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Title: BoosterpaQ Systems in Elevated Temperatures

To: Grundfos BoosterpaQ Partners

Most electrical equipment and motors have a maximum ambient temperature rating of 104 °F (40 °C). When the actual temperature of the equipment will exceed this, special care needs to be taken to ensure long equipment life.

It is possible to operate most equipment above these limits but a closer look at the actual duty cycle needs to be taken. For BoosterpaQ systems we can break the electrical equipment into three main categories:

Equipment Type	Brands/Types
1. Motors	Grundfos ML, Baldor
2. Drives	Grundfos MLE, Danfoss VLT, Baldor SmartMotor
3. Controls	PFU 2000, PMU 2000

1. Motors
Motors can be operated at temperatures above 104 °F with the following limits:
- The available output power (horsepower) will be reduced
- Motor bearing service intervals will be more frequent

2. Drives
Variable Speed Drives can be operated above 104 °F with the following limits:
- The available output current (which effects available output horsepower) will be reduced
- Some drive components will have a shorter lifetime

3. Controls
The controls, which in our case are the PFU controller and PMU advanced control interface, can also be operated at temperatures above 104 °F with the following limits:
- Shorter lifetime

De-rating equipment for these conditions.

Motors and drives carry a load and therefore can be de-rated according to load, temperature and elevation. The PFU and PMU controls however, do not carry a load and therefore have a “Not to Exceed” temperature limit.

De-rating Motors

The proper way to de-rate motors is to look at the actual temperature rise of the motor at design conditions. The ambient temperature plus the temperature rise of the motor is the actual temperature in the motor windings. Motors used with Variable Speed Drives should have a minimum of Class F insulation. A motor with Class F insulation has a temperature rise allowance of 115 °C. So when the ambient temperature is 40 °C (104 °F), the temperature rating of the motor is 155°C. All motors with class F insulation and a 1.15 service factor have a temperature rating of 155 °C by design. It is not recommended that the motor operate at this extreme condition continuously as it can be agreed that a cool running motor lasts longer.

To simplify the motor de-rate process, the de-rate chart found in the CR, CRE Pump Product Guide can be used for Baldor, Grundfos ML and Grundfos MLE motors.

De-rating Drives

When the ambient air temperature around a BoosterpaQ control panel that has variable speed drives mounted inside of it exceeds 104 °F, it becomes necessary to de-rate the drive output capacity. The drive itself will generate heat which will increase the internal panel temperature. When the temperature just outside the panel is over 104°F, the average internal panel temperature will always be above that, even with the exhaust fan running.

BoosterpaQ control panels with drives can be supplied with exhaust fan packages that can limit the temperature rise inside the panel to 10°F. So with an outside air temperature of 120°F, the resulting temperature inside the panel can be as high as 130°F.

Therefore to be on the “safe” side, if the expected ambient air temperature around a BoosterpaQ system with panel mounted drives is 120°F, the expected maximum drive temperature should be assumed to be 130°F.

The Danfoss VLT Instruction Manuals have charts for the purpose of de-rating the drives for temperatures above 104 °F (40°C).

Temperature Limits of PFU and PMU Control Enclosures

It is highly recommended that the PFU and PMU controls are always at or below 104°F to ensure the longest possible lifetime. But on a practical note, there are areas that are above this temperature for only a fraction of the time. Warm areas such as those found in Arizona and Nevada may be below

104°F for nine months out of the year but can have average temperatures above this for the remaining part of the year.

BoosterpaQ systems are supplied with two basic types of control panels, enclosures with drives and enclosures without drives.

Enclosure Type	**BoosterpaQ Types**
Without drives	ME, MES, MEH, MS, MSH
With drives	MF, MFH, Custom Units[1]

[1] Custom ME and MEH systems with panel mounted drives have been supplied for systems with pumps larger than 10 hp.

Enclosures without drives

These systems are normally supplied with a NEMA 4 rated enclosure. This is normally a dust tight enclosure with no openings to the environment in which there is no exhaust fan. If the ambient temperature just outside of the enclosure stays below 104°F the temperature limit of the PFU and PMU controls will not be exceeded. If the temperature of the air outside the enclosure is expected to exceed 104°F, an exhaust fan should be supplied with the system to ensure that the temperature remains cool in and around the controls. Adding an exhaust fan to this system will add a little cost to the system but is well worth the small investment given the expected lifetime of the system.

Since there is little heat generated within panels without drives this allows these types of enclosures to be exposed to higher ambient temperatures than panels with drives. The maximum allowable ambient temperature for an enclosure without drives is 130°F. This 130°F limit incorporates the use of the exhaust fan.

This temperature limit **does not** allow for direct sunlight exposure. These limits assume the enclosure is shaded/blocked from direct sunlight on all sides.

