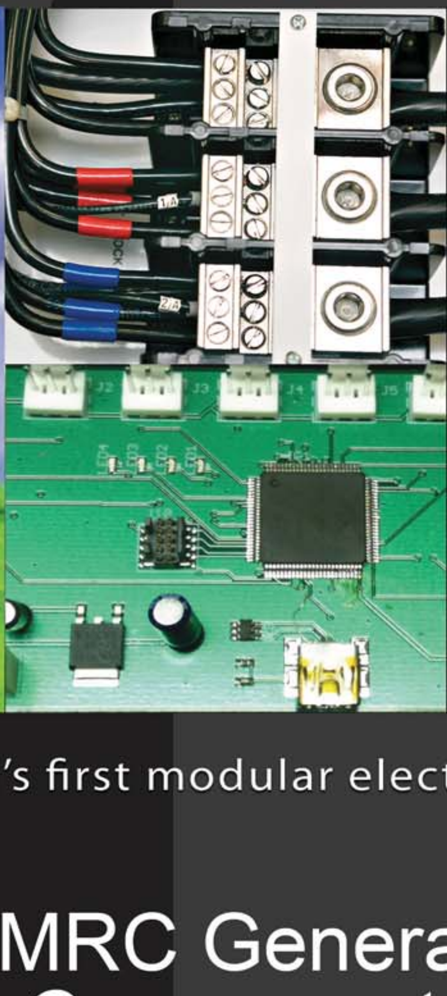

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MRC Generator System Base Component Selection Guide

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MRC Power Generator Division

Generator System Base Component Selection Guide

Revision 1.8

Revision Date: 5/8/3012

<u>NOTE:</u> This document is provided by MRC Engineering as a guideline for internal component selection, engineering, procurement, costing & fabrication departments. Cost estimates included in the selection tables are estimates based on quotes received within the last 30 days and are subject to change. Site specific requirements may mandate additional equipment not part of this platform specification process that will affect final cost.

Contents

Introduction

MRC generator systems are on mobile platforms and focused on the prime power market where us of alternative fuels brings economic benefit to the customer. This guide focuses on natural gas fueled generation systems for prime power.

To create a prime power system, the MRC 15X series load following generators are combined with a durable natural gas fueled engine to provide a self-contained electric generation platform for prime power[1] applications. A mobile or stationary platform can be constructed with the appropriate engine and MRC generator and power output options. This guide will assist you in selecting the correct components for a particular application and determining the estimated cost of the final system for that application.

The MRC prime power generation system is constructed with the engine-generator combination in a self-contained unit with or without an overall enclosure. With no overall enclosure, the MRC generator is covered with a small cover or housing to keep out direct environmental elements. This small generator cover is not required if the overall enclosure is used. The application will determine if the overall enclosure is required, or the overall enclosure may be considered a required option for certain applications. In additions to the engine-generator self-contained unit, a separate electronics enclosure with independent stand or mounting system is constructed. This enclosure contains the generator gen-set control unit, power conversion (inverter) unit, and any other equipment like satellite monitoring or industrial control interfaces to the customer external systems. At a minimum, the gen-set controller and some power conversion is usually required. Figure 1 shows a diagram of the base system unit and components for a typical system.

