Assessing natural ventilation flows - laboratory and analytical modelling

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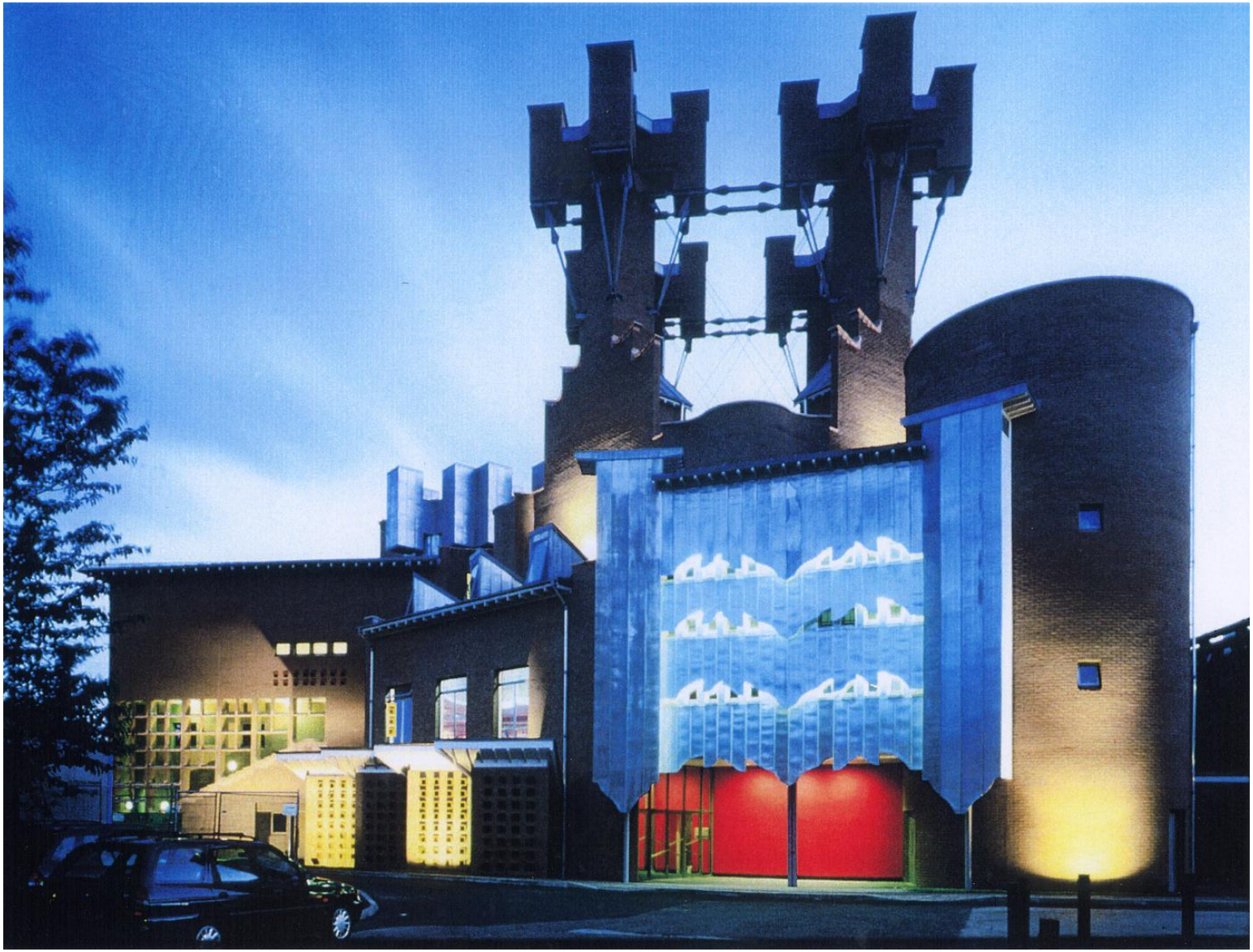
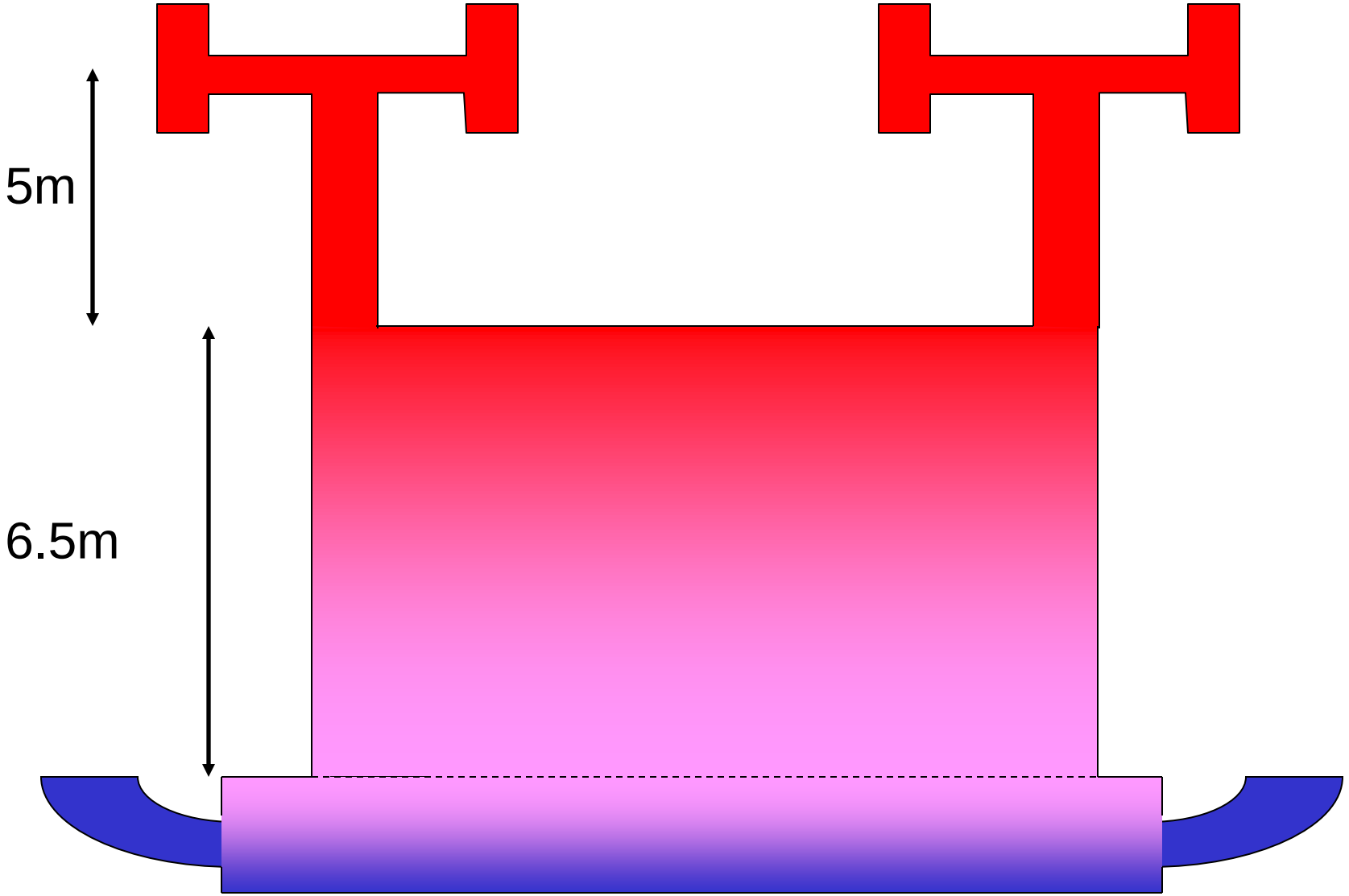
Contact Theatre Before

Before renovation

Contact Theatre, after renovation

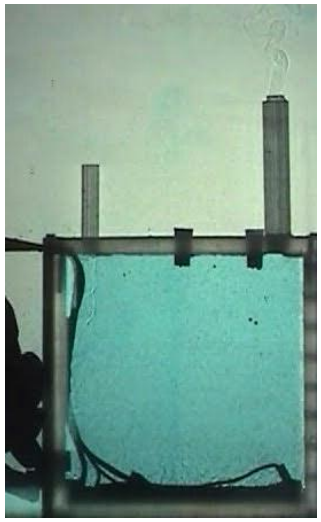


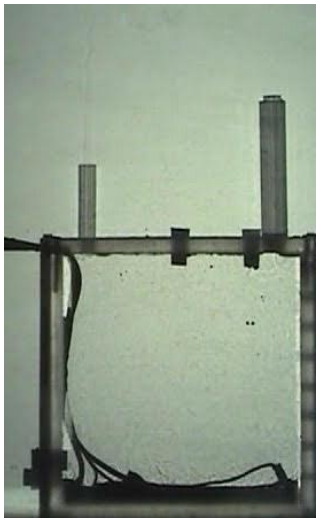
Contact Theatre, Studio

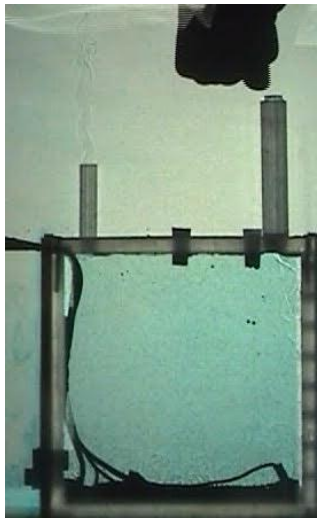


Concept - displacement ventilation when warmer inside

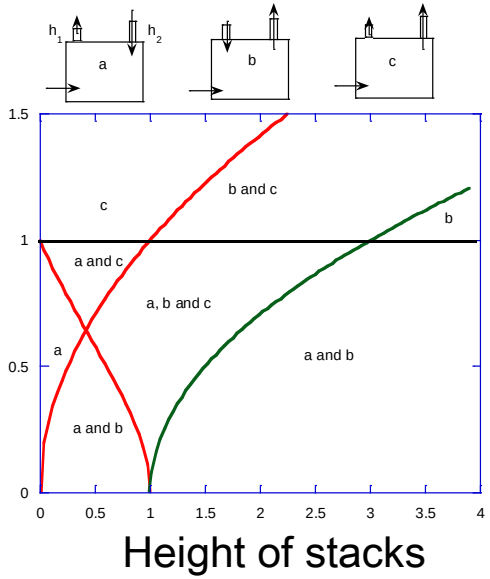
Multiple Stacks





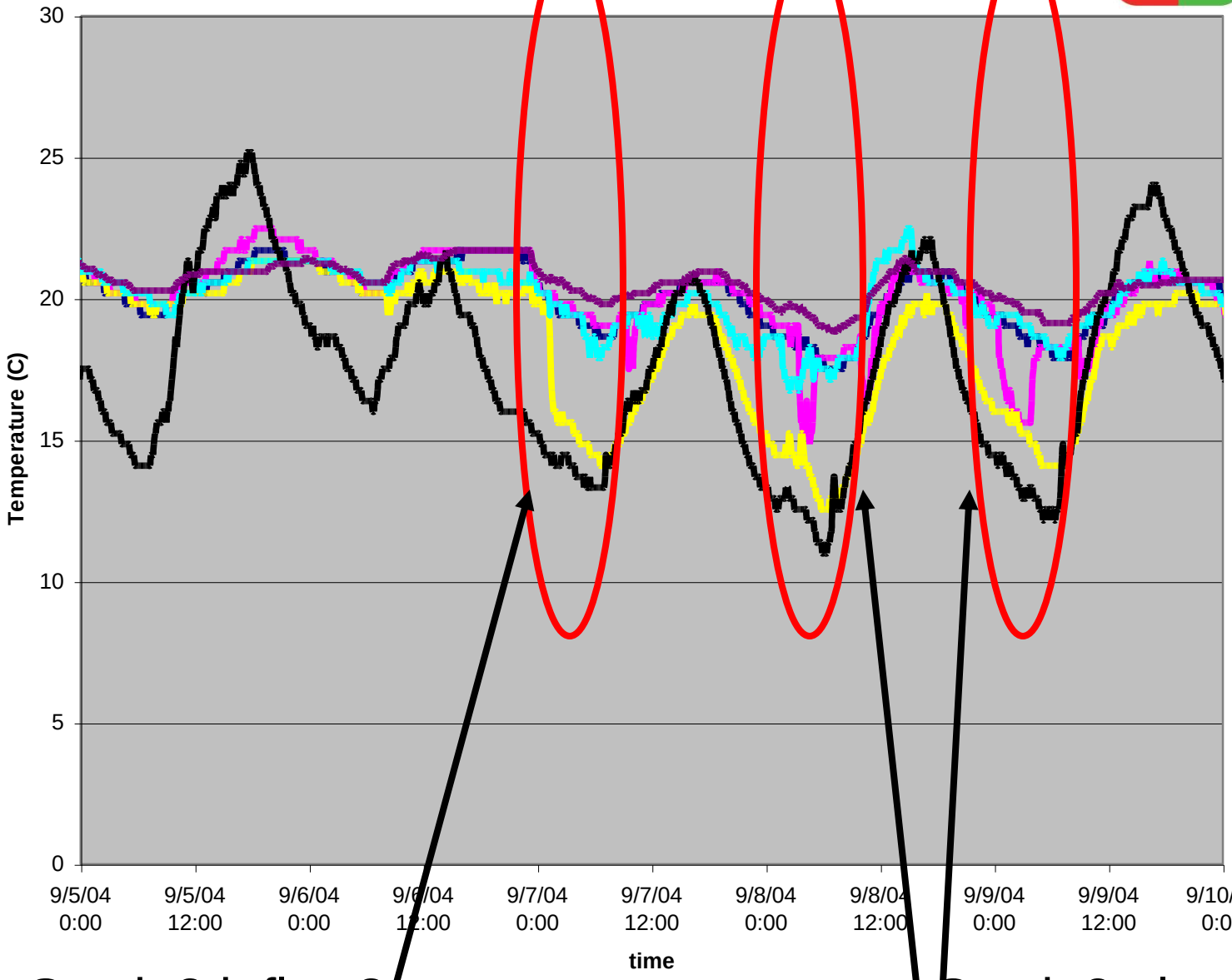


Area of lower aperture



Height of stacks

Contact Theatre, Studio



Evening/ Morning Warmer inside than outside

Stack 3 inflow?

