R1234yf System Enhancements and Comparison to R134a

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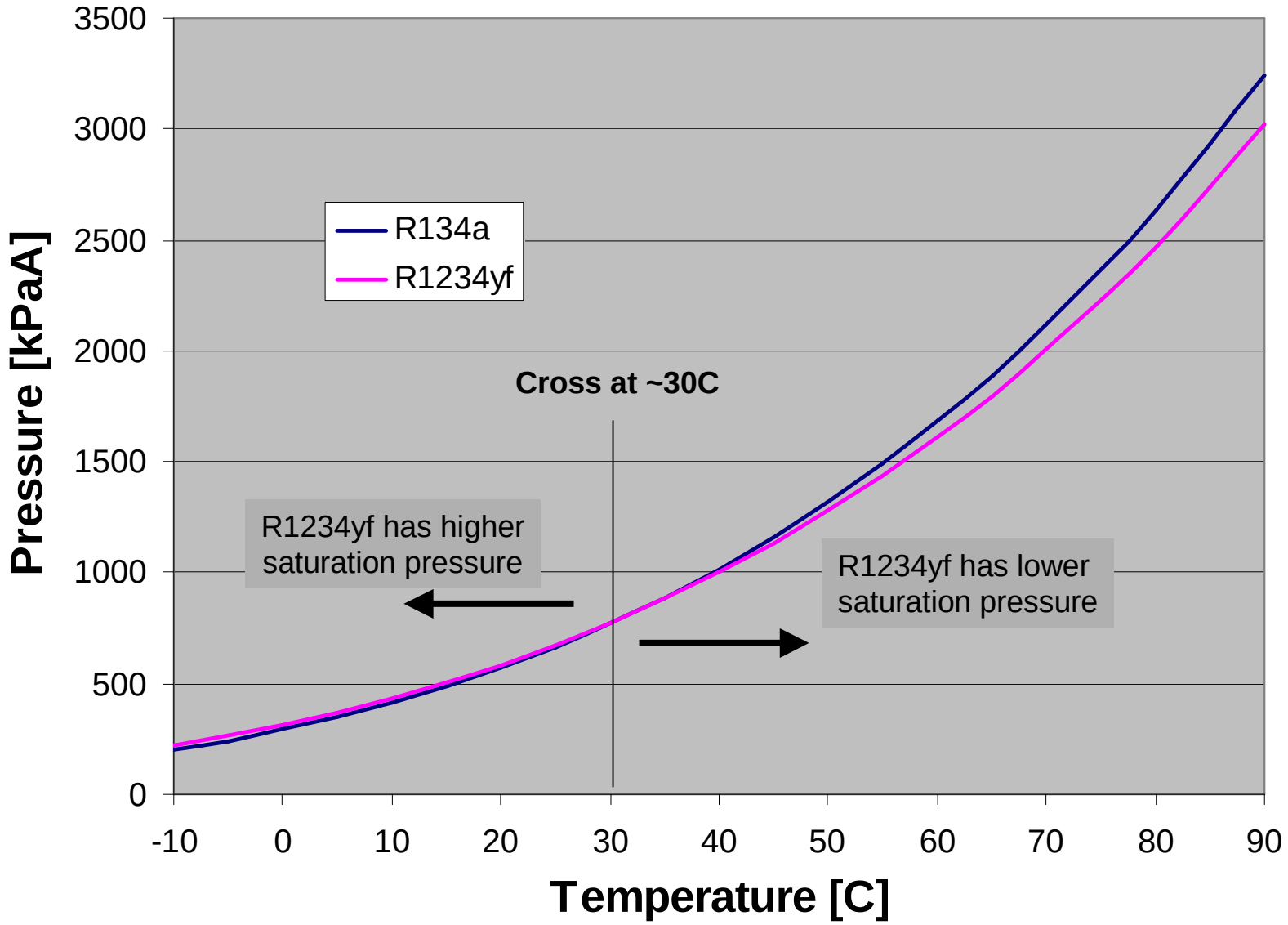
John Meyer

R1234yf Agenda

- System Performance Evaluation
  - TXV (Egelhof) and MCV (TGK) tuning
  - Baseline and enhanced system test results
    - IHX
    - Oil Separator
    - High Effectiveness Evaporator
- Compressor Durability

P-T for R134a and R1234yf



R134a Stand Evaluation

- Production system used for analysis
- 160cc variable displacement compressor
- 16mm IRD condenser
- 2.0T cross-charged TXV
- 58mm plate-fin evaporator
- Slightly modified discharge and liquid line
  - Modified for installation on stand
- Slightly modified SL
  - To allow for *in situ* torque calibration

