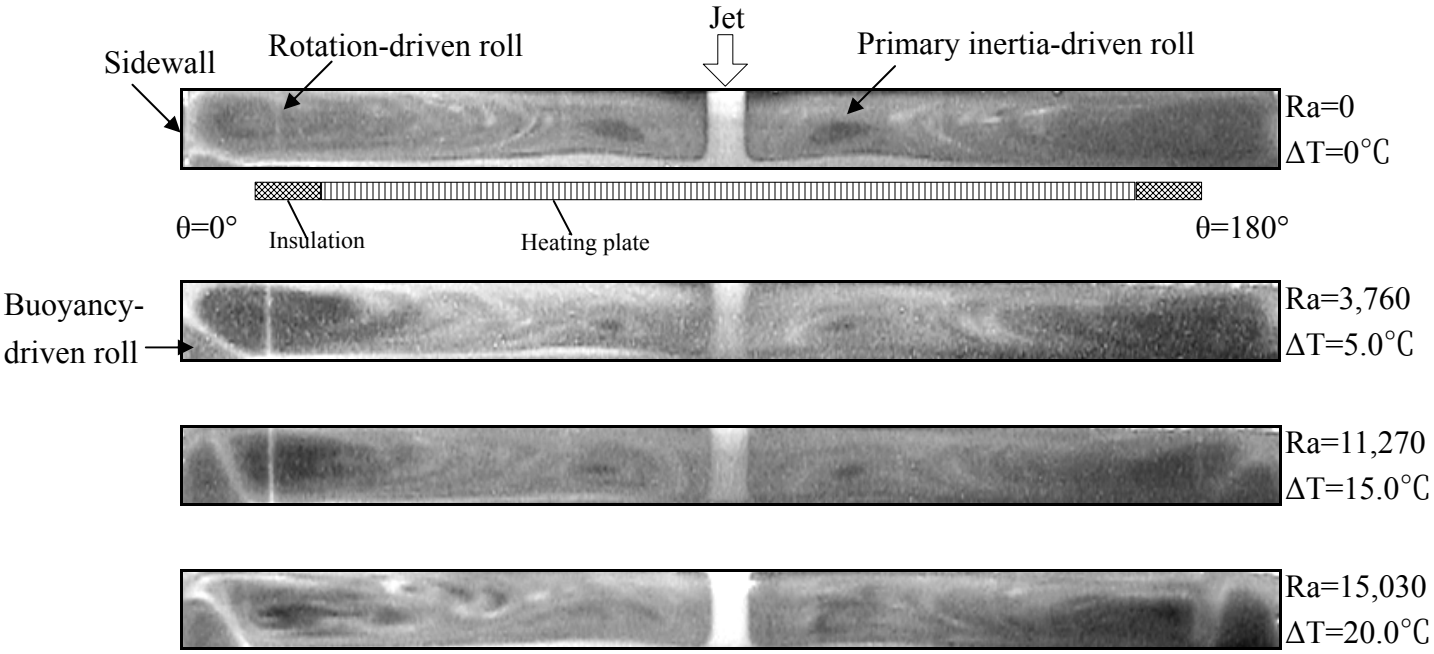
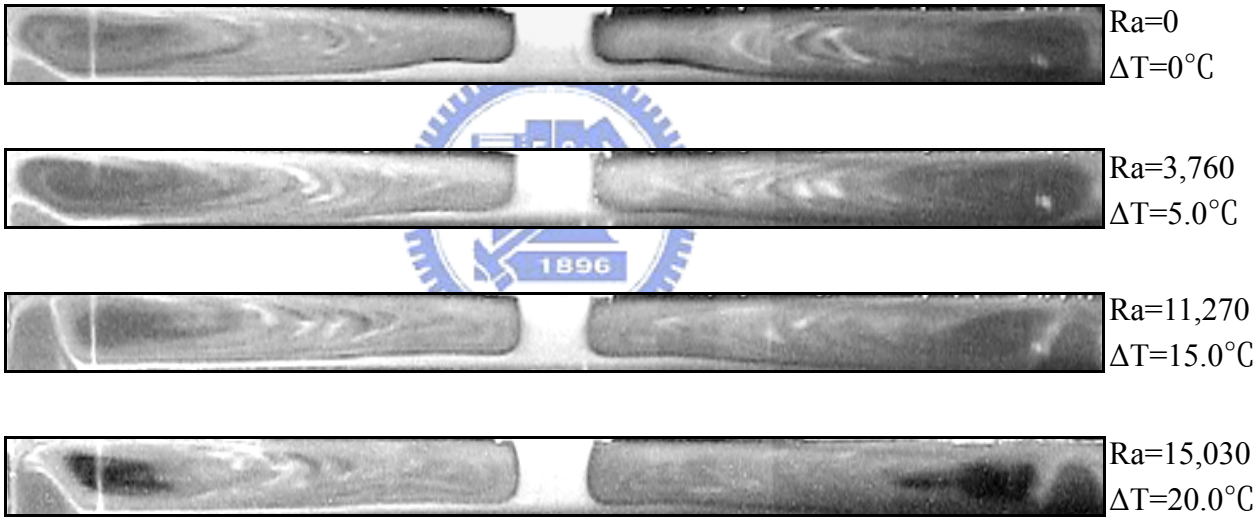
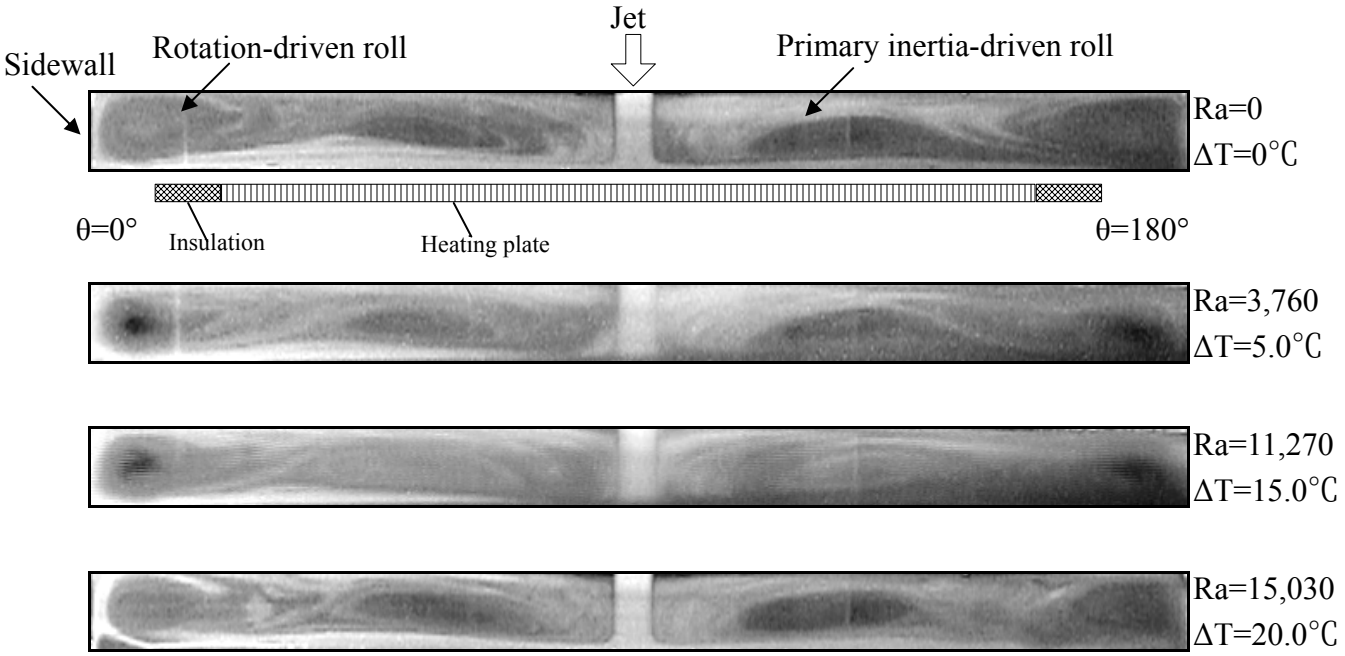


(a) D_j=10.0 mm & Re_j=135

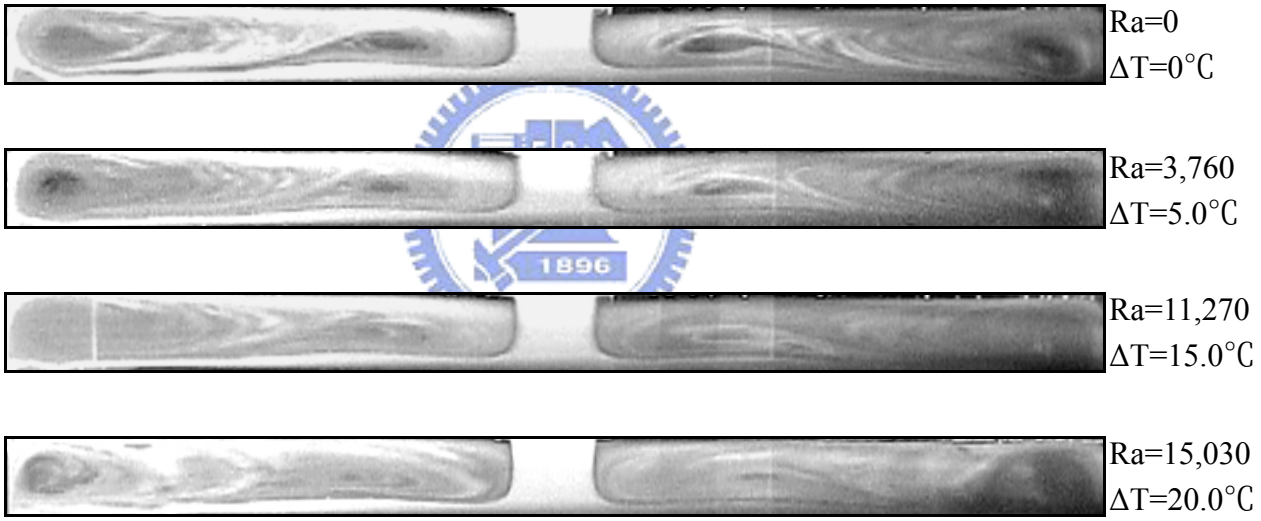


(b) D_j=22.1 mm & Re_j=61

Fig. 4.28 Side view flow photos taken at the cross plane $\theta = 0^\circ$ & 180° for various Rayleigh numbers at Q_j= 1.0 slpm and Re_Ω = 2,335 (Ω = 30 rpm) for (a) D_j =10.0 mm & Re_j = 135 and (b) D_j = 22.1 mm & Re_j = 61.

