IAS Solar Dish Technology Evaluation

Reference:
Preston Olsen and Elizabeth Olsen v. Commissioner
Docket Nos. 26469-14 and 21247-16

by

Thomas R. Mancini, PhD
TRMancini Solar Consulting, LLC

November 13, 2019

Plaintiff Exhibit
975

TRMancini Solar Consulting

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1. REPRESENTATIONS AND CERTIFICATIONS

1. I am retained by IRS Office of Chief Counsel

   a) to explain the basic concepts involved in workable solar energy power generation technology;

   b) to evaluate and explain the "IAS Solar Dish Technology" at issue in this case, which includes any equipment installed on sites identified by RaPower3 and any technological plans or schematics provided by International Automated Systems (IAS) and RaPower3;

   c) to determine whether the IAS Solar Dish Technology is currently converting sunlight into energy; and

   d) to opine on whether the IAS Solar Dish Technology is commercially viable on any scale (or may become commercially viable on any scale) to convert sunlight into electrical power.

2. I confirm that I have identified the facts and matters referred to in this report that are within my own knowledge and those that are not. Those that are within my own knowledge I confirm to be true. The opinions in this report represent my complete professional opinions on the matters discussed.

3. I have no present or past relationships with IAS, RaPower3 or the Parties in this case. My relationship with IRS Office of Chief Counsel is a contractual one to perform this evaluation as stated above.

4. I am the Principal of TRMancini Solar Consulting, LLC, and have more than 35 years of experience with Concentrating Solar Power (CSP) systems. As a Professor of Mechanical Engineering at New Mexico State University, USA (1975-1985), I performed research in solar power generation, passive solar cooling, active heating and cooling, and taught undergraduate and graduate courses in energy-related areas, heat transfer and fluid mechanics.

5. Prior to my current position, I was at Sandia National Laboratories[1] in Albuquerque, NM, (1986-2011) where I was a Distinguished Member of the Technical Staff working on CSP prior to becoming the Program Manager for Concentrating Solar Power at Sandia from 2002 to 2011.

6. I have been active in the American Society of Mechanical Engineers (ASME) as Chair of the Solar Energy Division, Chair and Member of the Energy Resources Board, and Chair

[1] Sandia Corporation operates Sandia National Laboratories under contract to the U.S. Department of Energy (DOE) and supports numerous federal, state, and local government agencies, private companies, and organizations. It is one of the DOE's Federally Funded Research and Development Centers (FFRDC).

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of the ASME Energy Committee. In 1994 I was elected to the rank of Fellow of the ASME.

7. From 1994 through 2011, I served on the International Energy Agency's (IEA) Solar Power and Chemical Energy Systems (SolarPACES) Implementing Agreement, which is the international organization tasked with the sharing of CSP R&D information between and among member governments. I chaired SolarPACES from 2004 through 2011.

8. Appendix I is my complete C.V. It also contains a list of all of my publications from the last 10 years and all of my solar energy-related publications regardless of date of publication.

9. During the last 4 years, I served as an Expert Witness for the following four cases:

    a. Evaluation of the Expected Lifetime of the Andasol Solar Parabolic Trough Plants, EISER Infrastructure Limited and Energia Solar Luxembourg S.à.r.l. vs. The Kingdom of Spain, International Center for Settlement of Investment Disputes, ICSID Case No. ARB/13/36, February 2016.

    b. Evaluation of the Expected Lifetime of the Andasol Solar Parabolic Trough Plants, ANTIN Infrastructure Services Luxembourg S.à r.l. ANTIN Energia Termosolar B.V. vs. The Kingdom of Spain, International Center for Settlement of Investment Disputes, ICSID Case No. ARB/13/31, October 2016.

    c. Evaluation of the Expected Lifetime of the REEF Solar Parabolic Trough Plants, REEF Infrastructure (G.P.) Limited REEF Pan-European Infrastructure Two Lux S.à r.l. vs. The Kingdom of Spain, International Center for Settlement of Investment Disputes, ICSID Case No. ARB/13/30, March 2017.

    d. IAS Solar Dish Technology Evaluation, United States Department of Justice, United States v. RaPower-3, et al., Civil No. 2:15-cv-00828 DN, April – June 2018.

10. I have been and am currently being compensated by the IRS Office of Chief Counsel at my consulting rate of $300/hour for work related to the evaluation of the IAS Solar Dish Technology, the preparation of this report, and any testimony I may provide.

11. The materials, including documents and in-person visits to sites identified by IAS and RaPower3, that I have examined and relied upon in preparing this report are cited in this report.

12. Appendix II is a glossary of terms that I use in this report.

13. My opinions are based on the detailed analysis presented in this report. I affirm that my opinions are solely and completely my own, that they are independent, and free of influence from anyone, including but not limited to the Parties in this case, IAS, RaPower3, and the IRS Office of Chief Counsel.

<u>Conclusion 1: Status of the IAS Solar Dish Technology</u>

The IAS Solar Dish Technology is in the research Stage 1 of development as described in Section 3 of this report. The "Technology" comprises separate component parts that do not work together in an operational solar energy system. The IAS Solar Dish Technology does not produce electricity or other useable energy from the sun.

<u>Conclusion 2: Commercialization Potential of the IAS Solar Dish Technology</u>

The IAS Solar Dish Technology is not now nor will it ever be a commercial-grade dish solar system converting sunlight into electrical power or other useful energy.

Thomas R. Mancini (signature) — Nov. 13, 2019

Thomas R. Mancini — ***DATE***

2. INTRODUCTION TO CSP TECHNOLOGY

14. Concentrating Solar Power ("CSP") Systems are different from the better-known photovoltaic solar systems. In a photovoltaic system, devices generate electricity directly from sunlight through a process that occurs naturally in semiconductor materials. Electrons in semiconductors are released by solar rays and travel through an electrical circuit, providing electricity to the grid. CSP systems operate by collecting the heat from sunlight and using it to replace the burning of a fossil fuel in a more conventional power cycle, *most* often the Rankine cycle.

2.1. The Architectures of CSP Systems

15. There are two fundamental architectures of CSP Systems. One type of system focuses sunlight along a line -- the parabolic trough and Compact Linear Fresnel Reflector. The other types of systems, power towers and dish/engine systems, focus sunlight at a point or on a small area. Each CSP power generation system has its own unique set of characteristics, such as concentration ratio (ability to concentrate sun light), system operating temperature, power cycle compatibility, and cost. The four generic CSP concentrator systems are shown schematically in Figure 1 below.

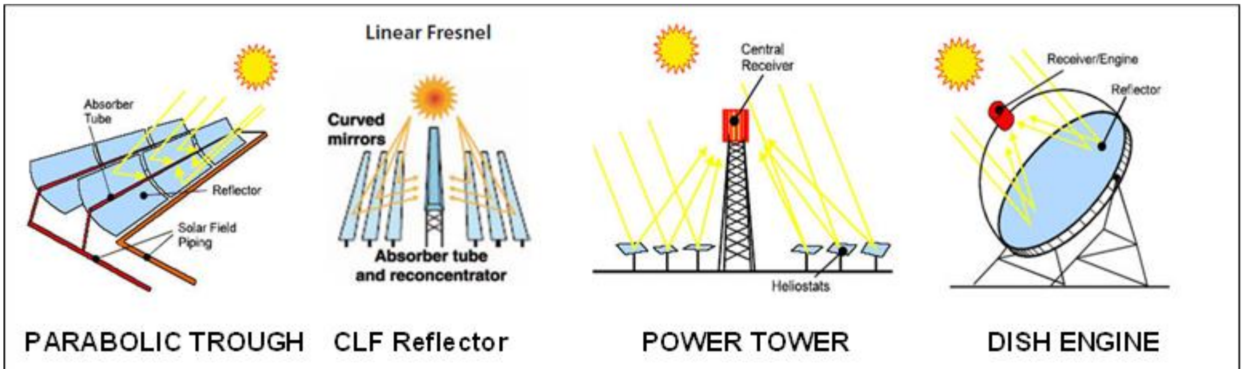

Figure 1 Four types of CSP Systems

16. The general convention is to define a solar collector as comprising a solar concentrator and a thermal receiver.

17. Parabolic trough systems use linear, parabolic-shaped concentrators to focus the sunlight onto glass-encapsulated receiver tubes located along the focal line of the collector. The troughs are oriented so that they track the sun in one direction, usually east to west, to collect solar energy over the course of a day. In a trough-electric system, the collector working fluid (also called a "heat transfer fluid"), typically a synthetic oil, is heated to temperatures up to 400°C in the receiver before passing through a heat exchanger converting a second working fluid, water, to pressurized steam. In a conventional Rankine-cycle, the steam powers a turbine generator to produce electricity.

18. Parabolic troughs are the most mature of the CSP technologies and, consequently, are considered lowest risk for commercial power plant designs. This is their greatest asset and the reason that they represent the highest numbers of commercial deployments. Negatives associated with parabolic trough plants include their low temperature of operation resulting in relatively low solar-to-electric conversion and the need to transport large amounts of heat transfer fluid in piping around the collector field with the resulting thermal losses. Parabolic trough plants can also be operated with or without thermal storage.

19. Compact Linear Fresnel Collectors (CLF Reflector) are an approximation of a parabolic trough in which individual long, linear optical facets (flat or slightly contoured) track the sun to reflect their solar images onto a large, linear receiver at a fixed location elevated above the field. One advantage of a CLFR System is that it requires larger pipes but fewer numbers of them in the field and can more readily accommodate a higher temperature collector working fluid such as molten salt resulting in potentially higher efficiency. The major negative of CLFR is that optically it is not as efficient as a parabolic trough.

20. In a power tower or central receiver system, a field of tracking mirrors called heliostats reflects the solar energy onto a receiver that is mounted on top of a centrally-located tower. To maintain the concentrated sunlight on the receiver at all times, each heliostat must track the sun in two axes over the course of the day. Water or molten salt is the collector working fluid and, as in a parabolic trough system, solar energy is used to generate steam to drive a Rankine-cycle turbine/generator. Power Towers do not require that the working fluid, water or molten salt, be piped around the field as they only need to accommodate a relatively small amount of working fluid to be heated in a centrally-located receiver. They are also capable of operating at temperatures similar to those of a coal-fired power plant, ~ 1000 F (560 C) resulting in higher Rankine Cycle efficiency. Most solar engineers consider power towers to be the best long-term option for producing large-scale power from CSP.

21. The fourth type of CSP system is the dish/engine system which uses a parabolic dish concentrator with a thermal receiver and a heat engine/generator located at the focus of the dish to generate power. The dishes are typically parabolic in shape with a glass reflective surface that focuses sunlight to a small focal region. The system operates by tracking the sun and reflecting the solar energy to the focus of the dish where it is absorbed by the receiver which is attached to an externally-fired engine/generator, typically a Stirling engine. The dish/engine system avoids the thermal losses resulting from the transport of a hot fluid through the collector field because each dish/ engine generates electricity. Then, the electricity (rather than heat) is transported from each dish/engine through electrical wires to a central transformer. Because of their highly accurate solar concentrators, high temperature of operation ~800 C (1400 F), and the high efficiency of the Stirling engines, these systems have demonstrated the highest solar-to-electric conversion efficiencies of

more than 30%. The high level of performance make dish/engine systems very attractive technologies for developers. The major drawbacks to dish systems is their relatively high cost of construction and operation in comparison to other CSP technologies and photovoltaics.

22. The general characteristics of the four types of CSP System are shown in Table 1 below.[2]

Table 1 Characteristics of CSP Systems

SYSTEMS	SOLAR CONCENTRATION	OPERATING TEMPERATURE	ANNUAL SYSTEM EFFICIENCY
Trough	~ 80 suns	400 C	~ 12 – 15 %
Linear Fresnel	~ 800 suns	400 – 560 C	~ 10 - 15 %
Power Tower	~ 800 suns	560 C	~ 15 – 24 %
Dish Engine	~ 3000 suns	800 C	~ 28 – 32 %

23. Each of the four CSP Systems uses the concentrated solar heat that they collect to produce electricity. In the case of parabolic trough, linear Fresnel, and power tower systems, power is produced in a Rankine-cycle power block and for a dish/Stirling system it is produced by the Stirling engine/generator.

24. The Rankine Cycle is a thermodynamic power cycle comprising four fundamental components: a high pressure pump, a boiler, a turbine, and a condenser. Most commonly used in a coal-fired power plant, in the Rankine cycle water (the cycle working fluid) is pumped through a boiler where it is converted to super-heated steam. The steam passes through a turbine/generator where it produces electrical power. The cycle is completed when the now low-pressure steam is cooled and condensed back to liquid water in a heat exchanger called a “condenser.” After the condenser, the water is sent to the high-pressure pump where the cycle is repeated. The efficiency of the cycle depends on all of components being properly designed to interface and operate with the others.

25. All dish/engine systems developed to date have used Stirling engines. The Stirling cycle is different from the Rankine cycle in how it produces electricity. In a dish/Stirling system, the Stirling engine is heated by the concentrated solar radiation from the dish. Inside the engine, the working fluid, typically hydrogen or helium, is contained and goes through a series of expansions, compressions, and heat transfer processes resulting in mechanical work that turns the generator producing electricity.

26. All CSP Systems are carefully designed and built to provide the highest solar-to-electric conversion possible. The fundamental issue is converting the low power density solar

[2] Mancini, T. R., J. M. Chavez, and G. J. Kolb, “The Promise and Progress of Solar Thermal Power,” Mechanical Engineering Magazine, vol. 116, no. 8, August, 1994, SAND94-1353J

resource to heat. This requires large concentrators to collect sufficient solar energy to produce heat for the selected power cycle. Consequently, it is important to minimize the loss of heat as it travels through the system so that these systems can produce the maximum amount of electricity. In the final assessment, the successful technologies will be those that produce the most energy for the lowest cost so that they can compete ultimately with the cost of electricity from conventional fossil fuels.

2.2. Commercialization of CSP Technologies

27. The data in Table 2 show that there are nearly 4,900 MW of CSP systems in operation in the world today.[3] Parabolic trough, CLFR and Power Towers are commercial systems. But dish/Stirling has yet to find market penetration and is generally considered an emerging technology. While 5,259 MW is more than 100 CSP power plants, it is worth noting that this represents less than 0.8% of the world electrical energy capacity.[4]

Table 2 Capacity of Commercially Deployed CSP Plants

CSP TECHNOLOGY	Commercial Operating Capacity in Megawatts (MW)
Parabolic Trough Plants	**4,505**
Power Tower Plants	**682**
CFLR Power Plants	**172**
Dish Stirling Plants	**0**
Total	**5,259**

28. As shown in Table 2, parabolic trough systems are the most widely deployed systems. This is due to the history and greater experience base with parabolic troughs than with other CSP systems. However, because of the relatively low operating temperature and resulting system efficiency and difficulty incorporating thermal energy storage from parabolic trough systems, the CSP community believes that the most logical, long-term CSP power generation system is a power tower with thermal energy storage.