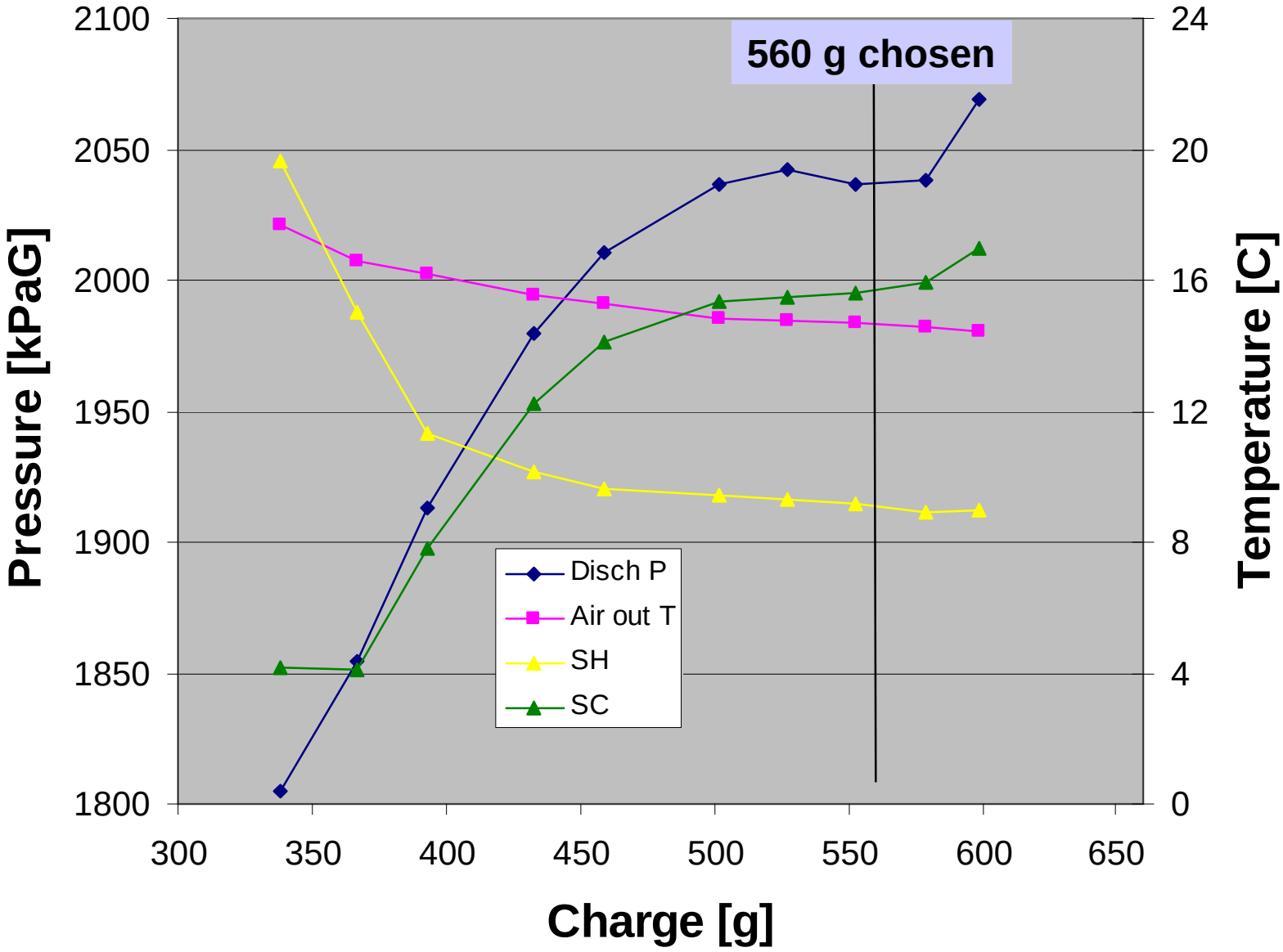
R1234yf – Stand Evaluation

- Changes to R134a system hardware
  - Same 16mm IRD condenser
  - Same 58mm plate-fin evaporator
  - Same VS16 compressor, new MCV set points
  - Same 200 cc PAG
  - 2.0T, 2.5T, 1.75T TXVs at high & low SH settings evaluated
  - Same slightly modified discharge and liquid line
  - Same slightly modified SL to allow for torque calibration

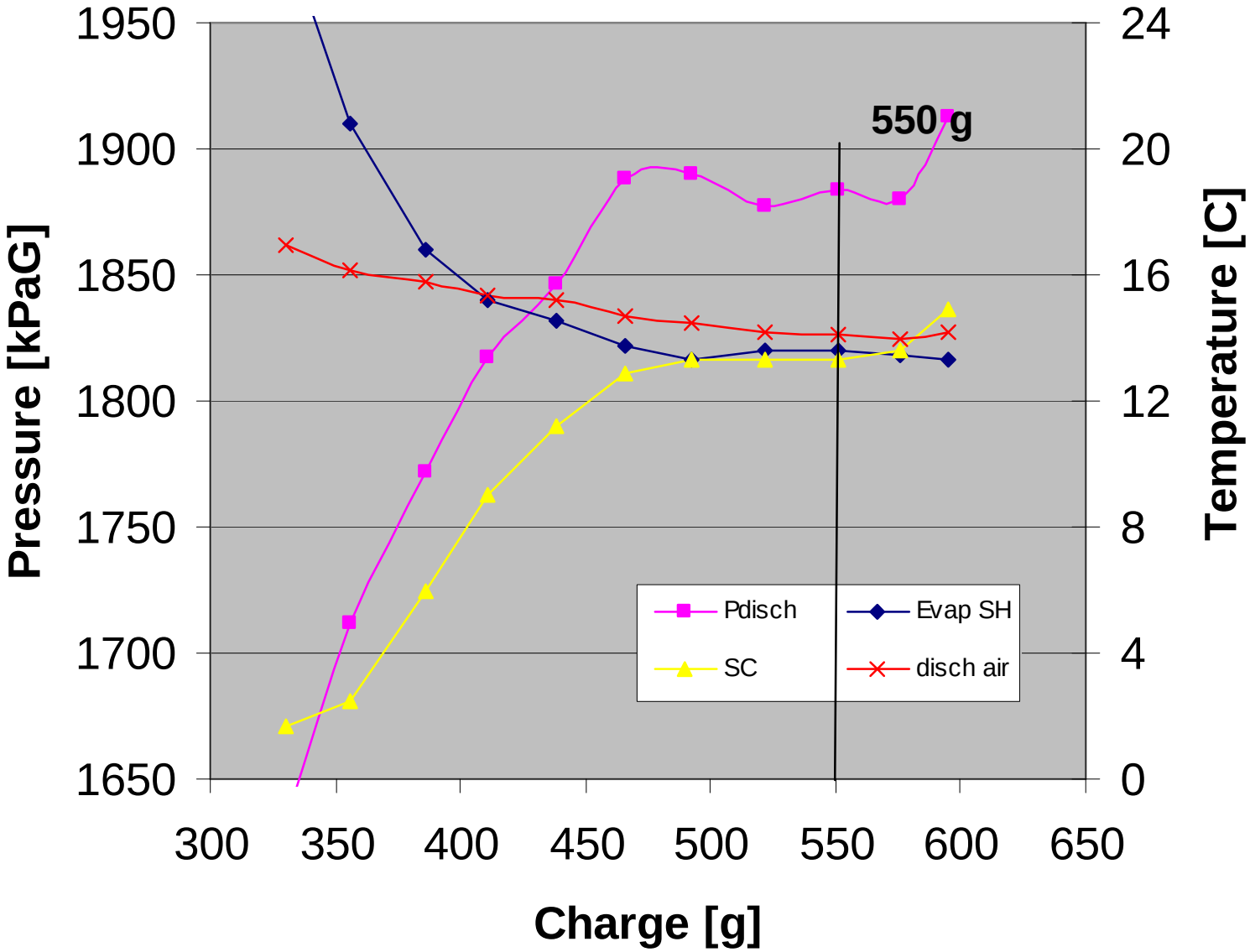
Evaluation Matrix

	Compressor	Condenser Airflow		Evaporator Airflow		
	RPM	l/s	Temp °C	Flow l/s	Temp °C	RH %
1	2500	700	45	140	43	40
2	1800	650	45	140	43	40
3	800	600	45	140	43	40
4	2500	700	37	140	35	40
5	1800	650	37	140	35	40
6	800	600	37	140	35	40
7	2500	700	27	100	25	40
8	1800	650	27	100	25	40
9	800	600	27	100	25	40