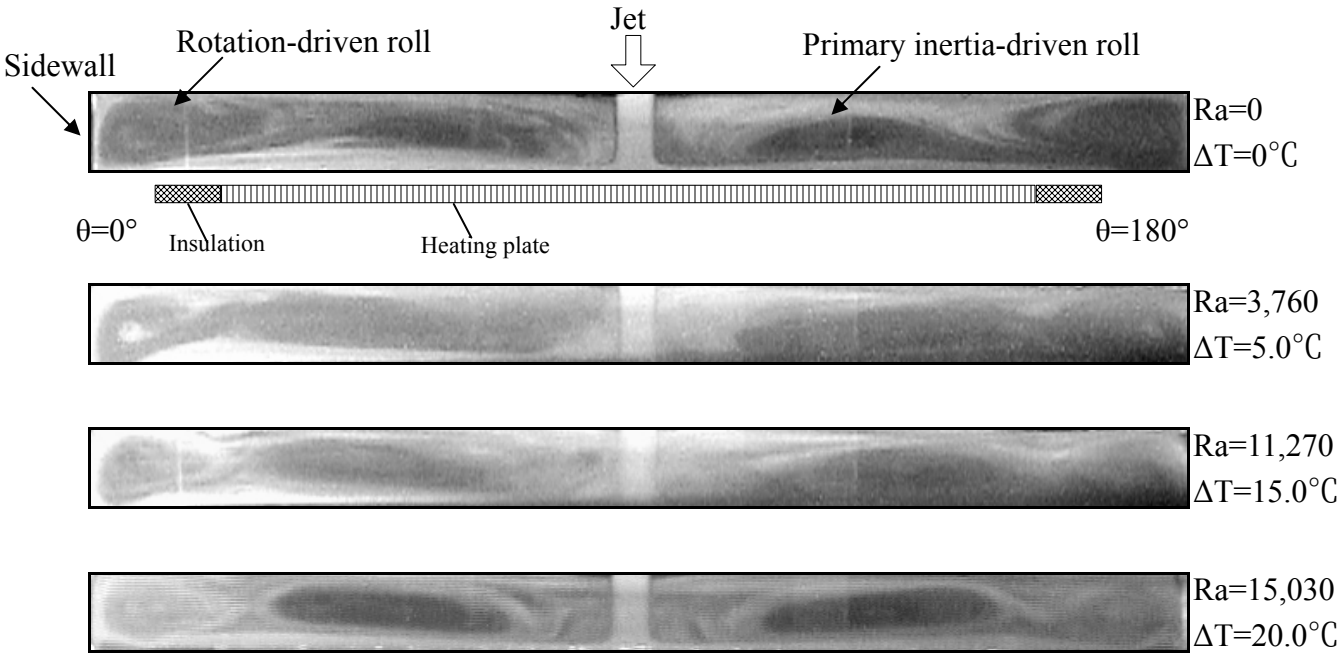


(a) D_j=10.0 mm & Re_j=406

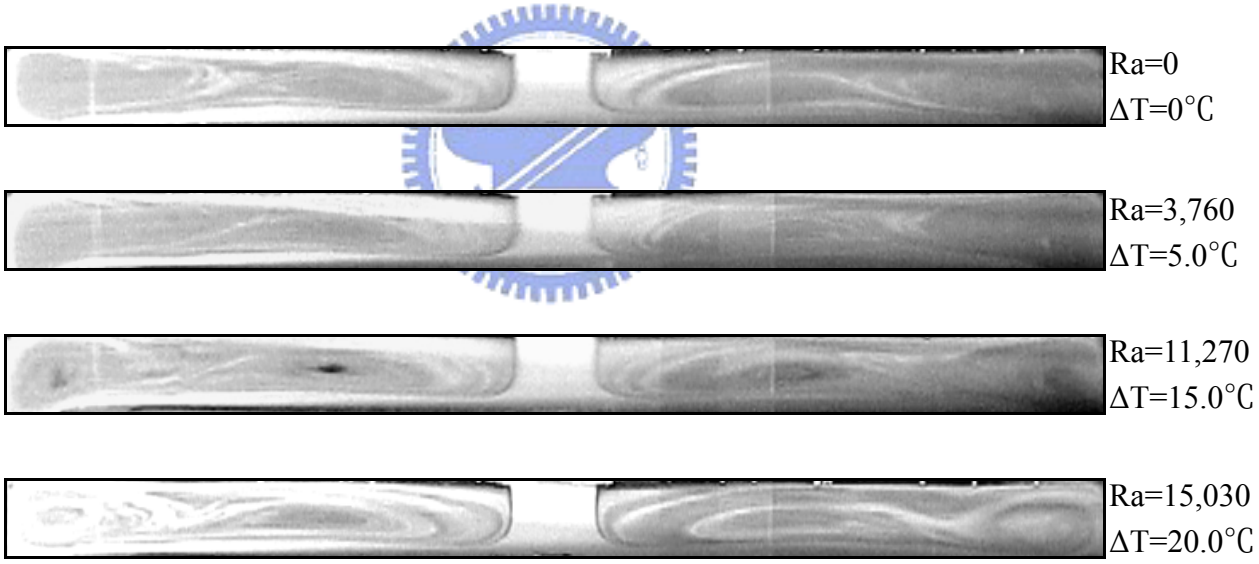


(b) D_j=22.1 mm & Re_j=184

Fig. 4.29 Side view flow photos taken at the cross plane $\theta = 0^\circ$ & 180° for various Rayleigh numbers at Q_j = 3.0 slpm and Re_Ω = 2,335 (Ω = 30 rpm) for (a) D_j =10.0 mm & Re_j = 406 and (b) D_j =22.1 mm & Re_j = 184.

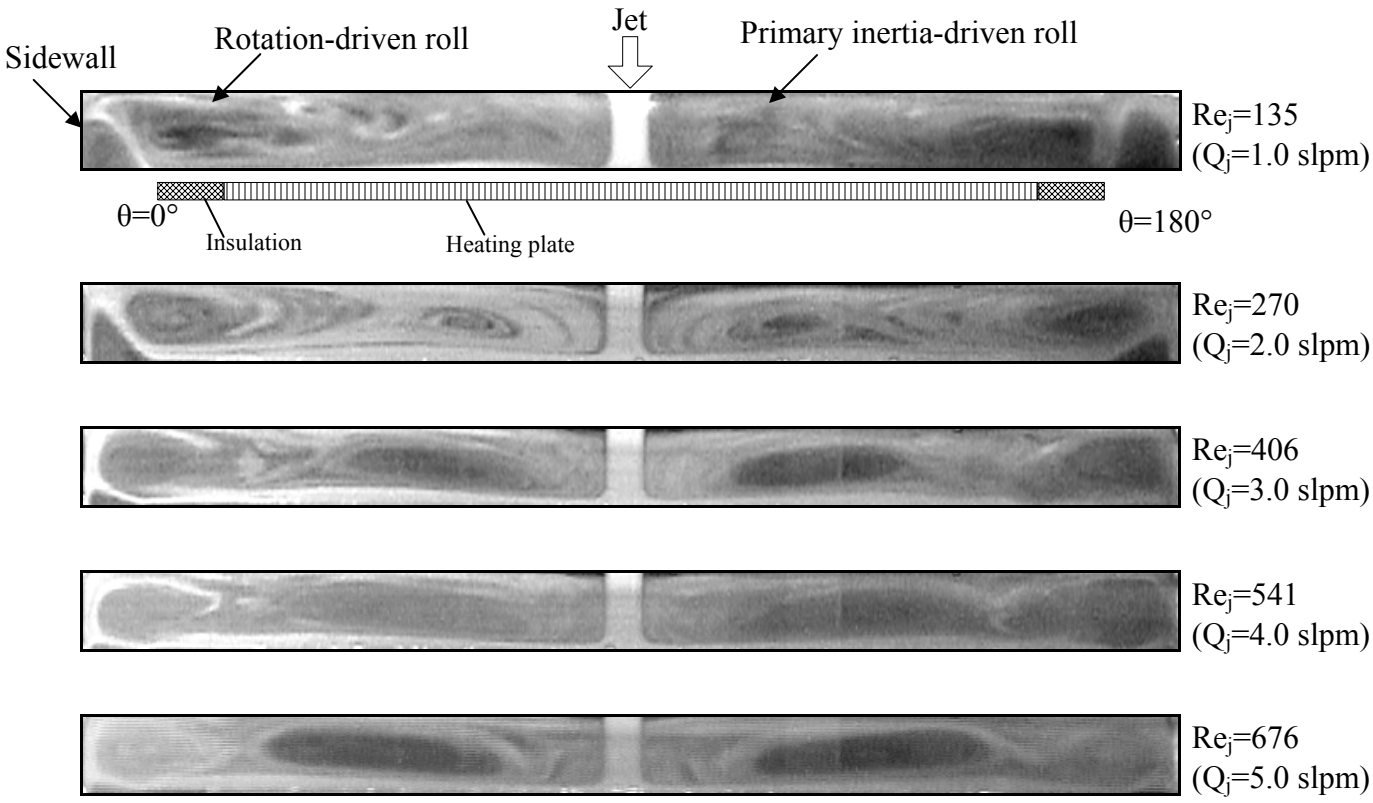


(a) D_j=10.0 mm & Re_j=676

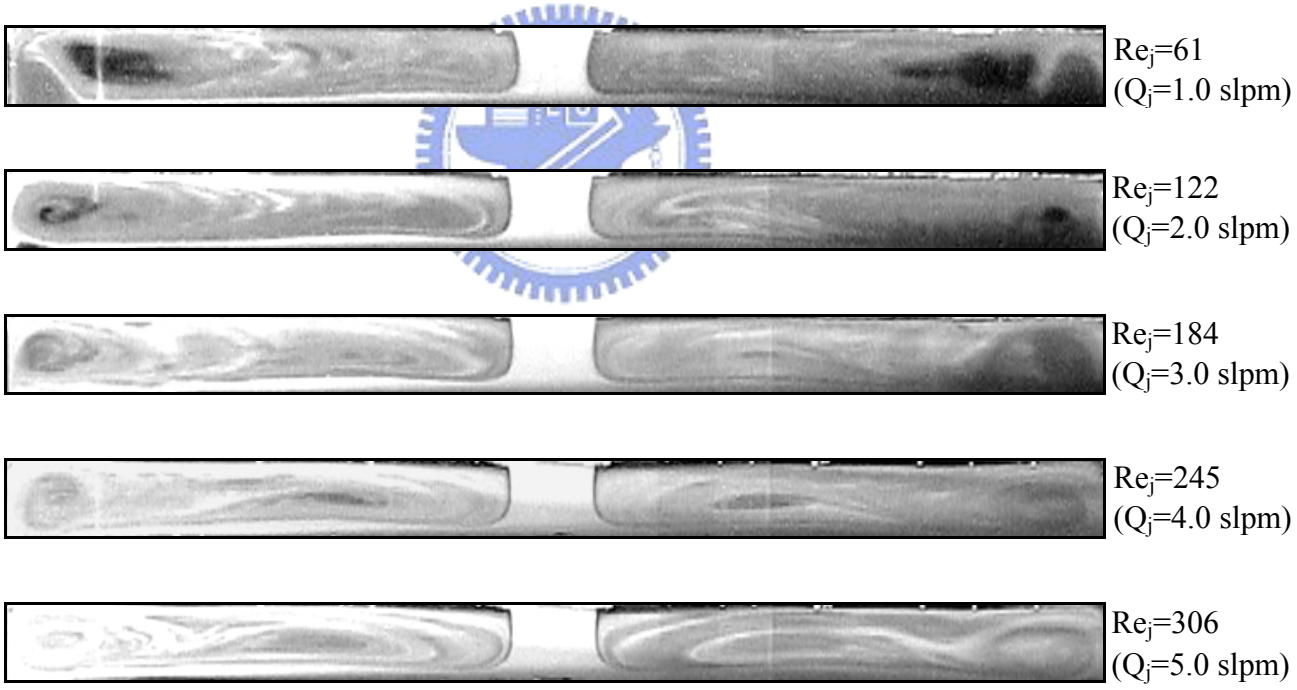


(b) D_j=22.1 mm & Re_j=306

Fig. 4.30 Side view flow photos taken at the cross plane $\theta = 0^\circ$ & 180° for various Rayleigh numbers at Q_j = 5.0 slpm and Re_Ω = 2,335 (Ω = 30 rpm) for (a) D_j = 10.0 mm & Re_j = 676 and (b) D_j = 22.1 mm & Re_j = 306.