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3 SolarPACES data, available at http://www.nrel.gov/csp/solarpaces/index.cfm (last accessed on October 30, 2019);
Solar Energy Industries Association, Concentrating Solar Power, 2019, available at http://www.seia.org/policy/solar-technology/concentrating-solar-power (last accessed on October 30, 2019);
Spanish Solar Thermal Industry, 2015. Protermo Solar. http://www.protermosolar.com/proyectos-termosolares/mapa-de-proyectos-en-espana/ (Last accessed on October 30, 2019)

4 2017 Renewable Energy Data Book, Denver, CO USA: NREL,https://www.nrel.gov/docs/fy19osti/72170.pdf

2.3. Dish/Stirling System Demonstrations

29. Although dish/Stirling systems have the highest potential efficiency, there are no dish/Stirling power plants in commercial operation today. This is not for lack of trying by the industry. After 20 years of research and development and 100's of millions of dollars of investment, why couldn't dish/engine technology succeed in the highly-subsidized solar power marketplace? The simple answer is that dish/Stirling systems could not compete with the falling costs of other CSP systems, power towers and parabolic troughs, and with the low cost of flat-plate photovoltaics.

30. Examining the technology-based reasons for dish/Stirling systems being unable to compete, I make the following observations.

    a) Due to their highly-accurate concentrators, high operating temperatures, and the efficiency of the Stirling engine, dish/Stirling systems have the potential to show the highest performance of any CSP or photovoltaic system.

    b) However, they are not able to achieve cost/performance goals because thermal energy storage cannot be readily integrated into dish/engine systems. Thermal energy storage extends the ability of a solar plant to generate electricity beyond times when solar energy is available (i.e., at night).

    c) Costs are high in part because of the cost of Stirling engines. All development plans for dish/Stirling systems require very high production rates for the Stirling engines to make them cost-effective.

    d) The relatively high initial system costs and, more importantly, the operating and maintenance costs of dish/Stirling systems are not likely to be reduced quickly or to sufficiently low levels to enable them to complete commercially with other renewables and fossil fuels.

31. Stirling Energy Systems is the company that has made the biggest investment in dish/Stirling systems' development. Based on my personal knowledge of Stirling Energy Systems' development, I know that they invested $100M to get their dish/Stirling technology to the Engineering Development Stage 4 market entry system demonstration (described in paragraph 35 below). At that stage, Stirling Engine Systems determined that they could not reduce costs sufficiently enough to compete in the subsidized renewable energy market. There are no commercial dish/Stirling systems operating today, primarily due to the high initial and operating costs. They cannot compete with other renewable technologies, even in subsidized markets.

32. Before proceeding with my evaluation of the IAS Solar Dish Technology, it is helpful to briefly review the stages of development for engineering projects.

3. STAGES OF TECHNOLOGY DEVELOPMENT

33. The Engineering Stages of Technology Development are a general methodology taught to engineers and used throughout the engineering disciplines in industry. I have used these Stages as reference points for projects throughout my career. There are more detailed versions of this process, but the following is a brief, simplified process based on a standard Mechanical Engineering curriculum.

Table 3 Stages of Engineering Technology Development

Stages	Description of Activities	Engineering Tools	Expected Outcomes
1. Research	Define boundaries Consider options Preliminary specifications	Scientific principles Mathematical models Simple experiments	Initial system specification Initial component/system models Proof of concept models
2. Demonstrate	Refine component options Consider component interface requirements	Simple computer models Advanced math models Engineering tests Data Analysis	Validation of science Define initial component designs Full test of components Component operational data
3. Prototype	Design components Build components Test components	Full component tests Database of component tests Refined designs/models	Validated component performance Component designs System specification
4. Market Entry	Build/test system prototype	Long-term testing Data collection/analysis Refine system model Evaluate O&M	Validated system performance Long-term O&M data Defined system specifications

34. In the **Research Stage**, the engineering team typically defines the problem and explores the options for achieving the desired output. For example, what is the desired power output of a dish system? What collectors, receivers, power blocks, etc. could achieve this output? The engineering team develops mathematical models of the components and assembles them into a systems model for analysis and further evaluation. Part of this process includes defining the pros and cons of each specific element and how it might impact the final system design. At this point, the analysis will also likely include a first-level cost analysis. From this, the engineers will develop an initial computer model of a system. The analysis might include more than one system option for further evaluation.

35. In the **Demonstration Stage**, the engineering team will develop more detailed computer models of the system components including a second-level cost analysis. They may identify key issues such as material requirements, working temperatures, etc. that require further evaluation. Engineers might design and build simple physical models of components, i.e., a receiver, a concentrator facet, etc., for testing under actual temperature and flow conditions to validate their computer models. After fully validating the technical performance, the engineers will likely “freeze” the design to a specific configuration and use computer models

to set the interface requirements and the specifications for each component. The component interface requirements are critical because they identify how the component parts will work together to create the system as a whole. The team is prepared to design the first system prototype based on this interface document. However, they likely have also identified potential issues and shortcomings and may focus on these as they proceed.

36. In the **Prototype Stage**, the first system prototype is built and tested under actual operating conditions. During short and long-term testing, a number of issues will arise that require redesign and reevaluation. One or more of the components may not perform acceptably and other design options may need to be considered. This is a long stage of the development process and requires iteration, extended operation of the prototype system, and the collection of detailed, long-term data. At the end of this process the engineers have a detailed, validated computer model of the system, second-generation detailed component and system designs, and a document defining the system specifications and interface requirements. The next step is to scale the system for market entry.

37. The first step in **Market Entry Stage** may be characterized by building, installing, and operating for an extended period of time a scaled system. One of the most important issues to identify is the actual scope and cost of Operation and Maintenance of the plant.

38. Once data and information has been collected from the scaled system operation, the engineering team will have the information required to support actual project development, i.e., to develop a detailed cost proposal, to secure financing, to obtain all regulatory permissions to operate a power plant, and to negotiate a utility-scale power purchase agreement, so that the project can be built and electricity provided to the grid.

39. It is important to recognize that there is substantial iteration built into this process. For example, one might find a problem with a component that occurs during Stage 4 long-term operation and choose to redesign and retest that component in order to meet system specifications and operational goals. This could involve as simple a task as replacing one material with another, for example carbon steel with stainless steel, and retesting and evaluating the component performance. Or, it could involve replacing an entire component design because it does not meet system requirements, i.e., replacing one receiver design with another and completing an acceptance test regime.

40. As I explained, this is not the only model for energy technology development. Some may differ in whether a particular activity is in Stage 1 or Stage 2 and there is a great deal of latitude in how and when tasks are undertaken. However, this is a simplified presentation of the development process and consistent with other process descriptions.

41. Regardless of the details associated with the engineering stages of development, the process typically involves a team of engineers having a range of education, work

experience, and engineering disciplines. For example, the team developing a solar dish system would typically involve senior and junior engineers with masters and bachelors degrees, mechanical engineers with power, structural design, metallurgy, and systems backgrounds, electrical engineers with controls and power experience, and perhaps a chemist or two.

4. EVALUATION OF THE IAS SOLAR DISH TECHNOLOGY

42. During my site visits on January 24, 2017 and April 4, 2017, the components of the IAS/RaPower3 Solar Dish Technology were not operating, were not assembled as a system, and were not producing electrical power or heat using solar energy.

43. Based on my observations during the site visits and the materials I have reviewed for this case, the IAS Solar Dish Technology is not currently capable of producing electrical power or heat using solar energy.

44. From the information I have reviewed, I see that over time, the designs of different and fundamental system components have changed. This alone reflects an absence of engineering expertise, discipline and rigor in the design and execution of the IAS Solar Dish Technology.

45. The most glaring example of the lack of engineering expertise is the fact that the components of the IAS Solar Dish Technology have not been designed to work together as a system. The components, including the dish, receiver, and turbine (to the extent that they have been designed at all), are stand-alone devices designed without consideration for the respective engineering interfaces or having the components work together as a system.

46. The most egregious examples of a lack of systems analysis in the design of the IAS Solar Dish Technology are:

   a) the incompatibility of the concentrator and receiver designs that lead to low optical and thermal efficiencies;

   b) the change of the collector working fluid from water to molten salt and then to synthetic oil resulting in a lower cycle operating temperature;

   c) the design of a turbine that will not work at the reduced cycle temperatures associated with using synthetic oil as a heat transfer fluid;

   d) the claims that a boiler and condenser are not required as part of the Rankine power cycle (they are required); and

   e) no sensors, controls, control system, and suitably sized generator are identified or even considered as part of the system.

47. Because of these and other serious flaws in the design and execution of the IAS Solar Dish Technology described below, and based on my observations during the site visits and the materials I have reviewed for this case, it is my opinion that the IAS Solar Dish Technology is not now and has never been capable of producing electrical power or heat using solar energy.

4.1. Documents and Information Reviewed

48. For any solar energy project design and/or operation, I would expect that the designer and/or operator would have the following kinds of documents:

    a) 400 to 600 detailed engineering analysis and design drawings for the solar dish, receiver, heat exchangers, and turbine-generator;

    b) detailed component models describing operation under a range of operational conditions;

    c) system performance models describing the system output as a function of the solar energy input;

    d) component interface documents describing in detail the physical and operational interfaces between the components, i.e., concentrator and receiver, receiver and piping, piping and pumps, flowrates and heat exchangers, steam flow and turbine, etc.;

    e) test and operational databases detailing the objectives and results of operational tests and results for system components;

    f) lists of materials for components including a cost analysis for the materials and manufacturing of the components;

    g) a bottom-up system cost analysis rolling up the component, manufacturing and installation cost for the IAS Solar Dish Technology; and

    h) system specifications and operational requirements.

49. I reviewed a large number of documents and other materials, including the documents provided by RaPower-3, LLC, International Automated Systems (IAS), Inc., and Neldon Johnson's Supplemented Production of Documents. The IRS Office of Chief Counsel Document Requests asked for the kinds of documents listed in paragraph 48.

50. But I did not see, in those documents or in any of the other materials I reviewed for this case, the kinds of documents, such as those listed in paragraph 48, that I would expect to review in the context of the engineering design and/or operation of a solar energy project at any Stage of Engineering Development.

51. I also understand from Mr. Johnson's testimony during his deposition[5] that he does not keep records of tests that he conducts on components of the IAS Solar Dish Technology or the purported system as a whole, or data from those tests.

[5] Deposition of Neldon Johnson taken in *United States v. RaPower-3, LLC; International Automated Systems, Inc.; LTB1, LLC; R. Gregory Shepard; Neldon Johnson; and Roger Freeborn*, Civ. No. 2:15-cv-00828 (D. Utah), June 28, 2017, included as Attachment 1 at 66:1-24; 69:4-10; 150:2-151:17; 152:13-153:4; 164:3-165:7; 186:20-188:19 (Attachment 1 includes referenced excerpts of the deposition; full copy available on the enclosed disc).

52. Among all of the documents I reviewed, the documents that I identify as having the most technical information are:

   a) New Solar Breakthrough May Compete with Gas, na/nd. I saw multiple versions of this document in the materials I reviewed. A version of this single document was produced to me in two parts, included as Attachments 2 and 3 to this report, which provide the basis of my analysis in this report. I received what appears to be a more recent version of this document, included as Attachment 4. Generally, both versions are similar and, in fact, in some areas are identical. But there are differences between the two documents and, where these differences are important, I will make note of the differences in my evaluation. Generally, this document (in any of its versions) is the most complete description of the IAS Solar Dish Technology. The document itself does not identify the author, but Mr. Johnson testified that he wrote parts of it and incorporated writings from other people into it.[6]

   b) 15 Years in the Making, IAS Research and Development Timeline, by Matthew Shepard, which is included as Attachment 5 to this report.

53. In all of the information that I reviewed, there were only a couple dozen engineering-type drawings, and limited or no analysis of the component and system design details and performance.

54. I visited the "Manufacturing Facility," the "R&D Site of IAS," and the "Construction Site of RaPower3," all in Millard County, Utah, identified by RaPower3 on January 24, 2017 and again on April 4, 2017. During the tour on April 4, a videographer took film of the visits to the three sites. These visits also provided me with technical information that I use in my analysis.

55. Throughout this report, I provide some technical and engineering analysis of the IAS Solar Dish Technology, its components, and evaluate what its possible performance would be if it were ever assembled into a working system for RaPower3. Because I do not have the engineering data that I would normally use for this type of analysis, I provide my best estimates based on the available materials and my own knowledge of scientific, technological, and engineering principles that apply to the components. Because I do not have actual data on the performance of the individual components, I am forced to make assumptions and estimates based on the information I reviewed and my experience.

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6 Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 173:6-185:2.

4.2. Qualifications of the Design Team

56. It is my understanding that the inventor and primary designer of the IAS Solar Dish Technology is Mr. Neldon Johnson. He is the only person identified by name who worked on design and performed engineering-type work on the IAS Solar Dish Technology[7].

57. My understanding of Mr. Johnson's education and technical background is that he does not have an engineering, physics, or science degree.[8]

58. In the documents and information I reviewed, I did not see resumes or curriculum vitae for Mr. Johnson, engineers, designers, technicians or others associated with the design and/or engineering of the IAS Solar Dish Technology.

59. Attachment 3 contains references to unnamed parties who purportedly analyzed or reviewed technical aspects of the IAS Solar Dish Technology. I did not see separate reports from these parties in the materials I reviewed, nor are the specific contributions of these parties clearly identified in these documents.

60. Unless I state otherwise below, without knowing these reviewers' names, biographies, C.V.s, and technical experience, and what data and information they were given to review, I cannot give serious consideration to information in these documents that purportedly came from these unnamed parties.

61. I will identify these reviewers as appropriate in the discussion of the components below.

62. In the documents and information I reviewed, I found no indication that any person is or was qualified to design, build, and/or bring to Engineering Stage 4, Market Entry, the IAS Solar Dish Technology. I found no indication that any person who worked on the IAS Solar Dish Technology has or had any substantial technical background, including a bachelors or masters degree in any relevant field. I found no indication that any person who worked on the IAS Solar Dish System for RaPower3 was or is a mechanical engineer with a power, structural design, metallurgy, or systems background or was or is an electrical engineer with controls and/or power experience.

4.3. Proposed IAS Solar Dish Technology

63. The design of the IAS Solar Dish System as proposed appears to be a hybrid of the parabolic trough and the dish/engine technologies. The proposed system purports to collect thermal energy from refractive dish technology using Fresnel lenses, and transfer the

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7 Deposition of Neldon Johnson, June 28, 2017, included as Attachment 1 at 134:21-135:19.

