Results of Audi A5 Evaluation with Alternate Refrigerants

Alternate Refrigerant Systems Symposium

June 10.-12.2008, Phoenix Arizona

Hans Hammer

Results of Audi A5 Evaluation with Alternate Refrigerants

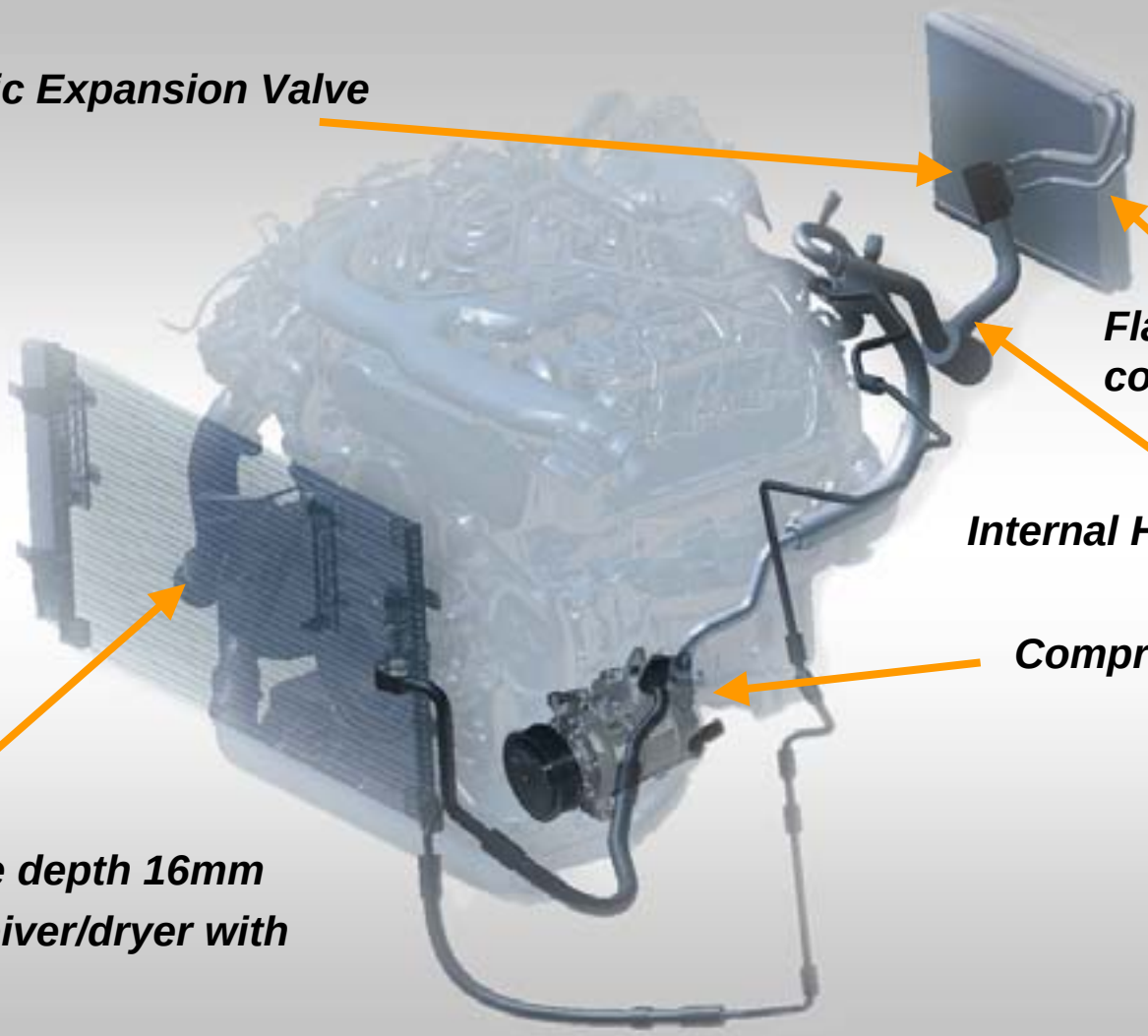
Content

- **Introduction**
- **System configuration**
- **Common Spec Book**
- **Test results**
- **Summary**
- **Outlook**

Introduction

- Energy efficiency of air conditioning systems is in the focus of development since the first introduction of externally controlled variable displacement compressors in the late 1990s
- Several investigations at various stages of development have been carried out with regard to performance and efficiency of R134a and R744 systems
- The recent introduction of an Internal Heat Exchanger (IHX) in an R134a system poses a new challenge for R744 system performance and efficiency
- Effect of R744 component optimization on system efficiency to be evaluated in this program

