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Standalone hydrogen generator based on chemical decomposition of water by aluminum

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Abstract

A standalone hydrogen generator (SHG) has been developed based on chemical decomposition of water in heterogeneous compositions containing finely dispersed aluminum powder and crystallohydrates of sodium metasilicate. The kinetics of hydrogen generation has been studied depending on constants of the aluminum activation and oxidation rate, and aluminum and oxygen concentrations. In the hydrogen accumulation kinetics, the length of the induction period is determined by the concentration of oxygen. The SHG design, hydrogen selection and capacity are discussed. The availability and low cost of domestically manufactured chemical agents make the SHG a promising choice as the source of hydrogen for various applications, including nuclear power plants (NPP).

Keywords: Hydrogen; Water; Aluminum; Aluminum oxide; Standalone hydrogen generator.

Introduction

At the present time, a growingly increased attention is given to studies into the generation of hydrogen from the interaction of powders of metals and alloys, specifically aluminum, with water. A decisive role in the process is played by the properties of metal oxides forming a surface film. High chemical stability of aluminum to water and steam effects is explained by the presence of surface films of aluminum oxide (Al_2O_3). To make aluminum active in the interaction with water, it is required to remove the surface oxide film. A number of techniques are used to activate aluminum, including treatment by sodium hydroxide, high temperature, high pressure, and gallium-indium alloys, which are however ecologically hazardous, complex and expensive [1–5]. Russian-patented hydrogen production methods [9,10] have been developed based on studies into the kinetics and the mechanism of reactions in hydroreactive heterogeneous compositions containing aluminum and silicon or calcium-containing compounds as activators [6–8].

For practical applications, it is desired that hydrogen is produced at the consumption point, which reduces greatly the cost of storage and transportation, and makes it easier to use [2,11]. This is achieved through the use of standalone hydrogen generators. This paper presents a description of a standalone hydrogen generator (SHG) patented in the Russian Federation [12], considers the kinetics of hydrogen generation with regard for the formulation of heterogeneous compositions and the environment components, and highlights some of the issues involved in control of the SHG hydrogen generation process.

Experiment

The hydrogen generator consists of two metal chambers in the form of cylinders mated through a threaded joint with a rubber gasket (Fig. 1).

The lower reaction chamber (1) is filled with a heterogeneous composition (2); the upper chamber (3) with a metallic bottom (4) is filled with an aqueous solution of sodium metasilicate crystallohydrate ($Na_2SiO_3 \cdot 9H_2O$) which acts as an aluminum activator; the aqueous activating solution is fed

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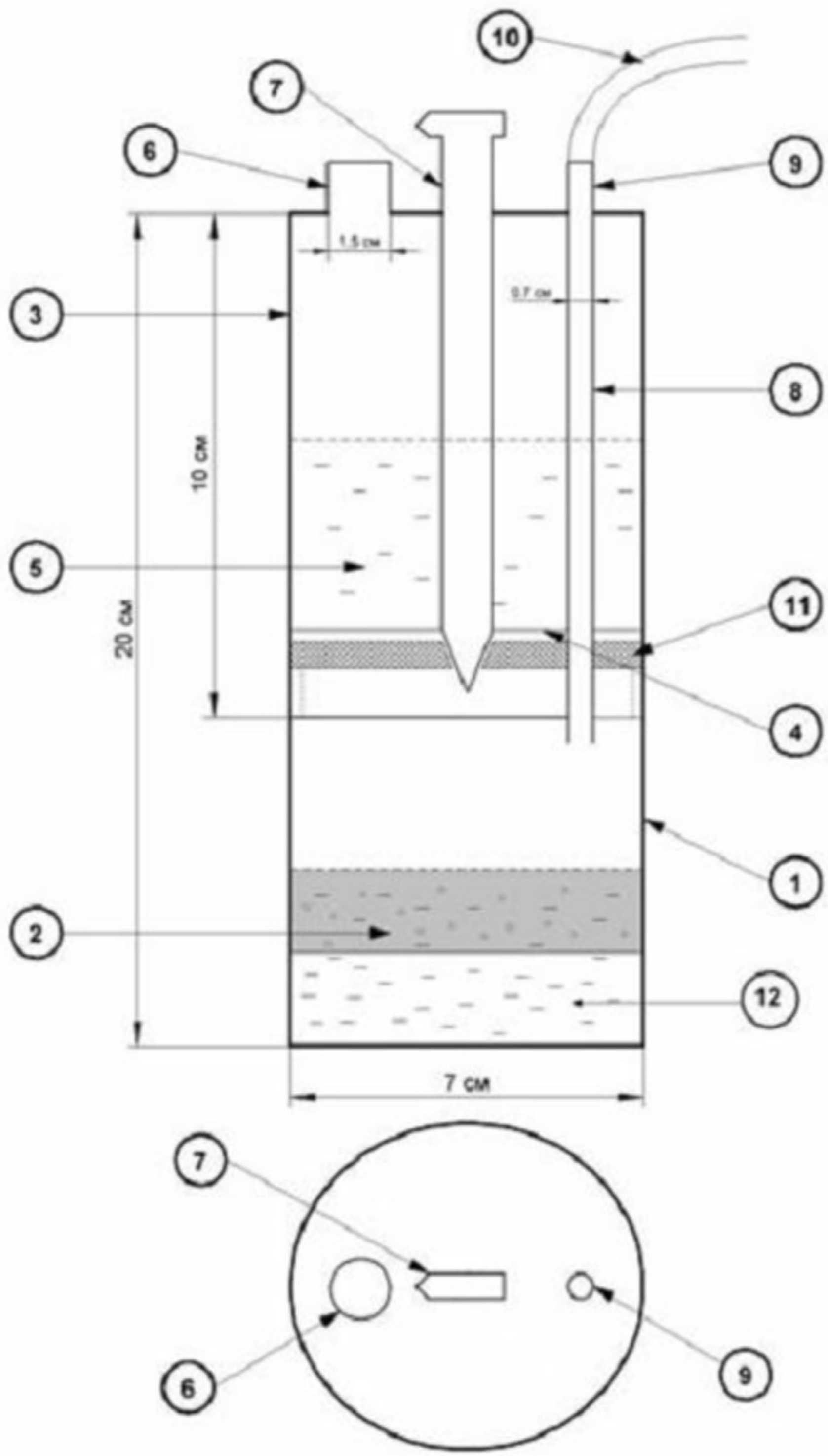

Fig. 1. Schematic of a standalone hydrogen generator model: 1 – lower reaction chamber; 2, 12 – hydroreactive heterogeneous composition; 3 – upper chamber; 4 – upper chamber metallic bottom; 5 – aqueous activating solution; 6 – solution filling window; 7 – reaction chamber aqueous activating solution feed regulator; 8 – lower chamber hydrogen blow-off tube; 9 – shell; 10 – flexible hydrogen discharge hose; 11 – packing ring.

from the upper chamber into the lower chamber using a threaded solution feed regulator (7) representing a rod with a tapered tail-end that makes it possible to supply the required amount of aqueous solution at the preset rate (see Fig. 1). The aqueous activating solution is filled through the window (6) in the chamber cover. The rate of the aqueous solution supply from the upper chamber to the lower chamber is regulated by the pointer of segment numbers (12), the indication of which is applied to the upper chamber cover surface.