# Appendix H

## Acoustical Analysis Report

# Aramis Solar Energy Generation and Storage Project

## Acoustical Analysis Report

September 2020 | IPO-01.03

*Prepared for:*

**Alameda County Planning Department**
224 West Winton Avenue
Hayward, CA 94544

*Prepared by:*

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# TABLE OF CONTENTS

# TABLE OF CONTENTS (cont.)

**LIST OF APPENDICES**



**LIST OF FIGURES**



**LIST OF TABLES**

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ac | alternating current |
| ADT | average daily trips |
| ASHRAE | American Society of Heating, Refrigeration, and Air Conditioning Engineers |
| APN | Assessor's Parcel Number |
| | |
| CadnaA | Computer Aided Noise Abatement |
| Caltrans | California Department of Transportation |
| CEQA | California Environmental Quality Act |
| CNEL | Community Noise Equivalent Level |
| County | Alameda County |
| CPSF | Clean Power San Francisco |
| CUP | Conditional Use Permit |
| | |
| dB | decibel |
| dBA | A-weighted decibel |
| dc | direct current |
| | |
| EBCE | East Bay Community Energy |
| | |
| HVAC | heating, ventilation, and air conditioning |
| Hz | Hertz |
| | |
| I-580 | Interstate 580 |
| in/sec | inches per second |
| | |
| kHz | kilohertz |
| kV | kilovolt |
| | |
| $L_{DN}$ | Day-Night sound level |
| $L_{EQ}$ | time-averaged noise level |
| $L_{MAX}$ | root mean squared maximum noise level |
| | |
| mPa | micro Pascal |
| MV | medium voltage |
| MW | megawatts |
| | |
| NSLU | noise sensitive land use |
| | |
| O&M | operation and maintenance |
| | |
| PG&E | Pacific Gas and Electric Company |
| PPV | peak particle velocity |
| PV | photovoltaic |

# ACRONYMS AND ABBREVIATIONS (cont.)

| | |
|---|---|
| RCNM | Roadway Construction Noise Model |
| rpm | revolutions per minute |
| SF | square feet/foot |
| SPL | sound pressure level |
| STC | Sound Transmission Class |
| $S_{WL}$ | Sound Power Level |
| TIS | Transportation Impact Study |
| TNM | Traffic Noise Model |
| USDOT | U.S. Department of Transportation |

# EXECUTIVE SUMMARY

This report presents an assessment of potential noise and vibration impacts during the construction, operation, and decommissioning of the proposed Aramis Solar Energy Generation and Storage Project (project). The project would construct a photovoltaic (PV) solar energy generation and storage facility with a capacity of 100 megawatts (MW) on approximately 410 acres in unincorporated Alameda County. Analysis within this report addresses the relevant issues listed in Section XIII, Noise, of Appendix G of the California Environmental Quality Act (CEQA) Guidelines.

Project construction would generate noise from the use of off-road construction equipment. Mitigation measure NOI-1 would restrict construction activity to the hours between 7:00 a.m. and 7:00 p.m. Monday through Friday, and between the hours of 8:00 a.m. and 5:00 p.m. on Saturday and Sunday. With implementation of the mitigation measure restricting the hours of noise generating activities, temporary project construction noise would be exempt from the County Noise Ordinance exterior noise standards. Construction would result in traffic noise from workers commuting to and from the project site and from trucks hauling material to and from the project site. The increase in ambient noise levels from project construction traffic on road segments in the project vicinity would not exceed the 3 dBA Day Night sound level ($L_{DN}$) threshold which represents the increase that is generally perceptible to humans in most outdoor environments. Construction noise impacts would be less than significant with mitigation incorporated.

Long-term on-site operational noise from equipment maintenance, PV panel washing, and vegetation management would not result in higher off-road equipment noise levels or longer activity duration than noise from off-road equipment currently used for agriculture and vegetation management on the project site and in the project vicinity. Noise from the project's substation electrical equipment would not exceed the County standard of 60 dBA for transformers and associated equipment in electrical substations, measured at the nearest NSLU. Noise from the project's inverter stations and energy storage buildings would not exceed the County daytime standard of 50 dBA or nighttime standard of 45 dBA. Project operational traffic would result in an increase in ambient noise levels along roads in the project vicinity of approximately 0.1 dBA $L_{DN}$, significantly below the 3 dBA $L_{DN}$ threshold. Operational noise impacts would be less than significant.

The use of off-road equipment during project construction, including impact pile drivers and vibratory rollers, and the use of off-road equipment during operational maintenance activity would not result in groundborne vibration levels at the closest residential structure above the Federal Transit Administration (FTA) thresholds for risk of architectural damage to non-engineered wood and masonry structures. Groundborne vibration impacts would be less than significant.

The closest airport or airstrip to the project site is the Livermore Executive Airport, approximately 3.2 miles southwest. The project is not within the Livermore Executive Airport influence area or within any of the designated airport noise compatibility zones. The project would not expose people residing or working in the project area to excessive noise levels from airport operations.

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# 1.0 INTRODUCTION

## 1.1 PURPOSE OF THE REPORT

This report analyzes potential noise and vibration impacts associated with the proposed Aramis Solar Energy Generation and Storage Project (project). The analysis includes a description of existing conditions in the project vicinity, an assessment of potential impacts associated with project construction, and an evaluation of project operational noise impacts. Analysis within this report addresses the relevant issues listed in Section XIII, Noise, of Appendix G of the California Environmental Quality Act (CEQA) Guidelines.

## 1.2 PROJECT LOCATION

The approximately 410-acre project site is located in the northeast area of unincorporated Alameda County, approximately 2.5 miles north of the City of Livermore. The project site is bounded by Manning Road to the north, North Livermore Avenue to the east, and a private driveway to the south. The western project site boundary generally follows the natural topography of Cayetano Creek and the adjacent hills. The project site comprises portions of four privately-owned parcels – Assessor's Parcel Numbers (APNs) 903-0006-001-02, 903-0007-002-01, 903-0006-003-07, and 902-0001-005-00. The project site consists of four noncontiguous development areas that are split into the following sections: the northern section, measuring approximately 103 acres; the central section, measuring approximately 269 acres; the southeastern section, measuring approximately 23 acres; and the southwestern section, measuring approximately 15 acres. The project site is within Sections 16 and 17 of Township 02 South, Range 02 East and unsurveyed land of the Las Positas Land Grant, Mount Diablo Base and Meridian. The project site is located within the "Tassajara, CA" and "Livermore, CA" U.S. Geologic Survey 7.5-minute quadrangles (see Figure 1, *Regional Location*, and Figure 2, *Aerial Map*).

## 1.3 PROJECT DESCRIPTION

The project is proposed by IP Aramis, LLC (a subsidiary of Intersect Power, LLC). The project applicant has applied to the Alameda County Community Development Agency for a Conditional Use Permit (CUP) from Alameda County to construct, operate, and maintain a solar photovoltaic (PV) and electric storage facility for at least 50 years and a Parcel Subdivision of APN 903-0006-001-02 to modify the eastern boundary of legal parcel of the proposed solar facility and create a distinct parcel. The solar facility would generate a 100 megawatts (MW) of PV power on approximately 410 acres. The project would provide solar power to utility customers by interconnecting to the nearby electricity grid at Pacific Gas and Electric Company's (PG&E) existing Cayetano 230 kilovolt (kV) substation located adjacent and interior to the project site. The project would serve East Bay Community Energy (EBCE), Clean Power San Francisco (CPSF), and/or PG&E customers by providing local generation capacity under a long-term contract.

The project would include individual PV modules arranged in rows onto single-axis tracker racking systems, which would in turn be affixed to steel piles. Each row (or array) would track the sun during the day, from east to west, to optimize power generation of the facility. The arrays would be connected by low-voltage underground or above-ground electrical wiring to a central inverter station or to string inverters located throughout the facility, where the electricity would be converted from direct current (DC) to alternating current (AC). The system would then step up the voltage of the electricity to a medium voltage (MV) of 34.5 kV (or lower suitable voltage) to match the collection system voltage. The power output from the inverter station would be conveyed to the on-site substation via collection cables. Medium-voltage lines would be buried for a majority of their length but would emerge above-ground and be mounted on up to two overhead wooden utility poles on either side of Manning Avenue and up to 10 additional wooden poles to cross Cayetano Creek and its tributaries, to cross an access driveway, and where a connection to the substation must be overhead.

The project substation would provide the circuit breakers, switches, protection relays, and other necessary equipment to reliably and safely protect the electrical infrastructure. The substation would step up the MV collected energy to the interconnection voltage via one or more step up transformers. The substation would occupy an approximately 5,000-square-foot area in a 0.9-acre dedicated area and would be located adjacent to the north of the PG&E Cayetano substation, allowing the gen-tie to be either overhead or underground. The substation would be set back from North Livermore Avenue by at least 250 feet. Overhead lines would be constructed on either tubular steel poles or wood H-frames and may be constructed to be single-circuit or double-circuit.

A battery storage system would be located on-site adjacent to the west of the PG&E Cayetano substation. The battery storage system would be designed to accept between 75 and 100 MW of system charging, and subsequently dispatch stored electricity during times of peak demand. The system would either be housed in electrical containers or in up to four 100-foot by 180-foot buildings. Various sizes and numbers of electrical enclosures would be used depending on the final battery vendor selected. Up to 50 large electrical enclosures or up to 1,000 small electrical enclosures would be clustered together to make up the battery storage system. Battery buildings or containers would have foundations with a cumulative floor area of 3 acres or less. Low voltage wiring from battery enclosures would be underground and converted as a bi-directional inverter station and transformed at the shared transformer.

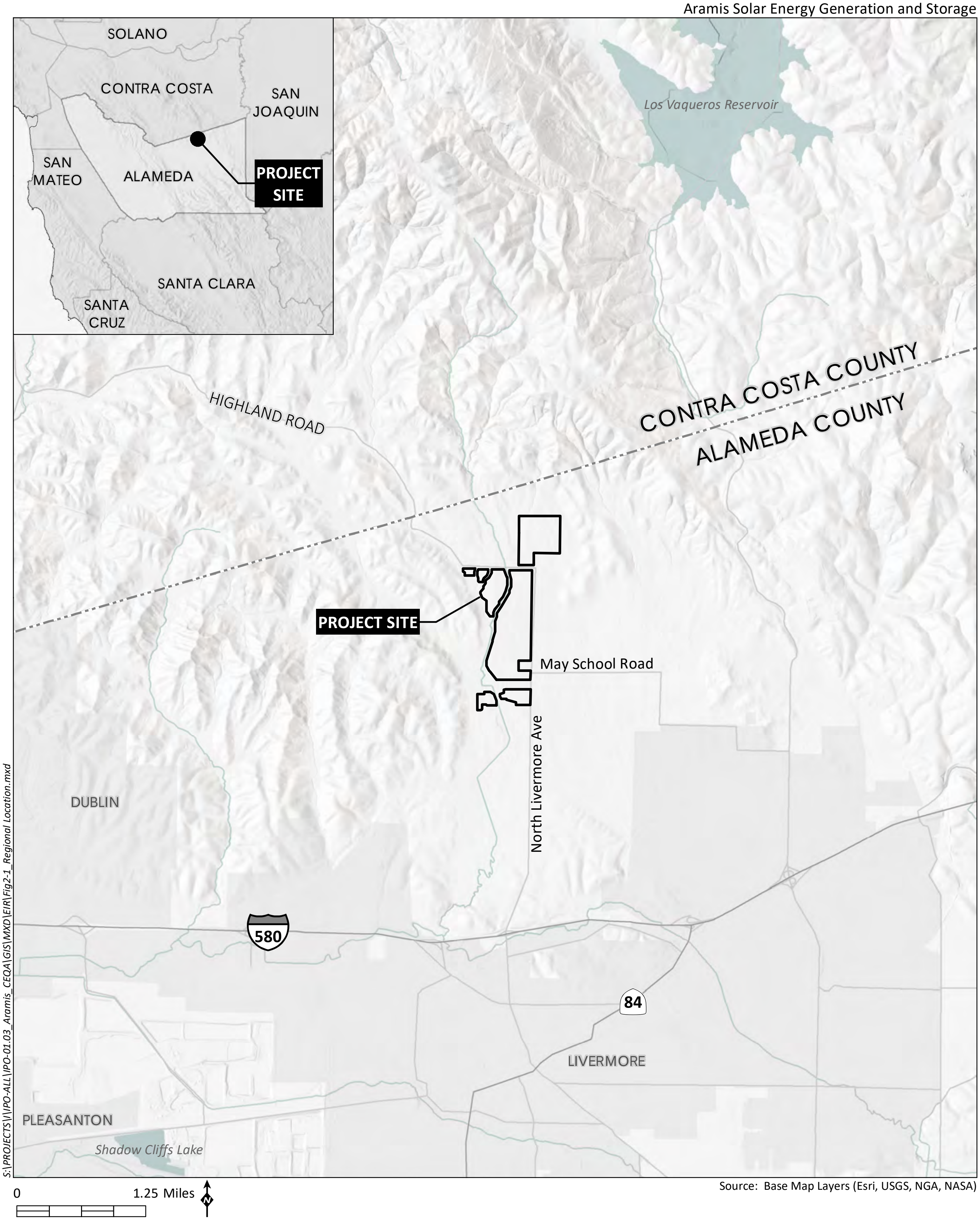
An approximately 400-square-foot operation and maintenance (O&M) building located near the project substation would be used to accommodate up to four permanent O&M staff. Water for the O&M building would be stored in a tank and filled on an as-needed basis. Wastewater would be held in a tank system and removed routinely (see Figure 3, *Site Plan*).

Long-term operation of the project would involve monitoring of the site remotely and up to four permanent staff on the site at a time for ongoing facility maintenance and repairs. Up to 12 workers could be on site once annually for module washing. The project would promote continued agricultural use of the project site. The proposed program for concomitant agricultural land uses during operation of the solar facility would be outlined in an Agricultural Management Plan prepared for the project and could include livestock grazing and commercial beekeeping operations.

## 1.4 NOISE, SOUND LEVEL AND VIBRATION DESCRIPTORS AND TERMINOLOGY

### 1.4.1 Descriptors

All noise level or sound level values presented herein are expressed in terms of decibels (dB), with A-weighting (dBA) to approximate the hearing sensitivity of humans. Time-averaged noise levels are expressed by the symbol $L_{EQ}$, with a specified duration. The Community Noise Equivalent Level (CNEL) is a 24-hour average, where noise levels during the evening hours of 7:00 p.m. to 10:00 p.m. have an




Source: Base Map Layers (Esri, USGS, NGA, NASA)

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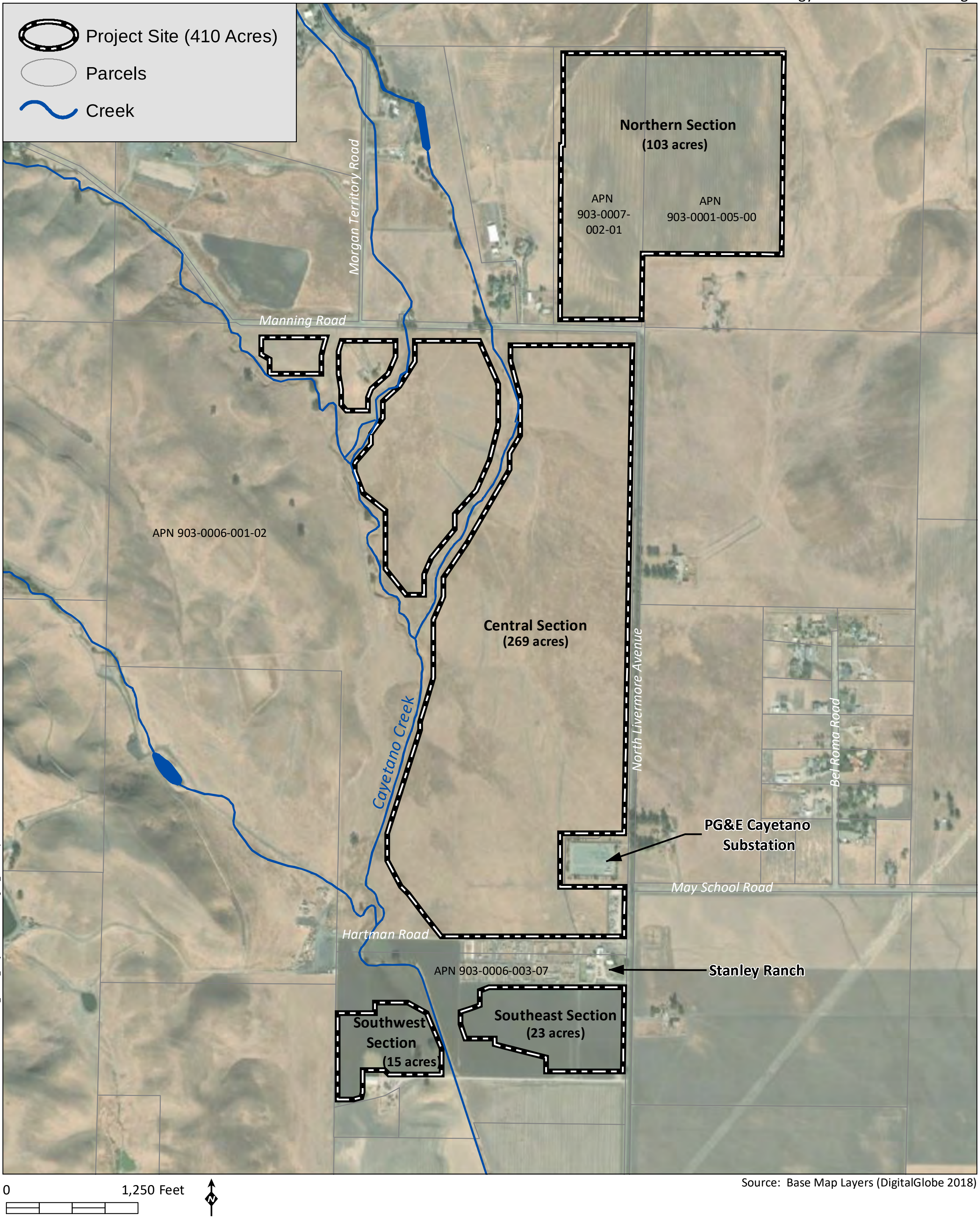
# Regional Location

Figure 1

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Source: Base Map Layers (DigitalGlobe 2018)

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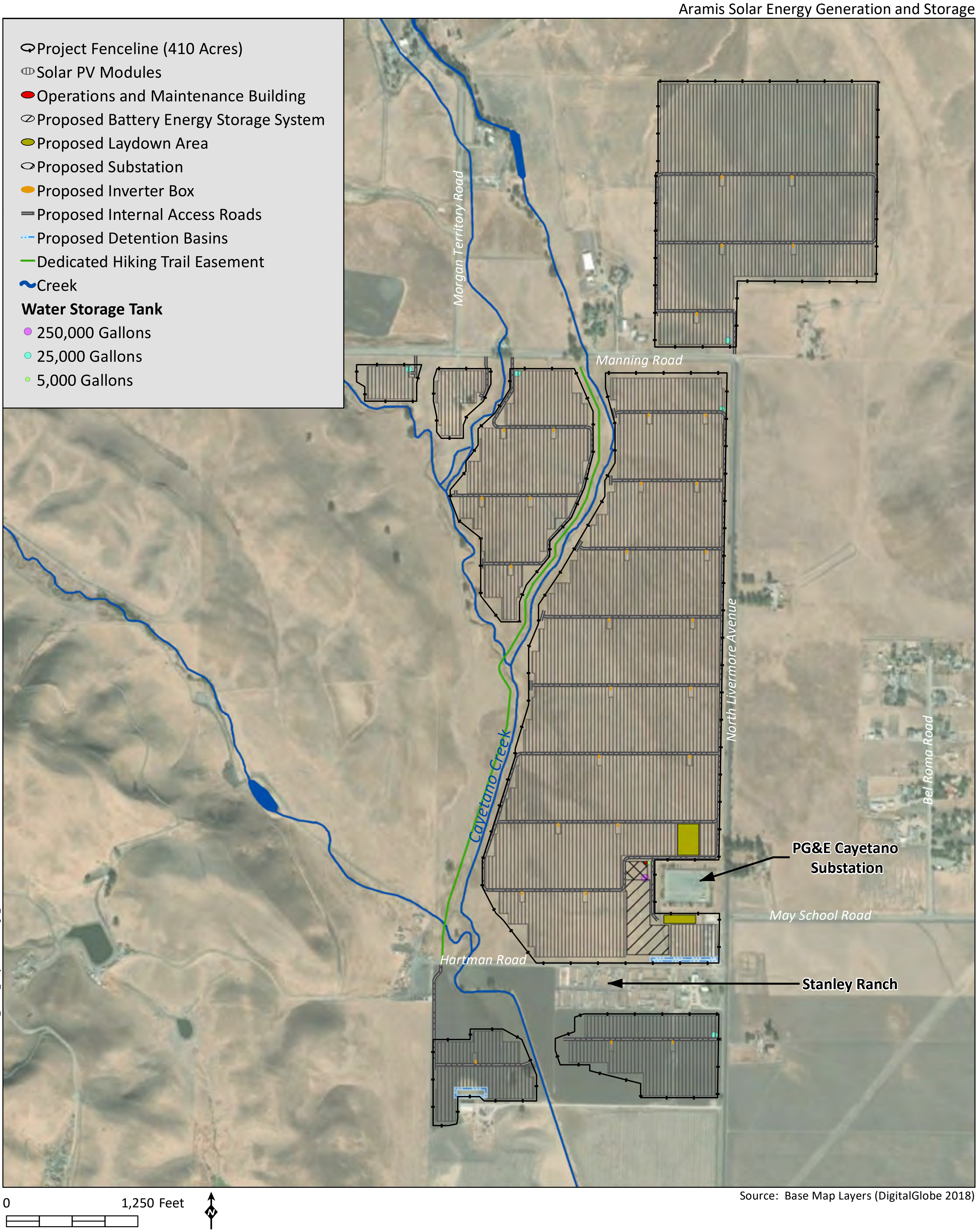
# Aerial Map

Figure 2

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# Site Plan

Figure 3

added 5 dBA weighting, and noise levels during the nighttime hours of 10:00 p.m. to 7:00 a.m. have an added 10 dBA weighting. This is similar to the Day Night sound level ($L_{DN}$), which is a 24-hour average with an added 10 dBA weighting on the same nighttime hours but no added weighting on the evening hours. Sound levels expressed in CNEL or $L_{DN}$ are always based on dBA. The maximum sound level ($L_{MAX}$) is the root mean squared (RMS) maximum level during a measurement period or noise event. This is different from “peak”, which is the maximum level of the raw noise source. The minimum sound level ($L_{MIN}$) is the RMS minimum level during a measurement period. These metrics are used to express noise levels for both measurement and municipal regulations, as well as for land use guidelines and enforcement of noise ordinances.

## 1.4.2 Terminology

### 1.4.2.1 Sound, Noise, and Acoustics

Sound can be described as the mechanical energy of a vibrating object transmitted by pressure waves through a liquid or gaseous medium (e.g., air) to a hearing organ, such as a human ear. Noise is defined as loud, unexpected, or annoying sound.

In the science of acoustics, the fundamental model consists of a sound (or noise) source, a receiver, and the propagation path between the two. The loudness of the noise source and obstructions or atmospheric factors affecting the propagation path to the receiver determines the sound level and characteristics of the noise perceived by the receiver. The field of acoustics deals primarily with the propagation and control of sound.

#### Sound Frequency

Continuous sound can be described by frequency (pitch) and amplitude (loudness). A low-frequency sound is perceived as low in pitch. Frequency is expressed in terms of cycles per second, or Hertz (Hz) (e.g., a frequency of 250 cycles per second is referred to as 250 Hz). High frequencies are sometimes more conveniently expressed in kilohertz (kHz), or thousands of Hertz. The audible frequency range for humans is generally between 20 Hz and 20,000 Hz.

#### Sound Pressure Levels and Decibels

The amplitude of pressure waves generated by a sound source determines the loudness of that source. Sound pressure amplitude is measured in micro-Pascals (mPa). One mPa is approximately one hundred billionth (0.00000000001) of normal atmospheric pressure. Sound pressure amplitudes for different kinds of noise environments can range from less than 100 to 100,000,000 mPa. Because of this wide range of values, sound is rarely expressed in terms of mPa. Instead, a logarithmic scale is used to describe sound pressure level (SPL) in terms of dBA. The threshold of hearing for the human ear is about 0 dBA, which corresponds to 20 mPa.

Because decibels are logarithmic units, SPL cannot be added or subtracted through standard arithmetic. Under the decibel scale, a doubling of sound energy corresponds to a 3-dBA increase. In other words, when two identical sources are each producing sound of the same loudness, the resulting sound level at a given distance would be 3 dBA higher than from one source under the same conditions. For example, if one automobile produces an SPL of 70 dB when it passes an observer, two cars passing simultaneously would not produce 140 dBA—rather, they would combine to produce 73 dBA. Under the decibel scale, three sources of equal loudness together produce a sound level 5 dBA louder than one source.

Under controlled conditions in an acoustical laboratory, the trained, healthy human ear is able to discern 1-dBA changes in sound levels, when exposed to steady, single-frequency ("pure-tone") signals in the mid-frequency (1,000 Hz–8,000 Hz) range. In typical noisy environments, changes in noise of 1 to 2 dBA are generally not perceptible. It is widely accepted, however, that people begin to detect sound level increases of 3 dB in typical noisy environments. Further, a 5-dBA increase is generally perceived as a distinctly noticeable increase, and a 10-dBA increase is generally perceived as a doubling of loudness.

No known studies have directly correlated the ability of a healthy human ear to discern specific levels of change in traffic noise over a 24-hour period. Many ordinances, however, specify a change of 3 CNEL or $L_{DN}$ as the significant impact threshold. This is based on the concept of a doubling in noise energy resulting in a 3-dBA change in noise, which is the amount of change in noise necessary for the increase to be perceptible to the average healthy human ear.

### 1.4.2.2 Groundborne Vibration Metrics

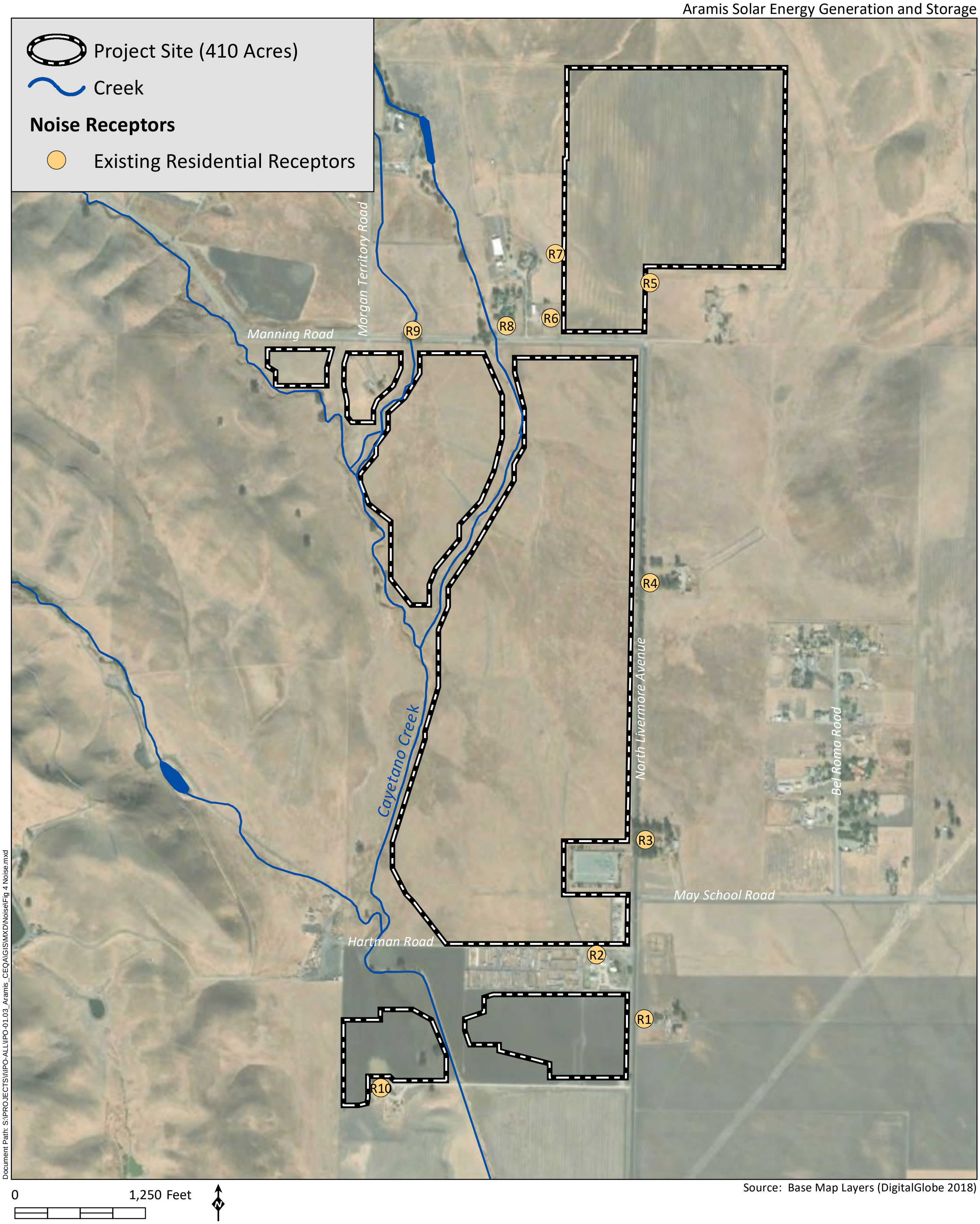
Groundborne vibration consists of rapidly fluctuating motions or waves transmitted through the ground with an average motion of zero. Sources of groundborne vibrations include natural phenomena and anthropogenic causes (e.g., explosions, machinery, traffic, trains, construction equipment). Vibration sources may be continuous (e.g., factory machinery) or transient (e.g., explosions). Several different methods are typically used to quantify vibration amplitude. One is the peak particle velocity (PPV); another is the RMS velocity. The PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. For the purposes of this analysis, a PPV descriptor with units of inches per second (in/sec) is used to evaluate construction-generated vibration for building damage and human complaints. Generally, a PPV of less than 0.08 in/sec does not produce perceptible vibration. At 0.12 PPV in/sec is the level at which there is a risk of architectural damage (e.g., cracking of plaster) to historical buildings and other vibration-sensitive structures and the level at which continuous vibration may become noticeable to building occupants. A level of 0.20 PPV in/sec is commonly used as a threshold for risk of architectural damage to non-engineered timber and masonry buildings (FTA 2018).

## 1.5 NOISE AND VIBRATION SENSITIVE LAND USES

Noise-sensitive land uses (NSLUs) are land uses that may be subject to stress and/or interference from excessive noise, including residences, hospitals, schools, hotels, resorts, libraries, sensitive wildlife habitat, or similar facilities where quiet is an important attribute of the environment. Noise receptors are individual locations that may be affected by noise. The closest existing sensitive receptors to the project site are rural single-family homes with the closest residential building located approximately 60 feet from the project site. Figure 4, *Receptor Locations*, shows the property line location closest to future project noise sources for the closest existing residences around the project site. There are no schools, hospitals, or daycare facilities within 1 mile of the project site.

## 1.6 REGULATORY FRAMEWORK

The project site is located in an unincorporated area of Alameda County. Regulatory requirements related to environmental noise are typically promulgated at the local level. However, federal and State agencies provide standards and guidelines to local jurisdictions. Noise standards for Alameda County, along with the State CEQA Guidelines, were considered in the noise assessment.