(a) D_j=10.0 mm



(b) D_j=22.1 mm

Fig. 4.31 Steady side view flow photos taken at the cross plane $\theta = 0^\circ$ & 180° for various jet Reynolds numbers at Ra = 15,030 (ΔT= 20.0℃) and Re_Ω = 2,335 (Ω = 30 rpm) for D_j = (a) 10.0 mm and (b) 22.1 mm.

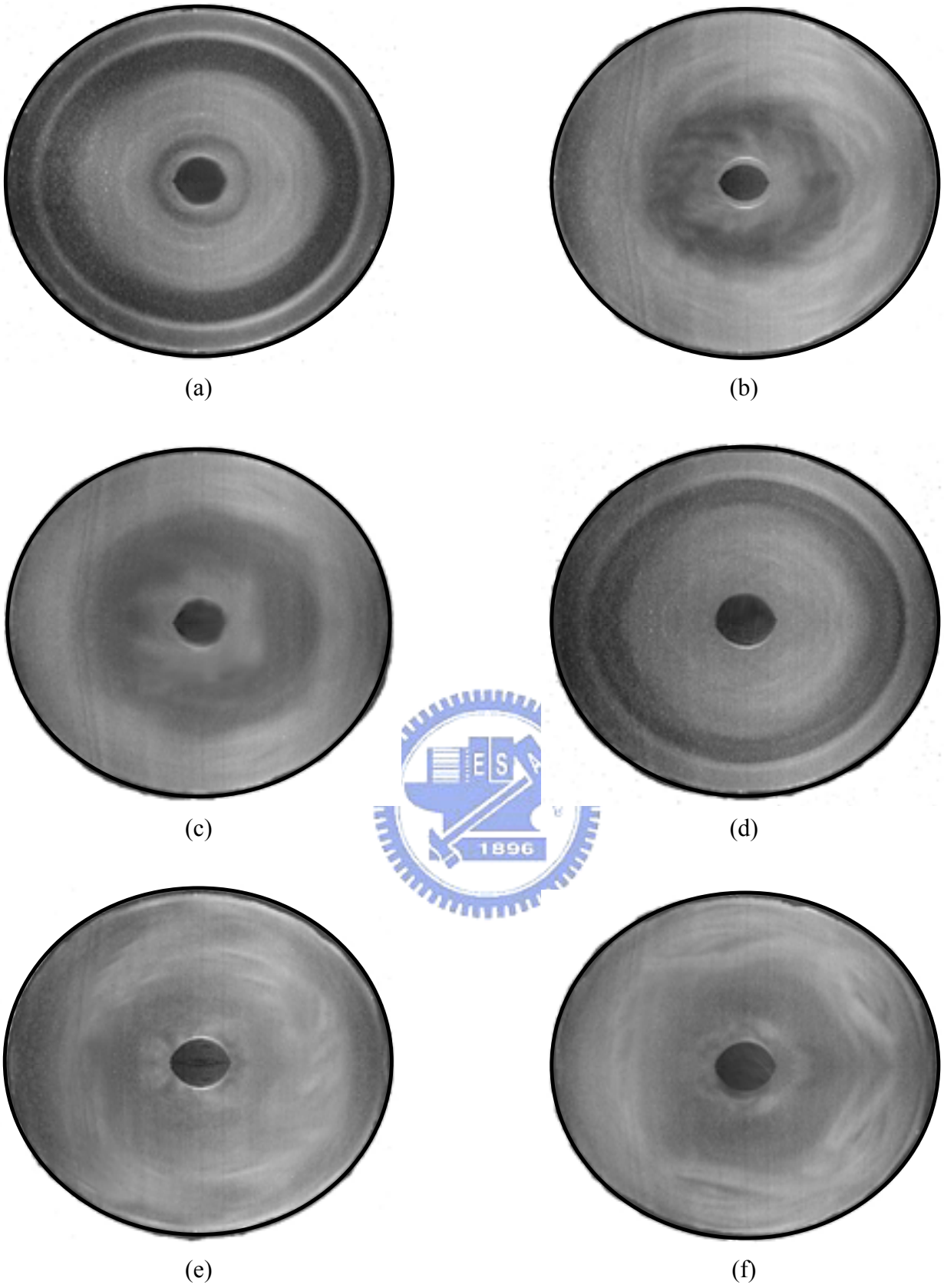
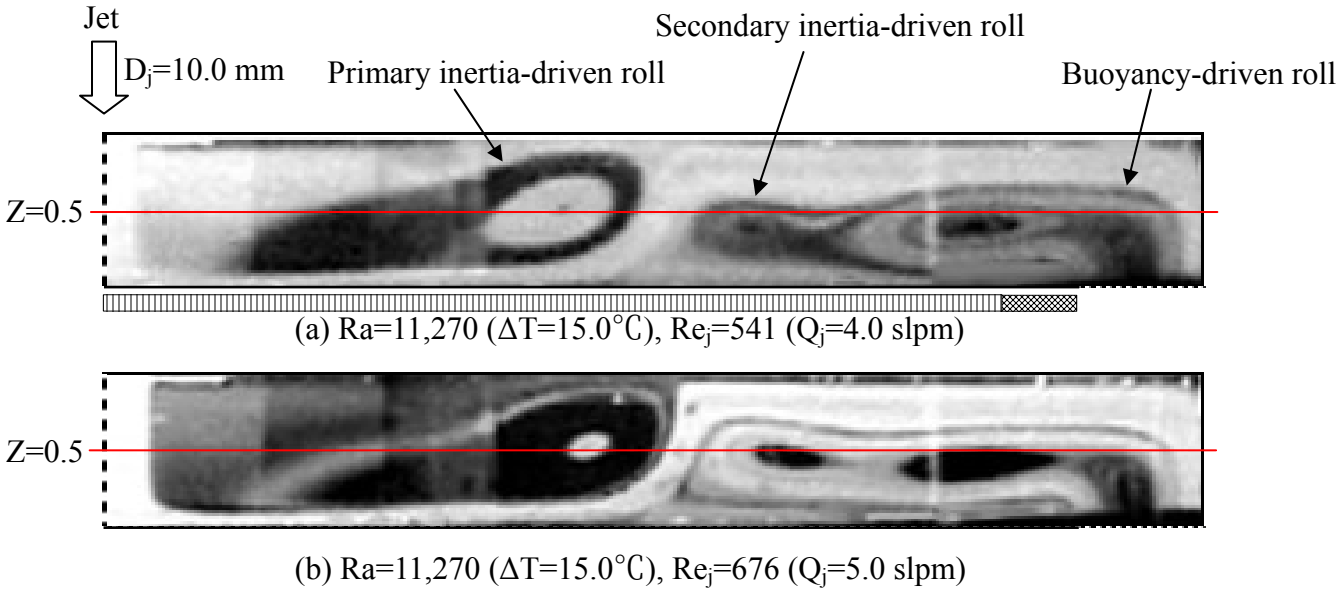
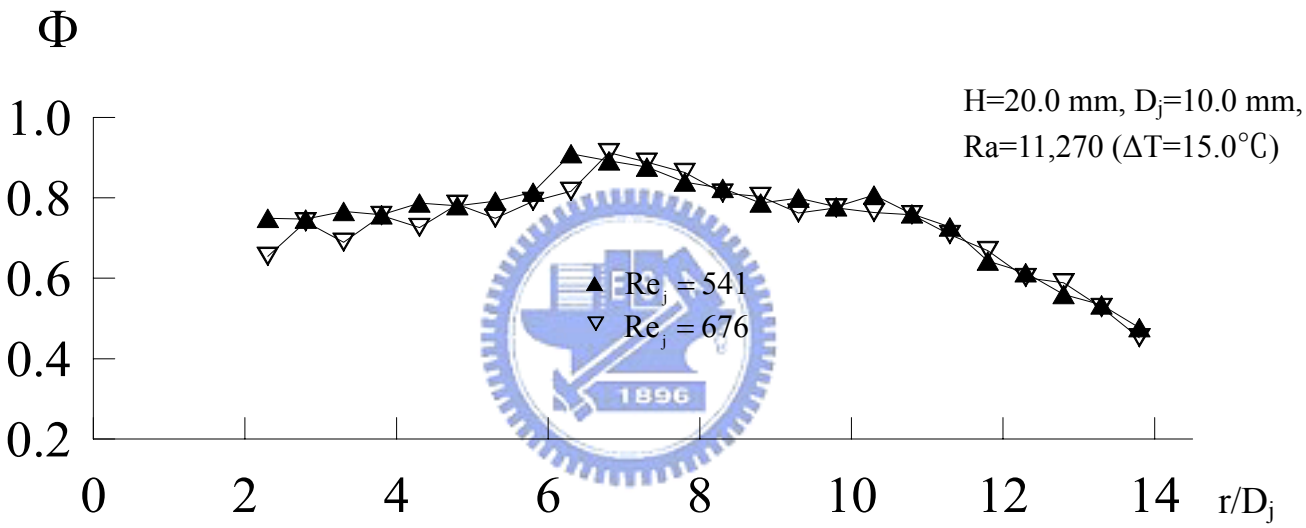


Fig. 4.32 Steady top view flow photos taken at the middle horizontal plane between the disk and chamber top with Ra = 15,030 (ΔT = 20.0°C) and Re_Ω = 2,335 (Ω = 30 rpm) for D_j =10 mm at Re_j = (a) 135, (b) 406, and (c) 676 and D_j = 22.1 mm at Re_j = (d) 61, (e) 184, and (f) 306.



(a) Ra=11,270 (ΔT=15.0℃), Re_j=541 (Q_j=4.0 slpm)

(b) Ra=11,270 (ΔT=15.0℃), Re_j=676 (Q_j=5.0 slpm)



(c) radial variation in non-dimensional steady air temperature

Fig. 4.33 Steady side view flow photos at the cross plane $\theta = 180^\circ$ with Re_Ω=0(Ω=0 rpm), Ra=11,270 (ΔT=15.0℃), H=20.0 mm, and D_j=10.0 mm at Re_j= (a)541 and (b)676, and (c) the corresponding radial variations of non-dimensional steady air temperature at Z=0.5.

