# 鰭管式熱交換器近年 專利分析研究

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# Outline



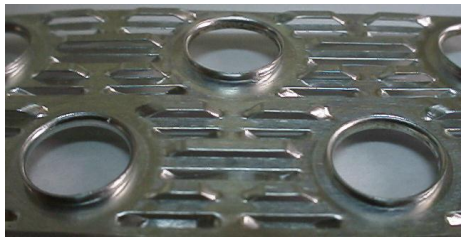
- Background
- Methods for Augmentation
- Recent US patents
- Conclusions

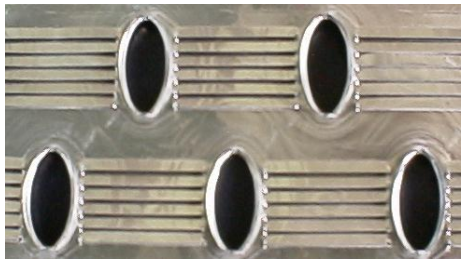
# Various Fin Patterns





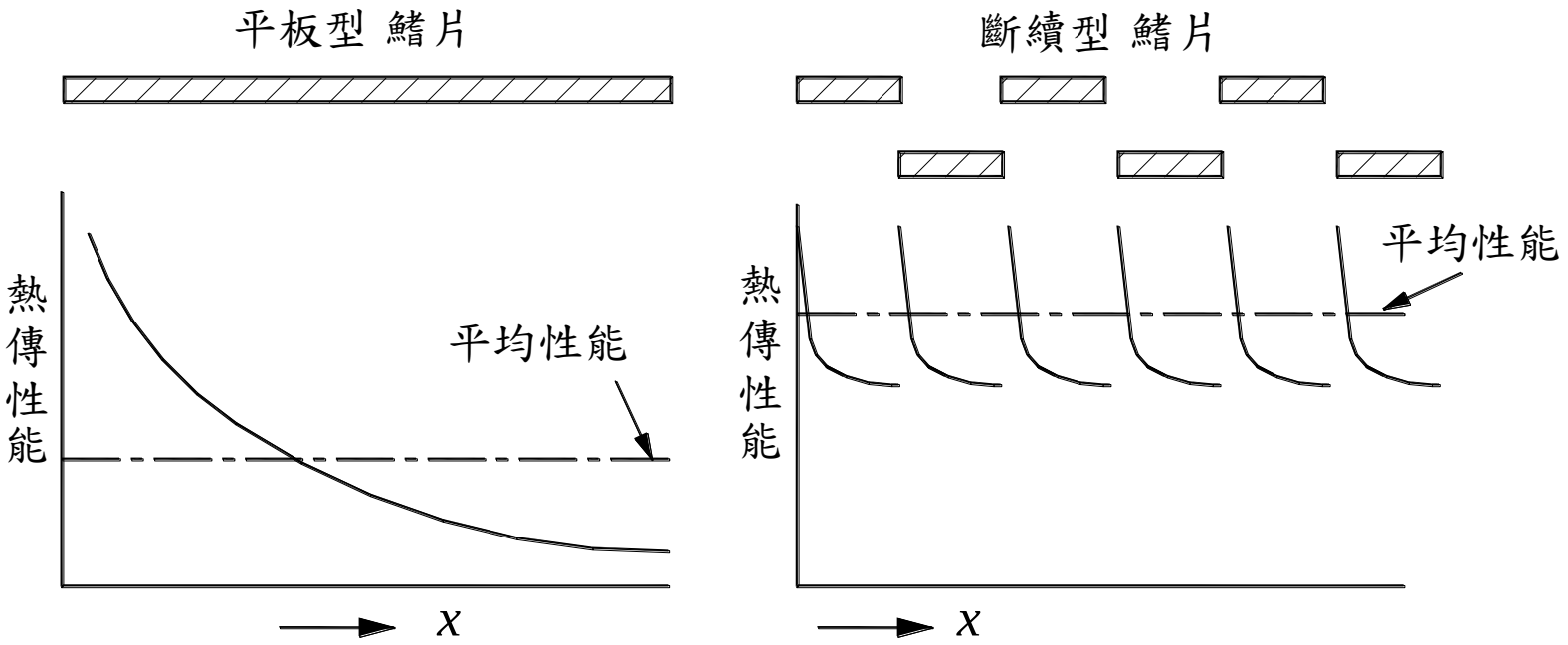




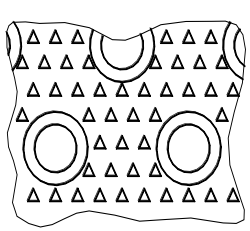


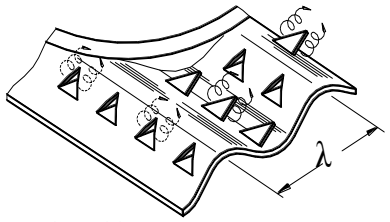
# 增加熱對流係數






- Thermal Boundary Layer Restart
- Instability
- Thermal Wake Management
- Swirl





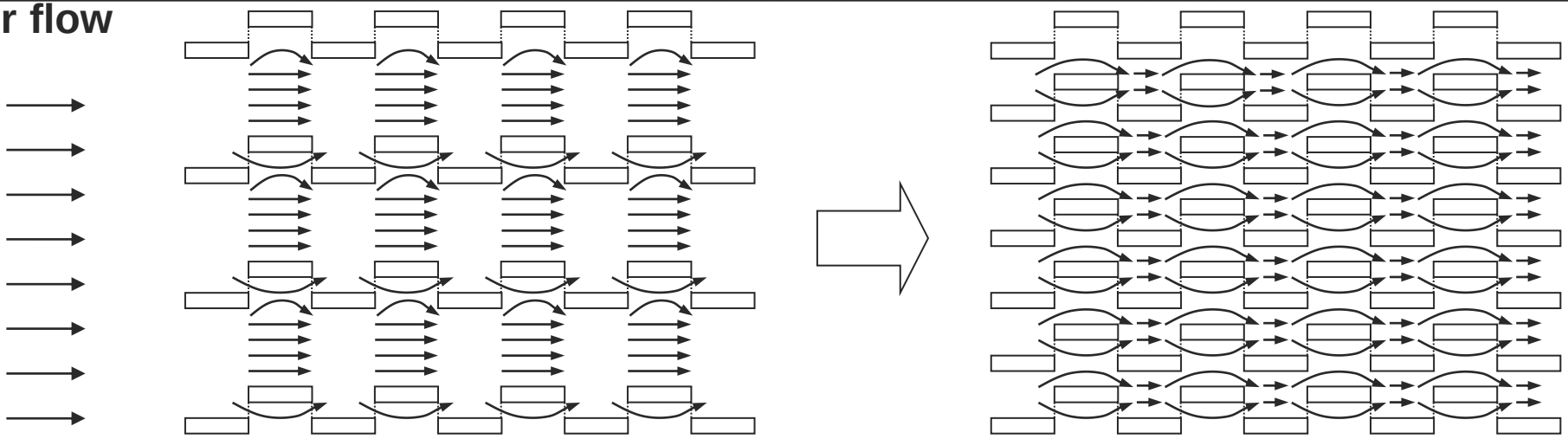

US patent 4817709

# Interrupted surfaces..

- Provide effective heat transfer augmentations at medium and high velocity with significant pressure drop penalty.
- Nearly ineffective at low velocity but still suffer from considerable pressure drop.
  - Duct flow effect.

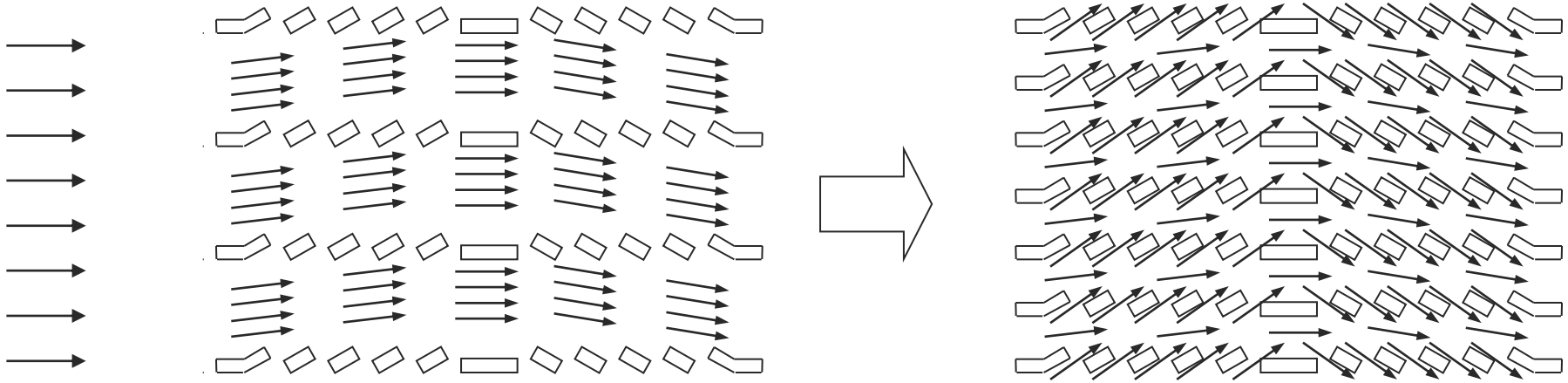
# Effects of Periodic Entrance/Exit

Air flow



# Louver directed vs. fin directed

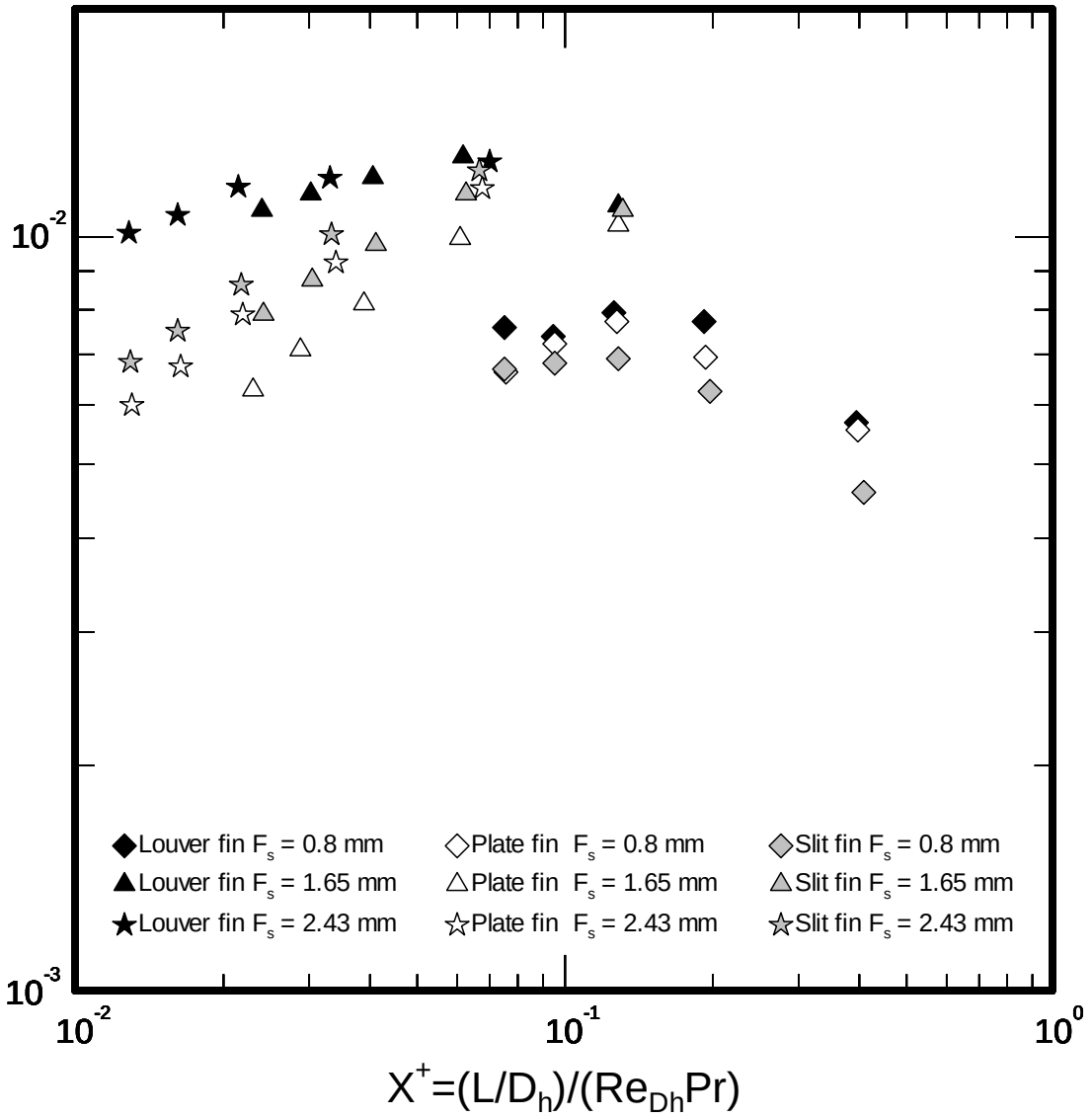
Air flow



SCHEMATIC OF DUCT FLOW VS. FIN-DIRECTED FLOW FOR LOUVER FIN GEOMETRY AT SMALLER AND LARGER FLOW VELOCITIES. (Yang et al. IJHMT, 2007)

