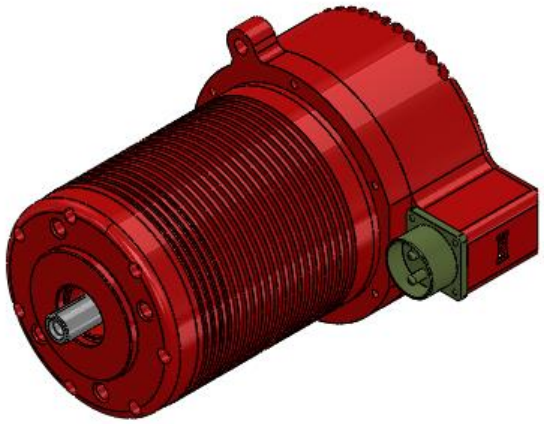
4KW 28VDC MOTOR USER MANUAL

1 Before you proceed

Carefully read and follow all instructions in this and any accompanying materials to prevent serious damage to your system. Failure to follow these instructions will be considered abuse and/or neglect.



If you have any questions about your system, Technical support is available Monday through Friday from 8:00am to 5:00pm pacific time. Technical assistance is also available by e-mailing customer support with your questions at support@kawakaviation.com.

2 Safety precautions

- Double check your connector polarity before plugging in. ***If reverse polarity power is applied, this will destroy the controller.***
- Keep clothing and loose items clear of the motor shaft. Failure to do so could result in injury.
- Take care not to get burned. Motor housing can reach up to 100C when running under load.

3 Introduction

The Kawak 28VDC brushless motor was developed in partnership with Castle Creations as a drive for a hover refill pump (HRP). The HRP is a water pump which is suspended below fire-fighting helicopters and allows them refill their water tanks from lakes or rivers without landing. The pump delivers 600 to 900 GPM (depending on hose size) allowing the helicopter to refill quickly and maximize firefighting capacity. The key features of motor for this application are:

- High power output from 28VDC
- Complete sealing of motor including double shaft seals
- Rugged aluminum housing
- Integrated electronic speed controller (ESC) for compactness and simplicity of operation.

These features also make the motor suitable for use as a drive motor for vehicle A/C compressors. The features of the motor important to this application are:

- high efficiency to minimize motor cooling requirements
- torque and thermal overload protection
- 50% additional surge output capability at start up to meet A/C pull-down requirements.

4 Anatomy of the Kawak 28V BLDC motor

Place holder: Cut away view showing:

- Motor rotor & stator
- Shaft bearings and seals
- Controller housing

5 Specifications

The integrated electronic speed controller (ESC) uses Castle Creations sensorless BLDC technology to deliver high output and efficiency while protecting the motor from overload.

Motor performance		
Supply voltage	28	V DC
No load current	5	A
No load speed	3700	RPM
Rated torque	12.4	Nm
Speed at rated torque, 28V[1]	3070	RPM
Power output at rated torque, 28V[1]	3.98	kW
Current at rated torque[1]	160	A
Max. efficiency	90%	
Torque constant[1]	0.082	Nm/A
Speed constant[1]	130	RPM/V
Speed/ torque gradient	48	RPM/Nm
Number of poles	8	
Protective Features		
Phase current limit[2]	180	A

[1] At full throttle. Motor input current at rated torque decreases in proportion to throttle. Motor no-load speed also declines in proportion to speed. Motor speed at rated torque declines more that proportionally with throttle (difference from no-load speed remains constant).

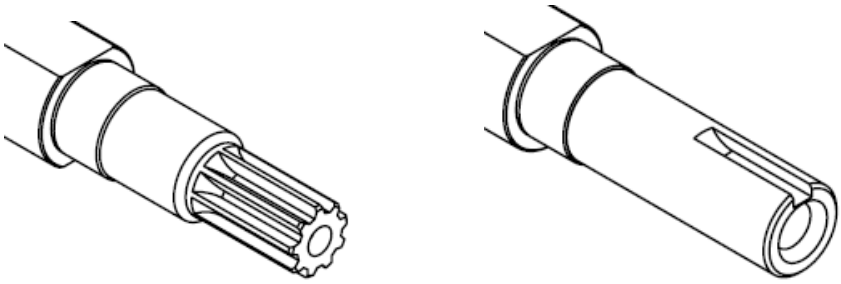
[2] Phase current is the current flowing through the ESC transistors. It equals the input current x throttle percentage.

