Internal Heat Exchanger Interaction with an Electronic Expansion Valve using HFO-1234yf

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Outline

- Project Scope
- Theory – Effect of an EXV in a MAC IHX System
- Experimental Setup
    - Equipment Layout
- Component Detail
- Test Conditions
- Results
- Conclusions and Future Work

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Project Scope

Development of an Electronic Expansion Valve in concert with an IHX to demonstrate a reduction in climate control energy usage.

The Environmental Protection Agency of the US Government has discussed possible fuel economy credits for usage of an electronically controlled expansion valve. The purpose of this project is to determine the benefit realized by utilization of an electronically controlled expansion valve on performance and system efficiency of a typical mobile air conditioning system.

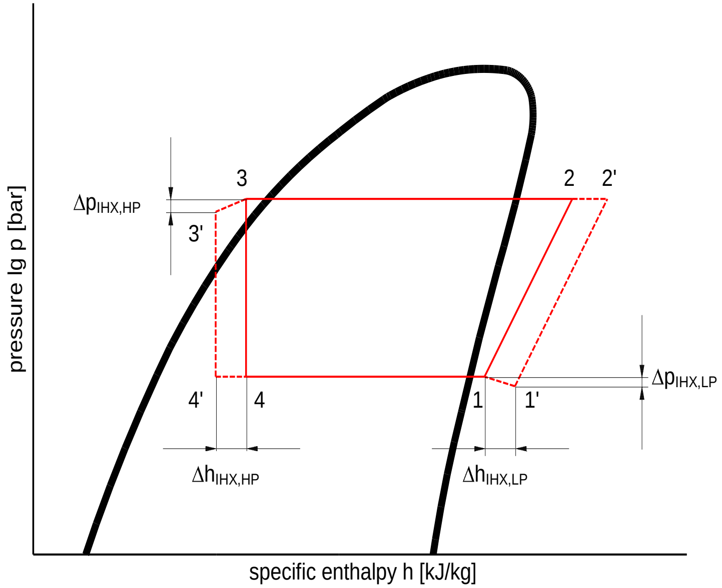
This presentation will discuss the effects of saturated refrigerant at the IHX low side inlet, system performance and system efficiency. This work will show if flooding liquid refrigerant into an IHX will reduce energy usage at equivalent climate load (enhance efficiency).

Effect of an EXV in a MAC IHX system

- Additional IHX effectiveness compared to a baseline TXV-IHX system

- Control of superheat at the compressor inlet, providing increase of control of compressor discharge temperature (offset baseline IHX degradation)

- Bottom line -> expect increase in compressor flow due to density increase at compressor inlet, improved cooling capacity, and reducing MAC fuel consumption compared to an IHX-TXV baseline



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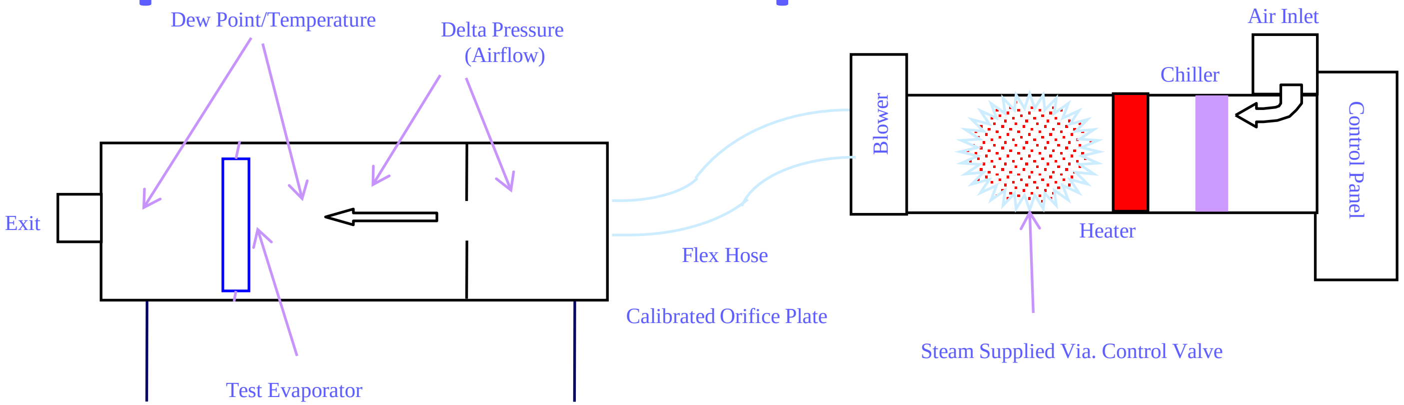
Experimental Setup



Evaporator Loop

Compressor – Sanden 171cc EVDC compressor

Condenser – 660 mm by 356 (4 pass) Delphi Micro-channel

Evaporator – 203 mm by 254 mm Delphi single tank U-flow

Hutchinson Coaxial IHX - 700 mm

Electronic Expansion Valve - SanHua 2.0 Ton

Condenser Loop

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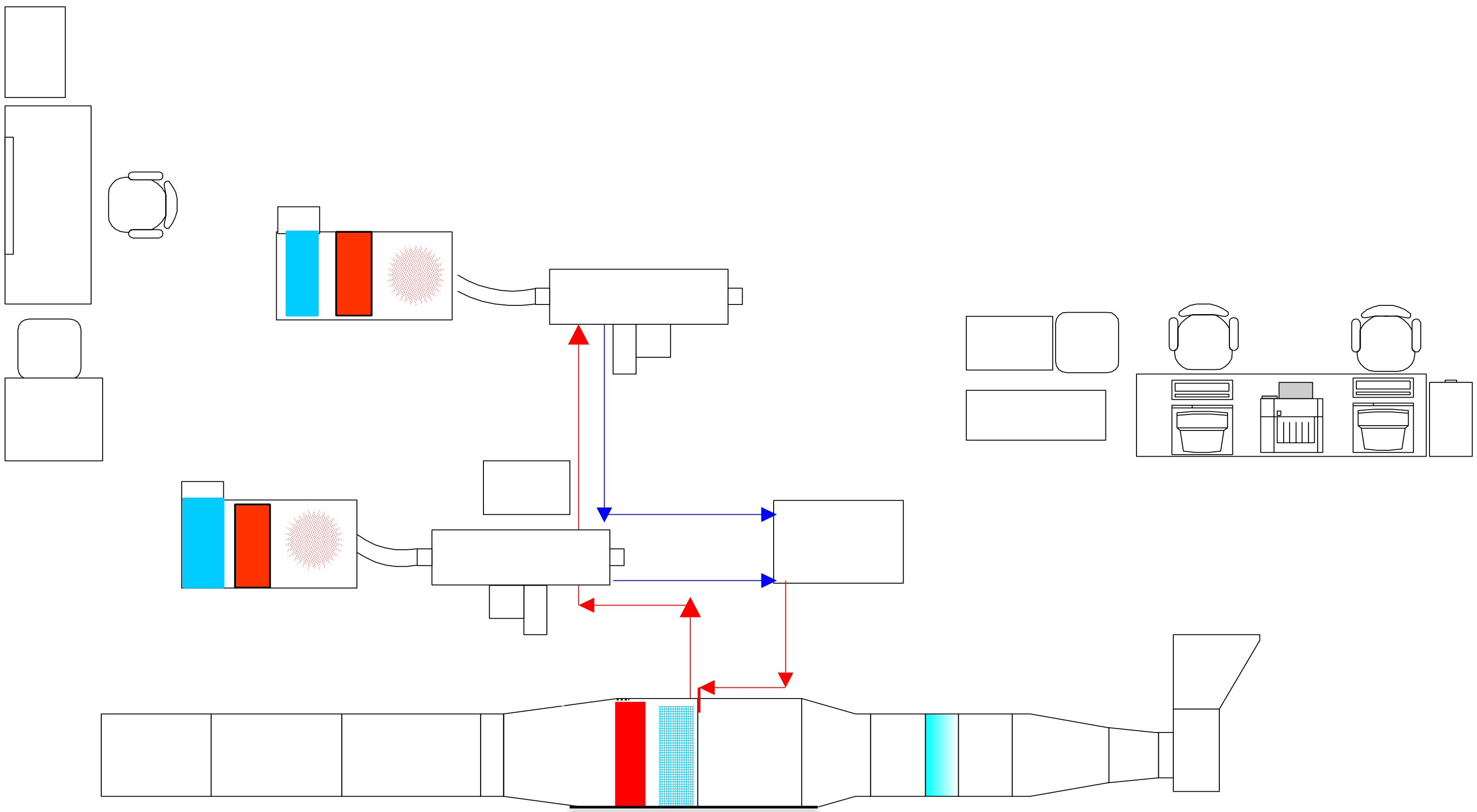
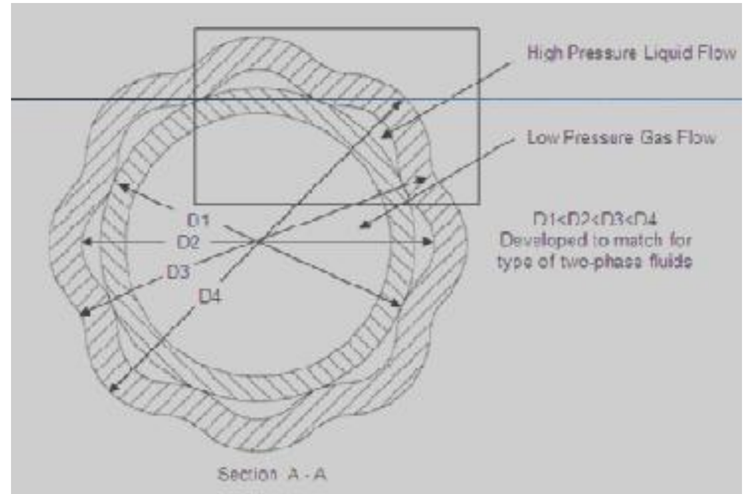
Equipment Layout – System Bench