# Interrupted surfaces..

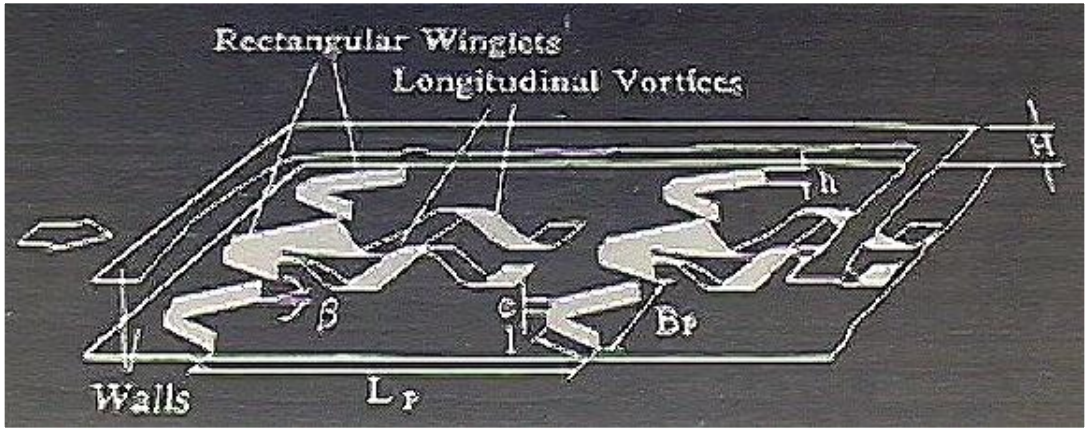
- Smaller fin spacing accentuates the duct flow effect, resulting in fully developed flow and deteriorate the heat transfer performance.




**INVERSE GRAETZ NUUMBER NUMBER $X^+$ VS. *j* FOR LOUVER, SLIT AND PLATE FIN. (Yang et al., IJHMT, 2007)**

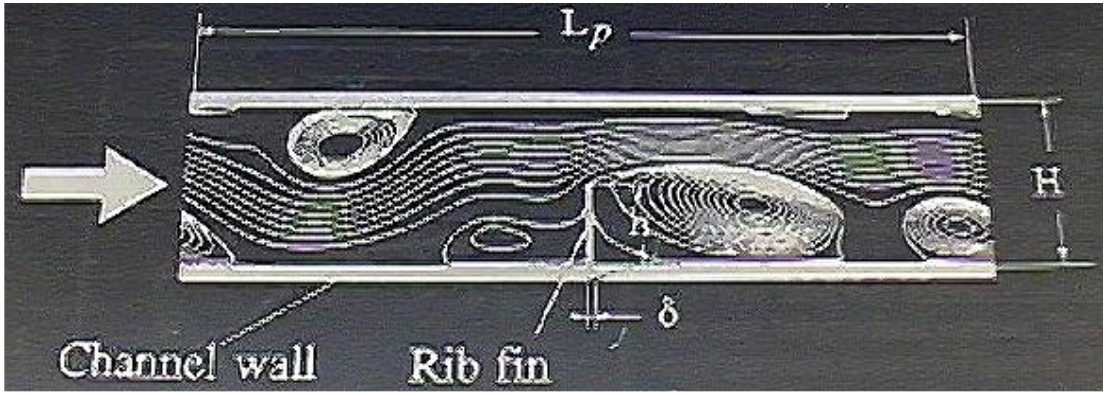
# Type of vortex generators

## Longitudinal vortex outperforms the transverse vortex




Longitudinal vortex

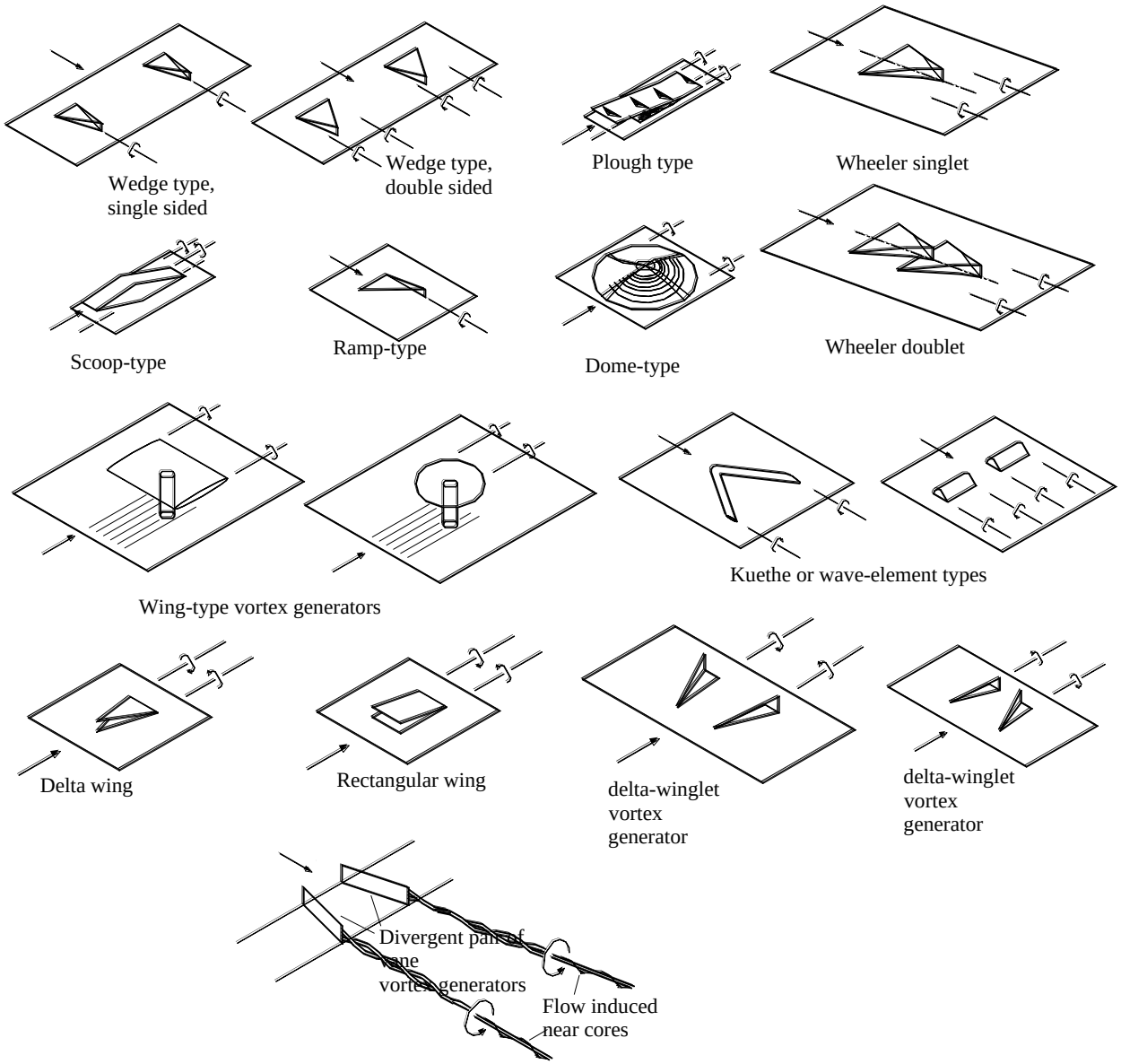
Transverse vortex



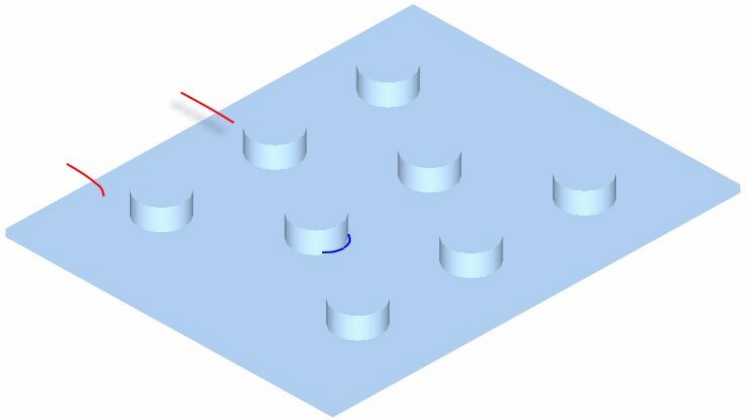
# Benefits of vortex generator

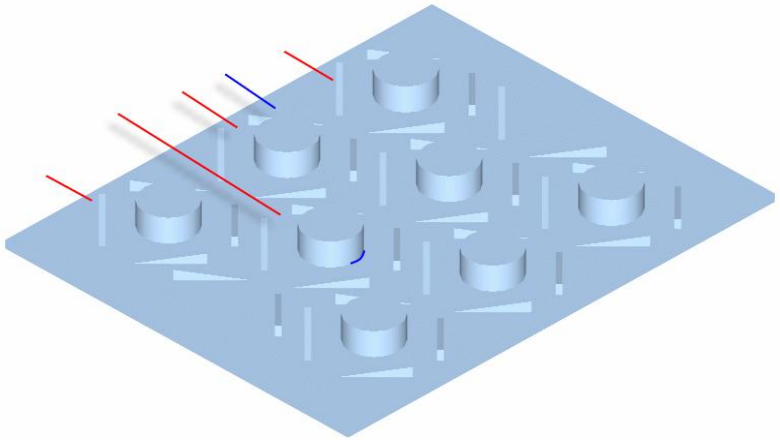
- Prevent Boundary Layer separation
- Improve heat transfer performance with acceptable pressure drop

# Typical LVGs



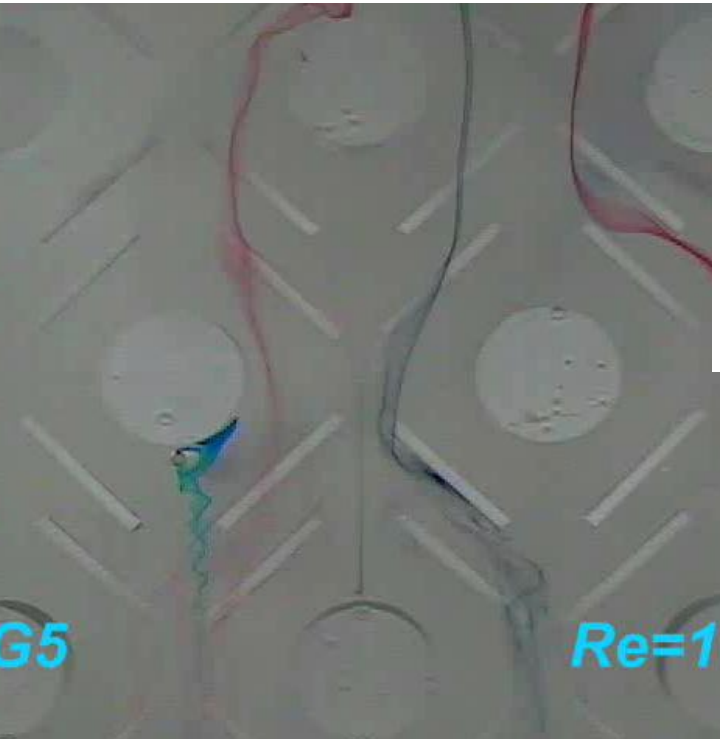
*Int. J. of Heat and Mass Transfer*, Vol. 45, pp. 1933-1944.
*Int. J. of Heat and Mass Transfer*, Vol. 45, pp. 3803-3815.

