Journal of Applied Science and Engineering, Vol. 22, No. 2, pp. 213–220 (2019) DOI: 10.6180/jase.201906_22(2).0002

Experimental Study on Flash Evaporation under Low-pressure Conditions

Haoyu Wu[1], Weimin Liu[1], Xiaoming Li[2], Fengyun Chen[1] and Longbin Yang[3]*

[1]The First Institute of Oceanography, State Oceanic Administration, Qingdao 266061, P.R. China
[2]School of Chemical and Biological Engineering, Taiyuan University of Science and Technology, Taiyuan 030024, P.R. China
[3]College of Power and Energy Engineering, Harbin Engineering University, Harbin 150001, P.R. China

Abstract

Flash evaporation is extensively used in industrial application. In order to investigate flash evaporation, a new experimental system equipped with the high-speed CCD digital camera and data acquisition instruments is established. A series of experiments has been carried out with various initial temperatures from 50.0 °C to 90.5 °C, initial water heights of 400 mm to 550 mm, and superheats ranging from 1.5 K to 17.8 K. It is revealed that flashing phenomenon process includes three stages: bubbles generation stage, boiling growth stage and boiling reduction stage. Moreover, the heat transfer characteristics and flow mechanism of each stage has explored. In addition, a correlation between the propagation speed of flash evaporation wave and superheat degree was obtained. Results indicated that the intensity of flash evaporation drastically increases with the increasing of superheat.

Key Words: Flash Evaporation, Low Pressure, Flash Evaporation Wave, Propagation Speed, Visualization

1. Introduction

Flash evaporation is one kind of violent boiling phenomenon when a liquid under rapid depressurization, large amounts of vapor generate by the latent heat of vaporization of liquid with a significant temperature drop. Compared with conventional evaporation, flash evaporation evaporates faster and produces more steam. Consequently, flash evaporation is widely used in industrial application, e.g. seawater desalination, steam accumulator, accident of pressure vessels and ocean thermal energy conversion [1].

Flash evaporation phenomena has been world-wide researched in recent years, previous research mainly focus on the effects of influencing parameters including initial water temperature, superheat and initial water height on flash evaporation of liquid in pool. O. Miyatake et al. [2] carried out experiments on static flash evaporation with equilibrium temperature from 40 °C to 80 °C, initial superheat ranging from 2.5 K to 5.5 K, and introduced non-equilibrium fraction (*NEF*) to characterize the temperature evolution of waterfilm and evaluate the final completion of flash phenomenon in a given system:

$$NEF = \frac{T(t) - T_e}{T_0 - T_e} = \frac{T(t) - T_e}{\Delta T} \tag{1}$$

where T_0 is the initial temperature of liquid, $T(t)$ the is temperature at a certain time.

Furthermore, many studies were conducted on the relation between flashing time, *NEF*, *NETD*, equilibrium time and initial superheat, initial temperature, water level. Jong-Il Kim et al. [3] carried out experiments on pool flash evaporation with the diameter of flash chamber at 152 mm, and derived the correlation between the critical time and non-equilibrium temperature difference. D. Saury et al. [4,5] studied the flash evaporation phenomenon in the flash chamber made of transparent glass materials. They explored the water mass evaporated by flash evaporation and looked at the influences of initial temperature and superheat on *NEF* evolution and evapo-

*Corresponding author. E-mail: yanglb@hrbeu.edu.cn

rated mass. Their results revealed that final evaporated mass presented an increscent proportional to the superheat degree. D. Zhang et al. [6,7] carried out experiments in a cuboid vessel (0.2 m × 0.2 m × 0.5 m) at superheat of 1.5 K to 53.6 K, initial water temperature from 44 °C to 109.9 °C, and analysed the influence of initial waterfilm levels on the temperature difference. The empirical equation between volumetric heat transfer coefficient and superheat and initial water film height on flash evaporation of aqueous NaCl solution was proposed.

In addition, many studies focused on the special phenomena (i.e. evaporation waves) caused by the phase change during a flash evaporation process. It has been observed that a vapor-liquid interface (i.e. the boiling front or the evaporation wave front) generated on the free surface and progresses into the superheated liquid [8−12].