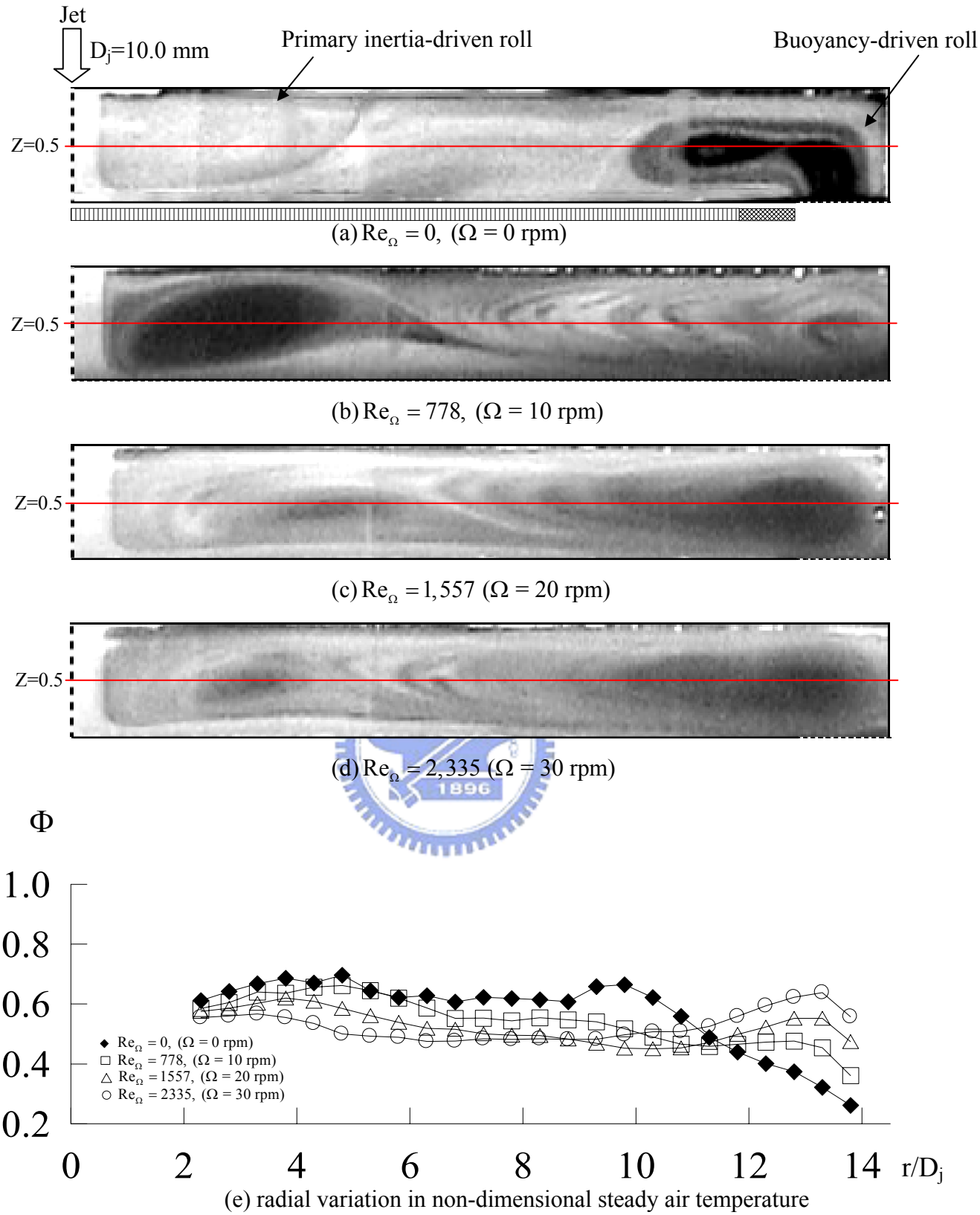
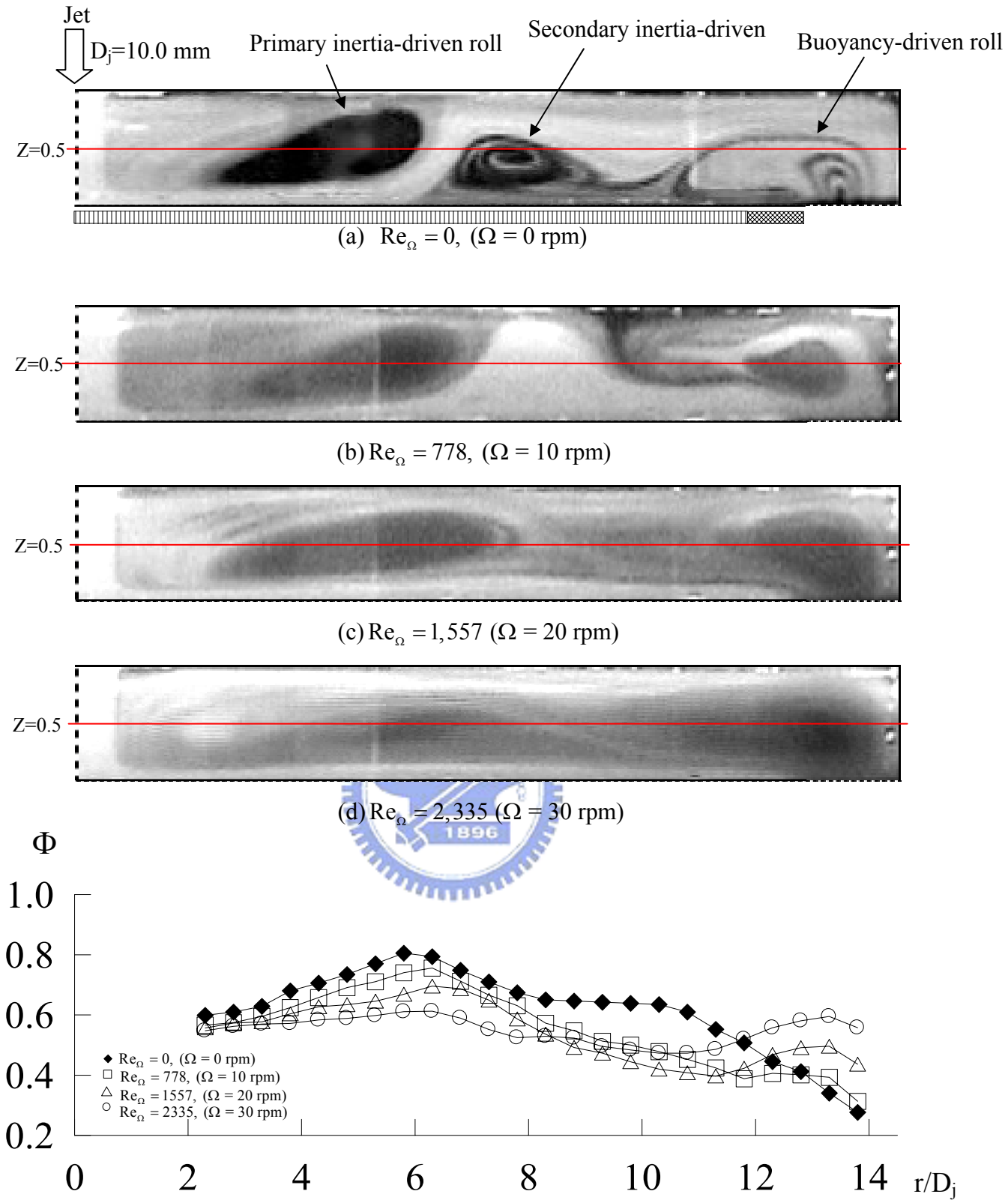


Fig. 4.34 Steady side view flow photos at the cross plane $\theta = 180^\circ$ with Re_j =135 (Q_j=1.0 slpm), Ra=3,760 (ΔT=5.0℃), H=20.0 mm and D_j=10.0 mm at Re_Ω = (a)0, (b)778, (c)1,557 and (d)2,335, and (e) the corresponding radial variations of non-dimensional steady air temperature at Z=0.5.



(e) radial variation in non-dimensional steady air temperature

Fig. 4.35 Steady side view flow photos at the cross plane $\theta = 180^\circ$ with Re_j = 406 (Q_j=3.0 slpm), Ra=3,760 (ΔT=5.0°C), H=20.0 mm, and D_j=10.0 mm at Re_Ω = (a)0, (b)778, (c)1,557, (d)2,335 and (e) the corresponding radial variations of non-dimensional steady air temperature at Z=0.5.