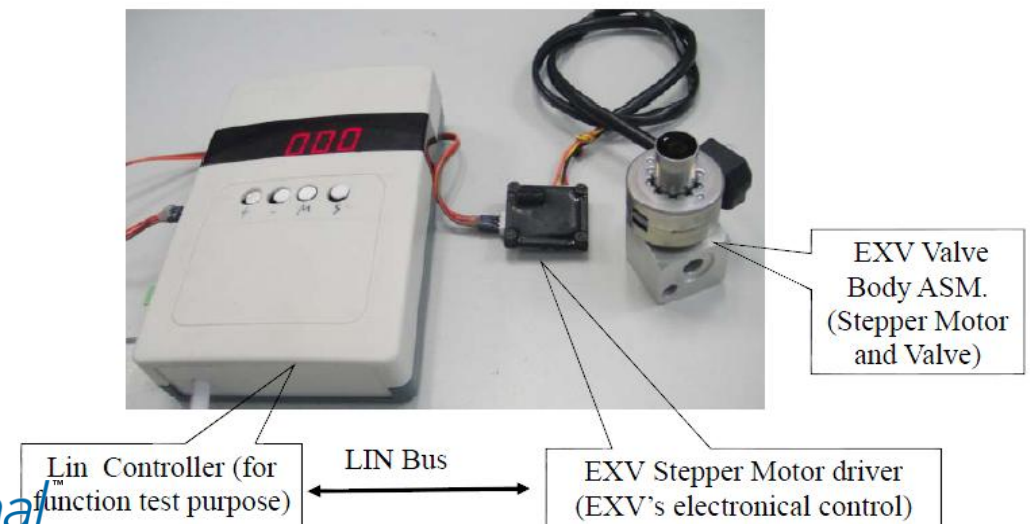


IHX and EXV Component Details

Hutchinson 700 mm Long IHX



SanHua Prototype Automotive EXV

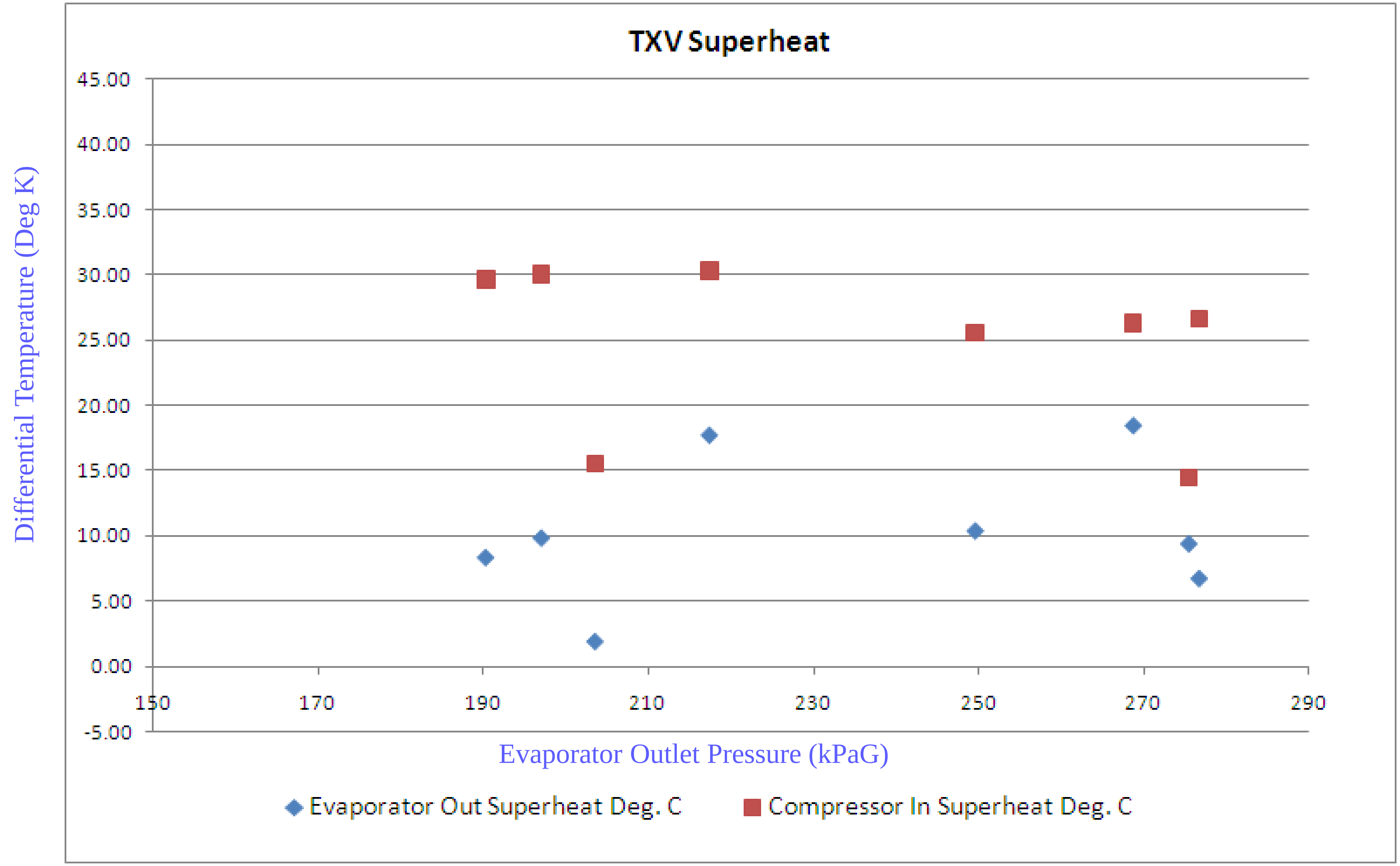


Test Conditions

Eight Load Data Points were measured at defined compressor RPM, condenser air in temperature, condenser airflow , evaporator air inlet temperature, evaporator air inlet dew point , and evaporator airflow.
Compressor inlet superheats of 6, 12, 18 and 24 Deg C were utilized to cover the range that would be expected with EXV and TXV usage

