

Manual for EMRAX motors





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Dear customer,

Congratulations on your purchase of EMRAX electric motor.

This drive is a Slovenian product of a completely new type of pancake axial flux synchronous electric motor, which will keep its capability for a long time if treated the right way. It can also work as a generator with the same technical data. Firstly the drive was developed for airplane. Therefore our target was to build reliable, low weight, high power direct drive electric motor with high efficiency. The drive was developed and tested by Roman Sušnik, dipl. ing. (company Enstroj) on electric glider airplane Apis EA2, it was also laboratory tested in Piktronik (January 2011), Siemens (May 2012) and Letrika (November 2014) company. Furthermore our customers give us some test results which are comparable with our tests. In February 2014 thermal tests were performed on EMRAX motors. Motor was exposed to -40°C to +160°C for 17 days (24h/day), this means 408 hours non-stop. EMRAX passed this examination with excellent results, without any damages.

We achieved our objective and built a high-powered, high torque, extremely light, direct drive, low noise electric motor, which efficiency is up to 98%. Because of the high torque EMRAX engine can achieve high power also at relatively low rotation speeds.

EMRAX allows a gearless drive without the usually essential step-up gear unit which causes power losses, additional weight, complexity and maintenances. The motor has much higher power-to-weight ratio compared to other brushless AC synchronous motors. Mechanical and no load electrical loses are very small, so our motors can run on higher RPM – in this case we can achieve very high motor power (up to 200 kWp). EMRAX can also deliver few times higher torque at higher RPM with some reduction drive.

Because of the small internal winding resistance and eddy currents in the motor we achieved a wide range operating at excellent motor efficiency (very low power dissipation).

Though many intensive tests that had already been made and though parts that were produced by modern CNC machines, the motor is still not a real series product. Many manufacturing processes are still made by hand, what makes every drive of the first series unique. So, our first customers are and they will be part of a field test and we are already excited which experiences they make with the new motor.



1. Technical data of EMRAX motors

EMRAX motors/generators are <u>BRUSHLESS SYNCHRONUS THREE PHASE AC (Alternating Current)</u> <u>MOTORS/GENERATORS</u>. We offer different EMRAX motor types (the number in the name means the diameter of the motor in mm):

<u>EMRAX 207:</u>

- High Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Medium Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Low Voltage (Air Cooled / Liquid Cooled / Combined Cooling)

EMRAX 228

- High Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Medium Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Low Voltage (Air Cooled / Liquid Cooled / Combined Cooling)

<u>EMRAX 268</u>:

- High Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Medium Voltage (Air Cooled / Liquid Cooled / Combined Cooling)
- Low Voltage (Air Cooled / Liquid Cooled / Combined Cooling)



EMRAX 207 Technical Data Table

Туре	EMRAX 207 High Voltage			м	EMRAX 207 edium Volta	ge	EMRAX 207 Low Voltage			
Technical data	-	ingin vontage				8-				
Air cooling = AC Liquid cooling = LC Combined cooling = Air + Liquid cooling = CC	AC	LC	сс	AC	LC	сс	AC	LC	сс	
Ingress protection	IP21	IP65	IP21	IP21	IP65	IP21	IP21	IP65	IP21	
Cooling medium specification (Air Flow = AF; Water Flow = WF – if inlet water temperature and/or ambient temperature are lower, then continuous power is higher)	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	
Weight [kg]	9,1	9,4	9,3	9,1	9,4	9,3	9,1	9,4	9,3	
Diameter ø / width [mm]					207 / 85					
Battery voltage range [Vdc]	500 (*580) – to get 70	00 RPMp)	300 (*350) – to get 70	00 RPMp)	115 (*135	5 – to get 70	00 RPMp)	
Peak motor power (few min at cold start / few seconds at hot start) [kW]					80					
Continuous motor power (depends on the motor RPM 3000 - 5000) [kW]	20 - 32	20 - 32	25 - 40	20 - 32	20 - 32	25 - 40	20 - 32	20 - 32	25 - 40	
Maximal rotation speed [RPM]				600	00 (*7000 pe	ak)				
Maximal motor current (for 2 min if cooled as described in Manual for EMRAX motors) [Arms]	200			320			800			
Continuous motor current [Arms]	100				160		400			
Maximal peak motor torque [Nm]					160					
Continuous motor torque [Nm]					80					
Torque / motor current [Nm/1Aph rms]		0,83			0,54			0,20		
Maximal temperature of the copper windings in the stator and also max. temp. of the magnets [°C]					120					
Motor efficiency [%]					93-98%					
Internal phase resistance at 25 °C $[m\Omega]$		12,0			5,7		0,8			
Input phase wire cross-section [mm ²]		10,2			15,2		38			
Induction Ld/Lq [μH]		125/130			52/56		7,2/7,5			
Controller / motor signal					sine wave					
Specific idle speed (no load RPM) [RPM/1Vdc]		15			22		58			
Specific load speed (depends on the controller settings) [RPM/1Vdc]	11 – 15			18 – 22			50 – 58			
Magnetic field weakening (for higher RPM at low torque) [%]	up to 100									
Magnetic flux – axial [Vs]		0,0393		0,0257 0,0						
Temperature sensor in the motor					kty 81/210					
Number of pole pairs					10					
Rotor Inertia (mass dia=160mm, m=4,0kg) [kg*cm²]					256					
Bearings SKF FAG	R/R 6206/6206 or R/AR 6206/7206 or AR/AR 7206/7206 (»O« orientation)									

*For a few seconds.

