of ILs a better HTF, the lack of a vapor pressure is a compliment to their higher heat capacity, higher volummetric density, and thus higher volumetric heat capacity. These favorable physical properties give ILs a pontential advantage over the current commerically used thermal fluids. Also within the past decade nanofluids have gained attention for thermal conductivity enhancment of fluids, but little analysis has been completed on the heat capacity effects of the nanoparticle addition. The idea of ILs or nanofluids as a HTF is not new, as there are several references that have proposed the idea. However, the use of ionic liquid nanofluids containing nanomaterials other than carbon nanotubes has never before been studied. Here, for the first time, nano-particle enhanced ILs (NEILs) have been shown to increase the heat capacity of the IL with no adverse side effects to the ILs thermal stability and, only at high nanoparticle loading, are the IL physical properties affected. An increase of volumetric heat capacity translates into a better heat transfer fluid as more energy is stored per volumetric unit in the solar concentrating section, thus more efficency in increased steam pressure. Results show that the properties of the NEIL are highly dependant on the suspended nanomaterial and careful materials selection is required to fully optimize the nanofluid properties.

The explicit UA program objective is to develop low melting point (LMP) molten salt thermal energy storage media with high thermal energy storage density for sensible heat storage systems. The novel Low Melting Point (LMP) molten salts are targeted to have the following characteristics: 1. Lower melting point (MP) compared to current salts (222ðC) 2. Higher energy density compared to current salts (300 MJ/m3) 3. Lower power generation cost compared to current salt In terms of lower power costs, the program target the DOE's Solar Energy Technologies Program year 2020 goal to create systems that have the potential to reduce the cost of Thermal Energy Storage

(TES) to less than $15/kWh-th and achieve round trip efficiencies greater than 93%. The project has completed the experimental investigations to determine the thermo-physical, long term thermal stability properties of the LMP molten salts and also corrosion studies of stainless steel in the candidate LMP molten salts. Heat transfer and fluid dynamics modeling have been conducted to identify heat transfer geometry and relative costs for TES systems that would utilize the primary LMP molten salt candidates. The project also proposes heat transfer geometry with relevant modifications to suit the usage of our molten salts as thermal energy storage and heat transfer fluids. The essential properties of the down-selected novel LMP molten salts to be considered for thermal storage in solar energy applications were experimentally determined, including melting point, heat capacity, thermal stability, density, viscosity, thermal conductivity, vapor pressure, and corrosion resistance of SS 316. The thermodynamic modeling was conducted to determine potential high temperature stable molten salt mixtures that have thermal stability up to 1000 °C. The thermo-physical properties of select potential high temperature stable (HMP) molten salt mixtures were also experimentally determined. All the salt mixtures align with the go/no-go goals stipulated by the DOE for this project. Energy densities of all salt mixtures were higher than that of the current solar salt. The salt mixtures costs have been estimated and TES system costs for a 2 tank, direct approach have been estimated for each of these materials. All estimated costs are significantly below the baseline system that used solar salt. These lower melt point salts offer significantly higher energy density per volume than solar salt - and therefore attractively smaller inventory and equipment costs. Moreover, a new TES system geometry has been recommended A variety of approaches were evaluated to use the low melting point molten salt. Two novel changes are recommended that 1) use the salt as a HTF through the solar trough field, and 2) use the salt to not only create steam but also to preheat the condensed feedwater for Rankine cycle. The two changes enable the powerblock to operate at 500°C, rather than the current 400°C obtainable using oil as the HTF. Secondly, the use of salt to preheat the feedwater eliminates the need to extract steam from the low pressure turbine for that purpose. Together, these changes result in a dramatic 63% reduction required for 6 hour salt inventory, a 72% reduction in storage volume, and a 24% reduction in steam flow rate in the power block. Round trip efficiency for the Case 5 - 2 tank "direct" system is estimated at>97%, with only small losses from time under storage and heat exchange, and meeting RFP goals. This attractive efficiency is available because the major heat loss experienced in a 2 tank "indirect" system - losses by transferring the thermal energy from oil HTF to the salt storage material and back to oil to run the steam generator at night - is not present for the 2 tank direct system. The higher heat capacity values for both LMP and HMP systems enable larger storage capacities for concentrating solar power.