Start up surge capability (10s)		240	A
ESC shutdown temperature		105	°C
Thermal data			
Motor case temperature rise at rated torque	5m/s air flow	41	°C
ESC temperature rise at rated torque[3]		49	°C
Max. ESC temperature		105	°C
Thermal time constant		15	min
Other specifications			
IP Rating		IP66	
Weight		11.8	kg

6 Physical connections

6.1 Shaft Connections

The motor is available with either a 5/8”-9 SAE splined shaft or ¾” keyed shaft as shown in Figure 1. The splined shaft is used to drive the HRP impeller, but is also suitable for driving hydraulic pumps. The ¾” keyed shaft is used with a pulley in the A/C compressor drive application.



ANSI B92.1-1996, 5/8”-9 Spline ANSI B17-1, ¾” Keyed Shaft

Figure 1: Standard Shaft Connections

6.2 Mounting Features

Figure 2 shows the motor’s mounting features. There are four 3/8”-16 threaded holes on the on the face for mounting along with two mounting “ears” near the opposite end. The ears have clearance holes for 3/8” bolts. A 3.25”-diameter pilot on the motor face provides for shaft alignment if needed.

[3] Measured at full throttle. ESC heat generation increases substantially at partial throttle due to transistor switching losses.

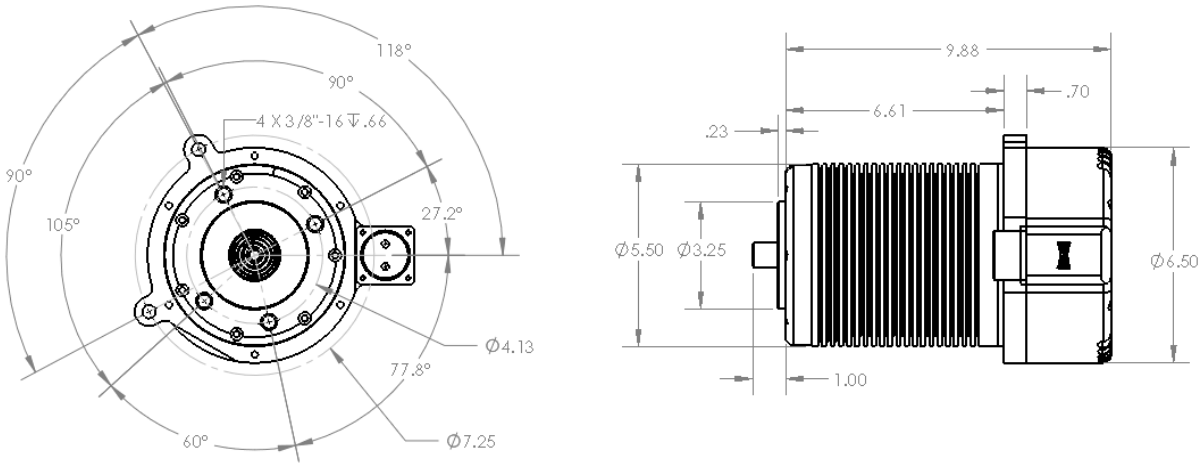


Figure 2: Motor mounting dimensions

6.3 Shaft Side Loads

When driving a pulley, a substantial side load is generated on the front motor bearings. These side loads have a strong influence on the estimated bearing life, as shown in Figure 3. To estimate side load:

1. Determine distance from motor face where side load is centered (dimension D in Figure 4).
2. Estimate front bearing radial load as $F_{radial,front} = F_{side}\left(1 + {}^{L_1}/_{L_2}\right)$ where Fside is the side load on the shaft.

