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AIR CONDITIONING & REFRIGERATION CENTER
ACRC
A NATIONAL SCIENCE FOUNDATION INDUSTRY/UNIVERSITY COOPERATIVE RESEARCH CENTER

EFFECT OF FLOW OBSTRUCTIONS

and engine compartment recirculated air on heat exchanger and system performance as simulated in the test bench

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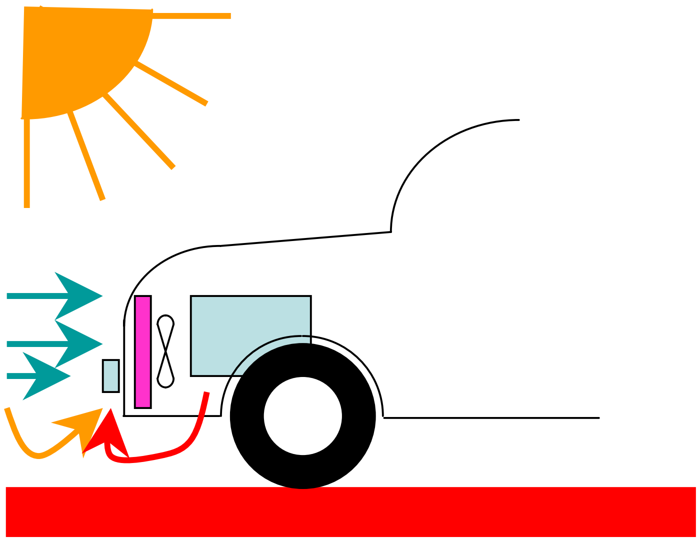
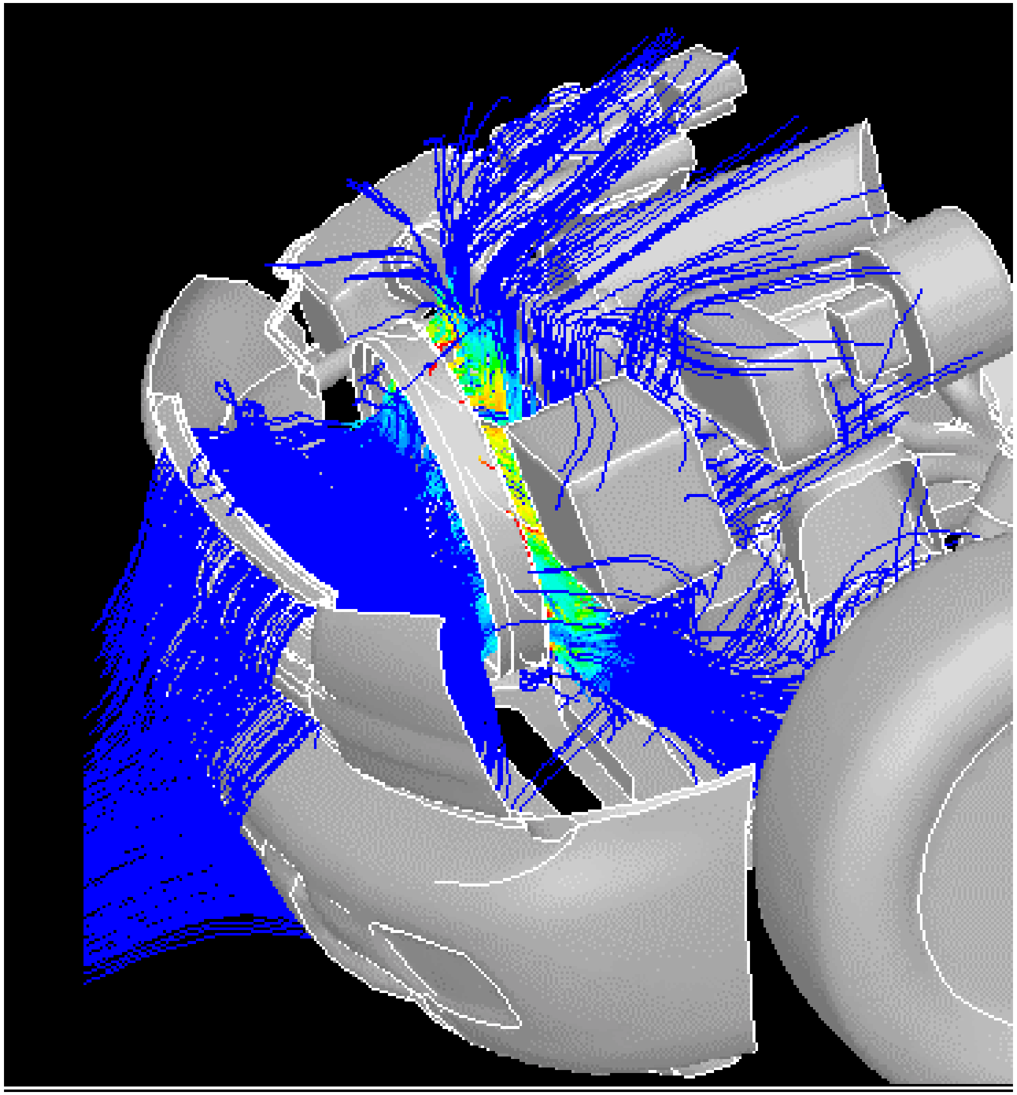
SAE®

We will:

- Define the problem;
- Identify differences between reality and experiments;
- Look at the experimental results:
  - Effect of flow obstruction (air side maldistribution);
- Discuss design with obstructions and maldistibution in mind.

A typical situation at the front





Effect of obstructions

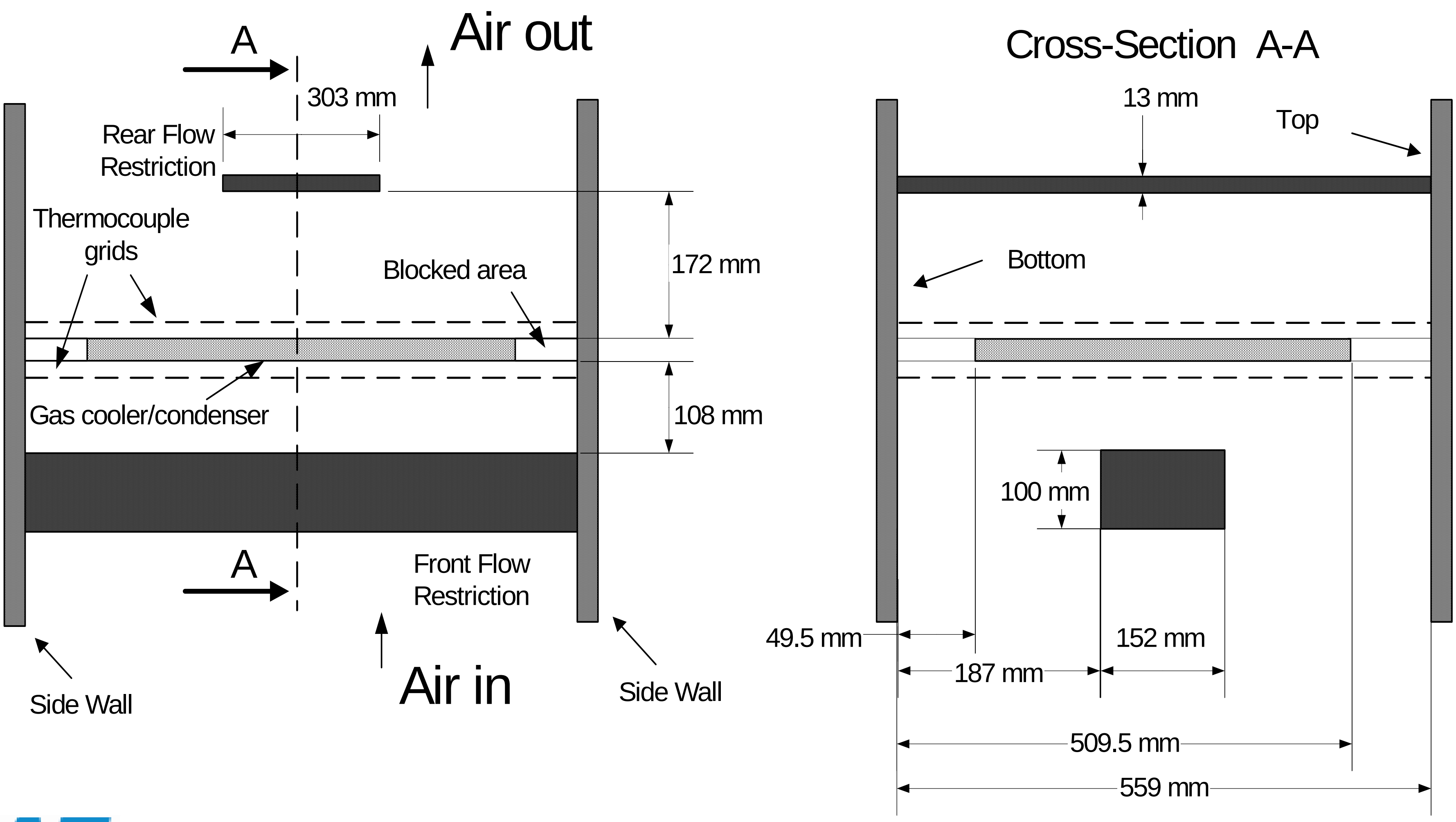
- AR CRP – check the sensitivity of four systems on barriers in most difficult situations – low rpm and flow, high T;
- Baseline – no obstructions;
- Distance of barriers:
  - 51 and 108 mm upstream (bumper)
  - 41 and 172 mm downstream (engine)
- Effect of system: Q and COP.