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The updated, cornerstone engineering resource of solar energy theory and applications. Solar technologies already provide energy for heat, light, hot water, electricity, and cooling for homes, businesses, and industry. Because solar energy only accounts for one-tenth of a percent of primary energy demand, relatively small increases in market penetration can lead to very rapid growth rates in the industry???which is exactly what has been projected for coming years as the world moves away from carbon-based energy production. Solar Engineering of Thermal Processes, Third Edition provides the latest thinking and practices for engineering solar technologies and using them in various markets. This Third Edition of the acknowledged leading book on solar engineering features: Complete coverage of basic theory, systems design, and applications Updated material on such cutting-edge topics as photovoltaics and wind power systems New homework problems and exercises

The proceedings entitled “Concentrated Solar Thermal Technologies: Recent Trends and Applications” includes the peer-reviewed selected papers those are presented during NCSTET 2016. The sub-topics under concentrated solar thermal technologies and applications included in the book are Solar Field; Receiver and Heat Exchanger; Coating; Thermal Energy Storage; Cooling; Process Heat; and Smart Grid and Policy Research. The domains mentioned cover topics from resource-assessment, collection to conversion of solar energy for applications, like, heating, cooling and electricity. The proceedings also include invited lectures from domain experts. The edited work will be useful for beginners and for the advanced level researchers in

the field of concentrated solar thermal technologies and their applications.
Featuring contributions by leading researchers in the field, Nanoparticle Heat Transfer and Fluid Flow explores heat transfer and fluid flow processes in nanomaterials and nanofluids, which are becoming increasingly important across the engineering disciplines. The book covers a wide range, from biomedical and energy conversion applications to materials properties, and addresses aspects that are essential for further progress in the field, including numerical quantification, modeling, simulation, and presentation. Topics include: A broad review of nanofluid applications, including industrial heat transfer, biomedical engineering, electronics, energy conversion, membrane filtration, and automotive An overview of thermofluids and their importance in biomedical applications and heat-transfer enhancement A deeper look at biomedical applications such as nanoparticle hyperthermia treatments for cancers Issues in energy conversion from dispersed forms to more concentrated and utilizable forms Issues in nanofluid properties, which are less predictable and less repeatable than those of other media that participate in fluid flow and heat transfer Advances in computational fluid dynamic (CFD) modeling of membrane filtration at the microscale The role of nanofluids as a coolant in microchannel heat transfer for the thermal management of electronic equipment The potential enhancement of natural convection due to nanoparticles Examining key topics and applications in nanoscale heat transfer and fluid flow, this comprehensive book presents the current state of the art and a view of the future. It offers a valuable resource for experts as well as newcomers interested in developing innovative modeling and numerical simulation in this growing field.
Ultra-High Temperature Thermal Energy Storage, Transfer and Conversion presents a

comprehensive analysis of thermal energy storage systems operating at beyond 800°C. Editor Dr. Alejandro Datas and his team of expert contributors from a variety of regions summarize the main technological options and the most relevant materials and characterization considerations to enable the reader to make the most effective and efficient decisions. This book helps the reader to solve the very specific challenges associated with working within an ultra-high temperature energy storage setting. It condenses and summarizes the latest knowledge, covering fundamentals, device design, materials selection and applications, as well as thermodynamic cycles and solid-state devices for ultra-high temperature energy conversion. This book provides a comprehensive and multidisciplinary guide to engineers and researchers in a variety of fields including energy conversion, storage, cogeneration, thermodynamics, numerical methods, CSP, and materials engineering. It firstly provides a review of fundamental concepts before exploring numerical methods for fluid-dynamics and phase change materials, before presenting more complex elements such as heat transfer fluids, thermal insulation, thermodynamic cycles, and a variety of energy conversation methods including thermophotovoltaic, thermionic, and combined heat and power. Reviews the main technologies enabling ultra-high temperature energy storage and conversion, including both thermodynamic cycles and solid-state devices Includes the applications for ultra-high temperature energy storage systems, both in terrestrial and space environments Analyzes the thermophysical properties and relevant experimental and theoretical methods for the analysis of high-temperature materials

