TEST DATA ON COPPER MICRO-CHANNEL HEAT SINKS

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Objective

- ❑ Test results on low cost, high performance, micro-channel heat sinks.
  - Data for two micro-channel geometries (2 fin height).
  - 1-pass or 2-pass on water side.
- ❑ Laminar water flow

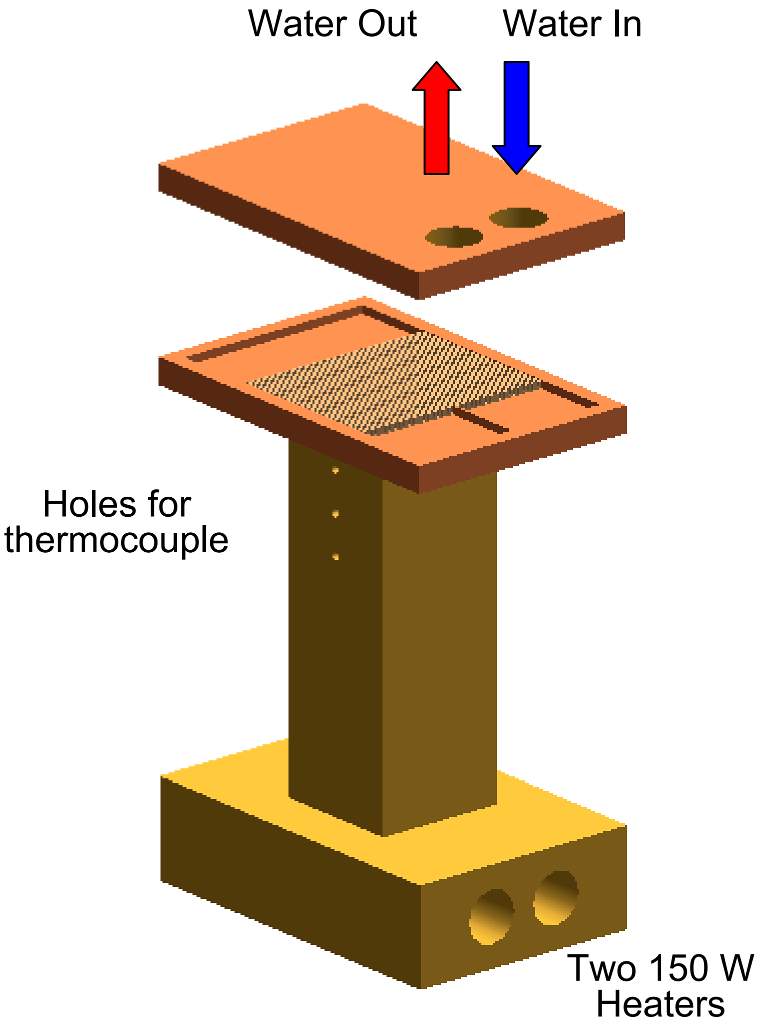
Test Setup

Dimensions:

- Heat sink: 20 mm long x 25 mm wide
- Source area: 16mm × 16mm.
- Spreader thickness: 2.5 mm

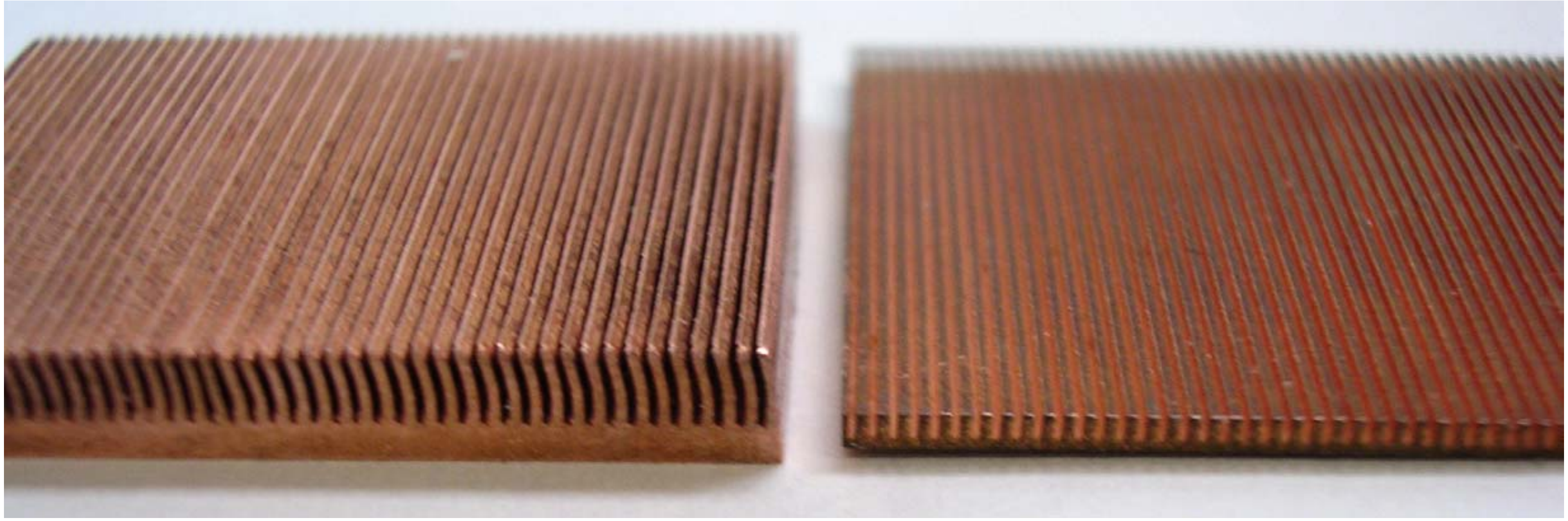
No interface resistance.

2-pass geometry illustrated.