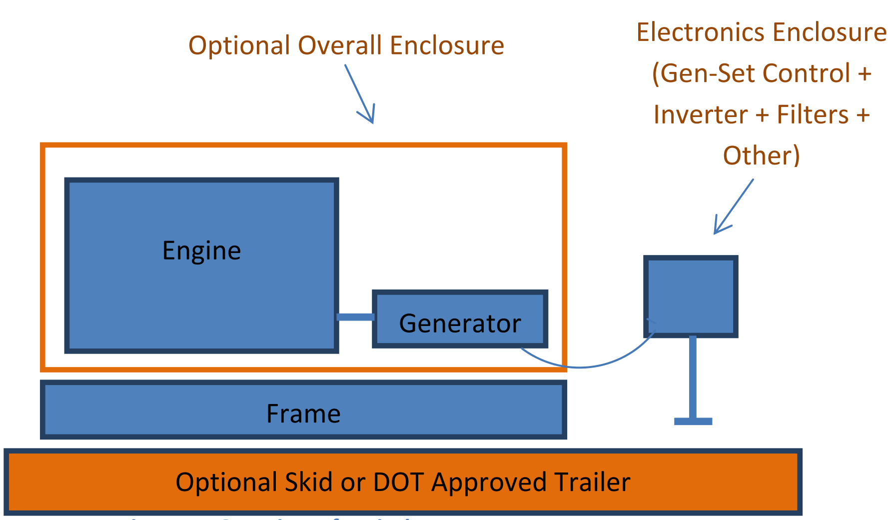


Figure 1 - Overview of typical power generator system

[1] Prime Power applications are those for which power is generated constantly or on a 24/7 schedule.

Generator System Configuration Guidelines

The following sections of this guide contain the recommended engine-to-generator matching based on MRC engineering specifications. It is to be used to select and configure a typical prime power system for a particular application. Refer to it as your basic guide for most prime power applications. It also contains the latest cost estimates, so it can be used to quickly estimate the total base system cost for any particular power range of applications. Appendix A contains sample worksheets for several typical applications as a reference on using the data in the tables included in this guide.

NOTE: All estimated costs in this guide are based on the most recent quotes and estimates. See appendix B for a summary table of components and quotes. All estimates are subject to change. Use the estimates to get a rough idea of the total cost of a system based on the selection criteria as determined by the application.

Power Output Range Selection

Start by understanding the continuous power demand requirements of the particular applications. This will be the 'prime power' rating required for continuous operation (24/7 operation). Table 1 gives the generator model(s) to be combined with a recommended engine platform. Match the electrical power output required for your application and find the generator model and number required. The generator units will be combined with the engine platform that you will select in a later section.

Electrical Power Output (Prime Rated) [2]	MRC Generator Model(s)	RPM	Generator Estimated Cost[3]
15 KW	MRC15X2P3DC	1200 (1800 MAX)	$9,934
50 KW	MRC15X6P3DC	1500 (1800 MAX)	$19,723
75 KW	MRC15X8P3DC	1800 (1900 MAX)	$24,832
100 KW	MRC15X10P3DC	1800 (1900 MAX)	$28,966
150 KW	MRC15X15P3DC	1800 (1900 MAX)	$39,823
200 KW	(2) MRC15X10P3DC [4]	1800 (1900 MAX)	$54,032
300 KW	(2) MRC15X15P3DC [5]	1800 (1900 MAX)	$78,096

Table 1- Generator selection table

[2] Prime Rated means the power output is specified for continuous duty operation at the specified power rating.
[3] The estimated cost is subject to change based on material cost fluctuations and is based on the initial purchase order price discount in quantities of 10 units.
[4] The 15X10 with a shaft coupling option can be combined to produce the required output. (See shaft coupling options table for details).
[5] The 15X15 with a shaft coupling option can be combined to produce the required output. (See shaft coupling options table for details).

MRC Generator Model(s)	MRC Shaft Coupling and Mounting Kit
MRC15X10P3DC	MRC-CPLK-15X10
MRC15X15P3DC	MRC-CPLK-15X15

Table 2- Shaft coupling kit table

Gen-Set Control Unit Selection

Every generator must have a gen-set control unit (GSCU) and associated power bus assembly. This control unit mates and interfaces with any of the engine platforms recommended in engine selection table. Match the highest capacity generator that will be used in your configuration and select the gen-set unit required from Table 3 below. Note that if two generators are used, as in the 300 KW case, only one GSCU is required.

MRC Generator Model(s)	GSCU Model	GSCU & Bus Assembly Estimated Cost
MRC15X2P3DC	MRC-GS-15X2	$1,300
MRC15X6P3DC	MRC-GS-15X6	$1,700
MRC15X8P3DC	MRC-GS-15X8	$1,800
MRC15X10P3DC	MRC-GS-15X10	$2,000
MRC15X15P3DC	MRC-GS-15X15	$2,250

Table 3 - GSCU selection table

AC Power Output Option Selection

Each MRC generator is a DC generator and the type and voltage rating needed for each application requires a ‘power conversion and normalization’ unit. The primary market is for oil field application that can tolerate ‘non pure sinusoidal’ power. This is any inductive or limited lighting application that can use a PWM based inverter or variable frequency drive. The ‘power conversion and correction’ unit has been engineered and matched to each MRC generator for use in driving pumps, fans, and industrial lighting. In some applications, filters and sinusoidal correction may be required. Each application requires a programming service and final engineering review to determine if the application can be supplied with the MRC PWM based inverters. In situations where ‘grid-tie’ or institutional AC power must be generated, a ‘grid-tie’ or ‘true sinusoidal’ inverter must be used. This is a ‘special option’ and MRC should be contacted for pricing and engineering specifics for that type of application.

