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Mechanisms of film boiling heat transfer of normally impacting spray

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Abstract—The heat transfer mechanisms of horizontally impacting sprays were studied experimentally. An impulse-jet liquid spray system and a solid particle spray system were used. The liquid spray system is capable of producing uniform droplets with the independent variables of droplet size, velocity, liquid flow rate, and air velocity. The horizontally impacting sprays give a lower heat transfer at film boiling than the corresponding vertically impacting spray. The film boiling heat transfer is mainly controlled by the liquid mass flux. At low liquid mass flux and low droplet Weber number, the heat transfer increases with the droplet Weber number. At high droplet Weber number or high liquid mass flux, the heat transfer is not significantly affected by the droplet Weber number.

INTRODUCTION

SIGNIFICANT heat transfer occurs when a liquid spray impacts a hot surface. As a result, this process has been used widely in industrial applications. Although the impacting heat transfer of specific sprays has been reported in literature, a general understanding of this process is still not available. Due to the complexity of involved mechanisms, there has been no comprehensive model established for the heat transfer of impacting sprays.

The heat transfer of impacting spray is composed of three mechanisms, namely, the droplet–wall impacting heat transfer, the air convective heat transfer, and the thermal radiative heat transfer. When the surface temperature is not extremely high, the first two heat transfer mechanisms are considered relatively important. However, these two mechanisms are complex. The droplet–wall impacting heat transfer is usually dependent upon the impacting dynamics of the droplets. However, when the rate of droplet impaction is increased, the interaction among droplets becomes more significant and the involved mechanisms get more complicated. The air convective heat transfer results from air which is intentionally supplied or naturally entrained into the spray. However, the air convective heat transfer composes of the convection due to bulk air flow and the local turbulence convection induced by the presence of droplets in the air. One difficulty in modeling spray cooling has been estimating the individual contributions of these two air convective heat transfer mechanisms.

Previous investigations, related to impacting spray heat transfer, can be divided into two categories: individual droplet impacting heat transfer and spray impacting heat transfer. Various experimental studies [1–6] have been conducted for the individual droplet impaction heat transfer. While the reported information is of much value, the results describe only the single droplet to wall impact heat transfer at conditions of very low liquid flux. On the other hand, some investigators [7–10] have studied the impacting spray heat transfer. Most of them used commercial full-cone nozzles to produce sprays. The sprays, however, had some particular size spectrums with their droplet velocity, liquid mass flux, and air flow rate varied dependently. Therefore, their results were not sufficiently general to allow for a proper understanding of the fundamental physics.

Liu and Yao [11] investigated analytically the contribution of each heat transfer mechanism to the overall impacting heat transfer of dilute sprays. However, the validity of the model has not been proved because appropriate experiments were not available.

Recently, the authors experimentally investigated the parametric effects such as droplet size, droplet impinging velocity, and liquid mass flux on the heat transfer of vertically impacting mono-dispersed sprays [12]. They used an impulsed multi-orifice spray generator to produce uniform droplets with independent control of droplet size, droplet velocity, and liquid mass flux. Although the parametric effects on the overall heat transfer were reported, individual heat transfer mechanisms in spray cooling were not analyzed on a parametric basis. The arrangement of the vertical spray impacting on horizontal surfaces also made it difficult to separate the heat transfer contribution of the fragmented droplets from the original droplets.

In this paper, the heat transfer results of horizontal sprays impacting on a vertical surface are reported.

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NOMENCLATURE

A	heat transfer area [cm^2]
D	diameter [mm]
e	emissivity of surface
G	mass flux [g s^{-1} cm^{-2}]
k	thermal conductivity [W cm^{-1} K^{-1}]
m	mass flow rate [g s^{-1}]
q''_w	total heat flux from heating surface, $q''_c + q''_a + q''_r$ [W m^{-2}]
q''_a	overall air convection heat flux, $q''_b + q''_t$ [W m^{-2}]
q''_b	bulk air convection heat flux [W m^{-2}]
q''_c	droplet–wall contact heat flux [W m^{-2}]
q''_r	thermal radiation heat flux [W m^{-2}]
q''_t	local air turbulence heat flux [W m^{-2}]
T	temperature [°C]
V	velocity [m s^{-1}]
We	Weber number, $\rho D V^2/\sigma$.

