Vol. 9, No. 1, pp. 54-57, June 2010

INTERNATIONAL
JOURNAL OF SAFETY
www.kosos.or.kr

Safety Design of the Loop Heat Pipe (LHP) by the Hazard Analysis

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(Received April 28, 2010; Accepted June 15, 2010)

Abstract: The LHP uses the capillary head instead of the mechanical pump to transfer the fluid. It does not have any moving parts and transfer the fluid by the capillary head between the vapor and liquid interface of the wick like a heat pipe (HP). Moreover, vapor and liquid flows in the same direction. It can reduce the loss of the pressure in the wick (very short wick in the evaporator) and can transfer large heat over long distance compared with HP. It is necessary that we do the hazard analysis that is a part of the safety design, for the benefit of eliminating and inhibit the hazard. In this paper, we describe the hazard analysis of LHP.

Key words: loop heat pipe, safety design, hazard analysis, hazard description table, hazard analysis table

1. Introduction

The LHP uses the capillary head instead of the mechanical pump to transfer the fluid. It does not have any moving parts and transfer the fluid by the capillary head between the vapor and liquid interface of the wick like a heat pipe (HP). Moreover, vapor and liquid flows in the same direction. It can reduce the loss of the pressure in the wick (very short wick in the evaporator) and can transfer large heat over long distance compared with HP. Therefore, it is reliable and reduced the total weight compared with a mechanical pump system. It can be adapted to the distributed heat sources in order to have a parallel configuration of the evaporator and in order to arrange the layout of the vapor and liquid tubes, too. Moreover, the accumulator put in front of the evaporator can keep the temperature constant varying the heat dissipation of the heat source. The heat transfer capability of LHP, that is limited to the several hundred watts by the capillary force of the wick structure inside the evaporator.

The compact designed LHP can transfer small and medium heat over short or middle distance. Moreover, it is effective in protecting environment because it does not demand a power to transfer the heat. It will better suit to control the temperature of a personal computer, a server, and a liquid crystal television of the mechanical industry.

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We evacuate the pipes of LHP and charge the fluid like a water and ammonia inside the pipes of LHP. As the evaporator of LHP absorbs heat of a electronic component, LHP will turn out high temperature and pressure. It is necessary that we must take safety measures and safety design.

In this paper, we describe the hazard analysis of LHP that is a part of safety design.

2. Safty Design

The safety of machinery defined by ISO is 'there is not unacceptable risk'. Therefore, the concept of safety of machinery has been varied from the Japanese way of foreseeing the danger to the Western way of assuring the safety. In other word the concept of zero-damage, damage will not be caused if people use properly, the concept of minimum-risk that safety design makes risk minimized. For example, let us consider the safety at the shop floor. We made just passive measures for safety, such as armors, workers' education, and training. Nowadays, however, safety design at the shop floor is carried out in order not to lead human error to the hazard on the assumption that human error necessarily happens. The safety design has also carried out so that we must minimize the risk even though hazards occur.

The procedure of safety design is as follows. First, we design products based on the safety standards. Second, we do the risk assessment of products and the control methods of the risk are proposed. Then we

Table 1. Hazard identification table

Hazard category	Hazard type / Hazardous item
Temperature Humidity	High humidity
	Low temperature
	High temperature
Contamination Corrosion	Bacteria and microbion
	Compatibility of liquid, volatile solvent, strong acid and alkali
	Hazardous and toxic materials
Structure	Stress corrosion
	Umbo and sharp edge
	Noise
	Destruction and abrasion
Electric shock	Static charge
	Electric leak
	Short
	Electric shock
Shock Vibration	Moving mechanism
	Rotated and accelerated body
	Shock and vibration
Burst	Pressure vessel
	Explosive ambiance
	Explosives
Fire	Ignition Source, Oxidant and Combustible Material
Natural calamity	Thunder, big wind, big rainfall typhoon and earthquake
Human disaster	Failure by operating error

check the effect of the risk and confirm within permissible range. Finally, we reduce the risk over the range to the acceptable level by the 3-step methods. You devise a countermeasure to reduce the risk.

3. Hazard Analysis

It is necessary that we do the hazard analysis that is a part of the safety design, for the benefit of eliminating and inhibit the hazard. First, we pick out the hazard of

Table 2. Hazard analysis table

Physical object	Description of hazard	Occurrence	Cause of hazard	Impact of hazard	Protective method	Degree of damage	Possibility of incidence	Risk level
LHP	Compatibility of liquid/ Pressure vessel	During use and storage	Chemi cal reaction between materi al and liqui d because of lack of bakng and cleaning	Rupture of pipe because of corrosion	Review of manufacturing process and production control	S2	K1	II
	High temperature/ Pressure vessel	During use and storage	Rise of temperature becaus e of high heat load	Rupture of pipe because of over pressure	Review of manufacturing process and production control	S2	K1	II
		During storage	Ambient temperaturerise	Rupture of pipe because of over pressure	Reconfirm heat load at design phase	S2	K1	II
				Rupture of pipe because ofover pressure	Reconfirm environment at design phase	S2	K1	II

existing in goods with the use of the hazard identification table indicated in Table 1.

