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Short Communication

Influence of Expansion Valves on Gasification in Ammonia Storage Systems

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Abstract

To use ammonia for industrial purposes, it should be stored under atmospheric conditions (1 atm, -33° C). The equipment necessary for ensuring these conditions includes multi-stage compressors and expansion valves. In this study, the influence of the expansion valves on the expansion of compressed ammonia was investigated, and related calculations were performed by making some assumptions.

Key words: Ammonia, ammonia storage, expansion valve, bernoulli equation.

Introduction

Ammonia, which is as a raw material used in industry, is an important component in the formulation of chemicals, and gasification of ammonia under ambient conditions requires an improvement in storage conditions. To realize such improvement, very expensive equipment is required, and currently, such improvement is realized by using multi-stage compressors in ammonia storage systems[1]. The results of this study indicate that expansion valves can be used between the compressors and the storage systems to adjust the compressor output pressure[2], thus ensuring appropriate ammonia pressure in the storage tanks.

Material and Methods

The influence of expansion valves on storage pressure can be explained by the Bernoulli equation[3]. Bernoulli which can be written for an energy system as

$(P_1/\delta_1) + (gz_1) + (v_1^2/2) = (P_2/\delta_2) + (gz_2) + (v_2^2/2)$

where

(P_1/δ_1) = flow work at the input of the expansion valve

(gz_1) = potential energy of ammonia flow at the input of the expansion valve.

$(v_1^2/2)$ = kinetic energy of ammonia flow at the input of the expansion valve.

(P_2/δ_2) = potential energy of ammonia flow at the output of the expansion valve.

(gz_2) = kinetic energy of ammonia flow at the output of the expansion valve.

$(v_2^2/2)$ = kinetic energy of ammonia's flow at the output of the expansion valve.

This equation needs some assumptions in order for us to understand the influence of expansion valves in ammonia storage systems. To do this, we first need to consider how the position of expansion valves in the system affects the energy balance.

Assumptions and calculations: Assumptions: (1) The linear velocity does not change at the input and output of the expansion valve. Therefore, the difference in the kinetic energy is zero: $(v_2^2/2) - (v_1^2/2) = 0$ (2). Because there is no height difference throughout the valve, the difference in the potential energy is zero: $(P_2/\delta_2) - (P_1/\delta_1) = 0$

Thus, the Bernoulli equation can be written as follow for the expansion valve: $(P_1/\delta_1) = (P_2/\delta_2)$

According to the stage number of the compressor used for the compression of ammonia, the compression pressure can reach 17 atm and the compression temperature can reach 40 °C[4]. However, storing ammonia at this temperature and pressure is undesirable in industries that use ammonia as a raw material. Use of such heated liquid ammonia results in chemical reactions that have high enthalpy[5]. Therefore, the pressure and temperature of ammonia passing through the expansion valve should be decreased before ammonia is stored[6]. Compressed ammonia at 17 atm can then expand to 2 atm (-9 °C)[7]. We can then apply the Bernoulli equation by referring to these values:

δ_1 = density of ammonia at 40°C

δ_2 = density of ammonia at -9°C

$\delta_{1(40\,°C)} / \delta_{2(9\,°C)} = 17/2 = 8.5$

$\delta_{1(40\,°C)} = 8.5 \times \delta_{2(9\,°C)}$

According to the ideal gas equation,

$P \times v = n \times R \times T$

$(n_1 \times R \times T_1/v_1 \times \delta_{1(43\,°C)}) = (n_2 \times R \times T_2/v_2 \times \delta_{2(43\,°C)})$

$n_1 = n_2$

$316\ K/v_1 \times 8.5 \times \delta_{2(-9°C)} = 264/v_2 \times \delta_{2(-9°C)}$

$v_1/v_2 = 316/8.5 \times 264 = 0.16$

$v_2/v_1 = D_2/D_1 = 6.16 = 6$

When the temperature decreased from 40 °C to -9 °C, we determined that the pipe entrance diameter of the expansion valve in the system was 1/6th of the diameter at the output of the expansion valve, resulting in a decrease of pressure from 17 to 2 atm.

