



# EXPEDITED PERMIT PROCESS FOR PV SYSTEMS

A Standardized Process for  
the Review of Small-Scale PV Systems

Prepared by

**Bill Brooks, P.E.**  
Brooks Engineering

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**Solar America Board for Codes and Standards**

[www.solarabcs.org](http://www.solarabcs.org)



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## EXECUTIVE SUMMARY

This report presents an expedited permit process for small-scale photovoltaic (PV) systems. The Solar America Board for Codes and Standards (Solar ABCs) recommends that local jurisdictions use this process for awarding building permits to installers of small PV systems. Use of this process simplifies the requirements for the contractor submitting the request and reduces the time needed for the local jurisdiction providing structural and electrical review of the permit application.

The term “expedited permit process” refers to an organized permitting process by which a majority of small, residential-sized photovoltaic systems can be permitted quickly and easily. It is not intended to apply to all types of PV systems. The primary need and value for this process is for systems of less than 10-15 kW of output power. A key difference between small and large projects is the inability of small projects to absorb engineering review costs. Standardizing the process as much as possible is in the contractor’s and jurisdiction’s interest. As projects increase in size and complexity, the ability to handle these projects via a standard framework diminishes.

The one-page expedited permit process and the accompanying guidelines explaining each step provide a means to differentiate PV systems that can be permitted quickly and easily due to their similarity with the majority of small-scale PV systems. Those systems with unique characteristics may be handled with minimal additions to this expedited process or may require additional information, depending on the uniqueness of the installation.

The diagrams shown in the *Expedited Permit Process* are available online at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting) in an interactive PDF format so that the diagrams can be filled out electronically and submitted either in printed form or via email to the local jurisdiction. An electronic format is used so that the supplied information is standardized and legible for the local jurisdiction. As this process evolves, and suggestions are received, Solar ABCs will publish additional drawings and diagrams on its website.

The expedited process does provide flexibility in the structural review process. The structural review section includes span tables and additional information found in Appendix B. PV systems with battery backup require a more detailed electrical drawing than this process provides.

*Appendix A* has an example included of a submittal. An assortment of special electrical topics is presented in *Appendix C*. Temperature tables included in *Appendix E* are used in applying the National Electrical Code’s temperature-dependent criteria. This document is intended to be usable throughout the United States and can provide standard installation design documentation for most locations within the U.S. and other regions that use the *National Electrical Code* (NEC), 2011 version (unless otherwise indicated).

## AUTHOR BIOGRAPHY

### Bill Brooks

Bill Brooks has worked with utility-interconnected PV systems since the late 1980s. He is a consultant to the PV industry on a variety of performance, troubleshooting, and training topics. Over the past 13 years, these training workshops have helped thousands of local inspectors and thousands of electricians and installers understand PV systems and how to properly install them.

His field troubleshooting skills have been valuable in determining where problems occur and to focus training on those issues of greatest need. Mr. Brooks has written several important technical manuals for the industry that are now widely used in California and beyond. His experience includes work on technical committees for the National Electrical Code, Article 690, and IEEE utility interconnection standards for PV systems. In 2008 he was appointed to Code Making Panel 4 of the National Electrical Code by the Solar Energy Industries Association.

Mr. Brooks holds Bachelor and Master of Science Degrees in Mechanical Engineering from N.C. State University and is a Registered Professional Engineer in both North Carolina and California.

Brooks Engineering Web site:

[www.brooksolar.com](http://www.brooksolar.com)

### Solar America Board for Codes and Standards

The Solar America Board for Codes and Standards (Solar ABCs) is a collaborative effort among experts to formally gather and prioritize input from the broad spectrum of solar photovoltaic stakeholders including policy makers, manufacturers, system designers, suppliers, installers, electric utilities, and consumers, resulting in coordinated recommendations to codes and standards making bodies for existing and new solar technologies. The U.S. Department of Energy funds Solar ABCs under the Solar America Initiative Market Transformation (SAI-MT) Program as part of its commitment to facilitate wide-spread adoption of safe, reliable, and cost-effective solar technologies.

For more information, visit the Solar ABCs web site:

[www.solarabcs.org](http://www.solarabcs.org).

### Acknowledgements

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## DEDICATION

This document is dedicated to two key individuals that represent the very best of those who have worked on the codes and standards processes as they relate to PV systems. These two amazing people, Tim Owens, of Santa Clara Building Department, and Chuck Whitaker, of BEW Engineering, passed away in the months prior to the release of this standardized permitting process.

### Tim Owens

Tim Owens passed away in December of 2008 at the age of 59 in the midst of a distinguished career in the electrical trades and code enforcement fields. While working as Chief Electrical Inspector for the City of San Diego in 1999, Tim was the first jurisdictional officer to put together a simplified permitting process for PV systems. His desire to see such a process become commonplace is what has driven this author to work on improving permitting and approval processes for PV systems over the past decade. The solar community lost a true friend and partner who was dedicated to the success of solar photovoltaic systems in California and the rest of the U.S.

### Chuck Whitaker

Chuck Whitaker passed away in early May of 2009 at the age of 52 in the midst of a distinguished career supporting the development and implementation of most of the codes and standards the govern and support PV systems both nationally and internationally. His passing coincided with the initial release of this standardized permitting process. The author had the privilege of knowing Chuck for two decades and working closely with him for over eight years as his employee and colleague. It is difficult to overstate Chuck's contribution to the PV industry; his influence is found in nearly every code and standard that has been developed for PV equipment and systems over the past 25 years. It is only fitting that this document—which includes his influence—be dedicated to his memory. A huge hole is left in the PV industry with Chuck's passing, and it is the hope of many of us in the codes and standards arena to be able to carry on his tireless work some semblance of the skill, wit, and humor that were the hallmarks of this amazing individual.

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## INTRODUCTION

The term “expedited permit process” refers to an organized permitting process by which a majority of small photovoltaic (PV) systems can be permitted quickly and easily. It is not intended to apply to all types of PV systems. The primary need and value for this process is for systems of less than 10-15 kW maximum power output. As PV systems increase in size and complexity, the ability to handle these projects via a standard framework diminishes. This is not to say that larger systems cannot be handled in a straightforward manner. Many larger PV system projects may be approved with minimum review as is required with smaller systems. A key difference between small and large projects is the inability of small projects to absorb engineering review costs. The expedited permit process is intended to simplify the structural and electrical review of a small PV system project and minimize the need for detailed engineering studies and unnecessary delays.

It is not the intent of an expedited process to circumvent the engineering process. Rather, the intent is to address the engineering concerns by recognizing the similarities among these smaller systems and establishing guidelines to determine when a PV project is within the boundaries of typical, well-engineered systems. To this end, a one-page permit form was devised to outline the process and define what qualifies for expedited permitting. An explanatory document accompanies the permit form so that contractors and local jurisdictions using the form have a description of how to provide the required information.

### WHAT QUALIFIES A PV PROJECT FOR EXPEDITED PERMITTING?

The permit form outlines what information is needed for the permit package and the minimum requirements needed for utilizing expedited permitting as summarized below.

1. The structural installation of the systems meets the following criteria:
  - a. the array is mounted on a code-compliant structure;
  - b. an engineered mounting system is used to attach the array to the structure; and,
  - c. the array has a distributed weight of less than 5 lbs./ft<sup>2</sup> and less than 45 lbs. per attachment.
2. The electrical design of the system can be described using the supplied standard electrical diagram and meets the following criteria:
  - a. all products are listed and identified for the application (i.e. modules, inverters, source combiners, etc.);
  - b. the array is composed of 4 series strings or less and,
  - c. the inverter output is 13.44 kW or less (maximum size for 70-amp breaker) and is connected on the load side of the service disconnect.

In order to complete the permit package, the applicant is required to provide the following:

1. a completed permit application
2. the proposed site diagram showing the relative location of major components
3. the proposed standard electrical diagram
4. the specification sheets and simple instruction manuals for major components.

Even though these stipulations may seem restrictive at first, the majority of PV systems installed in the U.S. will easily meet these requirements. For projects that do not meet these simplified criteria, additional steps may be necessary. Currently, the expedited process identifies steps to complete the review of the structural installation should the array be installed on a roof that is unfamiliar to the jurisdiction, or when a non-

typical mounting system is employed. For installations that do not meet the electrical installation criteria, detailed ampacity calculations, and other supporting documentation may be necessary to complete the review. A variety of special cases will be added to the standard electrical diagram case to accommodate project types that are composed of additional system installations (e.g. supply-side connections, modular inverter systems, and battery-based systems).

Finally, it should be noted that an expedited permit process solves only one of several challenges in the installation process of PV systems. Increasingly, local jurisdictions across the U.S. are placing less emphasis on the permit process and more emphasis on the field inspection process. This is a positive trend for the PV industry, as even the best permit package may do little to reduce challenges during a field inspection. Ultimately, the field inspection will illustrate how well a contractor is able to install a code-compliant PV system. A well-organized permit package may simply make a poor-quality contractor look good initially, while the final inspection can more clearly identify competent installers. Understanding that this permit process is only one portion of the code-enforcement process will help advocates and jurisdictions put the appropriate emphasis on the review and inspection portions of the process.

## THE PERMITTING PROCESS FOR PV SYSTEMS IN THE UNITED STATES

In order to understand how an expedited permitting process can be of assistance, we should first examine how permitting in general is conducted throughout the U.S. A common method that local jurisdictions utilize is to split the process into two discrete segments: 1) permitting, and 2) field inspection.

The first segment entails both the plan review and permitting process. Depending on the size of the jurisdiction, this process will vary. For large jurisdictions, there may be a group of people that focuses only on plan reviews and typically does not get involved in the field inspection process. For smaller jurisdictions, one person may be providing the plan review, field inspection, and other services of the office. Understanding that these processes can vary significantly is key in helping jurisdictions choosing to adopt a standardized process.

In addition to the more common standard plan review and inspection processes, there are a many other methods used across the U.S. Many rural areas do not require permits or inspections for construction. Other regions may use third-party inspectors who provide the local government with a certificate that an installation meets local code requirements.

Finally, some jurisdictions have a very minimal or non-existent permit process, with all the emphasis placed on the field inspection. This minimal permit process might include simply mailing, faxing, or emailing a short form into an office or going online and paying a fee. This expedited permit process may contain more steps than some jurisdictions require. However, even for those jurisdictions that do not require plan submittals, the documentation can be supplied at the field inspection for reference.

## PROBLEMS WITH THE EXISTING PROCESSES OF PERMITTING PV SYSTEMS

Given the differences in permitting processes across the U.S., and the significant variations in experience relating to system inspection at various jurisdictions, it becomes apparent why permitting issues have been cited as a barrier to the widespread installation of PV systems. Several articles and reports have been written, documenting general permitting difficulties and cite specific examples of difficulties and delays for





PV system projects as a result of the permitting process. A recent report entitled, *Taking the Red Tape out of Green Power*, written by Damian Pitt of the Network of New Energy Choices, outlines many of these issues (Pitt, 2008). The report highlights many issues that create barriers to successful PV system installations, and include references to complex and inconsistent permitting processes throughout various jurisdictions.

The expedited permit process proposed in this report will assist jurisdictions in removing complexities and creating a more consistent permitting process. The complexities of the permitting processes are often a result of jurisdictions requiring that multiple departments review permit applications. As a jurisdiction becomes familiar with the expedited permitting process, a simple review by a single department will often be sufficient. The second obstacle, lack of consistency among jurisdictions, is addressed by the very intent of the standard permitting process. As the Pitt report points out, it is not necessarily the amount of information required that is the problem, but rather the uncertainty of not knowing whether the information being supplied is sufficient (Pitt, 2008). Each time a request for additional information is issued by a jurisdiction, days are added to the approval timeframe for the project and costs increase for both the jurisdiction and the contractor.

## ACTIVITIES TO DEVELOP STANDARDIZED REVIEW PROCESSES

As we seek to develop a single, uniform permitting process for small-scale PV systems, we must acknowledge the fact that this is not a new concept. As long ago as 1999, the City of San Diego, under the leadership of the chief electrical inspector Tim Owens, attempted to standardize the permit process for PV systems. At about the same time, the Florida Solar Energy Center (FSEC) started their PV System Design Review and Approval program. This detailed design review and approval program was developed to support a Florida rebate program for PV systems up to 100 kW, and was later standardized into FSEC Standard 203-05, *Procedures for Photovoltaic System Design Review and Approval*. The approval is based on the system design complying with the applicable codes and standards, and its consistency with industry-accepted design practices.

Since the turn of the millennium, many other organizations and jurisdictions have developed standardized permit processes. In 2004, the Interstate Renewable Energy Council (IREC) and Pace University in New York put together the first Inspector Guideline for PV Systems. This project was funded by the U.S. Department of Energy (DOE) and received fairly widespread use throughout the U.S. Dozens of jurisdictions in California and across the U.S. have been using this document as a tool to help them review PV system projects and as a template to request information from contractors.

As PV systems began to proliferate in large markets such as California and New Jersey, the pressure to develop standardized permit processes increased. Other organizations such as the Sierra Club and SolarTech in the San Francisco Bay area, and the Colorado Solar Energy Industries Association (CoSEIA) began developing new processes. Although many of the new processes were based on the DOE guidelines, new items were added to address concerns that the DOE guidelines may not have covered. In addition to private organizations working on guidelines, numerous local jurisdictions developed guidelines as well. Among these jurisdictions are the City of Ventura, California, and regional International Code Council (ICC) chapters, such as the County of Sonoma and the ICC Tri-Chapter Uniform Code Committee (TUCC) in the San Francisco Bay area.

## UNIFYING THE EXISTING PERMITTING PROCESSES TO MOVE TOWARD A STANDARDIZED EXPEDITED PERMIT PROCESS

With all the energy and focus being placed on this specific issue, the timing was right to work with all these jurisdictions and organizations to determine whether a single process could be developed that met the concerns of all the parties and that could be used as a nationwide template for jurisdictions. By incorporating the major components of each of the developed processes, the Expedited Permit Process was drafted and released for review in early March, 2009. This new permitting process was significantly different from the previous DOE guidelines and included many of the unique aspects of the SolarTech and TUCC documents.

Over the course of March and April of 2009, numerous reviews of the draft document were provided by solar contractors, individuals at organizations including SolarTech, National Renewable Energy Laboratory (NREL), New Mexico State University (NMSU), California Solar Energy Industries Association (CalSEIA), CoSEIA, and jurisdictions that had expressed interest in reviewing the draft. As a result of these reviews, substantial updates and changes were made to the content of the process. In particular, the electrical diagram went from a single 11"x17" diagram with areas to fill in the specifications of the electrical components to two 8.5"x11" diagrams that can be filled in electronically using a PDF reader. Other comments suggested adding descriptions of special cases, such as making ac connections on the supply side of service disconnect and making ac connections to subpanels. Rather than incorporate these special topics into the body of the explanatory document, each item is addressed separately in the appendix under Special Electrical Topics.

The feature that sets the expedited permit process apart from other current standardization attempts is the development of a standard electrical diagram and standard wire sizing. This diagram is pivotal to the development of a standard permit process. Variations in how electrical design information is presented can be a major problem for jurisdictions approving projects. These variations often cause permitting delays as the jurisdictions are unsure about what information is being provided, or left out, when the permit application is submitted. This uncertainty often causes jurisdictions to set a one- or two-week turn around for PV projects. A standard diagram can remove that uncertainty and allow a jurisdiction to review and approve a project at the time of submittal. What is often termed "over the counter" approvals is one of the goals of the Expedited Permit Process. "Over the counter" refers to a local jurisdictional review provided by plan checkers that are available at the permitting counter. A highly organized standardized permit package makes this type of counter review possible.

### RECOMMENDATIONS ON APPLYING THE EXPEDITED PERMIT PROCESS

It is likely that various regions and jurisdictions across the United States have regulations and requirements that restrict their ability to adopt the expedited permitting process. At the same time, the issues that jurisdictions face when permitting PV systems are often similar. All jurisdictions must address the safety of PV systems as they affect structures and electrical hazards. The key is beginning with a consistent starting point in the development of a local or regional requirement. By using the new expedited permit process provided by the Solar America Board for Codes and Standards (Solar ABCs), jurisdictions can be assured that they are consistent in their application of codes and standards. Contractors can also be assured that the requirements for permitting will not vary dramatically among jurisdictions.

Solar ABCs recommends that this permitting process be used in its entirety. As jurisdictions begin to use this process and see opportunities to improve the guidelines the updates can be implemented and posted on the Solar ABCs website at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting). With





this approach, the latest version can be found and downloaded from a consistent location and jurisdictions can update their local processes as often as they deem necessary. By having a process that can be consistently updated, the permitting process can stay current with the design and installation practices as they change over time. The ultimate goal is to have the best and most up-to-date information on PV system design and installation practices in the hands of jurisdictions and contractors across the U.S. As codes are updated and changed, this flexible system can be adapted quickly and easily.

## REFERENCES

National Fire Protection Association, (2011), *National Electrical Code 2011*.

Pitt, D., (2008) *Taking the Red Tape Out of Green Power: How to Overcome Permitting Obstacles to Small-Scale Distributed Renewable Energy*. Network for New Energy Choices.

Retrieved 9/4/09 from <http://www.newenergychoices.org/uploads/redTape-rep.pdf>

## EXPEDITED PERMIT PROCESS FOR PV SYSTEMS

The Solar America Board for Codes and Standards (Solar ABCs) Expedited Permit Process provides a means to differentiate systems that can be permitted quickly and easily due to their similarity with the majority of small-scale PV systems. Those systems with unique characteristics may be handled with small additions to this Expedited Permit Process or may require much more information, depending on the uniqueness of the installation.

The following pages contain forms to use with the Expedited Permit Process. The forms are available as interactive PDF files at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting). In jurisdictions that have adopted the Expedited Permit Process for PV Systems, these forms can be filled out electronically and submitted in either printed form and via email. An electronic format is used so that the supplied information is standardized and legible for the local jurisdiction.



# EXPEDITED PERMIT PROCESS FOR SMALL-SCALE PV SYSTEMS

The information in this guideline is intended to help local jurisdictions and contractors identify when PV system installations are simple, needing only a basic review, and when an installation is more complex. It is likely that 50%-75% of all residential systems will comply with these simple criteria. For projects that fail to meet the simple criteria, resolution steps have been suggested to provide as a path to permit approval.

## **Required Information for Permit:**

1. Site plan showing location of major components on the property. This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays on dwellings with a 3' perimeter space at ridge and sides may not need separate fire service review.
2. Electrical diagram showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).
3. Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting system.

## **Step 1: Structural Review of PV Array Mounting System**

**Is the array to be mounted on a defined, permitted roof structure?**  Yes  No

*If No due to non-compliant roof or a ground mount, submit completed worksheet for the structure WKS1.*

### **Roof Information:**

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...)\_\_\_\_\_

*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*

2. Does the roof have a single roof covering?  Yes  No

*If No, submit completed worksheet for roof structure WKS1.*

3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).\_\_\_\_\_

### **Mounting System Information:**

1. Is the mounting structure an engineered product designed to mount PV modules with no more than an 18" gap beneath the module frames?  Yes  No

*If No, provide details of structural attachment certified by a design professional.*

2. For manufactured mounting systems, fill out information on the mounting system below:

a. Mounting System Manufacturer \_\_\_\_\_ Product Name and Model# \_\_\_\_\_

b. Total Weight of PV Modules and Rails \_\_\_\_\_ lbs

c. Total Number of Attachment Points \_\_\_\_\_

d. Weight per Attachment Point (b ÷ c) \_\_\_\_\_ lbs (if greater than 45 lbs, see WKS1)

e. Maximum Spacing Between Attachment Points on a Rail \_\_\_\_\_ inches (see product manual for maximum spacing allowed based on maximum design wind speed)

f. Total Surface Area of PV Modules (square feet) \_\_\_\_\_ ft<sup>2</sup>

g. Distributed Weight of PV Module on Roof (b ÷ f) \_\_\_\_\_ lbs/ft<sup>2</sup>

*If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.*

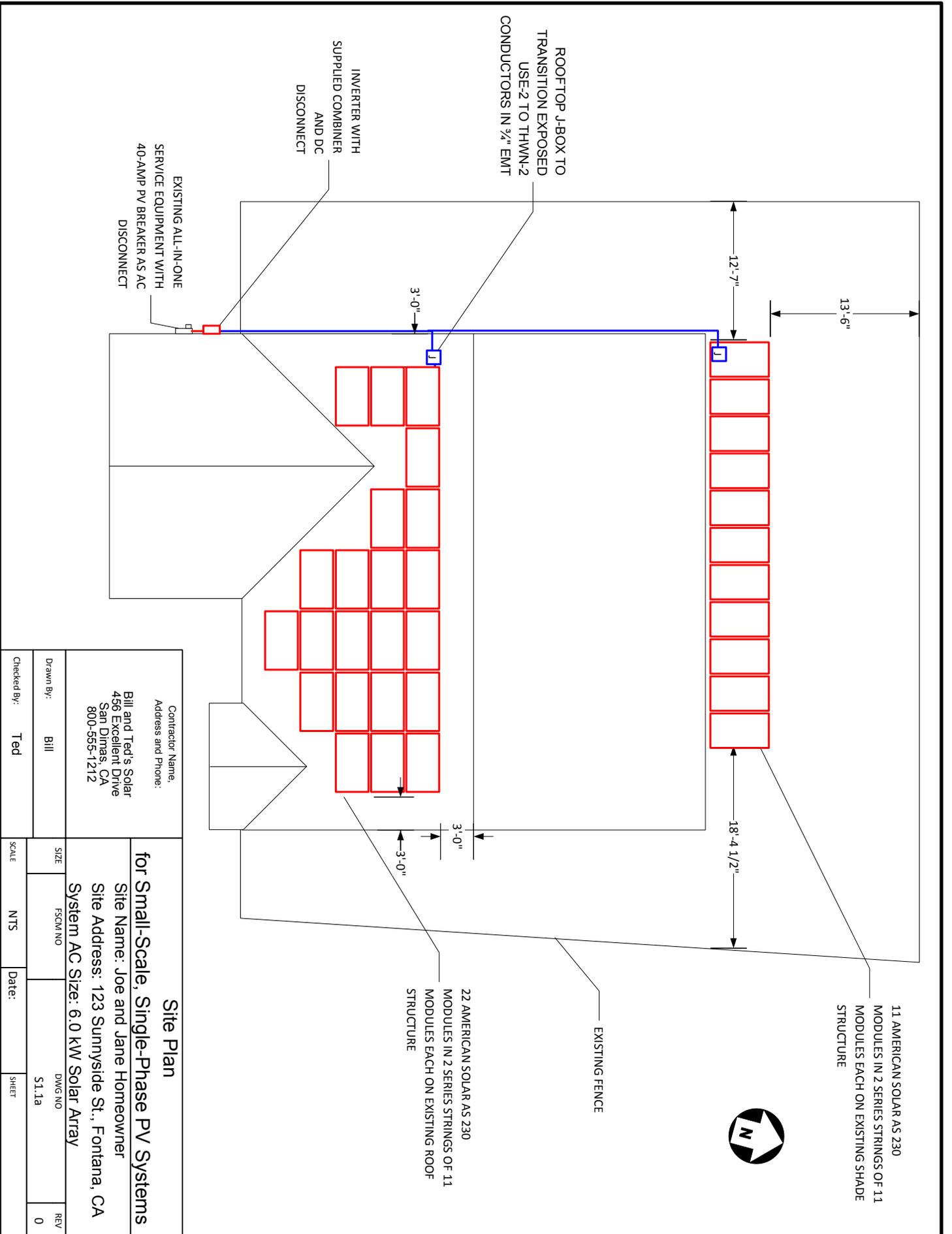
## **Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)**

**In order for a PV system to be considered for an expedited permit process, the following must apply:**

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
2. The PV array is composed of 4 series strings or less per inverter.
3. The total inverter capacity has a continuous ac power output 13,440 Watts or less
4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
5. One of the standard electrical diagrams (E1.1, E1.1a, E1.1b, or E1.1c) can be used to accurately represent the PV system. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

*Fill out the standard electrical diagram completely. A guide to the electrical diagram is provided to help the applicant understand each blank to fill in. If the electrical system is more complex than the standard electrical diagram can effectively communicate, provide an alternative diagram with appropriate detail.*

# SITE PLAN



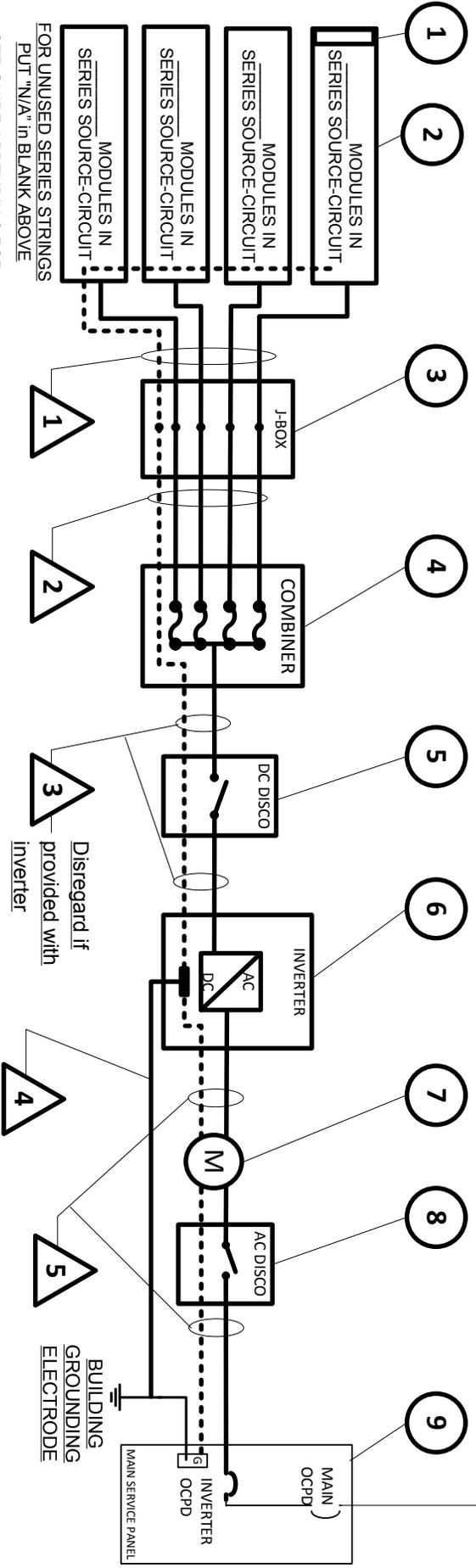
Contractor Name: Address and Phone: <b>Bill and Ted's Solar</b> 456 Excellent Drive San Dimas, CA 800-555-1212		<b>Site Plan</b> for Small-Scale, Single-Phase PV Systems Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., Fontana, CA System AC Size: 6.0 kW Solar Array	
Drawn By:	Bill	SIZE	FSCM NO
Checked By:	Ted	SCALE	NTS
		DWG/NO	REV
		S1.1a	0
		DATE:	SHEET

# STANDARD ELECTRICAL DIAGRAM

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE		
2	PV ARRAY		
3	J-BOX (IF USED)		
4	COMBINER (IF USED)		
5	DC DISCONNECT		
6	DC/AC INVERTER		
7	GEN METER (IF USED)		
8	AC DISCONNECT (IF USED)		
9	SERVICE PANEL		

(SEE NOTE 5 FOR INVERTER OCPDS, ALSO SEE GUIDE SECTION 9)

VAC, \_\_\_\_\_ A MAIN, \_\_\_\_\_ A BUS, \_\_\_\_\_ A INVERTER OCPD



FOR UNUSED SERIES STRINGS PUT "N/A" IN BLANK ABOVE

SEE GUIDE APPENDIX C FOR INFORMATION ON MODULE AND ARRAY GROUNDING

CONDUIT AND CONDUCTOR SCHEDULE				
TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE AND SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>			N/A / N/A
2	BARE COPPER EQ. GRD. COND. (EGC)			N/A / N/A
3	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A
4	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE AND SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>			N/A / N/A
2	BARE COPPER EQ. GRD. COND. (EGC)			N/A / N/A
3	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A
4	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			N/A / N/A

Contractor Name, Address and Phone:

Drawn By: \_\_\_\_\_

Checked By: \_\_\_\_\_

**One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems**

Site Name: \_\_\_\_\_

Site Address: \_\_\_\_\_

System AC Size: \_\_\_\_\_

SCALE	NTS	Date:	DWG NO. E1.1
			REV

# NOTES FOR STANDARD ELECTRICAL DIAGRAM

## PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT ( $I_{mp}$ )	A
MAX POWER-POINT VOLTAGE ( $V_{mp}$ )	V
OPEN-CIRCUIT VOLTAGE ( $V_{oc}$ )	V
SHORT-CIRCUIT CURRENT ( $I_{sc}$ )	A
MAX SERIES FUSE (OCPD)	A
MAXIMUM POWER ( $P_{max}$ )	W
MAX VOLTAGE (TYP 600V <sub>DC</sub> )	V
VOC TEMP COEFF (mV/°C <input type="checkbox"/> or %/°C <input type="checkbox"/> )	
IF COEFF SUPPLIED, CIRCLE UNITS	

## NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX:XX)

## INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	V
MAX POWER @ 40°C	W
NOMINAL AC VOLTAGE	V
MAX AC CURRENT	A
MAX OCPD RATING	A

## SIGNS-SEE GUIDE SECTION 7

### SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	A
RATED MPP VOLTAGE	V
MAX SYSTEM VOLTAGE	V
MAX CIRCUIT CURRENT	A
WARNING: ELECTRICAL SHOCK HAZARD-LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

### SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM	
AC POINT OF CONNECTION	
AC OUTPUT CURRENT	A
NOMINAL AC VOLTAGE	V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

## NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP \_\_\_\_\_°C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE \_\_\_\_\_°C
- 2.) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),
  - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH  $I_{sc}$  OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
  - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH  $I_{sc}$  OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

## NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

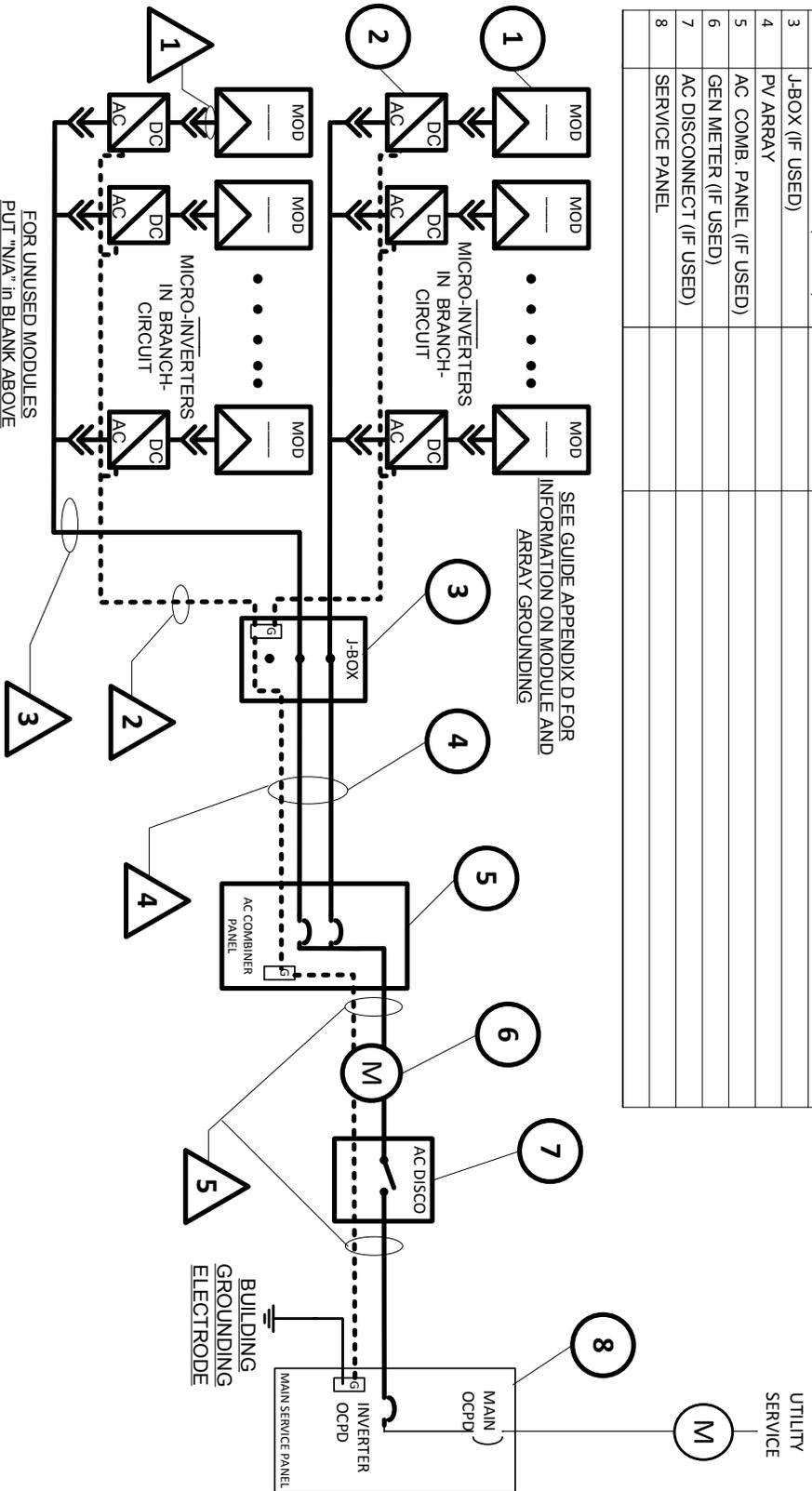
- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF \_\_\_\_\_ INVERTER OCPD(S), ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

## Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Contractor Name: _____ Address and Phone: _____		Site Name: _____ Site Address: _____ System AC Size: _____	
Drawn By: _____ Checked By: _____	SIZE _____ SCALE _____	FSCM NO _____ NTS _____	DWG NO _____ SHEET _____

# MICRO-INVERTER ELECTRICAL DIAGRAM

EQUIPMENT SCHEDULE			
○ TAG	DESCRIPTION	PART NUMBER	NOTES
1	PV DC or AC MODULE		
2	DC/AC INVERTER (MICRO)		
3	J-BOX (IF USED)		
4	PV ARRAY		
5	AC COMB. PANEL (IF USED)		
6	GEN METER (IF USED)		
7	AC DISCONNECT (IF USED)		
8	SERVICE PANEL		



CONDUIT AND CONDUCTOR SCHEDULE					
△ TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>	MFG	MFG Cable	N/A	N/A
2	EGC <input type="checkbox"/> X ALL THAT APPLY	MFG	MFG Cable	N/A	N/A
3	EXTERIOR CABLE LISTED W/ INV.	MFG	MFG Cable	N/A	N/A
4	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			SAME	SAME
	EGC <input type="checkbox"/> X ALL THAT APPLY			SAME	SAME
	NO DC GEC IF 690.35 SYSTEM				
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>			SAME	SAME
	EGC <input type="checkbox"/> X ALL THAT APPLY			SAME	SAME

Contractor Name: Address and Phone:		One-Line Standard Electrical Diagram for Micro-Inverter PV Systems	
Drawn By:		Site Name:	
Checked By:		Site Address:	
SIZE		System AC Size:	
FSCM NO		DWG NO	
NTS		REV	
Date:		0	
SCALE		SHEET	

# NOTES FOR MICRO-INVERTER ELECTRICAL DIAGRAM

**PV MODULE RATINGS @ STC (Guide Section 5)**

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT ( $I_{mp}$ )	
MAX POWER-POINT VOLTAGE ( $V_{mp}$ )	
OPEN-CIRCUIT VOLTAGE ( $V_{oc}$ )	
SHORT-CIRCUIT CURRENT ( $I_{sc}$ )	
MAX SERIES FUSE (OCPD)	
MAXIMUM POWER ( $P_{max}$ )	
MAX VOLTAGE (TYP 600V <sub>DC</sub> )	
VOC TEMP COEFF ( $mV/^{\circ}C$ <input type="checkbox"/> or $\%/^{\circ}C$ <input type="checkbox"/> )	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:  
 OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

**INVERTER RATINGS (Guide Section 4)**

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	
MAX POWER @ 40°C	
NOMINAL AC VOLTAGE	
MAX AC CURRENT	
MAX OCPD RATING	

**SIGNS-SEE GUIDE SECTION 7**

**SIGN FOR DC DISCONNECT**  
 No sign necessary since 690.51 marking on PV module covers needed information

**SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)**  
 SOLAR PV SYSTEM  
 AC POINT OF CONNECTION  
 AC OUTPUT CURRENT  
 NOMINAL AC VOLTAGE  
 THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

**NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):**

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP \_\_\_\_°C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE \_\_\_\_°C
- 2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
  - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH  $I_{sc}$  OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
  - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH  $I_{sc}$  OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

**NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):**

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF INVERTER OUTPUT CIRCUIT OCPD(S). ONE FOR EACH MICRO-INVERTER CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

Contractor Name:  
Address and Phone:

**Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems**

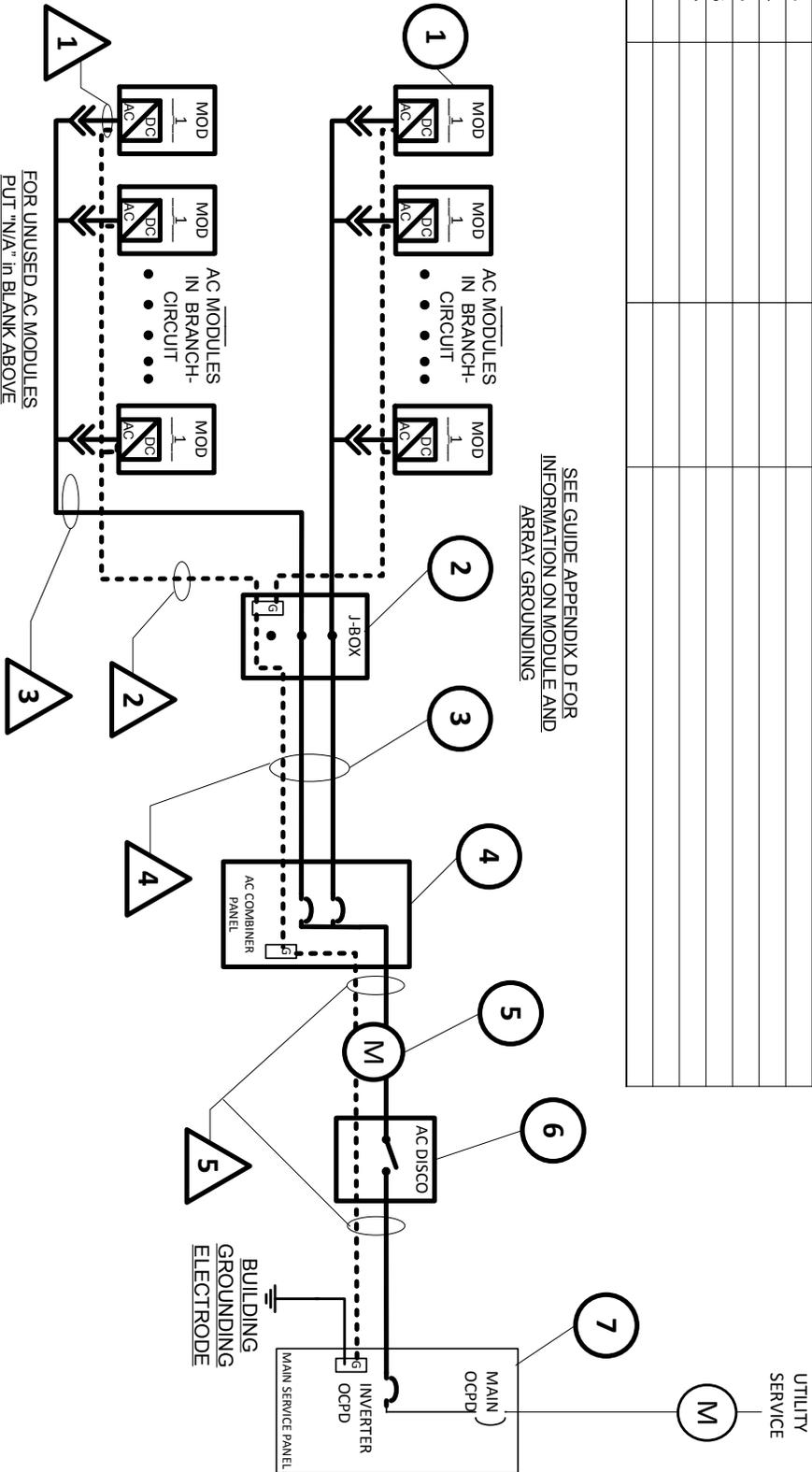
Site Name:  
Site Address:  
System AC Size:

Drawn By:	SIZE	FSCM NO	DWG NO	REV
Checked By:	SCALE	NTS	Date:	SHEET
			E.1.2a	

# AC MODULE ELECTRICAL DIAGRAM

EQUIPMENT SCHEDULE			
○ TAG	DESCRIPTION	PART NUMBER	NOTES
1			
2			
3			
4			
5			
6			
7			

SEE GUIDE APPENDIX D FOR INFORMATION ON MODULE AND ARRAY GROUNDING



FOR UNUSED AC MODULES PUT "N/A" in BLANK ABOVE

CONDUIT AND CONDUCTOR SCHEDULE					
△ TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>				
2	GEC <input type="checkbox"/> EGC <input type="checkbox"/> X ALL THAT APPLY	MFG	MFG Cable	N/A	N/A
3	EXTERIOR CABLE LISTED W/INV.	MFG	MFG Cable	N/A	N/A
4	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
	GEC <input type="checkbox"/> EGC <input type="checkbox"/> X ALL THAT APPLY				
	NO DC GEC. IF 690.35 SYSTEM				
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
	GEC <input type="checkbox"/> EGC <input type="checkbox"/> X ALL THAT APPLY				

Contractor Name, Address and Phone:		One-Line Standard Electrical Diagram for AC Module PV Systems	
Site Name: Site Address: System AC Size:		SIZE ESCMND	DWG/NO E1.1b
Drawn By:	Checked By:	SCALE NTS	REV SHEET
Date:			

# NOTES FOR AC MODULE ELECTRICAL DIAGRAM

**NOTES FOR ALL DRAWINGS:**

OCPPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

**AC MODULE RATINGS (Guide Appendix C)**

AC MODULE MAKE	
AC MODULE MODEL	
NOMINAL OPERATING AC VOLTAGE	
NOMINAL OPERATING AC FREQUENCY	
MAXIMUM AC POWER	
MAXIMUM AC CURRENT	
MAXIMUM OCPPD RATING	

**SIGNS-SEE GUIDE SECTION 7**

**SIGN FOR DC DISCONNECT**

N/A since no dc wiring

**SIGN FOR INVERTER OCPPD AND AC DISCONNECT (IF USED)**

<b>SOLAR PV SYSTEM</b>
<b>AC POINT OF CONNECTION</b>
AC OUTPUT CURRENT
NOMINAL AC VOLTAGE

THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

**NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):**

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP \_\_\_\_ °C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE \_\_\_\_ °C
- 2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR 6 OR LESS CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
- a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 12 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER OCPPD.
- b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 16 AMPS OR LESS WHEN PROTECTED BY A 20-AMP OR SMALLER OCPPD.

**NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):**

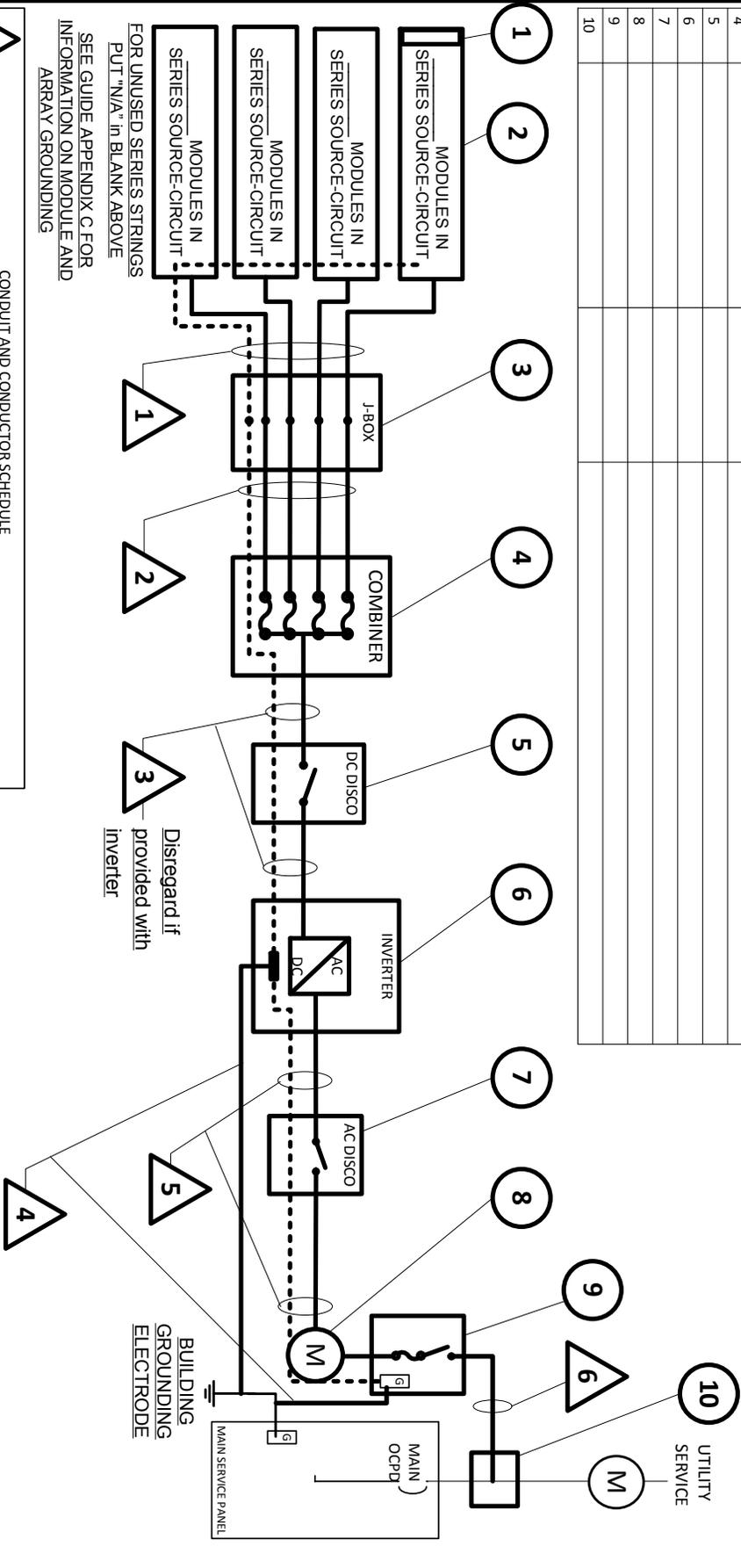
- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPPD RATING AT DISCONNECT (N/A)
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF \_\_\_\_\_ INVERTER OUTPUT CIRCUIT OCPPD(S). ONE FOR EACH AC MODULE CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

**Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems**

Contractor Name: Address and Phone:			
Drawn By:	Bill	SIZE	
Checked By:	Ted	FSCM NO	DWG NO
		SCALE	E1.2b
		NTS	REV
		Date:	0
		Date:	SHEET

# SUPPLY-SIDE CONNECTED ELECTRICAL DIAGRAM

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			



SEE GUIDE APPENDIX C FOR INFORMATION ON MODULE AND ARRAY GROUNDING

CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE 2- <input type="checkbox"/> or PV WIRE <input type="checkbox"/>				
2	BARE COPPER EQ. GRD. COND. (EGC)				
3	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
4	INSULATED EGC				
5	GROUNDING ELECTRODE COND.				
6	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				

Contractor Name:  
Address and Phone:

---

**One-Line Electrical Diagram for Supply-Side Connected Single-Phase PV Systems**

Site Name:  
Site Address:  
System AC Size:

---

Drawn By: \_\_\_\_\_

Checked By: \_\_\_\_\_

SIZE	FSCM NO	DWG NO	REV
SCALE	NTS	Date:	0
			SHEET

# NOTES FOR SUPPLY-SIDE CONNECTED ELECTRICAL DIAGRAM

## SIGNS-SEE GUIDE SECTION Z

### PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I <sub>MP</sub> )	A
MAX POWER-POINT VOLTAGE (V <sub>MP</sub> )	V
OPEN-CIRCUIT VOLTAGE (V <sub>OC</sub> )	V
SHORT-CIRCUIT CURRENT (I <sub>SC</sub> )	A
MAX SERIES FUSE (OCPD)	A
MAXIMUM POWER (P <sub>MAX</sub> )	W
MAX VOLTAGE (TYP 600V <sub>DC</sub> )	V
VOC TEMP COEFF (mV/°C <input type="checkbox"/> or %/°C <input type="checkbox"/> )	
IF COEFF SUPPLIED, CIRCLE UNITS	

### NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

### INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	V
MAX POWER @ 40°C	W
NOMINAL AC VOLTAGE	V
MAX AC CURRENT	A
MAX OCPD RATING	A

### SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	A
RATED MPP VOLTAGE	V
MAX SYSTEM VOLTAGE	V
MAX CIRCUIT CURRENT	A

WARNING: ELECTRICAL SHOCK  
 HAZARD-LINE AND LOAD MAY BE  
 ENERGIZED IN OPEN POSITION

### SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM	
AC POINT OF CONNECTION	A
AC OUTPUT CURRENT	A
NOMINAL AC VOLTAGE	V

THIS PANEL FED BY MULTIPLE  
 SOURCES (UTILITY AND SOLAR)

### NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP \_\_\_\_\_°C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE \_\_\_\_\_°C
- 2.) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5' ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
- a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>SC</sub> OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE
- b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>SC</sub> OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

### NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF \_\_\_\_\_ INVERTER OCPD(S). ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

## Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Contractor Name: Address and Phone:		Site Name: _____ Site Address: _____ System AC Size: _____	
Drawn By:	SIZE		
Checked By:	SCALE	NTS	DATE
			SHEET

# EXPEDITED PERMIT GUIDELINES FOR SMALL-SCALE PV SYSTEMS

## Section 1. Required Information for Permit

1. Site plan showing location of major components on the property. This drawing need not be to scale, but it should represent relative location of components at site. (see supplied example site plan).

*Explanation:* This is a simple diagram to show where the equipment is located on the property. This can be a zone-clearance plot plan with the equipment clearly shown and identified on the plan. If PV array is ground-mounted, clearly show that system will be mounted within allowable zoned setbacks. See site plan example drawing in permit process for reference.

2. Electrical diagram showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).

*Explanation:* The cornerstone of a simplified permit process is the ability to express the electrical design with a generic electrical diagram. This diagram has been designed to accurately represent the majority of single-phase, residential-sized PV systems. PV systems may vary dramatically in PV array layout and inverter selection. However, the majority of small-scale, residential-sized PV systems can be accurately represented by this diagram. This diagram must be fully completed filled out in order for the permit package to be submitted.

3. Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting system.

*Explanation:* At a minimum, specification sheets must be provided for all major components. In addition to the components listed, other important components may be specialty fuses, circuit breakers, or any other unique product that may need to be reviewed by the local jurisdiction. Installation manuals are also listed in this item. This is referring to the brief versions of manuals that are reviewed by the listing agency certifying the product. Some detailed installation manuals can be several dozens or hundreds of pages. If the local jurisdiction feels it is necessary to review these large documents, a good alternative would be for the documents to be supplied electronically, rather than in print.

## Section 2. Step 1: Structural Review of PV Array Mounting System

1. Is the array to be mounted on a defined, permitted roof structure?  Yes  No  
(structure meets modern codes)

*If No, submit completed worksheet for roof structure WKS1.*

*Explanation:* The reference to a defined, permitted roof structure refers to structures that have a clear inspection history so that verification of structural elements is unnecessary. If structural modifications have been made due to remodeling, those changes should be documented through the permit and review process. It also recognizes the fact that code enforcement for roof structural elements has been much more consistent across the United States in the last 35 years. However, there may be many local jurisdictions who have been carefully reviewing roof structures for a much longer period of time. The local jurisdiction should consider extending this limit based on the period that roofs have been consistently inspected. In areas where jurisdictional reviews have not extended 35 years into the past, the jurisdiction may need to get the information from WKS1 to be sure whether or not the proposed PV system is being installed on a typical roof structure or not.

### Roof Information:

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, wood shake, etc.) \_\_\_\_\_

*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc.).*

*Explanation:* There is a need to distinguish if a roof has a lightweight product. Roof structures supporting heavier roofing materials (e.g. slate, heavy masonry) may not have the assumed dead loading and live loading capacities that are found with lighter weight roofing materials. These are much less common roof types and often justify a further review to clarify whether the roof structure is either in compliance or needs enhancement.



2. If a composition shingle roof, does the roof have a single roof covering?  Yes  No

If No, submit completed worksheet for roof structure WKS1.

**Explanation:** Multiple composition roof layers may be taking a portion or all of the assumed additional weight allowance found in the 5 lbs/ft<sup>2</sup> allowance at the end of the mounting system section.

3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk.) \_\_\_\_\_

**Explanation:** The weatherproofing method needs to be specifically identified so that plan checkers and field inspectors are notified ahead of time of the method being used. Some jurisdictions may constrain weatherproofing methods and materials. Sealant information should confirm that the product is compatible with the roofing material.

### Mounting System Information:

1. Is the mounting structure an engineered product designed to mount PV modules with no more than an 18" gap beneath the module frames?  Yes  No

If No, provide details of structural attachment certified by a design professional.

**Explanation:** Non-engineered racking systems have undefined capabilities. PV systems should only be mounted using systems that are engineered and designed for that purpose. Structural loading of a roof is more complex when modules are angled more than 18" above the roof surface. For simplicity, this process has been limited to PV arrays that are mounted parallel to the roof surface or angled with no more than an 18" gap between the module frame and the roof surface. If an installer chooses to mount the PV modules with a larger gap or if they use a mounting system of unique design, then the mounting design would require a review by a design professional.

2. For manufactured mounting systems, fill out information on the mounting system below:

- a. Mounting System Manufacturer \_\_\_\_\_ Product Name and Model# \_\_\_\_\_ (self-explanatory)
- b. Total Weight of PV Modules and Rails \_\_\_\_\_ lbs (include total weight of all hardware used along with module weight)
- c. Total Number of Attachment Points \_\_\_\_\_ (self-explanatory)
- d. Weight per Attachment Point ( $b \div c$ ) \_\_\_\_\_ lbs (if greater than 45 lbs, see WKS1)

**Explanation:** 45 lbs has been used by some jurisdictions as a reasonable level below which point loading of roof joists and trusses can be ignored. Most standard mounting systems have point loadings of 25-35 lbs per attachment.

e. Maximum Spacing Between Attachment Points on a Rail \_\_\_\_\_ inches (see product manual for maximum spacing allowed based on wind loading)

**Explanation:** Depending on the wind loading requirements of a particular jurisdiction, the spacing or attachments may be dictated by the manufacturer's directions. For instance, a particular manufacturer may allow a 72" attachment spacing for a 90 MPH windspeed design, but the spacing reduces to a maximum of 48" when the design windspeed exceeds 100 MPH.

f. Total Surface Area of PV Modules (square feet) \_\_\_\_\_ ft<sup>2</sup>

**Explanation:** Take the surface area of a single module, and multiply it by the total number of modules in the roof-mounted system.

g. Distributed Weight of PV System on Roof ( $b \div f$ ) \_\_\_\_\_ lbs/ft<sup>2</sup>

If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.

**Explanation:** The 5 lbs/ft<sup>2</sup> limit is based on two things: 1) the roof is typical of standard code-compliant roof structures so that the structure either has the proper spans and spacing, or proper use of engineered trusses (first item under "Step 1: Structural Review"); and, 2) there is a single layer of roofing so that the normal weight allowance for additional roof layers is unused and available for the weight of the PV system. For applications on lightweight masonry roofing materials and other lightweight roofing products (e.g. metal, shake, etc.), these materials do not accept multiple layers and therefore the 5 lbs/ft<sup>2</sup> allowance is used to identify the maximum allowable additional weight for roofs that are exchanging the allowable live load for a dead load that prevents live load such as people walking on the roof.



### Section 3. Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

In order for a PV system to be considered for an expedited permit process, the following must apply:

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.

*Explanation:* PV utility-interactive inverters must be specifically listed and labeled for this application [NEC 690.60 and 690.4] (Brackets refer to sections in the 2011 NEC throughout this document.) Without this specific identification process an unacceptable amount of review would be necessary to approve an inverter. Inverters that pass UL1741 and are listed as “utility-interactive” have met the requirement. Over 500 inverters currently meet this requirement. An inclusive list of these inverters is available online at <http://gosolarcalifornia.com/equipment/inverter.php>.

PV modules must also be listed and identified for use in PV systems [NEC 690.4]. PV modules that pass UL1703 and have a 600-Volt maximum voltage meet the requirement. A list of these modules is available online at <http://gosolarcalifornia.com/equipment/pvmodule.php>. Source-circuit combiners must be listed and labeled to meet the dc voltage requirements of the PV system or be specifically tested for PV systems and clearly state the allowable maximum current and voltage [NEC 690.4].

2. The PV array is composed of 4 series strings or less, for AC module and micro-inverter arrays, PV array is composed of 4 branch circuits or less.

*Explanation:* The purpose of this requirement is to limit the number of options of what can comply as a “simple” system so that a single electrical diagram can be used to describe a large percentage of the systems being installed. The electrical diagram can handle up to 4 strings or branch circuits in parallel. This ensures that the conduit will have no more than eight current-carrying conductors, which the ampacity tables in this guide have been based upon.

3. The combined inverter continuous AC power output 13,440 Watts or less.

*Explanation:* The limit is set to stay generally within electrical interconnections that would be considered simple and possibly able to meet the 120% of busbar rating allowance in NEC 690.64(B) in a residence (Minimum breaker for a 13.44 kWac PV system is 70 amps at 240Vac). A 70-amp breaker is important since a 225-amp busbar in a 200-amp panel will allow a 70-amp PV breaker. Since this does happen from time to time, and an installer can choose to install such a panelboard, it is considered the largest “simple” PV system for purposes of this guideline. A table of breaker/ panelboard combinations is in Section 9 of this Guideline.

4. The ac interconnection point is on the load side of service disconnecting means (NEC 690.64(B)).

*Explanation:* Load side interconnections are by far the most common, particularly in residential applications. Any line side connection is covered by NEC 690.64(A) and 230.82. Although line side connections can be quite straightforward, they should require an additional step in the approval process and require a slightly different electrical drawing.

5. One of the standard electrical diagrams can be used to accurately represent the PV system:

- E1.1: Standard System
- E1.1a: Micro-Inverter
- E1.1b: AC Module
- E1.1c: Supply-Side Connected

Each diagram has a corresponding notes form. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

*Explanation:* The basis for a simplified permit is the use of the standard electrical diagram. Clearly, PV systems can vary significantly in PV array layout and inverter selection. However, the majority of small-scale, residential-sized PV systems can be accurately represented by this diagram. This diagram must be completely filled out in order for the permit package to be considered complete. This diagram is not intended for use with battery-based systems. Interactive PDF versions of all the standard electrical diagrams can be found at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting). These diagrams allow values to be input and the page to be saved and printed.



## Section 4. Inverter Information

A copy of the manufacturer's specification sheet is required for a permit submittal. In addition, a printed out digital photo of the inverter listing label can be very helpful for gathering the ratings of the equipment.

- a. INVERTER MAKE: This is the manufacturer's name (e.g. Motech, PV Powered, SMA, etc.)
- b. INVERTER MODEL #: This is the model number on the listing label (e.g. PVMate 3840U, PVP 5200, SB7000US, etc.)
- c. MAX DC VOLTAGE RATING: Provided either on listing label or specification sheet.
- d. MAX POWER @ 40°C: The maximum continuous output power at 40°C is required information for the listing label and the Go Solar California website. If the specification sheet does not clearly state the value, consult either of these other two sources.
- e. NOMINAL AC VOLTAGE: This is the ac output voltage of the inverter as configured for this project. Some inverters can operate at multiple ac voltages.
- f. MAX OCPD RATING: This is the maximum overcurrent protective device (OCPD) rating allowed for the inverter. This is either stated on the listing label or in the installation manual. Sometimes this is also listed on the specification sheet—but not always. It is important to check that the inverter OCPD rating in the panel is less than or equal to this maximum rating to preserve the listing of the inverter.

## Section 5. Module Information

A copy of the manufacturer's specification sheet is required for a permit submittal. In addition, a printed out digital photo of the module listing label can be very helpful for gathering the ratings of the equipment. A prerequisite for a code-approved installation is the use of PV modules listed UL 1703 [NEC 690.4]. For a current list of modules that are listed to UL 1703, visit the *Go Solar California* website, <http://gosolarcalifornia.com/equipment/pvmodule.php>.

*Explanation: This module information is particularly important since it is used to calculate several current and voltage parameters required by the National Electrical Code (NEC). Listing information is necessary for NEC testing requirements [NEC 90.7, 100, 110.3, 690.4].*

- a) MODULE MANUFACTURER: This is the manufacturer's name (e.g. BP Solar, Evergreen, Solar World, Sharp, SunPower, Suntech etc.)
- b) MODULE MODEL #: This is the model number on the listing label (e.g. BP175B, EGS185, SW175 Mono, ND-U230C1, SP225, STP175S, etc.)
- c) MAXIMUM POWER-POINT CURRENT ( $I_{MP}$ )  
*Explanation: The rated IMP is needed to calculate system operating current. This is the current of the module when operating at STC and maximum power.*
- d) MAXIMUM POWER-POINT VOLTAGE ( $V_{MP}$ )  
*Explanation: The rated  $V_{MP}$  is needed to calculate system operating voltage. This is the voltage of the module when operating at STC and maximum power.*
- e) OPEN-CIRCUIT VOLTAGE ( $V_{OC}$ )  
*Explanation: The rated  $V_{OC}$  is needed to calculate maximum system voltage specified in NEC 690.7.*
- f) SHORT-CIRCUIT CURRENT ( $I_{SC}$ )  
*Explanation: The rated  $I_{SC}$  is needed to calculate maximum current specified in NEC 690.8(A).*
- g) MAXIMUM SERIES FUSE (OCPD)  
*Explanation: The maximum series fuse (OCPD) rating is needed to ensure that the proper overcurrent protection is provided for the modules and array wiring.*
- h) MAXIMUM POWER ( $P_{MAX}$ ) at Standard Test Conditions (STC is 1000W/m<sup>2</sup>, 25°C cell temp, & Air Mass 1.5)  
*Explanation: Maximum power at STC specifies the rated power of the PV module under simulated conditions.*

i) MAXIMUM SYSTEM VOLTAGE

*Explanation:* Maximum system voltage (often but not always 600 V<sub>dc</sub>) is needed to show that the NEC 690.7 voltage does not exceed this value.

## Section 6. Array Information

This section defines the configuration of the PV array. PV arrays are generally made up of several modules in series, called “source circuits.” These source circuits are often paralleled with multiple other source circuits to make up the entire dc generating unit called an “array.” The last four items related to the PV array must be calculated and posted on a sign at the PV power source disconnect. The first two items a) and b) characterize the array design and provide the information necessary to calculate the four items needed to produce proper array identification for the PV power source sign discussed in Section 7 that is required at the site.

a) NUMBER OF MODULES IN SERIES

*Explanation:* For simplicity, this diagram only addresses the most common configuration of PV modules—multiple modules in series. Although single module PV power sources exist, it is more common to see PV arrays configured with as many as 12 to 24 modules in series.

b) NUMBER OF PARALLEL CIRCUITS

*Explanation:* Since single-phase inverters can be as large as 12 kW or more, and the largest PV source circuits are only about 2 to 5 kW, it is common for PV arrays to have two or more source circuits in parallel. From Example in Appendix A:

Number of modules in series = 14  
Number of parallel source circuits = 3  
Total number of modules = 14 × 3 = 42

c) LOWEST EXPECTED AMBIENT TEMP

*Explanation:* Up through the 2008 edition, the NEC has not clearly defined “lowest expected ambient temperature.” ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) has performed statistical analysis on weather data from the National Weather Service. These data include values for the mean extreme temperatures for the locations with temperature data. The mean extreme low temperature is the coldest expected temperature for a location. Half of the years on record have not exceeded this number, and the rest have exceeded this number. These data are supplied in the appendix for reference. The 2011 NEC includes an informational Note to 690.7 that specifies the use of the ASHRAE mean extreme value for lowest expected ambient temperature when calculating maximum system voltage.

d) HIGHEST CONTINUOUS TEMP (ambient)

*Explanation:* Up through the 2011 edition, the NEC has not clearly defined “highest continuous ambient temperature.” Continuous is defined in the NEC as a 3-hour period Article 100. ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) has performed statistical analysis on weather data from the National Weather Service. These data include design values of 0.4%, 1%, and 2% for each month signifying that the temperature only exceeds the recorded value up to the specified time for a given location with temperature data. The average for June, July, and August of the 2% value has been chosen by the Copper Development Association as the value that best represents a condition that would create the 3-hour continuous condition referred to in Article 100. Two percent of one month is about 14 hours. Since high temperatures usually last for several days in most locations, the assumption is that at least one or two 3-hour high temperature events will happen during a given month. These data are supplied in the appendix for reference. If a designer seeks a more conservative approach to temperature, the 0.4% data for hottest month of the year is an alternative value. 0.4% of one month is about 3 hours. Using the 0.4% value assumes that all 3 hours occur on the same day which would be the statistical worst case scenario. Both the 3-month average 2% data and the hottest single month 0.4% data are supplied in the appendix for reference.



## Section 7. Signs

### a) PV POWER SOURCE

#### i) RATED MPP (MAXIMUM POWER-POINT) CURRENT (sum of parallel source circuit operating currents)

*Explanation:* Rated MPP current is found by multiplying the module rated MPP current for a module series string by the number of source circuits in parallel.

From the example in Appendix A:

$$I_{MP} = 7.80 \text{ amps}$$

$$\text{Number of source circuits in parallel} = 3$$

$$7.80 \text{ amps} \times 3 = 23.4 \text{ amps}$$

#### ii) RATED MPP (MAXIMUM POWER-POINT) VOLTAGE (sum of series modules operating voltage in source circuit)

*Explanation:* Operating voltage is found by multiplying the module rated MPP voltage by the number of modules in a series source circuit.