Inlet flow obstruction

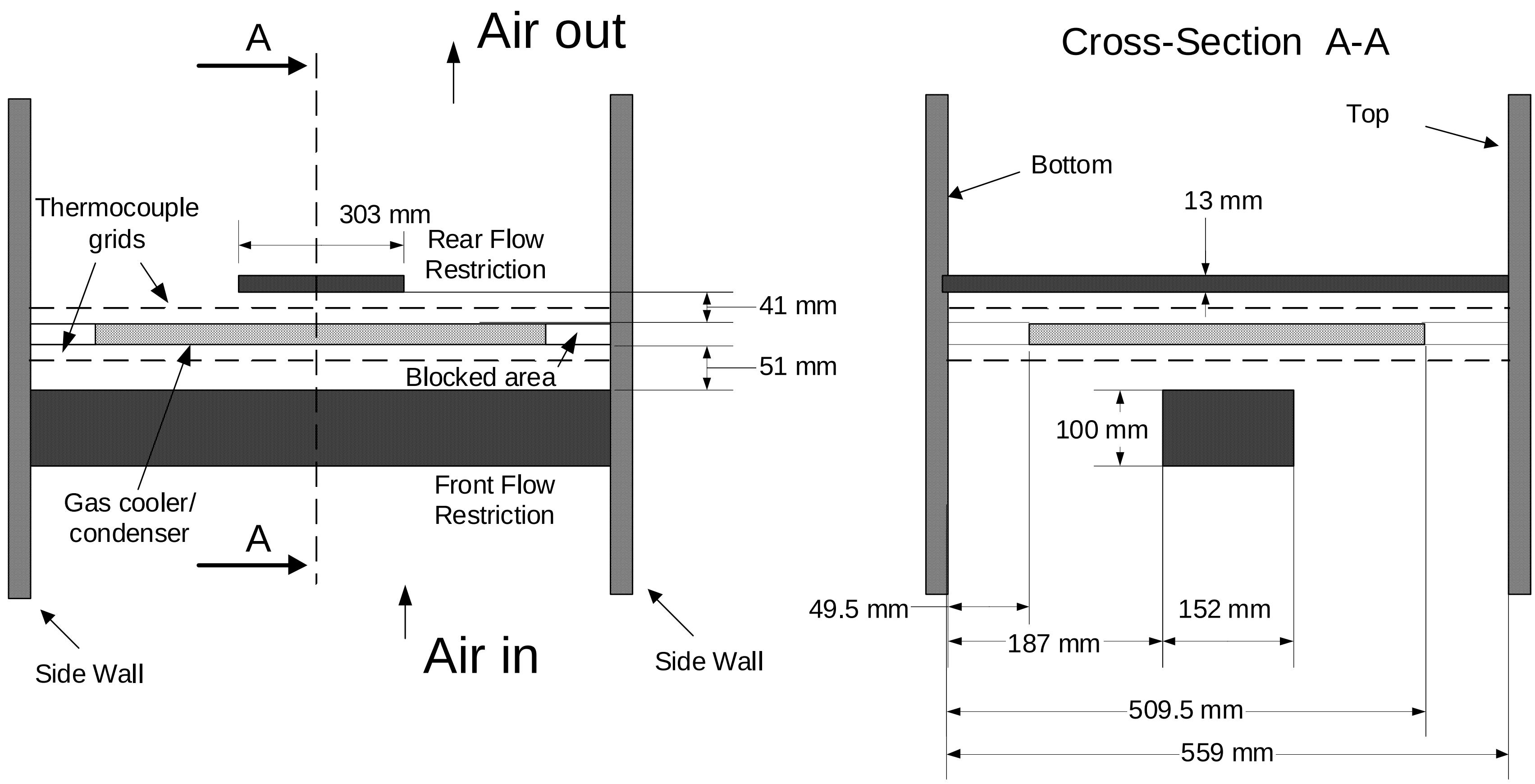
Flow restriction at the outlet

In condenser wind tunnel

Barriers far from HX



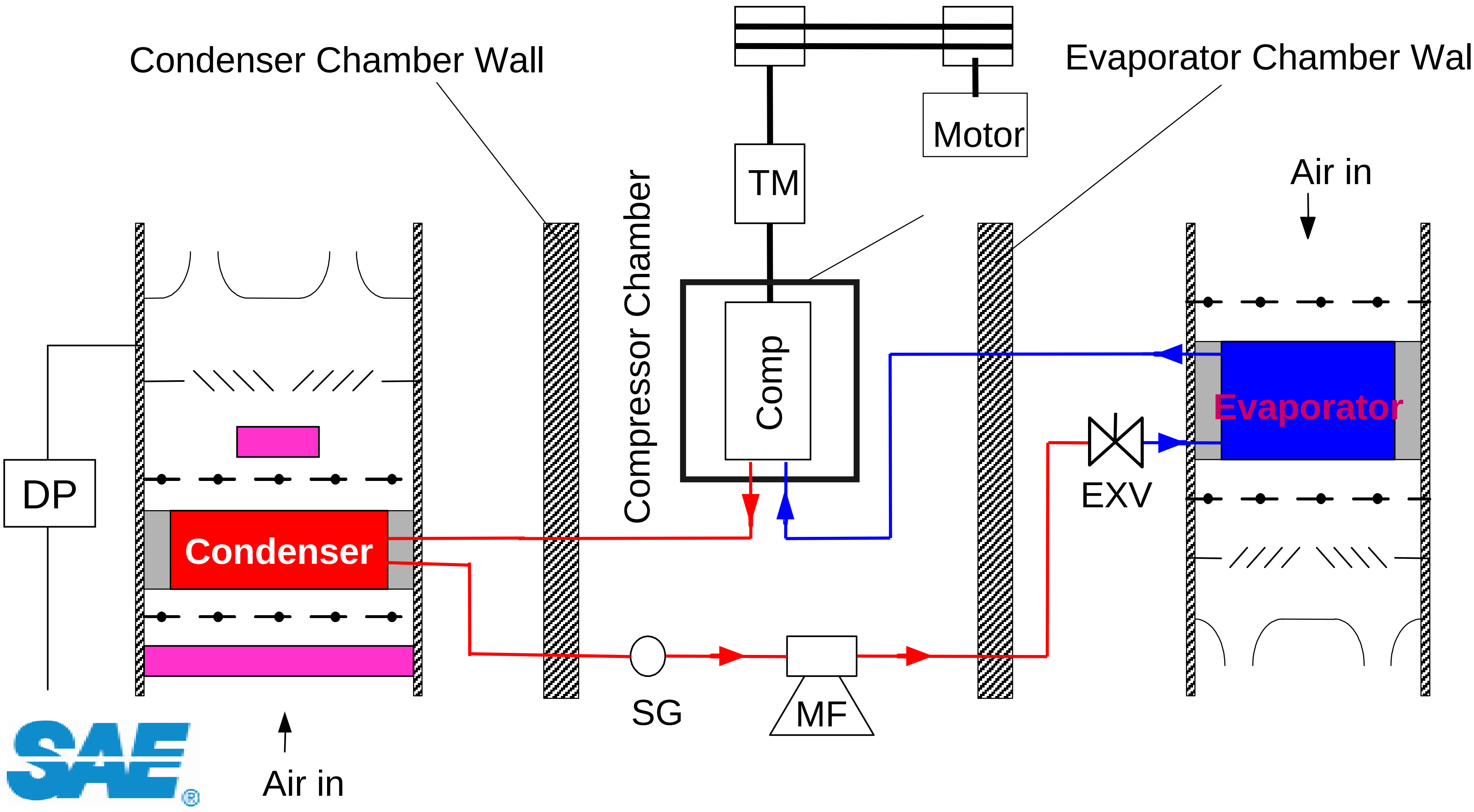
Close to HX


A
Air out
Cross-Section A-A
Top
Bottom
13 mm
Thermocouple grids
303 mm
Rear Flow Restriction
41 mm
51 mm
Blocked area
100 mm
Front Flow Restriction
Gas cooler/ condenser
A
49.5 mm
152 mm
187 mm
Side Wall
Air in
Side Wall
509.5 mm
559 mm

Problem in the lab:

Simulate unknown fan

Maintained constant DP.
Lab air flow is not sensitive to pressure drop ("stiff" fan).