Copper Micro-channels

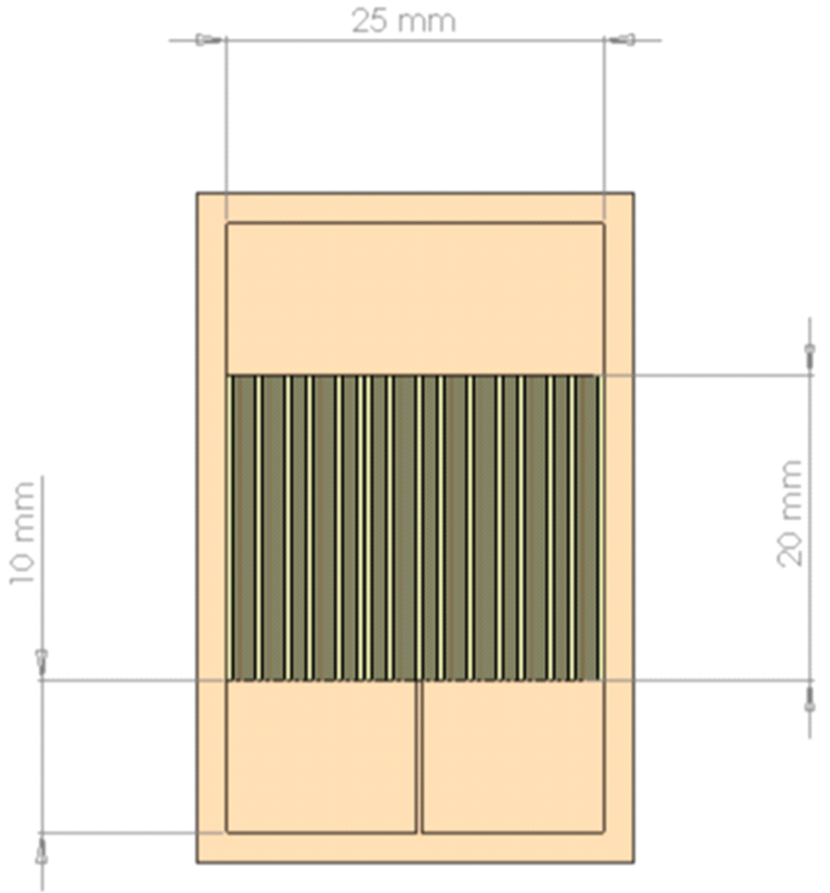
k = 340 W/m-K



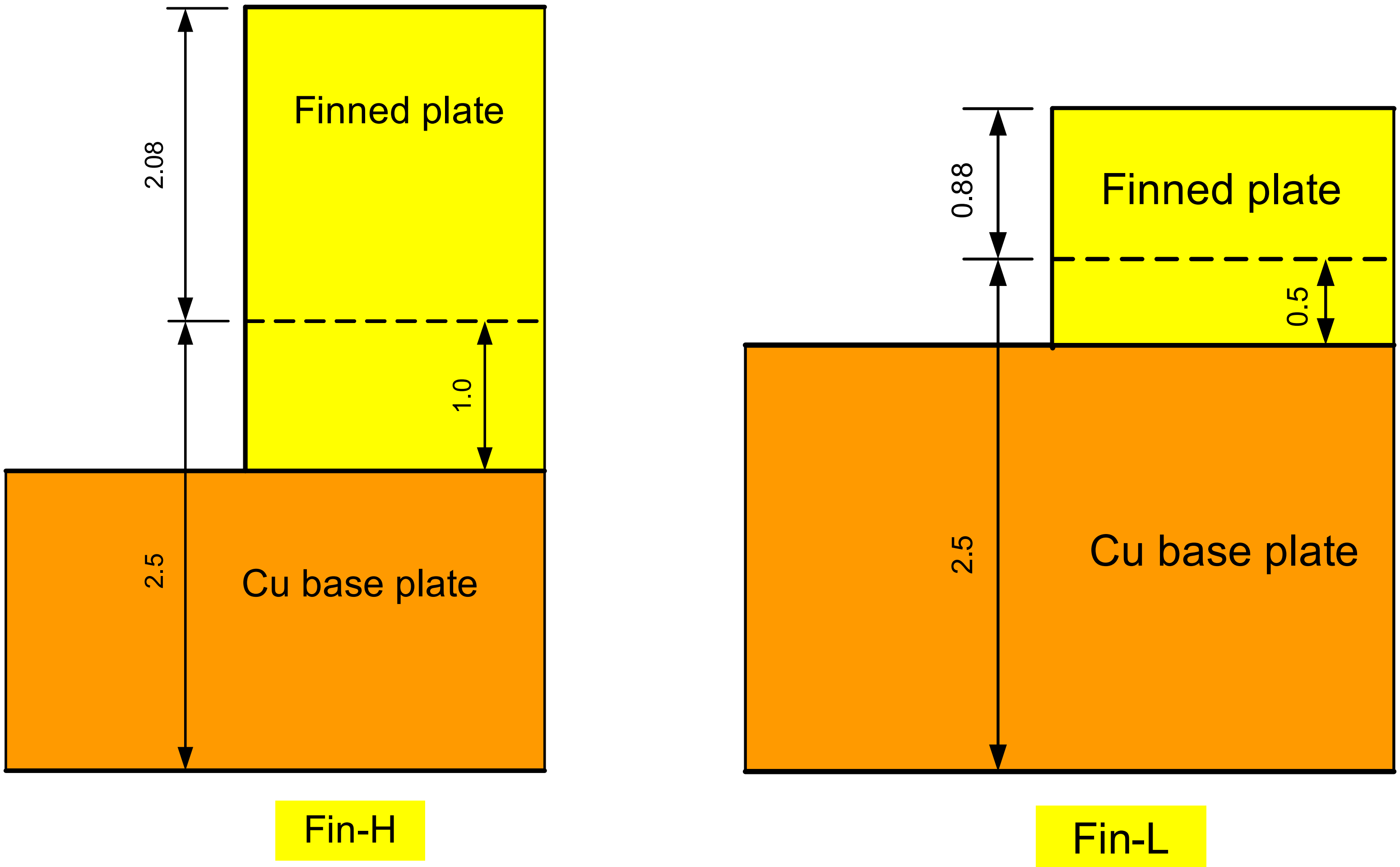
Fin-H Geometry
2.1 mm fin height
48 fins/in.
D_h = 0.491 mm, α = 0.133
Pred h = 7540 (q” = const)