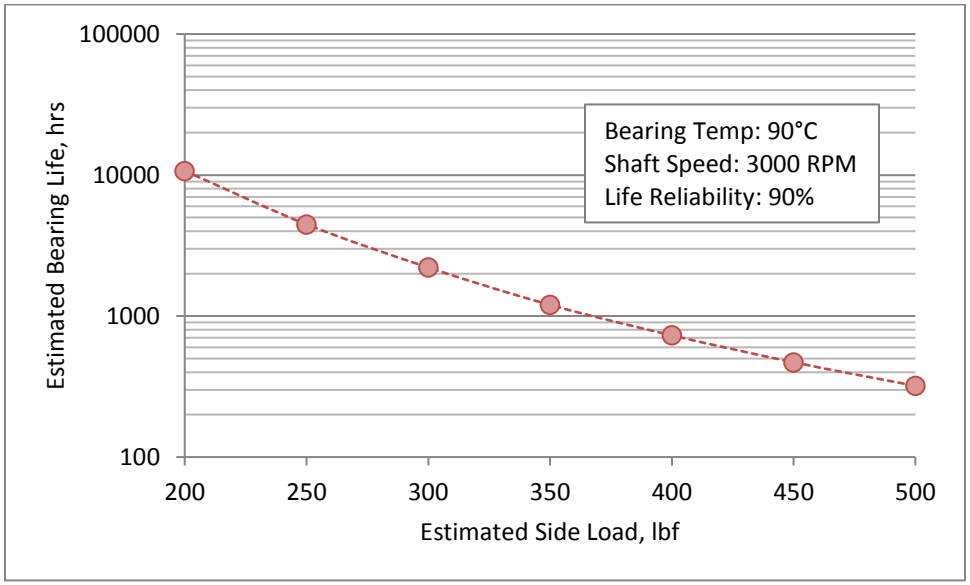


Figure 3: Front bearing estimated life vs radial load.

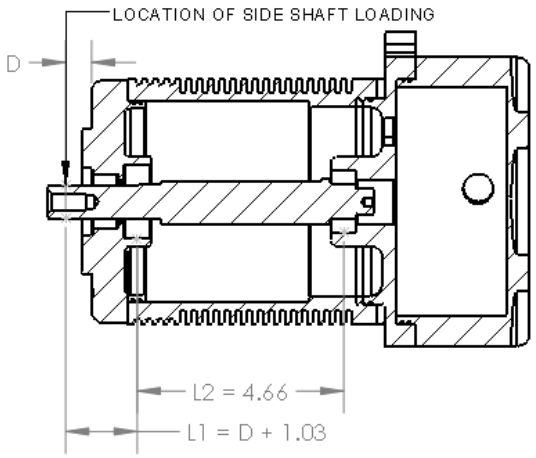


Figure 4: Dimensions for estimating front bearing radial load.

6.4 Typical Electrical hookup

The motor needs to energized with a motor contactor sized to interrupt at least 150A. Under normal conditions, the motor can draw up to 240A at start up for up to 10 seconds. Allowable current then ramps down at 5A per second to 180A. Fusing should be sized to accommodate this level of current draw.

6.5 Recommended power connector

The power connector on the motor is an Amphenol Industrial circular connector, part number MS3102R24-9P-11. The recommended mating part is Amphenol Industrial part number ACC06E24-9R-003 (Figure 5). This connector includes crimp sockets for #4 wire. See an Amphenol Industrial distributor for tools and other options.

Figure 5: Exploded view of mating power connector

7 Programming

Kawak provides a motor drawing to each customer which lists the settings with which their motors will ship. To make changes to the motor settings or update firmware after receipt, the following items are needed:

- CastleLink USB Programming Kit, P/N 010-0005-00
- CastleLink Software available on the Kawak website

7.1 Connection to motor

1. Remove the programming port plug using a 5/16" hex key wrench.
2. Pull the programming connector out of the port using a tweezers or screwdriver as shown in Figure 6
3. Plug CastleLink programmer USB cable into your computer. The programmer should light up with a solid red LED.
4. Plug the programming connector into the CastleLink programmer making sure orange wire on cable aligns with square wave symbol on programmer (Figure 7). The programmer's red and green LED should begin flickering to indicate communication.

