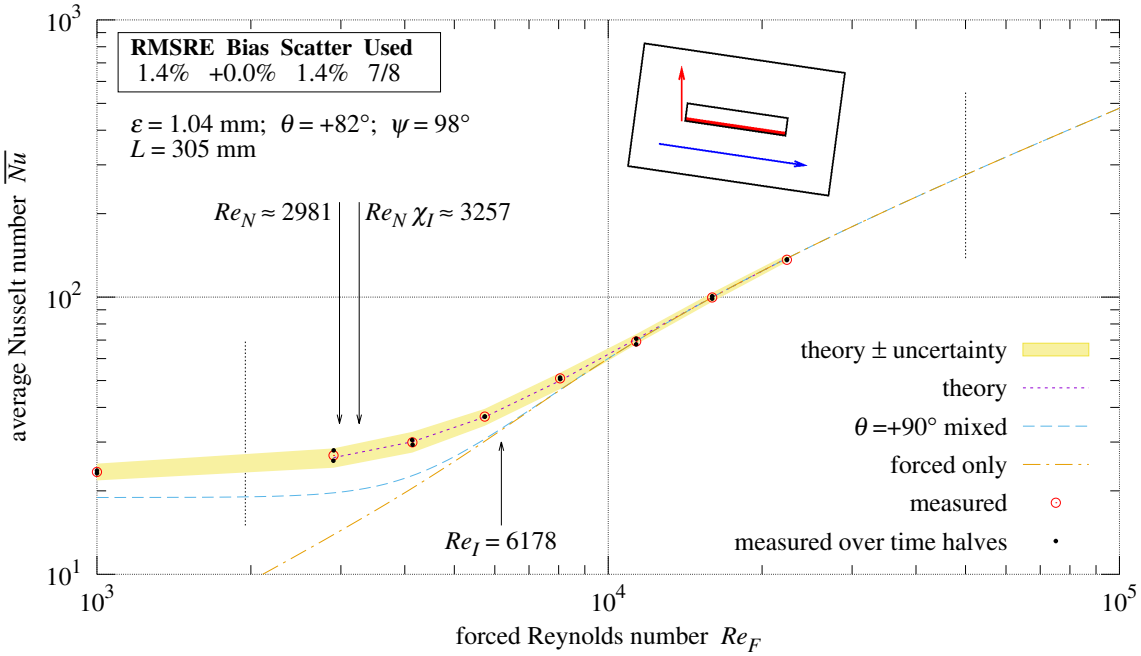
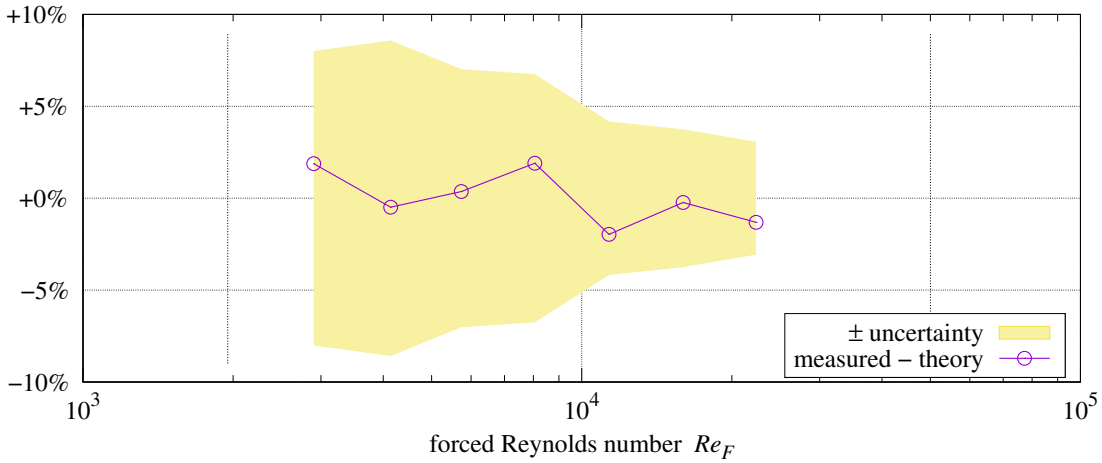
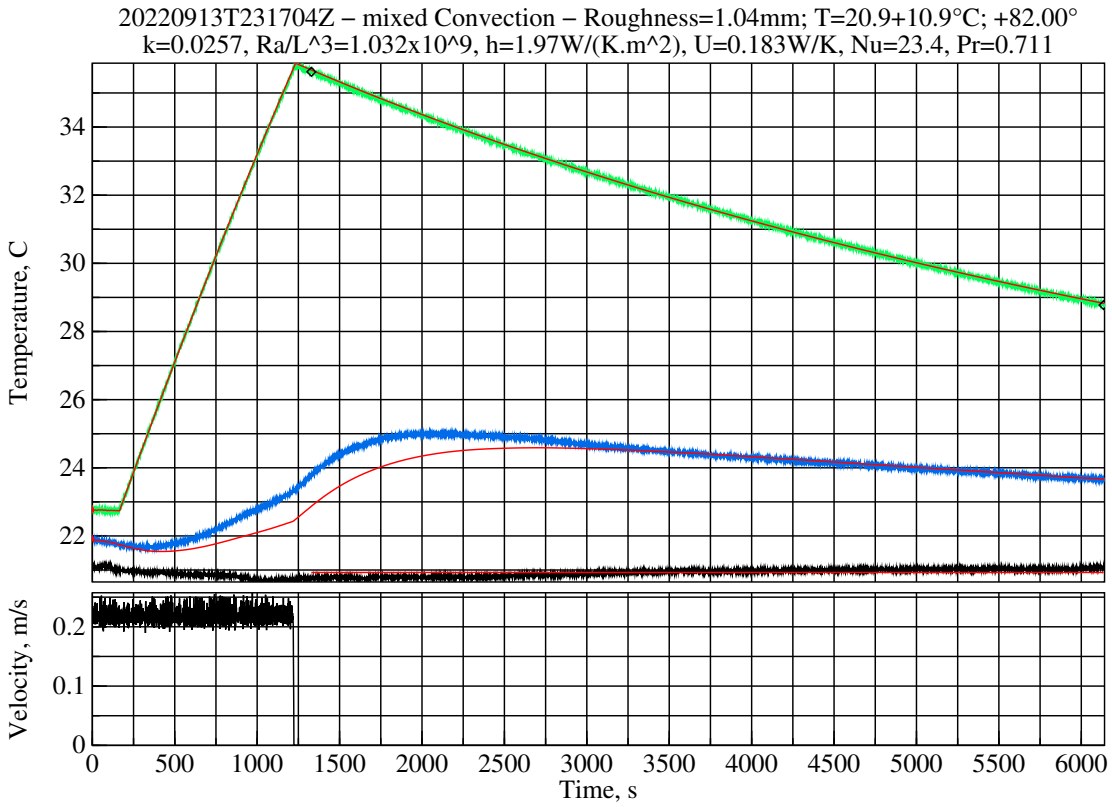


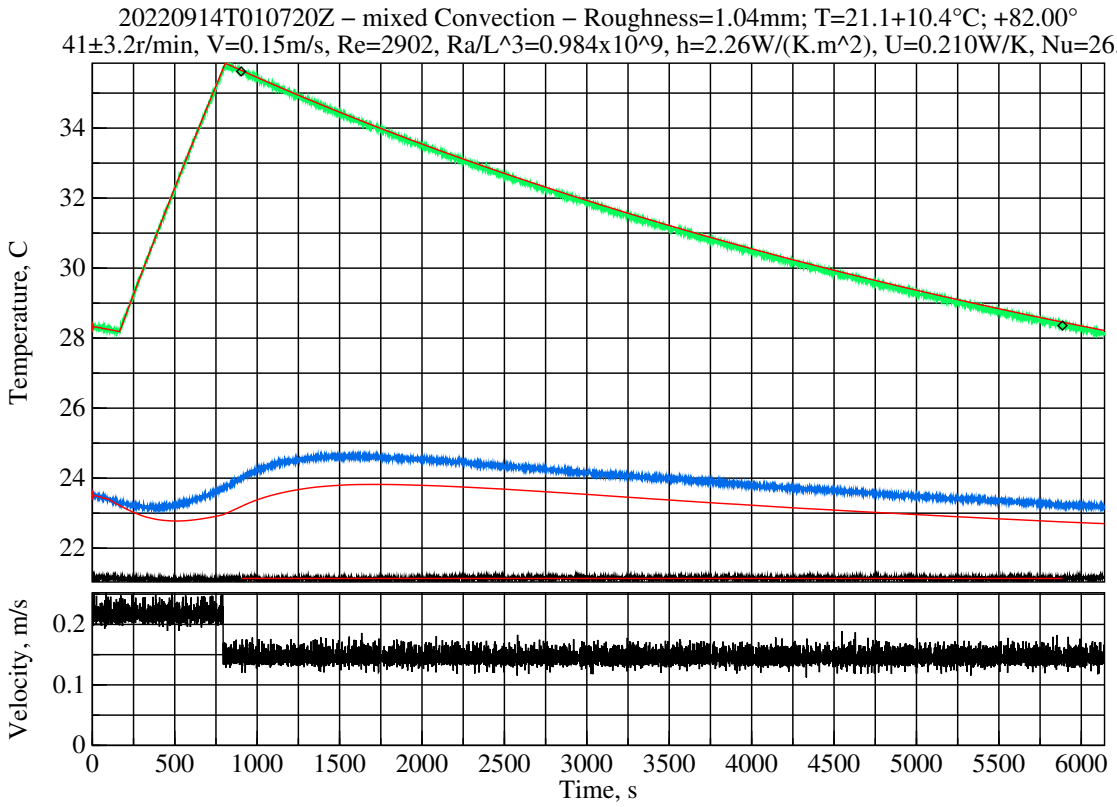
Inclined plate in opposing flow





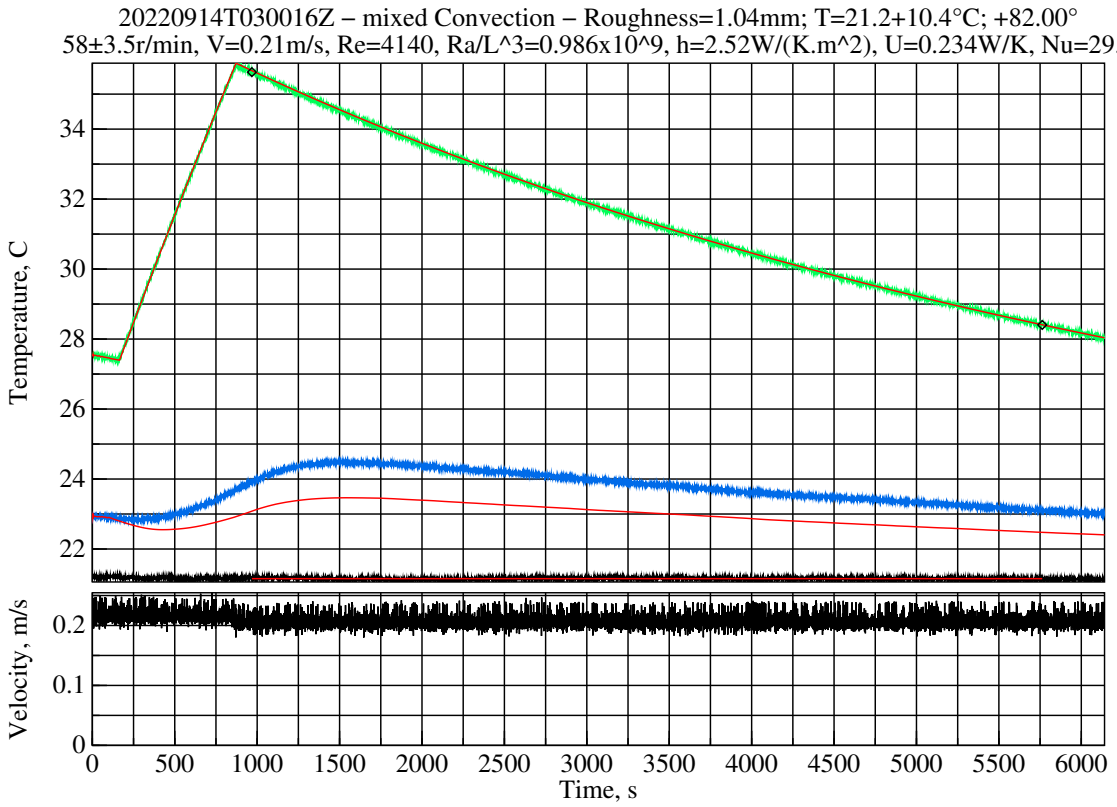
Estimated measurement uncertainties of natural convection at $\theta = 82.0$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
T	300K	+0.418%/K	0.50K	0.21%	LM35C temperature sensor
ΔT	10.9K	+32.3%/K	0.10K	3.23%	LM35C differential
T_{bb}	294K	+0.594%/K	0.50K	0.30%	radiative temperature
P	99.8kPa	+0.0009%/Pa	1.5kPa	1.28%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.072%/(J/K)	42J/K	3.07%	plate thermal capacity
L_c	0.305m	+940%/m	500um	0.47%	characteristic length
D_{PIR}	25.4mm	−753%/m	1.0mm	0.75%	insulation thickness
D_g	1.00mm	−764%/m	500um	0.38%	air gap
L_m	3.57mm	+2126%/m	500um	1.06%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.728\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.81%	PIR thermal conductivity
ϵ_{XPS}	0.515	+66.4%	0.010	0.66%	XPS emissivity
ϵ_{tp}	0.890	+79.9%	0.015	1.20%	tape emissivity
Ω_{tp}	0.540	+54.1%	0.020	1.08%	tape coverage
ϵ_{rs}	0.040	+283%	0.010	2.83%	test-surface emissivity
ϵ_b	0.190	+18.0%	0.020	0.36%	back emissivity
