TRANE®

BEYOND TOMORROW

Economic Perspectives from Chiller Design to Operation

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1 Dec 2017

Ingersoll Rand

Low Life Cycle Cost

Quietest Guarantee Sound Level

High Efficiency

Intelligent Control

Proven Durability

Legendary Reliability

Design x Construction

Building Operation

Design x Construction

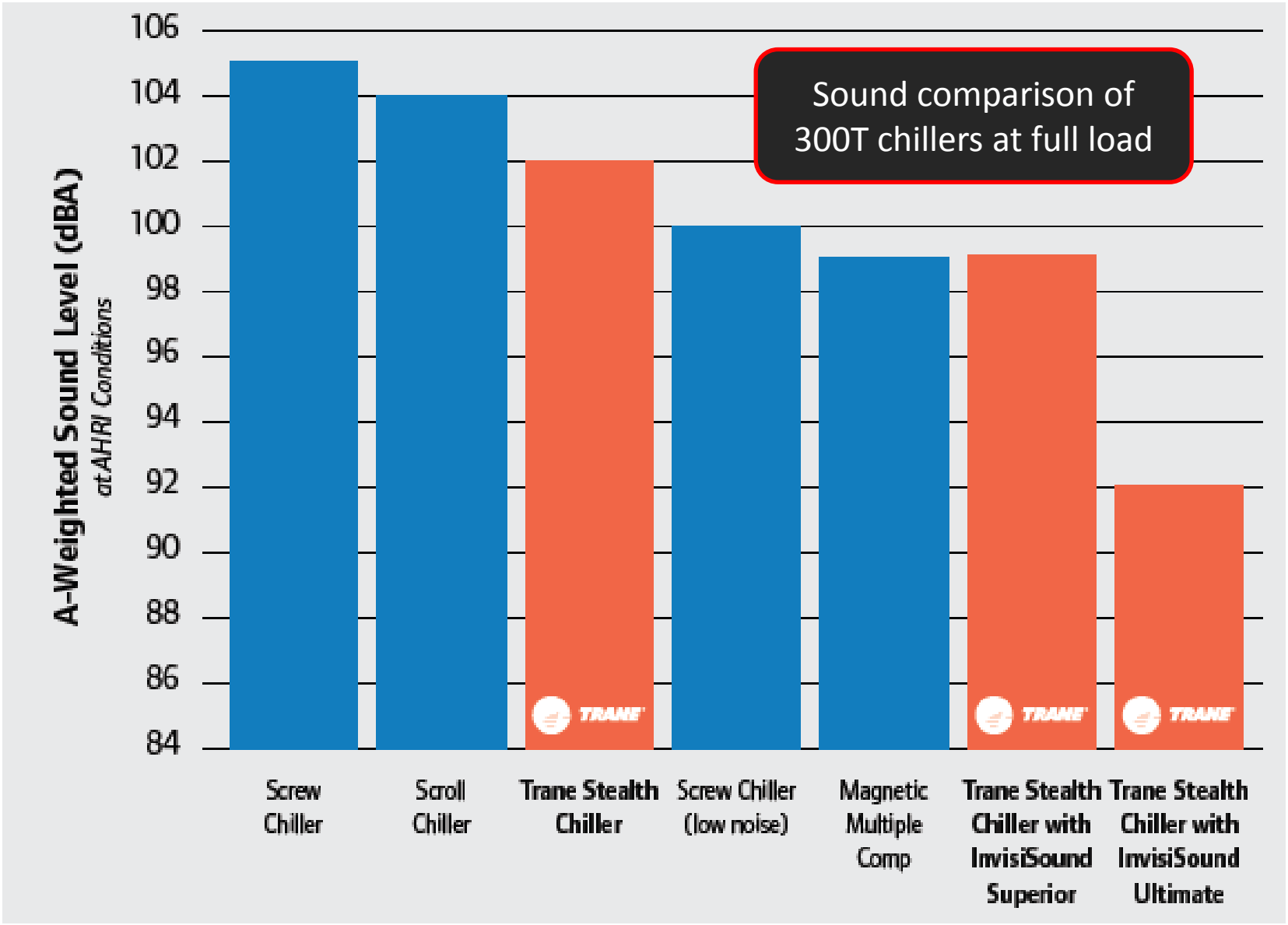
Acoustic Treatment
Electrical Installation
High Efficiency
Pump Head Energy

