TECHNICAL REPORT

Canned Motor Pumps for High Temperature Applications in Solar Thermal Power Stations

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1. INTRODUCTION

There are, in general, numerous technical and industrial processes which absorb or emit energy. Water and steam are often used to transmit heat within a temperature range of 0 °C through 200 °C because of their high specific heat value. Both machine and plant manufacturers and also end users predominantly employ heat transfer oils for heating or cooling applications at temperatures ranging from 200 °C through 450 °C. The following article describes the design and mode of operation of sealless canned motor pumps, including specifics for high temperature applications. Applications at temperatures up to 320 °C generally use conventional chemical standard pumps (with mechanical seals and pump feet on the base plate) which are separated from the conventional motor by a thermal barrier. Cost pressures on machine and plant manufacturers mean that they often omit compensators, thus at temperatures in excess of 320 °C the piping system nozzle loads and torques are transferred directly to the pump nozzles. This can result in damage to the pump casing, ranging from warping to distortion. A pump concept based on the API 685 standard is often the better solution for temperatures in excess of 320 °C and up to max. 450 °C. API 685, Edition 1 for sealless pumps has been available since 2002, filling the gap in API 610 for single stage, sealless pumps (magdrive pumps and canned motor pumps). The pump casing is equipped with mountings (pump feet) centred on the axle; standard practice for boiler feed pumps, for example, for decades. As a result, temperature-induced expansion of the pump casing can be evenly distributed up- and downwards.

Canned motor pumps are sealless centrifugal pumps in monobloc design, driven by a canned motor via a common shaft using electromagnetic principles. The rotor and stator of the asynchronous motor, in principle of conventional design, are protected from corrosion by the use of non-magnetic materials. Part of the flow is used to cool the motor and to lubricate the two identically designed

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Figure 1: Single-Stage Canned Motor Pump, Type CNPK 100x50x400

Figure 2: Single-Stage Canned Motor Pump, Type CNPF 150x100x290

hydro-dynamic slide bearings. After passing through the opening between the rotor and stator the partial flow is carried back through the hollow shaft to the pressure side of the impeller.

The advantages of the canned motor pump can be summarized as follows:

- *Double safety containments:* Even in the rare occurrence that the stator line is destroyed, none of the conveyed fluid can reach the external surroundings; thus 100 % leak-free.
- *No mechanical seals:* The sealless construction design means that these cost-intensive wear-and-tear parts are eleminated. This in turn means that three- to fourfold longer MTBF values (Mean Time Between Failure) can be achieved. The result: Reduced maintenance costs and long operating times.
- *No sealing system:* The sealless design and the medium-lubricated hydrodynamic slide bearings mean that no expensive, time-consuming installation of lubricating and cooling systems is required.
- *Close-coupled design:* The integral, compact close-coupled design means that no shaft alignment is required. A mechanical coupling and coupling protector are thus superfluous as is, often, the complicated base plate.
- *Low noise emissions:* Noise emissions are far below the usual levels for mechanical seal and magdrive pumps since the design means that no mechanical couplings, motor ball bearings or motor fans are required.

Two different design principles are available for high temperature applications:

a) Canned motor pumps with externally cooled motors [Figure 1],

b) Canned motor pumps with internally cooled motors [Figure 2].

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Figure 3: Single-Stage Canned Motor Pump, Type CNPK 250-630

2. CANNED MOTOR PUMPS WITH EXTERNALLY COOLED MOTORS

In this design, the pump is spatially separated from the canned motor by an intermediate component acting as a thermal barrier. This prevents heat transfer from the conveyed fluid to the motor. A relatively narrow, long circumferential gap equalizes the pressure differential between the hydraulics and the rotor cavity.

An auxiliary impeller is installed in the motor itself, recirculating the fluid in the rotor cavity through a heat exchanger mounted around the motor or a separately mounted external heat exchanger. Motor heat loss is absorbed by a cooling fluid. This creates two pump circuits with different temperatures. The operational circuit can be rated at temperatures of up to 450 °C, while the conveyed fluid in the secondary cooling/lubricating circuit has much lower temperatures of between 60 °C and 80 °C. As a result, the motor windings can be manufactured in long-lived Insulation Class H. Due to the pressure equalization in the thermal barrier's circumferential gap, there is hardly any fluid exchange between the two temperature levels. The use of a separate cooling circuit makes it unnecessary to cool the motor flow from the high operating temperature level to a level permitted for normal canned motors before carrying it into the delivery flow. Doing this would result in high energy loss. This cooling option and/or alignment can be used for single and multistage canned motor pumps. In addition to classic tubular heat exchangers, compact tube heat exchangers can also be used if costs so dictate.

Should no cooling water be available, then various models of air heat exchanger can also be used. These include simple honeycomb heat exchangers with ventilators, mounted above the unit and fixed to the base plate. [Figure 3] Separately installed system dry air heat exchangers (also with axial ventilators) are used for higher pump ratings.