Enclosures with drives

These systems are normally supplied with a NEMA 3R enclosure equipped with an exhaust fan system. The exhaust fan system is designed such that the drive(s) will provide full output capacity for the driven pump(s) at ambient temperatures up to 104°F. When the ambient temperature just outside of the enclosure exceeds 104°F, the actual temperature inside the panel starts to increase, which can affect the performance of the PFU/PMU controls as well as the drive itself. When in operation, the drive generates heat within the enclosure which must be removed. When the ambient temperature exceeds

104°F it starts to get difficult to remove enough heat to keep the drive and controls cool enough for proper operation.

But there is only so much heat an exhaust fan can remove from an enclosure with internal heat generation. When the PFU/PMU controls are exposed to excessive temperatures, erratic behavior can occur. Grundfos can supply control enclosures that can function properly in ambient air conditions of up to 120°F without the use of air conditioning or special cooling systems. This is accomplished by using larger exhaust fans or dual fan systems which may also include the use of larger control enclosures.

Important Notes about exhaust fan cooling

- There are filters to prevent excessive dust from entering the enclosure. These must be kept clean and checked regularly to ensure sufficient airflow for heat removal.
- BoosterpaQ control enclosures with drives have an adjustable thermostat for the exhaust fan. This should be set so that the fan is on when the internal panel temperature exceeds 104°F.
- A control enclosure that has a drive inside can reach an internal temperature of over 250 °F if the cooling fan is not operational or if the filters have become clogged. Normally the drive will have shut itself down due to its own temperature limit protection. However the PFU/PMU controls may exhibit erratic behavior before the drive shuts down.

Putting it all together

The best way to explain this de-rate process is through an example.

Let's say the system required is an MF 2CR45-2 with a 460 volt power supply. It has been communicated that the system can potentially operate in an ambient temperature of 120°F. This process involves de-rating the motors and drives. As long as the ambient temperature stays below 120°F, the PFU/PMU controls will function properly.

Step 1: De-rate Motors

The standard motor size for a CR45-2 is 15 horsepower. The chart from the CR/CRE Product Guide (see **Figure 1**) shows that the motor output P2 (P2 = motor output power) is de-rated to 96% at a temperature of 120°F. So the motor brake horsepower is de-rated to 14.4 (15 x 0.96 = 14.4). Since the pump type is known, the actual brake horsepower required for the pump should be taken into consideration. Looking at either the CR/CRE Product Guide or the curve viewer in WinCAPS the brake horsepower at maximum flow for a CR45-2 is approximately 15.4, which is above the de-rated

horsepower. The conservative approach would be to up-size the motor to 20 horsepower. The less conservative approach would be to look at the actual temperature rise of the motor.

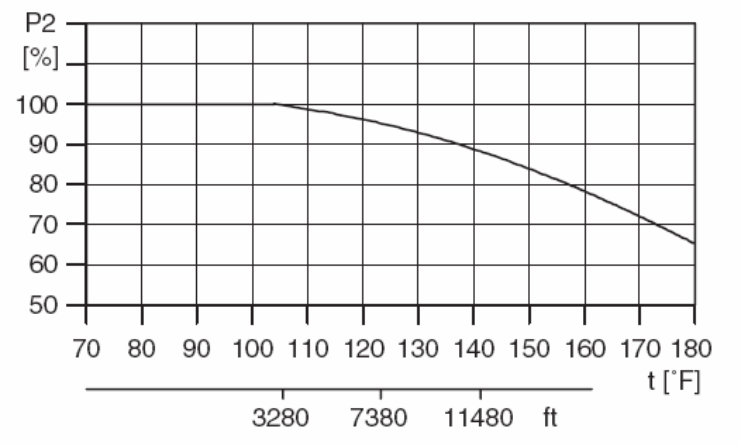

Figure 1
Motor De-rate chart from CR/CRE Product Guide

So taking the less conservative route, the actual motors specifications can be supplied, which are shown in following table.

Motor Type	F.L. Amps	S.F. °C Amps	F.L. Temp. Rise [°C]	S.F. Temp. Rise [°C]
Baldor TEFC, 15hp	17.0	19.5	97.0	114.0
Baldor TEFC, 20hp	23.0	26.2	80.0	102.0

With an ambient temperature of 120°F or 49°C, the 15hp motor will have an internal temperature of 146°C (49+97) at full load and 163°C (49+114) at service factor load. The CR45-2 pump can potentially require a little more than full load (15.4 bhp) so the resulting temperature rise would be about 100°C which means the internal motor temperature would be about 149°C. This is 6°C below the class F design temperature of 155°C.