ISES Solar World Congress is the most important conference in the solar energy field around the world. The subject of ISES SWC 2007 is Solar Energy and Human Settlement, it is the first time that it is held in China. This proceedings consist of 600 papers and 30 invited papers, whose authors are top scientists and experts in the world. ISES SWC 2007 covers all aspects of renewable energy, including PV, collector, solar thermal electricity, wind, and biomass energy.

Hybrid Nanofluids for Convection Heat Transfer discusses how to maximize heat transfer rates with the addition of nanoparticles into conventional heat transfer fluids. The book addresses definitions, preparation techniques, thermophysical properties and heat transfer characteristics with mathematical models, performance-affecting factors, and core applications with implementation challenges of hybrid nanofluids. The work adopts mathematical models and schematic diagrams in review of available experimental methods. It enables readers to create new techniques, resolve existing research problems, and ultimately to implement hybrid nanofluids in convection heat transfer applications. Provides key heat transfer performance and thermophysical characteristics of hybrid nanofluids Reviews parameter selection and property measurement techniques for thermal performance calibration Explores the use of predictive mathematical techniques for experimental properties

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This book addresses the evaluation and optimization of key elements in concentrating solar thermal (CST) technologies, such as solar receivers and working fluids, using computational fluid dynamics (CFD) modeling. It discusses both general and specific aspects, explaining the methodology used to analyze and evaluate the influence of different parameters on the facility performance. This information provides the basis for optimizing design and operating conditions in CST systems.

Introduction to nanofluids--their properties, synthesis, characterization, and applications Nanofluids are attracting a great deal of interest with their enormous potential to provide enhanced performance properties, particularly with respect to heat transfer. In response, this text takes you on a complete journey into the science and technology of nanofluids. The authors cover both the chemical and physical methods for synthesizing nanofluids, explaining the techniques for creating a stable suspension of nanoparticles. You get an overview of the existing models and experimental techniques used in studying nanofluids, alongside discussions of the challenges and problems associated with some of these models. Next, the authors set forth and explain the heat transfer applications of nanofluids, including microelectronics, fuel cells, and hybrid-powered engines. You also get an introduction to possible future applications in large-scale cooling and biomedicine. This book is the work of leading pioneers in the field, one of whom holds the first U.S. patent for nanofluids. They have combined their own first-hand knowledge with a thorough review of theliterature. Among the key topics are: * Synthesis of nanofluids, including dispersion techniques and characterization methods * Thermal conductivity and thermo-physical properties * Theoretical models and experimental techniques * Heat transfer applications in microelectronics, fuel cells, and vehicle engines This text is written for researchers in any branch of science and technology, without any prerequisite.It therefore includes some basic information describing conduction, convection, and boiling of nanofluids for those readers who may not have adequate background in these areas. Regardless of your background, you'll learn to develop nanofluids not only as coolants, but also for a host ofnew applications on the horizon.

Parabolic trough power systems that utilize concentrated solar energy to generate electricity are a proven technology. Industry and laboratory research efforts are now focusing on integration of thermal energy storage as a viable means to enhance dispatchability of concentrated solar energy. One option to significantly reduce costs is to use thermocline storage systems, low-cost filler materials as the primary thermal storage medium, and molten nitrate salts as the direct heat transfer fluid. Prior thermocline evaluations and thermal cycling tests at the Sandia National Laboratories' National Solar Thermal Test Facility identified quartzite rock and silica sand as potential filler materials. An expanded series of isothermal and thermal cycling experiments were planned and implemented to extend those studies in order to demonstrate the durability of these filler materials in molten nitrate salts over a range of operating temperatures for extended timeframes. Upon test completion, careful analyses of filler material samples, as well as the molten salt, were conducted to assess long-term durability and degradation mechanisms in these test conditions. Analysis results demonstrate that the quartzite rock and silica sand appear able to withstand the molten salt environment quite well. No significant deterioration that would impact the performance or operability of a thermocline thermal energy storage system was evident. Therefore, additional studies of the thermocline concept can continue armed with confidence that appropriate filler materials have been identified for the intended application.