If your application load is industrial with primarily motors and limited lighting, the VFD (PWM) type inverter can be used. The VFD (PWM) type is typically used to drive a single motor requiring speed control, but can be used to drive a limited number of motors in some applications. If your application has several motors, you may need to segment the drive of some motors by selecting multiple VFD type inverters. If this is done, do not exceed the total output capacity of the generator that you selected from Table 1. Using Table 4 or Table 5 , identify the prime rated power output, load type, phase, and voltage requirement for the application, then select the MRC inverter model to be 'paired' with the MRC generator selected earlier. Use Table 6 to select a VFD filter options when using the VFD type inverter. The filter is needed to correct for non-inductive or non-motor loads, like lighting and other resistive loads.

VFD (PWM) Type Power Conversion (Inverters)

AC Electrical Power Output (Prime Rated)	MRC Inverter Type[6] / Phase/ Voltage	MRC Inverter Model	Inverter Estimated Cost
15 KVA	VFD (PWM) / 1ϕ / 240	MRC-VPI-20-1P-240	$ 2,900
50 KVA	VFD (PWM) / 1ϕ / 240	MRC-VPI-60-1P-240	$ 4,900
75 KVA	VFD (PWM) / 3ϕ / 480	MRC-VPI-75-3P-480	$ 5,600
100 KVA	VFD (PWM) / 3ϕ / 480	MRC-VPI-115-3P-480	$ 6,875
150 KVA	VFD (PWM) / 3ϕ / 480	MRC-VPI-150-3P-480	$ 8,936
200 KVA	VFD (PWM) / 3ϕ / 480	MRC-VPI-225-3P-480	$ 10,400
300 KVA	VFD (PWM) / 3ϕ / 480	MRC-VPI-325-3P-480	$ 14,350

Table 4 - Inverter selection table (VFD/PWM)

TRUESINE™ Power Conversion (Grid-Tie and True Sinusoidal)

AC Electrical Power Output (Prime Rated)	MRC Inverter Type[7] / Phase/ Voltage	MRC Inverter Model	Inverter Estimated Cost[8]
15 KVA	TRUESINE™ / 1ϕ / 240	MRC-TPI-20-1P-240	TBD
50 KVA	TRUESINE™ / 1ϕ / 240	MRC-TPI-60-1P-240	TBD
75 KVA	TRUESINE™ / 3ϕ / 480	MRC-TPI-75-3P-480	TBD

[6] VFD (PWM) inverters can be used for variable frequency drive of inductive synchronous or asynchronous motors (shunt wound or axial). For limited lighting and inductive motor applications, an optional power correction filter can be installed to provide sinusoidal correction. For institutional applications that supply all types of loads, a true sinusoidal inverter is required. The TRUESINE™ inverter type should be used with a grid-tie option, if direct grid-tie is required.

[7] TRUESINE™ inverters are not variable frequency and can be used to supply all load types. With the grid-tie option they can be used for direct grid tie applications. (Additional equipment is required for grid-tie and each application should be custom engineered and have engineering approval in the local region).

[8] TRUESINE™ inverters vary greatly in price and are engineered for each application. Some applications are co-gen and grid-tie, or combinations of both. Additional switch and metering gear may be required.