Maximal battery voltage is 600 Vdc (EMRAX 207 High Voltage). Maximal RPM must not be exceeded.

It is possible to weaken the magnetic field (up to 100%) to get higher RPM at existing battery voltage. Maximal RPM must not be exceeded.

These data are valid for the motors, which were sold after January 2014.

EMRAX motors that had been made before May 2012 have 30% lower power/torque and RPM than new generation of EMRAX motors.



Graphs for EMRAX 207 High Voltage with **Combined Cooling (IP21)**:

Graphs do not show totally the same maximum efficiency and maximum RPM as described in Technical data tables. We are preparing new test graphs from Letrika company, which will show the same specifications as listed in Technical data tables.











-Power loss



EMRAX 228 Technical Data Table

Туре	EMRAX 228 High Voltage		EMRAX 228 Medium Voltage			EMRAX 228 Low Voltage				
Technical data						-8-				
Air cooling = AC Liquid cooling = LC Combined cooling = Air + Liquid cooling = CC	AC	LC	сс	AC	LC	сс	AC	LC	сс	
Ingress protection	IP21	IP65	IP21	IP21	IP65	IP21	IP21	IP65	IP21	
Cooling medium specification (Air Flow = AF; Water Flow = WF – if inlet water temperature and/or ambient temperature are lower, then continuous power is higher)	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	
Weight [kg]	12,0	12,3	12,3	12,0	12,3	12,3	12,0	12,3	12,3	
Diameter ø / width [mm]					228 / 86					
Battery voltage range [Vdc]	50 – 600	50 – 600 (*700 – to get 6500 50 – 450 (*540 – to get 6 RPMp) RPMp)					24 – 150 (*180 – to get 6500 RPMp)			
Peak motor power (few min at cold start / few seconds at hot start) [kW]					100					
Continuous motor power (depends on the motor RPM 3000 - 5000) [kW]	28 - 42	28 - 42	35 - 55	28 - 42	28 - 42	35 - 55	28 - 42	28 - 42	35 - 55	
Maximal rotation speed [RPM]	5500 (*6500 RPM peak)									
Maximal motor current (for 2 min if cooled as described in Manual for EMRAX) [Arms]	240			340			900			
Continuous motor current [Arms]		115		160			450			
Maximal motor torque (for a few seconds) [Nm]					240					
Continuous motor torque [Nm]					125					
Torque / motor current [Nm/1Aph rms]		1,1			0,75			0,27		
Maximal temperature of the copper windings in the stator and also max. temp. of the magnets [°C]					120					
Motor efficiency [%]					93 – 98					
Internal phase resistance at 25 °C [mΩ]		18			8,0			1,12		
Input phase wire cross-section [mm ²]	10,2			15,2			38			
Induction in Ld/Lq [µH]		175/180			75/80			10,6/11,2		
Controller / motor signal					sine wave					
Specific idle speed (no load RPM) [RPM/1Vdc]		9,8			14		40			
Specific load speed (depends on the controller settings) [RPM/1Vdc]	8 - 9,8			11 - 14			34 – 40			
Magnetic field weakening (for higher RPM at low torque) [%]	up to 100									
Magnetic flux – axial [Vs]		0,0542			0,0355			0,0131		
Temperature sensor in the motor					kty 81/210					
Number of pole pairs					10					
Rotor inertia (mass dia=175mm, m=5,5kg) [kg*cm²]					421					
Bearings SKF FAG	R/R 6206/6206 or R/AR 6206/7206 or AR/AR 7206/7206 (»O« orientation)									

*For a few seconds.

Maximal battery voltage is 700 Vdc (EMRAX 228 High Voltage). Maximal RPM must not be exceeded.

It is possible to weaken the magnetic field (up to 100%) to get higher RPM at existing battery voltage. Maximal RPM must not be exceeded. These data are valid for the motors, which were sold after January 2014.

EMRAX motors that had been made before May 2012 have 30% lower power/torque and RPM than new generation of EMRAX motors.



Graphs for EMRAX 228 High Voltage with **Combined Cooling (IP21)**:

Graphs do not show totally the same maximum efficiency and maximum RPM as described in Technical data tables. We are preparing new test graphs from Letrika company, which will show the same specifications as listed in Technical data tables.





