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Design and performance evaluation of swirl injectors for water evaporation at low pressure

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Abstract

This paper describes the design and performance evaluation of swirl injectors which find application in the spray flash desalination system at low pressures and temperatures. Water was sprayed into the vaporizer through a swirl injector as fine droplets. The vaporizer was maintained at low pressure. The maximum flow rate was 1 l/s. The injector performance was determined at different feed water temperatures, vacuum and water injection pressures. The effects of injector dimensions and flow parameters on droplet production were studied and analyzed. Droplet size of 0.7–0.9 mm from the theory compared with the experiments estimates. From this study, it is established that the droplet diameter in the range of 0.7–0.9 mm is optimum for flashing.

Keywords: Water spray; Swirl injector; Atomization; Mean droplet size

1. Introduction

This paper deals with the design and performance evaluation of swirl injectors which find application in spray flash vaporization desalination system [1] and OTEC system [2]. The experiments were conducted at different injection of water at temperatures between 26°C and 32°C, and the effects of other parameters were determined.

Little work was done in the field of spray flash evaporation. Muthunayagam [1] introduced a new concept for seawater desalination, where warm water from the upper strata of the ocean in the ambient temperature is injected into a flash evaporator at a low pressure. The resulting water vapour is condensed using the cold ocean water taken from lower levels of the ocean. Swirl injector is selected for injecting the feed water in to the vaporizer.

During the past decade there has been tremendous knowledge generation in the field of atomization, which is now developed into a major interdisciplinary field of research. The growth of interest has been accompanied by large strides in

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the area of spray analysis and in a proliferation of mathematical model for spray process [3].

Many works has progressed in the area of swirl atomizer design [3–6]. All of the reported works are with low flow rate and high pressure drop. No work is, however, reported for the condition of high flow with less pressure drop required [1]. Pressure swirl atomizers are here considered for the condition as they ensure fine droplets even at smaller injection pressures.

In swirl injector [3] the liquid enters through a channel, which is tangential to the axis of the injector. At the exit, the flow becomes a free sheet that later forms the spray. This important boundary, along with the aerodynamic interaction with the ambient gas, determines the behavior of the spray. Under the action of centrifugal force, the liquid spreads out in the form of a conical sheet as soon as it leaves the nozzle, and a hollow cone spray is formed. Knowledge of the flow field at the injector exit is necessary for spray prediction.

The main function of the injector is to transform the liquid to fine droplets to increase the ratio of the surface area to the volume to promote evaporation in the flash evaporator.

2. Parameters affecting mean droplet size (*D*) of swirl injector

The design parameters of swirl injectors are given in [4]. The design parameters include nozzle pressure differential (ΔP), liquid properties and geometric parameters of the injector. Liquid properties include density of the liquid (ρ_l), dynamic viscosity (μ_l), surface tension (σ_l). The geometric parameters include diameter of the swirl chamber (d_s), length of the swirl chamber (l_s), length of the exit orifice (l_o), diameter of the discharge orifice (d_o), diameter of the tangential inlet port (d_p). Fig. 1 shows the schematic of the swirl injector.

3. Design of swirl injector for high flow

The aim of the design is to determine the dimensions of the swirl injector for a mass flow rate (m) of 1 l/s with one inlet orifice (i). The design of the injector is focused towards the production of fine droplets and small pressure drops.

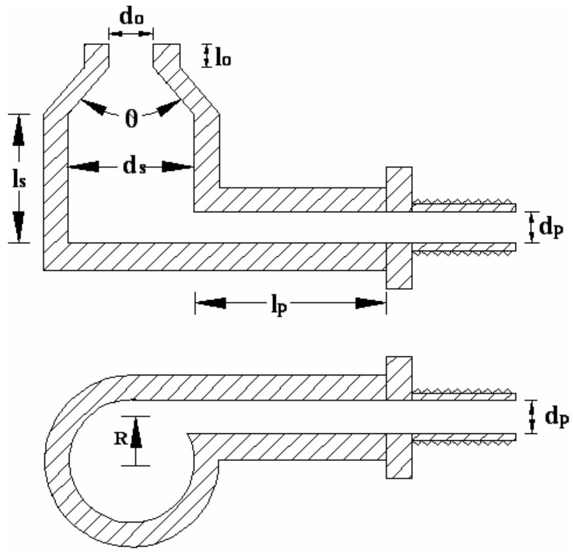

Fig. 1. Schematic of the swirl injector.

For the design of the injector the angle of spray (θ) was assumed and to be equal to 90°. The density of the water (ρ_l) was taken as 1000 kg/m^3. The pressure differential was taken in the range of 0.5–2.0 bar. Frictional losses are major considerations in the design of swirl injectors. The following equations were used to calculate the mean droplet size of the droplet [3].

Diameter of the orifice discharge (d_o):

$$d_o = \sqrt{\frac{4m}{\Pi \mu_d \sqrt{2\rho\Delta p}}} \quad (1)$$

Diameter of the eangential inlet orifice (d_p):

$$d_p = \sqrt{\frac{2Rd_o}{iK}} \quad (2)$$

Corrected diameter of the angential inlet orifice (d_p'):