DOCKET
07-AFC-5
DATE July 23 2009
RECD. July 23 2009

CH2MHILL

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July 23, 2009
File No.: 04.02.16.02
Project No. 357891

Mr. John Kessler, Project Manager
California Energy Commission
Systems Assessment and Facilities Siting Division
1516 9th Street, MS 15
Sacramento, CA 95814-5504

RE: Supplemental Data Response, Set 3A
Ivanpah Solar Electric Generating System (07-AFC-5)

Dear Mr. Kessler:

On behalf of Solar Partners I, LLC, Solar Partners II, LLC, Solar Partners IV, LLC, and Solar Partners VIII, LLC, please find attached one original and four hard copies and five CD copies of the Supplemental Data Response, Set 3A.

Please call me if you have any questions.

Sincerely,

CH2M HILL

John L. Carrier

John L. Carrier, J.D.
Program Manager

Enclosure
c: POS List
Project File

Ivanpah Solar Electric Generating System (ISEGS)

(07-AFC-5)

Supplemental Data Response, Set 3A

(Response to Data Request: Visual Resources)

Submitted to the

California Energy Commission

Submitted by

Solar Partners I, LLC; Solar Partners II, LLC; Solar Partners IV, LLC;
and Solar Partners VIII, LLC

July 23, 2009

With Assistance from

CH2MHILL
2485 Natomas Park Drive
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Contents

Section Page

Introduction

Attached is a supplemental response by Solar Partners I, LLC; Solar Partners II, LLC; Solar Partners IV, LLC; and Solar Partners VIII, LLC (Applicant) to the California Energy Commission (CEC) Staff's data request for the Ivanpah Solar Electric Generating System (Ivanpah SEGS) Project (07-AFC-5). This data request was the result of an email request received from John Kessler on July 13, 2009. As before, the responses are numbered for tracking and reference convenience. New attachments are numbered in reference to the Supplemental Data Request number. For example, a new document provided as part of the Data Response VR-3 would be called "Attachment VR3-1A."

The Applicant looks forward to working cooperatively with the CEC and Bureau of Land Management (BLM) staff and the other resource agencies as the Ivanpah SEGS Project proceeds through the licensing process. We trust that these responses address the Staff's questions and we remain available to have any additional dialogue the Staff may require.

Visual Resources (VR-2 through VR-6)

BACKGROUND

Staff remains concerned about a full and adequate characterization of potential glare effects of the solar receivers. In order to develop an analysis of this effect, the applicant is requested to provide the following information.

DATA REQUEST

VR-2 Please provide a detailed and specific description of all surfaces of the power tower on which reflected sunlight would fall, indicating the extent to which they are absorptive or reflective of the visible spectrum.

Response: There is not yet detail design of the tower but we can relate to the reflectance aspect of the anticipated surfaces. The Applicant has designed and built a ~200-foot tower for the SEDC (Pilot Plant) and the principle will remain the same.

The tower design incorporates a metal structure, with the corresponding exposed metal surfaces. The tower will be painted according to the acceptable standards for tall outdoor structures with a color that will blend with the surrounding environment such as browns or grays.

On top of the tower the Solar Receiver Steam Generator (SRSG) wraps around the tower in a rectangular shape. It is made up of multiple panels consisting of steel piping. The total receiver surface area is 1,400 square meters [approximately 20 meters (65.6 feet) high with a width and depth of approximately 17 meters (55.8 feet) each]. When the plant is not in operation there will be an insignificant amount of solar energy on the SRSG, that is dominantly diffusive and nonspecular. While in operation, the energy from the sun concentrated on the SRSG can be up to 600 suns total (typically 100 to 200 for half of the surfaces and 200 to 400 for the other half). The steel pipes that make up the SRSG are covered with a black coating that has a 95 percent absorption rate over the visual range (5 percent reflectance almost all diffused).

In addition to the SRSG at the top, on some lower levels of the tower, equipment such as vessels, pumps, and heat exchangers will be installed. The vast majority of the equipment will be inside the SRSG and not exposed visually. In the cases where components are exposed, it will be relatively small surface areas in comparison to the boiler-receiver surface cited above.

