HEAT TRANSFER ANALYSIS OF TRAY-TYPE HIDIC

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Design of Lift Tray is essential to predict the Distillation performance of HIDiC.
We are planning to investigate the relationships between slit pattern of lift tray and bubbling height.

CONCLUSION

Bubbling on Lift tray in tray-type HIDiC is investigated.

If liquid supply to wall is short, not only heat transfer capability but also tray efficiency become worth.
The liquid is sent to upper tray by vaporization.
It is similar to entrainment.

The enough liquid supply capability to wall can be confirmed by experimental results using toluene.

In the experiment conditions, liquid by bubbling reaches the ceil of the tray. Although heat transfer efficiency is high, entrainment occurs by bubbling and evaporation in HIDiC.

If Lift tray can be designed to make bubbling height insensitve to Vapor flow rate changes, heat transfer efficiency of HIDiC can be stable.

Double-tube Tray-type HIDiC by Kansai Chemical Engineering Co. Ltd.

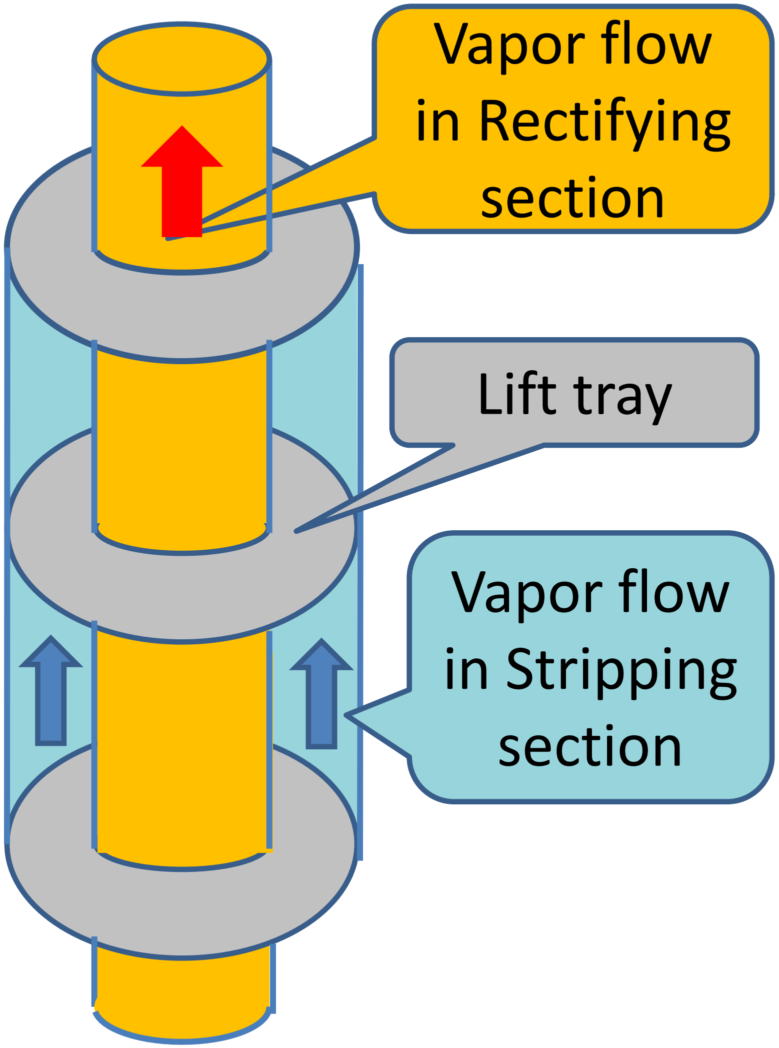

Fig. 1 Structure of HIDiC

Fig. 2 Lift tray in HIDiC

Fig. 3 Bubbling on Lift tray

http://www.tech.nedo.go.jp/PDF/100007366.pdf

Experiment of Heat Transfer in HIDiC by Kansai Chemical Engineering Co. Ltd.