In the present book, nanofluid heat and mass transfer in engineering problems are investigated. The use of additives in the base fluid like water or ethylene glycol is one of the techniques applied to augment heat transfer. Newly, innovative nanometer-sized particles have been dispersed in the base fluid in heat transfer fluids. The fluids containing the solid nanometer-sized particle dispersion are called "nanofluids." At first, nanofluid heat and mass transfer over a stretching sheet are provided with various boundary conditions. Problems faced for simulating nanofluids are reported. Also, thermophysical properties of various nanofluids are presented. Nanofluid flow and heat transfer in the presence of magnetic field are investigated. Furthermore, applications for electrical and biomedical engineering are provided. Besides, applications of nanofluid in internal combustion engine are provided.

This thesis presents an enhanced dynamic performance evaluation method for line-concentrating solar thermal collectors. Due to its dispatchability and large storage capacity, concentrating solar power is considered of high relevance in the future renewable energy mix for both, electricity generation and industrial process heat supply. To fully exploit this potential and legitimize investments within this sector, a reliable and meaningful performance testing is essential. The proposed flexible, dynamic performance evaluation method allows for a significant reduction of testing time, effort, and consequently costs—especially for complex test conditions as they prevail for systems of larger dimensions such as line-concentrating collectors. For this reason, the present thesis comprehensively addresses diverse aspects of dynamic in situ performance testing. It includes a wide application of the elaborated procedure to diverse test collectors, ranging from small-scale medium-temperature linear Fresnel collectors to large-scale high-temperature parabolic troughs, considering different heat transfer fluids and receiver designs. It therefore proves to be a powerful and beneficial extension of the current testing standard to more complex test situations. Flexible and simultaneously reliable certification procedures are considered crucial for the further establishment of solar thermal technologies and their global acceptance.

This document summarizes a workshop on thermal energy storage for concentrating solar power (CSP) that was held in Golden, Colorado, on May 20, 2011. The event was hosted by the U.S. Department of Energy (DOE), the National Renewable Energy Laboratory, and Sandia National Laboratories. The objective was to engage the university and laboratory research communities to identify and define research directions for developing new high-temperature materials and systems that advance thermal energy storage for CSP technologies. This workshop was motivated, in part, by the DOE SunShot Initiative, which sets a very aggressive cost goal for CSP technologies -- a levelized cost of energy of 6 cents per kilowatt-hour by 2020 with no incentives or credits.

Energy Storage not only plays an important role in conservinq the energy but also improves the performance and reliability of a wide range of energy systems. Energy storagp. leads to saving of premium fuels and makes the system morA cost effective by reducing the wastage of energy. In most systems there is a mismatch between the energy supply and energy demand. The energy storage can even out this imbalance and thereby help in savings of capital costs. Enerqy storage is all the more important where the enerqy source is intermittent such as Solar Energy. The use of jntermittent energy sources is likely to grow. If more and more solar energy is to be used for domestic and industrial applications then energy storage is very crucial. If no storage is used in solar energy systems then the major part of the energy demand will be met by the back-up or auxiliary energy and therefore the so called annual solar load fract]on will be very low. In case of solar energy, both short term and long term energy storage systems can be used whjch can adjust the phase difference between solar energy supply and energy demand and can match seasonal demands to the solar availability respectively. Thermal energy storage can lead to capital cost savings, fuel savjngs, and fuel substitution in many application areas. Developing an optimum thermal storaqe system is as important an area of research as developinq an alternative source of energy.