Stack 2 also inflow later?

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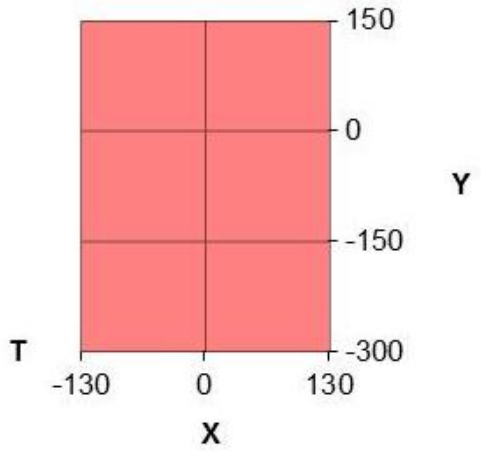
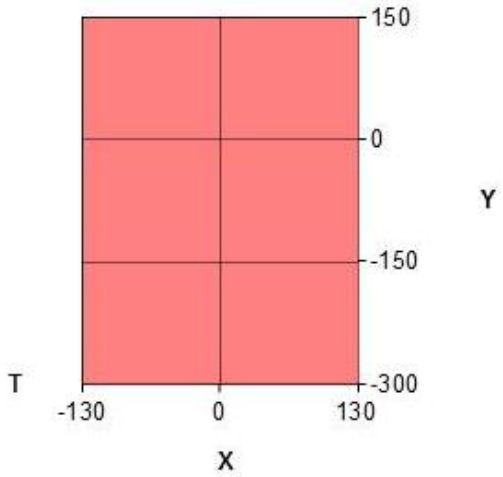
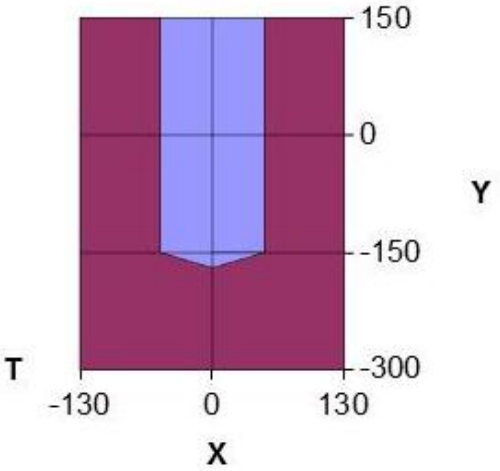
Stack 1 outflow



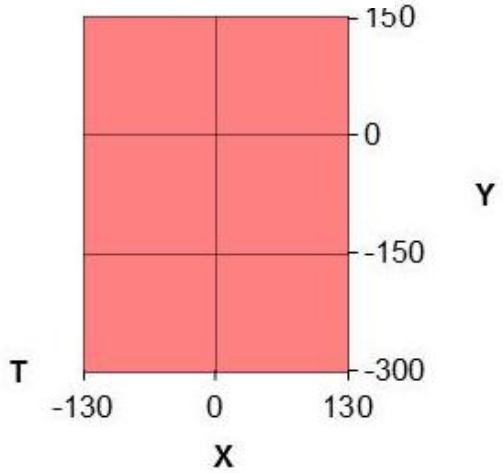
Stack 2 outflow

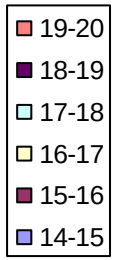


Stack 3 inflow



Stack 4 outflow





Stack 3 inflow → balance of base and stack areas

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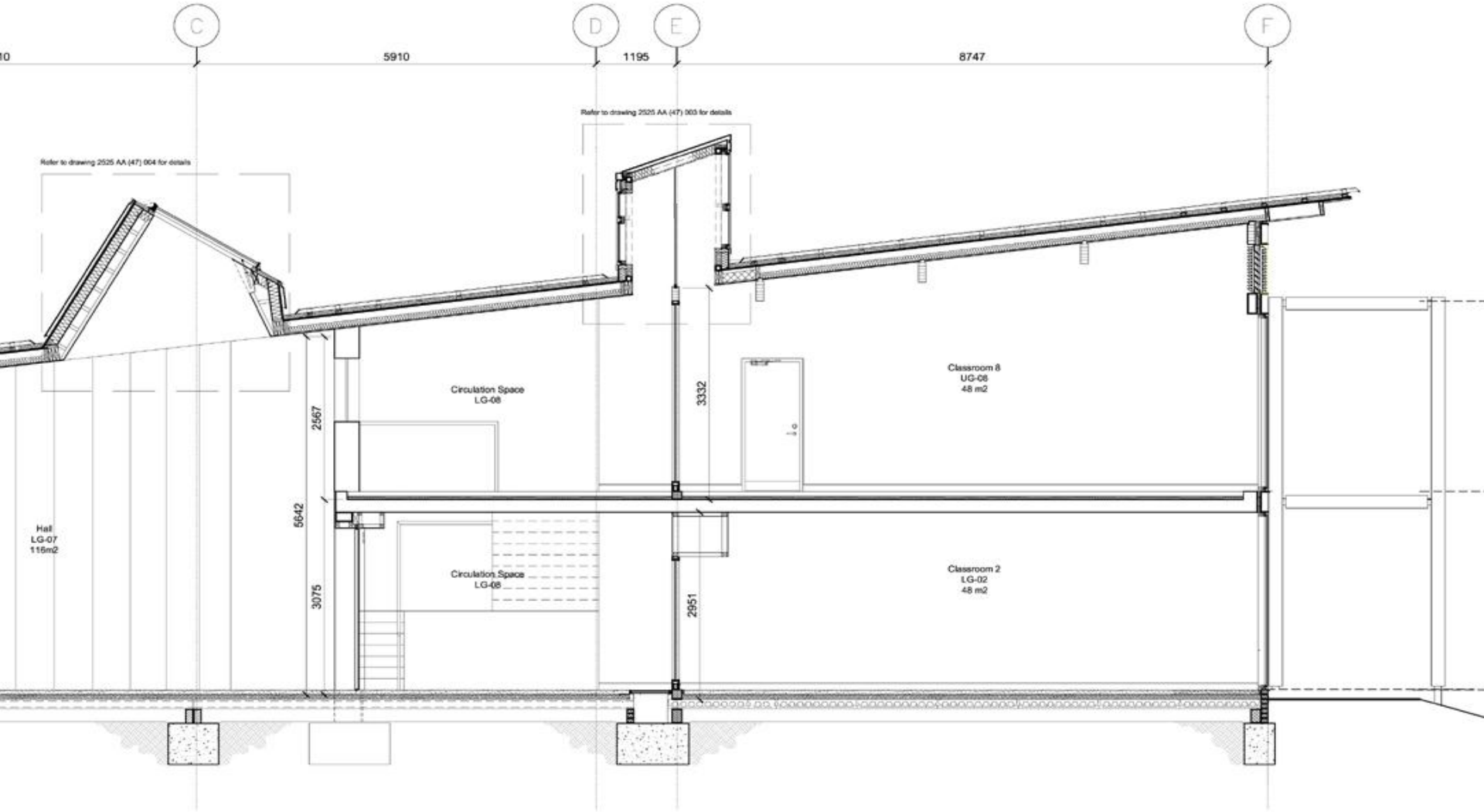
Detailed section