Source: Base Map Layers (DigitalGlobe 2018)

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# Receptor Locations

Figure 4

### 1.6.1 Federal Guidelines

#### 1.6.1.1 U.S. Environmental Protection Agency Recommendations

The USEPA provides guidance in Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety (NTIS 550\9-74-004, EPA, Washington, D.C., March 1974), which is commonly referenced as the "Levels Document." The Levels Document establishes a $L_{DN}$ of 55 dBA as the requisite level, with an adequate margin of safety for areas of outdoor uses, including residential and recreational areas. This document does not constitute USEPA regulations or standards but identifies safe levels of environmental noise exposure without consideration of costs for achieving these levels or other potentially relevant considerations. It is intended to "provide State and local governments as well as the Federal government and the private sector with an informational point of departure for the purpose of decision-making." The agency is careful to stress that the recommendations contain a factor of safety and do not consider technical or economic feasibility issues and therefore should not be construed as standards or regulations.

### 1.6.2 California Noise Control Act

The California Noise Control Act is a section within the California Health and Safety Code that describes excessive noise as a serious hazard to the public health and welfare and that exposure to certain levels of noise can result in physiological, psychological, and economic damage. It also finds that there is a continuous and increasing bombardment of noise in the urban, suburban, and rural areas. The California Noise Control Act declares that the State of California has a responsibility to protect the health and welfare of its citizens by the control, prevention, and abatement of noise. It is the policy of the State to provide an environment for all Californians free from noise that jeopardizes their health or welfare.

### 1.6.3 Alameda County General Plan and East County Area Plan

The Alameda County General Pan Noise Element does not contain policies or standards for acceptable noise levels. The East County Area Plan contains one policy pertaining to acceptable noise levels and applicable to the project (Alameda County 2000):

- Policy 288: The County shall endeavor to maintain acceptable noise levels throughout East County.

### 1.6.4 Alameda County Noise Ordinance

The Alameda County Code Chapter 6.60, *Noise*, contains ordinances to control unnecessary, excessive and annoying noise in the county. The following sections would be applicable to the project (Alameda County 2020):

6.60.040 - Exterior noise level standards.

A. It is unlawful for any person at any location within the unincorporated area of the county to create any noise or to allow the creation of any noise on property owned, leased, occupied or otherwise controlled by such person which causes the exterior noise level when measured at any single- or multiple-family residential, school, hospital, church, public library or commercial properties situated in either the incorporated or unincorporated area to exceed the noise level standards as set forth in Table 6.60.040A [shown in this report as Table 1].

**Table 1**
**ALAMEDA COUNTY NOISE LEVEL STANDARDS**

| Receiving Land Use — Single- Or Multiple-Family Residential, School, Hospital, Church or Public Library Properties Noise Level Standards, dBA | | | |
|---|---|---|---|
| **Category** | **Cumulative Number of Minutes in any one-hour time period** | **Daytime 7 a.m. to 10 p.m.** | **Nighttime 10 p.m. to 7 a.m.** |
| 1 | 30 | 50 | 45 |
| 2 | 15 | 55 | 50 |
| 3 | 5 | 60 | 55 |
| 4 | 1 | 65 | 60 |
| 5 | 0 | 70 | 65 |

Source: Alameda County Code Table 6.60.040A

B. In the event the measured ambient noise level exceeds the applicable noise level standard in any category above, the applicable standard shall be adjusted so as to equal said ambient noise level.

E. Notwithstanding the noise level standards set forth in this section, the noise level standard applicable to the emission of sound from transformers, regulators, or associated equipment in electrical substations shall be 60 dBA.

6.60.070 - Special provisions or exceptions.

E. Construction. The provisions of this chapter shall not apply to noise sources associated with construction, provided said activities do not take place before 7 a.m. or after 7 p.m. on any day except Saturday or Sunday, or before eight a.m. or after five p.m. on Saturday or Sunday.

# 2.0 ENVIRONMENTAL SETTING

## 2.1 SURROUNDING LAND USES

Land uses north, south, east of the northern section, and west of the project site include row crop cultivation, cattle grazing, rural residential housing, agricultural outbuildings, small-scale ground-mounted solar systems, and open space. An approximately 59-acre solar PV facility is proposed by SunWalker Energy, Livermore Community Solar Farm, east of the central section of the project site and northeast of the intersection of North Livermore Avenue and May School Road. The existing PG&E Cayetano substation is located west of the terminus of May School Road at North Livermore Avenue. The project site surrounds the existing substation to the north, west, and south. Refer to Figure 2 for an aerial image of the project site and surrounding land uses.

## 2.2 EXISTING NOISE ENVIRONMENT

The project site is located in a rural agricultural area of the County and is generally undeveloped. The site is currently used for oat and hay cultivation and cattle grazing. Noise sources in the project vicinity include seasonal agricultural equipment use for crop cultivation, traffic on North Livermore Avenue and other County roads, and electrical equipment [e.g., transformers] in the existing PG&E Cayetano substation.

# 3.0 ANALYSIS, METHODOLOGY, AND ASSUMPTIONS

## 3.1 METHODOLOGY

### 3.1.1 Noise Modeling Software

Modeling of the exterior noise environment for this report was accomplished using the computer noise model Computer Aided Noise Abatement (CadnaA) version 2017. CadnaA is a model-based computer program developed by *DataKustik* for predicting noise impacts in a wide variety of conditions. CadnaA assists in the calculation, presentation, assessment, and mitigation of noise exposure. It allows for the input of project-related information, such as noise source data, barriers, structures, and topography to create a detailed CadnaA model, and uses the most up-to-date calculation standards to predict outdoor noise impacts. The noise models used in this analysis were developed from Computer Aided Design (CAD) plans provided by the project applicant. Input variables included electrical equipment and building air conditioning system reference noise levels.

Modeling of the exterior transportation noise environment for this report was accomplished using the Traffic Noise Model (TNM) version 2.5. The TNM was released in February 2004 by the U.S. Department of Transportation (USDOT) and calculates the daytime average hourly $L_{EQ}$ from three-dimensional model inputs and traffic data (USDOT 2004). The one-hour $L_{EQ}$ noise level is calculated utilizing peak-hour traffic; when peak-hour traffic data is limited, peak-hour traffic volumes can be estimated based on the assumption that 10 percent of the average daily traffic would occur during a peak hour. The model-calculated one-hour $L_{EQ}$ noise output is the equivalent to the $L_{DN}$ (Caltrans 2013).

Project construction noise was analyzed using the Roadway Construction Noise Model (RCNM; USDOT 2008), which utilizes measured and estimated of sound levels from standard construction equipment.

## 3.2 ASSUMPTIONS

### 3.2.1 Construction

Project construction would be completed in four phases: Phase 1 site preparation (30 days), Phase 2 photovoltaic installation (150 days), Phase 3 electrical and gen-tie installation (75 days), and Phase 4 general construction operations, site clean-up and restoration (175 days). Phases 2 and 3 would occur concurrently and Phase 4 would span the entire construction duration (concurrent with Phases 1, 2, and 3). Phase 3 includes building construction and architectural coatings for the O&M and energy storage buildings.

#### 3.2.1.1 Off-road Equipment

Construction would require the use of equipment throughout the site. Construction activities would use a variety of construction equipment including, but not limited to graders, dozers, loaders/backhoes, trenchers, cranes, forklifts, water trucks, vibratory rollers, and piledrivers.

The most likely source of vibration during project construction would be pile drivers (used to install the PV panel rack system) and vibratory rollers (used to achieve soil and gravel compaction as part of building foundation and access road construction.

#### 3.2.1.2 Construction Traffic

Project construction activities would result in vehicles traveling to and from the project site including worker commute vehicles and trucks hauling the project electrical equipment, construction materials, and water. The project construction traffic was analyzed in the *Aramis Solar Energy Generation and Storage Project Transportation Impact Study* (TIS). The maximum worker commute trips would be 1,500 daily trips and 375 peak hour trips. The maximum truck haul trips would be 121 daily trips and 14 peak hour trips (CHS 2020). In addition, up to 30 truck trips per day (3 trips during the peak hour) may be required to haul water to the project site for dust suppression. The project construction traffic trip distribution would be 90 percent on North Livermore Avenue between the project site and Interstate 580 (I-580) and 10 percent on Manning Road between to project site and Morgan Territory Road (CHS 2020). The TIS includes intersection traffic counts for the I-580/North Livermore Avenue interchange and for Manning Road/Morgan Territory Road taken in February 2020. For the purpose of traffic noise modeling, existing traffic was assumed to consist of a typical mix of vehicle types for California rural roads: 96 percent autos and light trucks; 3 percent medium trucks; and 1 percent heavy trucks.

### 3.2.2 Operation

#### 3.2.2.1 Vehicular Traffic

While daily monitoring of the site would occur remotely, up to four permanent staff could be on the site at a time for ongoing facility maintenance and repairs. Up to 12 workers could be on the site once annually for module washing. To model the most conservative (highest) daily operational traffic noise, 12 workers were assumed be on the site each day with the same trip assumptions as the construction traffic: two commute trips per employee per day and two off-site trips per employee per day for a total of 48 maximum daily trips and 12 peak hour trips. The off-site employee trips include up to 4 truck trips per day to haul water to the project site. Operational trip distribution was assumed to be the same as the construction trip distribution analyzed in the TIS: 90 percent on North Livermore Avenue between the project site and I-580, and 10 percent on Manning Road between the project site and Morgan Territory Road.

#### 3.2.2.2 Electrical Equipment

##### Tracking Systems

Each row of PV panels would be equipped with a small electric motor and hydraulic or gear system to allow the panels to track the sun from east to west through the day. Typical one-axis tracking systems rotate the row of panels between 3 and 5 degrees approximately every 15 minutes during daylight. Each tracking movement would take a few seconds. Once or twice per day, a longer movement of 30 seconds to one minute would occur to place the panels in the stow position or to move the panels in preparation for sunrise. Noise from the tracking systems is anticipated to be significantly lower than, and not discernable from, the inverter and transformer noise, described below, and is not included in the operational noise modeling.

### String Inverter Stations

The operational noise modeling assumed that string inverter stations would be dispersed through the project at 29 sites within the PV modules (see Figure 3). Specifications for the project's inverter stations had not been developed at the time of this analysis. The project applicant provided specifications for a typical system that could be used: each PV power conditioning system (string inverter station) would convert up to 4,200 kW of DC power collected from the PV panels to AC power and step up the voltage to 34.5 kV for transmissions to the project substation. The power conditioning system would include inverters housed in an electrical enclosure with cooling fans, a step-up transformer, and associated electrical connection and control panels. The system specifications indicate a maximum sound level of 75 dBA at 3 feet for the inverter enclosure. The power conditioning system specifications do not indicate sound levels for the transformer. The National Electrical Manufacturers Association (NEMA) standards publication for transformers, regulators, and reactors provides maximum audible sound level specifications. For a liquid immersed 4,200 kilo volt-amps (kVA) transformer with auxiliary cooling (pump and heat exchanger/fan), the highest average sound power level would be 69 dBA (NEMA 2000). Noise from the string inverter stations would only occur during daylight hours when the PV panels are generating electricity.

### Substation

The project substation would require one or more transformers to step up the 34.5 kV power from the string inverter stations to the 230 kV power required for tie-in to the existing PG&E Cayetano substation. Specifications for the project's substation transformer had not been developed at the time of this analysis. Noise levels for the substation were modeled assuming one transformer with a capacity of 150,000 kVA (150 percent of the project's PV generation capacity). Per the NEMA standards, for a liquid immersed 150,000 kVA transformer with second stage auxiliary cooling (pump and heat exchanger/fan), the highest average sound power level would be 87 dBA (NEMA 2000). The substation would also include protective switches (e.g., circuit breakers) which can produce impulsive noise (very short noise events). Protective switching devices would only activate in emergency situations (e.g., power surges) and are not included as noise sources in the modeling.

### Energy Storage

Specification for the project's energy storage buildings had not been developed at the time of this analysis. Is was assumed that the energy storage buildings would have ventilation/cooling fans to circulate air through the battery rooms. Each of the four buildings was assumed to have six ventilation fans mounted on the exterior walls. This analysis assumes each fan would have a ventilation capacity of approximately 5,000 cubic feet per minute, using a 5-horsepower motor turning a 20-inch fan at approximately 1,100 revolutions per minute. Based on data from Greenheck Fan Corporation, each fan would have an overall outlet noise sound power level of 91 dBA. The manufacturer's noise data is provided below in Table 2, *Ventilation Fan Outdoor Sound Power*. The manufacturer's data sheets are included in Appendix B. Energy storage building ventilation fans were assumed to operate in steady state 24 hours per day.

**Table 2**
**VENTILATION FAN OUTDOOR SOUND POWER**

| Noise Levels in Decibels[1] (dB) Measured at Octave Frequencies | | | | | | | | Overall Noise Level in A-weighted Scale (dBA)[1] |
|---|---|---|---|---|---|---|---|---|
| 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz | |
| 91 | 87 | 83 | 78 | 77 | 71 | 66 | 61 | 92 |

Source: Greencheck Double Width Centrifugal Fan Catalog Supplement (see Appendix B)
Hz = hertz; kHz = kilohertz
[1] Sound Power Levels ($S_{WL}$)

Control equipment rooms within the energy storage buildings could require temperature control through the use of air conditioning systems. Specific air conditioning planning information for the project including the area of conditioned space, unit types, and locations was not available at the time of the analysis. To be conservative by analyzing the highest potential noise, one-third of each energy storage building was assumed to be conditioned and the air conditioning system was assumed to be mounted at ground level outside of each energy storage building without any sound enclosure. Standard air conditioning planning assumes one ton of air conditioning for every 350 SF of conditioned space (American Society of Heating, Refrigeration, and Air Conditioning Engineers [ASHRAE] 2012). Based on 6,000 SF of conditioned space, one 20-ton unit would be required for each energy storage building. This analysis assumes a 20-ton Carrier Centurion Model 50PG24 with a sound rating of 84.9 dBA sound power. This unit produces noise levels of 52 dBA $L_{EQ}$ at 50 feet. The manufacturer's noise data is provided below in Table 3, *Carrier 50PG24 Outdoor Sound Power*. The manufacturer's data sheets are included in Appendix B. Air conditioning systems were assumed to operate in steady state during the daytime and for 30 minutes out of each hour during the nighttime.

**Table 3**
**CARRIER 50PG24 OUTDOOR SOUND POWER**

| Noise Levels in Decibels[1] (dB) Measured at Octave Frequencies | | | | | | | Overall Noise Level in A-weighted Scale (dBA)[1] |
|---|---|---|---|---|---|---|---|
| 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz | |
| 90.0 | 86.3 | 83.6 | 82.9 | 80.3 | 74.9 | 71.4 | 84.9 |

Source: Carrier 50PG03-28 Product Data (see Appendix B)
Hz = hertz; kHz = kilohertz
[1] Sound Power Levels ($S_{WL}$)

## 3.3 GUIDELINES FOR THE DETERMINATION OF SIGNIFICANCE

The following significance thresholds are based on Section XIII, Noise, of Appendix G of the State CEQA Guidelines. A significant impact is identified if the project would result in any of the following:

(1) Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies;

(2) Generation of excessive groundborne vibration or groundborne noise levels; and

(3) For a project located within the vicinity of a private airstrip or an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels.

The significance of noise and vibration levels, or the increase in noise levels as a result of the project, are based on the following standards from the County Code or other agencies:

- **Temporary Construction Noise**: The County Code, (Section 6.60.070), specifies that construction activities are exempt from the provisions in the Alameda County Noise Control Ordinance if they are limited to the hours between 7:00 a.m. to 7:00 p.m., Monday through Friday, and between 8:00 a.m. to 5:00 p.m. on Saturdays.

- **Traffic Noise:** For traffic-related noise, impacts would be considered significant if implementation of the project would result in an increase of the existing ambient noise levels by 5 dBA or more, where the existing ambient level is less than 60 dBA $L_{DN}$; or an increase of the existing ambient noise level by 3 dBA or more, where the existing ambient level is 60 dBA $L_{DN}$ or more.

- **Permanent Operational Noise:** Noise generated by the project substation electrical equipment (e.g., transformers) would be significant if the level would exceed the County Code (Section 6.60.040 [E]) standard of 60 dBA for transformers, regulators, or associated equipment in electrical substations, measured at the receiving residential property. Assuming that the string inverter stations and energy storage building cooling/ventilation systems would operate for 30 or more minute in at least one hour per day, the noise generated by the string inverter stations and energy storage building cooling/ventilation systems would be significant if their combined noise would exceed the County Code (Section 6.040[A], Table 6.60.040A, Category 1) standard of 50 dBA $L_{EQ}$ during daytime hours (7:00 a.m. to 10:00 p.m.) or 45 dBA LEQ during nighttime hours (10:00 p.m. to 7:00 a.m.), measured at the receiving residential property line.

- **Construction Groundborne Vibration:** The County has not adopted thresholds for determining the significance of groundborne vibrations. The Federal Transit Administration (FTA) has guidelines and recommendations for ground-borne vibration thresholds for damage to structures based on the age and/or construction type of the structures near construction activity. Per the FTA, a ground-borne vibration level of 0.2 inch-per-second PPV would be considered the damage threshold criterion for non-engineered timber and masonry buildings and a ground-borne vibration level of 0.12 inch-per-second PPV would be considered the damage threshold criterion for buildings extremely susceptible to vibration damage (e.g., historical structures; FTA 2018). This analysis assumes a conservative threshold of 0.2 inch-per-second.

# 4.0 IMPACTS

## 4.1 ISSUE 1: TEMPORARY OR PERMANENT INCREASE IN NOISE LEVELS

### 4.1.1 Construction Noise

Construction activities would result in noise from the use of heavy construction equipment on the project site, from heavy trucks hauling electrical equipment, construction materials and water to the site, and from worker and vendor vehicles traveling to and from the site.

#### 4.1.1.1 Off-Road Equipment Noise

The County Code, (Section 6.60.070), specifies that construction activities are exempt from the provisions in the County Noise Control Ordinance if they are limited to the hours between 7:00 a.m. to 7:00 p.m., Monday through Friday, and between 8:00 a.m. to 5:00 p.m. on Saturdays.

The most substantial noise increases from construction activities that may affect nearby residences would occur during earth moving operations for installation of access roads and equipment pads. Construction equipment noise would be temporary and sporadic and would not be concentrated near residential property lines for extended periods. During these operations it is anticipated that a grader, dozer, and frontend loader could all be operating simultaneously within 50 feet of a residential property line. The combined total noise of all equipment at the residential property line would be 83.4 dBA $L_{EQ}$, above the 45 dBA to 70 dBA standard (depending on time of day and cumulative minutes per hour for the noise) for exterior noise received by residential land uses. The output from the construction noise model is included in Appendix A to this report. Provided that construction activity conforms to the hourly restrictions within the County Noise Control Ordinance, noise level limits would not apply. However, if noise generating construction activities would occur outside of the allowable times, impacts would be potentially significant. Mitigation measure NOI-1 would restrict the hours of construction activity to those specified in the County ordinance. Implementation of mitigation measure NOI-1 would reduce potential construction off-road equipment noise impacts to a less than significant level.

#### 4.1.1.2 On-Road Construction Traffic Noise

Noise levels at residential properties located along the project's proposed construction traffic routes were estimated using the TNM, described in Section 3.1. As discussed in Section 3.2., 90 percent of construction traffic would utilize North Livermore Avenue between the project site and I-580 and 10 percent of the construction traffic would utilize Manning Road north of the project. The closest residence to the construction traffic affected road segments centerlines would be 30 feet from North Livermore Avenue (approximately 1,600 feet south of the project site), and 35 feet from Manning Road (approximately 160 feet north of the project site). The predicted traffic noise level for the project affected road segments is shown in Table 4, *Construction Traffic Noise*.

**Table 4**
**CONSTRUCTION TRAFFIC NOISE**

| Roadway Segment | Distance to Nearest NSLU (feet)[1] | NSLU Type | dBA $L_{DN}$ at Nearest NSLU[2] | | |
|---|---|---|---|---|---|
| | | | Existing | 2011 + Project | Change in $L_{DN}$ |
| **North Livermore Avenue** | | | | | |
| Project Site to westbound I-580 | 30 | SF | 69.8 | 71.8 | +2.0 |
| **Manning Road** | | | | | |
| Project Site to Morgan Territory Road | 35 | SF | 65.9 | 66.5 | +0.6 |

Source: TNM 2.5; CHS 2020
I-580 = Interstate 580; MF = SF = Single-Family Residential.
1 Distance measured from roadway centerline.
2 Noise level assuming all traffic at the posted speed limit of 50 miles per hour.

As shown in Table 4, existing noise levels at all roadway segments at the closest residences already exceed 60 dBA $L_{DN}$ without the project. With the project construction traffic included, the maximum increase in noise levels be 2.0 dBA $L_{DN}$ and would not exceed 3 dBA $L_{DN}$ along any roadway segment. In addition, project construction traffic would be temporary and would cease once the project is operational. Therefore, project construction traffic noise would not result in the generation of a substantial temporary increase in ambient noise levels in the vicinity of the project and the impact would be less than significant.

### 4.1.1.3 Mitigation Measures

**NOI-1 Construction Hourly Limits.** Prior to issuance of any project Grading Permit or Building Permit, the County shall confirm that the Grading Plan, Building Plans, and construction specifications stipulate that the following construction noise mitigation measures shall be implemented for all project construction activity:

- Restrict noise-generating activities at the construction site or in areas adjacent to the construction site to the hours between 7:00 a.m. to 7:00 p.m., Monday through Friday, and between 8:00 a.m. to 5:00 p.m. on Saturdays, Sundays and County recognized public holidays; and

- Post a publicly visible sign at the primary project construction entrance listing the permitted construction days and hours, complaint procedures and who to notify in the event of a problem. The sign shall also include a listing of telephone numbers to be used during regular construction hours and off-hours to contact both the County and the construction contractor regarding noise complaints.

- If construction activities occur outside of the specified hours, noise levels shall be subject to the limits listed in Table 6.60.040A of the Alameda County Noise Control Ordinance.

### 4.1.1.4 Significance After Mitigation

Implementation of mitigation measure NOI-1 would reduce potential construction noise impacts to a less than significant level.

### 4.1.2 Decommissioning and Site Reclamation Noise

The solar facility is anticipated to have an operating life of at least 50 years. Once the operating life of the facility is over, it would be either repowered or decommissioned. If repowering were to be pursued, it would require the facility owner to obtain all required permit approvals. Project decommissioning would occur in accordance with the expiration or termination of the CUP and would involve the removal of above-grade facilities, buried electrical conduit, and all concrete foundations in accordance with a Decommissioning Plan. Equipment would be repurposed off-site, recycled, or disposed of in a landfill as appropriate.

Decommissioning is anticipated to take approximately six months to complete and would occur in 2073 or later. Decommissioning would be completed in three phases: Phase 1 would involve shutting down the systems and removing hazardous materials and wiring; Phase 2 would include removing the PV modules, inverters, substation(s), switching station, and energy storage system; Phase 3 would include removing site fencing and driveways and the final soils reclamation process. Decommissioning and reclamation activities are anticipated to require approximately 200 workers, generating 800 maximum daily worker trips and 40 daily truck trips.

Because it is anticipated that the intensity of project decommissioning and reclamation activities would be similar to or less than project construction activities, the resulting off-road equipment traffic noise for decommissioning would be assumed to be similar to or less than that resulting from project construction. As discussed in Section 4.1.1.2, above, construction traffic noise levels would not result in a significant increase in ambient noise levels and noise for off-road equipment use would be exempt from the noise standards in the County Noise Control Ordinance. Therefore, project decommissioning and reclamation noise would not result in a temporary increase in ambient noise levels in excess of standards and the impact would be less than significant.

### 4.1.3 Operational Noise

#### 4.1.3.1 Maintenance Noise

Operational sources of noise for the project would include periodic equipment maintenance, PV panel washing, and vegetation management that could require the use of off-road equipment including all-terrain vehicles, small tractors, portable generators, and portable water trailers with a pump. These periodic operational activities would occur for a few days per year and equipment use would be sporadic and would move throughout the project site. In addition, the use off-road equipment for maintenance is not anticipated to exceed the noise level of equipment currently used for agriculture and vegetation management (based on use intensity or duration) on the project site and in the project vicinity.

#### 4.1.3.2 Stationary Source Noise

The project's electrical equipment and building HVAC system noise was modeled as described in Section 3.2, above. The results of the project substation electrical equipment noise modeling for each of the modeled receptor locations is shown in Table 5, *Operational Substation Noise*. The results of the project string inverter station and energy storage building noise modeling (combined noise of all sources) is shown in Table 6, *Operational Inverter Station and Energy Storage Noise*. See Figure 4 for modeled receptor locations.

**Table 5**
**OPERATIONAL SUBSTATION NOISE**

| Receiver | Receiver Type | Noise Level (dBA $L_{EQ}$) | | |
|---|---|---|---|---|
| | | Estimated Noise | Standard[1] | Exceed Standards? |
| R1 | Rural Residential | 43.4 | 60 | No |
| R2 | Rural Residential | 48.3 | 60 | No |
| R3 | Rural Residential | 55.3 | 60 | No |
| R4 | Rural Residential | 39.9 | 60 | No |
| R5 | Rural Residential | 30.1 | 60 | No |
| R6 | Rural Residential | 30.9 | 60 | No |
| R7 | Rural Residential | 29.6 | 60 | No |
| R8 | Rural Residential | 31.4 | 60 | No |
| R9 | Rural Residential | 30.7 | 60 | No |
| R10 | Rural Residential | 28.1 | 60 | No |

Source: CadnaA version 2019

[1] 60 dBA $L_{EQ}$ exterior noise standard for transformers and associated electrical substation equipment per County Noise Ordinance Section 6.60.040 (E).

**Table 6**
**OPERATIONAL INVERTER STATION AND ENERGY STORAGE NOISE**

| Receiver | Receiver Type | Noise Level (dBA $L_{EQ}$) | | | | |
|---|---|---|---|---|---|---|
| | | Daytime (7 a.m. to 10 p.m.) | | Nighttime (10 p.m. to 7 a.m.) | | Exceed Standards? |
| | | Estimated Noise | Standard[1] | Estimated Noise | Standard | |
| R1 | Rural Residential | 40.4 | 50 | 34.8 | 45 | No |
| R2 | Rural Residential | 43.9 | 50 | 42.3 | 45 | No |
| R3 | Rural Residential | 42.0 | 50 | 39.7 | 45 | No |
| R4 | Rural Residential | 43.4 | 50 | 26.1 | 45 | No |
| R5 | Rural Residential | 43.7 | 50 | 19.0 | 45 | No |
| R6 | Rural Residential | 42.4 | 50 | 18.8 | 45 | No |
| R7 | Rural Residential | 41.2 | 50 | 17.9 | 45 | No |
| R8 | Rural Residential | 40.9 | 50 | 20.0 | 45 | No |
| R9 | Rural Residential | 39.5 | 50 | 19.6 | 45 | No |
| R10 | Rural Residential | 41.4 | 50 | 29.9 | 45 | No |

Source: CadnaA version 2019; County Noise Ordinance Sections 6.60.040 (E)

[1] 50 dBA $L_{EQ}$ daytime and 45 dBA $L_{EQ}$ exterior noise standard per County Noise Ordinance Table 6.60.040A for 30 minutes or more cumulative minutes of noise in any one hour.

As shown in Table 5, the maximum noise level from the project substation electrical equipment, measured at the closest residential property line, would be 55.3 dBA and would not exceed the County Noise Ordinance standard of 60 dBA for transformers and associated equipment in electrical substations. As shown in Table 6, the maximum combined noise level from the project's inverter stations and energy storage buildings, measured at the closest residential property line, would be 43.9 dBA during the daytime and 42.3 dBA during the nighttime. These noise levels would not exceed the County Noise Ordinance standard of 50 dBA and 45 dBA, respectively. Therefore, the project's operational stationarity source noise would not result in a permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance and the impact would be less than significant.

#### 4.1.3.3 Transportation Noise

Noise levels at residential properties located along the project-affected road segments were estimated using TNM and the anticipated maximum 12 peak hourly operational trips, as discussed in Section 3.2. 90 percent of project traffic would utilize North Livermore Avenue between the project site and I-580 and 10 percent of the project traffic would utilize Manning Road. The closest NSLU to the project traffic affected road segments centerlines would be 30 feet from North Livermore Avenue (approximately 1,600 feet south of the project site), and 35 feet from Manning Road (approximately 160 feet north of the project site). The predicted traffic noise level for the project affected road segments is shown in Table 7, *Operational Traffic Noise*.

**Table 7**
**OPERATIONAL TRAFFIC NOISE**

| Roadway Segment | Distance to Nearest NSLU (feet)[1] | NSLU Type | dBA $L_{DN}$ at Nearest NSLU[2] | | |
|---|---|---|---|---|---|
| | | | Existing | 2011 + Project | Change in $L_{DN}$ |
| **North Livermore Avenue** | | | | | |
| Project Site to westbound I-580 | 30 | SF | 69.8 | 69.9 | +0.1 |
| **Manning Road** | | | | | |
| Project Site to Morgan Territory Road | 35 | SF | 65.9 | 65.9 | +0.0 |

Source: TNM 2.5
I-580 = Interstate 580; MF = SF = Single-Family Residential.
1 Distance measured from roadway centerline.
2 Noise level assuming all traffic at the posted speed limit of 50 miles per hour.

As shown in Table 7, existing noise levels at all roadway segments at the closest NSLUs already exceed 60 $L_{DN}$ without the project. With the project traffic included, the maximum increase in noise levels would be 0.1 dBA $L_{DN}$ and would not exceed 3 dBA $L_{DN}$ along any roadway segment. Therefore, project operational traffic noise would not result in the generation of a substantial permanent increase in ambient noise levels in the vicinity of the project and the impact would be less than significant.

## 4.2 ISSUE 2: EXCESSIVE VIBRATION

### 4.2.1 Construction Vibration

During construction, the largest potential source of vibration during project construction would be an impact pile driver used to install PV panel rack support piers. The largest impact pile drivers could result in vibrations as high as 1.518 inches per second PPV at a distance of 25 feet (FTA 2018). The closest vibration sensitive land use to potential pile driving activity would be approximately 125 feet from the nearest PV panel location (a residence west of the project site, north of Manning Road). A 1.518 inches per second PPV vibration level would equal approximately 0.14 inches per second PPV at a distance of 125 feet.[1] This would be lower than the 0.2-inches per second PPV FTA threshold for non-engineered wood and masonry structures. The Cultural Resources report for the project identified two structures, a barn and a shed on the Stanley Ranch south of the Cayetano substation, eligible for list as historical buildings (HELIX 2020). Potential pile driving activity could occur approximately 190 feet north of the eligible shed, A 0.644 inches per second PPV vibration level would equal approximately 0.07 inches per

1 Equipment PPV = Reference PPV * $(25/D)^n$ (in/sec), where Reference PPV is PPV at 25 feet, D is distance from equipment to the receiver in feet, and n = 1.5 (the value related to the attenuation rate through typical soil); formula from FTA 2018.

second PPV at a distance of 190 feet. This would be lower than the 0.12-inches per second PPV FTA threshold for buildings extremely susceptible to vibration damage.

Another potential source of vibration during project construction activities would be a vibratory roller, which may be used as close at 75 feet of the nearest off-site residence (a residence west of the project site, north of Manning Road). A vibratory roller could create vibrations as high as 0.210 inches per second PPV at a distance of 25 feet (FTA 2018). A 0.210 inches per second PPV vibration level would equal approximately 0.04 inches per second PPV at a distance of 75 feet.[1] This would be lower than the 0.2 inches per second PPV FTA threshold for risk of architectural damage to non-engineered wood and masonry structures.