M. A. Grolmes and H. K. Fauske [8] first systematically conducted experimental study on the evaporation wave of water, Refrigerant-11, and methanol in tubes with diameters range from 0.2 inch to 15 inch. The results revealed that the smaller the tube diameter and the greater the degree of initial liquid superheat, the more likely the free surface flashing occurred.

L. G. Hill and B. Sturtevant [9] performed experiments with R12 and R114 in a glass tube with diameter of 2.5 cm. During the experiment, a quasi-steady evaporation wave and an apparently sharp, rough vapor-liquid interface composed of bubbles were observed. Moreover, three different flashing initiation modes depending on the liquid superheat were observed.

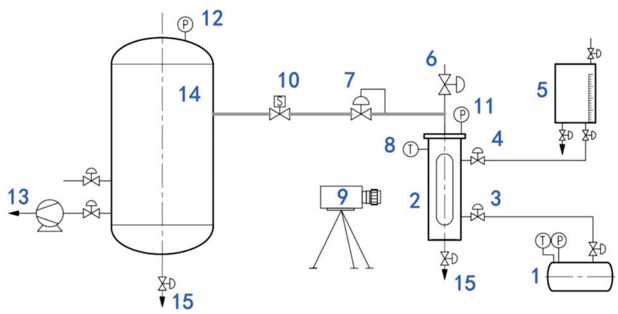
E. Hahne and G. Barthau [10] conducted adiabatic flash experiments with refrigerant 11 as test liquid in glass tubes with 32 mm to 252 mm diameters. The formation of the evaporation waves were observed under the superheats of 35 K to 50 K and the depressurization rates as low as 1 bar/s. In addition, the experiments on evaporation waves with metallic inserts in the test tube showed that the metallic inserts penetrating the liquid level promote the propagation velocity and inception superheat of boiling fronts.

P. Reinke and G. Yadigaroglu [11] also did evaporation waves experiments with propane, butane, water, and R134a in glass tubes of 14 mm-80 mm diameters. They used a glass funnel and a flattened pipe with a rectangular cross-section to investigate the influence of the cross-section area and shape on the boiling fronts. Qualitative and quantitative analysis of boiling fronts were conducted. Results suggested that the velocity of the evaporation wave was independent of channel diameter and shape. The measured velocities of boiling front increased linearly with the liquid superheat.

Flash evaporation has been extensively used in industrial application. Due to the flashing process is highly complex and rapid, it is difficult to measure and record the influence factors in entire flash process. In the above studies, the pressure drop is very large and the initial depressurization rate of up to approximately 12000 bar/s, which result in experimental conditions similar to industrial application without the influence of heterogeneous or homogeneous nucleation. The purpose of our work was to better understand the flash evaporation in a vacuum environment with low depressurization rate. In this study, we explored the internal mechanism leading to flash phenomenon with the high speed camera and data acquisition instruments, which could record the high quality images and data during the experiment.

2. Experimental System

The experimental system for water flash evaporation is designed and built up as showed in Figure 1. The subject of the system is composed of visualization flash chamber and vacuum system. The flash evaporation takes place in the flash chamber. The distilled water used in the experiment comes from feed water tank. It is heated to the demanding temperature by the heater and then flows into the flash chamber. The vacuum pressure of vacuum tank is controlled by a vacuum pump and a vacuum pres-



1- Heater; 2- Visualization flash chamber; 3- Intake valve; 4- Water filling valve; 5- Feed water tank; 6- Blow off valve; 7- Adjusting valve; 8- Thermocouples; 9- High speed CCD digital camera; 10- Electromagnetic valve; 11- Pressure transducer; 12- Vacuum pressure transducer; 13- Vacuum pump; 14- Vacuum tank; 15- Drain valve.

Figure 1. Schematic of experimental setup.

sure transducer. There is an electromagnetic valve and an adjusting valve positioned on the pipe connecting flash chamber with vacuum tank. To achieve visualization, two transparent glass windows is used to flash chamber, one is observing window and the other is lighting window. The two windows are completely symmetrical. A high speed CCD digital camera is placed in front of the observing window to record the images information of flash evaporation process. Besides, the temperature sensors and pressure transducers are set in the flash chamber to record the temperature and pressure in real-time via the data acquisition system.