100 KVA	TRUESINE™ / 3ϕ / 480	MRC-TPI-115-3P-480	TBD
150 KVA	TRUESINE™ / 3ϕ / 480	MRC-TPI-150-3P-480	TBD
200 KVA	TRUESINE™ / 3ϕ / 480	MRC-TPI-225-3P-480	TBD
300 KVA	TRUESINE™ / 3ϕ / 480	MRC-TPI-325-3P-480	TBD

Table 5 - Inverter selection table (TRUESINE™)

AC Electrical Power Output (Prime Rated)	VFD Output Filter	Filter Model	Filter Estimated Cost
15 KVA	SINEWAVE CORRECTION 1ϕ	MRC-FIL-20-1P-240	$ 700
50 KVA	SINEWAVE CORRECTION 1ϕ	MRC- FIL -60-1P-240	$ 1,800
75 KVA	SINEWAVE CORRECTION 3ϕ	MRC- FIL -75-3P-480	$ 2,500
100 KVA	SINEWAVE CORRECTION 3ϕ	MRC- FIL -115-3P-480	$ 2,900
150 KVA	SINEWAVE CORRECTION 3ϕ	MRC- FIL -150-3P-480	$ 3,900
200 KVA	SINEWAVE CORRECTION 3ϕ	MRC- FIL -225-3P-480	$ 5,400
300 KVA	SINEWAVE CORRECTION 3ϕ	MRC- FIL -325-3P-480	$ 9,200

Table 6 - VFD Inverter Filter Options Selection

Generator-Engine Matching

Once the generator model(s), gen-set, and power correction (inverter) requirements have been determined and the components selected, they must be integrated into a power-gen components with an engine platform. MRC has performed the research and matched all aspects of the MRC generation system with the industry leading high durability engine platforms from three manufacturers - Arrow, Cummins, and Waukesha.

The engine platform consists of the engine, radiator assembly, and exhaust, catalyst & emissions components, and ECU that is required to assemble into a mobile or permanent stand-alone engine system[9]. Once the engine platform is selected, the entire system will be mounted on a base that meets MRC requirements for generator mounting (length requirements). This base will be manufactured to fit onto a skid assembly or a DOT approved trailer. Additionally, the base must accommodate an overall 'enclosure' that covers the engine and generator components. The 'power conversion unit' (inverter) will be manufactured into a NEMA/UL compliant electrical cabinet according to MRC specifications. This power conversion unit will be a separately mounted assembly. This cabinet should be mounted on a frame that will accept mounting onto the wheeled trailer or the skid assembly or skid platform.

Using Table 7 below, find the power output rating for the application and select the engine platform to be integrated with the MRC generator, gen-set, and inverter that was previously selected.

[9] The Arrow engines include a bottom frame and light duty skid assembly. The Waukesha engines do not include frames.

Natural Gas @ Low Elevation (Less than 7000 FT)

Low elevation engines have a less than 8:1 compression ratio and operate at altitudes of fewer than 6000 to 7000 feet with moderate site tuning. Use high elevation engines for altitudes above 6000 to 7000 feet.

Electrical Power Output (Prime Rated)	Minimum/Maximum Braking Horsepower @ flywheel	Minimum/Maximum RPM	Engine Make/Model/Options [10]	Engine Estimated Cost
15 KW	18/27	1200/1800	Arrow/A32 or Arrow/A42	$ 13,667 $ 14,190
50 KW	65/88	1500/1800	Arrow/A62	$ 18,677
75 KW	90/120	1800/1900	Arrow/A62T/Turbo[11]	$ 23,158
100 KW	133/177	1800/1900	Cummins/G855	$ 61,000
150 KW	221/265	1800/1900	Cummins/GTA855e	$ 75,000
200 KW	290/354	1800/1900	Waukesha VGF / F18GSI or Cummins / KTA19GC	$ 95,192 $ 100,000
300 KW	470/531	1800/1900	Waukesha VGF / H24GSI	$ 124,689

Table 7 - Engine selection table (low elevation)

Natural Gas @ High Elevation (7000 FT or higher)

High elevation engines have a less than 10:1 compression ratio, pressure condenser modifications, timing modifications, turbo, and carburetion adjustments designed for high elevations. High elevation engines can be run in low elevations with tuning, although they tend to be higher priced due to the additional engine modifications. For the Arrow engines recommended in this document, the high elevation modifications are built into the base model, therefore, the engines recommended in this table are used in the low elevation applications, as shown in

[10] See appendix B for detailed specifications on the recommended engines.