From the example in Appendix A:

$$V_{MP} = 29.5 \text{ Volts}$$

$$\text{Number of modules in series} = 11$$

$$29.5 \text{ Volts} \times 11 = 325 \text{ Volts}$$

#### iii) MAXIMUM SYSTEM VOLTAGE [NEC 690.7]

*Explanation:* Maximum system voltage is calculated by multiplying the value of  $V_{oc}$  on the listing label by the appropriate value on Table 690.7 in the NEC, and then multiplying that value by the number of modules in a series string. The table in the NEC is based on crystalline silicon modules and uses lowest expected ambient temperature at a site to derive the correction factor. Some modules do not have the same temperature characteristics as crystalline silicon so the manufacturer's instructions must be consulted to determine the proper way to correct voltage based on lowest expected ambient temperature. As of the 2008 NEC, the manufacturer's temperature correction factor must be used for all modules, regardless of construction, if the information is supplied. All known listed modules currently provide this information.

From the example in Appendix A:

$$\text{Module } V_{oc} = 37.0 \text{ Volts}$$

$$\text{Rating temperature} = 25^{\circ}\text{C}$$

$$\text{Number of Modules in Series} = 11$$

$$\text{Lowest expected ambient temperature (ASHRAE)} = 1^{\circ}\text{C (Ontario, California)}$$

$$\text{Maximum System Voltage} = V_{MAX} = V_{oc} \times \# \text{ of Modules in Series} \times \text{Temperature Correction Factor}$$

*Method 1— Module Manufacturer's Temperature Correction Factor—Percentage Method*

$$\text{Temperature Coefficient for } V_{oc} = \alpha V_{oc} = -0.37\%/^{\circ}\text{C} = -0.0037/^{\circ}\text{C}$$

$$\text{Temperature Correction Factor} = 1 + \alpha \text{ VOC (\%)} \times (\text{Temp}_{LOW} - \text{Temp}_{RATING})$$

$$= 1 + (-0.0037/^{\circ}\text{C}) \times (-1^{\circ}\text{C} - 25^{\circ}\text{C})$$

$$= 1 + 0.0962 = 1.0962$$

$$V_{MAX} = 37\text{V} \times 11 \times 1.0962 = 446 \text{ Volts} < 500\text{Volts (compliant for a } 500V_{MAX} \text{ inverter)}$$

*Method 2— Module Manufacturer's Temperature Correction Factor—Voltage Method*

$$\text{Temperature Coefficient for } V_{oc} = \alpha V_{oc} = 137\text{mV}/^{\circ}\text{C} = 0.137 \text{ V}/^{\circ}\text{C}$$

$$\text{Temperature Correction Factor} = 1 + [\alpha \text{ VOC (V)} \times (\text{Temp}_{LOW} - \text{Temp}_{RATED}) \div \text{VOC}]$$

$$= 1 + [0.137 \text{ V}/^{\circ}\text{C} \times (-1^{\circ}\text{C} - 25^{\circ}\text{C}) \div 37\text{V}]$$

$$= 1 + [5.206\text{V} \div 37\text{V}] = 1.0963$$

$$V_{MAX} = 37\text{V} \times 11 \times 1.0963 = 446 \text{ Volts} < 500\text{Volts (compliant for a } 500V_{MAX} \text{ inverter)}$$

*Method 3—Table 690.7 Temperature Correction Factor*

From row for ambient temperature =  $-1^{\circ}\text{C}$  to  $-5^{\circ}\text{C}$  1.12

$$V_{MAX} = 37\text{V} \times 11 \times 1.12 = 456 \text{ Volts} < 500\text{Volts (compliant for a } 500V_{MAX} \text{ inverter)}$$

#### iv) MAXIMUM CIRCUIT CURRENT [NEC 690.8]

*Explanation:* The maximum circuit current is calculated by multiplying the rated  $I_{sc}$  of the PV module by the number of source circuits operating in parallel, then multiplying this value by 125% to account for extended periods of sunlight above the tested solar intensity (rated irradiance = 1000

$W/m^2$ ; maximum continuous irradiance =  $1250 W/m^2$ ). The NEC in 690.53 asks for the short-circuit current in the 2005 and 2008 editions, but the 2008 edition clarifies in a Fine Print Note that the intended value is the maximum circuit current as defined in 690.8 (A) and is a worst-case continuous short-circuit current value.

From the example in Appendix A:

$$I_{sc} = 8.4 \text{ amps}$$
$$\text{Number of source circuits in parallel} = 3$$
$$8.4 \text{ amps} \times 3 \times 1.25 = 31.5 \text{ amps}$$

b) WARNING SIGN REQUIRED BY NEC 690.17.

*Explanation:* Any time a switch can have the load side energized in the open position, a warning sign must be placed on the switch. This is nearly always true of the dc disconnect at the inverter. The line side of the switch is energized by the PV array, while the load side of the switch is often energized by input capacitors of the inverter. These capacitors can remain energized for five minutes or more as the bleed resistors dissipate the charge over time. The warning sign should read essentially as follows:

WARNING: ELECTRICAL SHOCK HAZARD—LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION

c) Point of Connection Sign [NEC 690.54]

(To be placed on the Solar AC Disconnect and AC Point of Connection locations)

i) AC OUTPUT CURRENT

*Explanation:* The ac output current, or rated ac output current as stated in the NEC, at the point of connection is the maximum current of the inverter output at full power. When the rated current is not specifically called out in the specification sheets, it can be calculated by taking the maximum power of the inverter, at  $40^\circ$ , and dividing that value by the nominal voltage of the inverter.

From the example in Appendix A:

$$\text{Maximum Inverter Power} = 7,000 \text{ watts}$$

$$\text{Nominal Voltage} = 240 \text{ Volts}$$

$$I_{RATED} = 7,000 \text{ W} / 240 \text{ V} = 29.2 \text{ amps}$$

ii) NOMINAL AC VOLTAGE

*Explanation:* The nominal ac voltage, or nominal operating ac voltage as stated in the NEC, at the point of connection is the nominal voltage (not maximum or minimum) of the inverter output. It will be the same as the service voltage. Most residential inverters operate at 240 Volts.

From the example in Appendix A:

$$\text{Nominal Voltage} = 240 \text{ Volts}$$

d) PV System Disconnect Location Directory [NEC 690.56(B)]

(To be placed at service disconnect, if PV System Disconnect is not located at the same location)

*Explanation:* For first responders, it may not be readily apparent that a PV system has been installed on site. This directory indicates that a PV system has been installed on site and shows the disconnect location. This is only required if the PV disconnect is not immediately adjacent to the existing service disconnect.

## Section 8. Wiring and Overcurrent Protection

### a) DC Wiring Systems:

#### Source-circuit conductors:

##### In Exposed Locations:

PV module interconnections are generally  $90^\circ\text{C}$  wet-rated conductors NEC 690.31 (A) FPN. The same conductor type is typically used for all home run conductors needed for source circuit conductors in exposed locations.

Allowable wire types are as follows:

- USE-2 single conductor cable for exposed locations. [NEC 690.31 (B)]
- PV Wire or PV Cable as a single conductor for exposed locations (required for all ungrounded systems). [NEC 690.31 (B), 690.3(0)(3)]



*Explanation for the need for High Temperature Conductors:* Typical temperature for PV modules in full sun at 20°C outdoor temperature is 50°C. This is a 30°C rise above outdoor temperatures. On the hottest day of the year, outdoor temperatures can reach a continuous temperature of 41°C in many hot locations throughout the United States. This means that the PV module could be operating at 71°C on the hottest day of the year (41°C + 30°C = 71°C). 75°C wire is insufficient for connection to a hot PV module under this condition.

To further support the concern over the high temperature of PV modules, a fine print note has been added to the 2005 NEC.

**“NEC 690.31 (A) FPN:** Photovoltaic modules operate at elevated temperatures when exposed to high ambient temperatures and to bright sunlight. These temperatures may routinely exceed 70°C (158°F) in many locations. Module interconnection conductors are available with insulation rated for wet locations and a temperature rating of 90°C (194°F) or greater.”

### **In Conduit on Rooftops:**

THREE OPTIONS FOR SOURCE CIRCUIT CONDUCTOR TYPE (INSIDE CONDUIT CHOOSE ONE) THWN-2, XHHW-2 and RHW-2

*Explanation:* Conductors in conduit, when exposed to direct sunlight, must account for the higher temperatures caused by intense sunlight and the proximity of the roof. The 2005 NEC first recognized the issue of sunlit conduit in a fine print note in NEC 310.10.

**“310.10 FPN No. 2:** Conductors installed in conduit exposed to direct sunlight in close proximity to rooftops have been shown, under certain conditions, to experience a temperature rise of 17°C (30°F) above ambient temperature on which the ampacity is based.”

The 2008 NEC codified this issue by classifying the temperatures based on the height above the roof surface. On residential roofs, where conduit typically is spaced between ½” and 3 ½” above the roof surface, the temperature adder is stated as 22°C above the ambient temperature according to NEC Table 310.15(B)(2)(c): in the 2008 NEC, and Table 310.15 (B)(3)(c) in the 2011 NEC. Using this adder, along with the ASHRAE 2% design data for the hottest location in the U.S. (Palm Springs, CA is 44°C), produces a design temperature of 66°C and correction factor of 0.58 for 90°C conductors based on NEC Table 690.31 and Table 310.16 in the 2008 NEC, and 310.15(B)(16) in the 2011 NEC. If nine conductors or less are in the exposed conduit (4 pairs of conductors or less), then the conduit fill correction factor is 0.7 according to NEC Table 310.15(B)(2)(a): in the 2008 NEC, and Table 310.15(B)(3)(a) in the 2011 NEC. Putting all these correction factors together means that the 30°C conductor ampacity can be calculated as follows:

If only two strings in parallel (no fuses):

$$I_{30^{\circ}\text{C}} = I_{\text{MAX}}/0.58/0.7 = 2.46 \times I_{\text{MAX}}$$

When  $I_{\text{SC}} = 12.8$  amps or less, then  $I_{\text{MAX}} = I_{\text{SC}} \times 1.25 = 16$  amps or less.

When  $I_{\text{MAX}} = 16$  Amps, then  $I_{30^{\circ}\text{C}} = 39.4$  Amps (10 AWG, 90°C required (NEC Table 310.16))

When  $I_{\text{SC}} = 9.6$  amps or less, then  $I_{\text{MAX}} = I_{\text{SC}} \times 1.25 = 12$  amps or less.

When  $I_{\text{MAX}} = 12$  Amps, then  $I_{30^{\circ}\text{C}} = 29.5$  Amps (12 AWG, 90°C required (NEC Table 310.16))

When  $I_{\text{SC}} = 6.4$  amps or less, then  $I_{\text{MAX}} = I_{\text{SC}} \times 1.25 = 8$  amps or less.

When  $I_{\text{MAX}} = 8$  Amps, then  $I_{30^{\circ}\text{C}} = 19.7$  Amps (14 AWG, 90°C required (NEC Table 310.16))

If fuses are needed to protect PV modules (most cases), a shortcut to choose a conductor of sufficient ampacity is to use the following calculation:

$$I_{30^{\circ}\text{C}} = I_{\text{FUSE}}/0.58/0.7 = 2.46 \times I_{\text{FUSE}}$$

When  $I_{\text{SC}} = 6.4$  amps or less, then  $I_{\text{MAX}} = I_{\text{SC}} \times 1.25 = 8$  amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 10 amps ( $I_{\text{FUSE}} = I_{\text{MAX}} \times 1.25 = 10\text{A}$ ).

When  $I_{\text{FUSE}} = 10$  Amps, then  $I_{30^{\circ}\text{C}} = 2.46 \times 10\text{A} = 24.6$  Amps (14 AWG, 90°C required (NEC Table 310.16) -10A fuse to protect the conductor)

When  $I_{\text{SC}} = 7.68$  amps or less, then  $I_{\text{MAX}} = I_{\text{SC}} \times 1.25 = 9.6$  amps. The minimum overcurrent protective device (OCPD) as required by NEC 690.8(B) is 12 amps ( $I_{\text{FUSE}} = I_{\text{MAX}} \times 1.25 = 12\text{A}$ ).

When  $I_{\text{FUSE}} = 12$  Amps, then  $I_{30^{\circ}\text{C}} = 2.46 \times 12\text{A} = 29.5$  Amps (12 AWG, 90°C required (NEC Table 310.16) -12A fuse to protect the conductor)



When  $I_{SC} = 9.6$  amps or less, then  $I_{MAX} = I_{SC} \times 1.25 = 12$  amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 15 amps ( $I_{FUSE} = I_{MAX} \times 1.25 = 15A$ ).

When  $I_{FUSE} = 15$  Amps, then  $I_{30^{\circ}C} = 2.46 \times 15A = 36.9$  Amps (10 AWG, 90°C required (NEC Table 310.16) -15A fuse to protect the conductor)

When  $I_{SC} = 12.8$  amps or less, then  $I_{MAX} = I_{SC} \times 1.25 = 16$  amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 20 amps ( $I_{FUSE} = I_{MAX} \times 1.25 = 20A$ ).

When  $I_{FUSE} = 20$  Amps, then  $I_{30^{\circ}C} = 2.46 \times 15A = 49.2$  Amps (8 AWG, 90°C required (NEC Table 310.16) -20A fuse to protect the conductor). However, the NEC in 240.4(B) allows a conductor with an ampacity that falls between two standard OCPD sizes to be rounded up to the next higher OCPD size. Since a 10 AWG conductor has an ampacity of 16.24A after conditions of use are applied ( $I_{10AWG} = 40A \times 0.58 \times 0.7 = 16.24$ ), it is acceptable to protect a 10 AWG conductor with a 20A fuse according to NEC 240.4(B).

Since the highest  $I_{SC}$  module commonly available as of the writing of this guide is less than 12.8 amps, 10 AWG conductors will always work regardless of location in the U.S. as long as there are no more than 9 current carrying conductors in the conduit and the conduit is at least 0.5" above the roof surface. Smaller wire can be used according to the  $I_{SC}$  of the modules being used and the number of conductors in the conduit. These calculations are provided so that contractors and jurisdictions will not need to repeat these standard calculations over and over.

The following table (Conductor Sizing Chart) summarizes the minimum wire size and overcurrent devices for circuits with overcurrent devices from 10 amps up to 400 amps in the hottest U.S. location. Wire size is adjusted for number of conductors in the raceway and is listed as minimum in case size needs to be increased to account for voltage drop on long circuits.

CONDUCTOR SIZING CHART FOR HOTTEST U.S. CLIMATE						
For Sunlit Raceway 0.5"-3.5" from Roof and Max 2% Design Temp - 47°C						
80% Duty Fuses		100% Duty Fuses		Minimum Conductor Size in Raceway		
Fuse Size	Max Rated ISC	Fuse Size	Max Rated ISC	Based on # of Cond. in Raceway (AWG)		
Amps	Amps	Amps	Amps	8 conductors	4-6 cond.	2 cond.
10	6.4	10	8	14	14	14
12	7.68	12	9.6	12	14	14
15	9.6	15	12	10	10	14
20	12.8	20	16	10	10	12
25	16	25	20	8	8	10
30	19.2	30	24	6	8	8
35	22.4	35	28	6	6	
40	25.6	40	32	4	4	6
45	28.8	45	36	3	4	6
50	32	50	40	2	3	4
60	38.4	60	48	2	3	4
70	44.8	70	56	1	2	3
80	51.2	80	64	2/O	1/O	2
90	57.6	90	72	3/O	2/O	1
100	64	100	80	3/O	2/O	1/O
110	70.4	110	88	4/O	3/O	2/O
125	80	125	100	250MCM	4/O	2/O
150	96	150	120	300MCM	250MCM	3/O
175	112	175	140	400MCM	350MCM	4/O
200	128	200	160	2-3/O	400MCM	300MCM
225	144	225	180	2-4/O	500MCM	350MCM
250	160	250	200	2-250MCM	2-4/O	500MCM
300	192	300	240	2-300MCM	2-250MCM	600MCM
350	224	350	280	2-400MCM	2-350MCM	700MCM
400	256	400	320	2-500MCM	2-400MCM	1000MCM

## b) AC Wiring Systems

Inverter Output Circuit overcurrent protection should be sized and protected according to the manufacturer's directions. The circuit and corresponding overcurrent protection should be sized at a 125% of the maximum continuous output of the inverter [NEC 215.3 Overcurrent for Feeder Circuits, and NEC 690.8(A)(3) and 690.8(B)]. The 125 percent increase over the maximum Inverter Output Circuit current is to account for the standard listing of overcurrent devices to 80% of maximum circuit current for continuous duty. Listed inverters have a maximum allowable overcurrent protection device requirement that is printed on the listing label or found in the installation manual.

*Explanation: For instance, the fictitious inverter in the example in Appendix A, the AI-7000 has a maximum continuous output of 29.2 amps and a maximum allowable overcurrent protection of 50 amps. This means that the minimum allowable overcurrent is 40 amps ( $29.2 \text{ amps} \times 1.25 = 36.5 \text{ amps}$ —round up to the next standard size, which is 40 amps) and a maximum of 50 amps. Normally the minimum allowable breaker size is used since the panelboard supply breakers are constrained to 120% of the panelboard busbar rating.*

*From the example in Appendix A:*

*Inverter continuous output rating = 7000 Watts*

*Nominal inverter voltage = 240 Volts*

*Maximum operating current =  $7000 \text{ Watts} / 240 \text{ Volts} = 29.2 \text{ Amps}$*

*Min. Inverter Output Circuit ampacity =  $29.2 \text{ Amps} \times 1.25 = 36.5 \text{ Amps}$*

### Section 9. AC Point of Connection

NEC 705.12 (D) in the 2011 NEC and 690.64 (B) in the 2008 NEC covers the requirements for Point of Connection of the PV inverter to the building electrical system. The most common method of connection is through a dedicated circuit breaker to a panelboard busbar. The sum of the supply breakers feeding the busbar of a panel can be up to 120% of the busbar rating. Appendix C treats this subject in detail.

*Explanation: A service panel containing a 200-amp busbar and a 200-amp main breaker will allow breakers totaling 120% of the busbar rating (240-amps). Since the main breaker is 200 amps, the PV breaker can be up to 40 amps without exceeding the 120% allowance. For a service panel with a 125-amp busbar and a 100-amp main breaker, this provision will allow up to a 50 amp breaker ( $125 \text{ amps} \times 1.2 = 150 \text{ amps}$ ;  $150 \text{ amps} - 100 \text{ amp main breaker} = 50 \text{ amp PV breaker}$ ).*

A provision in the 2005 NEC clarifies the fact that dedicated circuit breakers backfed from listed utility-interactive inverters do not need to be individually clamped to the panelboard busbars. This has always been the case, but many inspectors have employed the provisions of NEC 408.36(F) that the breaker be secured in place by an additional fastener. Utility-interactive inverters do not require this fastener since they are designed to shut down immediately should the dedicated breaker become disconnected from the bus bar under any condition. This provision is repeated in the 2008 NEC in a clear and concise statement:

**“NEC 690.64(B)(6) Fastening.** *Listed plug-in-type circuit breakers backfed from utility-interactive inverters complying with 690.60 shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.*”

Since 690.64(B) and 705.12(D) are nearly identical in the 2008 NEC, the 2011 NEC references 705.12(D) in 690.64(B) so that all utility interactive inverter interconnections are covered in the same section. This will help consistency among other inverter-based technologies such as fuel cells, wind, and micro-turbines. The table below, or Table of NEC 690.64(B) AC Interconnection Options, shows the how the maximum current of the inverter (column 1) requires a minimum size OCPD (column 2), which requires a minimum size conductor (column 3), which requires a compatible busbar/main breaker combination in the panelboard (column 4). The way to understand column 4, minimum busbar/main breaker combinations is to look at the row that coincides with the particular breaker being selected (from column 2) and use any combination from column 4 found





on that row or higher in the table. For instance, a 40-amp inverter breaker works with a 200/200 panel combination, but it also works with a 125/100 combination found on the row above. The 40-amp breaker does not work on the 150/150 combination, since the largest breaker would be 30 amps for the 150/150 combination. Conductor size is listed as minimum in case size needs to be increased to account for voltage drop on long circuits.

TABLE OF NEC 690.64(B) AC INTERCONNECTION OPTIONS

Maximum Inverter Current	Required Inverter OCPD Size	Minimum Conductor Size in Conduit	Minimum Busbar/Main Breaker Combinations (Busbar Amps/Main Amps)
64 Amps	80 Amps	4 AWG	400/400; 200/150
56 Amps	70 Amps	4 AWG	225/200; 250/225
48 Amps	60 Amps	6 AWG	300/300; 200/175
40 Amps	50 Amps	8 AWG	125/100; 150/125
36 Amps	45 Amps	8 AWG	225/225
32 Amps	40 Amps	8 AWG	200/200
24 Amps	30 Amps	10 AWG	150/150
16 Amps	20 Amps	12 AWG	100/100; 70/60
12 Amps	15 Amps	14 AWG	80/80

## Section 10. Grounding

### a) System Grounding

The NEC requires [NEC 690.41] that all systems operating above 50 volts have one conductor referenced to ground unless the system complies with the requirements of NEC 690.35 for ungrounded PV arrays. For most PV systems, this connection is made in the inverter during manufacture, not on site by the installer.

### b) Equipment Grounding

The code also requires that all exposed non-current-carrying metal parts of module frames, equipment, and conductor enclosures be grounded regardless of system voltage [NEC 690.43]. The grounding of module frames has received significant attention in the last several years. Many jurisdictions, with a heightened concern over the issue, have dramatically restricted effective grounding options. A discussion on module frame grounding is found in Appendix D.

### c) Sizing of Grounding Conductors

#### i) Equipment grounding conductor (EGC) sizing [NEC 690.45]

The size of the EGC is dependent on whether the system has ground fault protection (GFP) equipment or not. The provisions for GFP equipment are stated in NEC 690.5. Almost all inverters have GFP equipment integral to the inverter and require that the PV array be grounded at the inverter only.

##### (1) Systems with ground fault protection equipment

Size equipment grounding conductor according to NEC Table 250.122

##### (2) Systems without ground fault protection equipment

The NEC requires that equipment grounding conductors for systems without GFP equipment be sized for twice the minimum ampacity of the circuit conductors [NEC 690.45].

## ii) System grounding conductor sizing

### (1) AC System

Size grounding electrode conductor (GEC) according to NEC Table 250.66  
Normally the site already has the conductor and electrode installed for the ac building wiring.

### (2) DC System

Size grounding electrode conductor (GEC) according to NEC 250.166  
This results in a minimum size of 8 AWG. The maximum size of the GEC is dependent upon the type of grounding electrode or the maximum size conductor in the dc system, whichever is smaller.



## APPENDIX A: EXAMPLE SUBMITTALS

- Example 1: Standard String Inverter System
- Example 2: Micro-Inverter
- Example 3: AC Module
- Example 4: Supply-Side Connection

## Example 1: Standard String Inverter System

### Step 1: Structural Review of PV Array Mounting System

Is the array to be mounted on a defined, permitted roof structure?  Yes  No

*If No due to non-compliant roof or a ground mount, submit completed worksheet for the structure WKS1.*

#### Roof Information:

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...) **Yes— composition**  
*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*
2. If a composition shingle roof, does the roof have a single roof covering?  Yes  No  
*If No, submit completed worksheet for roof structure WKS1.*
3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).  
flashing

#### Mounting System Information:

1. Is the mounting structure an engineered product designed to mount PV modules, with no more than an 18" gap beneath the module frames?  Yes  No *If No, provide details of structural attachment certified by a design professional.*
2. For manufactured mounting systems, fill out information on the mounting system below:
  - a. Mounting System Manufacturer OmniRack Product Name and Model# ModMount 2.0
  - b. Total Weight of PV Modules and Rails 1124 lbs
  - c. Total Number of Attachment Points 34
  - d. Weight per Attachment Point (b ÷ c) 33 lbs (if greater than 45 lbs, see WKS1)
  - e. Maximum Spacing Between Attachment Points on a Rail 48 inches (see product manual for maximum spacing allowed based on maximum design wind speed)
  - f. Total Surface Area of PV Modules (square feet) 402 ft<sup>2</sup>
  - g. Distributed Weight of PV System on Roof (b ÷ f) 2.79 lbs/ft<sup>2</sup>  
*If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.*

### Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

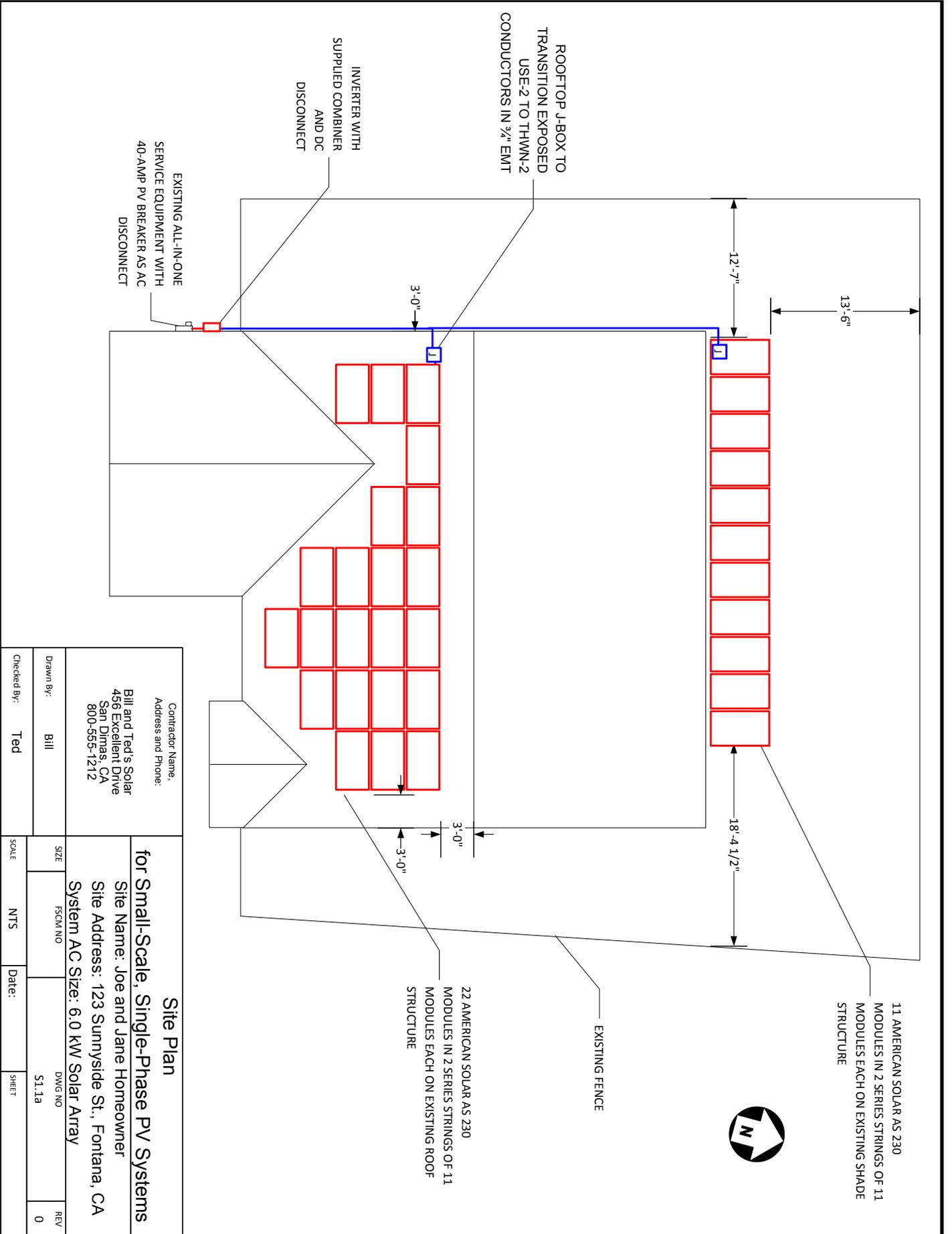
*In order for a PV system to be considered for an expedited permit process, the following must apply:*

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
2. The PV array is composed of 4 series strings or less per inverter.
3. The total inverter capacity has a continuous ac power output 13,440 Watts or less
4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
5. One of the standard electrical diagrams (E1.1, E1.1a, E1.1b, or E1.1c) can be used to accurately represent the PV system. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

*Fill out the standard electrical diagram completely. A guide to the electrical diagram is provided to help the applicant understand each blank to fill in. If the electrical system is more complex than the standard electrical diagram can effectively communicate, provide an alternative diagram with appropriate detail.*



# SITE PLAN FOR EXAMPLE 1 - STANDARD STRING INVERTER SYSTEM



**Contractor Name:**  
 Address and Phone:  
 Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-355-1212

**Site Plan**

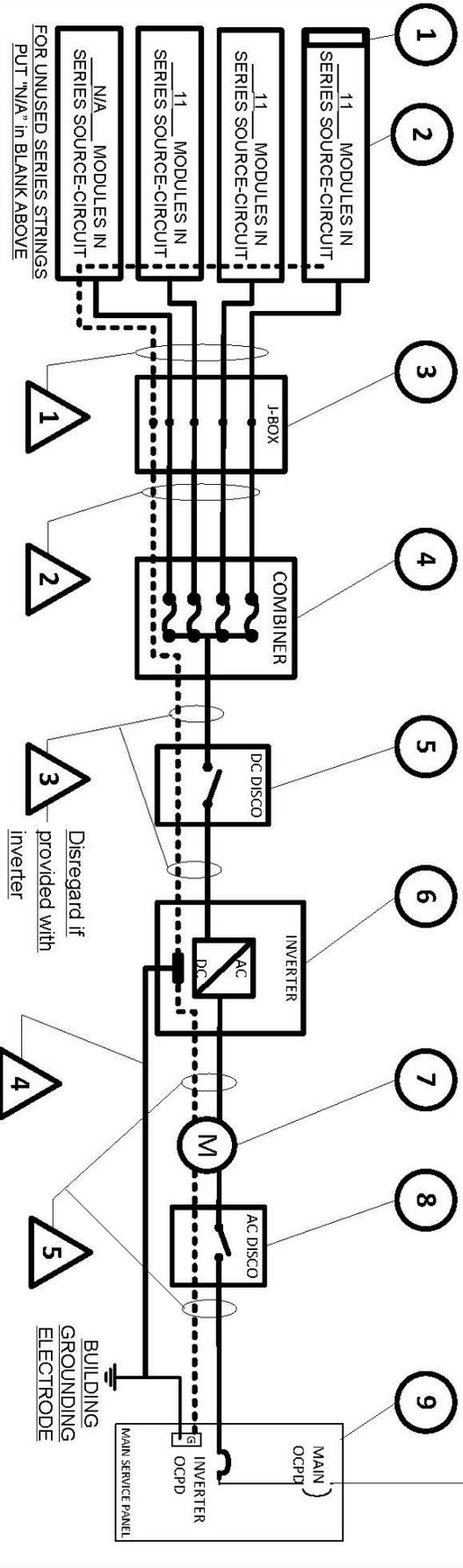
**for Small-Scale, Single-Phase PV Systems**  
 Site Name: Joe and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 6.0 kW Solar Array

Drawn By: Bill  
 Checked By: Ted

SCALE	NTS	Date:	SHEET
SIZE	FSCM NO	DWG NO	REV
		S1.1a	0

# DIAGRAM FOR EXAMPLE 1 - STANDARD STRING INVERTER SYSTEM

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE	AS 230	AMERICAN SOLAR, QUANTITY - 33 (SEE NOTES SHEET FOR DETAILS)
2	PV ARRAY	N/A	ARRAY IS 3 STRINGS WITH 11 MODULES PER SERIES STRING
3	J-BOX (IF USED)		6"x6"x4" NEMA 4, PVC JUNCTION BOX
4	COMBINER (IF USED)		15-A MAX FUSE W/15-A FUSES, 600VDC, 4-STRING MAX
5	DC DISCONNECT		MFR-supplied LISTED WITH INVERTER, 600VDC, 60-AMP (SEE GUIDE APPENDIX C)
6	DC/AC INVERTER	AL-7000	7000 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)
7	GEN METER (IF USED)	FORM 2S	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
8	AC DISCONNECT (IF USED)	D222NRB	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
9	SERVICE PANEL	SD200SL	240VAC, 200-A MAIN, 200-A BUS, 40-A INVERTER OCPD (SEE NOTE 5 FOR INVERTER OCPDS, ALSO SEE GUIDE SECTION 9)



FOR UNUSED SERIES STRINGS PUT "N/A" IN BLANK ABOVE  
SEE GUIDE APPENDIX C FOR INFORMATION ON MODULE AND ARRAY GROUNDING

CONDUIT AND CONDUCTOR SCHEDULE					
TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input checked="" type="checkbox"/> or PV WIRE <input type="checkbox"/>	10 AWG	8 BLACK	N/A	N/A
2	BARE COPPER EQ. GRD. COND. (EGC)	10 AWG	1 BARE CU	N/A	N/A
3	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	4-R, 4-W, 1-G	EMT	3/4"
4	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	N/A	N/A	N/A	N/A
5	INSULATED EGC	6 AWG	1 BARE CU	N/A	N/A
6	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	8 AWG	1-R, 1-B, 1-W	EMT	3/4"
7	INSULATED EGC	10 AWG	1 GREEN		