Fin-L Geometry
0.88 mm fin height
50 fins/in.
D_h = 0.288 mm, α = 0.284
Pred h = 10,600 (q” = const)

Micro-Channel Sample

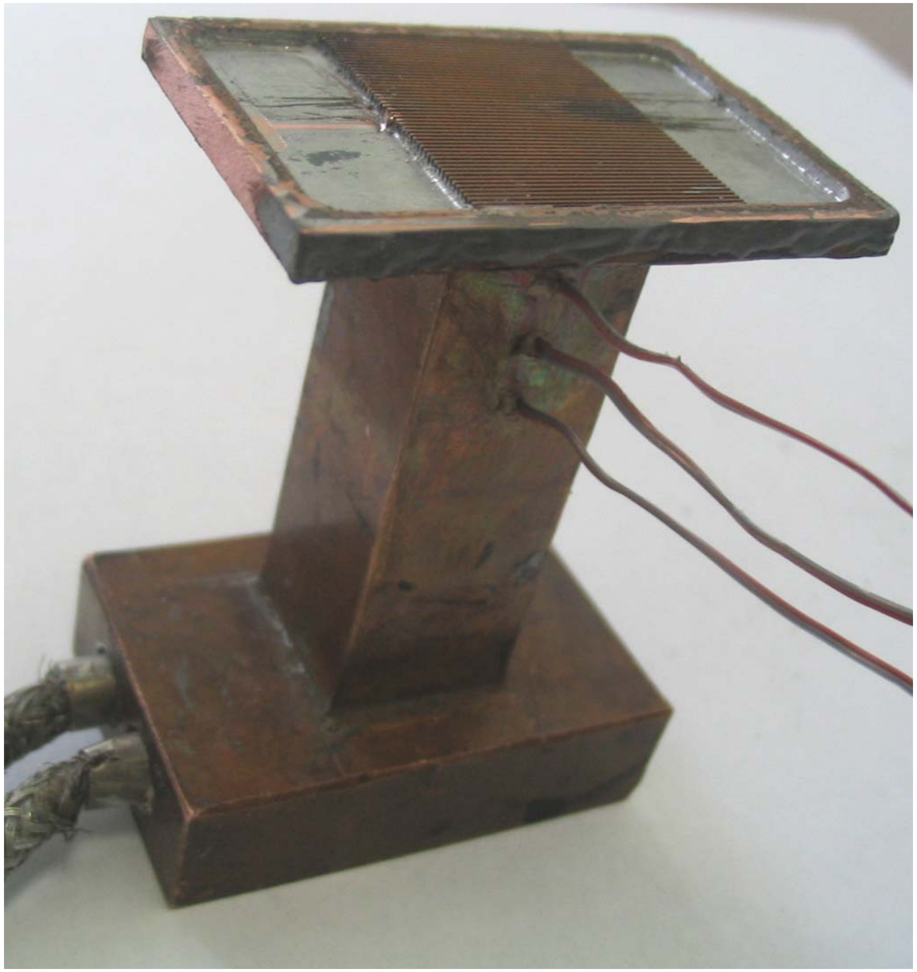


Test Geometry X-Section

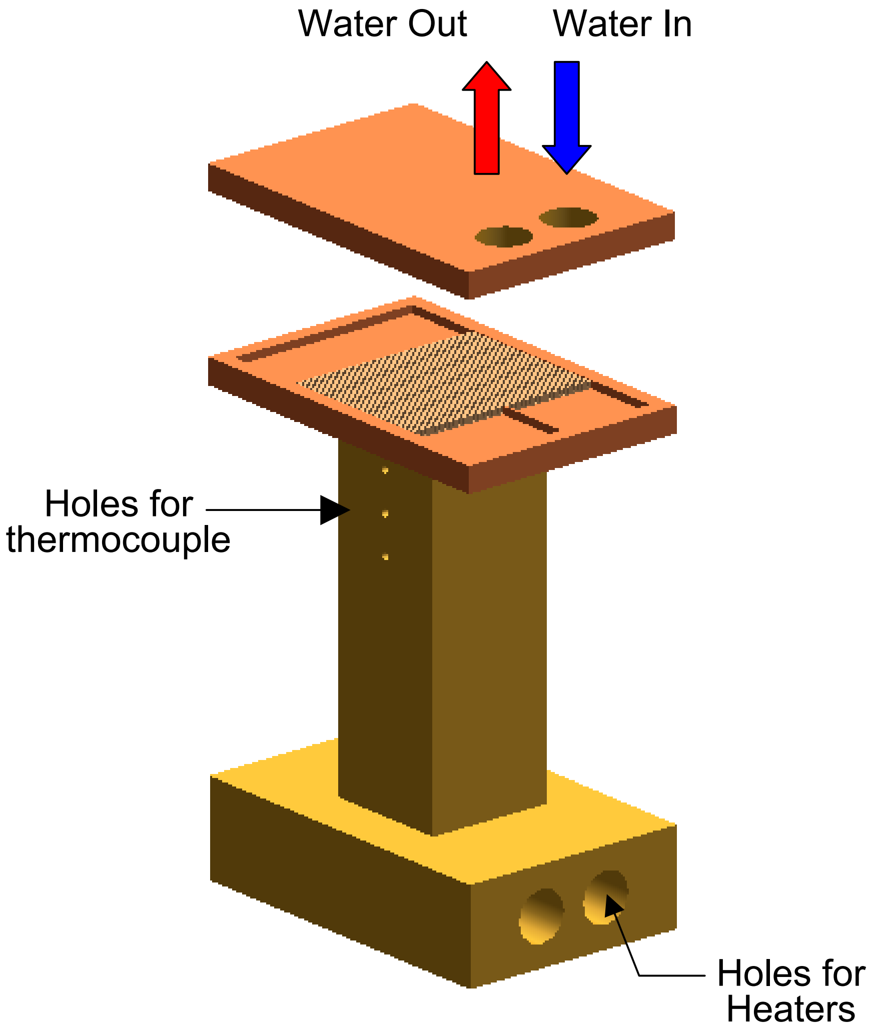


Test Configuration

- Width of micro-channel plate: 25 mm.
- Pass length: 20 mm.
- 2.5 mm spreader thickness under micro-channels.
- No interface resistance.