[11] **The A62T has an optional full enclosure at an estimated cost of $2,395.**

Electrical Power Output (Prime Rated)	Minimum/Maximum Braking Horsepower @ flywheel	Minimum/Maximum RPM	Engine Make/Model/Options [12]	Engine Estimated Cost
15 KW	18/27	1200/1800	Arrow/A32 or Arrow/A42	$ 13,667 $ 14,190
50 KW	65/88	1500/1800	Arrow/A62	$ 18,677
75 KW	90/120	1800/1900	Arrow/A62T/Turbo[13]	$ 23,158
100 KW	133/177	1800/1900	Cummins/G855	$ 61,000
150 KW	221/265	1800/1900	Cummins/GTA855e	$ 75,000
200 KW	290/354	1800/1900	Waukesha VGF / F18GSI or Cummins / KTA19GC	$101,141 $ 100,000
300 KW	470/531	1800/1900	Waukesha VGF / H24GSI	$ 132,482

Table 8 - Engine selection table (high elevation)

Summary

This document is a guideline on how to select and configure a typical base system for a particular application. A base system includes the primary components only. Refer to it as your basic guide for most applications. Appendix A contains sample worksheets for several typical applications.

[12] See appendix B for detailed specifications on the recommended engines.

[13] **The A62T has an optional full enclosure at an estimated cost of $2,395.**

Appendix A

The following example worksheet is intended as an example of how to use this guide to determine the base system components and estimated costs of base generation system.

NOTE: Additional costs must be considered that are not estimated in this guide; for example, the mounting system, fuel supply & control components, electrical hookup components, other hardware, on-site licensing, and other optional components. The worksheet lists some of those items, but does not include the estimated costs. The costs are a factor of each installation or the final delivery platform and installation site. In addition to the base costs and optional costs listed in this worksheet, each system must be engineered for each installation when 'grid-tie' or 'co-generation' with a TRUESINE inverter is required.

Example Worksheet #1

Description of the Application:

The customer requires a natural gas generator system for continuous prime power supply of a down-hole oil pump. The existing pump is driven by a VFD with a step up transformer increasing the voltage prior to supplying the pump. The existing system draws about 115 KW of power with peak draw up to 145 kW during startup.

Analysis and Base Component Selection for the Application:

The VFD (PWM) inverter for the MRC generator can be used to drive the step-up transformer. After identifying the voltage and phase on the primary of the step-up transformer (480/3ϕ) the generator size can be selected. For continuous of 115 KW with peak up to 145 KW, the 150 KW MAX prime power rating should be used for selecting the generator. Using Table 1 we select one MRC model MRC15X10P3DC generator capable of up to 100 KW of output.

Every MRC generator requires a GSCU, so we select the model MRC-GS-15X15 GSCU from Table 3. This gen-set will allow connection to any outside control, monitoring, and alarm systems, as well as provide basic control and monitoring of the MRC generator modules.

Since the output range is up to 480 Volts 3ϕ, the 150 KW VFD-type inverters should be used. From Table 4 we select the model MRC-VPI-150-3P-480 inverter for this power range. Note that the VFD type inverter is ideal for programming as a down-hole pump drive. Speed of the pump and torque vector control is programmable. Power correction using a filter is not required for direct drive of a single pump in a variable frequency application. However, if the step-up transformer is not a VFD rated transformer, power correction may be required. In this case the step-up is VFD rated and tuned.

The generator components must be integrated with the correct natural gas engine. Using Table 7 for low elevation locations, we select an engine for the electrical output of 150 KW. From the table we choose the Cummins GT855e engine.

Deployment & Platform Analysis:

For this application, the generator system should be self-contained and on a wheeled mobile platform. The generator is mounted onto the engine and the engine mounted on a frame for mounting onto a trailer. An enclosure must be built to cover the generator and engine. The gen-set control unit, inverter and other power correction components are mounted in a NEMA cabinet and UL certified. This enclosure is mounted on a frame for independent installation on the site or mounting on the trailer. A volume-pot and gas regulation unit must be mounted on the trailer or near the generator enclosure. Connection hardware will vary depending on the details of the gas supply on the deployment site.