Test Number	#1	#2	#3	#4	#5	#6	#7	#8
Test Code	I60	H45	M45	I45	I35	H35	M25	M25H
Condenser Control								
Inlet Air Temperature (˚C)	60	45	*45*	45	35	*35*	25	25
Inlet Air velocity (cmm)	40	60	*50*	40	40	*60*	50	50
Evaporator Stand Control								
Inlet Air Temperature (˚C)	35	35	*35*	35	35	*35*	25	25
Inlet Air Humidity (Dew Point)	10	10	*10*	10	23	*23*	18	18
Inlet Air Flow rate (l/s)	130	130	*130*	130	130	*130*	70	70
Evap EAT Set Point	3	3	3	3	3	3	3	10
Compressor Control								
Piston Compressor speed (rpm)	1100	2200	*2000*	1100	1100	*2200*	2000	2000

Typical TXV Control



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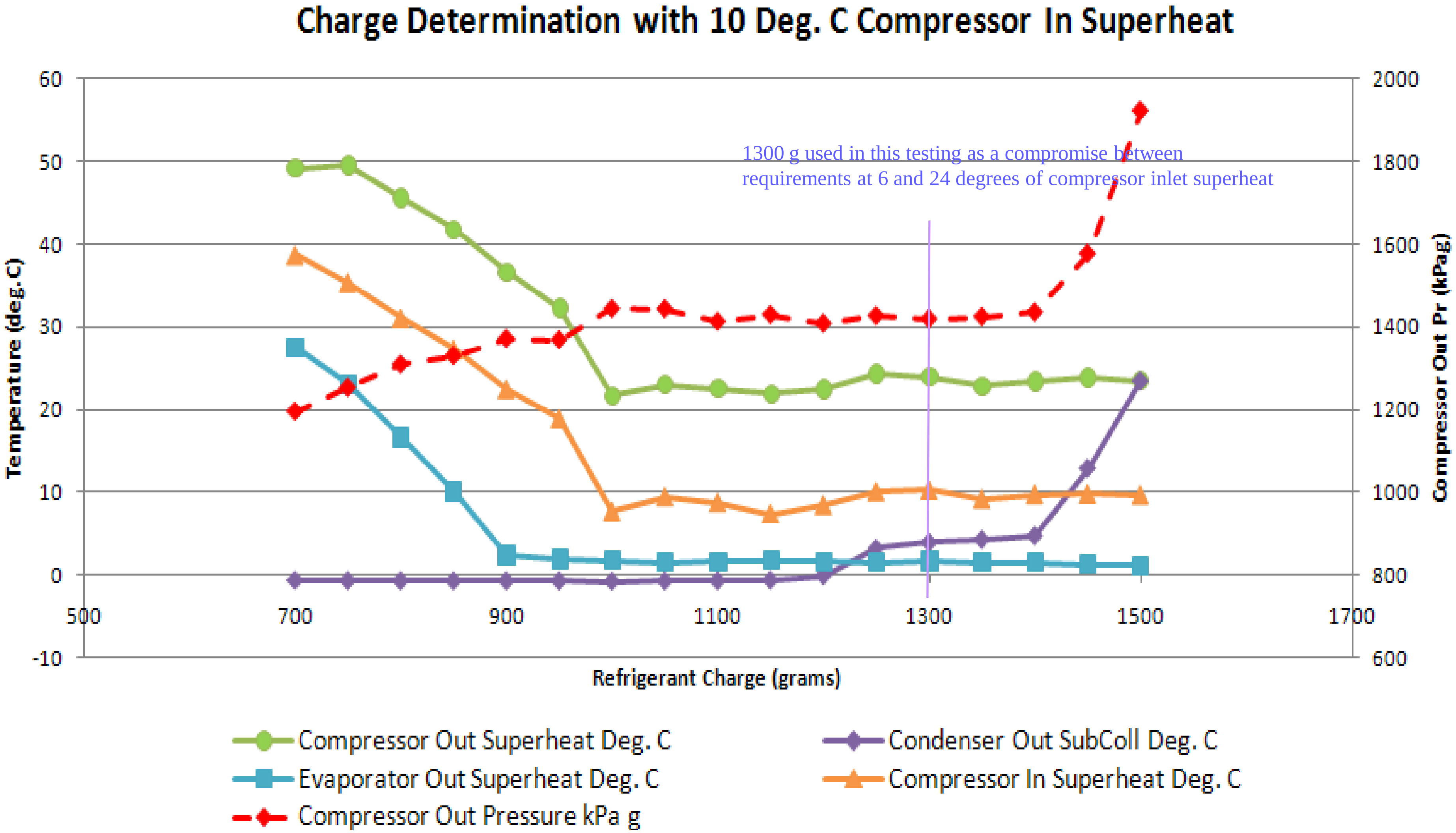
Test Conditions



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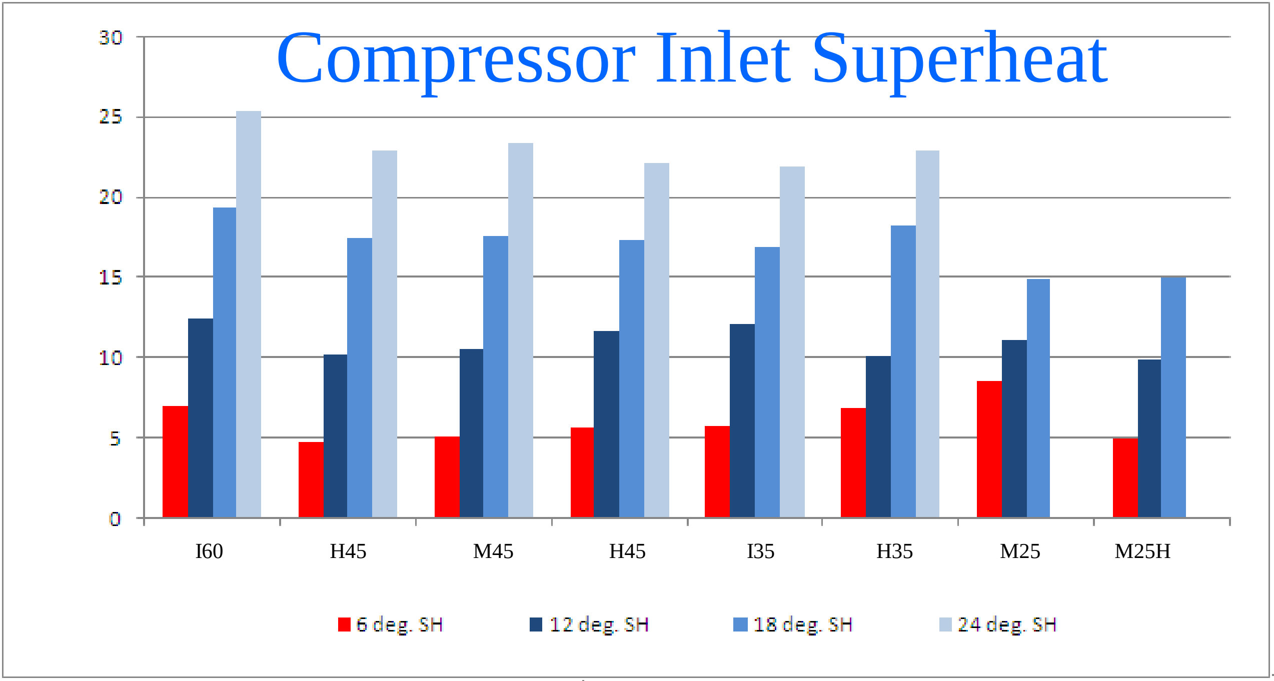