- 150 W electric heaters (2)



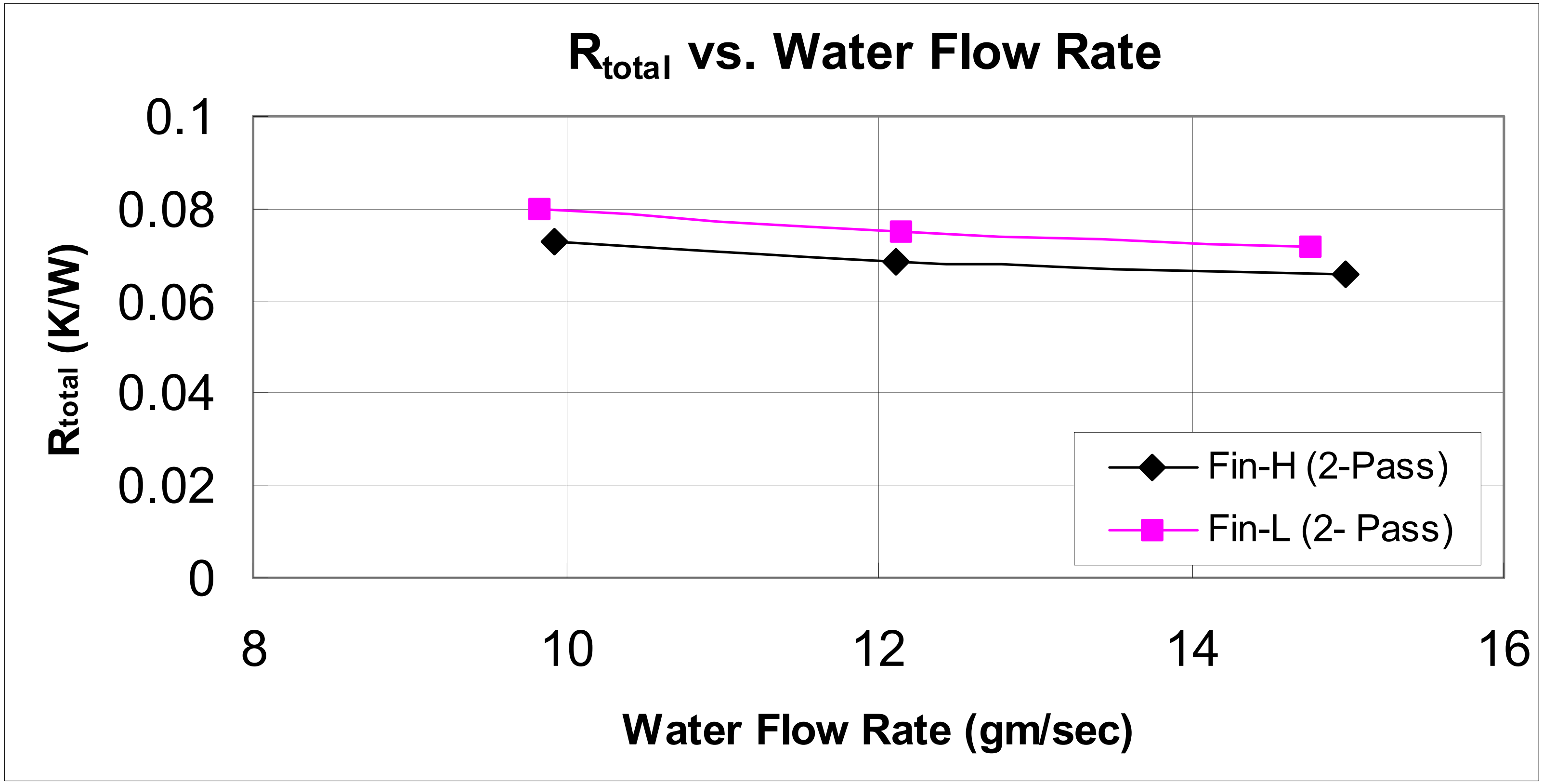
Test Setup (2-pass)



Test Measurements

- $\cong$ 20 C water inlet.
- Two 150 W cartridge heaters.
- Surf temp from extrapolated thermocouples.
- Heat input from q_{elec}.
- Heat balance (q_{elec}/q_{wat}) $\cong \pm$5% (-10% one test).
- Weigh method for water flow rate.
- Inverted manometer for water 👎p.