Contractor Name, Address and Phone: <b>Bill and Ted's Solar</b> 456 Excellent Drive San Dimas, CA 800-555-1212		<b>One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems</b> Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., Fontana, CA System AC Size: 6.1 kW Solar Array	
Drawn By:	Bill	SIZE:	FSCM NO.
Checked By:	Ted	SCALE:	NTS
		Date:	
		DWG NO:	E1.1
		REV:	0

# NOTES FOR ELECTRICAL DIAGRAM FOR EXAMPLE 1 - STANDARD STRING INVERTER SYSTEM

## PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	AMERICAN SOLAR
MODULE MODEL	AS 230
MAX POWER-POINT CURRENT (I <sub>MP</sub> )	7.80 A
MAX POWER-POINT VOLTAGE (V <sub>MP</sub> )	29.5 V
OPEN-CIRCUIT VOLTAGE (V <sub>OC</sub> )	37.0 V
SHORT-CIRCUIT CURRENT (I <sub>SC</sub> )	8.40 A
MAX SERIES FUSE (OCPD)	15 A
MAXIMUM POWER (P <sub>MAX</sub> )	230 W
MAX VOLTAGE (TYP 600V <sub>DC</sub> )	600 V
VOC TEMP COEFF (mV/°C □ or %/°C ☒)	-0.37
IF COEFF SUPPLIED, CIRCLE UNITS	

## NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

## INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	AMERICAN INVERTER
INVERTER MODEL	AI-7000
MAX DC VOLT RATING	500 V
MAX POWER @ 40°C	7000 W
NOMINAL AC VOLTAGE	240 V
MAX AC CURRENT	29 A
MAX OCPD RATING	50 A

## SIGNS-SEE GUIDE SECTION 7

### SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	19.6 A
RATED MPP VOLTAGE	430 V
MAX SYSTEM VOLTAGE	577 V
MAX CIRCUIT CURRENT	26.5 A
WARNING: ELECTRICAL SHOCK HAZARD-LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

### SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM	
AC POINT OF CONNECTION	
AC OUTPUT CURRENT	29 A
NOMINAL AC VOLTAGE	240 V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

## NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):

- 1) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP -1 °C
- 2) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE 37 °C
- 2) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
- a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 7.88 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE
- b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

## NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF 1 INVERTER OCPD(S). ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

## Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Contractor Name:  
 Address and Phone:  
 Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-555-1212

Site Name: Joe and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 6.0 kW Solar Array

Drawn By:	Bill	SIZE	ESQMN NO	DWGNO	REV
Checked By:	Ted	SCALE	NTS	Date:	0
				SHEET	

## Example 2: Micro-Inverter

### Step 1: Structural Review of PV Array Mounting System

Is the array to be mounted on a defined, permitted roof structure?  Yes  No

*If No due to non-compliant roof or a ground mount, submit completed worksheet for the structure WKS1.*

#### Roof Information:

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...) Yes— composition  
*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*
2. If a composition shingle roof, does the roof have a single roof covering?  Yes  No  
*If No, submit completed worksheet for roof structure WKS1.*
3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).  
flashing

#### Mounting System Information:

1. Is the mounting structure an engineered product designed to mount PV modules, with no more than an 18" gap beneath the module frames?  Yes  No *If No, provide details of structural attachment certified by a design professional.*
2. For manufactured mounting systems, fill out information on the mounting system below:
  - a. Mounting System Manufacturer OmniRack Product Name and Model# ModMount 2.0
  - b. Total Weight of PV Modules and Rails 1022 lbs
  - c. Total Number of Attachment Points 32
  - d. Weight per Attachment Point (b ÷ c) 32 lbs (if greater than 45 lbs, see WKS1)
  - e. Maximum Spacing Between Attachment Points on a Rail 48 inches (see product manual for maximum spacing allowed based on maximum design wind speed)
  - f. Total Surface Area of PV Modules (square feet) 365 ft<sup>2</sup>
  - g. Distributed Weight of PV System on Roof (b ÷ f) 2.8 lbs/ft<sup>2</sup>  
*If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.*

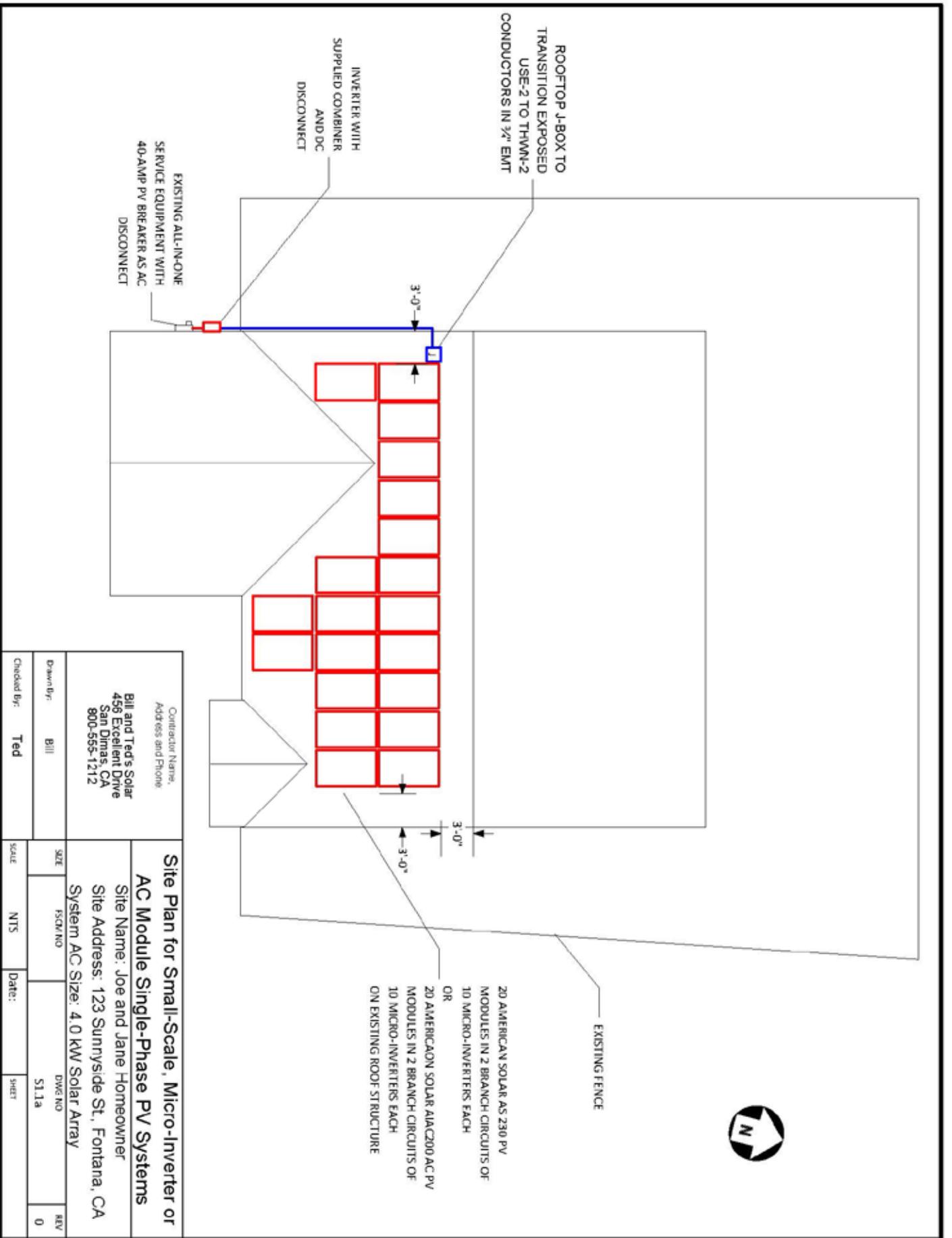
### Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

*In order for a PV system to be considered for an expedited permit process, the following must apply:*

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
2. The PV array is composed of 4 series strings or less per inverter.
3. The total inverter capacity has a continuous ac power output 13,440 Watts or less
4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
5. One of the standard electrical diagrams (E1.1, E1.1a, E1.1b, or E1.1c) can be used to accurately represent the PV system. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

*Fill out the standard electrical diagram completely. A guide to the electrical diagram is provided to help the applicant understand each blank to fill in. If the electrical system is more complex than the standard electrical diagram can effectively communicate, provide an alternative diagram with appropriate detail.*

# SITE PLAN FOR EXAMPLE 2 - MICRO-INVERTER

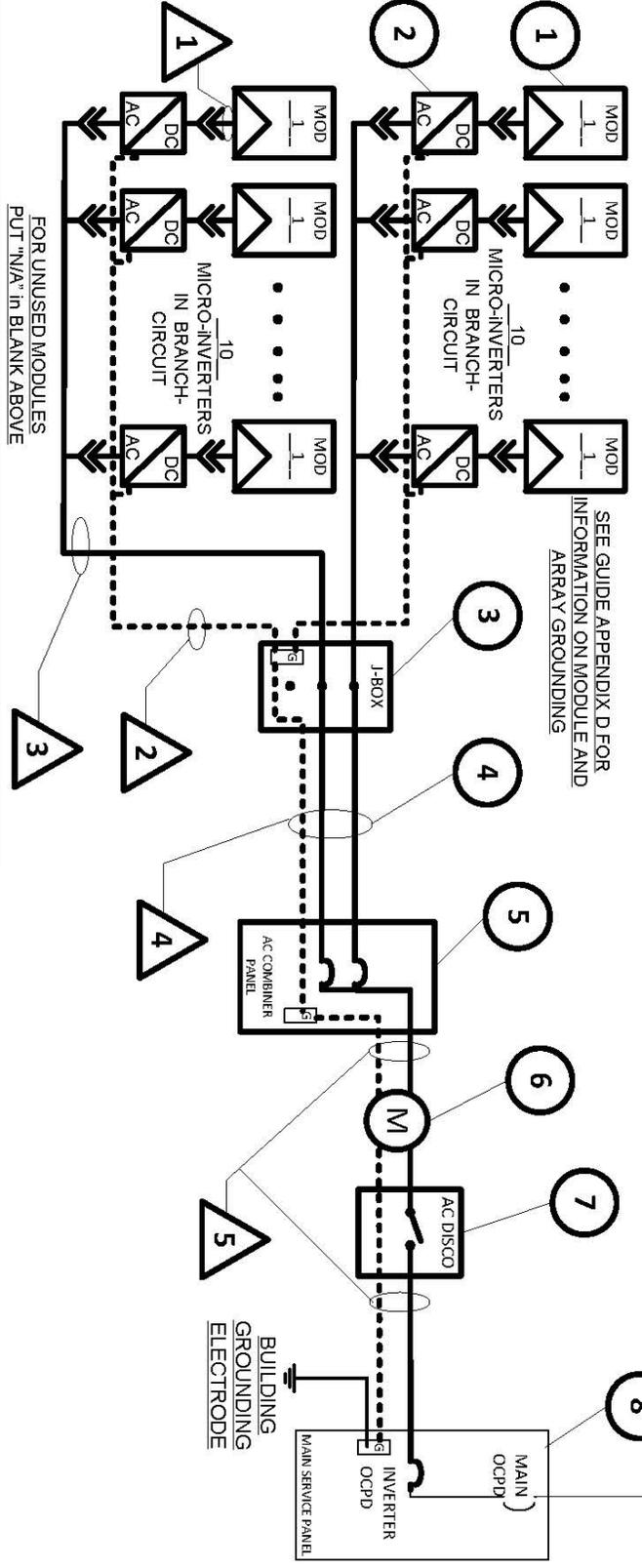


Contractor Name, Address and Phone  <b>Bill and Ted's Solar</b> 456 Excellent Drive San Dimas, CA 800-555-1212		<b>Site Plan for Small-Scale, Micro-Inverter or AC Module Single-Phase PV Systems</b>	
Drawn By: <b>Bill</b>	FSC# NO	DWE NO <b>S1.1a</b>	REV <b>0</b>
Checked By: <b>Ted</b>	SCALE <b>NTS</b>	Date:	SHEET
Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., Fontana, CA System AC Size: 4.0 kW Solar Array			

# ELECTRICAL DIAGRAM FOR EXAMPLE 2 - MICRO-INVERTER

**○ EQUIPMENT SCHEDULE**

TAG	DESCRIPTION	PART NUMBER	NOTES
1	PV DC or AC MODULE	AS 230	AMERICAN SOLAR. QUANTITY - 20 (SEE NOTES SHEET FOR DETAILS)
2	DC/AC INVERTER (MICRO)	AI-200	200 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)
3	J-BOX (IF USED)	N/A	6"x6"x4" NEMA 4, PVC JUNCTION BOX
4	PV ARRAY	N/A	2, 15-A AC CIRCUITS WITH 10 MICRO-INVERTERS PER CIRCUIT
5	AC COMB. PANEL (IF USED)	SD125SL	240VAC, 125-A MAIN LUG PANEL W/ 30-A BREAKER AS MAIN
6	GEN METER (IF USED)	FORM 2S	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
7	AC DISCONNECT (IF USED)	D222NRB	240VAC, 30-AMP UNFUSED (SEE GUIDE APPENDIX C)
8	SERVICE PANEL	SD200SL	240VAC, 200-A MAIN, 200-A BUS, 30-A INVERTER OCPD (SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)



**△ CONDUIT AND CONDUCTOR SCHEDULE**

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>	MFG	MFG Cable	N/A	N/A
2	GEC <input checked="" type="checkbox"/> X ALL THAT APPLY 6 AWG	MFG	1 BARE CU	N/A	N/A
3	EXTERIOR CABLE LISTED W/ INV.	MFG	MFG Cable	N/A	N/A
4	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	MFG	2-B, 2-R, 2-W	EMT	3/4"
	GEC <input checked="" type="checkbox"/> EGC <input checked="" type="checkbox"/> X ALL THAT APPLY 8 AWG	MFG	1 GREEN	SAME	SAME
	NO DC GEC IF 690.35 SYSTEM				
5	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	1-R, 1-B, 1-W	EMT	3/4"
	GEC <input checked="" type="checkbox"/> EGC <input checked="" type="checkbox"/> X ALL THAT APPLY 8 AWG	1 AWG	1 GREEN	SAME	SAME

Contractor Name, Address and Phone  
 Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-555-1212

One-Line Standard Electrical Diagram  
 for Micro-Inverter or AC Module PV Systems

Site Name: John and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 4.0 KW

Drawn By: Bill  
 Checked By: Ted

SCALE: NTS  
 DATE: \_\_\_\_\_

DWG NO: E1.1a  
 REV: 0

# NOTES FOR ELECTRICAL DIAGRAM FOR EXAMPLE 2 - MICRO-INVERTER

## PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	AMERICAN SOLAR
MODULE MODEL	AS 230
MAX POWER-POINT CURRENT (I <sub>MP</sub> )	7.80 A
MAX POWER-POINT VOLTAGE (V <sub>MP</sub> )	29.5 V
OPEN-CIRCUIT VOLTAGE (V <sub>OC</sub> )	37.0 V
SHORT-CIRCUIT CURRENT (I <sub>SC</sub> )	8.40 A
MAX SERIES FUSE (OCPD)	15 A
MAXIMUM POWER (P <sub>MAX</sub> )	230 W
MAX VOLTAGE (TYP 600V <sub>DC</sub> )	600 V
VOC TEMP COEFF (mV/°C <input type="checkbox"/> or %/°C <input checked="" type="checkbox"/> )	-0.37
IF COEFF SUPPLIED, CIRCLE UNITS	

## NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

## INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	AMERICAN INVERTER
INVERTER MODEL	AI-200
MAX DC VOLT RATING	60 V
MAX POWER @ 40°C	200 W
NOMINAL AC VOLTAGE	240 V
MAX AC CURRENT	0.83 A
MAX OCPD RATING	15 A

## SIGNS-SEE GUIDE SECTION 7

### SIGN FOR DC DISCONNECT

No sign necessary since 690.51 marking on PV module covers needed information

### SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	24 A
NOMINAL AC VOLTAGE	240 V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

## NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):

- 1) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP -1 °C
- 2) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE 37 °C
- 2) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5' ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),
  - a) 12 AWG 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
  - b) 10 AWG 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

## NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF 2 INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OUTPUT CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

## Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

Contractor Name:  
 Address and Phone:  
 Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-555-1212

Site Name: Joe and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 4.0 kW Solar Array

Drawn By:	Bill	SIZE	FSCM NO	DWG NO	REV
Checked By:	Ted	SCALE	NTS	Date:	ET.2a 0
		SHEET			

## Example 3: AC Module

### Step 1: Structural Review of PV Array Mounting System

Is the array to be mounted on a defined, permitted roof structure?  Yes  No

*If No due to non-compliant roof or a ground mount, submit completed worksheet for the structure WKS1.*

#### Roof Information:

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...) Yes— composition  
*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*
2. If a composition shingle roof, does the roof have a single roof covering?  Yes  No  
*If No, submit completed worksheet for roof structure WKS1.*
3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).  
flashing

#### Mounting System Information:

1. Is the mounting structure an engineered product designed to mount PV modules, with no more than an 18" gap beneath the module frames?  Yes  No *If No, provide details of structural attachment certified by a design professional.*
2. For manufactured mounting systems, fill out information on the mounting system below:
  - a. Mounting System Manufacturer OmniRack Product Name and Model# ModMount 2.0
  - b. Total Weight of PV Modules and Rails 1022 lbs
  - c. Total Number of Attachment Points 32
  - d. Weight per Attachment Point (b ÷ c) 32 lbs (if greater than 45 lbs, see WKS1)
  - e. Maximum Spacing Between Attachment Points on a Rail 48 inches (see product manual for maximum spacing allowed based on maximum design wind speed)
  - f. Total Surface Area of PV Modules (square feet) 365 ft<sup>2</sup>
  - g. Distributed Weight of PV System on Roof (b ÷ f) 2.8 lbs/ft<sup>2</sup>  
*If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.*

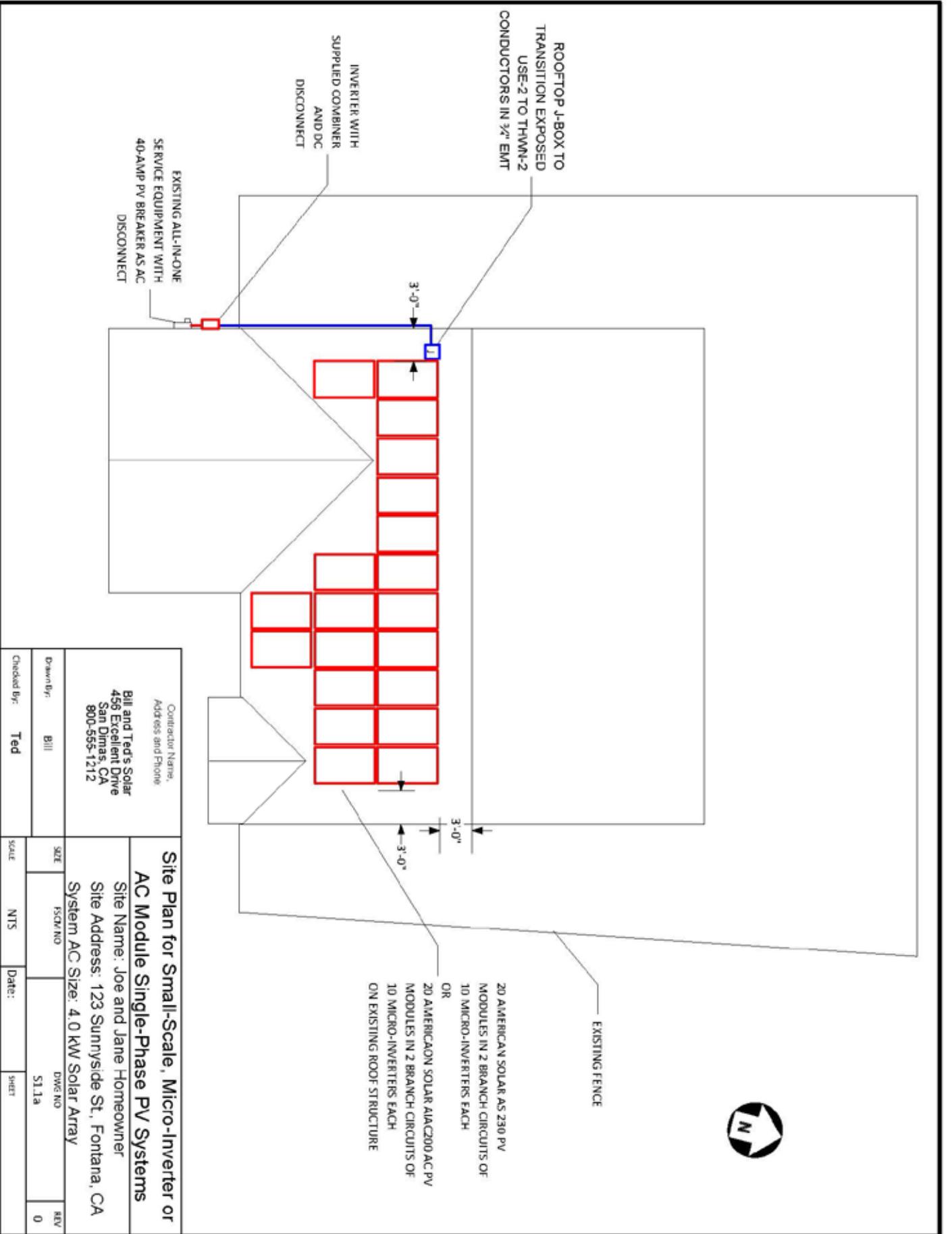
### Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

*In order for a PV system to be considered for an expedited permit process, the following must apply:*

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
2. The PV array is composed of 4 series strings or less per inverter.
3. The total inverter capacity has a continuous ac power output 13,440 Watts or less
4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
5. One of the standard electrical diagrams (E1.1, E1.1a, E1.1b, or E1.1c) can be used to accurately represent the PV system. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

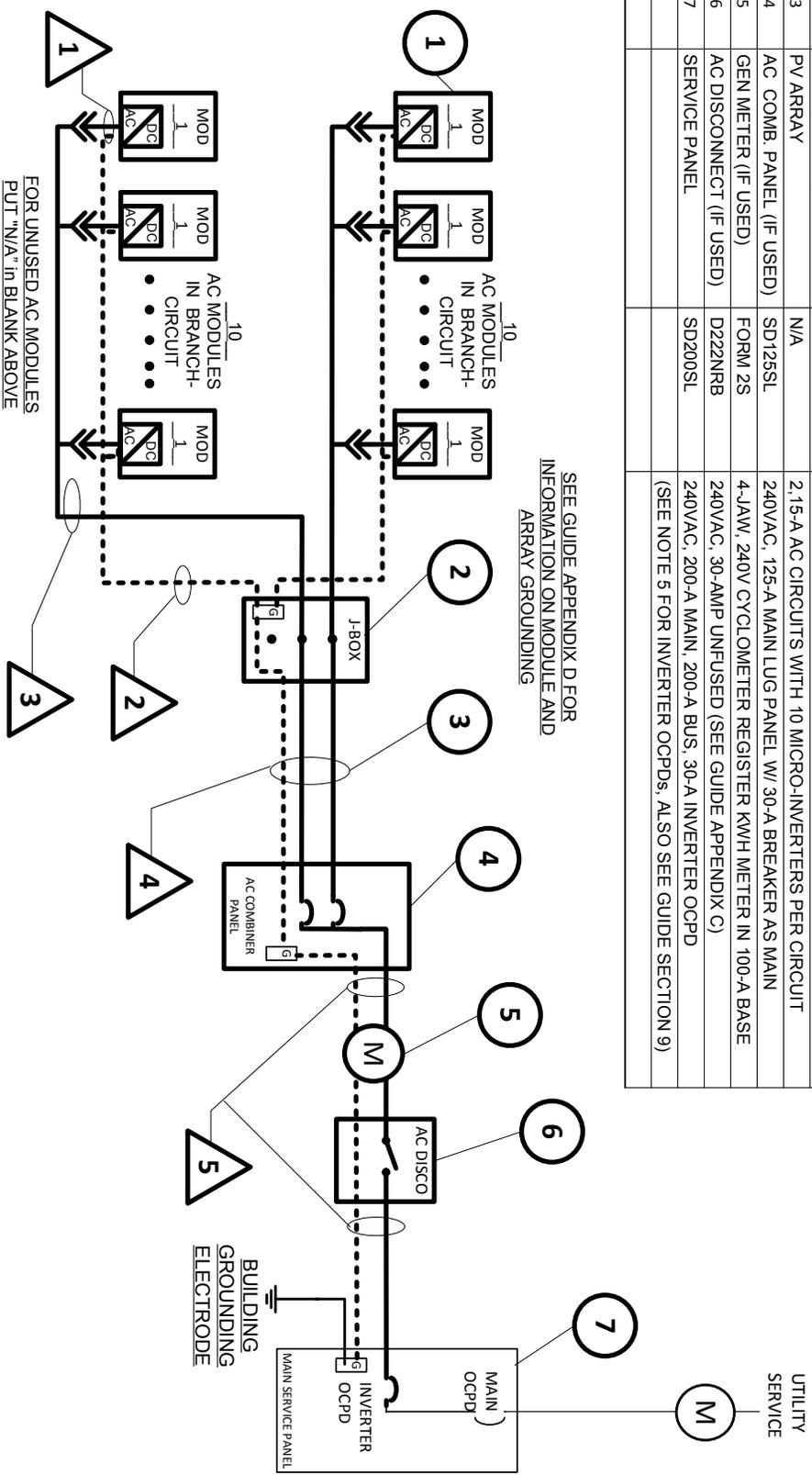
*Fill out the standard electrical diagram completely. A guide to the electrical diagram is provided to help the applicant understand each blank to fill in. If the electrical system is more complex than the standard electrical diagram can effectively communicate, provide an alternative diagram with appropriate detail.*

# SITE PLAN FOR EXAMPLE 3 - AC MODULE



# ELECTRICAL DIAGRAM FOR EXAMPLE 3 - AC MODULE

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	AC MODULE	ASAC 200	AMERICAN SOLAR, QUANTITY - 20 (SEE NOTES SHEET FOR DETAIL(S))
2	J-BOX (IF USED)	N/A	6"x6"x4" NEMA 4, PVC JUNCTION BOX
3	PV ARRAY	N/A	2, 15-A AC CIRCUITS WITH 10 MICRO-INVERTERS PER CIRCUIT
4	AC COMB. PANEL (IF USED)	SD125SL	240VAC, 125-A MAIN LUG PANEL W/ 30-A BREAKER AS MAIN
5	GEN METER (IF USED)	FORM 2S	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
6	AC DISCONNECT (IF USED)	D222NRB	240VAC, 30-AMP UNFUSED (SEE GUIDE APPENDIX C)
7	SERVICE PANEL	SD200SL	240VAC, 200-A MAIN, 200-A BUS, 30-A INVERTER OCPD (SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)



CONDUIT AND CONDUCTOR SCHEDULE					
TAG	DESCRIPTION OR CONDUCTOR TYPE	COND.	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>	MFG	MFG Cable	N/A	N/A
2	GEC <input checked="" type="checkbox"/> EGC <input checked="" type="checkbox"/> X ALL THAT APPLY	6 AWG	1 BARE CU	N/A	N/A
3	EXTERIOR CABLE LISTED W/ INV.	MFG	MFG Cable	N/A	N/A
4	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	12 AWG	2-B, 2-R, 2-W	EMT	3/4"
	GEC <input checked="" type="checkbox"/> EGC <input checked="" type="checkbox"/> X ALL THAT APPLY	8 AWG	1 GREEN	SAME	SAME
	NO DC GEC IF 690.35 SYSTEM				
5	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	1-R, 1-B, 1-W	EMT	3/4"
	GEC <input checked="" type="checkbox"/> EGC <input checked="" type="checkbox"/> X ALL THAT APPLY	8 AWG	1 GREEN	SAME	SAME

Contractor Name:  
Address and Phone:

One-Line Standard Electrical Diagram  
for AC Module PV Systems

Site Name: John and Jane Homeowner  
Site Address: 123 Sunnyside St., Fontana, CA  
System AC Size: 4.0 KW

Drawn By: Bill  
Checked By: Ted

SCALE: NTS Date: \_\_\_\_\_

SIZE: FSCM NO. DWG NO. E1.1b REV 0

# NOTES FOR ELECTRICAL DIAGRAM FOR EXAMPLE 3 - AC MODULE

NOTES FOR ALL DRAWINGS:  
 OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

AC MODULE RATINGS (Guide Appendix C)

AC MODULE MAKE	AMERICAN INVERTER
AC MODULE MODEL	AAAC-200
NOMINAL OPERATING AC VOLTAGE	240 V
NOMINAL OPERATING AC FREQUENCY	60 HZ
MAXIMUM AC POWER	200 W
MAXIMUM AC CURRENT	0.833 A
MAXIMUM OCPD RATING	15 A

SIGNS-SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

N/A since no dc wiring

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM  
 AC POINT OF CONNECTION

AC OUTPUT CURRENT	24 A
NOMINAL AC VOLTAGE	240 V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

## NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix F):

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP      -1 °C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE      37 °C
- 2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C), FOR 6 OR LESS CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),
  - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 12 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER OCPD.
  - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 16 AMPS OR LESS WHEN PROTECTED BY A 20-AMP OR SMALLER OCPD.

## NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT (N/A)
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF      2 INVERTER OUTPUT CIRCUIT (OCPD(S)), ONE FOR EACH AC MODULE CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

Contractor Name: Address and Phone:		Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems	
Bill and Ted's Solar 456 Excellent Drive San Dimas, CA 800-555-1212		Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., Fontana, CA System AC Size: 4.0 kW Solar Array	
Drawn By:	Bill	SIZE	FSCM NO
Checked By:	Ted	SCALE	NTS
		Date:	
		DWG NO	REV
		E.1.2b	0
		SHEET	

## Example 4: Supply-Side Connection

### Step 1: Structural Review of PV Array Mounting System

Is the array to be mounted on a defined, permitted roof structure?  Yes  No

*If No due to non-compliant roof or a ground mount, submit completed worksheet for the structure WKS1.*

#### Roof Information:

1. Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...) Yes— composition  
*If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*
2. If a composition shingle roof, does the roof have a single roof covering?  Yes  No  
*If No, submit completed worksheet for roof structure WKS1.*
3. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).  
flashing

#### Mounting System Information:

1. Is the mounting structure an engineered product designed to mount PV modules, with no more than an 18" gap beneath the module frames?  Yes  No *If No, provide details of structural attachment certified by a design professional.*
2. For manufactured mounting systems, fill out information on the mounting system below:
  - a. Mounting System Manufacturer OmniRack Product Name and Model# ModMount 2.0
  - b. Total Weight of PV Modules and Rails 1124 lbs
  - c. Total Number of Attachment Points 34
  - d. Weight per Attachment Point (b ÷ c) 33 lbs (if greater than 45 lbs, see WKS1)
  - e. Maximum Spacing Between Attachment Points on a Rail 48 inches (see product manual for maximum spacing allowed based on maximum design wind speed)
  - f. Total Surface Area of PV Modules (square feet) 402 ft<sup>2</sup>
  - g. Distributed Weight of PV System on Roof (b ÷ f) 2.79 lbs/ft<sup>2</sup>  
*If distributed weight of the PV system is greater than 5 lbs/ft<sup>2</sup>, see WKS1.*

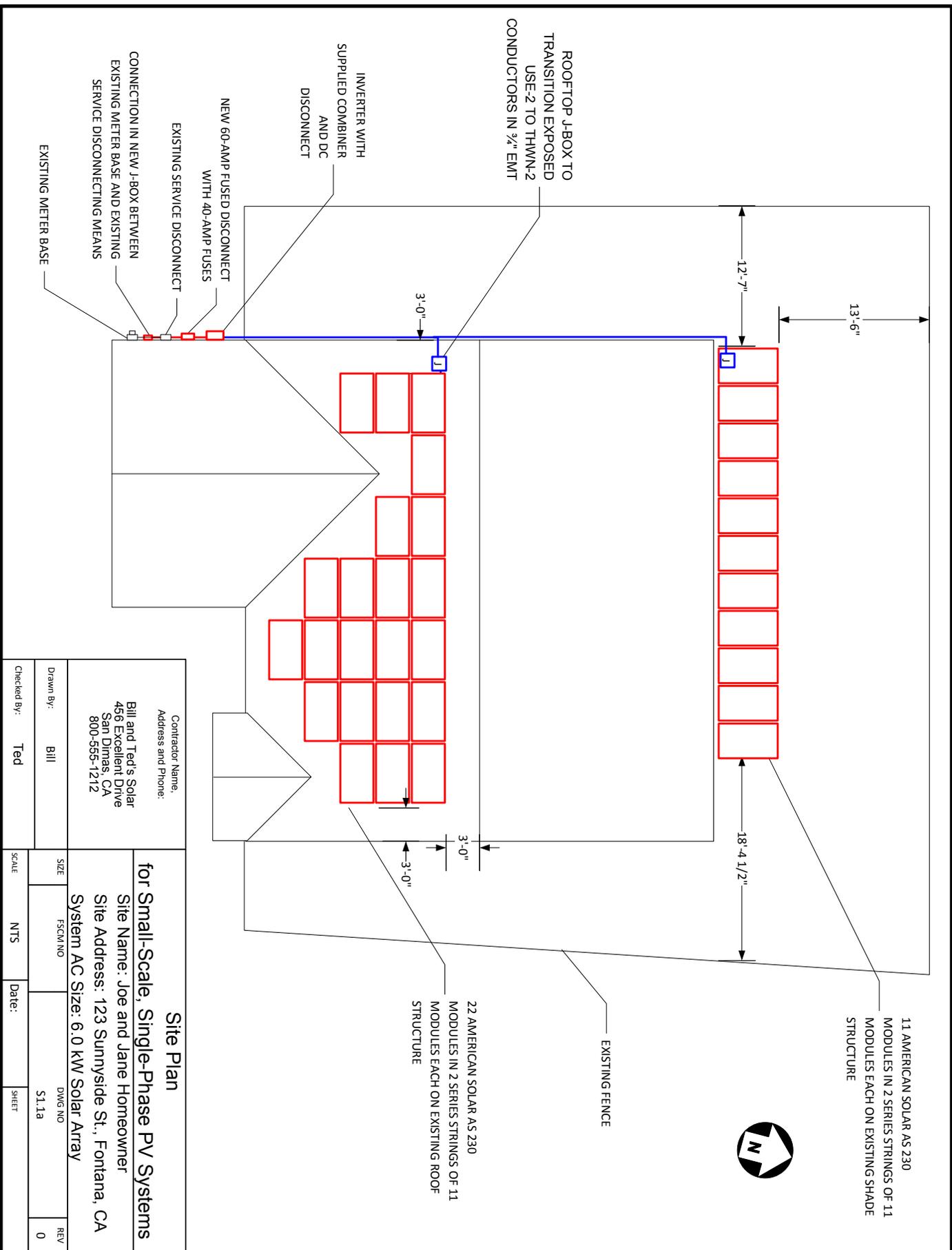
### Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

*In order for a PV system to be considered for an expedited permit process, the following must apply:*

1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
2. The PV array is composed of 4 series strings or less per inverter.
3. The total inverter capacity has a continuous ac power output 13,440 Watts or less
4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
5. One of the standard electrical diagrams (E1.1, E1.1a, E1.1b, or E1.1c) can be used to accurately represent the PV system. Interactive PDF diagrams are available at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting).

