

# SISTEMAS DE ÁGUA GELADA



PROGRAMA  
BRASILEIRO DE  
ELIMINAÇÃO DOS

**HCFCs**  
Projeto para o Gerenciamento de Chillers

## Projeto Demonstrativo para o Gerenciamento Integrado no Setor de Chillers

# CHILLERS COM CARGA DE AMÔNIA REDUZIDA

**Celina Bacellar – Johnson Controls Inc.**  
**24/02/2016 - Rio de Janeiro**

Execução



Implementação



*Empoderando vidas.  
Fazendo a diferença.*

Realização

Ministério do  
Meio Ambiente



# Industrial Refrigeration



1897: Founding of Thomas His. Sabroe & Co.

**STAL**  
REFRIGERATION

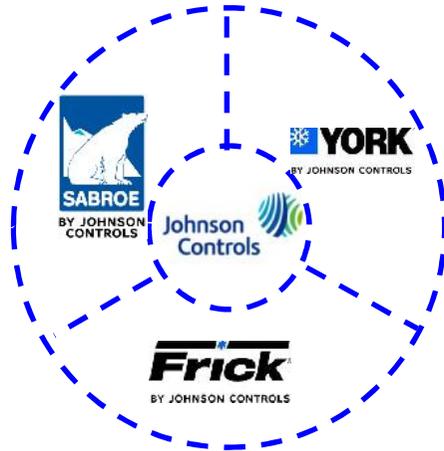
1997: Acquisition of ABB Stal Refrigeration

**YORK**

1999: Sabroe becomes part of YORK International



2004: Relaunch of the Sabroe brand name



**Johnson Controls**



1874: Founding of YORK Manufacturing Co.

**Frick**

1987: Acquisition of Frick

**Gram Refrigeration**

1995: Acquisition of Gram Refrigeration

**YORK**

2005: YORK International sold

# Responsabilidade & Sustentabilidade

## Posicionamento



A Refrigeração Industrial pode contribuir, significativamente, com soluções sustentáveis.

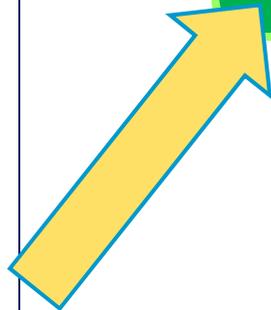
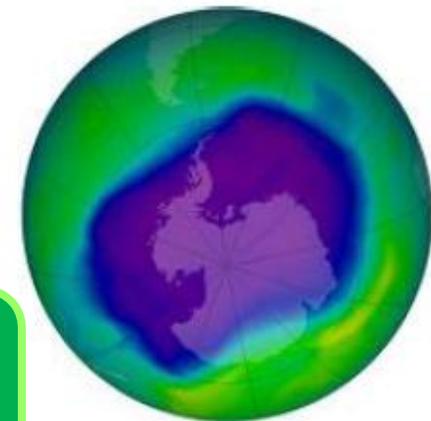
Como a Johnson Controls assume esta responsabilidade?

Foco em refrigerantes naturais como Amônia, CO<sub>2</sub> e Hidrocarbonetos.