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3. CANNED MOTOR PUMPS WITH INTERNALLY COOLED MOTORS

If not enough quality coolant, or no coolant at all, is available to cool the motor, then a different design principle must be employed. In addition, no matter what conveyed fluid is used, it will always need to be heated before initial operation; in the pump as well as in the canned motor. The temperatures required for this are generally in a range exceeding the maximum permitted temperature for the above-mentioned Insulation Class H. This is where canned motors equipped with special Insulation Class C windings come into play. So-called “hot motors” make it possible to solve various pumping tasks in the high temperature field. A silicone-ceramic insulating material is used, thus ensuring that appropriate measures to avoid oxidation of the copper wire can be taken. Windings of this type are able to withstand constant temperatures of 450 °C at the winding ends. They are rated for economical motor loads of up to 400 °C (temperature of the conveyed fluid). Fins at the centre of the motor's casing improve heat dissipation via natural convection. [see Figure 2]

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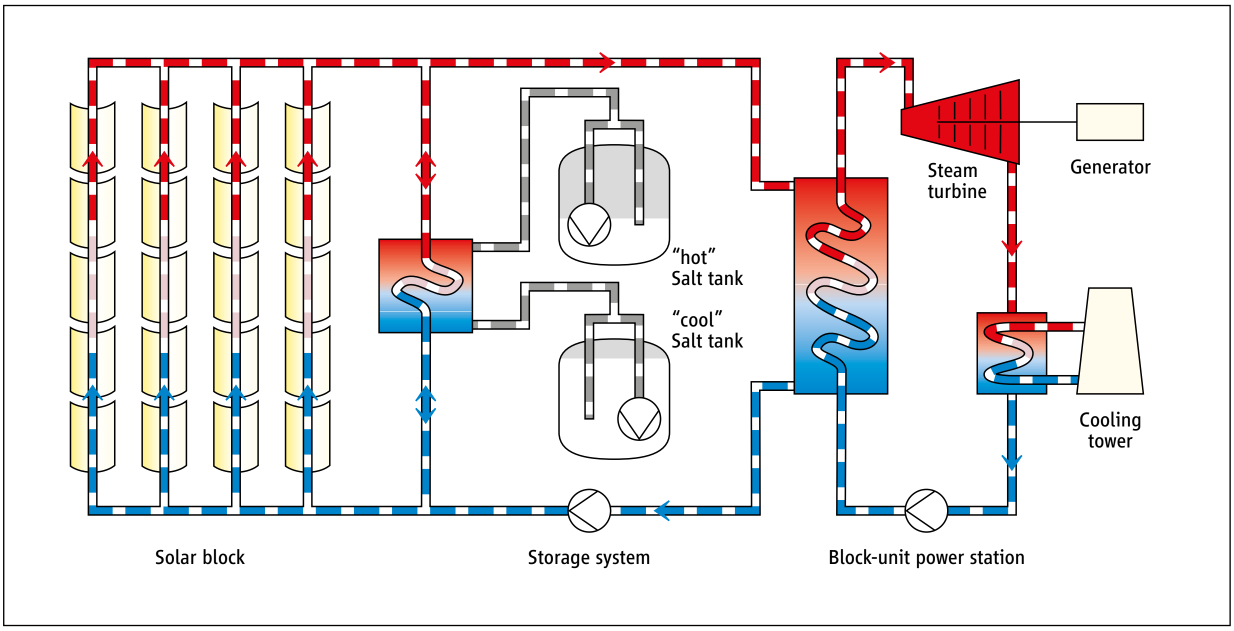

Figure 4: Simplified scheme of a CSP-plant /1/

4. NEW SOLAR ENERGY APPLICATIONS

A high temperature application of the future for canned motor pumps is installation in solar thermal power stations.

Solar thermal power stations are regarded as suitable industrial scale technology to create inexpensive electricity from solar power, particularly when such power stations are located in the Earth's so-called "sun belt". These concentrating systems are summarized under the term CSP (Concentrating Solar Power) technology. Four different types of solar thermal power plants are on the market, all categorized by the type of mirror system used: Parabolic trough power plants; solar power towers; Dish Stirling systems and Fresnel systems.

In Europe concepts and components have been tested at the international Plataforma Solar de Almeria (PSA) test field.

4.1 Parabolic Trough Power Plants with Heat Transfer Oil Intermediate Circuits

Parabolic trough power stations are considered a proven technology and are already currently being constructed on an industrial scale. For example, as an all-solar thermal power station with a capacity of up to 50 MW (CSP) in Spain [Figure 4] and as a hybrid solar thermal power station with ISCCS (Integrated Solar Combined Cycle System) in Egypt, with a capacity of up to 150 MW. Hybrid solar thermal power plants generate some of their electricity using natural gas. They consist of the solar element, the storage block and the power block. Parabolic trough solar thermal power stations use a pipe (receiver) with a heat transfer fluid in the focal line of the parabolic trough. One axis of the receiver tracks the sun's axis in such a way that the sunlight is always concentrated onto the heat transfer pipe. The concentrated solar