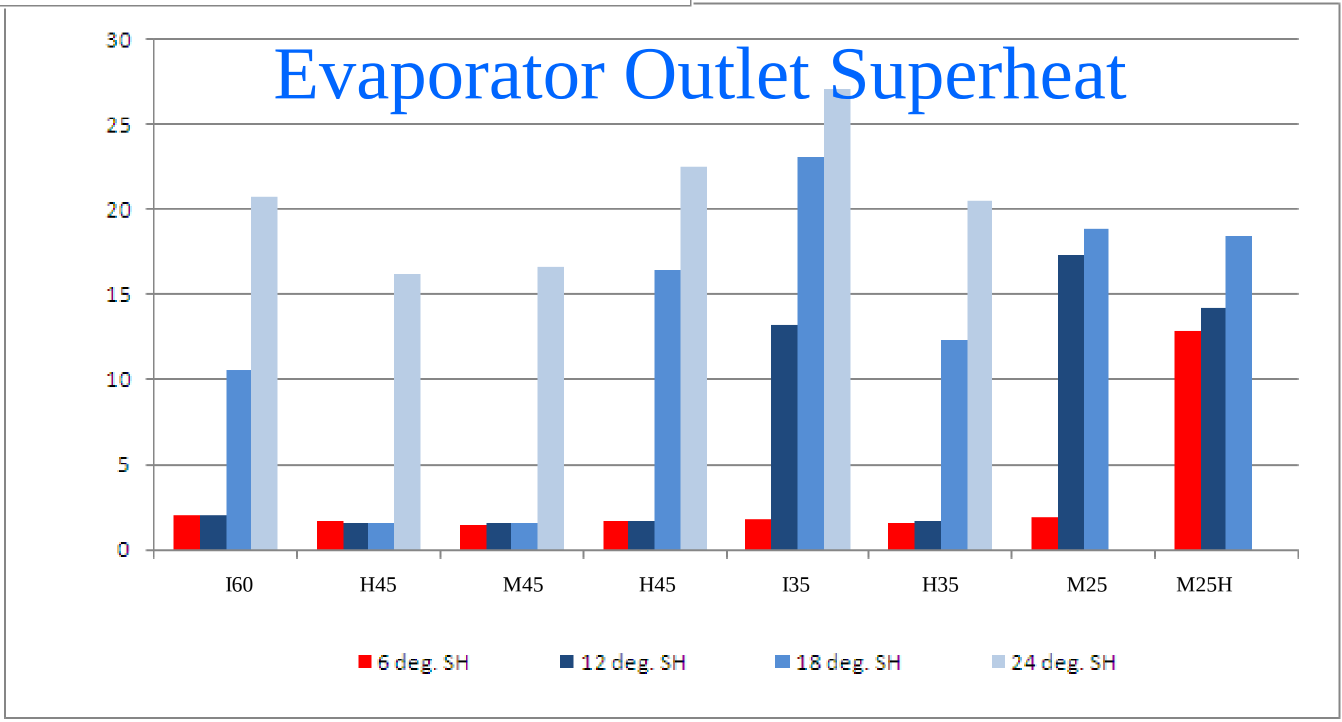

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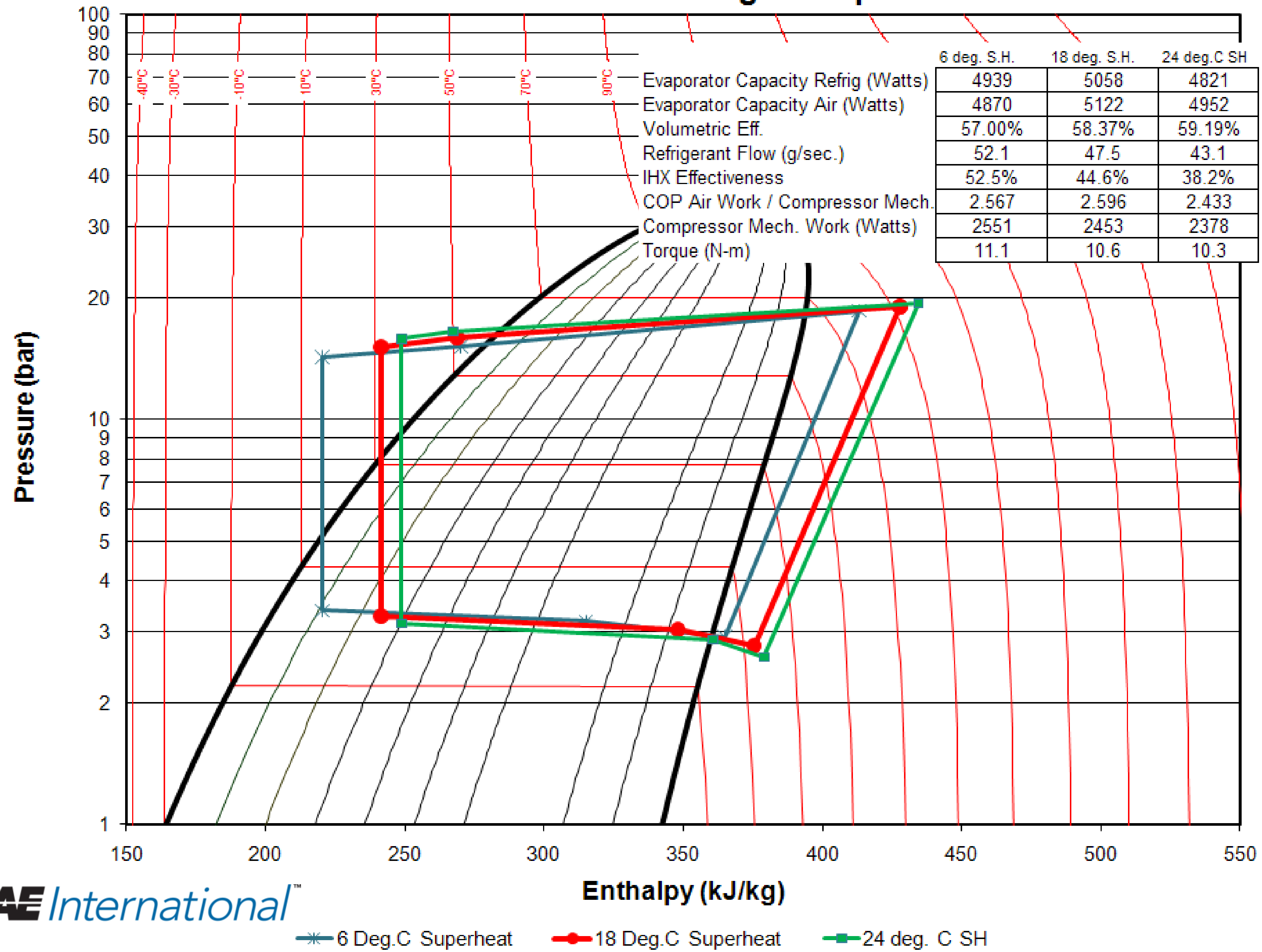
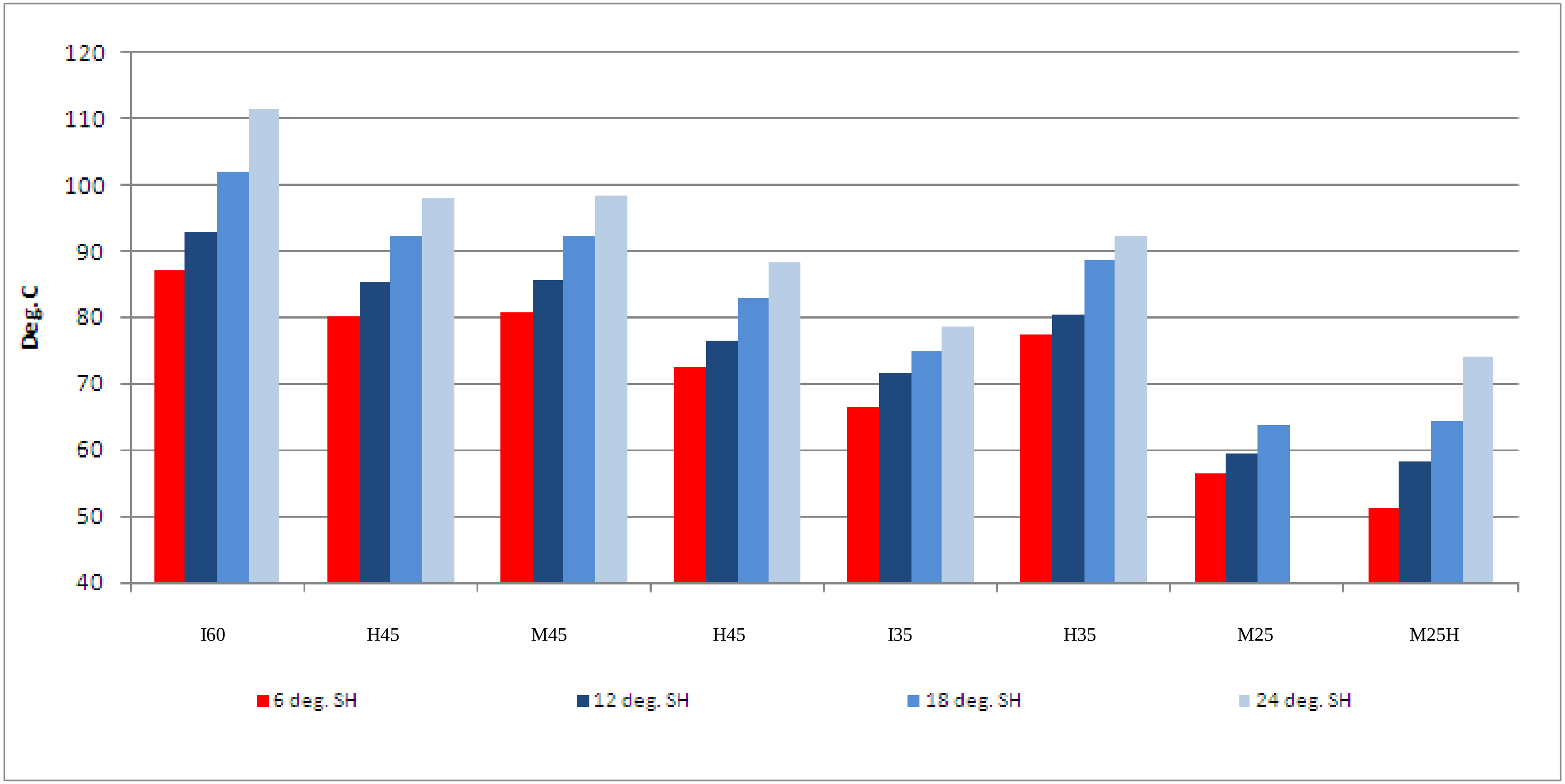
Pressure-Enthalpy
H-35 6 & 18 deg. C Superheat