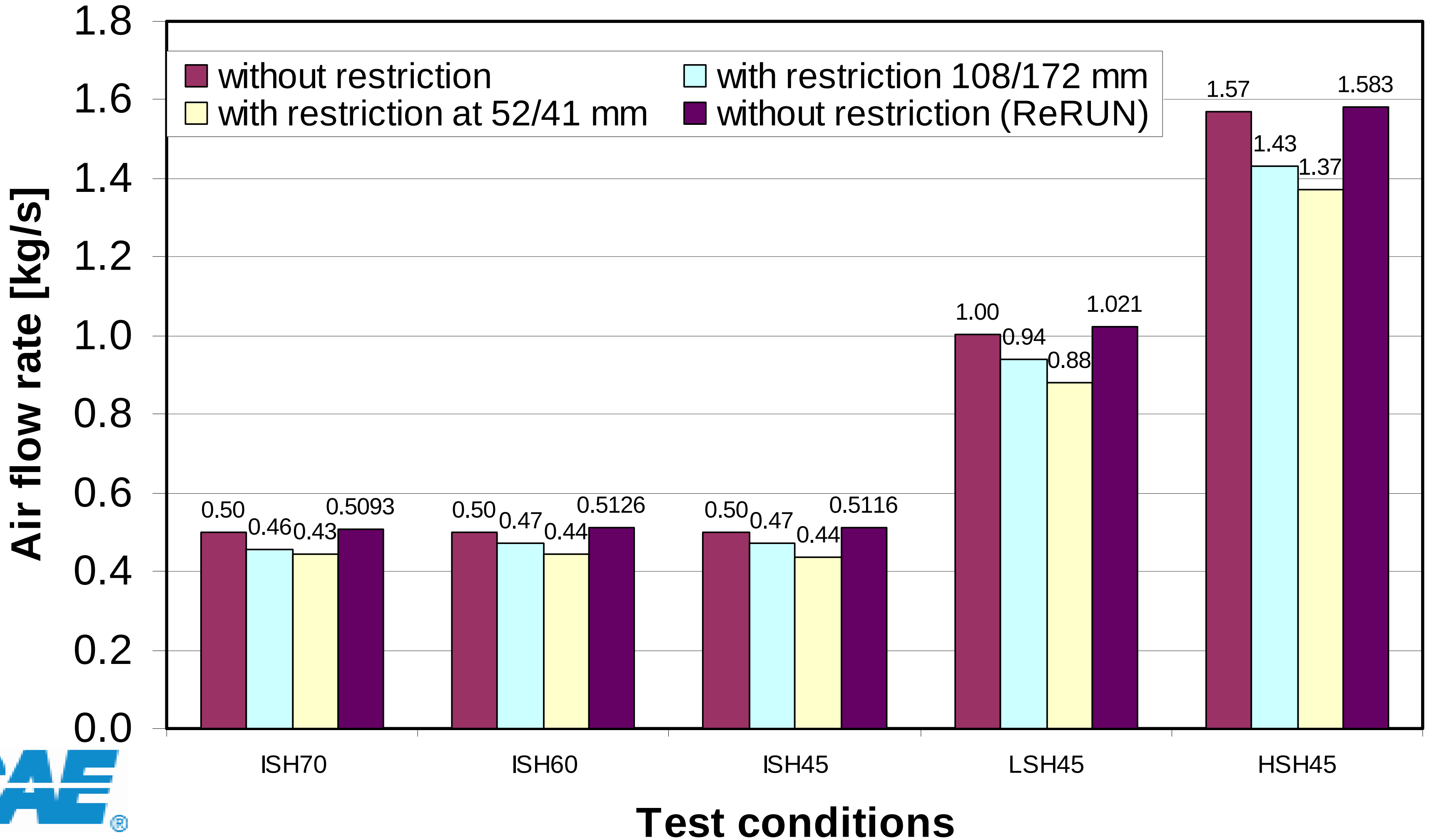
Short test matrix

	Basic Test Point Matrix					
	Evaporator Air			Cond/Gas Cooler Air		Comp
Test name	T (°C)	RH (%)	Flow (l/s)	T (°C)	Flow (l/s)	rpm
ISH70	45	27	109	70	425	900
ISH60	45	27	109	60	425	900
ISH45	45	27	109	45	425	900
LSH45	45	27	130	45	850	1500
HSH45	45	27	130	45	1320	2500