Greek symbols

ρ	density [g cm^{-3}]
σ	surface tension [dyne cm^{-1}] or Stefan–Boltzman constant in equation (1)
ε	heat transfer effectiveness.

Subscripts

a	air
d	liquid droplet
l	liquid
p	glass bead particles
sat	saturation
w	heating target surface.

The purpose of this study is to explore the contribution of each heat transfer mechanism to the overall heat transfer of a horizontally impacting spray. An impulsed liquid spray generator as well as a solid particle spray generator were used to determine both the overall heat transfer and the heat transfer effect of local turbulence resulting from the presence of particles in the air flow. Furthermore, the effect of droplet Weber number is also discussed to assist the explanation of the test results of sprays.

EXPERIMENTAL APPARATUS AND PROCEDURE

Two different heat transfer experiments were conducted: one was for the study of impacting liquid spray and the other was for the study of impacting solid particle spray. Figure 1 shows the schematic of the set-up for the first experiment. The apparatus is the same as those used in our previous study of vertical spray [12], except the droplet generator and the heating target are arranged so that the spray travels horizontally and is perpendicular to gravity. The purpose of having this arrangement is to avoid the secondary impactions of the splattered droplets after the first impaction on the heated target. This way the parametric effect of droplet impaction will be more clear.

The detailed description of the experimental system for the liquid spray generator has been presented in ref. [13], therefore only a brief introduction will be provided here. The principle of the droplet generation is to use the impulses produced by a piezo-electric transducer, which is located on the top of a liquid chamber, to break up the streams of liquid jets into uniform size droplets. The size of the droplets is determined by the frequency of the pulses when the nozzle opening and jet velocity are fixed. Air jets are added to the droplet generator to disperse the droplets. The convective heat transfer of the air to the target can be varied by changing the air flow rate of the jets. The droplet size, droplet velocity, and liquid mass flow rate can be varied independently. As already mentioned, the difference between the overall heat transfer, with and without droplets present in the air flow, would give the summation of the heat transfer of droplet–wall impaction and that of local air turbulence due to the presence of droplets in air flow.

Figure 2 shows the experimental device for solid particle spray heat transfer. Since the solid particles will impact the heated target with small contact areas and for very short duration, the particle–wall contact heat transfer could be insignificant. Therefore, the difference between the overall heat transfer with and without solid particles would give the effect of local air turbulence induced by the presence of particles. The solid particles used were soda-lime glass beads (80% round shape) of two different ranges of diameters 0.18–0.21 and 0.35–0.41 mm. The thermal diffusivity and conductivity of the soda-lime glass are reasonably comparable to that of water. The particle ejector was made from a Plexiglass cylinder 13.5 cm in diameter and 37.0 cm high. Three air pipes were connected to the chamber to provide different air flow rates while assuring that the glass beads were well dispersed.

A schematic of the heated target is shown in Fig. 1. The target is 14.4 cm long and made of copper. The top surface (4.32 cm in diameter) was plated with chrome of 2 μm thickness and was polished to a mirror finish. The total hemispherical emittance of the surface was estimated to be 0.15. A stainless-steel annular disk was attached to the top surface of the copper block by silver brazing. A total of 13 cartridge heaters, each with a maximum power of 350 W, were

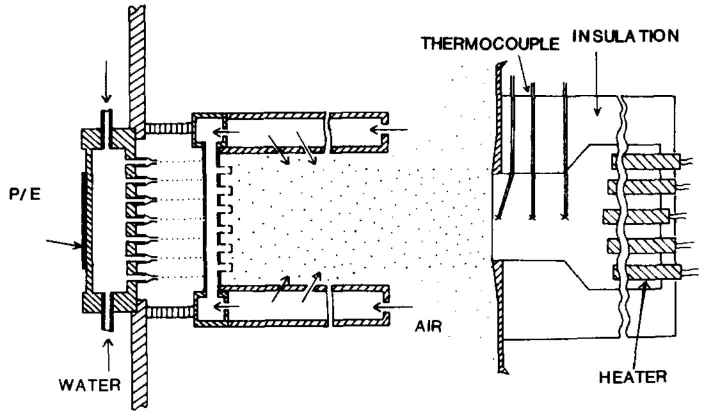

FIG. 1. Liquid spray generator and heated target.

