SUBMERSIBLE MOTOR ENGINEERING

9 Rye Lane Street
Maddington WA 6109
Western Australia
TEL: 61 8 9452 2922
FAX: 61 8 9452 2722

EMAIL: jayson@smeng.com.au
ABN: 27 098 297 539

Overheating in Submersible Motors.

23/7/15

General

The most common cause of failure in a Submersible Electric Motor is Overheating, as this causes the insulation materials in the motor to deteriorate until failure occurs. Sometimes the overheating can introduce other problems in the motor, before it fails, which accelerates the process.

The most common causes of overheating are as follows:

- Overloading.
- High ambient water temperature.
- Low flow rate of external cooling water.
- Very high flow rate of external cooling water.
- Low Supply Voltage.
- High Supply Voltage.
- Incorrect Installation Procedures.
- Voltage and Current Unbalance.
- Voltage surges and Spikes.
- Single Phasing.
- Phases Reversed.
- Build up of organic or mineral material on the outside of the motor.
- Rapid cycling - switching the motor on and off frequently and quickly.
- Incorrect Ramp Up time when using a VVVF Drive or a Soft Starter – Maximum 4 seconds is allowed. SME has a separate bulletin covering the use of submersible motors with VVVF Drives and Soft Starters.

The Effects of Overheating on different parts of the motor are as follows:

- Internal Cooling Fluid. The fluid will boil which will create steam inside the motor at high pressure. The steam will force it's way out of the motor, past the mechanical seals on the DE, or it can rupture the rubber bellows on the NDE. Steam will not transfer the heat from the internal components such as the stator windings or the rotor.

- Stator Windings. Without efficient heat transfer in the cooling fluid the insulation will breakdown and short circuits and or earth faults will occur. If the fault is violent other parts of the motor can be damaged such as the lamination stack.

- Bearings. The carbon sleeve bearings and thrust bearing will fail very rapidly without efficient fluid lubrication. Usually this occurs first in the upper sleeve bearing and leads to binding, rapid wear, and misalignment for the pump and the rotor.

- Rotor. If the sleeve bearings wear sufficiently this can allow the rotor to rub against the stator, which is called “poling”. This will cause localised high temperatures, and mechanical problems, that will quickly lead to catastrophic failure of the motor. It is quite common for some of the stator teeth to be dragged into the stator slot and cut through the wires in the stator winding, creating an earth fault.

- Bellows or seals may deteriorate and rupture allowing the external fluids and foreign matter to enter the motor. The foreign matter can be abrasive, which will encourage wear if the motor continues to run.

- Casings and Housings. In extreme situations it may be possible for the casing of the motor or the end brackets to warp and cause misalignment.

- If the motor is subject to electrolysis, or bacteria build up, this can accelerate due to higher temperatures, which in turn will cause even higher temperatures.

Possible Reasons for Overheating.

Overloading.
Overloading is usually caused by:
- Excessive hydraulic load.
- An oversized, or wrongly sized, pump fitted to the motor.
- Misalignment.
- Binding.
- Failure of a component in the motor or the pump,
- Foreign bodies, or solids, in the water being pumped.
- Over frequency.

Motors must be correctly selected to match the pump and the duty required.
If a motor is powered from a Generator Set, rather than the mains of a power utility it is possible that the supply frequency is higher than the motor/pump design frequency. The characteristics of normal pumps are very sensitive to speed. Increased speed due to increased frequency will almost certainly raise the duty point of the pump and this can cause the motor to be overloaded.
Overloading of a motor will almost certainly cause overheating.

High Ambient Water Temperature.
Submersible Motor Engineering (SME) specify the maximum ambient water temperature, the minimum cooling water flow in m/sec, and the maximum full load output power for the motor. All of these conditions can vary in practice and this will affect the ability of the motor to dissipate the internal heat that is generated by the motor in operation. If the motor overheats because the maximum ambient cooling water temperature is exceeded the life of the motor will be reduced.

Low/High External Cooling Water Flow.
The motor relies on the efficient transfer of heat from the external surface of the motor to the water flowing past the motor. If the flow is too slow the external water will heat up and create a similar condition to having a high ambient water temperature. Low flows are usually caused by:
- Low Pump flow rate.
- Incorrect application or design.
- Plugged or blocked suction inlet.
- Loss of suction.
- Closed or blocked discharge.
- Low pump speed.
- Loose impeller or impellers.
- Water flow into the pump from above the motor.
- Motor installed below the well screen.
- Pump suction inlet set at the same level as the well screen.
- Large gap between the motor and the well liner.
- Obstruction around the motor.
- Motor buried in sand or silt.
- Motor/Pump installed without a shroud in a tank or pit.

If the external cooling water is flowing too fast it may form a recirculating or turbulent layer along the surface of the motor. This layer may prevent the external surface of the motor from being able to dissipate the heat fast enough to cool the motor. High velocity flow conditions also cause a decrease in pressure which may cause dissolved minerals to precipitate out of the water forming a mineral plating on the surface of the motor which will also act as a form of thermal insulation and reduce the cooling capacity even further.
In some wells iron bacteria will grow on the external surface of the motor – in extreme cases this can be a much as 10mm in 3 months. This iron bacteria growth also acts as thermal insulation and as it grows out

towards the well liner it will force the external water flow rates to increase as the gap between the well liner and the bacteria surface on the motor reduces eventually causing excessive flow rates.

Low/High Voltages.
Low voltages will lead to increased currents, as voltage and current are generally proportional if saturation effects are neglected. Increased currents will lead to increased heating in the stator winding. Low voltages will also lead to lower full load speed and increased slip. The pump will have a reduced performance leading to reduced water flow past the motor and possibly reduced cooling capacity.
High voltages will lead to a reduced stator current, until the voltage is sufficiently high that the lamination iron starts to saturate, at which point the current will start in increase leading to increased temperature rise. High voltages will also cause the motor to have increased starting torque and increased starting current, which will probably lead to higher temperatures during starting.