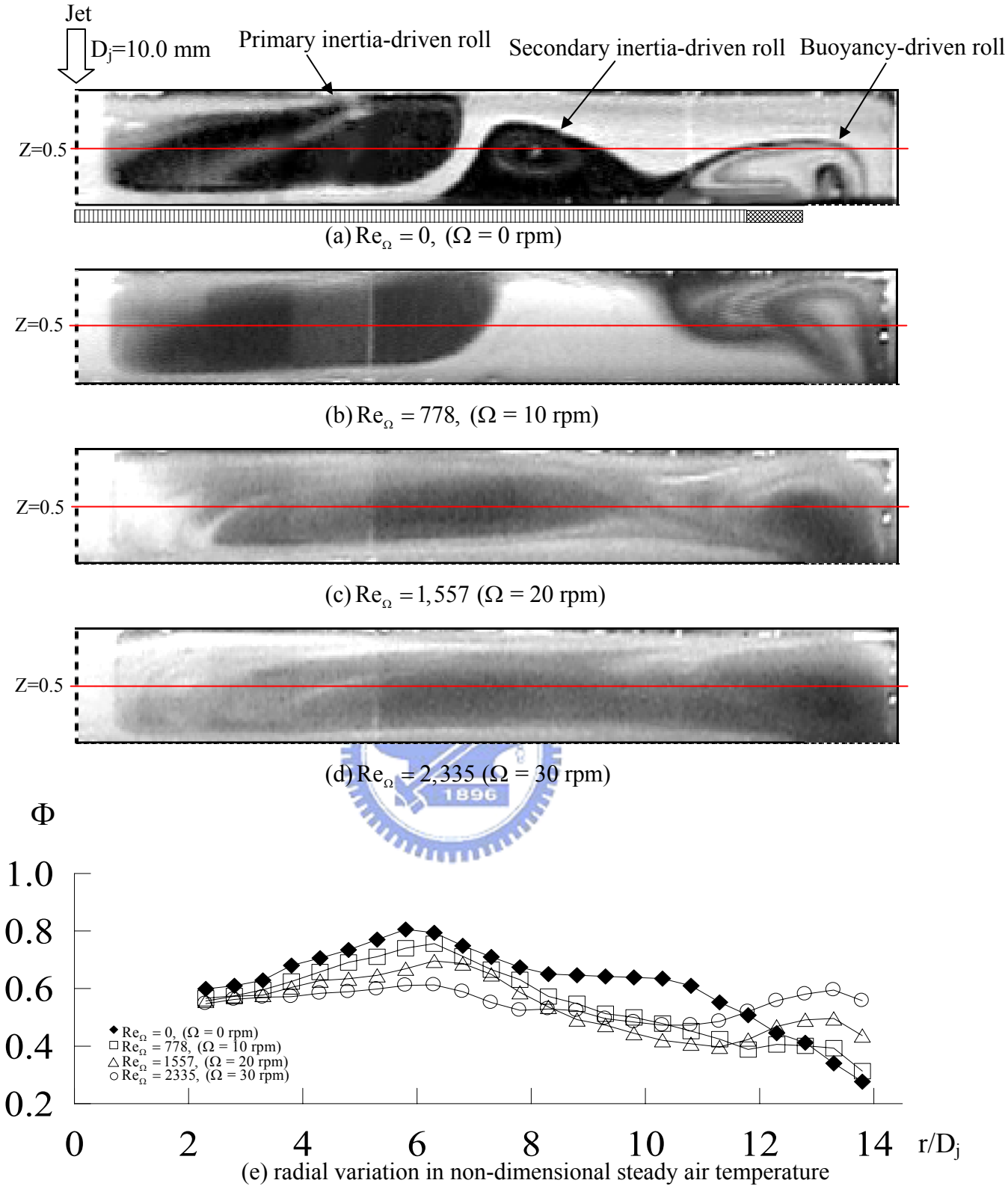
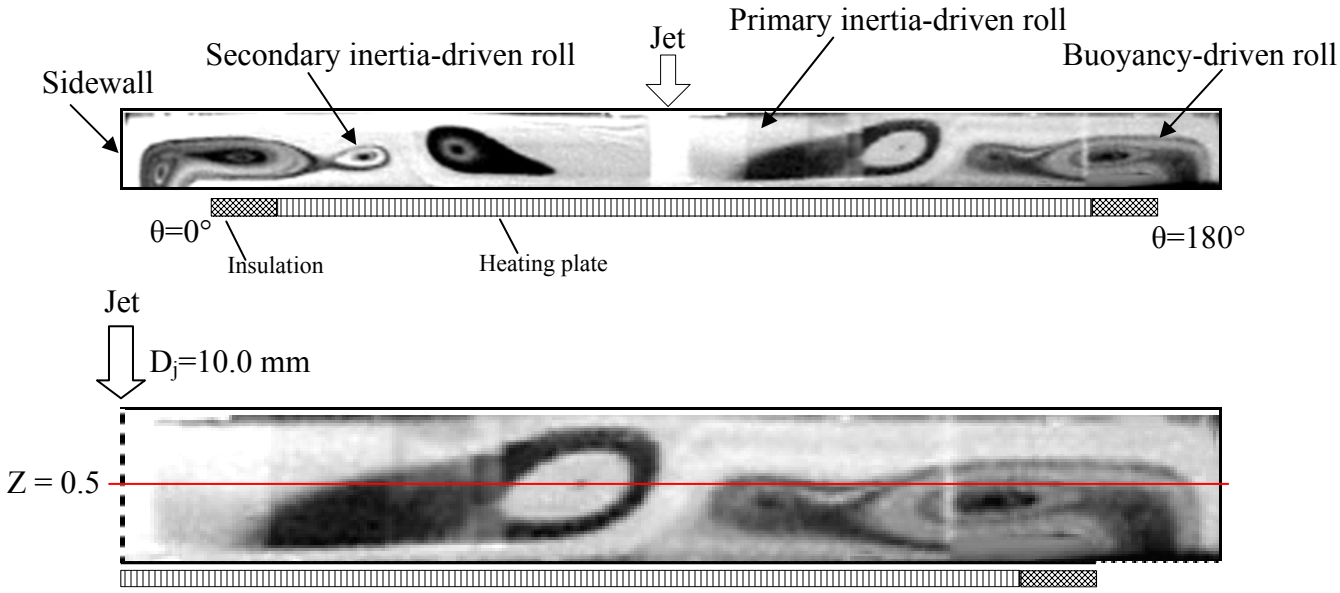
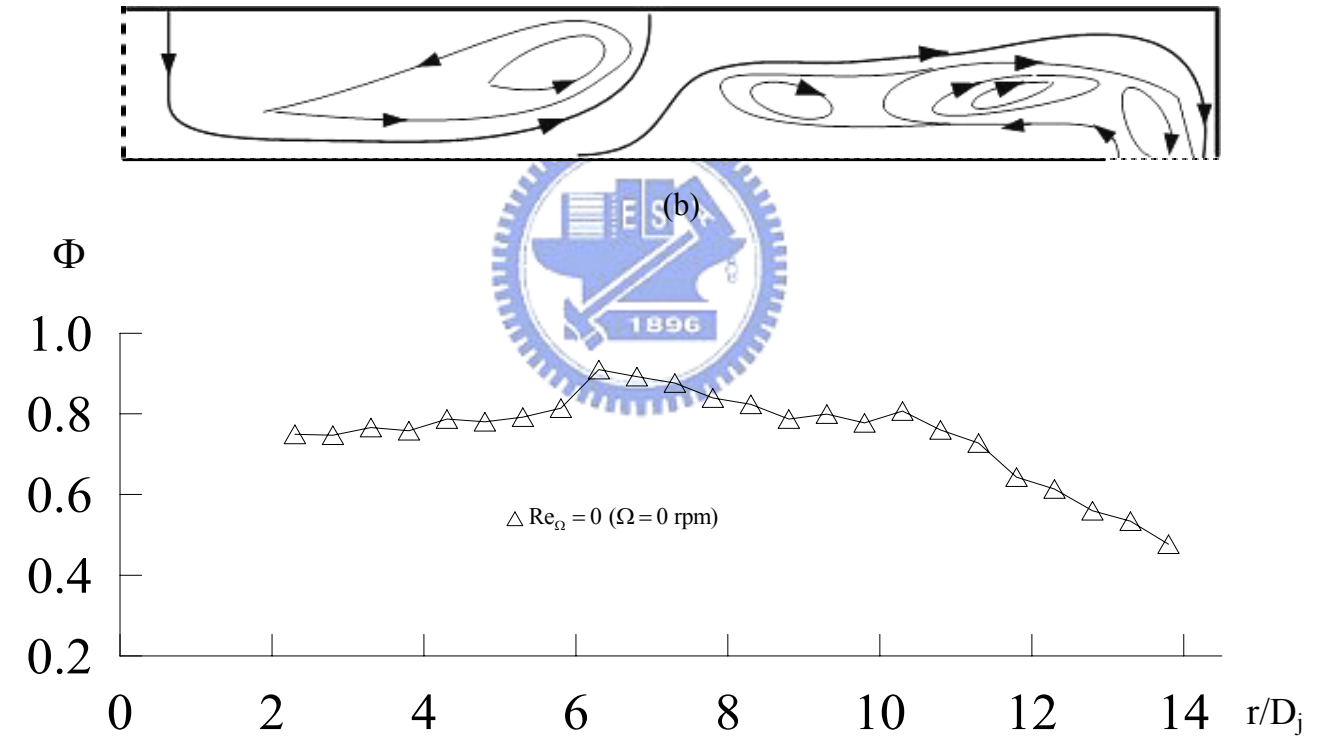


Fig. 4.36 Steady side view flow photos at the cross plane $\theta = 180^\circ$ with Re_j =541 (Q_j=5.0 slpm), Ra=3,760 (ΔT=5.0℃), H=20.0 mm, and D_j=10.0 mm at Re_Ω = (a)0, (b)778, (c)1,557, and (d)2,335 and (e) the corresponding radial variations of non-dimensional steady air temperature at Z=0.5.



(a) Ra=11,270 (ΔT=15.0℃), Re_j=541 (Q_j=4.0 slpm), and Re_Ω = 0 (Ω=0 rpm)



(c) radial variation in non-dimensional steady air temperature

Fig. 4.37 Steady side view flow photos at the cross plane θ = 0° & 180° with (a) Re_j = 541 (Q_j= 4.0 slpm), Ra=11,270 (ΔT=15.0℃), H=20.0 mm, D_j=10.0 mm and Re_Ω =0 (Ω =0 rpm), (b)the corresponding schematically sketched cross plane vortex flow at θ = 180°, and (c) the radial variation of non-dimensional steady air temperature at Z=0.5.