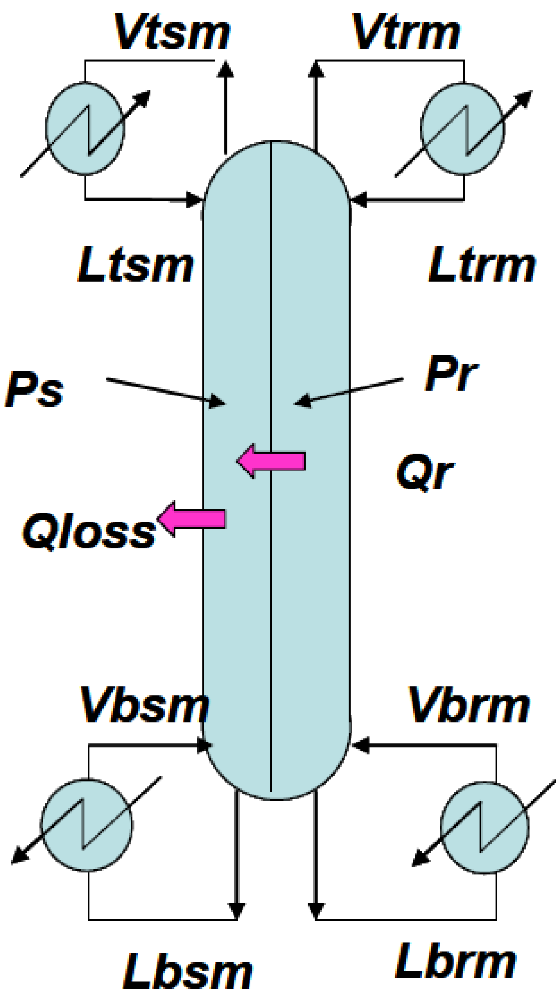

Fig. 4 Experiment system
for hear transfer measurement

Total reflux in each section.

$$Q_r = U \cdot A \cdot \Delta T$$

$$Q_r = L_{trm} \cdot H_{Ltr} + V_{brm} \cdot H_{Vbr} - V_{trm} \cdot H_{Vtr} - L_{brm} \cdot H_{Lbr}$$

$$\Delta T = \frac{(T_{Vtr} - T_{Vts}) - (T_{Lbr} - T_{Lbs})}{\ln \dfrac{T_{Vtr} - T_{Vts}}{T_{Lbr} - T_{Lbs}}}$$

$$\therefore U = Q_r / (A \cdot \Delta T)$$

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Global Heat Transfer Coefficient, U

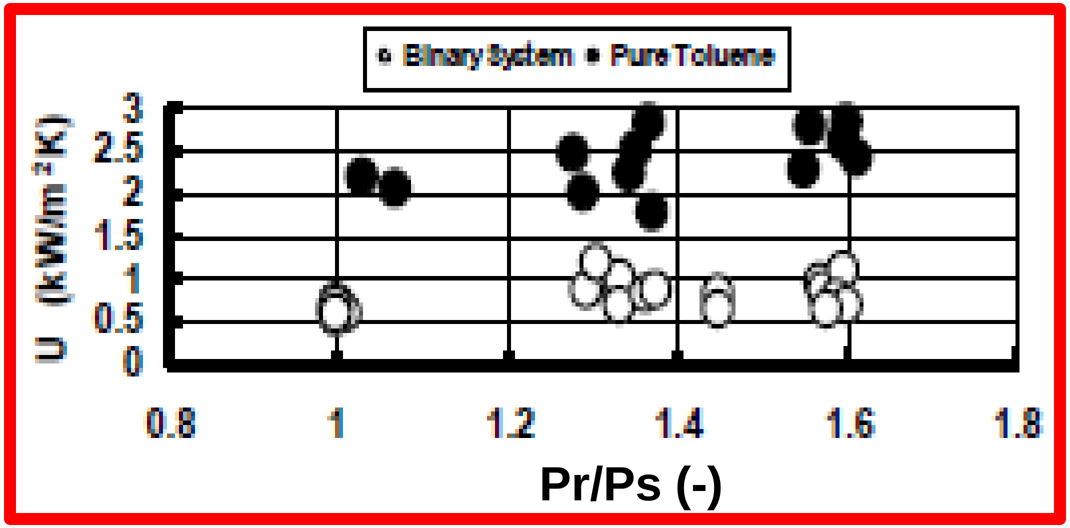

Fig. 5 Press. diff. and U

Temperature difference does not affect U.

U for pure Toluene is much larger than one for binary.