Above and below the boiler SRSG, there will be approximately 200 square meters (2,153 square feet) of high temperature protective panels (refractory), made of ceramic material with a white surface. During operation those surfaces will get up to about 20 suns. Reflectance of this surface is above 90 percent, all diffusive.

Under the boiler floor there will be a 144 square meter (12mx12m, or 1,550 sf) panel at each side of the tower (four panels). During solar operation it will have 5 square meter spots of beam light of no more than 8 suns. The white paint used on these panels will have 90 percent reflection, all diffused.

VR-3 For the anticipated portion of the reflected visible spectrum, please describe the type of reflection: specular, spread, diffuse, or compound.

Response: In answer to Data Request VR-1, and for each specific surface we have noted the type of reflectance of the visual range. We can summarize that all reflectance are diffused in character, both on the light painted surfaces, the white refractory panels and the high absorbance (receiver) surfaces.

VR-4 Please describe the extent to which the reflected visible portion is expected to produce glare, including blinding glare, direct glare, disability glare, and/or discomfort glare as described in the IES Lighting Handbook.

Response: During hours when the plant is not in operation this will not be an issue. During solar plant operation the dominant reflectance, or glare, will come from the SRSG on top of the tower. We have provided reports specifically referring to this issue and ascertaining no damage to the surrounding area or people, including the plant operators. The report is based on Sandia document SAND83-8035 – "10MWe Solar Thermal Central Receiver Pilot Plant: Beam Safety Tests and Analysis" which is included with this response as Attachment VR3-1A. Note that the report is not updated to the current design, and the Applicant will update the report when the boiler/tower design is final. In the interim, please note that since the margin of safety is so large, the safety aspects ascertained from the existing report still apply (even if a factor of 50 percent greater is applied).

The reflectance from the other surfaces of the tower is of negligible impact, similar to other industrial metal structures.

Concerning the glare from the boiler receiver on top of the tower, detailed calculations were made separately. The only potential damage is to the eyes, which would occur if someone stares at the SRSG continuously without blinking. Normal instincts that prevent us from damaging our eyes, such as blinking and looking away from bright objects, protect us from this glare atop the tower.

VR-5 In order to aid in evaluating the potential hazard of reflected light to aviation, please describe any ameliorative devices, structures, or shading which would eliminate or reduce the potential for any upward reflected portion of the visible spectrum from any reflective surface of the power towers, and indicate their expected effectiveness.

Response: No ameliorative devices, structures, or shading are necessary to reduce glare that would affect aviation. The dominant impact to aviation is during solar plant operation and the glare from the SRSG. The other parts of the tower are similar to other industrial structures with no reflectance disturbances, certainly not hazardous, to aviation. The Applicant has filed FAA form 7460-1 for this project and has received a determination from the FAA that the project is not a hazard to navigation. Copies of those letters have already been filed with the CEC.

CRITICAL ISSUE IDENTIFICATION

VR-6 Observational and analytical evidence obtained during the course of preparing the FSA has raised concerns about the potential glare effects of the solar receivers atop the project power towers. Staff is concerned that an adequate quantitative analysis of these potential impacts be made part of the evidentiary record. Such an analysis has not yet been produced.

Response: In Data Response Set 1A, filed on January 14, 2008, the Applicant provided the following documents:

- Attachment DR89-1, Beam Safety Design Parameters
- Attachment DR90-1, Radiant Flux from Solar Receiver on Distributed Power Towers
- Attachment DR90-2, Receiver Glare Safety Calculations

For the convenience of your contractor, these documents are being provided again. They provide quantitative calculations that demonstrate that glare effects are not a concern. As stated in the Radiant Flux from Solar Receiver on Distributed Power Towers document, to viewers the light reflecting from the top of the Solar Power Tower will appear like a 100-watt light bulb from a distance of 5.5 meters (18 feet).

ATTACHMENT VR3-1A

Receiver Glare Safety Calculations

Attachment too large for electronic filing, the full document including this attachment will be provided in the hard copies and on the CD copies.