	6 deg. S.H.	18 deg. S.H.	24 deg.C SH
Evaporator Capacity Refrig (Watts)	4939	5058	4821
Evaporator Capacity Air (Watts)	4870	5122	4952
Volumetric Eff.	57.00%	58.37%	59.19%
Refrigerant Flow (g/sec.)	52.1	47.5	43.1
IHX Effectiveness	52.5%	44.6%	38.2%
COP Air Work / Compressor Mech.	2.567	2.596	2.433
Compressor Mech. Work (Watts)	2551	2453	2378
Torque (N-m)	11.1	10.6	10.3

Compressor Discharge Temperature



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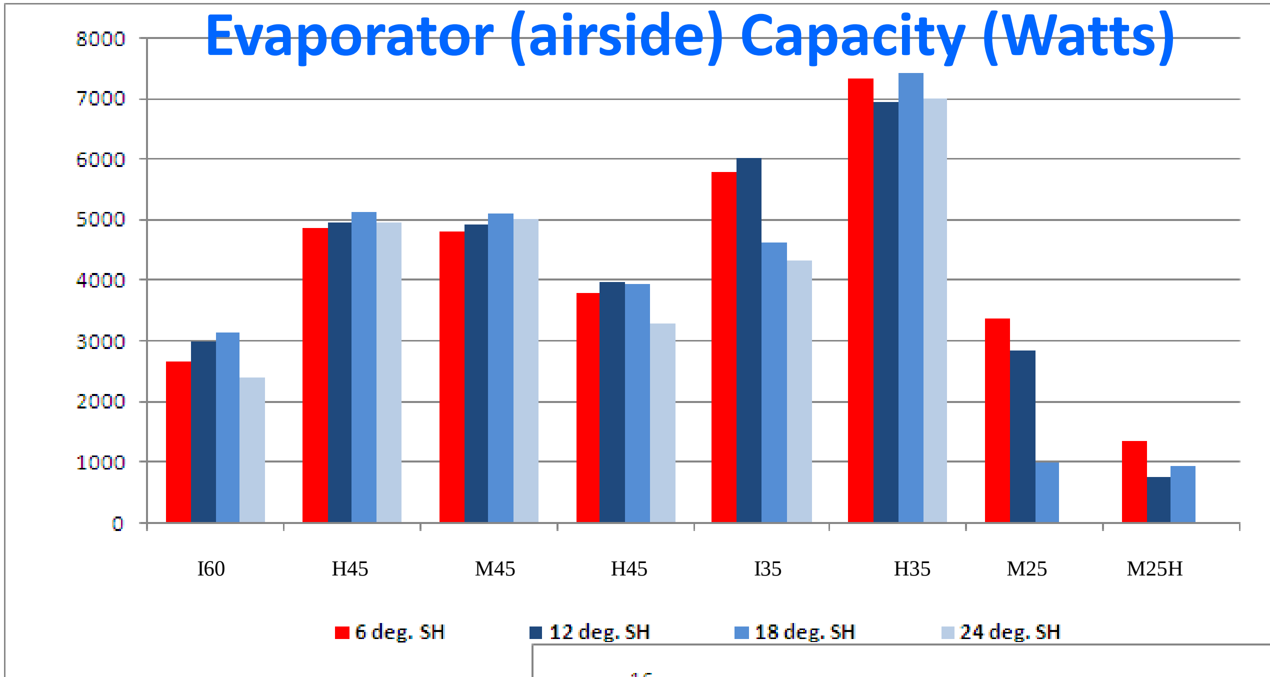
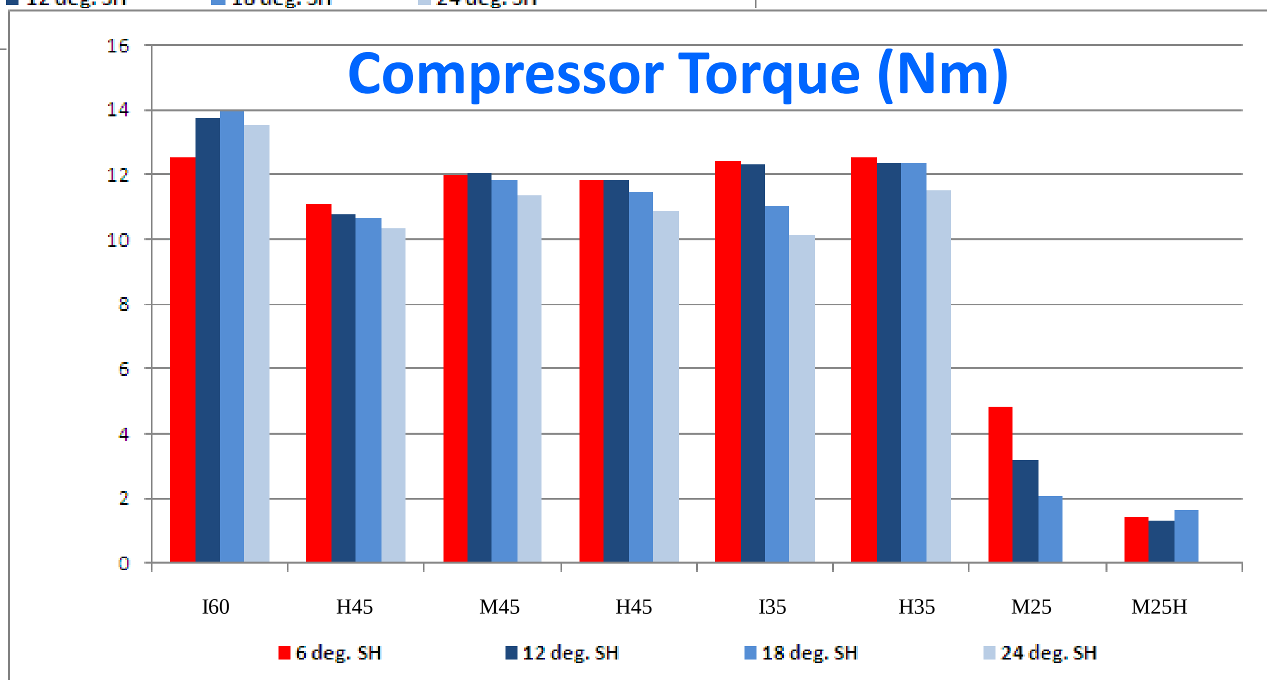