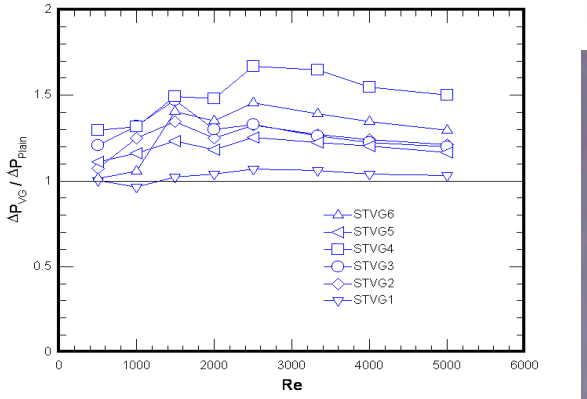


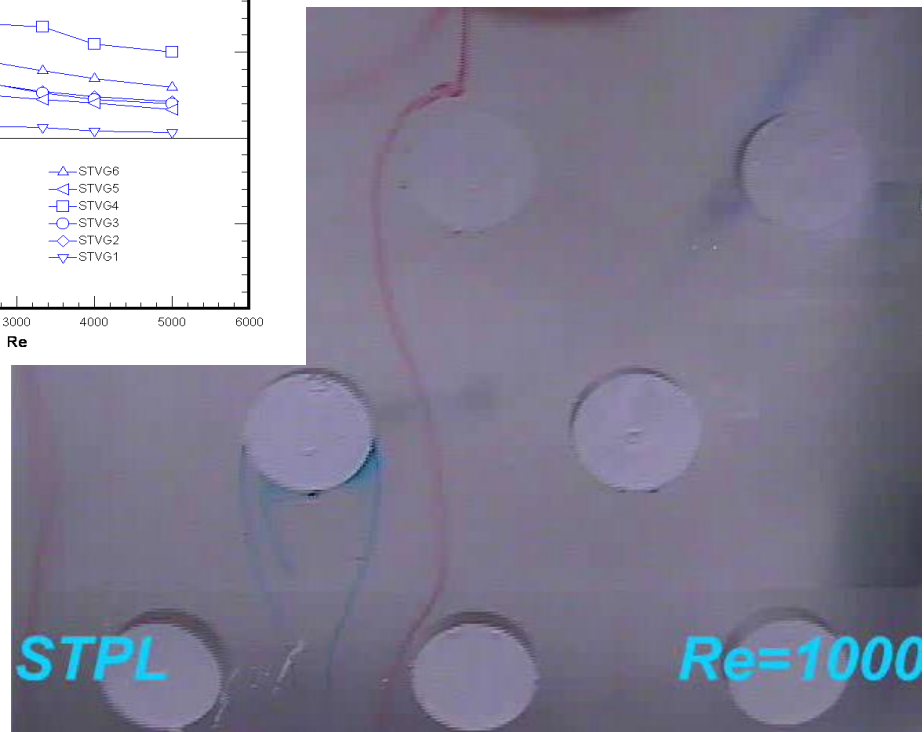


Re=1000,STVG5

Re=1500,STPL

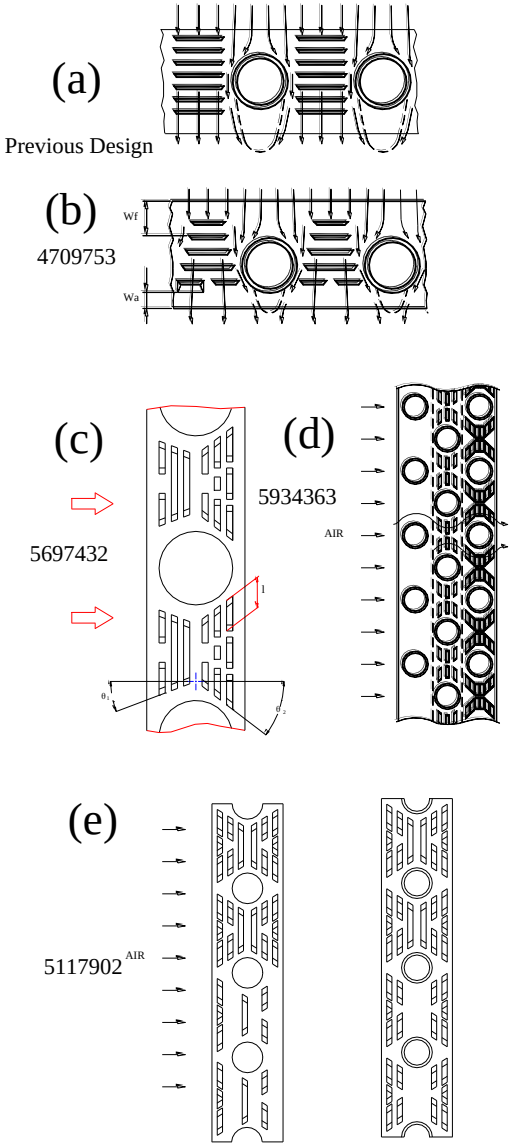


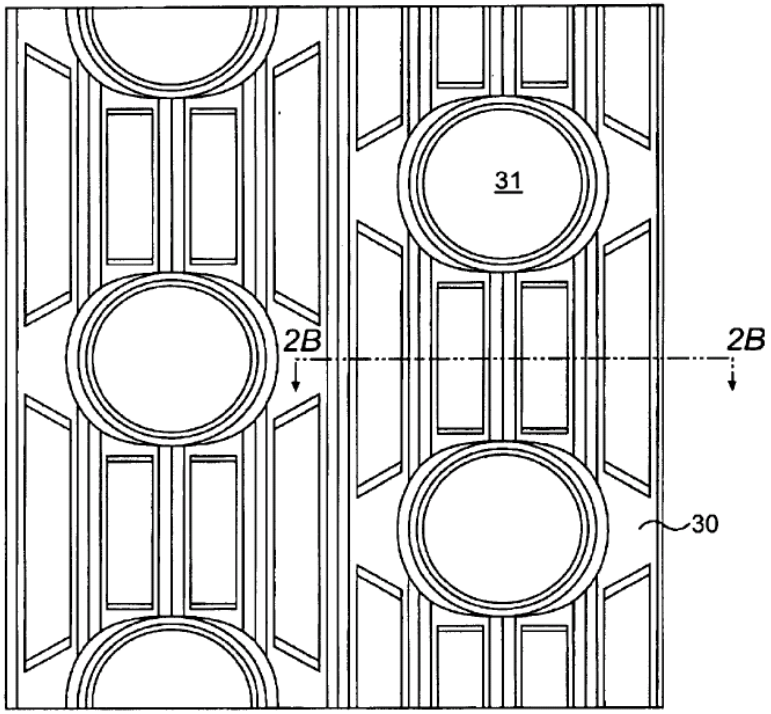
# Design by Non-uniformity

1. Place the enhancement at low heat transfer region.
2. Check the effective local temperature difference. Placing enhancements at those having lower temperature difference are generally more effective.

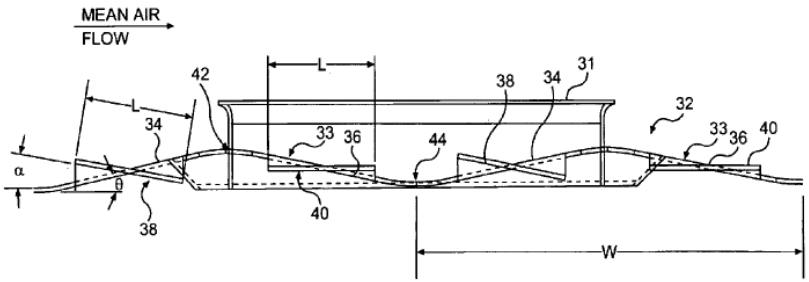


US patent (fin-and-tube HX)

From 2000~2009

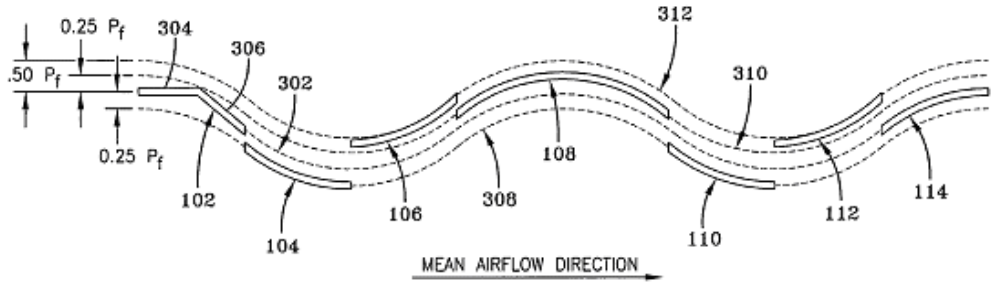



(a) enlarged view

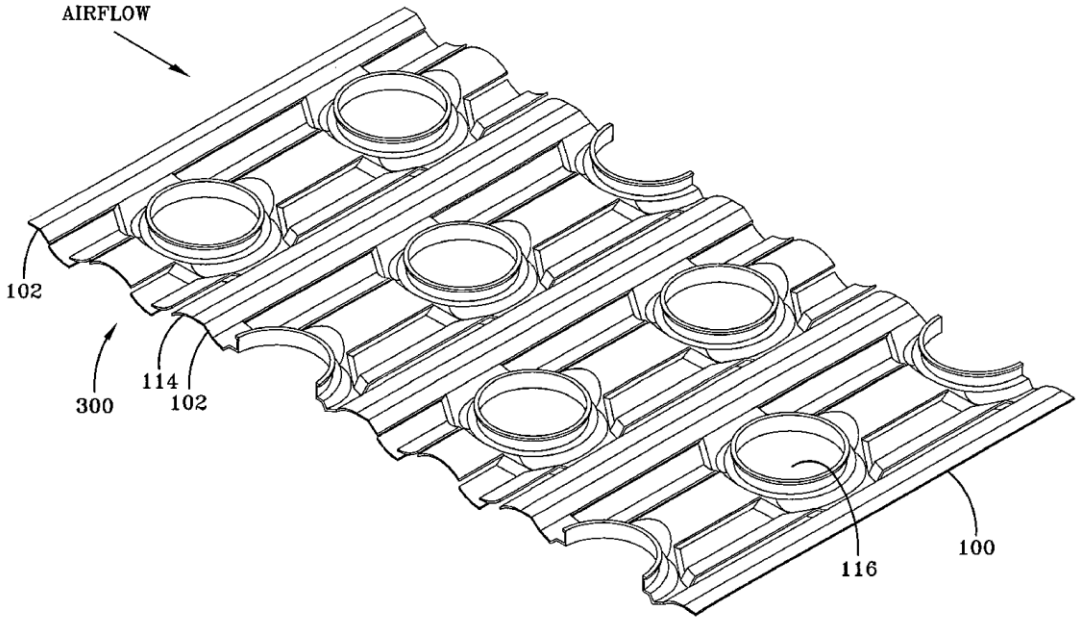



(b) cross-sectional view

Fig. 1 Schematic of the US patent US patent 6786724.