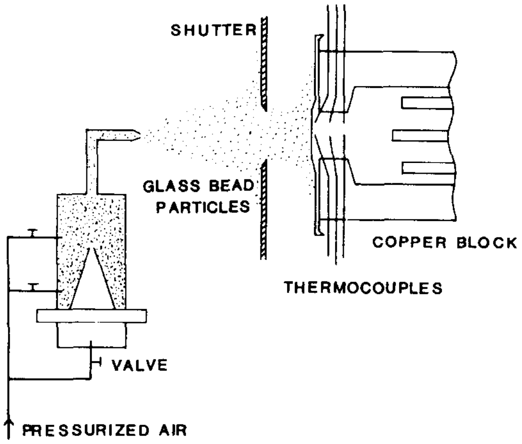

FIG. 2. Solid particle spray generator and heated target.

incorporated into the lower portion of the copper block, and were controlled by a variac. Six stainless-steel, sheathed, ungrounded chromel–alumel thermocouples (0.102 cm o.d.) were used. They were press fitted into the holes which were positioned at 0.159, 1.429 and 2.699 cm from the top of the surfaces. After the copper target was heated to about 500 °C by inserted cartridge heaters, liquid spray was applied. The experiments were conducted as a transient cooling process with the temperature histories from three thermocouples at different depths under the surface recorded on an IBM PC through a digital data acquisition system at 0.5 s time intervals. To obtain the surface heat flux and temperature, the temperature histories of the top two thermocouples at the centerline of the block were used in a one-dimensional inverse transient heat conduction [14].

RESULTS AND DISCUSSION

Liquid spray heat transfer

Experimental data were obtained for different combinations of parameters such as liquid flux, droplet size, and droplet impinging velocity. First, the effect of liquid mass flux on the overall heat transfer, at constant droplet size and droplet impinging velocity, was determined in the range of $G_l = 0.011$–$0.184\,\mathrm{g\,s^{-1}\,cm^{-2}}$ on the target. Then, the droplet size effect was investigated with two different droplet diameters of approximately 0.43 and 0.56 mm in both the low mass flux ($G_l = 0.017\,\mathrm{g\,s^{-1}\,cm^{-2}}$) and the medium mass flux ($G_l = 0.030\,\mathrm{g\,s^{-1}\,cm^{-2}}$) conditions. Although the droplet sizes differ by only 30%, the droplet volume and the droplet number density at the same mass flux differ by 2.2 times. Finally, two different droplet velocities of 3.2 and $4.2\,\mathrm{m\,s^{-1}}$ were examined to explore the effect of droplet impinging velocity. The range of the droplet impinging velocity in this research was restricted because a minimum flow rate is required to carry the liquid droplets to the heating target and a maximum value should not be exceeded to maintain the uniformity of the droplet size and the dispersion.

Figure 3 shows the overall heat transfer as a function of surface temperature in the range 90–430°C, at various liquid mass fluxes. The droplet size is constant ($D_d = 0.48$ mm) and the droplet impinging velocity is nearly constant ($V_d = 3.2\,\mathrm{m\,s^{-1}}$). The higher the liquid mass flux, the more the heat transfer capability. As shown in Fig. 4, the general trend of the cooling curve is very similar to that of the vertically downward impacting cases, which were presented in ref. [12]. At film boiling, the vertical impaction gives higher heat transfer, possibly because of the existence of secondary impactions due to rebounding droplets. At transition boiling, the horizontal impaction gives higher heat transfer. This is most likely due to easier vapor removal from the surface since there is little

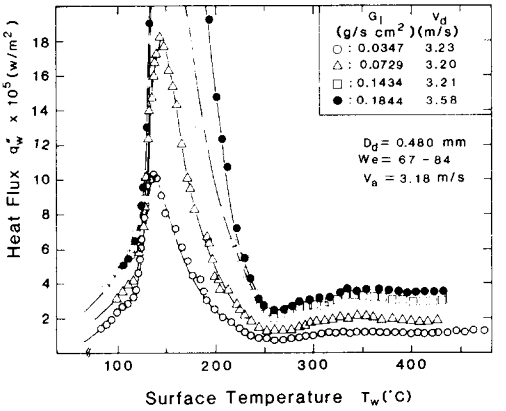

FIG. 3. Heat transfer of horizontal impacting spray at various liquid mass fluxes.

chance of the secondary droplets or liquid residue staying on the hot surface. With the vapor easily escaping from the surface, the contribution of the nucleate boiling component in transition boiling may become higher and the overall heat transfer enhanced. At nucleate boiling, the difference between the horizontal impaction and the vertical impaction is not obvious when the experimental uncertainty is considered.