At mild ambient Evaporator Capacity should have been held fixed



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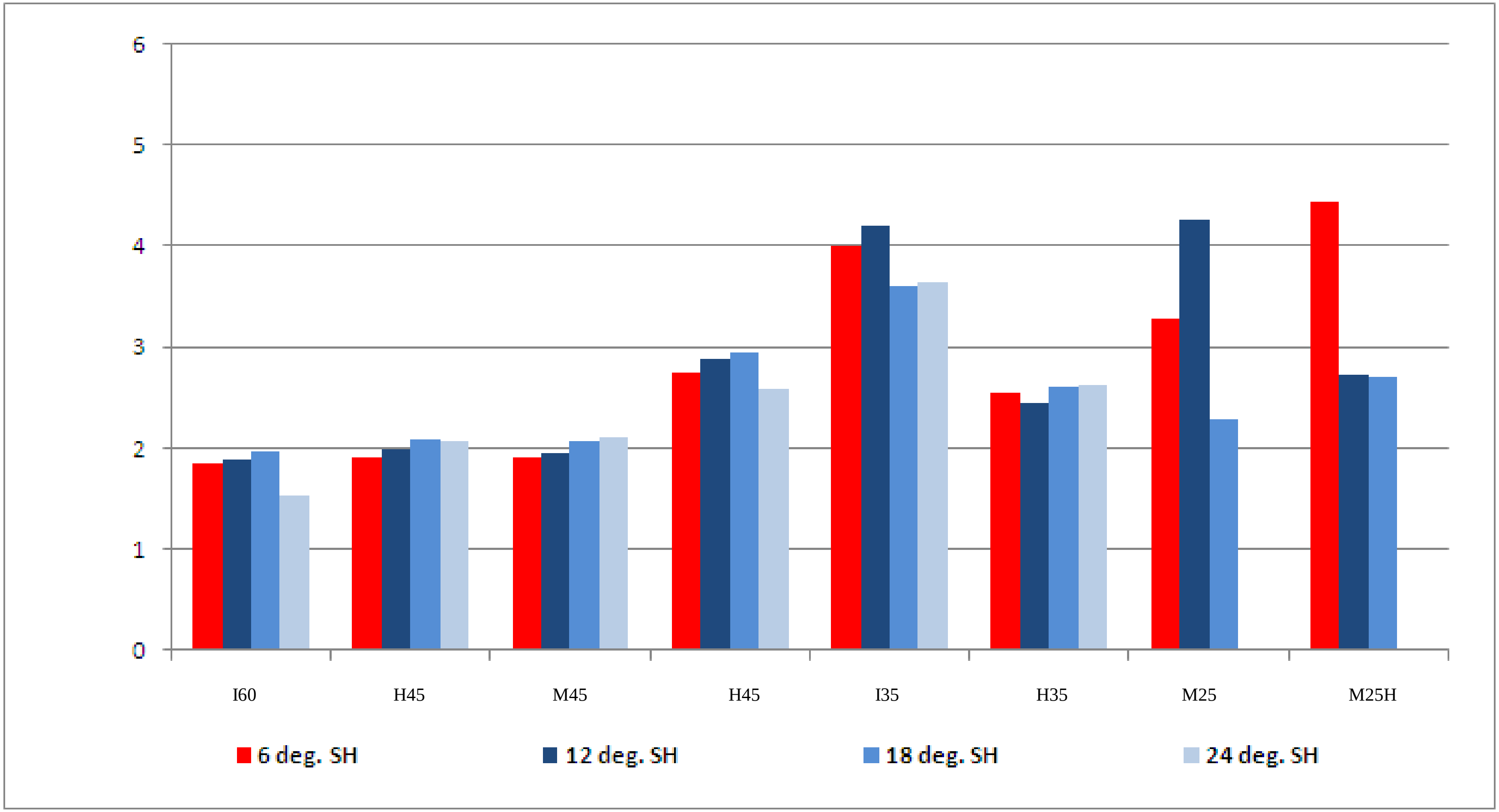
Coefficient of Performance (Airside Watts / Compressor Watts)



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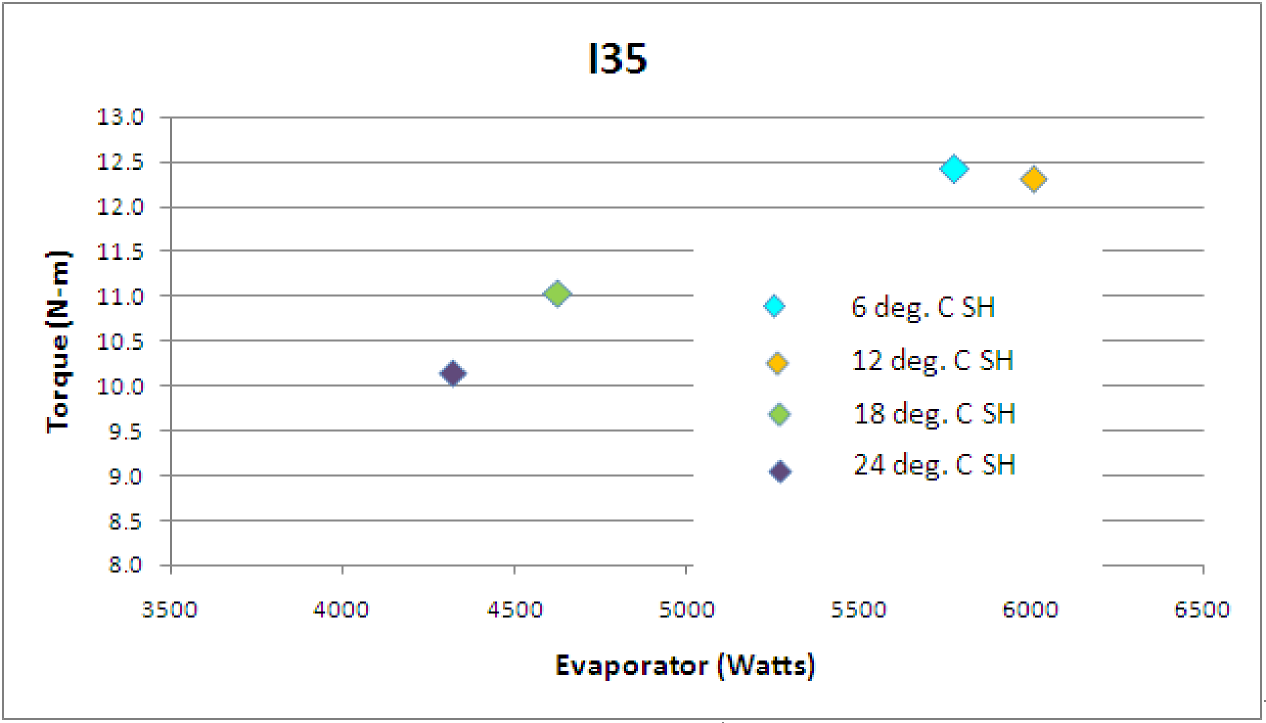