R134a Charge Determination

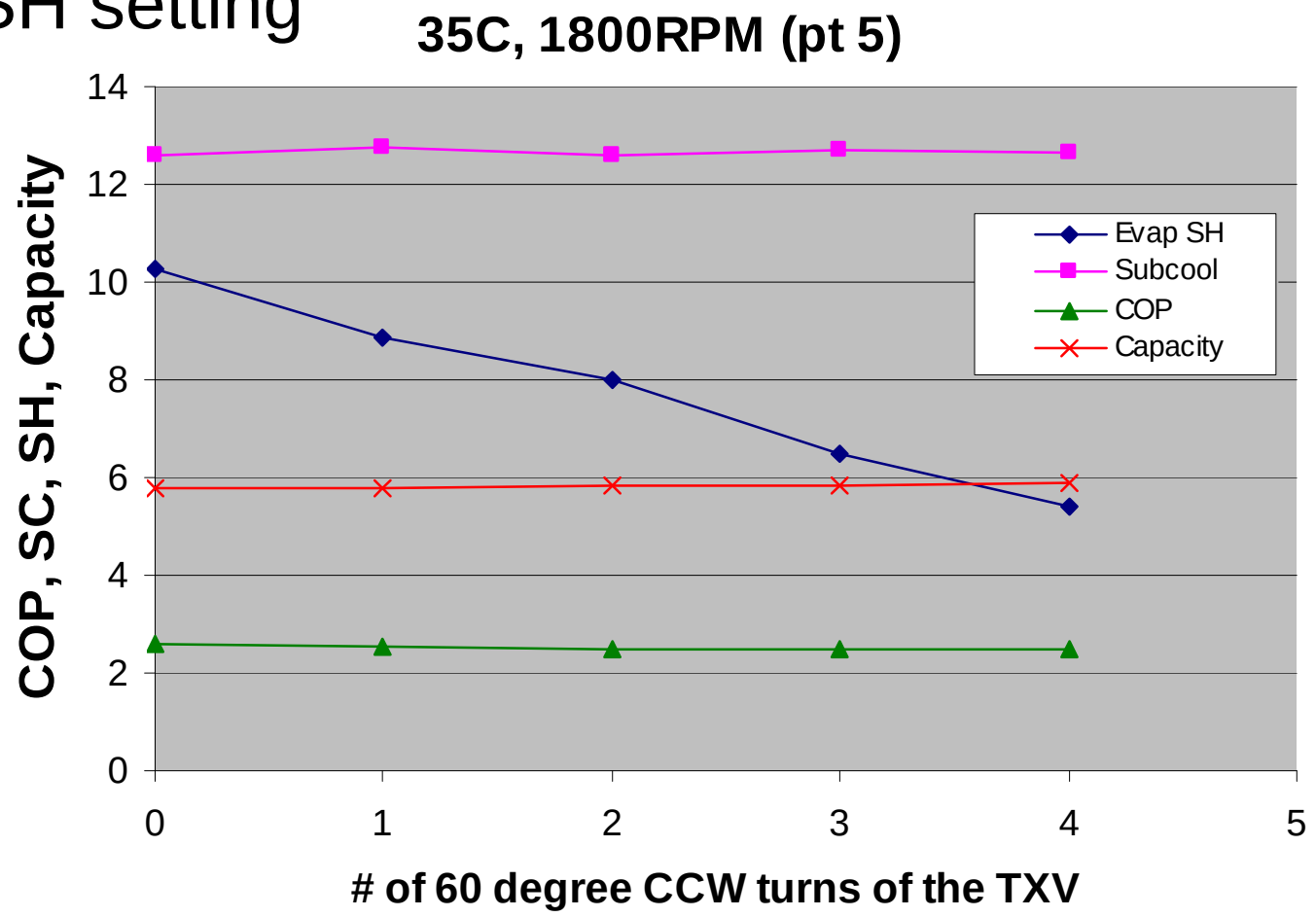


R1234yf Charge Determination

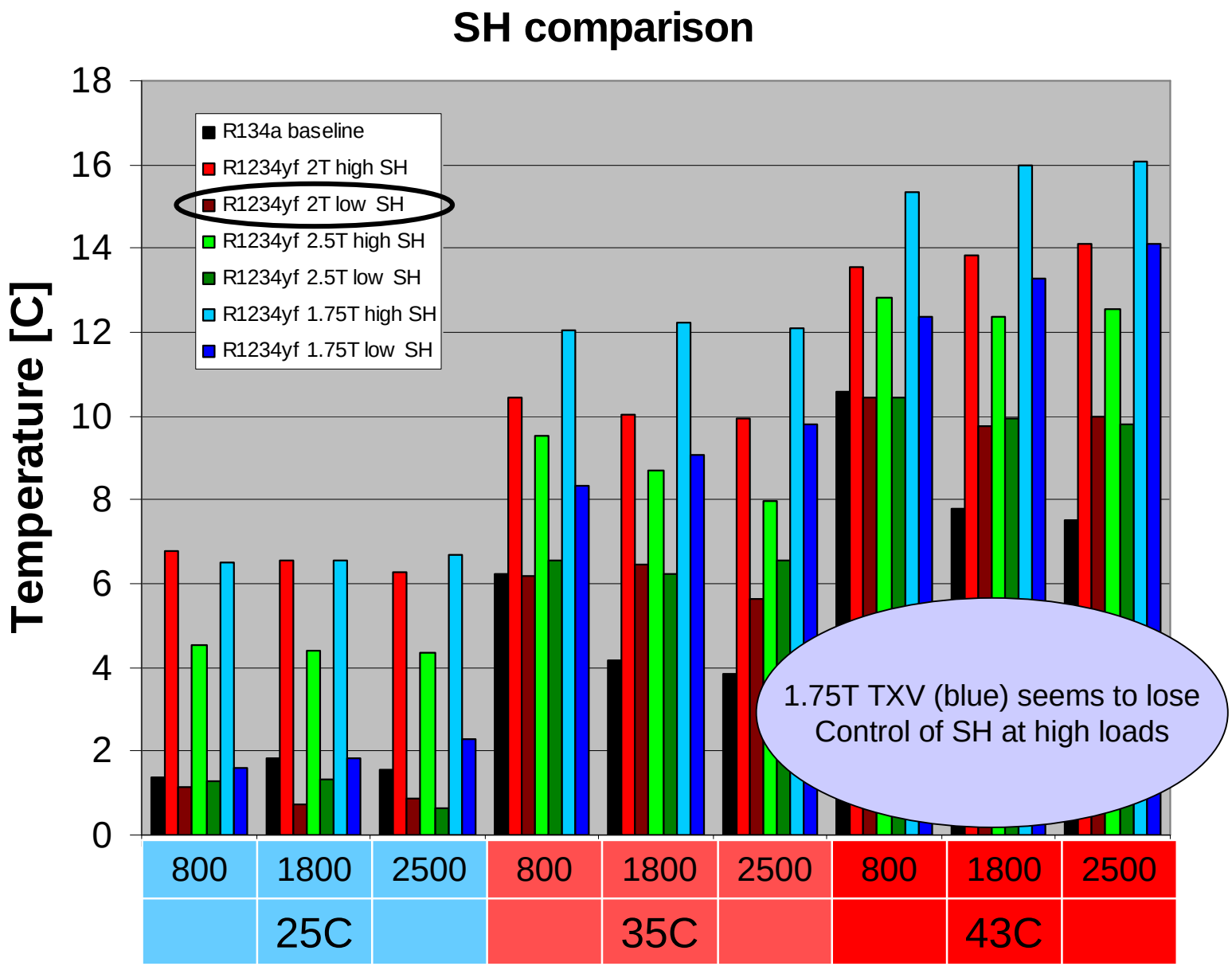


Adjusting R1234yf SH

- TXVs have a “set screw” to adjust SH setting
- Each valve was evaluated at a high and low SH setting