ATTACHMENT DR89-1

Beam Safety Design Parameters

Specification

ATTACHMENT DR89-1

REVISIONS

LTR	DESCRIPTION	BY	DATE	APPR.
A	Initial Release for comments	DF	17/1/07	
B		DF	21/1/07	
C	Appendix added	DF	22Jan 07	
D	Up-dated	AA	27Dec 07	

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Title: **100 MW SYSTEM BEAM SAFETY DESIGN PARAMETERS**

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Project	**01-DPT550**					
File Name	**01070121 Beam Safety AAmit RevD**					
Sheet	**1**	**of**	**10**	**Rev**	**D**	

Table of Contents

1. SCOPE

This document lists the basic system operating modes and procedures for starting up, focusing, de-focusing, and stowing the heliostat field of a LUZ II DPT-550 Central Tower Plant, while ensuring beam safety in and above the project site. It shall serve as the top-level specification for conceptual and detail design of solar field control algorithms, systems and software.

Procedures and beam safety statistical calculations assume a solar field consisting of 70,000 heliostats, each having a reflecting surface of 7.3 square meters, placed on a field covering 830 acres. Safety measures reflect principles and procedures developed for beam safety in the Solar 1 experimental plant at Daggett, California, with appropriate changes (see Sandia Report SAND83-8035, by T. D. Brumleve).

Warranty information is not included or implied by any information herein.

2. STATES AND TRANSITION

There are five main states for the solar field:

- Stow (long term hold / overnight hold / cleaning & maintenance) - The heliostats have been rotated down into the stow position, with the mirror surface 5° past vertical (i. e., inclined slightly toward the ground). There is no beam concentration in the stow position.
- Standby - The heliostats are focused on the standby aim points on the side of the tower or a ring at the height of the tower (70m, 230ft). In this state all beams diverge beyond the focal points or ring, and there is no concentration of beam energy outside of the plant boundaries.
- Normal Operation - All heliostats are focused on the receiver, except for heliostats in standby, stow or calibration position (beam directed to the tower structure as required for the Beam Characterization System). Heliostat beams again diverge after passing the tower, with no concentration outside of the plant boundaries.
- Wind Protection Stow – All heliostats are in a “face up” stow position, with free (random) azimuth and the mirror plane elevated not more then 5° from horizontal. With random azimuth orientations, no intensity concentration of more then 4 suns (4 kW/m^2) may converge outside of the plant boundaries. [see appendix A].
- Transition Mode – All heliostats are following a path defined for the transition that don’t concentrate a beam intensity of more then 4 suns (4kW/m^2) over 730ft (220m) in altitude (230ft tower height plus 500ft FAA rules prohibiting flight within 500 ft. of any man made obstruction).

In addition to the five principal operating modes there are the following sub-modes:

- Off-line: the heliostat does not respond to commands from the Heliostats Array Controller (HAC), a manual command is required to return to active status. The heliostat may be down for maintenance or repair.
- Track: the heliostats are tracking the designated receiver aim points.

- Beam Characterization: An individual heliostat is tracking the beam characterization system target located within the plant boundaries.
- Directed Position: A heliostat has been moved to a given position for maintenance or testing. Software interlocks ensure that no beam concentration over the safety limit will occur
- Mark: The heliostat is positioned for calibrating the position signals from the azimuth and elevation motor encoders. Software interlocks ensure that multiple beams are not concentrated at working elevations inside or outside plant boundaries.

3. BEAM SAFETY DURING TRANSITIONS

Beam Safety During Transitions: HAC will move groups of heliostats from the normal stow position or high wind protection stow position to a standby tracking point along imaginary lines or ring, to prevent concentrating the image from more than 4 suns (4kW/m^2) outside the plant boundaries on ground level or sky line (220m, 730ft). The process is reversed from the standby tracking point to either stow position. These paths are site dependent, and will vary by season.

Single heliostat transition will be performed by a direct command from the HAC or Heliostat controller (HC), to a pre-designated target and path that will ensure no constriction of energy over the set limit

Emergency beam removal: The Master Control System (MCS) will issue a transition command to all operating heliostats to move to standby aiming points, while all heliostats in stow position remain in stow.