*Fill out the standard electrical diagram completely. A guide to the electrical diagram is provided to help the applicant understand each blank to fill in. If the electrical system is more complex than the standard electrical diagram can effectively communicate, provide an alternative diagram with appropriate detail.*

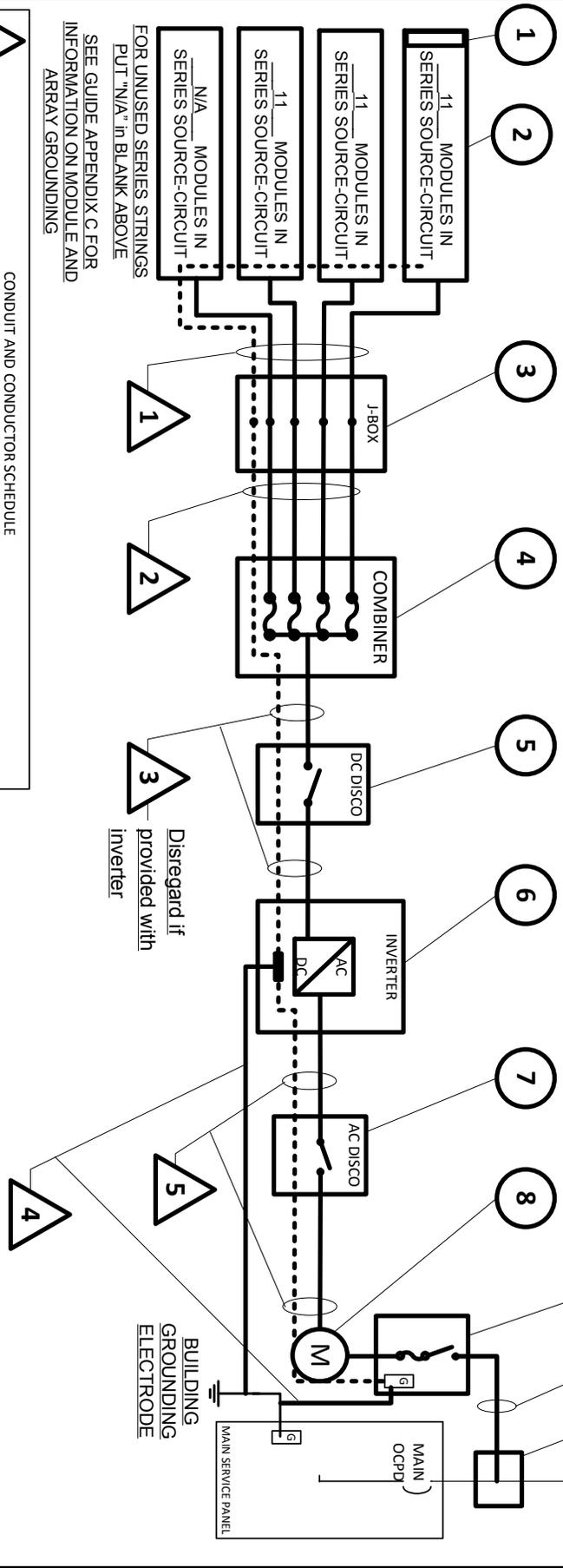
# SITE PLAN FOR EXAMPLE 4



<b>Site Plan</b>	
<b>for Small-Scale, Single-Phase PV Systems</b>	
Contractor Name: Address and Phone: <b>Bill and Ted's Solar</b> 456 Excellent Drive San Dimas, CA 800-555-1212	
Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., Fontana, CA System AC Size: 6.0 kW Solar Array	
Drawn By: <b>Bill</b> Checked By: <b>Ted</b>	Date: _____ Scale: _____
SIZE FSCMNO S1.1a	DWGNO S1.1a REV 0

# DIAGRAM FOR EXAMPLE 4 - SUPPLY SIDE ELECTRICAL DIAGRAM

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE	AS 230	AMERICAN SOLAR, QUANTITY - 33 (SEE NOTES SHEET FOR DETAILS)
2	PV ARRAY	N/A	ARRAY IS 3 STRINGS WITH 11 MODULES PER SERIES STRING
3	J-BOX (IF USED)		6"x6"x4" NEMA 4, PVC JUNCTION BOX
4	COMBINER (IF USED)		15-A MAX FUSE W/15-A FUSES, 600VDC, 4-STRING MAX LISTED WITH INVERTER, 600VDC, 60-AMP (SEE GUIDE APPENDIX C)
5	DC DISCONNECT		MFR-supplied
6	DC/AC INVERTER	AI-7000	7000 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)
7	AC DISCONNECT (IF USED)	D222NRB	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
8	GEN METER (IF USED)	FORM 2S	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
9	PV SYSTEM DISCONNECT	D222NRB	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
10	CONNECTION (DESCRIBE)	ILSCO IPC-4/0-6	KUP-L-TAP INSULATION PIERCING CONNECTORS IN NEMA 3R J-BOX



TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input checked="" type="checkbox"/> or PV WIRE <input type="checkbox"/>	10 AWG	8 BLACK	N/A	N/A
2	BARE COPPER EQ. GRD. COND. (EGC)	10 AWG	1 BARE CU	N/A	N/A
3	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	4-R, 4-W, 1-G	EMT	3/4"
4	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	N/A	N/A	N/A	N/A
5	INSULATED EGC	N/A	N/A	N/A	N/A
6	GROUNDING ELECTRODE COND.	6 AWG	1 BARE CU	N/A	N/A
7	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	8 AWG	1-R, 1-B, 1-W	EMT	3/4"
8	INSULATED EGC	10 AWG	1 GREEN	EMT	3/4"
9	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	6 AWG	1-R, 1-B, 1-W	EMT	3/4"

Contractor Name:  
Address and Phone:

Bill and Ted's Solar  
456 Excellent Drive  
San Dimas, CA  
800-555-1212

One-Line Electrical Diagram for Supply-Side  
Connected Single-Phase PV Systems

Site Name: Joe and Jane Homeowner  
Site Address: 123 Sunnyside St., Fontana, CA  
System AC Size: 6.1 kW Solar Array

Drawn By: Bill  
Checked By: Ted

SCALE: NTS  
Date:

SIZE: FSCM NO.  
DWG NO: EL.1c  
REV: 0

# NOTES FOR ELECTRICAL DIAGRAM EXAMPLE 4 - SUPPLY SIDE CONNECTION

**PV MODULE RATINGS @ STC (Guide Section 5)**

MODULE MAKE	AMERICAN SOLAR
MODULE MODEL	AS 230
MAX POWER-POINT CURRENT (I <sub>mp</sub> )	7.80 A
MAX POWER-POINT VOLTAGE (V <sub>mp</sub> )	29.5 V
OPEN-CIRCUIT VOLTAGE (V <sub>oc</sub> )	37.0 V
SHORT-CIRCUIT CURRENT (I <sub>sc</sub> )	8.40 A
MAX SERIES FUSE (OCPD)	15 A
MAXIMUM POWER (P <sub>max</sub> )	230 W
MAX VOLTAGE (TYP 600V <sub>dc</sub> )	600 V
VOC TEMP COEFF (mV/°C <input type="checkbox"/> or %/°C <input checked="" type="checkbox"/> )	-0.37
IF COEFF SUPPLIED, CIRCLE UNITS	

**NOTES FOR ALL DRAWINGS:**

OCPD = OVERCURRENT PROTECTION DEVICE  
 NATIONAL ELECTRICAL CODE® REFERENCES  
 SHOWN AS (NEC XXX.XX)

**INVERTER RATINGS (Guide Section 4)**

INVERTER MAKE	AMERICAN INVERTER
INVERTER MODEL	AI-7000
MAX DC VOLT RATING	500 V
MAX POWER @ 40°C	7000 W
NOMINAL AC VOLTAGE	240 V
MAX AC CURRENT	29 A
MAX OCPD RATING	50 A

**SIGNS—SEE GUIDE SECTION 7**

**SIGN FOR DC DISCONNECT**

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	19.6 A
RATED MPP VOLTAGE	430 V
MAX SYSTEM VOLTAGE	577 V
MAX CIRCUIT CURRENT	26.5 A

**WARNING: ELECTRICAL SHOCK HAZARD—LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION**

**SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)**

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	29 A
NOMINAL AC VOLTAGE	240 V

**THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)**

**NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):**

- 1) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP \_\_\_-1\_\_\_ °C
- 2) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE \_\_\_37\_\_\_ °C
- 2.) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),
  - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
  - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I<sub>sc</sub> OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

**NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):**

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES  NO  N/A
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES  NO  N/A
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF \_\_\_1\_\_\_ INVERTER OCPD(S), ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES  NO

**Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems**

Site Name: Joe and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 6.0 kW Solar Array

Contractor Name:  
 Address and Phone:

Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-555-1212

Drawn By:	Bill	SIZE	FSM NO	DWG NO	REV
Checked By:	Ted	SCALE	NTS	Date:	SHEET
					0

## APPENDIX B: STRUCTURAL

### B.1 Structure Worksheet—WKS1

#### *If array is roof mounted*

This section is for evaluating roof structural members that are site built. This includes rafter systems and site built trusses. Manufactured truss and roof joist systems, when installed with proper spacing, meet the roof structure requirements covered in item 2 below.

1. Roof construction:  **Rafters**  **Trusses**  **Other:** \_\_\_\_\_
2. Describe site-built rafter or or site-built truss system.
  - a. Rafter Size: \_\_\_ x \_\_\_ inches
  - b. Rafter Spacing: \_\_\_\_\_ inches
  - c. Maximum unsupported span: \_\_\_\_\_ feet, \_\_\_\_\_ inches
  - d. Are the rafters over-spanned? (see the IRC span tables in **B.2**.)  **Yes**  **No**
  - e. If **Yes**, complete the rest of this section.
3. If the roof system has
  - a. over-spanned rafters or trusses,
  - b. the array over 5 lbs/ft<sup>2</sup> on any roof construction, or
  - c. the attachments with a dead load exceeding 45 lbs per attachment;

it is recommended that you provide one of the following:

- i. A framing plan that shows details for how you will strengthen the rafters using the supplied span tables in B.2.
- ii. Confirmation certified by a design professional that the roof structure will support the array.

#### *If array is ground mounted:*

1. Show array supports, framing members, and foundation posts and footings.
2. Provide information on mounting structure(s) construction. If the mounting structure is unfamiliar to the local jurisdiction and is more than six (6) feet above grade, it may require engineering calculations certified by a design professional.
3. Show detail on module attachment method to mounting structure.





## B.2 Span Tables

A framing plan is required only if the combined weight of the PV array exceeds 5 pounds per square foot (PSF or lbs/ft<sup>2</sup>) or the existing rafters are over-spanned. The following span tables from the 2009 International Residential Code (IRC) can be used to determine if the rafters are over-spanned. For installations in jurisdictions using different span tables, follow the local tables.

### *Span Table R802.5.1(1),*

Use this table for rafter spans that have conventional light-weight dead loads and do not have a ceiling attached.

10 PSF Dead Load Roof live load = 20 psf, ceiling not attached to rafters, L/Δ=180							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	9-10	14-4	18-2	22-3	25-9
16	Hem-fir	#2 or better	9-2	14-2	17-11	21-11	25-5
24	Douglas Fir-larch	#2 or better	8-0	11-9	14-10	18-2	21-0
24	Hem-fir	#2 or better	7-11	11-7	14-8	17-10	20-9

Use this table for rafter spans that have heavy dead loads and do not have a ceiling attached.

20 PSF Dead Load Roof live load = 20 psf, ceiling not attached to rafters, L/Δ=180							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-6	12-5	15-9	19-3	22-4
16	Hem-fir	#2 or better	8-5	12-3	15-6	18-11	22-0
24	Douglas Fir-larch	#2 or better	6-11	10-2	12-10	15-8	18-3
24	Hem-fir	#2 or better	6-10	10-0	12-8	15-6	17-11

Span Table R802.5.1(2),

Use this table for rafter spans with a ceiling attached and conventional light-weight dead loads.

10 PSF Dead Load							
Roof live load = 20 psf, ceiling attached to rafters, L/Δ=240							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-11	14-1	18-2	22-3	25-9
16	Hem-fir	#2 or better	8-4	13-1	17-3	21-11	25-5
24	Douglas Fir-larch	#2 or better	7-10	11-9	14-10	18-2	21-0
24	Hem-fir	#2 or better	7-3	11-5	14-8	17-10	20-9

Use this table for rafter spans with a ceiling attached and where heavy dead loads exist.

20 PSF Dead Load							
Roof live load = 20 psf, ceiling attached to rafters, L/Δ=240							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-6	12-5	15-9	19-3	22-4
16	Hem-fir	#2 or better	8-4	12-3	15-6	18-11	22-0
24	Douglas Fir-larch	#2 or better	6-11	10-2	12-10	15-8	18-3
24	Hem-fir	#2 or better	6-10	10-0	12-8	15-6	17-11

Use the conventional light-weight dead load table when the existing roofing materials are wood shake, wood shingle, composition shingle, or light-weight tile. (The rationale for allowing these tables to be used is that the installation of a PV system should be considered as part of the live load, since additional loading will not be added to the section of the roof where a PV array is installed.)

Where heavy roofing systems exist (e.g. clay tile or heavy concrete tile roofs), use the 20 lbs/ft<sup>2</sup> dead load tables.





## APPENDIX C: MICRO-INVERTERS AND AC MODULES

### General

Micro-inverters and ac modules convert PV dc power to ac power on a module by module basis. The output of the PV module is fed directly into the inverter so that the majority, or all, of the field wiring is ac rather than dc. This array design has several advantages including the fact that, when the utility service is shut down, the only voltage that remains in the system is the low dc voltage that the module produces. In the 1999 NEC section 690.6, Alternating-Current (ac) Modules, was added to the electrical code. While a few products existed at that time, only recently has the number of installations increased sharply.

The fundamental difference between micro-inverters and ac modules is that an ac module does not have to meet the requirements for the dc side of a PV system. The dc wiring is considered internal to the unit and covered by the product listing process (the NEC defines the requirements of an ac module in NEC 690.6(A)). The product listing requirements for the inverter portion of an ac module is covered in the standard, UL 1741, entitled Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources. Article 110.3(B) requires that all equipment is installed according to the product instructions. Jurisdictions are encouraged to approve products that have been certified by a Nationally Recognized Testing Laboratory (NRTL) that is approved by OSHA to test the appropriate product evaluation standards (primarily UL1703 and UL1741) in Article 90.7. Since a micro-inverter is not covered by the 690.6(A) provision, it must comply with the requirements for the dc side of a PV system. In essence, a micro-inverter system is simply a very small PV system with a one (or two) module PV array.

### Common code issues for micro-inverters and ac modules

#### Conductors used for micro-inverters and ac modules

Cables and conductors connected to micro-inverters and ac modules have been called into question by various jurisdictions over the years. Since the wiring for these types of PV systems are often concealed under the PV module, 690.34 applies for connections that require access under the module. 690.34 states, *Access to Boxes. Junction, pull, and outlet boxes located behind modules or panels shall be so installed that the wiring contained in them can be rendered accessible directly or by displacement of a module(s) or panel(s) secured by removable fasteners and connected by a flexible wiring system.* This requires that a flexible wiring system be used to provide for access and servicing. The most common cable type used for the ac side of these systems is Type TC-ER, which is tray cable with extra reinforcing and protection. TC-ER when rated sunlight resistance meets all the requirements of 690.31(C), Flexible Cords and Cables that are required for tracking systems even though most micro-inverters are not installed in tracking systems. 690.31(C) cables must be rated for extra hard usage, for outdoor use, for wet locations, and for sunlight resistance, and meet the requirements of article 400. While Type TC-ER is not specifically mentioned in article 400, 400.4 states, *400.4 Types. Flexible cords and flexible cables shall conform to the description in Table 400.4. Types of flexible cords and flexible cables other than those listed in the table shall be the subject of special investigation.* Since the cable is part of the overall equipment listing, the cable, connectors, and cable to the junction box where the wiring method is transitioned to standard wiring methods is covered by the equipment listing and subjected to special investigation. Proper support of the cable is an important safety consideration and the installation instruction should provide detailed information on how to properly support the cable between modules and to the transitional junction box.

Another common issue for micro-inverters and ac modules is a shared OCPD for multiple units. Typical string inverters will each require a dedicated OCPD, which would be a burdensome requirement for a system with many micro-inverters or ac modules. This



feature allows up to 15 or 20 outputs to be paralleled with field wiring and protected by a single 15A or 20A breaker which does not need to be located at the array. Product documentation will describe the maximum number of units that could be paralleled in this manner on a single OCPD. This configuration is still be compatible with 690.64(B)(1) in that individual inverters/modules can still be disconnected individually, as described below.

Since the remaining requirements differ between micro-inverters and ac modules, the NEC requirements will be covered separately in the following sections.

## AC Module Systems in the NEC

Ac modules are defined by the NEC as a complete package of PV parts and electronics, independent of mounting structure, which produces ac power. 690.6 covers the installation requirements of ac modules. 690.6(C) permits a single disconnecting means to provide disconnect for multiple inverters on the same circuit. 690.6(D) permits one device to provide ground-fault protection for all the ac modules a single circuit. Note that this is not a requirement, but rather an allowance. An installer might want to provide this capability with a typical 15- or 20-amp GFCI breaker. While this sounds like a good idea, and appears to comply with 690.6(D), there are no GFCI breakers on the market, as of the writing of this document, that are listed for bidirectional power flow. Laboratory tests have shown that some GFCI breakers can be damaged while backfeeding power. A message to plan checkers and inspectors on this item—do not require GFCI breakers on circuits connected to ac modules until it is a code requirement and specifically listed products are available to properly provide protection.

## Marking

Ac module marking is covered specifically in 690.52. These markings are:

- (1) Nominal operating ac voltage
- (2) Nominal operating ac frequency
- (3) Maximum ac power
- (4) Maximum ac current
- (5) Maximum overcurrent device rating for ac module protection

690.52(5) would normally be the maximum rating of the branch circuit breaker feeding the circuit to the ac modules. The markings of 690.51 (PV module) and 690.53 (PV power source) are not required on the ac module.

The output of ac modules is defined as an inverter output circuit [690.6(B)] and the overcurrent protection for that circuit is permitted to follow the requirements of 240.5(B)(2) for fixture wires. This is significant in that it allows products to have smaller wire connected to OCPDs. By allowing smaller conductors in circuits with larger OCPDs, a product is allowed to have small conductors connected directly to the ac module while feeding power into a larger feeder. The fixture wire provisions even allow as small as 18AWG conductors to be protected by a 20-amp OCPD provided that the circuit is no longer than 20 feet. This is permissive language and does not trump the sizing and OCPD for standard wiring systems. It does allow specialty wiring systems that are evaluated as part of the product listing. Once the circuit reaches the inverter output circuit's OCPD, all aspects of an ac module are identical to other utility-interactive PV systems from that point onward.

## Micro-Inverter Systems in the NEC

The term “micro-inverter” is not used in the NEC through the 2011 version. Therefore, the requirements for micro-inverter installations must be ascertained from a series of code requirements that relate to these devices. The key sections of article 690 that provide specific guidance to micro-inverter installations are covered here sequentially.

## Maximum system voltage

690.7 defines maximum system voltage as it applies to the dc PV array. Since the PV array is only one or two modules, the worst-case value for most of the U.S. would be to



multiply the module rated open-circuit voltage (Voc) by 1.25 since that covers crystalline silicon modules down to 40°F or -40°C. For simplicity, take the maximum allowable dc voltage for the micro-inverter and divide that value by 1.25. This means that a micro-inverter with a 60-Volt maximum system voltage can use any crystalline-silicon module that has a rated Voc of 48 Volts or less without exceeding maximum voltage. For situations where this simplified 1.25 factor does not work, the standard calculations for maximum system voltage, detailed in section 6 of this guideline, should be used.

### **Disconnecting Means**

Since most micro-inverters are mounted in locations that are not readily accessible (e.g. sloped rooftops), then we must review the requirements of *690.14 (D) Utility-Interactive Inverters Mounted in Not-Readily-Accessible Locations*.

This provision specifically allows micro-inverters to be installed in places that are not readily accessible like rooftops. In order to meet the requirements, the micro-inverter must have dc and ac disconnects in sight of the inverter. These disconnects would also be in a not-readily accessible locations so 690.14(D)(3) requires that an additional ac disconnect be in a readily accessible location. This provision can be met as simply as a circuit breaker at the ac point of connection in the main service panel on a house. Lastly, 690.14(D)(4) requires that a sign be placed at the service entrance notifying where the inverters are located on the premises. The cited article 705.10 allows large numbers of inverters to be identified in groups rather than individually.

690.14(D) begs the question as to whether disconnects now have to be mounted with the micro-inverters. Bulky, vertically mounted disconnects would clearly make micro-inverters impractical. However, the exception at the end of 690.17 clarifies that a connector may be used as a disconnect provided the connector meets the requirements of 690.33 and is identified for the application. All the requirements in 690.33 apply, but the most specific relates to interruption of the circuit, 690.33(E).

*690.33(E) Interruption of Circuit. Connectors shall be either (1) or (2): (1) Be rated for interrupting current without hazard to the operator. (2) Be a type that requires the use of a tool to open and marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."*

Some micro-inverter manufacturers have their connectors certified as capable of interrupting maximum current without hazard to the operator. Those that do not have this certification must have connectors that require a tool along with the required marking to prevent inadvertent disconnect under load.

### **System and Equipment Grounding of Micro-Inverters**

Since all the dc requirements remain in effect for a micro-inverter, the system grounding rules apply. If a product requires a conductor to be grounded, a grounding electrode (GEC) must be run from the inverter to the grounding electrode system. The minimum size GEC for dc or ac systems is 8AWG [250.166 or 250.66]. Since micro-inverters may choose to ground the dc side of the system, those inverters will need an 8AWG conductor run to the grounding electrode system. 690.47(C)(3) allows for the dc GEC to be combined with the ac equipment grounding conductor (EGC) and for that combined conductor to be terminated at the grounding busbar in the service equipment where the ac circuit originates. This means that a bare or sunlight resistant 8AWG or 6AWG can be run, outside of a raceway and adjacent to the ac conductors, to pick up both the GEC and EGC requirements of a micro-inverter array. At the point where the current carrying conductors transition from the array to the wiring method going to the service panel, the combined GEC/EGC can be irreversibly spliced to a stranded 8AWG to be landed at the grounding busbar in the service equipment.

If the inverter is ungrounded, no GEC is required. Therefore, the EGC must simply be that required by the OCPD supplying the circuit and sized according to Table 250.122. The EGC can now easily be incorporated into the ac connector system provided that it the EGC is the first to make and last to break according to 690.33(D).

## Marking

Again, since dc requirements remain for micro-inverters, 690.53, marking for the PV power source applies. In this case, manufacturing a new sign is somewhat problematic since the dc disconnect is a connector. 690.53 requires that the sign be mounted on or adjacent to the PV power source disconnect. Alternatively, the PV module, as required in 690.51, has very similar marking requirements and the marking is adjacent to the PV power source disconnect, the dc connectors. The purpose of the 690.53 sign is to identify the PV array connected to an inverter since the array is often not visible from the location of the inverter, or the size of array is not obvious at the inverter. In the case of the micro-inverter, the array is essentially being held in the hands of the person operating the PV power source disconnect, with the array plainly marked [690.51], so the intent of 690.53 is met.



## APPENDIX D: SPECIAL ELECTRICAL TOPICS

### Module Frame Grounding

Module frame grounding has been a subject of confusion and controversy for many years. The primary concern raised by industry experts, including the Solar ABCs, has been the fact that the anodized aluminum frames in contact with anodized aluminum rails may not create an adequate and reliable electrical connection for bonding and grounding requirements. Until this issue was raised, many inspectors and contractors were satisfied with grounding the metal support structure rather than grounding individual modules. Several standard and new grounding methods can address the electrical bond of the module frame to its support by penetrating each nonconductive surface with a sharp, metallurgically compatible device. This device may be as simple as a stainless steel star washer, or as unique as a specially designed grounding clip with sharp points to pierce the anodizing, addressing the concern of creating a solid electrical connection that will resist corrosion.

PV module grounding options include a variety of methods, such as grounding screws or lugs on each module connected to a ground wire, or methods that create an electrical bond between the module frame and its support structure. Installation manuals for PV modules have become more explicit about grounding methods. The appropriate grounding means are to be defined in the module installation instructions as part of the UL1703 listing. While equipment grounding requirements for PV modules still require some level of interpretation by the local jurisdiction, clarifying language is being proposed for the UL1703 standard that should address most of the current ambiguities.

### AC Connection to Building Electrical Systems

#### AC Connection to Load Side of Main Service Panel

The connection of a PV system's inverter output circuit to the load side of the Main Service panel is the most common installation method. This type of connection is governed by the requirements of NEC 705.12(D) and 690.64(B) in the 2008 NEC. These requirements dictate that the maximum sum of the current ratings of overcurrent protection devices (OCPDs) that can be fed into a conductor or busbar is 120% of the busbar or conductor rating [NEC 705.12(D)(2)]. For example, if a busbar has a current rating of 225-amps, and a main breaker rated at 200-amps, then the maximum breaker rating for a PV inverter is 70-amps as shown below:

Maximum allowable OCPD: Busbar = 225A; 120% of Busbar =  $225A \times 1.2 = 270A$

Existing Main OCPD = 200A

Maximum PV OCPD = Maximum allowable OCPD - Existing Main OCPD =  $270A - 200A = 70A$

To determine the maximum size inverter that can be fed into a 70A OCPD, remember that most circuit breakers and other OCPDs are limited to 80% of their current rating for continuous operation. This means that 70A circuit breaker must be sized so that 56A can pass through the breaker on a continuous basis (3-hours or more). Since PV inverters are rated based on their maximum power at 40C for a continuous 3-hour period, an inverter capable of a continuous 56A is capable of 11,648 Watts at 208Vac; 13,440Wac at 240Vac; and 15,512Wac at 277Vac.

The only way to put more current into the load side of the service panel in this example, is to reduce the size of the main OCPD. To the extent that the main OCPD is reduced, the PV inverter OCPD may be increased. However, any time a main OCPD is reduced, a load calculation following the requirements of NEC Article 220 must be calculated to show that the load on the main OCPD will not see more than an 80% continuous load at the chosen OCPD rating.

If no other panel boards exist on this service, the only other opportunity to install a larger PV system is to make a supply-side service connection [NEC 705.12(A) in the 2011 NEC and 690.64(A) in the 2008 NEC]. This method is discussed in the AC Supply Side Connection section in this Appendix.

## AC Connection to Subpanel

When a site service contains more than one panel board, the panels fed from the main service panel are referred to as subpanels. The NEC, in 705.12(D) and NEC 690.64(B) (1) in the 2008 NEC, allows the inverter OCPD to be connected at any location in the premises wiring system, provided that the 120% of busbar and conductor ampacity limitation is observed.

For example, a large residence has a main panel with a 400-amp rating with a 400-amp main OCPD. From a 200-amp breaker in this 400-amp panel is a 200-amp panel at the opposite end of the residence. In this example, the PV array is located much closer to the 200-amp panel, so the preferred interconnection point is the 200-amp panel. As long as the inverter OCPD complies with limitations of the 200-amp panel, the inverter can interconnect at that panel.

With a 200-amp busbar and a 200-amp main breaker, the largest PV OCPD allowed in that panel is 40-amps (see discussion on AC Connection to Load Side of Main Service Panel in this Appendix). Assuming a 40-amp PV OCPD is sufficient for the PV inverter (e.g. 7000 Watt inverter), the issues of concern in the subpanel are addressed.

Now consider the current flow at the main service panel. The 2011 NEC instructs the installer to calculate the sum of the supply OCPDs at the main service panel based on the rating of inverter OCPD, which is 40-amps, not the 200-amp feeder breaker that feeds the subpanel [NEC 705.12(D)(2) and NEC 690.64(B)(2) in the 2008 NEC]. Clearly, the 40-amp PV OCPD does not exceed the 120% of busbar rating in the 400-amp panel, whereas, had the 200-amp feeder breaker value been used in the calculation, the installation would have been in violation.

To further extend this example, should another PV inverter be desired, due to the large electrical consumption of the residence, there is still ampacity allowance in the 400-amp main panel busbar. The allowable inverter OCPD size would be calculated as follows:

Maximum allowable OCPD: Busbar = 400A; 120% of Busbar =  $400A \times 1.2 = 480A$

Existing Main OCPD = 400A; Inverter OCPD in 200A subpanel = 40A

Maximum PV OCPD in 400A panel = Maximum allowable OCPD - Existing Main OCPD  
- Inverter OCPD in 200A subpanel =  $480A - 400A - 40A = 40A$

Therefore an additional 40A inverter OCPD could be placed in the main panel without any changes to the panel.

Should a larger PV system be desired than could be handled by the two 40A breakers in this example, refer to the discussions in AC Connection to Load Side of Main Service Panel in this Appendix.

## AC Supply Side Connection

When the size of PV system is relatively large relative to the size of the site service, it is fairly common to consider a supply side connection for the inverter OCPD. Whenever the 120% allowance for OCPDs connected to busbars or conductors cannot be observed, due to size of the required PV OCPD and the limited size of the service panel, the supply side connection may be the only alternative available. A supply side connection is defined as a connection made between the service meter and the service disconnect.





Not all services can be legally connected at this point. For instance, many all-in-one meter panels, used routinely in new residential construction, have no means of making such a connection without violating the listing of the product. On the other end of the size spectrum, many large 3,000-amp service panels have no space for such a connection. To further complicate this situation, some utilities have begun requiring metering current transformers to be installed on the load side of service OCPD, making a supply side connection impossible.

With those complications aside, we will discuss the situations where a supply side connection is possible and does not violate the equipment listings of the service equipment. The NEC covers supply side connections in 705.12(A) and 690.64(A) in the 2008 NEC. These sections refer back to article 230.82. The supply side connection for the PV system must have a disconnect and OCPD located immediately adjacent to the main service disconnect as specified in 230.91. If the connection is not adjacent, then there must be sign or directory showing where the disconnect(s) are located [NEC 690.56(B)]. Even though the tap rule, discussed in Article 240.99 does not apply to supply side connections, the conductors connecting the supply side connection to the PV OCPD are sized according to the OCPD rating. Therefore, if a 60-amp fused disconnect is used as the PV OCPD, the conductor size between the supply side connection and the PV OCPD need only be 6AWG, regardless of the size of service conductors.

The method of termination of PV conductors to the supply conductors or busbar, depends on the service equipment and conductors. In any case, the service voltage will need to be interrupted to tie in to the service conductors or busbar (very rare exceptions outlined in NFPA 70E are involved at facilities like hospitals where the cut-in process must be done while energized.) Typical termination methods include several options:

1. lugging to an accessible perforated bus within service equipment;
2. using an empty set of double-barrel lugs within service equipment;
3. using piercing lugs on conductors between the meter and service disconnect;
4. any lug identified for making connections to conductors of the size range installed.