EMRAX 228 High Voltage LC



Owner's manual for the brushless AC synchronous motor EMRAX







EMRAX 268 Technical Data Table

Туре	EMRAX 268		EMRAX 268			EMRAX 268			
Technical data	ŀ	Low Voltage Low Voltage Low Volta					Low Voltage	9	
Air cooling = AC Liquid cooling = LC Combined cooling = Air + Liquid cooling = CC	AC	LC	сс	AC	LC	сс	AC	LC	сс
Ingress protection	IP21	IP65	IP21	IP21	IP65	IP21	IP21	IP65	IP21
Cooling medium specification (Air Flow = AF; Water Flow = WF – if inlet water temperature and/or ambient temperature are lower, then continuous power is higher)	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	AF speed 25 m/s; 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C	inlet WF 8 l/min - 40°C; ambient air 25°C
Weight [kg]	19,9	20,3	20,3	19,9	20,3	20,3	19,9	20,3	20,3
Diameter ø / width [mm]					268/91				
Battery voltage range [Vdc]	50 – 600 (*700 – to get 3400 RPMp)			50 – 400 (*700 - to get 5000 RPMp)			24 – 130 Vdc (*240 to get 5000 RPMp)		
Peak motor power (for few min at cold start / few seconds at hot start) [kW]	160			200			160		
Continuous motor power (depends on the motor RPM 2000 - 4000) [kW]	40 - 75	40 – 75	50 - 90	40 - 80	40 - 80	50 - 100	40 - 75	40 – 75	50 - 90
Maximal rotation speed [RPM]				4000 RPI	VI (*5000 RI	PM peak)			
Maximal motor current (for 2 min if cooled as described in Manual) [Arms]	240			360			1000		
Continuous motor current [Arms]	125			180			500		
Maximal motor torque (for a few seconds) [Nm]					500				
Continuous motor torque [Nm]					250				
Torque / motor current [Nm/1Aph rms]		2,0		1,4			0,5		
Maximal temperature of the copper windings in the stator and also max. temp. of the magnets [°C]					120				
Motor efficiency [%]					93 - 98				
Internal phase resistance at 25 °C [mΩ]		26		11,5			1,7		
Input phase wire cross-section [mm ²]		10,2			15,2		38		
Induction in Ld/Lq [µH]	_	350/370			150/160		19/21		
Controller / motor signal					sine wave				
Specific idle speed (no load RPM) [RPM/1Vdc]	5,4			8,2			22,2		
Specific load speed (depends on the controller settings) [RPM/1Vdc]	4,5 – 5,4			7 – 8,2			18 - 22,2		
Magnetic field weakening (for higher RPM at lower torque) [%]	up to 100								
Magnetic flux – axial [Vs]	0,1014				0,0664		0,0245		
Temperature sensor in the motor					kty 81/210				
Number of pole pairs					10				
Rotor inertia (mass dia=195mm, m=9,8kg) [kg*cm²]					932				
Bearings SKF _ FAG	R/R 6206/6206 or R/AR 6206/7206 or AR/AR 7206/7206 (»O« orientation)								

*For a few seconds.

Maximal battery voltage is 700 Vdc (EMRAX 268 High Voltage). Maximal RPM must not be exceeded.

It is possible to weaken the magnetic field (up to 100%) to get higher RPM at existing battery voltage. Maximal RPM must not be exceeded. These data are valid for the motors, which were sold after January 2014.

EMRAX motors that had been made before May 2012 have 30% lower power/torque and RPM than new generation of EMRAX motors.



2. Intended usage of EMRAX motor/generator and corresponding components

The drive right now is in the testing phase in the field. The customer assumes responsibility to share experiences made with the drive with the manufacturer, so that the manufacturer can gather know-how and identify possible weaknesses.

Before selling EMRAX motor, every EMRAX is tested at standard parameters (described in Technical data tables) in our company operating as a generator and as a motor with Unitek BAMOCAR D3 or BAMO D3 controller.

The drive is built according to the state of the art and to approved safety-related rules. However, risks for life and limb of the user or other parties as well as damages to the device or other material assets can arise.

Only use the system in technically soundness, safety-conscious, according to the intended usage and be aware of dangers! Especially faults which can affect the safety should be cleared immediately!

Do not to use the motor in salt environment directly.

Avoid full throttle idle running at higher voltages. Speed (motor rotation) must be limited in the controller SW according to Technical data table for each EMRAX type.

EMRAX motor must be used in accordance with operating and cooling conditions, which are described in Technical data table for each EMRAX type, otherwise the warranty does not apply.