ϵ_{wt}	0.900	+133%	0.025	3.34%	wind-tunnel emissivity
θ	82.0°	−2.50%/°	0.50°	1.25%	plate angle
				6.95%	combined bias uncertainty



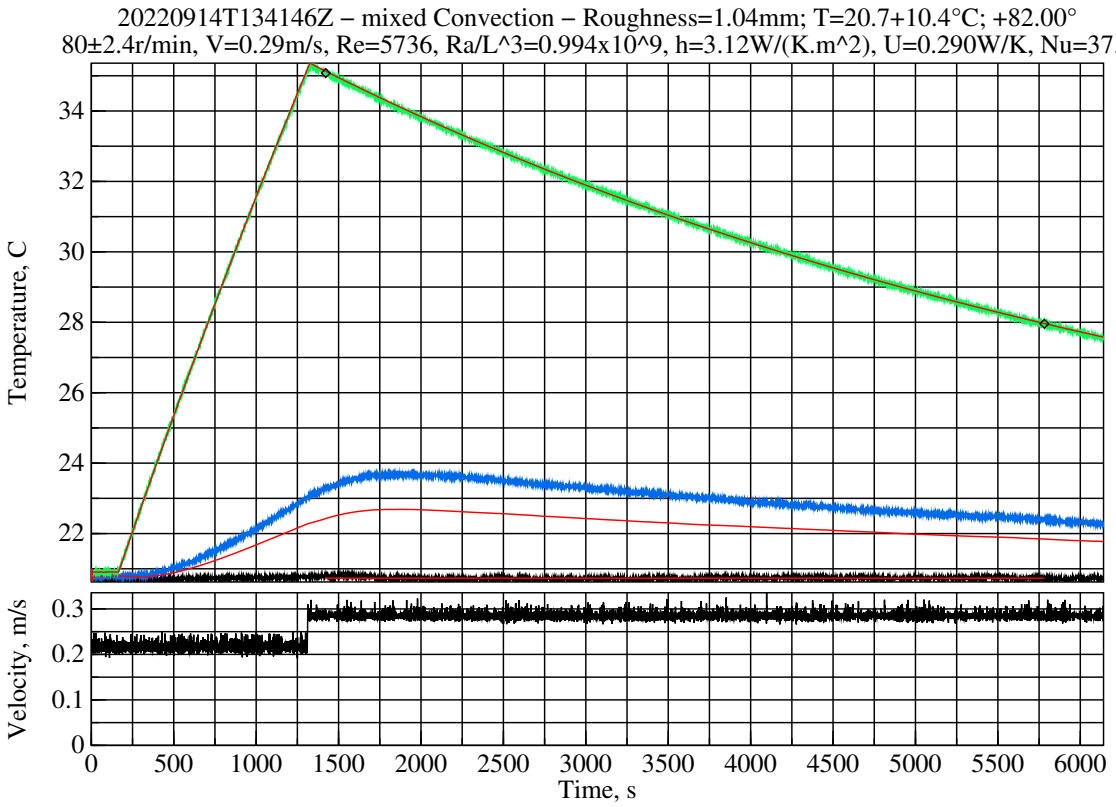
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 2902$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.4K	+30.7%/K	0.10K	3.07%	LM35C differential
T_{bb}	294K	+0.509%/K	0.50K	0.25%	radiative temperature
P	99.8kPa	+0.0010%/Pa	1.5kPa	1.44%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.067%/(J/K)	42J/K	2.85%	plate thermal capacity
η	0.402	+78.9%	0.004	0.32%	anemometer calibration
L_c	0.305m	+832%/m	500um	0.42%	characteristic length
ς	2.00mm	+2792%/m	100um	0.28%	post height
D_{PIR}	25.4mm	−818%/m	1.0mm	0.82%	insulation thickness
D_g	1.00mm	−829%/m	500um	0.41%	air gap
L_m	3.57mm	+1992%/m	500um	1.00%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.804\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.89%	PIR thermal conductivity
k_{XPS}	$28.5\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.141\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.4\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.20%	XPS thermal conductivity
ϵ_{XPS}	0.515	+57.8%	0.010	0.58%	XPS emissivity
ϵ_{tp}	0.890	+69.6%	0.015	1.04%	tape emissivity