R1234yf vs R134a; Evaporator SH



R1234yf TXV and MCV Evaluation

- Cross charge TXVs from Egelhof
- 2.0, 2.5, and 1.75T valves tested
- 1.75T TXV is undersized
- TXV at low SH
  - Although no strong indication that low SH leads to improved performance:
    - » Low SH facilitates IHX integration
    - » Improved evaporator discharge air stratification
- MCVs from TGK
- Initial MCV calibration slightly off
- Gen II MCVs better tuned for this system

R1234yf Evaporator Stratification

- 4x4 thermocouple matrix on evaporator outlet
  - Stratification = $T_{max} - T_{min}$
- With similar SH settings, R1234yf shows slightly improved stratification

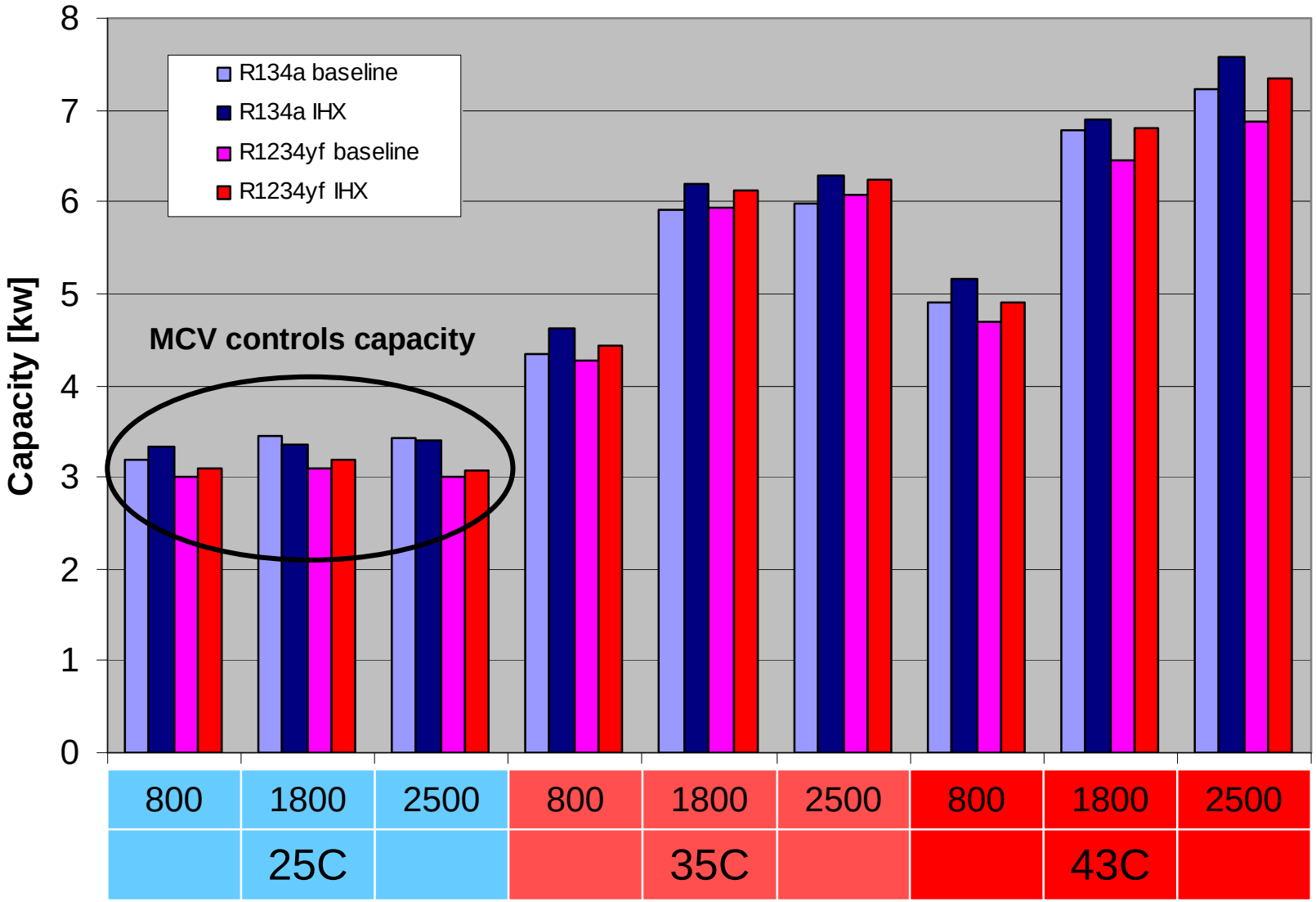
Baseline R1234yf System Defined

- Same compressor, heat exchangers, lines, lubricant
- 2.0T TXV from Egelhof at “low” SH setting
- “GEN II” MCV from TGK