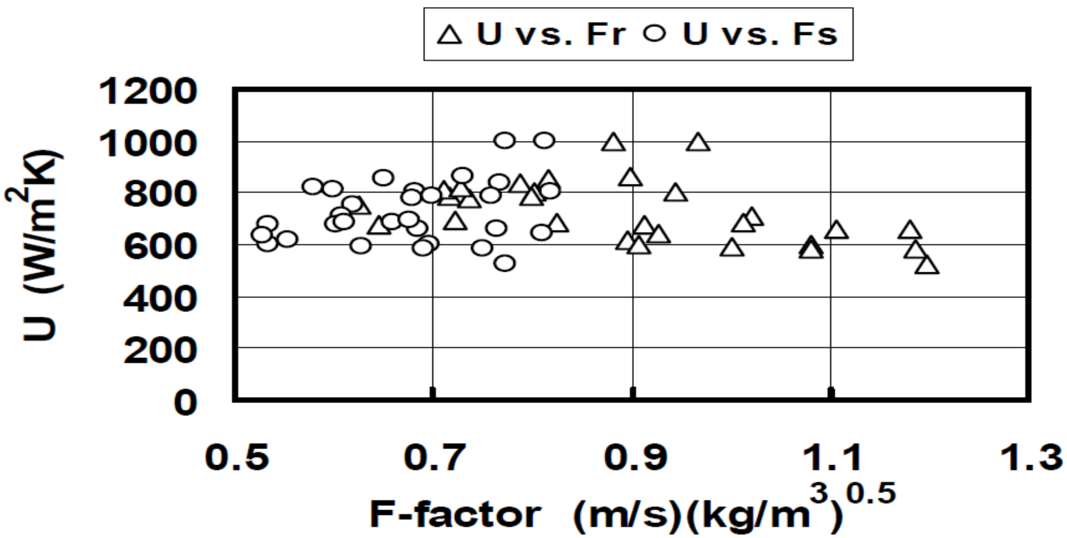

Fig. 6 Vapor flow and U

Although vapor flow rate affects bubbling, it does not affect U.

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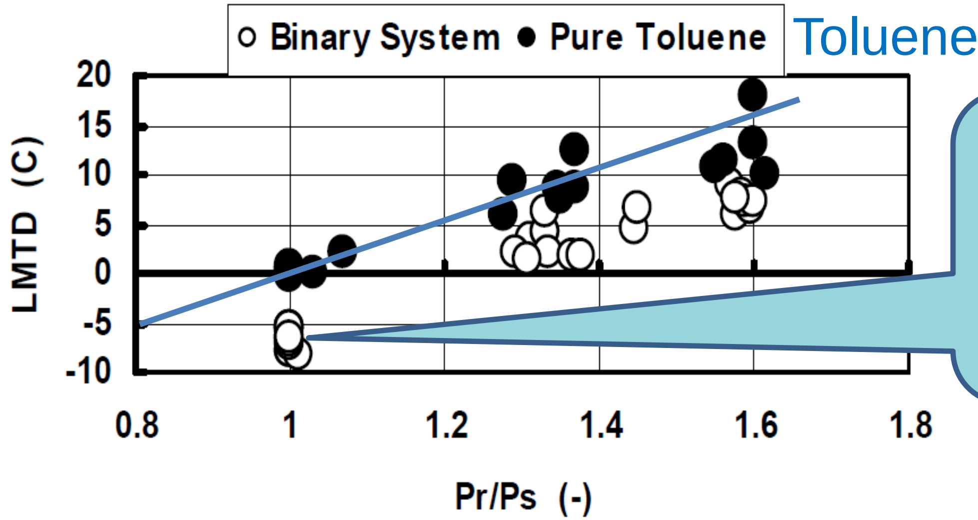
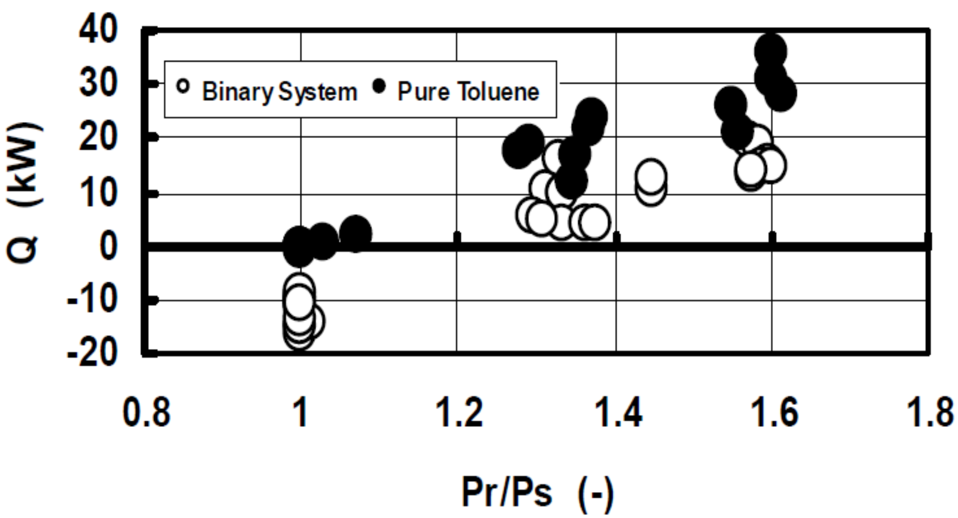
ΔT and Q in Experiment



Compositions are different in rectifying and stripping sections. Temperature difference is generated even when pressures are same.

Fig. 7 Press. diff. and Logarithmic Temp. Diff.