Therefore, although vibrations from pile driving and vibratory rollers may be perceptible to nearby receptors, temporary groundborne vibration impacts associated with project construction would be less than significant.

### 4.2.2 Operational Vibration

Long-term operation of the project would require the use of equipment and vehicles for periodic equipment maintenance, PV panel washing, and vegetation management. The largest potential source of vibration from off-road equipment used during project operation activities would be a loaded water truck, which could be used within 75 feet of the nearest off-site residence. A loaded heavy truck operating off-road could create vibrations as high as 0.076 inches per second PPV at a distance of 25 feet (FTA 2018). A 0.076 inches per second PPV vibration level would equal approximately 0.01 inches per second PPV at a distance of 75 feet.[1] This would be substantially lower than the 0.2 inches per second PPV FTA threshold for risk of architectural damage non-engineered wood and masonry structures. Therefore, groundborne vibration impacts associated with project operational use of water trucks or other off-road equipment would be less than significant.

## 4.3 ISSUE 3: AIRPORT NOISE EXPOSURE

The closest airport or airstrip to the project site is the Livermore Executive Airport, approximately 3.2 miles southwest. The project is not within the Livermore Executive Airport influence area or within any of the designated airport noise compatibility zones (Alameda County 2012). Therefore, the project would not expose people residing or working in the project area to excessive noise levels from airport operations and the impact would be less than significant.

## 4.4 ISSUE 4: CUMULATIVE NOISE IMPACTS

The project, in combination with past present and reasonably foreseeable project could result in cumulative noise impacts. For cumulative noise issues, the only identified cumulative projects would be the proposed Livermore Community Solar Farm project, located across North Livermore Avenue from the project site, and the proposed Oasis Fund Livermore Grow Facility, located adjacent to the northern section of the project site on Morgan Territory Road.

### 4.4.1 Cumulative Construction Noise

Noise from construction activities at the Livermore Community Solar Farm and Oasis Fund Livermore Grow Facility projects could overlap with project construction activities. As discussed above, noise from construction equipment that occurs between the hours of 7:00 a.m. and 7:00 p. between 7:00 a.m. to 7:00 p.m., Monday through Friday, or between 8:00 a.m. to 5:00 p.m. on Saturdays would be exempt from the County Noise Ordinance exterior noise level standard. These restrictions would apply to construction of all the cumulative projects. Mitigation measure NOI-1 requires the proposed project's noise generating construction activities to be limited to those hours or be subject to the specified exterior noise limits. Therefore, noise from project off-road construction equipment would result in a less than cumulatively considerable impact with mitigation incorporated.

According to the Livermore Community Solar Farm Project Draft Environmental Impact Report, the maximum peak hour construction traffic on North Livermore Avenue would be 25 worker vehicles and 2 trucks (Placeworks 2020). According to the Initial Study/Mitigated Negative Declaration air quality analysis for the proposed Oasis Fund Livermore Grow Facility, the maximum peak hour construction traffic on North Livermore Avenue would be 23 worker trips and 1 truck trip (Raney 2019). The noise level resulting from the existing traffic plus the maximum potential combined construction traffic for the two cumulative projects and the proposed project was modeled using the TNM, as described in Section 3.1. The results of the cumulative construction traffic noise modeling are shown in Table 8, *Cumulative Construction Traffic Noise*.

**Table 8**
**CUMULATIVE CONSTRUCTION TRAFFIC NOISE**

| Roadway Segment | Distance to Nearest NSLU (feet)[1] | NSLU Type | dBA $L_{DN}$ at Nearest NSLU[2] | | |
|---|---|---|---|---|---|
| | | | Cumulative | Cumulative + Project | Change in $L_{DN}$ |
| **North Livermore Avenue** | | | | | |
| Project Site to westbound I-580 | 30 | SF | 70.2 | 72.1 | +2.1 |

Source: TNM 2.5; CHS 2020; Placeworks 2020; Raney 2019
I-580 = Interstate 580; MF = SF = Single-Family Residential.
1 Distance measured from roadway centerline.
2 Noise level assuming all traffic at the posted speed limit of 50 miles per hour.

As shown in Table 8, with the project construction traffic included, the maximum increase in cumulative noise levels be 2.1 dBA LDN and would not exceed 3 dBA LDN. In addition, project construction traffic would be temporary and would cease once the project is operational. Therefore, the noise from project construction traffic would result in a less than cumulatively considerable impact.

### 4.4.2 Cumulative Operational Noise

Noise from the electrical equipment (e.g., transformers, inverters) from the project, the Livermore Community Solar Farm project, and the existing PG&E Cayetano substation could contribute cumulatively to ambient noise levels in the project vicinity. However, each electrical equipment noise source would be required to meet the County Noise Ordinance exterior noise level standard of 60 dBA $L_{EQ}$ for transformers and associated substation electrical equipment. The proposed project substation transformer would be located at least 500 feet from the existing Cayetano substation transformer and at least 800 feet from the proposed Livermore Community Solar Farm project transformers and inverters. With adherence to the County Noise Ordinance exterior noise standards, in combination with the anticipated distances between the proposed and existing electrical equipment, the contribution of operational noise from the project's electrical equipment to the existing noise environment would not be cumulatively

As discussed in Section 3.2, the project would generate 12 peak hour operational vehicle trips (11 on North Livermore Avenue). The proposed Livermore Community Solar Farm project is anticipated to generate a maximum of 10 daily peak hour operational trips (Placeworks 2020), and the Oasis Fund Livermore Grow Facility project is anticipated to generate a maximum of 11 peak hour operational trips (Raney 2019). The noise level resulting from the existing traffic plus the maximum potential combined operational traffic for the two cumulative projects and the proposed project was modeled using the TNM, as described in Section 3.1. The results of the cumulative operational traffic noise modeling are shown in Table 9, *Cumulative Operational Traffic Noise*.

**Table 9**
**CUMULATIVE OPERATIONAL TRAFFIC NOISE**

| Roadway Segment | Distance to Nearest NSLU (feet)[1] | NSLU Type | dBA $L_{DN}$ at Nearest NSLU[2] | | |
|---|---|---|---|---|---|
| | | | Cumulative | Cumulative + Project | Change in $L_{DN}$ |
| **North Livermore Avenue** | | | | | |
| Project Site to westbound I-580 | 30 | SF | 70.0 | 70.0 | +0.0 |

Source: TNM 2.5; CHS 2020; Placeworks 2020; Raney 2019
I-580 = Interstate 580; MF = SF = Single-Family Residential.
1 Distance measured from roadway centerline.
2 Noise level assuming all traffic at the posted speed limit of 50 miles per hour.

As shown in Table 9, with the project operational traffic included, there would be no discernable increase in cumulative traffic noise levels. Therefore, the operational trips from the proposed project would not generate a perceptible increase in traffic noise in the project vicinity, over the traffic noise levels from existing traffic plus traffic from the Livermore Community Solar Farm project and the Oasis Fund Livermore Grow Facility project. The noise from project operational traffic would result in a less than cumulatively considerable impact.

# 5.0 LIST OF PREPARERS

| | |
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# 6.0 REFERENCES

Alameda, County of. 2020. Code of Ordinances. Online content updated on July 7, 2020. Available at: https://library.municode.com/ca/alameda_county/codes/code_of_ordinances.

2012. Livermore Executive Airport – Airport Land Use Compatibility Plan. Available at: https://www.acgov.org/cda/planning/generalplans/documents/LVK_ALUCP_082012_FULL.pdf.

2000. East County Area Plan. Available at: https://www.acgov.org/cda/planning/generalplans/documents/EastCountyAreaPlancombined.pdf.

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). 2012. ASHRAE Handbook.

California Department of Transportation (Caltrans). 2013. Technical Noise Supplement (TeNS) to the Traffic Noise Protocol. September. Available at: http://www.dot.ca.gov/hq/env/noise/pub/TeNS_Sept_2013B.pdf.

CHS Consulting Group (CHS). 2020. Aramis Solar Energy Generation and Storage Project Transportation Impact Study. April.

Federal Transit Administration (FTA). 2018. Transit Noise and Vibration Impact Assessment. Available at: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf.

HELIX Environmental Planning (HELIX). 2020. Aramis Solar Energy Generation and Storage Project Cultural Resources Assessment Report. September.

National Electrical Manufacturers Association (NEMA). 2000. NEMA Standards Publication No. TR 1-1993 (R2000), Transformers, Regulators and Reactors.

Placeworks. 2020. Livermore Community Solar Farm Draft EIR, State Clearinghouse Number: 2018092012. March.

Raney Planning & Management, Inc. 2019. Oasis Fund Livermore Grow Facility Initial Study/Mitigated Negative Declaration. PLN2019-00258. December.

U.S. Department of Transportation (USDOT). 2008. Roadway Construction Noise Model. Available at: https://www.fhwa.dot.gov/Environment/noise/construction_noise/rcnm/index.cfm.

2004. Traffic Noise Model Version 2.5. Available at: https://www.fhwa.dot.gov/environment/noise/traffic_noise_model/tnm_v25/.

# Appendix A

## Construction Noise Modeling Outputs

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CadnaA Noise Source Input

| Name | ID | Type | Oktave Spectrum (dB) | | | | | | | | | | | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weight. | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | A | lin | |
| Inverter 1 | I1 | Lw (c) | | | | | | | 81.1 | | | | 81.1 | 81.1 | |
| Transformer 1 | T1 | Lw | | | | | | | 69.0 | | | | 69.0 | 69.0 | |
| Transformer 2 | T2 | Lw | | | | | | | 87.0 | | | | 87.0 | 87.0 | |
| Fan1 | Fan1 | Lw | | | 91.0 | 87.0 | 83.0 | 78.0 | 77.0 | 71.0 | 66.0 | 61.0 | 81.6 | 93.2 | |
| AC1 | AC1 | Lw | | | | 90.0 | 86.3 | 83.6 | 82.9 | 80.3 | 74.9 | 71.4 | 87.6 | 93.0 | |

CadnaA Substation Noise Output

| Name | M. | ID | Level Lr | | Limit. Value | | Land Use | | | Height | | Coordinates | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Day | Night | Day | Night | Type | Auto | Noise Type | | | X | Y | Z |
| | | | (dBA) | (dBA) | (dBA) | (dBA) | | | | (m) | | (m) | (m) | (m) |
| R1 | | R1 | 43.4 | 43.4 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608401.78 | 4177083.95 | 1.52 |
| R2 | | R2 | 48.3 | 48.3 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608243.24 | 4177273.29 | 1.52 |
| R3 | | R3 | 55.3 | 55.3 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608396.86 | 4177572.08 | 1.52 |
| R4 | | R4 | 39.9 | 39.9 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608390.83 | 4178385.21 | 1.52 |
| R5 | | R5 | 30.1 | 30.1 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608370.99 | 4179256.78 | 1.52 |
| R6 | | R6 | 30.9 | 30.9 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608118.52 | 4179151.07 | 1.52 |
| R7 | | R7 | 29.6 | 29.6 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608115.84 | 4179294.60 | 1.52 |
| R8 | | R8 | 31.4 | 31.4 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607955.39 | 4179069.62 | 1.52 |
| R9 | | R9 | 30.7 | 30.7 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607688.81 | 4179058.96 | 1.52 |
| R10 | | R10 | 28.1 | 28.1 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607680.48 | 4176862.65 | 1.52 |

CadnaA Inverter and Energy Storage Noise Output

| Name | M. | ID | Level Lr | | Limit. Value | | Land Use | | | Height | | Coordinates | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Day | Night | Day | Night | Type | Auto | Noise Type | | | X | Y | Z |
| | | | (dBA) | (dBA) | (dBA) | (dBA) | | | | (m) | | (m) | (m) | (m) |
| R1 | | R1 | 40.4 | 34.8 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608401.78 | 4177083.95 | 1.52 |
| R2 | | R2 | 43.9 | 42.3 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608243.24 | 4177273.29 | 1.52 |
| R3 | | R3 | 42.0 | 39.7 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608396.86 | 4177572.08 | 1.52 |
| R4 | | R4 | 43.4 | 26.1 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608390.83 | 4178385.21 | 1.52 |
| R5 | | R5 | 43.7 | 19.0 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608370.99 | 4179256.78 | 1.52 |
| R6 | | R6 | 42.4 | 18.8 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608118.52 | 4179151.07 | 1.52 |
| R7 | | R7 | 41.2 | 17.9 | 0.0 | 0.0 | | x | Total | 1.52 | r | 608115.84 | 4179294.60 | 1.52 |
| R8 | | R8 | 40.9 | 20.0 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607955.39 | 4179069.62 | 1.52 |
| R9 | | R9 | 39.5 | 19.6 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607688.81 | 4179058.96 | 1.52 |
| R10 | | R10 | 41.4 | 29.9 | 0.0 | 0.0 | | x | Total | 1.52 | r | 607680.48 | 4176862.65 | 1.52 |

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# Appendix B

## Equipment Manufacturer Data Sheets

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Example Technical Specification

# Universal Power Conditioner System PV / ESS Inverter

**(Preliminary - Under Development)**

**TMEIC**

# Table of Contents

# 1. PURPOSE, STANDARDS, AND SCOPE

## 1.1. Statement of Purpose

TMEIC will provide broad-based customer support including post sales application support and commissioning services. The equipment described in the specification below is intended to be used as a Grid-Connected Photovoltaic Inverter System for a photovoltaic generation power plant.

## 1.2. General Scope

This specification will cover the design, fabrication, commissioning, and supply of the following equipment:

| Equipment | Description |
|---|---|
| Inverter Unit | 4200kW/4200kVA (5x 840kW units, maximum output at 25°C) |
| MV/LV 3-phase Transformer (MV TR) - Liquid-Filled MTR Pad mounted | 3360/4200kVA, 630V - 34.5kV |
| PV Skid | Outdoor type |

## 1.3. Documentation

All submittals will be in electronic form and will include:

- Final Specification
- Test Reports
- Instruction Manual
- Installation Manual
- Schematic Diagrams
- Outline Drawing

## 1.4. Packaging, Transportation and Storage

The equipment may be divided into several sections for protection during transportation when necessary. The equipment will be properly packaged for the respective mode of transportation. Customer is responsible for disposal of packaging materials. Special notations such as “Fragile”, “This side Up”, “Center of Gravity, “Weight”, etc.. when necessary, will be clearly labeled on each package. Manufacturer’s recommendations for storage should be followed upon receipt.

## 1.5. Product Testing

Testing will be carried out at the manufacturer’s facility for each piece of equipment. Test reports of major equipment will be submitted.

## 1.6. Maintenance Contract

Performing scheduled inspections and maintenance will improve the reliability of the equipment and prolong its service life. It is recommended that periodical inspections and maintenance be performed by specialists of the service representative. Such maintenance is not included in this scope and can be quoted separately. The warranty is dependent upon performing periodical inspections and maintenance as per the manufacturer’s manual.

## 1.7. Commissioning

The equipment presented in this specification will require authorized startup & commissioning services by TMEIC.

The commissioning scope includes but is not limited to the following:

- De-energized checks including proper installation of equipment, torque mark verification, and proper electrical connections between major equipment.
- Energized checks including software updates, verification of set-points and IP addresses, and proper operation of communications and equipment.
- Commissioning tests will be performed per TMEIC Commissioning Checklist

Note: Testing of grid protection relay is not included. Post-shipping tests of the MV Transformer, such as NETA tests, are not included and can be quoted separately.

The commissioning scope and price are based on the following conditions:

- The pre-commissioning checklist must be filled out and returned to the TMEIC project manager at least two weeks before resources will be scheduled to mobilize to site.
- DC voltage and polarity from array inputs inside the DC recombiner box have been verified and documented by others.
- Back feed is available upon arrival of TMEIC technicians.
- De-energized and energized checks will be completed during the same trip.
- Inverters will be available for commissioning continuously.
- Conditions outside of the TMEIC technician's control which result in delay may be subject to extra charge. Conditions could include, but not limited to: Waiting time for grid connection, bad weather to clear out, other related equipment required for PV inverter commissioning to be installed.
- Technicians will not travel with commissioning spares; critical spares will be available either via client stock on hand, or via TMEIC customer support process.
- Brief operations and maintenance overview can be provided immediately following the conclusion of commissioning to available onsite personnel. This is not a formal O&M training class. TMEIC offers regularly scheduled formal classroom and hands-on training. Schedule, curriculum, and pricing can be found at https://www.tmeic.com/customer-support/commissioning-training-field-service.

Any deviation from these conditions will result in extra charges in accordance with TMEIC's published rate sheet during the time that the work is completed. See TMEIC Terms and Conditions for additional information.

**Added Services** Technical advisory services for supervision of equipment installation and post commissioning services can be quoted but are not within the scope of TMEIC commissioning services.

## 1.8. Dispatch of TMEIC Engineers

Except for the purpose of implementing the repair under the warranty set forth in 3.3.5, the dispatch of TMEIC engineers for any service whatsoever will be made under a separate agreement offering the buyer to pay additional fees for services.

## 1.9. Rules & Standards

| | |
|---|---|
| IEEE 1547 | IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems. |
| UL1741-SA | Inverter, Converter, Controllers and Interconnection System Equipment for Power Systems. |
| NEC 2017 / NFPA 70 | National Electric Code 2017 |
| IEEE 1547.1 | IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems. |
| IEC 62109-1 | Safety of power conversion equipment for use in photovoltaic power systems-Part 1: General Requirements |
| IEC 62109-2 | Safety of power converters for use in photovoltaic power systems – Part 2: particular requirements for inverters |
| IEC 62933-5-1:2017 | Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification |
| IEC 61000-6-2 | Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments |
| IEC 61000-6-4 | Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments |
| IEC 61727 | Photovoltaic (PV) systems - Characteristics of the utility interface |
| IEC 62116 | Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures |
| BDEW TR3, TR4 | |

## 1.10. Dimensional Units

All bolts, nuts and screws will conform to the Metric Thread of ISO (International Organization for Standardization**.** All manufacturing and design of the equipment will conform to the metric system standards.

## 1.11. Site Conditions

Grounding System
The inverter must be negatively grounded providing a grounding resistance of less than 5 ohms.

Installation and Operation Environment
When installing or operating the inverter and related devices, ensure that the installation and operation environment complies with Table 1. Failing to observe these standards may result in deterioration of the insulation, causing short life and malfunctions. Before installation, measure and evaluate the environment of the installing location. The inverter must be protected from marine environments and must be sealed from corrosive gas and salty air in accordance with Table1. The warranty is dependent upon meeting the environmental conditions.

Table 1. Inverter installation and operation environment guidelines

| No. | Item | Environment Standard |
|---|---|---|
| 1 | Installation location | Outdoors |
| 2 | Full power ambient temperature range | -25 ~ 25DegC |
| | Operational Ambient temperature | -25 ~ 60DegC (10% power reduction from 25-50C, 100% power reduction from 50-60C) |
| 3 | Relative humidity | The relative humidity must be held between 5 and 95%. There must be no condensation due to temperature change. |
| 4 | Altitude | Up to 2000 meters above sea level. |
| 5 | Air pressure | The air pressure must be maintained in the range 860 to 1060 hPa. (pending) |
| 6 | Vibration and mechanical shock (pending) | Vibrations in the installation environment must have frequencies lower than 10 Hz, or higher than 20 Hz.<br>For vibrations less than 10 Hz, the resulting acceleration must not exceed 0.5G.<br>For vibrations between 20 Hz and 50Hz, the resulting acceleration must not exceed 0.5G.<br>For vibrations between 50Hz and 100Hz, the total amplitude must not exceed 0.1 mm. |
| 7 | Dust | Dust in the air where the inverter is installed must not exceed normal atmospheric dust levels. In particular, that dust must not include electrically conductive particles, oils or fats, or organic materials such as silicone. |
| 8 | Flammability | There should be no flammable or explosive gas present. |
| 9 | Corrosive factors | Inverter should be installed in an environment rated less than C4 corrosive factor for Steel, Zinc, and Copper as defined by ISO 9266. |

# 2. DETAILS OF EQUIPMENT SUPPLIED [Base Bid]

## 2.1. PCS Circuit and Common Features

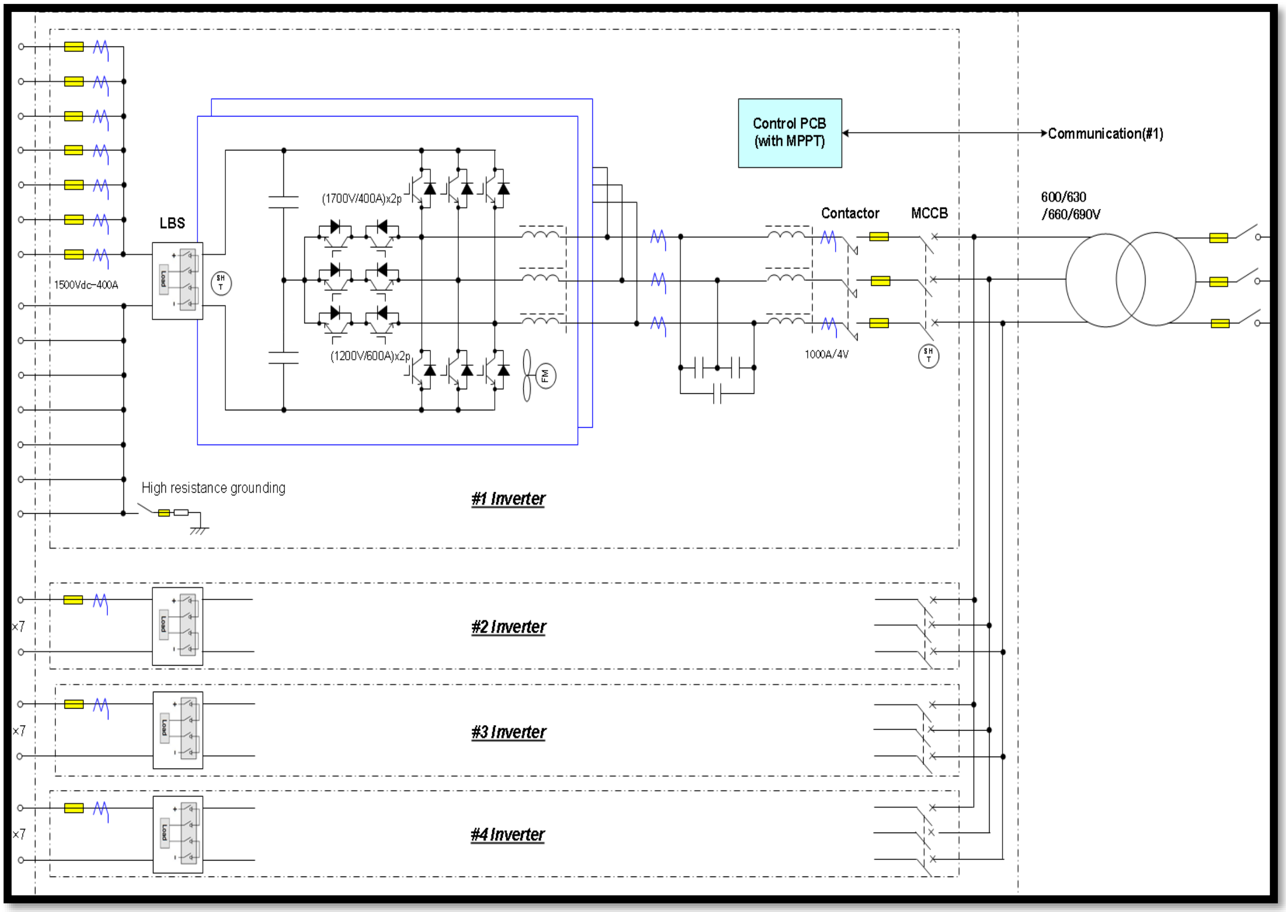


Figure 2.1: Circuit diagram of 4 PCS coupled

Benefits and Features:

1. Stackable Power Blocks: 800kW-4600kW
2. Modular Design
3. Each UPCS (PV or ESS) has independent:
    a. Operation, Control System, Cooling System
    b. Isolation on DC (Load Break Switch) and AC (MCCB and Contactor)
    c. DC inputs (PV 8 inputs per block, ESS 1 input per block)
    d. Individual MPPT tracking
4. For PV-PCS, Negative Grounding with CTs on each input.
5. For ESS-PCS, the system shall also include the Pre-Charge Circuit, which is connected to the DC battery side.

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Mailing Address: 2060 Cook Drive, Salem, VA 24153

**840kW Inverter Unit**

**Main Circuit Type**

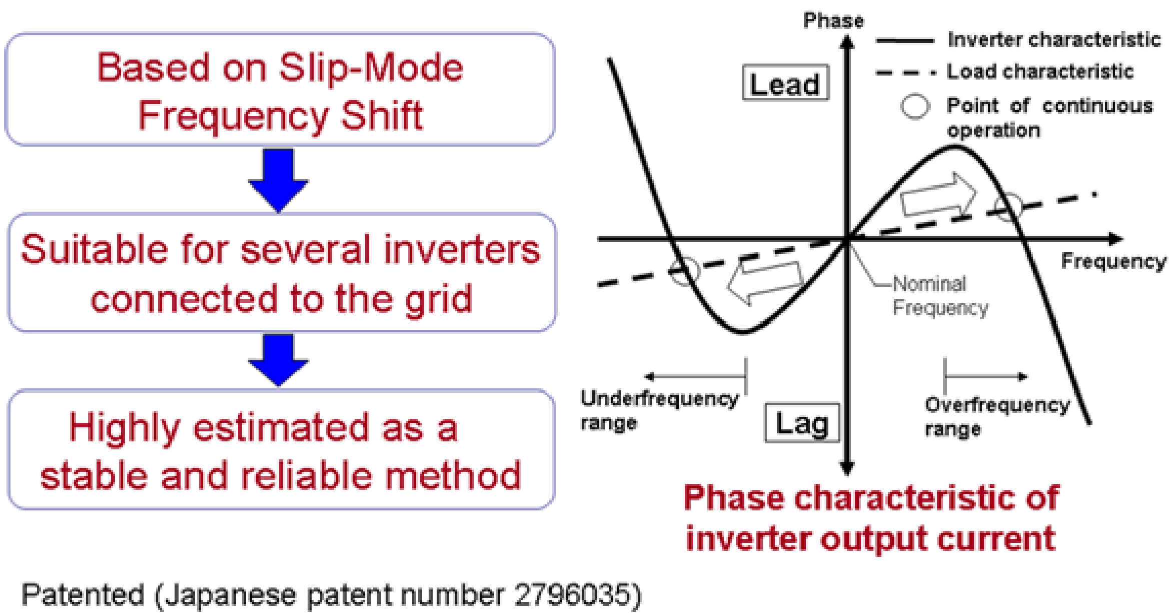
| | |
|---|---|
| Conversion method | Voltage source inverter with instantaneous current control |
| Switching method | Pulse Width Modulation (PWM) control |
| Inverter configuration | Three-phase bridge |
| Isolation method | External Transformer is required to isolate inverter |
| Cooling method | Forced Air cooling |

**Grid Connection Features**

(1) **Anti-islanding protection**
The objective of this system feature is to detect the islanding condition and drive the system to a stable operating condition.

(2) **Reactive Power Control**
Reactive power can be injected to the grid according to the grid voltage through the TMEIC Power Plant Controller. The TMEIC Power Plant Controller will communicate with each inverter via a communication port, in a Modbus protocol.

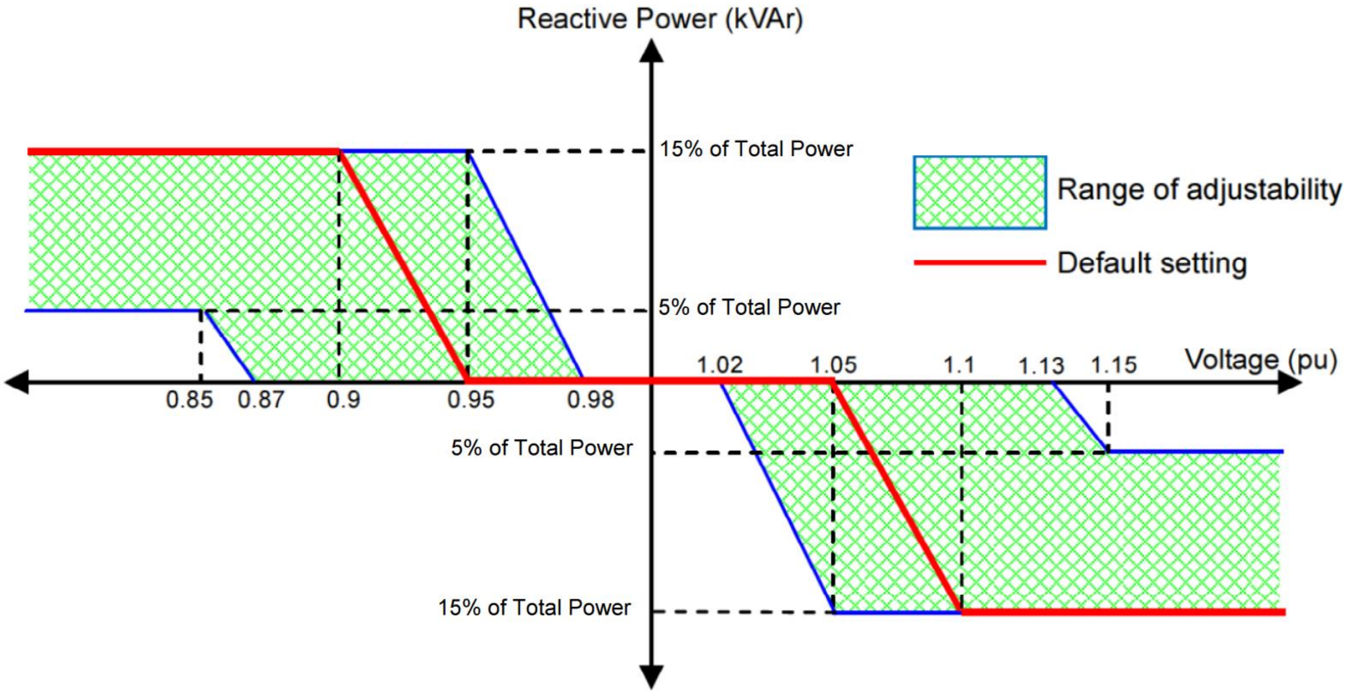
(3) **Active Power Limit**
Site wide active power can be controlled via TMEIC's Power Plant Controller.



**Grid Support Functionality (1741-SA smart features)**

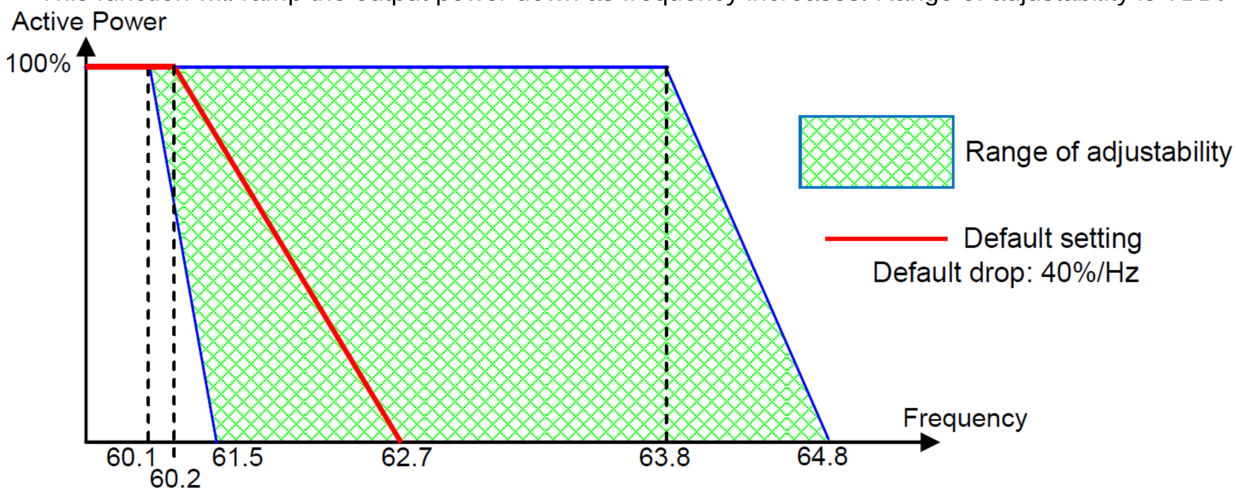
**(1) Volt-Var**

This function operates under reactive power priority, which means that the inverter will derate for active power instead of reactive power when the maximum kVA rating of MVA is reached.