Figure 6: Programming cable

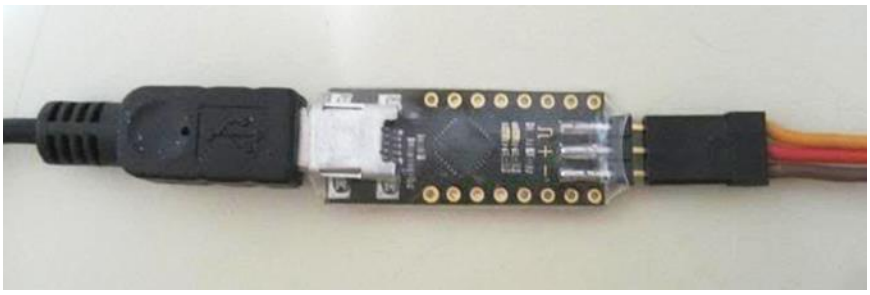


Figure 7: Connecting CastleLink programmer

7.2 Software Installation

1. Run the CastleLinkInstall application provided by Kawak.
2. When finished, Open the CastleLink software using either the link added to your Start Menu or the desktop icon.
3. The program may inform you that a newer version is available and ask if you would like to update – select "No".
4. The initial startup screen should appear as shown in Figure 8.

   If you do not see this, check the connection status at the lower left. A red "USB Connected" light indicates the programmer has not been detected. Check USB cable connection.

   A red "Device Linked" light indicates the programmer is not able to talk to the ESC. Check the connection of the motor programming cable to the programmer.

   Contact Kawak if problem is not resolved.

Figure 8: Initial CastleLink screen

7.3 Settings description

Once connected to the motor, the various settings can be accessed by selecting the different tabs across the top of the window. The following table provides explanation of the settings.

Tab	Setting
Throttle	**Control Mode**: Determines how motor speed is controlled. **Full Throttle:** In this mode, the motor will run at the maximum speed for the supplied voltage. Although speed will vary with load, this is the most efficient mode for the motor and allows it to stay coolest for a given load. **Fixed Speed:** In this mode, the ESC adjusts the throttle setting to maintain a target speed. Due to switching losses which occur at partial throttle, the ESC losses will be higher and the ESC will run hotter than at full throttle. If the desired speed is higher than the motor can run with the available voltage, then the motor runs at full throttle.
	Desired Speed: This is the target speed for the fixed speed control mode. The minimum value is 750 RPM. The ESC will shut down if speed drops below 750 RPM after the first 10 seconds of operation.
	Magnetic Poles: This parameter is used to calculate drive frequency needed to achieve the target speed. It will always be a multiple of 2. The standard Kawak motor has 8 poles.
	Initial Spool-Up Rate: This setting controls how quickly the motor speed ramps up in fixed speed mode. This only applies to the fixed speed control mode. A high ramp rate is recommended, although a slow ramp rate may provide a quieter spool up.
	Governor Gain: The governor gain only applies to fixed speed mode. It adjusts how responsive the ESC is to deviations from the target speed. The higher the governor gain is set, the more steady the motor speed will be but the less steady motor power draw will be.
Cutoffs	**Current Limiting:** The 'Current Limiting' cutoff limits winding current. This protects the ESC from damage by high currents that occur when the motor is overloaded. It may be set from 100A to 240A. However, maximum steady state current limit is 180A for full throttle operation and 130A for fixed speed operation. For selections above these levels, the ESC will only allow the selected current for the first 10 seconds and will then ramp down to the maximum steady state. Note that current recorded in log is input current which is the product of motor power (PWM duty) and input current. So motor current limiting may be active even though input current is below setting.
	Pullback Temperature: The ESC will begin derating the phase current limit when this temperature is reached. Derating will increase linearly from 0% at pullback to 75% at shutdown temperature. Typically, the maximum value is used for this setting. Allowable settings are 175F to 215F.