Ω_{tp}	0.540	+47.1%	0.020	0.94%	tape coverage
ϵ_{rs}	0.040	+247%	0.010	2.47%	test-surface emissivity
ϵ_{wt}	0.900	+114%	0.025	2.86%	wind-tunnel emissivity
θ	82.0°	−1.70%/°	0.50°	0.85%	plate angle
				6.33%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	40.9r/min	+0.776%/(r/min)	3.2r/min	2.45%	fan rotation rate
				8.01%	RSS combined uncertainty



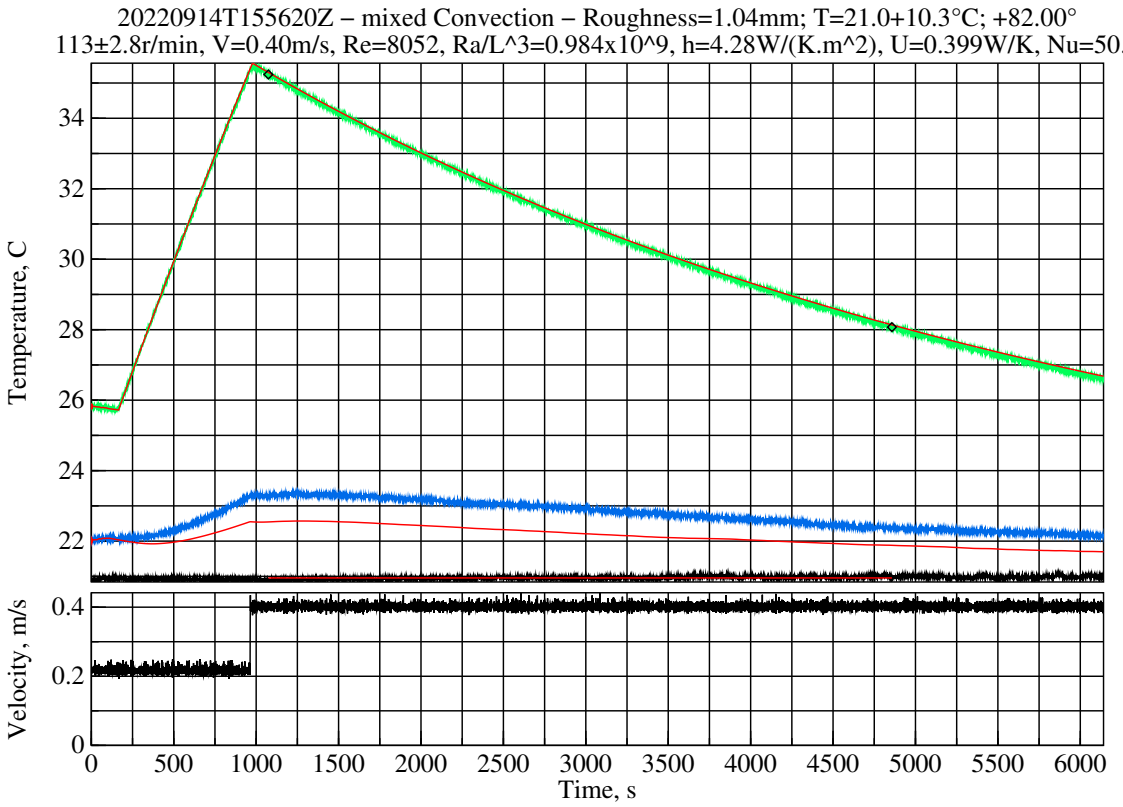
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 4139$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.4K	+28.0%/K	0.10K	2.80%	LM35C differential
T_{bb}	294K	+0.444%/K	0.50K	0.22%	radiative temperature
P	99.8kPa	+0.0010%/Pa	1.5kPa	1.57%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.062%/(J/K)	42J/K	2.63%	plate thermal capacity
η	0.402	+131%	0.004	0.53%	anemometer calibration
L_c	0.305m	+778%/m	500um	0.39%	characteristic length
D_{PIR}	25.4mm	−781%/m	1.0mm	0.78%	insulation thickness
D_g	1.00mm	−792%/m	500um	0.40%	air gap
L_m	3.57mm	+1814%/m	500um	0.91%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.771\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.86%	PIR thermal conductivity