Acoustic Treatment

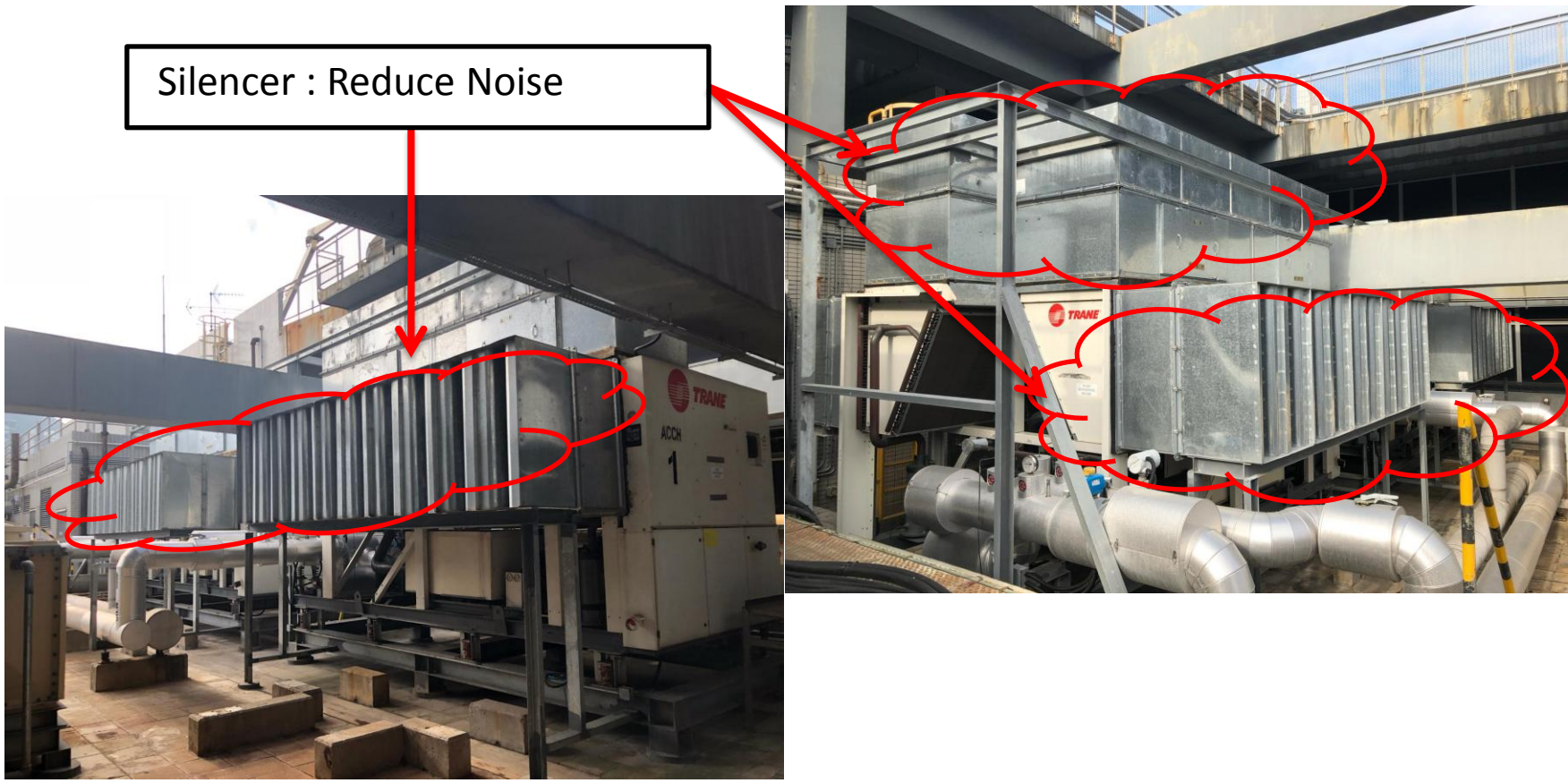
Electrical Installation

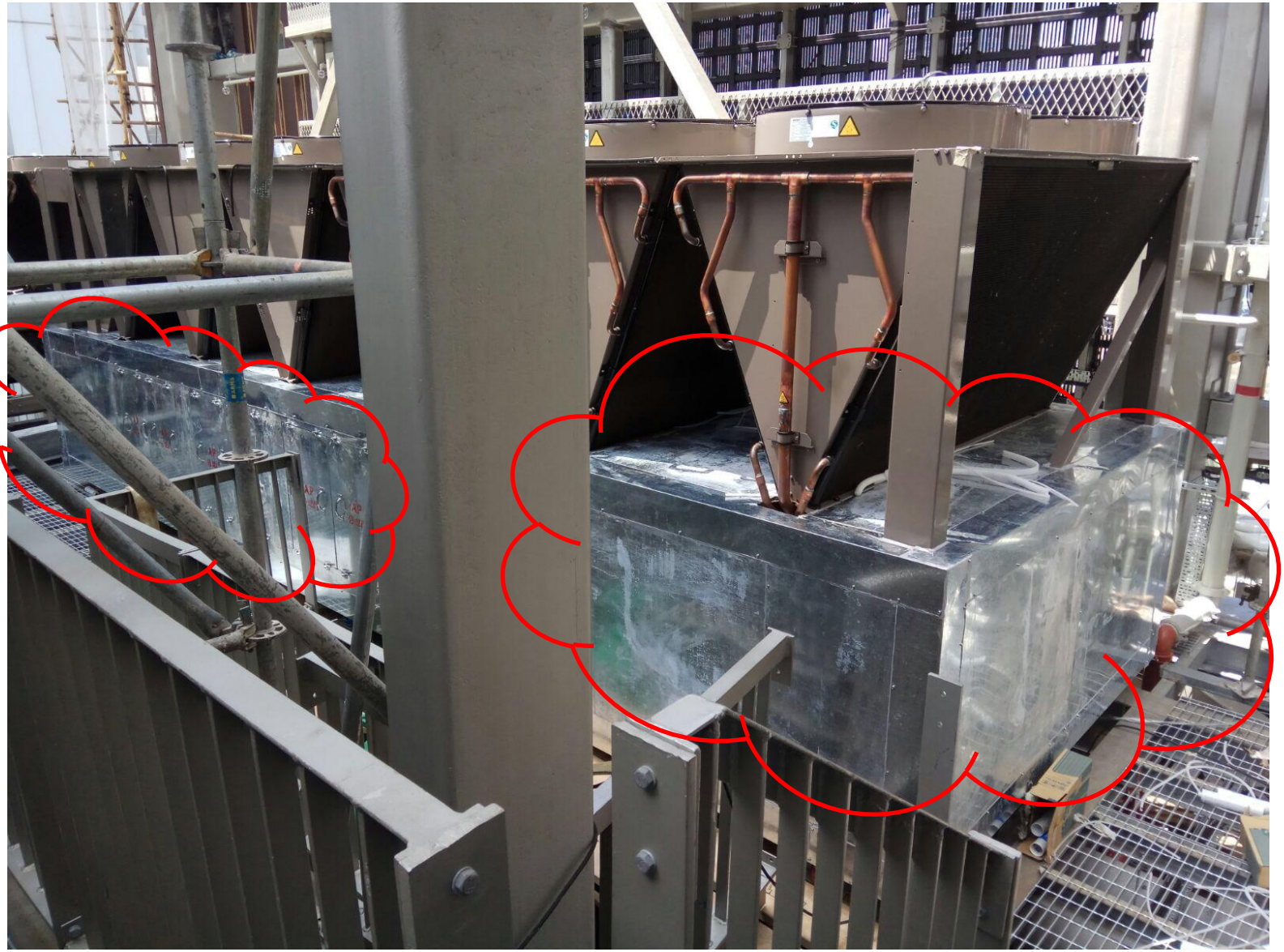
High Efficiency

Pump Head Energy

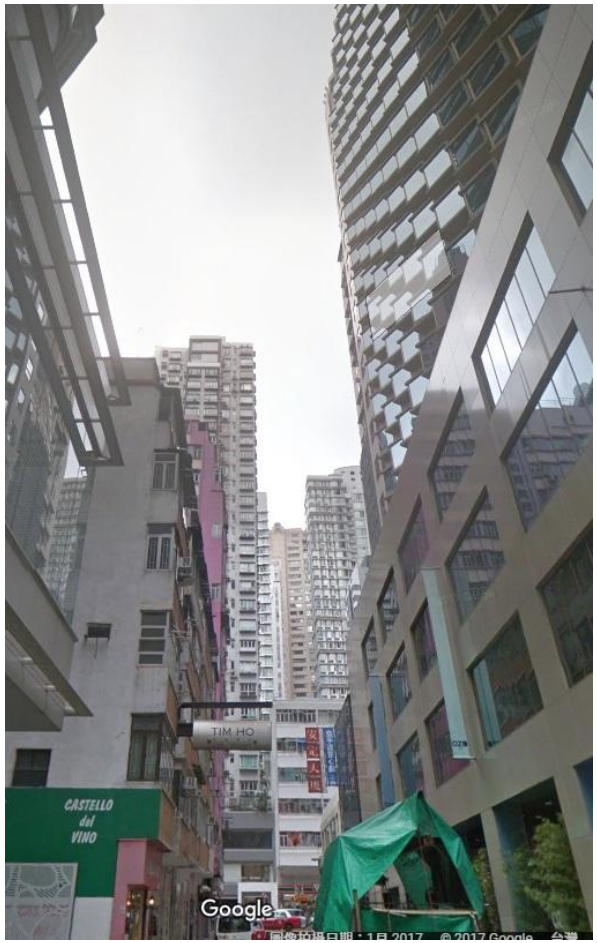

Sound comparison of 300T chillers at full load
A-Weighted Sound Level (dBA)
at AHRI Conditions
106
104
102
100
98
96
94
92
90
88
86
84
Screw Chiller
Scroll Chiller
Trane Stealth Chiller
Screw Chiller (low noise)
Magnetic Multiple Comp
Trane Stealth Chiller with InvisiSound Superior
Trane Stealth Chiller with InvisiSound Ultimate

Tradition Noise Reduction

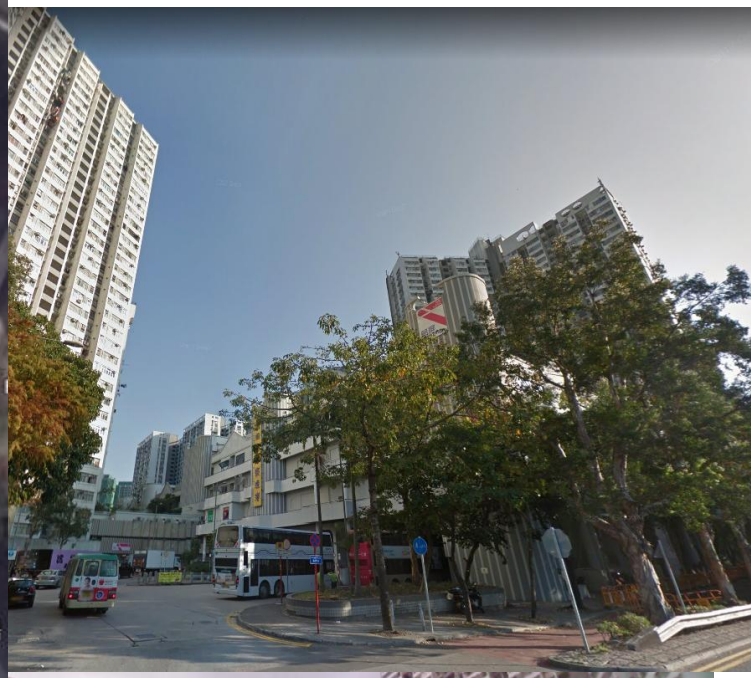




Acoustic barrier : To prevent the sound wave reflection


CASTELLO
del
VINO
TIM HO
Google

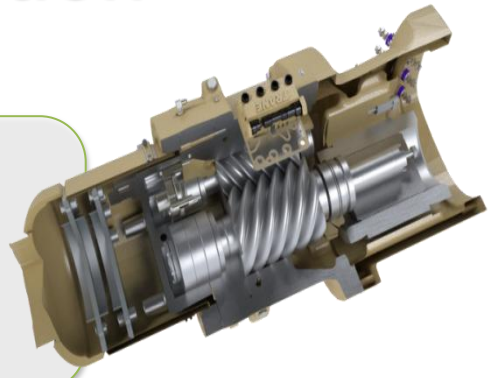

朗屏路
朗屏路
朗屏鄉玉屏樓
石屏樓
朗屏商場
朗屏鄉石屏樓
朗屏體育館
鏡屏樓
朗屏邨八角廣場
朗屏鄉畫屏樓
朗屏鄉鏡屏樓



Coming……

Installation and Operation
Sound options

- InvisiSound™ Standard
  - compressor muffler
  - low noise fans



TRANE

3 levels of sound attenuation

- InvisiSound™ Superior
  - suction and discharge wraps
  - lower speed fans

- InvisiSound™ Ultimate
  - compressor bellows
  - patented compressor enclosure
  - noise setback option

Acoustic reduction treatments provide freedom to choose the unit sound level that meets the job requirements


TRANE

Quietest Guarantee Sound Level

Low Speed
~3,000rpm

Low Pressure

Acoustic Treatment

HK$200K to HK$350K

HK$200K

Acoustic Treatment

Electrical Installation

High Efficiency
Pump Head Energy

Electrical Installation (ACB / MCCB & Cables) :-

400A (50m Cables) : HK$100K

630A (50m Cables) : HK$130K (Diff. 30K)

800A (50m Cables) : HK$200K (Diff. 70K)

1000A (50m Cables) : HK$250K (Diff. 50K)

Acoustic Treatment
Electrical Installation

High Efficiency Pump Head Energy

Table 6.12b : Minimum Coefficient of Performance for Chiller[@2] at Full Load

Air-cooled

Type of compressor	Reciprocating		Scroll		Screw		VSD Screw		Centrifugal	VSD Centrifugal
Capacity Range (kW)	Below 400 kW	400 kW & above	Below 400 kW	400 kW & above	Below 500 kW	500 kW & above	Below 500 kW	500 kW & above	All Ratings	All Ratings
Minimum COP at cooling (free air flow[@1])	2.8	2.9	2.8	2.9	2.9	3.0	2.8 (3.6)[@5]	2.9 (3.7)[@5]	3.2	3.1 (4.0)[@5]

Water-cooled

Type of compressor	Reciprocating / Scroll			Screw			VSD Screw			Centrifugal			VSD Centrifugal		
Capacity Range (kW)	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 500 kW	500 to 1000 kW	Above 1000 kW	Below 1000 kW	1000 kW to 3000 kW	Above 3000 kW	Below 1000 kW	1000 kW to 3000 kW	Above 3000 kW
Minimum COP (Cooling)	4.2	4.7	5.3	4.8	5.0	5.5	4.7 (6.1)[@5]	4.9 (6.3)[@5]	5.2 (6.7)[@5]	5.4[@3] / 5.6[@4]	5.7	5.8	5.1 (6.6)[@5]	5.5 (7.1)[@5]	5.6 (7.2)[@5]

Air-Cooled Screw Chiller (VSD & Constant Speed) :-

2.8 to 3.0 (BEC) vs (Installed) 3.55

18% to 26% up

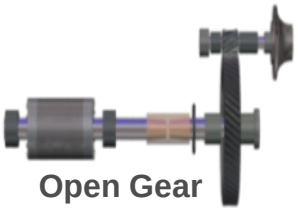
Water Cooled Centrifugal Chiller (VSD & Constant Speed) :-

5.5 to 5.7 (BEC) vs (Installed) 6.4

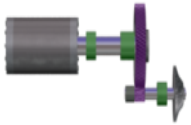
12% to 16% up

Technology Comparison

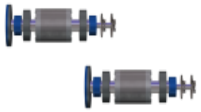
Evaluation of Design Choice Advantages



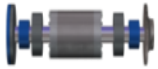
Open Gear Drive



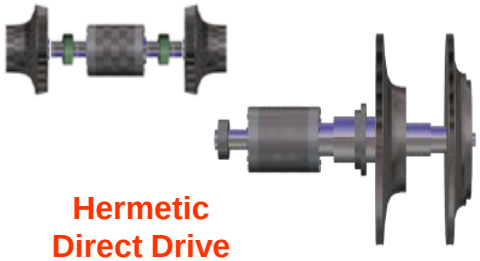
Hermetic Gear Drive



Multi Stage Maglev



Single Stage Maglev



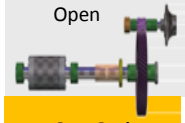
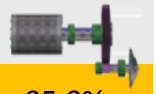
Hermetic Direct Drive

Characteristic	Design Choice				Benefits
Compressor Speed	High	☐	Low	☑	Delivering lowest acoustic and vibration characteristics
Motor Layout	Open Drive	☐	Semi-Hermetic	☑	Operation in a pristine environment, dissipating motor heat into condenser refrigerant
Operating Stability	Single-Stage	☐	Multi-Stage	☑	Stable operating envelope to meet the dynamic system needs and deliver the highest efficiency
Number of Bearings	Over 6-8	☐	Two	☑	Lowering the possibility of failure with fewer elements in the design
Operating Pressure	Med/High	☐	Low	☑	First charge is your last charge (efficiency)

Reliability through Simplicity of Design!