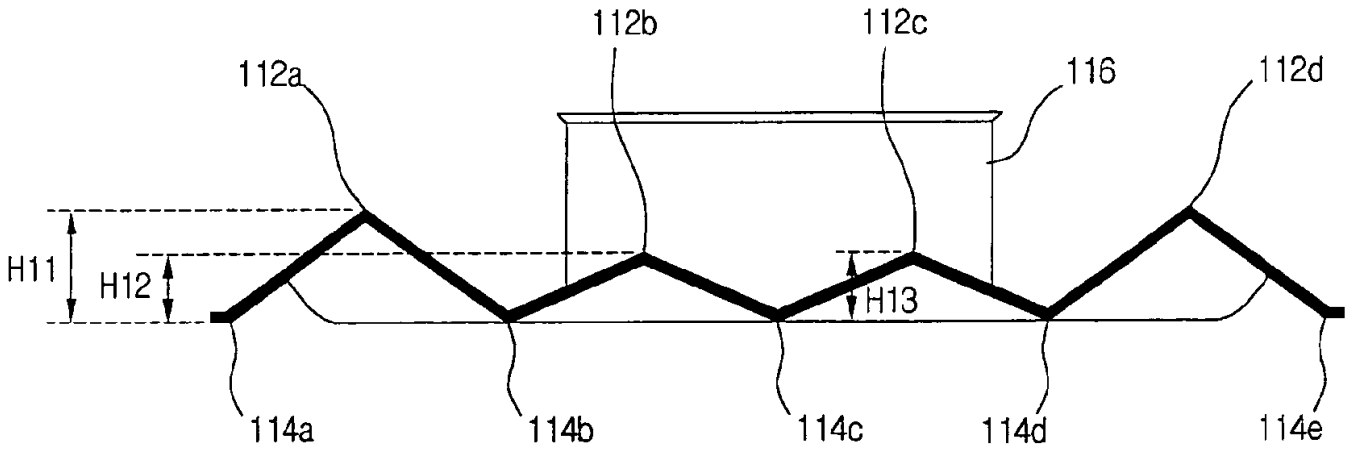



(a) cross-sectional view

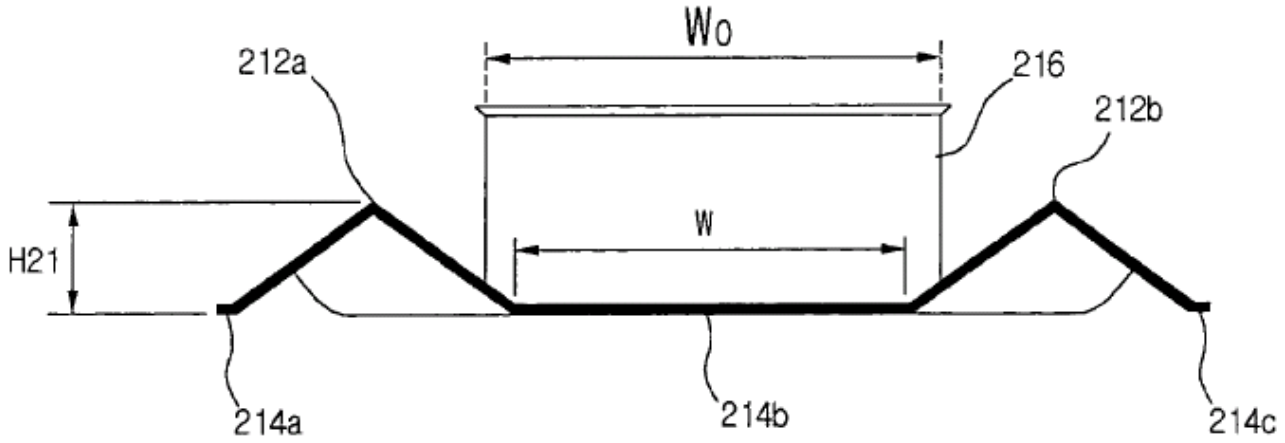



(b) isometric view

Fig. 2 Schematic of the US patents of 7124813 and 6976529.

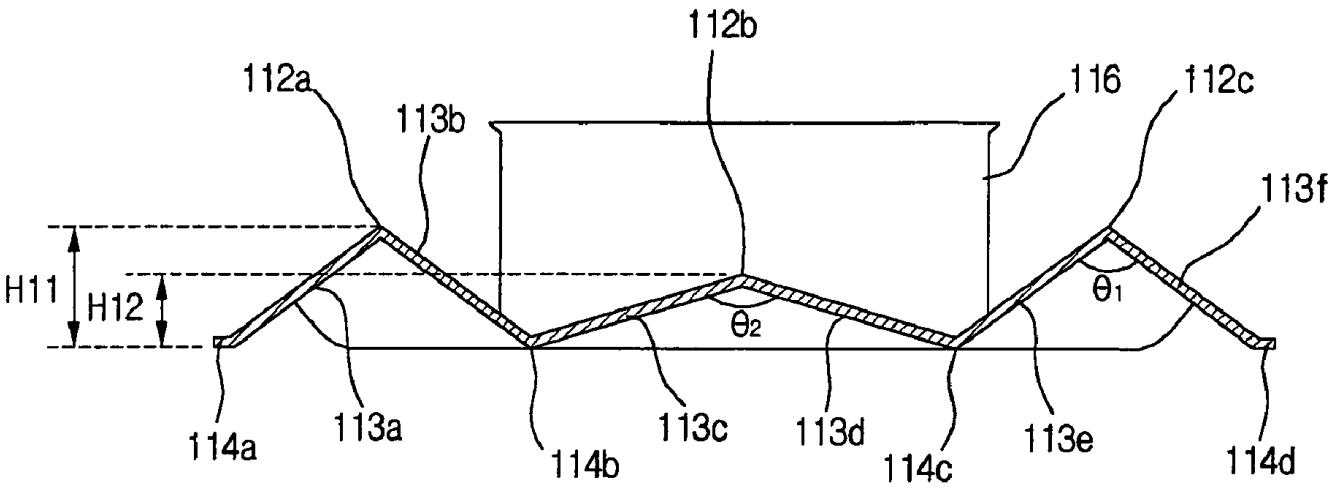



(a) variable peak/valley deign.

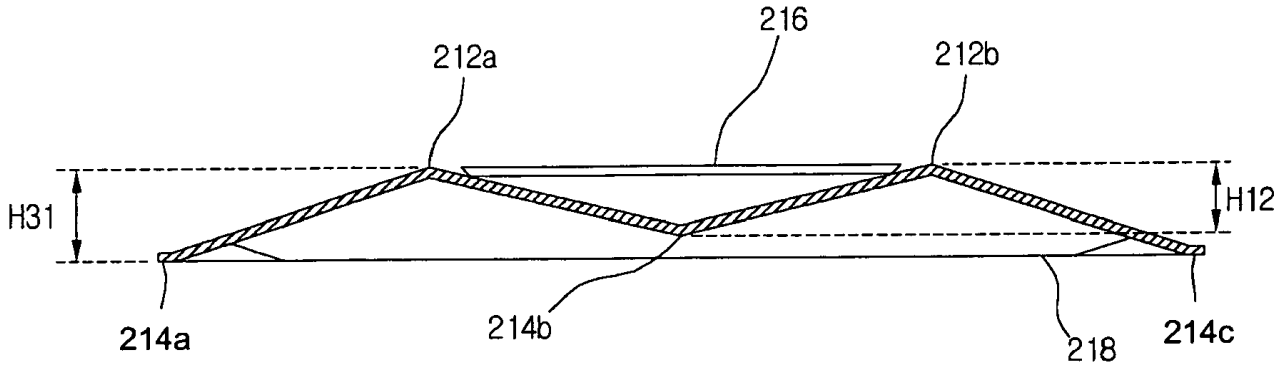



(b) plain portion amid peaks

Fig. 3 Schematic of the US patent 7261147.

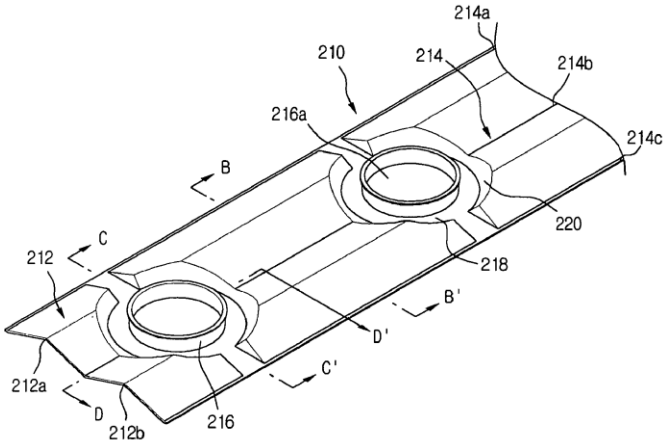



(a) design with $\theta_1 < \theta_2$

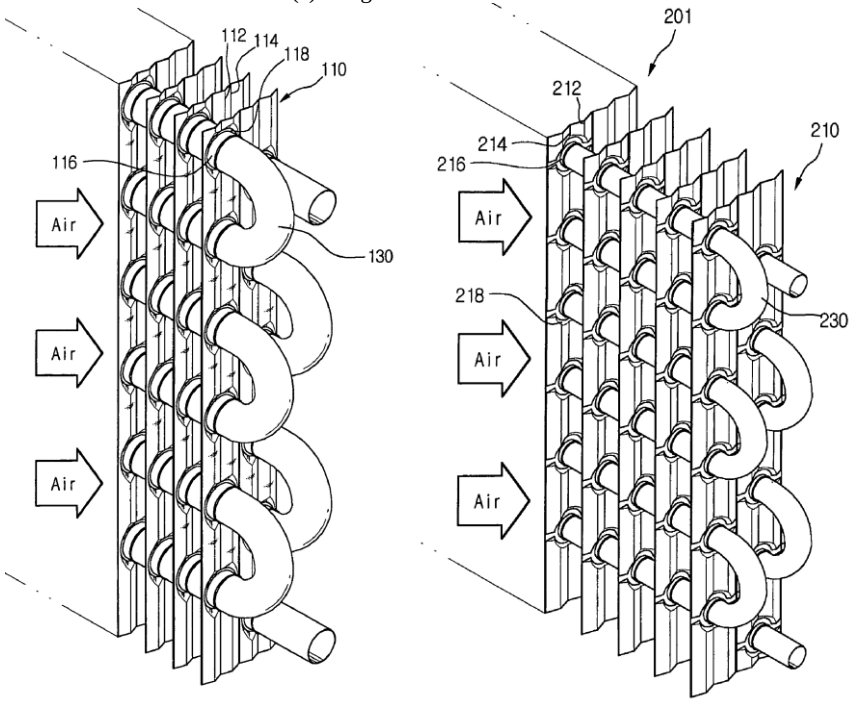



(b) design with shallow valley

Fig. 4 Schematic of US patent 7219716.