Effect of proximity

Condenser air flow rate

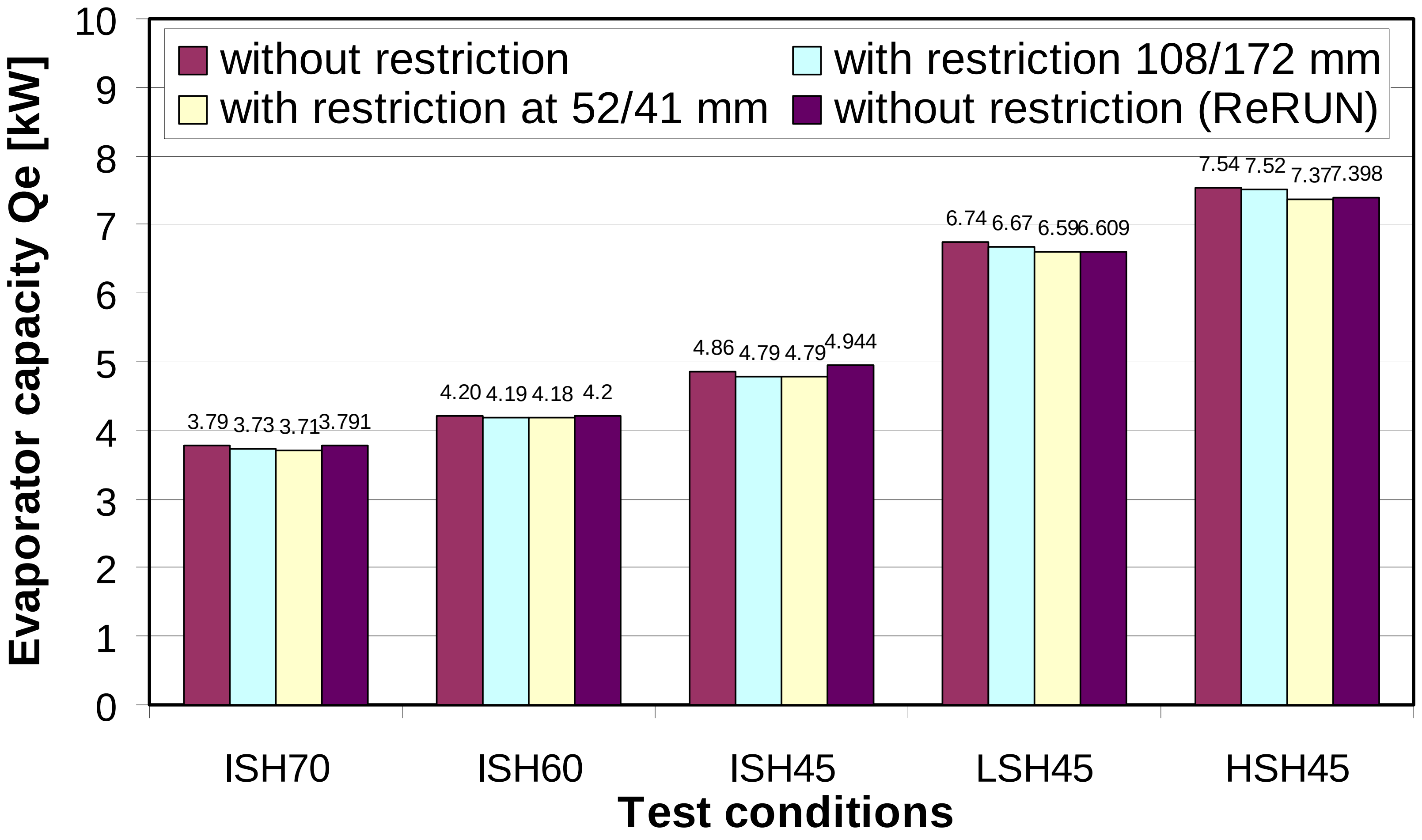
Example



Effect of proximity

Cooling capacity

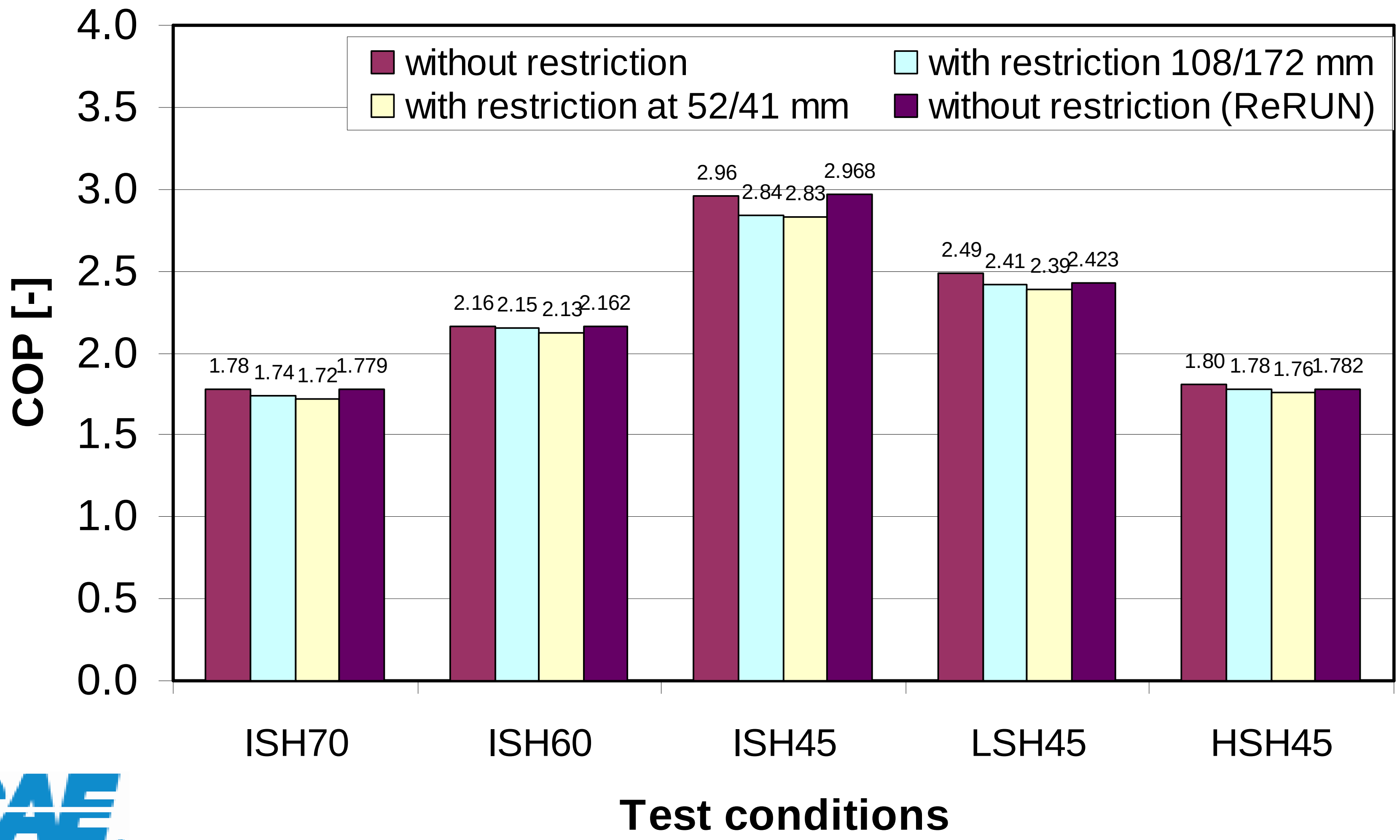
Example



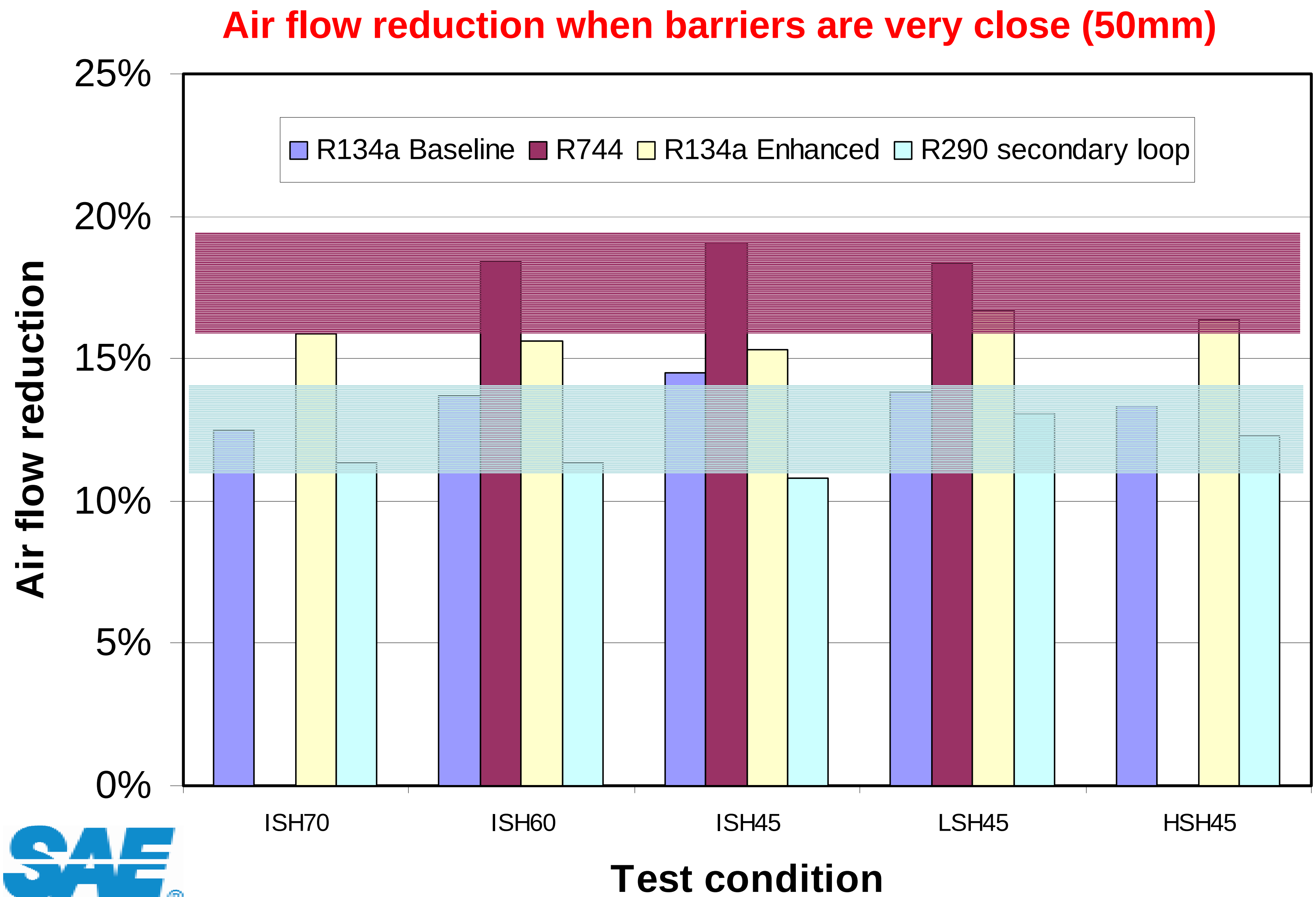
Effect of proximity

Efficiency

Example

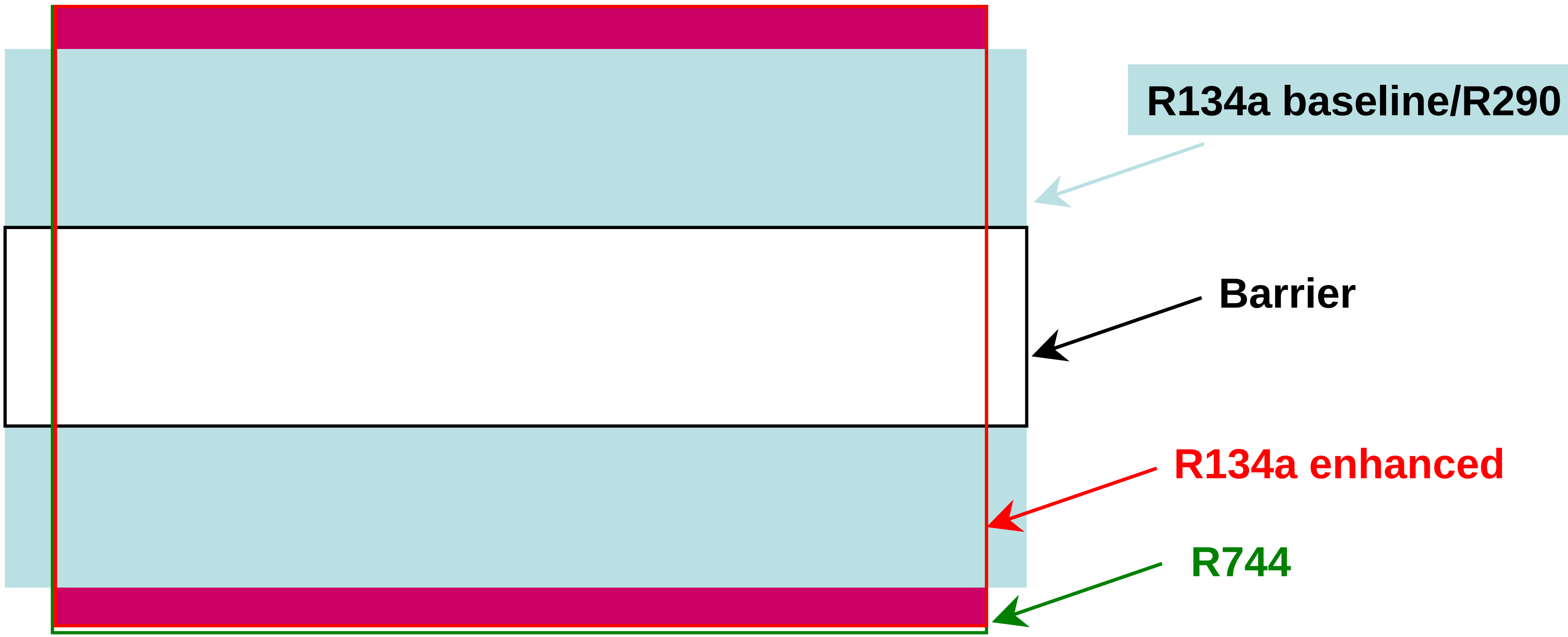


What about various systems?