**(2) Frequency – Watt**

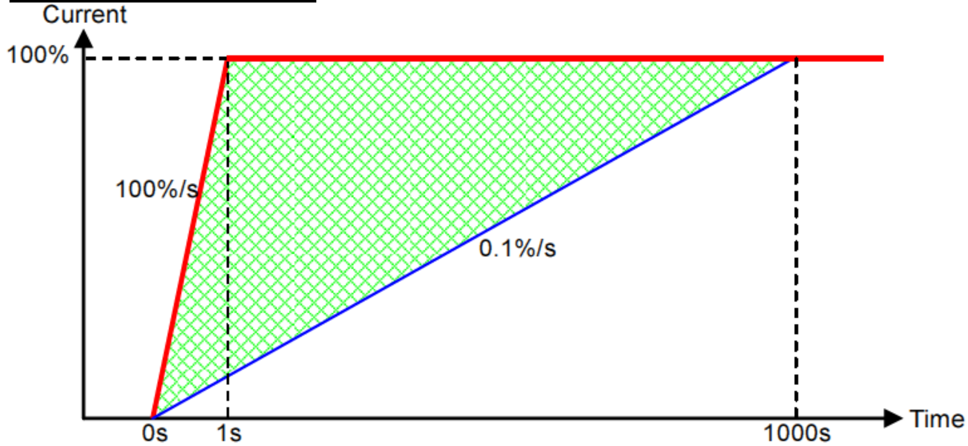
This function will ramp the output power down as frequency increases. Range of adjustability is TBD.




**(3) Dynamic VAR Compensation**

Inverter capable of injecting reactive current during low voltage ride through events. Capability shall be in line with limits set forth in BDEW TR3, TR4.

**(4) <u>Ramp Rate Adjustability</u>**




Range of adjustability: 100%/s to 0.1%/s

Range of adjustability

Default setting: 100%/s

Normal and soft-start ramp rate are under the same settings. They cannot be programmed independently.

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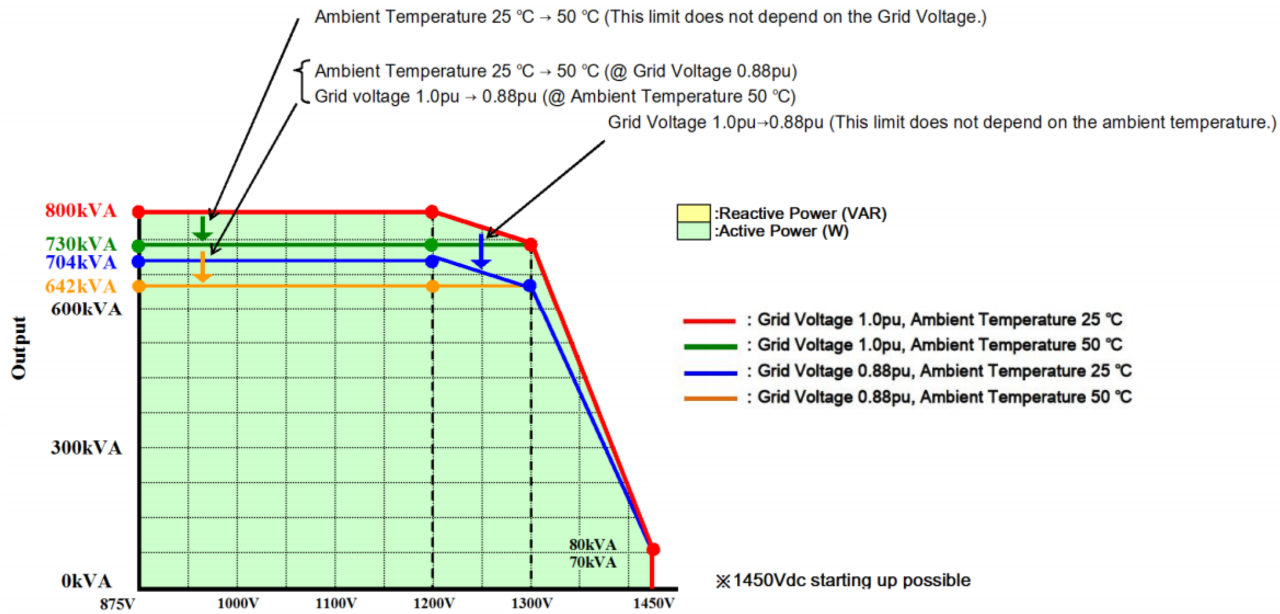
**<u>Temperature Derate Curve</u>**

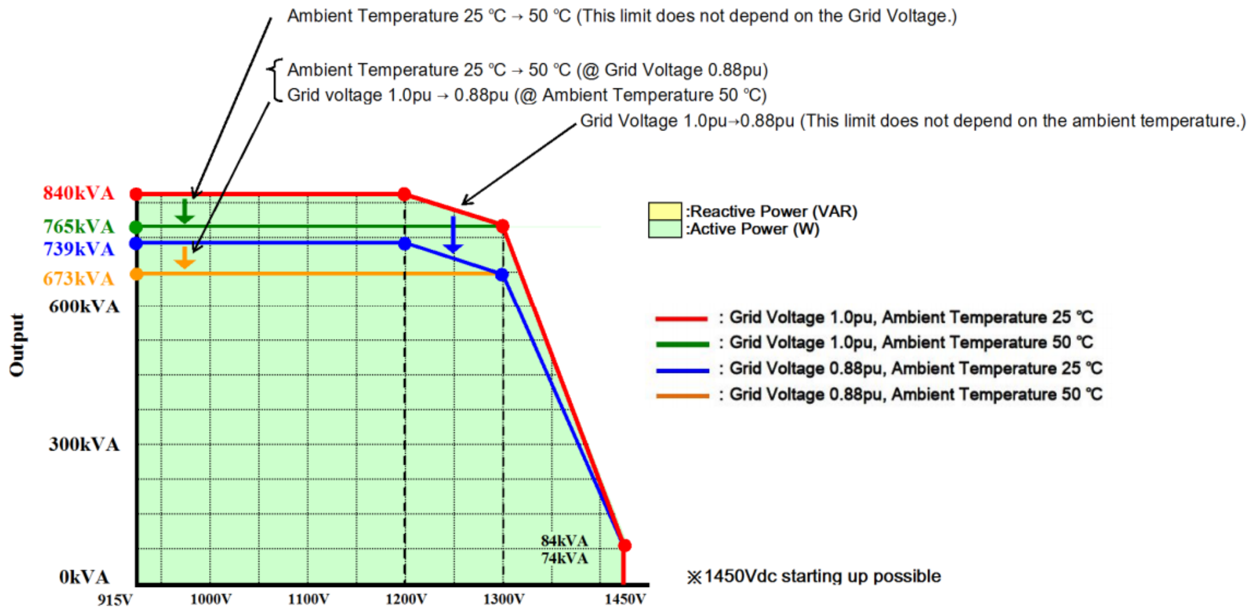
The curves below define the inverter de-rate characteristics at different ambient and grid voltage conditions.

# PVU-L0800GR Derating curve




Derating curve of 800kW Inverter(600Vac)

# PVU-L0840GR Derating curve




**Derating curve of 840kW Inverter(630Vac)**

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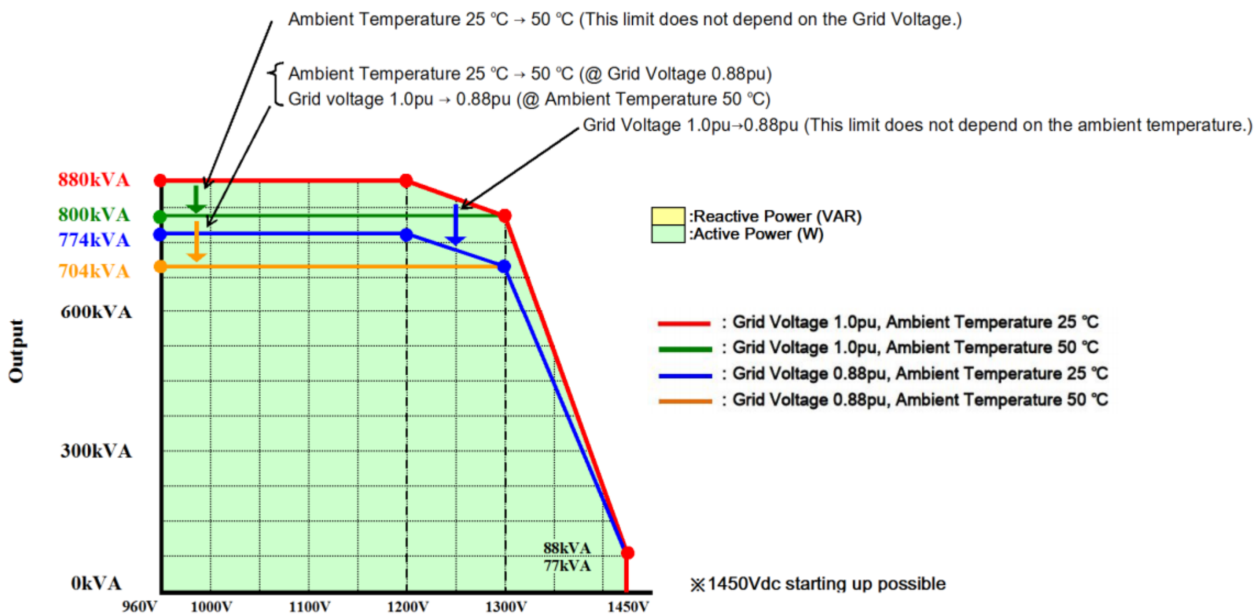
# PVU-L0880GR Derating curve



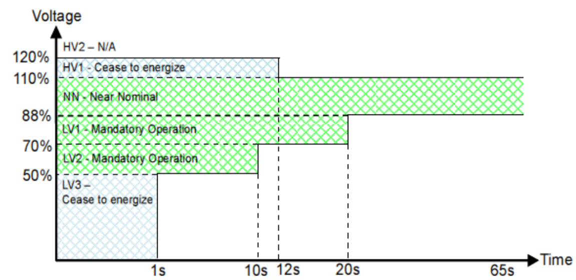

**Derating curve of 880kW Inverter(660Vac)**

## LVRT and FRT Functionality

Fault Ride through Capabilities for Universal PCS with Rule 21 for illustration. The inverter is capable of more than what is shown below.

### Voltage

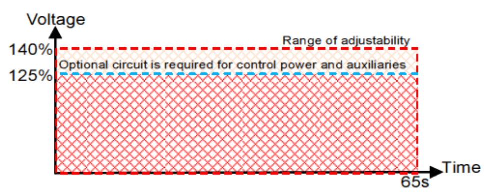
Rule 21




| Name | | Description | Default setting | |
|---|---|---|---|---|
| | | | % of nominal | trip time |
| OVR | OVR4 | Grid overvoltage detection level 4 | 120% | - |
| | OVR3 | Grid overvoltage detection level 3 | 110% | 12s |
| | UVR2 | Grid overvoltage detection level 2 | 110% | 12s |
| | UVR1 | Grid overvoltage detection level 1 | 110% | 12s |
| UVR | UVR1 | Grid undervoltage detection level 1 | 88% | 20s |
| | UVR2 | Grid undervoltage detection level 2 | 70% | 10s |
| | UVR3 | Grid undervoltage detection level 3 | 50% | 1s |
| | UVR4 | Grid undervoltage detection level 4 | 50% | 1s |
| Cease to energize | | Cease to energize for overvoltage | 110% | - |
| | | Cease to energize for undervoltage | 50% | - |

*Inverter will provide Dynamic Var Compensation as per BDEW TR3 and TR4, as well as the elimination of momentary cessation of current.

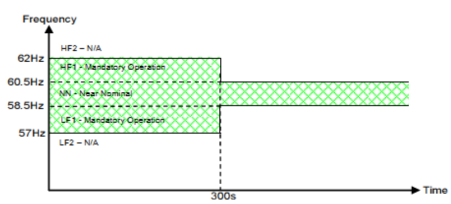
Range of Adjustability




**Remarks:**
1) For voltage settings over 125%, an optional circuit is required for the control power supply.
2) The inverter is not set to supply reactive power during the fault above the settings prior to the fault.
3) For overvoltage events, there may be an impact on power quality when the DC voltage is close to the minimu
4) Current may be not perfectly sinusoidal for some asymmetrical faults.

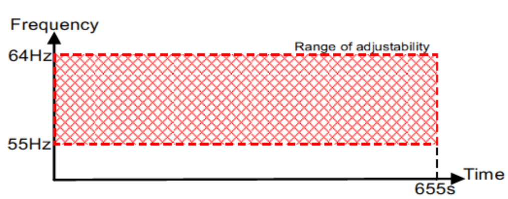
### Frequency

Rule 21




| Name | | Description | Default setting | |
|---|---|---|---|---|
| | | | Frequency | Trip time |
| OFR | OFR3 | Grid over-frequency detection level 3 | 62Hz | - |
| | OFR2 | Grid over-frequency detection level 2 | 60.5Hz | 300s |
| | UFR1 | Grid over-frequency detection level 1 | 60.5Hz | 300s |
| UFR | UFR1 | Grid under-frequency detection level 1 | 58.5Hz | 300s |
| | UFR2 | Grid under-frequency detection level 2 | 58.5Hz | 300s |
| | UFR3 | Grid under-frequency detection level 3 | 58.5Hz | 300s |
| | UFR4 | Grid under-frequency detection level 4 | 58.5Hz | 300s |
| | UFR5 | Grid under-frequency detection level 5 | 57Hz | - |

Range of adjustability




**Remarks:**
1) Maximum continuous operation is 64Hz for UL1741-SA compliant inverters and 63Hz for other models

**Structural Specification**

| | | |
|---|---|---|
| (1) General Construction of Equipment | | TBD |
| (2) Inverter Cabinet Dimensions (Height X Width X Depth) | | : 1950mm X 1150mm X 1150mm |
| (3) Weight | | : TBD |
| (4) Paint | Outside general surface | : Sand White |
| | Inside surface | : Sand White |
| | Base | : Sand White |
| (5) Input/output interface | DC input | : Bottom Cable Entry |
| | AC output | : Output on back/side of the inverter |
| | Control Wire | : TBD |
| | Grounding Wire | : TBD |

## 2.2. PV-PCS

## Control Method for PV-PCS

| | |
|---|---|
| DC side control functions | Maximum Power Point Tracking (MPPT) control |
| Grid side control functions | Active power control, reactive power control, Voltage Control Mode* |
| Operation | Auto start/stop (soft-start at startup) |
| Other functions | Output power limiter. (If the capacity of solar power exceeds the generation capacity of the Inverter, the Inverter limits the output power) |

*Voltage Control Mode is available via TMEIC Power Plant Controller integration.

## Electrical Ratings of PV-PCS

| Item | Specification | | | |
|---|---|---|---|---|
| **Rated AC Voltage** | 600VAC | 630VAC | 660VAC | 690VAC |
| **Rated Power@25℃** | 800kW | 840kW | 880kW | 920kW |
| **Rated Power @50℃** | 730kW | 765kW | 800kW | 840kW |
| **MPPT Range** | 875-1300VDC | 915-1300VDC | 960-1300VDC | 1005–1300VDC |
| **Rated Frequency** | 50/60 Hz | | | |
| **Maximum Efficiency** | 98.5% | | | |
| **CEC Efficiency** | 98.5% | | | |
| **Inverter Dimensions (Tentative)** | 1100 X 1900 X 1100 mm (W X H X D) | | | |
| **Weight (tentative)** | <1000kgs | | | |
| **Enclosure Rating** | NEMA 3R | | | |
| **Installation** | Outdoor | | | |
| **AC Protection** | MCCB and Fuse | | | |
| **DC Protection** | Fuses | | | |
| **Communication** | Modbus TCP | | | |
| **DC Inputs** | Maximum 8 per Inverter<br>Each input rating is a maximum of 400A | | | |
| **Harmonic Distortion of AC Current** | ≦3% THD (At rated power) | | | |
| **Standard Control Power Supply** | Control Power Supply from Inverter output and Capacitor backup circuit (3 sec. compensation) | | | |
| **Maximum Line Up** | Maximum Line up of a total of 6 panels | | | |
| **Noise Level** | 75dBA at 1 meter | | | |
| **Short Circuit Ratio** | Above 2.0 (Below 2.0, TMEIC will do simulations and confirm) | | | |
| **Short Circuit Withstand Current** | AC Side– 65kA DC Side – 100kA (20ms) | | | |
| **Cooling Method** | Independent Forced Air Cooling with no Air Filters | | | |

* Maximum output power rating is de-rated by input DC voltage, output AC voltage and temperature condition.
** Transition from constant DC voltage mode to MPPT mode occurs 10V before minimum MPPT range for each respective o.
*** Rated output power and power factor variation range is only for rated voltage condition.

## Protective Functions

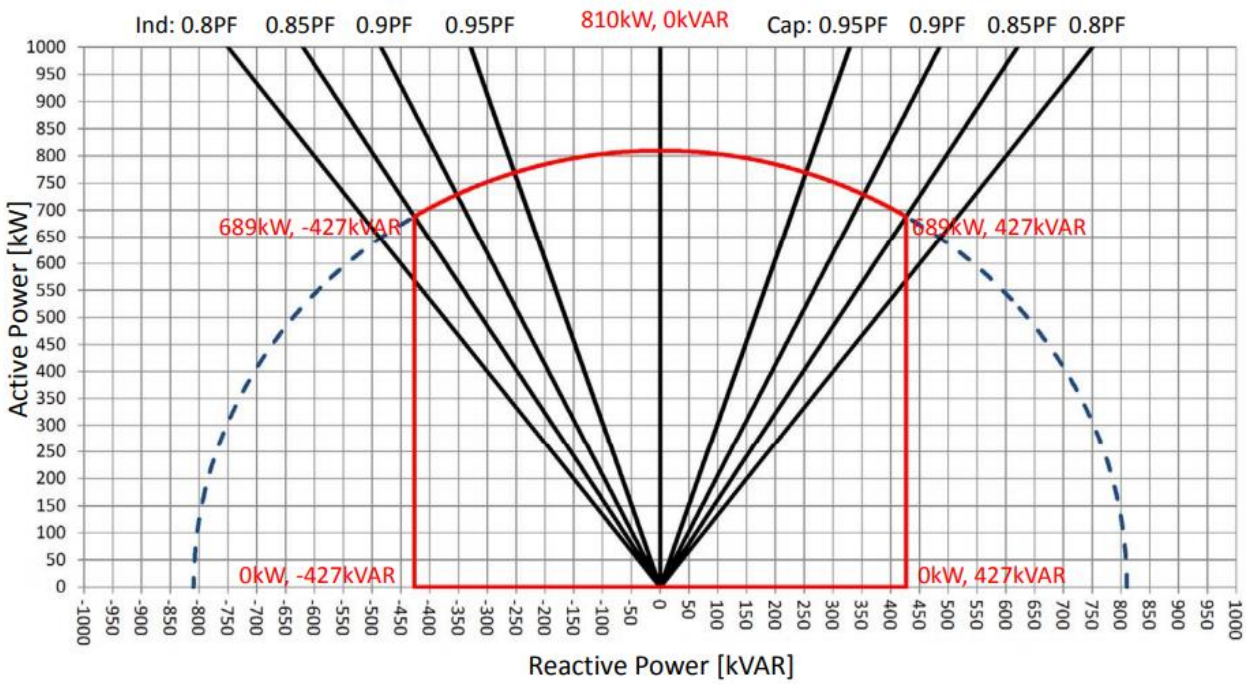
| | |
|---|---|
| Input (DC) side | Ground Fault, DC Reverse Current, Over Voltage, Over Current |
| Grid (AC) side | Anti-islanding, Over/Under Voltage, Over/Under Frequency, Over current |

## Protective Devices

| | |
|---|---|
| Input (DC) side | Surge protective device: IN=10kA/UCpv=1500V |
| Grid (AC) side | Surge protective device: IN=15kA/AC690V |

## Power Factor Control

The D-Curve depicted below shows the Ninja PF characteristics. The inverter offers a power factor range from +/- 0.85; the example PQ curve below is shown with derated power at 35C ambient temperature. PF characteristics will be de-rated according to the change of AC voltage, DC voltage, and ambient temperature.




* Operation area will be curtailed by input DC voltage, output AC voltage.

PQ curve for PVU-L0840GR (35℃)

## 2.3 ESS-PCS

### Control Method of ESS-PCS

| | |
|---|---|
| DC side control functions | DC Voltage will depend on the State of Charge of Battery |
| Grid side control functions | Active power control, reactive power control, Voltage Control Mode* |
| Operation | Dependent on the command from an external controller |

### Electrical Ratings of ESS-PCS

| Item | Specification | | |
|---|---|---|---|
| **Rated AC Voltage** | 480VAC | 600VAC | 630VAC |
| **Rated Power@25℃** | 630 kW | 800 kW | 840 kW |
| **Rated Power @50℃** | 570kW | 730 kW | 765 kW |
| **MPPT Range** | 710-1300 VDC | 875-1300 VDC | 915-1300VDC |
| **Rated Frequency** | 50/60 Hz | | |
| **Maximum Efficiency** | 98.5% | | |
| **CEC Efficiency** | 98.5% | | |
| **Inverter Dimensions (Tentative)** | 1100 X 1900 X 1100 mm (W X H X D) | | |
| **Weight (tentative)** | <1000kgs | | |
| **Enclosure Rating** | IP 55/ NEMA 3R | | |
| **Installation** | Outdoor | | |
| **AC Protection** | MCCB and Fuse | | |
| **DC Protection** | Fuses | | |
| **Communication** | Modbus TCP | | |
| **DC Inputs** | 1 per Inverter | | |
| **Harmonic Distortion of AC Current** | ≦3% THD (At rated power) | | |
| **Standard Control Power Supply** | Control Power Supply from Inverter output and Capacitor backup circuit (3 sec. compensation) | | |
| **Maximum Line Up** | Maximum Line up of a total of 6 panels | | |
| **Noise Level** | 75dBA at 1 meter | | |
| **Short Circuit Ratio** | Above 2.0 (Below 2.0, TMEIC will do simulations and confirm) | | |
| **Short Circuit Withstand Current** | AC Side– 65kA DC Side – 100kA (20ms) | | |
| **Cooling Method** | Independent Forced air cooling with no Air Filters | | |

* Maximum output power rating is de-rated by input DC voltage, output AC voltage and temperature condition.
** Transition from constant DC voltage mode to MPPT mode occurs 10V before minimum MPPT range for each respective o.
*** Rated output power and power factor variation range is only for rated voltage condition.

## Protective Functions

| | |
|---|---|
| Input (DC) side | Ground Fault, DC Reverse Current, Over Voltage, Over Current |
| Grid (AC) side | Anti-islanding, Over/Under Voltage, Over/Under Frequency, Over current |

## Protective Devices

| | |
|---|---|
| Input (DC) side | Surge protective device: IN=10kA/UCpv=1500V |
| Grid (AC) side | Surge protective device: IN=15kA/AC690V |

## Power Factor Control

The D-Curve depicted below shows the 840kW Outdoor ESS-PCS PF characteristics. The inverter offers a power factor range from +/-0.8 at full rated power with 1pu grid voltage, nominal DC voltage and 25C ambient temperature. PF characterisitics will be de-rated according to the change of AC voltage, DC voltage, and ambient temperature.

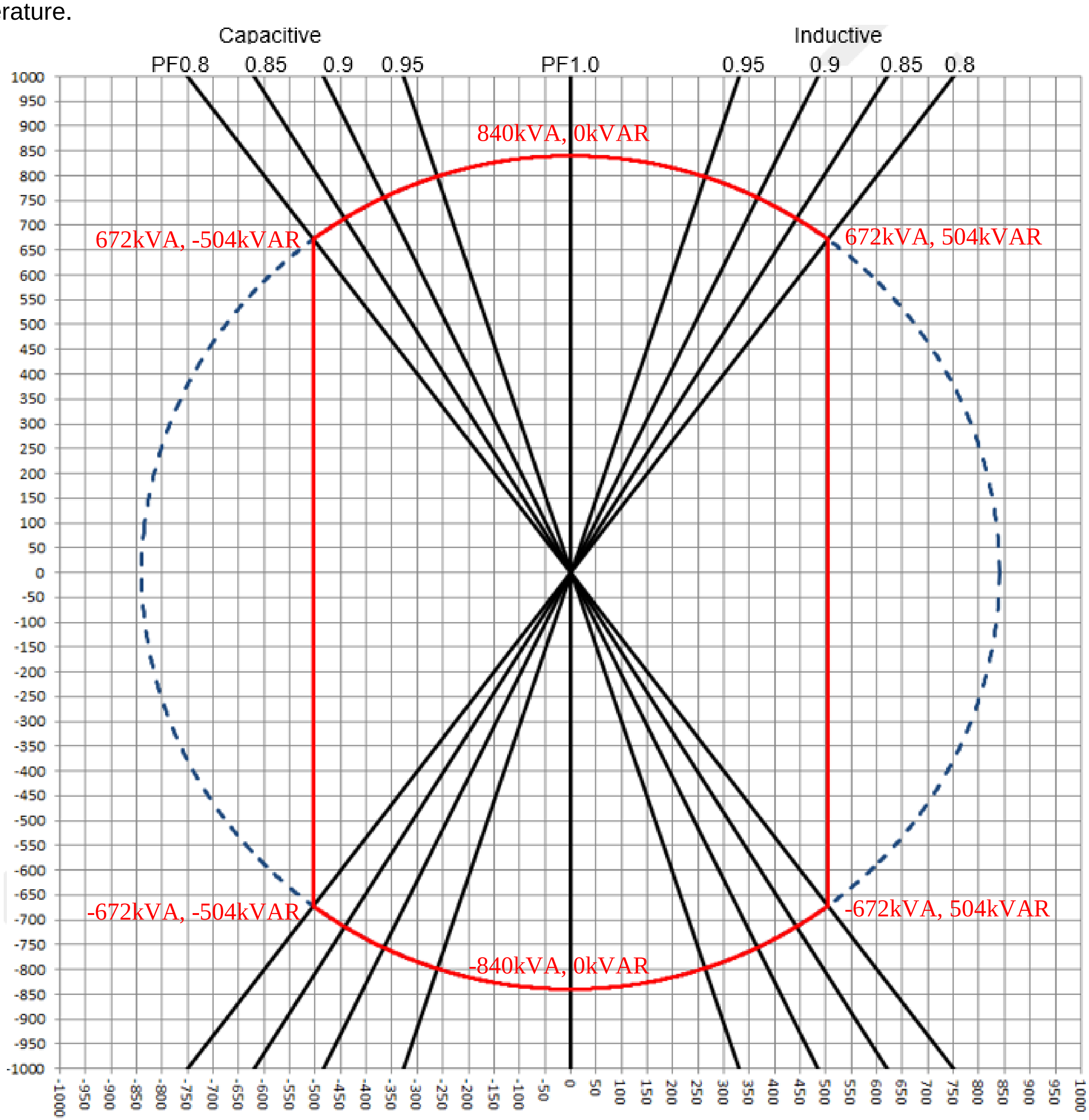



Figure 5.2: P-Q Curve of ESS-PCS @ 25°C, 630Vac(Grid Voltage= 1p.u.), Nominal Vdc

## 2.4 System Line Up and Configuration

The Universal PCS can operate as an ESS-PCS, a PV-PCS and a hybrid that consists of PV-PCS and ESS-PCS on a common low Voltage AC same bus. When the system is a PV-PCS only or an ESS-PCS only, units are placed in parallel to form an Inverter System of consisting of the following rating:

Table 2.4.1: PV Only @25℃

| Panel Rating | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 920kW | 690VAC | 920 kW | 1840 kW | 2760 kW | 3680 kW | 4600 kW | 5520 kW |
| 880kW | 660VAC | 880 kW | 1760 kW | 2640 kW | 3520 kW | 4400 kW | 5280 kW |
| 840kW | 630VAC | 840 kW | 1680 kW | 2520 kW | 3360 kW | 4200 kW | 5040 kW |
| 800kW | 600VAC | 800 kW | 1600 kW | 2400 kW | 3200 kW | 4000 kW | 4800 kW |

Table 2.4.2: PV Only @35℃

| Panel Rating | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 920kW | 690VAC | 888 kW | 1776 kW | 2664 kW | 3552 kW | 4440 kW | 5328 kW |
| 880kW | 660VAC | 848 kW | 1696 kW | 2544 kW | 3392 kW | 4240 kW | 5088 kW |
| 840kW | 630VAC | 810 kW | 1620 kW | 2430 kW | 3240 kW | 4050 kW | 4860 kW |
| 800kW | 600VAC | 772 kW | 1544 kW | 2316 kW | 3088 kW | 3860 kW | 4632 kW |

Table 2.4.3: PV Only @40℃

| Panel Rating | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 920kW | 690VAC | 872 kW | 1744 kW | 2616 kW | 3488 kW | 4360 kW | 5232 kW |
| 880kW | 660VAC | 832 kW | 1664 kW | 2496 kW | 3328 kW | 4160 kW | 4992 kW |
| 840kW | 630VAC | 795 kW | 1590 kW | 2385 kW | 3180 kW | 3975 kW | 4770 kW |
| 800kW | 600VAC | 758 kW | 1516 kW | 2274 kW | 3032 kW | 3790 kW | 4548 kW |

Table 2.4.4: PV Only @50℃

| Panel Rating | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 920kW | 690VAC | 840 kW | 1680 kW | 2520 kW | 3360 kW | 4200 kW | 5040 kW |
| 880kW | 660VAC | 800 kW | 1600 kW | 2400 kW | 3200 kW | 4000 kW | 4800 kW |
| 840kW | 630VAC | 765 kW | 1530 kW | 2295 kW | 3060 kW | 3825 kW | 4590 kW |
| 800kW | 600VAC | 730 kW | 1460 kW | 2190 kW | 2920 kW | 3650 kW | 4380 kW |

Table 2.4.5: ESS Only @25℃

| Panel Ration | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 840kW | 630VAC | 840 kW | 1680 kW | 2520 kW | 3360 kW | 4200 kW | 5040 kW |
| 800kW | 600VAC | 800 kW | 1600 kW | 2400 kW | 3200 kW | 4000 kW | 4800 kW |
| 630kW | 480VAC | 630 kW | 1260 kW | 1890 kW | 2520 kW | 3150 kW | 3780 kW |