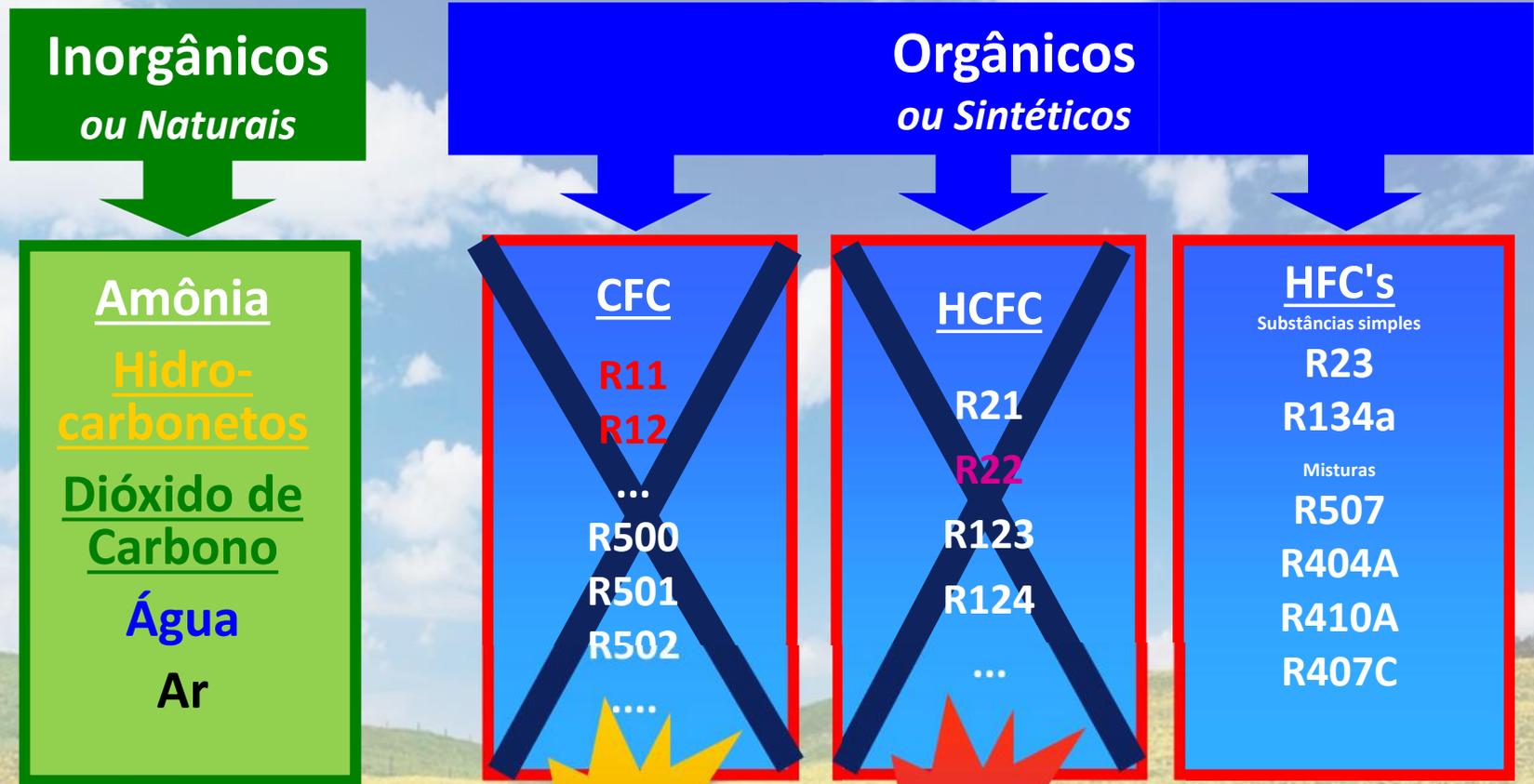
Minimizar as cargas de refrigerantes nos sistemas.

Oferece uma ampla gama de compressores e chillers com alta eficiência energética.

Motiva, fortemente, minimizar o consumo total de energia em plantas.



# Atual situação dos fluidos refrigerantes



GWP Reduzido  
ODP 0 (zero)  
\$ Baixo  
Conhecimento Elevado

1996

2040

Elevado  
0 (zero)  
Elevado  
Parcial

# Refrigerantes



Refrigerante	ODP	GWP
<b>1 – CFC</b>		
R-11	1.00	3500
R-12	1.00	7300
R-502 (R22/R115)	0.34	4300
<b>2 – HCFC</b>		
R-22	0.055	1500
R-123	0.02	85
<b>3 – HFC</b>		
R-23	0.0	12000
R-32	0.0	650
R-134a	0.0	1200
R-143a	0.0	2900
R-507 (R125/R143a)	0.0	3800
R-404A (R125/R143a/R134a)	0.0	3700
R-407C (R132/R125/R134a)	0.0	1600
R-410A (R32/R125)	0.0	1900
<b>4 – Inorgânicos ou Naturais</b>		
R-717	0.0	0.0
R-718	0.0	0.0
R-290	0.0	3.0
R-744	0.0	1.0