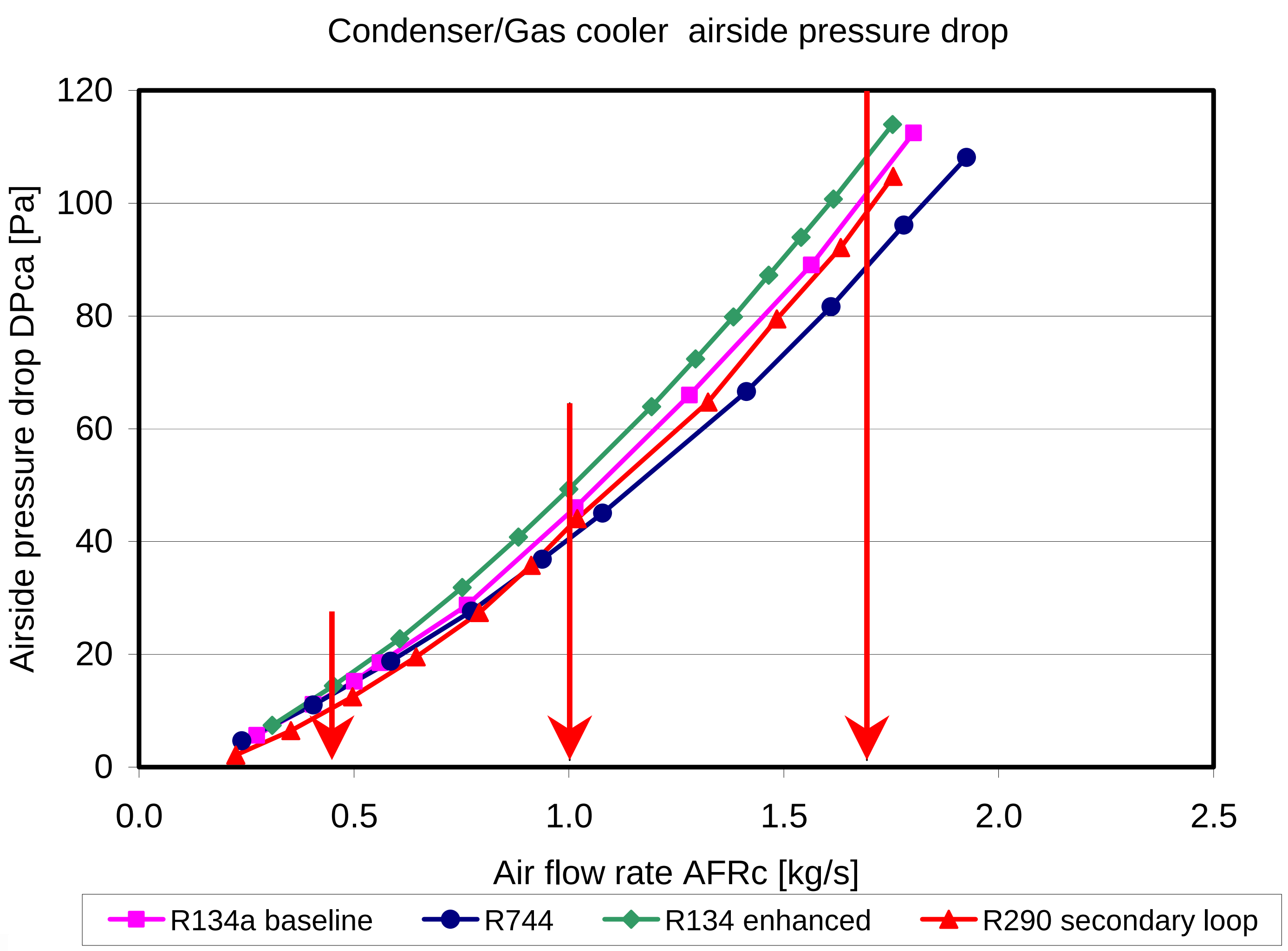
Why difference?

1. Shape matters!



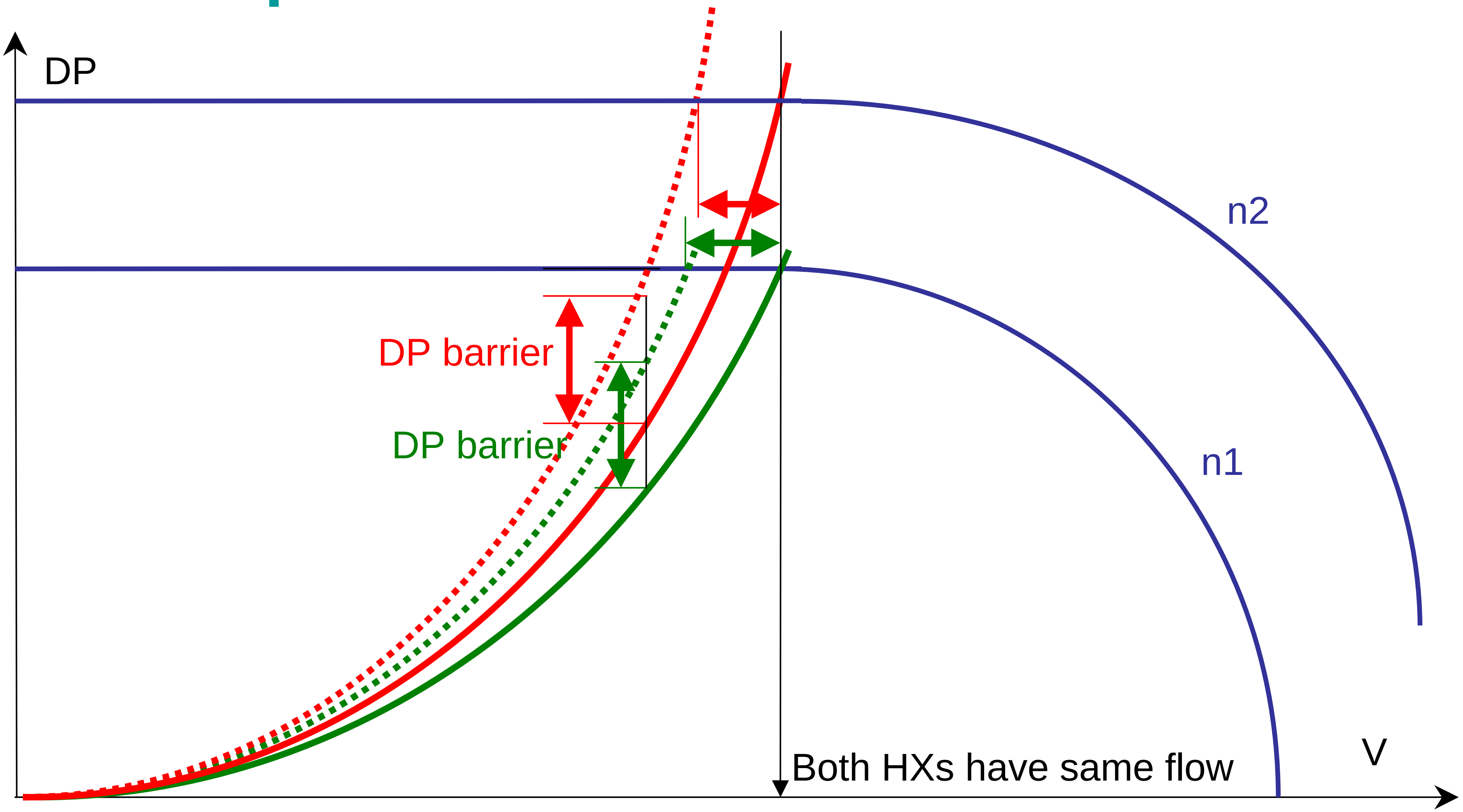
Why difference?