The heat transfer results indicated in Figs. 3 and 4 are the summation of the three major types of heat transfer. They are the drop-wall contact heat transfer, air convective heat transfer, and thermal radiative heat transfer from the wall. In both the nucleate and transition boiling regions, evaporation is the dominant heat transfer mechanism. However, at the film boiling region, once droplets impact on a hot plate, they will bounce back due to the formation of a vapor cushion. Thus, the contact heat transfer is less effective than the case of nucleate boiling, while air convection and thermal radiation heat transfer become relatively more important than before. The accurate evaluation of each heat transfer component at this film boiling condition is essential to the modeling of impacting spray at high temperatures. However, no information is presently available, in open literature, about the contribution of various heat transfer mechanisms. Therefore, our primary concern is the determination of impacting spray heat transfer mechanisms in the film boiling region.

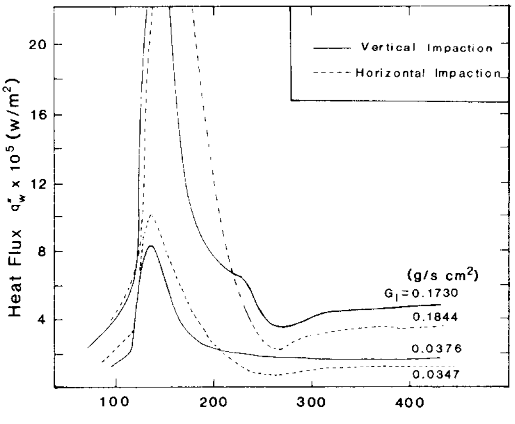

FIG. 4. Comparison of the heat transfer of horizontal and vertical impacting sprays.

Heat transfer mechanisms

The thermal radiative heat transfer can be easily estimated. Liu and Yao [11] assumed, in their analytical study of impacting spray heat transfer, that the hot surface was an infinite plate and the opposite water spray was another gray, infinite plate. Since the emissivity of deep water is 0.96 [15], the total emissivity of the water spray could be approximated as unity. Therefore, the spray which is at a lower temperature and with a large thickness acts like a black sink. The radiation heat flux can be simplified as

$$q''_r = \sigma e_w(T_w^4 - T_l^4). \tag{1}$$

Let $e_w = 0.15$ for a polished chrome plate, $T_w = 400°\text{C}$, and $T_l = 26°\text{C}$, the typical thermal radiative heat flux is calculated as $q''_r = 0.168\ \text{W cm}^{-2}$. The fractions of the radiative heat transfer to the overall spray cooling are about 1.5 and 0.5% for $G_l = 0.0347$ and $0.1844\ \text{g s}^{-1}\ \text{cm}^{-2}$, respectively. As expected, the thermal radiative heat transfer is very small in the present range of surface temperature.

Figure 5 shows the result of bulk air convective heat transfer on the heating target for $V_a = 3.18$ and $4.41\ \text{m s}^{-1}$. The experiment was conducted without liquid droplets, but only with air set at the above referenced velocities. The heat transfer results presented in Fig. 5 are the summation of the bulk air convection and the thermal radiative heat transfer between the hot surface and the environment. The typical thermal radiation is about $0.168\ \text{W cm}^{-2}$ for this case. The bulk air convective heat flux is about $3.6\ \text{W cm}^{-2}$. Comparing Figs. 3 and 5 at $T_w = 350°\text{C}$, the radiative heat transfer is about 5% of the bulk air convection, but the bulk air convections are about 29 and 11% of the overall spray heat transfer at $G_l = 0.0347$ and $0.1844\ \text{g s}^{-1}\ \text{cm}^{-2}$, respectively. It should be noted that the effect of local turbulence due to the presence of droplets in the air flow was not studied here and will be explored later in the solid particle spray heat transfer experiments. It was also noticed that the air convection contribution of 29% occurs at conditions of lower liquid mass flux and relatively high air velocity of $3.18\ \text{m s}^{-1}$. This is an extreme condition.