k_{XPS}	$28.5\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.143\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.4\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.20%	XPS thermal conductivity
ϵ_{XPS}	0.515	+50.6%	0.010	0.51%	XPS emissivity
ϵ_{tp}	0.890	+61.0%	0.015	0.91%	tape emissivity
Ω_{tp}	0.540	+41.3%	0.020	0.83%	tape coverage
ϵ_{rs}	0.040	+217%	0.010	2.17%	test-surface emissivity
ϵ_{wt}	0.900	+99.7%	0.025	2.49%	wind-tunnel emissivity
θ	82.0°	−1.21%/°	0.50°	0.61%	plate angle
				5.76%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	58.3r/min	+0.905%/(r/min)	3.5r/min	3.18%	fan rotation rate
				8.59%	RSS combined uncertainty



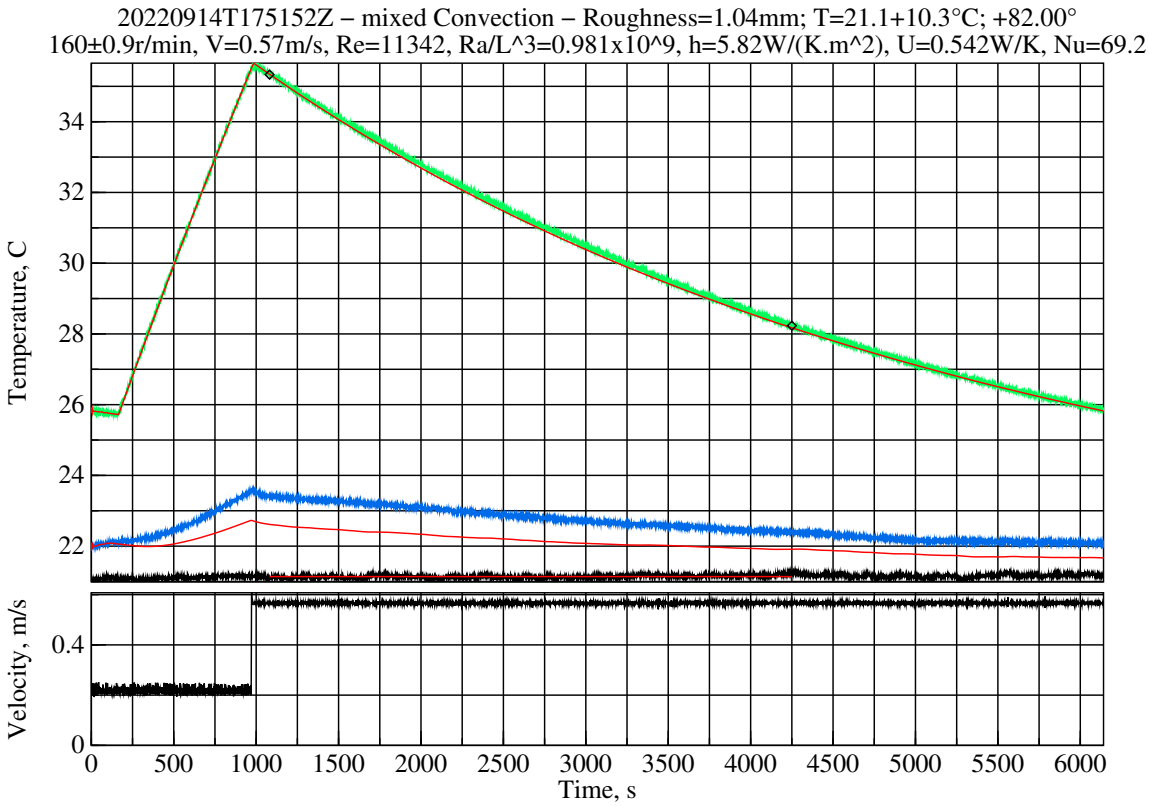
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 5735$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.4K	+24.6%/K	0.10K	2.46%	LM35C differential
P	100kPa	+0.0012%/Pa	1.5kPa	1.76%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.055%/(J/K)	42J/K	2.34%	plate thermal capacity
η	0.402	+199%	0.004	0.80%	anemometer calibration
L_c	0.305m	+734%/m	500um	0.37%	characteristic length
L_T	8.34mm	+3323%/m	100um	0.33%	post length
ς	2.00mm	−7730%/m	100um	0.77%	post height
D_{PIR}	25.4mm	−681%/m	1.0mm	0.68%	insulation thickness
D_g	1.00mm	−690%/m	500um	0.35%	air gap