2. DP and test conditions matter!

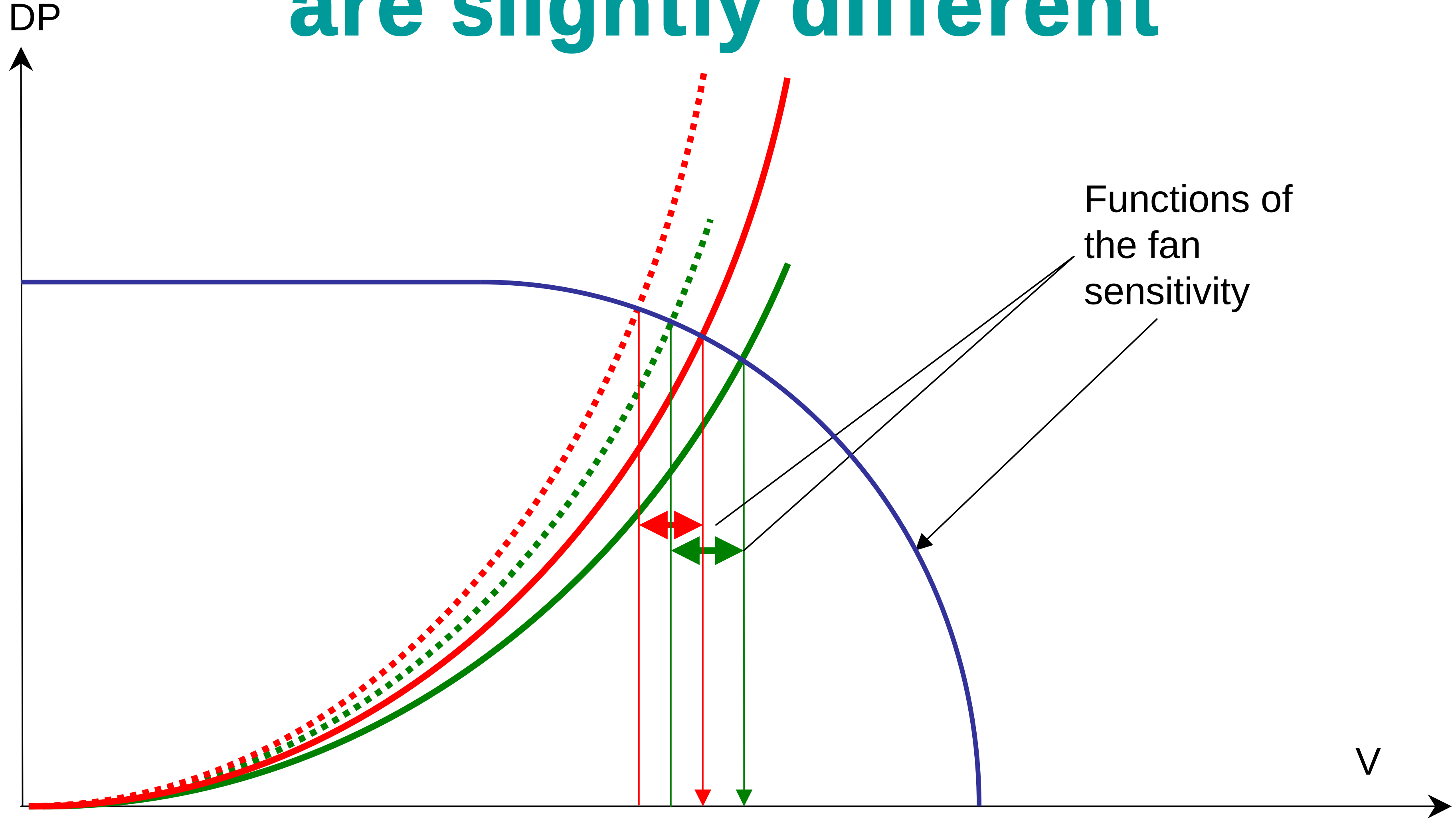


We have assumed constant DP

Consequence: lower DP HX is more affected

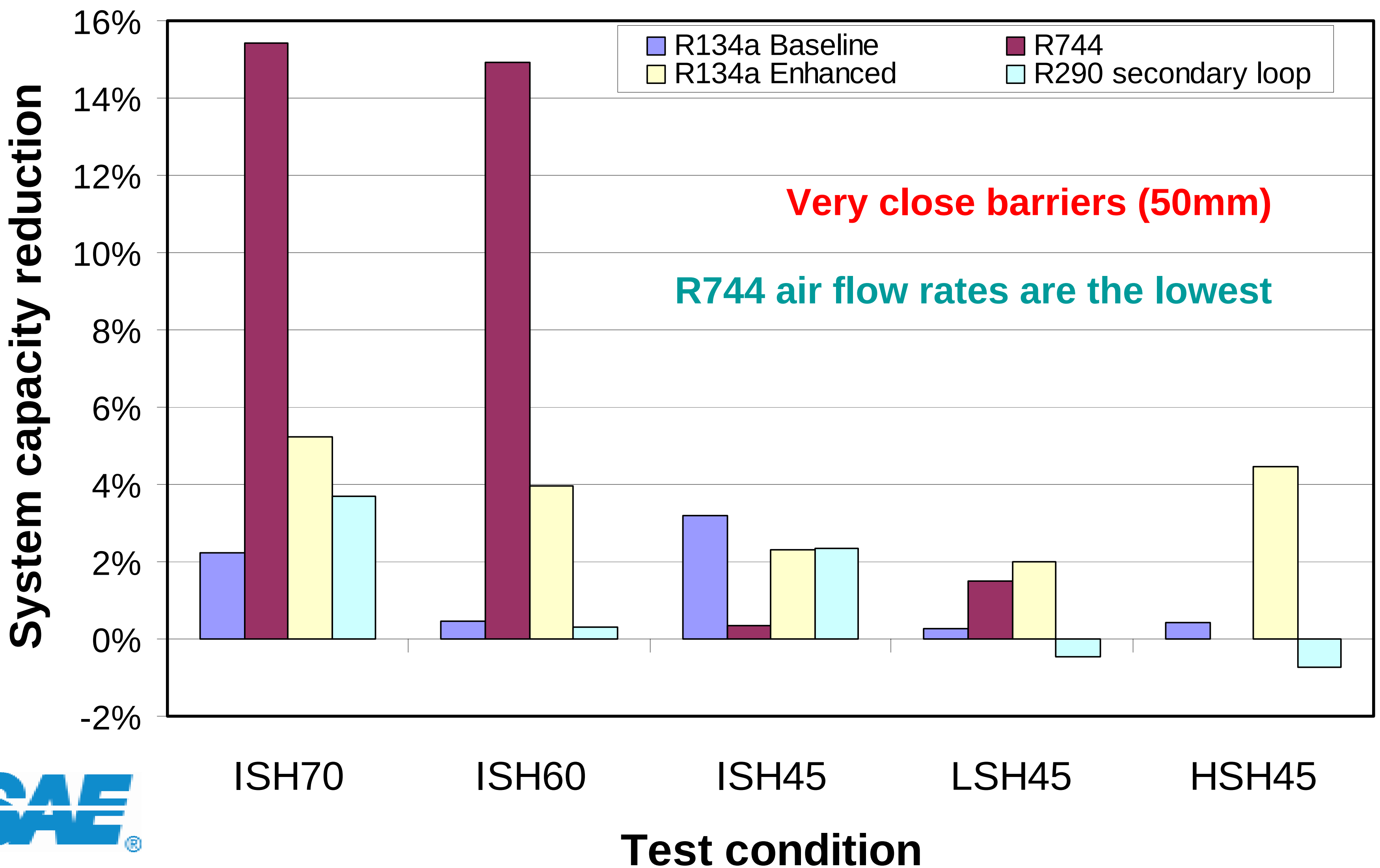


In reality fan/HX interactions are slightly different



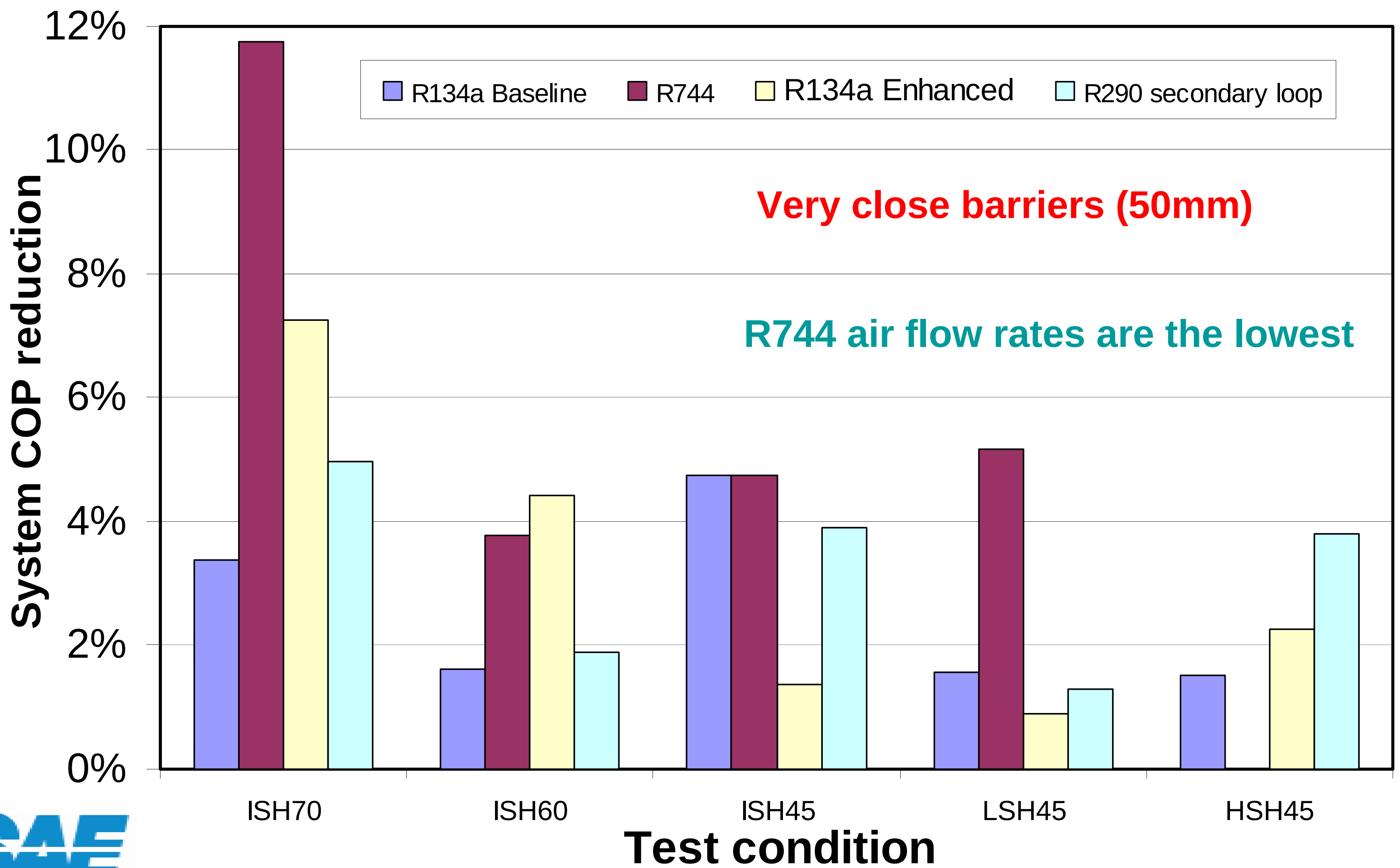
Capacity reduction due to barriers:

R744 more sensitive at high temperatures less at low



COP reduction due to barriers:

