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Hydrogen permeation model of parabolic trough receiver tube

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Abstract

Hydrogen gas formed by the thermal decomposition of organic heat transfer fluids can permeate through parabolic trough receiver tubes into the vacuum annulus, leading to significant heat losses in the receiver which reduces the parabolic trough power plant efficiency. This problem is quite important as these systems are being developed to drive down the cost of electricity. Thus, hydrogen permeation in parabolic trough power plants must be understood to develop strategies to reduce or prevent hydrogen gas accumulation in the receiver annulus. Hydrogen permeation model for parabolic trough receivers was developed based on measurements of hydrogen permeability of solar-selective coatings. The model was then used to study the effects of the hydrogen generation rate, the hydrogen pressure in the receiver tubes and the hydrogen barrier coating on the hydrogen permeation into the annulus. The hydrogen generation rate plays a significant role in the hydrogen permeation process, with the hydrogen pressure, permeability and adsorb area all related to balancing the hydrogen permeation rate with the hydrogen generation rate.

Keywords: Hydrogen permeation model; Parabolic trough receiver; Heat transfer fluid; Hydrogen barrier coating

1. Introduction

Concentrating solar power (CSP) systems are entering the commercial ramp-up phase after a demonstration period of 25 years since the first plant installation. By early 2010, the global capacity of CSP plants was close to 1 GW. Presently projects in development or under construction in more than a dozen countries are expected to total 15 GW, with most based on the parabolic trough technology (IEA, 2010). In China, the first 50 MW commercial parabolic trough power plant will be constructed by China Datang New Energy Co., a subsidiary of China's power giant China Datang Group.

As a key component of parabolic trough power plants, the parabolic trough receiver is used to absorb the solar radiation reflected by the parabolic trough collectors. The parabolic trough receiver, illustrated in Fig. 1, consists of a steel central pipe coated with a sputtered solar-selective coating, a glass tube surrounding the central steel tube and bellows to seal the tube. The vacuum-tight enclosure between the steel pipe and the glass tube is evacuated, which significantly reduces heat losses at high operating temperatures and protects the solar-selective coating from oxidation. The pressure in the receiver must be kept at or below the Knudsen gas conduction range to mitigate convection losses within the annulus, typically below 10^{-2} Pa to ensure good performance during its expect lifetime 25 years (Price et al., 2002).

However, significant heat losses in a large number of parabolic trough receiver modules have been observed recently in several solar fields, with the main contribution to the thermal losses identified as the slow permeation of hydrogen gas generated by decomposition of the organic heat transfer fluids through the steel tube wall into the

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