L_m	3.57mm	+1545%/m	500um	0.77%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.675\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.75%	PIR thermal conductivity
ϵ_{XPS}	0.515	+41.0%	0.010	0.41%	XPS emissivity
ϵ_{tp}	0.890	+49.4%	0.015	0.74%	tape emissivity
Ω_{tp}	0.540	+33.4%	0.020	0.67%	tape coverage
ϵ_{rs}	0.040	+176%	0.010	1.76%	test-surface emissivity
ϵ_{wt}	0.900	+80.5%	0.025	2.01%	wind-tunnel emissivity
θ	82.0°	−0.698%/°	0.50°	0.35%	plate angle
				5.14%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	80.4r/min	+0.994%/(r/min)	2.4r/min	2.39%	fan rotation rate
				7.02%	RSS combined uncertainty



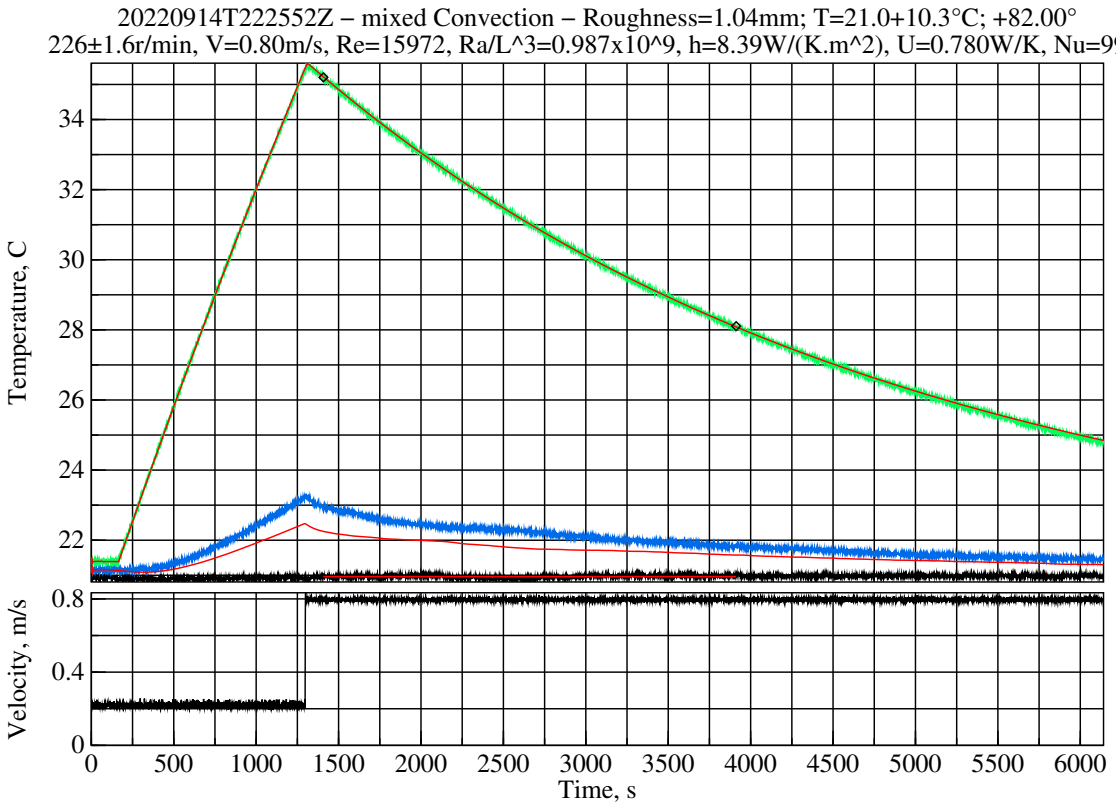
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 8052$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+20.8%/K	0.10K	2.08%	LM35C differential
P	100kPa	+0.0012%/Pa	1.5kPa	1.86%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.047%/(J/K)	42J/K	2.00%	plate thermal capacity
η	0.402	+249%	0.004	1.00%	anemometer calibration
L_c	0.305m	+641%/m	500um	0.32%	characteristic length
L_T	8.34mm	+6169%/m	100um	0.62%	post length
ς	2.00mm	−15713%/m	100um	1.57%	post height
D_{PIR}	25.4mm	−533%/m	1.0mm	0.53%	insulation thickness
D_g	1.00mm	−541%/m	500um	0.27%	air gap