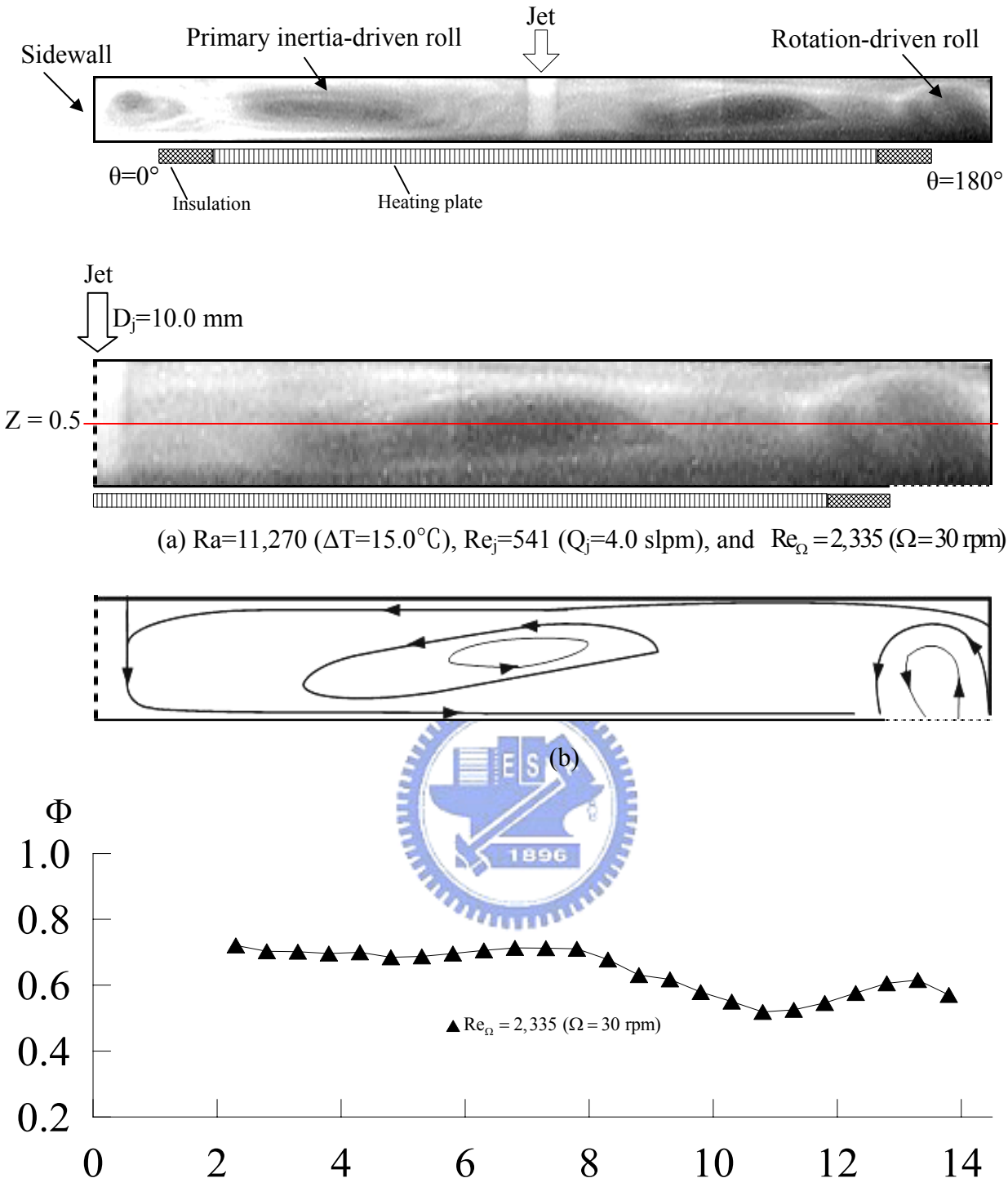
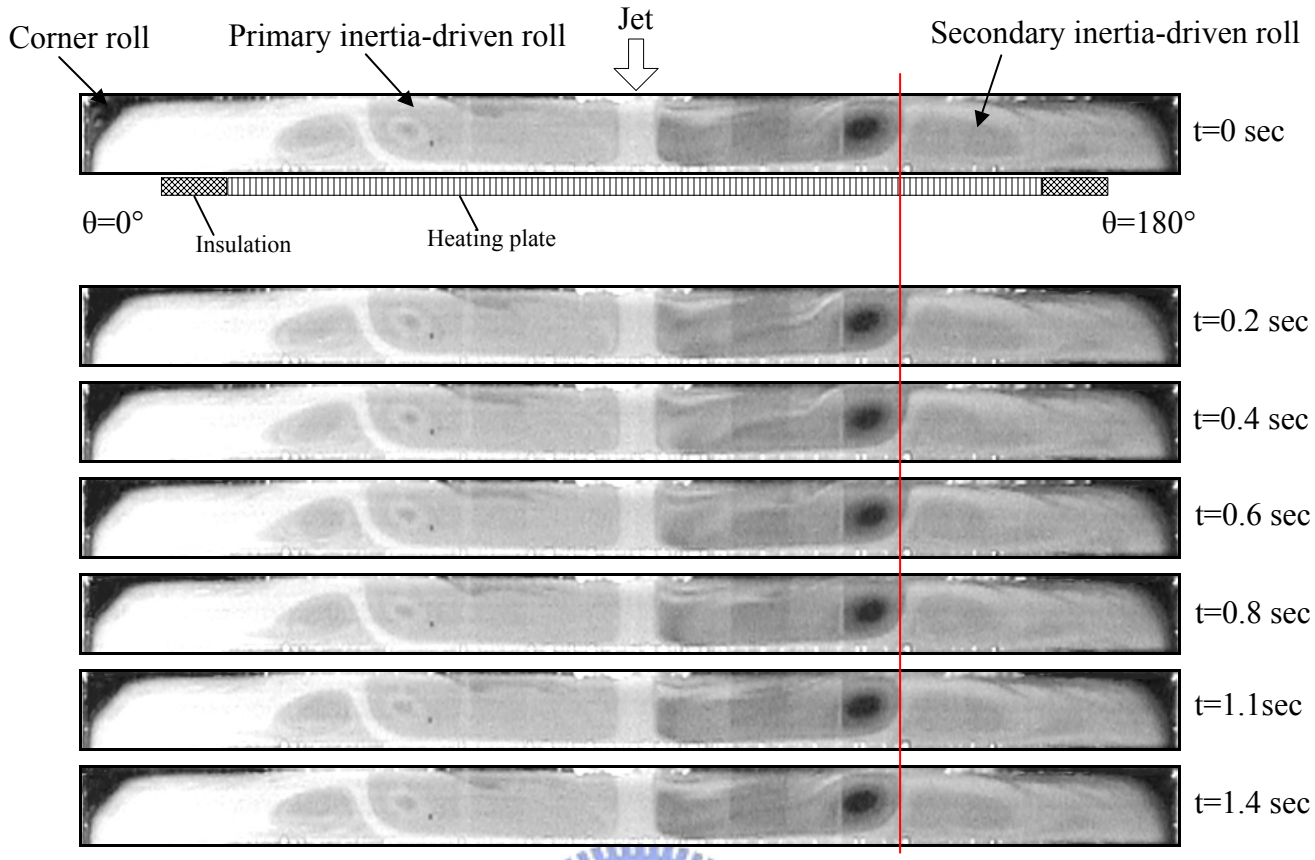
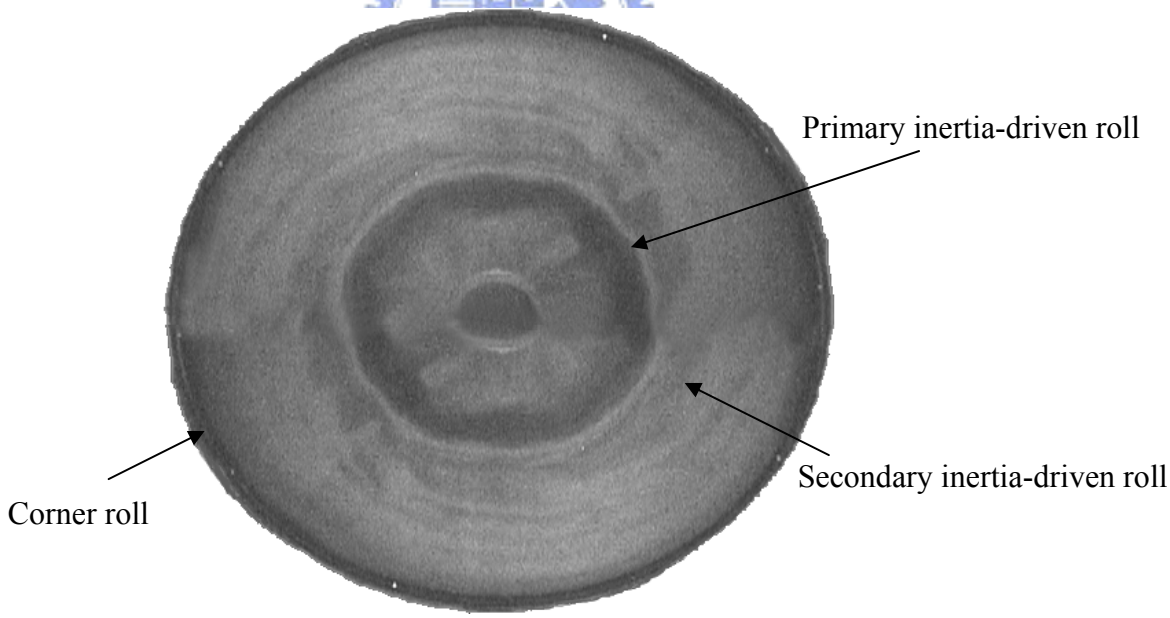


Fig. 4.38 Steady side view flow photos at the cross plane $\theta = 0^\circ$ & 180° with (a) Re_j = 541 (Q_j= 4.0 slpm), Ra=11,270 (ΔT= 15.0°C), H=20.0 mm, D_j=10.0 mm and Re_Ω=2,335 (Ω = 30 rpm), (b)the corresponding schematically sketched cross plane vortex flow at $\theta = 180^\circ$ and (c) the radial variation of non-dimensional steady air temperature at Z=0.5.

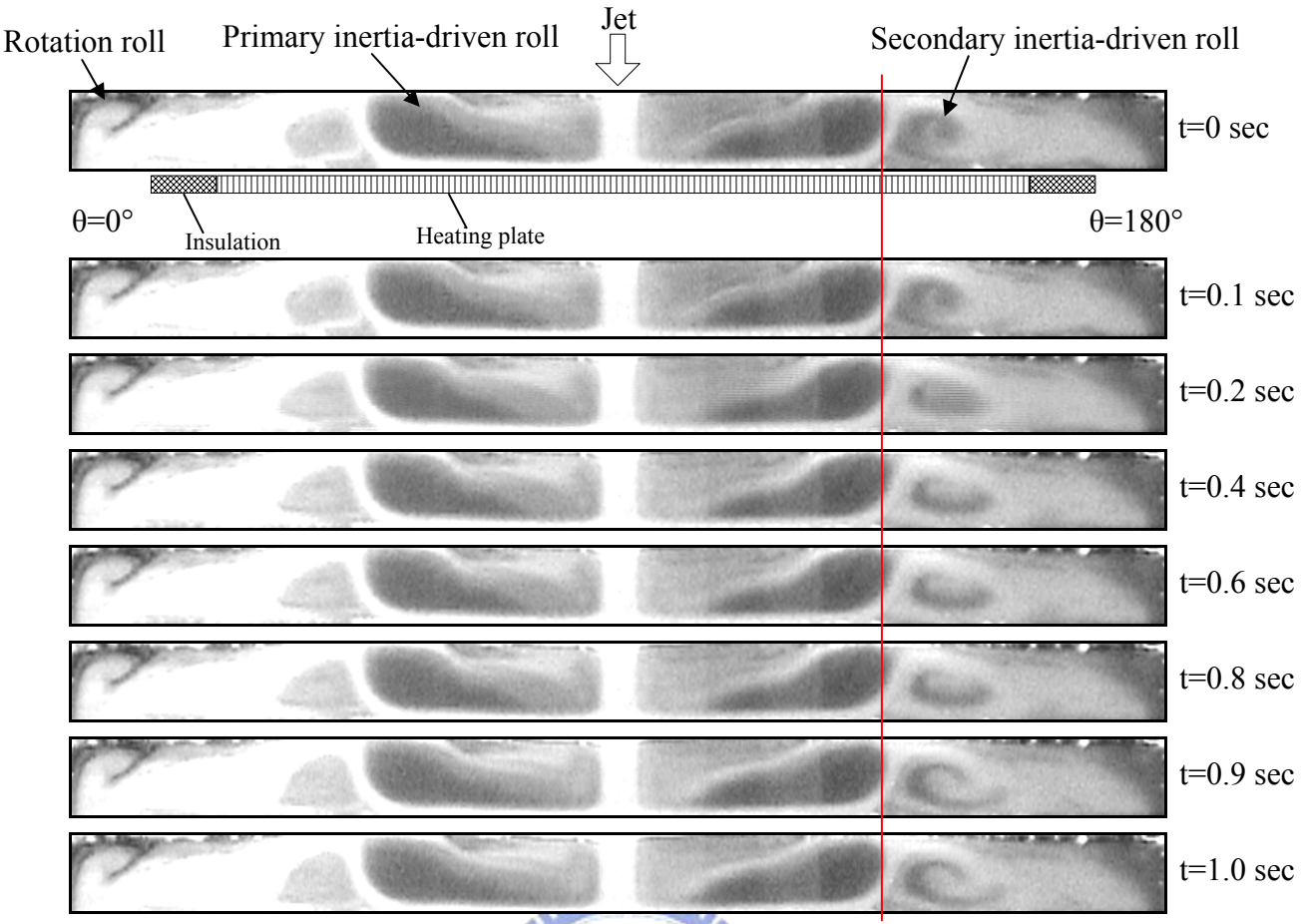


(a) Time dependent flow (t_p=1.4 sec), $Re_\Omega = 0$ ($\Omega = 0$ rpm)

