Applied Thermal Engineering 39 (2012) 132–139

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

# Optimizing the process for emptying carbon dioxide cylinders used for hydrogen sweeping in high-power electrical generators

J.M. Blanco*, F. Peña

*Dpto. ing. nuclear y mecánica de fluidos, Escuela Técnica Superior de Ingeniería de Bilbao, Universidad del País Vasco/E.H.U. Alameda de Urquijo s/n (48013) Bilbao, Spain*

ARTICLE INFO

*Article history:*
Received 24 June 2011
Accepted 18 January 2012
Available online 28 January 2012

*Keywords:*
Thermoelectric power plant
Carbon dioxide
Hydrogen
Cooling
Generators

ABSTRACT

High-power alternators in large thermal power plants are generally cooled by hydrogen. Operating an electric power generator produces large amounts of heat that must be removed to improve efficiency. This means that the filling and emptying process needs to be performed in an inert atmosphere. Operating experience has shown that carbon dioxide is the most suitable fluid for this purpose because its molecular weight is considerably higher than that of hydrogen. On average, 90% of the contents of each cylinder are in a liquid state. As the process for discharging the cylinder proceeds, the gas progressively gets cool and may give rise to what is referred to as “dry ice,” rendering useless the rest of the content. This article describes the study and implementation of an experimental solution that optimizes the emptying of these cylinders in a power plant, thereby making a considerable saving because of their better exploitation.



## 1. Introduction

The use of hydrogen ($H_2$) for cooling purposes in power generators is commonplace in large power plants, as its cooling capacity is much better than air, whereby the size of the alternators can be considerably reduced for the same target power, as can be seen in Table 1 [1].

On a mass basis, $H_2$ is about 14 times more efficient than dry air in terms of heat dissipation; Water liquid is about 4 times but its capacity for heat removal with regard to dry air becames much lower because it presents an extremely low value for the thermal conductivity as can also be seen in the above mentioned table. However, we have to take into account that hydrogen's superior cooling properties are drastically increased as its pressure increases. $H_2$ in a pure state is suitable for this purpose, but when mixed with air, it becomes combustible. What makes it especially dangerous is that the explosive range of $H_2$ in air is broad, from concentrations that range between 4% and 74%. Monitoring $H_2$ purity is important for two reasons: The first one is efficiency: The purer the $H_2$, the more efficient the generator because $H_2$ has less wind age loss than air does. The second reason is the explosive mixture ratio; therefore, the purer the $H_2$, the safer the generator will be according to Turbine-Generator Auxiliary Systems [2].

The process for both filling and emptying the $H_2$ in the alternators must necessarily be performed in an inert atmosphere. Operating experience has shown that carbon dioxide ($CO_2$) is the ideal fluid for this purpose given that its molecular weight is considerably higher than that of $H_2$. $CO_2$ is a gas at standard temperature and pressure and exists in Earth's atmosphere in this state. The standard conditions for temperature and pressure have been mostly defined under the International Union of Pure and Applied Chemistry (IUPAC) as 0 °C (273.15 K) for temperature and 101,325 Pa (1 atm) for pressure.

Each cylinder delivers a load of around 30 kg of $CO_2$, corresponding to a volume of about 16 $Nm^3$. It may be assumed that under these conditions, approximately 90% of the contents are in liquid state. Thus, the process of discharging the cylinder involves a continuous vaporization of the liquid, whereby the temperature inside the cylinder will gradually fall unless a thermodynamic equilibrium is established around the cylinder. Fig. 1 shows the pressure–temperature phase diagram for the $CO_2$ where the most important phase change curves are depicted. As can be seen, $CO_2$ presents no liquid state for pressures below 516,757 Pa (5.1 atm).

One of a major generators' manufacturer such as General Electric, in accordance with their own regulatory instructions GEK-103763 and GEI-74441C respectively, establishes that only $CO_2$ cylinders that unload in vapor-phase should be used for this purpose, so those fitted with a siphon and which therefore unload liquid, requiring later a vaporizer, must be rejected in thermal power plants.

* Corresponding author. Tel.: + 34 946014250; fax: + 34 946014159.
*E-mail address:* jesusmaria.blanco@ehu.es (J.M. Blanco).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.01.044