Associated Architects

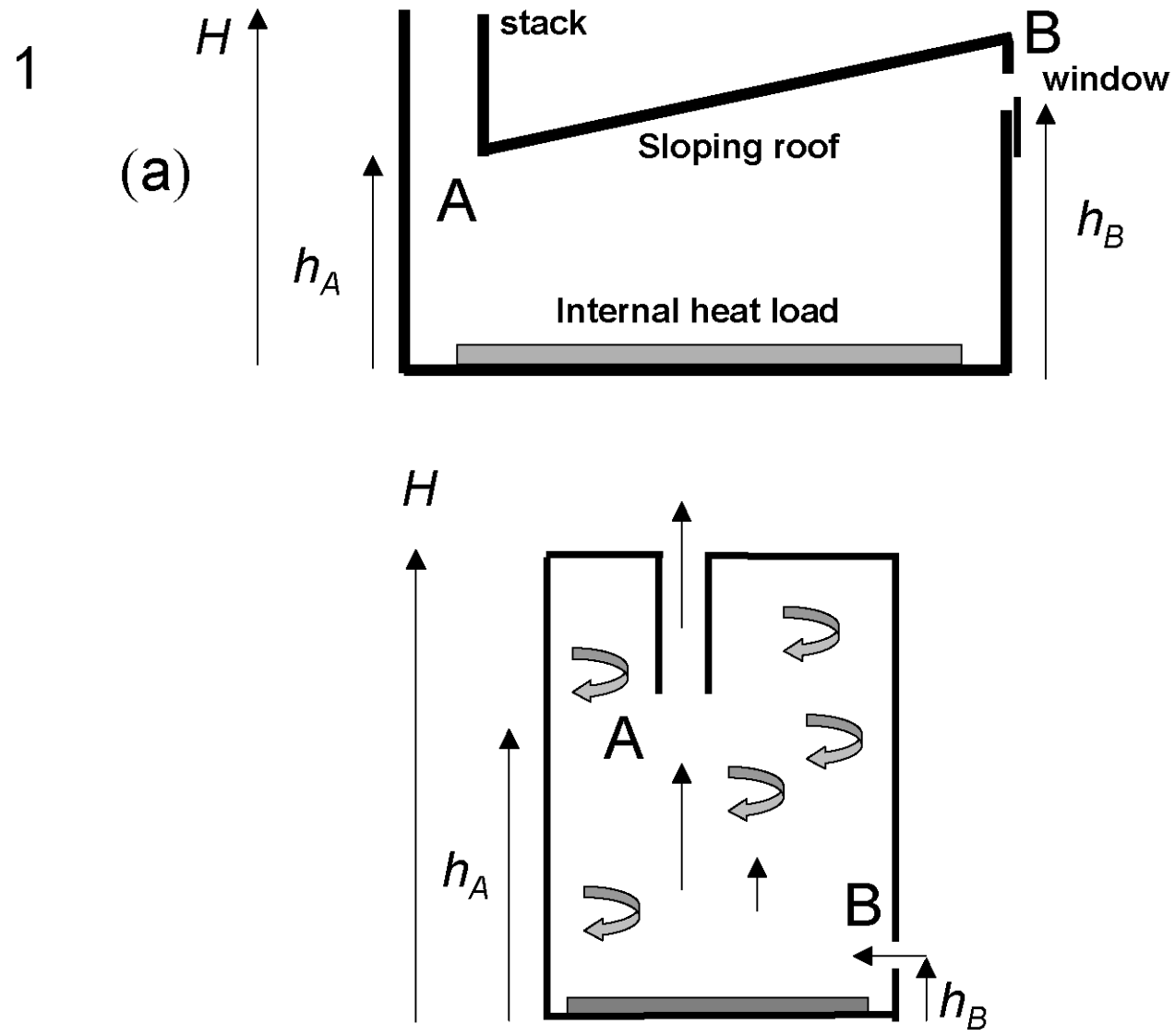
HOARE LEA

worcestershire countycouncil

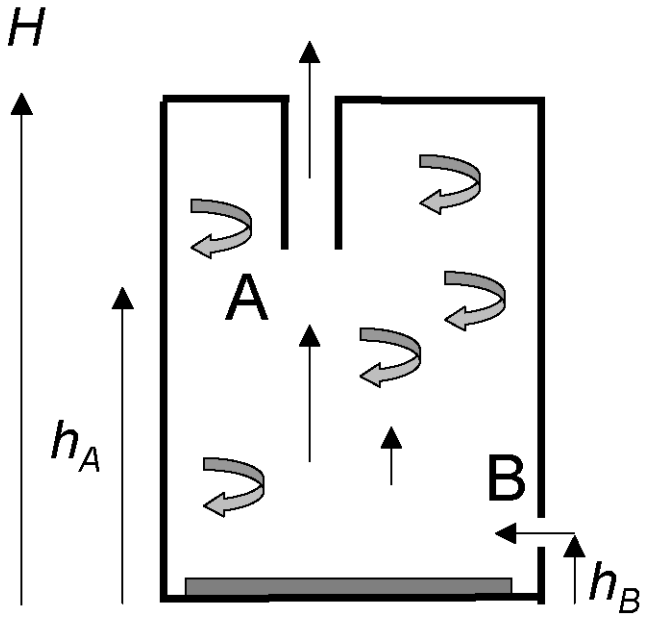
BP INSTITUTE FOR MULTIPHASE FLOW

Hagley School

Distributed heating at base



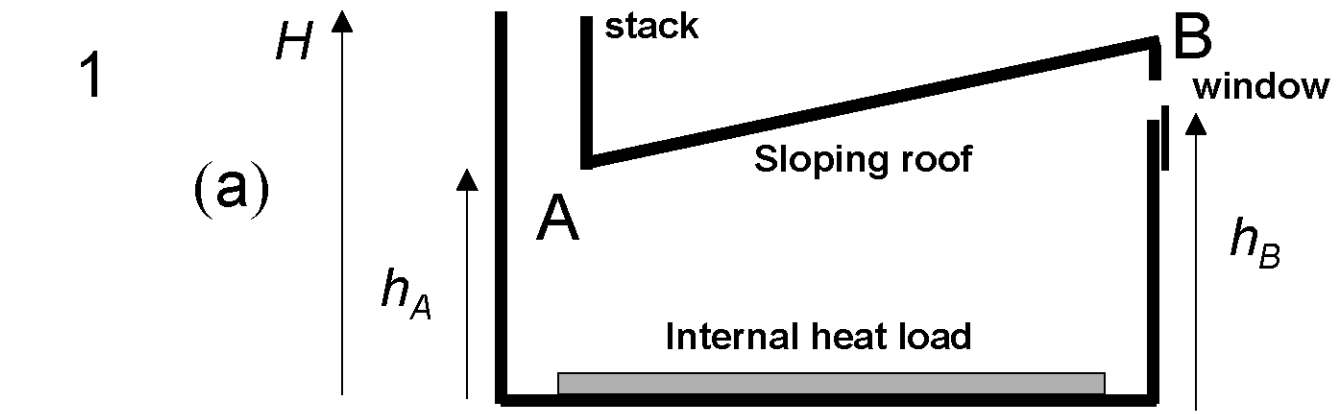
Flow calculation for outflow from stack

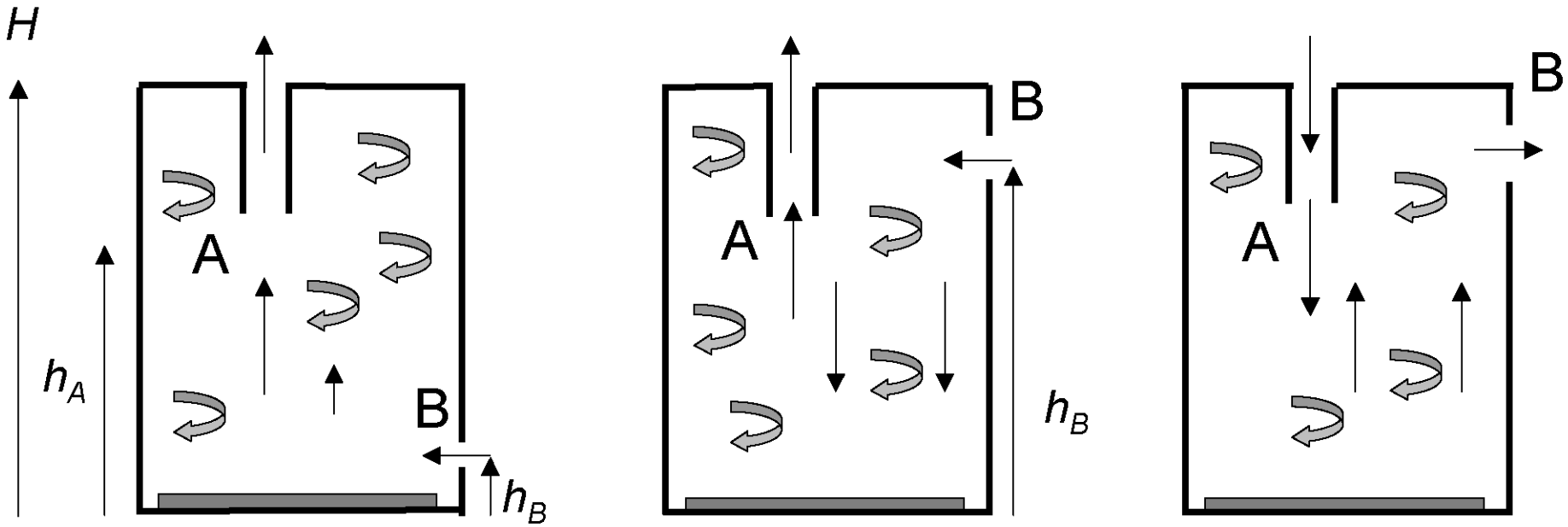


Vol flux = f(H-h_B)

1

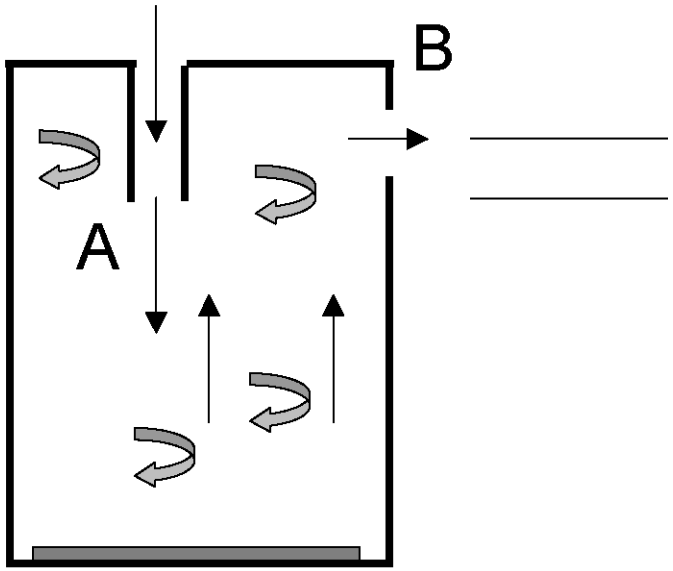
(a)


H
stack
B
window
Sloping roof
A
h_A
h_B
Internal heat load


H
A
B
h_A
h_B
A
B
h_B
A
B

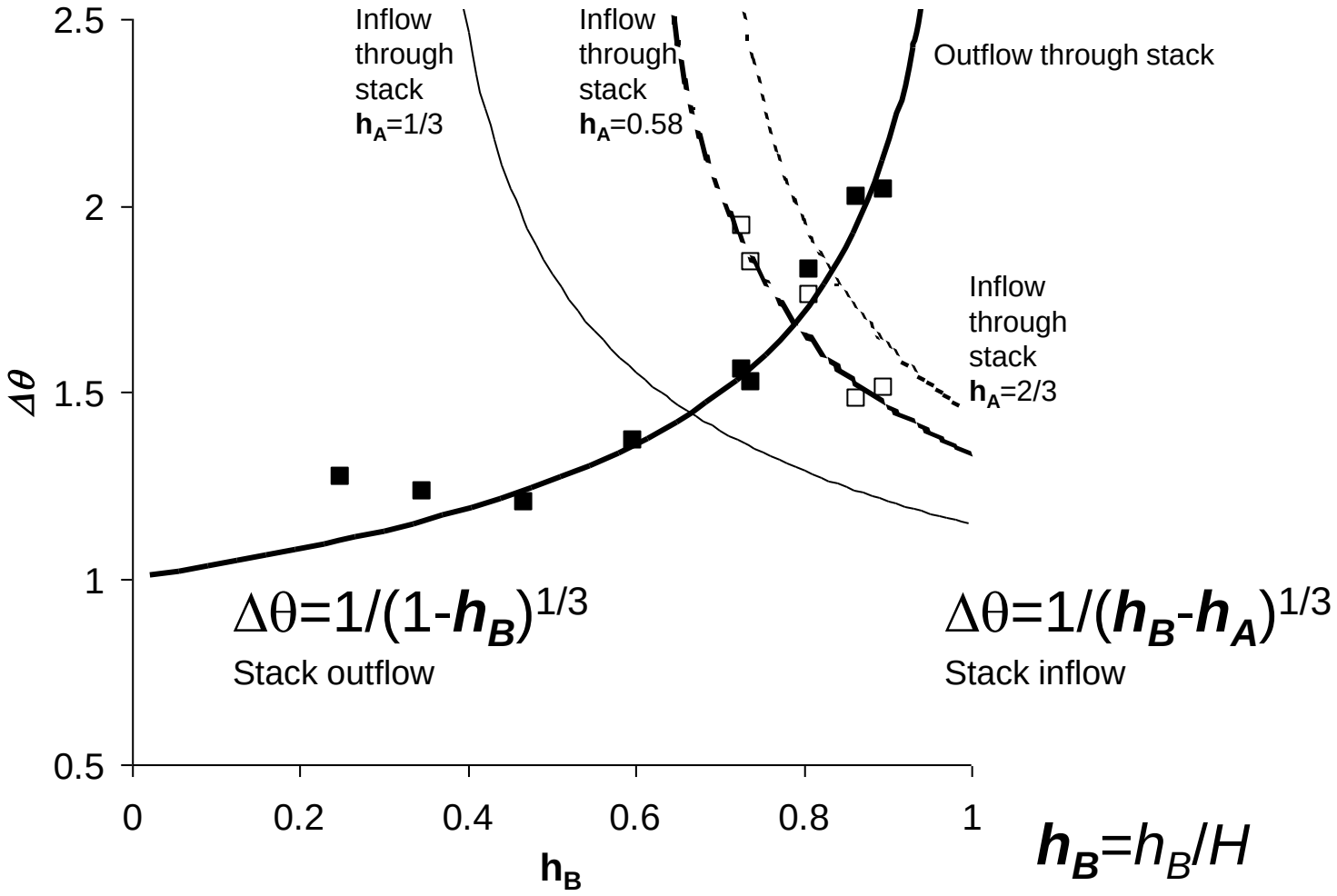
Note $h_B > h_A$

Flow calculation for inflow through stack

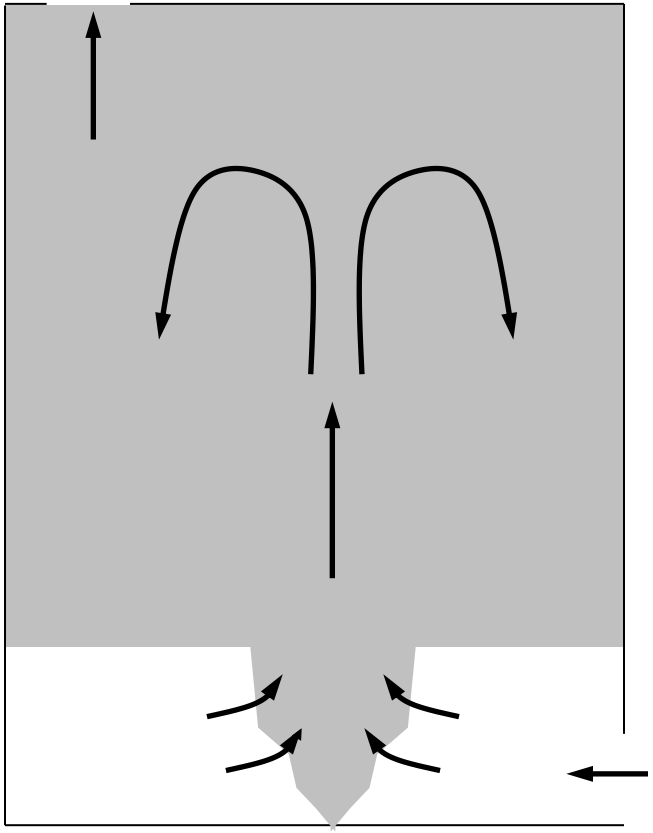


h_B-h_A

Vol flux = f(h_{B-}-h_A)


2.5
2
1.5
1
0.5
Δθ
0
0.2
0.4
0.6
0.8
1
h_B
Inflow through stack h_A=1/3
Inflow through stack h_A=0.58
Outflow through stack
Inflow through stack h_A=2/3
Δθ=1/(1-h_B)^1/3
Stack outflow
Δθ=1/(h_B-h_A)^1/3
Stack inflow
h_B=h_B/H