Design Choices Impact Efficiency

Centrifugal Chiller Comparison

Refrigerant	R-134a 0.460 kW/ton	R-513A 0.469 kW/ton -2%	R-123 0.433 kW/ton +7%	R-1233zd 0.436 kW/ton +6%	R-514A 0.434 kW/ton +7%
Chiller Cycle	Sub-Cooler 0.415 kW/ton		Refrigerant Economizer 0.388 kW/ton +7%		
Compressor	Gear Drive		Direct Drive		Direct Drive
	Open	Hermetic	Single Stage	Mult Stage	Mult Stage
					 
Motor	95.0%	95.0%	97.0%	97.0%	95.0%	97.0%
Drive Train	97.9%	98.1%	100%	100%	100%	100%
Impeller	82.8%	81.4%	78.8%	75.1%	83.3%	84.1%
Production						
@ 300 tons	Maglev (Multi Stage)		0.540 kW/ton	0.318 kW/ton	CVHS (300)	0.478 kW/ton	0.296 kW/ton
@ 700 tons	Maglev (Single Stage)		0.540 kW/ton	0.330 kW/ton	CVHF (700)	0.484 kW/ton	0.317 kW/ton
@ 1,500 tons	Gear Drive (Single Stage)		0.530 kW/ton	0.340 kW/ton	CVHH (1500)	0.504 kW/ton	0.312 kW/ton

Unit Design Choices Drive Real Efficiency Paybacks

Application Reference

Job Showcase

2012

Project: Hysan Place

Type: Commercial / Hysan Development Co Ltd

Size: 808,958 sq ft

Award: LEED Platinum, BEAM Plus Platinum

Model	Qty.	Capacity (RTon)	COP_{adj} [1]	vs BEC 2015 [2]
CVHF1070-142L-142L	5	950	6.39	Better **14.11%**

1) Based on AHRI 550/590 conditions
2) Min. requirement of BEC for VSD centrifugal chiller is 5.6 @>3000kW, 5.5>1000kW AND <3000kW

Application Reference

Job Showcase

2013

Project: HKU Centennial Campus

Type: Higher Education / University Of Hong Kong

Size: 793,124 sq ft

Award: LEED Platinum, BEAM Plus Platinum

Model	Qty.	Capacity (RTon)	COP_{adj}[1]	vs BEC 2015[2]
CVHF770-142L-142L	4	900	6.25	Better **8.32%**
CVHE450-080S-080L	2	360	6.34	Better **11.82%**

1) Based on AHRI 550/590 conditions
2) Min. requirement of BEC for VSD centrifugal chiller is 5.6 @>3000kW, 5.5>1000kW AND <3000kW

Application Reference

Job Showcase

2016

Project: HKUST Campus

Type: Higher Education / The Hong Kong University of Science and Technology

Size: 107,640 sq ft

Award: 2016 Energy Project of the Year Award (APR)

Model	Qty.	Capacity (RTon)	COP_{adj} [1]	vs BEC 2015 [2]
CVHF1100-142L-142L	3	1,200	6.63	Better **14.31%**

1) Based on AHRI 550/590 conditions
2) Min. requirement of BEC for CSD centrifugal chiller is 5.8 @>3000kW

Case Study

District Cooling System (DCS)

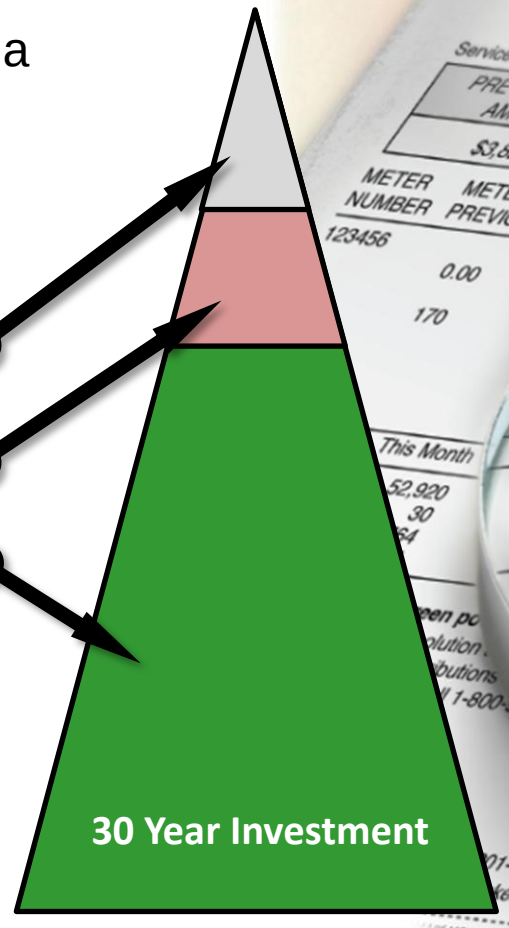
Item	Specifications	Trane CenTraVac™	Savings / Benefits
Origin	-	USA	-
Capacity (tons)	2500	2500	-
Refrigerant	R134a	HFO-1233zd	-
Power Supply	11kV/3/50	11kV/3/50	-
Power Input (kW)	1490	1339.6	**Less 150.4 kW**
Full load COP (kW/kW)	5.9	6.56	**11.19% better**
Full load efficiency (kW/ton)	0.596	0.536	**11.19% better**
Evaporator water Pressure Drop (kPa)	65 (max)	21.7	**Less 43.3kPa**
Condenser water Pressure Drop (kPa)	70 (max)	20.3	**Less 49.7kPa**

Life Cycle Cost

Setting your system for great payback

Where is money spent over a 30 year lifetime?

First Cost	4.9%
Service	6.6%
Power	88.5%



Understanding the impact of unit performance on your electrical bill

- "Demand" (kW)
  - *rate of electricity used*
- "Energy" (kWh)
  - *quantity of electricity used*
- Other charges
  - *power factor*
  - *ratchets rates*
  - *time of use*
  - *seasonal (winter & summer)*

A Balanced Approach, with a Focus on Efficiency

Building Operation

Refrigeration Cycle 冷媒循環

Condenser
冷凝器

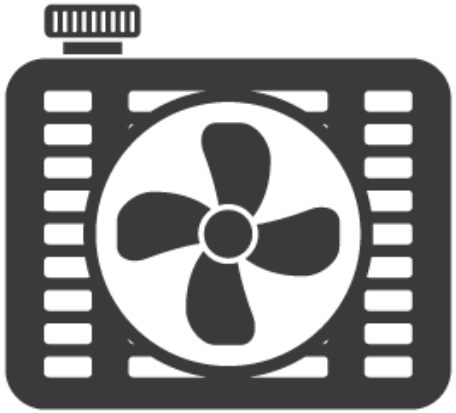
Compressor
壓縮機

Evaporator
蒸發器

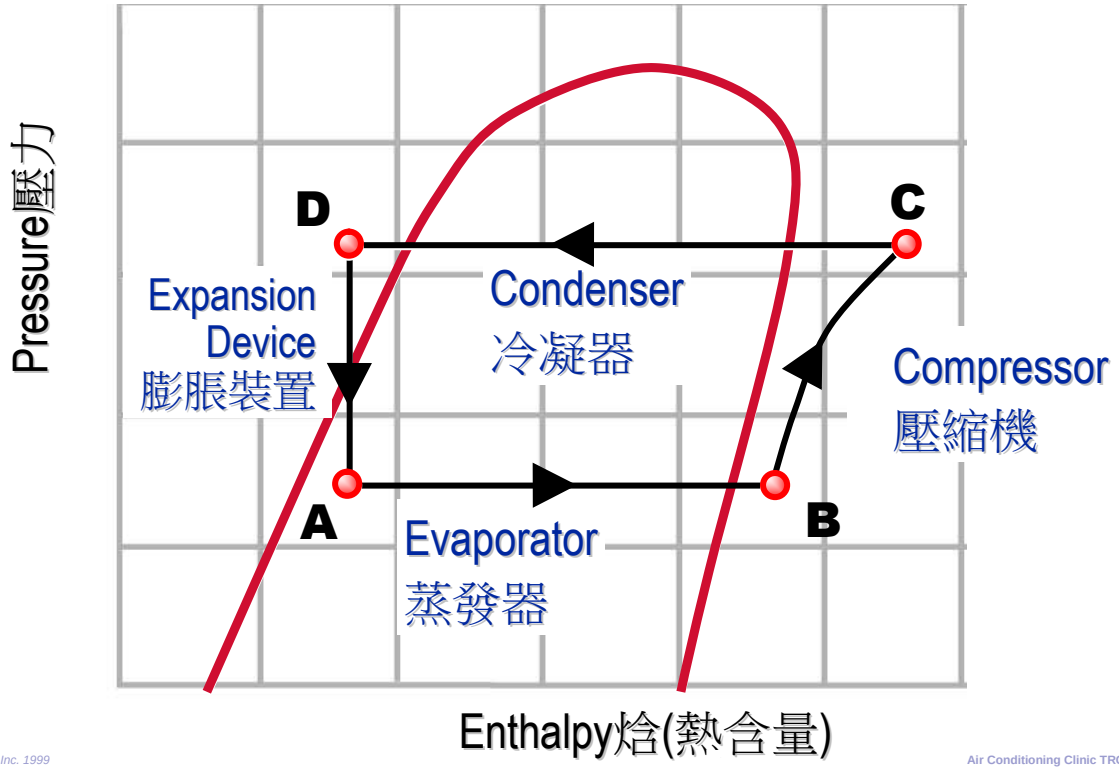
Control :
Electronic
Expansion Device
電子膨脹裝置

CONDENSER

EVAPORATOR
COMPRESSOR
CONTROL
REFRIGERANT



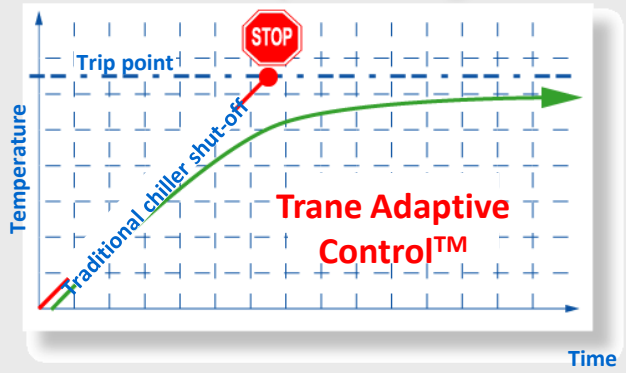
Refrigeration Cycle製冷循環

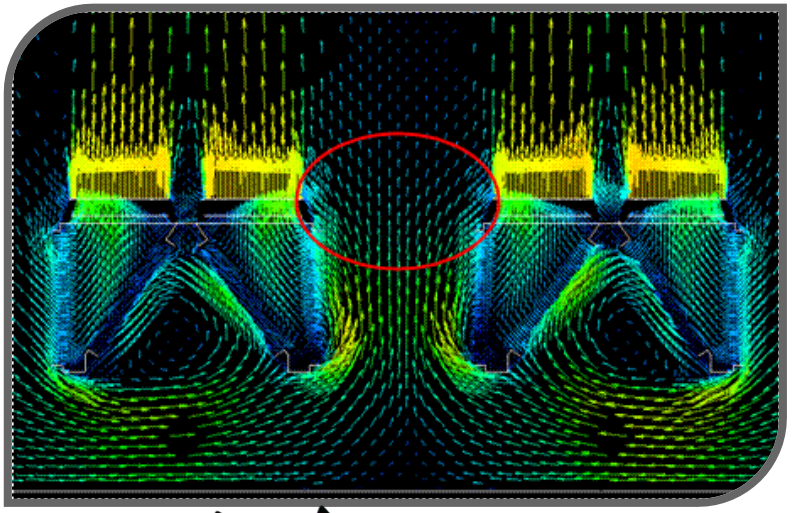


Reliability Features

Adaptive Controls™

- "Smart" controller that adds reliability and helps to avoid nuisance trips
- Chiller will take corrective action based on its operating conditions





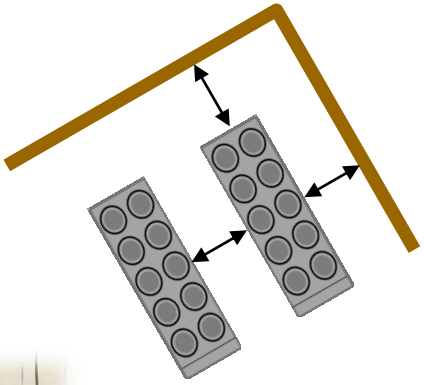
Corrective action:
- ✓ High condensing pressure
- ✓ Low suction pressure
- ✓ Overcurrent