L_m	3.57mm	+1220%/m	500um	0.61%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.531\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.59%	PIR thermal conductivity
ϵ_{XPS}	0.515	+30.3%	0.010	0.30%	XPS emissivity
ϵ_{tp}	0.890	+36.5%	0.015	0.55%	tape emissivity
Ω_{tp}	0.540	+24.7%	0.020	0.49%	tape coverage
ϵ_{rs}	0.040	+130%	0.010	1.30%	test-surface emissivity
ϵ_{wt}	0.900	+59.4%	0.025	1.48%	wind-tunnel emissivity
				4.63%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	113r/min	+0.884%/(r/min)	2.8r/min	2.46%	fan rotation rate
				6.75%	RSS combined uncertainty



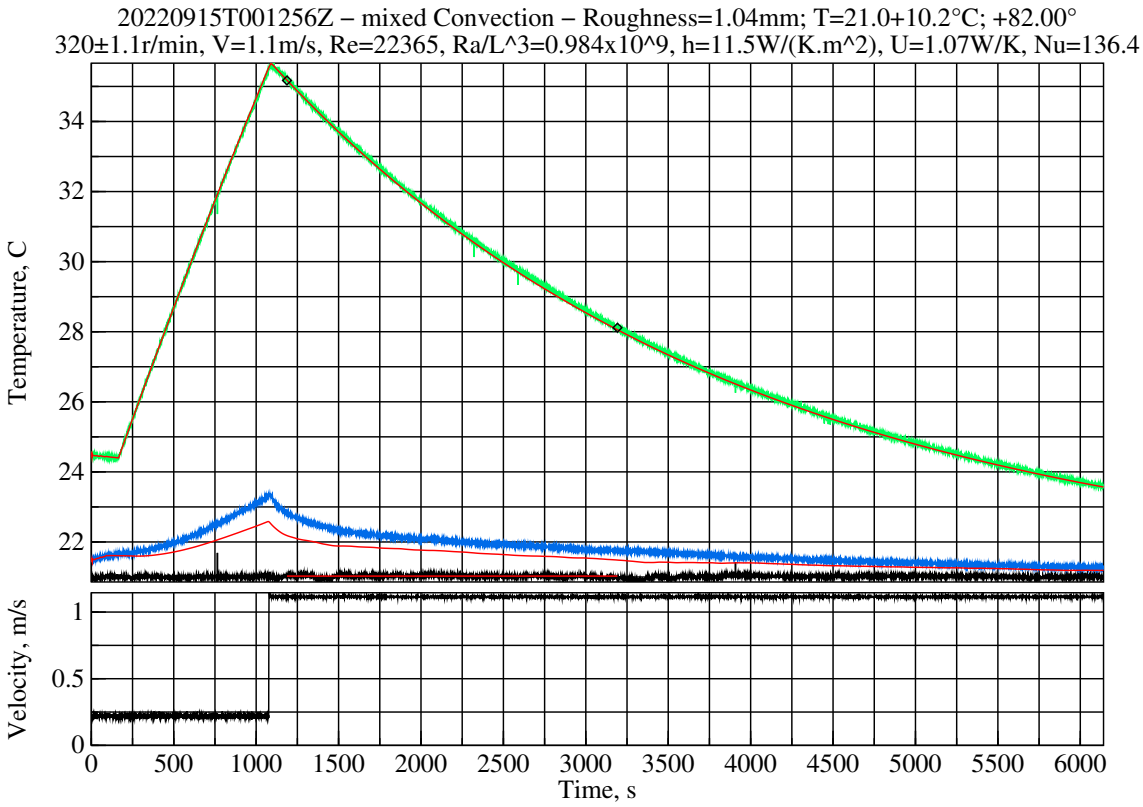
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 11342$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+17.6%/K	0.10K	1.76%	LM35C differential
P	100kPa	+0.0012%/Pa	1.5kPa	1.74%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.040%/(J/K)	42J/K	1.71%	plate thermal capacity
η	0.402	+252%	0.004	1.01%	anemometer calibration
L_c	0.305m	+483%/m	500um	0.24%	characteristic length
L_T	8.34mm	+7880%/m	100um	0.79%	post length
ς	2.00mm	−15292%/m	100um	1.53%	post height
D_{PIR}	25.4mm	−397%/m	1.0mm	0.40%	insulation thickness
D_g	1.00mm	−402%/m	500um	0.20%	air gap