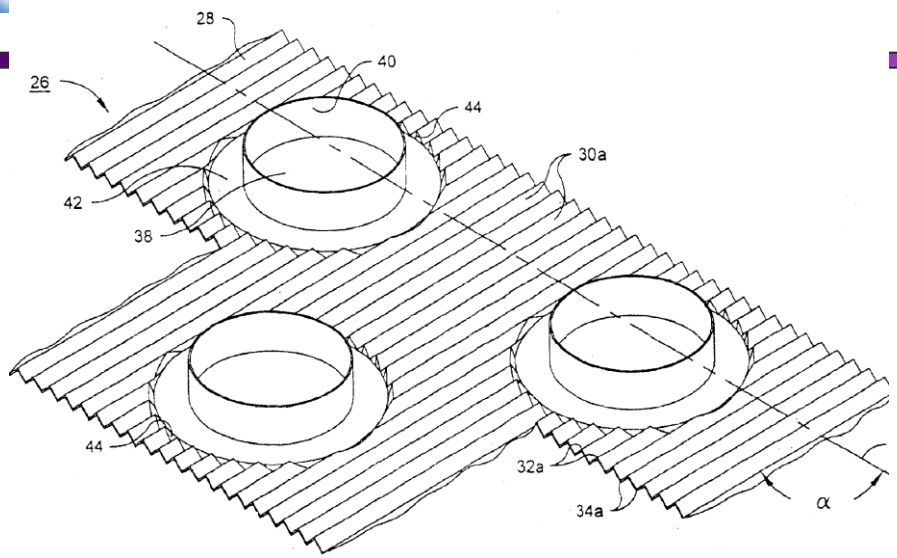



(a) design with wake removal

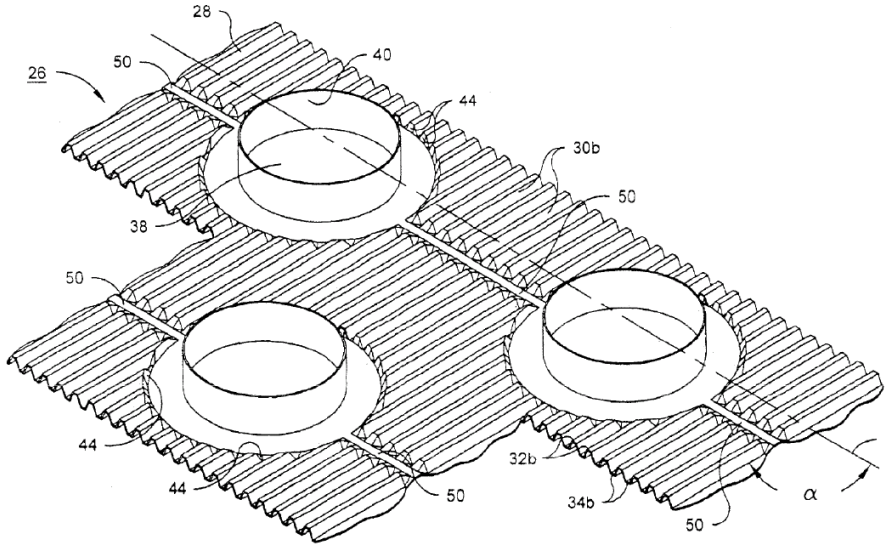



(b) conventional design (c) proposed design

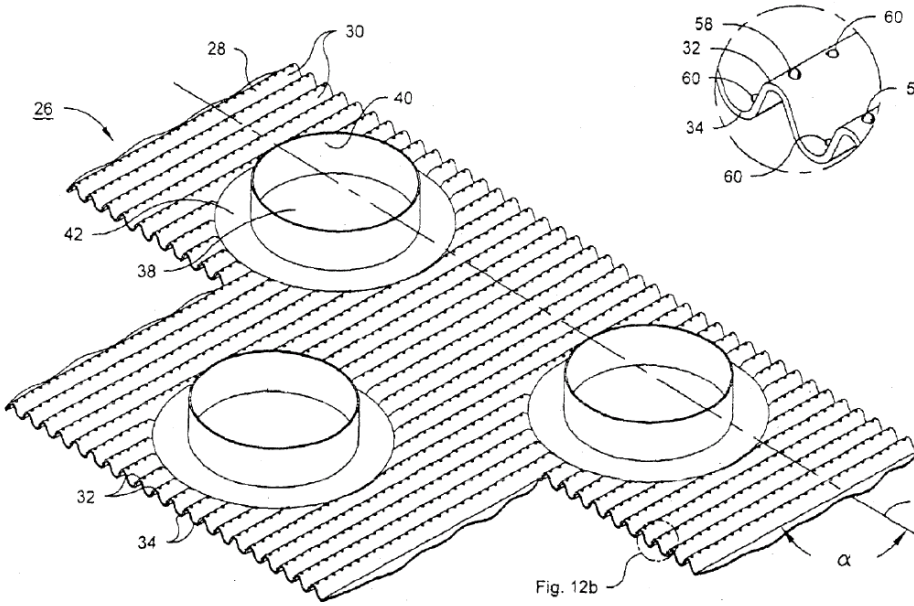
**Fig. 5 Schematic of the US patent 7182127.**




(a) basic design

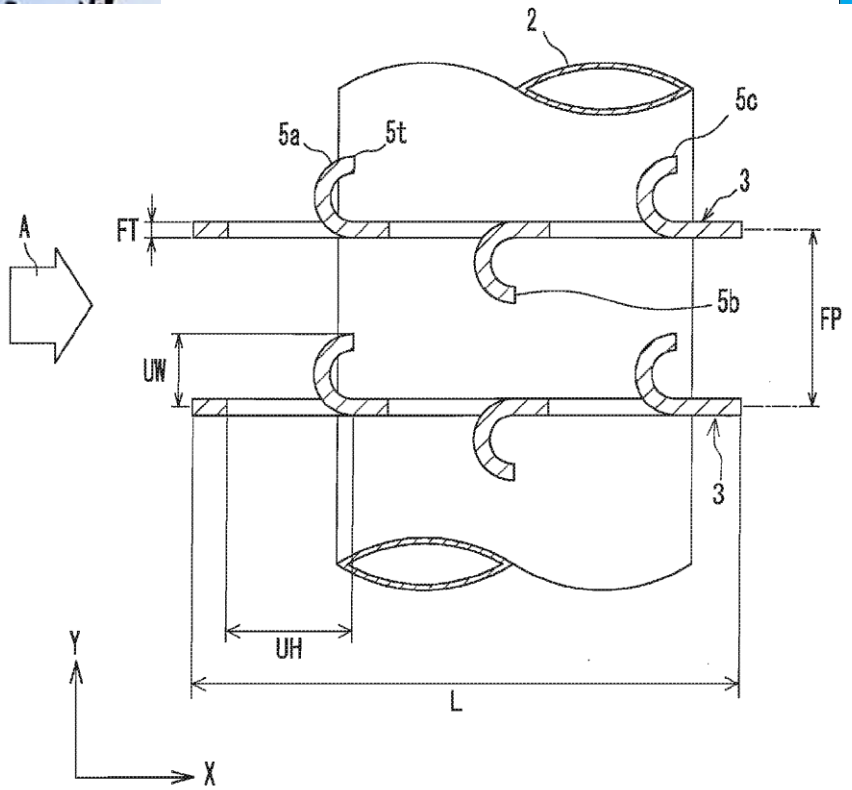



(b) a drainage path deign

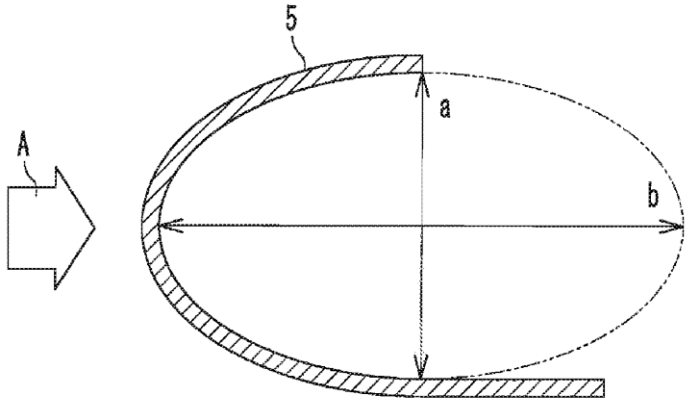



(c) design with tiny holes to promote mixing between adjacent fins

Fig. 6 Schematic of the US patent 6889759.

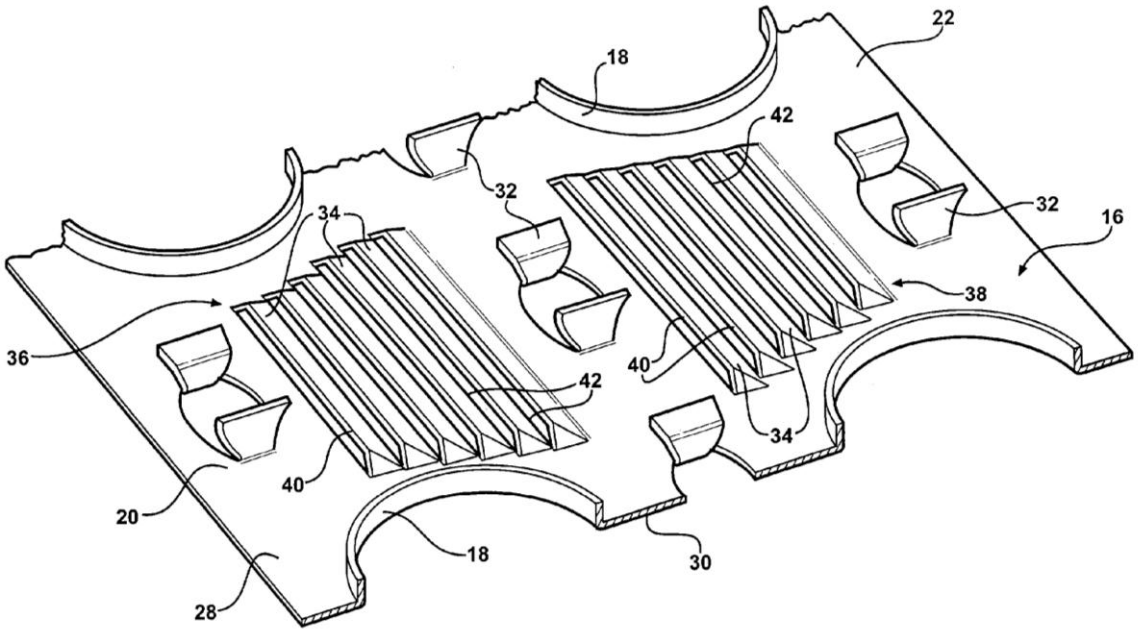



(a) an enlarge view of the fin design

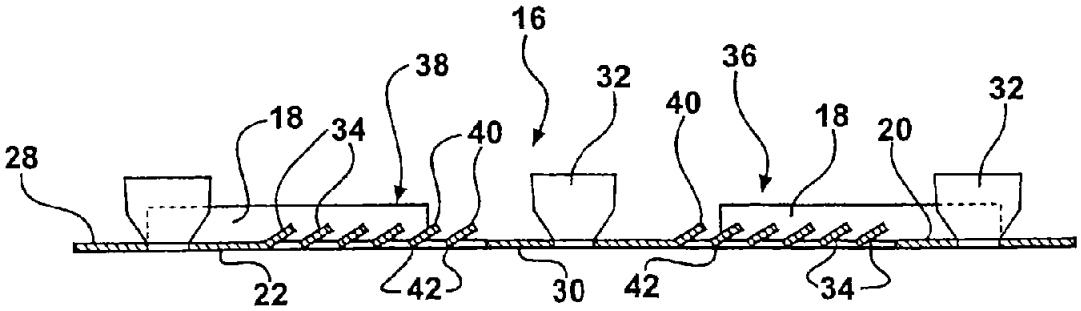



(b) definition of ellipicity a/b

Fig. 7 Schematic of the US patent US patent Pub. No. 2009/0050303 A1.