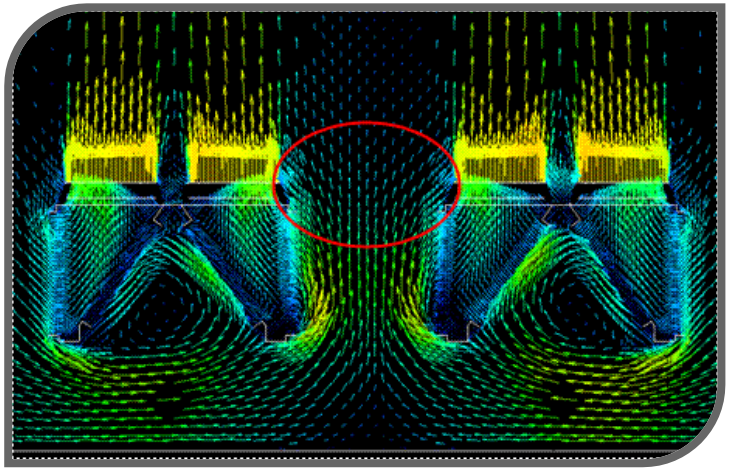
High Condensing Pressure → Lower efficiency

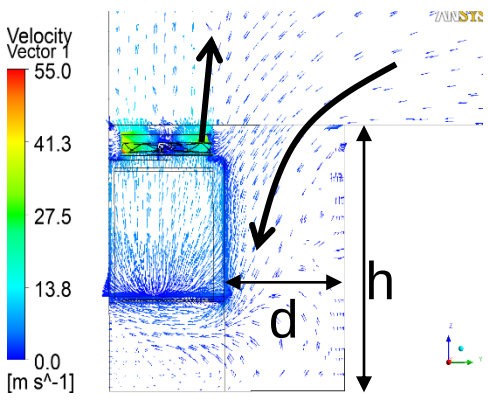
Installation and Operation

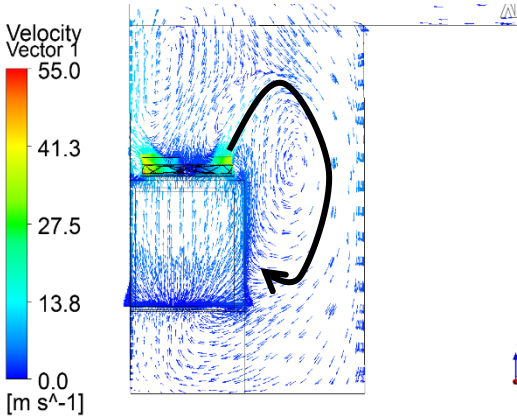
Closest spacing in the industry

- Decorative walls
- Close spacing
- Pit applications



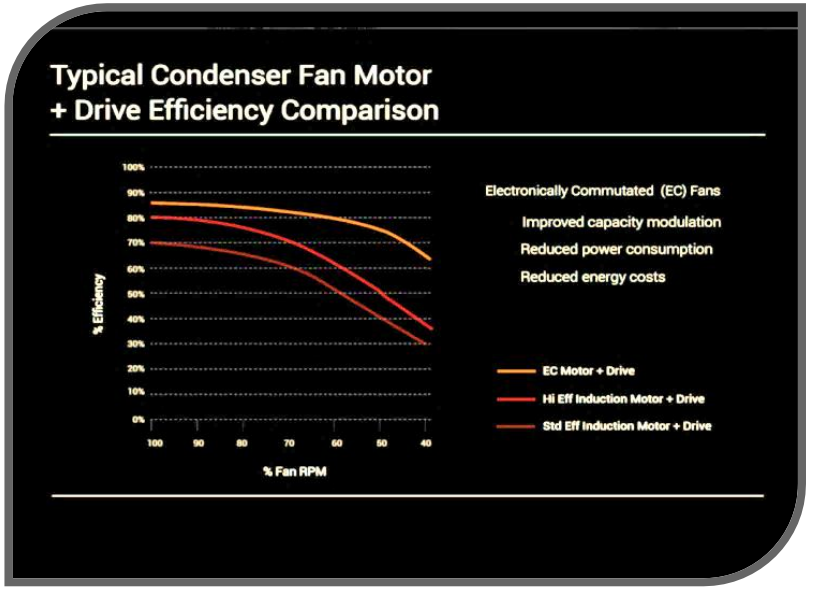






Efficiency drivers

- Condenser fan motor
  - Electronically Commutated (EC) fans
  - Integral VSD
  - Permanent magnet motor
  - 2% efficiency improvement at full load
  - 5% efficiency improvement at part load



Tips :-

1. **Keep the Condenser in good condition**
2. **Proper water treatment**
3. **Check the approach temperature (water vs condensing temp.)**