Localised heating at base



Two layer stratification

Volume flux from plume to upper layer

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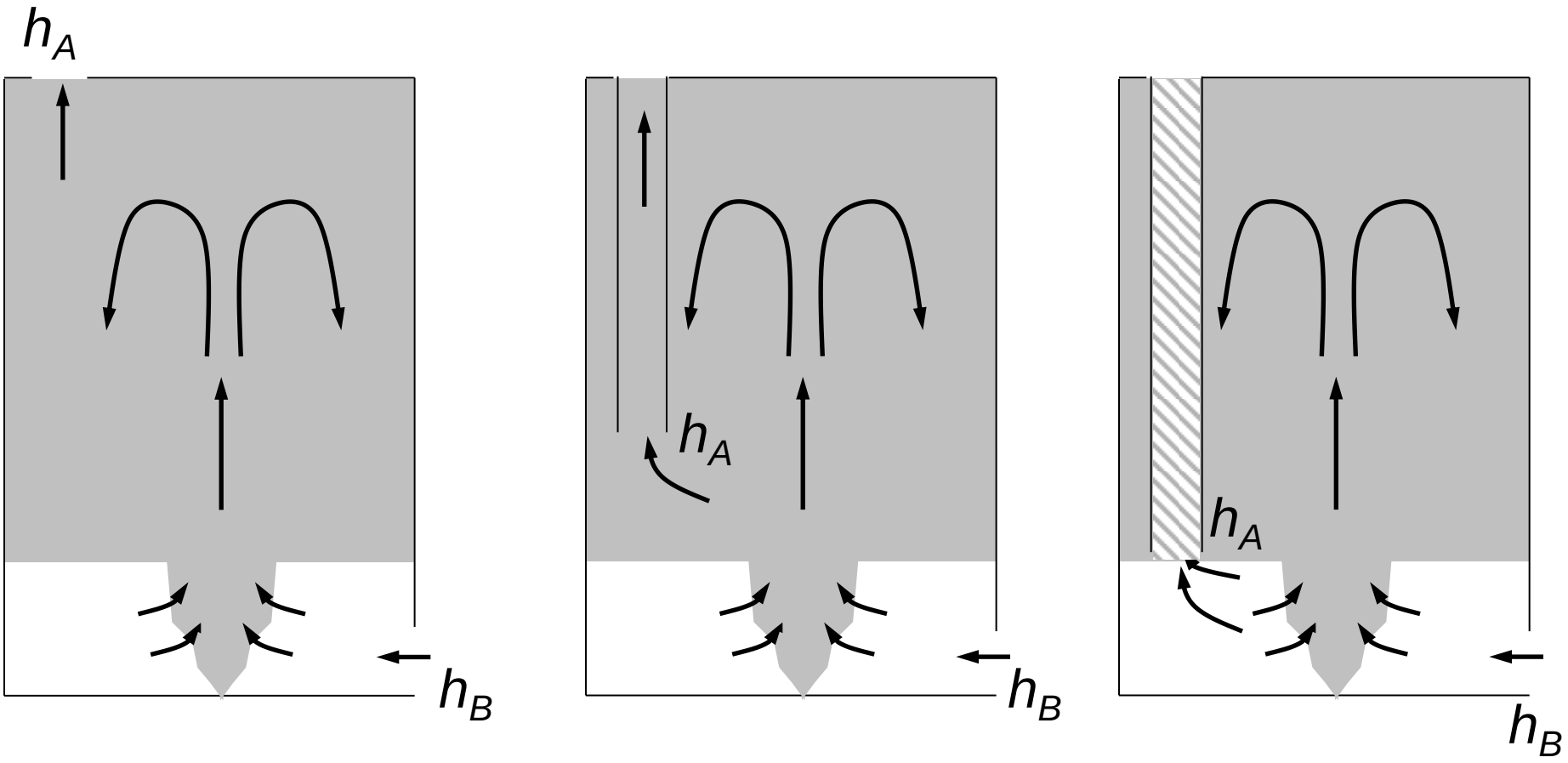
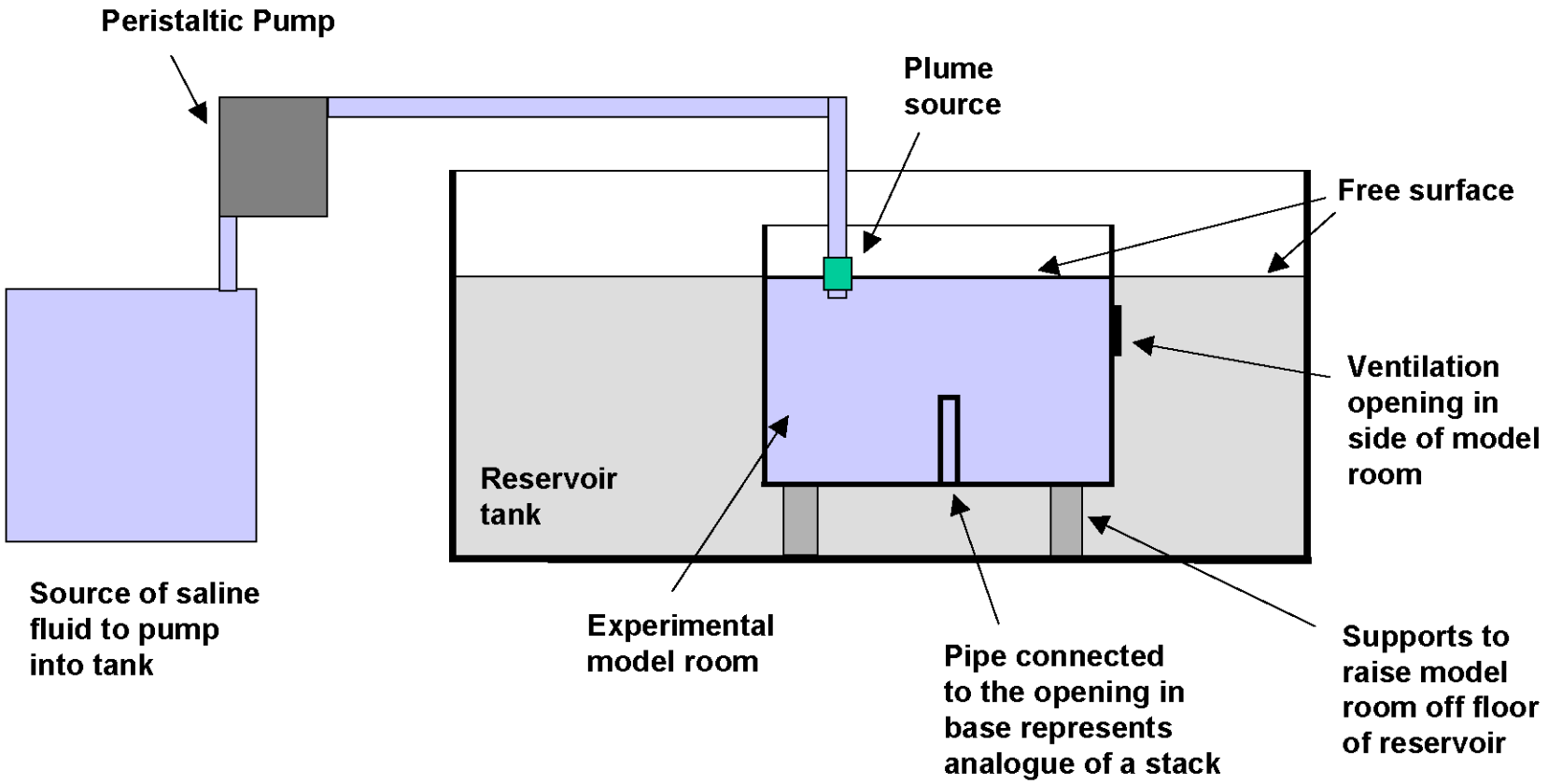
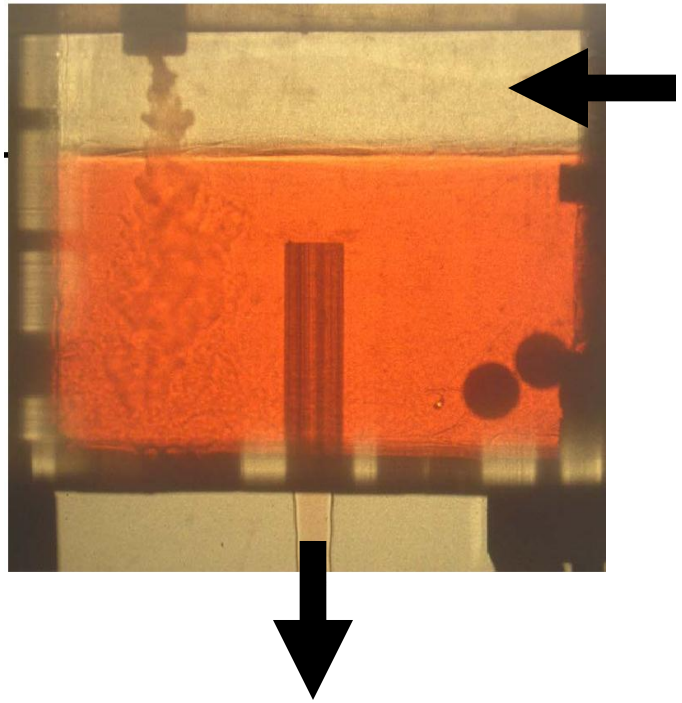
Localised heating at base



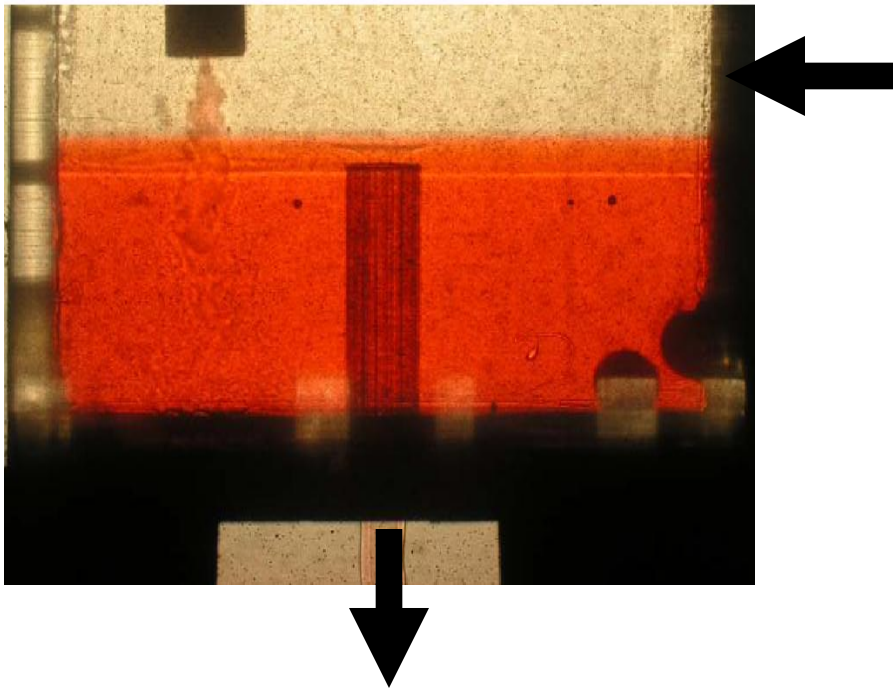
Pure hot layer outflow

Mixed outflow

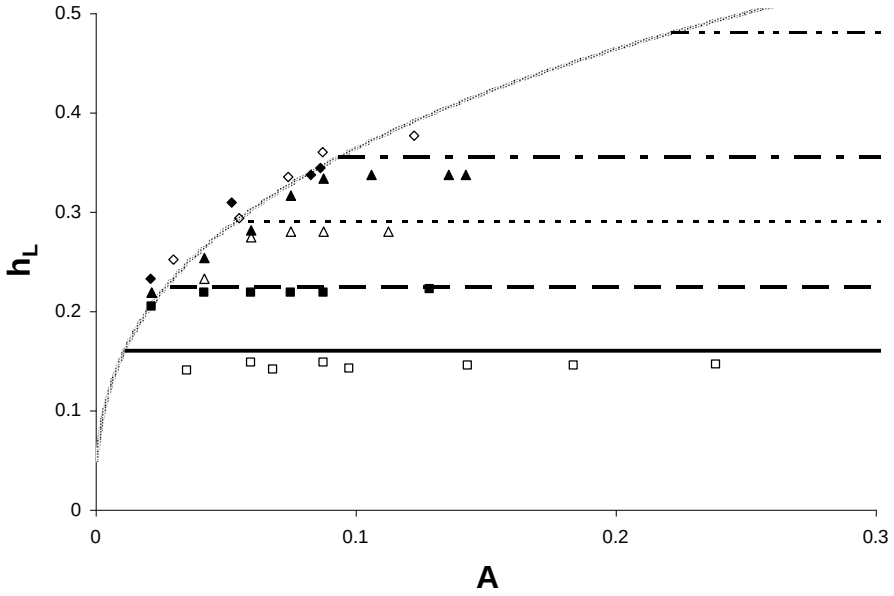

Peristaltic Pump
Plume source
Free surface
Ventilation opening in side of model room
Reservoir tank
Source of saline fluid to pump into tank
Experimental model room
Pipe connected to the opening in base represents analogue of a stack
Supports to raise model room off floor of reservoir