8 Deposition of Neldon Johnson, June 28, 2017, included as Attachment 1 at 16:8-17:17; Deposition of Neldon Johnson in *Securities & Exchange Comm'n v. International Automated Systems, Inc. and Neldon P. Johnson*, Civ. No. 2:98CV 0562S, (D. Utah May 10, 2001), included as Attachment 6 at 6:12-7:11, 10:14-11:9 (Attachment 6 contains excerpts of this deposition; full copy available on the enclosed disc).

collected thermal energy to a centrally located turbine/generator for electrical power production using a Rankine cycle.

64. A schematic diagram of the system, as best I understand it, is proposed in Attachment 2 to be configured as shown below in Figure 2.[9]

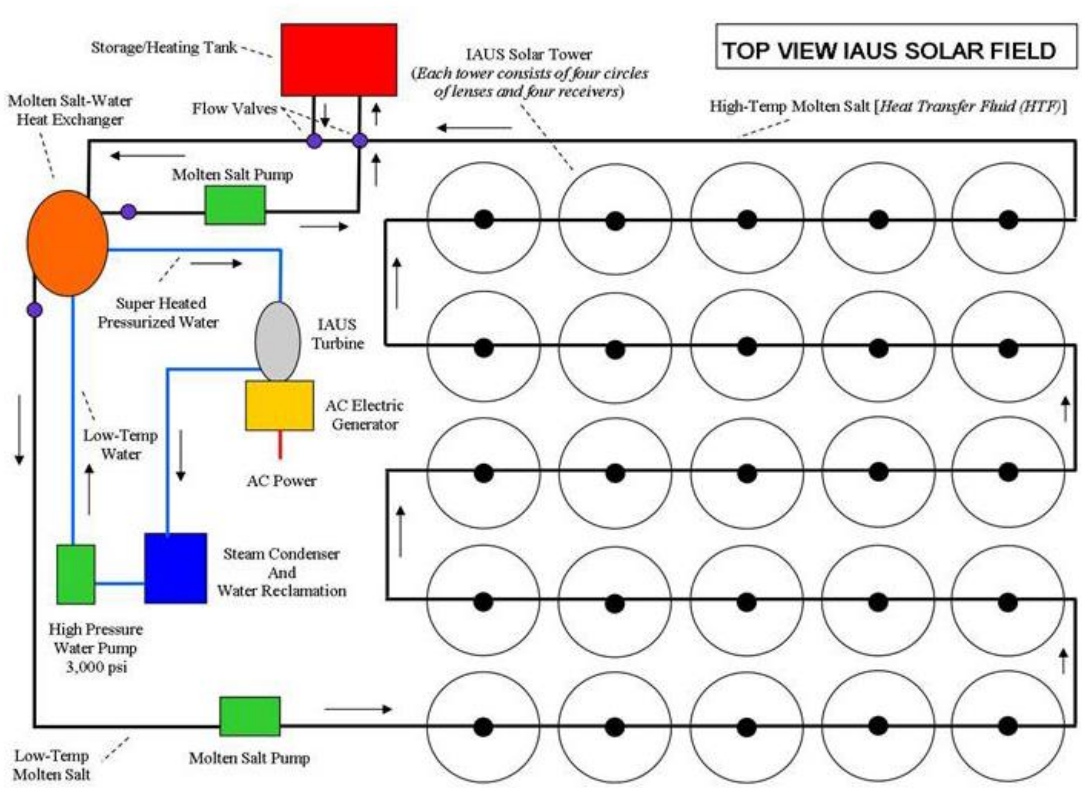

Figure 2 System Diagram Proposed for the IAS Solar Dish Technology

65. According to Attachment 2, the dark line in Figure 2 represents the flow of the working fluid through the system with each of the circles representing a solar collector. As the molten salt flows in through the collector field, it collects heat until it reaches the heat exchanger where the hot molten salt provides the heat to boil water, producing steam to drive Rankine cycle power block containing the turbine/generator and produce electric power for the grid. One issue is the single molten salt storage tank shown by the red box in Figure 2 above. In a typical molten salt storage system, there would be two storage tanks, one for hot salt and one for cold salt. When the system is operating, the cold salt would be removed from its tank, heated in the collector field, and deposited for storage in the hot tank. When needed to produce power, the hot salt would be removed and passed through the heat exchanger then returned to the cold tank. It is not viable for the storage system to have a single tank

[9] Attachment 2 at page 18.

as depicted above because mingling hot salt and cold salt in a single tank will dilute the hot salt, reducing the temperature of the salt available to power the system.

66. The system described in Figure 2 is sometimes referred to as a central engine system. Unlike the dish/engine systems described in paragraphs 15 and 21 above where each dish has a dedicated engine/generator and provides power through wires, the central engine system approach uses a centrally-located engine that is supplied with molten salt heated by a series of concentrators in the collector field. Heat is collected from each of the dishes in parallel so that all dishes "dump" heated fluid into a common hot header system. Because each collector will provide molten salt heated to a different temperature, the salt will only be heated to the average temperature provided by the field. Therefore, the performance of the system will be defined and limited by the heating capacity of the poorest performing solar collectors.

67. The proposed IAS system in Figure 2 uses 25 concentrators in the collector field, connected in a series. A single turbine and power block would be powered by 25 collectors and together they would form a larger unit for power production. IAS claims that this unit can be replicated throughout a large field to produce larger amounts of power.

68. I am aware of only two experiments to evaluate central engine systems, one by LaJet Energy Co. and the other a U.S. Department of Energy sponsored project with Georgia Power Company referred to as the Shenandoah Solar Total Energy Project (STEP). Both projects operated during the mid 1980s.

69. As far as I know, there is no published data on the performance of the LaJet dish project. My knowledge of the project comes from working with LaJet and Cummins Power Generation on the design of their dish/Stirling systems. The project at Warner Springs, CA, used LaJet's, reflective stretched-membrane dishes to boil water and produce steam to drive a 3.7 MW turbine generator. It was beset by a number of problems with components including the receivers and the concentrators and was terminated after only 3 years of operation.[10] The solar concentrators were made of a reflective silver film that was thought at the time to have a long lifetime but actually degraded due to environmental exposure. After the Warner Springs Project, LaJet sold their technology to Cummins Power Generation who proceeded to build and test a more conventional dish/Stirling system, similar to the ones described in paragraph 21 above.

70. Because it was a DOE project, the Shenandoah STE Project was far better documented than the LaJet effort. Prof. William B. Stine of Cal Poly Pomona was under contract to the DOE to evaluate the STE Project and other DOE activities and published some of his results

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[10] Private communication with former LaJet Chief Engineer Mr. Monte McGlaun, April, 17, 2017.

in an online book[11]. The Shenandoah STEP central engine system uses solar energy collected from a field of 114 parabolic dish collectors to supply process steam, electricity, and cooling. The system provided energy to the Bleyle knitwear plant and electricity to the Georgia Power Company grid. Figure 16.17 of Prof. Stine's book shows the energy flows throughout the plant.[12] The collector working fluid that moves the heat around the plant is steam. The steam must move through large ducts between the receivers and the central engine. In the Shenandoah STEP, the dish concentrators collect 3348 kW of solar radiation but 781 kW (23%) of the energy is lost before it reaches the central engine. The heat loss is due to the receivers and the transport of heat through the system.

71. Because I was the Sandia Project Manager at the time, I know that the supplier of the dishes for the Shenandoah STEP, Solar Kinetics Inc., abandoned the central engine approach and went on to develop a dish/Stirling system (which moves electricity rather than heat) with Stirling Thermal Motors.

72. CSP researchers generally agree that the major weakness of central engine systems, similar in design to the proposed system for the IAS Solar Dish Technology, is the requirement that large amounts of heat must be transported via pipes to a centrally-located engine/generator. As was demonstrated in the STEP Project, the process of transporting hot collector working fluid throughout the collector field results in large thermal losses that drive efficiency down and costs up.

73. It is my opinion that the proposed IAS Solar Dish System of Figure 2 is subject to the same issues and problems that I've identified for previous central engine systems. In the materials that I reviewed, I saw no indication that anyone associated with the IAS Solar Dish Technology has considered, much less resolved, any of these issues.

4.4. The Solar Concentrator

74. Typical solar dishes are point-focus, solar concentrators that must accurately track the sun in two axes, azimuth and elevation, maintaining the focus of the dish always on a small area where the thermal receiver is located. As illustrated in Table 2, dishes are the highest performing solar concentrators, capable of very high concentration of solar energy and, potentially, of very high-temperature, high-efficiency operation. This high level of performance requires that the dish structure be very stiff, precisely track the sun, and operate under 30 – 35 mph wind loads all while directing an accurately focused beam of

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[11] Section 16.2.3 Shenandoah Solar Total Energy Project, Power From The Sun, copyright © 2001 by William B. Stine and Michael Geyer, http://www.powerfromthesun.net/Book/chapter16/chapter16.html

[12] Figure 16.17, Power From The Sun. Section 16.2.3 Shenandoah Solar Total Energy Project, Power From The Sun, copyright © 2001 by William B. Stine and Michael Geyer, http://www.powerfromthesun.net/Book/chapter16/chapter16.html

solar energy into a small receiver aperture. This high level of performance also requires dishes to survive winds of ~ 100 mph.

75. Figure 3 is a photograph of the IAS refractive dish concentrator[13].

Figure 3 IAS Solar Dish

76. The lenses used in the IAS Solar Dish design are Fresnel lenses made from acrylic plastic. Shown below in Figure 4 is a diagram of how a Fresnel lens is constructed.[14]

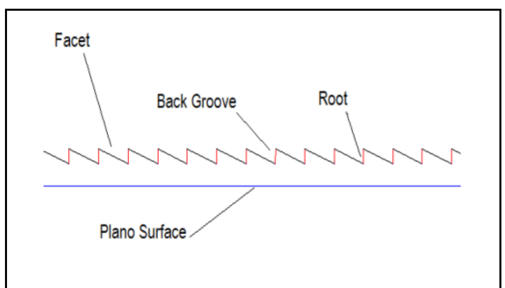

Figure 4 Fresnel Lens

The lens is an approximation of a continuous curved lens with each of the small facets having a slightly different and precise angle so that each incident solar ray is bent in a slightly different direction. Attachment 2 claims that the optical lenses are efficient, durable, require only low

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[13] Attachment 7, Photograph taken by the Author during the January 24, 2017 visit to the IAS Site.
[14] Attachment 3 at US001855.

maintenance, and will "endure extreme weather conditions for more than 60 years with low degradation."[15] None of these claims is supported by analysis, test data, or reference in the documents and information I reviewed.

77. Murray and French[16] tested acrylic sheets used for photovoltaic applications in a diverging solar simulator at irradiance levels of up to 50 kW/m^2 and found a 22% reduction in solar energy transmission after 10 years simulated laboratory exposure and 40% reduction after 25 years equivalent exposure. The acrylic material Murray and French analyzed is the same acrylic material used to manufacture IAS Solar Dish lenses. The reduced transmissivity would result in equivalent reduction in the power produced by the proposed IAS Solar Dish System.

78. From the documents that I reviewed, I understand that the concept of the IAS Dish design shown in Figure 3 is to have the 4 circular concentrator lens assemblies located at the top of the tower track the sun so that the planes of the four circular lenses remain perpendicular to the incoming solar rays throughout the day. Each of the acrylic lenses refracts (bends) the incoming solar rays so that the focus of each lens assembly impinges on a receiver hanging from the stringers below the lens array.

79. A typical dish receiver is designed to intercept the concentrated beam of solar energy (also called a "solar image") provided by the concentrator and transfer the absorbed solar energy to a circulating working fluid. To minimize thermal losses from the receiver, it must have as small an aperture as possible. To absorb the maximum amount of solar energy, the receiver aperture must be as large as needed to intercept the concentrated sunlight. This requires a tradeoff between the size of the solar image from the concentrator and the size of the receiver. While the solar receiver requires as small a concentrated solar beam as possible to reduce thermal losses, it is a difficult and expensive for the solar concentrator to direct the solar energy to a single small area on the receiver.

80. Because the IAS Solar Dish design has four circular Fresnel lens elements, it has a unique challenge, i.e., to accurately focus four highly concentrated solar images with stability on four separate receivers at the same time. Considering the path of a single incident beam of solar energy from its point of incidence on the outside surface of lens to the concentrated region on the receiver surface, some of the issues for the IAS Dish design are:

a) because the Fresnel lens is an approximation of a continuous lens, its ability to provide an accurate solar image depends on its design, how well it is manufactured, how precisely it is installed and held on the dish, and its cleanliness;

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[15] Attachment 2 at page 5.

[16] Solar Radiation Durability of Materials, Components and Systems for Photovoltaics, M. P. Murray, and French, R. H, IEEE Conference, 978-1-4244-9965-6/11, June 2011, Case Western Reserve Univ., Cleveland, OH.

b) the lens assemblies must be rigidly supported in their mounting frames and the frames must also not deflect too much or the solar image will grow and not impact the receiver;

c) the two-axis tracking system must be very accurate to assure that the lens assemblies are properly oriented to the incoming solar radiation;

d) the structure of the dish must be rigid so that the tracking will be accurate; and

e) the receiver hangers must be stiff and not sway due to the tracking of the structure and wind loads. Any motion of the supports will reduce the intercept factor because the receiver will not always be optimally aligned to capture the concentrated sunlight.

81. All optical lenses in solar energy systems require cleaning to maintain maximum transmissivity of sun light. Accumulated dust and dirt can degrade their optical performance.

82. The Fresnel lenses in the IAS Solar Dish are as subject to dust and dirt accumulation as are all other optical lens. Unlike mirrored surfaces that have a single surface that must be cleaned (as with parabolic troughs, for example), the IAS Fresnel lens would have to be cleaned on both the top and bottom surfaces. In addition, the top side of the lens surface has small, delicate grooves that can collect dust and dirt and could be easily damaged when cleaning.

83. Lucite, the original manufacturer of the lenses, recommends keeping lenses clean with “an occasional washing with mild soap or detergent and water solution” or a combination of ammonia and water.[17] “Fine hair scratches may be removed or minimized by the use of a mild automobile cleaner polish.”[18] But “cleansing materials containing abrasives ….should never be used.”[19] “Gasoline, acetone, chlorinated solvents, or denatured alcohol tend to soften the surface of the plastic and often cause cracking.”[20]

84. I have also seen claims that the optical lenses do not need to be washed.[21] This is simply not correct. The issue of cleaning the lenses raises questions of if/how IAS plans to maintain the initially high transmission of the acrylic lenses. .

85. Attachment 2 also claims that the lenses maintain their focal point without “manual fine-tuning.”[22] This claim is not supported by analysis, test data, or reference in the documents and information I reviewed.