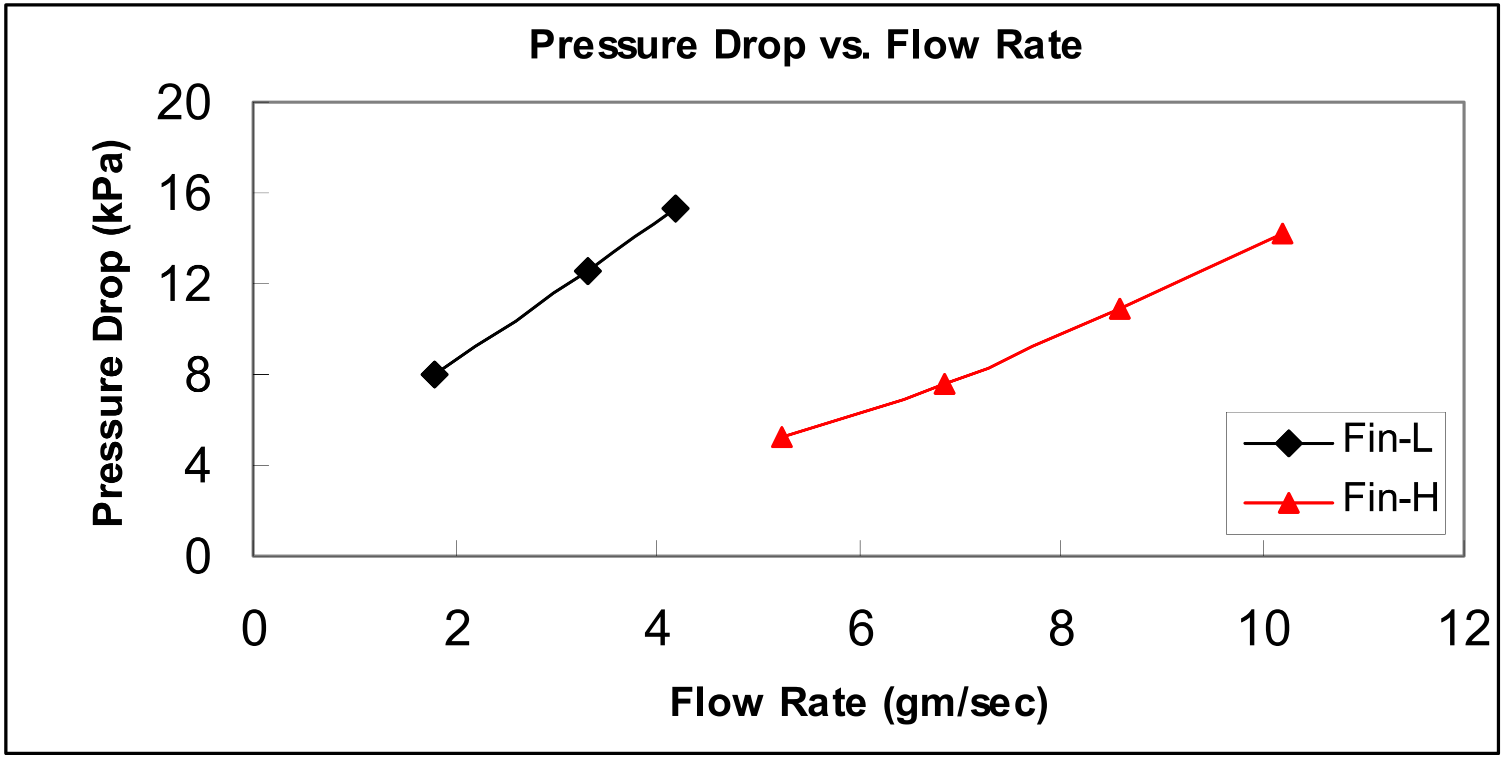
2-Pass Test Results – R_{total} ($q \cong 200$ W)