Experiments were conducted at the different droplet impinging velocities of 3.2 and $4.2\ \text{m s}^{-1}$, but with the same droplet diameter of 0.48 mm. The results show that the general trends of the cooling curve are similar

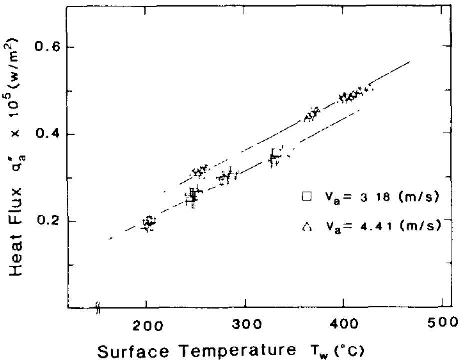

FIG. 5. Bulk air convection (without particles) at different velocities.

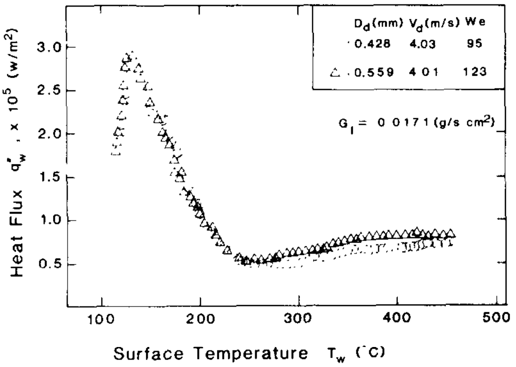

FIG. 7. Effect of droplet size at low liquid mass flux.

to those appearing in Fig. 3; however, the overall heat transfer in the film boiling region is increased with the increased droplet velocity. Since two different air flow rates were used to obtain the different droplet impacting velocities, the direct comparison of the overall heat transfer results are not appropriate to reveal the parametric effects of the droplet impinging velocity. Therefore, the contribution of bulk air convection was removed by subtracting the bulk air convective heat transfer from the overall heat transfer. The results of heat transfer without bulk air convection component are compared in Fig. 6 for two different droplet velocities at horizontal impactions. In the same figure, the corresponding heat transfer of vertically impacting spray is also shown for comparison. The heat transfer data presented in Fig. 6, therefore, are mainly the summation of the drop–wall contact heat transfer and the local turbulence heat transfer due to the presence of droplets in air flow. As mentioned before, the radiative heat flux is small in these cases. The comparison reveals two interesting features of the droplet–wall contact heat transfer. Firstly, the film boiling heat flux in the vertically downward impacting spray is always higher than that in the corresponding horizontally impacting spray. As stated before, this is possibly because the vertically impacting spray has the contribution of the secondary impactions of their splattered droplets. Groendes [16] reported photographic results that a single droplet of 4.7 mm diameter struck a heated target of 6.25 cm^2 three times before the droplet was finally bounced off the heating target. The repetition of impaction increases the total heat transfer rate. Generally, the vertically impacting spray has about 1.5 times better effectiveness, in terms of liquid evaporation, than the horizontally impacting spray. Secondly, comparing between the two cases of horizontally impacting sprays, the heat flux depends upon the droplet impinging velocity at low liquid mass flux; however, this dependency becomes less obvious at higher liquid mass flux.

The effect of droplet size on the overall film boiling heat transfer of horizontally impacting spray is presented in Figs. 7 and 8 for $G_l = 0.0171$ and $0.030\,\mathrm{g\,s^{-1}\,cm^{-2}}$, respectively. Even though the difference of the droplet sizes (0.56 vs 0.43 mm) is relatively small, this effect is observed in the film boiling region at $G_l = 0.0171\,\mathrm{g\,s^{-1}\,cm^{-2}}$ (Fig. 7), but the effect is not apparent in both the transition and nucleate boiling regions. It is interesting to point out that the increase of droplet size also implies the decrease of droplet

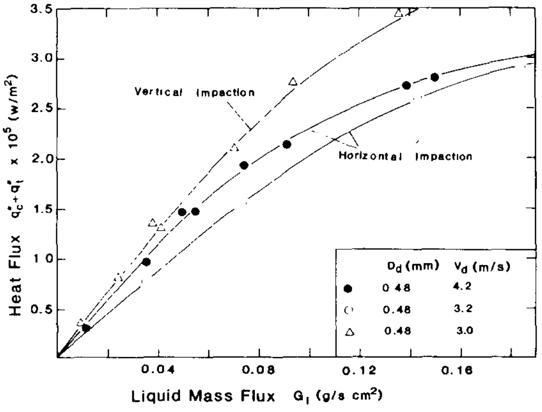

FIG. 6. Droplet–wall contact heat transfer and radiative heat transfer as a function of liquid mass flux at different droplet velocities and orientations.