System configuration **R134a**



Thermostatic Expansion Valve

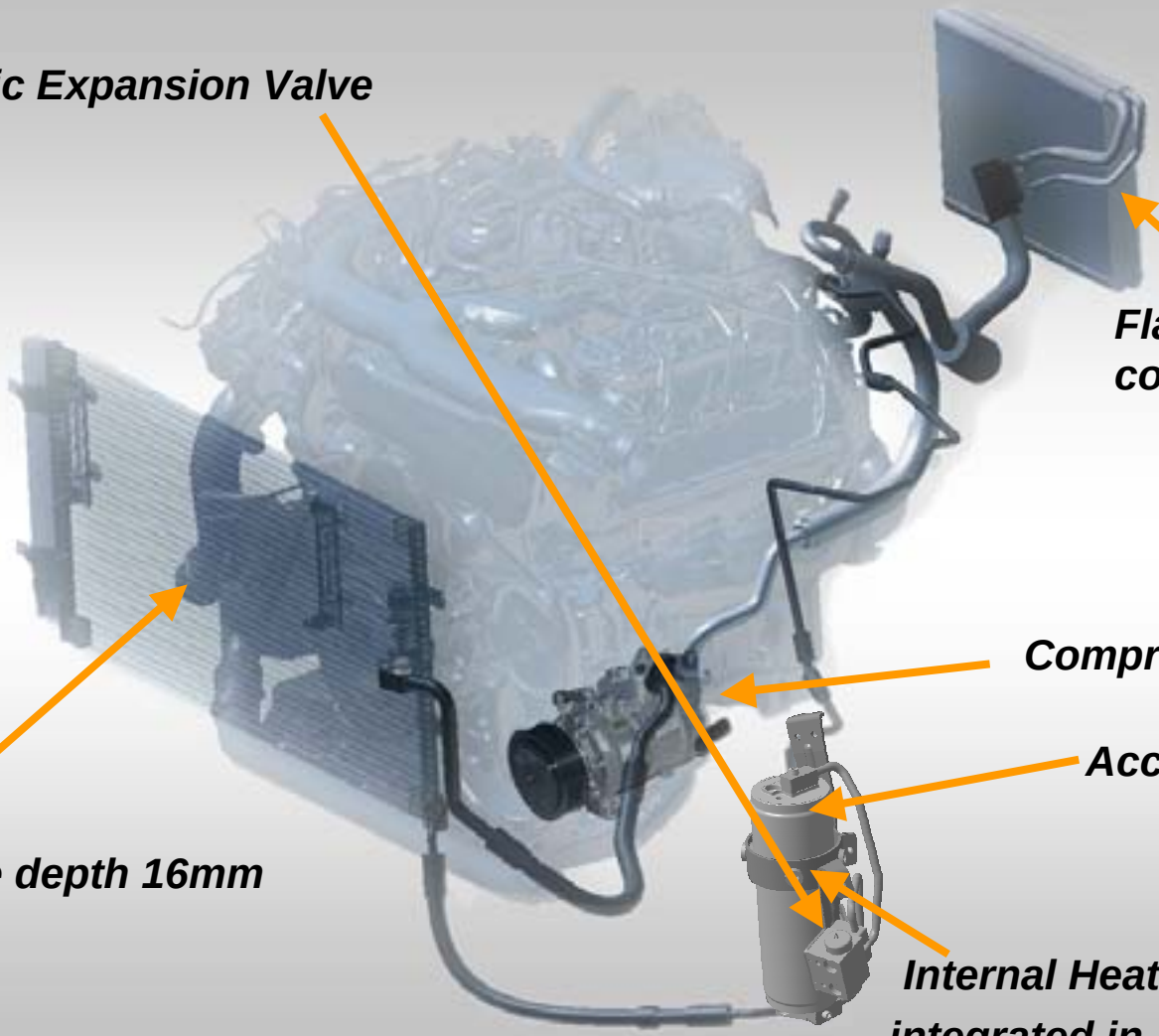
Flat tube Evaporator core depth 40mm

Internal Heat Exchanger

Compressor 140cc

Condenser core depth 16mm
Integrated Receiver/dryer with subcool area

System configuration **R744**



Thermostatic Expansion Valve

Flat tube Evaporator core depth 38mm

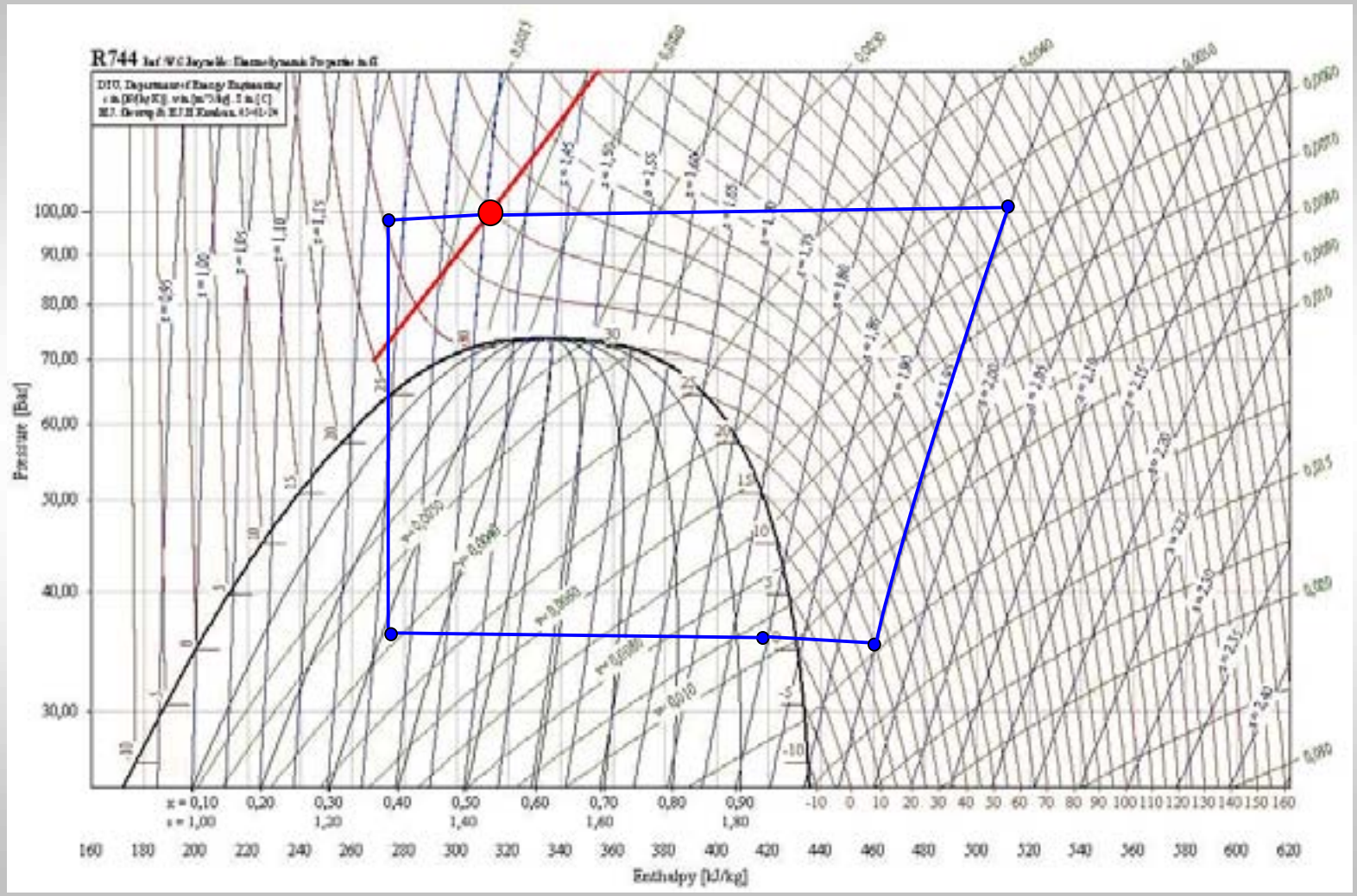
Compressor 28cc

Accumulator

Gascooler core depth 16mm

Internal Heat Exchanger, integrated in Accumulator

System configuration **R744**

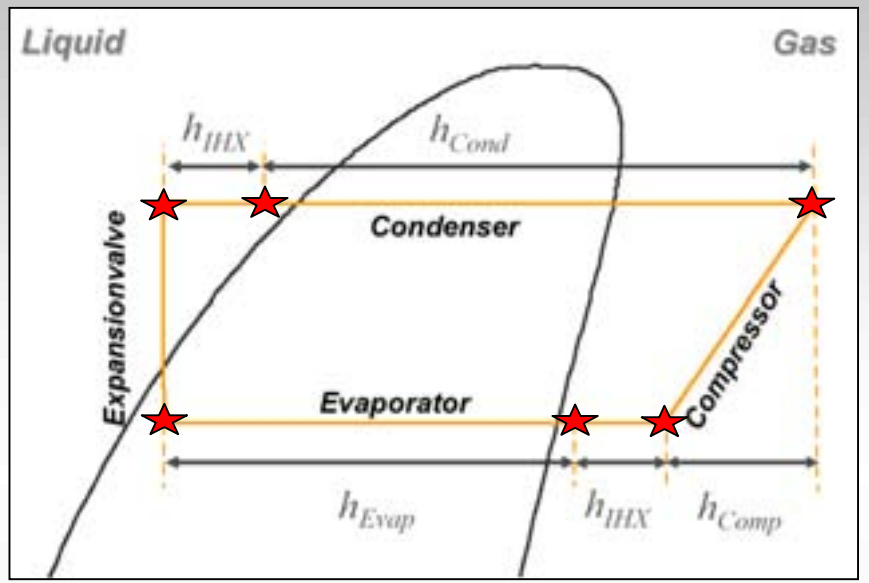


Common Spec Book – Bench Test

Series of measurement	Compressor speed	Air temperature upstream of condenser	Air velocity upstream of of condenser	"Set point" air downstream from evaporator (mean value)	Evaporator air volume	Conditions evaporator entry	Remarks