Vaporized liquid is increased according to the increase of Q.

The ratio of vaporized flow and inlet vapor flow is low.

Bubbling is almost constant.

Fig. 8 Press. diff. and Transferred heat

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Heat Transfer in HIDiC

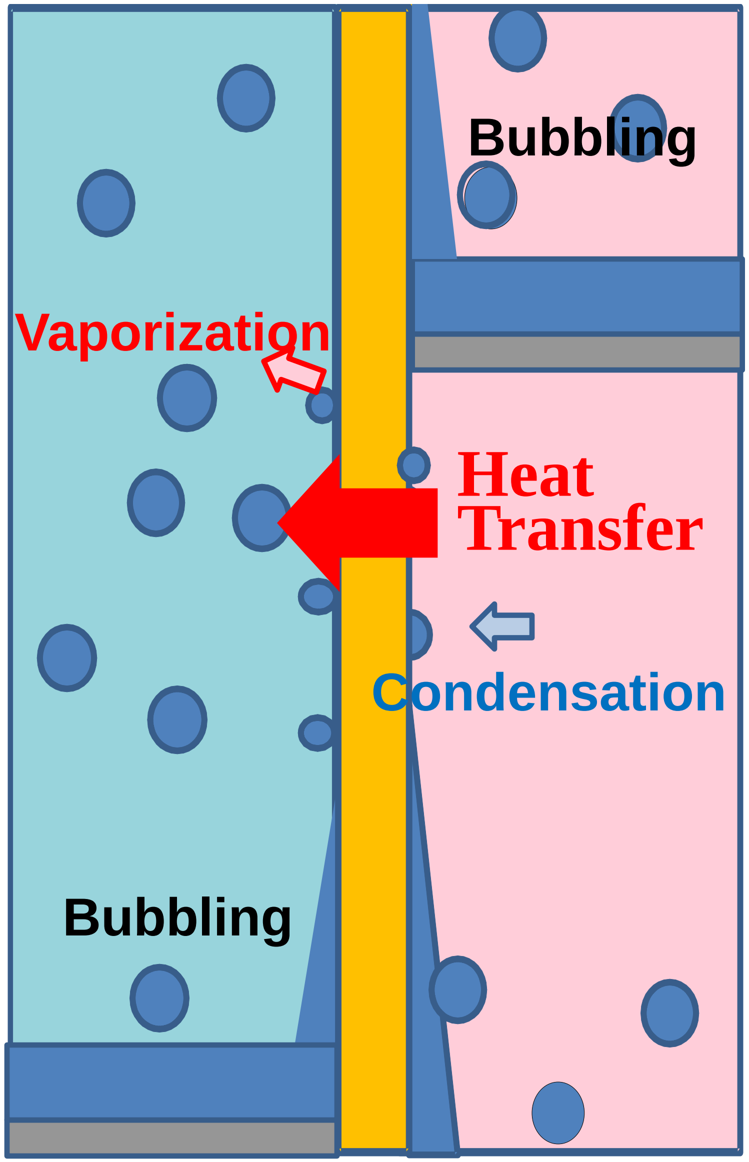

Fig. 9 Mechanism of heat transfer

Vaporization and Condensation are realized by heat transfer through the wall.

Heat transfer efficiency is essential to design of HIDiC.

In stripping section of lift tray HIDiC, liquid supply to wall is generated by bubbling.

If the whole liquid supplied is vaporized, the vaporized flow is similar to entrainment and tray efficiency becomes low.

The mechanism to determine heat transfer efficiency is analyzed.