Cost Analysis & Estimate:

From our analysis, the base generator system cost can be determined:

1. BASE GENERATOR UNIT #_MRC15X15P3DC____ $____39,823________
2. GEN-SET UNIT #_MRC-GS-15X15______ $____2,250_________
3. INVERTER UNIT #_MRC-VPI-150-3P-480 $____8,936_________
4. BASE ENGINE UNIT #__GTA855e__________ $____75,000________

All of the additional items not included in the base cost can vary greatly from application to application. These items vary depending on the engine and generator selected and is engineered independently for each unit. They include the cost of the engine-generator enclosure, engine frame/mounting, skid or trailer, gas supply components, hookup hardware, cabling and conduit, electronics enclosure, and other external mechanical and electrical components required for installation. Note that some options are dependent on the deployment location and governing regulations and rules for that location. The following outline is a placeholder for those costs:

1. ENGINE FRAME $__________________
2. RADIATOR MOUNTING $__________________
3. EXHAUST/CATALYST MOUNTING $__________________
4. SKID $__________________
5. TRAILER $__________________
6. INVERTER ENCLOSURE MOUNTING FRAME $__________________

7. CABLING/CONDUIT INV. ENC. TO GEN. $_________________
8. CABLING/CONDUIT TO LOAD/ROC $_________________
9. GAS REGULATOR/VOLUME-POT $_________________
10. GAS CONNECTION HARDWARE/PIPE $_________________
11. FULL ENCLOSURE $_________________
12. FULL ENCLOSURE HARDWARE $_________________
13. GEN. ENCLOSURE+HARDWARE $_________________

Appendix B

The following table (Table 9) contains details about latest quotes and summary specifications for the engines recommended in this guide.

Engine Make	Engine Model	Vendor Contact	Last Quote(s)	Description of included features
Arrow	A Series, VR Series	Doug Waggoner 918-346-3750	5/1/12 *See email quote below	*See Arrow product description in the design guide file
Cummins	G855	Robby Severance Power Systems Representative Cummins Southern Plains, LLC Direct: 405-948-2211 Fax: 405-946-3336 Mobile: 405-820-6694	5/1/12 – 61,000	• Cummins natural gas engine (to operate on dry processed pipeline gas) • Steel sub-base with integral isolation Unit • mounted 104 deg. F ambient radiator • Heavy duty air cleaner • EPA SI NSPS capable catalyst for stationary prime applications • Lube oil and antifreeze • EP SI NSPS **compliant capable** for stationary prime applications
Cummins	GT855e	Robby Severance Power Systems Representative Cummins Southern Plains, LLC Direct: 405-948-2211 Fax: 405-946-3336 Mobile: 405-820-6694	5/1/12 – 75,000	• Cummins natural gas engine (to operate on dry processed pipeline gas) • Steel sub-base with integral isolation Unit • mounted 104 deg. F ambient radiator • Heavy duty air cleaner • EPA SI NSPS capable catalyst for stationary prime applications • Lube oil and antifreeze • EP SI NSPS **certified** for stationary prime applications

Cummins	KTA19GC	Robby Severance Power Systems Representative Cummins Southern Plains, LLC Direct: 405-948-2211 Fax: 405-946-3336 Mobile: 405-820-6694	5/1/12 – 100,000	• Cummins natural gas engine (to operate on dry processed pipeline gas) • Steel sub-base with integral isolation Unit • mounted 104 deg. F ambient radiator • Heavy duty air cleaner • EPA SI NSPS capable catalyst for stationary prime applications • Lube oil and antifreeze • EP SI NSPS **compliant capable** for stationary prime applications
Waukesha	F18GSI	Johnathan Staley 713-202-9836 staley@wpi.com	4/25/12 – 101,141.00 / 95,192.00	*See Waukesha specification for the VGF series engines in the design guide file
Waukesha	H24GSI	Johnathan Staley 713-202-9836 staley@wpi.com	4/25/12 - 132,482.00 / 124,689.00	*See Waukesha specification for the VGF series engines in the design guide file