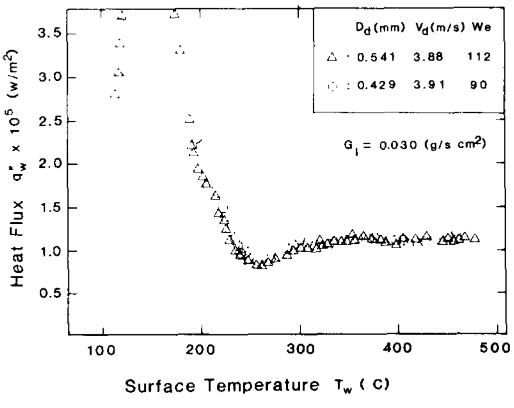

FIG. 8. Effect of droplet size at medium liquid mass flux.

number density to the third power of size ratio. On the other hand, the size effect is not observed in the entire boiling curve at $G_1 = 0.030\,\mathrm{g\,s^{-1}\,cm^{-2}}$. This comparison is in good agreement with our previous results for vertical spray as well as with other investigators' results [8, 9]. The possible reason is that when the liquid mass flux is low, each individual droplet behaves rather independently so that the droplet–wall contact heat transfer depends on the droplet dynamics. The droplet dynamics, in turn, depend on the droplet size and droplet impinging velocity. When the liquid mass flux is high, the evolution of droplet dynamics during impact would be interferred by other adjacent droplets. Thus the droplet–wall contact heat transfer becomes less dependent upon the detailed droplet dynamics.

From the liquid spray experiments, the following facts were deduced:

(1) More than 70% of the total heat transfer in spray cooling process could be attributed to the droplet–wall contact heat transfer and to the local air turbulence induced by the presence of liquid droplets in the air.
(2) Vertically impacting spray has greater heat transfer rate than horizontally impacting spray due to the secondary effect of splattered droplets.
(3) In dilute spray, the impacting heat transfer at film boiling increases with the increased liquid mass flux, droplet size, and droplet velocity. In dense spray, the droplet size and the droplet impinging velocity do not have any apparent effect on the heat transfer due to the possible interference of the droplet impacting dynamics.

Solid particle spray heat transfer

As discussed previously, the air convective heat transfer of the impacting spray consists of two different heat transfer contributions: the bulk air convection and the local turbulence convection, which is due to the presence of droplets in the air flow. It would be desirable to compare the relative contributions of these two different mechanisms. For this reason, we conducted a second type of heat transfer experiment by studying the solid particle spray heat transfer. In solid particle spray the particle–wall impaction heat transfer will be insignificant because the impaction time is very short and the contact area is very small. However, the overall air convection and the thermal radiation will be still similar to that of a corresponding liquid spray.

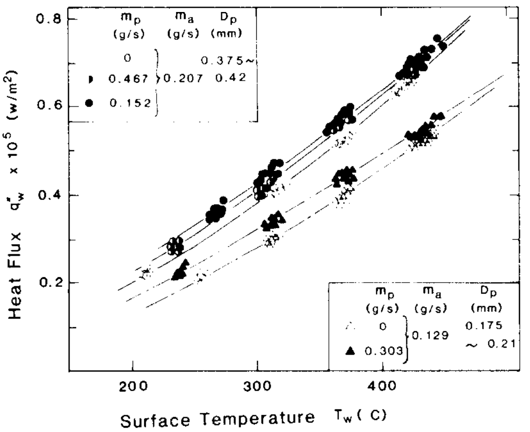

FIG. 9. Effect of the presence of solid particles to the impaction heat transfer.

Figure 9 shows the results of the solid particle spray impaction heat transfer for particle diameters in the ranges 0.175–0.21 and 0.35–0.41 mm. In the same figure the results of bulk air heat transfer without particles are also shown. The addition of solid particles in air flow increases the overall heat transfer only slightly. The heat fluxes at $T_w = 370$°C with glass beads of both particle sizes are approximately 10% greater than the result of purely air flow. For the larger size of particles, as the total amount of particles in air flow increases from 0.152 to $0.467\,\mathrm{g\,s^{-1}}$, the overall heat transfer even decreases a little bit. The reason for this decrease is not clear at this moment. However, it is apparent that the existence of the solid particles in the air flow does not drastically increase the overall air convective heat flux. In the present study of liquid spray, for example refer to Fig. 3, the ratio of the liquid mass flux to the air flux is about the same range as that in the solid particle spray experiment. Since the glass has a density about 2.5 times that of water and the local turbulence convection is mainly induced by the wakes of the suspended particles in terms of their volume, the possible heat transfer enhancement of the liquid spray with a same mass flux ratio will be about 2.5% of the bulk air convection. It could be, therefore, stated that the contribution of local turbulence convection to the overall air convection is limited in the present study.