	[min-1]	[°C]	[m/s]	[°C]	[kg/min]		
1	900	60	1,5				
2	900		1,5				
3	1800	45	2	3	9	45°C / 25%	
4	2500		3				
5	4000		4				
6	1800	45	2	3	5	45°C / 25%	
7	900	60	1,5				
8	900		1,5				
9	1800	45	2	3	9	35°C / 25%	REC
10	2500		3				
11	4000		4				
12	1800	45	2	3	5	35°C / 25%	
13	900	50	1,5				
14	900		1,5				
15	1800	35	2	3	9	35°C / 40%	
16	2500		3				
17	4000		4				
18	1800	35	2	3	5	35°C / 40%	
20	900	40	1,5				
22	900		1,5				
24	1800	25	2	3 / 10	6,5	25°C / 50%	
26	2500		3				
28	4000		4				
30	1800	25	2	3 / 10	4	25°C / 50%	
32	900	30	1,5				
34	900		1,5				
36	1800	15	2	3 / 10	6,5	15°C / 80%	
38	2500		3				
40	4000		4				
42	1800	15	2	3 / 10	4	15°C / 80%	

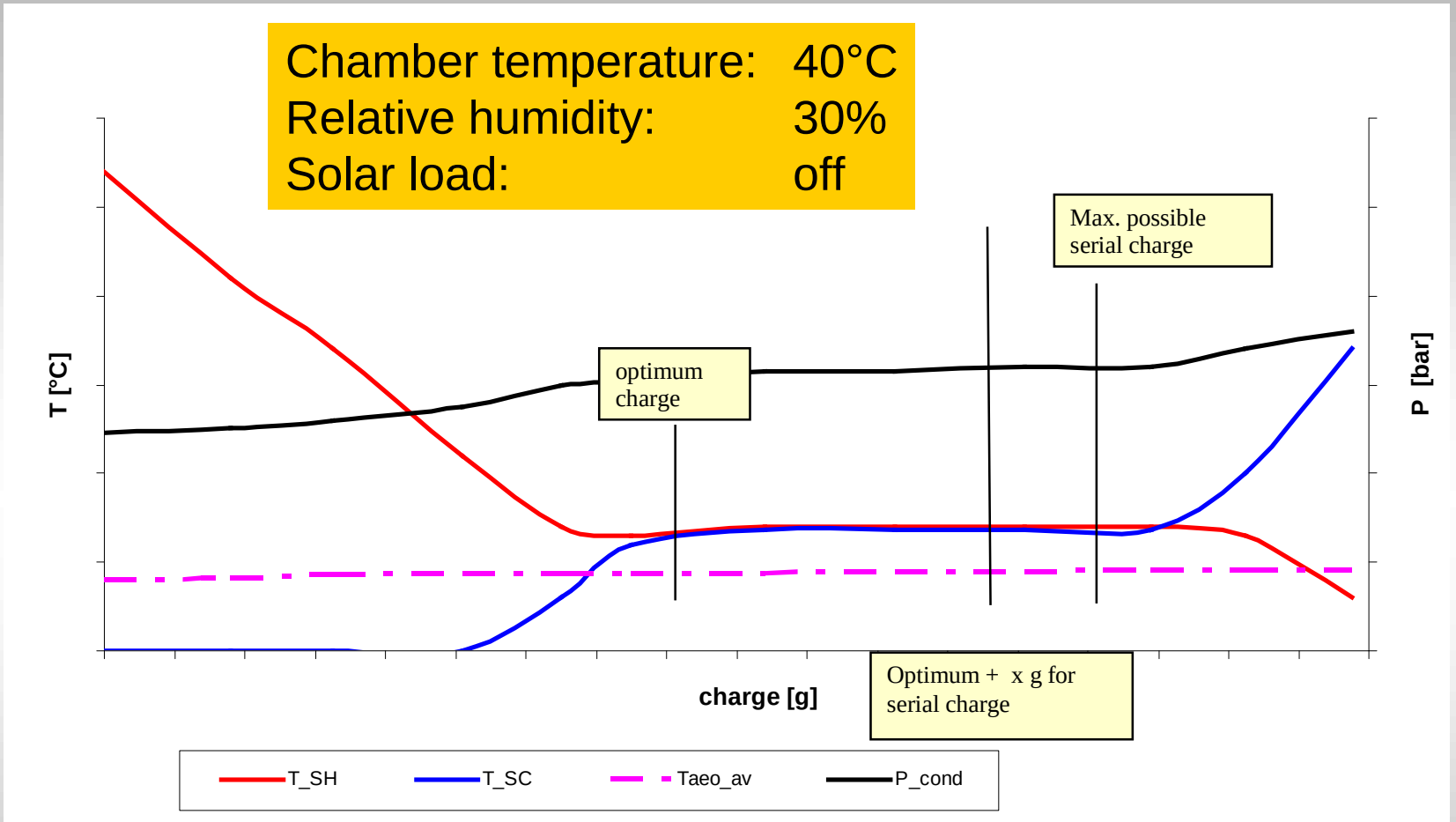
Points may be omitted for time saving reasons