The 20hp motor on the other hand will have an internal temperature of 123°C (49+80) at full load. But since the CR45-2 will never require 20 horsepower the temperature rise will always be less than 80°C.

The more reliable choice would be the 20 hp motor however we must also keep in mind that many systems are over-sized and for this particular system the pump may never exceed a load of 15 horsepower.

Step 2: De-rate Drive(s)

Grundfos uses the following drive types on BoosterpaQ MF systems:

Model	**Range**
Danfoss VLT 2800	3/60/460 up to 25hp
Danfoss VLT 8000	3/60/208 up to 25hp
	3/60/460 up to 60hp

The Danfoss VLT Instruction Manuals have charts (see **Figure 2**) for the purpose of de-rating the drives for temperatures above 104 °F (40°C).

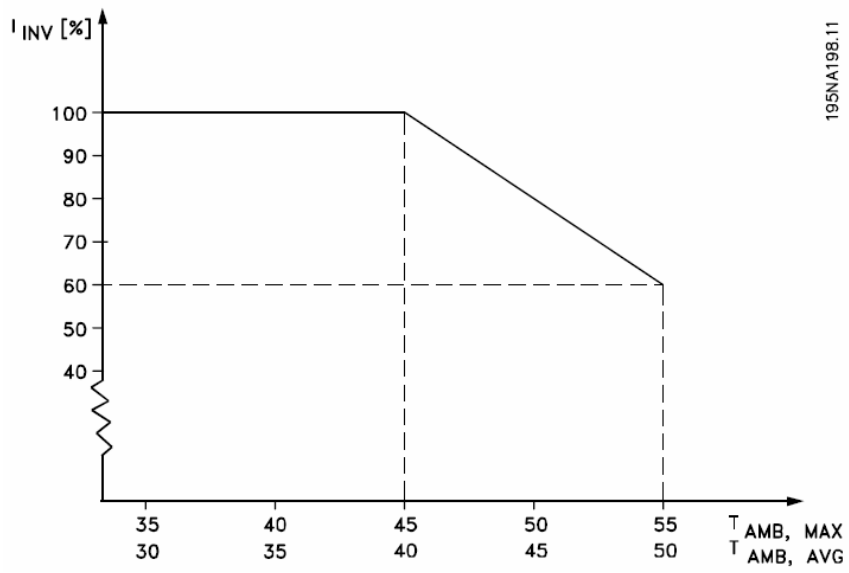

Figure 2
De-Rate Chart for Danfoss VLT 2800

The chart in Figure 2 shows what the available output current (I_{INV}) is, as a function of ambient temperature. For a 15hp VLT 2800 drive (Type 2880) the nominal output current is 24.0 Amps. The internal panel temperature can be as high as 130°F which is 54.4°C. The Danfoss de-rate chart has two temperatures on the horizontal axis, one is the maximum temperature and the other is the average temperature. To use this chart, the average temperature over a 24 hour period must be at least 5°C (9°F) lower than the maximum temperature (which is usually the case in hot environments as the temperature is lower in the early AM and evening). For a maximum temperature of 54.4°C, the available drive output current will only be 60% of the rated drive current (I_{INV}). So the available output current for the 15hp drive will be 24.0 x 0.6 = 14.4 Amps. This will most likely not be enough current to drive the required motor. The drive will be at least one size larger than the standard in these cases. The available current on a 20 hp drive should be calculated. The available output current for the 20hp drive (Type 2881) will be 32.0 x 0.6 = 19.2 Amps.

The actual motor current that is required for this system should not exceed 19.2 Amps. If the 20hp motor is selected you will notice that it has a potential full load current of 23.0 amps. However knowing that the pump can only load the motor to just over 15 hp, the actual motor current will be less. In this case, the motor part load information should be referenced. At 75% load (15 hp), the current draw on the 20hp motor is 17.7 amps. In this case it would be acceptable to use this motor with the de-rated 20hp drive.

Conclusion

As you can see, a proper de-rate of the entire pump station is an involved process. If all the application and environmental details are determined, a reliable pump system can be selected that will result in many years of trouble free operation. Because this is an important and time consuming process, the Grundfos BoosterpaQ application engineering department can assist you with equipment sizing if the job site parameters are determined.

If it has been decided that this equipment is to be installed in an environment where the ambient temperature can exceed 104 °F, as a minimum the equipment should be covered so as to prevent direct sunlight exposure to the motors and controls. Even though this equipment can operate satisfactorily in temperatures above 104°F it should be understood that the lifetime of certain parts of this equipment will be shortened. Variable Speed Drives operating in an ambient temperate at or below 95 °F with clean filtered airflow can easily give 10-15 years of trouble free service. And not to forget the mechanical parts, motor bearing service intervals will become more frequent due to the higher temperatures within the motors.