4. REFERENCE

1. T. D. Brumleve "10 MWe Solar Thermal Central Receiver Pilot Plant: Beam Safety Tests and Analyses", SAND83-8035, 1984.
2. T. D. Brumleve & j. c. Gibson, "Measurement Challenges in Solar Central Reviver System Test Facility", 7th Energy Technology Conference, 1980.
3. T. D. Brumleve, "Eye Hazard and Glint Evaluation for thr 5 MW Solar Central Thermal Test Facility", Sandia National Laboratories, SAND-8022, 1977.

5. APPENDIX A - Calculations of Beam Intensity and Safety

A reference for this calculation is from the "*10 MWe Solar Thermal Central Receiver Pilot Plant: Beam Safety Tests and Analyses, pp. 26-31: SAND83-8035*"

The maximum <u>safe intensity</u> of one heliostat:

$$I_s = \frac{\pi}{4}\frac{E_r I_{smp}}{kI}\frac{\beta^2}{\rho} = \frac{\pi}{4}\frac{8.5*0.243}{0.00525*0.1}\frac{\beta^2}{\rho} = 3090\frac{\beta^2}{\rho} =$$

$$= 3090\frac{0.0118^2}{0.94} = 0.457\,{}^{w}\!\big/_{cm^2} = 4.57\,{}^{kw}\!\big/_{m^2}$$

Comparing to Solar One, for which $I_s = 0.49\text{w/cm}^2$, we have lower intensity.

We are using a more conservative safe intensity that is equivalent to 4 suns (4 x 1 kW/m^2).

Where:
E_r – retinal irradiance.
d_r – diameter of the retinal image in meters.
$k = \frac{\pi v \tau d_p^2}{4f^2} \quad \left[\frac{\text{W-m}}{\text{cm}^2}\right]$ - Physical property of the human eye (ref 3 pg.21)
L – Radiance.
I – Intensity.
β – Total divergence angle from the heliostat.
ρ – Reflectivity of the mirror.
I_S – safe intensity.
d_{rs} – maximum safe image diameter.
E_{rs} – Safe retinal irradiance, $E_{rs} = \frac{0.002}{d_{rs}}$, (ref 2).
$(\ )_{mp}$ – Human property.

Beam concentration:

At a distance of 500m, which is the heliostat's focal distance, the beam area is:

$$0.7 + 2.5rad * 500m = 1.95m$$

$$2.5rad * 500m = 1.25m$$

$$\rightarrow 1.95m * 1.25m = 2.4m^2$$

The total radiation from the single heliostat is $\frac{7.5kw}{2.4m^2} = 3.125\,{}^{kw}\!\big/_{m^2}$

This is the highest intensity from a heliostat, less than the I_S of 4.5kw/m^2 (equivalent to four suns).

To check a random beam hazard to low-flying aircraft, we will consider the conditions required to create a hazard to aircraft pilots and the probability of their occurrence. At an elevation of 1000m above the ground the radiance of a single heliostat is less then one sun (1kW/m^2), and is therefore not hazardous to aircraft pilots. The probability of two heliostat beams crossing in the same place in the sky dome at an altitude of 1000m is calculated as follows. The dome surface (S) of one heliostat at 1000m altitude is 30,000 m^2 based on ±5° of freedom. The probability of a spot of 14m^2

$$\{\, S = (3.25m + 0.00125rad * 1000m)(2.25m + 0.00125rad * 1000m) = 14m^2 \,\}$$

intersecting with another 14m^2 on a 30,000 m^2 dome

is $p_h = \dfrac{14m^2}{(H[m] * 0.174rad)^2}$; $P_{2/1000} \approx 4.6 * 10^{-4} \approx {}^{1}\!/_{2200}$.

As the altitude (H) increases the probability of a conjunction decreases and the irradiance of each heliostat is reduced significantly.

The probability of any two random heliostat beams crossing in the sky is given by:

$$P = \frac{p_{n/h}\dbinom{\text{number of heliostats in the field}}{\text{number of heliostat crossing}}}{(\text{number of heliostats})^2} \approx \frac{0.000467\dbinom{70,000}{2}}{70,000^2} \approx 0.00023 \approx \frac{1}{4300}$$

At 1000m the beam spot is 14m^2 and E = 0. 53kw/m^2, 2 spots have E = 1.07kw/m^2.