Simulation model of Lift tray HIDiC

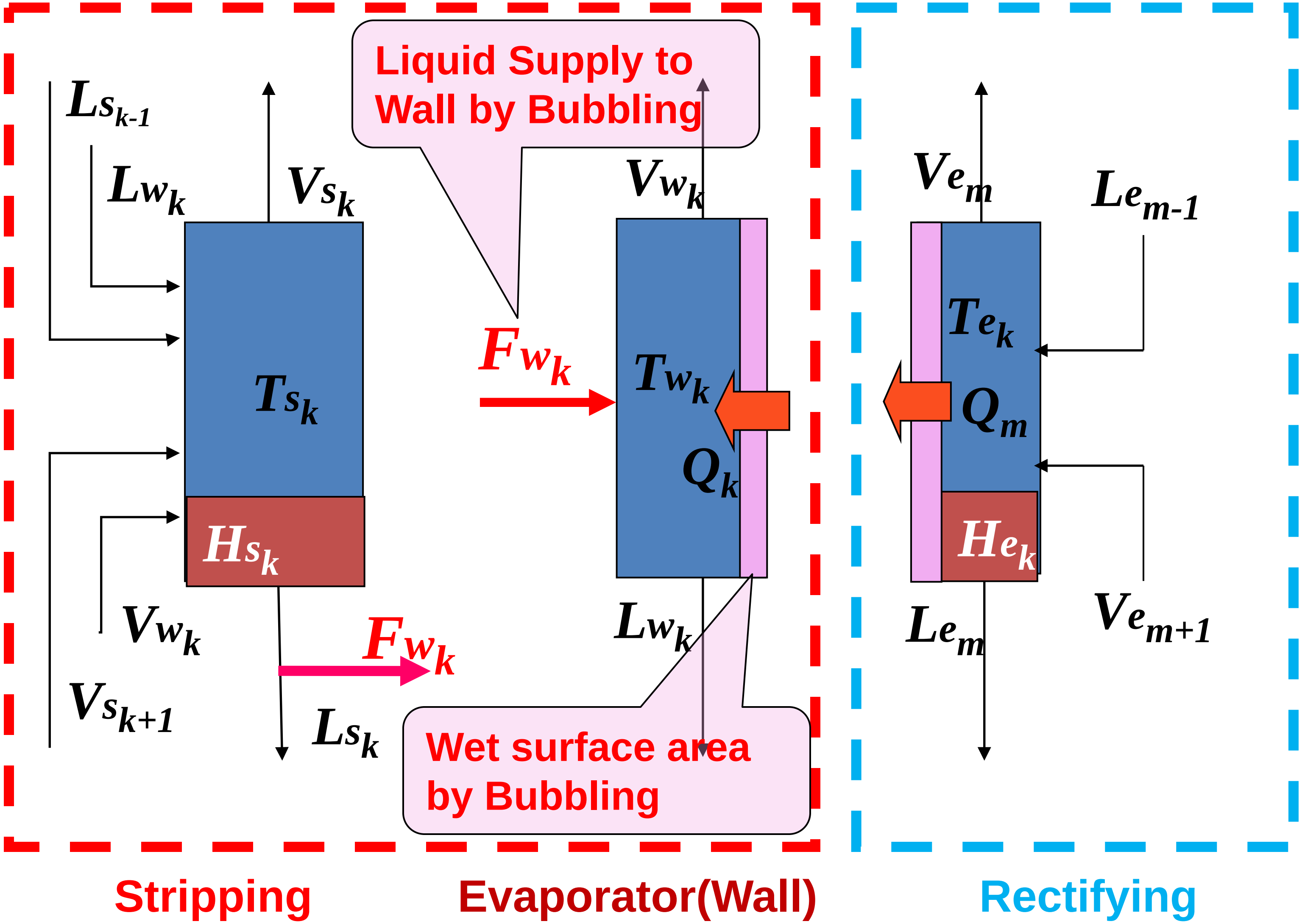

Fig. 10 Three sections on a tray

Behavior of Evaporator is essential to performance of HIDiC.