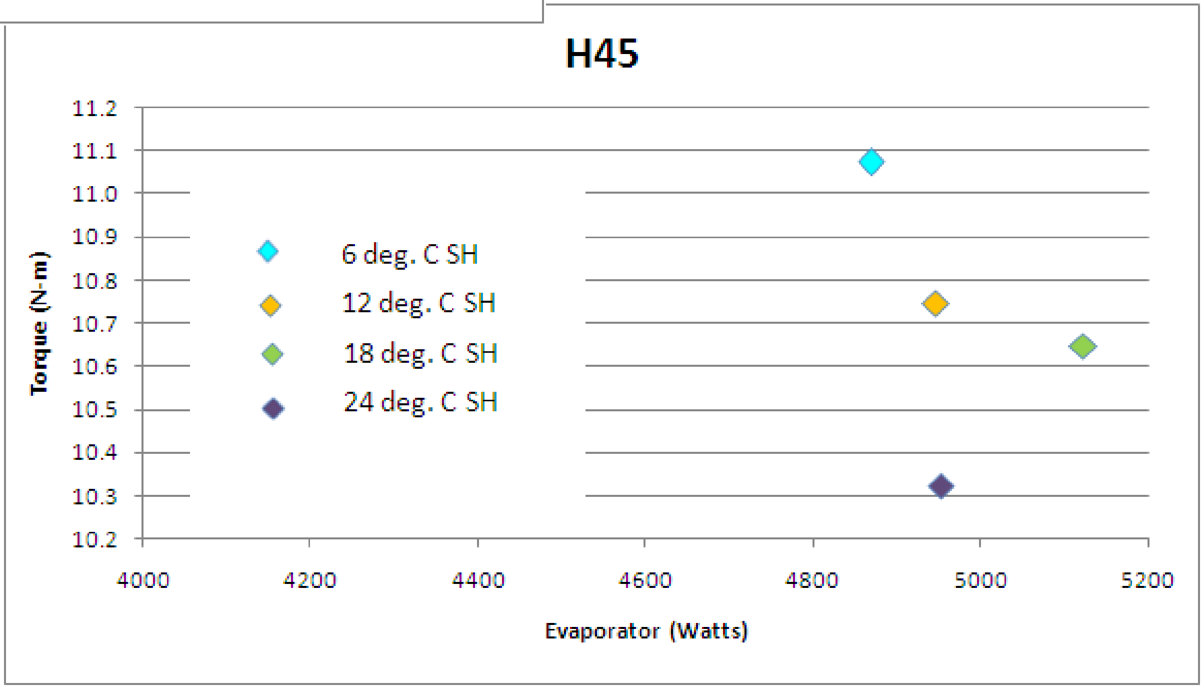

↘ Better
More Evaporator Work
Less Compressor Work

↖ Worse
Less Evaporator Work
More Compressor Work

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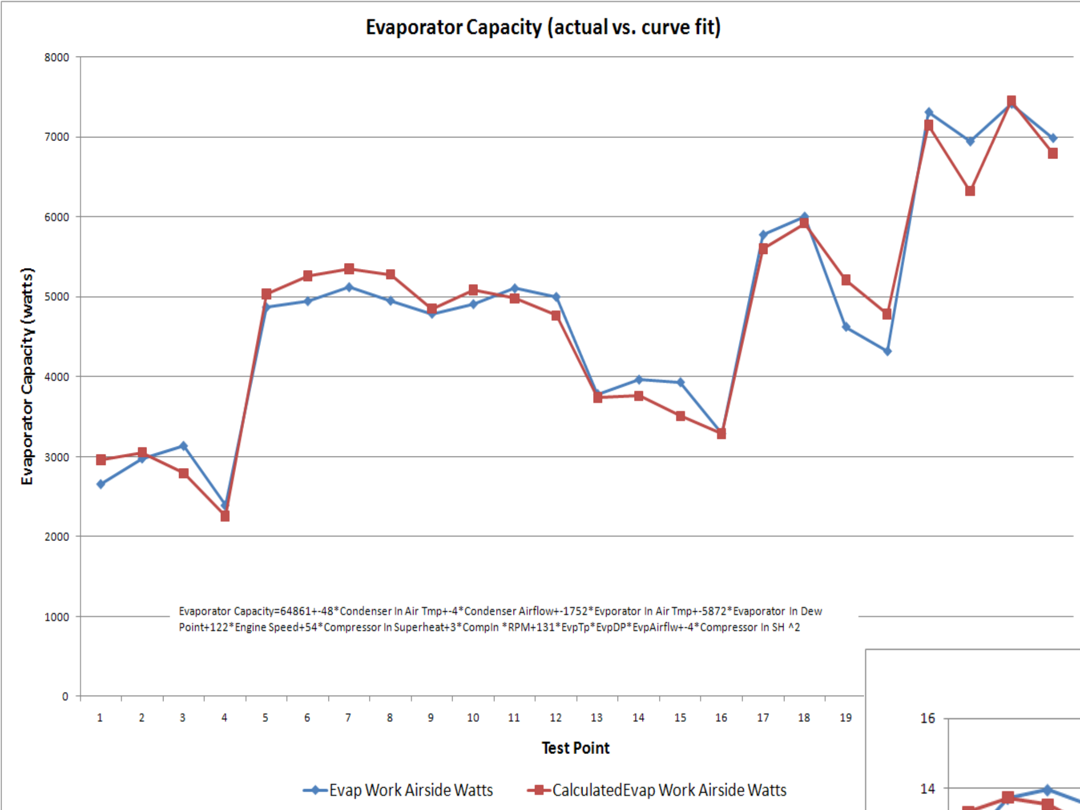
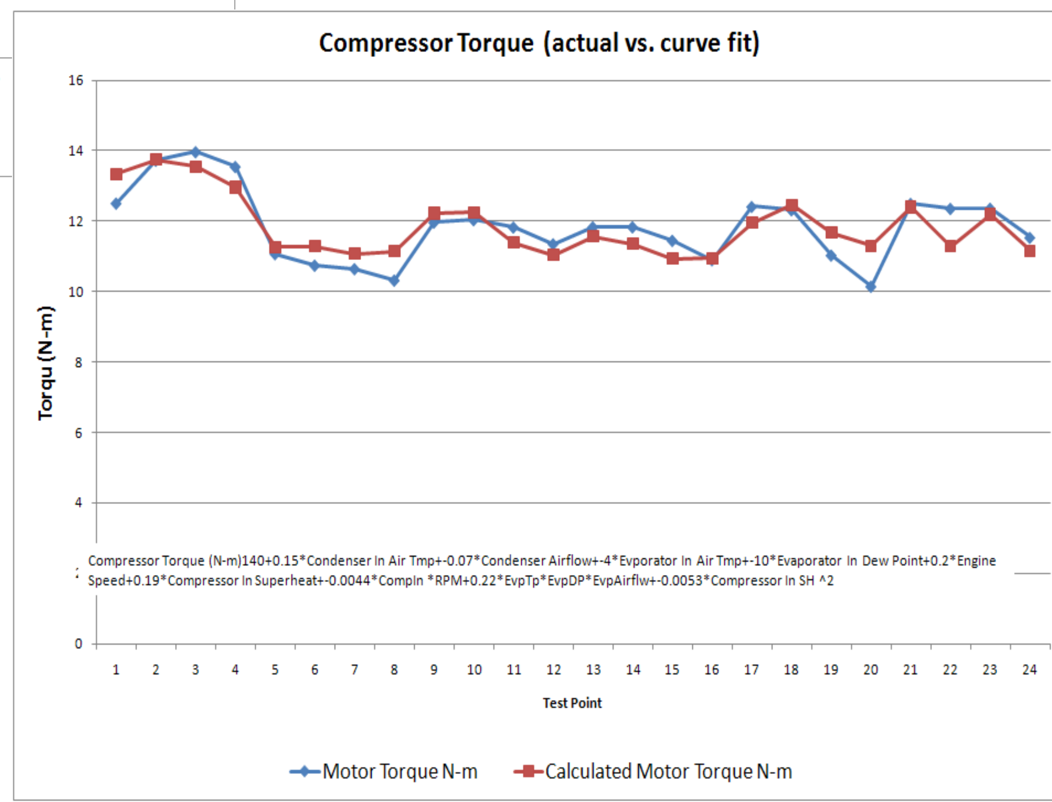
Curve Fitting