R_{tot} ratio (Fin-L/Fin-H) = 1.1

R_{total} = LMTD/q

2-Pass Water Pressure Drop

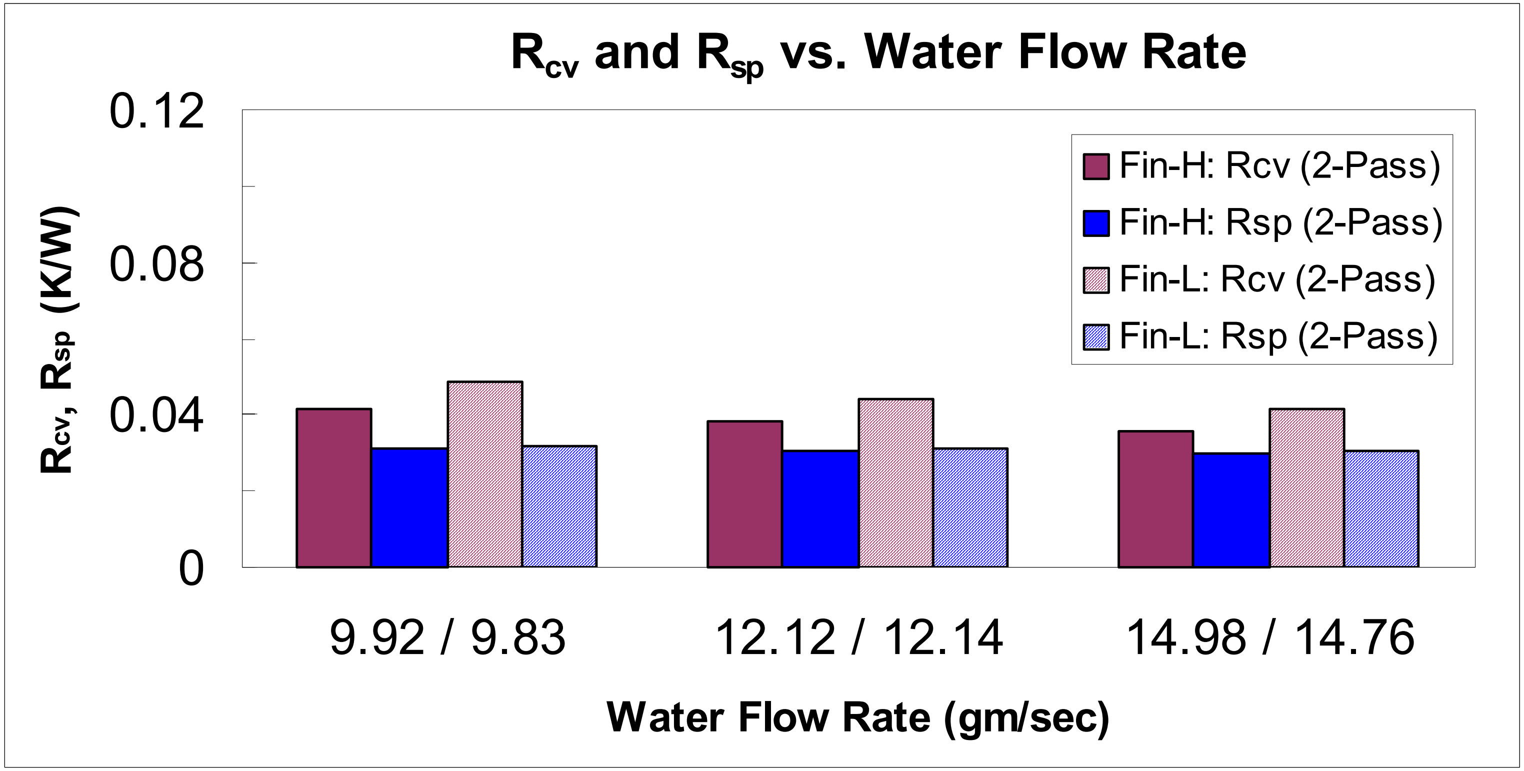


Δp of Fin-H is ¼ that of Fin-L

10 kPa = 1.45 psi

10 g/s = 0.6 ml/m

2-Pass Spreading and Convection Resist.



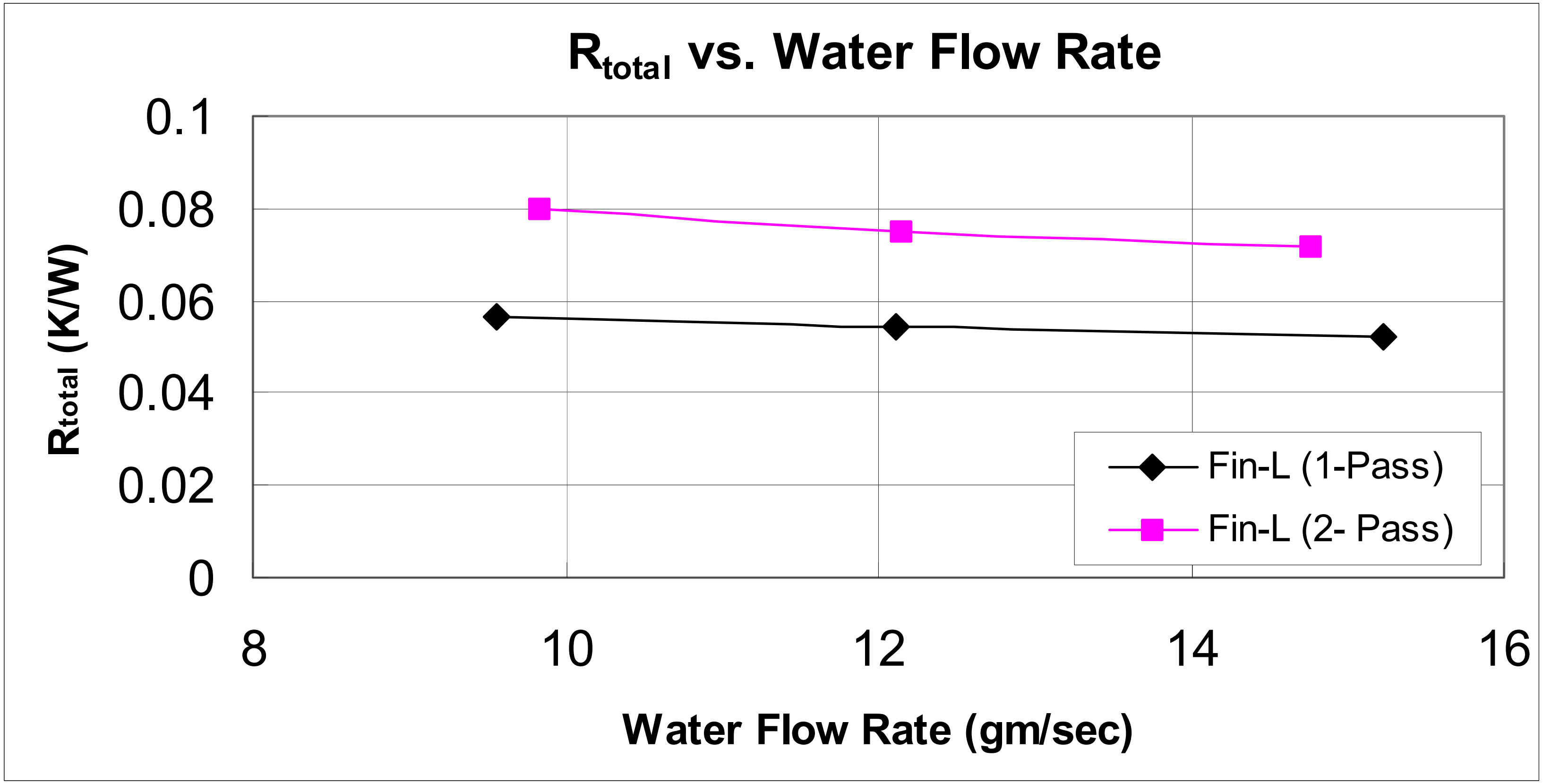
$R_{cv}/R_{tot} = 0.57$

20 × 25 mm spreader area

Spreading Resistance Calculation

- Flow length = 20 mm
- Inlet and outlet regions each 10 mm long.
- Heat transfer exists in inlet/outlet regions. h = ?
- L_{sp} = 20 mm (?)
- R_{sp} calculation is ambiguous.