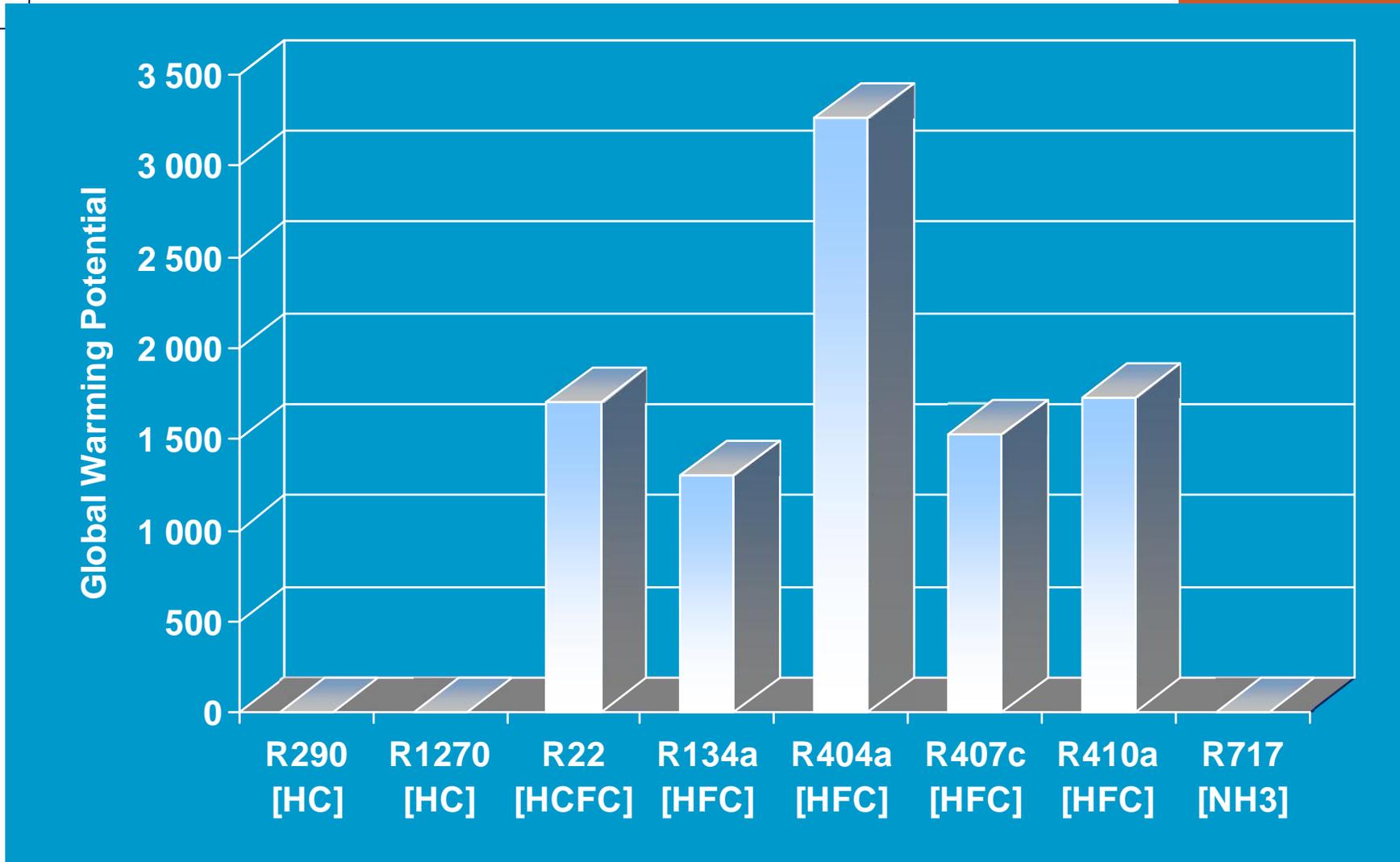
## ODP - Ozone Depletion Potential:

Parâmetro que mede o potencial de um produto de destruir a camada de Ozônio.

## GWP - Global Warming Potential:

Parâmetro que mede o potencial de aquecimento do globo provocado pelos gases presentes na atmosfera ( $\text{CO}_2=1$ ).