Results and Discussion

In this study, the influence of the kind of equipment used in ammonia storage systems on the physico-chemical properties of the ammonia prior to storage and the mechanism of this change was debated.

Ammonia as a raw material in industrial processes must be stored appropriately to because of its commercial properties before use in chemical reactions[8]. Due to its low boiling point, it has a tendency to gasify under storage conditions and this gasified amount affects the storage conditions. Therefore, this gasified amount should be liquefied by a compressor. When designing the storage tank, the whole system must be considered in terms of this need for liquefaction[9]. In general, gaseous ammonia compressed by a compressor cannot be stored under` the required conditions after this compression, because the compressed ammonia has higher pressure and temperature conditions than the storage conditions[10]. To decrease the pressure and temperature between storage tanks and compressors, the best mechanical system to use without adding extra equipment is expansion valves. An expansion valve and the pressure and temperature values at which the compressed ammonia is stored are shown in figure-1; the valve consists of a valve plane, which is used to change the pipe diameter. The use of the expansion valve is advantageous because the pipe diameter can be changed without incurring extra equipment costs.

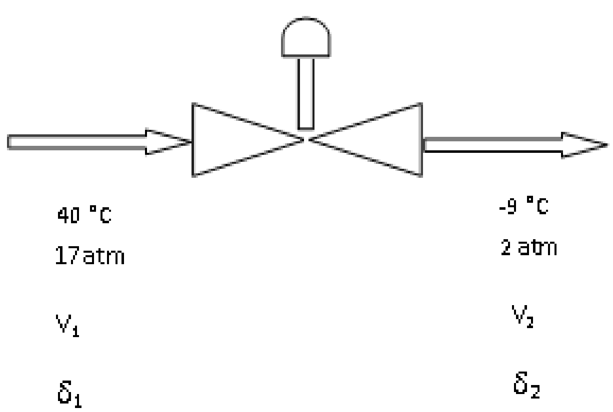

Figure-1
Expansion valve

The purpose of the calculations using the Bernoulli energy equation is to ensure that we obtain the most appropriate result under the most likely conditions that would allow the expansion valve consisting of a mechanical valve plane to have wide applications in industry. The result obtained at the conclusion of these calculations has been applied to various industrial processes and it demonstrates flexibility according to the design values. However, the result is a rate parameter that is appropriate to all such industrial applications.

While calculating the pipe diameters at the input and output of the expansion valve, we made some assumptions. We also made some assumptions while performing these calculations. By assuming that the ammonia flow speed does not change on the valve plane, it is assumed that the kinetic energy is stable at both the input and output of the valve. On the other hand, it is thought that because there is no height difference on the plane where the expansion valve is placed in the pipeline, i.e., leading from the output of the compressor to the storage tanks, that there is no difference in the potential energy at the input and output of the expansion valve. According to these assumptions, one parameter that we can calculate for the expansion valve in the Bernoulli equation is the flow work of ammonia that occurs on the pipeline plane. On the basis of this fact, we have utilized the ideal gas equation for a gaseous- liquid ammonia solution passing through the pipeline and have calculated the pipe diameters on the valve plane on the basis of the density difference of ammonia at the input and output of the expansion valve.

Conclusion

In this study, the decrease in temperature from the compressor output temperature to the storage temperature was calculated; it was found that this decrease was related to the ratio of the compressor output pressure and the expansion valve output pressure. Accordingly, for the system under consideration in this study, the ratio of the valve input diameter and output diameter was calculated to be 1/6. This result enables us to appropriately regulate the required pipe diameter and line design values to achieve the most efficient working flow speed. This result can also be applied to expansion valves systems on similar planes.

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