Installing lugs on service conductors will often require removal of service conductors and conduit and reinstalling conductors with a junction box to accommodate the connection.

A standard diagram has been added to the list of standard diagrams for permit submittals. The key issue in the permit process is to clearly define the code approved method of making the electrical connection on the supply side of the service disconnect. An example of the diagram, based on Example 1 in Appendix A, is provided on the next page. This diagram is available as a blank interactive PDF at [www.solarabcs.org/permitting](http://www.solarabcs.org/permitting)

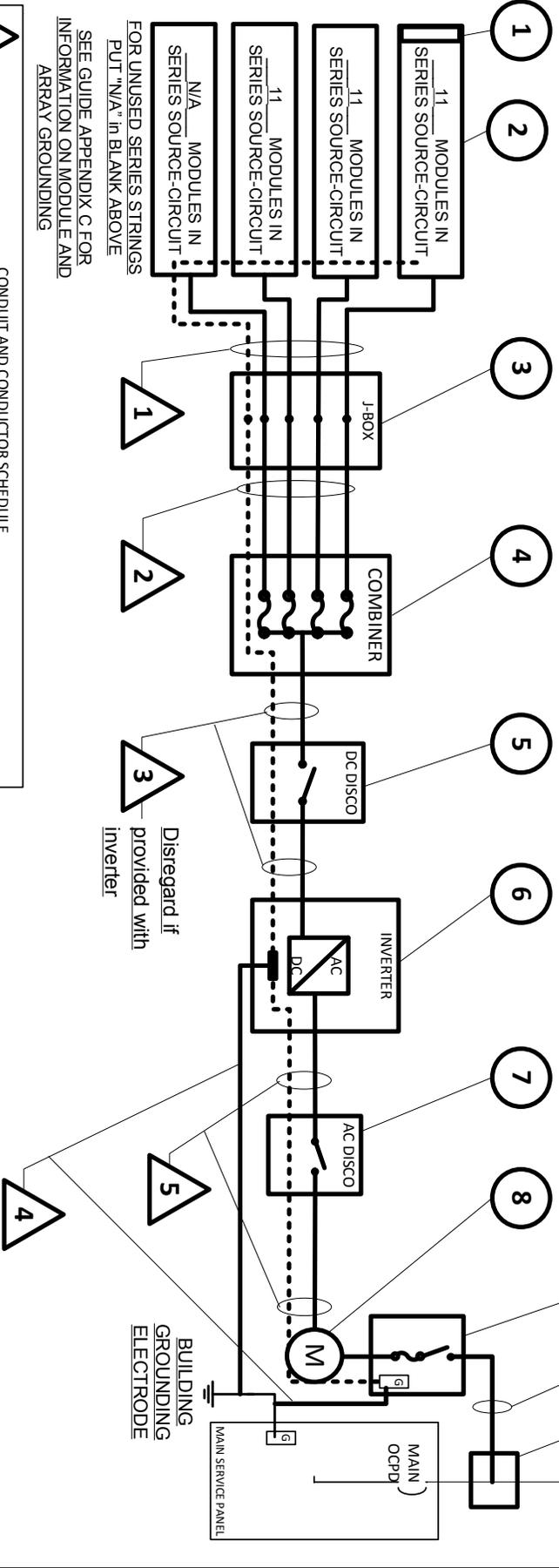
### Source Circuit Overcurrent Protection

Source circuit overcurrent protection must be sized so that both the PV module and the conductor from the module to the overcurrent device are properly protected [NEC 690.9 (A), 240.20 (A)]. PV modules must be protected so that the maximum series fuse rating, printed on the listing label, is not exceeded. It is important to note that even though the listing label states “fuse” rating, a more accurate term would be the “maximum series overcurrent protection” rating since either a fuse or a circuit breaker may be used to satisfy this listing requirement. The module may be protected either by installing fuses or circuit breakers in a series string of modules or by the design of the PV system.

Inverters listed with a maximum utility back feed current that is well above 2 amps (typically equal to the maximum allowable output overcurrent protection) must be assumed to provide back feed current to the PV array. Each source circuit must have overcurrent protection that is greater than or equal to the minimum PV Source Circuit current rating and less than or equal to the maximum series fuse rating.

# DIAGRAM FOR EXAMPLE 1

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE	AS 230	AMERICAN SOLAR, QUANTITY - 33 (SEE NOTES SHEET FOR DETAILS)
2	PV ARRAY	N/A	ARRAY IS 3 STRINGS WITH 11 MODULES PER SERIES STRING
3	J-BOX (IF USED)	MFR-supplied	6"x6"x4" NEMA 4, PVC JUNCTION BOX
4	COMBINER (IF USED)	MFR-supplied	15-A MAX FUSE W/15-A FUSES, 600VDC, 4-STRING MAX LISTED WITH INVERTER, 600VDC, 60-AMP (SEE GUIDE APPENDIX C)
5	DC DISCONNECT	MFR-supplied	7000 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)
6	DC/AC INVERTER	AI-7000	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
7	AC DISCONNECT (IF USED)	D222NRB	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
8	GEN METER (IF USED)	FORM 2S	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
9	PV SYSTEM DISCONNECT	D222NRB	KUP-L-TAP INSULATION PIERCING CONNECTORS IN NEMA 3R J-BOX
10	CONNECTION (DESCRIBE)	ILSCO IPC-4/0-6	



FOR UNUSED SERIES STRINGS PUT "N/A" IN BLANK ABOVE  
SEE GUIDE APPENDIX C FOR INFORMATION ON MODULE AND ARRAY GROUNDING

### CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE 2- <input checked="" type="checkbox"/> or PV WIRE <input type="checkbox"/>	10 AWG	8 BLACK	N/A	N/A
2	BARE COPPER EQ. GRD. COND. (EGC)	10 AWG	1 BARE CU	N/A	N/A
3	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	4-R, 4-W, 1-G	EMT	3/4"
4	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	N/A	N/A	N/A	N/A
5	INSULATED EGC	N/A	N/A	N/A	N/A
6	GROUNDING ELECTRODE COND.	6 AWG	1 BARE CU	N/A	N/A
7	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	8 AWG	1-R, 1-B, 1-W	EMT	3/4"
8	INSULATED EGC	10 AWG	1 GREEN	EMT	3/4"
9	THWN-2 <input checked="" type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	6 AWG	1-R, 1-B, 1-W	EMT	3/4"

Contractor Name, Address and Phone:  
 Bill and Ted's Solar  
 456 Excellent Drive  
 San Dimas, CA  
 800-555-1212

One-Line Electrical Diagram for Supply-Side Connected Single-Phase PV Systems  
 Site Name: Joe and Jane Homeowner  
 Site Address: 123 Sunnyside St., Fontana, CA  
 System AC Size: 6.1 kW Solar Array

Drawn By: Bill  
 Checked By: Ted

Scale: NTS  
 Date:

Sheet: 0



*Explanation: For source circuit with a maximum circuit current of 6.8 amps and a maximum series fuse rating of 15 amps, The minimum fuse rating would be 9 amps (next larger fuse rating above 8.5 amps;  $6.8A \times 1.25 = 8.5A$ ) and the maximum would be 15 amps.*

For inverters listed with a maximum utility back feed current that is 2 amps or less (e.g. Fronius IG 4000), two source circuits can be connected to the inverter without requiring overcurrent protection on either circuit.

*Explanation: If an array containing two strings in parallel is connected to an inverter that is a limited back feeding source (2 amps or less), the maximum current in a string is equal to the current from the other string in parallel plus the maximum back-fed current from the inverter. If the maximum current of each string is 6.8 Amps, and the inverter provides 2 amps, then the maximum current in a fault at any PV module is 8.8 Amps and the maximum series fuse rating of the module will never be exceeded (i.e. a module with an  $I_{sc}$  of 5.4 amps will have a maximum series overcurrent device rating of at least 10 amps).*

For smaller inverters listed with a maximum utility back feed current that is no larger than the module maximum overcurrent device rating (e.g. Enphase M200 with a 1.6 amp utility backfeed), a single source circuit can be connected to the inverter without requiring overcurrent protection on the array circuit.

*Explanation: If a single string array (could be a single module array) is connected to an inverter that provides less than the rated module maximum overcurrent device rating in backfeed current, it is equivalent to having that size overcurrent device prevent current flow from the utility and the array is protected. The maximum reverse fault current at any PV module is the amount of the inverter utility backfeed current and the maximum series fuse rating of the module will never be exceeded.*

## Disconnecting Means

The NEC defines disconnecting means in the following way:

“NEC Article 100 Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.”

A primary purpose of a disconnecting means is to open a circuit providing a source of supply so that the equipment fed by that source can be maintained without exposing the operator to hazardous voltages. NFPA 70E, Standard of Electrical Safety in the Workplace refers to this as an electrically safe work condition.

## Disconnecting Means in Inverters

Various inverters have provided a variety of integral dc and ac disconnects. These disconnects may or may not provide the necessary isolation for maintenance. The key in differentiating whether the supplied disconnects provide the appropriate isolation is to review the primary method of maintenance and repair of the device. If the device has a standard means of removing the parts needing service, without exposing the technician to hazardous voltages (anything over 50 Volts), the supplied disconnects meet the intent of maintenance disconnecting means. If the technician is exposed to voltages above 50 Volts during service, even with the supplied disconnecting means, external disconnecting means may be necessary.

It is important to point out that every currently available PV inverter that does not operate on a battery system has input capacitors. These capacitors may remain energized for five or more minutes after all external sources are removed from an inverter. Internal bleed resistors remove this voltage over a prescribed time period, and warning labels are provided on the inverter to identify this hazard. This hazard is typical of electrical equipment using significant capacitance. This capacitive source is controlled by warning signage and bleed resistors and not generally by internal or external disconnects. Disconnects should not be required to control the capacitive source during maintenance or service of the inverter.

## Utility-Required Disconnecting Means

Utilities may require some method to isolate PV systems from their grid during maintenance procedures. The isolation device is usually required to provide a visible break in order to comply, and molded-case circuit breakers do not meet that requirement. Several utilities, including the utility with the most PV installations in the U.S., Pacific Gas & Electric, have adopted a policy of allowing residential PV systems with self-contained meters (the most common residential-type meter) to provide the necessary visible break via removal of the meter. For installations with current-transformer meters, a separate visible-break switch is almost always required. When the utility requires a visible-break switch, this switch may be used to provide the NEC-required ac switch for maintaining the inverter if the inverter is located in the immediate vicinity of the switch.

## Provisions for the Photovoltaic Power Source Disconnecting Means

The NEC states in 690.14(C)(1), “Location. The photovoltaic disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the system conductors.”

- a) Readily accessible—NEC Article 100 defines, “*Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.*”
- b) The “readily accessible” provision is primarily for emergency operation. If the disconnect is not mounted in close proximity of the service entrance disconnect (usually within 10 feet of the meter location or service disconnect switch), then a diagram or directory must be provided to clearly identify where the disconnecting means is located.
- c) A rooftop disconnect on a residential roof will normally not qualify as a readily accessible disconnect.

An exception to this requirement was added to the 2005 NEC to provide additional clarification for residential and building integrated PV systems. This exception reads:

*“Exception: Installations that comply with 690.31(E) shall be permitted to have the disconnecting means located remote from the point of entry of the system conductors.”*

NEC 690.31(E) states:

**“(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building.** Where direct current photovoltaic source or output circuits of a utility-interactive inverter from a building-integrated or other photovoltaic system are run inside a building or structure, they shall be contained in metal raceways or metal enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means. The disconnecting means shall comply with 690.14(A) through 690.14(D).”

Although metal-clad cable is not specifically called out in 690.31(E), in the 2005 and 2008 NEC, many jurisdictions consider installations with metal-clad cable as meeting the intent of this provision. The 2011 NEC specifically allows MC cable in this application by adding the phrase, “Type MC metal-clad cable that complies with 250.118 (10),” to the list of allowed wiring methods. Note that this section specifically mentions building-integrated systems. The way the 2002 NEC was written, a roof-integrated PV system cannot reasonably comply with 690.14(C)(1) as written.



## APPENDIX E: COSTS OF PERMITS

Each jurisdiction may have different internal costs structures and approaches to working with solar PV systems. The following section is provided as a suggestion in developing the cost structure for a local jurisdiction.

*Explanation: Costs for permits are often based on the overall project cost. This works well for many conventional projects because this accurately represents the scale of the project. However, with a PV installation, the equipment costs are much higher than with other projects of similar scope. It is therefore recommended that an alternative permit fee scale be used for PV system installations. The scope of a PV installation is similar to that of installing a retrofitted residential HVAC system. The permitting costs for a PV system should be similar to those for an HVAC system.*

*Although initial plan review and field inspection costs may be slightly higher for the first few systems, those costs should reduce as the local jurisdiction becomes familiar with the installations. A subdivision of more than 10 units should be considered for an additional fee reduction based on the repetitive nature of the reviews. A suggested fee schedule is as follows:*

*Small PV system (up to 4 kW): \$75 - \$200*

*Large PV system (up to 10 kW): \$150 - \$400*

*For systems of 10-50 kW, consider a permit cost of \$15 - \$40 per kW.*

*For systems of 50-100 kW, consider a permit cost of \$1,500.*

*For systems of 100-500 kW, consider a permit cost of \$3,000.*

*For systems up to 1000 kW, consider a permit cost of \$3,000-\$5,000.*

## APPENDIX F: TEMPERATURE TABLES

### Design Temperatures For Various U.S. Cities

The tables on the following pages indicate low and high ambient design temperatures that must be used when designing code-compliant PV systems. These temperatures have been provided by ASHRAE, and are given in degrees Celsius. The high temperatures are used for conductor sizing and calculations of minimum array operating voltage. The low temperatures are used in the NEC 690.7 calculation.

This website provides an alternative method of viewing this same data:

<http://www.solarabcs.org/about/publications/reports/expedited-permit/map/index.html>

*There are several numbers listed for each site. A description of each number follows:*

**Elev.:** the elevation in meters of the meteorological site.

**High Temp (0.4%):** this air temperature is only exceeded during 3 hours (not necessarily continuous) of a summer month (June through August). This number is slightly more conservative than the 2% value.

**High Temp (2%):** this number is likely exceeded during 14 hours (not necessarily continuous) over a summer month (June through August). The Copper Development Association recommends that this number be used for ampacity calculations.

**Distance above roof:** The high temperature numbers refer only to the air temperature. According to the National Electrical Code, the temperature within rooftop raceways shall be assumed higher than ambient; these temperatures are dependent upon the minimum height of that conduit above the roof (NEC 2008 Table 310.15(B)(2)(c), or NEC 2011 Table 310.15(B)(3)(c)). The three figures here (0.5", 3.5", 12") are based off the High Temp (2%) numbers. Conduit that touches the roof, or is less than 0.5" above the roof is not listed since it is poor practice to mount conduit this close to the roof in general.

**Extreme Min:** The lowest expected ambient temperature for this site. This number should be used for the calculations for maximum system voltage required in NEC 690.7. An Informational Note in 690.7(A) in the 2011 NEC specifies this value, the Extreme Annual Mean Minimum Design Dry Bulb Temperature from ASHRAE Handbook—Fundamentals, as the proper value for lowest expected ambient temperature.



## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
AK	ADAK NAS	6	17	14	36	31	28	-11
AK	AMBLER	88	27	24	46	41	38	N/A
AK	ANAKTUVUK PASS	657	24	21	43	38	35	N/A
AK	ANCHORAGE INTL AP	40	24	21	43	38	35	-26
AK	ANCHORAGE MERRILL FIELD	42	25	22	44	39	36	-26
AK	ANCHORAGE/ELMENDORF	59	26	23	45	40	37	-29
AK	ANNETTE ISLAND AP	34	25	22	44	39	36	-13
AK	ANVIK	99	24	22	44	39	36	-34
AK	BARROW W POST-W ROGERS ARPT	4	18	13	35	30	27	-43
AK	BARTER ISLAND (DEW)	12	16	13	35	30	27	N/A
AK	BETHEL AIRPORT	46	25	22	44	39	36	-35
AK	BETTLES FIELD	196	29	25	47	42	39	-48
AK	BIG DELTA ALLEN AAF	388	28	25	47	42	39	-42
AK	CAPE LISBURNE(AWOS)	3	17	14	36	31	28	N/A
AK	CAPE NEWENHAM AFS	161	18	16	38	33	30	N/A
AK	CAPE ROMANZOFF AWOS	123	20	18	40	35	32	N/A
AK	COLD BAY ARPT	31	17	15	37	32	29	-16
AK	CORDOVA	15	24	21	43	38	35	-22
AK	DEADHORSE	18	23	18	40	35	32	-45
AK	DILLINGHAM MUNI	29	24	21	43	38	35	-33
AK	DUTCH HARBOR	4	19	16	38	33	30	-10
AK	FAIRBANKS INTL ARPT	138	30	26	48	43	40	-43
AK	FAIRBANKS/EIELSON A	167	30	26	48	43	40	-44
AK	FIVE FINGER ISLAND	21	20	18	40	35	32	-9
AK	FORT YUKON	138	29	26	48	43	40	-49
AK	FT. RICHARDSON/BRYA	115	26	23	45	40	37	-31
AK	GALENA A.	49	28	25	47	42	39	-46
AK	GULKANA INTERMEDIATE FIELD	481	27	25	47	42	39	-41
AK	HOMER ARPT	22	21	18	40	35	32	-20
AK	HOOPER BAY	6	19	17	39	34	31	N/A
AK	ILIAMNA ARPT	49	26	21	43	38	35	-29
AK	INDIAN MTN AFS AWOS	372	27	24	46	41	38	N/A
AK	JUNEAU INT'L ARPT	7	26	23	45	40	37	-18
AK	KAKE SEAPLANE BASE	0	22	20	42	37	34	-14
AK	KENAI MUNICIPAL AP	28	24	20	42	37	34	-33
AK	KETCHIKAN INTL AP	29	24	21	43	38	35	-14
AK	KING SALMON ARPT	15	25	22	44	39	36	-34
AK	KLAWOCK	15	22	21	43	38	35	-12
AK	KODIAK AIRPORT	34	24	20	42	37	34	-17
AK	KOTZEBUE RALPH WEIN MEMORIAL	5	23	19	41	36	33	-39
AK	LAKE HOOD SEAPLANE	40	26	23	45	40	37	-24
AK	MCGRATH ARPT	103	28	25	47	42	39	-46
AK	MCKINLEY PARK	524	26	23	45	40	37	N/A
AK	MEKORYUK	15	18	15	37	32	29	-29
AK	MIDDLETON ISL. AMOS	37	20	17	39	34	31	-9
AK	MINCHUMINA	213	26	24	46	41	38	N/A
AK	NENANA MUNICIPAL AP	110	30	26	48	43	40	-46
AK	NOME MUNICIPAL ARPT	7	24	20	42	37	34	-36
AK	NORTHWAY AIRPORT	525	28	25	47	42	39	-47
AK	PALMER MUNICIPAL	76	26	23	45	40	37	-28
AK	PETERSBURG	33	23	21	43	38	35	-16
AK	POINT HOPE (AWOS)	4	18	14	36	31	28	N/A
AK	PORT HEIDEN	29	21	17	39	34	31	-24
AK	SAINT MARY'S (AWOS)	95	24	21	43	38	35	-34
AK	SAND POINT	7	18	15	37	32	29	-12
AK	SEWARD	18	26	20	42	37	34	-17
AK	SHEMYA AFB	31	13	11	33	28	25	-8
AK	SHISHMAREF (AWOS)	2	19	15	37	32	29	N/A
AK	SITKA JAPONSKI AP	20	20	18	40	35	32	-11
AK	SKAGWAY AIRPORT	13	24	22	44	39	36	-18
AK	SOLDOTNA	34	25	22	44	39	36	-33
AK	SPARREVOHN AFS	484	24	22	44	39	36	-35
AK	ST PAUL ISLAND ARPT	9	14	12	34	29	26	-18
AK	TALKEETNA STATE ARPT	109	28	24	46	41	38	-35
AK	TATALINA LRRS	301	27	24	46	41	38	N/A
AK	TIN CITY AFS (AWOS)	83	20	15	37	32	29	N/A
AK	TOGIAC VILLAGE AWOS	6	22	19	41	36	33	-31
AK	UNALAKLEET FIELD	6	25	20	42	37	34	N/A
AK	VALDEZ PIONEER FIEL	38	23	21	43	38	35	-21
AK	VALDEZ WSO	11	25	21	43	38	35	-17

## TEMPERATURE TABLE CONTINUED



State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
AK	WHITTIER	9	24	21	43	38	35	-16
AK	WRANGELL	13	23	21	43	38	35	-13
AK	YAKUTAT STATE ARPT	9	22	19	41	36	33	-20
AL	ANNISTON METROPOLITAN AP	183	37	34	56	51	48	-11
AL	AUBURN-OPELIKA APT	236	36	33	55	50	47	-9
AL	BIRMINGHAM MUNICIPAL AP	192	37	34	56	51	48	-12
AL	CAIRNS AAF/OZARK	91	37	35	57	52	49	-8
AL	CENTREVILLE WSMO	138	36	34	56	51	48	-11
AL	DAUPHIN ISLAND	9	32	31	53	48	45	-2
AL	DOTHAN MUNICIPAL	98	37	35	57	52	49	-8
AL	GADSDEN MUNI (AWOS)	173	36	34	56	51	48	-12
AL	HUNTSVILLE INTL/JONES FIELD	196	36	34	56	51	48	-13
AL	MAXWELL AFB/MONTGOM	53	38	36	58	53	50	-6
AL	MOBILE REGIONAL AP	67	36	34	56	51	48	-7
AL	MONTGOMERY DANNELLY FIELD	62	37	35	57	52	49	-9
AL	MUSCLE SHOALS REGIONAL AP	171	37	35	57	52	49	-12
AL	TUSCALOOSA MUNICIPAL AP	57	37	35	57	52	49	-11
AR	BATESVILLE (AWOS)	141	38	35	57	52	49	-13
AR	BENTONVILLE (AWOS)	395	36	34	56	51	48	-16
AR	EAKER AFB	80	39	36	58	53	50	-15
AR	EL DORADO GOODWIN FIELD	87	38	36	58	53	50	-9
AR	FAYETTEVILLE DRAKE FIELD	384	37	34	56	51	48	-17
AR	FLIPPIN (AWOS)	350	38	35	57	52	49	-15
AR	FORT SMITH REGIONAL AP	141	39	36	58	53	50	-13
AR	HARRISON FAA AP	422	36	34	56	51	48	-15
AR	JONESBORO MUNI	82	37	35	57	52	49	-15
AR	LITTLE ROCK ADAMS FIELD	78	39	36	58	53	50	-11
AR	LITTLE ROCK AFB	103	40	37	59	54	51	-13
AR	LITTLE ROCK/ADAMS F	351	37	34	56	51	48	-12
AR	PINE BLUFF FAA AP	65	38	36	58	53	50	-9
AR	ROGERS (AWOS)	415	36	33	55	50	47	-15
AR	SILOAM SPRING(AWOS)	364	37	34	56	51	48	-15
AR	STUTTGART (AWOS)	68	37	35	57	52	49	-9
AR	TEXARKANA WEBB FIELD	122	39	36	58	53	50	-9
AR	WALNUT RIDGE (AWOS)	83	37	34	56	51	48	-13
AZ	CASA GRANDA (AWOS)	446	44	42	64	59	56	-4
AZ	DAVIS-MONTHAN AFB	809	42	40	62	57	54	-3
AZ	DOUGLAS BISBEE-DOUGLAS INTL A	1250	39	37	59	54	51	-9
AZ	FLAGSTAFF AIRPORT	2135	32	29	51	46	43	-21
AZ	GRAND CANYON NATL P	2065	34	32	54	49	46	-22
AZ	KINGMAN (AMOS)	1050	41	38	60	55	52	-8
AZ	LUKE AFB/PHOENIX	331	46	43	65	60	57	-1
AZ	NOGALES INTL	1236	39	37	59	54	51	-6
AZ	PAGE MUNI (AMOS)	1304	40	37	59	54	51	-9
AZ	PHOENIX SKY HARBOR INTL AP	337	45	43	65	60	57	1
AZ	PRESCOTT LOVE FIELD	1540	37	34	56	51	48	-12
AZ	SAFFORD (AMOS)	950	42	39	61	56	53	-7
AZ	TUCSON INTERNATIONAL AP	779	43	41	63	58	55	-3
AZ	WINSLOW MUNICIPAL AP	1488	39	36	58	53	50	-15
AZ	YUMA INTL AIRPORT	63	46	43	65	60	57	2
AZ	YUMA MCAS	65	46	43	65	60	57	2
CA	ALAMEDA NAS	4	30	26	48	43	40	3
CA	ARCATA AIRPORT	64	21	19	41	36	33	-3
CA	BAKERSFIELD MEADOWS FIELD	150	42	39	61	56	53	-2
CA	BEALE AFB/MARYSVILE	38	41	38	60	55	52	-3
CA	BISHOP AIRPORT	1263	40	38	60	55	52	-13
CA	BLUE CANYON AP	1610	31	28	50	45	42	-8
CA	BLYTHE RIVERSIDE CO ARPT	120	47	44	66	61	58	-1
CA	BURBANK-GLENDALE-PASSADENA AP	223	38	35	57	52	49	1
CA	CAMARILLO (AWOS)	23	28	27	49	44	41	1
CA	CAMP PENDLETON MCAS	24	32	29	51	46	43	-2
CA	CARLSBAD/PALOMAR	100	28	25	47	42	39	4
CA	CASTLE AFB/MERCED	60	40	37	59	54	51	-3
CA	CRESCENT CITY FAA AI	17	19	18	40	35	32	-1
CA	DAGGETT BARSTOW-DAGGETT AP	588	45	42	64	59	56	-5
CA	EDWARDS AFB	706	43	40	62	57	54	-10
CA	EL TORO MCAS	117	34	31	53	48	45	3
CA	EUREKA	18	19	18	40	35	32	-1
CA	FRESNO YOSEMITE INTL AP	100	42	39	61	56	53	-2
CA	FULLERTON MUNICIPAL	29	34	31	53	48	45	2

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
CA	GEORGE AFB	876	42	38	60	55	52	-6
CA	HAYWARD AIR TERM	14	33	28	50	45	42	1
CA	IMPERIAL	-17	46	44	66	61	58	-1
CA	JACK NORTHROP FLD H	21	31	26	48	43	40	4
CA	LANCASTER GEN WM FOX FIELD	713	42	38	60	55	52	-9
CA	LEMOORE REEVES NAS	71	41	39	61	56	53	-3
CA	LIVERMORE MUNICIPAL	121	41	36	58	53	50	-3
CA	LOMPOC (AWOS)	27	26	23	45	40	37	-2
CA	LONG BEACH DAUGHERTY FLD	12	33	30	52	47	44	2
CA	LOS ANGELES INTL ARPT	99	28	26	48	43	40	4
CA	MARCH AFB/RIVERSIDE	462	40	37	59	54	51	-2
CA	MCCLELLAN AFB	25	41	38	60	55	52	-3
CA	MODESTO CITY-COUNTY AP	30	42	38	60	55	52	-2
CA	MONTAGUE SISKIYOU COUNTY AP	805	38	34	56	51	48	N/A
CA	MONTEREY PENINSULA	50	24	22	44	39	36	1
CA	MOUNT SHASTA	1078	35	31	53	48	45	-12
CA	MOUNTAIN VIEW MOFFETT FLD NAS	10	33	29	51	46	43	0
CA	NAPA CO. AIRPORT	17	35	31	53	48	45	-4
CA	NORTON AFB/SAN BERN	353	41	38	60	55	52	-2
CA	OAKLAND METROPOLITAN ARPT	27	29	25	47	42	39	1
CA	ONTARIO	304	39	37	59	54	51	-1
CA	PALM SPRINGS INTL	145	47	44	66	61	58	3
CA	PALM SPRINGS THERMAL AP	-36	47	44	66	61	58	-5
CA	PASO ROBLES MUNICIPAL ARPT	249	42	38	60	55	52	-6
CA	POINT ARENA	19	17	15	37	32	29	2
CA	POINT ARGUELLO	34	21	18	40	35	32	5
CA	POINT MUGU NF	4	26	24	46	41	38	2
CA	PORTERVILLE (AWOS)	135	41	38	60	55	52	-2
CA	PT.PIEDRAS BLANCA	21	21	20	42	37	34	3
CA	RED BLUFF MUNICIPAL ARPT	108	44	40	62	57	54	-4
CA	REDDING MUNICIPAL ARPT	153	44	40	62	57	54	-4
CA	RIVERSIDE MUNI	256	39	36	58	53	50	-1
CA	SACRAMENTO EXECUTIVE ARPT	8	41	37	59	54	51	-3
CA	SACRAMENTO MATHER AIRPORT	29	42	38	60	55	52	-3
CA	SACRAMENTO METROPOLITAN AP	10	41	37	59	54	51	-3
CA	SALINAS MUNICIPAL AP	24	29	25	47	42	39	-1
CA	SAN DIEGO LINDBERGH FIELD	9	29	26	48	43	40	5
CA	SAN DIEGO MIRAMAR NAS	146	32	30	52	47	44	1
CA	SAN DIEGO NORTH ISLAND NAS	8	28	25	47	42	39	4
CA	SAN DIEGO/BROWN FLD	159	31	28	50	45	42	2
CA	SAN DIEGO/MONTGOMER	129	32	28	50	45	42	3
CA	SAN FRANCISCO INTL AP	6	29	25	47	42	39	2
CA	SAN JOSE INTL AP	15	36	32	54	49	46	0
CA	SAN LUIS CO RGNL	66	32	28	50	45	42	-2
CA	SANDBERG	1379	35	32	54	49	46	-5
CA	SANTA BARBARA MUNICIPAL AP	6	29	26	48	43	40	-1
CA	SANTA MARIA PUBLIC ARPT	73	29	25	47	42	39	-3
CA	SANTA ROSA (AWOS)	45	38	34	56	51	48	-3
CA	STOCKTON METROPOLITAN ARPT	8	41	38	60	55	52	-3
CA	TRAVIS AFB/FAIRFLD	18	40	36	58	53	50	-3
CA	TRUCKEE-TAHOE	1798	34	30	52	47	44	N/A
CA	TUSTIN MCAF	17	34	31	53	48	45	2
CA	UKIAH MUNICIPAL AP	191	41	37	59	54	51	-3
CA	VISALIA MUNI (AWOS)	89	39	37	59	54	51	-3
CO	AKRON WASHINGTON CO AP	1409	38	34	56	51	48	-23
CO	ALAMOSA SAN LUIS VALLEY RGNL	2299	32	29	51	46	43	-30
CO	ASPEN PITKIN CO SAR	2444	32	28	50	45	42	-24
CO	BUCKLEY ANGB/DENVER	1726	36	33	55	50	47	-22
CO	COLORADO SPRINGS MUNI AP	1881	35	32	54	49	46	-23
CO	CORTEZ/MONTEZUMA CO	1803	37	34	56	51	48	-19
CO	CRAIG-MOFFAT	1915	35	31	53	48	45	-31
CO	DENVER INTL AP	1655	37	34	56	51	48	-23
CO	DENVER STAPLETON INT'L ARPT	1611	36	34	56	51	48	-25
CO	DENVER/CENTENNIAL	1793	36	33	55	50	47	-23
CO	DURANGO/LA PLATA CO	2038	34	32	54	49	46	-21
CO	EAGLE COUNTY AP	1992	33	30	52	47	44	-28
CO	FORT COLLINS (AWOS)	1529	38	34	56	51	48	-23
CO	FORT COLLINS(SAWRS)	1525	34	32	54	49	46	-23
CO	GRAND JUNCTION WALKER FIELD	1475	39	36	58	53	50	-17
CO	GREELEY/WELD (AWOS)	1420	38	35	57	52	49	-27