Heat Transfer in Stripping section of HIDiC

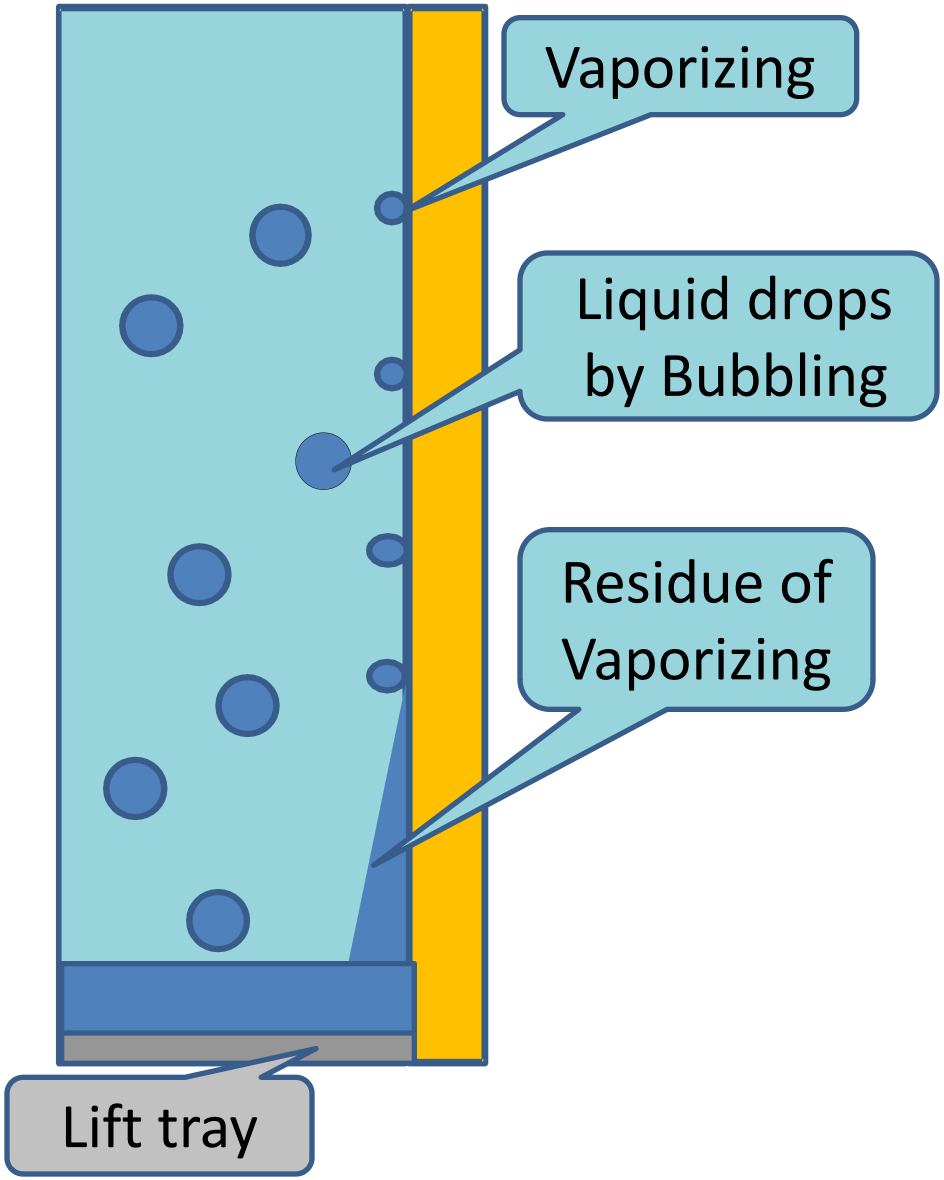

Fig. 11 Behavior in Stripping section

Liquid supply to the wall is generated by bubbling.

How is the liquid drops vaporized at the wall?

If supplied liquid is more than vaporization rate, liquid film is generated on the wall.

Their rate affects the film thickness and vaporized flow composition.

Bubbling must be analyzed to predict the performance of HIDiC.