# Environmental qualities



Ammonia (R-717) and Hydrocarbons (R-290 e R- 1270) have:  
ODP = 0 (Ozone Depletion Potential)  
GWP (Global Warming Potential) < 3 \* (\* 100 years horizon)

# Sistemas com carga de amônia reduzida



As altas cargas de refrigerante estão onerando os proprietários de sistemas de refrigeração que utilizam amônia devido aos atuais **requisitos legais**.

Nos EUA, instalações contendo 500 lb (227 kg) de amônia ou mais devem ser reportadas ao comitê de planejamento de emergência local.

Instalações que contenham mais de uma quantidade limite (TQ - threshold quantity) de amônia devem, também, apresentar um plano de gestão de riscos para a Agência de Proteção Ambiental dos EUA – EPA.

Califórnia: 500 lb (227 kg). Geral: 10.000 lb (4536 kg). **Europa: 6.600 lb (3000kg)**

Para todos os sistemas de refrigeração com amônia, independentemente da carga, **perdas** de mais de 100 lb (45 kg) devem ser comunicadas ao Centro de Resposta Nacional dentro de 15 minutos a contar do momento em que a pessoa no comando da instalação tomar conhecimento da perda.

**A amônia não é o único refrigerante sob pressão legal.**

# Sistemas de Refrigeração com carga de refrigerante reduzida



O que motiva a busca por soluções de baixas cargas de amônia?

O aumento dos requisitos de segurança (**regulamentação**) em plantas de refrigeração com amônia vem colocando enorme pressão sobre os proprietários devido ao aumento do custo da conformidade (**compliance**).

Em todo o mundo, proprietários de instalações frigoríficas estão à procura de soluções de refrigeração com baixa carga de amônia.

## Resultados:

Elimina / reduz o plano de gestão de risco EPA (RMP) e os requisitos de processo de gestão de segurança OSHA (PSM) para instalações de amônia.

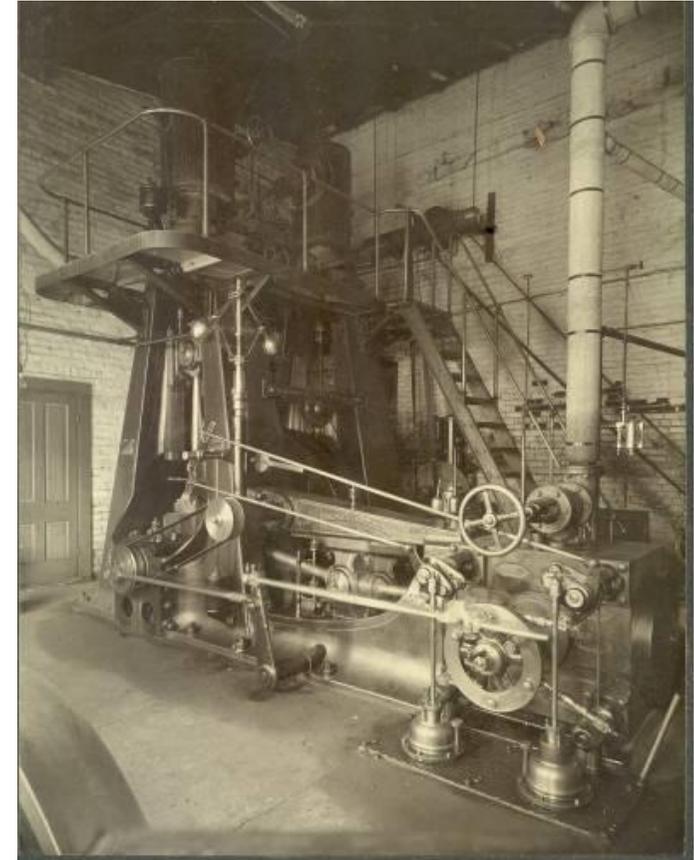
# Amônia – R 717



- Refrigerante natural usado há + 150 anos
- Não agride a camada de ozônio
- Não provoca efeito estufa
- Alta eficiência termodinâmica
- Preço bastante reduzido
- Substância natural biodegradável
- Auto alarme: Detectável a partir de 5 ppm
- Não é acumulativa no corpo humano
- Não poluidora

**Chillers com Amônia:**

**Investimento  
de longo prazo!**



Frick ammonia compressor built in 1886. Installed at Gipp's Brewery, Peoria, IL. Operated until 1946.