## TEMPERATURE TABLE CONTINUED



State	Station	Elev (M)	High Temp (°C)		Distance above roof			Extreme Min (°C)
			0.4%	2% Avg	0.5"	3.5"	12"	
CO	GUNNISON CO. (AWOS)	2339	31	28	50	45	42	-31
CO	HAYDEN/YAMPA (AWOS)	2012	33	30	52	47	44	-25
CO	LA JUNTA MUNICIPAL AP	1285	40	37	59	54	51	-21
CO	LAMAR MUNICIPAL	1129	40	37	59	54	51	-22
CO	LIMON	1635	36	33	55	50	47	-25
CO	MONTROSE CO. ARPT	1755	37	34	56	51	48	-19
CO	PUEBLO MEMORIAL AP	1439	39	36	58	53	50	-24
CO	RIFLE/GARFIELD RGNL	1691	38	34	56	51	48	-22
CO	TRINIDAD LAS ANIMAS COUNTY AP	1751	36	33	55	50	47	-23
CT	BRIDGEPORT SIKORSKY MEMORIAL	5	33	30	52	47	44	-14
CT	HARTFORD BRADLEY INTL AP	55	35	32	54	49	46	-20
CT	HARTFORD BRAINARD FD	6	36	32	54	49	46	N/A
CT	OXFORD (AWOS)	222	33	30	52	47	44	-19
CT	WILLIMANTIC (ASOS)	76	34	32	54	49	46	-19
DE	DOVER AFB	7	36	33	55	50	47	-13
DE	GEORGETOWN/SUSSEX	16	36	33	55	50	47	-11
DE	WILMINGTON NEW CASTLE CNTY AP	24	36	33	55	50	47	-15
FL	APALACHICOLA MUNI AP	6	35	33	55	50	47	-5
FL	CAPE SAN BLAS	2	31	30	52	47	44	-2
FL	CECIL FIELD	27	37	35	57	52	49	-6
FL	CRESTVIEW BOB SIKES AP	56	37	35	57	52	49	-9
FL	CROSS CITY AIRPORT	13	36	34	56	51	48	-6
FL	DAYTONA BEACH INTL AP	13	35	33	55	50	47	-2
FL	DESTIN FT. WALTON	7	34	32	54	49	46	N/A
FL	EGLIN AFB/VALPARAIS	20	36	33	55	50	47	-6
FL	FORT LAUDERDALE HOLLYWOOD INT	3	34	33	55	50	47	5
FL	FORT MYERS PAGE FIELD	6	35	34	56	51	48	2
FL	GAINESVILLE REGIONAL AP	50	35	34	56	51	48	-5
FL	HOMESTEAD AFB	5	34	33	55	50	47	5
FL	HURLBURT FIELD (AF)	12	35	33	55	50	47	-5
FL	JACKSONVILLE INTL ARPT	10	36	34	56	51	48	-5
FL	JACKSONVILLE NAS	7	37	35	57	52	49	-4
FL	JACKSONVILLE/CRAIG	13	36	34	56	51	48	-4
FL	KEY WEST INTL ARPT	6	33	32	54	49	46	10
FL	KEY WEST NAS	7	33	32	54	49	46	10
FL	MACDILL AFB/TAMPA	8	35	34	56	51	48	1
FL	MARATHON AIRPORT	2	34	33	55	50	47	N/A
FL	MAYPORT NS	4	37	34	56	51	48	-3
FL	MELBOURNE REGIONAL AP	8	35	33	55	50	47	0
FL	MIAMI INTL AP	9	34	33	55	50	47	5
FL	MIAMI/KENDALL-TAMIA	3	34	33	55	50	47	4
FL	MOLASSES REEF	11	31	30	52	47	44	9
FL	NAPLES MUNICIPAL	7	34	32	54	49	46	3
FL	NASA SHUTTLE FCLTY	3	34	33	55	50	47	0
FL	OCALA MUNI (AWOS)	27	35	34	56	51	48	-6
FL	ORLANDO EXECUTIVE AP	34	35	34	56	51	48	1
FL	ORLANDO INTL ARPT	32	35	34	56	51	48	-1
FL	ORLANDO SANFORD AIRPORT	17	36	34	56	51	48	1
FL	PANAMA CITY BAY CO	6	36	33	55	50	47	-4
FL	PENSACOLA FOREST SHERMAN NAS	9	36	34	56	51	48	-6
FL	PENSACOLA REGIONAL AP	36	36	34	56	51	48	-6
FL	SARASOTA BRADENTON	10	35	33	55	50	47	0
FL	SOMBRERO KEY	37	32	31	53	48	45	11
FL	SOUTHWEST FLORIDA I	9	35	34	56	51	48	1
FL	ST AUGUSTINE ARPT	3	35	33	55	50	47	N/A
FL	ST PETERSBURG CLEAR	3	35	34	56	51	48	1
FL	ST. AUGUSTINE	9	34	31	53	48	45	0
FL	TALLAHASSEE REGIONAL AP	21	37	35	57	52	49	-8
FL	TAMPA INTERNATIONAL AP	3	34	33	55	50	47	-1
FL	TYNDALL AFB	7	35	32	54	49	46	-5
FL	VENICE PIER	5	32	30	52	47	44	1
FL	VERO BEACH MUNICIPAL ARPT	9	35	33	55	50	47	0
FL	WEST PALM BEACH INTL ARPT	6	34	33	55	50	47	3
FL	WHITING FIELD NAAS	61	36	34	56	51	48	-7
GA	ALBANY DOUGHERTY COUNTY AP	59	37	36	58	53	50	-8
GA	ATHENS BEN EPPS AP	244	37	35	57	52	49	-11
GA	ATLANTA (NEXRAD)	296	36	33	55	50	47	-11
GA	ATLANTA HARTSFIELD INTL AP	313	37	34	56	51	48	-11
GA	AUGUSTA BUSH FIELD	45	38	36	58	53	50	-10
GA	AUGUSTA/DANIEL FLD	128	37	35	57	52	49	-6

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
GA	BRUNSWICK MALCOLM MCKINNON AP	7	36	33	55	50	47	-5
GA	COLUMBUS METROPOLITAN ARPT	120	37	35	57	52	49	-9
GA	DEKALB PEACHTREE	313	36	34	56	51	48	-9
GA	DOBBINS AFB/MARIETT	330	36	34	56	51	48	-12
GA	FORT BENNING	88	38	36	58	53	50	-10
GA	FULTON CO ARPT BROW	263	36	34	56	51	48	-11
GA	GAINESVILLELEE GIL	389	35	33	55	50	47	-8
GA	HUNTER AAF	13	38	35	57	52	49	-5
GA	MACON MIDDLE GA REGIONAL AP	110	38	35	57	52	49	-9
GA	MOODY AFB/VALDOSTA	71	37	35	57	52	49	-7
GA	ROME R B RUSSELL AP	196	38	35	57	52	49	-11
GA	SAVANNAH INTL AP	16	37	35	57	52	49	-7
GA	VALDOSTA WB AIRPORT	60	37	35	57	52	49	-7
GA	WARNER ROBINS AFB	92	38	36	58	53	50	-8
GA	WAYCROSS WARE CO AP	43	38	35	57	52	49	-6
HI	BARBERS POINT NAS	10	34	32	54	49	46	13
HI	HILO INTERNATIONAL AP	11	30	29	51	46	43	15
HI	HONOLULU INTL ARPT	5	32	32	54	49	46	14
HI	KAHULUI AIRPORT	15	32	31	53	48	45	13
HI	KANEHOE BAY MCAS	6	30	29	51	46	43	16
HI	KONA INTL AT KEAHOL	15	31	30	52	47	44	14
HI	LIHUE AIRPORT	45	30	29	51	46	43	14
HI	MOLOKAI (AMOS)	137	31	30	52	47	44	13
IA	AMES MUNI ARPT	291	34	32	54	49	46	-26
IA	ANKENY REGIONAL ARP	275	37	34	56	51	48	-22
IA	ATLANTIC	360	36	33	55	50	47	N/A
IA	BOONE MUNI	354	35	33	55	50	47	N/A
IA	BURLINGTON MUNICIPAL AP	214	37	33	55	50	47	-23
IA	CARROLL	375	35	33	55	50	47	N/A
IA	CEDAR RAPIDS MUNICIPAL AP	266	36	33	55	50	47	-26
IA	CHARITON	320	37	33	55	50	47	-23
IA	CHARLES CITY	343	33	32	54	49	46	N/A
IA	CLARION	354	35	32	54	49	46	N/A
IA	CLINTON MUNI (AWOS)	216	35	32	54	49	46	-25
IA	CRESTON	394	36	33	55	50	47	-23
IA	DAVENPORT NEXRAD	259	34	32	54	49	46	-25
IA	DES MOINES INTL AP	294	37	33	55	50	47	-25
IA	DUBUQUE REGIONAL AP	329	34	31	53	48	45	-26
IA	ESTHERVILLE MUNI	401	34	31	53	48	45	-26
IA	FAIR FIELD	244	37	34	56	51	48	N/A
IA	FORT DODGE (AWOS)	355	35	32	54	49	46	-27
IA	KEOKUK MUNI	205	38	34	56	51	48	N/A
IA	MARSHALL TOWN MUNI	296	34	32	54	49	46	-26
IA	MASON CITY MUNICIPAL ARPT	373	35	32	54	49	46	-28
IA	OTTUMWA INDUSTRIAL AP	258	37	33	55	50	47	-24
IA	SIOUX CITY SIOUX GATEWAY AP	336	37	33	55	50	47	-26
IA	SPENCER	408	36	32	54	49	46	-28
IA	STORM LAKE	454	36	33	55	50	47	N/A
IA	WASHINGTON	230	36	33	55	50	47	N/A
IA	WATERLOO MUNICIPAL AP	268	36	33	55	50	47	-28
IA	WEBSTER CITY	342	35	33	55	50	47	-25
ID	BOISE AIR TERMINAL	874	39	36	58	53	50	-17
ID	BURLEY MUNICIPAL ARPT	1267	37	33	55	50	47	-20
ID	CALDWELL (AWOS)	740	39	35	57	52	49	-13
ID	CHALLIS	1546	36	32	54	49	46	-29
ID	COEUR D'ALENE(AWOS)	707	36	32	54	49	46	-18
ID	ELK CITY (RAMOS)	1249	38	34	56	51	48	-15
ID	IDAHO FALLS FANNING FIELD	1446	36	33	55	50	47	-26
ID	JOSLIN FLD MAGIC VA	1297	38	34	56	51	48	-16
ID	LEWISTON NEZ PERCE CNTY AP	438	40	35	57	52	49	-14
ID	MCCALL ARPT	1530	33	29	51	46	43	-26
ID	MOUNTAIN HOME AFB	912	40	37	59	54	51	-19
ID	MULLAN (AWRS)	1011	32	30	52	47	44	-21
ID	POCATELLO REGIONAL AP	1365	37	34	56	51	48	-24
ID	SALMON/LEMHI (AWOS)	1233	36	31	53	48	45	-24
IL	AURORA MUNICIPAL	215	35	32	54	49	46	-25
IL	CAHOKIA/ST. LOUIS	126	37	34	56	51	48	-17
IL	CHICAGO MIDWAY AP	188	36	33	55	50	47	-22
IL	CHICAGO OHARE INTL AP	205	36	33	55	50	47	-24
IL	DECATUR	213	36	33	55	50	47	-22

## TEMPERATURE TABLE CONTINUED



State	Station	Elev (M)	High Temp (°C)		Distance above roof			Extreme Min (°C)
			0.4%	2% Avg	0.5"	3.5"	12"	
IL	GLENVIEW NAS	199	36	33	55	50	47	-24
IL	LAWRENCEVILLEVIN.	131	36	33	55	50	47	-18
IL	MARSEILLES ISLAND	225	36	33	55	50	47	-25
IL	MATTOON/CHARLESTON	220	35	32	54	49	46	-20
IL	MOLINE QUAD CITY INTL AP	181	37	34	56	51	48	-25
IL	MOUNT VERNON (AWOS)	146	36	34	56	51	48	-21
IL	PEORIA GREATER PEORIA AP	202	36	33	55	50	47	-23
IL	QUINCY MUNI BALDWIN FLD	234	37	33	55	50	47	-23
IL	ROCKFORD GREATER ROCKFORD AP	227	35	33	55	50	47	-26
IL	SCOTT AFB/BELLEVEILL	135	37	35	57	52	49	-19
IL	SOUTHERN ILLINOIS	128	36	34	56	51	48	-17
IL	SPRINGFIELD CAPITAL AP	187	36	33	55	50	47	-23
IL	STERLING ROCKFALLS	197	35	32	54	49	46	-25
IL	UNIV OF ILLINOIS WI	236	36	33	55	50	47	-23
IL	W. CHICAGO/DU PAGE	231	35	32	54	49	46	-24
IN	EVANSVILLE REGIONAL AP	118	36	34	56	51	48	-19
IN	FORT WAYNE INTL AP	252	35	32	54	49	46	-23
IN	GRISSOM ARB	253	36	33	55	50	47	-23
IN	HUNTINGBURG	161	35	33	55	50	47	N/A
IN	INDIANAPOLIS INTL AP	246	35	32	54	49	46	-22
IN	LAFAYETTE PURDUE UNIV AP	194	36	33	55	50	47	-23
IN	MONROE CO	264	34	32	54	49	46	-21
IN	SOUTH BEND MICHIANA RGNL AP	236	36	32	54	49	46	-22
IN	TERRE HAUTE/HULMAN	175	36	33	55	50	47	-23
KS	CHANUTE MARTIN JOHNSON AP	308	38	35	57	52	49	-19
KS	COFFEYVILLE MUNI	230	38	36	58	53	50	-17
KS	CONCORDIA BLOSSER MUNI AP	452	40	37	59	54	51	-21
KS	DODGE CITY REGIONAL AP	790	40	37	59	54	51	-20
KS	ELKHART (AWOS)	1099	39	37	59	54	51	N/A
KS	FT RILEY/MARSHALL A	324	40	37	59	54	51	-20
KS	GARDEN CITY MUNICIPAL AP	878	39	37	59	54	51	-22
KS	GOODLAND RENNER FIELD	1124	39	36	58	53	50	-23
KS	GREAT BEND (AWOS)	575	41	37	59	54	51	-19
KS	HAYS MUNI (AWOS)	609	41	38	60	55	52	-20
KS	HILL CITY MUNICIPAL AP	677	42	38	60	55	52	-21
KS	LAWRENCE MUNI ARPT	254	39	36	58	53	50	-21
KS	LIBERAL MUNI	901	39	37	59	54	51	-18
KS	MANHATTAN RGNL	330	40	37	59	54	51	-22
KS	MCCONNELL AFB	414	40	37	59	54	51	-17
KS	MEDICINE LODGE ASOS	469	41	38	60	55	52	-17
KS	NEWTON (AWOS)	467	40	36	58	53	50	-17
KS	OLATHE/JOHNSON CO.	334	37	35	57	52	49	-20
KS	PARSONSITRI CITY	274	38	36	58	53	50	-19
KS	RUSSELL MUNICIPAL AP	568	41	37	59	54	51	-21
KS	SALINA MUNICIPAL AP	391	41	38	60	55	52	-20
KS	TOPEKA FORBES FIELD	329	38	35	57	52	49	-20
KS	TOPEKA MUNICIPAL AP	270	38	35	57	52	49	-21
KS	WICHITA MID-CONTINENT AP	408	41	37	59	54	51	-18
KS	WICHITA/COL. JABARA	433	41	36	58	53	50	-17
KS	WINFIELDDARK CITY	353	40	37	59	54	51	-17
KY	BOWLING GREEN WARREN CO AP	164	36	33	55	50	47	-17
KY	CAPITAL CITY ARPT	245	35	32	54	49	46	-17
KY	CINCINNATI NORTHERN KY AP	269	36	32	54	49	46	-21
KY	FORT CAMPBELL (AAF)	173	37	34	56	51	48	-16
KY	FORT KNOX/GODMAN	239	37	33	55	50	47	-18
KY	HENDERSON CITY	117	35	33	55	50	47	-19
KY	JACKSON JULIAN CARROLL AP	414	34	31	53	48	45	-18
KY	LEXINGTON BLUEGRASS AP	301	35	33	55	50	47	-19
KY	LONDON-CORBIN AP	369	34	32	54	49	46	-18
KY	LOUISVILLE BOWMAN FIELD	170	37	34	56	51	48	-18
KY	LOUISVILLE STANDIFORD FIELD	149	36	34	56	51	48	-17
KY	PADUCAH BARKLEY REGIONAL AP	126	36	34	56	51	48	-17
KY	SOMERSET(AWOS)	283	37	34	56	51	48	-13
LA	ALEXANDRIA ESLER REGIONAL AP	36	38	35	57	52	49	-7
LA	ALEXANDRIA INTERNATIONAL	27	37	35	57	52	49	-7
LA	BARKSDALE AFB	54	38	35	57	52	49	-9
LA	BATON ROUGE RYAN ARPT	23	35	34	56	51	48	-6
LA	FORT POLK (ARMY)	102	37	35	57	52	49	-6
LA	GRAND ISLE	10	32	31	53	48	45	0
LA	LAFAYETTE REGIONAL AP	13	35	34	56	51	48	-6

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
LA	LAKE CHARLES REGIONAL ARPT	3	35	34	56	51	48	-5
LA	MONROE REGIONAL AP	25	37	36	58	53	50	-8
LA	NEW ORLEANS ALVIN CALLENDER F	0	35	33	55	50	47	-5
LA	NEW ORLEANS INTL ARPT	6	36	34	56	51	48	-4
LA	NEW ORLEANS LAKEFRONT AP	3	35	34	56	51	48	-1
LA	PATTERSON MEMORIAL	3	36	33	55	50	47	-3
LA	SALT POINT (RAMOS)	3	34	33	55	50	47	N/A
LA	SHREVEPORT DOWNTOWN	55	39	37	59	54	51	-6
LA	SHREVEPORT REGIONAL ARPT	79	38	36	58	53	50	-8
LA	SOUTHWEST PASS	12	32	31	53	48	45	2
MA	BARNSTABLE MUNI BOA	17	32	28	50	45	42	-16
MA	BOSTON LOGAN INT'L ARPT	9	35	32	54	49	46	-17
MA	BUZZARDS BAY	17	27	23	45	40	37	-15
MA	CHATHAM MUNI ARPT	19	31	27	49	44	41	N/A
MA	LAWRENCE MUNI	46	34	32	54	49	46	-18
MA	MARTHAS VINEYARD	21	31	27	49	44	41	-17
MA	NEW BEDFORD RGNL	25	34	31	53	48	45	-17
MA	NORWOOD MEMORIAL	15	35	32	54	49	46	N/A
MA	OTIS ANGB	40	32	29	51	46	43	-16
MA	PLYMOUTH MUNICIPAL	45	34	31	53	48	45	-18
MA	PROVINCETOWN (AWOS)	2	32	28	50	45	42	-14
MA	SOUTH WEYMOUTH NAS	49	35	32	54	49	46	-19
MA	WORCESTER REGIONAL ARPT	310	32	29	51	46	43	-20
MD	ANDREWS AFB	86	37	34	56	51	48	-15
MD	BALTIMORE BLT-WASHNGTN INT'L	47	37	34	56	51	48	-15
MD	PATUXENT RIVER NAS	12	36	33	55	50	47	-13
MD	SALISBURY WICOMICO CO AP	18	36	33	55	50	47	-14
MD	THOMAS POINT	12	33	30	52	47	44	-10
ME	AUBURN-LEWISTON	88	33	30	52	47	44	-27
ME	AUGUSTA AIRPORT	110	33	30	52	47	44	-23
ME	BANGOR INTERNATIONAL AP	59	33	30	52	47	44	-27
ME	BAR HARBOR (AWOS)	26	30	27	49	44	41	-22
ME	BRUNSWICK NAS	23	33	30	52	47	44	-24
ME	CARIBOU MUNICIPAL ARPT	190	32	28	50	45	42	-31
ME	GREENVILLE (AMOS)	316	30	28	50	45	42	-30
ME	HOULTON INTL ARPT	145	32	29	51	46	43	-32
ME	LORING AFB/LIMESTON	227	32	28	50	45	42	-29
ME	MATINICUS ROCK	27	22	19	41	36	33	-18
ME	MT DESERT ROCK	16	21	18	40	35	32	-18
ME	NORTHERN AROOSTOOK	309	29	27	49	44	41	-28
ME	PORTLAND INTL JETPORT	19	33	30	52	47	44	-23
ME	PRESQUE ISLE MUNICIP	163	31	29	51	46	43	-34
ME	ROCKLAND/KNOX(AWOS)	17	31	27	49	44	41	-21
ME	SANFORD MUNI (AWOS)	74	34	31	53	48	45	-27
ME	WATERVILLE (AWOS)	101	32	29	51	46	43	N/A
ME	WISCASSET	21	32	29	51	46	43	-23
MI	ALPENA COUNTY REGIONAL AP	211	34	30	52	47	44	-26
MI	ANTRIM CO ARPT	190	33	30	52	47	44	-25
MI	BENTON HARBOR/ROSS	196	34	31	53	48	45	-19
MI	CADILLAC WEXFORD CO AP	398	33	30	52	47	44	-29
MI	CHIPPEWA CO INTL	250	31	28	50	45	42	-27
MI	COPPER HARBOR RAMOS	186	31	26	48	43	40	-22
MI	DETROIT CITY AIRPORT	191	35	32	54	49	46	-19
MI	DETROIT METROPOLITAN ARPT	202	35	32	54	49	46	-20
MI	DETROIT WILLOW RUN AP	218	35	32	54	49	46	-20
MI	ESCANABA (AWOS)	187	31	27	49	44	41	-26
MI	FLINT BISHOP INTL ARPT	234	35	31	53	48	45	-23
MI	GRAND RAPIDS KENT COUNTY INT'	245	34	31	53	48	45	-22
MI	GROSSE ISLE ARPT	176	34	31	53	48	45	-16
MI	HANCOCK HOUGHTON CO AP	329	33	28	50	45	42	-24
MI	HARBOR BEACH(RAMOS)	183	35	31	53	48	45	-17
MI	HOLLAND/TULIP CITY	210	33	30	52	47	44	-19
MI	HOUGHTON LAKE ROSCOMMON CO AR	354	33	30	52	47	44	-26
MI	HOWELL	293	34	32	54	49	46	-20
MI	IRON MOUNTAIN/FORD	360	34	30	52	47	44	-29
MI	IRONWOOD (AWOS)	375	33	29	51	46	43	-30
MI	JACKSON REYNOLDS FIELD	311	33	31	53	48	45	-22
MI	KALAMAZOO BATTLE CR	273	34	32	54	49	46	-20
MI	LANSING CAPITAL CITY ARPT	266	34	31	53	48	45	-24
MI	MACKINACK ISLAND	300	33	28	50	45	42	-26

## TEMPERATURE TABLE CONTINUED



State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
MI	MANISTEE (AWOS)	189	32	29	51	46	43	-21
MI	MANISTIQUE (AMOS)	178	28	25	47	42	39	-22
MI	MARQUETTE COUNTY ARPT	431	33	29	51	46	43	-30
MI	MENOMINEE (AWOS)	191	33	29	51	46	43	-26
MI	MUSKEGON COUNTY ARPT	193	32	30	52	47	44	-20
MI	NEWBERRY LUCE CO.	265	32	28	50	45	42	-26
MI	OAKLAND CO INTL	306	34	31	53	48	45	-20
MI	OSCODA WURTSMITH AFB	193	35	31	53	48	45	-22
MI	PASSAGE ISLAND	209	22	19	41	36	33	-24
MI	PELLSTON EMMET COUNTY AP	218	33	30	52	47	44	-29
MI	ROCK OF AGES	223	25	21	43	38	35	-26
MI	SAGINAW TRI CITY INTL AP	204	35	32	54	49	46	-21
MI	SAULT STE MARIE SANDERSON FIE	221	32	28	50	45	42	-29
MI	SELFRIDGE ANGB	177	35	32	54	49	46	-20
MI	ST.CLAIR COUNTY INT	198	33	32	54	49	46	-22
MI	STANNARD ROCK	212	26	23	45	40	37	-20
MI	STURGIS/KIRSH MUNI	282	33	32	54	49	46	-21
MI	TRAVERSE CITY CHERRY CAPITAL	192	34	31	53	48	45	-23
MN	AITKIN NDB(AWOS)	367	32	29	51	46	43	-33
MN	ALBERT LEA (AWOS)	383	34	31	53	48	45	-28
MN	ALEXANDRIA MUNICIPAL AP	436	35	31	53	48	45	-31
MN	AUSTIN MUNI	375	34	31	53	48	45	-28
MN	BAUDETTE INTERNATIONAL AP	330	32	29	51	46	43	-35
MN	BEMIDJI MUNICIPAL	420	33	30	52	47	44	-34
MN	BENSON MUNI	317	36	32	54	49	46	-30
MN	BRAINERD/WIELAND	374	34	30	52	47	44	-33
MN	CAMBRIDGE MUNI	287	37	32	54	49	46	-31
MN	CLOQUET (AWOS)	390	33	29	51	46	43	-31
MN	CRANE LAKE (AWOS)	350	33	29	51	46	43	-34
MN	CROOKSTON MUNI FLD	273	32	30	52	47	44	-34
MN	DETROIT LAKES(AWOS)	426	33	30	52	47	44	-32
MN	DULUTH HARBOR (CGS)	186	33	29	51	46	43	-27
MN	DULUTH INTERNATIONAL ARPT	432	32	28	50	45	42	-32
MN	ELY MUNI	455	32	29	51	46	43	-37
MN	EVELETH MUNI (AWOS)	421	33	29	51	46	43	-35
MN	FAIRMONT MUNI(AWOS)	354	33	31	53	48	45	-26
MN	FARIBAULT MUNI AWOS	322	34	31	53	48	45	-29
MN	FERGUS FALLS(AWOS)	361	35	31	53	48	45	-31
MN	FLYING CLOUD	283	35	32	54	49	46	-27
MN	FOSSTON(AWOS)	388	33	30	52	47	44	-35
MN	GLENWOOD (ASOS)	425	36	31	53	48	45	-30
MN	GRAND MARAIS MUNI	548	29	26	48	43	40	-30
MN	GRAND RAPIDS(AWOS)	413	32	28	50	45	42	-32
MN	HALLOCK	250	33	31	53	48	45	-34
MN	HIBBING CHISHOLM-HIBBING AP	414	32	29	51	46	43	-36
MN	HUTCHINSON (AWOS)	323	34	32	54	49	46	-30
MN	INTERNATIONAL FALLS INTL AP	361	32	29	51	46	43	-37
MN	LITCHFIELD MUNI	347	34	31	53	48	45	-28
MN	LITTLE FALLS (AWOS)	342	35	32	54	49	46	-32
MN	MANKATO(AWOS)	311	33	31	53	48	45	-26
MN	MARSHALL/RYAN(AWOS)	359	35	32	54	49	46	-27
MN	MINNEAPOLIS/BLAINE	278	35	32	54	49	46	-26
MN	MINNEAPOLIS/CRYSTAL	265	36	32	54	49	46	-26
MN	MINNEAPOLIS-ST PAUL INT'L ARP	255	36	32	54	49	46	-28
MN	MONTEVIDEO (AWOS)	315	34	32	54	49	46	-28
MN	MORA MUNI (AWOS)	309	33	31	53	48	45	-31
MN	MORRIS MUNI (AWOS)	347	33	31	53	48	45	-30
MN	NEW ULM MUNI (AWOS)	308	34	32	54	49	46	-27
MN	ORR	397	33	29	51	46	43	-35
MN	OWATONNA (AWOS)	350	33	31	53	48	45	-28
MN	PARK RAPIDS MUNICIPAL AP	440	33	30	52	47	44	-34
MN	PEQUOT LAKE (AMOS)	390	36	31	53	48	45	-35
MN	PIPESTONE (AWOS)	529	34	31	53	48	45	-28
MN	PRINCETON MUNI	306	35	31	53	48	45	-29
MN	RED WING	239	35	32	54	49	46	-28
MN	REDWOOD FALLS MUNI	314	36	33	55	50	47	-29
MN	ROCHESTER INTERNATIONAL ARPT	402	33	31	53	48	45	-29
MN	ROSEAU MUNI (AWOS)	323	33	29	51	46	43	-35
MN	SILVER BAY	331	32	28	50	45	42	-34
MN	SOUTH ST PAUL MUNI	250	35	32	54	49	46	-26

## TEMPERATURE TABLE CONTINUED

State	Station	Elev (M)	High Temp (°C)		Distance above roof			Extreme Min (°C)
			0.4%	2% Avg	0.5"	3.5"	12"	
MN	ST CLOUD REGIONAL ARPT	312	35	31	53	48	45	-32
MN	ST JAMES MUNI ARPT	325	34	32	54	49	46	-25
MN	ST PAUL DOWNTOWN AP	217	36	31	53	48	45	-28
MN	THIEF RIVER(AWOS)	340	32	29	51	46	43	-33
MN	TOFTE (RAMOS)	241	29	25	47	42	39	-29
MN	TWO HARBORS	328	32	28	50	45	42	-31
MN	WHEATON NDB (AWOS)	313	33	31	53	48	45	-30
MN	WILLMAR	344	34	31	53	48	45	-31
MN	WINONA MUNI (AWOS)	200	36	32	54	49	46	-28
MN	WORTHINGTON (AWOS)	480	34	31	53	48	45	-26
MO	CAPE GIRARDEAU MUNICIPAL AP	107	37	34	56	51	48	-18
MO	COLUMBIA REGIONAL AIRPORT	274	37	34	56	51	48	-21
MO	JEFFERSON CITY MEM	167	38	35	57	52	49	-19
MO	JOPLIN MUNICIPAL AP	300	37	35	57	52	49	-18
MO	KAISER MEM (AWOS)	265	38	35	57	52	49	-18
MO	KANSAS CITY DOWNTOWN AP	229	38	35	57	52	49	-19
MO	KANSAS CITY INT'L ARPT	312	38	35	57	52	49	-21
MO	KIRKSVILLE REGIONAL AP	294	37	34	56	51	48	-22
MO	POPLAR BLUFF(AWOS)	146	36	34	56	51	48	-16
MO	SEDALIA MEMORIAL	277	38	35	57	52	49	-18
MO	SPICKARD (AWOS)	270	38	35	57	52	49	N/A
MO	SPRINGFIELD REGIONAL ARPT	387	37	34	56	51	48	-19
MO	ST LOUIS LAMBERT INT'L ARPT	216	37	35	57	52	49	-19
MO	ST LOUIS SPIRIT OF ST LOUIS A	141	37	34	56	51	48	-20
MO	VICHY ROLLA NATL ARPT	347	38	34	56	51	48	-19
MO	WHITEMAN AFB	255	38	35	57	52	49	-20
MS	COLUMBUS AFB	68	37	35	57	52	49	-11
MS	GOLDEN TRI(AWOS)	80	37	35	57	52	49	-10
MS	GREENWOOD LEFLORE ARPT	41	37	35	57	52	49	-10
MS	HATTIESBURG LAUREL	93	38	35	57	52	49	-8
MS	JACKSON INTERNATIONAL AP	101	37	35	57	52	49	-9
MS	KEESLER AFB/BILOXI	8	36	34	56	51	48	-6
MS	MCCOMB PIKE COUNTY AP	129	36	34	56	51	48	-8
MS	MERIDIAN KEY FIELD	95	37	35	57	52	49	-10
MS	MERIDIAN NAAS	97	38	36	58	53	50	-11
MS	NATCHEZ/HARDY(AWOS)	83	36	34	56	51	48	-7
MS	TUPELO C D LEMONS ARPT	110	37	35	57	52	49	-12
MT	BILLINGS LOGAN INT'L ARPT	1088	38	34	56	51	48	-27
MT	BOZEMAN GALLATIN FIELD	1356	36	32	54	49	46	-33
MT	BUTTE BERT MOONEY ARPT	1687	34	30	52	47	44	-35
MT	CUT BANK MUNI AP	1170	34	30	52	47	44	-33
MT	DILLON AIRPORT	1592	34	30	52	47	44	-26
MT	GLASGOW INTL ARPT	699	37	34	56	51	48	-33
MT	GLENDIVE(AWOS)	749	38	34	56	51	48	-31
MT	GREAT FALLS	1130	36	31	53	48	45	N/A
MT	GREAT FALLS INTL ARPT	1115	36	32	54	49	46	-31
MT	HAVRE CITY-COUNTY AP	792	37	34	56	51	48	-35
MT	HELENA REGIONAL AIRPORT	1179	37	33	55	50	47	-30
MT	JORDAN (RAMOS)	811	38	35	57	52	49	-37
MT	KALISPELL GLACIER PK INT'L AR	906	35	31	53	48	45	-27
MT	LEWISTOWN MUNICIPAL ARPT	1264	35	31	53	48	45	-31
MT	MALMSTROM AFB	1056	36	33	55	50	47	-30
MT	MILES CITY MUNICIPAL ARPT	803	39	36	58	53	50	-31
MT	MISSOULA INTERNATIONAL AP	972	37	33	55	50	47	-25
MT	SIDNEY-RICHLAND	605	37	33	55	50	47	-32
NC	ASHEVILLE REGIONAL ARPT	661	33	31	53	48	45	-15
NC	CAPE HATTERAS	3	32	30	52	47	44	-4
NC	CAPE LOOKOUT	11	31	29	51	46	43	-6
NC	CHARLOTTE DOUGLAS INTL ARPT	234	37	34	56	51	48	-11
NC	CHERRY POINT MCAS	9	36	33	55	50	47	-9
NC	DIAMOND SHOALS (LS)	0	30	28	50	45	42	-3
NC	FAYETTEVILLE RGNL G	59	38	35	57	52	49	-10
NC	FORT BRAGG/SIMMONS	93	38	35	57	52	49	-10
NC	FRYING PAN SHOALS	24	30	29	51	46	43	-2
NC	GREENSBORO PIEDMONT TRIAD INT	270	35	33	55	50	47	-13
NC	HATTERAS BILLY MITCHELL AP	3	33	31	53	48	45	-6
NC	HICKORY REGIONAL AP	362	36	33	55	50	47	-13
NC	JACKSONVILLE (AWOS)	29	37	34	56	51	48	-11
NC	NEW BERN CRAVEN CO REGL AP	7	36	34	56	51	48	-9
NC	NEW RIVER MCAF	8	36	34	56	51	48	-9