Be aware of the following safety instructions BEFORE STARTING:

- It is essential to permanently check the loads driven by the motor for damages, cracks etc. The use of damaged loads can lead to heaviest injuries.
- The frequency converter needs to be mounted jacked up, so that a vibration free use is unconditionally guaranteed. If this is not the case, vibrations can cause contact faults and further the breakdown of devices. This may lead to damages to the electronic system or to components in its environment.
- Before starting, the right direction of rotation has to be checked and if necessary be changed
 motor connectors UVW must be set according to the controller phase positions. UVW (1, 2, and 3) connectors of the motor are parallel to UVW output phases from the controller.
- The drive should be if possible directly connected to the frequency controller, without any inserted connectors. If this is not possible, only use high current capable, low-impedance, the best quality connectors. Shoddy connectors lead to voltage peaks and can destroy the frequency converter. Oftentimes unplugging the connector can cause contact problems which may also lead to a destruction of the converter. We also recommend main vacuum switch between the batteries and controller and suitable DC fuse.
- Only use high current connector systems between the motor, converter and the battery. The connectors have to be checked before every use. If the coating is used up, the internal discs in the jacks get play or have lost their resilience, they have to be replaced.
- Shoddy or used up connectors are the most common reason for destructions of the drive, the controller and possible components around it.
- The electric connectors and cables must be connected professional and have to be isolated by a **shrink** hose (Figure 26). Mixing up the polarity of the battery or a short circuit leads to a destruction of the drive and means an acute fire hazard and danger of life!



• The cables should be as shorter as possible. For longer cables diameter of the cable must be bigger. **Power cables must be shielded and distant enough from communication cables**.

3. Mounting the drive

Only use the drive if properly mounted on eight (at the back side of the motor) M8 boreholes destined for that at the stator (Figure 4). EMRAX has an external rotor, which must not at all, not even for trying, be connected to the frequency converter or the power source if the motor is not fixed in the way described above. Propeller and flanged shaft can be mounted on the front motor side on six M8 boreholes destined for that in the rotor (Figure 5; Figure 6). These screws must be screwed down into the rotor (Figure 4):

- at least 15 mm and not more than 16, 0 mm for EMRAX 207
- at least 15,5 mm and not more than 16,5 mm for EMRAX 228
- at least 17,5 mm and not more than 18,5 mm for EMRAX 268

4. Two EMRAX motors connected serially (EMRAX TWIN)

Two EMRAX motors can be connected serially – this is EMRAX TWIN (Figure 15; Figure 16). The first motor needs Prolonged motor shaft from back motor side and the second motor needs Prolonged flanged shaft from front motor side (with 4 inner splines) (Figure 10). The first motor is connected to the second motor using these shafts. These two shafts must be made by Enstroj. If other shafts are used to connect two motors the warranty does not apply. Enstroj also offers a stainless steel carrier for EMRAX TWIN – X shape carrier (Figure 15; Figure 18). Motors are assembled in this system at Enstroj. EMRAX TWIN has doubled power/torque compared to single EMRAX motor. If resolver or encoder is used it must be mounted as tandem on the back side of the second motor (Figure 16; Figure 19).

5. Power transmission and shafts

Power transmission to the load is accomplished by a flange joint with an extension shaft from the rotor. The motor power transmission to the load can be made from the front side and/or back side of the motor:

- If the power transmission is <u>from front side of the motor</u>, than the prolonged flanged shaft is needed. It can be ordered from Enstroj – Prolonged flanged shaft from front motor side (with 4 inner splines) (Figure 5; Figure 13) or customer provides it by himself if custom made splines are needed (inner, outer ...).
- If the power transmission is <u>from back side of the motor</u> customer needs prolonged motor shaft. It can be ordered by Enstroj Prolonged shaft from back motor side (Figure 5; Figure 14). If custom made shaft is needed, customer can make it by himself in this case prolonged motor shaft from back motor side must be send to Enstroj before the motor is assembled (this shaft has to be made precisely for our motors according to our drawings). Before sending the shaft customer must contact Enstroj. Note, that also if prolonged shaft from back motor side is used the 6 M8 screws must be screwed down into the rotor on the front side of the motor, because they carry the torque from rotor rings to the prolonged shaft (Figure 4; Figure 5):
 - $\circ~$ at least 15 mm and not more than 16, 0 mm for EMRAX 207
 - $\circ~$ at least 15,5 mm and not more than 16,5 mm for EMRAX 228
 - $\circ~$ at least 17,5 mm and not more than 18,5 mm for EMRAX 268



• If the motor power transmission is <u>from front and back motor side</u>, than the motor needs prolonged flanged shaft from front motor side and prolonged motor shaft from back motor side. These shafts can be ordered from Enstroj - Prolonged flanged shaft from front motor side (with 4 inner splines) (Figure 5; Figure 13) and Prolonged motor shaft from back motor side (Figure 5; Figure 14). If custom made shafts are needed, customer can make them by himself – in this case prolonged motor shaft from back motor side must be send to Enstroj before the motor is assembled (this shaft has to be made precisely for our motors according to our drawings). Before sending the shaft customer must contact Enstroj.

Prolonged motor shaft and standard motor shaft cannot be replaced once the motor is assembled.