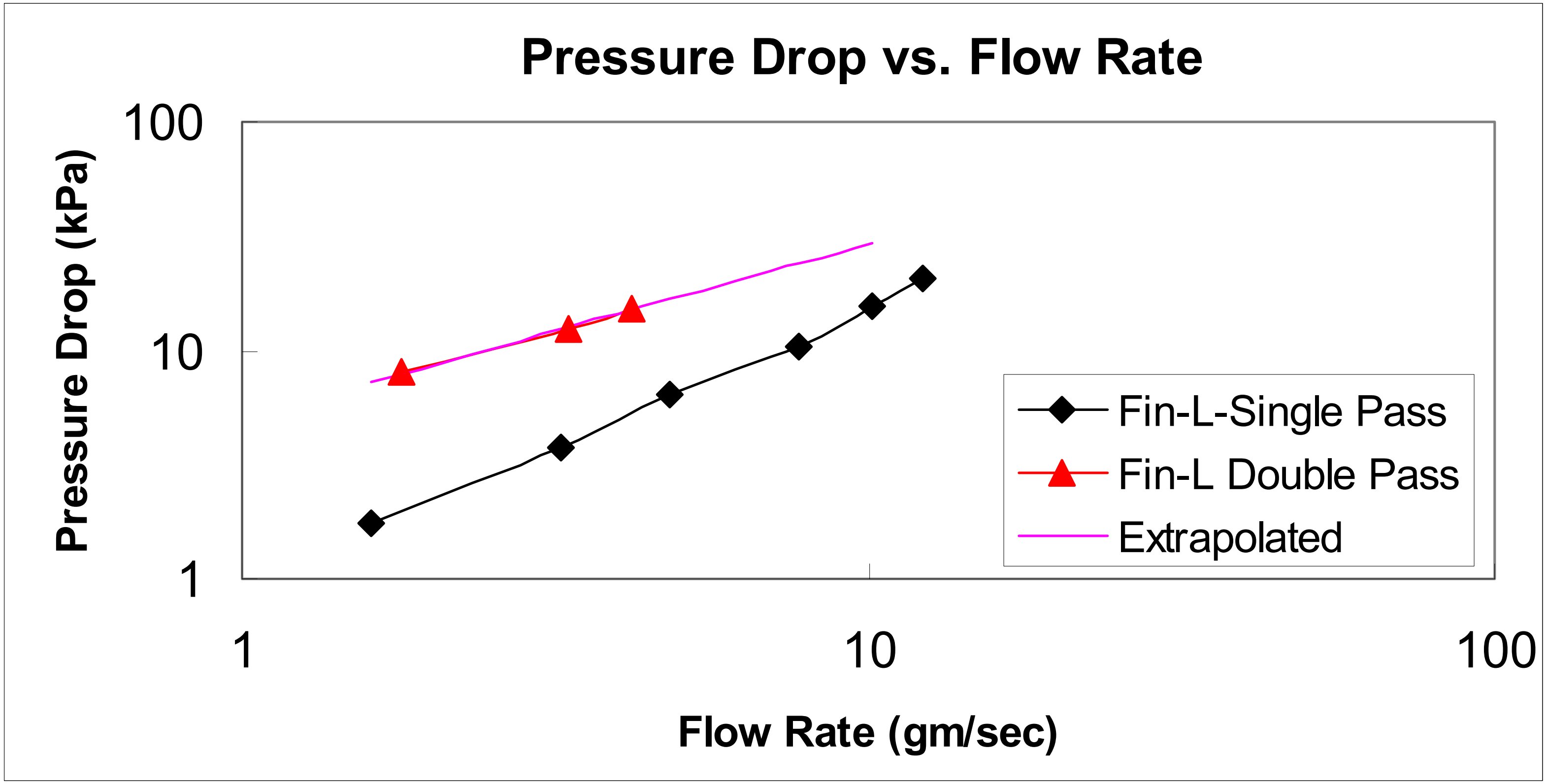
R_{total}: 2-Pass vs. 1-Pass (Fin-L)



Heat Balance: 1-p (0.90), 2-p (1.05)