Table 2.4.6: ESS Only @35℃

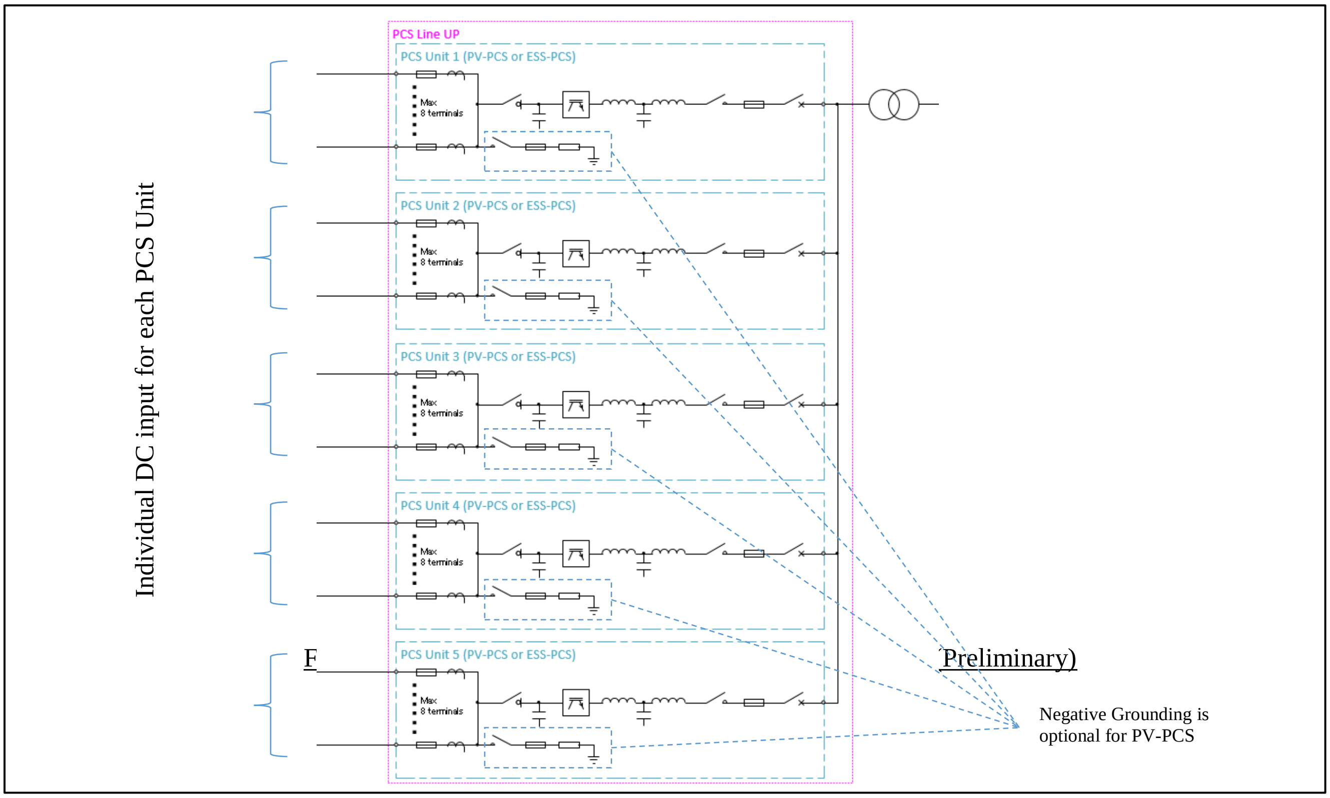
| Panel Ration | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 840kW | 630VAC | 810 kW | 1620 kW | 2430 kW | 3240 kW | 4050 kW | 4860 kW |
| 800kW | 600VAC | 772 kW | 1544 kW | 2316 kW | 3088 kW | 3860 kW | 4632 kW |
| 630kW | 480VAC | 606 kW | 1212 kW | 1818 kW | 2424 kW | 3030 kW | 3636 kW |

Table 2.4.7: ESS Only @40℃

| Panel Ration | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 840kW | 630VAC | 795 kW | 1590 kW | 2385 kW | 3180 kW | 3975 kW | 4770 kW |
| 800kW | 600VAC | 758 kW | 1516 kW | 2274 kW | 3032 kW | 3790 kW | 4548 kW |
| 630kW | 480VAC | 594 kW | 1188 kW | 1782 kW | 2376 kW | 2970 kW | 3564 kW |

Table 2.4.8: ESS Only @50℃

| Panel Ration | AC Voltage | 1 PCS | 2PCS | 3PCS | 4PCS | 5PCS | 6 PCS |
|---|---|---|---|---|---|---|---|
| 840kW | 630VAC | 765 kW | 1530 kW | 2295 kW | 3060 kW | 3825 kW | 4590 kW |
| 800kW | 600VAC | 730 kW | 1460 kW | 2190 kW | 2920 kW | 3650 kW | 4380 kW |
| 630kW | 480VAC | 570 kW | 1140 kW | 1710 kW | 2280 kW | 2850 kW | 3420 kW |


PCS Line UP
PCS Unit 1 (PV-PCS or ESS-PCS)
PCS Unit 2 (PV-PCS or ESS-PCS)
PCS Unit 3 (PV-PCS or ESS-PCS)
PCS Unit 4 (PV-PCS or ESS-PCS)
PCS Unit 5 (PV-PCS or ESS-PCS)
Max 8 terminals
Individual DC input for each PCS Unit
Negative Grounding is optional for PV-PCS
F
Preliminary)

## 2.5 System Line Up with Hybrid System of PV and ESS

In a hybrid system, the Line UP consists of both the PV-PCS and the ESS-PCS in the same system. In such a system, typically TMEIC proposes to have one ESS system per line up. In this case the system shall consist of five Inverters and one Energy storage Inverter. The transformer is rated as per the PV inverters only. The system reduces the overall losses and improves the roundtrip efficiency of the system.

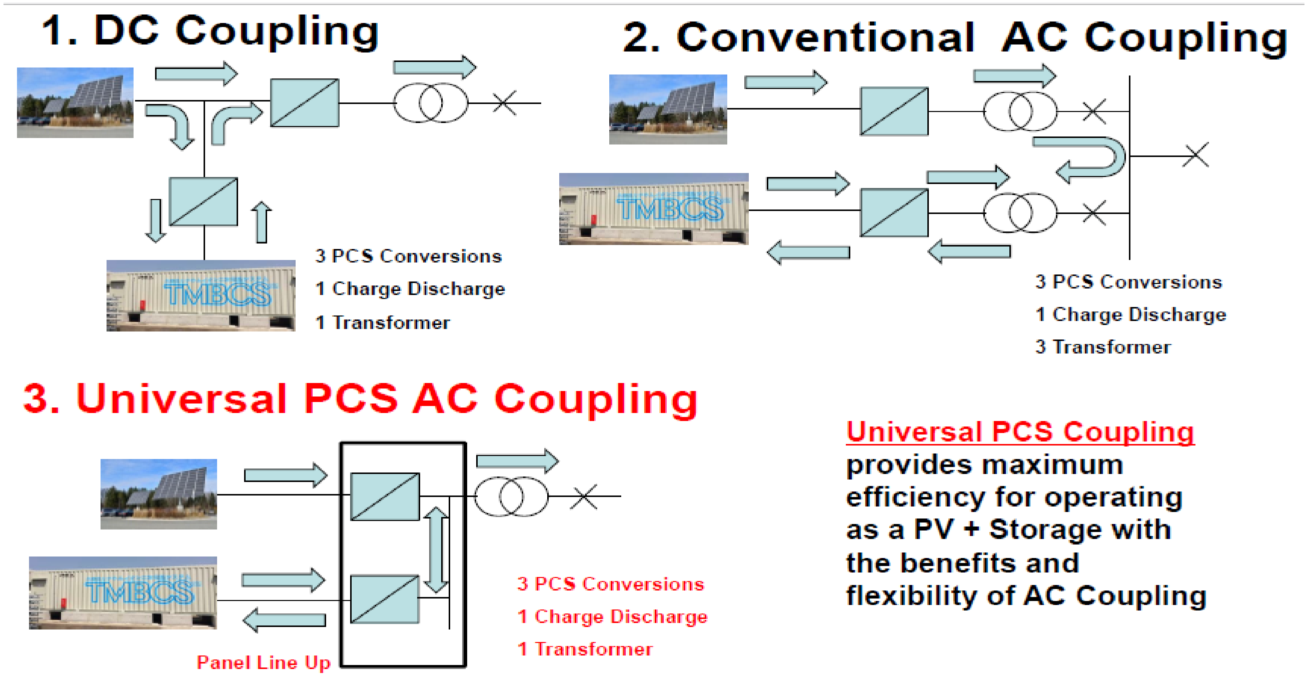



Figure 2.5.2 Comparisons of DC Coupling/Conventional AC Coupling/Universal PCS AC Coupling

The step up transformer rating depends on the requirement of the system and application. The limitation of the step up transformer is based on 5 PCS Units/ transformer; however with adequate control to ensure that excess power from the PV is stored in the ESS the line can be increased.

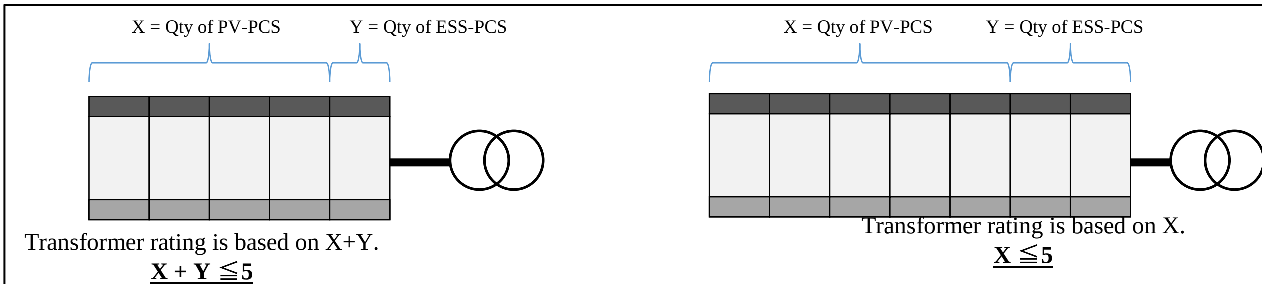



Figure 6.3: Examples of the Hybrid configuration and transformer rating

# 3. BILL OF MATERIAL (Per PCS)

### 3.1. A. Inverter

5 x 840kW/840kVA Universal PCS inverter units will be installed, per skid.

### 3.1. B. Integration

Generic System configuration is shown in Figure 1. The equipment described below will be installed on the

| | |
|---|---|
| **Engineering** | Package integration engineering for 4.2MW Skid. |
| **Control Circuit and Communication Wiring** | Control circuit and communication wiring for TMEIC supplied equipment are included. |
| **Auxiliary Power** | No Auxiliary Equipment is included in this quote.<br><br>Example configurations:<br><br>10kVA 3-phase transformer with 208/120V panelboard and 7 breakers<br><br>40kVA 3-phase transformer with 480V and 208/120V panelboards, 7 breakers each |
| **Canopy Shade Structure** | Not included |
| **Customer Furnished Equipment (CFE)** | SCADA, DAS and site data controller should be provided by others. Wiring and Installation of customer supplied equipment is not included in the base price. Optional pricing can be provided with additional information on CFE equipment. FO cables and tracker motor wiring are also not included. |
| **Stairs and Safety Railings** | If the skid(s) are to be mounted on piers requiring stairs and safety railings, the stairs and safety railings are not part of this quote and will be supplied by others. |
| **Stamped Drawings** | PE stamped drawings may be included, if required. |
| **Back-up Power Requirement** | This quote does not include any backup power provision (UPS or Generator). If this is required, it will be quoted separately. This can also affect the length of the skid and overall skid pricing. |

**Note: The skid dimensions are approximately 29'L x 4'W. Customer is to provide other means for additional maintenance space if required to meet any code or county specific requirements.**

***TMEIC Corporation***
Office: 1325 Electric Rd, Roanoke, VA 24018 USA
Mailing Address: 2060 Cook Drive, Salem, VA 24153

## 3.1. C. MV 3-Phase Transformer for 5 x 840kW/840kVA Inverter Lineup

| Item | Specifications (customized for project) |
|---|---|
| **kVA** | 3360kVA / 4200kVA |
| **Special Application** | Two-Winding |
| **Temperature Rise** | 65 degree rise at 30C ambient, 40C maximum ambient temperature |
| **Cooling Class** | ONAF (actively cooled) (ONAN / KNAN / KNAF also available) |
| **Frequency** | 60 Hz |
| **Duty Cycle** | Designed for step-up operation |
| **Insulating fluid** | Mineral Oil (biodegradable fluids available) |
| **Elevation** | Designed for operation at 1000 m (3300 ft.) above sea level |
| **Sound Level** | NEMA TR1 Standard |
| **High Voltage** | 34500 Delta Volts, 150 kV BIL (available in other voltages/configurations) |
| **Electrostatic Shield** | Electrostatic Shield between Primary & Secondary Windings. Ground Shield Bushing |
| **kV Class** | 35 kV |
| **High Voltage Configuration** | Dead Front, Loop Feed |
| **High Voltage Bushings** | 600 amp Cooper dead break one-piece bushings (Qty: 6) |
| **Neutral Bushings** | 250 amp 2 hole spade bushing |
| **Load-break Switching** | 15-38 kV, 2 Position switch |
| **Switch Cover** | Padlock cover over Switch (Outside of Cabinet) |
| **Overcurrent Protection** | Internal Cartridge in Series with Parallel oil-immersed partial range current limiting fuse x 6 |
| **Expulsion Fuses** | Internal Expulsion (ABB pro-link) x 3 |
| **Low Voltage** | 630 Ungrounded Wye Volts, 30 kV BIL (available in other configurations) |
| **kV Class (LV)** | 1.2 kV |
| **Low Voltage Bushings** | Integral aluminum 8-hole spade bushings (Qty: 3) |
| **Bushing Supports** | Standard LV Bushing Support Assembly |
| **Cabinet hardware** | Penta-head cabinet door bolts |
| **Coatings** | Touch-up paint (Qty: 2) |
| **Taps** | 2 - 2.5% taps above and 2 - 2.5% taps below nominal |
| **Certifications** | UL Listed (UL logo on nameplate), ANSI C57 |
| **Notifications** | Shock and Arc Flash Warning Decal |
| **Gauges & Fittings** | Liquid level gauge with Alarm Contact, Thermometer, dial-type with Alarm Contact, Pressure/vacuum gauge with Alarm Contact, Schrader valve, Pressure relief device, 50 SCFM, Drain valve with sampler (1”) located outside of cabinet, with cover Oil Fill Plug |
| **Tank accessories** | IEEE standard two-hole ground pads (Qty: 3), Nitrogen Blanket |
| **Special Feature** | Load break switch located outside cabinet on HV side padlocked door, Padlock cover over drain valve |

### 3.1. D. Factory Tests

The following standard factory tests will be performed on the MV Transformer according to ANSI C57.12.90 including:

- Ratio, Polarity and Phase Rotation Test
- Resistance Test
- Routine Impulse Test
- Applied Potential Test
- Induced Potential Test
- Loss Test
- Leak Test
- Nameplate verifications, alarm, trip setting verifications
- Physical and Mechanical inspections
- Demag Test
- No-Load Loss and Excitation Current

Transformer is pressurized at manufacturer’s facility and may vary depending on site location and conditions; customer is responsible for maintaining transformer pressure per manufacturer’s recommendations.

## 3.1. E. Power Plant Controller (Option)

Hardware

1 - RTAC SEL-3355-4 Real Time Automation Controller

| Communications | |
|---|---|
| Ethernet Ports | 2 rear; 10 or 100/Mbps, RJ-45 |
| USB Ports | 2 front, 4 rear |
| Encrypted Communications | RDP |
| Protocols | DNP3, Modbus TCP/IP |

| Physical | |
|---|---|
| Dimensions | 19"" (W) x 5.22"" (H) x 11.49"" (D) |
| | 482.6mm (W) x 132.6mm (H) x 291.8mm (D) |
| Weight | 20 lbs. (9.072kg) |
| Enclosure | Treated for chemically harsh / humid environments |
| Power Supply | 125/250 VDC or 120/240 VAC, 160W HV power supply |
| Operating Temperature | -40C to +75C |
| Maximum Altitude | 2000m |

**Power Plant Controller Function**

One Power Plant Controller communicates over an Ethernet network to control multiple power converters for a single site.

1) Sequential Start-up/Shut-down
- Based on a command from the HMI, the Power Plant Controller issues a single command to start and stop all inverters.

2) Power Factor Control
- Using power generation feedback from the inverter network, the Power Plant Controller will calculate a reactive current reference for each power converter such that the total power factor does not change with load.

3) Output Limitation Control
- Using power generation feedback from the inverter network, the Power Plant Controller will calculate a power limit for each inverter such that the power output of the entire site does not exceed a preset value.

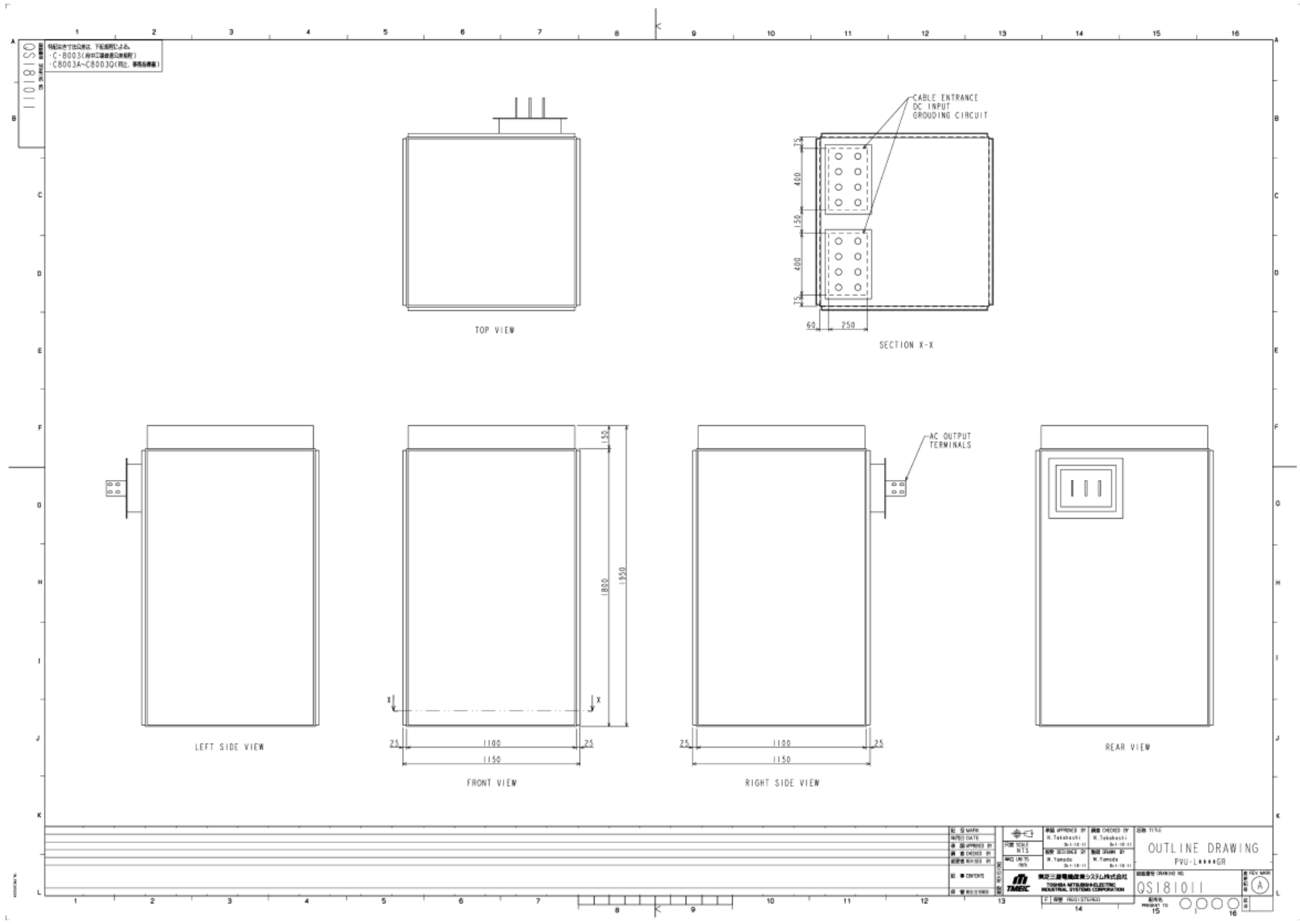
4) Power slew rate control
- Based on an adjustable power slew rate the Power Plant Controller controls the rate at which power output from the system changes.

5) Live Trending
- Capable of monitoring inverter signals such as input current, total power output, power factor etc.

6) Data Historian
- Record of all site signals that are processed by the Power Plant Controller. One-second poll rate data is kept on an external hard drive for one year before old data is overwritten.

7) Dynamic Power Factor Control:
- Using feedback from a Power Factor meter at the POCC (customer supplied), the Power Plant Controller will adjust the behavior of the inverters to meet a required PF at the measured point.
- VAR levels will be set and dynamically adjusted to keep the Power Factor (as measured at the PF meter) to a setting within a range.
- The Ninja inverters can produce VARs to support a power factor range of +/-0.8 at the inverter. The resultant range of Power Factor at the PF meter will depend on the site equipment between the inverters and the PF meter. Refer to D-Curve provided in Temperature Derate Curve section.
- These ranges can be achieved when the DC bus voltage is greater than 915VDC and the grid voltage is no more than 10% above nominal.
- Total apparent power (available as real power or VAR) is 4200 kVA at temperatures up to -20 ~ 25DegC, 1 pu, and 915Vdc ~ 1300Vdc condition. Please refer to derate curves provided in Temperature Derate Curve section.

## 3.1. F.   Structural Outline *Preliminary



**50PG03−28**
**Ultra High Efficiency Single Package Electric Cooling with Optional Electric Heat Commercial Rooftop Units with PURON® (R−410A) Refrigerant, Optional EnergyX™ (Energy Recovery Ventilator)**

Carrier®
Turn to the Experts℠

# Product Data

CENTURION

EnergyX model shown

DEALER DESIGN AWARDS
the NEWS | GOLD

BUILDINGS magazine
Editors' Choice
TOP 100 PRODUCTS
2005

Puron®
the environmentally sound refrigerant

# Operation Air Quantity Limits

### 50PG03-16 Units

| UNIT 50PG | COOLING (cfm) | | HEATING (cfm) ELECTRIC HEAT | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| 03 | 600 | 1000 | 600 | 1000 |
| 04 | 900 | 1500 | 900 | 1500 |
| 05 | 1200 | 2000 | 1200 | 2000 |
| 06 | 1500 | 2500 | 1500 | 2500 |
| 07 | 1800 | 3000 | 1800 | 3000 |
| 08 | 2250 | 3750 | 2250 | 3750 |
| 09 | 2550 | 4250 | 2550 | 4250 |
| 12 | 3000 | 5000 | 3000 | 5000 |
| 14 | 3750 | 6250 | 3750 | 6250 |
| 16 | 4500 | 7500 | 4500 | 7500 |

50PG

### 50PG20-28 Units

| 50PG | COOLING | | ELECTRIC HEAT | ELECTRIC HEAT (Vertical) | ELECTRIC HEAT (Horizontal) |
|---|---|---|---|---|---|
| | Minimum Cfm | Maximum Cfm | | Minimum Cfm | Minimum Cfm |
| 20 | 5000 | 9,000 | High Heat (75 kW) | 4,500 | 5,400 |
| | | | Medium Heat (50 kW) | 3,750 | 4,800 |
| | | | Low Heat (25 kW) | 3,750 | 3,750 |
| 24 | 5500 | 10,000 | High Heat (75 kW) | 4,500 | 5,400 |
| | | | Medium Heat (50 kW) | 3,750 | 4,800 |
| | | | Low Heat (25 kW) | 3,750 | 3,750 |
| 28 | 6500 | 12,000 | High Heat (75 kW) | 4,500 | 5,400 |
| | | | Medium Heat (50 kW) | 3,750 | 4,800 |
| | | | Low Heat (25 kW) | 3,750 | 3,750 |

### Outdoor Sound Power (Total Unit)

| UNIT 50PG | A-WEIGHTED* (dB) | OCTAVE BAND LEVELS dB | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| 03 | 75.0 | 82.6 | 79.9 | 75.7 | 73.3 | 70.0 | 64.3 | 58.4 | 50.5 |
| 04 | 73.2 | 79.8 | 77.2 | 74.1 | 70.1 | 68.0 | 63.6 | 58.4 | 51.9 |
| 05 | 71.9 | 79.7 | 79.6 | 72.6 | 69.6 | 66.0 | 61.4 | 56.4 | 48.5 |
| 06 | 78.5 | 82.2 | 82.6 | 79.5 | 75.7 | 73.9 | 68.6 | 64.0 | 56.3 |
| 07 | 78.5 | 87.5 | 83.0 | 78.5 | 76.3 | 73.8 | 68.4 | 63.8 | 56.5 |
| 08 | 80.0 | 91.7 | 83.6 | 81.0 | 77.9 | 75.0 | 69.9 | 66.0 | 59.3 |
| 09 | 79.9 | 89.1 | 82.7 | 80.0 | 77.7 | 75.0 | 70.2 | 66.3 | 57.8 |
| 12 | 80.0 | 90.4 | 83.1 | 80.9 | 77.8 | 75.2 | 70.0 | 66.1 | 57.6 |
| 14 | 83.3 | 86.4 | 85.9 | 85.3 | 81.8 | 78.2 | 72.2 | 67.9 | 59.9 |
| 16 | 84.0 | 90.3 | 85.2 | 83.5 | 81.1 | 79.0 | 73.7 | 70.5 | 65.4 |
| 20 | 81.7 | 90.2 | 84.8 | 80.7 | 79.0 | 77.6 | 71.4 | 66.7 | 60.7 |
| 24 | 84.9 | 90.0 | 86.3 | 83.6 | 82.9 | 80.3 | 74.9 | 71.4 | 66.5 |
| 28 | 84.9 | 90.0 | 86.3 | 83.6 | 82.9 | 80.3 | 74.9 | 71.4 | 66.5 |

LEGEND
**db** – Decibel
*Sound Rating ARI or Tone Adjusted, A–Weighted Sound Power Level in dB. For sizes 03–12, the sound rating is in accordance with ARI Standard 270–1995. For sizes 14–28, the sound rating is in accordance with ARI 370–2001.

**Outdoor Sound Power (Total Unit)**
**with High CFM EnergyX**

| UNIT 50PG w/ERV | A–WEIGHTED* (dB) | OCTAVE BAND LEVELS dB | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| **03** | 83.0 | 82.8 | 81.4 | 79.7 | 78.1 | 77.9 | 76.5 | 72.5 | 70.1 |
| **04** | 82.7 | 80.2 | 79.6 | 79.1 | 77.3 | 77.6 | 76.5 | 72.5 | 70.1 |
| **05** | 82.6 | 80.1 | 81.1 | 78.8 | 77.2 | 77.4 | 76.4 | 72.4 | 70.0 |
| **06** | 83.8 | 82.4 | 83.4 | 81.6 | 79.1 | 78.8 | 76.9 | 72.9 | 70.2 |
| **07** | 83.8 | 87.6 | 83.8 | 81.1 | 79.3 | 78.8 | 76.9 | 72.9 | 70.2 |
| **08** | 87.3 | 92.0 | 86.8 | 84.5 | 82.4 | 81.8 | 80.5 | 78.0 | 74.2 |
| **09** | 87.2 | 89.6 | 86.4 | 84.1 | 82.4 | 81.8 | 80.5 | 78.1 | 74.2 |
| **12** | 87.3 | 90.8 | 86.5 | 84.5 | 82.4 | 81.8 | 80.5 | 78.0 | 74.2 |
| **14** | 88.2 | 87.2 | 88.0 | 87.0 | 84.2 | 82.7 | 80.8 | 78.2 | 74.3 |
| **16** | 91.4 | 93.2 | 92.8 | 88.2 | 86.3 | 85.5 | 84.4 | 83.4 | 78.4 |
| **20** | 91.2 | 93.1 | 92.7 | 87.4 | 85.8 | 85.2 | 84.2 | 83.3 | 78.3 |
| **24** | 91.7 | 93.0 | 93.0 | 88.2 | 86.9 | 85.8 | 84.5 | 83.5 | 78.5 |
| **28** | 91.7 | 93.0 | 93.0 | 88.2 | 86.9 | 85.8 | 84.5 | 83.5 | 78.5 |

LEGEND
**dB** – Decibel
* Sound Rating ARI or tone Adjusted, A–Weighted Sound Power Level in dB. For sizes 03–12, the sound rating is in accordance with ARI Standard 270–1995. For sizes 14–28, the sound rating is in accordance with ARI 370–2001.