2.1 Data Acquisition System

Temperature in the experiments is gauged by stainless-steel sheathed 10 points profile probe with accuracy of 0.2 K, diameter of 6 mm and time constant of 0.04 s. We set up 10 copper-constantan thermocouples inserts in the probe to measure the temperature distribution along the vertical direction. The sealed thermocouples are fixed in sequence with the vertical distance 100 mm along the axial line of the flash chamber. The temperature signals are sampled by OMB-DAQ-56 with 20 channels and accuracy of 0.002% in full scale.

The pressure in the flash chamber and vacuum tank are measured by Rosemount 3051 absolute pressure sensors with accuracy of 0.075% in full scale. The pressure signals are sampled by LabVIEW and NI USB-6210. Besides, two vacuum pressure gauges are installed in the top of the flash chamber and vacuum tank, respectively. The pressure gauges accuracy is 0.4% in full scale.

The high speed CCD digital camera is located in front of visualization window to record the evolution process of flash evaporation in the flash chamber, with full-resolution of 800 × 600 and the maximum full-resolution recording speed of up to 6814 frame/sec.

2.2 Experimental Procedure

- Close the electromagnetic valve. The distilled water in the flash chamber is heated to be required temperature by the heater, remove the dissolved gases in the bulk water.
- Through the drain valve and altimeters, adjust the water level to the experimental demanded level.
- Turn on the vacuum pump to achieve the pressure of vacuum tank to required pressure. Adjust the pressure of the flash chamber by adjusting valve. Make sure the pressure inside the vacuum tank is lower than the flash chamber.
- Turn on the high speed CCD digital camera, and then set up the data acquisition systems.
- When the electromagnetic valve is turned on, flash evaporation suddenly take place in the flash chamber. Moreover, the high speed digital camera and the data acquisition systems start to record data of entire flashing process.

2.3 Uncertainty Analysis

The uncertainty analysis results for all experimental parameters are calculated using the Moffat method as shown in Table 1.

3. Results and Discussion

NEF is the simplified dimensionless superheat for the flash evaporation process. The evolution of *NEF* versus time of flash evaporation is shown in Figure 2. It shows *NEF* evolution is similar to the temperature evolution, they decrease exponentially with time. The results agree with that of the others' research such as O. Miyatake, D. Saury and D. Zhang et al. Figure 2 also shows two *NEF* curves of the flash evaporation at initial water level of 450 mm and initial temperature of 89 °C with superheat of 17 K. The two randomly selected curves are in good agreement. The results demonstrate that the experimental system has good repeatability and the experimental data are authentic.

3.1 Flash Evaporation Process

O. Miyatake et al. [2] had divided the flash process into fast evaporation stage and gradual evaporation stage depending on the waterfilm temperature evolution. At the beginning, the water temperature dropped quickly and bubbles generated violently in the liquid. Subsequently, the drop slowed down to nearly zero and the bubble just

Table 1. Uncertainty analysis results

Parameter	Absolute uncertainty	Minimal measured value	Uncertainty
T (°C)	0.2	51.2	0.004
H (m)	0.0005	0.1	0.005
P_0 (MPa)	0.0004	0.01	0.040
P_v (MPa)	0.0004	0.012	0.033
NEF	-	-	0.005

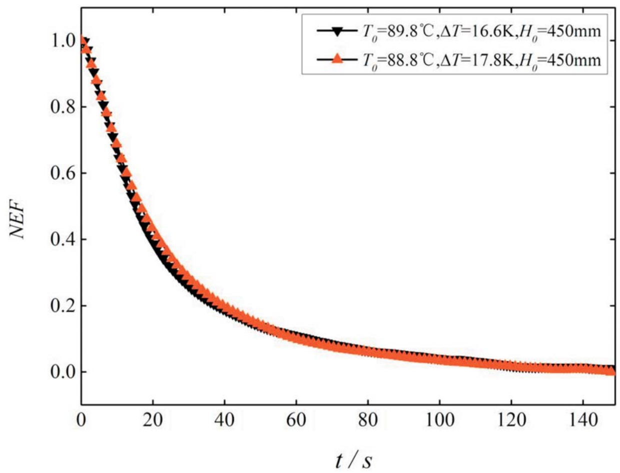


Figure 2. Reproducibility of this experiment.