Measuring Points



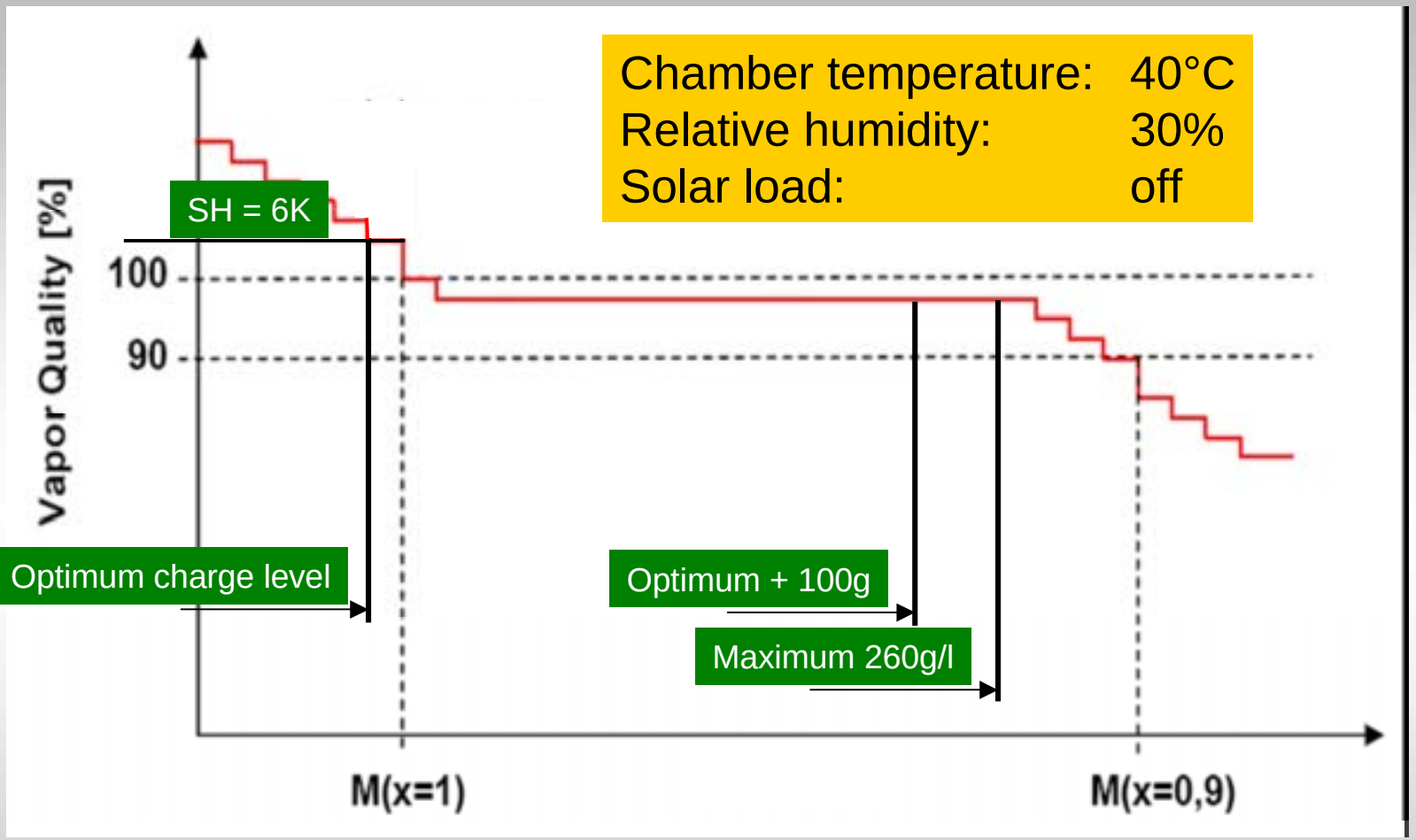
★ Pressure/temperature measurement

Common Spec Book – Vehicle test: charge determination



Engine speed: **1600 rpm**
Air velocity: **32 km/h**
Duration: **stable conditions for at least 5 min.**

Vehicle test: charge determination R744 (system spec R744)



Engine speed: **1600 rpm**
Air velocity: **32 km/h**
Duration: **stable conditions for at least 5 min.**

Common Spec Book – Vehicle test: VDA Standard Pull Down

Climatic Wind Tunnel

Chamber temperature:	40°C
Relative humidity:	40%
Solar load:	1000 W/m²

Control Unit Setting

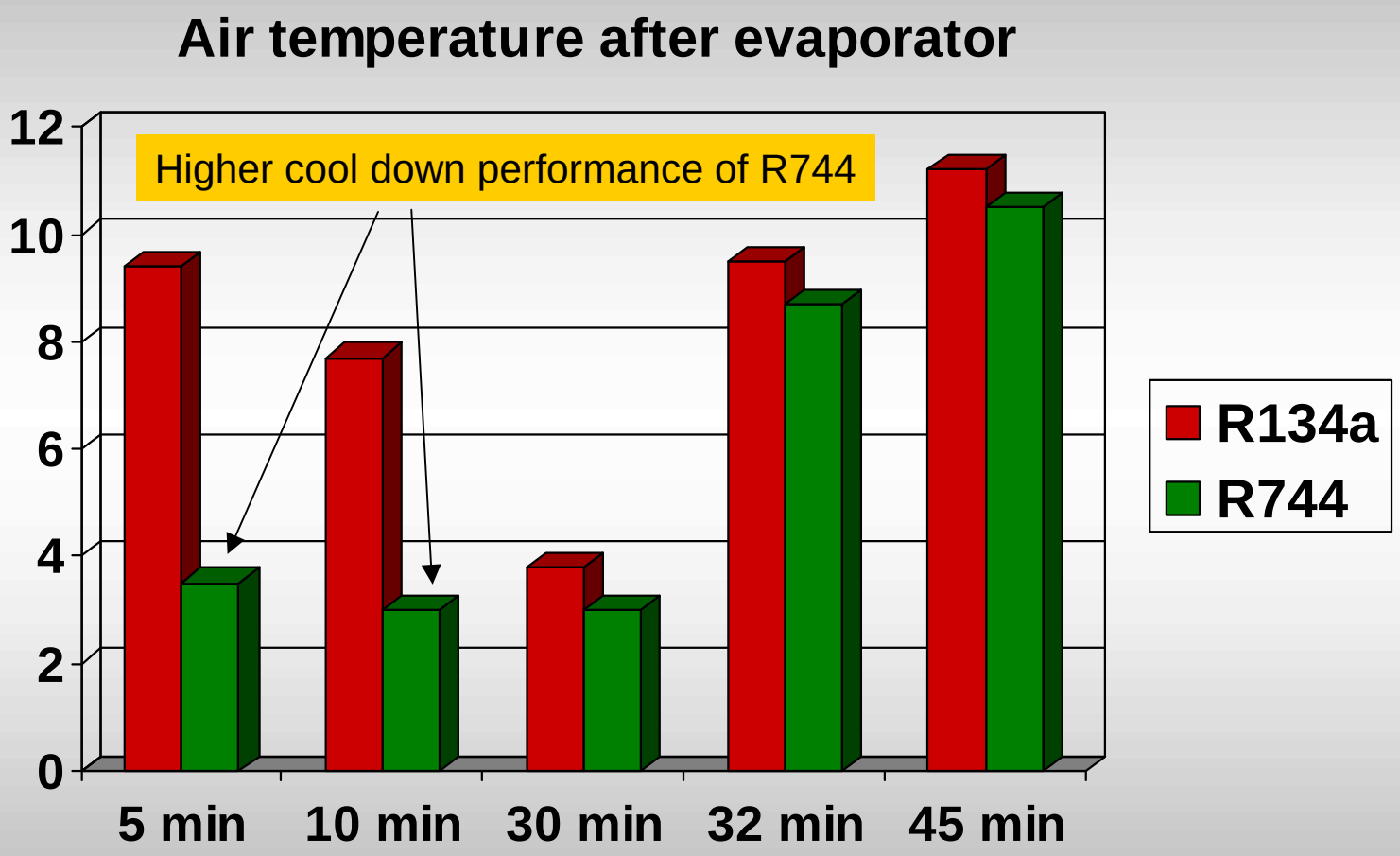
Cooling:	max
Blower:	max
Grill outlet:	“face level” open
Recirculation:	100%