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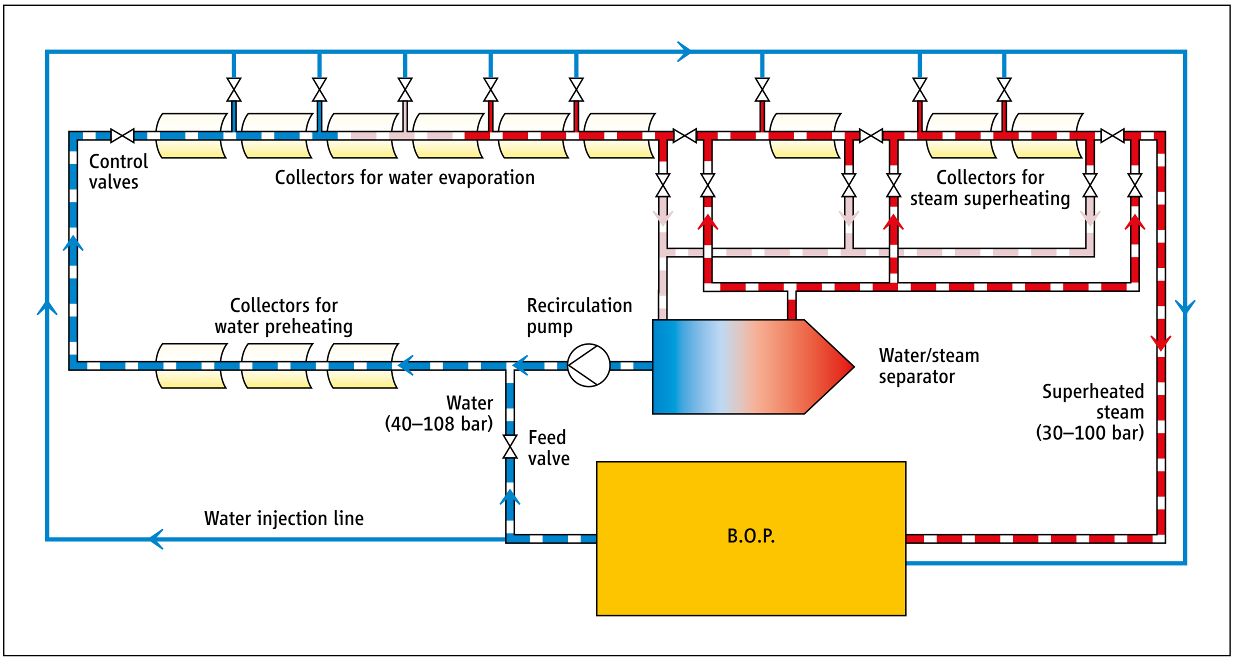

Figure 5: Simplified scheme of a DISS-plant /2/

radiation heats the heat transfer fluid, generally a synthetic heat transfer oil, to approximately 400 °C. Individual troughs are connected to one another using distribution lines. These distribution lines carry the heat transfer oil to a heat exchanger, which vaporizes water. Just as in a conventional power plant, this steam drives a steam turbine. The steam turbines' output is transferred to a generator to produce electricity. If a thermal storage block is integrated into the system (molten salt storage block) then provision of electricity becomes plannable, since the solar thermal power station can then also generate electricity after sundown. Hermetic CNPK canned motor pumps [see Figure 1] are used to recirculate the 400 °C synthetic thermal oil; in the examples above using an external tube heat exchanger (Spain) or a dry air heat exchanger (Egypt) [see Figure 3] which are mounted either over the pumps or, due to their size, next to the pumps. All pumps are operated using a frequency converter to facilitate handling of the varying flow rates during the course of the day while also providing maximum efficiency.

4.2 Parabolic Trough Power Stations with Direct Vaporization

Direct steam creation in parabolic trough power stations replaces the two-circuit system currently employed with a single heat transfer fluid, namely water. Without discussing the advantages of direct vaporization in detail, suffice it to say that research into the corresponding technical challenges has been taking place for some 8 years now at the world's largest direct vaporization plant, the DISS (Direct Solar System) Parabolic Trough Test Station at Plataforma Solar de Almeria (PSA) in Spain. [Figure 5]. Each of the two 500 m long collection lines is living proof of the functional reliability of direct vaporization in real conditions. A hermetic CAMKT 30/6 (PN 100) type high pressure pump operating at 100 bar system pressure and 400 °C and with an external heat exchanger is used to recirculate the water [Figure 6]. This high pressure pump is a multistage canned motor pump in barrel design. Thanks to the barrel design the pump requires only one single seal instead of 6 static seals. Asia's first parabolic trough power station, based on the direct vaporization

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Figure 6: Multistage Canned Motor Pump, Type CAMKT 30/6)

principle and located in Kanchanaburi Province in Central Thailand, also uses a hermetic Type CAMKT 44/3 (PN 100) high pressure pump with an external heat exchanger. Based on the experience gained in Almeria this pump is also a barrel design.

Canned motor pumps for high temperature applications are used in many technical and industrial processes requiring the supply of process heat. Solar thermal energy has opened up a new field of application in which, thanks to their special characteristics, canned motor pumps are the pump of choice.

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