CONDENSER

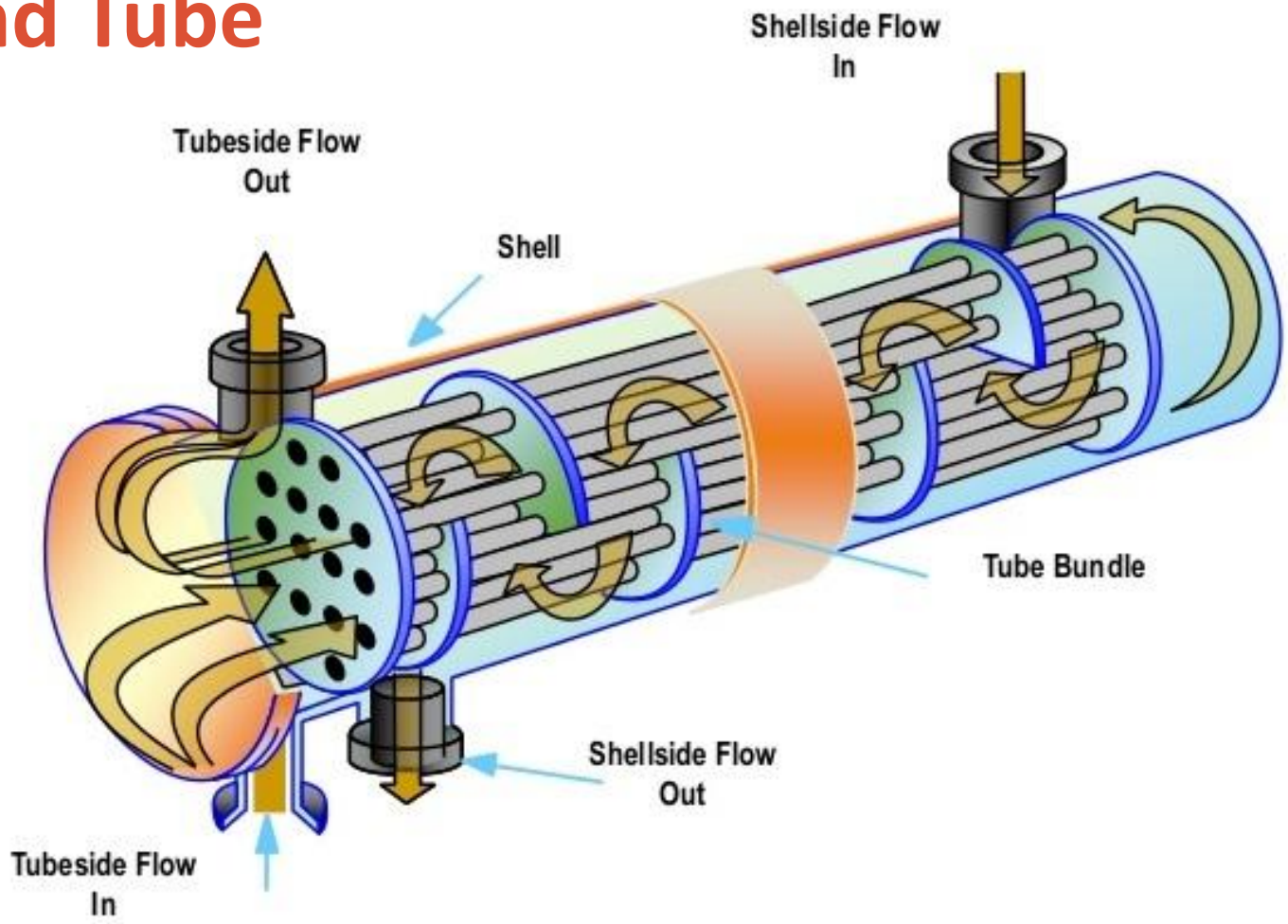
EVAPORATOR

COMPRESSOR

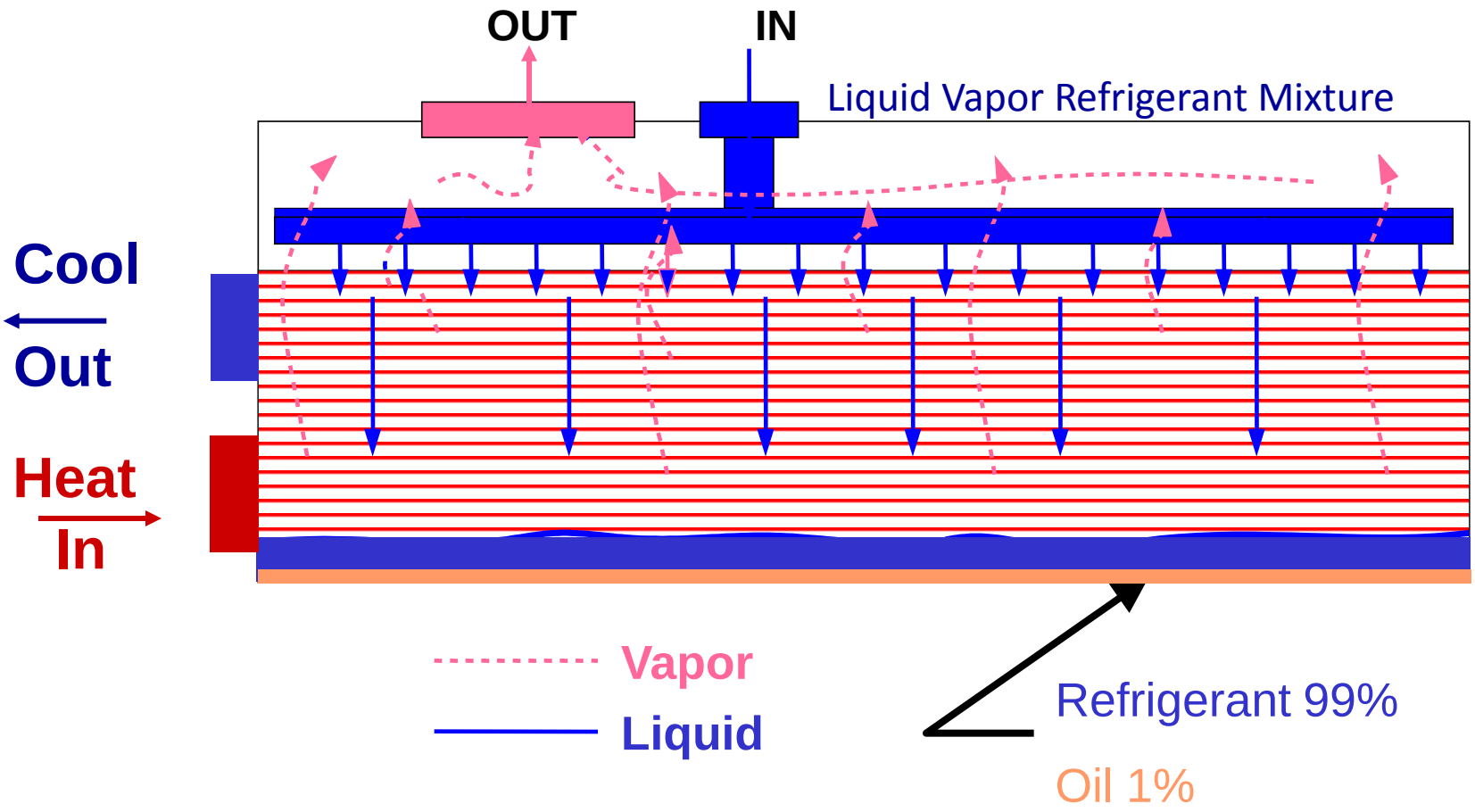
CONTROL

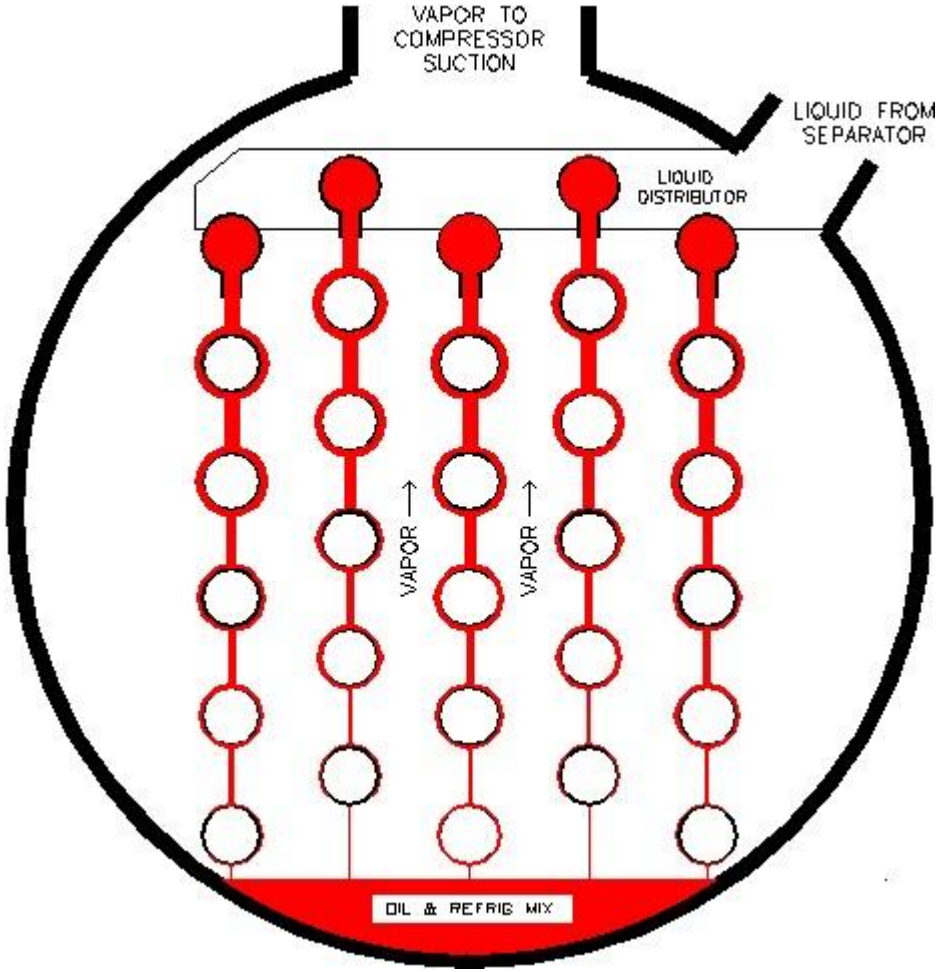
REFRIGERANT

Traditional Shell and Tube



Evaporator Flow





Falling Film Evaporator

- Less Refrigerant
- Better Heat Transfer
- Oil Concentrator

How do we achieve these efficiency levels?

Efficiency drivers

New CHIL evaporator design

- Compact, High-performance, Integrated, Low-charge
- Premium efficiency heat transfer tubes
- Up to 40% less refrigerant

New CHIL evaporator design

Tips :-

1. **Keep the Evaporator in good condition**
2. **Proper Water Treatment**
3. **Check the approach temperature (water vs condensing temp.)**

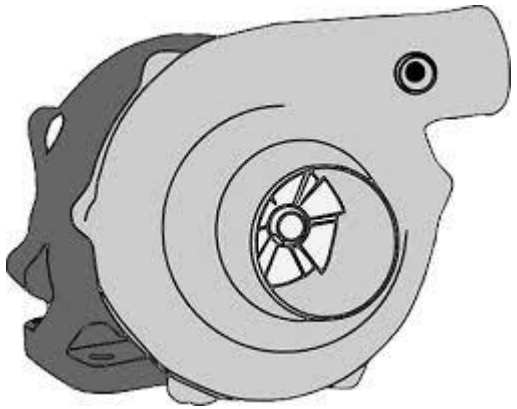
CONDENSER

EVAPORATOR

COMPRESSOR

CONTROL

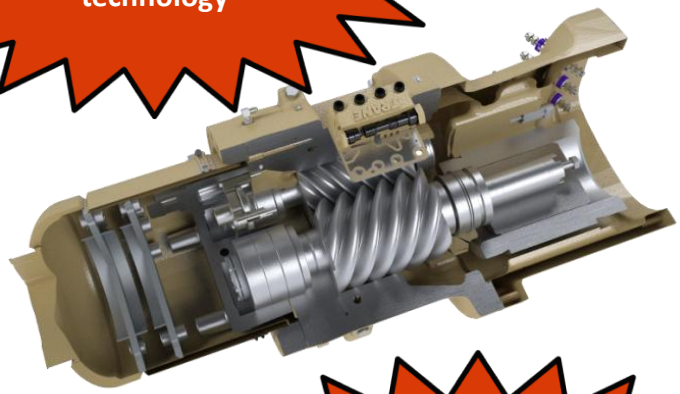
REFRIGERANT



Efficiency drivers

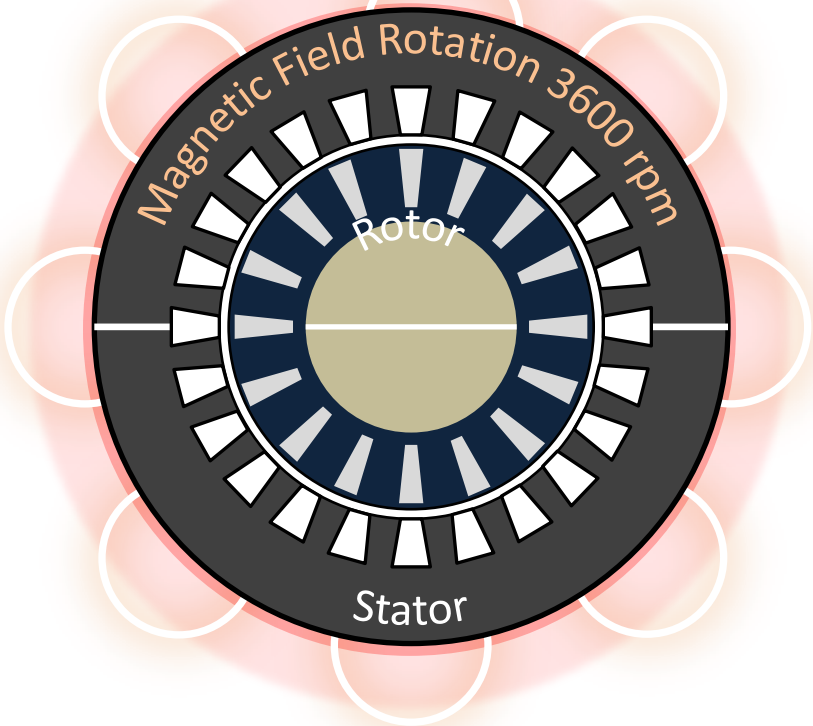
- New compressor design
  - Delivers peak efficiency under all operating conditions
  - Optimized for variable speed operation
  - Up to a 10% improvement in compressor efficiency
  - **Permanent magnet motors**

New specific speed compressor technology



Peak efficiency under all operating conditions!

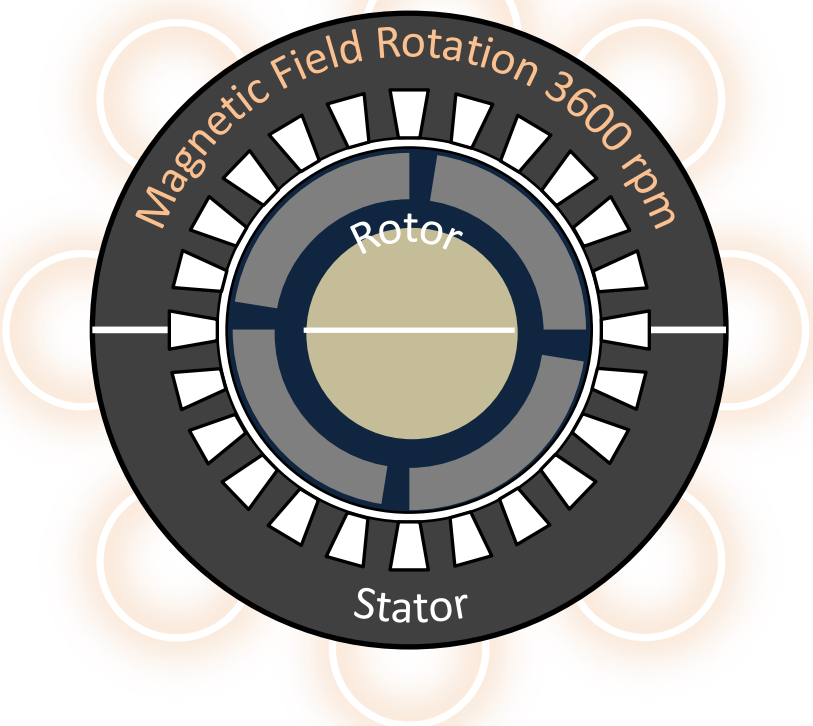
Induction Motor



Rotational Slip

Induction motor "slips" in order to establish a magnetic field in the rotor to produce torque. The power in the rotor is lost as heat. As more torque is required, more slip occurs.