Our shafts are made from hardened steel. Weights of our shafts:

- Standard motor shaft (Figure 1; Figure 2; Figure 8) (included in standard EMRAX motor): 0,65 kg
- Prolonged flanged shaft from front motor side (with 4 inner splines) (Figure 5; Figure 13): 0,60 kg
- Prolonged motor shaft from back motor side (Figure 5; Figure 14): **1,00 kg** (so the motor with this shaft is 1,00 kg 0,65 kg = 0,35 kg heavier than EMRAX with standard shaft)
- Motor shaft with inner splines for EV (Audi/VW transmission gear) side (Figure 11; Figure 12): 0,75 kg

6. Direction of rotation of the drive

EMRAX motors can work as sensorless or with sensor drive control.

- <u>Sensorless</u>: Sensorless commutation can be used for e. g. boats and for applications which do not need high torque at the start applications with propellers. The drive can be driven in counter clockwise well as in clockwise rotation. The pole reversal can be achieved by a change of two of the three motor phase cables or by modifying the software settings by the manufacturer of the controller. Three phase power connectors UVW are shown below on the Figure 22 U (black), V (red), W (blue). In this case controller with sensorless option is needed.
- <u>Sensor drive control</u>: It must be used for e. g. EV and for propeller stopping at the right position. Sensors that can be used are resolver, encoder or hall sensors. Resolver or encoder can be bought from Enstroj – in this case the sensor is mounted by a holder to the motor. If controller needs hall sensors, they must be installed during motor assembly in Enstroj (Figure 20; Figure 21). If the controller uses sensor drive control auto tuning and pre-setting into the controller SW must be done. If using EMRAX TWIN application with two controllers, than tandem resolvers are needed (Figure 16).

7. EMRAX as a generator

Specifications (power/torque) for EMRAX generators are the same as for the motors if the generator is driven <u>with controller</u>. If the generator works without controller, than the power/torque is approximately 40% lower – because there is no control of the right electrical-mechanical angle on load application. If using EMRAX as generator we recommend using liquid cooled type, especially for higher power.

8. The section bearings

Bearings of the rotor are not qualified for forces higher than bearings FAG or SKF model 6206 or 7206 can transfer. Distance between the bearings is 47 mm. Each standard EMRAX motor includes 2 x 6206 bearing



type. We can also include different bearings into the motor at assembling according to the Order Form. Bearings of the motor cannot be replaced. Bearing type depends on the load:

- If the motor is used for radial load only, the front bearing and the back bearing are the same type 6206.
- If the motor is used for axial load with pull <u>OR</u> push mode (one direction) one 7206 and one 6206 bearing is needed e.g. for pull application front bearing is 6206, back bearing is 7206.
- If the motor is used for axial load with pull <u>AND</u> push mode (two directions), than two 7206 bearings are needed ("O bearing arrangement").

In case of doubts, the case of operation shall be discussed with the manufacturer. If the radial or axial load is higher than bearings can bear, than the system must have additional shaft with suitable stronger bearings (belt transmission, chain transmission, gear transmission, direct drive very high load propellers).

A static redundant dimensioning caused by the thrust bearing is to be avoided in any case. Certain resilience in the mount of the drive or the thrust bearing is satisfactory. Required is a clean rotation of the extension shaft. The shaft must be able to be rotated smooth and easy by hand after mounting.

9. EMRAX motor ingress protection (IP CODE)

- **IP21** (Figure 28): 1. Option: <u>Air cooling only</u>.
 - 2. Option: <u>Combined cooling air and liquid</u>

Technical data are described in Technical data tables.

• **IP65** (Figure 29):

Totally closed motor – <u>Liquid cooling only</u>. Dimensions and weight of this motor are the same as for EMRAX with IP21. Continuous power/torque is up to 20% lower, peak is the same compared to EMRAX with IP21.

10. Motor cooling

It is important to care for a sufficient cooling of the motor at any time. A high load of the motor while insufficient cooling is only approvable for a short time of usage. In every case, the electronic measuring (temperature sensor) provided by the manufacturer, should be used to protect the motor from overload.

EMRAX motors have to be used under standard cooling conditions, which are described in Technical data tables (using EMRAX at non-standard conditions causes a forfeit of warranty claims):

• The EMRAX motor <u>must not exceed the temperature below -30°C and above 120°C (not above 110°C for the motors, which were sold before January 2014)</u> on cooper windings and on the magnets. These values are also valid for the **bearings**. If the temperature exceeds these values, it causes a forfeit of warranty claims. Indicator for exceeded temperatures is placed in the motor. In case of disconnection of the temperature sensor, which has to be on the cooper windings, the controller has to stop the motor. The motor temperature sensor detector in the controller must always be enabled, during the motor operation. The temperature of the magnets, so the magnets temperature (outer/surface temperature of the motor) has to be measured with thermal camera. Also in this case it must be considered that the surface motor temperature is lower compared to magnet temperature – difference is approximately 10-20 °C (depends on the load).