Pure “hot” layer outflow



Mixed outflow



h_A=0.48

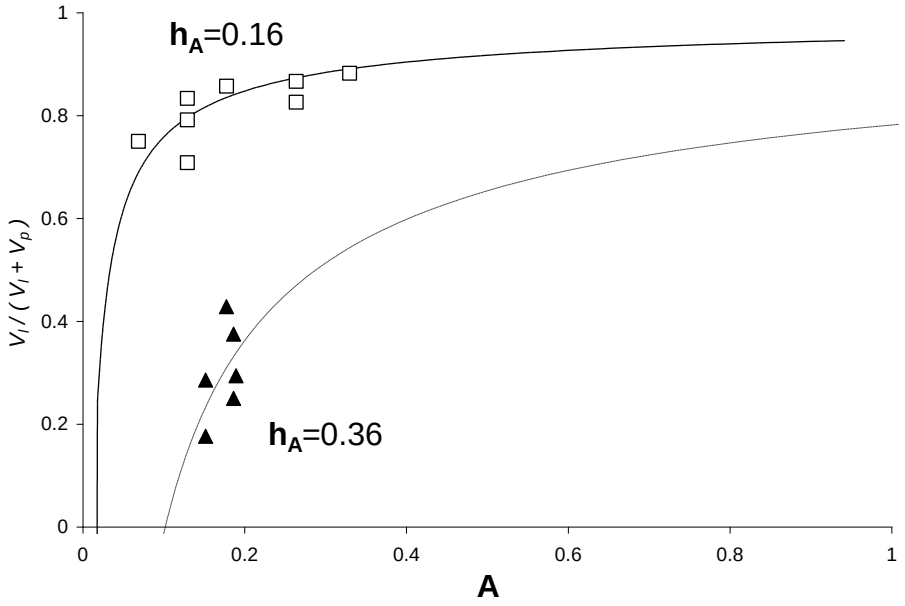
h_A=0.36

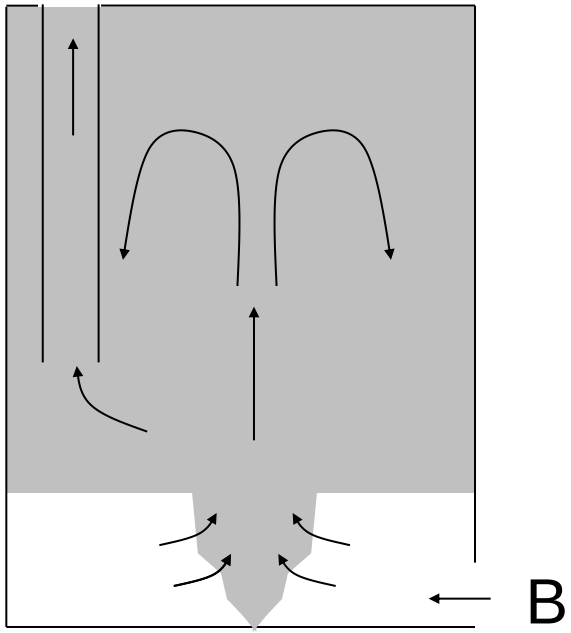
h_A=0.3

h_A=0.22

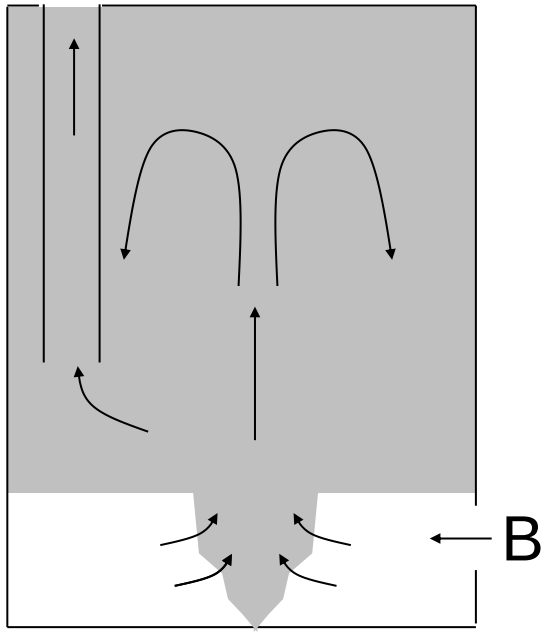
h_A=0.16

Buoyancy in stack, function of average density
Conservation of buoyancy
Volume flux through stack driven by buoyancy
Volume flux in plume MTT

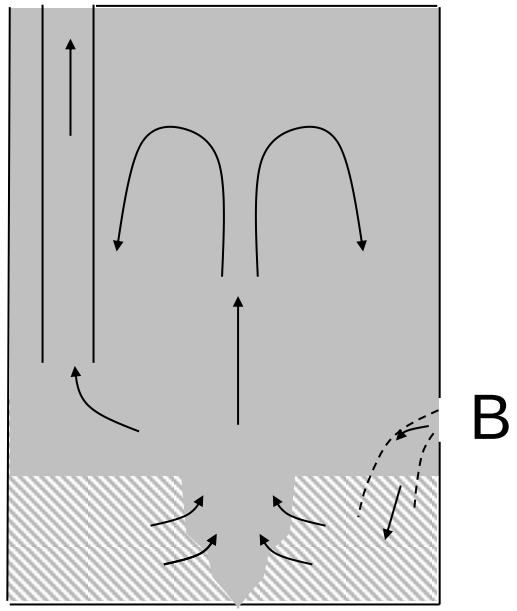




I



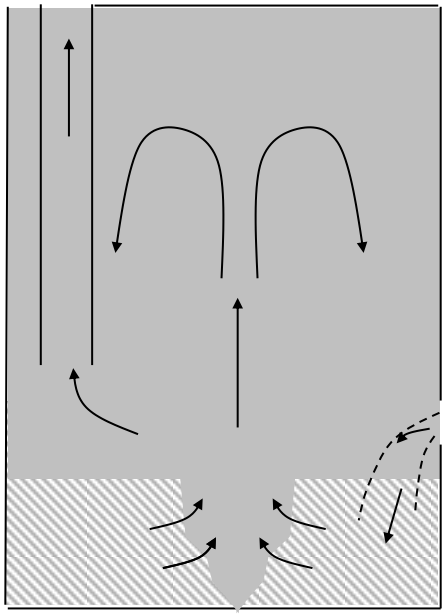
I



II

-ve buoyant plume from B
+ve buoyant plume from “heater”

Entrainment by descending plume
Virtual origin (Turner, Buoyancy Effects in Fluids)



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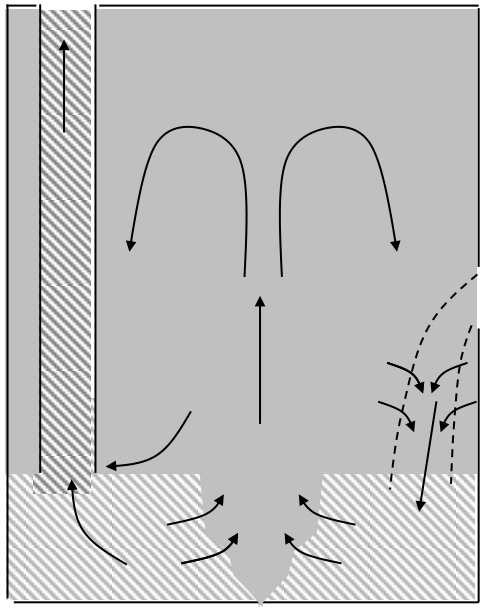

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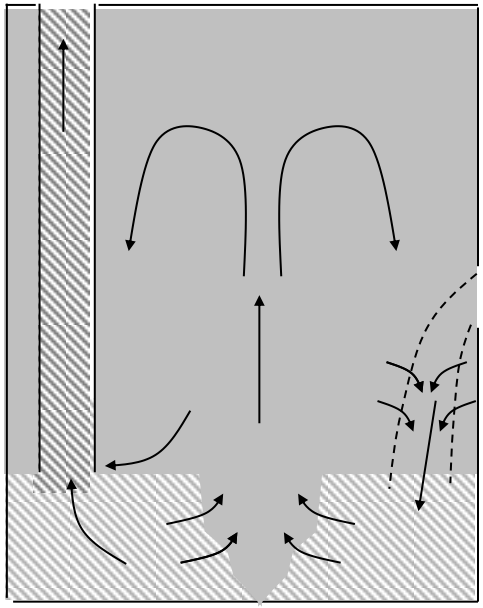

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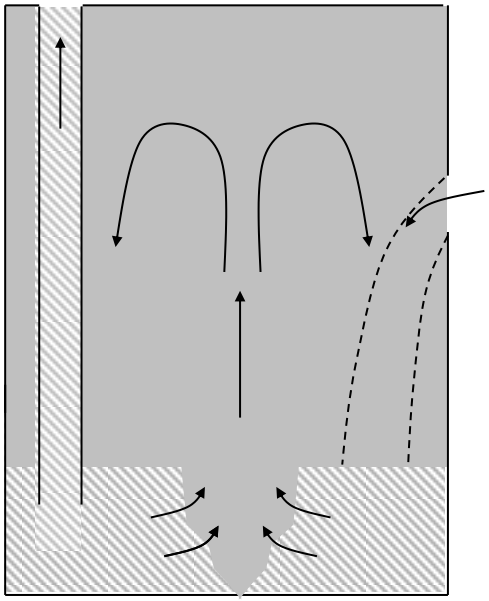

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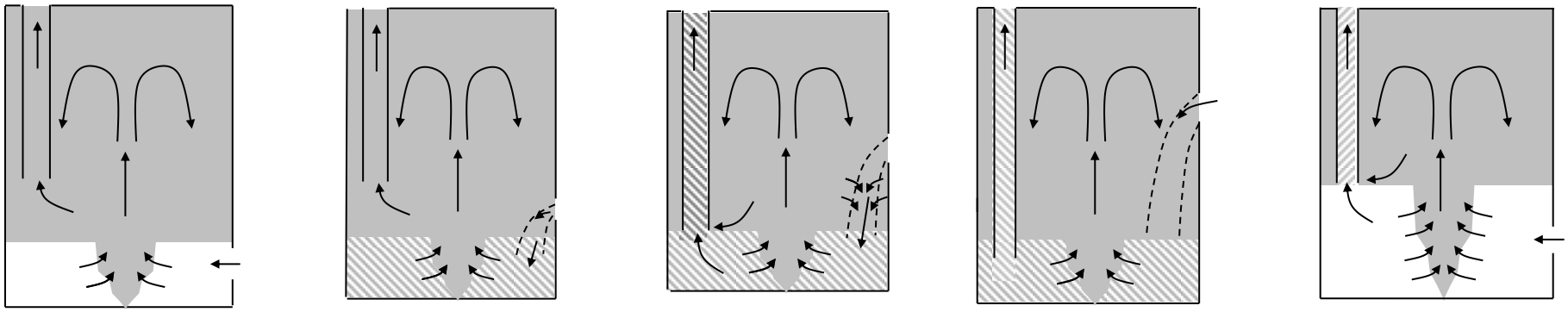
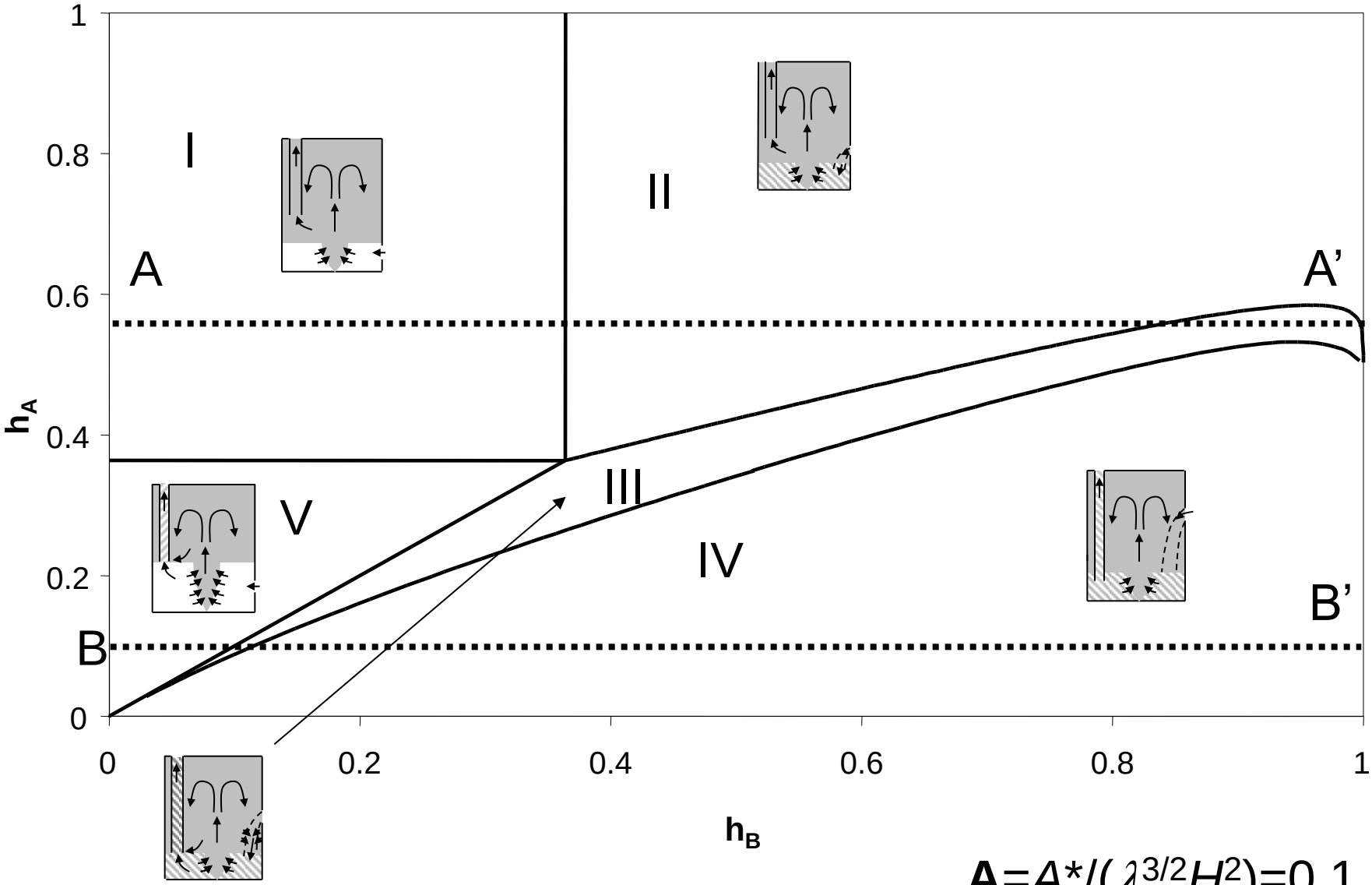
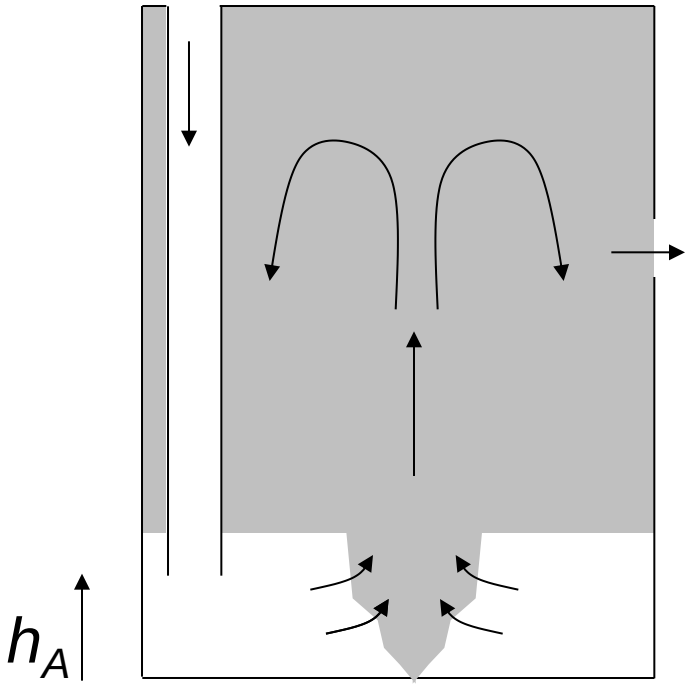