Tab	Setting
	Shutdown Temperature: The ESC will shut down when this temperature is reached. Allowable settings are 175F to 245F. Typically, a value just above the pullback temperature is used. Once shutdown, the motor will not restart until it has cooled below the lockout temperature: 85C when current limit is above 160A and 100C for current limits at or below 160A.
Motor	**Motor Start Power:** This setting controls how much power is allowed into the motor to get it started for the first few revolutions from a dead stop. For centrifugal pumps, starting torque is typically low and a low to medium setting can be used. For compressors where starting torque may be high, it is best to use a high setting. The numeric value is the percentage of maximum allowable start power.
	Motor Timing: Motor timing advance changes the timing advance range used on the motor. Generally, low advance gives more efficiency and less power. High advance gives more power at the expense of efficiency (motor heat). The controller automatically determines the correct and best range of timing advance for the motor, and this setting allows you to move up or down within that range.
	Direction: The direction setting determines the direction of shaft rotation. It is specified as clockwise or counterclockwise when looking at the motor face.
Other	**Live Link Enable:** Live link is a data reporting protocol used to send real-time data out over the programming connector. The Castle SerialLink adapter is required to use this. In addition, the middle pin must be removed from SerialLink header that plugs into the programming cable--failure to do so will cause skewed ESC readings. Also, SerialLink ground must be isolated from motor ground—skewed ESC current readings can result otherwise. See SerialLink manual on Castle website for details.
	Full Synchronous Enable: This setting controls how ESC operates at partial throttle. The ESC provides part throttle operation by switching very quickly between applying the full supply voltage to the windings and shorting them. This setting controls how current flows through the ESC during the shorted-out time, called recirculation. When disabled, current flows through diodes on the ESC which cause significant power dissipation. When enabled, current flows through the switching transistors which provide less resistance. At full throttle, there is no recirculation and this setting makes little difference.

Tab	Setting
Logging	**Logging Enables:** These settings allow selection of what ESC data is recorded in the log. The logged data can be downloaded and viewed after running the motor using the CastleLink program. Selecting more items will decrease the amount of time you can log data. Conversely, selecting fewer items will give you a longer logging duration. **Input Current:** This is the amount of current that motor is drawing from your power source. **Input Ripple:** This is the change in voltage, or ripple voltage, measured each time the motor is pulsed. The motor is pulsed several thousand times per second while it is running. Higher Ripple Voltages will result in higher controller temperature, and may indicate an inadequate battery or overloaded battery/motor setup. Lower Ripple Voltages are always better. **Input Voltage:** This is the voltage detected by the ESC from your power source. **Controller Temperature:** This is the temperature measured on your ESC. **Controller Motor Power Output:** This is the percentage of full power your ESC is delivering to your motor. It is the also known as PWM duty. **Motor RPM:** This is the electrical cycles per minute. Multiply by 2/n to get shaft RPM, where n is the number of magnetic poles. (i.e., multiply by 0.25 for standard Kawak motor).
	Sample Frequency: This setting selects how often the controller logs data, in samples per second. So, a setting of 1 will log data once per second (1Hz) while a setting of 10 will log data 10 times per second (10Hz).
	Automatic Data Reset: On power-up if the Data Log Buffer is filled above this percentage all data is erased and logging starts over. Kawak recommends using 50%. This ensures at least half of the buffer will be available at the start of each run.
Software	This tab allows the user to see the current firmware version installed on the ESC and update if needed.
Save-Print	This tab allows the user to save settings to a file and to print the settings.

8 Motor operation

When power is applied to the motor there is a brief inrush of current as the 7200 uF of buffer capacitors in the ESC are charged. With a few milliseconds, the ESC boots up and begins starting the motor. At this point, the ESC does not know the orientation of the motor and begins exciting the motor windings in a fixed sequence. Sometimes the shaft may appear to oscillate or even rotate backward half a turn during this process. However, as soon as the shaft begins to rotate, the ESC is able to detect the orientation of the rotor

and synchronize the winding excitation to the movement of the rotor and begin smoothly spin the motor up to operating speed. Typically, the whole process takes about 1 second.

During operation, the ESC has two main protective features. First it monitors the motor phase current (a.k.a, winding current) and reduces switching duty as needed to keep the phase current under the current cutoff setting. The ESC can only maintain the highest current limit settings for the first 10 seconds, after which it ramps down the allowable current to 180A for full throttle operation or down to 130A for partial throttle operation. Figure 9 illustrates this for a current limit setting of 240A.