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[17] Attachment 8 at Lucite0058.
[18] Attachment 8 at Lucite0058.
[19] Attachment 8 at Lucite0057.
[20] Attachment 8 at Lucite0057.
[21] Deposition of R. Gregory Shepard taken in *United States v. RaPower-3, LLC; International Automated Systems, Inc.; LTB1, LLC; R. Gregory Shepard; Neldon Johnson; and Roger Freeborn*, Civ. No. 2:15-cv-00828 (D. Utah), May 22, 2017, included as Attachment 9 at 192:8-193:14 (Attachment 9 contains excerpts of this deposition; full copy available on the enclosed disc).
[22] Attachment 2 at page 5.

86. In the materials I reviewed, there are no analyses, no design details, no engineering drawings, no test data or performance data regarding: the two-axis tracking system accuracy; the stiffness of the concentrator structure and lens assemblies; the performance of the concentrator with and without wind load; the accuracy of the Fresnel lens assembly; the flux in the receiver plane provided by the Fresnel lens assembly; or the ability of the acrylic lens material to survive weather conditions and be cleaned.

87. Using the limited technical information I have already identified in this report and my own observations of the technology as it existed during my site visits, I have analyzed the IAS Solar Dish Technology as if it were operating as a system. The first step of my analysis is to evaluate the optical efficiency of the solar concentrator which includes the amount of concentrated solar energy that is intercepted by the receiver. My analysis, assumptions and references are listed in Appendix III.

88. To determine the interface between the dish and the receiver once the solar energy has passed through the lens assembly, we need to determine the size of the solar image in the plane of the solar receiver. This is commonly done using one of two techniques: 1) measuring the solar flux distribution in the receiver plane, or 2) using a calorimeter (like a solar receiver) to measure the power absorbed using different aperture diameters. Because I saw no test data for the lens in the documents I reviewed, I used the video clip Solar Lens Test[23] from the RaPower3 Website to estimate the image diameter in the focal plane at 1 meter.

89. Attachment 3 states that "The power generating requirements determine the diameter. For this project, the lens diameter of 436 inches has an area of 96.32 sq. meters and has a 100 kW collection capacity potential."[24] The more recent document at Attachment 4 states that the diameter of the circular lens is 22 feet.[25] I used the information from Attachment 4 because it is consistent with what I saw during my two visits to the Manufacturing Facility, the R&D Site, and the Construction Site.

90. Using the area of one circular lens on a good solar day (1 kW/m^2), the 22 foot diameter for one of the circular lenses, the transmissivity reported by Lucite[26] for the solar energy spectrum, assuming a 95% accuracy for the lens manufacturing accuracy, and 6.9% loss due to soiling and dust, I estimate that one of the four lenses on a dish will transmit 27.75 kW of solar energy under normal operating conditions. This calculation is shown in Appendix III.

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[23] Attachment 10, available on the enclosed disc.
[24] Attachment 3 at US001855.
[25] Attachment 4 at Ra3 023534.
[26] Attachment 11 at Lucite0751

91. Next, because I do not have engineering design drawings for any proposed receiver, I used the photograph of the tubular receiver[27] (also shown in Figure 5(c)) taken during my tour of the Manufacturing Facility to estimate the dimensions of the receiver aperture at 60 cm by 50 cm. The receiver area is less than 38% the area of the image provided by the circular lens assembly but, since the flux profile is most likely a Gaussian one, I estimated the intercept factor at 0.6. The video clip at Attachment 10, available on the enclosed disc, was taken with the lens assembly supported by a construction crane so there were no structural deflections or alignment issues included in the image. Allowing for a 90% tracking accuracy and including structural deflection, I calculate a revised intercept factor for the receiver of 0.54 and 15.0 kW of solar energy actually incident on one receiver surface. The total power available from a dish would be four times this amount or 60 kW.

92. Analysis shows that the solar image in the receiver plane is much larger than expected based on the ray-trace model.[28] The receiver aperture is too small to collect all of the transmitted solar energy but it is much larger than it should be to have low heat losses. This could be due to inaccurate manufacture of the lens tooling, poor alignment of the lenses within the lens assembly, or inaccurate determination of the focal plane. Table 4 below is a summary of the optical characteristics of the IAS Solar Dish as reported in Attachment 3[29] and the results based on my analysis. The low value for the optical efficiency as reported by me is due to a combination of factors in the manufacture of the lenses, a lack of stiffness in the concentrator tracking structure, and the low intercept factor.

Table 4 Evaluation of Optical Characteristics Of the IAS Solar Dish

PARAMETER	IAS[30]	My Calculations[31]	MY REFERENCE
Transmissivity	0.90	0.89	Lucite0751
Lens Cleanliness	0.931	0.931	Same as IAS.
Lens Manufacture Accuracy	1.00	0.95	Engr. Est.
Receiver Intercept	1.00	0.54	Engr. Est.
Optical Efficiency	0.84	0.425	

93. During my site visits on January 24 and April 4, 2017, I did not see an IAS concentrator in working order -- receiving or concentrating solar energy while tracking the sun.

[27] Attachment 12, Photograph of the receiver taken by the Author on his January 24, 2017 visit to the Manufacturing Facility.
[28] Attachment 3 at US-001863.
[29] Attachment 3 at US-001888.
[30] Attachment 3 at US 001888.
[31] Appendix III.

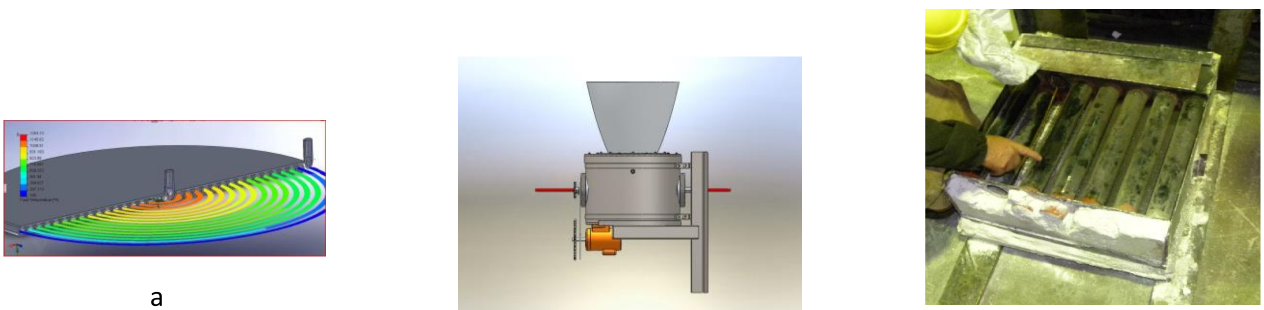
94. At the IAS R&D Site, none of the lens assemblies were fully populated with lenses and most of the lenses that were on the concentrators were broken. Also, I did not see any receivers at the IAS R&D Site or installed on the concentrators.

95. Of the solar concentrators with receiver supports installed, the supports were not sufficiently stiff to keep the receiver mounts from moving in the wind. For example, the light breeze on April 4, caused the receiver supports to sway even though the IAS dish was not tracking the sun.[32] If the dish were operational (which it is not), this movement would affect the tracking intercept factor because the receiver will not always be aligned to capture the solar image which is transmitted by the lens assemblies.

96. Based on the information provided and my analysis, my opinion is that the solar concentrator design is at Stage 1: Research Phase of the Engineering design process of Table 3.

4.5. The Solar Receiver

97. Shown in Figure 5 are three of the solar receiver design concepts[33] I saw proposed for use in the IAS Solar Dish Technology in the materials I reviewed.



a b c

Figure 5 Three of the IAS Receiver Design Concepts

98. In the materials I reviewed, there is no analysis, no design details, no engineering drawings, no test data or performance data regarding the design of the thermal receivers. There is also no consistent set of design criteria relating to the selection of the collector working fluid and whether or not the system will have thermal energy storage.

99. The initial concept, (a) in Figure 5, is a coiled receiver that (according to Attachment 2) purportedly contains water at 1100F (570 C) and has a thermal efficiency 90%[34]. According

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[32] Attachment 13, available on the enclosed disc, Video 12_4_38-5_15.
[33] For Figure 5(a): Attachment 2 at page 7; Figure 5(b), Attachment 2 at page 8; Figure 5(c), Attachment 12 and Attachment 15, available on the enclosed disc, Site Tour Video Clip 3 10:30:24 through 10:31:50.
[34] Attachment 2 at pages 6-7.

to statements in Attachment 2, this concept would purportedly supply super-heated liquid water to the turbine.[35] This is thermodynamically impossible as supercritical water only exists at temperatures below the critical point of 705 F. This concept actually would supply superheated vapor to the turbine. Transport of steam vapor around the collector field would require larger piping or ducts for transport of water and would have to accommodate the steam at 1100 F (570 C) and high pressure of 3200 psi (230 kg/cm^2).

100. During my visits January 24 and April 4, 2017 I did not see an actual receiver like Figure 5(a) at the Manufacturing Facility or at the IAS R&D Site, or the RaPower3 Construction Site. There is no indication, in any of the materials I reviewed, that the receiver in Figure 5(a) has ever actually been used in a system with the IAS Solar Dish Technology to generate electricity.

101. The receiver concept shown in Figure 5(b) has a spherical ball as the thermal receiver, a secondary concentrator (the cone at the top) ostensibly to improve the intercept factor, and a motor control most likely meant to “adjust” the attitude of the receiver to capture the solar radiation. The motor and the cone to improve the solar intercept may be design responses to adjust to the swaying motion of the suspended receivers and the large size of the solar image produced by the concentrator. Attachment 2 Figure 4.1, “New solar receiver showing the concentrator along with the movable heat exchanger,” is the only description of this receiver in Attachment 2.[36]

102. During my visits January 24 and April 4, 2017, I saw several “Magic Balls”[37] for the receiver in Figure 5(b) at the Manufacturing Facility. There were numbers of cones for the receiver in storage also at the Manufacturing Facility. There were cones at the IAS R&D Site, but they were generally broken, bent, and in pieces, strewn about the site. I saw no actual assembled units of the receiver depicted in Figure 5(b) nor did I see any of these receivers in operation. There is no indication, in any of the materials I reviewed, that the receiver in Figure 5(b) has ever actually been used in a system with the IAS Solar Dish Technology to generate electricity.

103. From the materials I reviewed and comments made by Mr. Johnson[38], the receiver shown in Figure 5(c) appears to be the most recent concept being considered for use in a system with the IAS Solar Dish Technology.

104. Mr. Johnson described the configuration of the receiver in Figure 5(c) during my site visit on April 4, 2017[39]. Shown in Figure 5(c) are seven glass tubes coated black on their inside surfaces. My understanding based on Mr. Johnson’s description is that the receiver is

[35] Attachment 2 at page 9.
[36] Attachment 2 at page 8.
[37] Attachment 14 at Gregg_P&R-000576
[38] Attachment 15, available on the enclosed disc, Site Tour Video Clip 3 10:30:24 through 10:31:50.
[39] Attachment 15, available on the enclosed disc, Site Tour Video Clip 3 10:30:24 through 10:31:50.

intended to work as follows: a copper heat exchanger coil would be inserted into each tube and a molten salt or, as discussed below, synthetic oil heat transfer fluid, would be circulated through the coil. The remaining space within the glass tube would be filled with sodium/potassium nitrate salt mixture. The black coating on the inside surface of the glass tube would absorb incident solar radiation, heat the coiled tube and salt, which in turn would heat the oil flowing through the heat exchanger coil. The hot collector working fluid would then be transferred to a common header pipe from the solar collectors in the field.

105. The location of the black surface on the inside of the glass tubing is poor engineering design because it locates the hottest point in the receiver on the glass where heat is readily lost to the environment. During the site visit on April 4, Mr. Johnson also showed us a more conventional receiver tube design[40] comprising a black coated pipe located along the center axis of a glass tube in which a vacuum is created. This is precisely what a parabolic trough receiver is and it has much lower heat losses because the solar energy absorbed on the black pipe is insulated by the vacuum.

106. Apparently, Mr. Johnson does not recognize the advantages of the trough tubular design in contrast to his current design of the black-painted glass tube.

107. During my visit to the IAS R&D Site on April 4, 2017, I was informed by Mr. Johnson that he would replace the molten-salt working fluid with synthetic oil.[41] This was also confirmed by his statements during his deposition.[42] In Appendix III, I calculate the thermal losses from the IAS receiver in Figure 5(c) by assuming that the temperature of the black coating is at 400C, the highest working temperature of the hot oil used in the receiver, and that of the environment at 21C. The results show that the losses from the four receivers on a dish would be almost 23 kW or about 38% of the total energy incident on the receiver, resulting in a receiver efficiency of 62%.

108. For comparison, I calculated the actual thermal losses from a standard parabolic trough receiver using the results of a peer-reviewed paper. Burkholder and Kutscher[43] measure the thermal losses from a Schott PTR Receiver tube, which is similar to the tubular receiver described by Mr. Johnson in paragraph 105, at a temperature of 400C. I calculate the Schott PTR receiver's efficiency at 96%. These calculations are shown in Appendix III.

109. The limited information provided on the receiver design of Figure 5(c) and the tube he showed during the April 4, 2017 tour does not explain the purpose of the molten salt on the inside of the receiver, and I do not understand it. It may provide a small amount of thermal storage but could also create some significant problems.

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[40] Attachment 15, available on the enclosed disc, Site Tour Video Clip 3 10:30:24 through 10:31:50.
[41] Attachment 15, available on the enclosed disc, Site Tour Video Clip 3 10:30:24 through 10:31:50.
[42] Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 161:16 – 163:3
[43] Heat Loss Testing of Schott's 2008 PTR70 Parabolic Trough Receiver F. Burkholder and C. Kutscher, National Renewable Energy Laboratory, Technical Report NREL/TP-550-45633, May 2009

110. I am not aware of molten salt ever being used with copper piping. Parabolic trough systems use a stainless steel piping in the receivers and carbon steel piping when transporting hot oil at 400 C. At higher temperatures, nickel alloys are the most common metals used in molten salt systems. Also, molten salt will expand and contract as it melts and freezes at 220 C. I saw no indication in the materials I reviewed that Mr. Johnson has considered materials compatibility for molten salt and copper or the molten salt expansion-freezing issue and the stresses it will put on the piping.

111. In paragraph 91, I discussed the mismatch between the size of the receiver aperture for the receiver of Figure 5(c) and the size of the solar image. In fact, even though the receiver aperture is too small for the solar image created by each of the circular lens assemblies on the IAS dish, it is far too large in actual area. This results in excessive thermal losses.

112. In my opinion, this is one example of how the designs of the components of the IAS Solar Dish Technology appear to have been done independently and without consideration of the requirements of the system as a whole. In the absence of an interface specification document to define the respective design parameters for different components, there is no clarity on how the component parts of the system should/will work together.