R744 more sensitive at high temperatures less at low

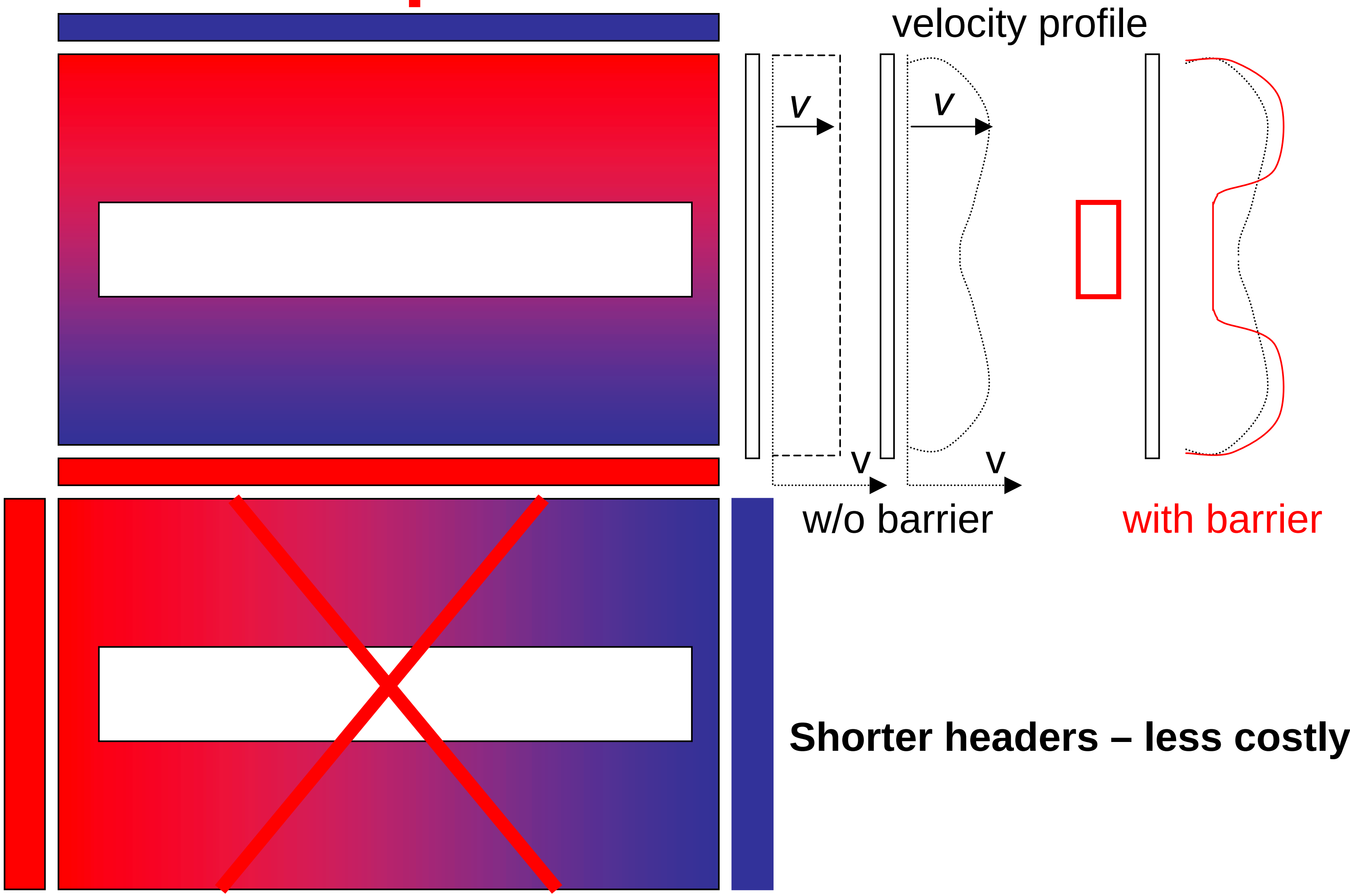


How to design HX to be less affected by barriers and maldistribution?

- **First understand:**
  - **air side maldistribution;**
  - **refrigerant side heat transfer;**
  - **refrigerant side maldistribution;**
  - **operation of the heat exchanger and system effects;**
- **Then be creative.**

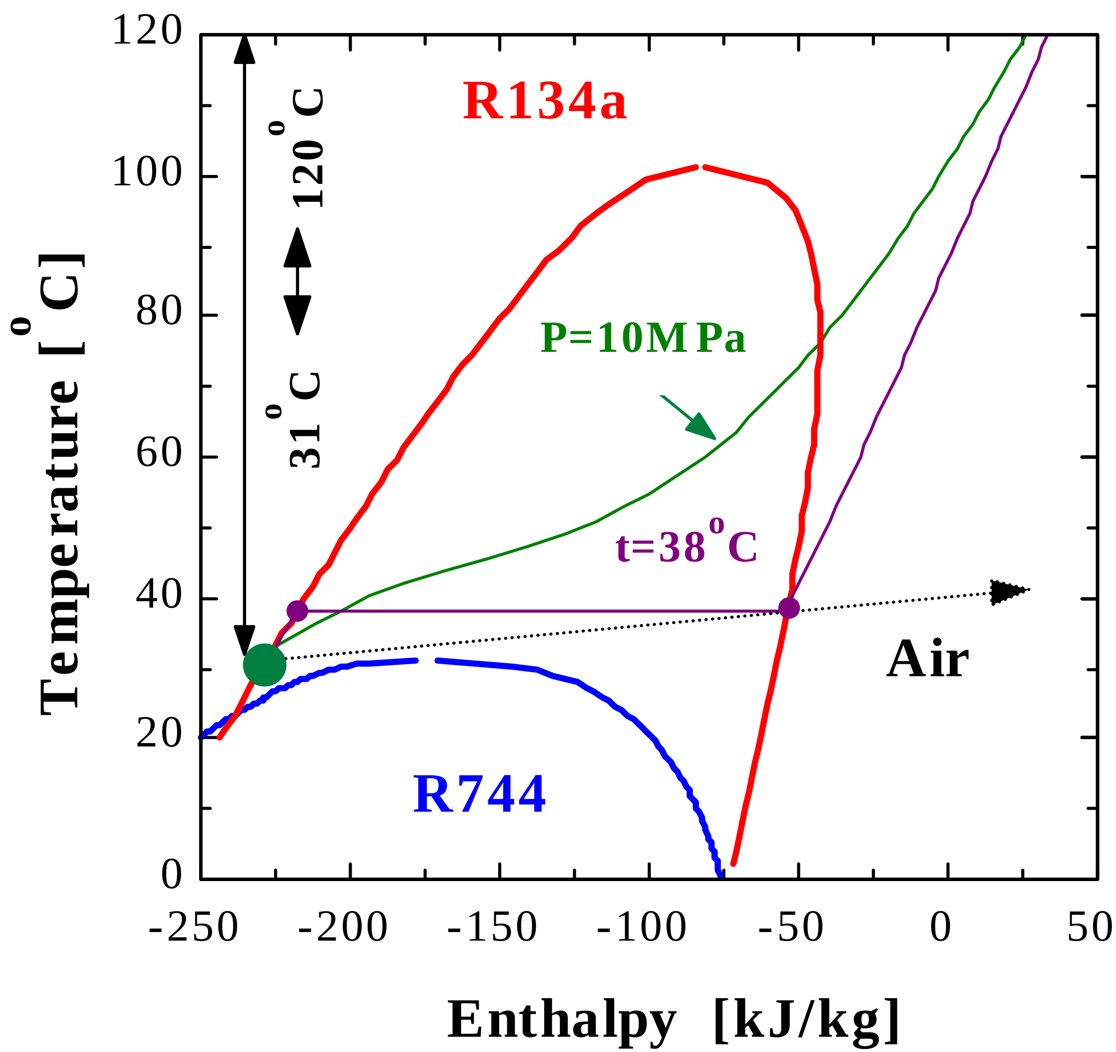
Arranging refrigerant flow orientation is one way to improve performance of R744 when barriers obstruct air flow:

Expose gas cooler exit to lower temp. – sacrifice less important area!