- Liquid cooling flow must be filtered cross the filter which holes diameter or diagonal must not exceed 2 mm.
- IP21:
 - Air cooling only (EMRAX Air Cooled): Fresh air has to be served to the drive symmetrically and sufficiently (air speed must be 25 m/s at maximal 25°C air temperature and at maximal 200 kPa pressure). This has to be ensured by intake ports or other air conduction measures. Motor can be protected with some net against the dirt.
 - Combined cooling Air and Liquid (EMRAX with combined cooling): Liquid cooling flow must be <u>8 litres per minute</u> at 40 °C inlet water/glycol temperature and ambient air temperature has to be 25°C or less. Inlet water temperature and ambient and temperature can also be lower in this case the continuous motor power is higher. This is valid for all EMRAX sizes (207, 228 and 268). To achieve inlet water/glycol flow app 8 litres per minute the inlet pressure for the different motor types must be: <u>1.0 bar for EMRAX 207</u>; <u>1.2 bar for EMRAX 228</u> and <u>1.5 bar for EMRAX 268</u>. Maximum inlet liquid flow pressure must not exceed 2 bar. This motor has combined cooling, so it is important, that beside liquid cooling <u>also air cooling</u> is assured this means that the air around the motor must exchange and that the ambient air temperature must be as described in Technical data tables (25°C or less) to get the best performances of the motor (the motor must not be closed into some box). Liquid cooling is important for the stator, air cooling is important for the rotor (Figure 30). Motor can be protected with some net against the dirt.

• **IP65**:

Liquid Cooling (EMRAX Liquid Cooled): Totally closed motor – only liquid cooling. Liquid cooling flow must be <u>8 litres per minute</u> at 40 °C inlet water/glycol temperature and ambient air temperature has to be 25°C. Inlet water temperature and ambient and temperature can also be lower – in this case the continuous motor power is higher. This is valid for all EMRAX sizes (207, 228 and 268). To achieve inlet water/glycol flow app 8 litres per minute the inlet pressure for the different motor types must be: <u>1,0 bar for EMRAX 207</u>; <u>1,2 bar for EMRAX 228</u> and <u>1,5 bar for EMRAX 268</u>. Maximum inlet liquid flow pressure must not exceed 2 bar. Also the air around the motor must exchange and the ambient air temperature must be as described in Technical data tables (25°C or less) to get the best performances of the motor (the motor must not be closed into some box).

*Pressures values for inlet water flow are valid if the inlet water pipe between the motor and a pump is up to 2 meters (diameter 12 mm). If the tube is longer (depends on each specific system), then higher pressure must be taken into account.

11. EMRAX materials.

Because of the extremely high power / torque as well as a need for corrosion resistance the engines are made from quality materials. Stator part, outer ring, front and rear disk are made of aluminium quality 6082. **Minimum aluminium thickness - 3.0 mm** is on the outer ring. Outer ring, front and rear aluminium disk are anodized in black. The motor shaft is made of hardened steel. Stator is additional coated with epoxy coating.

Because of the difference of the magnetic field on the magnets (tolerance 1-2%) the generator voltage between EMRAX motors can be different for 1-2% at the same rotation. This difference in voltage between the EMRAX motors also depends on the other motor materials.



12. Maintenance

- The drive does not need any maintenance.
- However it has to be considered that no foreign objects at all can enter the interior of the drive this • is especially important for EMRAX motors with IP21 (Air Cooled and with Combined Cooling). Further, it is necessary to protect the motor from humidity, dirt, paint, glues, salt, iron particles, etc. If this is ignored, a proper functionality of the motor cannot be guaranteed and irreparable damages are possible. To prevent objects falling inside the motor (especially iron chips, iron fillings!), the motor ventilation holes (ring and side holes) MUST be protected with some tape for the time the motor is being assembled into the system and at the time when the drive is not in use. Also the drive must be protected from these objects when it is already mounted in the system (especially if the motors are mounted close to the ground and if there are any iron particles – in this case we recommend to protect the motor with some fine net, so that cooling stays sufficient at the same time). Anyway if the foreign object enters the motor do not at all simply keep on using the **drive**. In this case contact company Enstroj and explain what happened. Unintended handling leads to secondary damages. Opening or disassembling of the motor causes a forfeit of warranty **claims!** Also for opening the motor special tools are needed to prevent any damages to the motor and to the person who opens the motor. Enstroj can remove the foreign object from the motor and at the same time also checks the interior of the motor and protect the stator again. Removing particles from the motor, inspection and protection of the stator costs 150 euros per motor. Customer also has to pay shipping costs and potential duty costs that apply.
- In case of damage, ship the drive back to Enstroj for repairs (but firstly contact Enstroj).
- Keep magnetic memory cards or electronic devices out of the rotor's close-up range, because the alternating magnetic field can cause a delete of data. Be also careful with medical devices (e.g. pacemakers) which are sensitive to alternating magnetic fields.

13. Motor connection with controller

We are NOT selling the controllers – they have to be bought directly from the producers.