113. During my site visits on January 24 and April 4, 2017, I did not see the receiver in Figure 5(c) in operation in any system, or in operation with any other component of IAS Solar Dish Technology.

114. There is no indication, in any of the materials I reviewed, that the receiver in Figure 5(c) has ever actually been used in any system, or with any other component of the IAS Solar Dish Technology.

115. During my site visits on January 24 and April 4, 2017, I did not see any IAS receiver in operation either in testing or in operation in any system, or with any other component of IAS Solar Dish Technology at the Manufacturing Facility, at the R&D Site or at the Construction Site.

116. Based on the lack of design, engineering analysis, and performance test data for the receiver, and my observations on the site visits, it is my opinion that the IAS solar receiver design is at Stage 1: Research Phase of the Engineering design process of Table 3.

4.6. The Collector Working Fluid

117. In the information that I reviewed, different working fluids have been identified as options to collect the heat from the solar collector field. In Attachment 2, water is initially identified as the working fluid and stated incorrectly to be liquid at 1100 F, as discussed in paragraph 99. The system schematic diagram of Figure 2, above, identifies the collector working fluid as molten salt. But then, during my visit to the R&D Site on April 4, 2017, I was informed by

Mr. Johnson that he would replace the molten-salt working fluid with synthetic oil.[44] This was confirmed in Mr. Johnson's deposition.[45]

118. Each of these choices of the collector working fluid has a major impact on the design of the receiver, heat transfer piping, and boiler heat exchanger. None of these "options" can be considered independently of the system design as a whole and each directly affect the designs of all of the components.

119. In the materials I reviewed, there is no analysis, no design details, no engineering drawings, no test data or performance data regarding the collector working fluid.

120. Changing the collector working fluid completely alters the design specifications for the other system components, including the receiver, pumps, piping, heat exchangers, and boiler. Because different collector working fluids have different properties and different temperature ranges of operation, component designs for one working fluid will not work for a different one.

121. First, considering water/steam as the collector working fluid, as initially claimed in Attachment 2, the collector working fluid is not liquid water as stated but superheated steam vapor at 1100 F (590 C) and a pressure of more than 3200 pounds per square inch (psi) (230 kg/cm^2). As demonstrated in the LaJet and Shenandoah projects, steam ducts would be required to transport high temperature, high pressure steam around the collector field resulting in high thermal losses that severely penalize the performance of the technology.

122. Second, the system design drawing in Attachment 2 (Figure 2 above) clearly identifies the collector working fluid as molten salt. The significance of using molten salt (a 60:40 mixture of sodium/potassium nitrates) as the working fluid is that it provides a potentially high temperature of operation ~565 C (1050 F) and the means for storing thermal energy. The drawback of using molten salt as the working fluid is that it freezes at 220 C (431F) and is corrosive when in contact with common metals, especially at higher temperatures.

123. The design of Attachment 2 (Figure 2) contains a single molten salt storage tank which cannot operate because the addition of hot salt to cold salt would substantially compromise thermal storage by diluting the fluids and reducing the mixture temperature. All molten salt storage systems in commercial operation today use a two-tank system comprising separate hot and cold tanks. Hot molten salt from the collector field is typically collected in the hot tank for use in the boiler at night or when the sun is not available to generate steam for the turbine. The cold salt is then put into the cold tank which supplies cold salt to the collector field to be heated and either used directly in the boiler or stored for later use in the hot tank.

[44] Attachment 15, available on the enclosed disc.
[45] Attachment 1, Deposition of Neldon Johnson, June 28, 2017, 161:16 – 163:3

TRMancini Solar Consulting

124. Because the molten salt freezes at relatively high temperatures (220 C), it is normally used in a configuration that requires only short runs of piping that must be heat traced (i.e., the pipes must have their own independent electrical heating) at all times. If molten salt freezes in a pipe, it is a long, difficult process to thaw it out and reestablish salt flow. Therefore, it would not be recommended to use molten salt as the working fluid in piping systems described in Attachment 2 (Figure 2).

125. During my visit to the R&D Site on April 4, 2017, I was informed by Mr. Johnson that he would replace the molten-salt collector working fluid with synthetic oil.[46] This would have a significant impact on the design and potential performance of the IAS Solar Dish Technology because oil has a lower working temperature than molten salt. Using oil reduces the maximum Rankine cycle operating temperature from about 1000 F (550 C) to ~ 750 F (400 C) because the oil degrades at and above 400 C.

126. There are no piping diagrams for the distribution and routing of any of the collector working fluids identified in Attachment 2 through the solar field or through the power block. But, the type of piping layout required would be similar to the ones used in parabolic trough systems that also use synthetic oil working fluid at temperatures near 750 F (400 C) and supply and return piping headers for the collector field.

127. One of the operational issues associated with the trough systems has been oil leaks at the flexible connections, high-temperature flex hoses and/or rotating joints, that are required between the fixed headers and the rotating collectors. Parabolic trough systems have ~32 flex-hose-type connections per MW of installed power. I estimate that a system using IAS Solar Dish Technology will have more than 500 connections per MW of installed capacity. When visiting the R&D Site, I observed what appeared to be metal-reinforced tubing similar to what would be obtained at a hardware store for washing machine hoses dangling from the solar collectors. As these hoses may be intended to transport the hot oil, it is my opinion that they are not adequate or appropriate for this application because they will not be able to operate at the required 400 C (750 F) temperatures.

128. Operation and maintenance of flexible connections in the field represents a significant O&M issue for parabolic trough plants. Due to the significantly larger number of hoses required, it is my opinion that this will be an even greater challenge for any system that uses IAS Solar Dish Technology, i.e., increasing thermal losses and operation and maintenance costs.

129. In the information that I have reviewed, there is no indication that anyone has accounted for or is even aware of the potential issues associated with the design and operation of the flexible connections in the collector field of the proposed IAS Solar Dish Plant.

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[46] Attachment 15, available on the enclosed disc; Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 161:16 – 163:3.

130. The decision of which collector working fluid to use has a direct impact on the operating conditions of the system's power cycle, as I will describe below in the "Turbine Design" section.

131. During my site visits on January 24 and April 4, 2017, I did not see the IAS Solar Dish Technology working with any collector working fluid.

132. Based on the information and materials I have reviewed, I understand that Mr. Johnson just recently decided to us a synthetic oil as the collector working fluid with the IAS Solar Dish Technology. Because the choice of working fluid is critical to the design and construction of system components and component interface requirements, it is my opinion that the entire IAS Solar Dish System is at Stage 1: Research Phase of the Engineering design process of Table 3.

4.7. The Bladeless Turbine

133. The IAS bladeless turbine is shown disassembled in Figure 6.[47] There is a film clip movie of it running without back pressure or load from the RaPower3 Website[48].

Figure 6 IAS Turbine

134. There are no engineering analyses, no engineering drawings, and no short-term or long-term test results and no performance data for the turbine in the materials I reviewed.

135. Attachment 2 asserts that the collector heat transfer fluid will be water/steam.[49] Assuming that water/steam is the collector heat transfer fluid, Attachment 2 also claims that the turbine requires no heat exchangers (neither a boiler nor a condenser) because the same water/steam would also be the cycle working fluid. Mr. Johnson maintains that he can use the water heated in the collector field as the cycle working fluid directly in the turbine and forego the need for a boiler or a condenser.

136. Further, in Mr. Johnson's proposed configuration, he maintains that the turbine housing will be the condenser. But there is not sufficient heat transfer area in the turbine housing alone to provide the required conditions for stable operation of the turbine. The condenser serves the power cycle by removing the heat of condensation and by maintaining back pressure on the turbine for high Rankine cycle efficiencies.

[47] Attachment 16, Photograph taken by author January 24, 2017.
[48] Attachment 17, available on the enclosed disc, Video Clip from RaPower3 Website: SolarTech04.
[49] Attachment 2 at page 9.

137. If the system is operated without a boiler, the water from the collector field would have to be continuously treated or it would deposit minerals on the turbine and piping in the system. Mineral deposits or other impurities in the water will degrade performance of any component and can ultimately lead to system break-down. I saw no indication in the materials I reviewed that anyone has evaluated this concern.

138. None of these claims is supported by analysis, test data, or reference in the documents and information I reviewed.

139. Mr. Johnson has also claimed that molten salt is the collector heat transfer fluid. If molten salt is used as the collector working fluid, then both boiler and condenser heat exchangers are required to maintain separation between the molten salt and the steam in the Rankine cycle and support high efficiency of the power block. The use of molten salt also requires a specially designed boiler made of nickel alloys to produce steam supply for the turbine.

140. If synthetic oil is used as the collector working fluid, similar to the molten salt, the system requires both boiler and condenser heat exchangers for the same reasons.

141. In Attachment 3, Sierra Engineering Inc. is identified as the designer performing the parametric sizing and performance of the bladeless steam turbine.[50] The document also names other unidentified, "third party" reviewers of the turbine design and other components of the IAS Solar Dish Technology.[51] Reports from Sierra Engineering and other reviewers were not in the materials I reviewed. I am not able to determine what parts, if any, of Attachment 3 contain the actual evaluations of these reviewers or if the contents were modified by someone other than the reviewers.

142. Information purportedly from Sierra Engineering Inc. lists the baseline 1 MW turbine design as having inlet conditions of 3200 psia steam at a temperature of 1000 F.[52] Because I have no engineering information of any kind for the turbine, I cannot confirm that their recommendations, as listed in the document, have been incorporated in the final design.

143. The turbine analysis and design purportedly from Sierra Engineering Inc. appears to be very complete in that it includes thermodynamics, fluid flow, and structural analysis models. The assumptions for the models are listed and seem reasonable.[53]

144. Attachment 3 states "It is important to note that the minimum steam inlet temperature is above 760 F; at lower temperatures the nozzle exhaust velocity will not be sonic."[54] This means that the purported Sierra Engineering Inc. turbine design is for the system with inlet steam conditions listed above, i.e., 3200 psia and 1000 F. These inlet steam conditions can

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[50] Attachment 3 at US001871.
[51] Attachment 3 at US001870.
[52] Attachment 3 at US001872.
[53] Attachment 3 at US001871-86.
[54] Attachment 3 at US001878.

only potentially be achieved if the collector working fluid is superheated steam or molten salt.

145. However, if the IAS Solar Dish Technology utilizes synthetic oil, then the collector working fluid has a maximum temperature of only 400 C (750 F). This limits the maximum system steam operating temperature of any system proposing to use the IAS Solar Dish Technology to less than 400 C (750 F) temperature because of heat transport and boiler heat exchanger losses. In other words, according to the analysis presented in Attachment 3, the turbine as designed will not work with synthetic oil as the collector working fluid.

146. Also noted in Attachment 3, purportedly by the Sierra engineers; "Turbine specific power (Shaft Power/Mass Flow) improves with increasing steam inlet temperature. This should result in the increased overall cycle efficiency, as reduced flow rates will also reduce pump power. Thus the figure of merit should be turbine specific power and not turbine component efficiency."[55] The important point here is that the Rankine cycle efficiency determines how much power is provided to the power grid, not the turbine efficiency alone. In the materials I reviewed, it appears that IAS erroneously used turbine efficiency (rather than Rankine cycle efficiency) to calculate system efficiency.[56]

147. During my site visits on January 24 and April 4, 2017, I did not see the IAS turbine in operation. I saw the same disassembled turbine in the same location at the Manufacturing Facility on both of my visits. I did not see any turbine parts being manufactured at the Manufacturing Facility. Also, I saw no turbines at the IAS R&D Site or at the RaPower3 Construction Site.

148. According to Attachment 5, the turbine was designed and developed from 2001 – 2004 and underwent "long-term testing" from 2006 through 2010, and a proof-of-concept test in 2004. Because the turbine is such an important part of the IAS Solar Dish Technology, it is difficult to understand why it has not been further developed since 2010. Based on the materials I reviewed, it appears that the IAS Turbine has not had any long-term operation and that its actual performance in any system using IAS Solar Dish Technology (or in any other system) has never been documented.

149. It is my opinion that the turbine design is at Stage 1: Research Phase of the Engineering design process of Table 3.

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[55] Attachment 3 at US001878.
[56] Attachment 3 at US001887.

4.8. The Balance-of-Plant Components

150. There are other parts of a solar dish technology that are required to operate a system. I've called these balance-of-plant components and I will discuss some of the more important ones briefly below.

151. There are no engineering analyses, no engineering drawings, and no short-term or long-term test results or performance data in the information I reviewed for any of the balance-of-plant components discussed below.

152. Each of the components and operations within the plant require controls. In fact, the only controller that I saw during my site visits was a tracking controller at the IAS R&D Site that purportedly was providing azimuth and elevation control for a dish. I have no way of knowing whether or not this controller can operate as intended because the dish was not tracking the sun. Also, there is no information or test data in any of the materials I reviewed for this controller.

153. Temperature, pressure and flowrate sensors are required to track conditions throughout any system that might use IAS Solar Dish Technology. These measurements are used to control the flowrate of the collector working fluid, monitor the operation of the boiler and condenser heat exchangers, the receivers, and, most importantly, the turbine. In some cases, individual components, like the concentrators and turbine, will have dedicated control systems that will interact with and report data to a system controller. The system controller is a computer with multiple displays monitoring and showing the conditions throughout the plant and providing alarms when component or system operation falls outside of normal operating parameters.

154. Also, I was surprised that there were no solar pyranometers at the IAS R&D Site. Total and direct-normal pyranometers are used to measure the total and direct-normal components of the incident sunlight. This measurement is required for testing and during operation to determine when and how the plant is operated. I have never been at a solar test facility that did not have at least one, if not several, total and direct-normal pyranometers.

155. A solar plant will also have an operations manual that describes the different modes of operation of the plant including but not limited to start up, shut down, low solar radiation operation, normal operation and emergency shutdown. Each of these modes of operation include a series of steps that must be followed in order to protect the equipment.

156. In the materials I reviewed and during my two visits, I saw no information on instrumentation and controls, including hardware, software, or even a document describing the control/operational methodology for a system that might use IAS Solar Dish Technology.

157. Any solar energy generation plant requires a generator. The generator is directly coupled to the turbine and generates the electricity that is put on the grid. The system design of Figure 2 is a unit of 25 dishes and a 1 MW turbine design. Therefore, the generator must be matched with the turbine and provide 1 MW capacity. In the materials I reviewed, I did not see information describing specifications for any generator, let alone a 1 MW (1,000 kW) one.

158. In fact during my two site visits, I saw only two small 7.5 kW motor/generators. One, at the Manufacturing Facility and a second one at the IAS R&D Site. A 7.5 kW generator does not match the other components proposed for the IAS Solar Dish Technology. As noted in the previous paragraph, the proposed turbine is supposed to accommodate the output of 25 dishes at a scale of 1 MW. A 7.5 kW generator would be much too small for a single dish even if IAS proposed using a small turbine, which they are not.