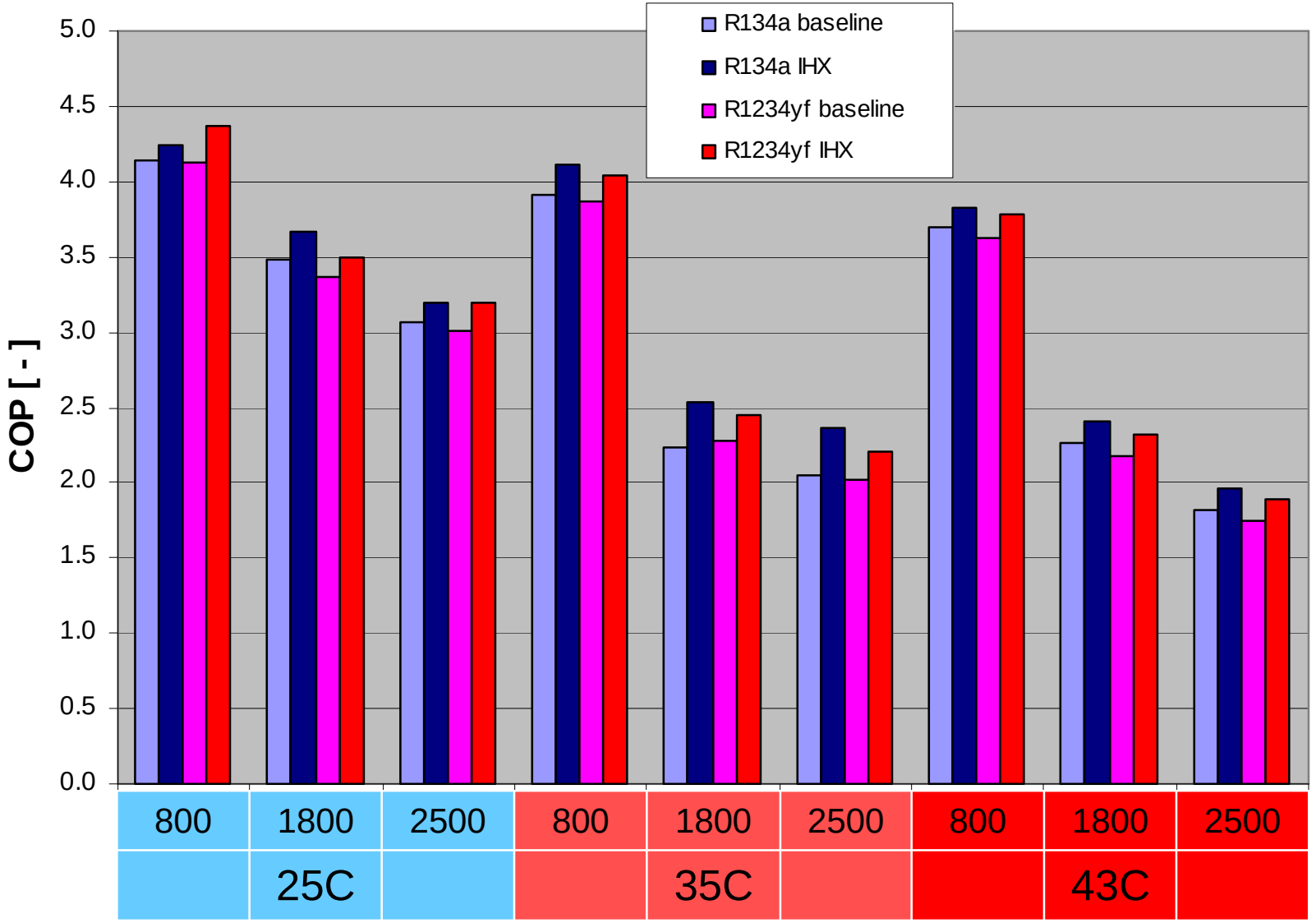
R1234yf Enhancements

- Internal Heat Exchanger (IHX)
  - Production Intent (SOP ‘09)
  - Fully validated with R134a
- Oil Separator
- High efficiency evaporator
  - Tube-fin
  - Same package
  - Lower air-side pressure drop