Drive Cycle

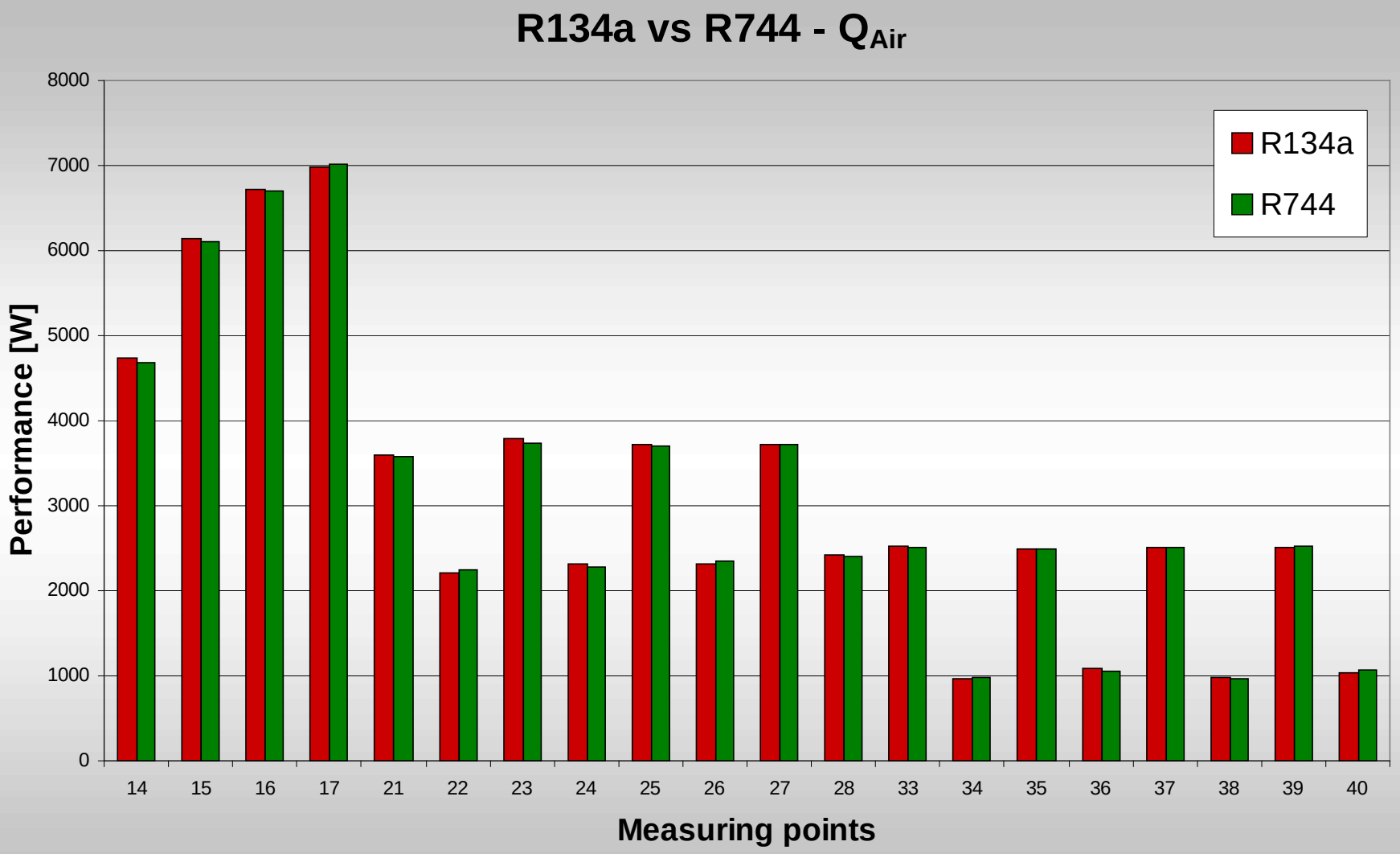
Phase1: Air velocity:	32 km/h
engine speed:	3rd gear/ according to power transmission
Time:	30 minutes
Phase2: Air velocity:	0 km/h
engine speed:	Idle
Time:	15 minutes