I II III IV V



$\mathbf{A}=A^*/(\lambda^{3/2}H^2)=0.1$



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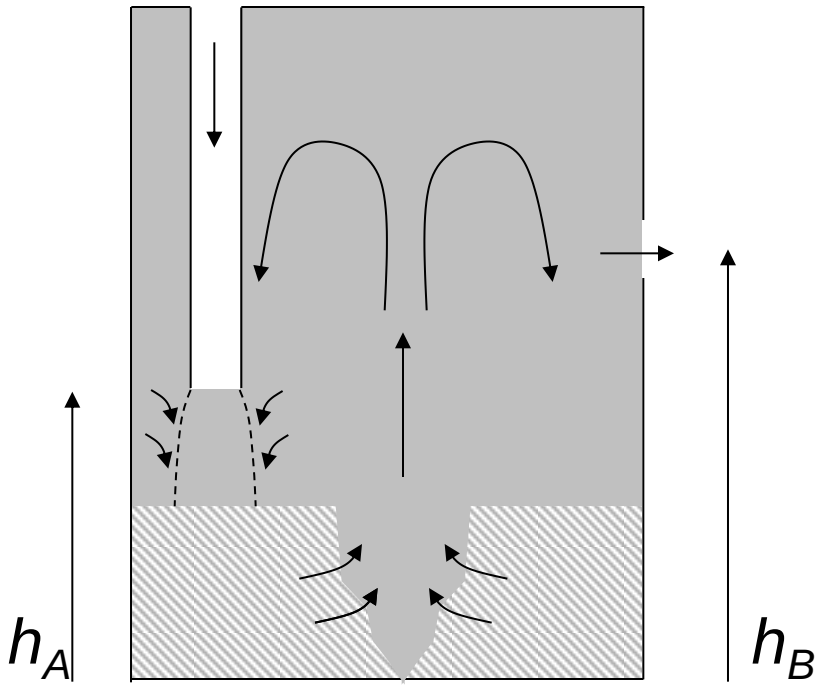

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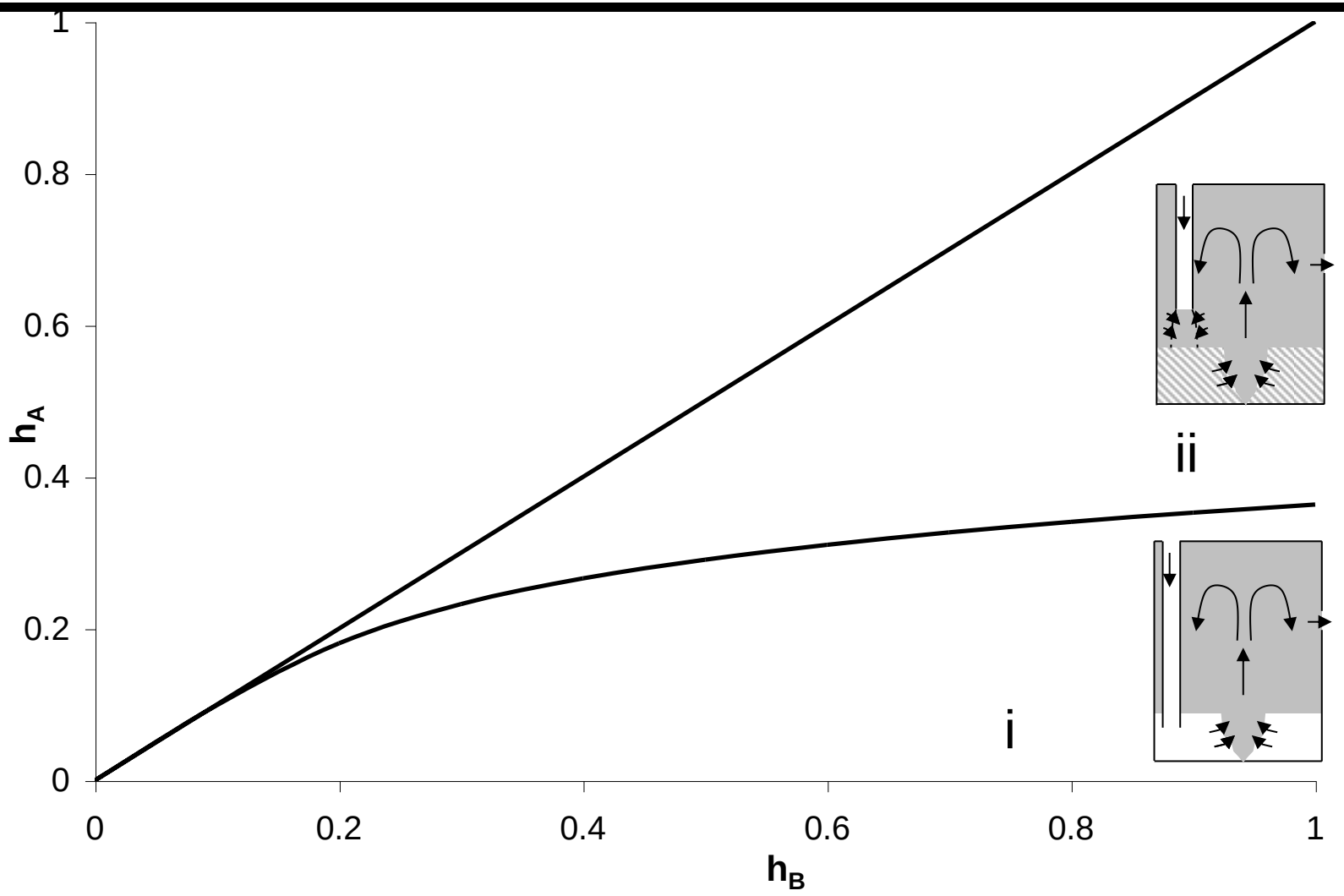
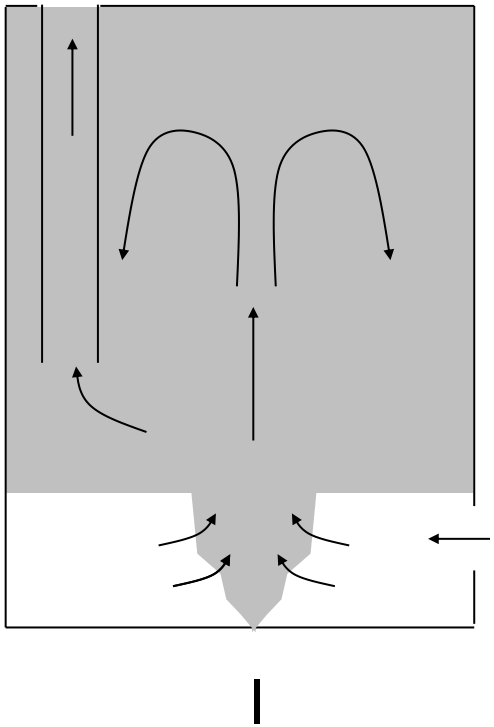
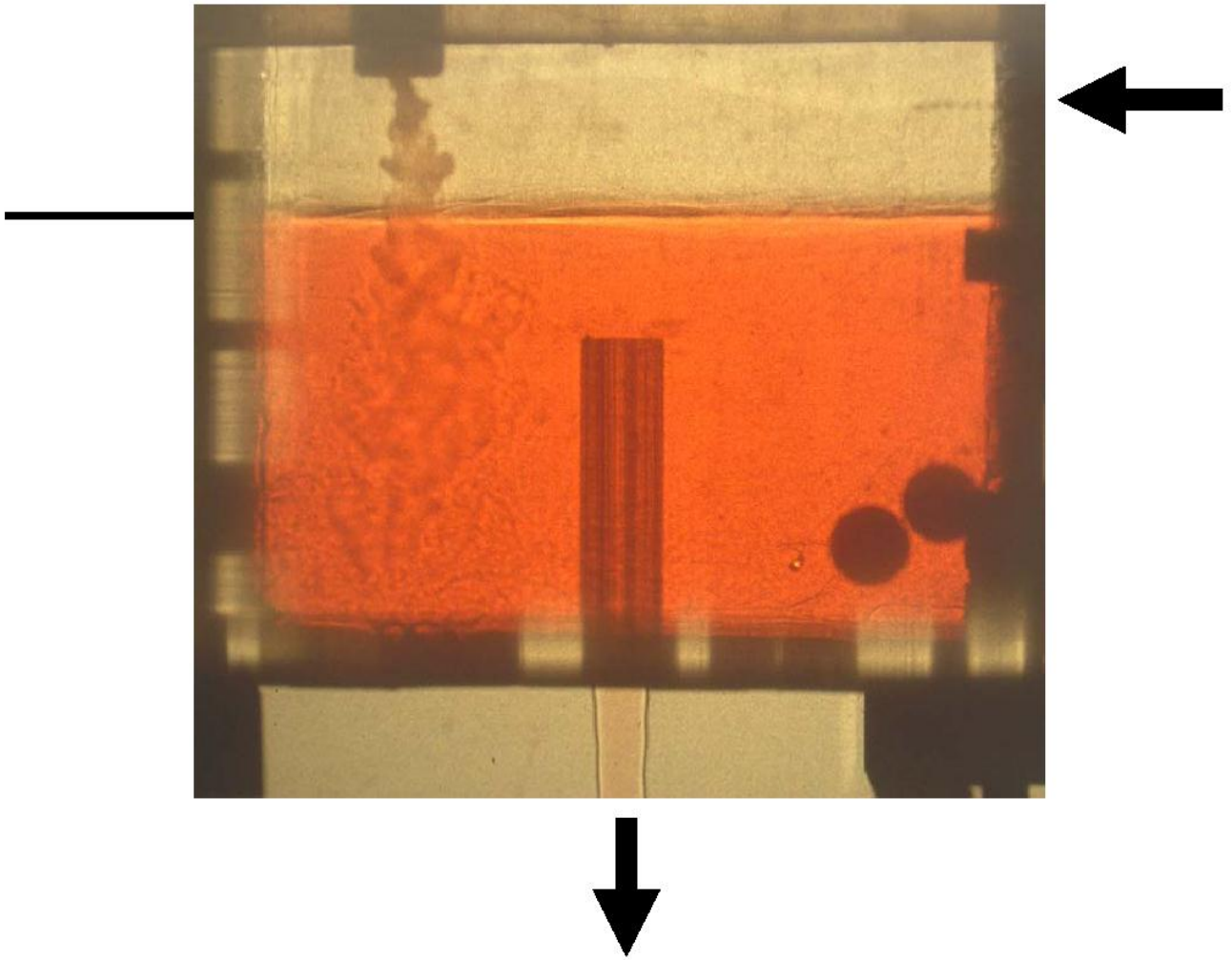
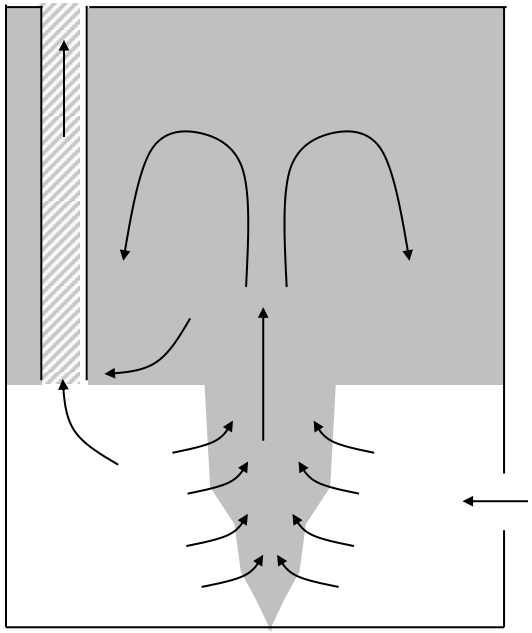