R134a vs 1234yf – IHX; Capacity

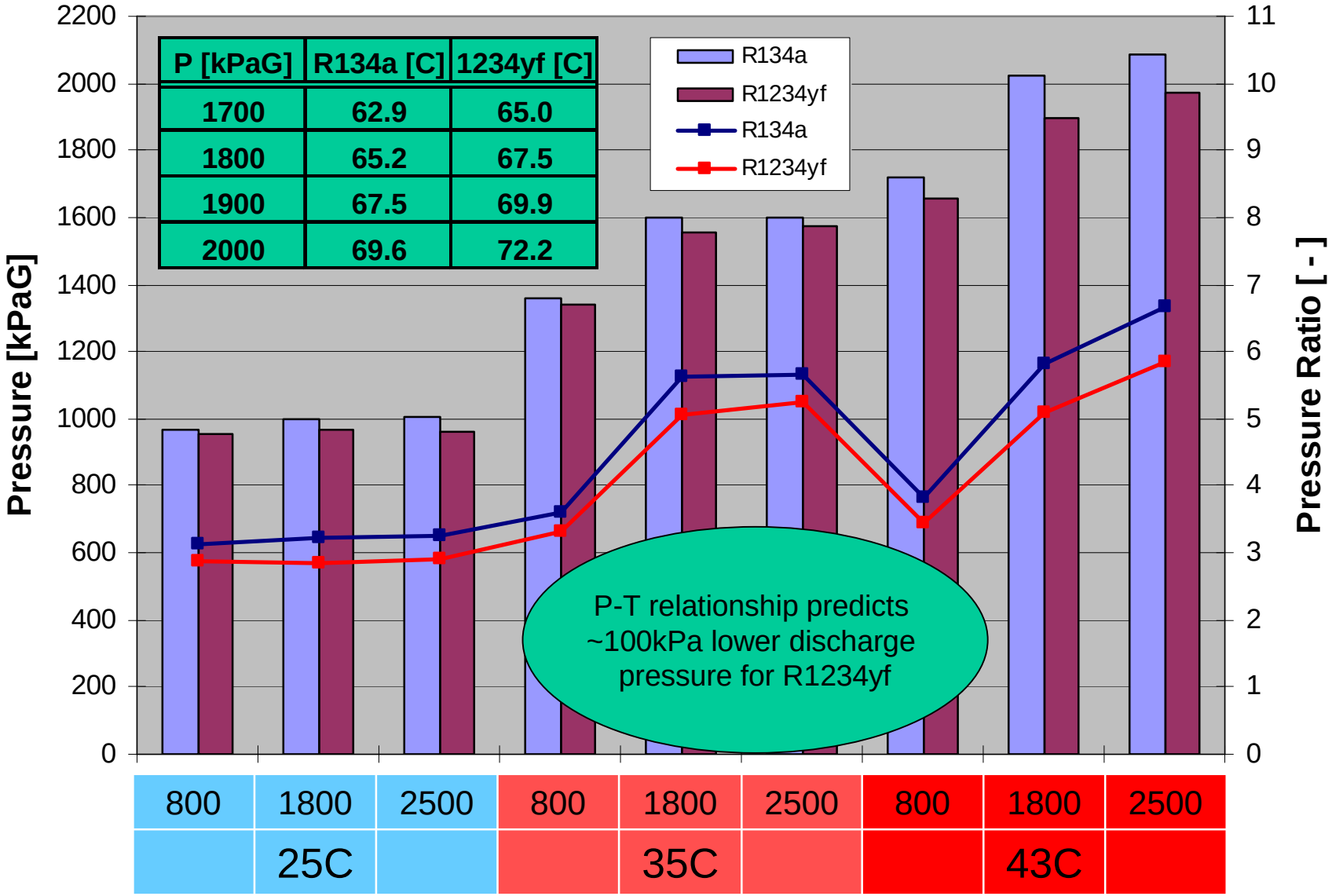


R134a vs 1234yf – IHX; Efficiency

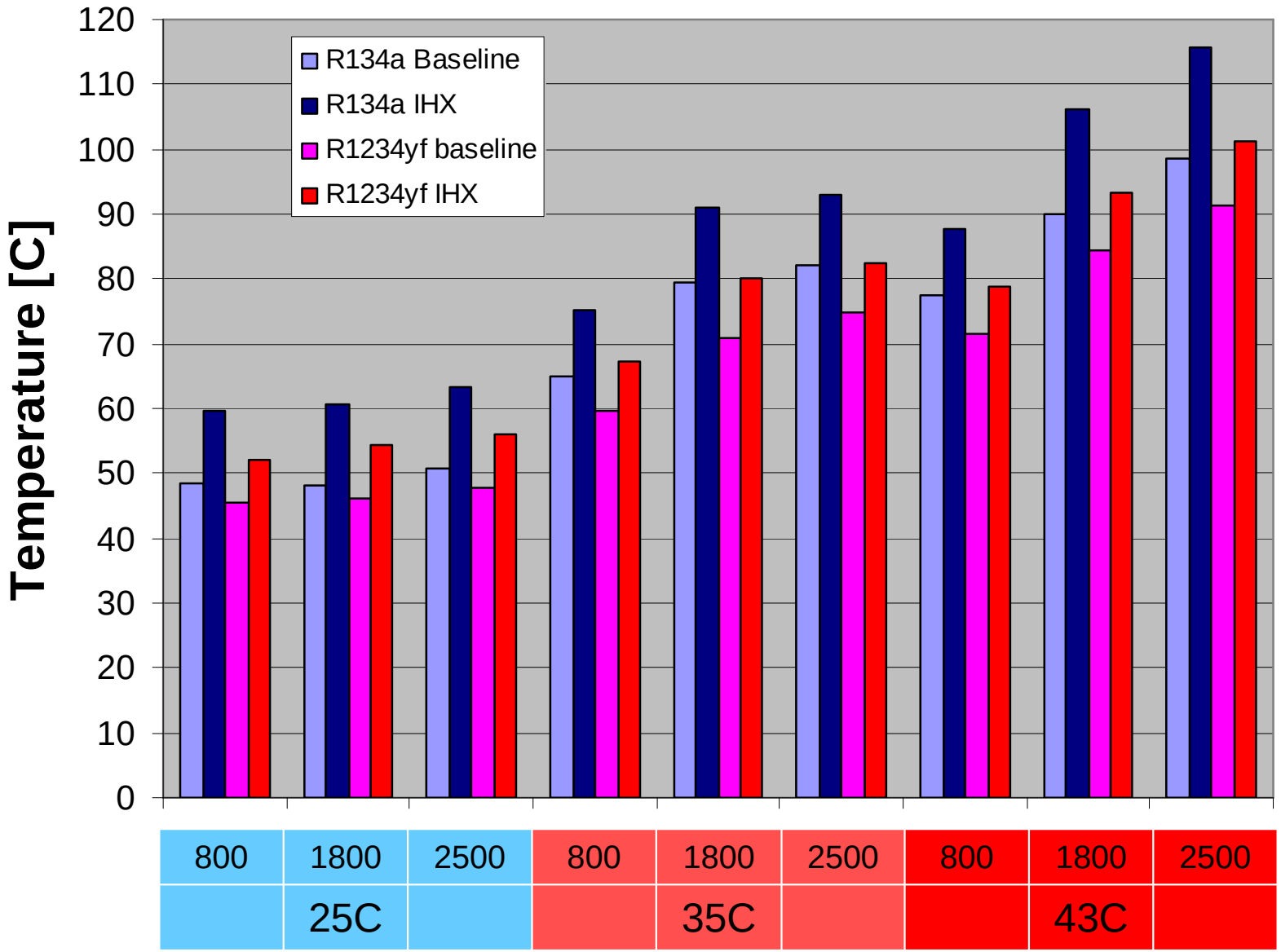


Discharge and Pressure Ratio

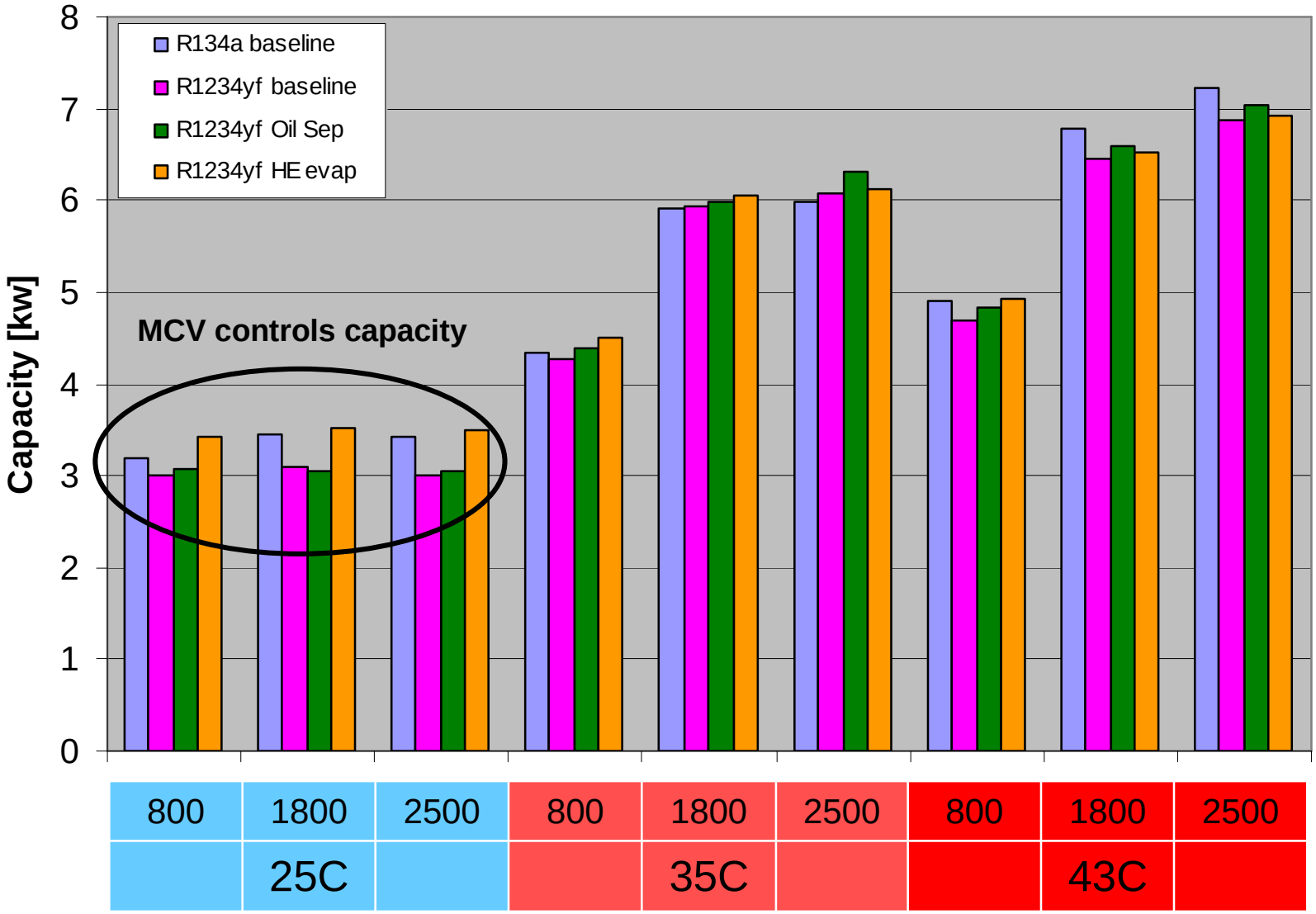
P [kPaG]	R134a [C]	1234yf [C]
1700	62.9	65.0
1800	65.2	67.5
1900	67.5	69.9
2000	69.6	72.2