Permanent Magnet Motor



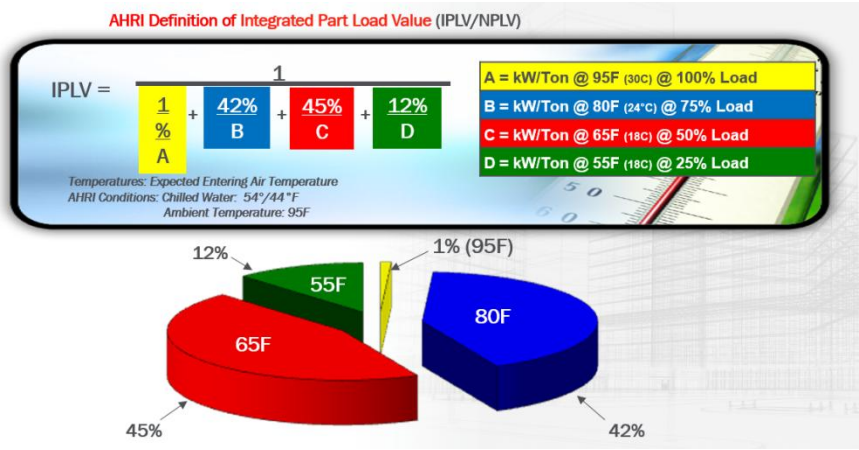
No Rotational Slip

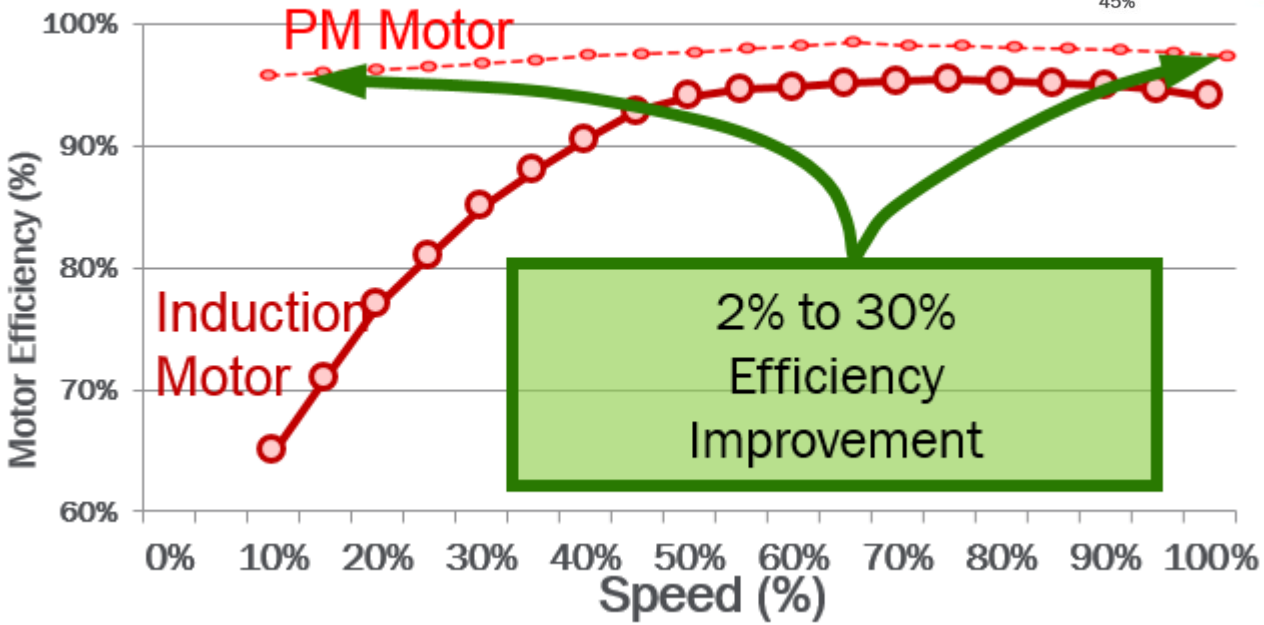
Permanent magnet motor has its rotor magnetic field permanently provided by the magnets. No external power is necessary as in the induction motor.

Permanent Magnet motor eliminates losses due to slip…
Resulting in 2-4 % higher efficiency.

Efficiency drivers

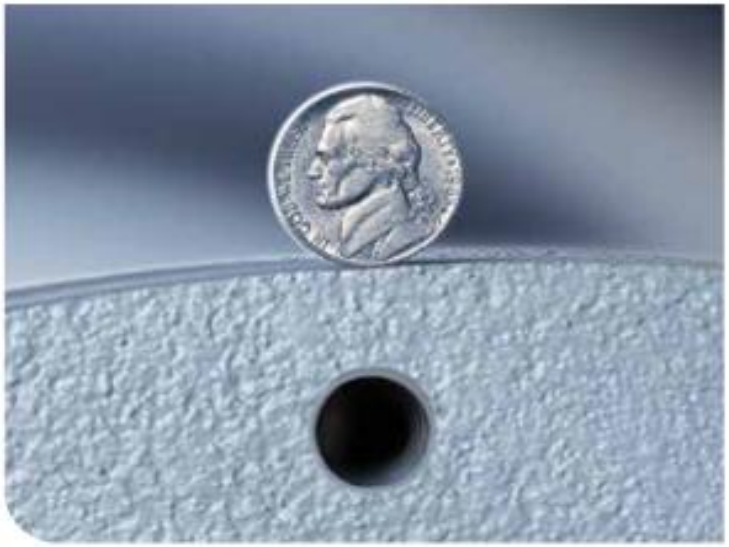
Permanent Magnet Motors



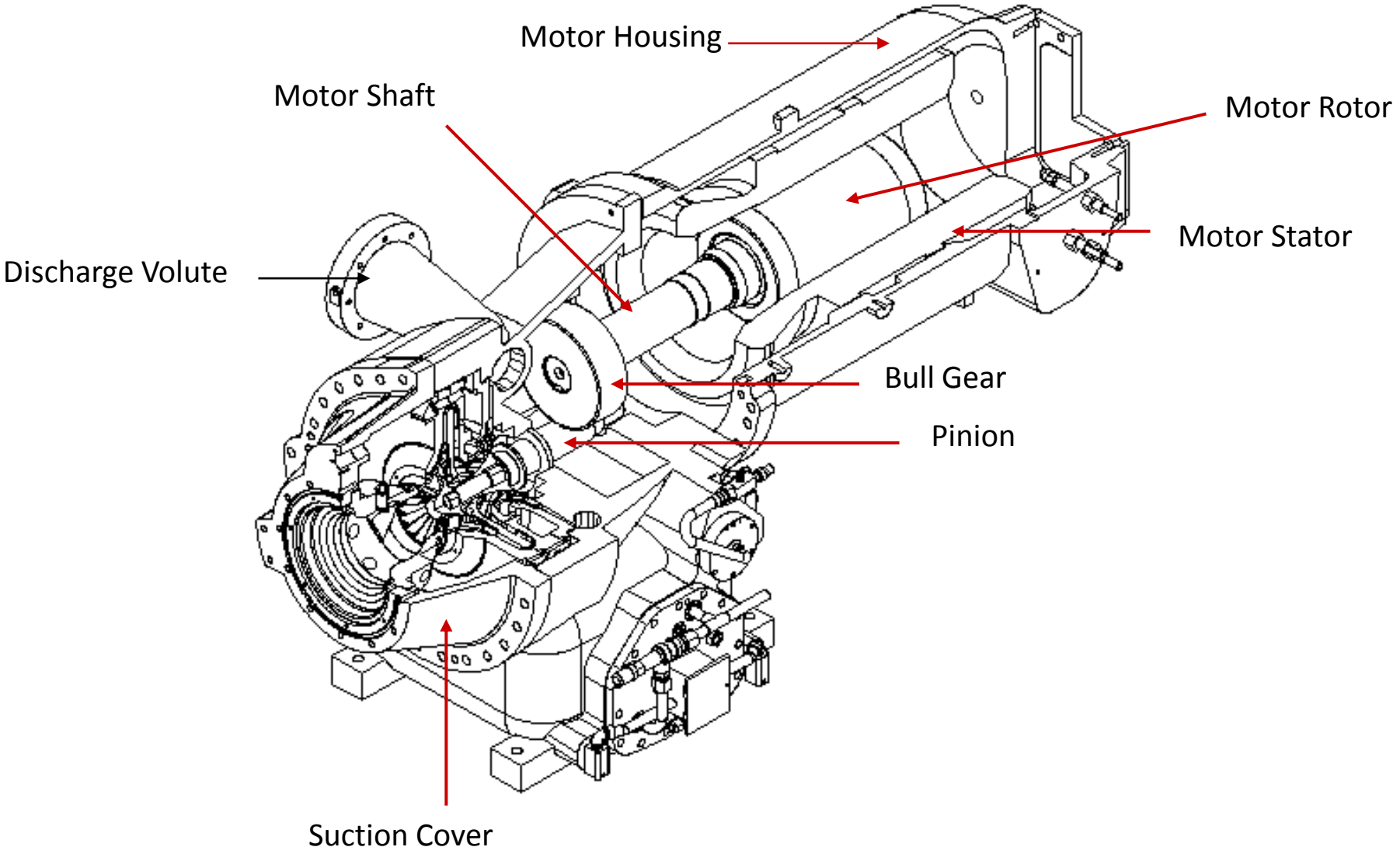


Full load vibration test (Nickel Test)

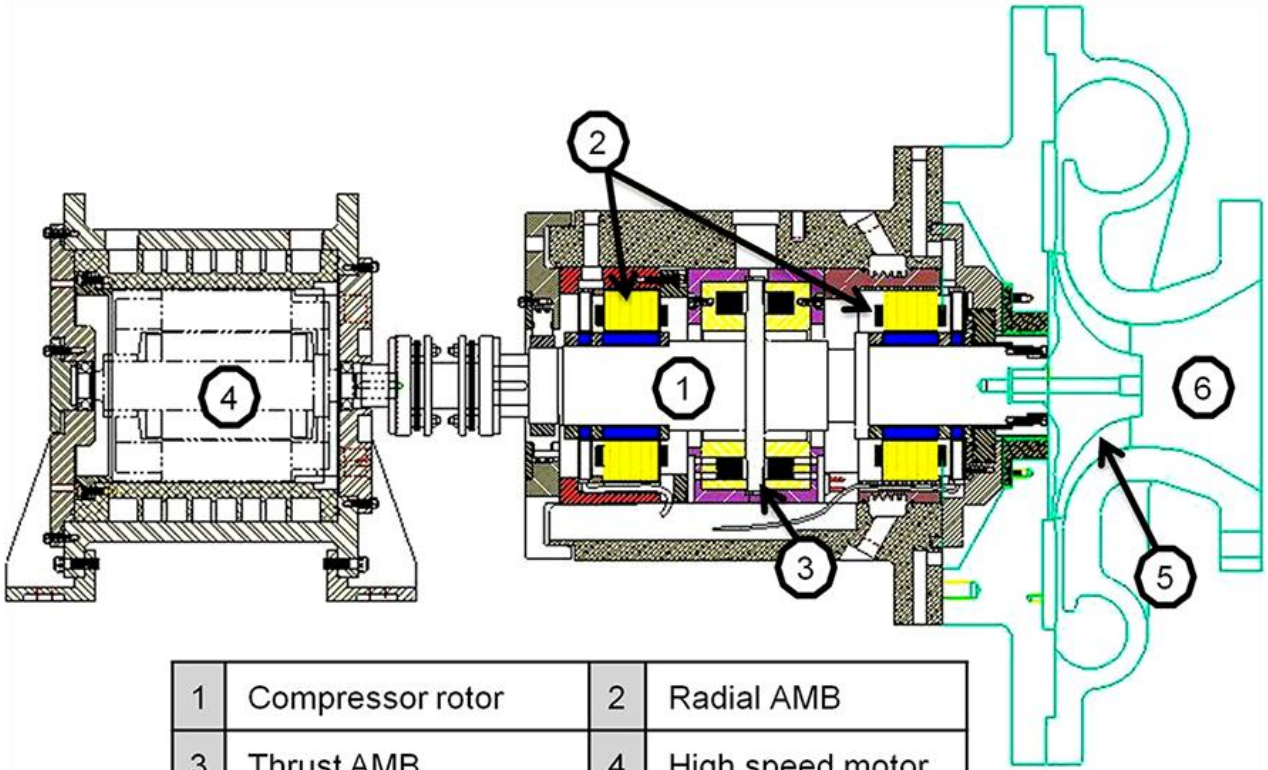
- Trane performs a vibration test on the assembled centrifugal chiller at the time of the 100 percent load test.
- The levels of vibration generated by the operating unit are so low, a nickel can balance on the edge of the main compressor-motor assembly