Optional controllers for EMRAX motors:

CONTROLLERS FOR EMRAX HIGH AND MEDIUM VOLTAGE MOTORS:

- UNITEK BAMOCAR D3 with <u>resolver</u> application liquid cooled up to 400 Adc / 400 Vdc and 400 Adc / 700 Vdc. Suitable for EMRAX High Voltage and Medium Voltage motors. Link to BAMOCAR D3 price: <u>http://www.unitek-online.de/pdf/download/Allgemeines/Preise.pdf</u>
- LETRIKA CONTROLLER More info: http://www.letrika.com/sl/izdelki/druge-komponente/krmilniki/

CONTROLLERS FOR EMRAX LOW VOLTAGE MOTORS:

- EMSISO EDRIVE with encoder sin/cos application (RLS RM44SC) or hall sensors 500 A continuous, 600 A peak.
 - More info: http://www.emsiso.com/
- SEVCON Gen4Size6 with encoder sin/cos application (RLS RM44AC). Electrical frequency 600 Hz max. This means motor rotation 3500 RPM. It has 550 A boost 10 sec; 450 A peak 2 min; 180 A continuous current.

More info: http://www.sevcon.com/media/2104/gen4_web.pdf,



*Low voltage controllers for EMRAX Low Voltage motors must have high output current (depends on the motor size 207, 228 or 268 – take a look at the Technical data tables) to achieve the same power as EMRAX High Voltage.

OTHER CONTROLLERS

- Some years ago we used Piktronik SAC41 (or SAC50) controllers which are suitable for EMRAX High Voltage and EMRAX Medium Voltage motors.
- There are no or no qualified experiences of other frequency converters (RMS, Mission MC 600). Anyway some customers have good experiences also with those controllers.

Important additional information:

- It is difficult to find controllers with very high voltage / current that EMRAX motors require. We found a solution how to drive one motor with two controllers and enable the motor high current to operate with full performances. In this case we can make two sequences of stator wiring and electrical connectors (2x UVW) on the motor, so each controller is connected to one sequence. In this case tandem resolver / encoder is needed. Another option is that two controllers can operate with divided signal from one resolver / encoder – but this is not common for the majority of controllers.
- We recommend that EMRAX TWIN is driven with 2 controllers one controller for each motor in this case tandem resolver must be mounted on the back side of the second motor (Figure 16; Figure 19). Anyway EMRAX TWIN can be driven by one controller this controller must deliver very high phase current it is hard to find such controller), also in this case the mechanical angular degree must be to totally configured in the right position on both motors and also both motors must operate under the same temperature conditions (cooling!). Separate EMRAX motors cannot be driven with one controller each motor needs one controller.
- EMRAX motors should be used with the controllers with **sinusoidal commutation**. If using the controller with trapezoidal commutation the motor will not work at its best performance, also it would be louder.

Starting EMRAX motor:

- It is important to read the manuals for the EMRAX motor and fro the controllers!
- Manuals for combining EMRAX motors with Unitek controllers are published on our website (pdf files): <u>http://www.enstroj.si/Electric-products/controllers.html</u>. There is also a manual for connecting the LTN resolver wires and BASE URF files (NDrive software for Unitek Bamocar D3) suitable for EMRAX motors. Before rotating EMRAX motor auto tuning must be made – instruction file Parameters for Unitek BAMOCAR D3 and BAMO D3 controller for synchronization with EMRAX motor is also published on the link above.
- Be aware of the following safety instructions BEFORE STARTING:
 - It is essential to permanently check the loads driven by the motor for damages, cracks etc. The use of damaged loads can lead to heaviest injuries.
 - The frequency converter needs to be mounted jacked up, so that a vibration free use is unconditionally guaranteed. If this is not the case, vibrations can cause contact faults and further the breakdown of devices. This may lead to damages to the electronic system or to components in its environment.



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- Before starting, the right direction of rotation has to be checked and if necessary be changed
 motor connectors UVW must be set according to the controller phase positions. UVW (1, 2, and 3) connectors of the motor are parallel to UVW output phases from the controller.
- The drive should be if possible directly connected to the frequency controller, without any inserted connectors. If this is not possible, only use high current capable, low-impedance, the best quality connectors. Shoddy connectors lead to voltage peaks and can destroy the frequency converter. Oftentimes unplugging the connector can cause contact problems which may also lead to a destruction of the converter. We also recommend main vacuum switch between the batteries and controller and suitable DC fuse.
- Only use high current connector systems between the motor, converter and the battery. The connectors have to be checked before every use. If the coating is used up, the internal discs in the jacks get play or have lost their resilience, they have to be replaced.
- Shoddy or used up connectors are the most common reason for destructions of the drive, the controller and possible components around it.
- The electric connectors and cables must be connected professional and have to be isolated by a **shrink hose** (Figure 26). Mixing up the polarity of the battery or a short circuit leads to a destruction of the drive and means an acute fire hazard and danger of life!
- The cables should be as shorter as possible. For longer cables diameter of the cable must be bigger. **Power cables must be shielded and distant enough from communication cables**.

14. Using EMRAX for electric vehicles (EV)

The usage depends on the place where the motor will be mounted.