appeared on the vapor-liquid interface. And they had defined the intersection of the two slopes as the flash time. Most researchers agreed on this definition and did further study [4–7]. Figure 3 illustrates a typical water temperature evolution during flashing process. The water temperature drops rapidly and then slowly falls until a certain value (T_e). The tangent slope at any point on the water temperature curve T represents its instantaneous drop rate and the slope of any tangent is negative. The least slope tangent (at point B in Figure 3) represents the greatest drop rate of water temperature evolution during the flashing. Hence, the turning point (C) of the fast/gradual flash evaporation stage is defined as the intersection of the horizontal line T_e and the least slope tangent of the curve T. Since the gradual stage has a much lower flash rate than the fast stage, most researchers believed that the duration of the fast evaporation stage is the flash duration time [0, t_{tp}] [13,14].

And on the basis of that, considering the beginning of water temperature evolution and different vapor bubble generation characteristics in the initial stage, the flashing process can be divided into three stages: bubble generation stage, boiling growth stage, and boiling decaying stage. The turning point (A) of the bubble generation stage is defined as the intersection of the horizontal line T_0 and the least slope tangent along the curve T.

Generally, the flash evaporation is an unsteady process. According to the photos took by the high speed digital camera, we can very clear that nucleation, bubble growth, and break-up during the flash evaporation. As shown in Figure 4, when the electromagnetic valve is opened, the water in the flash chamber suddenly becomes superheated, and the heat cannot be stored in the liquid as sensible heat. The released heat is converted into the latent heat of vaporization. And vapor bubbles begin to generate. The bubbles then expand and collapse to form a vapor/water mixture. The two-phase mixture grows downward and originates the disturbance to the bottom of water. When the disturbance is propagated to the bottom of the flash chamber, the water temperature drops greatest (B). Subsequently, the temperature of the body water gradually equilibrates along with steady boiling (C). Afterwards, it enters the boiling decay stage. The water temperature drops slowly, and boiling only occurs near the surface of the liquid. In this process, bubbles nucleation, collision, coalescence, and bursting occur almost simultaneously and interact with each other.

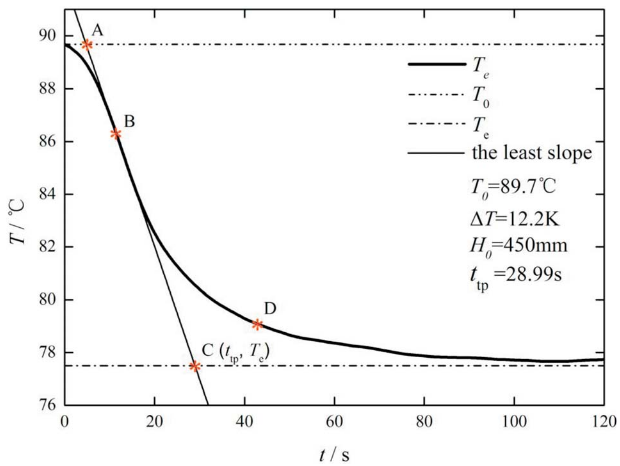


Figure 3. Water temperature evolution (T_0 = 89.7 °C, ΔT = 12.2 K, H_0 = 450 mm).

3.1.1 Bubble Generation Stage

The bubble nucleation is classified as homogeneous nucleation and non-homogeneous nucleation. Homoge-

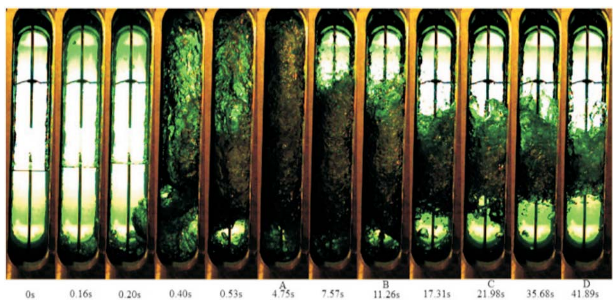


Figure 4. Flash evaporation process corresponding to Figure 3.

neous nucleation is the typical process of forming steam in liquids for a long lived metastable state. The cause is that the activated process surmounts a free energy barrier between the metastable and more stable phase via a nucleating fluctuation in the form of a critical droplet. The evaporation process formed by the existing nucleus is non-homogeneous nucleation. The need of much lower superheats resulted from the heterogeneous nucleation site of the droplets. The flashing also can be assorted homogeneous flashing and non-homogeneous flashing according to the difference in the nucleation [10]. Most studies focus on the non-homogeneous flashing due to the fact that it is relatively easy to happen in experiments [15,16].