# PHYSICAL DATA



## 50PG03-07

| BASE UNIT 50PG | | 03 | 04 | 05 | 06 | 07 |
|---|---|---|---|---|---|---|
| NOMINAL CAPACITY (Tons) | | 2 | 3 | 4 | 5 | 6 |
| OPERATING WEIGHT (lb) | | | | | | |
| Unit* | | 704 | 704 | 775 | 829 | 874 |
| Economizer | | | | | | |
| Vertical | | 40 | 40 | 40 | 40 | 40 |
| Horizontal | | 50 | 50 | 50 | 50 | 50 |
| Humidi-MiZer™ Adaptive Dehumidification System | | 22 | 22 | 31 | 27 | 26 |
| Roof Curb | | | | | | |
| 14-in. | | 122 | 122 | 122 | 122 | 122 |
| 24-in. | | 184 | 184 | 184 | 184 | 184 |
| COMPRESSOR | | Fully Hermetic Scroll | | | | |
| Quantity | | 1 | 1 | 1 | 1 | 1 |
| Oil Type | | Copeland 3MA | | | | |
| Number of Refrigerant Circuits | | 1 | 1 | 1 | 1 | 1 |
| Oil (oz) | | 38 | 42 | 42 | 66 | 56 |
| REFRIGERANT TYPE | | R-410A (Puron® Refrigerant) | | | | |
| Expansion Device | | TXV | TXV | TXV | TXV | TXV |
| Operating Charge (lb) — Standard Unit | | 7.3 | 9.0 | 15.7 | 16.6 | 19.0 |
| Operating Charge (lb) — Unit with Humidi-MiZer System | | 11.75 | 13.50 | 25.00 | 22.00 | 22.70 |
| CONDENSER COIL | | Enhanced Copper Tubes, Aluminum Lanced Fins | | | | |
| Condenser A (Outer) | | | | | | |
| Rows...Fins/in. | | 1…17 | 1…17 | 2…17 | 2…17 | 2…17 |
| Face Area (sq ft) | | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 |
| Condenser B (Inner) | | | | | | |
| Rows...Fins/in. | | — | 1…17 | 2…17 | 2…17 | 2…17 |
| Face Area (sq ft) | | — | 12.6 | 12.6 | 12.6 | 12.6 |
| HUMIDI−MIZER COIL | | Enhanced Copper Tubes, Aluminum Lanced Fins | | | | |
| Rows...Fins/in. | | 1…17 | 1…17 | 1…17 | 1…17 | 1…17 |
| Face Area (sq ft) | | 6.4 | 6.4 | 9.3 | 9.3 | 9.3 |
| CONDENSER FAN | | Propeller | | | | |
| Quantity…Diameter (in.) | | 1…24 | 1…24 | 1…24 | 1…24 | 1…24 |
| Nominal Cfm (Total, all fans) | | 3500 | 3500 | 3500 | 4500 | 4500 |
| Motor Hp | | 1/8 | 1/8 | 1/8 | 1/4 | 1/4 |
| Nominal Rpm — High Speed | | 825 | 825 | 825 | 1100 | 1100 |
| Nominal Rpm — Low Speed | | 300 | 300 | 300 | 300 | 300 |
| EVAPORATOR COIL | | Enhanced Copper Tubes, Aluminum Double-Wavy Fins, Face Split | | | | |
| Rows…Fins/in. | | 2…15 | 2…15 | 2…15 | 3…15 | 4…15 |
| Face Area (sq ft) | | 9.3 | 9.3 | 9.3 | 9.3 | 9.3 |
| EVAPORATOR FAN | | Centrifugal Type, Belt Drive | | | | |
| Quantity…Size (in.) | Low | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 |
| | High | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 | 1...12 x 9 |
| Type Drive | Low | Belt | Belt | Belt | Belt | Belt |
| | High | Belt | Belt | Belt | Belt | Belt |
| Nominal Cfm | | 800 | 1200 | 1600 | 2000 | 2400 |
| Maximum Continuous Bhp | Low | 0.85 | 0.85 | 0.85 | 0.85/2.40† | 2.40 |
| | High | 0.85 | 0.85 | 1.60/2.40† | 1.60/2.40† | 3.10 |
| Motor Nominal Rpm | | 1620 | 1620 | 1620 | 1725 | 1725 |
| Motor Frame Size | Low | 48Y | 48Y | 48Y | 56Y | 56Y |
| | High | 48Y | 48Y | 56Y | 56Y | 56Y |
| Fan Rpm Range | Low | 482-736 | 482-736 | 596-910 | 690-978 | 796-1128 |
| | High | 656-1001 | 796-1128 | 828-1173 | 929-1261 | 1150-1438 |
| Motor Bearing Type | | Ball | Ball | Ball | Ball | Ball |
| Maximum Fan Rpm | | 2000 | 2000 | 2000 | 2000 | 2000 |
| Motor Pulley Pitch Diameter Range (in.) | Low | 1.9-2.9 | 1.9-2.9 | 1.9-2.9 | 2.4-3.4 | 2.4-3.4 |
| | High | 1.9-2.9 | 2.4-3.4 | 2.4-3.4 | 2.8-3.8 | 4.0-5.0 |
| Fan Pulley Pitch Diameter (in.) | Low | 6.8 | 6.8 | 5.5 | 6.0 | 5.2 |
| | High | 5.0 | 5.2 | 5.0 | 5.2 | 6.0 |
| Nominal Motor Shaft Diameter (in.) | Low | $^1/_2$ | $^1/_2$ | $^1/_2$ | $^5/_8$ | $^5/_8$ |
| | High | $^1/_2$ | $^1/_2$ | $^5/_8$ | $^5/_8$ | $^7/_8$ |
| Belt…Pitch Length (in.) | Low | 49.3 | 49.3 | 49.3 | 49.3 | 49.3 |
| | High | 49.3 | 49.3 | 49.3 | 49.3 | 52.3 |
| Belt…Type | Low | AX | AX | AX | AX | AX |
| | High | AX | AX | AX | AX | AX |
| Pulley Center Line Distance Min. (in.) | Low | 16.2 | 16.2 | 16.2 | 16.2 | 16.2 |
| | High | 16.2 | 16.2 | 16.2 | 16.2 | 16.2 |
| Pulley Center Line Distance Max. (in.) | Low | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 |
| | High | 20.2 | 20.2 | 20.2 | 20.2 | 20.2 |
| Speed Change per Full Turn of Movable Pulley Flange (rpm) | Low | 48 | 48 | 59 | 58 | 66 |
| | High | 65 | 62 | 69 | 66 | 58 |
| Movable Pulley Maximum Full Turns from Closed Position | Low | 5 | 5 | 5 | 5 | 5 |
| | High | 5 | 5 | 5 | 5 | 5 |
| Factory Pulley Setting (rpm) | Low | 482 | 482 | 596 | 690 | 796 |
| | High | 656 | 796 | 828 | 929 | 1150 |
| Fan Shaft Diameter at Pulley (in.) | | 3/4 | 3/4 | 3/4 | 3/4 | 3/4 |
| HIGH-PRESSURE SWITCH (psig) | | | | | | |
| Cutout | | 660 ± 10 | 660 ± 10 | 660 ± 10 | 660 ± 10 | 660 ± 10 |
| Reset (Auto.) | | 505 ± 20 | 505 ± 20 | 505 ± 20 | 505 ± 20 | 505 ± 20 |
| RETURN-AIR FILTERS | | Throwaway | | | | |
| Quantity…Size (in.) | | 4…16 x 20 x 2 | 4…16 x 20 x 2 | 4…16 x 20 x 2 | 4…16 x 20 x 2 | 4…16 x 20 x 2 |

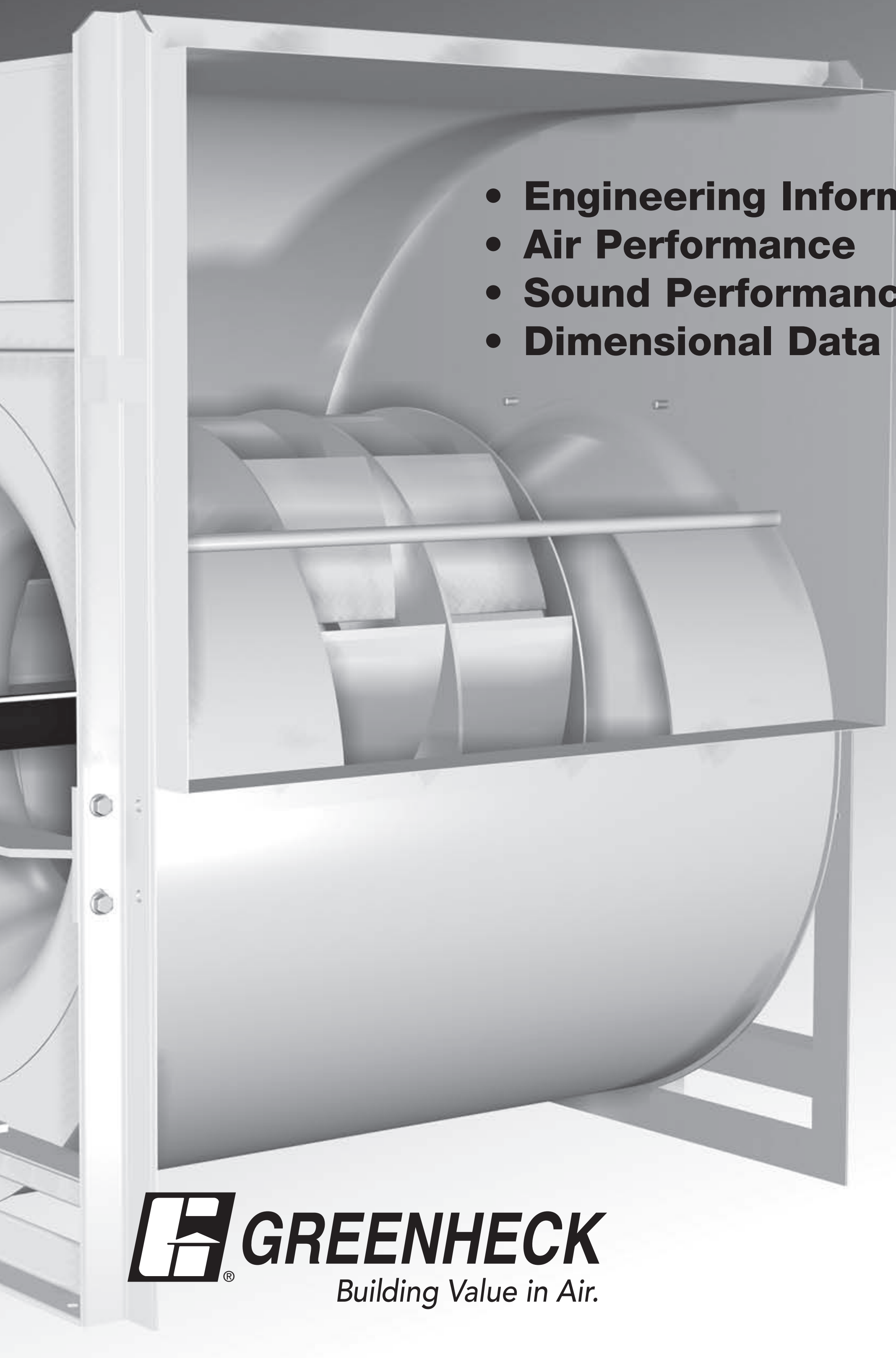
LEGEND

**TXV** – Thermostatic Expansion Valve

*Aluminum evaporator coil/aluminum condenser coil.

† Single phase/three phase

# Double Width Centrifugal Fan Catalog Supplement



- Engineering Information
- Air Performance
- Sound Performance
- Dimensional Data

GREENHECK®
Building Value in Air.

November 2004

# Table of Contents



amca CERTIFIED RATINGS SOUND and AIR PERFORMANCE
AIR MOVEMENT AND CONTROL ASSOCIATION, INC.
PRINTED IN THE UNITED STATES OF AMERICA

Greenheck Fan Corporation certifies that the backward inclined and airfoil centrifugal fans shown herein are licensed to bear the AMCA Seal. The ratings shown are based on tests and procedures performed in accordance with AMCA Publication 211 and Publication 311 and comply with the requirements of the AMCA Certified Ratings Program.

GREENHECK
Building Value in Air.

## Motor Selection

Greenheck centrifugal fans can be supplied with any motor that is commercially available and is appropriate for the fan size and performance required. The table shows motor frame sizes corresponding to those motors readily available.

Notes:

1. Fractional horsepower motor frame sizes shown may change due to variations in voltage, special features and manufacturer. 2. Motors shown are ball bearing, continuous duty. Two speed motors are two winding, 1/3 reduction in RPM. 3. Single phase motors are capacitor start.

### 1800 RPM Motors

| HP | Single Speed | | | | | | | | | 2 SP 2 WDG | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Open | | | TE | | Explosion Resistant | | High Efficiency | | Open | |
| | | | | | | | | Open | TE | | |
| | 115V 1PH | 230 1PH | 3PH | 115V 230V 1PH | 3PH | 115V 230V 1PH | 3PH | 230V 460V 3PH | 230V 460V 3PH | 115V 1PH | 3PH |
| ¼ | 48 | 48 | 48 | 48 | 48 | 48 | 48 | | | 48 | |
| ⅓ | 48 | 48 | 56 | 56 | 56 | 56 | 56 | | | 56 | |
| ½ | 56 | 56 | 56 | 56 | 56 | 56 | 56 | | | 56 | |
| ¾ | 56 | 56 | 56 | 56 | 56 | 56 | 56 | | | 56 | |
| 1 | 56 | 56 | 143T | 56 | 143T | | 56 | 143T | 143T | | 56 |
| 1½ | 145T | 145T | 145T | 145T | 145T | | 145T | 145T | 145T | | 56 |
| 2 | 182T | 182T | 145T | 182T | 145T | | 145T | 145T | 145T | | 182T |
| 3 | | | 182T | | 182T | | 182T | 182T | 182T | | 184T |
| 5 | | | 184T | | 184T | | 184T | 184T | 184T | | 215T |
| 7.5 | | | 213T | | 213T | | 213T | 213T | 213T | | 254T |
| 10 | | | 215T | | 215T | | 215T | 215T | 215T | | 256T |
| 15 | | | 254T | | 254T | | 254T | 254T | 254T | | 256T |
| 20 | | | 256T | | 256T | | 256T | 256T | 256T | | 284T |
| 25 | | | 284T | | 284T | | 284T | 284T | 284T | | 286T |
| 30 | | | 286T | | 286T | | 286T | 286T | 286T | | 324T |
| 40 | | | 324T | | 324T | | 324T | 324T | 324T | | 326T |
| 50 | | | 326T | | 326T | | 326T | 326T | 326T | | 365T |
| 60 | | | 364T | | 364T | | 364T | 364T | 364T | | |
| 75 | | | 365T | | 365T | | 365T | 365T | 365T | | |
| 100 | | | 405T | | 405T | | 405T | 405T | 405T | | |
| 125 | | | 405T | | 444T | | 444T | 405T | 444T | | |
| 150 | | | 444T | | 445T | | 445T | 444T | 445T | | |

### 3600 RPM Motors

**3600 RPM motors are recommended for fan speed over 2700 RPM**

| HP | Single Speed | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Open | | | TE | | Explosion Resistant | | High Efficiency | |
| | | | | | | | | Open | TE |
| | 115V 1PH | 230 1PH | 3PH | 115V 230V 1PH | 3PH | 115V 230V 1PH | 3PH | 230V 460V 3PH | 230V 460V 3PH |
| ⅓ | 48 | 48 | | | 56 | | | | |
| ½ | 48 | 48 | 56 | 56 | 56 | | | | |
| ¾ | 56 | 56 | 56 | 56 | 56 | | | | |
| 1 | 56 | 56 | 56 | 56 | 56 | | | | |
| 1½ | 143T | 143T | 143T | 143T | 143T | | 143T | 143T | 143T |
| 2 | 145T | 145T | 145T | 145T | 145T | | 145T | 145T | 145T |
| 3 | 182T | 182T | 145T | 182T | 182T | | 182T | 145T | 182T |
| 5 | | 184T | 182T | 182T | 184T | | 184T | 182T | 184T |
| 7.5 | | 213T | 184T | 184T | 213T | | 213T | 184T | 213T |
| 10 | | 215T | 213T | 213T | 215T | | 215T | 213T | 215T |
| 15 | | | 215T | | 254T | | 254T | 215T | 254T |
| 20 | | | 254T | | 256T | | 256T | 254T | 256T |
| 25 | | | 256T | | 284TS | | 284TS | 256T | 284TS |
| 30 | | | 284TS | | 286TS | | 286TS | 284TS | 286TS |
| 40 | | | 286TS | | 324TS | | 324TS | 286TS | 324TS |
| 50 | | | 324TS | | 326TS | | 326TS | 324TS | 326TS |

The model number codes on this page are a complete guide to ordering or specifiing Greenheck centifugal fan models.

## Belt Drive Model Number Code

36 - BIDW - 41 - 3 - CW - TH - II - A 500

Fan Size
*12 - 73*

BI - Backward Inclined Wheel, Double Width

AF - Airfoil Wheel, Double Width

Series 41 Construction
Series 21 Construction

Arrangement 3

Rotation
*cw, ccw*

Discharge Position
*TH = Top Horizontal*
*BH = Bottom Horizontal*
*UB = Up Blast*
*DB = Down Blast*
*TAU = Top Angular Up*
*BAU = Bottom Angular Up*
*TAD = Top Angular Down*
*BAD = Bottom Angular Down*

Fan Class
*I, II, III*

Motor RPM
*M = 3500*
*A = 1770*

Motor Horsepower
10 = 1
15 = 1.5
20 = 2
30 = 3
50 = 5
75 = 7.5
100 = 10
200 = 20
300 = 30
400 = 40
500 = 50
600 = 60
750 = 75
1000 = 100
1250 = 125

## Motor Starting Torque

When selecting a motor for an industrial process fan, the motor must be capable not only of driving the fan at operating speed, but also must be capable of accelerating the fan wheel, shaft and drive to the operating speed.

The fan performance tables and curves in this catalog show the brake horsepower required to operate the fan once it is brought to speed. For applications requiring a large air volume at a low static pressure, the BHP required at the fan's operating RPM may not be sufficient to initially start the fan. If the time required to bring the fan to speed is excessive, the motor winding insulation can be damaged due to excessive temperature rise and the life of the motor seriously affected.

For a belt drive industrial process fan the required motor starting torque capability can be expressed by the following formula:

$$WR^2_M = WR^2_F \times \left(\frac{FRPM}{MRPM}\right)^2 \times (1.1)$$

$WR^2_M$ = The moment of inertia that the motor must be capable of turning at the motor shaft, LB-Ft.$^2$

$WR^2_F$ = The moment of inertia of the fan wheel, LB-Ft.$^2$

FRPM = Fan RPM

MRPM = Motor RPM

## V Belt Drives

**Constant Speed Drives**

Advantages of constant speed drives include low vibration levels, ease of assembly and low cost. Fan speed changes can be accomplished in most cases simply by changing the motor pulley.

Constant speed drives are recommended over variable speed drives for applications that require motors 15 Hp and larger, and all applications requiring 3600 RPM motors.

**Variable Speed Drives**

Variable speed drives allow the fan speed to be changed by adjusting the pitch diameter of the motor pulley. The power to the fan must be off and locked out and the belts must be removed before manually adjusting the variable pitch pulley.

## High Temperature Operating Limits

| Temperature | Material | Arrangement | Options Included |
|---|---|---|---|
| -20 to 180° F | Steel, Alum., SS | 3 | None |

## Moments of Inertia (Lb-Ft$^2$)

Moments of inertia are shown for steel wheels. Aluminum wheels are one-third of the value shown.

| Fan Size | STEEL BACKWARD INCLINED CENTRIFUGAL WHEELS | | | STEEL AIRFOIL CENTRIFUGAL WHEELS | | |
|---|---|---|---|---|---|---|
| | Class I | Class II | Class III | Class I | Class II | Class III |
| 12 | 2.2 | 2.7 | 3.8 | – | – | – |
| 13 | 3.1 | 4.3 | 5.6 | – | – | – |
| 15 | 5.4 | 6.1 | 7.8 | – | – | – |
| 16 | 7.9 | 8.9 | 10.5 | – | – | – |
| 18 | 12.5 | 13.8 | 18.9 | 15.6 | 16.9 | 23.9 |
| 20 | 17.3 | 19.1 | 35.2 | 21.6 | 23.4 | 38.1 |
| 22 | 32.0 | 32.0 | 52.3 | 38.8 | 38.8 | 57.2 |
| 24 | 44.2 | 49.4 | 71.3 | 54.1 | 54.1 | 78.2 |
| 27 | 66.2 | 79.1 | 96.9 | 80.2 | 85.5 | 129 |
| 30 | 105 | 136 | 144 | 118 | 139 | 178 |
| 33 | 152 | 198 | 210 | 172 | 234 | 261 |
| 36 | 260 | 303 | 399 | 267 | 362 | 428 |
| 40 | 435 | 505 | 628 | 444 | 582 | 665 |
| 44 | 642 | 863 | 927 | 638 | 842 | 955 |
| 49 | 971 | 1310 | 1380 | 1130 | 1300 | 1450 |
| 54 | 1760 | 2120 | 2130 | 1700 | 2100 | 2430 |
| 60 | 2850 | 3480 | 3700 | 3210 | 3180 | 3530 |
| 66 | 4650 | 5070 | 5350 | 4590 | 4550 | 5290 |
| 73 | 6950 | 7570 | 7950 | 6860 | 6860 | 7860 |

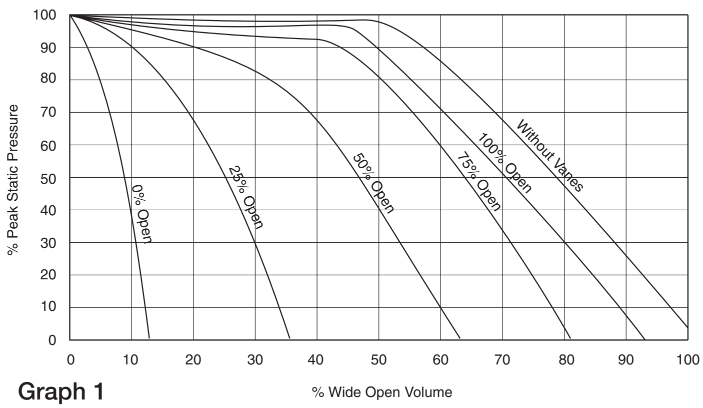
## Fan RPM Limitations

The maximum allowable wheel RPM shown on the fan performance pages are for fans of standard steel operating at 70°F. Since the strength of the fan wheel, shaft and bearings decrease with an increase in temperature, maximum allowable speeds must be reduced by the correction factors shown below.

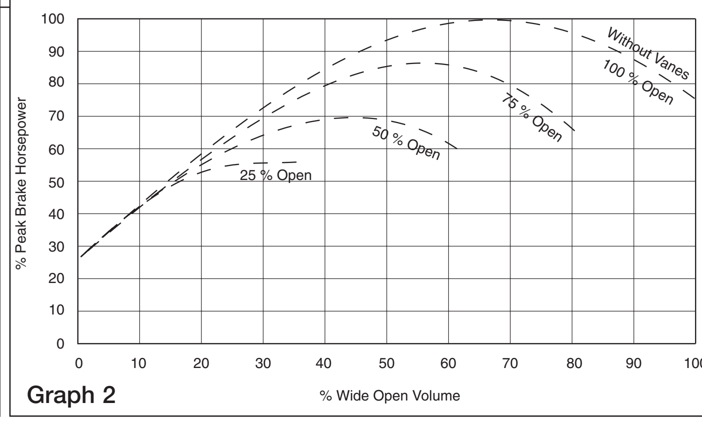
| RPM Correction Factors For High Temperatures | | | |
|---|---|---|---|
| Temperature (Degrees F) | Wheel Material | | |
| | Aluminum | Steel | 316 SS |
| 70 | 1.00 | 1.00 | 1.00 |
| 200 | 1.00 | .97 | .92 |

### Inlet Vane Performance

As inlet vanes are closed they impart a spin to the airflow in the direction of wheel rotation and reduce airflow, static pressure and brake horsepower as shown in the graphs below. The graphs show how CFM, static pressure and brake horsepower are affected as inlet vanes are modulated from 100% open to 0% open in a typical variable air volume system. Graph 3 provides RPM and BHP correction factors for fans equipped with inlet vanes.



Graph 1



Graph 2

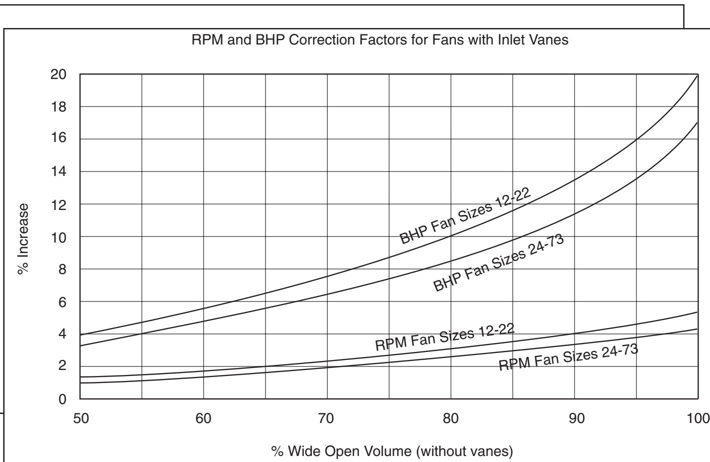
## RPM & BHP Corrections

To compensate for pressure drop through inlet vanes, a percentage increase in fan RPM and BHP at full load design conditions must be applied.

Enter graph 3 with “% wide open volume” (see page 9 for calculation of % WOV) and the appropriate fan size.

Move horizontally left to the “% increase” scale. Record the % increase.

Increase the selected fan RPM by the % increase shown. Also increase the BHP by the % increase shown.



Graph 3

Use the chart below to determine minimum torque required for an inlet vane actuator.

### Minimum Recommended Actuator Torque For Inlet Vanes (In-Lbs) for Double Width Fans

| | Fan Size | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class | 12 | 13 | 15 | 16 | 18 | 20 | 22 | 24 | 27 | 30 | 33 | 36 | 40 | 44 | 49 | 54 | 60 | 66 | 73 |
| I | 52 | 60 | 66 | 76 | 94 | 114 | 136 | 220 | 260 | 280 | 320 | 360 | 540 | 640 | 740 | 860 | 1000 | 1200 | 1400 |
| II | 76 | 86 | 98 | 116 | 146 | 176 | 220 | 320 | 360 | 400 | 460 | 520 | 840 | 980 | 1160 | 1360 | 1600 | 1920 | 2200 |
| III | 108 | 126 | 144 | 172 | 220 | 260 | 320 | 440 | 520 | 560 | 660 | 760 | 1240 | 1480 | 1760 | 2000 | 2400 | 3000 | 3400 |

## Effect of Air Density - Temperature and Elevation

Ratings in the fan performance tables and curves of this catalog are based on standard air (clean, dry air with a density of .075 pounds per cubic foot, barometric pressure at sea level of 29.92 inches of mercury, temperature of 70°F.). Selecting a fan to operate at conditions other than standard air requires an adjustment to both static pressure and brake horsepower.

A cubic foot of air has a constant volume regardless of temperature or elevation. However, air density changes with non-standard temperature or elevation. Therefore, when selecting a fan to operate at a non-standard air density using standard air density tables and curves, corrections must be made to parameters affected by air density. These parameters are static pressure and brake horsepower.

For example, a size 30 BIDW centrifugal fan is to deliver 35,000 cfm at 4.5 inches static pressure. Elevation is 4,000 feet, temperature is 100°F.

The 4.5 inches static pressure refers to the static pressure at the operating air density, in this case at 4,000 feet, 100°F. Intuitively, we realize that at higher than standard elevations and temperatures, air density will be lower than standard. Therefore, we must determine what static pressure at standard air density will equate to 4.5 inches static pressure at our operating density. Since standard air density is greater than operating air density in this case, we would expect the corrected static pressure to be greater than the operating static pressure.

### AIR DENSITY CORRECTION FACTORS

| Air Temp. °F | Elevation (Feet Above Sea Level) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000 | 11000 | 12000 | 13000 | 14000 | 15000 |
| 0 | 0.87 | 0.90 | 0.94 | 0.97 | 1.01 | 1.05 | 1.08 | 1.13 | 1.17 | 1.22 | 1.26 | 1.31 | 1.37 | 1.43 | 1.48 | 1.54 |
| 50 | 0.96 | 1.00 | 1.04 | 1.08 | 1.11 | 1.15 | 1.20 | 1.24 | 1.30 | 1.34 | 1.40 | 1.45 | 1.51 | 1.57 | 1.63 | 1.70 |
| 70 | 1.00 | 1.04 | 1.08 | 1.12 | 1.16 | 1.22 | 1.25 | 1.30 | 1.35 | 1.40 | 1.45 | 1.51 | 1.57 | 1.64 | 1.70 | 1.77 |
| 100 | 1.06 | 1.10 | 1.14 | 1.18 | 1.22 | 1.27 | 1.32 | 1.37 | 1.42 | 1.48 | 1.54 | 1.60 | 1.66 | 1.74 | 1.80 | 1.88 |
| 150 | 1.15 | 1.19 | 1.24 | 1.30 | 1.33 | 1.38 | 1.44 | 1.49 | 1.55 | 1.61 | 1.67 | 1.74 | 1.81 | 1.89 | 1.96 | 2.04 |
| 200 | 1.25 | 1.29 | 1.34 | 1.40 | 1.44 | 1.50 | 1.56 | 1.61 | 1.68 | 1.75 | 1.81 | 1.89 | 1.96 | 2.05 | 2.13 | 2.21 |
| 250 | 1.34 | 1.39 | 1.44 | 1.50 | 1.55 | 1.61 | 1.67 | 1.74 | 1.80 | 1.88 | 1.95 | 2.02 | 2.10 | 2.20 | 2.28 | 2.37 |
| 300 | 1.43 | 1.49 | 1.54 | 1.60 | 1.66 | 1.72 | 1.79 | 1.86 | 1.93 | 2.01 | 2.08 | 2.16 | 2.25 | 2.35 | 2.43 | 2.53 |
| 350 | 1.53 | 1.58 | 1.64 | 1.71 | 1.77 | 1.84 | 1.91 | 1.98 | 2.06 | 2.14 | 2.22 | 2.31 | 2.40 | 2.51 | 2.60 | 2.71 |
| 400 | 1.62 | 1.68 | 1.75 | 1.81 | 1.88 | 1.94 | 2.03 | 2.09 | 2.19 | 2.27 | 2.37 | 2.45 | 2.54 | 2.66 | 2.75 | 2.87 |
| 500 | 1.81 | 1.88 | 1.95 | 2.02 | 2.10 | 2.18 | 2.26 | 2.35 | 2.44 | 2.54 | 2.63 | 2.73 | 2.84 | 2.97 | 3.08 | 3.20 |
| 600 | 2.00 | 2.07 | 2.15 | 2.23 | 2.31 | 2.40 | 2.50 | 2.59 | 2.69 | 2.84 | 2.91 | 3.02 | 3.14 | 3.28 | 3.40 | 3.54 |
| 700 | 2.19 | 2.27 | 2.35 | 2.44 | 2.53 | 2.63 | 2.73 | 2.83 | 2.94 | 3.07 | 3.17 | 3.31 | 3.44 | 3.59 | 3.72 | 3.88 |
| 800 | 2.38 | 2.48 | 2.57 | 2.67 | 2.76 | 2.86 | 2.98 | 3.09 | 3.21 | 3.33 | 3.45 | 3.59 | 3.74 | 3.90 | 4.05 | 4.21 |
| 900 | 2.56 | 2.66 | 2.76 | 2.87 | 2.97 | 3.07 | 3.20 | 3.33 | 3.46 | 3.58 | 3.71 | 3.87 | 4.02 | 4.20 | 4.35 | 4.53 |
| 1000 | 2.76 | 2.87 | 2.989 | 3.09 | 3.20 | 3.31 | 3.45 | 3.59 | 3.73 | 3.86 | 4.00 | 4.17 | 4.33 | 4.53 | 4.69 | 4.89 |

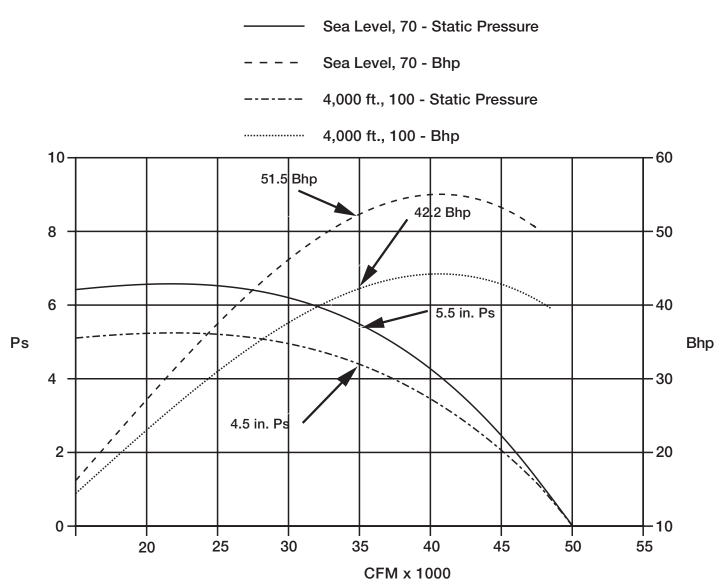
The accompanying table gives air density correction factors for non-standard temperatures and elevations.

The example below shows the relationship of fan performance at sea level and at 4,000 ft. elevation and 100°F.

**EXAMPLE**

The following example shows how to properly select the fan described above:

1. Since the air volume delivered by the fan is not affected by density, airflow remains 35,000 cfm.
2. Determine correction factor from chart for an elevation of 4,000 feet and air temperature of 100°F. The correction factor is 1.22.
3. Multiply the specified operating static pressure by the correction factor to determine the standard air density equivalent static pressure (Corrected static pressure = 4.5 in. x 1.22 = 5.5 in. static pressure).
4. Refer to the fan performance table for a 30 BIDW. At 35,000 cfm and 5.5 in. static pressure: Fan rpm = 1521, Bhp = 51.5.
5. 1571 Fan rpm is required to produce the desired performance.
6. Since the horsepower selected refers to standard air density, this must be corrected to reflect actual Bhp at the lighter operating air. Operating Bhp = standard Bhp ÷ 1.22, or 51.5 ÷ 1.22 = 42.2 Bhp.




If a fan is selected to operate at high temperatures, the motor must be of sufficient horsepower to handle the increased load at any lower operating temperature where the air is more dense. Assume the air entering the 30 BIDW fan at start-up is 0°F. For 0°F and 4,000 feet elevation the air density correction factor is 0.97. Bhp at 0°F = 51.5 ÷ 0.97 = 53.9, therefore, a 60 hp motor is required.