1
0.8
0.6
0.4
0.2
0
h_A
0
0.2
0.4
0.6
0.8
1
h_B
ii
i







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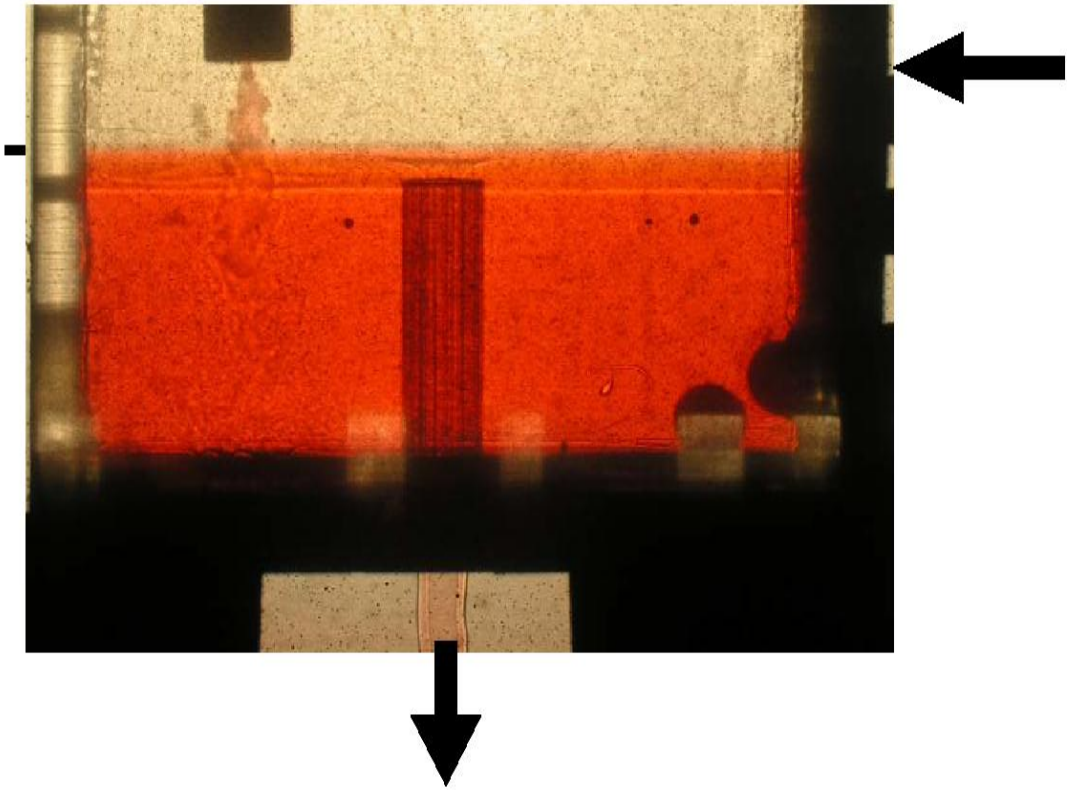

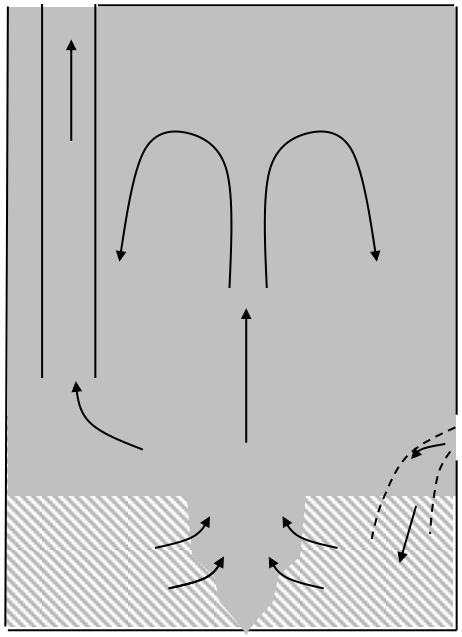

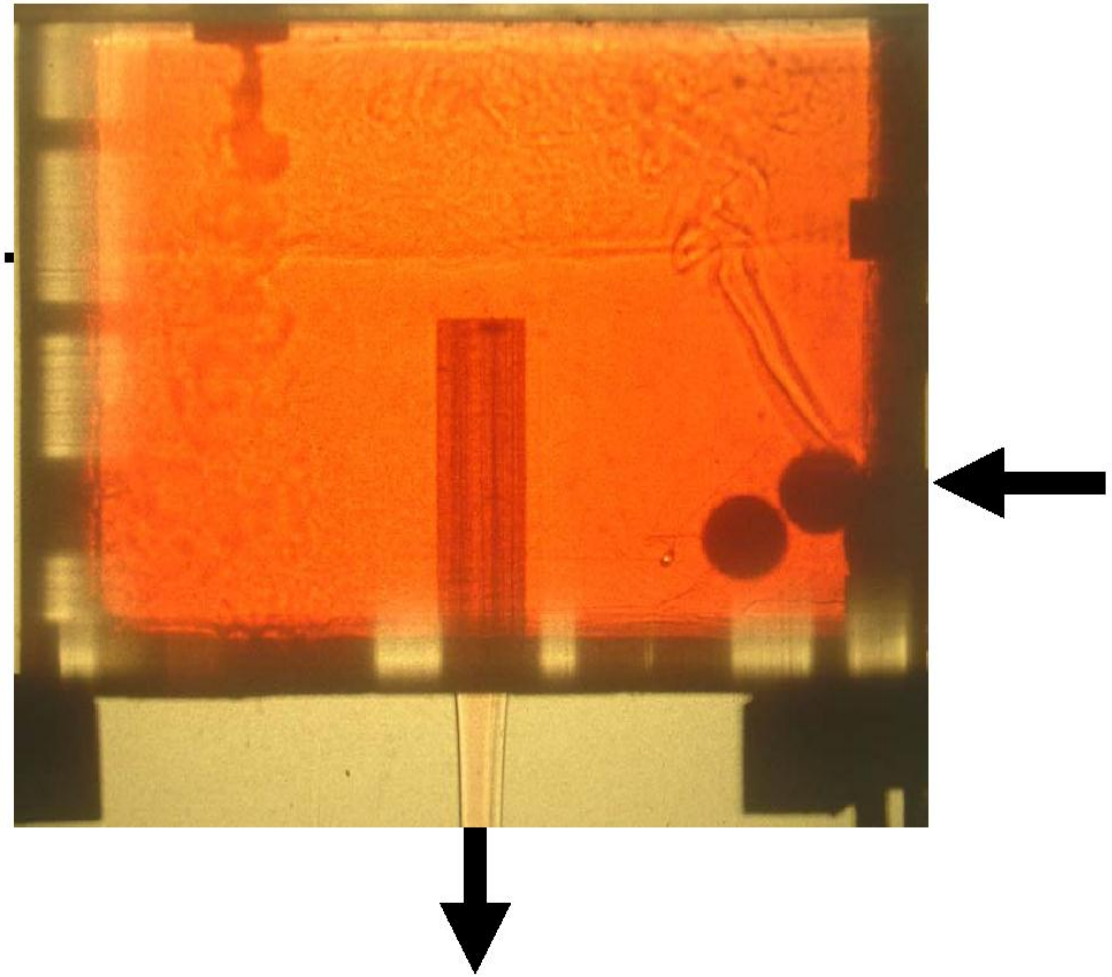

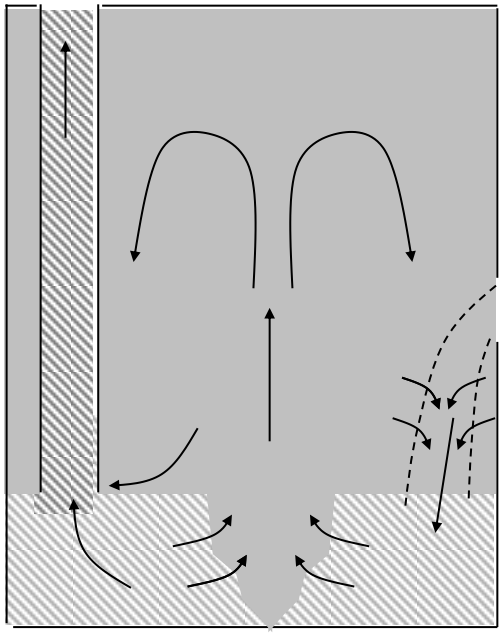

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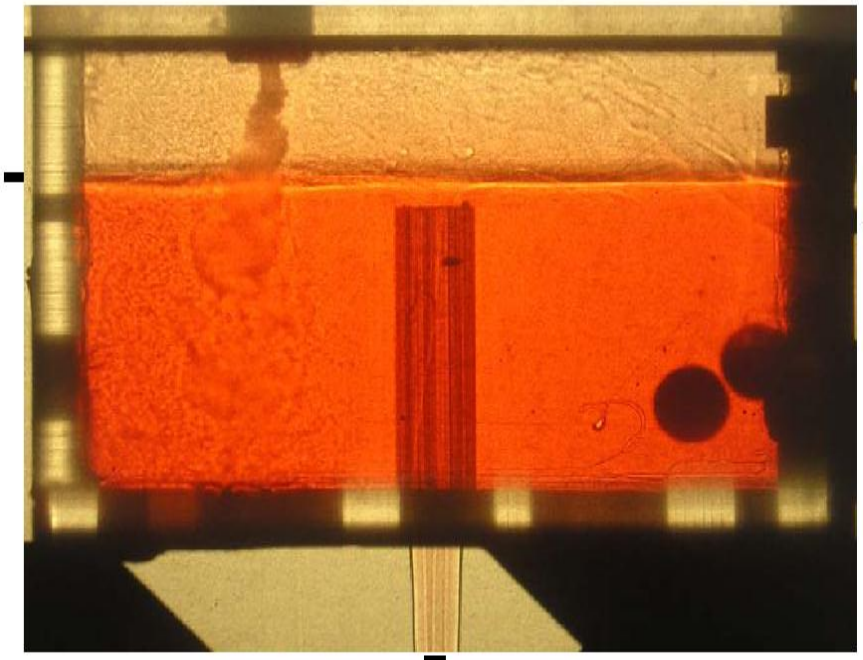