Although the inner walls of flash chamber has processed with derusting and polishing, the intake and the sensors installed in the flash chamber bring in inclusion and cavitation about what to be active nucleation sites in the flashing process. Figure 5 shows the non-homogeneous nucleation in the bubble generation stage. Non-homogeneous nucleation mostly occurs on the solid/liquid interface [17]. It can be obviously seen that, a parasitic nucleation site is activated at the wall surface of the flash chamber in form of few and big bubble in the liquid. The bubble growth in this stage is much greater than the spontaneous nucleation. It indicates that nucleating fluctuation is the major dynamic force for the bubble generation stage of flashing process.

3.1.2 Boiling Growth Stage

The boiling growth stage is considered as the major stage of the flashing process. The duration does not last long, yet the boiling intensity is the greatest of the three stages. Subsequently, the evaporation wave progresses into the superheated liquid downwards with fluctuation in bulk water, which result from immediately generating many vapor bubbles.

In Figure 6 the boiling growth stage of the flashing, the front of the evaporation wave appears as an extremely complicated, rough, but clear interface, which separates the upper two-phase flow region and the lower stagnant superheated water. The disturbances among the superheated water increase strongly, especially in the two-phase mixed region. At the beginning, evaporation wave starts to develop on the liquid surface, which suddenly becomes instable with the collision, break-up and coalesce [10,11]. With the evaporation wave progressing into the superheated liquid, the mass and inner energy is consumed and the cooled liquid layer is continuously removed by the entrained droplets in upward flowing. The water level rises higher to the maximum swelling height. Moreover, the front of evaporation wave reaches the maximum propagation depth. That means flash evaporation always simultaneously exposes upward and downward. In this stage, the interfacial forces is thought as main driving force that acting on bubbles by interaction between drag force and mass force [18].

3.1.3 Boiling Decaying Stage

The boiling decaying stage is the most lasting stage in flashing process. The boiling is not as violent as the boiling growth stage. As shown in Figure 7, the water level comes to fall back to the initial level during this stage. In addition, the front of the evaporation wave propagation gradually decays as vapor bubbles production decreasing, which can be attributed to the decreasing superheat. The bulk water slowly reaches the equilibrium state with the continuous transmission between the super-

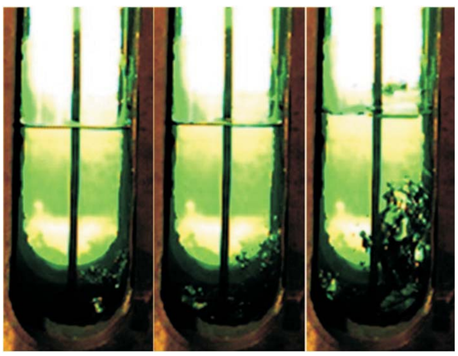
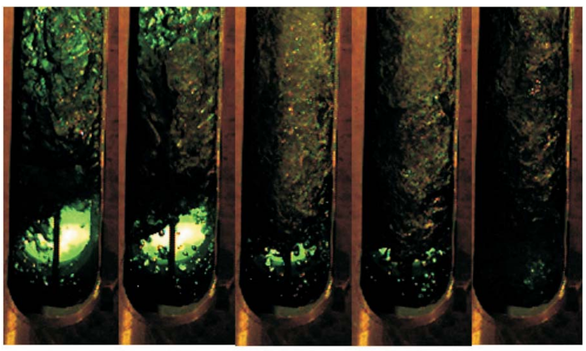


Figure 5. Non-homogeneous nucleation in flash evaporation (ΔT = 12 K, T_0 = 90 °C, H_0 = 500 mm, fps = 150).



3.41s 3.47s 3.55s 3.60s 5.93s

Figure 6. The boiling growth stage.

heated liquid below and the cooled liquid upper. The temperature stratification and density distribution exists in liquid corresponding water level. The thermal energy of lower superheated liquid transform into sensible heat to the upper liquid boiling. Hence, the flashing tends to take place nearby water surface.