Heat Transfer in Rectifying section of HIDiC

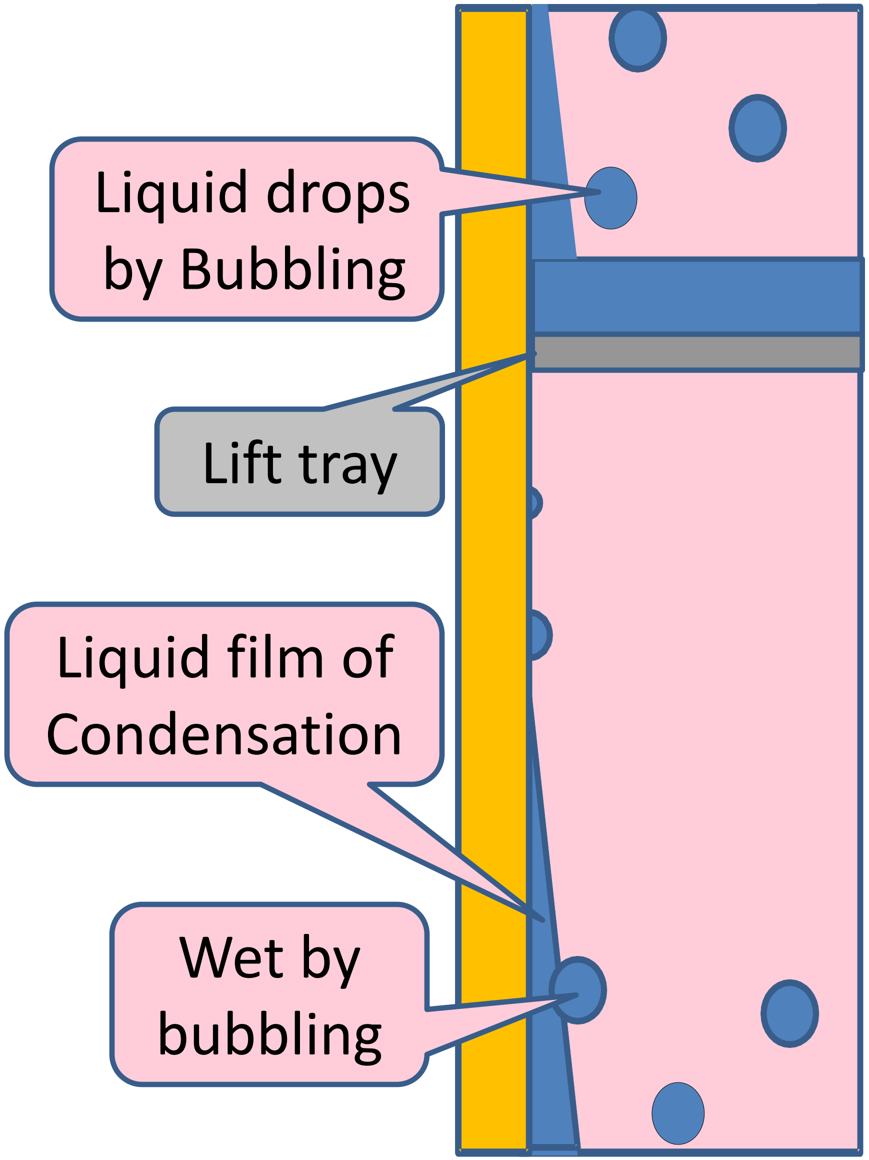

Fig. 12 Behavior in Rectifying section

For condensation at wall,
dry surface is better.

The wall becomes wet by not only condensation but also bubbling.

Thickness of liquid film affect s heat transfer efficiency.

Bubbling depends on vapor flow.

The heat transfer efficiency for condensation must be affected by vapor flow rates.

Heat Transfer in Wall

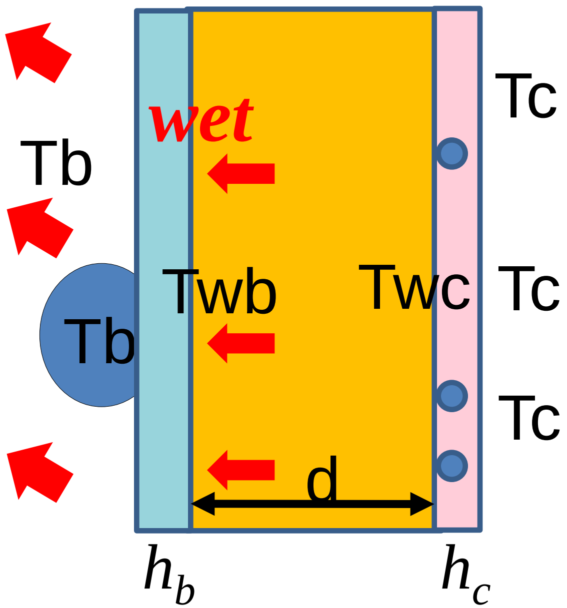

Fig. 13 vaporization at wet wall

Heat Transfer Coefficient of 6mm thick

Carbon Steel λ=50W/m･K λ/d=8.3kW/m²･K

In the experimental results using toluene,

U≒2.7kW/m²･K (Fig. 5)

$$\frac{1}{\frac{1}{h_b}+\frac{1}{h_c}}=\frac{1}{\frac{1}{2.7}-\frac{1}{8.3}}=4$$

Condensation heat transfer coefficient h_c is large.

$$if\ \ h_c=10,\ h_b=6.7 \qquad\qquad if\ \ h_c=15,\ h_b=5.5$$

Vaporization heat transfer coefficient h_b is also large.
As shown in Fig.5, the heat transfer coefficients are not affected by transferred heat duty.

Heat transfer and Vaporization rate (Toluene)

In the experimental results using toluene,
U≒2.7kW/m^2・K (Fig. 5)

The largest temperature difference in the experiment is ΔT=20K.(Fig. 7)

If ΔT=20K, vaporizing liquid volume per second corresponds to 0.6mm thick film.

Liquid supply by bubbling must be larger than it.

If ΔT is smaller, vaporizing liquid volume is smaller and liquid film thickness become thicker.

However, as shown in Fig. 5, ΔT does not affect U.

Therefore, liquid film thickness does not affect vaporization heat transfer efficiency.

Heat transfer and Vaporization rate (Binary)

Bubbling capability of Vapor flow does not depend on the liquid composition very much. (pure toluene or binary)

Therefore, Liquid supply per second by bubbling must be larger than 0.6mm thick film.

For binary system, $U \fallingdotseq 0.7 kW/m^2 \cdot K$ (Fig. 5)

Even when $\Delta T = 20K$, vaporizing liquid volume per second corresponds to 0.08mm thick film.

Liquid Supply by bubbling is much more than vaporization.

The surface of vaporization must be wet.

If surface is dry, vaporization occur locally

Heat transfer at dry surface is very bad.