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Kiryat Mada 11 - Amot Bldg #6 P.O. Box 45220 Har Hotzvim Jerusalem 91450 Israel Ph: +972 (0)77-202-5000 Fax: +972 (0)2 571-1059	Project	01-DPT550						
	File Name	01070121 Beam Safety AAmit RevD						
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Specification

To reach an intensity of 4.5kw/m^2 would require a conjunction of eight heliostat beams. The probability for eight beams to cross in a 1000m altitude is calculated as follows:

$$\frac{\left(\frac{1}{2500}\right)^{7}\binom{70,000}{8}}{70,000^{2}} \approx 1.08\times10^{-28}$$

The likelihood of a random heliostat beam hazard to aircraft pilots is therefore infinitesimally remote, before even considering beam attenuation losses (approximately 5% every 500 meters), beam scattering caused by mirror vibration, and the duration of exposure required to constitute a real hazard..

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Sheet	**10**	**of**	**10**	**Rev**	**D**	

ATTACHMENT DR90-1

Radiant Flux from Solar Receiver on Distributed Power Towers

ATTACHMENT DR90-1

Internal Memo

To: Yoel Gilon, Arieh Amit

From: Danny Franck

CC:

Date: December 13, 2007

Re: Radiant Flux From Solar Receiver On Distributed Power Towers

---

This document discusses the intensity and some effects of energy emitted from solar receivers mounted on our distributed power towers, such as those planned for the Ivanpah project. The calculation of the radiant flux from the receiver is based on assumptions and calculations included in Sandia document SAND83-8035 – "10MWe Solar Thermal Central Receiver Pilot Plant: Beam Safety Tests and Analysis", T.D. Burmleve, pp.28-31,72, 76, 80.

The conclusion is that the retinal irradiance E_r impinging on a human eye from the receiver is several scales smaller than the one from the sun (see Table 1. below, and accompanying calculations), and the radiation intensity (I) from the receiver at the nearest project fence line (300m from the receiver) is 14 times less than the Maximum Permissible Exposure (MPE[1]) for continuous viewing. **In every day terms, looking at the receiver from the nearest site boundary is like viewing a 100W light bulb from a distance of 5.5m (18ft).**

For people passing on highway I-15 the radiance from the receiver will not be significant, as I-15's closest approach to the field boundaries is over one mile from the closest solar field and more than two kilometers from the closest tower. The resulting potential exposure to motorists is about 5500 times less than Maximum Permissible Exposure (MPE) for continuous exposure – about like viewing a 100W light bulb from a distance of over 130 ft.

The following is a more detailed discussion and calculations supporting the general conclusions summarized above. The maximum safe exposure (MPE) which can be tolerated by the human eye is defined as:

MPE for a momentary exposure (0.15s) is $1.0 W/cm^2 = 10{,}000 W/m^2$.
MPE for continuous exposure is $0.1 W/cm^2 = 1000 W/m^2$.

The E_r from the sun's radiance on the retina is $85{,}000 W/m^2$.

We calculate the retinal irradiance from the receiver as follows:

$I = \frac{D2^{\square} * \phi * \rho}{2\pi R^{2}}$ = Intensity of the light reflected from the receiver at distance R.

$E_r = k * I$ = Retinal irradiance, where k = human eye factor = 52.5W/m^2

I used only half sphere that the light can be reflected to ($2\pi R^{2}$).

Er - Retinal irradiance [W/m^2]
D - Receiver diameter [m]
I – intensity [W/m^2]
R – Distance from the receiver [m]
Φ – Flux on the receiver [W/m^2].
ρ – Reflectivity [%]
k – human eye factor, k = 52.5W/m^2.

E_r was calculated using the following assumptions:

Φ = 600kW/m^2

D = 12m,

ρ = 5%,

R = 100 – 1000m.

The real total flux from the receiver is significantly lower than 600kW/m^2. Table 1 below presents the resulting irradiance at various distances R from the receiver.