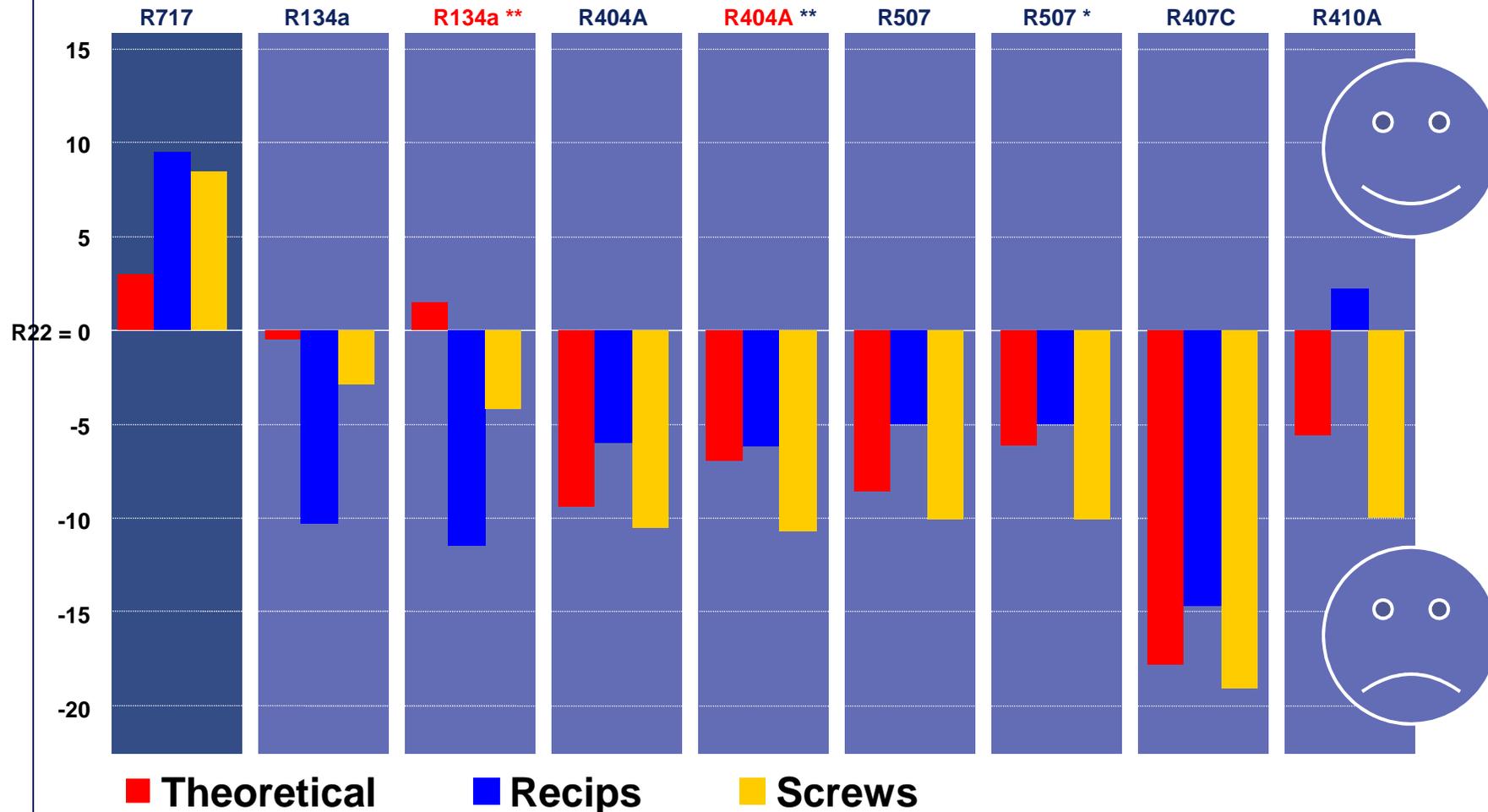
# Ammonia



- Ammonia is produced in natural, biological processes
- Industrially produced ammonia is about 3% of the total amount present in nature
- Only a few per cent is used as refrigerant
  - More than 80% is used as fertilizers and the rest in various industrial processes
- The refrigerant number is R717
  - The 700-group identifies inorganic compounds also including R718 (water) and R744 (CO<sub>2</sub>)