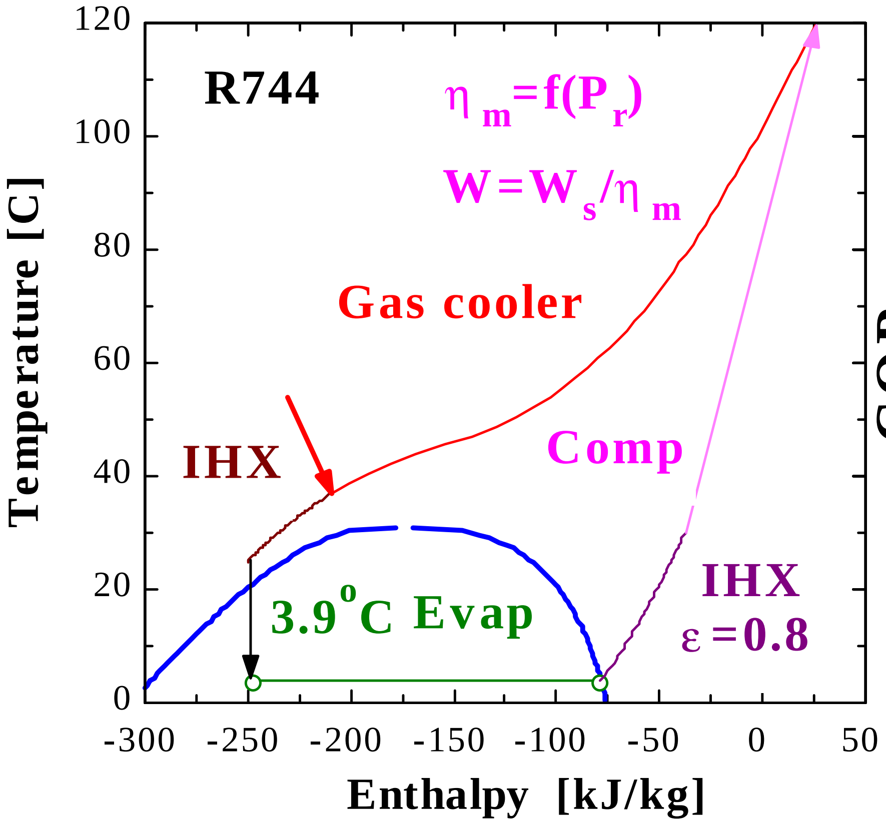
System effects

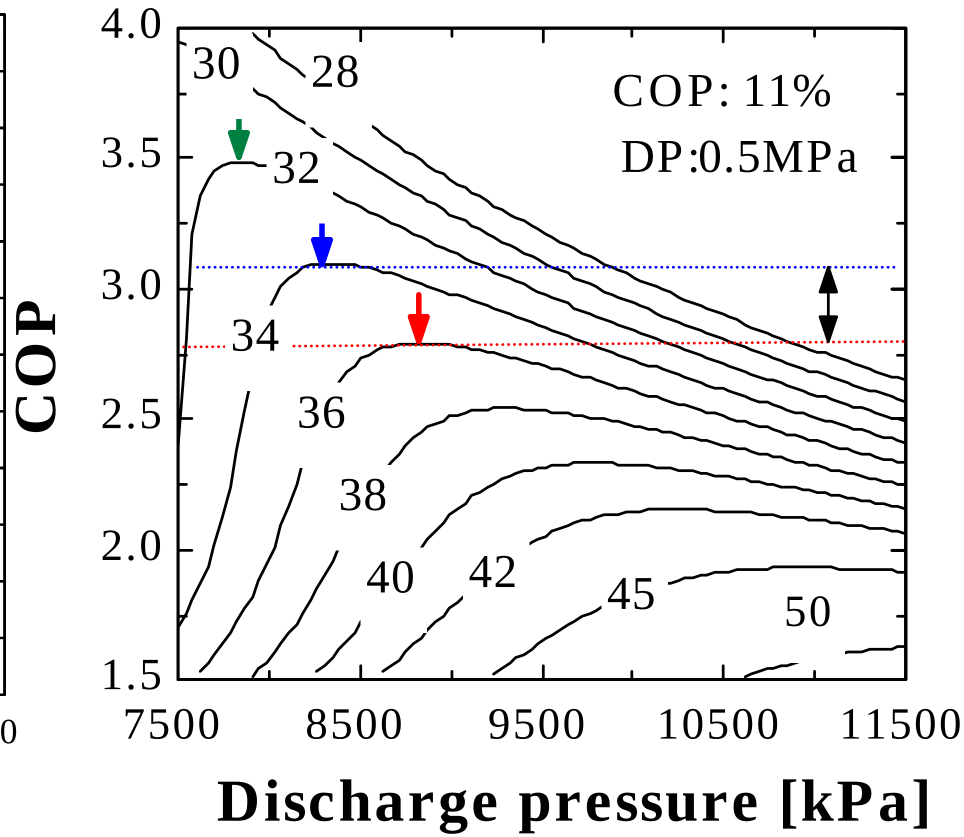
Reducing approach TD benefits R744 very much



From: Yin, Bullard, Hrnjak, 2002

R744 is very sensitive to gas cooler exit conditions





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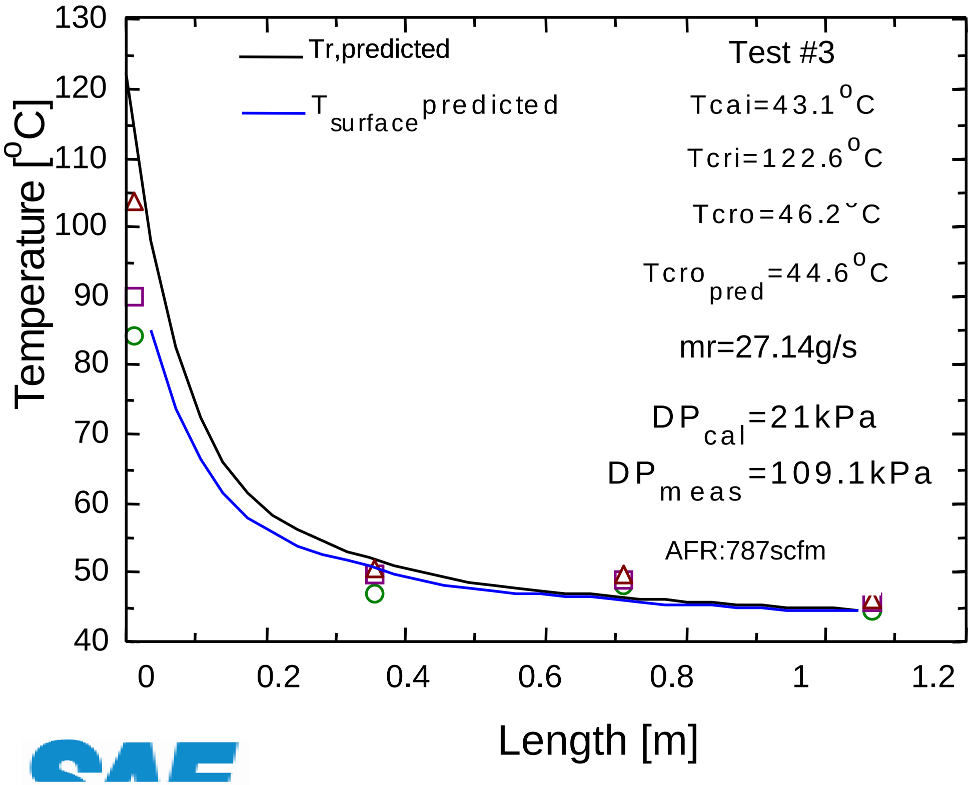
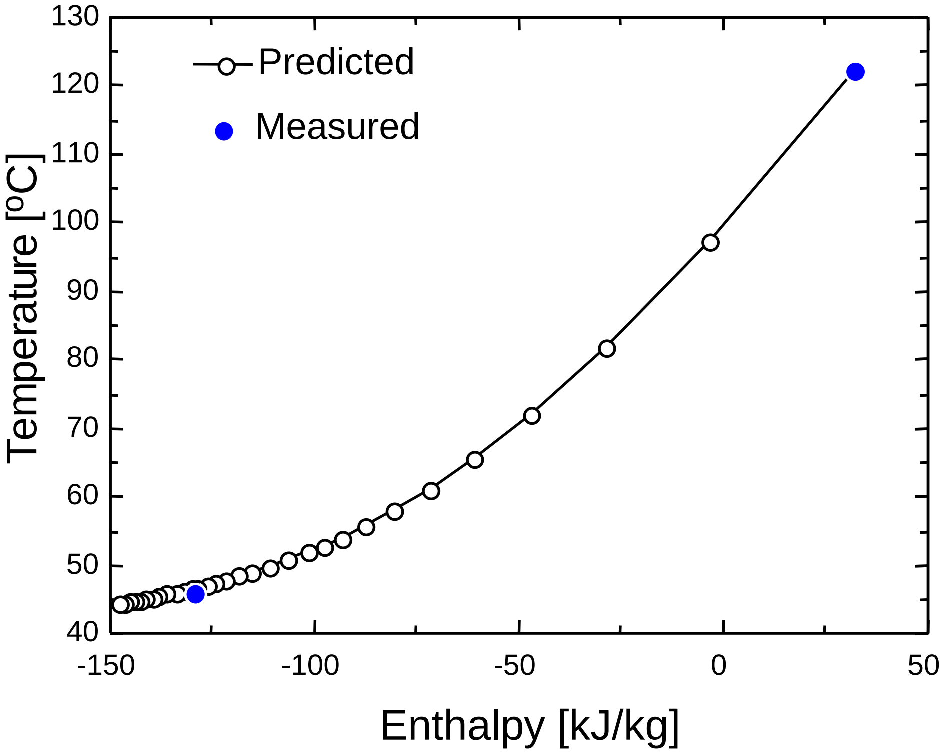
But, most of the heat in gas cooler is exchanged in inlet zone

Refrigerant temperature drop in a single pass gas cooler



Enthalpy change as a function of refrigerant temperature



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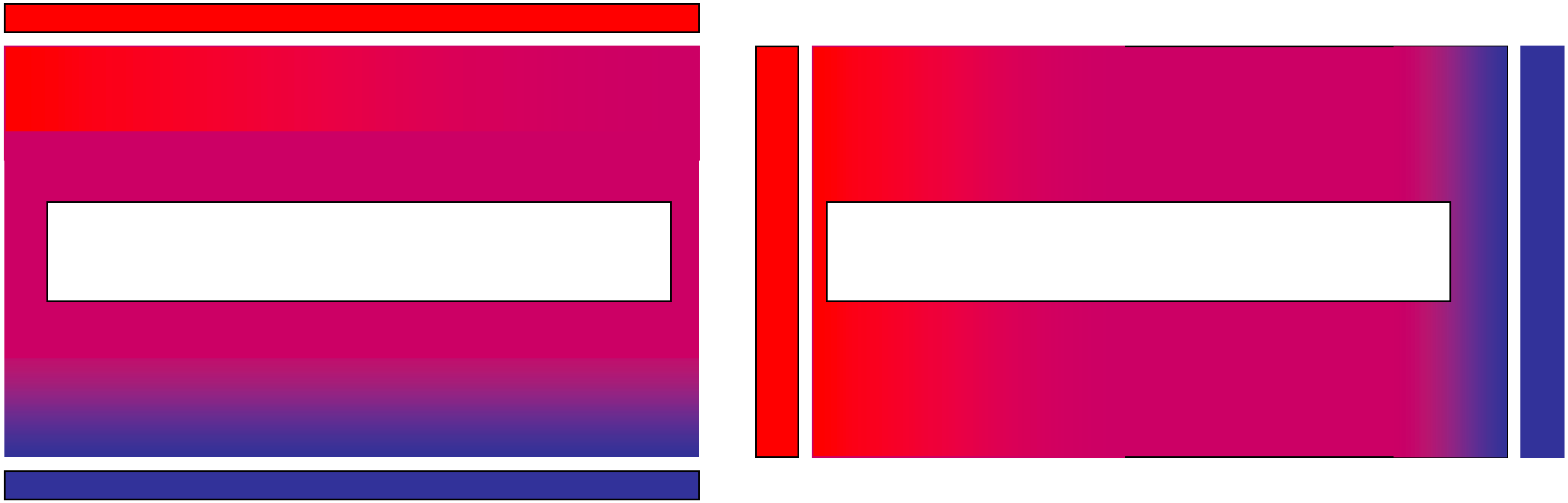
Same approach with R134a?



Summary

- Barriers reduce capacity and COP;
- Effect is perhaps less than expected;
- Results should be carefully interpreted due to simulation of unknown fan – R744 had less air even having lower DP;
- R744 system examined was more sensitive to recirculation than R134a at higher temperatures and less at lower temps;
- Effects of air side maldistribution could be reduced by good design.