Table 1. Flux On Retina From Receiver

Distance [m]	I [W/m^2]	Er [W/m^2]
100	68.75	3610
160	25.25	1410
200	17.19	902
300	7.64	401
400	4.30	226
500	2.75	144
600	1.91	100
700	1.40	74
800	1.07	56
900	0.85	45
1000	0.69	36

The flux from the receiver at 160m has the same effect as a 100W bulb at a distance of 3m (10ft); the flux from the receiver at the Ivanpah project boundaries is equal to that of the light bulb at a distance of 5.5m (assuming 100% emissivity of the light bulb).

For comparison purposes, Table 2 below presents the irradiance on a retina from a 100W light bulb at various distances.

Table 2. Flux On Retina From 100W Light Bulb

distance [m]	I [W/m^2]	Er [W/m^2]
3	28.1	1447.6
5	8.4	439.6
10	2.5	139.8

(This document's detailed calculations are in "00 071217 Glare From Reciver DF,RevB.xlsx".)

The calculation of the Er from a light bulb:

$$I = \frac{P/_{4\pi R^2} * \rho}{4\pi R^2}$$

$$Er = k * I$$

Er - Retinal irradiance
D - Bulb diameter
I – intensity
R – Distance from the bulb
P – Bulb power
ρ – Reflectivity
k – human eye factor, k = 52.5W/m^2.

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[1] SAND83-8035, 10MWe Solar Thermal Central Receiver Pilot Plant: Beam Safety Tests and Analysis", T.D. Burmleve, pp 72

ATTACHMENT DR90-2

Receiver Glare Safety Calculations

ATTACHMENT DR90-2

Receiver Glare Safety Calculations

Receiver Extreme

INPUTS:

Flux on reciver [kW/m^2]	600
reflectivity [%]	5.00%
Receiver Diameter [m]	12
source radiance [w/m^2*sr]	30
k [w/m^2]	52.5

RESULTS:

distance [m]	I [W/m^2]	solid angle	L (of the source)	Er
100	**68.75**	0.018334649	260417	**3609.63**
160	**26.86**	0.007161972	666667	**1410.01**
200	**17.19**	0.004583662	1041667	**902.41**
300	**7.64**	0.002037183	2343750	**401.07**
400	**4.30**	0.001145916	125000	**225.60**
500	**2.75**	0.000733386	156250	**144.39**
600	**1.91**	0.000509296	187500	**100.27**
700	**1.40**	0.000374177	218750	**73.67**
800	**1.07**	0.000286479	250000	**56.40**
900	**0.85**	0.000226354	281250	**44.56**
1000	**0.69**	0.000183346	312500	**36.10**
2000	**0.17**	4.58366E-05	625000	**9.02**

Bulb

INPUTS:

Bulb Power [W]	100
reflectivity [%]	100.00%
Bulb Diameter [m]	0.1
source radiance [w/m^2*sr]	100
k [w/m^2]	52.5
bulb surface area	3.14E-02

RESULTS:

distance [m]	I [W/m^2]	Er
3	**28.1**	**1477.60**
5	**10.1**	**531.94**
5.5	**8.4**	**439.62**
10	**2.5**	**132.98**
40	**0.16**	**8.31**

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA

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APPLICATION FOR CERTIFICATION
FOR THE *IVANPAH SOLAR ELECTRIC GENERATING SYSTEM*

DOCKET NO. 07-AFC-5
PROOF OF SERVICE
(Revised 7/20/09)

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DECLARATION OF SERVICE

I, Mary Finn , declare that on July 23, 2009, I served and filed copies of the attached, Supplemental Data Response 3A. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: [www.energy.ca.gov/sitingcases/ivanpah].

The documents have been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(*Check all that Apply*)

FOR SERVICE TO ALL OTHER PARTIES:

X sent electronically to all email addresses on the Proof of Service list;

X by personal delivery or by depositing in the United States mail* at Sacramento, California on July 24, 2009 with first-class postage thereon fully prepaid and addressed as provided on the Proof of Service list above to those addresses NOT marked "email preferred."

AND

FOR FILING WITH THE ENERGY COMMISSION:

X sending an original paper copy and one electronic copy, mailed and emailed respectively, to the address below (*preferred method*);

OR

______ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 07-AFC-5
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512
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I declare under penalty of perjury that the foregoing is true and correct.

Mary Finn

*or by other delivery service, e.g., Fed Ex, UPS, courier, etc.