3.2 Flashing Characteristic Parameters and Influencing Factors

3.2.1 Propagation Depth

As shown in Figure 8, the propagation depth is defined as the difference between height of initial water surface and the most advanced front of propagation waves during the boiling growth stage. Although the front of evaporation wave is not very smooth, the evaporation wave progresses with nearly constant velocity into the superheated liquid. The velocity is about three orders of magnitude smaller than the sound speed in the pure water. This result has examined by the other studies [10]. The propagation depth is the key parameter to evaluate the intensity of the flashing, which is under influence of superheat degree, initial water temperature and initial waterflim height.

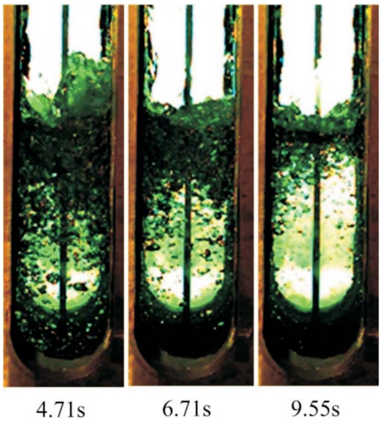


Figure 7. The boiling decaying stage. (ΔT = 5.0 K, H_0 = 500 mm, T_0 = 90.5 °C).

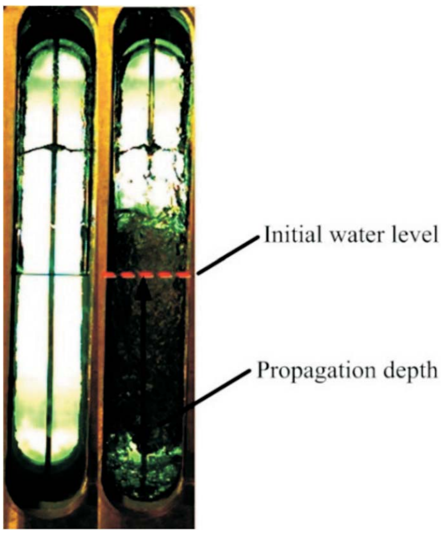


Figure 8. The propagation depth of flash evaporation wave.

Figure 9 illustrates variation of propagation depth under different initial superheat (ΔT), the two curves of H_f with 90 °C and 50 °C as initial temperature, respectively. It is observed that the both two curves almost increase linearly with ΔT. Figure 9 also indicates that the calculated result matches well with experimental results. The slope of the curve at 90 °C is much greater than the 50 °C's. Accordingly, higher initial temperature of water yields a faster increase H_f curve. This result also suggests that the initial temperature and superheat degree has an impact on the flashing process.

It can be found that the propagation depth (H_f) increases with the initial temperature (T_0). This may be explained as follow. The resistance of nucleation of vaporization reduces when superheat increases, which leads the essential heat for the evaporation to be less, thus it is easier for vaporization cores to grow.

Figure 10 displays the dependence of propagation depth on superheat (ΔT) under different initial water heights (H_0). It illustrates that H_f is approximately proportional to the degree of superheat. In addition, under the same superheat, propagation depth obviously increases

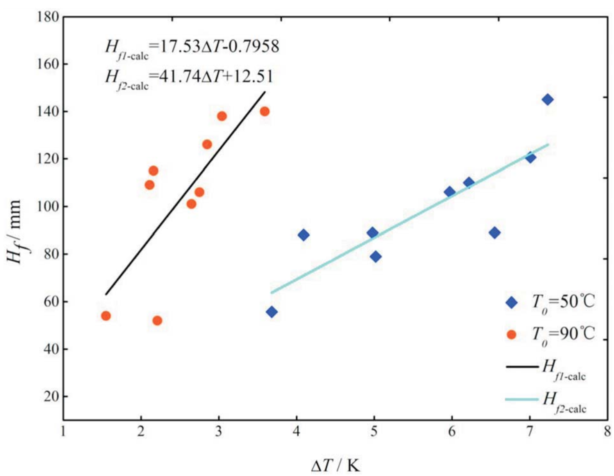


Figure 9. Propagation depth evolution under different initial temperature.

with the reducing of initial waterflim height. The result also suggests that decreasing H_f can increase the intensity of flashing by more sufficient vaporization.