159. There is no information in the materials I reviewed about either an on-site generator, or any other generator that has been used or proposed to be used with the IAS Solar Dish Technology.

160. Heat exchangers are used to transfer heat from a hot fluid to a colder one, typically without allowing them to mix. This requires large surface areas with minimal resistance to heat transfer and sufficient structural integrity to maintain the separation of the two fluid streams. The two fluids often have significantly different temperatures and densities, for example hot oil and superheated steam. Heat exchangers are well developed technology used in power plants and other industrial applications. In any system that would use IAS Solar Dish Technology, heat exchangers are required for the boiler and condenser of the Rankine cycle.

161. Attachment 2 contains a brief description of a tubeless heat exchanger that Mr. Johnson says he has designed.[57] During my visit to the Manufacturing Facility on January 24, 2017, I asked Mr. Johnson to describe how his new, tubeless heat exchanger design worked. Mr. Johnson could not or would not explain it to me. Apart from the brief description in Attachment 2, there is no information in any of the materials I reviewed on this or any other heat exchangers.

162. Based on Figure 2, I calculate that (if they worked as proposed) each unit of an IAS Solar system comprised of 25 dishes, 100 receivers, and a Rankine cycle power block and using IAS' bladeless turbine would produce 1 MW of electrical power. Mr. Shepard also claimed that there were 200 structures started at the Construction Site.[58] I do not believe that the proposed IAS Solar Dish Technology can or will perform as claimed. However, if

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[57] Attachment 2 at page 12.

[58] Deposition of R. Gregory Shepard, May 22, 2017, Attachment 9 at 156:25-157:19.

these assertions were the case, then the IAS must believe that "plant" at the Construction site will produce 8 MW.

163. If any solar plant is transferring 8 MW of power to the grid, it must be connected through a substation. If a nearby substation with sufficient excess capacity is not available, the solar plant would have to build their own substation as part of the project.

164. When asked about the grid connection during both of my visits, Mr. Johnson pointed to a power pole and said that was where they were going to connect to the grid.[59] But a transmission line is insufficient for a solar power plant producing 8 MW of power for the grid.

165. I saw no substation on my visits to the IAS R&D Site, the RaPower3 Construction Site, or the Manufacturing Facility. I have seen no information in materials I reviewed indicating that this issue has been given serious consideration.

166. If they have been considered at all, it is my opinion that the balance-of-plant components described in this section are at best at Stage 1: Research Phase of the Engineering design process of Table 3.

4.9. Comparison of IAS Solar Dish Technology Projected Performance

167. As I have shown, the IAS Solar Dish Technology is not actually a "system." The various component parts of the Technology are not designed to work together, and do not work together. Nonetheless, in Attachment 3, Mr. Johnson presents a "waterfall chart"[60] showing his numbers for the performance of each of the components of the IAS Solar Dish Technology. A waterfall chart shows the efficiency of a system as the energy flows sequentially through the components from the collector through the generator resulting in a prediction of the overall system performance in the form of solar-to-electric conversion efficiency. I've reproduced Mr. Johnson's numbers in Table 5 along with the results of my calculations shown in Appendix III. Note: the IAS column of Table 5 is from Attachment 3 and is identical to the same table as reported in the more recent version of the document.[61]

168. Two of the elements in Table 5 are for "transient effects due to cloud cover" and "power plant availability". Numbers for these two elements are only available once the plant is in operation, which the IAS Solar Dish Technology has not been. So it is not possible for me to even estimate what these parameters should be. However, I do note that the power plant availability of 96% would represent an excellent, mature coal-fired power plant and I do not

[59] Attachment 13, available on the enclosed disc, Video 18_4_09-4_25.
[60] Attachment 3 at US-001887.
[61] Attachment 4 at Ra3 023592.

believe this is appropriate for any solar technology. Because I do not have actual performance data, I have used Mr. Johnson's numbers for these two variables.

169. Another parameter listed in Table 5 is the "Electrical Loss Efficiency" of 0.86.[62] Attachment 3 identifies "Electrical Loss Efficiency" as a "parasitic load more compatible to the solar tower and dish due to piping configuration."[63] This is not a term that is known to me and I am not sure what he is trying to represent. There is no discussion or explanation of this term in either Attachment 3 or Attachment 4, nor does there appear to be any technical, engineering basis for this value. Consequently, I will also use Mr. Johnson's value for this parameter.

170. IAS values shown in Table 5 assume that all component parts work together to receive solar radiation and convert it to electricity (which they do not do).

Table 5 Estimated Waterfall Efficiency of a System Using IAS Solar Dish Technology

System Parameter	IAS	My Analysis	Comments
Solar Collector Efficiency	0.838	0.425	There are issues with the size of the image from the concentrator likely due to inaccurate lens manufacture and/or the structure being too flexible.
Transient Effects	0.920	0.920	There is no data to support this, and I cannot estimate this, so I used Mr. Johnson's value for this parameter.
Receiver Thermal Efficiency	0.900	0.618	Mr. Johnson's estimate and my calculation.
Piping Losses	0.961	0.850	Due to the larger numbers of connections, piping losses for this system will be greater than a parabolic trough system. Engr. Est.
Electrical Loss Efficiency	0.860	0.860	There is no data to support this, and I cannot estimate this so I used Mr. Johnson's value for this parameter.
Rankine Cycle Efficiency	0.435	0.290	Mr. Johnson uses a turbine efficiency, that doesn't apply to the design, and he also uses the turbine efficiency in place of the Rankine cycle efficiency. I've used the correct parameter -- Rankine cycle efficiency based on the proposed working temperature - 400 C
Power Plant Availability	0.960	0.960	This is representative of a mature, well developed coal-fired power plant.
Generator Efficiency	0.960	0.960	Reasonable assumption
Solar-To-Electric Conversion Efficiency	0.239	0.047	

62 Attachment 3 at US001887, Attachment 4 at Ra3 023592.
63 Attachment 3 at US001889.

171. The comparison listed in Table 5 highlights three of the major technical issues identified in previous sections of the report; i.e.,

a) the large solar images cast by the circular Fresnel lenses, resulting from inaccurate manufacture of the lens tooling, poor alignment of the lenses within the lens assembly, and/or inaccurate determination of the focal plane and low receiver intercept;

b) the poor thermal efficiency of the receiver because of the design which locates the black surface on the inside of the glass tubes; and

c) IAS does not understand the basic engineering principles of power production of the Rankine cycle and the actual performance of their bladeless turbine.

172. Based on my analysis, the system would convert just 6.6 kW of the 141 kW of solar energy incident on the four circular Fresnel lens concentrators into electricity, resulting in the listed solar-to-electric efficiency of 4.7 %.

173. All of the components of the IAS Solar Dish Technology are at Stage 1 of the engineering technology development process. The components have been "designed" as stand-alone devices without consideration of how they would be incorporated into a system. Consequently, there is no actual "system" at this time.

174. There is no consideration of systems engineering in what are purported to be the "designs" of the various components presented in Attachments 2, 3, or 4. In my opinion, any system that proposes to use IAS Solar Dish Technology is (at best) at Stage 1: Research Stage of the Engineering design process of Table 3.

175. Mr. Johnson testified that he has produced electricity using the IAS Solar Dish Technology. Because of the inherent flaws in this technology and because I saw no corroborating records or data of the purported production of electricity, his testimony does not alter my conclusion about the status of the Technology.

Conclusion 1: Status of the IAS Solar Dish Technology

The IAS Solar Dish Technology is in the research Stage 1 of development. The "Technology" comprises separate component parts that do not work together in an operational solar energy system. The IAS Solar Dish Technology does not produce electricity or other useable energy from the sun.

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5. COMMERCIALIZATION POTENTIAL OF THE IAS SOLAR DISH TECHNOLOGY

176. All of the materials I have reviewed indicate that the IAS Solar Dish Technology is at Stage 1 of the Engineering Process. It is my opinion that it will never be commercially viable technology.

177. The three primary reasons that the technology will not be commercialized are

a) The lack of an operational system that uses IAS Solar Dish Technology and significant progress toward developing a system after more than a decade of purported development.

b) IAS does not have the capability or the resources to develop a solar dish power system or a commercial, utility-scale solar project.

c) The concept of a central engine solar dish project based on Fresnel lens technology and a self-developed turbine has fundamental flaws that make it economically, if not technically, infeasible.

178. I will discuss these issues in the context of the technical and development issues.

179. Based on the representation of the status of the technology I saw in my review of the materials and documents and my visits to the IAS R&D Site, I expected to see multiple dishes operating, producing power, and supplying power to the utility grid.[64] I expected to see several dishes with receivers collecting solar energy and transporting it in the form of hot molten salt through pipes to a heat exchanger. In the heat exchanger, the hot salt would boil water to steam to power the turbine generator in a standard Rankine cycle. What I saw at the site was entirely different.

180. Overall, the IAS R&D Site was dirty and disorganized, comprising 17 dishes and three equipment trailers. None of the dishes was fully functional during either of my visits.[65] Lens facets were broken and missing[66] with plastic strewn on the ground and old receivers were broken and lying on the ground as well. One of the trailers housed what we were told was a heat exchanger[67] and the other two trailers contained equipment in varying stages of assembly. Electrical wires were lying on the floors of the trailers in pools of water. Overall the site had the appearance of not having been recently used for any test activity and certainly not to generate electricity.

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[64] For example, the IAUS Research and Development Timeline in Attachment 5 claims that the solar towers were "Commercial-Ready" as of 2014 – 2015.

[65] For example, Attachment 13, Video 12_4_00-4_23, shows the towers on the R&D Site. If these dishes were tracking the sun, they would be in alignment. The different angles of each dish show that they are not tracking the sun. Further, on a number of the towers, there is no receiver installed to capture any concentrated solar radiation.

[66] Attachment 13, available on the enclosed disc, Video 12_4_00-4_23 and Video 12_4_38-5_15.

[67] Attachment 13, available on the enclosed disc, Video 16_1_38-1_59; Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 89:25-91:1.

181. I saw no turbines, receivers, or piping for heat transfer fluid at the R&D Site. I also saw no test equipment for measuring the optical performance of the solar dishes, the heat transfer in the receivers, or the power generation. It is not clear that either a turbine or molten salt have ever been tested at the site. The only "operation" I saw during either visit was the burning of a piece of wood using one of the solar concentrators that had only partial, broken lenses installed.[68]

182. I asked to see the grid connection and was taken to a junction box on the back side of the generator trailer and where the power comes onto the site.[69] Mr. Johnson said that he puts power onto the line at this connection. The R&D Site was in the same degraded condition during both of my visits.

183. To perform the testing of the IAS Solar Dish Technology components and any proposed system that would use it, I estimate that it would require a Test Team of at least 3 to 5 engineers and 7 to 10 technicians.

184. According to the materials I have reviewed, Mr. Johnson appears to be the only "designer" of the system and its components. But his claims about the IAS Solar Dish Technology and the documents that I've reviewed indicate to me that he lacks an understanding of fundamental physics, i.e., thermodynamics, heat transfer and fluid mechanics.

185. There were 5 or 6 workers present at the R&D Site during both of my visits. At least some of them appeared to be the same workers who were present at the Manufacturing Facility. I have no names or resumes for these workers, so I cannot evaluate their technical abilities or competence to test or operate solar energy technology.

186. The requisite test equipment, calorimeters, thermocouples, total and direct-normal solar pyranometers, flow meters, strain gages, and data acquisition equipment was not visible to me or in use at the Manufacturing Facility, the R&D Site or the Construction Site.

187. For all of these reasons, staffing and basic resources at all three locations is inadequate to support the work that IAS claim they are doing.

188. Although, in my opinion, the IAS Solar Dish Technology is at Stage 1 of the Engineering Process, Mr. Johnson and others have started fabricating some concentrator structural parts, stockpiling them at the Manufacturing Facility, and erecting structures at the RaPower3 Construction Site.[70]

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[68] Attachment 13, available on the enclosed disc, Video 16_12_24-12_41.

[69] Attachment 13, available on the enclosed disc, Video 16_8_32-8_57; Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 95:18-96:20.

[70] Deposition of Neldon Johnson, June 28, 2017, Attachment 1 at 52:20-24, 86:22-25.

189. In my opinion, it is premature to build component parts when, as I showed above, there is no system that uses the IAS Solar Dish Technology to produce electricity.

190. Based on the IAS' representation of the status of their Solar Dish Technology in the materials I reviewed, I expected to visit a manufacturing facility similar to other commercial solar manufacturing plants that I have previously toured. I anticipated seeing a professionally organized and operated plant that would be clean, organized, and in full operational mode. The facility would have separate production lines to manufacture collector components, solar receivers, turbines, heat exchangers, concentrators, and system controllers, with individual component quality control. There would be subassembly stations for the components including quality control and functional/operational tests to assure compliance within pre-specified operational parameters defined for each subassembly by a System Component Interface Document. Last, I would expect to see holding areas with numbers of subassemblies, collector facets and assemblies, receivers, turbine-generator assemblies, heat exchangers, control systems, etc. ready for shipping to the site for installation.

191. But the IAS/RaPower3 Manufacturing Facility was dirty and cluttered, much like a farm shop, and there was very little activity during either of my two visits. The only ongoing work on both of my visits was the fabrication of limited numbers of structural concentrator parts and lens facets.

192. During both of my visits to the IAS/RaPower3 Manufacturing Facility, there were insufficient numbers of workers, only between six and ten people, to support the fabrication of all of the equipment required for a system that would use IAS Solar Dish Technology. I estimate that a manufacturing facility to meet the scope of production described by the IAS would require at least 50 to 100 workers of which at least 10 would be manufacturing engineers.

193. There also did not appear to be sufficient manufacturing equipment of the types or numbers needed to produce the components in the quantities required for the hundreds or thousands of components that the purported system requires.

194. While there were a number of bins with some of the solar concentrator parts and two stations for assembling optical facets, there were only two or three people assembling facets during my visits. There was no quality control activity or subassembly testing to qualify performance.

195. There were no assembly lines for the manufacture of receivers, turbines, heat exchangers, or concentrator and system controllers; i.e., there was no equipment, parts, manufacturing activity for any of these components. In fact, I saw only one disassembled

turbine, one receiver, and one or two small generators (insufficient for even one concentrator) and all were at the same location in the shop during both of my tours.

196. I saw no quality control or test equipment for verifying/evaluating the specifications or performance of the parts and components, i.e., the optical facets, the thermal receivers, the turbines, etc.

197. The disheveled condition of the IAS/RaPower3 Manufacturing Facility and the IAS R&D Site indicate a disorganized, low-cost operation that does not support the level of development and commitment as represented by IAS/RaPower3.