Incorrect Installation Procedures.

The pump and motor must be assembled correctly. Any Misalignment or Binding can cause overloading of the motor.
Misalignment occurs when components are not machined correctly or not assembled correctly. All the components in the motor and the pump must be concentric within the tolerances specified by the manufacturer. Special attention must be paid to component fits, the balance and vibration of rotating components, clean assembly conditions with no foreign objects or matter in the assembly, especially between the flange faces.
Binding is usually caused because there is insufficient room for axial or radial movement in the pump or because the shaft coupling is not fitted correctly. The coupling should not be pinned or fixed with a grub screw to the motor shaft – it should be free to slide on the shaft to allow for thermal expansion of the motor shaft.
All water filled motors must be correctly filled prior to installation as the motor relies on this water to remove the heat generated in the water. If a motor is not properly filled there is a strong possibility the motor will overheat.
Great care must be taken during installation to ensure that whole motor/pump assembly is not damaged. Special care must be taken when lifting the motor/pump to the vertical position prior to lowering down the hole. Make sure the shaft is not subjected to excessive bending forces, which could bend the shaft.

Voltage and Current Unbalance.
This is probably the single most common cause of motor failure. Generally this is caused by voltage imbalance, leading to current unbalance. Unbalanced currents will definitely lead to increased temperature rise in the stator winding. If the motor is fully loaded – not de-rated – it will almost certainly lead to stator windings exceeding safe temperature limits.
SME motors require that the Voltage balance must be within 3%.

Voltage Unbalance can be calculated using the following formula:

Voltage Unbalance % = 100 x Max. Voltage variation from Average / Average Voltage

SME has a separate bulletin especially covering Voltage and Current Unbalance.

Voltage Surges and Spikes.
A High Voltage Surge is when the supply voltage increases substantially for a period of milliseconds or seconds. A spike occurs when there is a very high voltage transient for nanoseconds or milliseconds.
A surge is quite likely to occur when a generator supplying a motor runs out of fuel. When the fuel mix becomes very lean the engine speeds up and the output voltage from the generator increases. Spikes are usually caused by the switching of electrical equipment on the supply system – not necessarily the actual contactors or circuit breakers operating the motor. Very large surges or spikes can be caused by indirect lightning strikes on the supply system.
This is a complex subject, however, in general, small voltage increase/short duration surges will tend to stress the windings causing gradual deterioration over a period of time, and eventually catastrophic failure of the windings.
Large voltage increase/long duration surges will severely stress the winding and connection points – the weakest point in the winding or connections will fail usually causing a short circuit which can have enough energy to blow a hole in the lamination pack or even through the stator casing.
Small spikes will stress and degrade the windings and connection, while a large spike will almost certainly lead to immediate catastrophic failure.

Single Phasing.
Single phasing occurs when 1 phase of a 3-phase supply is lost, i.e. there is no voltage on one phase.

In a Delta connected motor current will continue to flow in all 3 phases of the winding, but extremely high currents will flow in the phase connected directly between the 2 remaining voltage connections – this phase will overheat and fail very quickly if the motor is not shut down very quickly.
In a Star connected motor current will continue to flow in the 2 phases connected between the 2 remaining voltage connections – these 2 phases will overheat and fail is this condition is not detected very quickly and the motor disconnected from the supply.
If the motor is not operating and is switched on to a Single Phasing supply it will almost certainly not start and will draw high starting current as described above - until it is disconnected. If the motor is already running and 1 phase drops out for whatever reason the motor will probably continue to run at reduced speed while drawing heavy current.

Phase Reversal.
Phase reversal will result in the motor running in the wrong direction and in general the pump will operate very inefficiently, probably not drawing enough water past the motor to cool it properly.

Build up or organic or mineral material on the outside of the motor.
Organic deposits are usually caused by iron bacteria. These bacteria produce a layer, or crust, of iron and/or magnesium compounds on the outside of the motor. These encrustations act as a thermal barrier and contain the heat within the motor. The presence of iron bacteria is usually a pre-existing condition.
Mineral deposits will cause the same type of thermal barrier as organic deposits. Chemical reactions precipitate the minerals present in the water and deposit them on the external surface of the motor. The most common mineral deposits are carbonates, iron, manganese, and silicates.

Rapid Cycling.
Rapid cycling causes the motor to overheat, as it does not get sufficient time to cool down from the previous start/run. When a motor is started it draws 4 to 6 times the normal full load current. This increased current creates high temperatures in the stator and rotor windings. This is especially a problem if the motor is already hot because it has been operating at its nominal full load temperature. Several starts in quick succession will almost certainly cause the motor to overheat which will cause a degradation of the stator winding insulation and other internal components. Eventually the deteriorated conditions inside the motor will cause it to fail.
SME recommends that motors be allowed to cool for 15 minutes before being restarted. In some circumstances motors may require even longer to cool down, especially if the ambient water temperature is high.
SME also recommend that a motor is allowed to run for about 1 minute after start up to allow the heat generated during the starting cycle to partially dissipate.
The whole installation should be designed to keep the number of starts required by the motor to a minimum, which will increase the life of the motor.

Summary
Motor overheating is usually a symptom of other problems. Failure to investigate and determine the true reason for the overheating will lead to motor failures, extended down times, repeated repairs, and higher maintenance costs.
All SME motors above 6” are fitted with 4 x PT100s to allow the internal motor temperatures to be monitored. SME recommend that all these PT100s are connected to a display/protection device and that each PT100 is set to trip the motor at 3 degrees C. above the steady state operating temperature for each PT100.