Chapter 8

CONCLUSIONS

A practically pure liquid-vapor system and stepwise heating of a liquid-vapor interface are experimentally realized in He II environment. In this environment, He II evaporation phenomena induced by the thermal pulse impingement onto a He II-vapor interface is experimentally investigated. In addition to direct the He II evaporation investigation, other two studies are pursued in a series of experiment for further understanding of the He II evaporation phenomena. One is the reflection of a second sound thermal pulse from a He II free surface. The other is He II condensation induced by an evaporation wave impingement onto a He II free surface from vapor side. The following conclusions are drawn through the present investigation.

1. He II evaporation

   (a) Evaporation wave
   It is found that the wave front of an evaporation wave develops to a weak shock wave and the profile of an evaporation wave is quite similar to that of an impinging thermal pulse onto a He II-vapor interface in both the temperature and the pressure. The Mach number of a propagating evaporation wave front is almost unity or slightly larger than unity, and the experimental data are in good agreement with the Rankine-Hugoniot relation.

   (b) Visualization
   It is demonstrated that a laser holographic interferometer can be applied to the visualization of thermo-fluid dynamic phenomena

in He II environment. The visualization revealed that a shock is formed at the evaporation wave front, a thermal pulse dose not change the sign of the temperature variation upon reflection from a free surface. The propagation speed of the evaporation wave obtained from the visualization pictures based on the time-of-flight method, nearly equal to the speed of sound in helium vapor satisfactory agrees with that measured with the superconductive temperature sensor. The density rise in the evaporation wave can be obtained from the amount of the fringe shift in the interferogram taken in the finite-fringe mode, and the result fairy agrees with that computed directly from the temperature and pressure measurement data.

(c) Condensation coefficient of He II
The condensation coefficient α_c of He II in evaporation process is obtained from the direct comparison of the experimental result with the kinetic theory analysis result[5]. It is confirmed that the temperature dependence of the condensation coefficient is reasonable, even at very low temperatures and near the λ point. The coefficient seems to approach to unity below $1.3\,K$, just as the experimental value of the striking coefficient in quantum evaporation process[58], and it drops drastically near the λ point.

(d) Non-linear effect of slip boundary condition
It is found that the non-linear effect on the slip boundary condition begins to arise at relatively small temperature rise of a free surface, or relatively small speed ratio.

(e) Numerical simulation of vapor flow region
The vapor flow region induced by a thermal pulse impingement is numerically simulated by solving the Navier-Stoke equation supplemented with the linear slip boundary condition. It is confirmed that the experimental result of the pressure and the temperature rises in the evaporation wave is qualitatively in good agreement with the numerical result.

2. Reflection of a second sound
   The reflection coefficient R_{22} of a thermal pulse for the reflection from a He II-vapor interface is directly measured with a superconductive temperature sensor. The experimental result is in good agreement with the value converted from the condensation coefficient obtained experimentally. The satisfactory agreement between data obtained in the two independent measurements indicates both the measurements of α_c and R_{22} are valid.

3. Effect of super thermal conduction on He II condensation

   (a) The significant effect of super thermal conduction on the He II condensation is confirmed by the comparison of the experimental result of the pressure behind a reflection wave on a rigid wall covered with superfluid thin film with that on a He II free surface.

   (b) The pressure amplitude reflection coefficient R_{GG} is also experimentally obtained as a function of temperature. R_{GG} considerably increases as the temperature approaches to the λ point because of diminishing the effect of super thermal conduction.

   (c) It can be concluded that the decrease in the condensation coefficient of He II at the temperature approaches to the λ point is caused by diminishing the effect of the super thermal conduction judging from the conclusions of 3.(a) and 3.(b).