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
NC	PITT GREENVILLE ARP	8	37	35	57	52	49	-10
NC	POPE AFB	66	38	36	58	53	50	-10
NC	RALEIGH DURHAM INTERNATIONAL	133	36	34	56	51	48	-12
NC	RICHMOND INTERNATIONAL AP	50	37	34	56	51	48	-13
NC	SEYMOUR-JOHNSON AFB	33	38	35	57	52	49	-10
NC	SOUTHERN PINES AWOS	141	36	34	56	51	48	-13
NC	WILMINGTON INTERNATIONAL ARPT	12	36	34	56	51	48	-9
NC	WINSTON-SALEM REYNOLDS AP	296	36	33	55	50	47	-13
ND	BISMARCK MUNICIPAL ARPT	506	38	33	55	50	47	-33
ND	DEVILS LAKE (AMOS)	443	35	32	54	49	46	-33
ND	DEVILS LAKE(AWOS)	443	33	29	51	46	43	-33
ND	DICKINSON MUNICIPAL AP	787	38	33	55	50	47	-31
ND	FARGO HECTOR INTERNATIONAL AP	274	36	32	54	49	46	-32
ND	GRAND FORKS AFB	276	35	32	54	49	46	-32
ND	GRAND FORKS INTERNATIONAL AP	254	34	31	53	48	45	-33
ND	JAMESTOWN MUNICIPAL ARPT	455	36	32	54	49	46	-31
ND	LIDGERWOOD (RAMOS)	351	38	33	55	50	47	-31
ND	MINOT AFB	497	36	33	55	50	47	-33
ND	MINOT FAA AP	522	35	32	54	49	46	-31
ND	WILLISTON SLOULIN INTL AP	581	37	34	56	51	48	-34
NE	AINSWORTH MUNICIPAL	789	40	34	56	51	48	-26
NE	ALLIANCE MUNICIPAL	1198	39	35	57	52	49	-30
NE	BEATRICE MUNICIPAL	403	39	35	57	52	49	-23
NE	BREWSTER FIELD ARPT	704	38	35	57	52	49	-22
NE	COLUMBUS MUNI	451	37	33	55	50	47	-25
NE	FREMONT MUNI ARPT	379	37	33	55	50	47	N/A
NE	GRAND ISLAND CENTRAL NE REGIO	566	39	35	57	52	49	-25
NE	HASTINGS MUNICIPAL	596	39	35	57	52	49	-23
NE	KEARNEY MUNI (AWOS)	649	38	34	56	51	48	-23
NE	LINCOLN MUNICIPAL ARPT	362	39	35	57	52	49	-24
NE	MCCOOK MUNICIPAL	786	42	38	60	55	52	-22
NE	NORFOLK KARL STEFAN MEM ARPT	473	37	34	56	51	48	-26
NE	NORTH PLATTE REGIONAL AP	850	39	35	57	52	49	-26
NE	O'NEILL/BAKER FIELD	619	39	34	56	51	48	-25
NE	OFFUTT AFB/BELLEVUE	319	38	34	56	51	48	-22
NE	OMAHA EPPLEY AIRFIELD	299	38	34	56	51	48	-24
NE	OMAHA WSFO	399	36	34	56	51	48	-25
NE	SCOTTSBLUFF W B HEILIG FIELD	1206	39	35	57	52	49	-28
NE	SIDNEY MUNICIPAL AP	1313	39	34	56	51	48	-27
NE	TEKAMAH (ASOS)	312	37	34	56	51	48	-26
NE	VALENTINE MILLER FIELD	792	40	36	58	53	50	-29
NH	BERLIN MUNICIPAL	353	31	29	51	46	43	-32
NH	CONCORD MUNICIPAL ARPT	106	34	32	54	49	46	-25
NH	DILLANT HOPKINS	153	33	31	53	48	45	-25
NH	ISLE OF SHOALS	19	29	26	48	43	40	-17
NH	JAFFREY MUNICIPAL	317	32	30	52	47	44	-23
NH	LACONIA MUNI (AWOS)	166	33	31	53	48	45	-24
NH	LEBANON MUNICIPAL	182	34	31	53	48	45	-27
NH	MANCHESTER AIRPORT	71	36	33	55	50	47	-21
NH	MOUNT WASHINGTON	1910	18	16	38	33	30	-36
NH	PEASE INTL TRADEPOR	31	34	31	53	48	45	-19
NJ	ATLANTIC CITY INTL AP	20	36	33	55	50	47	-16
NJ	BELMAR-FARMINGDALE	26	36	32	54	49	46	-14
NJ	CAPE MAY CO	7	34	31	53	48	45	-13
NJ	MCGUIRE AFB	45	36	33	55	50	47	-16
NJ	MILLVILLE MUNICIPAL AP	23	36	33	55	50	47	-17
NJ	NEWARK INTERNATIONAL ARPT	9	37	34	56	51	48	-15
NJ	TETERBORO AIRPORT	2	36	33	55	50	47	-16
NJ	TRENTON MERCER COUNTY AP	65	37	33	55	50	47	N/A
NM	ALAMOGORDO WHITE SA	1313	39	38	60	55	52	N/A
NM	ALBUQUERQUE INTL ARPT	1620	37	35	57	52	49	-12
NM	CANNON AFB/CLOVIS	1309	38	36	58	53	50	-14
NM	CARLSBAD CAVERN CITY AIR TERM	994	41	39	61	56	53	-11
NM	CLAYTON MUNICIPAL AIRPARK	1516	36	34	56	51	48	-19
NM	CLOVIS MUNI (AWOS)	1284	37	35	57	52	49	-14
NM	FARMINGTON FOUR CORNERS REGL	1677	37	34	56	51	48	-17
NM	GALLUP SEN CLARKE FLD	1971	35	32	54	49	46	-23
NM	HOLLOMAN AFB	1248	39	37	59	54	51	-11
NM	ROSWELL INDUSTRIAL AIR PARK	1118	39	37	59	54	51	-13
NM	SIERRA BLANCA RGNL	2078	33	31	53	48	45	-13



## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
NM	TAOS MUNI APT(AWOS)	2161	33	31	53	48	45	-23
NM	TRUTH OR CONSEQUENCES MUNI AP	1481	38	36	58	53	50	-10
NM	WHITE SANDS	1244	39	37	59	54	51	-12
NV	CALIENTE (AMOS)	1335	39	37	59	54	51	N/A
NV	ELKO MUNICIPAL ARPT	1547	38	34	56	51	48	-24
NV	ELY YELLAND FIELD	1909	35	32	54	49	46	-25
NV	EUREKA (RAMOS)	1993	36	32	54	49	46	-20
NV	FALLON NAAS	1199	39	37	59	54	51	N/A
NV	LAS VEGAS MCCARRAN INTL AP	665	45	42	64	59	56	-4
NV	LOVELOCK DERBY FIELD	1190	40	36	58	53	50	-19
NV	MERCURY DESERT ROCK AP	1009	42	39	61	56	53	-7
NV	NELLIS AFB	573	46	43	65	60	57	-6
NV	RENO TAHOE INTERNATIONAL AP	1341	38	35	57	52	49	-15
NV	TONOPAH AIRPORT	1656	37	35	57	52	49	-17
NV	WINNEMUCCA MUNICIPAL ARPT	1315	39	36	58	53	50	-21
NY	ALBANY COUNTY AP	89	34	31	53	48	45	-23
NY	AMBROSE LIGHT	21	32	28	50	45	42	-13
NY	BINGHAMTON EDWIN A LINK FIELD	499	32	29	51	46	43	-22
NY	BUFFALO NIAGARA INTL AP	215	32	30	52	47	44	-20
NY	DUNKIRK	197	29	27	49	44	41	-16
NY	ELMIRA CORNING REGIONAL AP	291	35	32	54	49	46	-23
NY	FORT DRUM/WHEELER-S	207	32	29	51	46	43	-28
NY	GALLOO ISLAND	76	27	25	47	42	39	-22
NY	GLENS FALLS AP	102	33	31	53	48	45	-29
NY	GRIFFISS AFB	158	34	31	53	48	45	-26
NY	ISLIP LONG ISL MACARTHUR AP	33	34	31	53	48	45	-15
NY	JAMESTOWN (AWOS)	525	31	28	50	45	42	-20
NY	MASSENA AP	65	33	30	52	47	44	-30
NY	MONTICELLO(AWOS)	428	32	29	51	46	43	N/A
NY	NEW YORK J F KENNEDY INT'L AR	7	35	31	53	48	45	-14
NY	NEW YORK LAGUARDIA ARPT	9	36	33	55	50	47	-14
NY	NEWBURGH/STEWART	177	35	31	53	48	45	-20
NY	NIAGARA FALLS AF	179	33	30	52	47	44	-20
NY	PLATTSBURGH AFB	72	32	30	52	47	44	-28
NY	POUGHKEEPSIE DUTCHESS CO AP	49	36	33	55	50	47	-22
NY	REPUBLIC	26	35	32	54	49	46	-13
NY	ROCHESTER GREATER ROCHESTER I	169	34	31	53	48	45	-20
NY	SUPERIOR SHOALS	79	29	27	49	44	41	-23
NY	SYRACUSE HANCOCK INT'L ARPT	127	33	31	53	48	45	-24
NY	UTICA ONEIDA COUNTY AP	227	33	30	52	47	44	-24
NY	WATERTOWN AP	102	31	29	51	46	43	-32
NY	WHITE PLAINS WESTCHESTER CO A	121	35	32	54	49	46	-17
OH	AKRON AKRON-CANTON REG AP	377	34	31	53	48	45	-21
OH	CINCINNATI MUNICIPAL AP LUNKI	152	36	33	55	50	47	-19
OH	CLEVELAND HOPKINS INTL AP	245	34	31	53	48	45	-20
OH	COLUMBUS PORT COLUMBUS INTL A	249	35	32	54	49	46	-20
OH	DAYTON INTERNATIONAL AIRPORT	306	35	32	54	49	46	-21
OH	FINDLAY AIRPORT	248	35	32	54	49	46	-22
OH	LANCASTER/FAIRFIEL	264	34	32	54	49	46	-21
OH	MANSFIELD LAHM MUNICIPAL ARPT	400	33	31	53	48	45	-22
OH	OHIO STATE UNIVERSI	283	34	32	54	49	46	-18
OH	RICKENBACKER ANGB	230	36	33	55	50	47	-19
OH	SOUTH BASS ISLAND	178	31	29	51	46	43	-17
OH	TOLEDO EXPRESS AIRPORT	211	35	32	54	49	46	-21
OH	WRIGHT-PATERSON AFB	250	36	33	55	50	47	-21
OH	YOUNGSTOWN REGIONAL AIRPORT	362	34	31	53	48	45	-21
OH	ZANESVILLE MUNICIPAL AP	275	34	32	54	49	46	-21
OK	ALTUS AFB	414	41	39	61	56	53	-13
OK	CLINTON-SHERMAN	586	41	38	60	55	52	-13
OK	FORT SILL	369	41	37	59	54	51	-13
OK	GAGE AIRPORT	671	39	37	59	54	51	-19
OK	HOBART MUNICIPAL AP	479	41	38	60	55	52	-14
OK	LAWTON MUNICIPAL	338	41	38	60	55	52	-12
OK	MCALESTER MUNICIPAL AP	235	40	36	58	53	50	-14
OK	OKLAHOMA CITY WILL ROGERS WOR	398	40	36	58	53	50	-14
OK	OKLAHOMA CITY/WILEY	396	40	37	59	54	51	-15
OK	PONCA CITY MUNICIPAL AP	304	40	37	59	54	51	-16
OK	STILLWATER RGNL	308	41	37	59	54	51	-15
OK	TINKER AFB	384	39	36	58	53	50	-14
OK	TULSA INTERNATIONAL AIRPORT	206	39	36	58	53	50	-15

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
OK	TULSA/LLOYD JONES	193	39	37	59	54	51	-14
OK	VANCE AFB	408	40	37	59	54	51	-16
OR	ASTORIA REGIONAL AIRPORT	7	27	23	45	40	37	-5
OR	AURORA STATE	60	37	32	54	49	46	-5
OR	BAKER MUNICIPAL AP	1028	36	33	55	50	47	-23
OR	BURNS MUNICIPAL ARPT	1271	38	33	55	50	47	-23
OR	CAPE ARAGO (LS)	23	19	17	39	34	31	0
OR	CORVALLIS MUNI	77	38	33	55	50	47	-8
OR	EUGENE MAHLON SWEET ARPT	114	37	32	54	49	46	-8
OR	KLAMATH FALLS INTL AP	1247	35	32	54	49	46	-18
OR	LA GRANDE MUNI AP	828	37	32	54	49	46	-17
OR	LAKEVIEW (AWOS)	1441	34	31	53	48	45	-21
OR	MC MINNVILLE MUNI	51	37	32	54	49	46	-5
OR	MEACHAM	1136	33	30	52	47	44	-28
OR	MEDFORD ROGUE VALLEY INTL AP	405	40	36	58	53	50	-8
OR	NEWPORT STATE BEACH	11	18	17	39	34	31	-2
OR	NORTH BEND MUNI AIRPORT	5	22	20	42	37	34	-4
OR	PENDLETON E OR REGIONAL AP	462	39	35	57	52	49	-16
OR	PORTLAND INTERNATIONAL AP	33	36	32	54	49	46	-6
OR	PORTLAND/HILLSBORO	62	37	32	54	49	46	-8
OR	REDMOND ROBERTS FIELD	940	37	33	55	50	47	-19
OR	SALEM MCNARY FIELD	61	37	32	54	49	46	-8
OR	SEXTON SUMMIT	1171	32	28	50	45	42	-8
PA	ALLENTOWN LEHIGH VALLEY INTL	117	35	32	54	49	46	-17
PA	ALTOONA BLAIR CO ARPT	448	34	31	53	48	45	-19
PA	BRADFORD REGIONAL AP	655	31	28	50	45	42	-25
PA	BUTLER CO. (AWOS)	380	33	31	53	48	45	-19
PA	DUBOIS FAA AP	556	32	29	51	46	43	-22
PA	ERIE INTERNATIONAL AP	225	32	30	52	47	44	-18
PA	FRANKLIN	469	31	29	51	46	43	-20
PA	HARRISBURG CAPITAL CITY ARPT	106	37	33	55	50	47	-17
PA	JOHNSTOWN CAMBRIA COUNTY AP	696	32	29	51	46	43	-20
PA	MIDDLETOWN HARRISBURG INTL AP	95	37	33	55	50	47	-15
PA	PHILADELPHIA INTERNATIONAL AP	9	36	34	56	51	48	-14
PA	PHILADELPHIA NE PHILADELPHIA	36	37	33	55	50	47	-15
PA	PITTSBURGH ALLEGHENY CO AP	388	34	32	54	49	46	-20
PA	PITTSBURGH INTERNATIONAL AP	367	34	31	53	48	45	-20
PA	READING SPAATZ FIELD	108	37	33	55	50	47	N/A
PA	WASHINGTON (AWOS)	361	33	31	53	48	45	N/A
PA	WILKES-BARRE SCRANTON INTL AP	293	34	31	53	48	45	-19
PA	WILLIAMSPORT REGIONAL AP	160	36	32	54	49	46	-19
PA	WILLOW GROVE NAS	110	36	33	55	50	47	-17
RI	BLOCK ISLAND STATE ARPT	33	31	27	49	44	41	-14
RI	PAWTUCKET (AWOS)	134	33	30	52	47	44	N/A
RI	PROVIDENCE T F GREEN STATE AR	19	35	32	54	49	46	-17
SC	ANDERSON COUNTY AP	236	37	34	56	51	48	-10
SC	BEAUFORT MCAS	12	37	34	56	51	48	-6
SC	CHARLESTON INTL ARPT	15	37	34	56	51	48	-7
SC	COLUMBIA METRO ARPT	69	38	36	58	53	50	-10
SC	FLORENCE REGIONAL AP	46	38	35	57	52	49	-9
SC	FOLLY ISLAND	5	33	30	52	47	44	-3
SC	GREER GREENV'L-SPARTANBRG AP	296	37	34	56	51	48	-11
SC	MYRTLE BEACH AFB	8	36	33	55	50	47	-8
SC	SHAW AFB/SUMTER	74	38	35	57	52	49	-9
SD	ABERDEEN REGIONAL ARPT	396	38	33	55	50	47	-32
SD	BROOKINGS (AWOS)	502	34	31	53	48	45	-30
SD	BUFFALO (AMOS)	915	40	34	56	51	48	-29
SD	CHAMBERLAIN (AMOS)	530	41	35	57	52	49	-27
SD	CHAN GURNEY MUNI	408	38	33	55	50	47	-25
SD	CUSTER (RAMOS)	1707	34	30	52	47	44	-28
SD	ELLSWORTH AFB	980	39	35	57	52	49	-26
SD	HURON REGIONAL ARPT	393	38	34	56	51	48	-30
SD	MITCHELL (AWOS)	397	39	34	56	51	48	-27
SD	MOBRIDGE	508	39	34	56	51	48	-30
SD	PIERRE MUNICIPAL AP	526	41	36	58	53	50	-28
SD	RAPID CITY REGIONAL ARPT	966	40	35	57	52	49	-27
SD	SIOUX FALLS FOSS FIELD	435	37	33	55	50	47	-29
SD	WATERTOWN MUNICIPAL AP	530	36	32	54	49	46	-29
TN	BRISTOL TRI CITY AIRPORT	465	34	32	54	49	46	-17
TN	CHATTANOOGA LOVELL FIELD AP	210	37	34	56	51	48	-12



## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
TN	CROSSVILLE MEMORIAL AP	570	33	31	53	48	45	-18
TN	DYERSBURG MUNICIPAL AP	103	36	34	56	51	48	-12
TN	JACKSON MCKELLAR-SIPES REGL A	129	36	34	56	51	48	-15
TN	KNOXVILLE MCGHEE TYSON AP	299	36	33	55	50	47	-15
TN	MEMPHIS INTERNATIONAL AP	101	37	35	57	52	49	-12
TN	MILLINGTON MUNI ARP	98	38	36	58	53	50	-14
TN	NASHVILLE INTERNATIONAL AP	184	37	34	56	51	48	-15
TX	ABILENE DYESS AFB	545	40	38	60	55	52	-12
TX	ABILENE REGIONAL AP	546	39	37	59	54	51	-11
TX	ALICE INTL AP	55	39	37	59	54	51	-2
TX	AMARILLO INTERNATIONAL AP	1099	38	36	58	53	50	-17
TX	AUSTIN/BERGSTROM	151	39	37	59	54	51	-7
TX	BEEVILLE CHASE NAAS	58	39	37	59	54	51	-5
TX	BROWNSVILLE S PADRE ISL INTL	7	36	35	57	52	49	0
TX	BURNET MUNI.	391	38	36	58	53	50	-6
TX	CAMP MABRY	201	39	37	59	54	51	-5
TX	CHILDRESS MUNICIPAL AP	595	40	38	60	55	52	-12
TX	COLLEGE STATION EASTERWOOD FL	100	38	37	59	54	51	-6
TX	CORPUS CHRISTI INTL ARPT	13	36	35	57	52	49	-3
TX	CORPUS CHRISTI NAS	6	34	34	56	51	48	-1
TX	COTULLA FAA AP	146	41	39	61	56	53	-4
TX	COX FLD	171	38	36	58	53	50	-10
TX	DALHART MUNICIPAL AP	1217	38	36	58	53	50	-17
TX	DALLAS HENSLEY FIELD NAS	151	39	37	59	54	51	-9
TX	DALLAS LOVE FIELD	149	39	37	59	54	51	-8
TX	DALLAS/REDBIRD ARPT	201	40	37	59	54	51	-8
TX	DALLAS-FORT WORTH INTL AP	182	39	37	59	54	51	-9
TX	DEL RIO INTERNATIONAL AP	313	40	38	60	55	52	-4
TX	DRAUGHON MILLER CEN	213	39	37	59	54	51	-7
TX	EL PASO INTERNATIONAL AP	1194	40	38	60	55	52	-9
TX	FORT HOOD/GRAY AAF	312	39	37	59	54	51	-8
TX	FORT STOCKTON PECOS	941	39	38	60	55	52	-8
TX	FORT WORTH ALLIANCE	226	40	38	60	55	52	-9
TX	FORT WORTH MEACHAM	215	40	37	59	54	51	-10
TX	FORT WORTH NAS	198	40	37	59	54	51	-10
TX	GALVESTON/SCHOLES	3	34	33	55	50	47	-2
TX	GEORGETOWN (AWOS)	240	38	36	58	53	50	-7
TX	HARLINGEN RIO GRANDE VALLEY I	11	38	37	59	54	51	0
TX	HONDO MUNICIPAL AP	284	38	37	59	54	51	-7
TX	HOUSTON BUSH INTERCONTINENTAL	32	37	35	57	52	49	-4
TX	HOUSTON WILLIAM P HOBBY AP	14	36	35	57	52	49	-3
TX	HOUSTON/D.W. HOOKS	46	38	36	58	53	50	-4
TX	HOUSTON/ELLINGTON	12	37	35	57	52	49	-3
TX	JUNCTION KIMBLE COUNTY AP	533	39	37	59	54	51	-10
TX	KELLY AFB	208	39	37	59	54	51	-6
TX	KILLEEN MUNI (AWOS)	258	39	37	59	54	51	-6
TX	KINGSVILLE	18	37	36	58	53	50	-3
TX	LAREDO INTL AIRPORT	155	40	39	61	56	53	-2
TX	LAUGHLIN AFB	327	42	39	61	56	53	-5
TX	LONGVIEW GREGG COUNTY AP	114	39	36	58	53	50	-8
TX	LUBBOCK INTERNATIONAL AP	988	39	36	58	53	50	-14
TX	LUFKIN ANGELINA CO	96	38	36	58	53	50	-7
TX	MARFA AP	1478	36	34	56	51	48	-14
TX	MC GREGOR (AWOS)	180	39	37	59	54	51	-7
TX	MCCALLEN MILLER INTL AP	34	39	37	59	54	51	0
TX	MCKINNEY MUNI ARPT	176	39	37	59	54	51	-10
TX	MIDLAND INTERNATIONAL AP	872	40	37	59	54	51	-11
TX	NACOGDOCHES (AWOS)	108	38	36	58	53	50	-7
TX	PALACIOS MUNICIPAL AP	5	34	33	55	50	47	-3
TX	PINE SPRINGS GUADALUPE MOUNTA	1663	36	33	55	50	47	-12
TX	PORT ARANSAS	6	30	30	52	47	44	0
TX	PORT ARTHUR JEFFERSON COUNTY	5	35	34	56	51	48	-4
TX	RANDOLPH AFB	232	39	37	59	54	51	-6
TX	REESE AFB	1014	40	37	59	54	51	-14
TX	ROCKPORT/ARANSAS CO	8	34	33	55	50	47	0
TX	SABINE	6	32	31	53	48	45	-3
TX	SAN ANGELO MATHIS FIELD	577	40	37	59	54	51	-10
TX	SAN ANTONIO INTL AP	247	38	36	58	53	50	-6
TX	SAN ANTONIO/STINSON	176	39	37	59	54	51	-4
TX	SAN MARCOS MUNI	182	38	37	59	54	51	-5

## TEMPERATURE TABLE CONTINUED

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
TX	SANDERSON (RAMOS)	865	39	36	58	53	50	-8
TX	STEPHENVILLE CLARK FIELD	403	38	36	58	53	50	-10
TX	VICTORIA REGIONAL AP	36	37	35	57	52	49	-4
TX	WACO REGIONAL AP	155	39	37	59	54	51	-8
TX	WICHITA FALLS MUNICIPAL ARPT	314	41	38	60	55	52	-12
TX	WINK WINKLER COUNTY AP	860	42	40	62	57	54	-11
UT	CEDAR CITY MUNICIPAL AP	1712	37	34	56	51	48	-21
UT	HILL AFB/OGDEN	1459	37	33	55	50	47	-16
UT	LOGAN-CACHE AIRPORT	1358	38	34	56	51	48	-24
UT	MILFORD MUNICIPAL AP	1534	39	35	57	52	49	-22
UT	PRICE/CARBON COUNTY	1799	36	33	55	50	47	-19
UT	PROVO MUNI (AWOS)	1369	38	34	56	51	48	-15
UT	SAINT GEORGE (AWOS)	896	44	41	63	58	55	-6
UT	SALT LAKE CITY INT'L ARPT	1288	39	36	58	53	50	-16
UT	VERNAL	1608	37	33	55	50	47	-20
UT	WENDOVER USAF AUXILIARY FIELD	1291	38	35	57	52	49	-16
VA	ABINGTON	631	32	31	53	48	45	-16
VA	CHESAPEAKE	23	31	28	50	45	42	-8
VA	DANVILLE FAA AP	180	36	34	56	51	48	-12
VA	DINWIDDIE CO	60	38	36	58	53	50	-14
VA	FARMVILLE	125	37	34	56	51	48	-16
VA	FORT BELVOIR/DAVISO	27	38	35	57	52	49	-17
VA	HILLSVILLE	834	31	29	51	46	43	-15
VA	HOT SPRINGS/INGALLS	1156	31	28	50	45	42	-19
VA	LANGLEY AFB/HAMPTON	3	36	33	55	50	47	-10
VA	LEESBURG/GODFREY	119	37	34	56	51	48	-14
VA	LYNCHBURG REGIONAL ARPT	286	35	33	55	50	47	-15
VA	MANASSAS MUNI(AWOS)	59	36	33	55	50	47	-16
VA	MARION / WYTHEVILLE	780	33	32	54	49	46	-17
VA	MARTINSVILLE	287	36	34	56	51	48	-15
VA	MECKLENBURG/BRUNS.	430	37	34	56	51	48	N/A
VA	MELFA/ACCOMACK ARPT	15	36	34	56	51	48	N/A
VA	NEWPORT NEWS	16	37	34	56	51	48	-11
VA	NORFOLK INTERNATIONAL AP	9	36	34	56	51	48	-9
VA	NORFOLK NAS	5	37	34	56	51	48	-9
VA	OCEANA NAS	7	36	33	55	50	47	-10
VA	QUANTICO MCAS	4	36	33	55	50	47	-13
VA	ROANOKE REGIONAL AP	358	36	33	55	50	47	-14
VA	SHANNON ARPT	26	37	35	57	52	49	-15
VA	STAUNTON/SHENANDOAH	366	37	34	56	51	48	-17
VA	VIRGINIA TECH ARPT	650	33	31	53	48	45	-15
VA	WALLOPS ISLAND UAU	15	35	32	54	49	46	-11
VA	WASHINGTON DC DULLES INT'L AR	99	36	34	56	51	48	-17
VA	WASHINGTON DC REAGAN AP	20	37	34	56	51	48	-12
VA	WINCHESTER RGNL	222	37	34	56	51	48	-15
VA	WISE/LONESOME PINE	817	31	29	51	46	43	N/A
VT	BURLINGTON INTERNATIONAL AP	104	34	31	53	48	45	-26
VT	MONTPELIER AP	342	32	29	51	46	43	-28
VT	MORRISVILLESTONE	223	31	29	51	46	43	-28
VT	RUTLAND STATE	246	31	29	51	46	43	-26
VT	SPRINGFIELD/HARTNES	176	33	31	53	48	45	-25
WA	ARLINGTON MUNI	42	32	27	49	44	41	-9
WA	BELLINGHAM INTL AP	46	29	26	48	43	40	-10
WA	BREMERTON NATIONAL	137	34	29	51	46	43	-8
WA	DESTRUCTION ISLAND	39	19	17	39	34	31	-2
WA	FAIRCHILD AFB	743	36	32	54	49	46	-19
WA	FELTS FLD	610	38	34	56	51	48	-17
WA	FRIDAY HARBOR	33	29	25	47	42	39	-5
WA	GRAY AAF	92	34	29	51	46	43	-10
WA	HANFORD	223	41	37	59	54	51	-16
WA	HOQUIAM AP	5	28	23	45	40	37	-4
WA	KELSO WB AP	6	35	29	51	46	43	-8
WA	MC CHORD AFB/TACOMA	88	34	29	51	46	43	-10
WA	OLYMPIA AIRPORT	61	35	30	52	47	44	-11
WA	OMAK	382	39	35	57	52	49	-16
WA	PASCO	123	41	36	58	53	50	-17
WA	PEARSON FLD	8	37	32	54	49	46	-7
WA	PULLMAN/MOSCOW RGNL	778	36	32	54	49	46	-18
WA	QUILLAYUTE STATE AIRPORT	63	29	25	47	42	39	-7
WA	SEATTLE BOEING FIELD	9	33	29	51	46	43	-7



## TEMPERATURE TABLE CONTINUED

State	Station	Elev (M)	High Temp (°C)		Distance above roof			Extreme Min (°C)
			0.4%	2% Avg	0.5"	3.5"	12"	
WA	SEATTLE SEATTLE-TACOMA INTL A	132	33	29	51	46	43	-6
WA	SHELTON/SANDERSON	82	35	30	52	47	44	-7
WA	SMITH ISLAND	18	22	18	40	35	32	-3
WA	SNOHOMISH CO	189	30	26	48	43	40	-5
WA	SPOKANE INTERNATIONAL AP	721	37	33	55	50	47	-20
WA	STAMPEDE PASS	1209	29	25	47	42	39	-15
WA	TACOMA NARROWS	91	33	28	50	45	42	-4
WA	TATOOSH ISLAND	48	19	17	39	34	31	-2
WA	WALLA WALLA CITY COUNTY AP	367	41	36	58	53	50	-14
WA	WENATCHEE/PANGBORN	375	38	34	56	51	48	-16
WA	WEST POINT (LS)	9	24	21	43	38	35	-3
WA	WHIDBEY ISLAND NAS	14	25	22	44	39	36	-9
WA	WILLIAM R FAIRCHILD	91	30	25	47	42	39	-6
WA	YAKIMA AIR TERMINAL	325	38	34	56	51	48	-18
WI	ANTIGOLANG(AWOS)	464	33	29	51	46	43	N/A
WI	APPLETON/OUTAGAMIE	280	35	31	53	48	45	-24
WI	DEVILS ISLAND	211	30	25	47	42	39	-24
WI	EAGLE RIVER UNION	500	32	28	50	45	42	-31
WI	EAU CLAIRE COUNTY AP	273	36	32	54	49	46	-30
WI	FOND DU LAC CO.	246	34	31	53	48	45	-24
WI	GREEN BAY AUSTIN STRAUBEL INT	214	34	31	53	48	45	-27
WI	HAYWARD MUNI ARPT	370	36	30	52	47	44	-32
WI	JUNEAU/DODGE CO	285	33	30	52	47	44	-23
WI	KENOSHA RGNL	232	36	32	54	49	46	-23
WI	LA CROSSE MUNICIPAL ARPT	200	36	33	55	50	47	-27
WI	MADISON DANE CO REGIONAL ARPT	264	34	32	54	49	46	-26
WI	MANITOWAC MUNI AWOS	198	33	29	51	46	43	-23
WI	MARSHFIELD MUNI	389	35	30	52	47	44	-27
WI	MILWAUKEE MITCHELL INTL AP	211	35	32	54	49	46	-24
WI	MOSINEE/CENTRAL WI	389	34	30	52	47	44	-28
WI	PARK FALLS MUNI	469	31	29	51	46	43	N/A
WI	PHILLIPS/PRICE CO.	449	33	29	51	46	43	-32
WI	RHINELANDER ONEIDA	507	33	29	51	46	43	-30
WI	RICE LAKE MUNICIPAL	347	34	30	52	47	44	-29
WI	SHEBOYGAN	228	34	30	52	47	44	N/A
WI	SHEBOYGAN	189	32	28	50	45	42	-22
WI	STURGEON BAY	221	32	28	50	45	42	-24
WI	WATERTOWN	254	34	31	53	48	45	-25
WI	WAUSAU MUNICIPAL ARPT	365	34	31	53	48	45	-29
WI	WISCONSIN RAPIDS	308	34	31	53	48	45	-27
WI	WITTMAN RGNL	253	34	31	53	48	45	-24
WV	BECKLEY RALEIGH CO MEM AP	766	31	29	51	46	43	-20
WV	BLUEFIELD/MERCER CO	874	31	29	51	46	43	-19
WV	CHARLESTON YEAGER ARPT	299	35	32	54	49	46	-18
WV	ELKINS ELKINS-RANDOLPH CO ARP	603	32	30	52	47	44	-24
WV	HARRISON MARION RGN	380	33	32	54	49	46	-17
WV	HUNTINGTON TRI-STATE ARPT	255	35	33	55	50	47	-18
WV	MARTINSBURG EASTERN WV REG AP	163	37	33	55	50	47	-18
WV	MORGANTOWN HART FIELD	382	34	31	53	48	45	-19
WV	PARKERSBURG WOOD COUNTY AP	263	35	32	54	49	46	-19
WY	BIG PINEY (AMOS)	2126	32	29	51	46	43	-33
WY	CASPER NATRONA CO INTL AP	1612	37	34	56	51	48	-29
WY	CHEYENNE MUNICIPAL ARPT	1872	34	31	53	48	45	-26
WY	CODY MUNI (AWOS)	1553	36	32	54	49	46	-28
WY	GILLETTE/GILLETTE-C	1230	38	34	56	51	48	-28
WY	JACKSON HOLE	2016	32	28	50	45	42	-31
WY	LANDER HUNT FIELD	1694	36	33	55	50	47	-27
WY	LARAMIE GENERAL BREES FIELD	2217	32	29	51	46	43	-31
WY	ROCK SPRINGS ARPT	2056	34	30	52	47	44	-26
WY	SHERIDAN COUNTY ARPT	1209	38	34	56	51	48	-29
WY	WORLAND MUNICIPAL	1283	39	35	57	52	49	-34
WY	YELLOWSTONE LAKE (RAMOS)	2388	27	24	46	41	38	-33



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