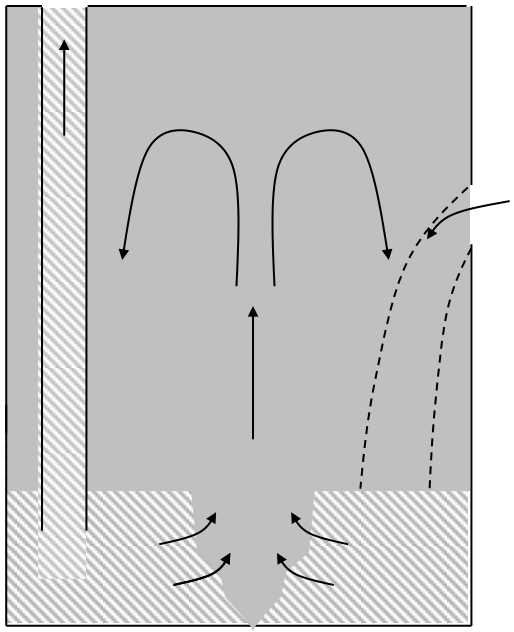

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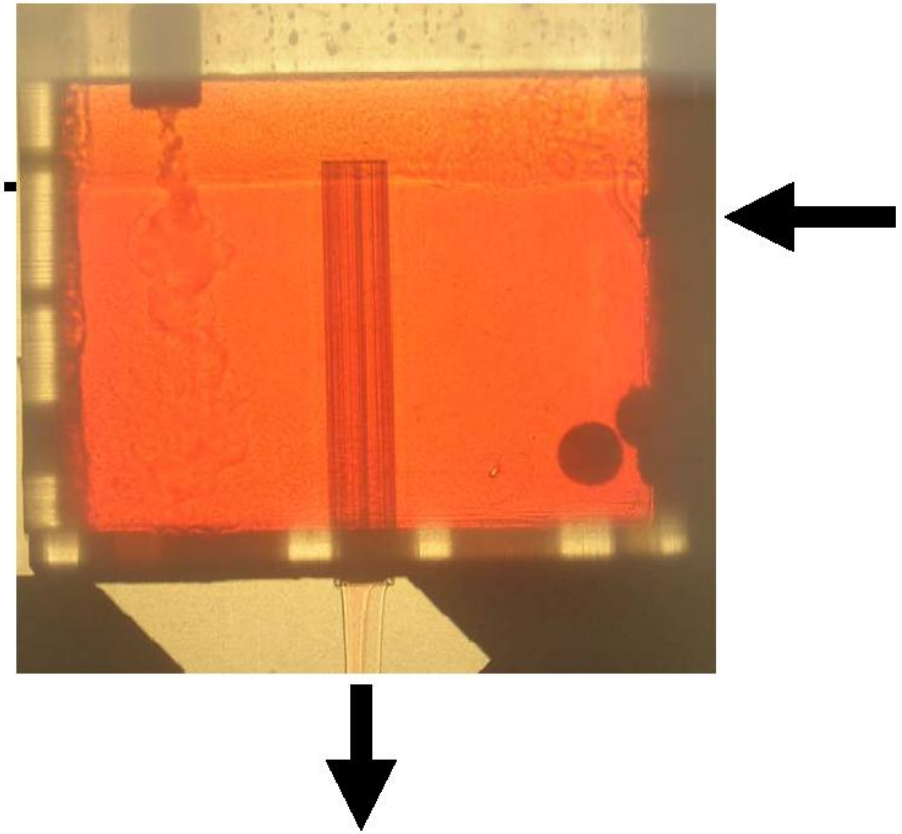
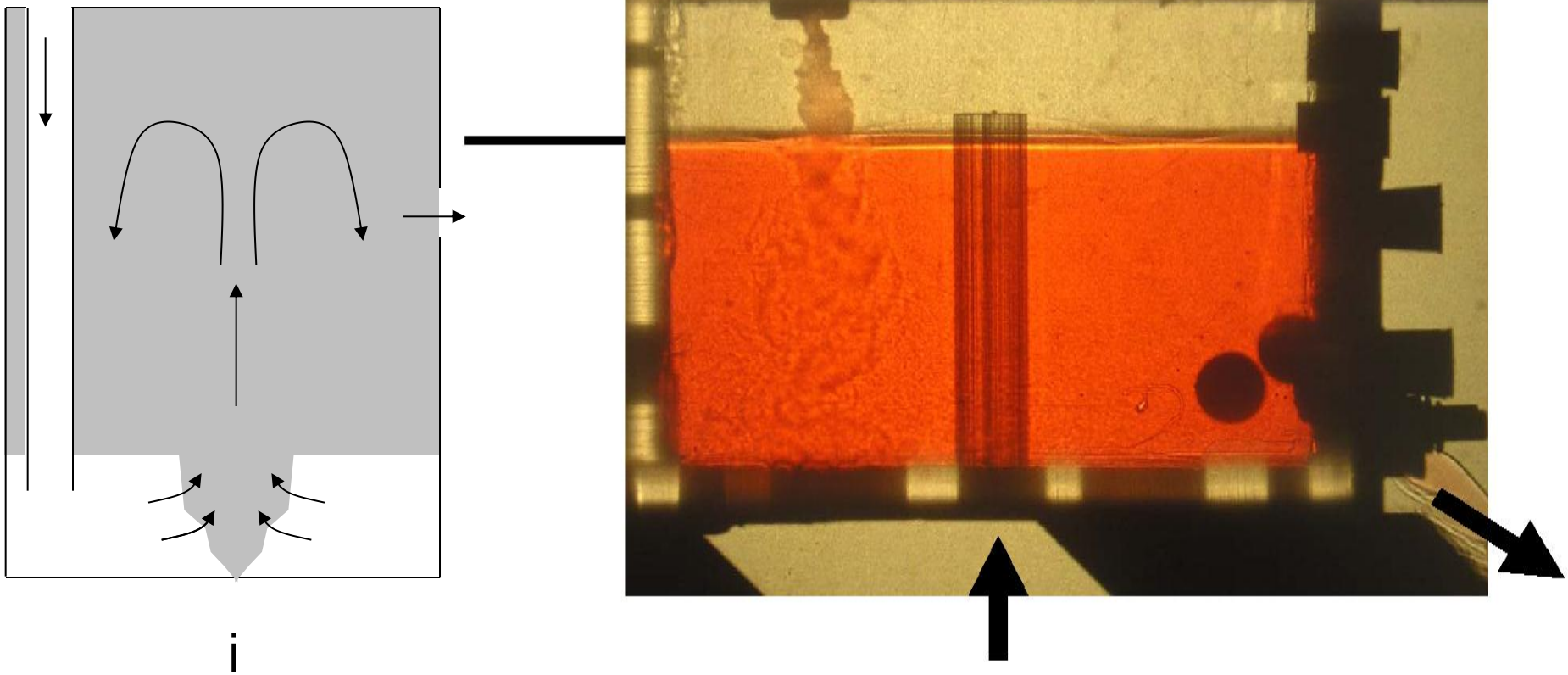
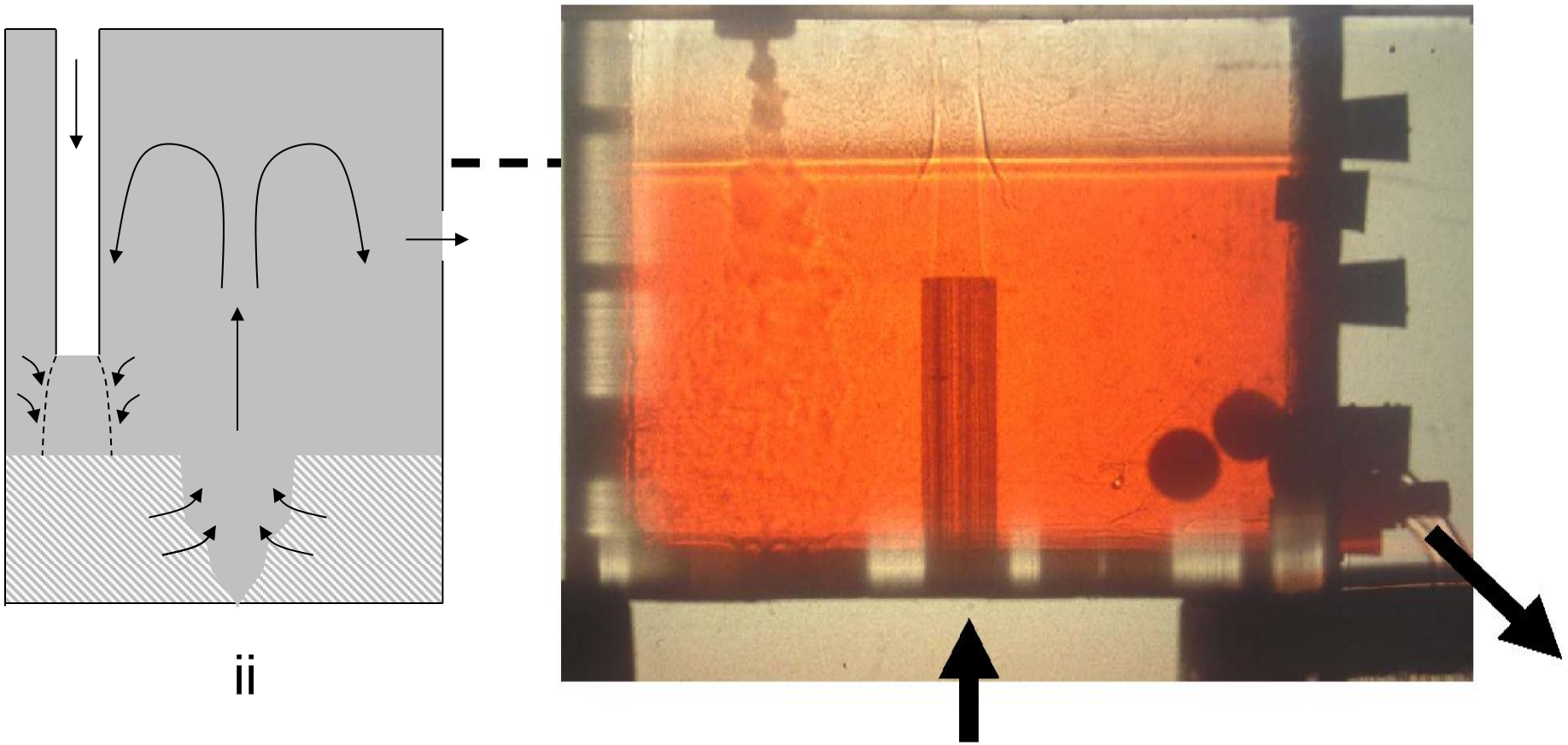
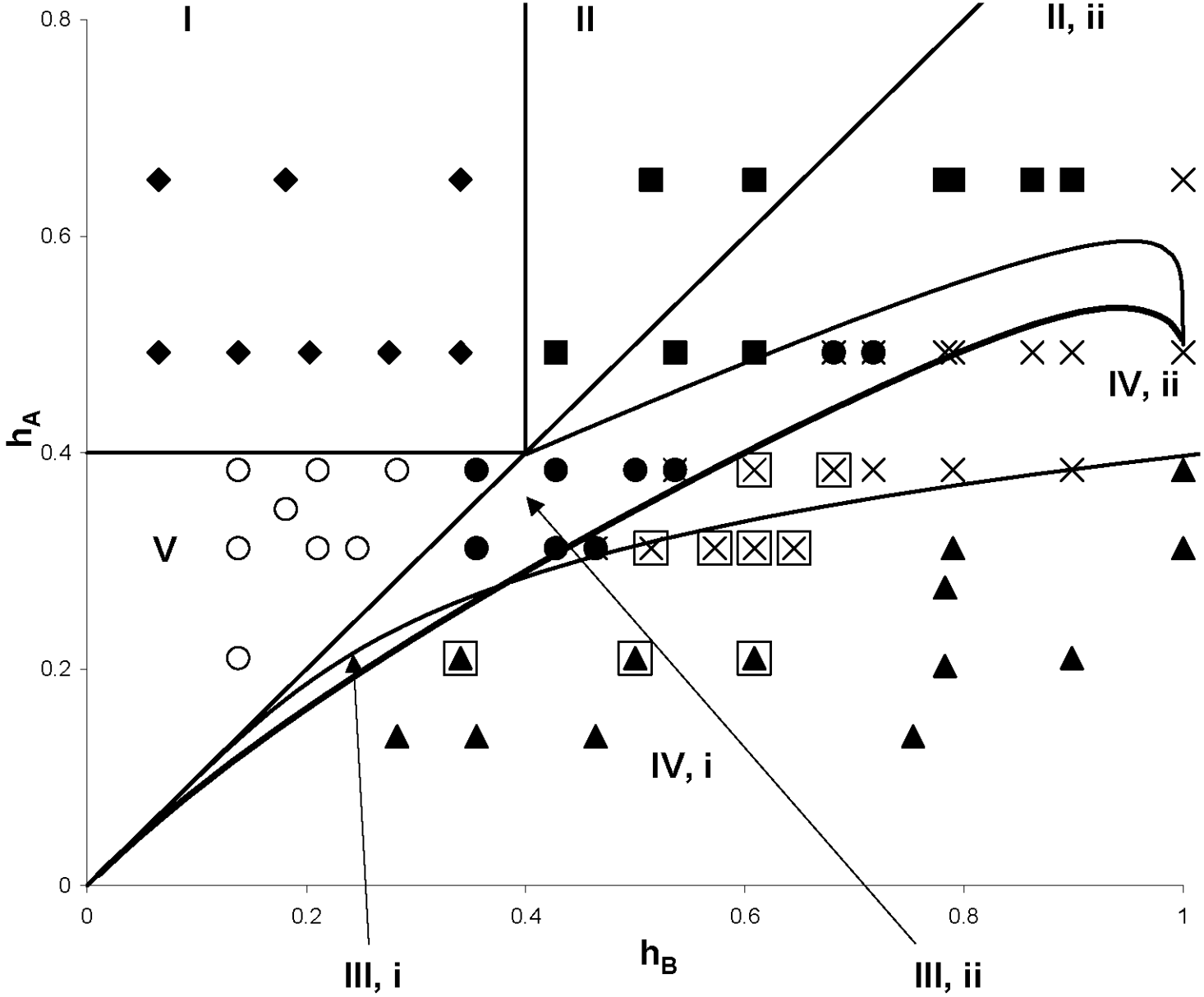




i


ii


I
II
II, ii
IV, ii
V
IV, i
III, i
III, ii
h_A
h_B
0
0.2
0.4
0.6
0.8
1

Collaborators

- Andy Woods + BPI team
- Mark Tucker, Purdue

Building and Environment **43**, 1719-1733

Applications to hybrid buildings