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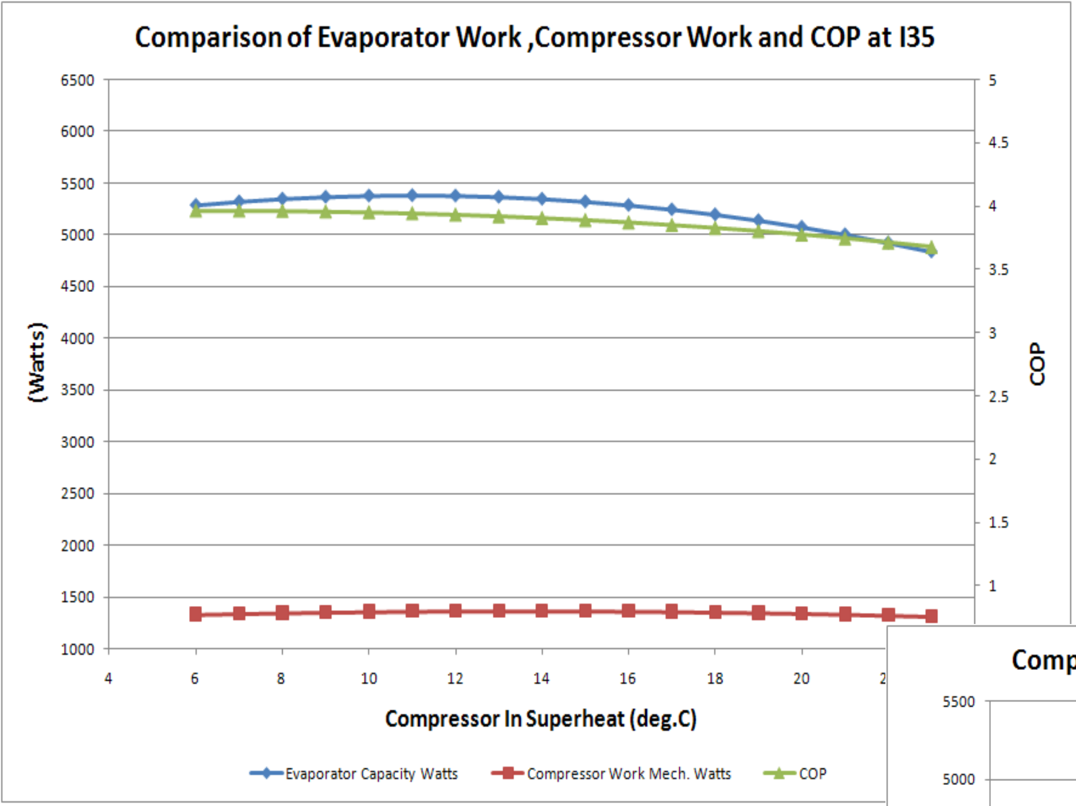

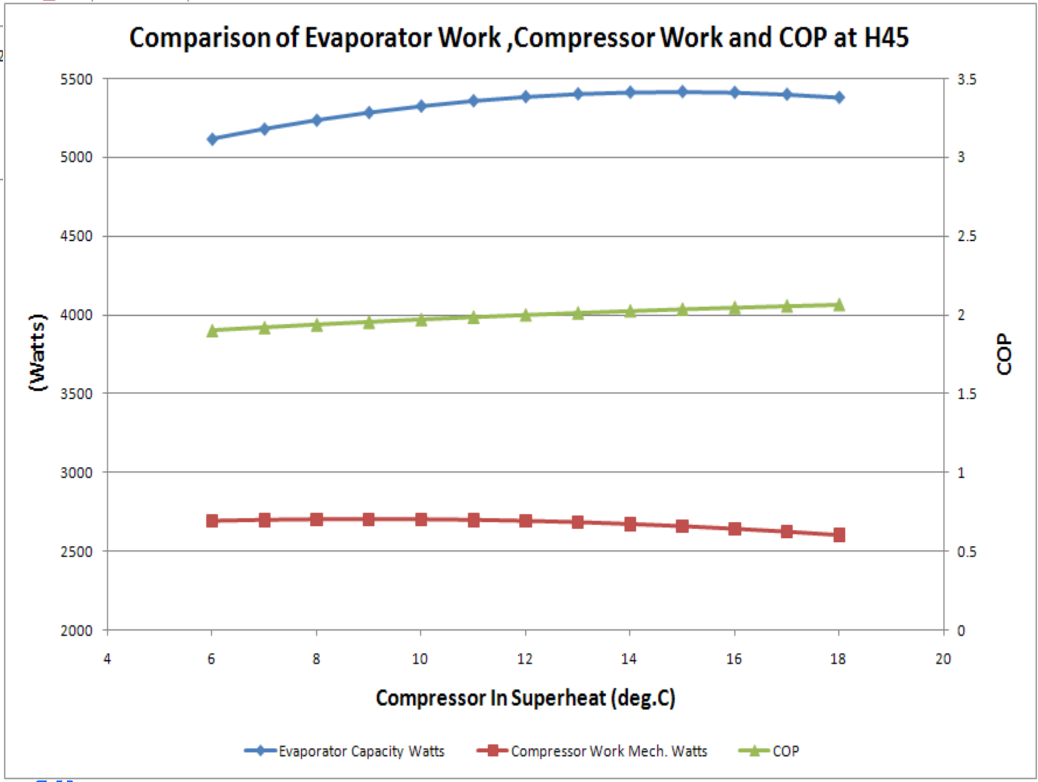

Regression Output

Conclusion

- Accurate COP calculations when flooding the Evaporator comprehend the IHX heat transfer to calculate the true exit condition of the evaporator
- An EXV with positive shut off in multiple heat exchanger systems improves comfort and reduces pumping loss (fuel consumption improvement)
- An EXV provides the ability of using one evaporator assembly for multiple usage (one HVAC Module for multiple refrigerants, and or multiple compressor configurations)
- An EXV provides precision in control of the IHX and compressor inlet condition

Conclusion

- The EXV and control algorithm can perform as well as any given TXV while performing better under specific conditions. Value judgments can be used to select the optimal setting for a given specific customer condition (compressor work verses evaporator capacity).
- Refrigerant Charge level testing with an EXV is complex due to the multitude of compressor inlet superheat operational points and differing EXV inlet conditions. The amount of refrigerant liquid present in the IHX inlet is a strong influence on operation.

Future Work

Dynamic response algorithm development of the EXV

Evaluation of energy usage on a given driving cycle to estimate the customer impact on possible energy saving.

Evaluation of dual heat exchanger systems to demonstrate improved efficiency due to reduced pumping loss of idle heat exchanger

EXV with a Electronic Variable Compressor should use compressor capacity control to “match” the evaporator capacity under all evaluation conditions regardless of EXV setting.

Thank you!

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