L_m	3.57mm	+943%/m	500um	0.47%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.397\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.44%	PIR thermal conductivity
ϵ_{XPS}	0.515	+21.4%	0.010	0.21%	XPS emissivity
ϵ_{tp}	0.890	+25.9%	0.015	0.39%	tape emissivity
Ω_{tp}	0.540	+17.5%	0.020	0.35%	tape coverage
ϵ_{rs}	0.040	+92.3%	0.010	0.92%	test-surface emissivity
ϵ_{wt}	0.900	+42.0%	0.025	1.05%	wind-tunnel emissivity
				4.01%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	160r/min	+0.633%/(r/min)	0.93r/min	0.59%	fan rotation rate
				4.18%	RSS combined uncertainty



Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 15972$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+15.2%/K	0.10K	1.52%	LM35C differential
P	100kPa	+0.0011%/Pa	1.5kPa	1.61%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.036%/(J/K)	42J/K	1.51%	plate thermal capacity
η	0.402	+248%	0.004	1.00%	anemometer calibration
L_T	8.34mm	+9107%/m	100um	0.91%	post length
ς	2.00mm	−12012%/m	100um	1.20%	post height
D_{PIR}	25.4mm	−292%/m	1.0mm	0.29%	insulation thickness
L_m	3.57mm	+742%/m	500um	0.37%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.294\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.33%	PIR thermal conductivity
ϵ_{tp}	0.890	+18.2%	0.015	0.27%	tape emissivity