It is noticed that these results are not in close agreement with that reported by Shimizu *et al.* [17]. They conducted experiments of impinging jet heat transfer with gas–solid suspensions (tiny graphite particles in nitrogen gas jet). They reported that the addition of solid particle in gas jet drastically increased the heat transfer rate (up to six times) at the stagnation region on the heating target. The increase of heat transfer over their total heated surface, however, was much less significant. The particle size which they used was very small ($D_p = 0.01$ mm) and velocity of the gas jet was very high. The particle diameter used in the present study is approximately 30 times greater than that used by Shimizu *et al.* [17], therefore the number density of particles in the present study is 1/27,000 of that in their study if the particle volume flow rate is kept the same. As a result, less amount of air was disturbed due to the much smaller number density of particles in the present study. Of course, there also exist undetermined effects of the particle size on the local turbulence. A larger particle may either damp out turbulence of gas flow due to its

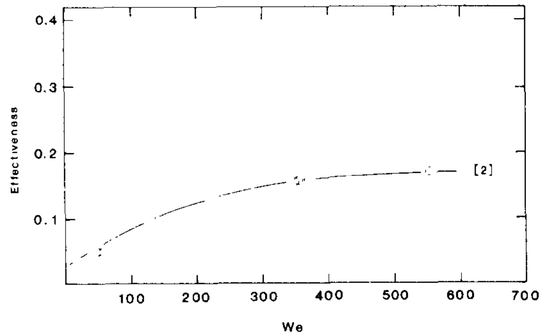

FIG. 10. Heat transfer effectiveness at various Weber numbers for single droplet impactions at film boiling.

larger inertia or increase the turbulence due to its wake and relative velocity. Therefore, the difference between the results of [17] and the present study is not unreasonable.

Effect of droplet Weber number

As described previously, when the liquid mass flux of the spray is low the impacting heat transfer at film boiling increases with the increasing of droplet velocity and the droplet size. Since the spray is dilute at this condition, the droplet impaction dynamics of the spray will be more like the behavior of a single droplet impacting on a hot surface at film boiling which was reported in refs. [1–6]. For a better understanding of the present experimental results, the relevant data base of single droplet impaction has been re-examined.

The impacting dynamics, and therefore the heat transfer, of a droplet will be strongly dependent upon its incoming Weber number which is defined as

$$We = \frac{\rho_l V^2 d}{\sigma} \tag{2}$$

where the liquid density is used due to the concern of the impaction behavior. The droplet impaction heat transfer is usually presented in the form of its heat transfer effectiveness ε which is the ratio of the actual heat transferred to the droplet (including heat-up and evaporation) to the total heat required for the complete evaporation of the droplet. The data in ref. [2], which are close to the conditions of the present study, are converted in terms of Weber number and heat transfer effectiveness in Fig. 10. It is observed that when the Weber number is low the effectiveness increases as the Weber number is increased. The dependency diminishes when the Weber number is higher than 350. The same trend of Weber number effects is observed in refs. [1, 3–5].

In the present study of the film boiling conditions, the values of the droplet Weber number are generally less than 150. Therefore, the higher the droplet velocity, the higher the impaction heat transfer. When the droplet size is increased, the droplet Weber number and its heat transfer effectiveness are also increased. Larger droplets imply less droplet number density at a constant liquid mass flux. Since the heat transfer effectiveness is based upon the volume of the droplet, at the same liquid mass flux, the increase of heat transfer effectiveness gives a higher overall impaction heat transfer although the droplet impaction frequency is reduced. On the other hand, as expected from Fig. 10, an unlimited increase of the droplet velocity or size will not lead to ever increased impaction heat transfer when the droplet Weber number goes beyond 350.