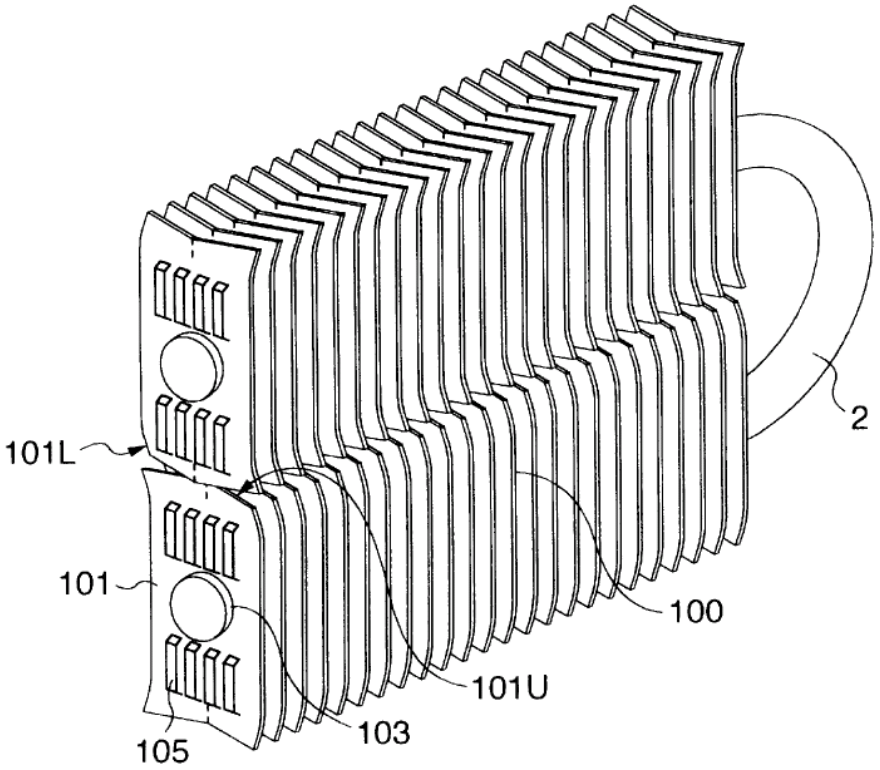



(a) isometric view

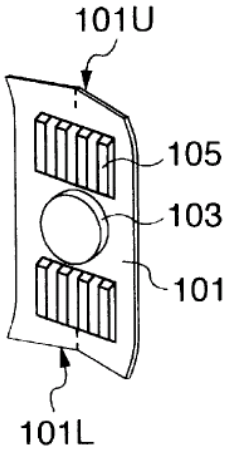



(b) cross-sectional view

Fig. 8 Schematic of the US patent 7021370.

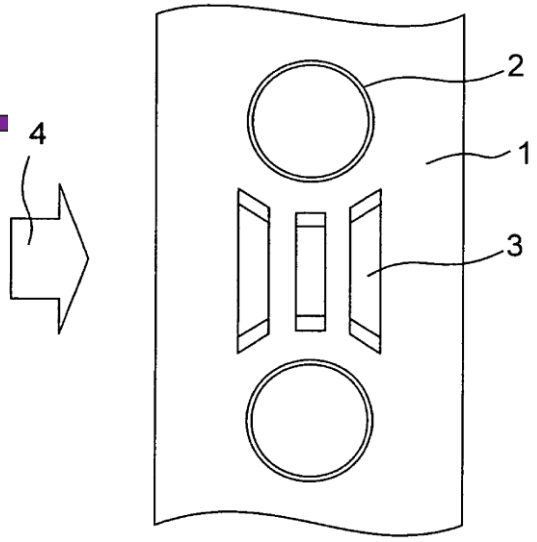



(a) fin assembly

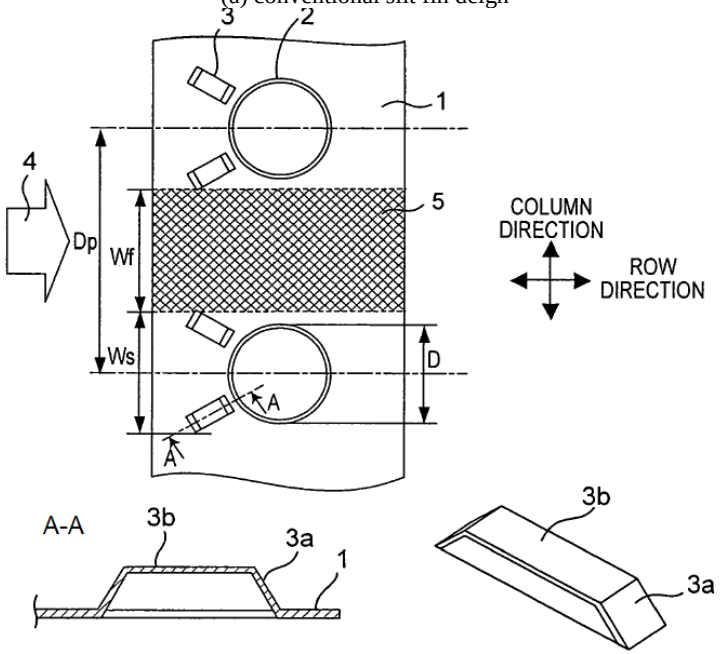



(b) individual fin

**Fig. 9 Schematic of the US patent 6050328**

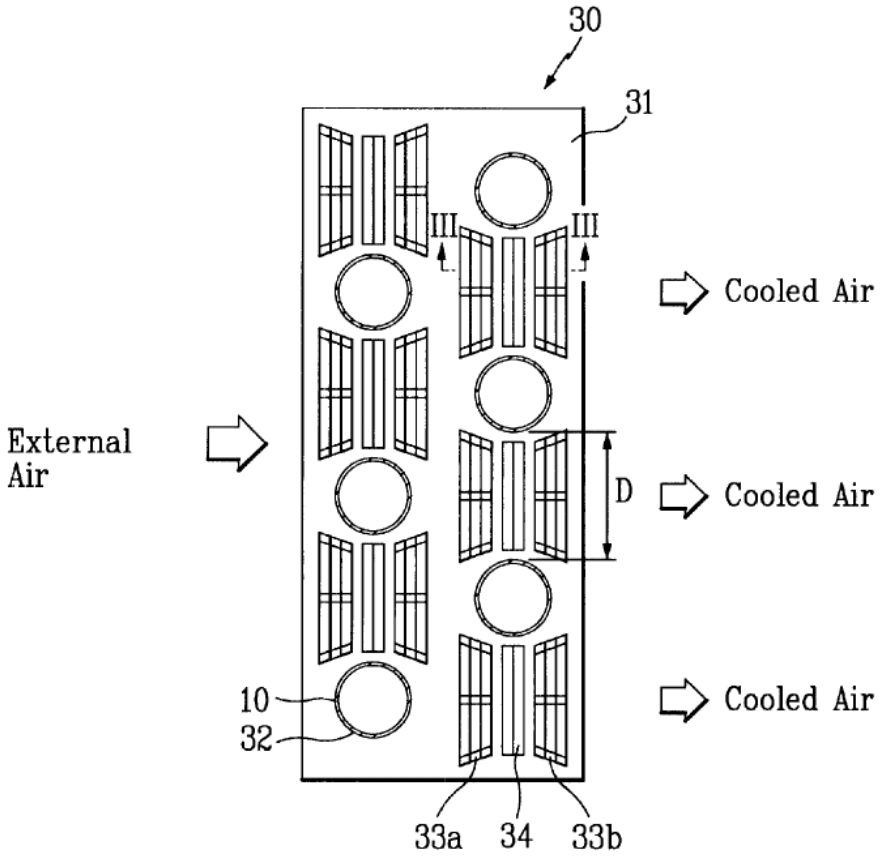



(a) conventional slit fin deign

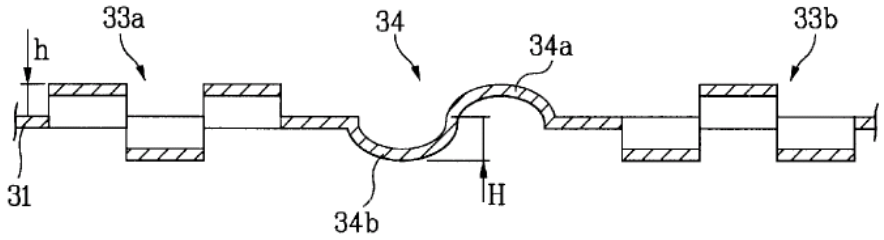



(b) aligned slit fin deign

**Fig. 10 Schematic of the US patent 7578339.**

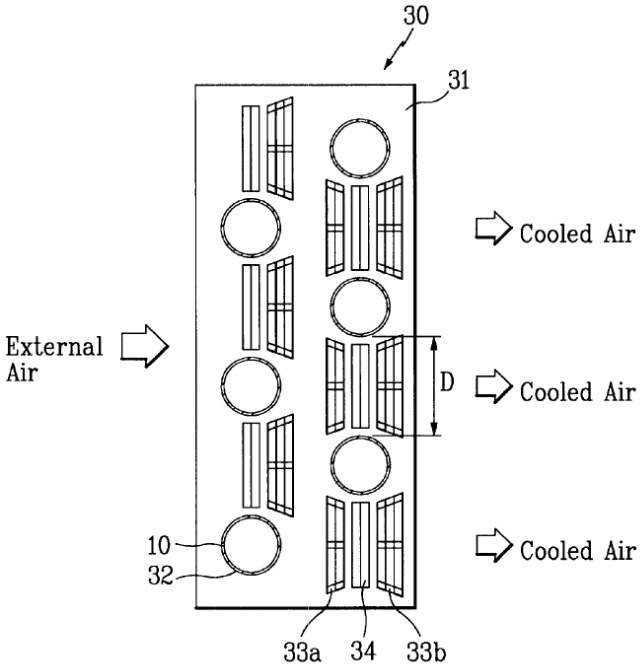



(a) fin design

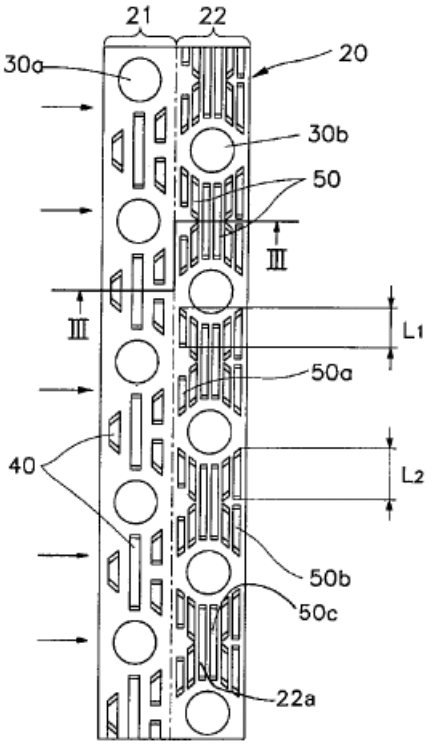



(b) condensate drainage design

Fig. 11 Schematic of the US patent 6334326.