198. In my opinion, it is premature to start construction of a system using component parts when the component parts have not been validated and an assembled system has not been demonstrated through actual operation. But, I visited the RaPower3 Construction Site where assembly of some structural concentrator parts has started.

199. The RaPower3 Construction Site had a number of collector structural units lying on the ground along with a pile of pedestal piping. We were told that there were a total of 200 concentrator structures installed at the RaPower3 Construction Site. What I saw was the structural piping assembled to support the solar concentrators. Also, some solar lens support structures were stacked at one location on the site.[71] I did not see any towers with lens assemblies installed at the top during either of my visits.

200. It should be noted that I saw no heat transfer piping, no receivers, no turbines, no controls or other components installed or stockpiled at the RaPower3 Construction Site. The steel piping in storage at the site and installed as collector supports is rusted. Because rusting components will tend to flake and jam mechanical parts and quickly lose tolerance, a commercial operation would have either sand blasted and galvanized or painted the structural elements of the solar concentrators.

201. There was very little activity at the RaPower3 Construction Site during both of my visits. About 5 technicians were moving materials around and some of them were the same technicians present at the Manufacturing Facility and the IAS R&D Site. I estimate that a team of 2 engineers and 10 to 15 technicians would be required to install a 1 MW system comprised of a single unit using IAS Solar Dish Technology.

202. Last, there is no evidence that the IAS Solar Dish Development Project has a Project Development Team. The development of a utility-scale solar power project is a unique and specialized commercial activity that requires highly-knowledgeable personnel familiar with local, state, and federal energy requirements and regulations. I estimate that a Project

[71] The stack of lenses, with dish assemblies visible behind it, appears in Attachment 13, available on the enclosed disc, Video 10_0_47-0_57. A wider view of the dish assemblies on the Construction site appears in Attachment 13, available on the enclosed disc, Video 11_0_06-0_38.

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Development Team would require at least 3 to 5 full-time people who would likely engage outside consultants to prepare the required legal, environmental, and regulatory compliance documentation. In the materials I have reviewed, I have not seen any indication that a Project Development Team or anyone with utility-scale project development experience is working on this project.

203. Mr. Johnson said that he is the Engineering Procurement Contractor (EPC) and will provide all of the Operation and Maintenance (O&M) at the RaPower3 Construction Site. Note: An Engineering Procurement and Construction contractor is responsible for all the activities from detailed plant design, procurement of equipment, construction, initial operation and commissioning of the plant prior to handover of the project to the owner. In the materials I have reviewed, I have not seen any indication that Mr. Johnson, or anyone else affiliated with the IAS Solar Dish Technology, has either the experience or the resources to support any of these activities.

204. In the materials I have reviewed, there is no indication that any person or entity has agreed to pay for any electricity or other energy produced by IAS Solar Dish Technology.

205. In my opinion, the staffing and equipment at the Manufacturing Facility, IAS R&D Site, and the RaPower3 Construction Site are inadequate to support the commercialization of the technology.

206. Also, as I have previously discussed, there are no dish/engine systems in commercial operation today anywhere in the world. In my opinion the concept of a central engine solar dish project has fundamental flaws that make it much less likely to be commercialized than the more conventional dish/Stirling system with the engine and generator mounted on each dish.

207. The IAS Solar Dish Technology, which is based on Fresnel lens technology and a self-developed turbine, is not technically viable and very likely not economically competitive.

208. My experience with Stage 1 solar system designs, such as this one, is that at the beginning of development all problems are small and solvable and it is only when the developer gets to Stages 3 and 4 prototype and demonstration that the real performance and cost issues become apparent.

209. Because of the fundamental flaws in the components of the IAS Solar Dish Technology, the lack of engineering capability, staffing, and resources supporting this project, and the fact that, after more than a decade of work, the IAS Solar Dish Technology is still at Stage 1 of engineering development, it is my opinion that there will never be a commercially viable system that uses the Technology.

Conclusion 2: Commercialization Potential of the IAS Solar Dish Technology

The IAS Solar Dish Technology is not now nor will it ever be a commercial-grade dish solar system converting sunlight into electrical power or other useful energy.

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APPENDIX I RESUME OF DR. THOMAS R. MANCINI
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December 2016

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Professional Experience:

August 2011 to present

TRMancini Solar Consulting draws on more than 35 years of experience with solar thermal technology and policy development to provide consultation on Concentrating Solar Power (CSP, aka solar thermal electric technologies) technology development, energy policy, and project development in the U.S. and internationally.

January 1985 to July 2011

Sandia National Laboratories, Albuquerque, NM, Program Manager, Distinguished Member of the Technical Staff (DMTS), and Senior Member of the Technical Staff (SMTS)

March 2002 to July 2011: CSP Program Manager at Sandia National Laboratory (SNL) responsible for budget, technology development planning, staffing, and program execution. This involved working with the U. S. Department of Energy CSP Program and the National Renewable Energy Laboratory during a time of Program growth and expansion by industry into the renewable market place. During this time, the DOE budget increased from a close-out budget of $6m to more than $50M annually for the CSP Program.

March 2004 to February 2011: Chair of the International Energy Agency's (IEA) Solar Power and Chemical Energy Systems (SolarPACES) Working Group. SolarPACES is the international group dedicated to the development and deployment of CSP technology worldwide. During this time, the membership of the group grew from about 10 to 18 countries and it reached out to industry involving its first industrial member.

March 1999 to December 2001: Program Manager Biomass Power, SNL, responsible for budget, technology development planning, staffing, and program execution. Started the DOE Small Biopower Program and implemented technical rigor in the evaluation of biomass power systems.

January 1995 to July 1999: DMTS, SNL, Task leader for Dish-Engine Development and Project manager for a large cost-shared program with industry to develop a commercial dish/Stirling power generator. Activities involved working with DOE Program Managers in Washington, D. C., staff members at the National Renewable Energy Laboratory, staff members at Sandia National Laboratories and industrial contractors.

Task Leader for solar market development activities in the International Energy Agency's Solar Power and Chemical Energy Systems (Solar PACES) program working with colleagues in Russia, Spain, Germany, and Israel.

Professional Experience (cont.):

January 1985 to December 1995: SMTS at SNL and Task Lead for Solar Concentrator Development; Manager of Innovative Concentrator Project, SKI Sheet-Metal Concentrator Project, Stretched-Membrane Dish Development Project, Sol-Gel Mirror Development Project, NASA SCAD Testing Feasibility Study, Faceted, and Stretched-Membrane Dish Development Project.

August 1975 to December 1985

Assistant, Associate and Full Professor of Mechanical Engineering, New Mexico State University, Las Cruces, New Mexico. Responsibilities included: teaching courses in thermodynamics, dynamics, heat transfer, fluid mechanics, honors technology and society, and solar energy; and conducting research in solar heating and cooling, and solar power systems. Advised and graduated 10 graduate students.

1984 to 1985: Full Professor of Mechanical Engineer, NMSU, Las Cruces, New Mexico.

1979 to 1984: Associate Professor of Mechanical Engineering, NMSU, Las Cruces, New Mexico.

1982 to 1984: Adjunct Associate Professor of Petroleum Engineering, New Mexico Institute of Mining and Technology, Socorro, New Mexico.

1975 to 1979: Assistant Professor of Mechanical Engineering, New Mexico State University, Las Cruces, New Mexico.

September 1969 to August 1975

1975: Research Associate in the Mechanical Engineering Department of Colorado State University, Fort Collins, Colorado. Responsible for the development of a numerical model of a solar, absorption air-conditioning system.

1974: Assistant Civil Engineer in the Civil Engineering Department of Colorado State University. Responsible for the collection and reduction of wind tunnel data for determining wind loads on buildings and other structures.

1973: Instructor in the Mechanical Engineering Department of Colorado State University. Taught Junior and Senior level Heat Transfer courses. 1969 to 1973: Graduate Research Assistant in the Mechanical Engineering Department of Colorado State University. Responsible for experimental research in double-diffusive natural convection.

Education: Doctor of Philosophy Degree in Mechanical Engineering from Colorado State University, June 1975

Master of Science Degree in Mechanical Engineering from Colorado State University, August 1970

Bachelor of Science Degree in Mechanical Engineering from Colorado State University, June 1969

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Professional Activities/ Awards:

2004 to 2011: Chair of the IEA Solar Power and Chemical Energy Systems (SolarPACES) Working Group

2002 ASME Solar Division Yellott Award

Chair ASME/COE Energy Committee 2000 – 2003

ASME Energy Committee, 1997 – 2004

1997 ASME Dedicated Service Award

Associate Editor for Solar Thermal Power of the ASME Journal of Solar Energy Engineering, 1995 - 2001

1994 Elected Fellow of the American Society of Mechanical Engineers

1991 Member of the ASME Energy Resources Board

1991 – 1992 ASME Solar Energy Division Chair

1986 – 1988 ASME SED, Chair of the Solar Thermal Committee

Organized more than 10 technical conferences for ASME, IEA, and other organizations.

Technical Publications:

More than 70 publications in the technical literature in such broad topic areas as passive solar cooling, active heating and cooling, and solar power generation.

The following is a list of Dr. Mancini's publications in the technical area of solar energy. The "*bold italic*" references are those related to concentrating solar technology.

Handbook of Clean Energy Systems, Volume I: Renewable Energy: Chapter XX: Introduction to Concentrating Solar Power Systems, T. R. Mancini, Handbook Editor: Jinyue Yan, Volume 1 Editors: Prof. Hong-xing Yang and Prof. Robert F. Boehm, Wiley, June 2015, ISBN: 978-1-118-38858-7.

Mancini, T. R., and P. Heller, et. al. "Dish-Stirling Systems: An Overview of Development and Status," JSEE 2002, Vol 125, No. 2, May 2003.

Stone, K. W., Mancini, T. R. et. al., "Performance of the SES/Boeing Dish Stirling System," ASME Solar Energy Conference, Washington D. C., April 2001.

Stone, K. W., Mancini, T. R. et. al., "SES/Boeing Dish Stirling System Operation," ASME Solar Energy Conference, Washington D. C., April 2001.

Mancini, T. R., "Solar Dish/Stirling Systems," invited, "keynote" lecture, European Stirling Conference, Osnabruck, Germany, February 1998.

Advances in Solar Energy, Chapter on Solar Thermal Power, publication of the American Solar Energy Society, Mancini, T. R., Kolb G. J., and Prairie, M. R., April 1997.

Mancini, T. R., "Solar Dish/Engine Systems," invited "keynote" lecture, 8th Symposium on Solar Electricity, Sede Boqer, Israel, November 1997.

Mancini, T. R., "Advances in Solar Concentrators,'" presented at the SOLTECH Conference, Palm Springs, California, March 1996.

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Mancini, T. R., "An Overview of Parabolic Dish Concentrator Development," Proceedings of the Fifth Task III Meeting, Solar PACES, Paul Scherrer Institute, Villigen, Switzerland, March 1995.

Proceedings of the 30th Intersociety Energy Conversion Engineering Conference, Orlando, FL, Editors D. Y. Goswami, L. D. Kannberg, T. R. Mancini, S. Somasundaram, ASME Publications, 1995.

Mancini, T. R., and Gallup D. R., "Comparative Analysis of Solar Thermal Power Generation: A User's Perspective," invited keynote presentation at the Comparative Analysis of Solar Power, Jerusalem, Israel, February, 1994.

Gallup, D. R., and T. R. Mancini, "The Utility-Scale Joint-Venture Program," Proceedings of the 29th IECEC Conference, Monterey, CA, August 1994.

Mancini, T. R., "The DOE Solar Thermal Electric Program," invited overview paper, Proceedings of the 29th IECEC Conference, Monterey, CA, August, 1994.

Mancini, T. R., J. M. Chavez, and G. J. Kolb, "The Promise and Progress of Solar Thermal Power," Mechanical Engineering Magazine, vol. 116, no. 8, August, 1994.

Mancini, T. R., "An Overview of Concentrators and Receivers for Solar Thermal Systems," invited keynote presentation at the 7th International Symposium on Solar Thermal Concentrating Technologies," Moscow, Russia, September 26-30, 1994.

Dudley, V. J., G. J. Kolb, A. R. Mahoney, T. R. Mancini, C. W. Matthews, M. Sloan, and D. Kearney, "SEGS LS-2 Solar Collector," SAND94-1884, Sandia National Laboratories Report, Albuquerque, NM, December 1994.

"Analysis and Design of Two Stretched-Membrane Parabolic Dish Concentrators," by T. R. Mancini Proceedings of the 1991 ASME-JSES-JSME International Solar Energy Conference, Reno, NV, March 17-22, 1991.

Alpert, D. J., Mancini, T. R., Houser, R. M., Grossman, J. W., Schissel, P. O., Carasso, M., Jorgensen, G., and Scheve, M., Solar Concentrator Development in the United States, Solar Energy Materials, pp. 307-319, Elsevier Science Publishers B. V., 1991.

Grossman, J.W., Mancini, T. R, Houser R. M., and Erdman, W. W., "Task 3 Report: On-Sun Test and Evaluation of the NASA STAR Facets," Report for the National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, June 1991.

Solar Engineering 1991, Editors T. R. Mancini, K. Watanabe, and D. E. Klett, Proceedings of the Second ASME-JSES-JSME International Solar Energy Conference, Reno, Nevada, March 17-22, 1991.

"Analysis and Design of Two Stretched-Membrane Parabolic Dish Concentrators," by T. R. Mancini, ASME Journal of Solar Energy Engineering, August 1991.

Alpert, D. J., Mancini, T. R., Houser, R. M., Grossman, J. W., Schissel, P. O., Carasso, M., Jorgensen, G., and Scheve, M., Solar Concentrator Development in the United States, presented at the 5th Symposium on Solar High-Temperature Technologies, Davos, Switzerland, August 1990.

Solar Energy in the 1990s, Editors T. R. Mancini and W. M. Worek, SED-Vol. 10, The

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American Society of Mechanical Engineers, November, 1990.

Holmes, J. T., Alpert, D. J., Mancini, T. R., Murphy, L. M., Schissel, P. O., Development of Concentrating Collectors for Solar Thermal Systems, Proceedings of the 24th Intersociety Energy Conversion Engineering Conference, vol. 6, pp. 1971-1978, Washington D. C., August 1989.

Mancini, T. R., Cameron, C. P., and Goldberg, V. R., NASA SCAD Concentrator Terrestrial Testing Feasibility Study, Report for the National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, September 1988.

Ratzel, A. C., Boughton, B. D., Mancini, T. R., and Diver, R. B., "CIRCE: A Computer Code for the Analysis of Point-Focus Concentrators," presented at the ASME-JSES Solar Energy Conference, Honolulu, Hawaii, March 1987.

Leonard, J. A., Diver, R. B., and Mancini, T. R., Proceedings of the Concentrating Solar Collector Workshop, SAND87-0131, Sandia National Laboratories, Albuquerque, New Mexico, June 1987.