Hermetic Type

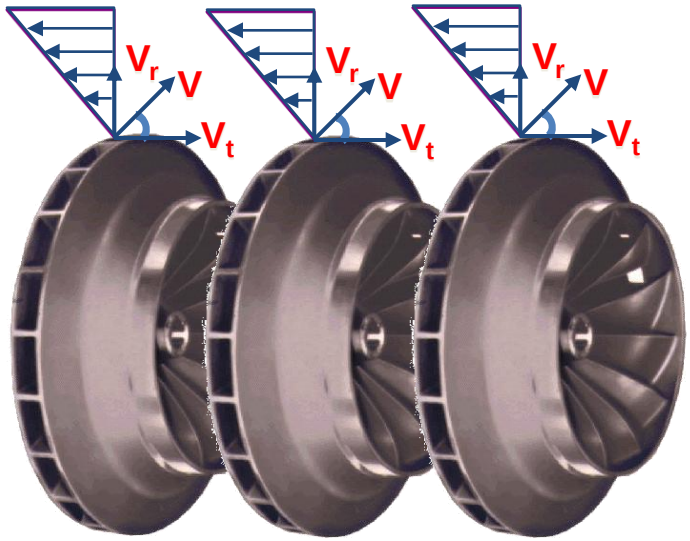


Open Type

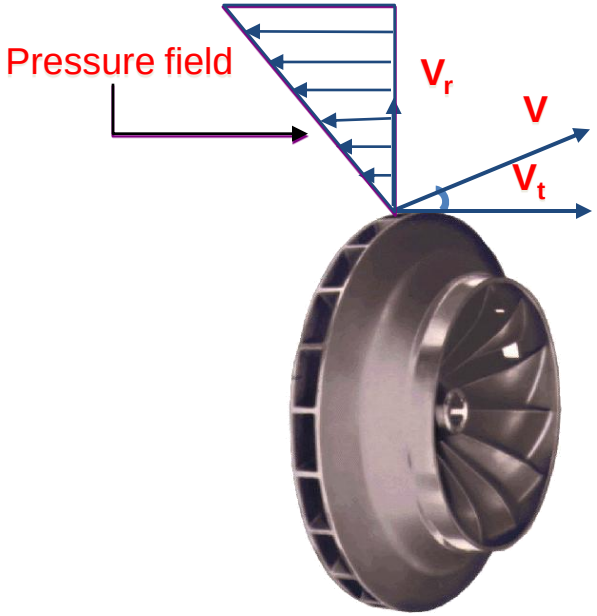


1	Compressor rotor	2	Radial AMB
3	Thrust AMB	4	High speed motor
5	Unshrouded impeller	6	Inlet

Multi-stage Advantages



Two or Three Stage



Single Stage

- Surge resistant
- Higher Efficiency

  - Less Frictional Losses
  - One or two stage economizer cycle

Tips :-

1. **Avoid running in Surge Zone (Especially in Night Mode)**
2. **Carry out vibration analysis**
3. **Carry out oil analysis before deciding change of oil**
4. **Check Shaft Seal Leakage for Open Type**

CONDENSER

EVAPORATOR

COMPRESSOR

CONTROL

REFRIGERANT

Reliability Features

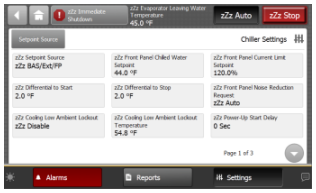
UC800 Controller with TD7 Interface

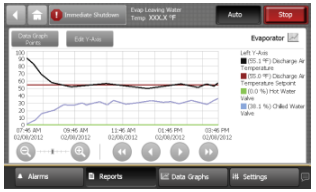
Adaptivew™ Controls

- Industry leading algorithms to optimize control during rapidly changing conditions
- Feedforward adaptive control
- Rapid Restart capability

TD7 Adaptiview™ Interface

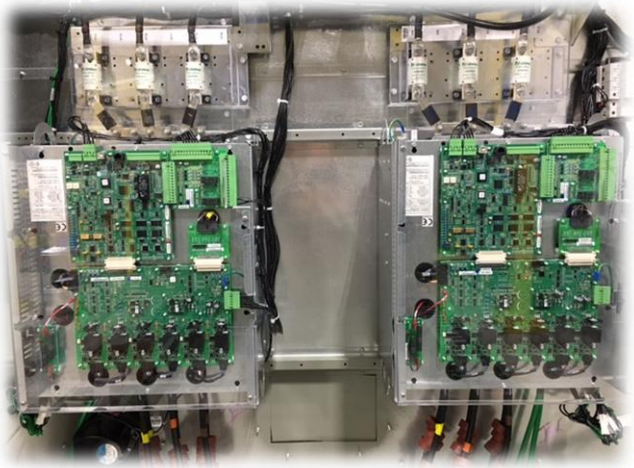
- Color touchscreen display
- UV resistant
- IP56 compliant
- Historical diagnostics
- Standard and custom reports
- Stand alone control





Efficiency drivers

Industry leading efficiency and sound levels!

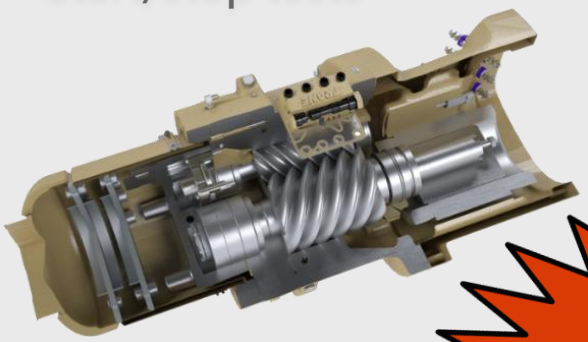


- AFD3 Adaptive Frequency™ Drive
  - Trane third-generation Adaptive Frequency™ drive
  - Part load efficiency improvement of more than 40%
  - Designed to work with new compressor design

Reliability Features

R-410A Screw Compressor, AFD3 Adaptive Frequency™ Drive

- Trane designed and manufactured
- Accelerated life testing
  - High pressure ratio tests
  - High/low tests
  - Flooded starts/stops tests
  - Start/stop tests



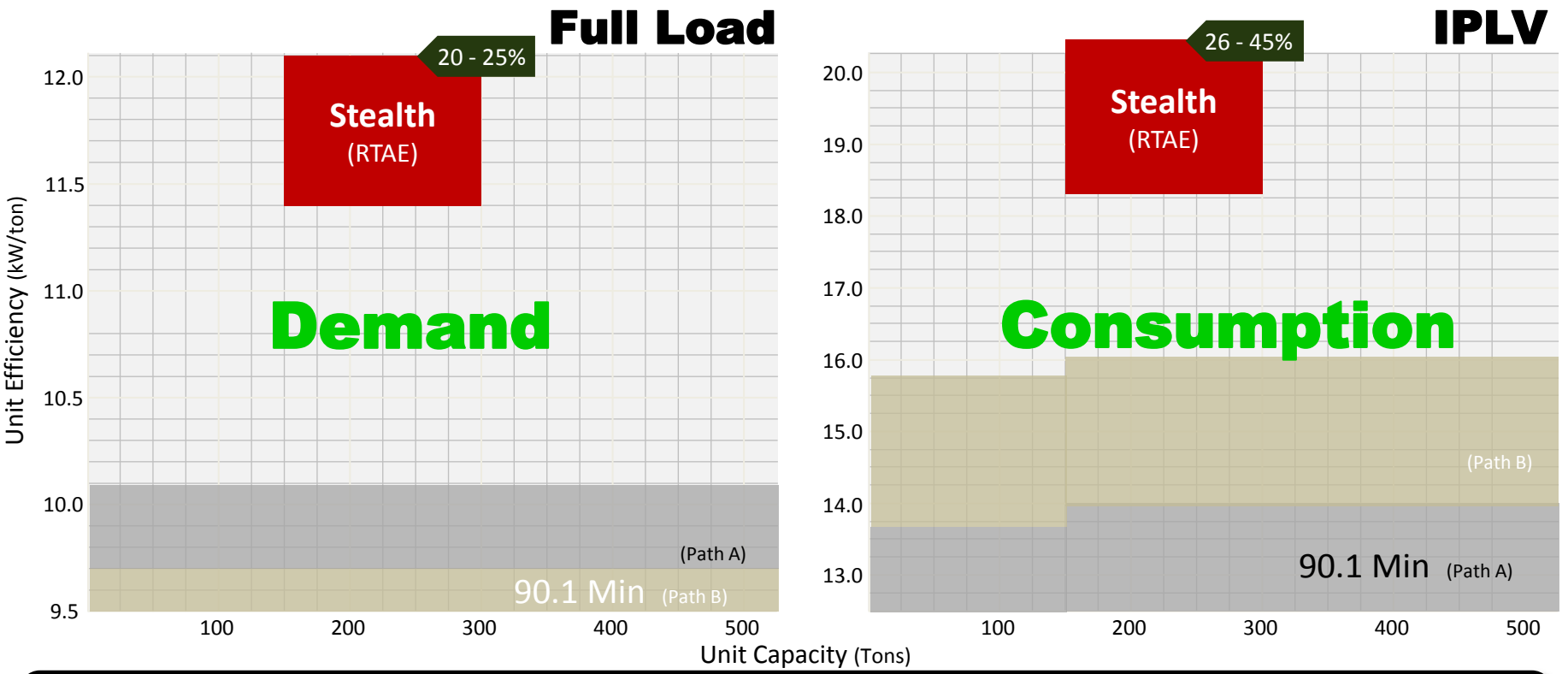
- Trane designed and manufactured
  - Robust fully integrated software
  - Chiller safeties and protections
  - Fluid cooled drive
  - Uses polymer film capacitors
  - Serviceable components

AFD3 designed to last the life of the chiller!