Test results – Vehicle Test

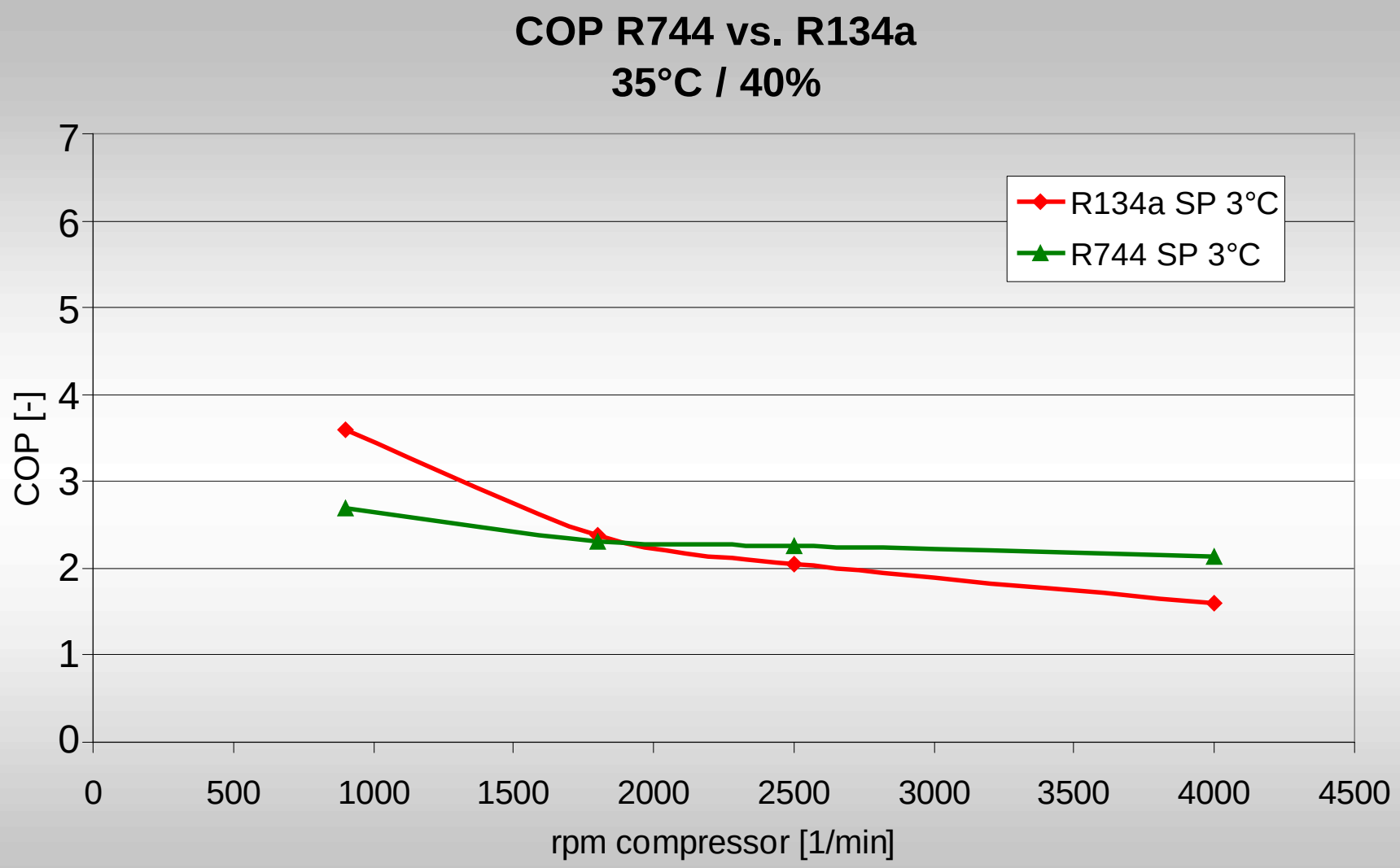
A/C-Performance – VDA Pull-Down



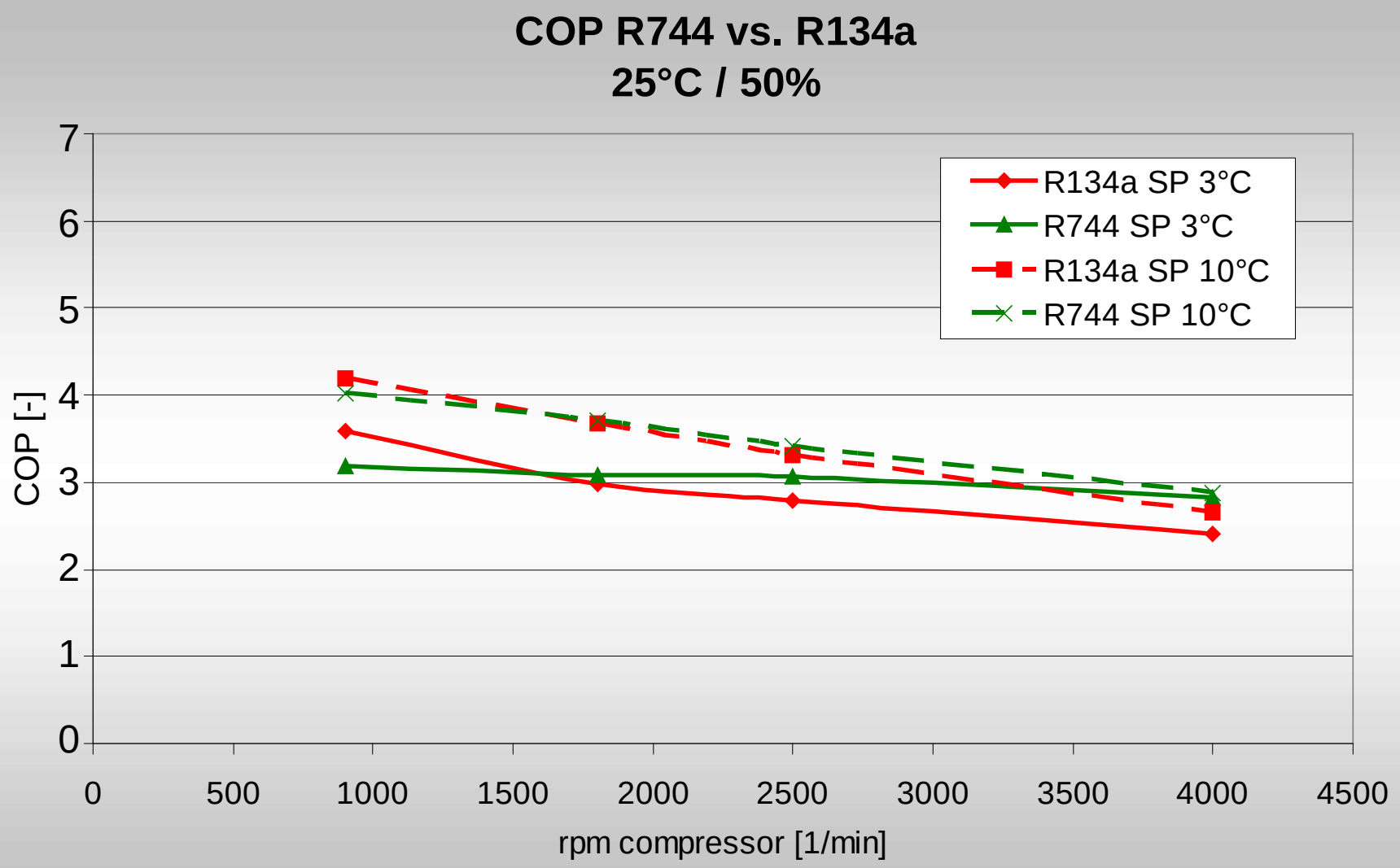
Test results – Bench Test



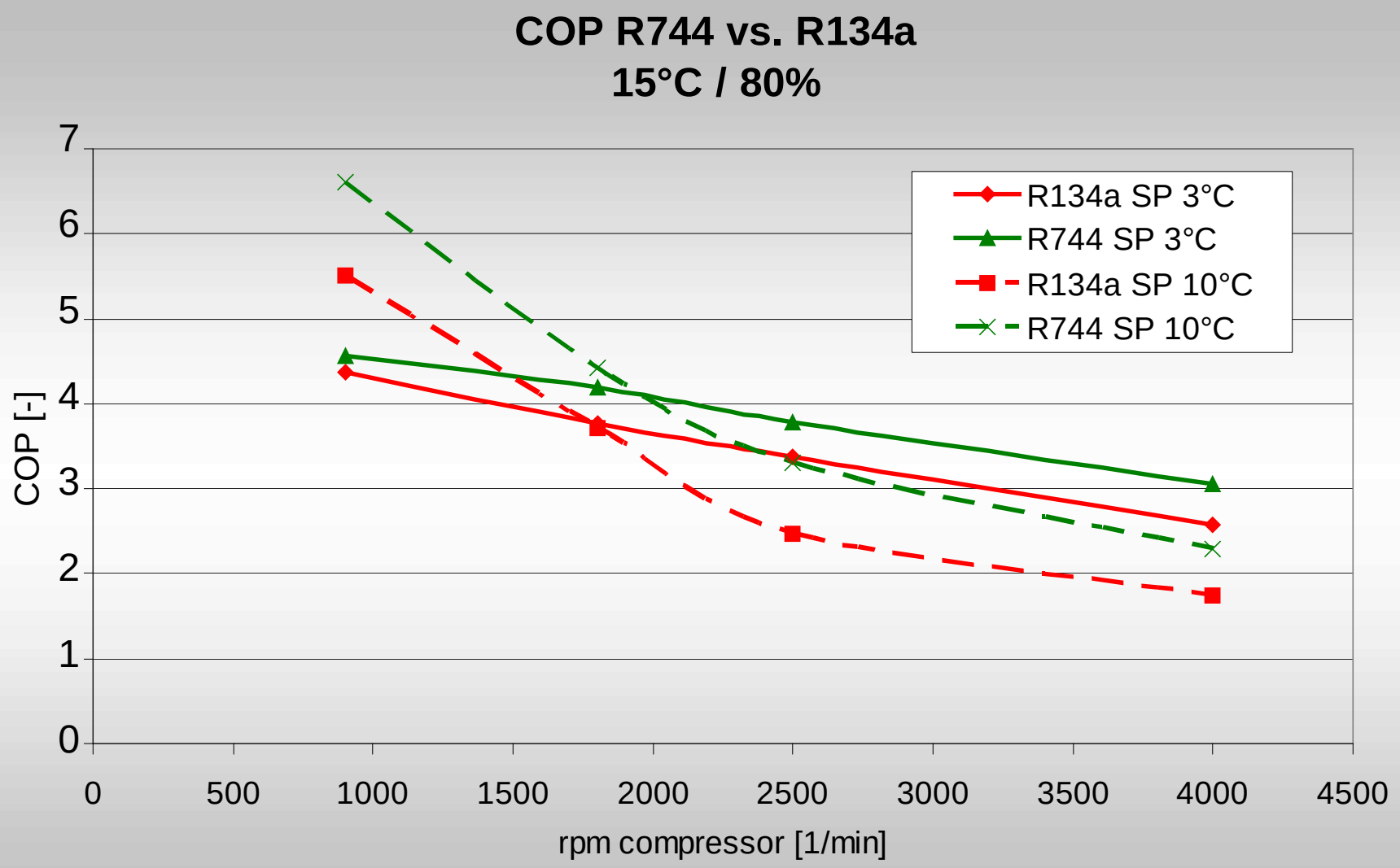
Test results – Bench Test



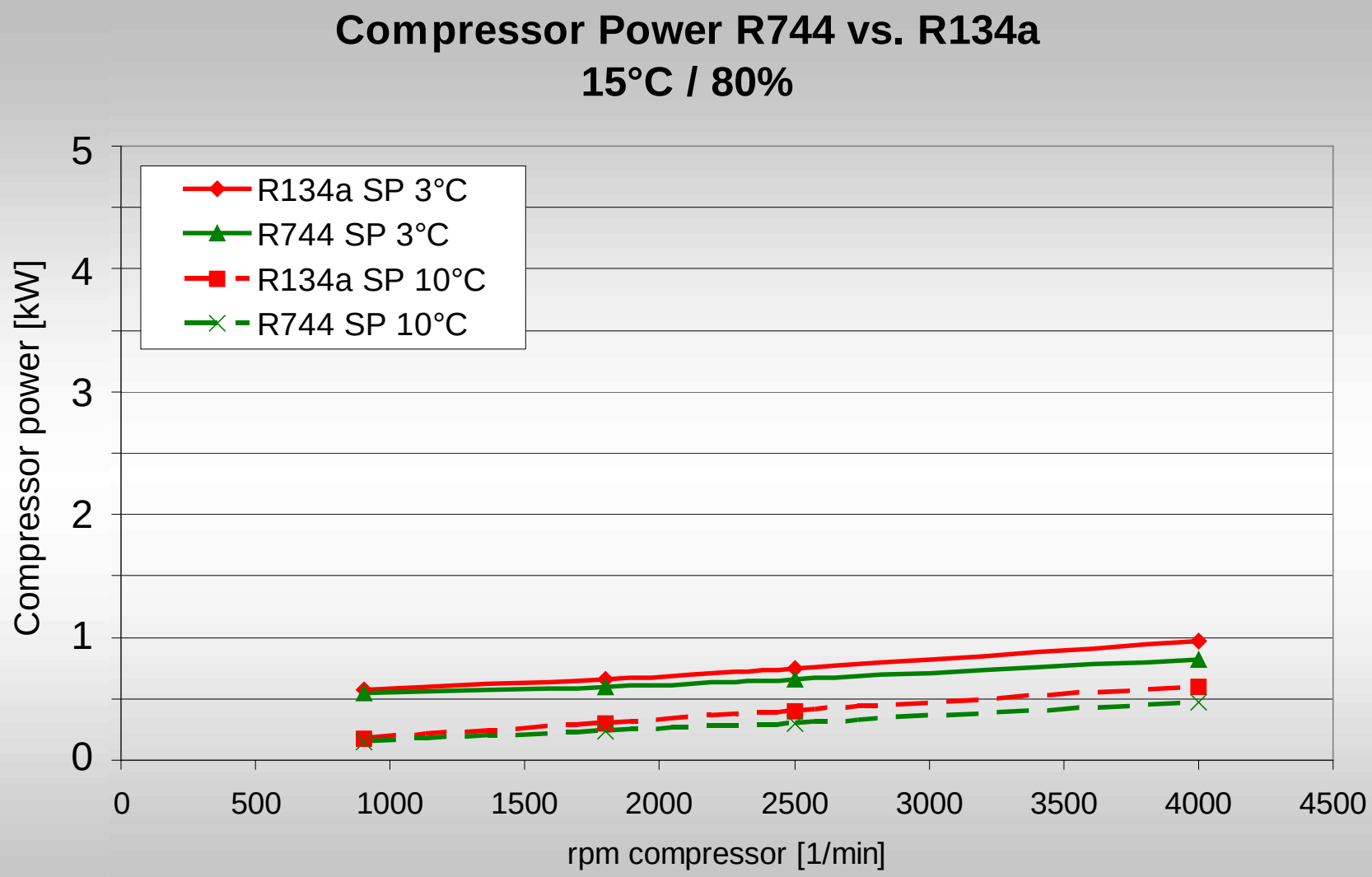
Test results – Bench Test



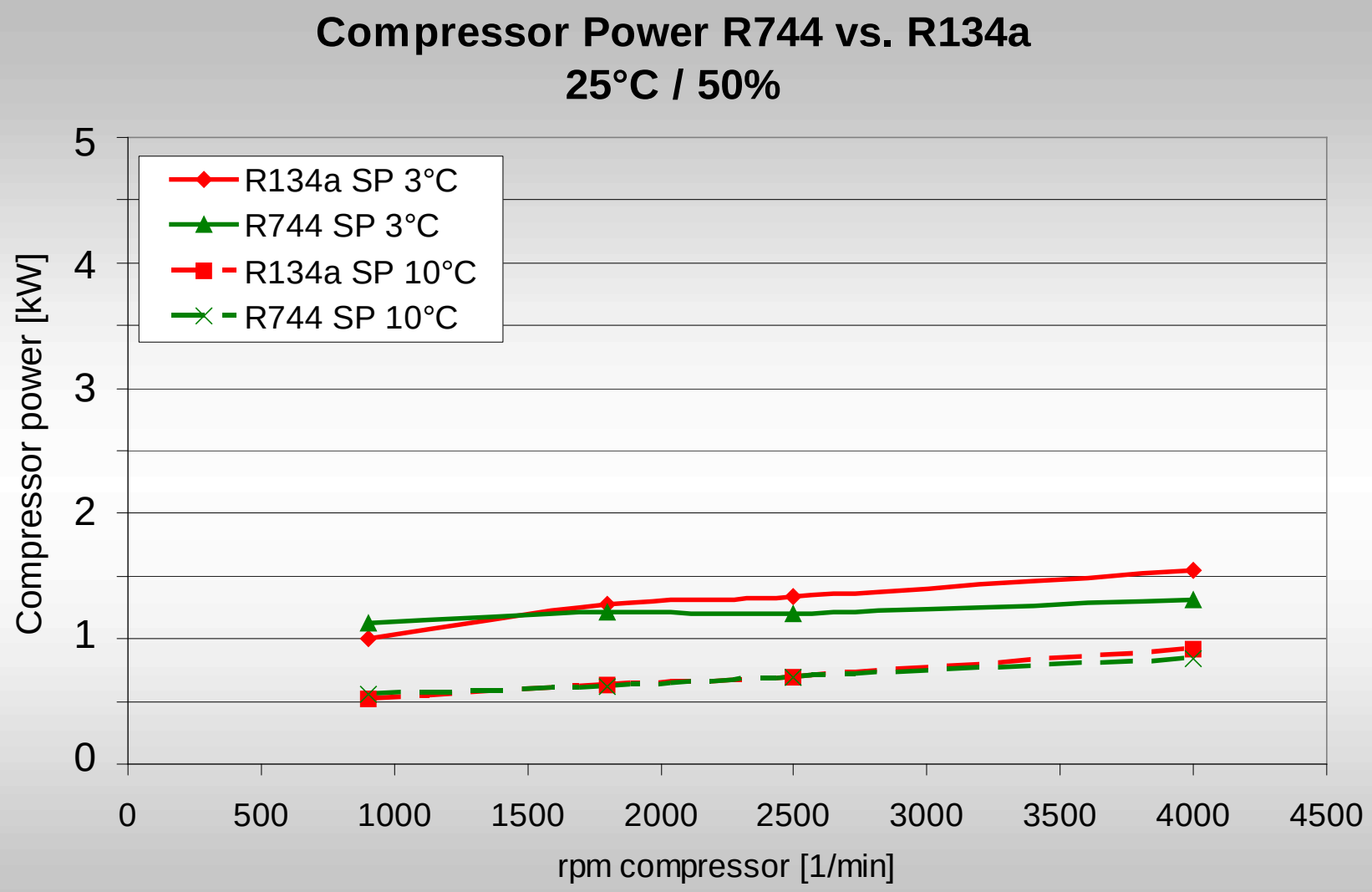
Test results – Bench Test



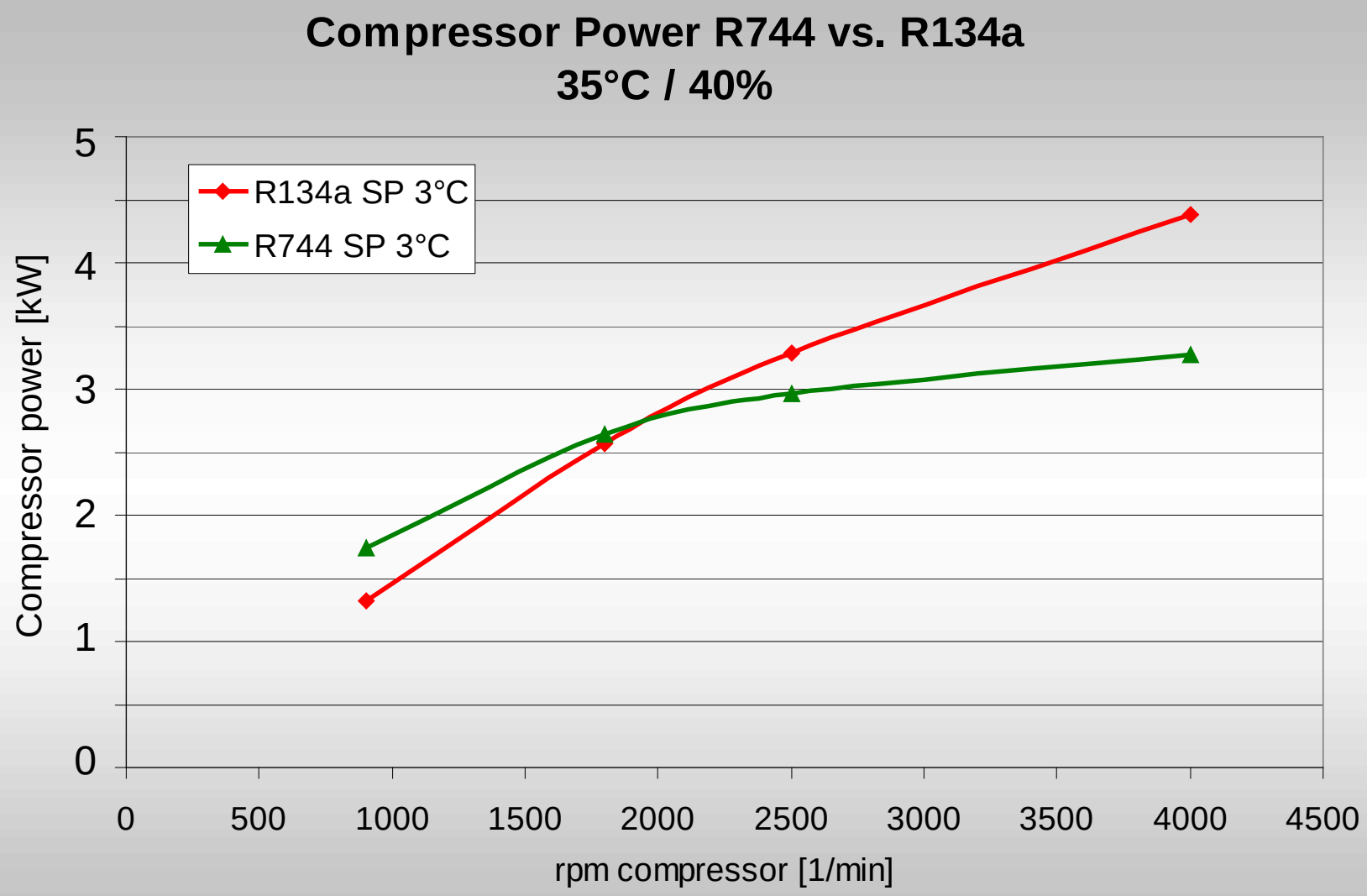
Test results – Bench Test



Test results – Bench Test



Test results – Bench Test



Summary

- Common Spec Book proved to be a valuable tool to compare performance and efficiency of refrigerants
- The R744 system outperforms the R134a system in dynamic cool down behavior
- Results show lack of efficiency under idling conditions
- Bench test results need to be confirmed in vehicle fuel economy testing

Outlook

- Results are just a snapshot of actual development status
- Potentials for improvement for either of the refrigerants are on sight
- First introduction of next generation refrigerant will not achieve highest level of efficiency
- To find one global refrigerant superior in efficiency under all ambient conditions will be challenging and might end up in a compromise

Results of Audi A5 Evaluation with Alternate Refrigerants

Questions?