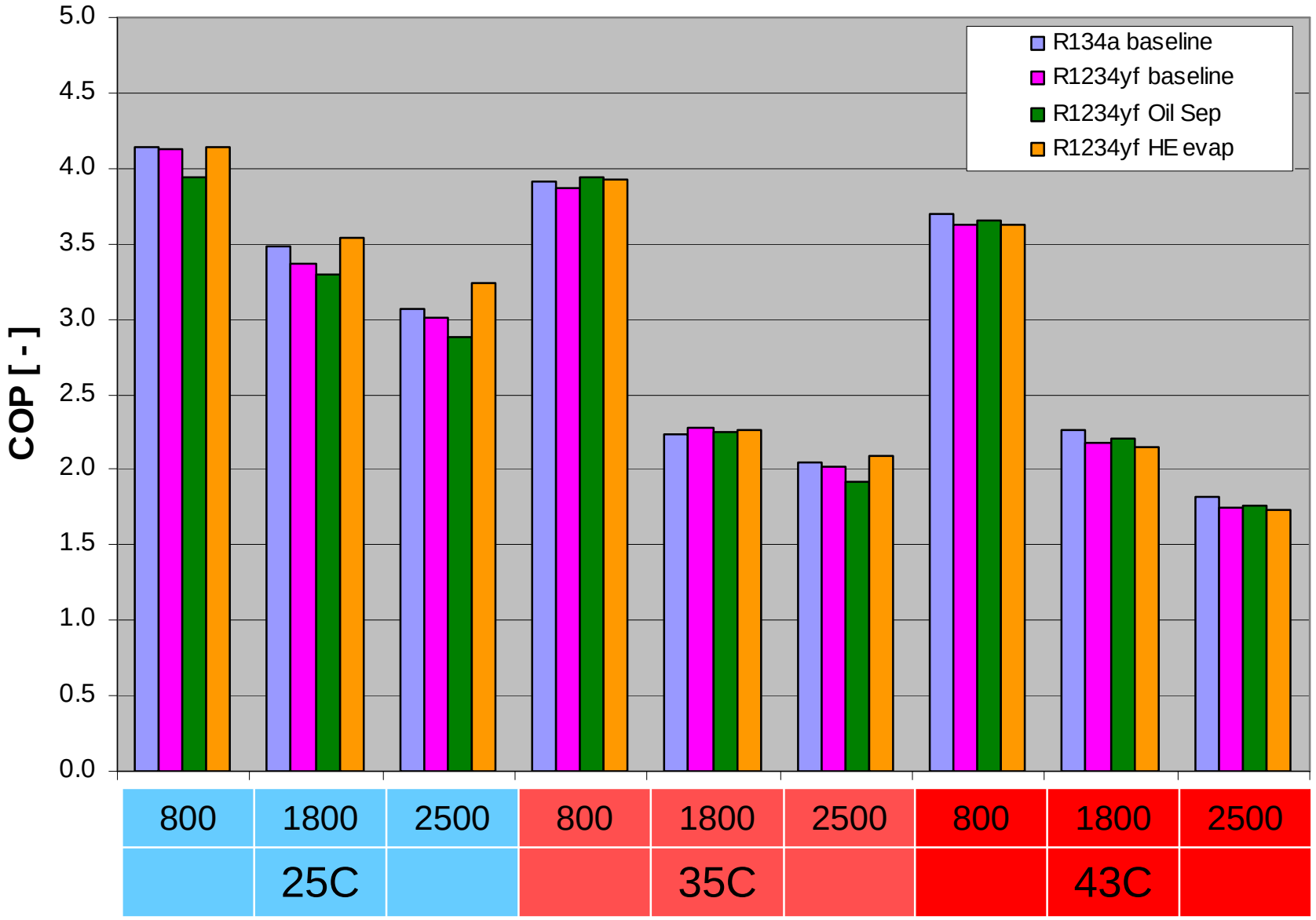
R134a vs 1234yf – IHX; Compressor Discharge Temperature