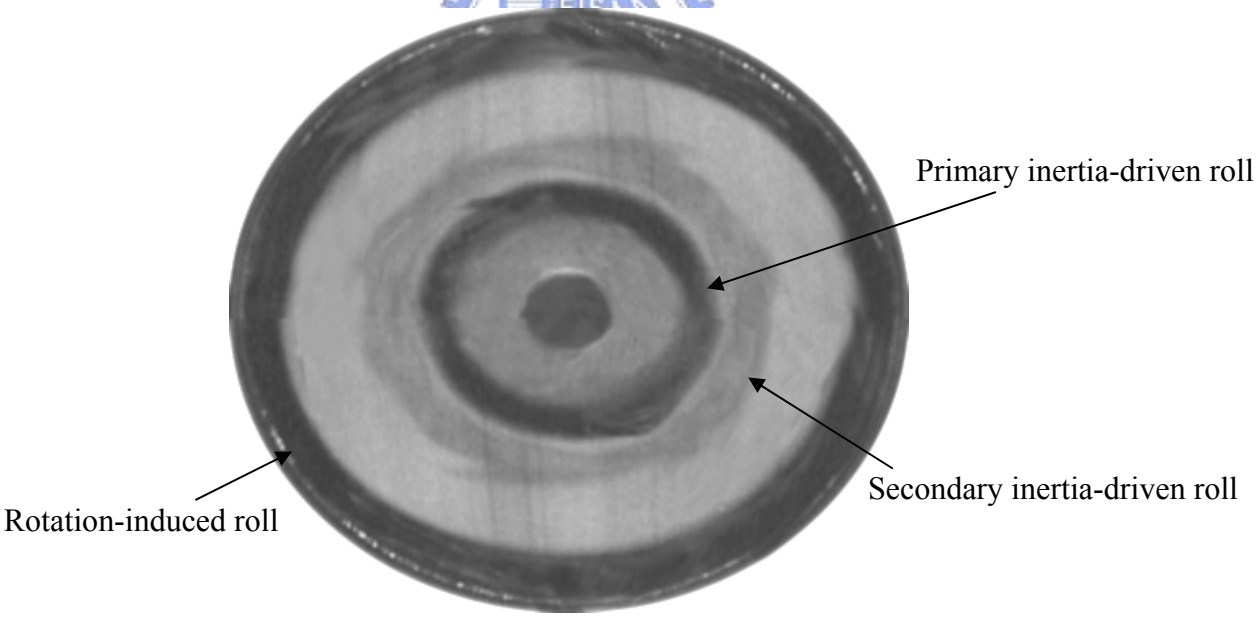


(b)

Fig. 4.39 Time-periodic vortex flow for H=20.0 mm, $Re_\Omega = 0$ ($\Omega = 0$ rpm), and Ra=0 ($\Delta T = 0$ ℃) at Re_j=839 (Q_j=6.2 slpm) illustrated by (a) side view flow photos taken at the vertical plane $\theta = 0^\circ$ & 180° at selected time instants in a typical periodic cycle and (b) top view flow photo taken at middle horizontal plane halfway between the injection pipe exit and heated disk at certain time instant in the cycle (t_p= 1.4 sec).



(a) Time dependent flow (t_p=1.0 sec), $Re_\Omega = 389$ ($\Omega = 5$ rpm)



(b)

Fig. 4.40 Time-periodic vortex flow for H=20.0 mm, $Re_\Omega = 389$ ($\Omega = 5$ rpm), and Ra=0 ($\Delta T = 0$ ℃) at Re_j= 839 (Q_j=6.2 slpm) illustrated by (a) side view flow photos taken at the vertical plane $\theta = 0^\circ$ & 180° at selected time instants in a typical periodic cycle and (b) top view flow photo taken at middle horizontal plane halfway between the injection pipe exit and heated disk at certain time instant in the cycle (t_p= 1.0 sec).

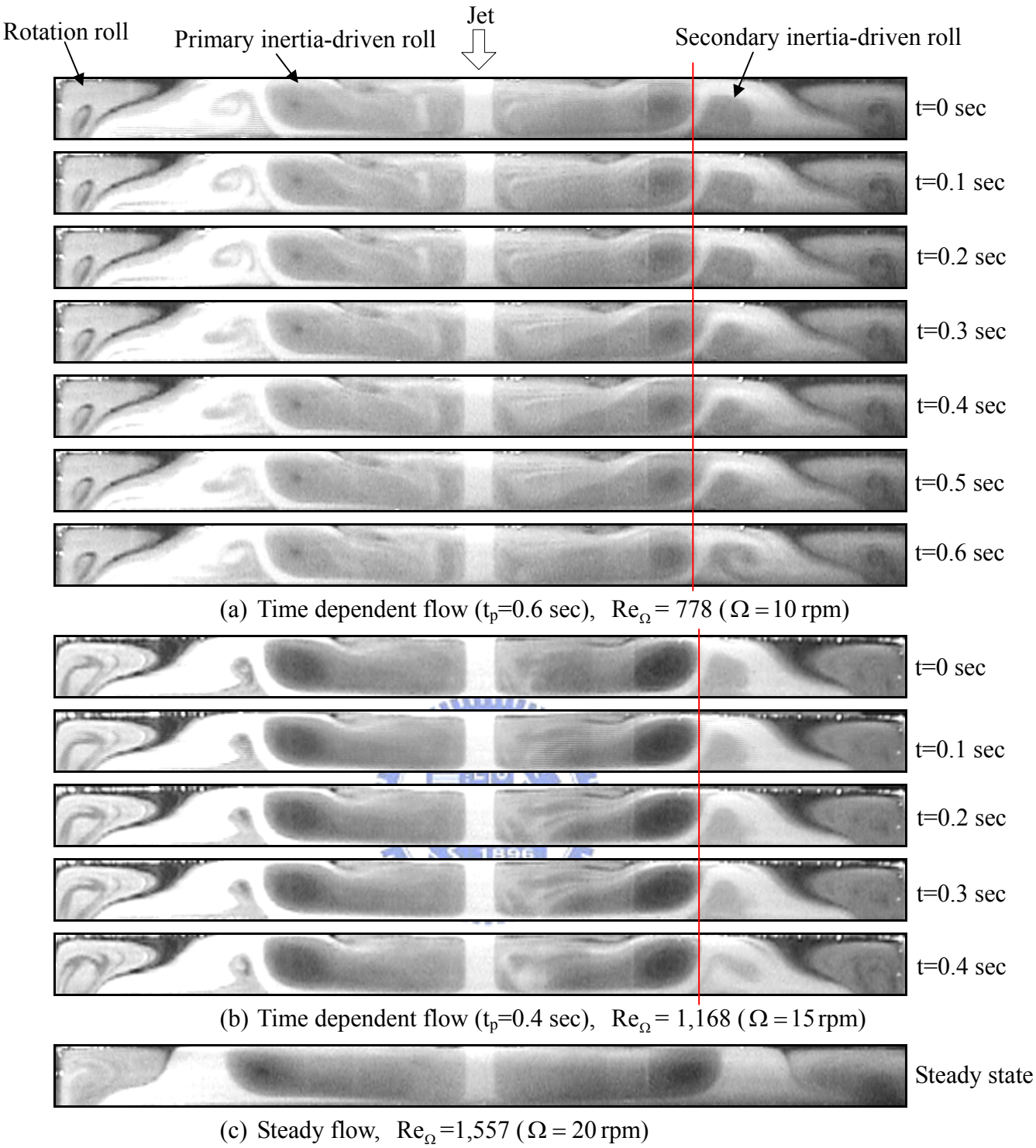
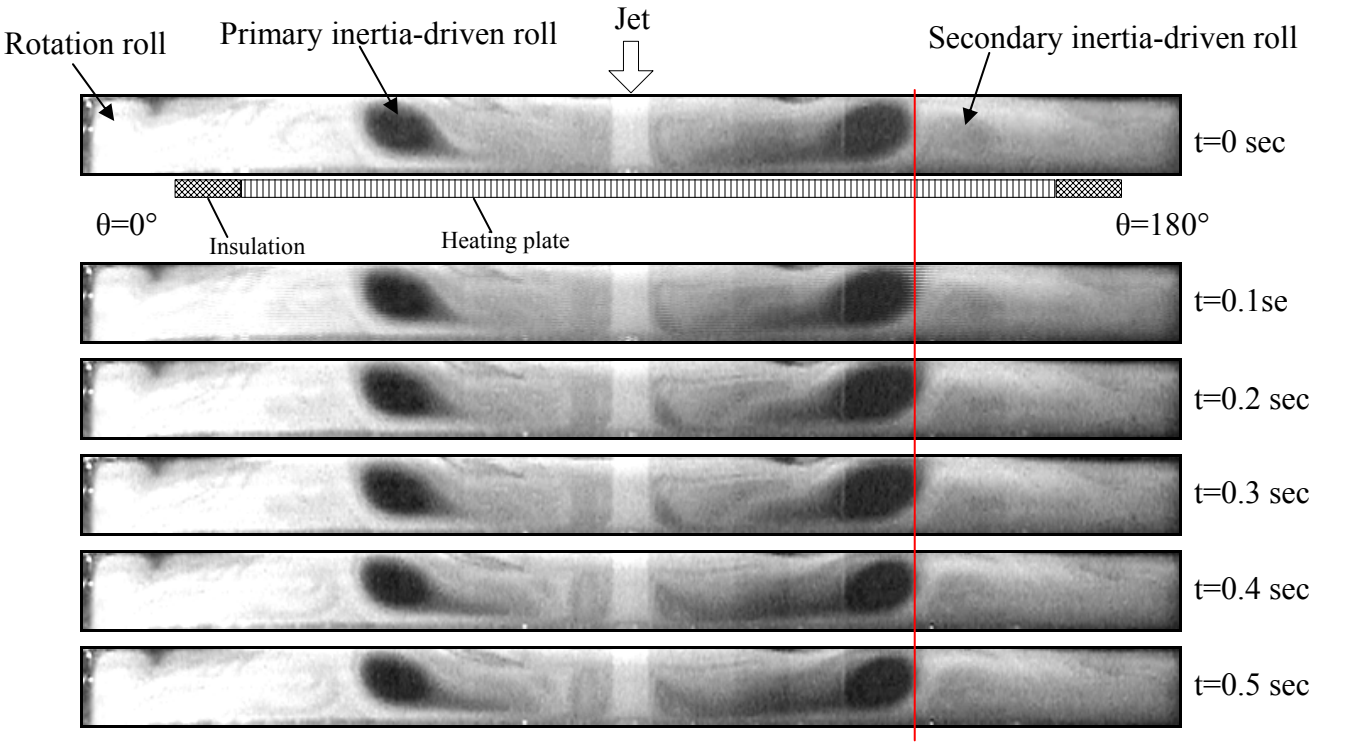
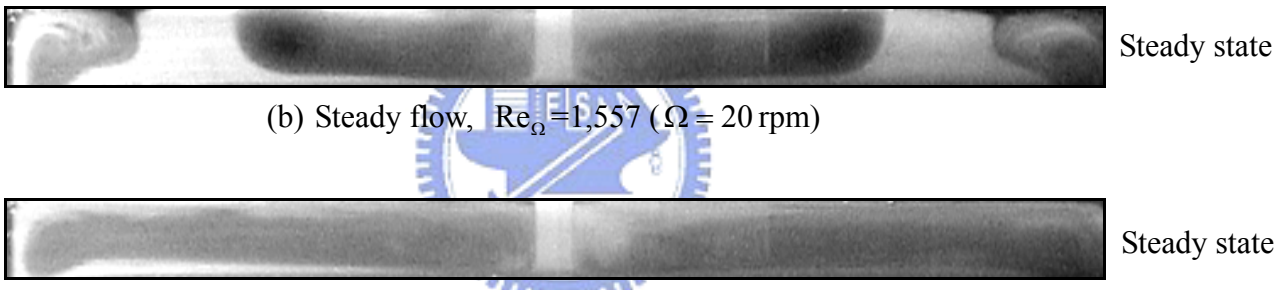


Fig. 4.41 Vortex flows for H=20.0 mm, and Ra=0 ($\Delta T = 0\,^{\circ}C$) at Re_j=839 (Q_j=6.2 slpm) illustrated by side view flow photos taken at the vertical plane $\theta = 0^{\circ}$ & 180° at selected time instants in a typical periodic cycle for various rotational Reynolds number: (a) Re_Ω = 778 (t_p=0.6 sec), (b) Re_Ω = 1,168 (t_p=0.4 sec), and (c) Re_Ω =1,557 (steady state).