Mancini, T. R., "The DOE Innovative Concentrator Project," Solar Engineering 1986, publication of the ASME Solar Energy Division, 1986.

Mancini, T. R., "Innovative Point-Focus Concentrator Projects," presented at the American Solar Energy Society Conference, Boulder, Colorado, June 1986.

Mancini, T. R., Performance Evaluation of the New Mexico State University Passive Solar House, Final Report submitted to the U. S. Department of Energy, San Francisco Operations Office, June 1983.

Mancini, T. R., "The Performance of a Roof-Pond Solar House: The New Mexico State University Experience," 8th Annual Passive Solar Conference, Glorieta, New Mexico, September 1983.

Mancini, T. R., "The New Mexico State University Passive Cooling Test Facility," Passive and Hybrid Cooling Workshop Manual, Solar Rising Conference, Philadelphia, Pennsylvania, May 1981.

Mancini, T. R., Suter, K. J., and Price, D. M., "The New Mexico State University Passive Skytherm Solar House: Summer Cooling Data 1981," presented at the ASME Solar Energy Division meeting, Albuquerque, New Mexico, April 1981.

Mancini, T. R., Mulholland, G. P., and Wilson, D. B., The Utilization of Solar Energy in the Potash Industry at Carlsbad, New Mexico, Final Report submitted to the New Mexico Energy and Minerals Department, March 1980.

Abernathy, G. H., and Mancini, T. R., Solar Powered Agricultural Irrigation Pump, New Mexico Energy Institute, Report No. 21, Las Cruces, New Mexico, February 1979.

Mancini, T. R., Smith, P. R., and Petersen, J. L., Preliminary Performance Evaluation of the New Mexico State University Solar House, New Mexico Energy Institute, Report No. 17, Las Cruces, New Mexico, May 1979.

Mancini, T. R., Fox, J. B., and Mulholland, G. P., Solar Radiation Simulation, Final Project Report submitted to the White Sands Missile Range, White Sands, New Mexico, May 1979.

Mancini, T. R., An Economical Solar Heated and Cooled House for Southern New

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Mexico, Final Project Report submitted to the New Mexico Energy Institute, Las Cruces, New Mexico, July 1979.

Mancini, T. R., Evaluation of a Roof-Pond Solar House, Final Project Report submitted to the Department of Energy, July 1979.

Fate, R. E., and Mancini, T. R., “The Performance of a Roof-Pond Solar House,” Proceedings of the Fourth Annual Passive Solar Conference, Kansas City, Missouri, October 1979.

Mancini, T. R., Performance Evaluation of the New Mexico State University Solar House, Final Report submitted to the New Mexico Energy Institute, Las Cruces, New Mexico, December 1979.

Miller, W. C., and Mancini, T. R., “The Effects of Selected Parameters on the Heating and Cooling Performance of a Passive Solar House,” Proceedings of the Second Annual Passive Solar Conference, Philadelphia, Pennsylvania, March 1978.

Mancini, T. R. and Matzkanin, R. L., “The New Mexico State University Solar House,” Proceedings of the Solar Heating and Cooling Operational Results Conference, Colorado Springs, Colorado, December 1978.

Matzkanin, R. L., and Mancini, T. R., “Performance Evaluation of the New Mexico State University Solar House,” ASME paper No. 78HA/SOL-8, ASME Winter Annual Meeting, San Francisco, California, December 1978.

Miller, W. C., and Mancini, T. R., “Numerical Simulation of a Solar Heated and Cooled House Using Roof Ponds and Movable Insulation,” Proceedings of the Solar World Conference, AS/ISES, Orlando, Fla., June 1977.

Moore, R., Smith, P. R., and Mancini, T. R., et. al., “A Unique Solar Residence Using Conventional Construction Techniques,” Proceedings of the Solar World Conference, AS/ISES, Orlando, Fla., June 1977.

Abernathy, G. H., and Mancini, T. R., “Design and Installation of a Solar-Powered Irrigation Pump,” Paper No. 77-4020, presented at the American Society of Agricultural Engineers, Raleigh, North Carolina, 1977.

Abernathy, G. H., and Mancini, T. R., “Can Sunshine Power the Pump?,” Agricultural Engineering Magazine, Vol. 58, No. 10, October 1977.

Mancini, T. R, Peterson, J. L., and Smith, P. R., “Preliminary Performance Evaluation of the New Mexico State University Solar House,” ASME Heat Transfer in Solar Energy Systems, December 1977.

Wilbur, P. J. and Mancini, T. R., “Energy Storage in a Solar Absorption Air Conditioning System,” Solar Energy, Vol. 18, pp. 569 to 576, 1976.

APPENDIX II: GLOSSARY OF TERMS

The following definitions are generally accepted by the CSP and electrical power communities[72] and will be used throughout this report.

Capacity: The ability to produce electrical power to meet system load requirements, typically represented at the nominal or rated load conditions in megawatts (MW).

CLFR: Compact Linear Fresnel Reflector solar concentrator. This is a variant of a parabolic trough in which linear reflector facets track and focus sunlight in one dimension while the receiver moves to intercept the reflected beam.

Areva's CLF Reflector

Collector: the solar concentrator and thermal receiver.

Concentrating Solar Power (CSP): also referred to as Solar Thermal Electric Power; it uses the heat absorbed from the sun to drive a conventional power cycle and produce electricity for delivery to the electric power grid.

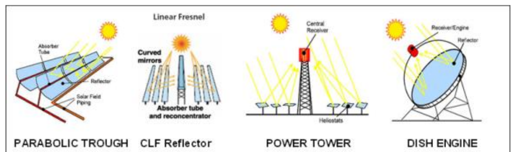

Figure 1 Four types of CSP Systems

Concentration ratio: the simple concentration ratio is represented by the projected area of the concentrator divided by the projected area of the receiver.

Concentrator: a curved, reflective mirror or a Fresnel lens that concentrates the solar energy along a line (trough) or at a point or on a small area (dish, and power tower).

Conversion System or Power Block: The equipment comprising that part of a CSP system that uses the concentrated solar heat to produce electricity. In the case of parabolic trough and power tower systems, it is Rankine cycle (defined below) equipment and for a dish/Stirling system it is the Stirling engine and generator (defined below).

Dish: a solar concentrator, typically in the shape of a paraboloid of revolution, that focus the incident solar radiation at its respective focal point. For this discussion, the term dish is also used for a Fresnel™ refractive, point focus concentrator. A dish tracks the sun in two axes to maintain the focal image(s) always at a fixed point(s) on the receiver(s).

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72 Specifying Steam and Rating Conditions for Special Purpose Steam Turbines, J. S. Aalto, Manager of Application Engineering, Industrial and Power Systems, General Electric Company, Fitchburg, MA. n.ed.; U.S. Energy Information Agency Glossary website, available at http://www.eia.gov/tools/glossary/index.cfm (last accessed on October 30, 2019);
PNUCC Committee Report Capabilities of Electric Power Resources, March 2011.

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Dish/Engine/Stirling: A CSP system that uses a parabolic dish, a thermal receiver located at the focal point, and an externally heated engine, usually a Stirling engine cycle, to produce electricity.

Efficiency: The ratio of net power generated to total fuel or solar energy input to the cycle.

Fresnel™ Lens: is a flat approximation of a continuous lens in which each of the plano-centric annular regions has the corresponding curvature of the continuous lens.

Generator: In power plant engineering, generator is a generic term that refers to the electrical equipment that is rotated by the steam turbine to produce electricity. It is often an alternator but, even then, commonly referred to as a generator.

Heat Exchangers: These are large, wall-separated pieces of equipment used for transferring heat from a hot fluid source to a different, colder fluid. Examples of heat exchangers are: coal boilers where hot combustion gases heat and boil water passing through tubes; condensers where cold water condenses and cools steam; and the boiler in a Parabolic Trough plant where the hot oil heats water and produces steam.

Infinia 3.5 kW Dish Stirling Systems

Heliostat: A slightly curved mirror used to focus sunlight in a power tower system.

HTF: The Heat-Transfer Fluid (HTF) that flows through the solar receivers and used to generate steam for the power conversion cycle. For a dish system, the working fluid is generally contained within the heat engine.

MW: (megawatt) a capacity equivalent to 1000 kilowatts.

MWHr: (megawatt hour) is power or the electricity produced by a generator operating at a constant 1 MW output for 1 hour.

Molten Salt: For this discussion, molten salt is molten sodium-potassium nitrate (60% $NaNO_3$ and 40% KNO_3). It is used as a liquid storage material and also a heat-transfer fluid to store heat which can be used to provide electricity at night or during periods when the sun is not shining.

Net Power: The power delivered to the grid (MWHrs) over some period of time.

One Sun: The power of the sun at a good solar location on the Earth ~ 1 kWatt/ m^2

Parabolic Trough: a parabolic shaped solar concentrator that focuses along a line. Parabolic troughs track the sun in one direction, mostly from east to west over the course of the day.

Andasol Parabolic Trough Plant

Power Tower or Central Receiver: A CSP system comprising a thermal receiver mounted on top of a central tower and illuminated by a field of slightly curved mirrors (heliostats). The heat is removed from the receiver by a working fluid and used to power a Rankine cycle producing electricity.

Ivanpah Power Tower Plant

Pyranometer: A pyranometers is a device for measuring solar radiation. There are two fundamental types of pyranometers to measure total radiation and direct normal radiation. Total radiation is what would be measured typically on a horizontal surface and includes the radiation coming directly from the sun (direct normal radiation) and the scattered component of radiation coming from other directions (diffuse radiation) Direct normal radiation is important because it is the only component that can be concentrated.

Rankine cycle: a thermodynamic power cycle in which the input is heat and the output is electrical power. For this discussion, water is heated producing high-temperature steam that is used to turn a turbine connected to an electric power generator to produce electricity for the utility grid. The cycle is completed by condensing the steam back to water.

Reflective Concentrator: is a concentrator that utilizes the reflection of solar rays to concentrate the solar energy.

Refractive Concentrator: is one that that refracts or bends the solar rays as they pass through it; like a Fresnel lens.

Secondary Concentrator: is a reflective element (often a cone-shaped device) placed on the receiver in order to effectively increase the size of the receiver aperture without incurring the increased thermal losses from actually having a larger receiver aperture.

Thermal Energy Storage System: an energy storage system comprising molten sodium-potassium nitrate salt, which is heated by the solar energy from temperatures of about 265°C to 390°C. The system often includes hot and cold storage tanks, pumps for moving the molten salt, and heat exchangers for transferring heat from the solar field to the salt and in a separate heat-transfer loop from the hot salt to water producing steam.

Thermal Receiver or receiver: the component of a CSP system on which solar energy is concentrated. The receiver absorbs the heat from the sun at a high temperature and transfers the heat to a working fluid, usually steam.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two

APPENDIX III ANALYSIS OF THE IAS SOLAR DISH TECHNOLOGY

IAS Solar Dish Technology Analysis			
SOLAR CONCENTRATOR			Comments:
4 CIRCULAR LENSES			
Diameter m	6.70		Ra3 023532
Area sq m	35.26		
Focal Length m	11.43		Ref 16 page 22
Solar Racidation kW/m2	1000.00		Good Solar Day 1 kW/m2
Lens assy Area X Solar Radiation kW	35.26		Reference 16 p. 23
Accuracy of the lens manufacturing	0.95		Engineering Estimate
Transmissivity T	0.89		Lucite 0751
Dirt soiling	0.93		Same loss as assumed by IAS.
Energy per single lens transmitted throught the lens kW	27.75		Product of the numbers listed
RECEIVER INTERCEPT CALCULATION			
Struct deflect, lens deflection and alignment and tracking errors	0.90		Effect of movement of the structure, deflection of lens structure, deflection of receiver supports Engineering Estimate
Area of Solar Image in Receivr plane m2	0.79		Movie: Solar Lens on RaPower3 Website Engineering Estimate of the image diameter 1 m
Receiver area m2	0.30		Dimensions of Receiver Aperture Estimate Photograph of the Receiver Engineering Estimate based on 0.60 m x 0.50 m
Receiver Intercept Factor	0.54		Engineering Estimate of intercept factor as 0.60 Note: greater than ratio of areas due to likely flux distribution. Multiply times structural deflection and tracking errors

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APPENDIX III ANALYSIS OF THE IAS SOLAR DISH TECHNOLOGY (cont.)

POWER SUPPLIED BY SINGLE LENS			Comments:
Optical Efficiency of dish	42.5%		Product of optical parameters accuracy, transmissivity, soiling, and intercept
Total Solar Incident on one Receiver kW	15.0		Product of receiver intercept and power transmitted through a siingle lens
Total Solar per on Dish (4 circular lenses) kW	59.9		4 times the power provided by a single lens assembly
RECEIVER HEAT LOSS CALCULATIONS			
			Iterative solution method
Outer Glass Temp	654.0		Assume glass Temperature
Degrees R	1114.0		In absolute degrees R
Conduction through glass	19450.4		Calculate conduction losses through the glass multiply times 7 tubes and use 0.5 surface area of 0.22 m2 per tube.
Radiation Losses from Glass Tube	9401.7		Calculate radiation losses mujltiply times 7 tubes and use 0.85 surface area of 0.22 m2 per tube
Convection Losses from Glass Tube	10139.3		Calculate convection losses from multiply times 7 tubes and use 0.85 surface area of 0.22 m2 per tube
Rad + Conv	19541.03		Add the losses and iterate until the conduction is equal to the lossses by conection + radiation
Thermal losses from one receiver kW	5.7		From Radiation and convection losses above
Total Thermal losses from the 4 Receivers in kW	22.9		Multiply single receiver losses by 4 receivers.
Thermal loss fractioof the thermal losses	38.2%		Thermal loss divided by total input to the receiver
Receiver Thermal efficiency	61.8%		Absorbed Heat divided by total input to the receiver

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APPENDIX III ANALYSIS OF THE IAS SOLAR DISH TECHNOLOGY (cont.)

THERMAL LOSSES FROM SCHOTT RECIEVER			Comments:
Solar incidence W/m2	1000		Good Solar Day 1 kW/m2
Concentration of trough	80		General CR
Diameter of tube m	0.07		Reported diameter
Thermal Losses W/m	210		Reference schott receiver tube losses
Schott Rec Efficiency	96.3%		Thermal Efficiency of Schott Receiver
Rankine Cycle Efficiency			
Coal Fired Power Plant T C	540		Coal Plant Operating Temperature
Ambient Temperature c	21		
	0.64		Coal Plant Carnot Effieincey
Actual Coal Fired Effiency	0.33		Typical Coal Plant efficiency
IAS Operating T C	400		
	0.56		IAS Carnot Efficiency
IAS Actual Efficiency	0.29		Apply same fraction of actual/Carnot
			to get Receiver Efficiency