## Effect Of Installation On Performance

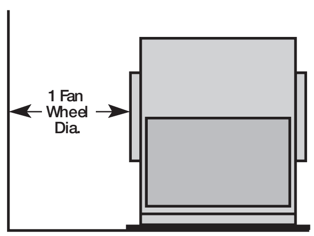
Ratings presented in the performance tables and curves of this catalog were derived from tests made in accordance with AMCA Standard 210 – “Laboratory Methods of Testing Fans for Ratings.” The AMCA test procedure utilizes an open inlet and a straight outlet duct to assure maximum static regain.

Any installation with inlet or discharge configurations that deviate from this standard may result in reduced fan performance. Restricted or unstable flow at the fan inlet can cause pre-rotation of incoming air or uneven loading of the fan wheel yielding large system losses and increased sound levels. Free discharge or turbulent flow in the discharge ductwork will also result in system effect losses.

Static pressure losses due to inlet and discharge conditions can be expressed in terms of system effect factors. The static pressure for selection of the fans equals the system static pressure plus the system effect factor.

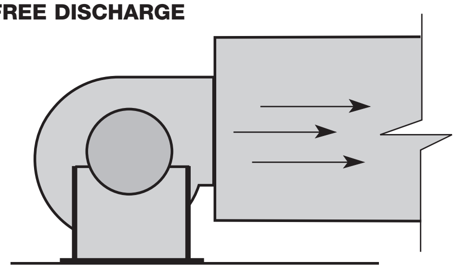
Some common inlet and discharge conditions which affect fan performance are:

**NON-DUCTED INLET CLEARANCE**



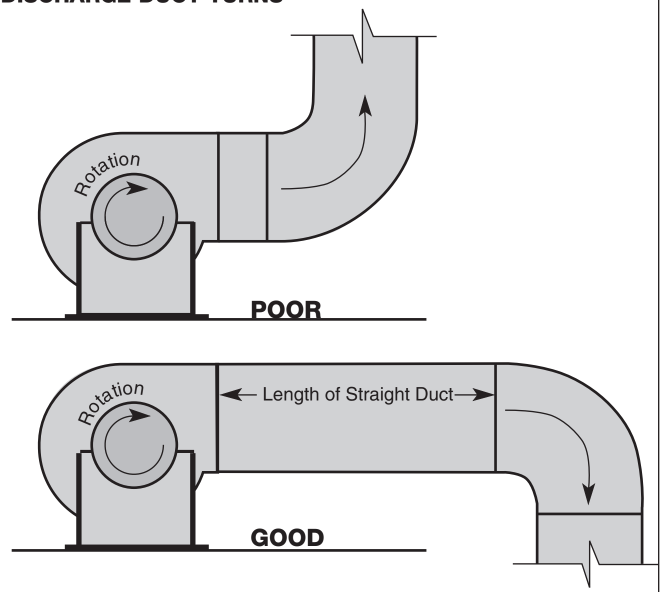

Installation of a fan with an open inlet too close to a wall or bulkhead will cause reduced fan performance. It is desirable to have one fan wheel diameter if possible and a minimum of three fourths of a wheel diameter between the fan inlet and the wall. System effect curve #2 depicts the pressure loss for one-half wheel diameter clearance.

**FREE DISCHARGE**



Free or abrupt discharge into a plenum results in a reduction in fan performance. The effect of static regain in discharge is not realized. System effect curve #1 depicts the pressure loss for free or abrupt discharge.

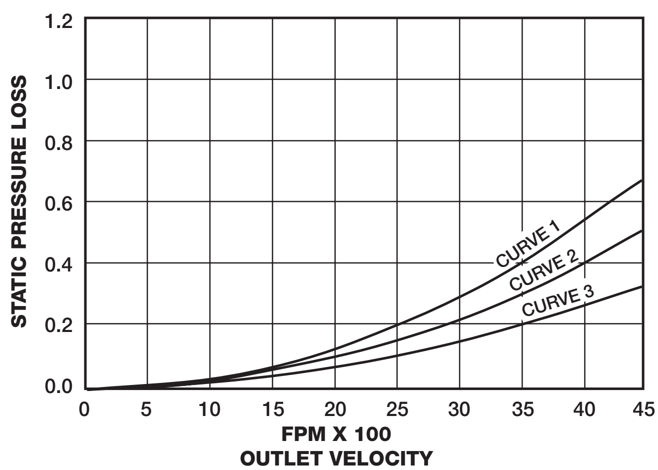
**DISCHARGE DUCT TURNS**




Duct turns located near the fan discharge should always be in the direction of the fan rotation.

Fan performance is reduced when duct turns are made immediately off the fan discharge. To achieve cataloged fan performance there should be at least three equivalent duct diameters of straight ductwork between the fan discharge and any duct turns. Curve #3 shows the system effect factor for two diameters of straight ductwork and curve #1 for one diameter.

**SYSTEM EFFECT FACTOR CURVES**




Additional information on system effect factors can be found in AMCA Publication 201 – “Fans and Systems” and ASHRAE Handbooks.

# Sound Performance Data

**AMCA Licensed Ratings**
Sound tests of Model BIDW and AFDW were conducted in Greenheck's AMCA Registered sound laboratory in accordance with AMCA Standard 300. Inlet and outlet sound ratings comply with AMCA Publication 311, qualifying these models to bear the AMCA seal for sound and air performance. The sound power levels published here can be compared directly with those of other similarly rated fans, or used as a baseline to determine sound levels in occupied spaces.

The sound data in this brochure is the result of extensive testing, which included both inlet and outlet sound tests on double width centrifugal fans. Typically, fan manufacturers publish only inlet sound for double width fans. The assumption they make is that outlet sound is identical to inlet sound. Sound data based on this assumption is simply not accurate enough for today's sound sensitive installations. This assumption also ignores duct end corrections for outlet sound.

**Test Methods**
AMCA standard 300 clearly defines methods used to test fans in a reverberant sound test room. The reverberant room is specifically designed to allow sound waves to be dispersed evenly throughout the room. The walls have a hard surface that reflects sound and are positioned to prevent resonances which could result in quiet areas within the room.

Sound power cannot be directly measured. The test method is based on a Reference Sound Source (RSS) substitution for determining fan sound power. The RSS is a laboratory calibrated device which has a known sound power output level. The test fan is installed as shown below. The RSS is energized and the sound pressure levels in the reverberant room are recorded. The fan is then operated without the RSS and the fan sound pressure levels are recorded for various points of operation. Since the sound power levels of the RSS are known, the substitution method is used to determine the sound power levels of the fan. This method is illustrated in the following example.

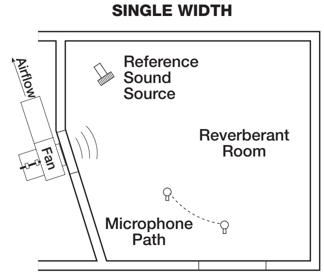
Calculating Fan Sound Power

| Octave Band | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Center Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| Calibrated RSS Sound Power (Lwr) | 82 | 81 | 81 | 81 | 81 | 81 | 79 | 78 |
| Measured RSS Sound Pressure (Lpq) | 70 | 74 | 75 | 76 | 75 | 74 | 69 | 61 |
| Difference (Lwr-Lpq) | 12 | 7 | 6 | 5 | 6 | 7 | 10 | 17 |
| Measured Fan Sound Pressure (Lpm) | 68 | 72 | 69 | 69 | 68 | 62 | 57 | 46 |
| Substitution (Lwr-Lpq, from above) | +12 | +7 | +6 | +5 | +6 | +7 | +10 | +17 |
| Fan Sound Power (Lw) | 80 | 79 | 75 | 74 | 74 | 69 | 67 | 63 |

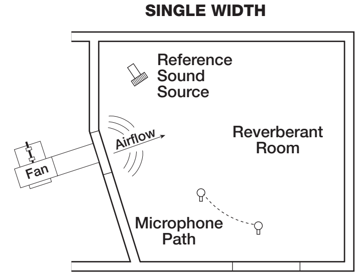
Units in dB

**Test Setups**
The illustrations at right show where the sound levels were measured with respect to the fan. Inlet sound was tested as in Figure 2 of Standard 300 and outlet sound was tested as in Figure 3. Inlet and outlet sound were determined in the same inlet and outlet configurations as the air tests. (Installation Type B - free inlet, ducted outlet.)

Since double width fans are more often ducted at the inlet, they are tested only for sound radiated from the fan inlet.




AMCA Standard 300 - Figure 2:
Fan Inlet Sound Testing
Installation Type B:
Free Inlet, Ducted Outlet




AMCA Standard 300 - Figure 3:
Fan Outlet Sound Testing
Installation Type B: Free Inlet, Ducted Outlet
(Ratings include the effects of duct end correction)

**Interpreting Sound Data**
Sound power levels in this brochure are presented as dB (re $10^{-12}$ watts) in each of the eight full octave bands with center frequencies from 63 Hz to 8000 Hz. They are also presented as a single A-weighted sound power level, LwA. Charts are provided covering the full range of fan speeds and percent wide open volume (%WOV) for each fan size. Outlet sound power data is based on a ducted outlet and therefore includes duct end reflection corrections.



GREENHECK
The Solution Company.

**Outlet Sound - Duct End Corrections**

This correction accounts for sound that is reflected back into the duct where there is an abrupt termination of the duct.

AMCA Standard 300 requires that outlet sound power for fans with ducted outlets include Duct End Corrections. These corrections account for any sound power that may be present in the duct but is not measured in the reverberant room, because it is reflected back into the duct at the discharge.

Duct end corrections are included in all outlet sound power ratings.

**Duct End Corrections (dB)**

| Size | Double Width Fans | | |
|---|---|---|---|
| | 63 Hz | 125 Hz | 250 Hz |
| 18 | 9 | 5 | 2 |
| 20 | 9 | 4 | 1 |
| 22 | 8 | 4 | 1 |
| 24 | 7 | 3 | |
| 27 | 6 | 3 | |
| 30 | 6 | 2 | |
| 33 | 5 | 2 | |
| 36 | 5 | 2 | |
| 40 | 4 | 1 | |
| 44 | 4 | 1 | |
| 49 | 3 | | |
| 54 | 3 | | |
| 60 | 2 | | |
| 66 | 2 | | |
| 73 | 2 | | |

**Tolerance and Application**

The certification process in AMCA Standard 311 call for a precertification test to verify original test results. Check tests are also required every 3 years for each model licensed. Test data must agree with the published sound power within the following tolerance levels:

| Octave Band | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Center Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| Tolerance | +6 | +3 | +3 | +3 | +3 | +3 | +3 | +3 |

These tolerance levels are a good indication of the variance that could occur from one fan or test setup to another. Once installed, however, there are many other factors that can affect the sound power generated by a fan.

The lower frequencies (below 125 Hz) are greatly affected by vibration. Fan wheel balance, motor balance, drive alignment, etc., all affect the vibration level of the fan and can increase sound power in the 1st and 2nd octaves. When ducts are not properly isolated from the fan, these vibrations can be transmitted into the ducts, which can generate additional low frequency sound.

Sound power generated by a fan can also be influenced by system effects. System effects are pressure losses caused by inlet or outlet restrictions, or other conditions causing non-uniform airflow at the inlet or discharge of a fan (see AMCA publication 201). Examples include inlet or outlet elbows too close to a fan, restricted inlets, and fan accessories. While system effects can prevent fans from reaching their designed air performance, they can also result in increased sound power levels. Typically, system effects cause pressure fluctuations which influence the lower frequencies. Poor inlet conditions can also greatly increase sound levels at the blade passage frequency (BPF). The blade passage frequency refers to how often a blade or wheel fin passes a stationary location of the housing and can be calculated using the following equation:

$$\text{BPF (Hz)} = \frac{\text{Fan RPM x Number of Blades}}{60}$$

(All Greenheck wheels have 9 blades)

Sound is becoming increasingly critical for most fan installations. Greenheck employs extensive research and testing to provide sound data that is as thorough and accurate as possible. However, sound pressure levels in occupied spaces are affected by the acoustical qualities of the space, distance from source to receiver, etc. Therefore, published sound power data can be used only as a baseline for determining the resulting sound pressure levels an occupant hears. While Greenheck provides products which meet published sound power levels, no manufacturer can be responsible for poor installations or system designs beyond their control. For further information on installation practices, see AMCA publication 201, “Fans and Systems.”

**Sound Power**

Sound power data is charted for the full range of RPM and percent wide open volume (% WOV) for belt drive and RPM and static pressure for direct drive in each unit size.

The % WOV is a convenient way to indicate the operating point (pressure and CFM) for a given fan RPM. To calculate the % WOV for a given fan size, use the equation given on the performance page.

$$\text{\% WOV} = \frac{\text{CFM x 100}}{\text{RPM x K}}$$

Use the following procedure to calculate sound data for a specific Fan RPM and % WOV:

1. Determine the eight sound power levels for the specified % WOV using the higher Fan RPM shown.
2. Determine the eight sound power levels for the specified % WOV using the lower Fan RPM shown.
3. Interpolate between the higher and lower sound power levels using the specified RPM.

## Sample Fan Selection

The purpose of these two pages is to demonstrate the manual centrifugal fan selection process. These pages also contain helpful tips to check your fan selection as well as a step by step set of instructions on how to use this manual to properly select a centrifugal fan.

An important point to remember when manually selecting a centrifugal fan is that more than one fan is available to meet the desired performance (CFM and Ps). Selection criteria such as unit size, efficiency, speed, outlet velocity, horsepower, or construction material may also dictate which fan is chosen.

Sound and Air performance are identical for Greenheck Series 21 and 41 Centrifugal fans.

The following example explains the model number code for both series of centrifugal fans.

**20-BIDW-41**

- Fan Size (20)
- BI - Backward Inclined wheel; AF - Airfoil wheel
- DW - Double width, Double inlet
- 21 - Series 21 Construction; 41 - Series 41 Construction

**A** The Outlet Area is used for the Outlet Velocity (OV) calculation.
$OV = \frac{CFM}{OA}$

**B** The Maximum BHP can be calculated for a given fan RPM along the fan curve.

**C** The minimum starting HP is determined by the inertia ($WR^2$) of the fan and motor. See page 4 for a complete motor starting torque chart.

**D** The maximum fan RPM for each fan class is listed.

**E** Constant HP curves are plotted for each motor HP size.

**F** The % WOV is used to identify the fan operating point. The lines in the fan curve or the equation can be used.

### 20 BIDW

Wheel Diameter = 20 in.
**A** Outlet Area = 4.14 ft.$^2$
Tip Speed = 5.24 x RPM
**B** Maximum BHP = $(RPM/832)^3$

**D** Maximum RPM Class I = 1960
Maximum RPM Class II = 2554
Maximum RPM Class III = 3219

**C** Minimum Motor Size For Starting Torque: ¾ HP

| CFM | OV | 0.25 RPM | 0.25 BHP | 0.50 RPM | 0.50 BHP | 0.75 RPM | 0.75 BHP | 1.00 RPM | 1.00 BHP | 1.25 RPM | 1.25 BHP | 1.50 RPM | 1.50 BHP | 1.75 RPM | 1.75 BHP | 2.00 RPM | 2.00 BHP | 2.25 RPM | 2.25 BHP | 2.50 RPM | 2.50 BHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3000 | 724 | 489 | 0.20 | 596 | 0.34 | 699 | 0.52 | | | | | | | | | | | | | | |
| 3800 | 917 | 561 | 0.31 | 654 | 0.47 | 736 | 0.65 | 823 | 0.87 | 900 | 1.11 | 977 | 1.37 | | | | | | | | |
| 4600 | 1111 | 639 | 0.45 | 723 | 0.65 | 797 | 0.85 | 865 | 1.07 | 936 | 1.31 | 1005 | 1.59 | 1069 | 1.87 | 1132 | 2.17 | | | | |
| 5400 | 1304 | 720 | 0.65 | 796 | 0.87 | 864 | 1.11 | 927 | 1.35 | 987 | 1.60 | 1042 | 1.85 | 1105 | 2.16 | 1165 | 2.48 | 1221 | 2.81 | 1274 | 3.14 |
| 6200 | 1497 | 803 | 0.89 | 874 | 1.16 | 936 | 1.42 | 995 | 1.69 | 1050 | 1.96 | 1103 | 2.25 | 1154 | 2.54 | 1201 | 2.83 | 1257 | 3.19 | 1310 | 3.55 |
| 7000 | 1690 | 888 | 1.19 | 954 | 1.50 | 1012 | 1.80 | 1066 | 2.10 | 1119 | 2.40 | 1167 | 2.71 | 1215 | 3.03 | 1262 | 3.35 | 1306 | 3.67 | 1348 | 4.00 |
| 7800 | 1884 | 974 | 1.57 | 1035 | 1.92 | 1090 | 2.25 | 1142 | 2.58 | 1190 | 2.91 | 1237 | 3.25 | 1282 | 3.59 | 1324 | 3.94 | 1367 | 4.30 | 1409 | 4.66 |
| 8600 | 2077 | 1061 | 2.02 | 1119 | 2.41 | 1171 | 2.78 | 1219 | 3.14 | 1265 | 3.51 | 1309 | 3.87 | 1352 | 4.25 | 1393 | 4.62 | 1432 | 5.00 | 1471 | 5.39 |
| 9400 | 2270 | 1149 | 2.56 | 1203 | 2.98 | 1252 | 3.39 | 1298 | 3.79 | 1342 | 4.19 | 1384 | 4.59 | 1424 | 4.99 | 1463 | 5.40 | 1502 | 5.81 | 1539 | 6.22 |
| 10200 | 2463 | 1238 | 3.19 | 1288 | 3.64 | 1335 | 4.10 | 1379 | 4.54 | 1421 | 4.97 | 1461 | 5.41 | 1499 | 5.84 | 1536 | 6.27 | 1573 | 6.71 | 1609 | 7.15 |
| 11000 | 2657 | 1328 | 3.93 | 1374 | 4.41 | 1419 | 4.90 | 1461 | 5.39 | 1501 | 5.85 | 1539 | 6.32 | 1576 | 6.79 | 1612 | 7.26 | 1646 | 7.72 | 1680 | 8.20 |
| 11800 | 2850 | 1419 | 4.77 | 1461 | 5.28 | 1504 | 5.81 | 1544 | 6.34 | 1583 | 6.85 | 1619 | 7.35 | 165[illegible] Step 1 | [illegible] | [illegible]689 | 8.36 | 1722 | 8.85 | 1755 | 9.35 |
| 12600 | 3043 | 1509 | 5.74 | 1548 | 6.27 | 1589 | 6.83 | 1628 | 7.40 | 1665 | 7.96 | 1700 | 8.50 | 1734 | 9.03 | 1767 | 9.57 | 1800 | 10.1 | 1831 | 10.6 |
| 13400 | 3236 | 1600 | 6.83 | 1637 | 7.39 | 1675 | 7.98 | 1712 | 8.58 | 1748 | 9.19 | 1782 | 9.77 | 1815 | 10.3 | 1847 | 10.9 | 1878 | 11.5 | 1908 | 12.1 |
| 14200 | 3429 | 1691 | 8.05 | 1726 | 8.65 | 1762 | 9.27 | 1797 | 9.90 | 1832 | 10.5 | 1865 | 11.2 | 1897 | 11.8 | 1928 | 12.4 | 1958 | 13.0 | 1987 | 13.6 |
| 15000 | 3623 | 1782 | 9.41 | 1816 | 10.1 | 1849 | 10.7 | 1883 | 11.4 | 1916 | 12.0 | 1949 | 12.7 | 1980 | 13.4 | 2010 | 14.0 | 2039 | 14.7 | 2067 | 15.3 |

| CFM | OV | 2.50 RPM | 2.50 BHP | 3.00 RPM | 3.00 BHP | 3.50 RPM | 3.50 BHP | 4.00 RPM | 4.00 BHP | 4.50 RPM | 4.50 BHP | 5.00 RPM | 5.00 BHP | 5.50 RPM | 5.50 BHP | 6.00 RPM | 6.00 BHP | 6.50 RPM | 6.50 BHP | 7.00 RPM | 7.00 BHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7000 | 1690 | 1348 | 4.00 | 1444 | 4.80 | 1534 | 5.63 | 1619 | 6.49 | 1700 | 7.39 | 1786 | 8.38 | | | | | | | | |
| 7800 | 1884 | 1409 | 4.66 | 1486 | 5.39 | 1571 | 6.23 | 1655 | 7.15 | 1734 | 8.09 | 1809 | 9.05 | 1881 | 10.0 | 1959 | 11.1 | | | | |
| 8600 | 2077 | 1471 | 5.39 | 1547 | 6.18 | 1619 | 6.98 | 1692 | 7.85 | 1770 | 8.85 | 1845 | 9.86 | 1916 | 10.9 | 1984 | 12.0 | 2049 | 13.0 | 2119 | 14.2 |
| 9400 | 2270 | 1539 | 6.22 | 1610 | 7.06 | 1680 | 7.92 | 1746 | 8.80 | 1809 | 9.68 | 1881 | 10.7 | 1952 | 11.8 | 2020 | 12.9 | 2085 | 14.1 | 2148 | 15.2 |
| 10200 | 2463 | 1609 | 7.15 | 1677 | 8.05 | 1743 | 8.96 | 1808 | 9.89 | 1870 | 10.8 | 1929 | 11.8 | 1989 | 12.8 | 2056 | 14.0 | 2121 | 15.2 | 2184 | 16.4 |
| 11000 | 2657 | 1680 | 8.20 | 1747 | 9.15 | 1810 | 10.1 | 1871 | 11.1 | 1932 | 121.0 | 1990 | 13.1 | 2046 | 14.1 | 2100 | 15.2 | 2158 | 16.3 | 2220 | 17.6 |
| 11800 | 2850 | 1755 | 9.35 | 1818 | 10.4 | 1880 | 11.4 | 1938 | 12.4 | 1995 | 13.5 | 2052 | 14.6 | 2108 | 15.6 | 2161 | 16.7 | 2212 | 17.8 | 2262 | 19.0 |
| 12600 | 3043 | 1831 | 10.6 | 1892 | 11.7 | 1951 | 12.8 | 2008 | 13.9 | 2063 | 150.0 | 2116 | 16.1 | 2170 | 17.3 | 2223 | 18.4 | 2274 | 19.6 | 2323 | 20.7 |
| 13400 | 3236 | 1908 | 12.1 | 1967 | 13.2 | 2023 | 14.3 | 2079 | 15.5 | 2133 | 167.0 | 2185 | 17.8 | 2235 | 19.0 | 2285 | 20.2 | 2336 | 21.4 | 2384 | 22.7 |
| 14200 | 3429 | 1987 | 13.6 | 2044 | 14.8 | 2099 | 16.0 | 2152 | 17.2 | 2204 | 185.0 | 2255 | 19.7 | 2305 | 20.9 | 2352 | 22.2 | 2399 | 23.4 | 2447 | 24.7 |
| 15000 | 3623 | 2067 | 15.3 | 2122 | 16.6 | 2175 | 17.8 | 2227 | 19.1 | 2276 | 204.0 | 2326 | 21.7 | 2375 | 23.0 | 2422 | 24.3 | 2467 | 25.6 | 2512 | 27.0 |
| 15800 | 3816 | 2148 | 17.1 | 2201 | 18.5 | 2253 | 19.8 | 2303 | 21.2 | 2352 | 225.0 | 2398 | 23.9 | 2446 | 25.2 | 2492 | 26.6 | 2537 | 28.0 | 2581 | 29.4 |
| 16600 | 4009 | 2229 | 19.1 | 2281 | 20.5 | 2331 | 22.0 | 2380 | 23.4 | 2428 | 24.8 | 2474 | 26.2 | 2518 | 27.6 | 2564 | 29.0 | 2608 | 30.5 | 2651 | 31.9 |
| 17400 | 4202 | 2312 | 21.3 | 2362 | 22.8 | 2411 | 24.3 | 2458 | 25.8 | 2505 | 27.2 | 2550 | 28.7 | 2593 | 30.2 | 2636 | 31.7 | 2679 | 33.2 | 2722 | 34.7 |
| 18200 | 4396 | 2395 | 23.7 | 2444 | 25.2 | 2491 | 26.8 | 2538 | 28.3 | 2582 | 29.9 | 2626 | 31.4 | 2669 | 32.9 | 2711 | 34.5 | 2752 | 36.0 | 2793 | 37.6 |
| 19000 | 4500 | 2470 | 26.1 | 2526 | 27.8 | 2573 | 29.4 | 2618 | 31.0 | 2661 | 32.7 | 2704 | 34.3 | 2746 | 35.9 | 2787 | 37.5 | 2827 | 39.1 | 2867 | 40.7 |

| CFM | OV | 7.00 RPM | 7.00 BHP | 7.50 RPM | 7.50 BHP | 8.00 RPM | 8.00 BHP | 8.50 RPM | 8.50 BHP | 9.00 RPM | 9.00 BHP | 10.00 RPM | 10.00 BHP | 11.00 RPM | 11.00 BHP | 12.00 RPM | 12.00 BHP | 13.00 RPM | 13.00 BHP | 14.00 RPM | 14.00 BHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9000 | 2173 | 2130 | 14.7 | 2195 | 15.9 | 2262 | 17.1 | | | | | | | | | | | | | | |
| 9900 | 2391 | 2170 | 15.9 | 2231 | 17.1 | 2289 | 18.4 | 2346 | 19.6 | 2405 | 20.9 | 2526 | 23.7 | | | | | | | | |
| 10800 | 2608 | 2211 | 17.3 | 2272 | 18.5 | 2330 | 19.8 | 2387 | 21.1 | 2442 | 22.4 | 2548 | 25.1 | 2656 | 28.0 | 2766 | 31.1 | | | | |
| 11700 | 2826 | 2255 | 18.7 | 2313 | 20.0 | 2371 | 21.4 | 2428 | 22.7 | 2482 | 24.1 | 2588 | 26.9 | 2689 | 29.8 | 2785 | 32.7 | 2887 | 35.9 | 2988 | 39.2 |
| 12600 | 3043 | 2323 | 20.7 | 2371 | 21.9 | 2417 | 23.1 | 2469 | 24.4 | 2524 | 25.9 | 2629 | 28.8 | 2729 | 31.8 | 2825 | 34.9 | 2918 | 38.0 | 3006 | 41.1 |
| 13500 | 3260 | 2392 | 22.9 | 2440 | 24.2 | 2486 | 25.4 | 2530 | 26.7 | 2574 | 28.0 | 2670 | 30.8 | 2770 | 33.9 | 2866 | 37.1 | 2958 | 40.4 | 3047 | 43.6 |
| 14400 | 3478 | 2463 | 25.3 | 2509 | 26.6 | 2555 | 27.9 | 2599 | 29.2 | 2643 | 30.6 | 2726 | 33.3 | 2812 | 36.2 | 2907 | 39.5 | 2999 | 42.8 | 3087 | 46.2 |
| 15300 | 3695 | 2538 | 27.8 | 2581 | 29.2 | 2625 | 30.6 | 2669 | 32.0 | 2712 | 33.4 | 2795 | 36.2 | 2874 | 39.1 | 2951 | 42.0 | 3040 | 45.4 | 3129 | 49.0 |
| 16200 | 3913 | 2616 | 30.6 | 2658 | 32.1 | 2699 | 33.5 | 2740 | 34.9 | 2782 | 36.4 | 2864 | 39.4 | 2943 | 42.4 | 3019 | 45.4 | 3092 | 48.4 | 3170 | 51.8 |
| 17100 | 4130 | 2695 | 33.6 | 2737 | 35.1 | 2777 | 36.6 | 2817 | 38.1 | 2856 | 39.7 | 2935 | 42.7 | 3013 | 45.9 | 3088 | 49.0 | 3160 | 52.2 | | |
| 18000 | 4347 | 2775 | 36.9 | 2816 | 38.4 | 2856 | 40.0 | 2896 | 41.6 | 2934 | 43.1 | 3008 | 46.3 | 3083 | 49.6 | 3158 | 52.9 | | | | |
| 18900 | 4565 | 2857 | 40.3 | 2897 | 42.0 | 2936 | 43.6 | 2975 | 45.2 | 3013 | 46.9 | 3086 | 50.2 | 3157 | 53.6 | | | | | | |
| 19800 | 4782 | 2942 | 44.1 | 2980 | 45.8 | 3017 | 47.5 | 3055 | 49.2 | 3092 | 50.9 | 3165 | 54.3 | | | | | | | | |
| 20700 | 5000 | 3028 | 48.1 | 3065 | 49.8 | 3101 | 51.6 | 3137 | 53.4 | 3173 | 55.1 | | | | | | | | | | |
| 21600 | 5217 | 3114 | 52.3 | 3150 | 54.2 | 3186 | 56.0 | | | | | | | | | | | | | | |
| 22500 | 5434 | 3201 | 56.9 | | | | | | | | | | | | | | | | | | |

Static Pressure In Inches.

Performance shown is for model BIDW arrangement 3, installation type B - free inlet, ducted outlet.
Performance ratings do not include the effects of appurtenances in the airstream.
Power rating (BHP) does not include drive losses.

# Fan Selection Procedure

**STEP 1**
**Enter the performance table with the desired CFM and Ps. Obtain the fan RPM, BHP and Class.**

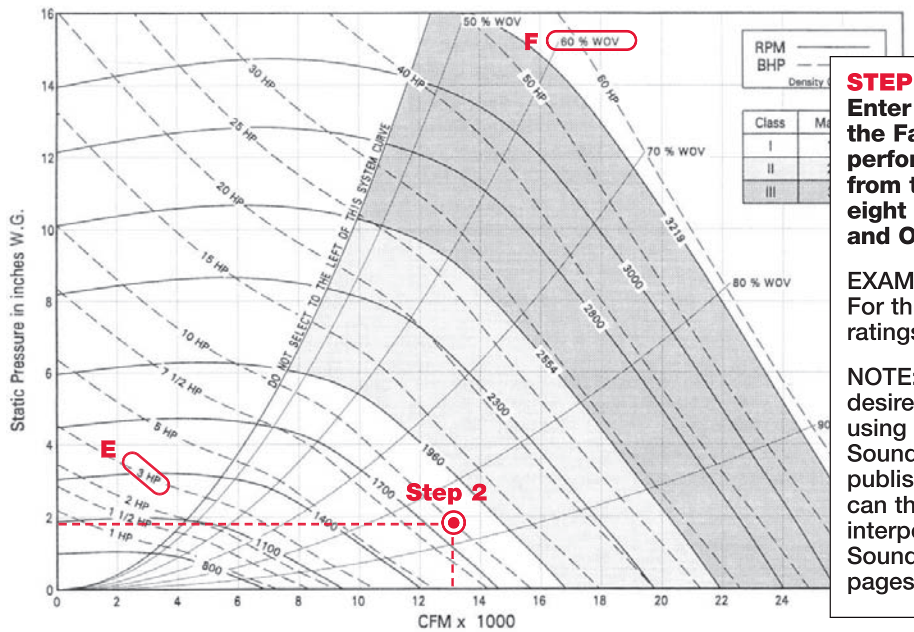
EXAMPLE
For this example, we will use 13,400 cfm at 2.0 Ps. This gives us a fan RPM of 1,847, requiring 10.9 Bhp, with Class I construction.

NOTE: If your specific fan selection requires inlet vanes or if the fan operating point is not at standard air (70˚C), refer to the inlet vane and air density correction factor tables found on pages 5 and 6.

**STEP 2**
**Enter the Fan Curve with the desired CFM and Ps. Obtain the fan operating point, % WOV, Motor HP and verify fan class by curve shading.**

EXAMPLE
For this example, the fan operating point is at 85% WOV using a 15 hp motor.

## 20 BIDW




**STEP 3**
**Enter the Fan Sound Table with the Fan RPM from the performance table and the % WOV from the fan curve. Obtain the eight octave ratings for inlet (Lwi) and Outlet (Lwo) Sound Power.**

EXAMPLE
For this example, the eight octave ratings are circled in the table below.