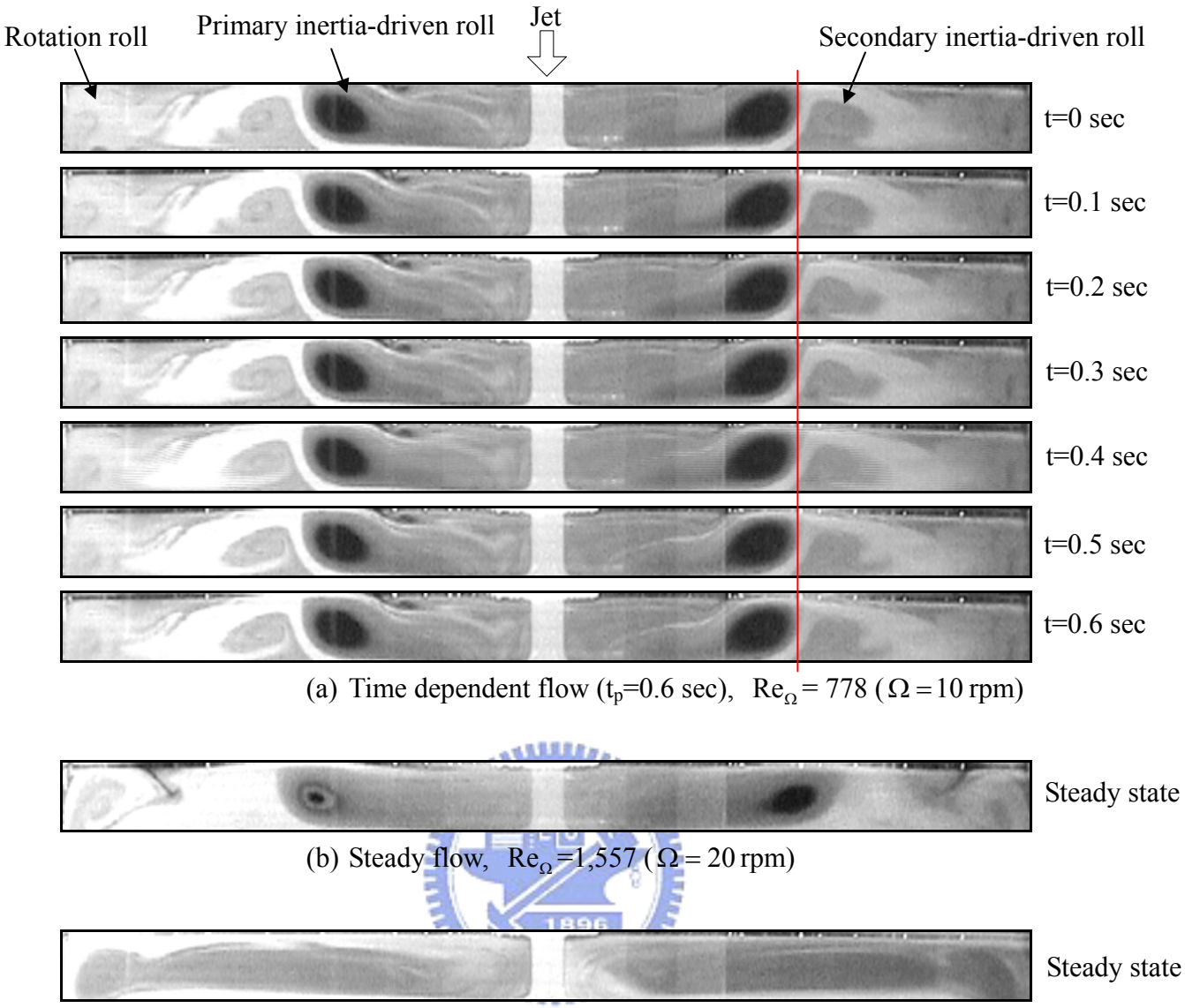
(a) Time dependent flow (t_p=0.5 sec), Re_Ω = 778 (Ω = 10 rpm)



(b) Steady flow, Re_Ω =1,557 (Ω = 20 rpm)

(c) Steady flow, Re_Ω =2,335 (Ω =30 rpm)

Fig. 4.42 Steady and time-periodic vortex flows for H=20.0 mm and Ra=3,760 ($\Delta T = 5.0\,^{\circ}C$) at Re_j=839 (Q_j=6.2 slpm) for (a) Re_Ω =778 (t_p=0.5 sec), (b) Re_Ω =1,557 (steady state), and (c) Re_Ω =2,335 (steady state).

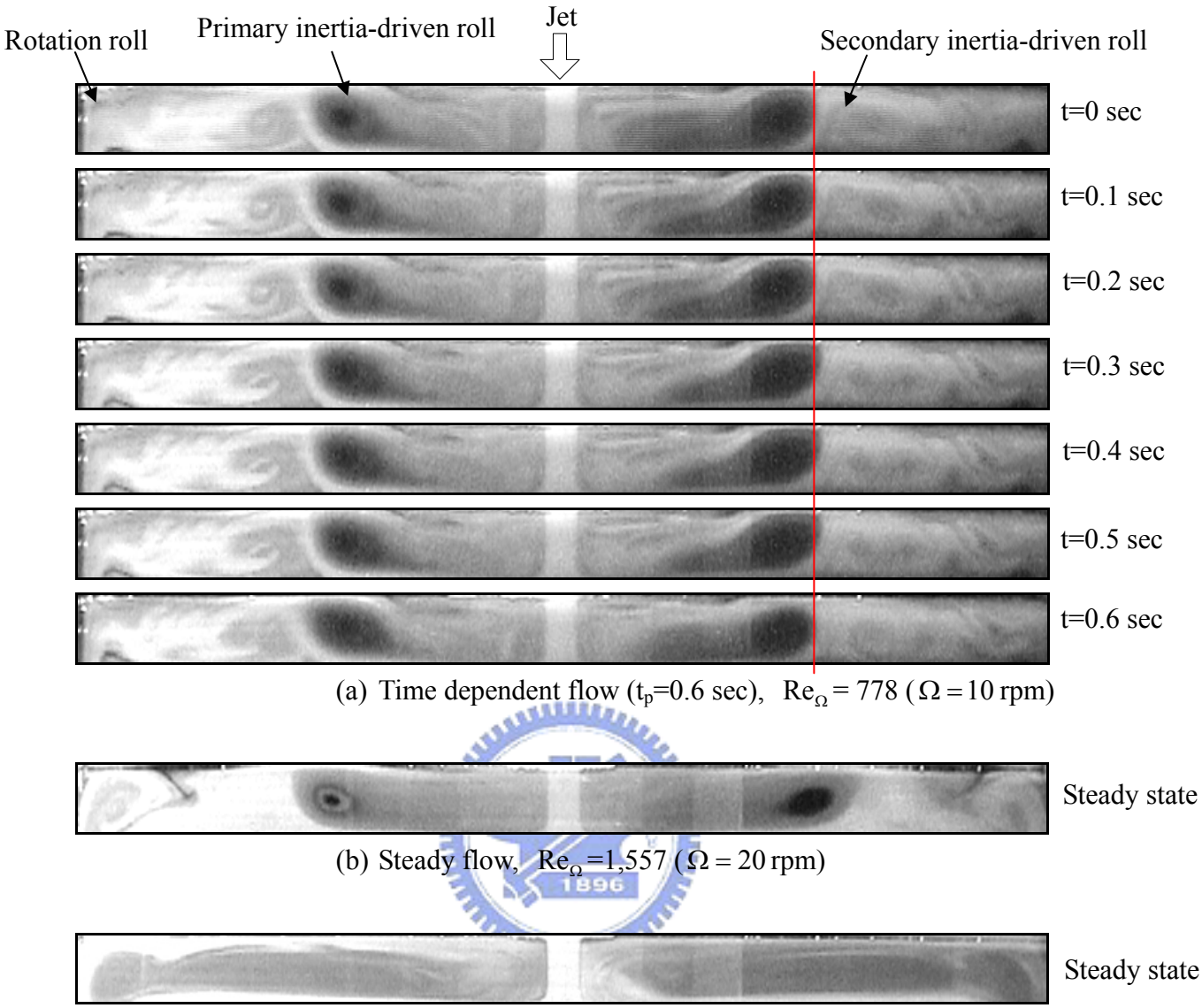


(a) Time dependent flow (t_p=0.6 sec), Re_Ω = 778 (Ω = 10 rpm)

(b) Steady flow, Re_Ω =1,557 (Ω = 20 rpm)

(c) Steady flow, Re_Ω =2,335 (Ω =30 rpm)

Fig. 4.43 Steady and time-periodic vortex flows for H=20.0 mm and Ra=7,520 (ΔT=10.0 ℃) at Re_j=893 (Q_j=6.6 slpm) for (a) Re_Ω =778 (t_p=0.6 sec), (b) Re_Ω =1,557 (steady state), and (c) Re_Ω =2,335 (steady state).



(a) Time dependent flow (t_p=0.6 sec), Re_Ω = 778 (Ω = 10 rpm)

(b) Steady flow, Re_Ω =1,557 (Ω = 20 rpm)

(c) Steady flow, Re_Ω =2,335 (Ω =30 rpm)

Fig. 4.44 Steady and time-periodic vortex flows for H=20.0 mm and Ra=11,270 (ΔT=15.0 ℃) at Re_j=933 (Q_j=6.9 slpm) for (a) Re_Ω =778 (t_p=0.6 sec), (b) Re_Ω =1,557 (steady state), and (c) Re_Ω =2,335 (steady state).