Unit Efficiency

Full and IPLV Efficiency

Screw



Providing a wide range of performances over 90.1 - 2013

@ AHRI Standard Conditions

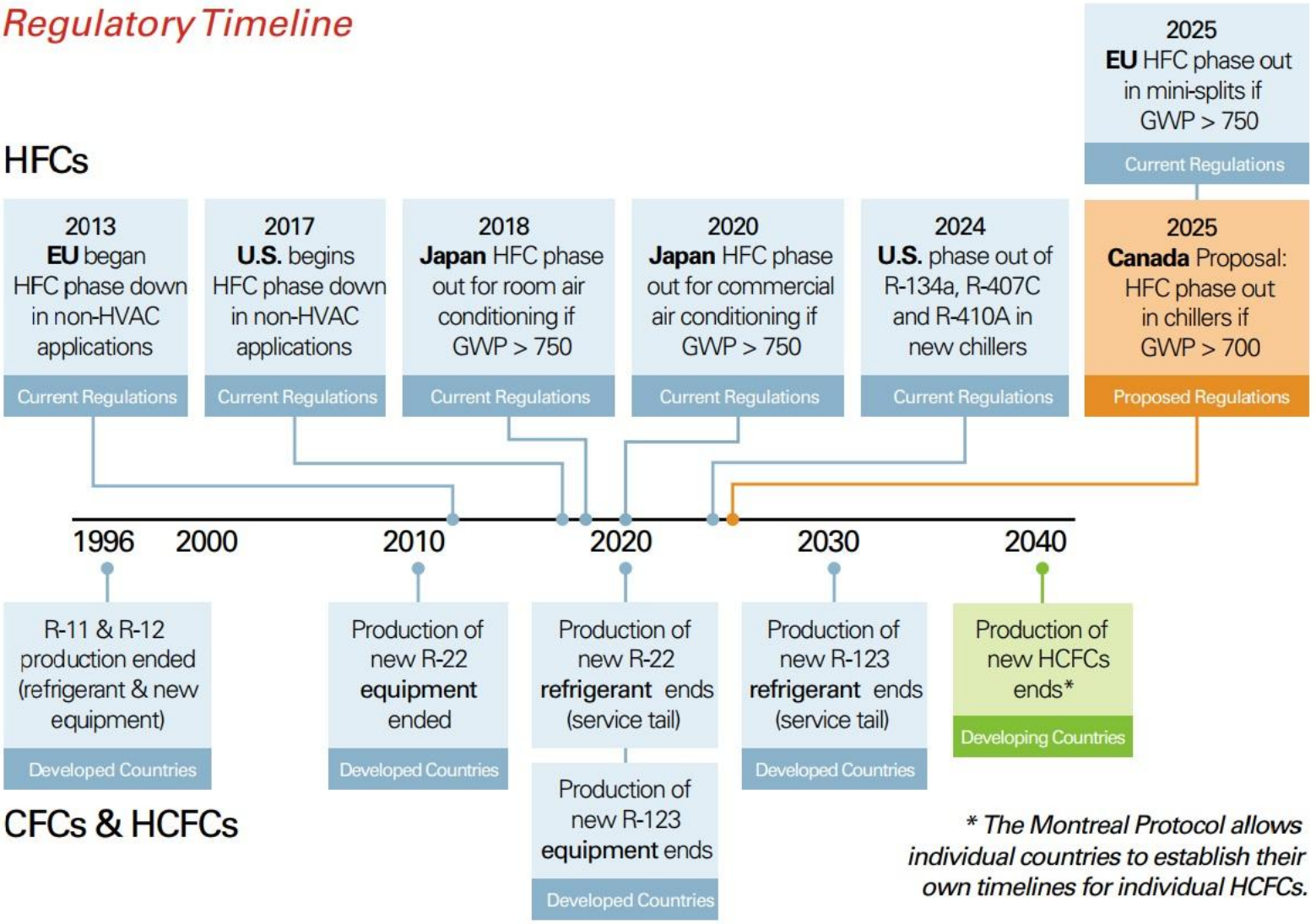
Tips :-

1. **Keep up to date Firmware**
2. **Use Genuine Parts**
3. **Analyze Operation History Data**

CONDENSER
EVAPORATOR
COMPRESSOR
CONTROL

REFRIGERANT

Regulatory Timeline



** The Montreal Protocol allows individual countries to establish their own timelines for individual HCFCs.*

Temperature Glide

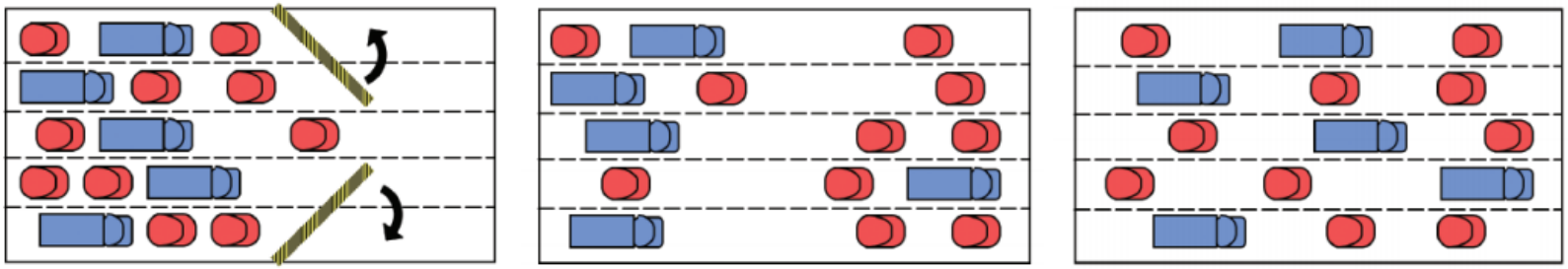
Refrigerant can behave like stopped traffic

If traffic is stopped, then allowed to move suddenly, the cars will take off quickly and the trucks will take some time to rumble up to speed. Refrigerant acts quite similarly.

This is like the molecules in refrigerant A jumping quickly into the bubbles, while the molecules in refrigerant B stay in the liquid. The average speed is low, just as the boiling point is lower at this point.

If you stand about one mile down the road, you will see a bunch of cars go by with a truck or two, then you will see a bunch of trucks with a car or two. This is like the liquid and vapor being at different compositions. The average speed is higher, as the boiling point is getting higher.

Go 10 miles down the road and the trucks have caught up to the cars. Similarly, the refrigerant A and B molecules come together as vapor. The speed is higher still, like the boiling point.◆



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Refrigerant Number

ASHRAE Standard 34

- 000 Series Methane Based, e.g. R-11, -12, -22
- 100 Series Ethane Based, e.g. R-123, -125, -134a,
- 200 Series Propane Based
- 300 Series Cyclic Organic Compounds
- 400 Series Zeotrope, e.g. R-404A, -410A, -452A, -452B
- 500 Series Azeotrope, e.g. R-513A, -514A, -515A
- 600 Series Organic Compounds, e.g. R-600
- 700 Series Inorganic Compounds, e.g. R-717, -744
- 1000 Series Unsaturated Organic Compounds, e.g. R-1234yf, -1234ze(E), -1233zd(E), -1336mzz(Z), -1130(E)

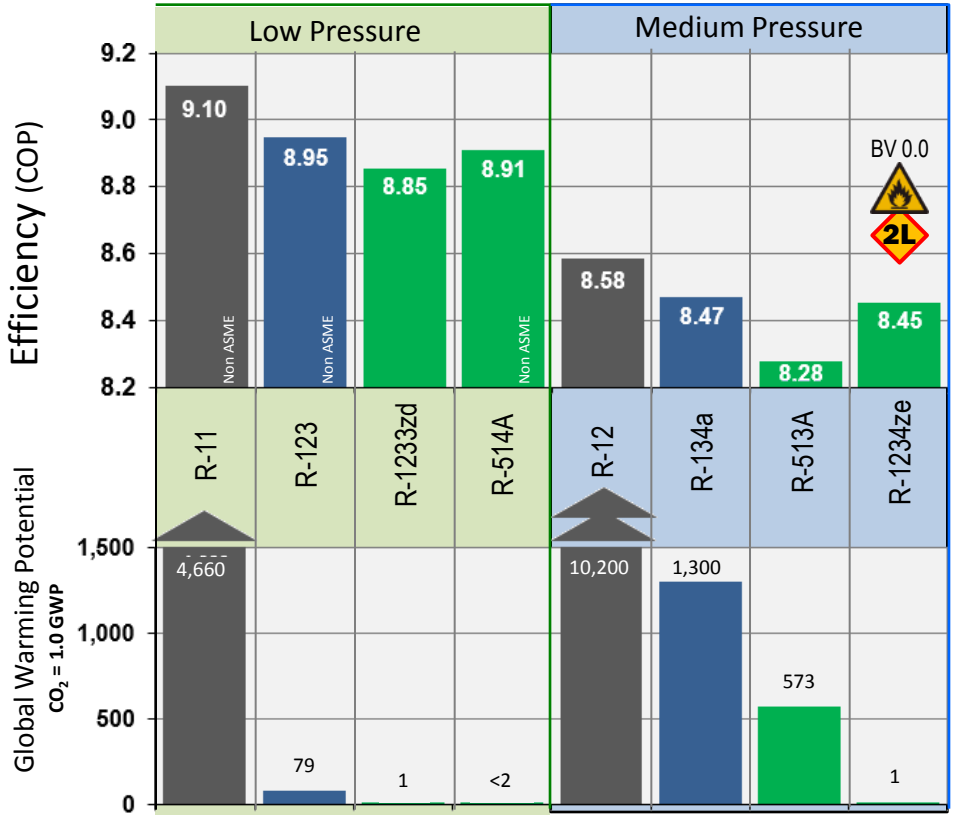
Refrigerant Table

10/01/2017

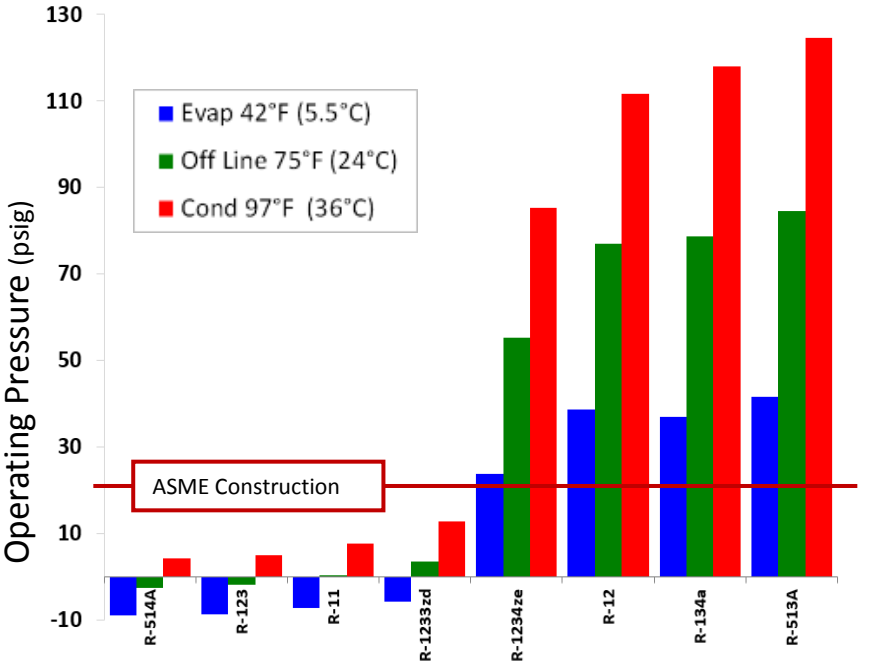
Refrigerant	ODP	GWP	Refrigerant Class	Atmospheric Life	Composition	Phase Out Schedule
Low Pressure Refrigerant						
R123	0.02	79	B1	475 days	HCFC Homogeneous	Yes
R1233zd	Zero (0.0002)	1	A1	26 days	HFO Homogeneous	No
R514a (Opteon XP30)	Zero (0.00006)	1.75	B1	22 days	HFO Blend	No
Medium Pressure Refrigerant						
R134a	Zero (0.000015)	1300	A1	4,900 days	HFC Homogeneous	Yes
R513a (Opteon XP10)	Zero	573	A1	2,158 days	HFO Blend	No
High Pressure Refrigerant						
R410a	Zero	2100	A1	6,200 days	HFC Blend	Yes
R22	0.055	1810	A1	4,344 days	HCFC Homogeneous	Yes

Efficiency impacted by Refrigerant Choice…

Centrifugal & Screw Chillers in particular



	R-514A	R-123	R-11	R-1233zd	R-1234ze	R-12	R-134a	R-513A
EVAP	(8.95)	(8.63)	(7.34)	(5.87)	23.66	38.73	37.00	41.59
OFF	(2.58)	(1.99)	0.09	3.37	55.21	76.84	78.65	84.53
COND	4.15	4.96	7.65	12.85	85.16	111.53	117.96	124.45



Industry commitments and available options are increasing

Tips :-

1. **MUST weight Refrigerant before dumping back**

TRANE®

Ingersoll Rand