R134a vs 1234yf – Oil Separator & High Efficiency Evaporator; Capacity

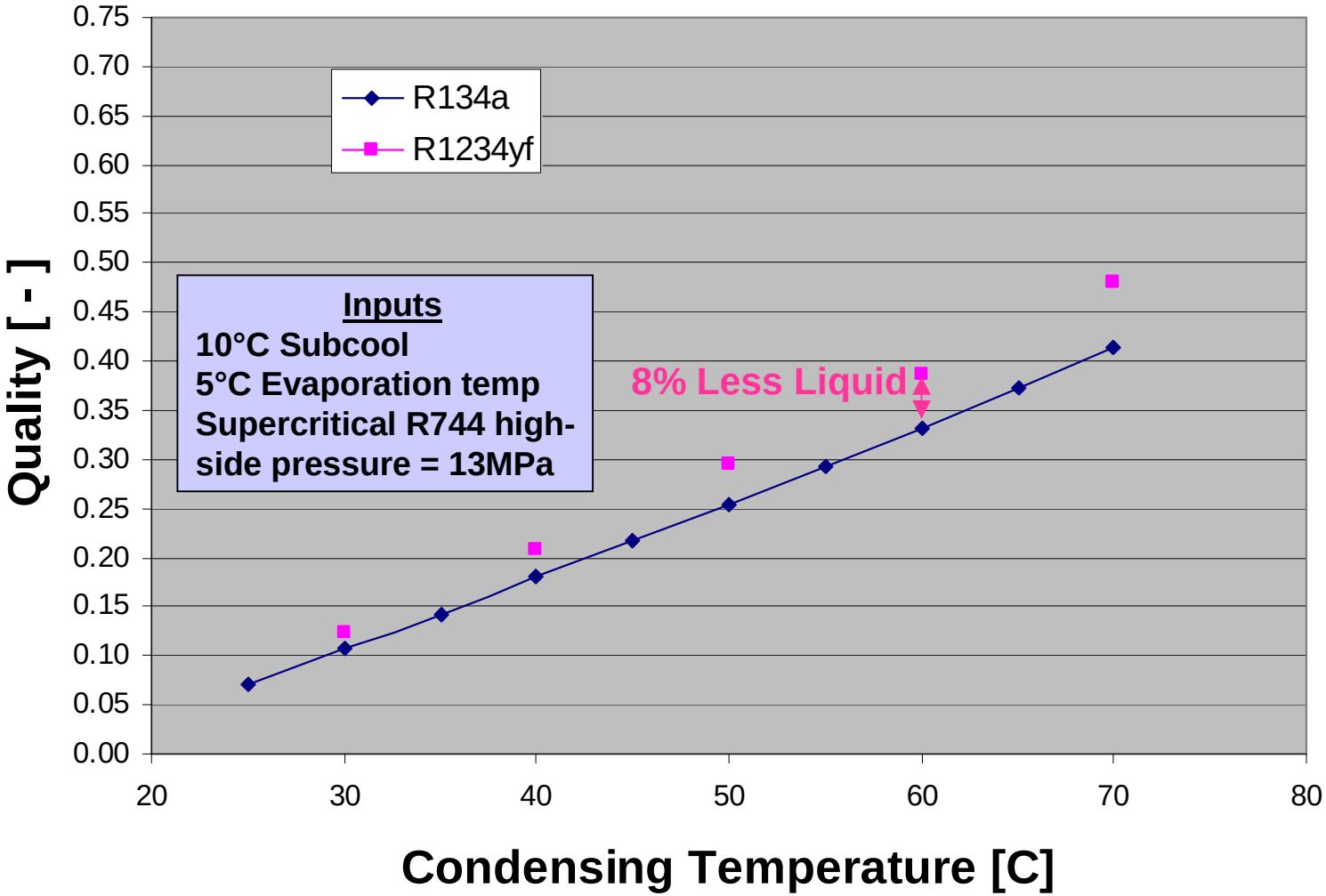


R134a vs 1234yf – Oil Separator & High Efficiency Evaporator; Efficiency



Evaporator Inlet Quality

- Higher quality = less liquid = lower capacity



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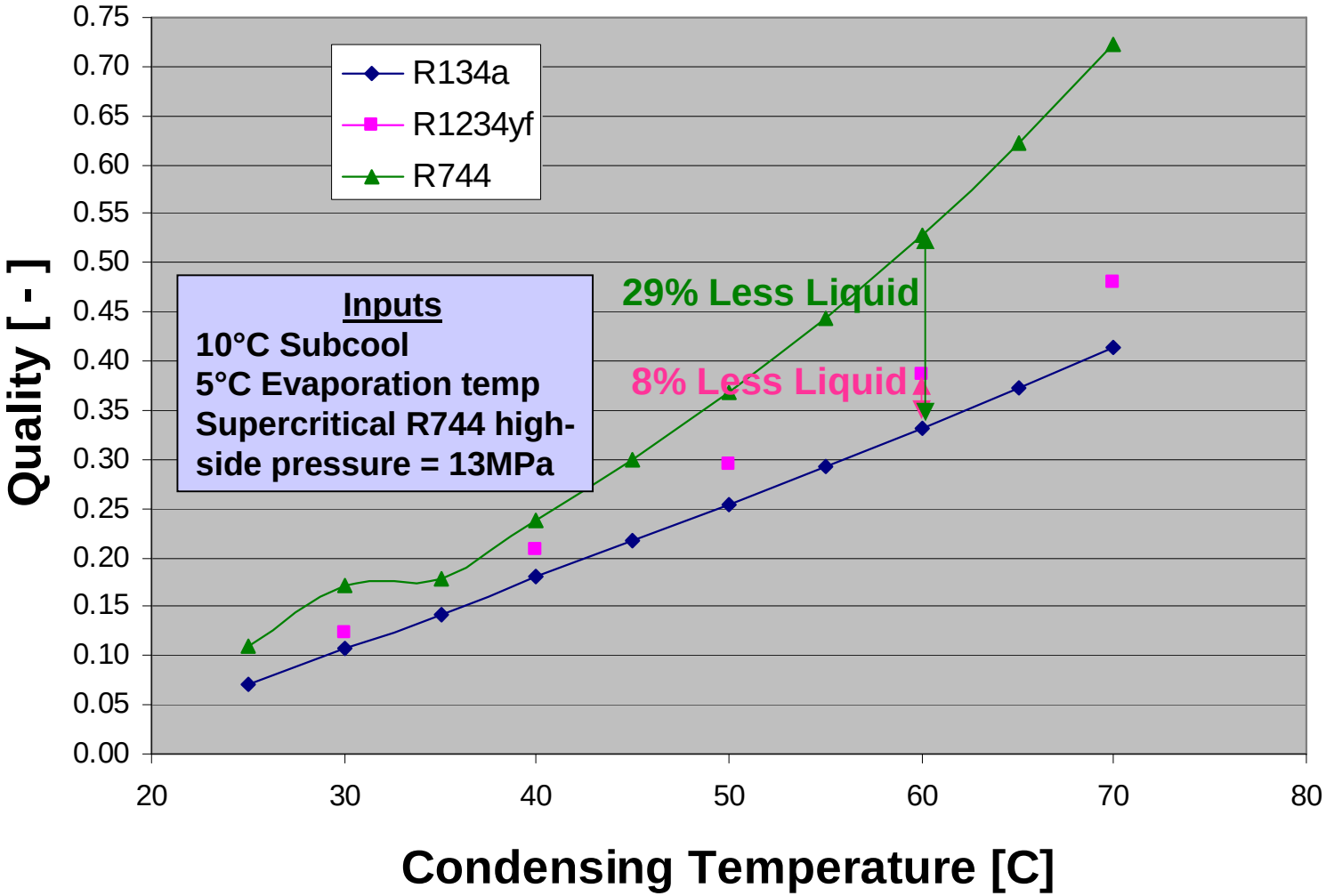


R1234yf Performance Summary

- Baseline R1234yf system used same tonnage TXV with modified bulb charge and adjusted MCV
- R1234yf has approximately 8-10°C cooler compressor discharge temperature vs R134a
- As near drop-in, capacity and efficiency fall slightly short of R134a

R1234yf Performance Summary (cont)

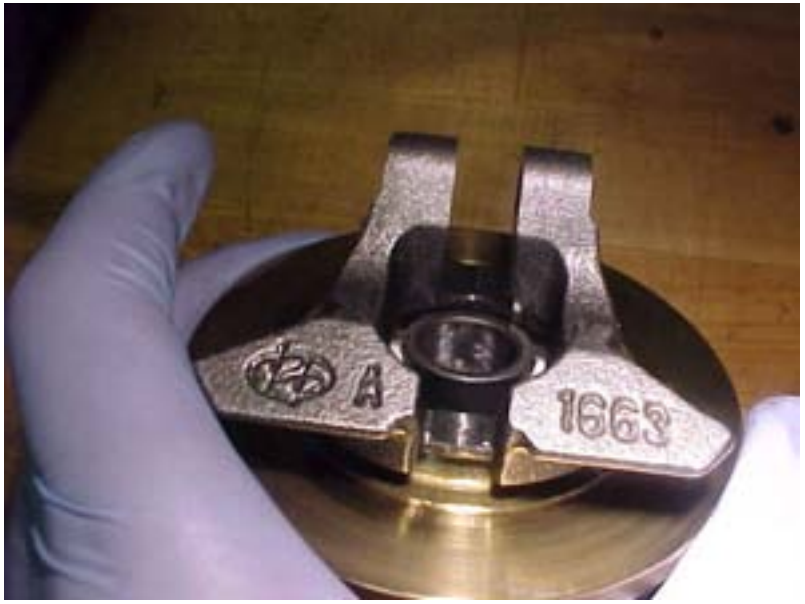
- R1234yf with IHX
  - ~Matches/exceeds R134a baseline capacity
  - Has slightly higher average efficiency than baseline R134a across all points
  - ~Matches R134a compressor discharge temperature
- R1234yf with Oil Separator
  - Small increase in capacity and efficiency
  - Falls short of baseline R134a at high ambient
- R1234yf with High Efficiency Evaporator
  - Small increase in capacity and efficiency
  - Falls short of baseline R134a at high ambient

R1234yf Compressor Testing

Initial Compressor Durability

- High Pressure Low Charge – high load and temperature test
  - » Completed initial testing - No issues
- High Speed – high friction and high temperature test
  - » Completed initial testing – No issues

Durability Teardown Results



Acknowledgements

- Thanks to….
  - TGK for prototype MCVs
  - Egelhof for prototype TXVs
  - JCS for tube-fin evaporator
  - Honeywell and DuPont for R1234yf