Second, we fill the description of hazard, occurrence, cause of hazard, impact of hazard, protective method, degree of damage, possibility of incidence and risk level in the hazard analysis table indicated in Table 2. It is important that we must reflect above actions on the goods.

Figure 1 shows the flowchart of the hazard analysis.

(1) We identify the cause of hazard existing in goods and pick out the hazard item.

(2) We estimate the degree of damage indicated in Table 3 and the possibility of incidence indicated in Table4.

(3) We identify the cause of hazard existing in goods and pick out the hazard item.

(4) We estimate the degree of damage indicated in Table 3 and the possibility of incidence indicated in Table4.

(5) We judge the risk level of hazard from Table 5. If the impact of hazard is within an allowance, we go on the section (5). If the impact of hazard is out of an allowance, we go on the section (4).

(6) We remove the impact of hazard in the following manner.

(a) We design to reduce the impact of hazard.

(b) If we should not reduce it by the above-described method, we must use the safety equipment.

(c) If we should not reduce it by the above-described method, we must use the protection instrument.

(d) If we should not reduce it by the above-described method, we must use the warning notice.

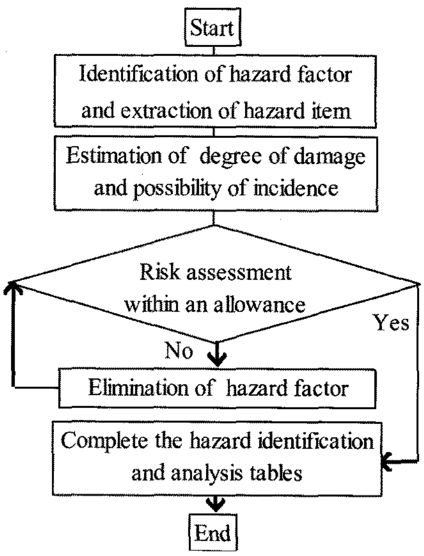

Fig. 1. Flowchart of hazard analysis.

Table 3. Degree of damage

Degree of damage	Degree	Target of damage
S1	Scratch	Minor hazard
S2	Slight injury	Hazard without interruption of service
S3	Heavy injury	Disability hazard, injury grade8-14
S4	Death, physical disability	Injury grade1-7

Table 4. Possibility of incident

Possibility of Incidence	Degree	Possibility of Incidence
K1	Infrequently	Once a year
K2	Occasionally	Once a month
K3	At moments	Once a week
K4	Continually	Several times a day

Table 5. risk level

Possibility / Degree	K1 Infrequently	K2 Occasionally	K3 At moments	K4 Continually
S1 Scratch	I	II	II	III
S2 Slight injury	II	III	III	IV
S3 Heavy injury	III	IV	IV	V
S4 Death, physical disability	IV	V	V	V

If we should not reduce it by the above-described method, we use the training and operation manual.

We take steps to meet the situation and make up hazard description and hazard analysis table.

4. HAZARD ANALYSIS OF LHP

4.1 Description of Lhp

Figure 2 indicates the operation principle of the LHP.

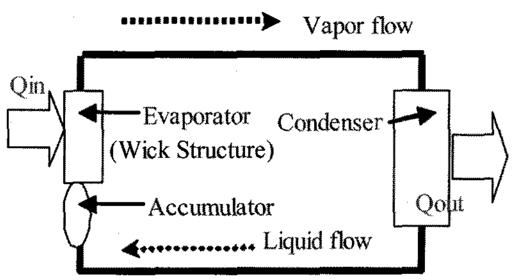

Fig. 2. Concept of LHP.

As soon as we added the heat to the evaporator, the liquid changes to the vapor in the wick structure of the evaporator. The vapor flows to the condenser through the vapor tube, discharges the latent heat to the condenser, and changes to the liquid. The liquid flows into the evaporator by the capillary pressure of the wick structure of the evaporator through the liquid tube.

4.2 Hazard Identification Table of Lhp

Table 1 shows the hazard descriptions of LHP.

We can abstract 'pressure vessel', 'compatibility with liquid' and 'high temperature' with LHP hazard.

4.3 Hazard Analysis Table of Lhp

Table 2 shows the hazard analysis table of LHP. We make up this table from hazard descriptions of LHP. We determine the degree of damage based on the Table 3, the possibility of incidence based on the Table4 and the risk level based on the Table 5. Risk levels of LHP are II within an allowance. We confirm that actions to reduce the hazard of LHP are correct.

5. Conclusion

Nowadays the concept of machinery safety will drastically make a difference. You must make the machines based on the international safety standard. We hope that you make good use of hazard analysis design explained on this paper and you find it informative.

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