# Choose the right refrigerant

Comparison of refrigerants by COP\*



COP vs. R22 at 0 °C / +35 °C

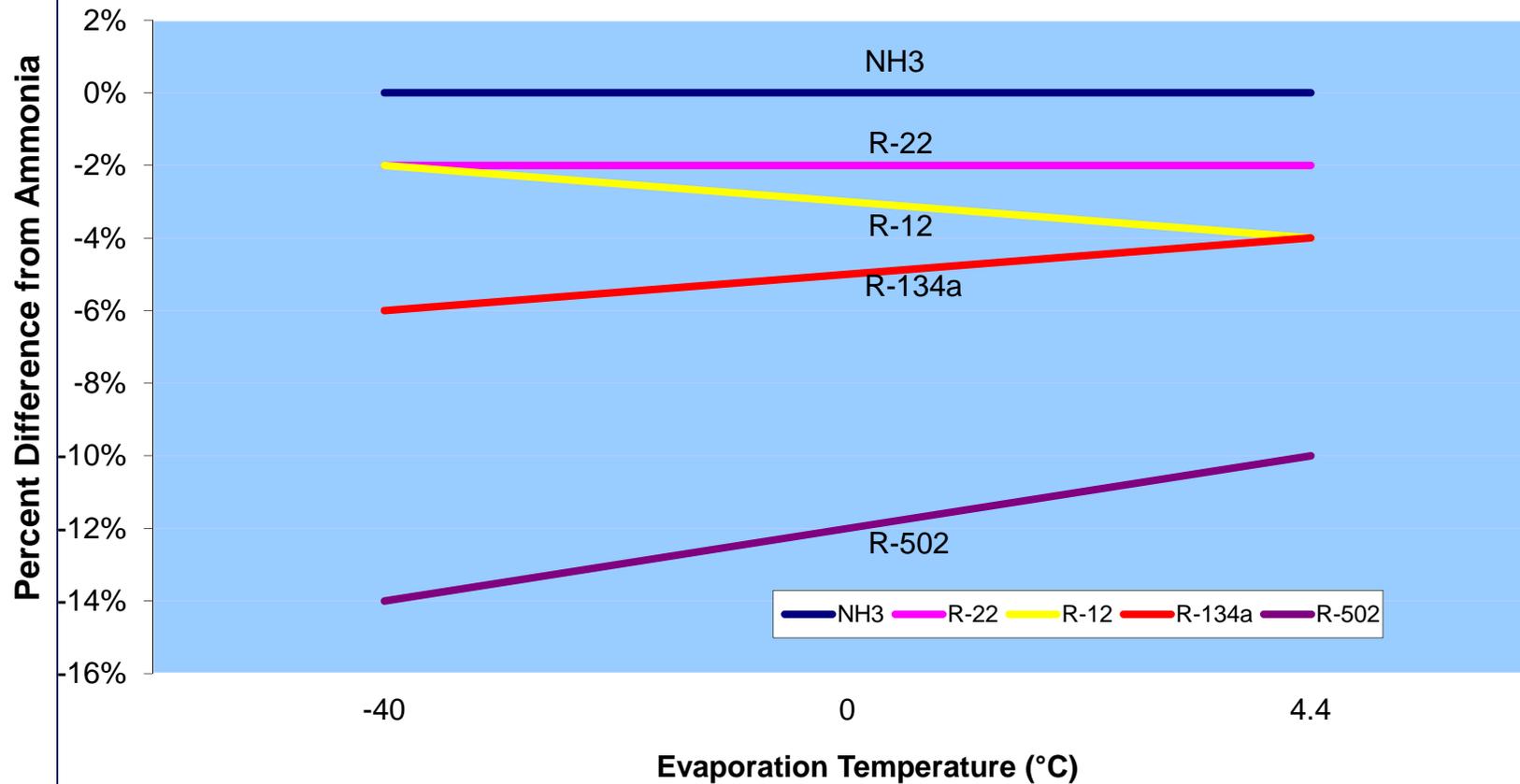
ET = 0°C, CT = +35°C (ET<sub>DEW</sub> CT<sub>BUB</sub>), SH = 0K, SC = 2K