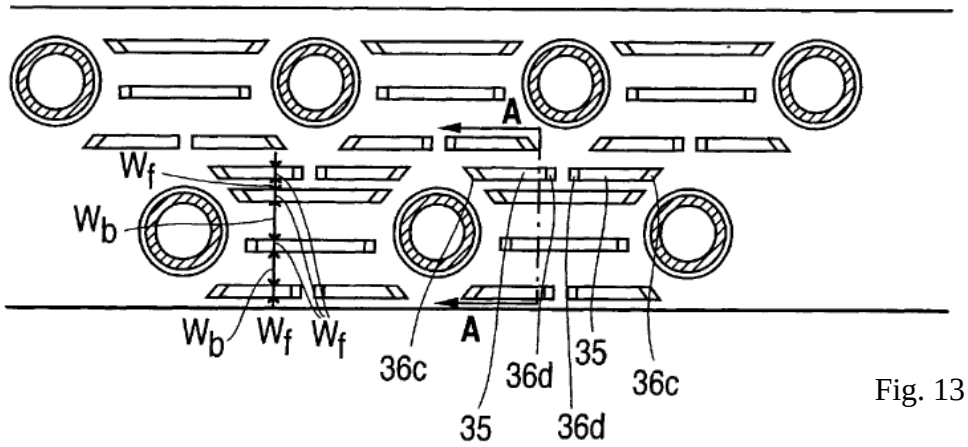



(a) US patent 6334326



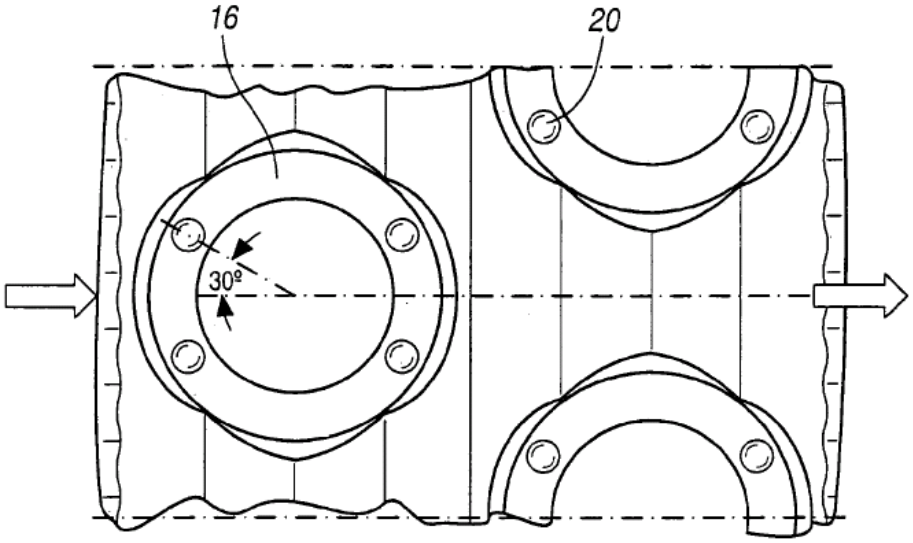


(c) US patent 6026893

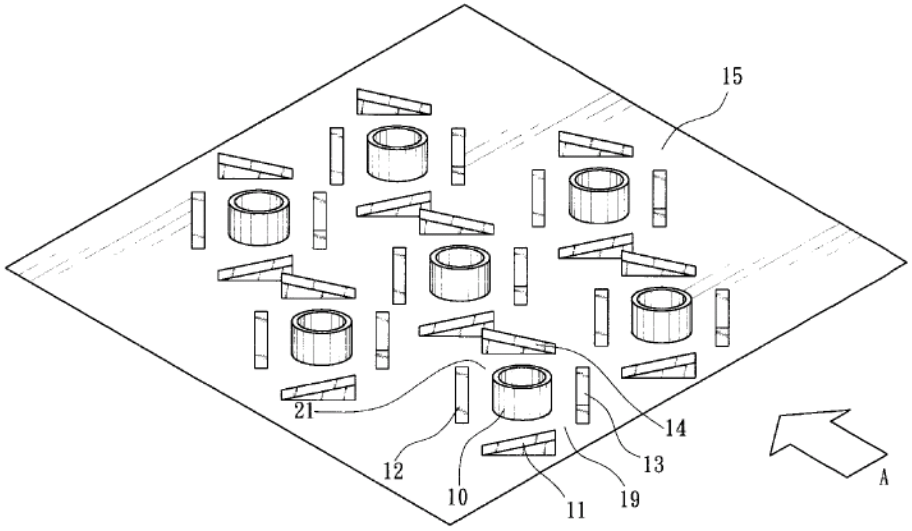



(b) US patent 6227289

Fig. 13 Schematic of the US patents of 6334326, 6227289, and 6026893.




(a) US patent 7004242




(b) US patent 6578627.

Experimental Thermal and Fluid Science 33 (2008) 58–66

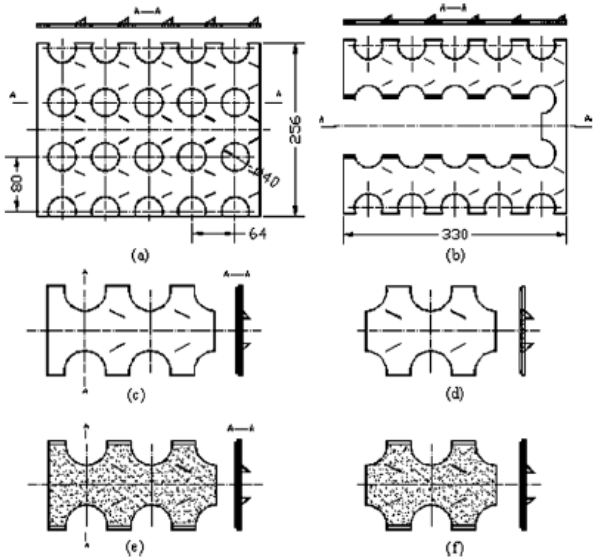



Fig. 3. Test core of in line tube bank fin, (a) support plate, (b) plate forming flow passages, (c) fin surface I-1, (d) fin surface I-2, (e) fin surface II-1, (f) fin surface II-1.

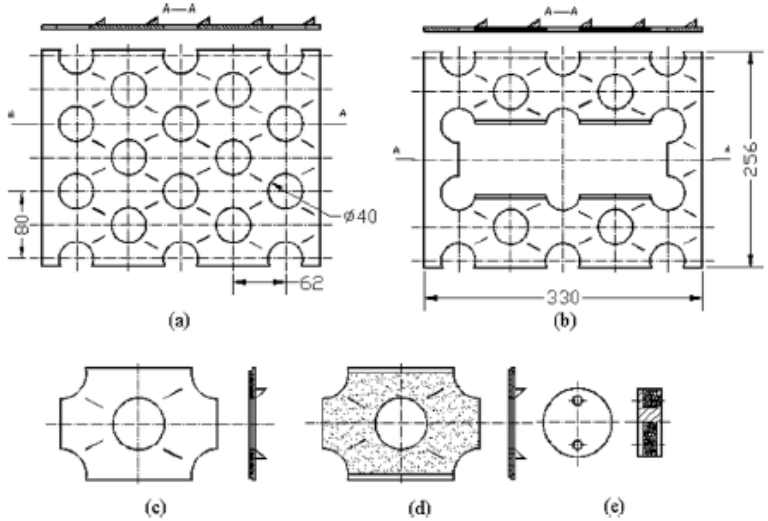



Fig. 4. Test core of staggered tube bank fin, (a) plate forming flow passages, (b) Support plate, (c) fin surface II, (d) fin surface I, (e) tube with cast naphthalene.

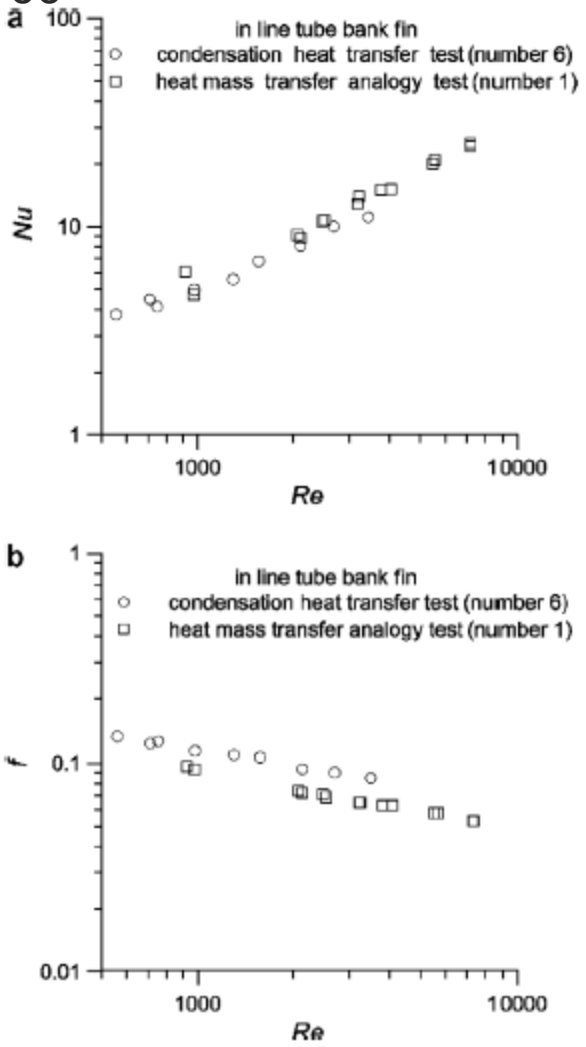



Fig. 7. Comparison of heat/mass analogy test results (Number 1) with condensation test results (Number 2), (a) *Nu* and (b) *f*.

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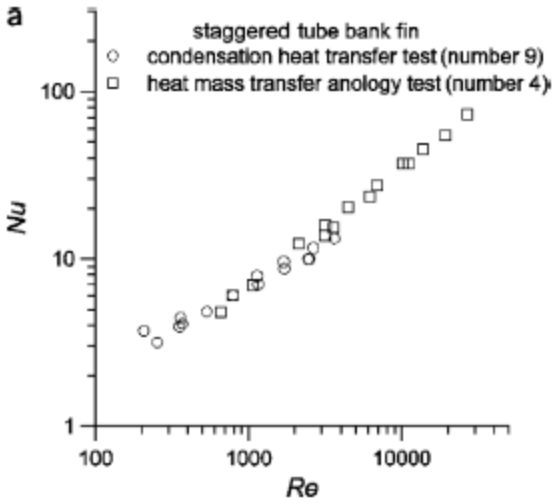



Fig. 10. Comparison of heat/mass analogy test results (Number 7) with condensation test results (Number 8), (a) *Nu* and (b) *f*.

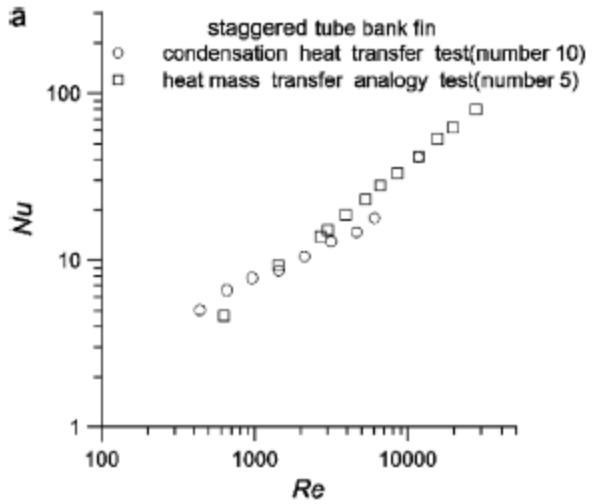



Fig. 11. Comparison of heat/mass analogy test results (Number 9) with condensation test results (Number 10), (a) *Nu* and (b) *f*.