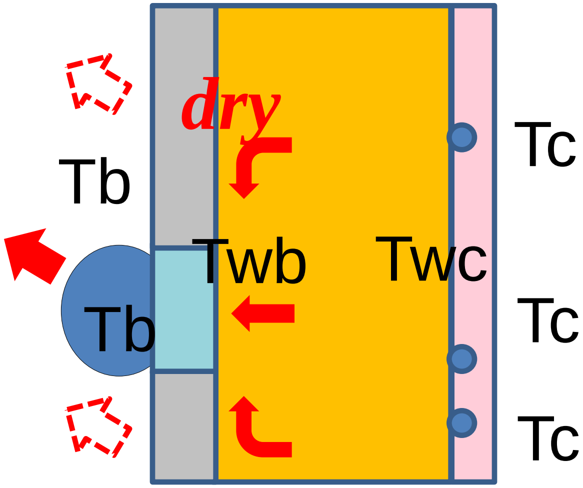

Fig. 14 vaporization at dry wall

In the experimental results using toluene,
U≒2.7kW/m²·K (Fig. 5)

$$\frac{1}{\frac{A}{h_b A'}+\frac{1}{h_c}}=\frac{1}{\frac{1}{2.7}-\frac{A}{8.3A'}}$$

$$if \;\; h_c = 10 \;\&\; A'/A = 0.7, \; h_b = 15$$

$$if \;\; h_c = 15 \;\&\; A'/A = 0.7, \; h_b = 11$$

Vaporization heat transfer coefficient must be very high.

If dry area exists, the area must be affected by bubbling.
Bubbling must be affected by F-factor.
However, U is not affected by F-factor as shown in Fig. 6.

Whole surface must be wet by bubbling.

Bubbling on Lift tray

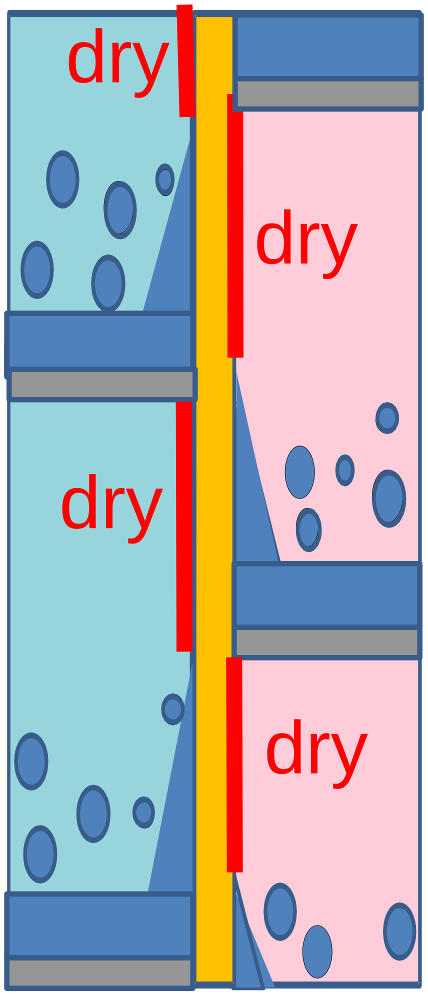

Fig. 15 Height of bubbling

If whole surface of the wall becomes wet by bubbling, liquid drops by bubbling arrive at the ceil and Entrainment occurs.

If entrainment is avoided by enlargement of tray intervals, dry area appears on the wall.

The dray area affects heat transfer efficiency very much.

If lift tray can be designed to control bubbling height, heat transfer efficiency can be controlled.

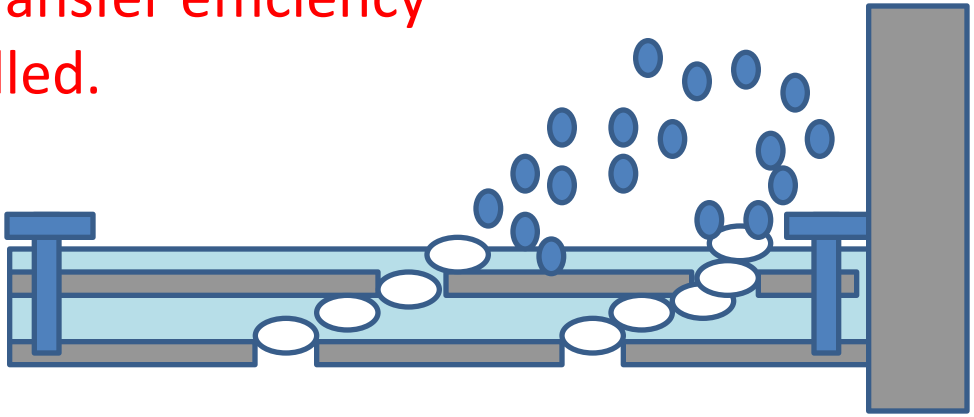

Fig. 16 Design of lift tray considering bubbling