CONCLUSIONS

The heat transfer mechanisms of impacting spray cooling was investigated experimentally using an impulse-jet liquid spray system and a solid particle spray system. The following conclusions were obtained:

(1) In the film boiling region, a vertically impacting spray has higher heat transfer than a horizontal impacting spray due to the secondary contacts of splattered droplets. However, at transition boiling region, the horizontal spray provides better heat transfer than a corresponding vertical spray.
(2) The heat transfer of impacting spray increases when the liquid mass flux is increased.
(3) In dilute spray, the impaction heat transfer at film boiling conditions increases as the droplet Weber number is increased. At high Weber number the impaction heat transfer will be less affected by the increase of Weber number. In dense spray, droplet Weber number does not affect the heat transfer significantly.
(4) In the range of the present study, drop–wall contact heat transfer is much higher than the bulk air convective heat transfer in the film boiling region. The local turbulence air convection caused by the presence of particles in air stream is less than that of the bulk air convection.

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MECANISMES DU TRANSFERT DE CHALEUR PAR EBULLITION EN FILM POUR UN BROUILLARD IMPACTANT FRONTALEMENT

Résumé—Les mécanismes de transfert thermique pour des brouillards impactants sont étudiés expérimentalement. On utilise un système de jets sous pression de brouillards liquides. Il est possible de produire des gouttelettes uniformes avec des paramètres indépendants de taille, de vitesse, de débit pour les gouttelettes et de vitesse d'air. Les brouillards impactant horizontalement donnent un transfert de chaleur plus faible à l'ébullition en film que dans le cas de l'impaction verticale. Le transfert thermique par ébullition en film est principalement gouverné par le débit-masse de liquide. Aux faibles débit-masse et nombre de Weber de goutte, le transfert thermique augmente avec le nombre de Weber. Aux grands nombres de Weber ou aux grands débits de liquide, le transfert de chaleur n'est pas sensiblement affecté par le nombre de Weber.

MECHANISMUS DES FILMSIEDENS BEI SENKRECHT AUFTREFFENDER SPRÜH-STRÖMUNG

Zusammenfassung—Der Wärmeübertragungsmechanismus bei horizontal auftreffender Sprühströmung wurde experimentell untersucht. Ein Impulsstrahl-Flüssigkeits-Sprühsystem und ein Feststoffpartikel-Sprühsystem wurden benutzt. Das Flüssigkeits-Sprühsystem ermöglicht es, gleichmäßige Tropfen mit den unabhängigen Variablen Tropfengröße, Geschwindigkeit, Flüssigkeitsmassenstrom und Luftgeschwindigkeit zu erzeugen. Horizontal auftreffende Sprüh-Strömungen ergeben beim Filmsieden niedrigere Wärmeubergangskoeffizienten als die entsprechenden vertikalen Strömungen. Der Wärmeübergang beim Filmsieden wird hauptsächlich von der Massenstromdichte der Flüssigkeit beeinflußt. Bei niedriger Flüssigkeitsmassenstromdichte und niedriger Weber-Zahl der Tropfen steigt der Warmeübergang mit der Weber-Zahl der Tropfen an. Bei hoher Weber-Zahl der Tropfen oder hoher Flüssigkeitsmassenstromdichte wird der Wärmeübergang nicht entscheidend von der Weber-Zahl der Tropfen beeinflußt.

МЕХАНИЗМЫ ТЕПЛОПЕРЕНОСА ПРИ ПЛЕНОЧНОМ КИПЕНИИ ПЕРПЕНДИКУЛЯРНО УДАРЯЮЩЕЙСЯ О ПОВЕРХНОСТЬ СТРУИ АЭРОЗОЛЯ

Аннотация—Механизмы теплопереноса в случае параллельных поверхности струй аэрозоля исследовались экспериментально с использованием системы импульсной струи аэрозоля жидкости и струи аэрозоля твердых частиц. При распыле жидкости образуются однородные капли, и размер капель, их скорость, расход жидкости и скорость воздуха описываются независимыми переменными. Для горизонтальных струй наблюдаются более низкие значения плотности теплового потока при пленочном кипении, чем при соответствующих нормально ударяющихся струях. Теплоперенос при пленочном кипении определяется в основном величиной потока массы жидкости. При малом значении последнего и небольших числах Вебера для капли, теплоперенос увеличивается с ростом числа Вебера. При больших числах Вебера или больших значениях потока массы жидкости значение числа Вебера не оказывает существенного влияния на перенос тепла.