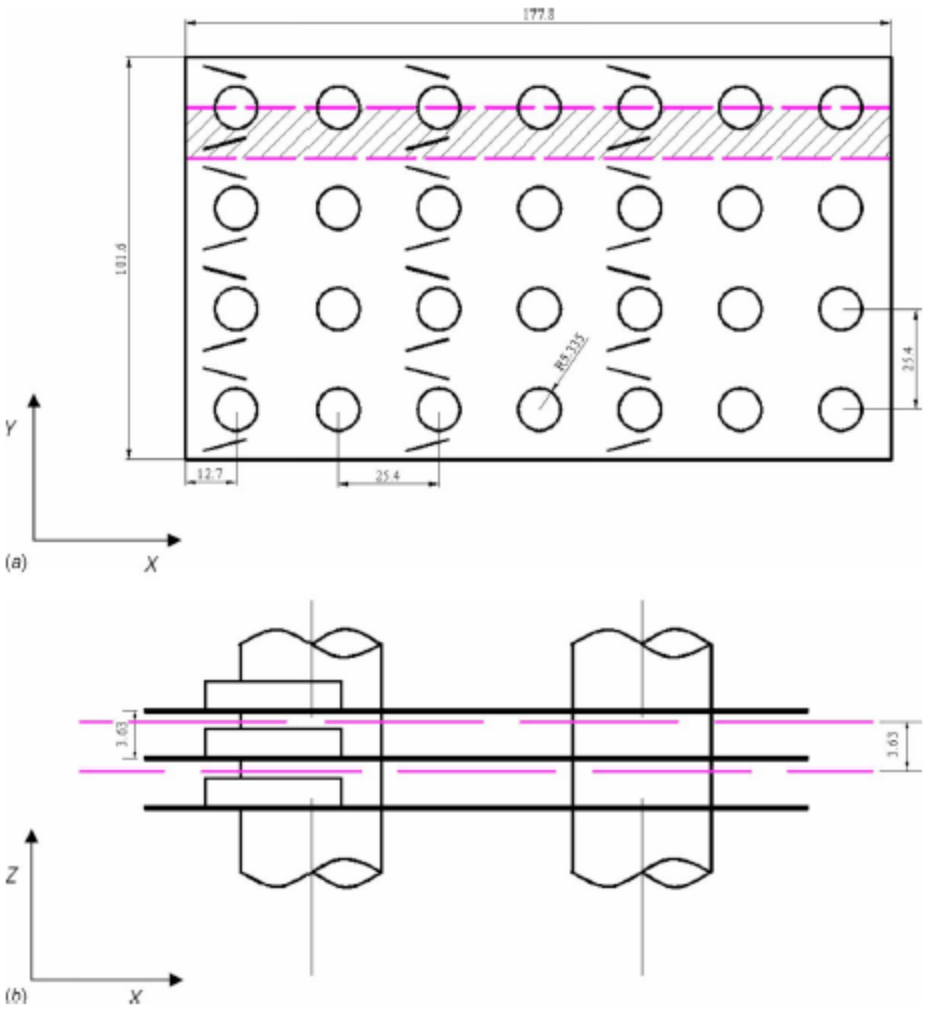



Fig. 4 Coordinate system and computational domain

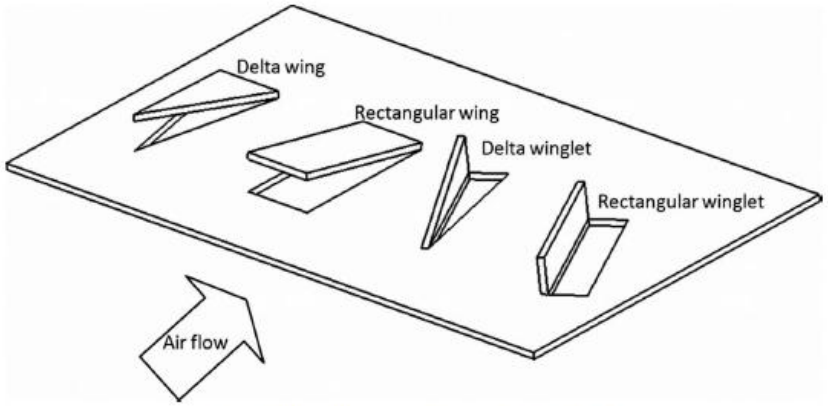



Fig. 2 Four basic vortex generator forms

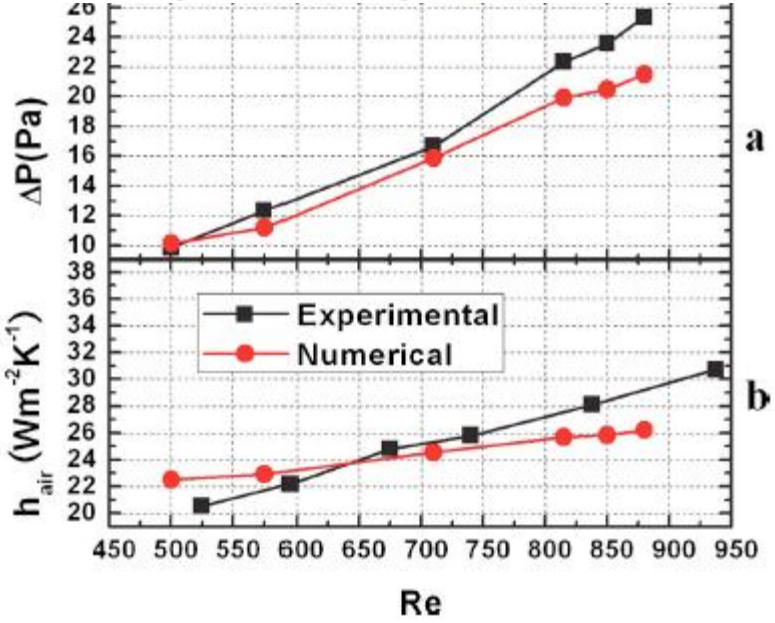



Fig. 5 Experimental numerical comparison of $h_{air}$ and $\Delta P$ for model validation

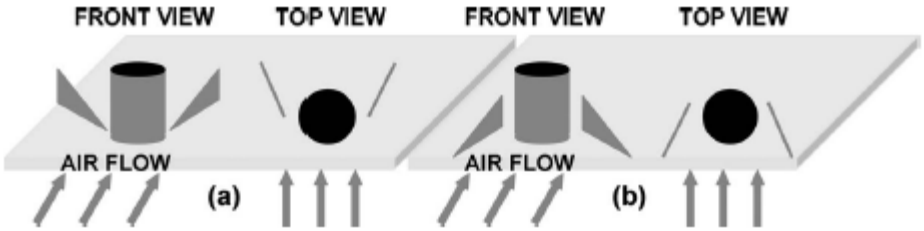
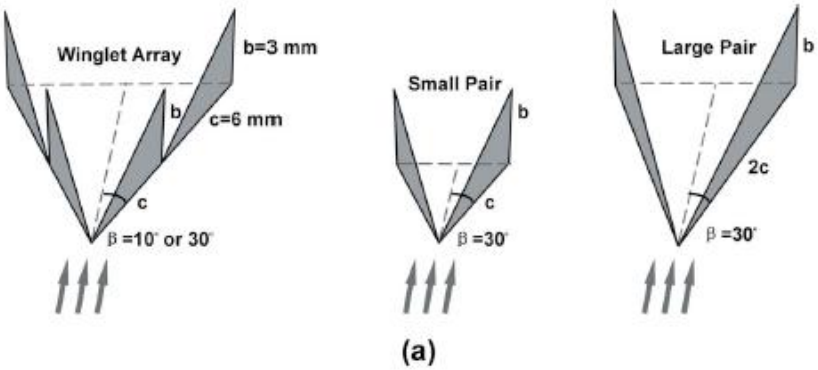
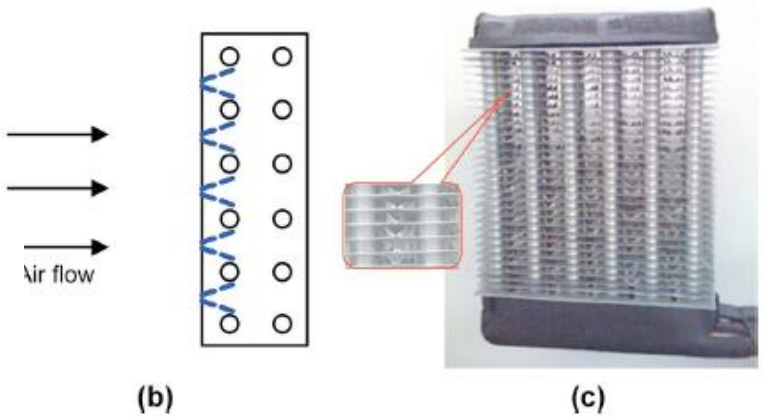



Fig. 1 Configuration of winglet-type VG on a fin surface: (*a*) common-flow-down and (*b*) common-flow-up




(*a*) Geometry of the proposed VG array and the single pair; (*b*) ectional view and (*c*) photograph of the test heat exchanger with d VGs at the leading edge

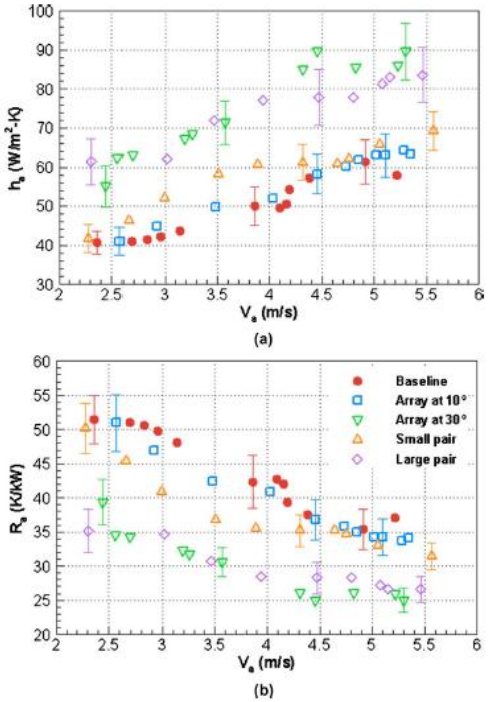



Fig. 6 Baseline and VG-enhanced thermal performance as a function of frontal air velocity: (*a*) air-side heat-transfer coefficient and (*b*) air-side thermal resistance

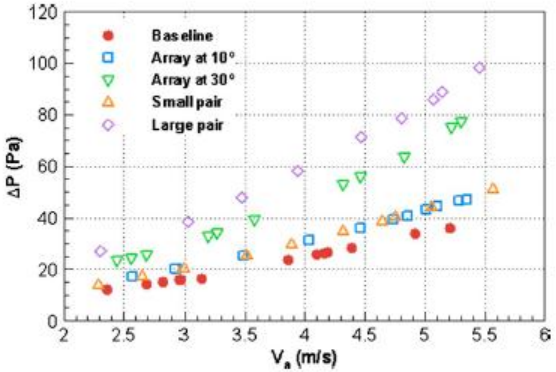
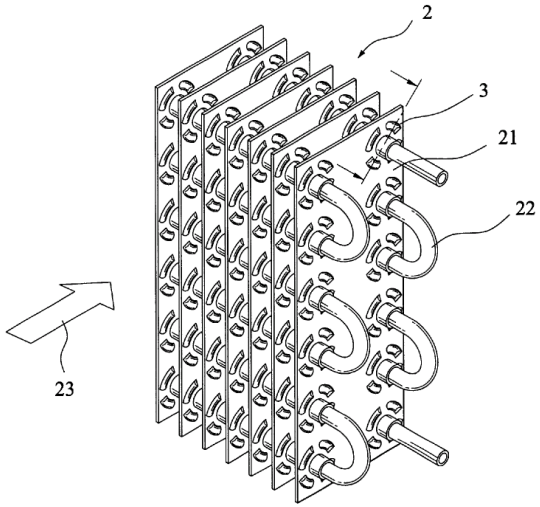
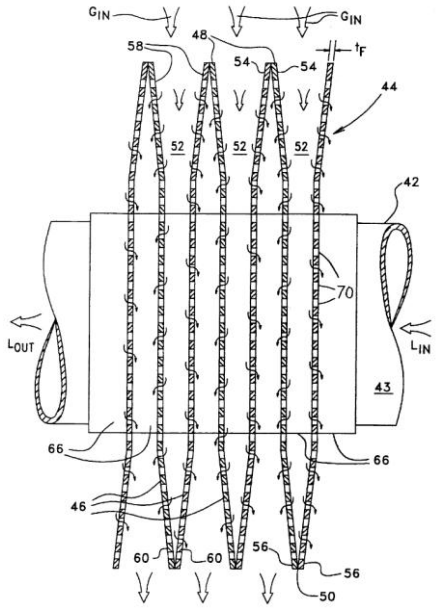



Fig. 7 Pressure drop across the heat exchanger with and without VGs




(c) US patent 6349761




(d) US patent 6378605

Fig. 14 Schematic of the US patents of 7004242, 6578627, 6349761, and 6378605.

# 結 論



- 斷續型鰭片仍是市場的主流，但其增加的壓損相當的大，而且當鰭片間距具較小，其熱傳效果並不好。比較好的鰭片間距應在1.3 mm 以上。
- 在較低操作流速下，發展區中鰭片透過各種熱傳增強模式是非常有效，如斷續型或具渦流產生器鰭片。而在完全發展區，傳統的熱傳增強型鰭片則失去其優勢。
- 為解決這個問題，採用不對稱的設計產生不穩定流場為有效的方式。
- 現有的專利分析顯示，已有相當多設計採用渦流產生器的概念，但目前市場上仍以斷續型鰭片為主。

# *Thanks for Your Attention*