3.2.2 Propagation Velocity

The propagation velocity is defined as the mean ratio of propagation depth to the corresponding time within a superheated liquid. Figure 11 depicts experimental result of propagation velocity versus superheat (ΔT). According to these variation laws, an approximate linear correlation between propagation velocity and superheat was obtained. Obviously, there is a better agreement between the experimental and calculating values of the propagation velocity. The propagation velocity increases with increasing superheat. Small superheat means minor driving force for the bubble nucleation.

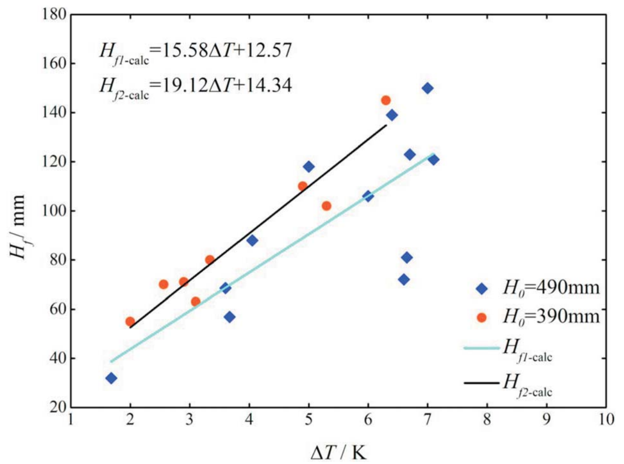


Figure10. Propagation depth evolution under different initial waterflim heights.

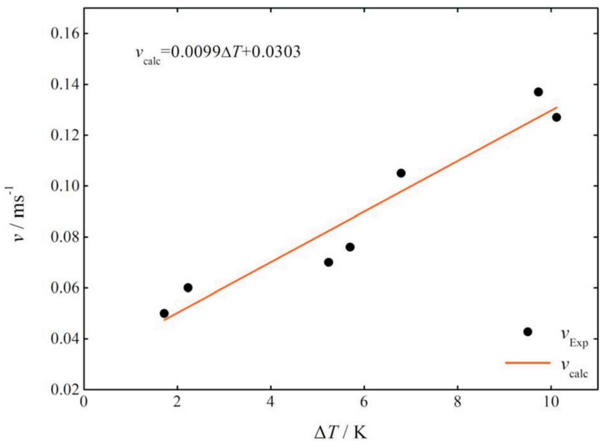


Figure 11. Propagation velocity versus initial superheat under initial condition (T_0 = 90 °C, H_0 = 450 mm).

4. Conclusions

In this paper a series of experiments were carried out to study thermal energy transformation and characteristic parameters in the flashing at different initial water heights, initial temperature and superheat degree with a wide range, the results of the present experimental study could be summarized as follows:

Depending on the images information about the entire flashing process, we divided the flash into three stages: the bubble generation stage, the boiling growth stage and the boiling decaying stage, which had different flow and heat transfer characteristic. The vaporization nucleis on the wall of the flash chamber was the main source of bubbles generating during the bubble generation stage.

The superheat degree plays an important role in the propagation of flash evaporation wave. Propagation depth and propagation velocity both increase with the rising superheat. Increased initial temperature and decreased initial water heights can promote the completion of flash evaporation.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China under Grant [number 51709055] and China-Korea Joint Ocean Research Center.

Nomenclature

Symbols

H_0	initial height of water (m)
H_f	propagation depth (m)
NEF	non equilibrium fraction (—)
NETD	non equilibrium temperature difference (K)
P_0	initial pressure of the flash chamber (Pa)
P_v	initial pressure of the back pressure (Pa)
T_0	initial temperature of the water (°C)
T_e	equilibrium temperature (°C)
$T(t)$	temperature at a certain time (°C)
t_{tp}	flash duration time (s)
v	propagation velocity (m/s)

Greek

ΔT	superheat (K)

Subscript

Exp experimental value
calc calculated value

References

[1] Shao, Y. X., Y. J. Li, L. B. Yang, X. J. Zhang, L. J. Yang, H. Y. Wu, R. Z. and Xu (2014) New experimental system for high pressure and high temperature flashing evaporation experiments, *Applied Thermal Engineering* 66(1–2), 148–155. doi: 10.1016/j.applthermaleng.2014.01.020

[2] Miyatake, O., K. Murakami, Y. Kawata, and T. Fujii (1973) Fundamental experiments with flash evaporation, *Heat Transfer-Japanese Research* 2(4), 89–100.