Ω_{tp}	0.540	+12.3%	0.020	0.25%	tape coverage
ϵ_{rs}	0.040	+65.1%	0.010	0.65%	test-surface emissivity
ϵ_{wt}	0.900	+29.5%	0.025	0.74%	wind-tunnel emissivity
				3.47%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	226r/min	+0.441%/(r/min)	1.6r/min	0.72%	fan rotation rate
				3.75%	RSS combined uncertainty



Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 22365$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.2K	+13.8%/K	0.10K	1.38%	LM35C differential
P	100kPa	+0.0010%/Pa	1.5kPa	1.46%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.032%/(J/K)	42J/K	1.37%	plate thermal capacity
η	0.402	+222%	0.004	0.89%	anemometer calibration
L_T	8.34mm	+9231%/m	100um	0.92%	post length
ς	2.00mm	−7999%/m	100um	0.80%	post height
D_{PIR}	25.4mm	−218%/m	1.0mm	0.22%	insulation thickness
L_m	3.57mm	+613%/m	500um	0.31%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.220\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.24%	PIR thermal conductivity
ϵ_{rs}	0.040	+47.1%	0.010	0.47%	test-surface emissivity
ϵ_{wt}	0.900	+21.3%	0.025	0.53%	wind-tunnel emissivity
				3.01%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	320r/min	+0.279%/(r/min)	1.1r/min	0.30%	fan rotation rate
				3.07%	RSS combined uncertainty