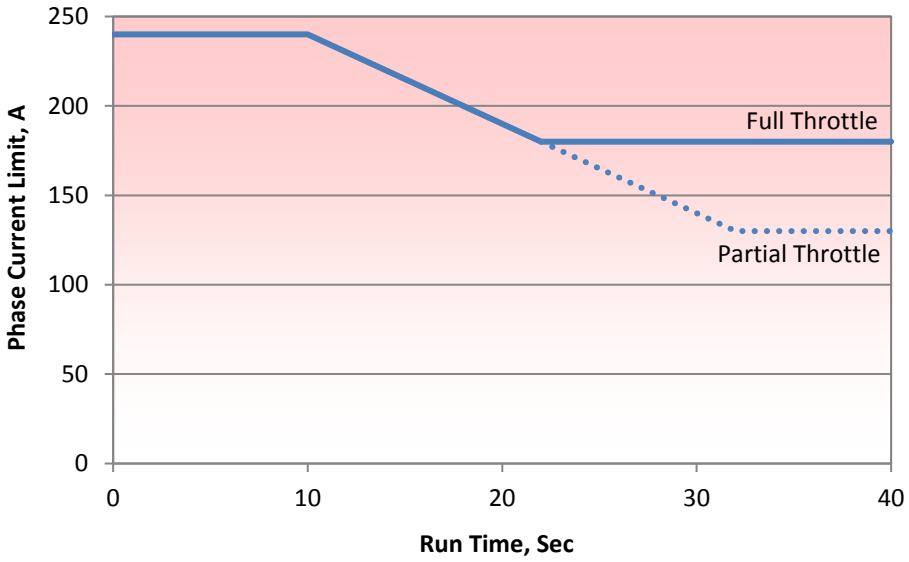


Figure 9: Current limit behavior for "burst" settings.

In pump and fan applications where load is strongly dependent on speed, overloading the motor results in limited speed--the motor runs at the speed where the phase current equals the limit. In compressor applications where load is weakly related to speed, overloading the motor results in the motor stalling rapidly. When speed drops below 750 RPM, the ESC will shutdown.

The second main protective feature is a temperature-based derating of the phase current limit. Figure 10 shows the derating curve. Derating begins at the pullback temperature and ramps linearly down to 25% of nominal current limit at the shutdown temperature. The pullback and shutdown temperature are settable through CastleLink over the range shown in the Figure. The recommended setting is as shown in the figure and will ensure the motor does not fail prematurely. Higher settings will allow operation in more extreme environments, but may lead to premature failure of the ESC and/or motor bearings.

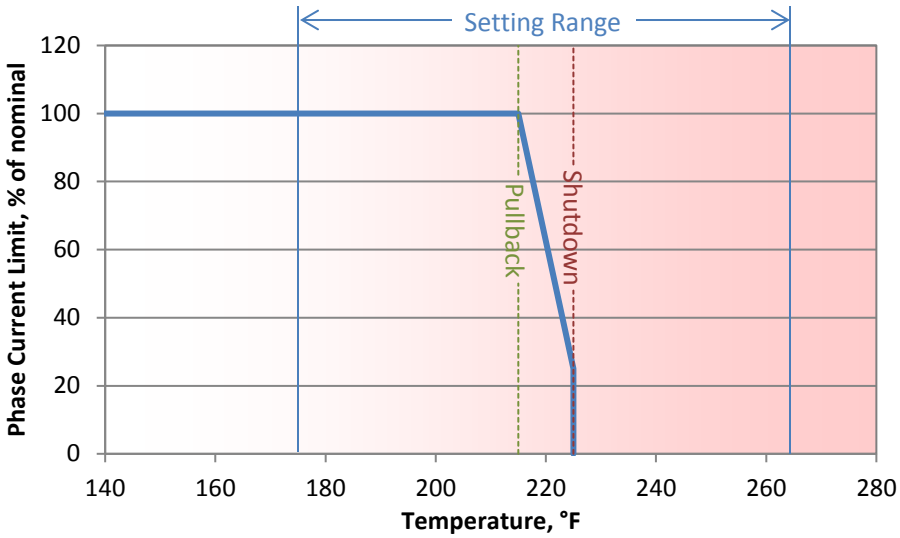


Figure 10: Phase current limit derating with temperature.