[3] Kim, J. I., and N. Lior (1997) Some critical transition in pool flash evaporation, *Heat Mass Transfer* 40(10), 2263–2372. doi: 10.1016/S0017-9310(96)00296-7

[4] Saury, D., S. Harmand, and M. Siroux (2002) Experimental study of flash evaporation of a water film, *International Journal of Heat and Mass Transfer* 45(16), 3447–3457. doi: 10.1016/S0017-9310(02)00056-X

[5] Saury, D., S. Harmand, and M. Siroux (2005) Flash evaporation from a water pool: influence of the liquid height and of the depressurization rate, *International Journal of Thermal Sciences* 44(10), 953–965. doi: 10.1016/j.ijthermalsci.2005.03.005

[6] Zhang, D., D. T. Chong, and J. J. Yan (2012) Experimental study on static flash evaporation of aqueous NaCl solution, *International Journal of Heat and Mass Transfer* 55(23–24), 7199–7206. doi: 10.1016/j.ijheatmasstransfer.2012.07.036

[7] Zhang, D., D. T. Chong, J. J. Yan, and Y. S. Zhang (2012) Study on steam-carrying effect in static flash evaporation, *International Journal of Heat and Mass Transfer* 55(17–18), 4487–4497. doi: 10.1016/j.ijheatmasstransfer.2012.03.013

[8] Grolmes, M. A., and H. K. Fauske (1974) Axial propagation of free surface boiling into superheated liquids in vertical tubes, Proc. Fifth Intl. Heat Transfer Conf, Tokyo, Japan., Sep. 2–7, 30–34.

[9] Hill, L. G., and B. Sturtevant (1989) An experimental study of evaporation waves in a superheated liquid, IUTAM Symp. on Adiabatic Waves in Liquid-Vapor Systems, Göttingen, Germany, Aug. 28–Sep. 1, 25–37. doi: 10.1007/978-3-642-83587-2_3

[10] Hahne, E., and G. Barthau (2000) Evaporation waves in flashing process, *International Journal of Multiphase Flow* 26(4), 531–547. doi: 10.1016/S0301-9322(99)00031-2

[11] Reinke, P., and G. Yadigaroglu (2001) Explosive vaporization of superheated liquids by boiling fronts, *International Journal of Multiphase Flow* 27(9), 1487–1516. doi: 10.1016/S0301-9322(01)00023-4

[12] Simões-Moreira, J. R., and J. E. Shepherd (1999) Evaporation waves in superheated dodecane, *Journal of Fluid Mechanics* (382), 63–86. doi: 10.1017/S0022112098003796

[13] Zhang, D., B. C. Zhao, J. J. Yan, and Q. Z. Yang (2014) Experimental study on static flash vaporization of aqueous NaCl solution at different flash speed: steam-carrying effect, *International Journal of Heat and Mass Transfer* 79, 618–627. doi: 10.1016/j.ijheatmasstransfer.2014.08.077

[14] Zhang, D., D. T. Chong, J. J. Yan, and B. C. Zhao (2013) Experimental study on static flash evaporation of aqueous NaCl solution at different flash speed: heat transfer characteristics, *International Journal of Heat and Mass Transfer* 65, 584–591. doi: 10.1016/j.ijheatmasstransfer.2013.06.042

[15] Yang, L. J. (2012) *Experimental Study on Flash Evaporation after Pressure Drop*, M.S thesis, Harbin Engineering University, Harbin.

[16] Wu, H. Y. (2014) *Experimental Study of Heat and Mass Transfer of Flash Evaporation*, M.S thesis, Harbin Engineering University, Harbin.

[17] Lu, Z. Q. (2002) *Two Phase Flow and Boiling Heat Transfer*, 1st ed., Tsinghua University Press, Beijing.

[18] Liao, Y. X., D. Lucas, E. Krepper, and R. Rzehak (2013) Flashing evaporation under different pressure levels, *Nuclear Engineering and Design* 265, 801–813. doi: 10.1016/j.nucengdes.2013.09.027

Manuscript Received: Jul. 23, 2018
Accepted: Dec. 17, 2018