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Experimental study of glass to metal seals for parabolic trough receivers

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ABSTRACT

The breakage of the glass to metal sealing is the primary ongoing issue for the solar receiver tubes in parabolic trough solar power systems. Sealing failure leads to loss of the vacuum inside the tube which substantially reduces the collector efficiency. It is a technical difficulty to obtain good glass to metal seals with high mechanical strength and long-term temperature resistance during current receiver manufacturing. The paper describes the development of the glass to metal seals in the parabolic trough receivers and presents a new method that uses the high-frequency induction heating to band a new borosilicate glass to the Kovar alloy ends. Kovar pre-oxidization experiments were used to measure the relation curves of Kovar oxidation weight gain during heating. The preoxidation of Kovar and the sealing process are guided by a series tests to measure the gas tightness, sealing strength, seal interface microstructure and thermal shock. The results show that excellent glass-to-Kovar sealing can be obtained with a Kovar oxidation weight gain of about 0.3–0.8 mg/cm^2. Finally, a new solar receiver was developed by the new sealing method.

1. Introduction

Parabolic trough solar concentrator with evacuated tubular receiver is the main technology used in solar thermal electric power generation plants as the most proven and lowest cost large-scale solar power technology available today [1]. It generates electricity using concentrated sunlight as the heat source for a Rankine power cycle. The solar collector field consists of rows of single-axis-tracking, linear parabolic mirrors that concentrate the solar beam radiation onto receivers located along the focal line of each parabolic trough. Heat transfer fluid pumped through the receivers is heated by convection from the sun-heated receiver walls. Then, the heat transfer fluid travels to a power block where it generates steam in a series of heat exchangers. The energy in the steam is converted to electricity in a Rankine steam-turbine power cycle [2].

The parabolic trough receiver, also named heat collecting element, typically consists of a metal pipe with a solar selective coating inside an evacuated glass tube to thermally insulate the metal pipe. The receiver incorporates glass to metal seals and metal bellows to achieve the necessary vacuum tightness enclosure and to accommodate the thermal expansion difference between the metal pipe and the glass tube [3]. A diagram of the parabolic trough receiver tube is shown in Fig. 1.

The receiver is one of the most important elements in the systems for converting the solar energy into thermal energy, with a key influence on the overall efficiency of the parabolic trough solar power plant. Data from existing commercial parabolic trough power stations show that failure of the glass to metal seal is the main cause of damage to the receiver, which is the primary ongoing issue [4–6]. The long-term integrity of glass-metal seal with high mechanical strength and temperature resistance is the key technical difficulty and bottleneck in receiver manufacturing.

Recent years the glass to metal seals have been a major revival of interest for the new applications. Glass to metal sealing is traditionally a fusion technique with the glass melted in contact with the metal parts to be sealed to. The melted glass flows into the metal parts where it wets the surface and reacts to form an interface. Experience has shown that the glass to metal seal method need to be taken into consideration in the successful design and manufacture of high-quality seals, particularly if an adequate component lifetime is to be achieved [7]. The glass to metal sealing includes metal decarburizing, metal oxidizing and sealing of the glass to the metal. At present, the four major glass to metal sealing methods are matched thermal expansion seals, unmatched expansion seals, soldered seals and mechanical joints [8]. For tubular seals, last two

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