R_{total} = LMTD/q

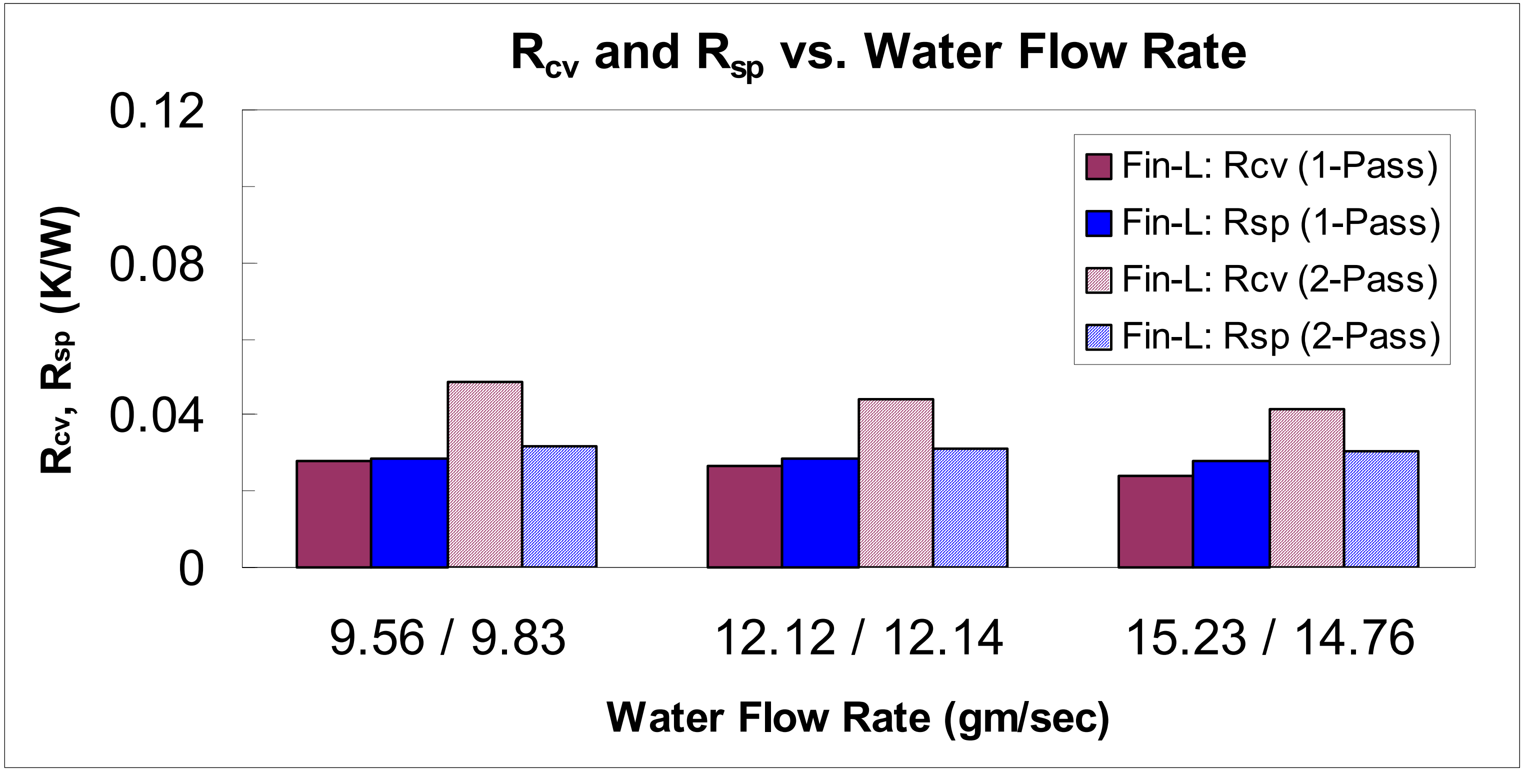
2-Pass vs. 1-Pass Pressure Drop (Fin-L)



Δp (1-pass/2-pass) $\cong$ 0.38

10 kPa = 1.45 psi

1-Pass vs. 2-Pass R_{sp} and R_{cv} (Fin-L)



20 × 25 mm spreader area

Effect of Heat Sink Plan Area

- Tested size:
  - $A_{base} = 20 \times 25 = 500\ mm^2$.
  - $A_{hot} = 16 \times 16 = 256\ mm^2$.
  - 1-pass $R_{tot} = 0.056$ K/W and $R_{cv} \cong R_{tot}/2 \cong 0.028$ K/W
- Consider $A_{base} = A_{hot} = 16 \times 16\ mm^2$.
  - $R_{sp} = 0$ and $R_{cv} \cong 2 \times 0.028 = 0.056$ K/W
  - $R_{tot} \cong 0.056$ K/W
- What is required A_{hot}?

Evaluation of Results for Fin-L

Flow rate g/s	**Reynolds Number** (Ch/Hdr)	**Pred h** F.D. flow kW/m^2-k	**Pred h** $x^+ = 0.11$ kW/m^2-k	**Exp h** L_{sp} = 20 mm kW/m^2-k
9.8	386/405	10.7	16.6	16.8
13.0	474/513	10.7	16.6	17.7
17.2	578/645	10.7	16.6	19.3

1-Pass

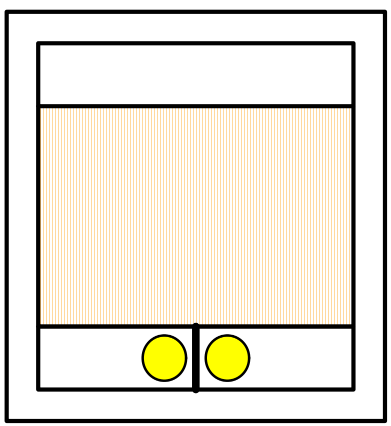
Flow rate g/s	**Reynolds Number** (Ch/Hdr)	**Pred h** F.D. flow kW/m^2-k	**Pred h** x+ = 0.11 kW/m^2-k	**Exp h** L_{sp} = 20 mm kW/m^2-k
9.83	419/1030	10.6	16.4	9.7
12.1	517/1272	10.6	16.4	10.6
14.8	629/1547	10.6	16.3	11.4

2-Pass

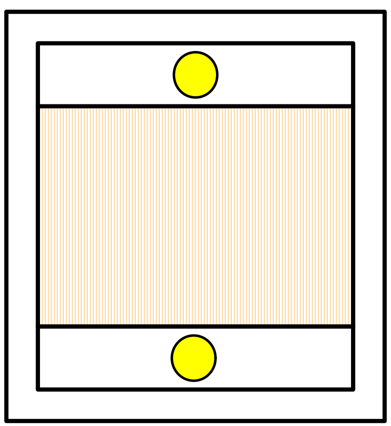
Predicted h for laminar flow with q” = const.

1-Pass vs. 2-Pass?

- Preferred manifold arrangement?
  - 1-pass: Connections on opposite ends.
  - 2-pass: Both connections adjacent.



2-pass



1-pass

Conclusions

- Low cost, high performance, micro-channel heat sinks.
  - Data for two fin heights: 2.1 mm and 0.88 mm
  - 1-pass and 2-pass data (Fin-L). 2-pass (Fin-H)
- 2-pass geometries:
  - $R_{tot} \cong 0.072\text{-}0.08$ K/W at 10 g/s water flow.
  - Δp of Fin-H is 25% that of Fin-L.
- 1-pass Fin-L has R_{tot} 70% that of 2-pass geometry.
  - $R_{tot} = 0.056$ K/W for 1-pass Fin-L with 9.6 g/s water.
  - $R_{cv}/R_{tot} = 0.50$