NOTE: The exact % WOV for your desired performance can be found using the equation at the top of the Sound Power Table if it is not published. The eight octave ratings can then be found using the interpolation instructions found in the Sound Performance section on pages 8 and 9.

% WOV = (CFM X 100) / (RPM X 8.58)

### Sound Power [dB Ref $10^{-12}$ watts]

Step 3

**Inlet Sound Power, Lwi**

| RPM | %WOV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | LwiA |
|---|---|---|---|---|---|---|---|---|---|---|
| 550 | 100 | 78 | 75 | 74 | 78 | 68 | 62 | 56 | 52 | 76 |
| | 80 | 76 | 73 | 71 | 75 | 67 | 60 | 54 | 50 | 74 |
| | 60 | 75 | 70 | 70 | 76 | 67 | 60 | 54 | 50 | 74 |
| | 50 | 75 | 69 | 69 | 76 | 67 | 60 | 54 | 50 | 75 |
| | 40 | 74 | 69 | 69 | 77 | 67 | 60 | 54 | 50 | 75 |
| 800 | 100 | 79 | 91 | 83 | 82 | 76 | 72 | 64 | 60 | 83 |
| | 80 | 80 | 89 | 81 | 78 | 72 | 67 | 59 | 54 | 80 |
| | 60 | 77 | 83 | 76 | 77 | 71 | 67 | 59 | 54 | 77 |
| | 50 | 76 | 80 | 74 | 76 | 71 | 67 | 60 | 55 | 77 |
| | 40 | 77 | 78 | 74 | 76 | 71 | 67 | 60 | 55 | 77 |
| 1100 | 100 | 85 | 92 | 91 | 89 | 85 | 81 | 74 | 70 | 90 |
| | 80 | 84 | 88 | 88 | 87 | 81 | 77 | 69 | 65 | 87 |
| | 60 | 83 | 84 | 83 | 83 | 79 | 76 | 70 | 65 | 85 |
| | 50 | 80 | 83 | 82 | 83 | 79 | 76 | 70 | 66 | 84 |
| | 40 | 80 | 83 | 82 | 83 | 78 | 75 | 70 | 66 | 84 |
| 1600 | 100 | 91 | 94 | 98 | 95 | 92 | 89 | 83 | 78 | 97 |
| | 80 | 88 | 91 | 96 | 93 | 90 | 86 | 80 | 75 | 95 |
| | 60 | 87 | 88 | 93 | 89 | 86 | 83 | 78 | 75 | 92 |
| | 50 | 87 | 88 | 91 | 88 | 85 | 82 | 78 | 75 | 91 |
| | 40 | 89 | 88 | 90 | 87 | 85 | 82 | 78 | 76 | 90 |
| 2200 | 100 | 98 | 100 | 103 | 105 | 98 | 96 | 91 | 88 | 105 |
| | 80 | 95 | 97 | 100 | 103 | 96 | 92 | 87 | 84 | 102 |
| | 60 | 92 | 93 | 98 | 99 | 93 | 91 | 87 | 84 | 100 |
| | 50 | 93 | 93 | 98 | 97 | 93 | 90 | 87 | 84 | 99 |
| | 40 | 95 | 95 | 98 | 98 | 92 | 90 | 88 | 86 | 99 |
| 3219 | 100 | 105 | 109 | 110 | 114 | 110 | 106 | 102 | 98 | 115 |
| | 80 | 103 | 106 | 107 | 111 | 107 | 102 | 98 | 94 | 112 |
| | 60 | 100 | 102 | 105 | 107 | 104 | 101 | 97 | 94 | 109 |
| | 50 | 101 | 103 | 105 | 105 | 103 | 100 | 97 | 94 | 108 |
| | 40 | 103 | 105 | 106 | 106 | 103 | 99 | 98 | 96 | 108 |

**Outlet Sound Power, Lwo**

| RPM | %WOV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | LwoA |
|---|---|---|---|---|---|---|---|---|---|---|
| 550 | 100 | 90 | 78 | 75 | 68 | 67 | 59 | 52 | 47 | 73 |
| | 80 | 90 | 77 | 71 | 64 | 64 | 54 | 47 | 45 | 70 |
| | 60 | 83 | 74 | 68 | 63 | 62 | 54 | 48 | 45 | 67 |
| | 50 | 82 | 73 | 67 | 63 | 63 | 54 | 48 | 45 | 67 |
| | 40 | 82 | 73 | 67 | 63 | 63 | 54 | 48 | 46 | 67 |
| 800 | 100 | 93 | 96 | 83 | 77 | 77 | 71 | 63 | 57 | 84 |
| | 80 | 90 | 92 | 81 | 73 | 72 | 64 | 57 | 52 | 80 |
| | 60 | 87 | 84 | 76 | 72 | 69 | 63 | 57 | 53 | 75 |
| | 50 | 87 | 82 | 74 | 72 | 68 | 62 | 57 | 54 | 74 |
| | 40 | 89 | 83 | 73 | 71 | 68 | 62 | 57 | 54 | 74 |
| 1100 | 100 | 99 | 93 | 90 | 86 | 86 | 80 | 74 | 67 | 90 |
| | 80 | 96 | 92 | 88 | 83 | 81 | 74 | 67 | 61 | 86 |
| | 60 | 91 | 87 | 83 | 78 | 77 | 71 | 66 | 61 | 82 |
| | 50 | 91 | 86 | 82 | 77 | 76 | 71 | 66 | 62 | 81 |
| | 40 | 92 | 86 | 81 | 76 | 75 | 70 | 66 | 62 | 80 |
| 1600 | 100 | 105 | 98 | 98 | 94 | 93 | 89 | 85 | 77 | 98 |
| | 80 | 102 | 95 | 96 | 91 | 92 | 87 | 81 | 73 | 96 |
| | 60 | 100 | 91 | 93 | 87 | 87 | 83 | 77 | 72 | 92 |
| | 50 | 100 | 92 | 92 | 86 | 86 | 81 | 76 | 72 | 91 |
| | 40 | 100 | 93 | 92 | 85 | 84 | 81 | 76 | 72 | 90 |
| 2200 | 100 | 109 | 105 | 106 | 109 | 102 | 97 | 93 | 88 | 109 |
| | 80 | 107 | 101 | 101 | 105 | 98 | 93 | 89 | 83 | 105 |
| | 60 | 103 | 97 | 96 | 99 | 96 | 91 | 86 | 81 | 100 |
| | 50 | 104 | 98 | 95 | 97 | 94 | 89 | 85 | 81 | 99 |
| | 40 | 107 | 100 | 95 | 95 | 92 | 89 | 85 | 81 | 98 |
| 3219 | 100 | 117 | 115 | 113 | 118 | 114 | 108 | 104 | 99 | 118 |
| | 80 | 115 | 112 | 109 | 113 | 110 | 104 | 100 | 94 | 114 |
| | 60 | 111 | 108 | 105 | 107 | 106 | 102 | 97 | 92 | 110 |
| | 50 | 112 | 109 | 104 | 105 | 104 | 100 | 96 | 92 | 108 |
| | 40 | 116 | 112 | 106 | 103 | 102 | 99 | 95 | 92 | 107 |

The sound power level ratings shown are in decibels, referred to $10^{-12}$ watts calculated per AMCA Standard 301. Values shown are for inlet Lwi, LwiA and outlet Lwo, LwoA sound power levels for Installation Type B: free inlet, ducted outlet. Outlet ratings include the effects of duct and correction.

# 20 BIDW

Wheel Diameter = 20 in.
Outlet Area = 4.14 ft.$^2$
Tip Speed = 5.24 x RPM
Maximum BHP = (RPM/832)$^3$

Maximum RPM Class I = 1960
Maximum RPM Class II = 2554
Maximum RPM Class III = 3219

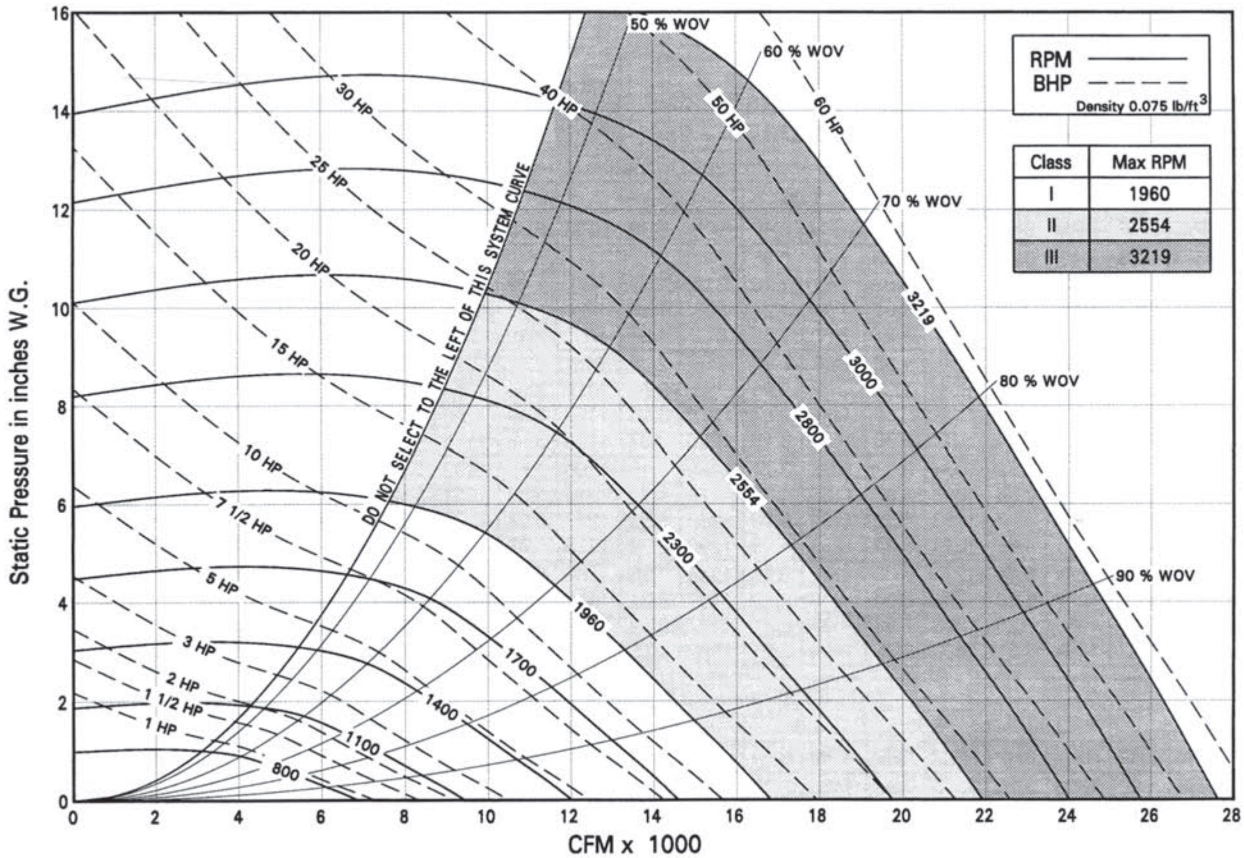
Minimum Motor Size
For Starting Torque: ¾ HP

| CFM | OV | Static Pressure In Inches | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.25 | | 0.50 | | 0.75 | | 1.00 | | 1.25 | | 1.50 | | 1.75 | | 2.00 | | 2.25 | | 2.50 | |
| | | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP |
| 3000 | 724 | 489 | 0.20 | 596 | 0.34 | 699 | 0.52 | | | | | | | | | | | | | | |
| 3800 | 917 | 561 | 0.31 | 654 | 0.47 | 736 | 0.65 | 823 | 0.87 | 900 | 1.11 | 977 | 1.37 | | | | | | | | |
| 4600 | 1111 | 639 | 0.45 | 723 | 0.65 | 797 | 0.85 | 865 | 1.07 | 936 | 1.31 | 1005 | 1.59 | 1069 | 1.87 | 1132 | 2.17 | | | | |
| 5400 | 1304 | 720 | 0.65 | 796 | 0.87 | 864 | 1.11 | 927 | 1.35 | 987 | 1.60 | 1042 | 1.85 | 1105 | 2.16 | 1165 | 2.48 | 1221 | 2.81 | 1274 | 3.14 |
| 6200 | 1497 | 803 | 0.89 | 874 | 1.16 | 936 | 1.42 | 995 | 1.69 | 1050 | 1.96 | 1103 | 2.25 | 1154 | 2.54 | 1201 | 2.83 | 1257 | 3.19 | 1310 | 3.55 |
| 7000 | 1690 | 888 | 1.19 | 954 | 1.50 | 1012 | 1.80 | 1066 | 2.10 | 1119 | 2.40 | 1167 | 2.71 | 1215 | 3.03 | 1262 | 3.35 | 1306 | 3.67 | 1348 | 4.00 |
| 7800 | 1884 | 974 | 1.57 | 1035 | 1.92 | 1090 | 2.25 | 1142 | 2.58 | 1190 | 2.91 | 1237 | 3.25 | 1282 | 3.59 | 1324 | 3.94 | 1367 | 4.30 | 1409 | 4.66 |
| 8600 | 2077 | 1061 | 2.02 | 1119 | 2.41 | 1171 | 2.78 | 1219 | 3.14 | 1265 | 3.51 | 1309 | 3.87 | 1352 | 4.25 | 1393 | 4.62 | 1432 | 5.00 | 1471 | 5.39 |
| 9400 | 2270 | 1149 | 2.56 | 1203 | 2.98 | 1252 | 3.39 | 1298 | 3.79 | 1342 | 4.19 | 1384 | 4.59 | 1424 | 4.99 | 1463 | 5.40 | 1502 | 5.81 | 1539 | 6.22 |
| 10200 | 2463 | 1238 | 3.19 | 1288 | 3.64 | 1335 | 4.10 | 1379 | 4.54 | 1421 | 4.97 | 1461 | 5.41 | 1499 | 5.84 | 1536 | 6.27 | 1573 | 6.71 | 1609 | 7.15 |
| 11000 | 2657 | 1328 | 3.93 | 1374 | 4.41 | 1419 | 4.90 | 1461 | 5.39 | 1501 | 5.85 | 1539 | 6.32 | 1576 | 6.79 | 1612 | 7.26 | 1646 | 7.72 | 1680 | 8.20 |
| 11800 | 2850 | 1419 | 4.77 | 1461 | 5.28 | 1504 | 5.81 | 1544 | 6.34 | 1583 | 6.85 | 1619 | 7.35 | 1655 | 7.85 | 1689 | 8.36 | 1722 | 8.85 | 1755 | 9.35 |
| 12600 | 3043 | 1509 | 5.74 | 1548 | 6.27 | 1589 | 6.83 | 1628 | 7.40 | 1665 | 7.96 | 1700 | 8.50 | 1734 | 9.03 | 1767 | 9.57 | 1800 | 10.1 | 1831 | 10.6 |
| 13400 | 3236 | 1600 | 6.83 | 1637 | 7.39 | 1675 | 7.98 | 1712 | 8.58 | 1748 | 9.19 | 1782 | 9.77 | 1815 | 10.3 | 1847 | 10.9 | 1878 | 11.5 | 1908 | 12.1 |
| 14200 | 3429 | 1691 | 8.05 | 1726 | 8.65 | 1762 | 9.27 | 1797 | 9.90 | 1832 | 10.5 | 1865 | 11.2 | 1897 | 11.8 | 1928 | 12.4 | 1958 | 13.0 | 1987 | 13.6 |
| 15000 | 3623 | 1782 | 9.41 | 1816 | 10.1 | 1849 | 10.7 | 1883 | 11.4 | 1916 | 12.0 | 1949 | 12.7 | 1980 | 13.4 | 2010 | 14.0 | 2039 | 14.7 | 2067 | 15.3 |

| CFM | OV | Static Pressure In Inches | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.50 | | 3.00 | | 3.50 | | 4.00 | | 4.50 | | 5.00 | | 5.50 | | 6.00 | | 6.50 | | 7.00 | |
| | | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP |
| 7000 | 1690 | 1348 | 4.00 | 1444 | 4.80 | 1534 | 5.63 | 1619 | 6.49 | 1700 | 7.39 | 1786 | 8.38 | | | | | | | | |
| 7800 | 1884 | 1409 | 4.66 | 1486 | 5.39 | 1571 | 6.23 | 1655 | 7.15 | 1734 | 8.09 | 1809 | 9.05 | 1881 | 10.0 | 1959 | 11.1 | | | | |
| 8600 | 2077 | 1471 | 5.39 | 1547 | 6.18 | 1619 | 6.98 | 1692 | 7.85 | 1770 | 8.85 | 1845 | 9.86 | 1916 | 10.9 | 1984 | 12.0 | 2049 | 13.0 | 2119 | 14.2 |
| 9400 | 2270 | 1539 | 6.22 | 1610 | 7.06 | 1680 | 7.92 | 1746 | 8.80 | 1809 | 9.68 | 1881 | 10.7 | 1952 | 11.8 | 2020 | 12.9 | 2085 | 14.1 | 2148 | 15.2 |
| 10200 | 2463 | 1609 | 7.15 | 1677 | 8.05 | 1743 | 8.96 | 1808 | 9.89 | 1870 | 10.8 | 1929 | 11.8 | 1989 | 12.8 | 2056 | 14.0 | 2121 | 15.2 | 2184 | 16.4 |
| 11000 | 2657 | 1680 | 8.20 | 1747 | 9.15 | 1810 | 10.1 | 1871 | 11.1 | 1932 | 121.0 | 1990 | 13.1 | 2046 | 14.1 | 2100 | 15.2 | 2158 | 16.3 | 2220 | 17.6 |
| 11800 | 2850 | 1755 | 9.35 | 1818 | 10.4 | 1880 | 11.4 | 1938 | 12.4 | 1995 | 13.5 | 2052 | 14.6 | 2108 | 15.6 | 2161 | 16.7 | 2212 | 17.8 | 2262 | 19.0 |
| 12600 | 3043 | 1831 | 10.6 | 1892 | 11.7 | 1951 | 12.8 | 2008 | 13.9 | 2063 | 150.0 | 2116 | 16.1 | 2170 | 17.3 | 2223 | 18.4 | 2274 | 19.6 | 2323 | 20.7 |
| 13400 | 3236 | 1908 | 12.1 | 1967 | 13.2 | 2023 | 14.3 | 2079 | 15.5 | 2133 | 167.0 | 2185 | 17.8 | 2235 | 19.0 | 2285 | 20.2 | 2336 | 21.4 | 2384 | 22.7 |
| 14200 | 3429 | 1987 | 13.6 | 2044 | 14.8 | 2099 | 16.0 | 2152 | 17.2 | 2204 | 185.0 | 2255 | 19.7 | 2305 | 20.9 | 2352 | 22.2 | 2399 | 23.4 | 2447 | 24.7 |
| 15000 | 3623 | 2067 | 15.3 | 2122 | 16.6 | 2175 | 17.8 | 2227 | 19.1 | 2276 | 204.0 | 2326 | 21.7 | 2375 | 23.0 | 2422 | 24.3 | 2467 | 25.6 | 2512 | 27.0 |
| 15800 | 3816 | 2148 | 17.1 | 2201 | 18.5 | 2253 | 19.8 | 2303 | 21.2 | 2352 | 225.0 | 2398 | 23.9 | 2446 | 25.2 | 2492 | 26.6 | 2537 | 28.0 | 2581 | 29.4 |
| 16600 | 4009 | 2229 | 19.1 | 2281 | 20.5 | 2331 | 22.0 | 2380 | 23.4 | 2428 | 24.8 | 2474 | 26.2 | 2518 | 27.6 | 2564 | 29.0 | 2608 | 30.5 | 2651 | 31.9 |
| 17400 | 4202 | 2312 | 21.3 | 2362 | 22.8 | 2411 | 24.3 | 2458 | 25.8 | 2505 | 27.2 | 2550 | 28.7 | 2593 | 30.2 | 2636 | 31.7 | 2679 | 33.2 | 2722 | 34.7 |
| 18200 | 4396 | 2395 | 23.7 | 2444 | 25.2 | 2491 | 26.8 | 2538 | 28.3 | 2582 | 29.9 | 2626 | 31.4 | 2669 | 32.9 | 2711 | 34.5 | 2752 | 36.0 | 2793 | 37.6 |
| 19000 | 4500 | 2470 | 26.1 | 2526 | 27.8 | 2573 | 29.4 | 2618 | 31.0 | 2661 | 32.7 | 2704 | 34.3 | 2746 | 35.9 | 2787 | 37.5 | 2827 | 39.1 | 2867 | 40.7 |

| CFM | OV | Static Pressure In Inches | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7.00 | | 7.50 | | 8.00 | | 8.50 | | 9.00 | | 10.00 | | 11.00 | | 12.00 | | 13.00 | | 14.00 | |
| | | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP | RPM | BHP |
| 9000 | 2173 | 2130 | 14.7 | 2195 | 15.9 | 2262 | 17.1 | | | | | | | | | | | | | | |
| 9900 | 2391 | 2170 | 15.9 | 2231 | 17.1 | 2289 | 18.4 | 2346 | 19.6 | 2405 | 20.9 | 2526 | 23.7 | | | | | | | | |
| 10800 | 2608 | 2211 | 17.3 | 2272 | 18.5 | 2330 | 19.8 | 2387 | 21.1 | 2442 | 22.4 | 2548 | 25.1 | 2656 | 28.0 | 2766 | 31.1 | | | | |
| 11700 | 2826 | 2255 | 18.7 | 2313 | 20.0 | 2371 | 21.4 | 2428 | 22.7 | 2482 | 24.1 | 2588 | 26.9 | 2689 | 29.8 | 2785 | 32.7 | 2887 | 35.9 | 2988 | 39.2 |
| 12600 | 3043 | 2323 | 20.7 | 2371 | 21.9 | 2417 | 23.1 | 2469 | 24.4 | 2524 | 25.9 | 2629 | 28.8 | 2729 | 31.8 | 2825 | 34.9 | 2918 | 38.0 | 3006 | 41.1 |
| 13500 | 3260 | 2392 | 22.9 | 2440 | 24.2 | 2486 | 25.4 | 2530 | 26.7 | 2574 | 28.0 | 2670 | 30.8 | 2770 | 33.9 | 2866 | 37.1 | 2958 | 40.4 | 3047 | 43.6 |
| 14400 | 3478 | 2463 | 25.3 | 2509 | 26.6 | 2555 | 27.9 | 2599 | 29.2 | 2643 | 30.6 | 2726 | 33.3 | 2812 | 36.2 | 2907 | 39.5 | 2999 | 42.8 | 3087 | 46.2 |
| 15300 | 3695 | 2538 | 27.8 | 2581 | 29.2 | 2625 | 30.6 | 2669 | 32.0 | 2712 | 33.4 | 2795 | 36.2 | 2874 | 39.1 | 2951 | 42.0 | 3040 | 45.4 | 3129 | 49.0 |
| 16200 | 3913 | 2616 | 30.6 | 2658 | 32.1 | 2699 | 33.5 | 2740 | 34.9 | 2782 | 36.4 | 2864 | 39.4 | 2943 | 42.4 | 3019 | 45.4 | 3092 | 48.4 | 3170 | 51.8 |
| 17100 | 4130 | 2695 | 33.6 | 2737 | 35.1 | 2777 | 36.6 | 2817 | 38.1 | 2856 | 39.7 | 2935 | 42.7 | 3013 | 45.9 | 3088 | 49.0 | 3160 | 52.2 | | |
| 18000 | 4347 | 2775 | 36.9 | 2816 | 38.4 | 2856 | 40.0 | 2896 | 41.6 | 2934 | 43.1 | 3008 | 46.3 | 3083 | 49.6 | 3158 | 52.9 | | | | |
| 18900 | 4565 | 2857 | 40.3 | 2897 | 42.0 | 2936 | 43.6 | 2975 | 45.2 | 3013 | 46.9 | 3086 | 50.2 | 3157 | 53.6 | | | | | | |
| 19800 | 4782 | 2942 | 44.1 | 2980 | 45.8 | 3017 | 47.5 | 3055 | 49.2 | 3092 | 50.9 | 3165 | 54.3 | | | | | | | | |
| 20700 | 5000 | 3028 | 48.1 | 3065 | 49.8 | 3101 | 51.6 | 3137 | 53.4 | 3173 | 55.1 | | | | | | | | | | |
| 21600 | 5217 | 3114 | 52.3 | 3150 | 54.2 | 3186 | 56.0 | | | | | | | | | | | | | | |
| 22500 | 5434 | 3201 | 56.9 | | | | | | | | | | | | | | | | | | |

Performance shown is for model BIDW arrangement 3, installation type B - free inlet, ducted outlet.
Performance ratings do not include the effects of appurtenances in the airstream.
Power rating (BHP) does not include drive losses.




% WOV = (CFM X 100) / (RPM X 8.58)

## Sound Power [dB Ref $10^{-12}$ watts]

**Inlet Sound Power, Lwi**

| RPM | %WOV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | LwiA |
|---|---|---|---|---|---|---|---|---|---|---|
| 550 | 100 | 78 | 75 | 74 | 78 | 68 | 62 | 56 | 52 | 76 |
| | 80 | 76 | 73 | 71 | 75 | 67 | 60 | 54 | 50 | 74 |
| | 60 | 75 | 70 | 70 | 76 | 67 | 60 | 54 | 50 | 74 |
| | 50 | 75 | 69 | 69 | 76 | 67 | 60 | 54 | 50 | 75 |
| | 40 | 74 | 69 | 69 | 77 | 67 | 60 | 54 | 50 | 75 |
| 800 | 100 | 79 | 91 | 83 | 82 | 76 | 72 | 64 | 60 | 83 |
| | 80 | 80 | 89 | 81 | 78 | 72 | 67 | 59 | 54 | 80 |
| | 60 | 77 | 83 | 76 | 77 | 71 | 67 | 59 | 54 | 77 |
| | 50 | 76 | 80 | 74 | 76 | 71 | 67 | 60 | 55 | 77 |
| | 40 | 77 | 78 | 74 | 76 | 71 | 67 | 60 | 55 | 77 |
| 1100 | 100 | 85 | 92 | 91 | 89 | 85 | 81 | 74 | 70 | 90 |
| | 80 | 84 | 88 | 88 | 87 | 81 | 77 | 69 | 65 | 87 |
| | 60 | 83 | 84 | 83 | 83 | 79 | 76 | 70 | 65 | 85 |
| | 50 | 80 | 83 | 82 | 83 | 79 | 76 | 70 | 66 | 84 |
| | 40 | 80 | 83 | 82 | 83 | 78 | 75 | 70 | 66 | 84 |
| 1600 | 100 | 91 | 94 | 98 | 95 | 92 | 89 | 83 | 78 | 97 |
| | 80 | 88 | 91 | 96 | 93 | 90 | 86 | 80 | 75 | 95 |
| | 60 | 87 | 88 | 93 | 89 | 86 | 83 | 78 | 75 | 92 |
| | 50 | 87 | 88 | 91 | 88 | 85 | 82 | 78 | 75 | 91 |
| | 40 | 89 | 88 | 90 | 87 | 85 | 82 | 78 | 76 | 90 |
| 2200 | 100 | 98 | 100 | 103 | 105 | 98 | 96 | 91 | 88 | 105 |
| | 80 | 95 | 97 | 100 | 103 | 96 | 92 | 87 | 84 | 102 |
| | 60 | 92 | 93 | 98 | 99 | 93 | 91 | 87 | 84 | 100 |
| | 50 | 93 | 93 | 98 | 97 | 93 | 90 | 87 | 84 | 99 |
| | 40 | 95 | 95 | 98 | 98 | 92 | 90 | 88 | 86 | 99 |
| 3219 | 100 | 105 | 109 | 110 | 114 | 110 | 106 | 102 | 98 | 115 |
| | 80 | 103 | 106 | 107 | 111 | 107 | 102 | 98 | 94 | 112 |
| | 60 | 100 | 102 | 105 | 107 | 104 | 101 | 97 | 94 | 109 |
| | 50 | 101 | 103 | 105 | 105 | 103 | 100 | 97 | 94 | 108 |
| | 40 | 103 | 105 | 106 | 106 | 103 | 99 | 98 | 96 | 108 |

**Outlet Sound Power, Lwo**

| RPM | %WOV | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | LwoA |
|---|---|---|---|---|---|---|---|---|---|---|
| 550 | 100 | 90 | 78 | 75 | 68 | 67 | 59 | 52 | 47 | 73 |
| | 80 | 90 | 77 | 71 | 64 | 64 | 54 | 47 | 45 | 70 |
| | 60 | 83 | 74 | 68 | 63 | 62 | 54 | 48 | 45 | 67 |
| | 50 | 82 | 73 | 67 | 63 | 63 | 54 | 48 | 45 | 67 |
| | 40 | 82 | 73 | 67 | 63 | 63 | 54 | 48 | 46 | 67 |
| 800 | 100 | 93 | 96 | 83 | 77 | 77 | 71 | 63 | 57 | 84 |
| | 80 | 90 | 92 | 81 | 73 | 72 | 64 | 57 | 52 | 80 |
| | 60 | 87 | 84 | 76 | 72 | 69 | 63 | 57 | 53 | 75 |
| | 50 | 87 | 82 | 74 | 72 | 68 | 62 | 57 | 54 | 74 |
| | 40 | 89 | 83 | 73 | 71 | 68 | 62 | 57 | 54 | 74 |
| 1100 | 100 | 99 | 93 | 90 | 86 | 86 | 80 | 74 | 67 | 90 |
| | 80 | 96 | 92 | 88 | 83 | 81 | 74 | 67 | 61 | 86 |
| | 60 | 91 | 87 | 83 | 78 | 77 | 71 | 66 | 61 | 82 |
| | 50 | 91 | 86 | 82 | 77 | 76 | 71 | 66 | 62 | 81 |
| | 40 | 92 | 86 | 81 | 76 | 75 | 70 | 66 | 62 | 80 |
| 1600 | 100 | 105 | 98 | 98 | 94 | 93 | 89 | 85 | 77 | 98 |
| | 80 | 102 | 95 | 96 | 91 | 92 | 87 | 81 | 73 | 96 |
| | 60 | 100 | 91 | 93 | 87 | 87 | 83 | 77 | 72 | 92 |
| | 50 | 100 | 92 | 92 | 86 | 86 | 81 | 76 | 72 | 91 |
| | 40 | 100 | 93 | 92 | 85 | 84 | 81 | 76 | 72 | 90 |
| 2200 | 100 | 109 | 105 | 106 | 109 | 102 | 97 | 93 | 88 | 109 |
| | 80 | 107 | 101 | 101 | 105 | 98 | 93 | 89 | 83 | 105 |
| | 60 | 103 | 97 | 96 | 99 | 96 | 91 | 86 | 81 | 100 |
| | 50 | 104 | 98 | 95 | 97 | 94 | 89 | 85 | 81 | 99 |
| | 40 | 107 | 100 | 95 | 95 | 92 | 89 | 85 | 81 | 98 |
| 3219 | 100 | 117 | 115 | 113 | 118 | 114 | 108 | 104 | 99 | 118 |
| | 80 | 115 | 112 | 109 | 113 | 110 | 104 | 100 | 94 | 114 |
| | 60 | 111 | 108 | 105 | 107 | 106 | 102 | 97 | 92 | 110 |
| | 50 | 112 | 109 | 104 | 105 | 104 | 100 | 96 | 92 | 108 |
| | 40 | 116 | 112 | 106 | 103 | 102 | 99 | 95 | 92 | 107 |

The sound power level ratings shown are in decibels, referred to $10^{-12}$ watts calculated per AMCA Standard 301. Values shown are for inlet Lwi, LwiA and outlet Lwo, LwoA sound power levels for Installation Type B: free inlet, ducted outlet. Outlet ratings include the effects of duct end correction.