Options:

- Direct drive
- On the Differential
- In the Transmission Gear

Firstly you should to know how high torque you need on the driven wheels.

1.) If you use the Transmission Gear than one EMRAX 207 gives enough power (1900 Nm peak / 900 Nm cont. - at the first step on TG).

2.) EMRAX 228 mounted in the TG is better option. You can expect much better EV acceleration; also you can drive up on hill at higher transmission step. Expected torque is 3800 Nm peak / 1900 Nm cont. - in the first TG step).

3.) EMRAX 228 is useable for lighter EV if it is mounted directly on the differential (near 1000 Nm peak / 500 Nm cont. on the wheels at all range of motor RPM).

4.) EMRAX 268 is useable for heavier vehicles if it is mounted directly on the differential (app 1600 Nm peak / 800 Nm cont. on the wheels at all range of motor RPM).

5.) If EMRAX 268 is mounted in the TG, than you can expect very high torque 6000 Nm peak / 3000 Nm cont. on the wheels at all range of motor RPM.

You can also use EMRAX TWIN. Torque/power is doubled. Peak torque means that the power can last from one to two minutes.



15. EMRAX DISCLAIMER

Enstroj company does not take any responsibility for difficulties, which are the result of inappropriate configuration, electric system structure and settings which are not in accordance with the latest version of Manual for EMRAX motors. Every motor is tested before shipping at temperature conditions and parameters, which are described in Technical data tables (in Manual for EMRAX motors). If EMRAX motors are not used in accordance with this manual it causes a forfeit of warranty claims. Components of company Enstroj have been developed for usage on electric airplanes, cars, boats, power plants. Company Enstroj assumes no liability in case when a customer uses components for the purposes for which they have not been developed or tested, and especially not for the purpose of presenting a direct threat to human life or health.



16. EMRAX 3D drawings are published on this links:

http://www.enstroj.si/Electric-products/emrax-200.html http://www.enstroj.si/Electric-products/emrax-228-motorsgen.html http://www.enstroj.si/Electric-products/emrax-268.html

17. EMRAX FIGURES

Figure 1: EMRAX 228 with resolver - dimensions



EMRAX 228

Figure 2: Front motor side

Figure 3: Back motor side







Figure 4: EMRAX 207, 228 and 268 mounting dimensions

EMRAX 268 500 Nmp







Figure 6: EMRAX 228 power transmission options (shafts) 02 – dimensions for 228 motor



Figure 7: EMRAX shafts





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Figure 8: Standard motor shaft



Figure 9: EMRAX prolonged shafts





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Figure 10: Shafts for EMRAX TWIN

Prolonged motor shaft from back motor side and Prolonged flanged shaft from front motor side (with 4 inner splines) merged together – for EMRAX TWIN



Figure 11: Motor shaft with inner splines for EV (for Audi/VW transmission gear)







Figure 12: Standard motor shaft and shaft for EV compared

Figure 13: EMRAX with Prolonged flanged shaft from front motor side (with 4 inner splines)







Figure 14: EMRAX with prolonged motor shaft from back motor side – resolver must be mounted on the front motor side

Figure 15: EMRAX TWIN with X shape carrier



EMRAX 228 TWIN - two motors wired serial with prolonged shaft

The first motor has stronger prolonged shaft. On this shaft goes prolonged flanged shaft for the second motor. On the first motor at the front side the customer can also add prolonged flanged shaft for sprocket or some other driving part. We can also make single motor with prolonged shaft. In this case it needs special holder for encoder / resolver, which must be mounted on the front motor side. The motor can run with sensor or sensorless. Twin motors need special iron construction (A-shape or X-shape design).





Figure 16: EMRAX TWIN with X shape carrier and tandem resolver

Figure 17: EMRAX stainless steel carrier – X shape and A shape



X-shape steel carrier for EMRAX TWIN.

A-shape steel carrier for EMRAX TWIN.



<image>

Figure 18: X shape carrier for EMRAX TWIN

Figure 19: Resolver / encoder with holder



Figure 20: EMRAX with hall sensors 01

Figure 21: EMRAX with hall sensors 02

Figure 22: EMRAX 207, 228 and 268 phase connectors

Figure 24: Connecting motor phase connectors ors with controller cables 02

Figure 25: Connecting motor phase connectors with controller cables 03

Figure 26: Electrical phase connectors isolated with shrink hose 01

Figure 27: Electrical phase connectors isolated

Figure 28: EMRAX with IP21

Figure 29: EMRAX with IP65

Figure 30: EMRAX cooling

Dutlet hot air

Figure 31: Transmission gear and propeller mounting

18. Service

In case of a fault or damage(s), contact company Enstroj.

ENSTROJ d.o.o. Pod hribom 4 1235 Radomlje Slovenia, Europe Tel.: 0038641-966-065 E-mail: <u>enstroj@siol.net</u> Web site: <u>www.enstroj.si</u>

We now wish you lots of fun and success with your high performance EMRAX engine.