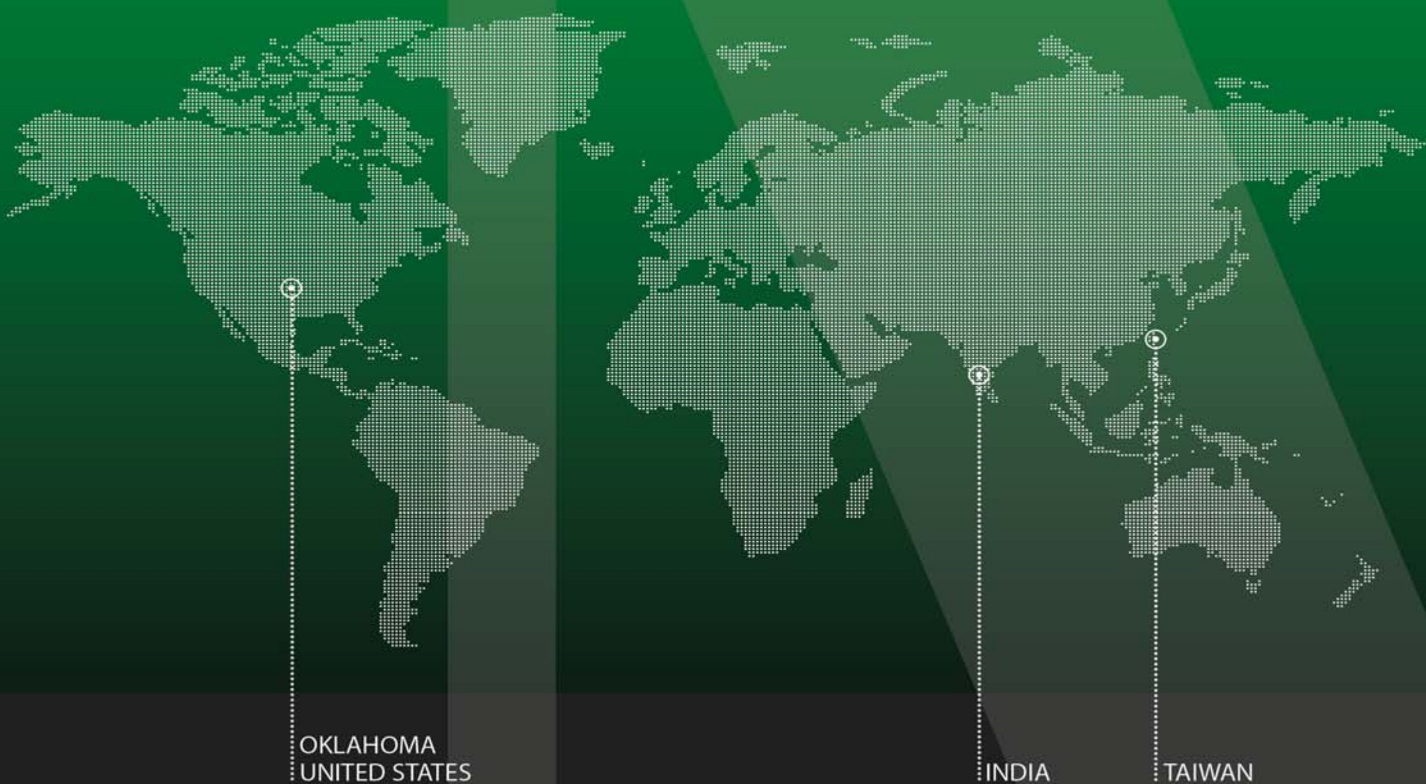
Table 9 - Engine quotes and summary specifications

Arrow Quotes:

Arrow Pricing

Model	hp	Price With Non-insulated Enclosure, No Doors	Price w/o Enclosure	EPA Certifiable Package Part Number	EPA Package Cost	ECU
A32	24.5	$ 8,000	$ 7,800	EPA certified engine (pending approval).		not required
A42	24-47	$ 9,921	$ 8,323	AFR-A42 Altronic	$ 5,866.77	included
A54	26-68	$ 11,934	$ 11,245	AFR-A54 Altronic	$ 5,866.77	included
A54C	35-72	$ 12,934	$ 12,245	AFR-A54 Altronic	$ 5,866.77	included
A62	40-80	$ 13,344	$ 12,810	AFR-A62 Altronic	$ 5,866.77	included
A62T	50-110	$ 15,549	$ 15,015	AFR-A62 Turbo	$ 8,142.92	included
A90	109		$ 26,800	AFR-A62 Turbo	$ 8,142.92	naturally aspirated

Full enclosures can run between $1,000 and $2395. Above quotes include radiator, skid, shade and rain frames without doors.



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