\*\* Note: with heat exchanger, SH = 20K, Pressure loss = 1K

# Advantages of Ammonia



### Coefficient of Performance for Refrigerants



# Por que escolher a amônia?

## Quais são as vantagens?



- Tecnologia conhecida
- Melhor eficiência (COP)
- Melhor coeficiente de transferência de calor
- Disponível e com baixo preço em todo o mundo
- Equipamentos de menor porte - mesma capacidade
- Ideal tanto para compressores alternativos quanto de parafuso
- Maior área de aplicação (de LT -50°C a HP +90°C)
- Simples e flexível para fazer extensão de planta ou em paralelo
- ODP = 0; GWP = 0

# Vantagens da amônia



**A amônia ser um refrigerante natural é apenas uma pequena parte da solução...**

**A eficiência do ciclo da amônia é a real resposta!**

# Safety: Disadvantages of Ammonia



- Low concentrations ruled toxic
  - Short Term Exposure Limit 35 - 50 ppm
  - However self alarming at 5 ppm
  - 1500 ppm – instant reaction to flee
- Considered flammable
  - In narrow range of concentrations of 16-25% by volume of air in presence of open flames
  - To transport – non flammable fluid
- Ammonia is not compatible with copper
  - Special hermetic motors must be utilized
  - Either steel/aluminum piping is required
  - Advantages of enhanced heat transfer diminished

# Aspectos de Segurança



## Programa de Gestão de Riscos



Educação é a chave para Segurança!

# Tendências no uso de Amônia



- Mercado Europeu de chillers é fortemente baseado em amônia
- + 90% dos chillers produzidos para o Mercado da região norte da Europa usam amônia
- Atualmente, ainda *poucos* chillers nos EUA usam amônia  
Exceção: multinacionais europeias que empregam a sua política corporativa de refrigerante naturais.

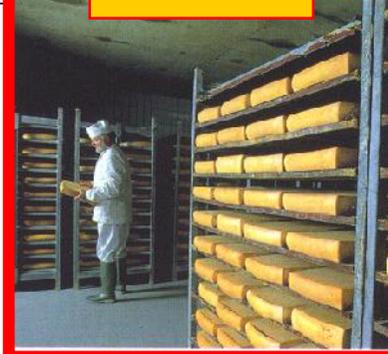
# Áreas de Aplicação



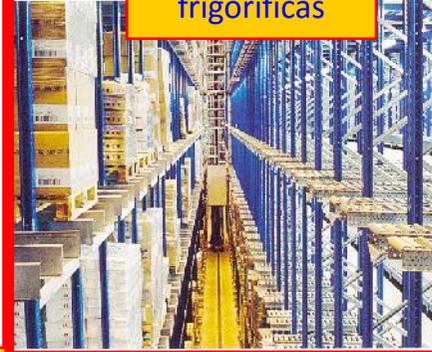
Resfriamento de concreto



Laticínios



Câmaras frigoríficas



Ar Condicionado



Resfriamento de solo



Pistas de gelo



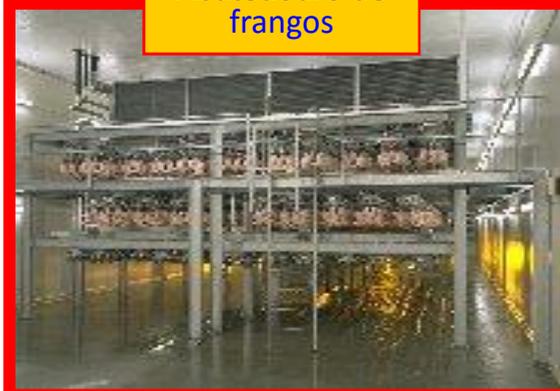
Frigoríficos



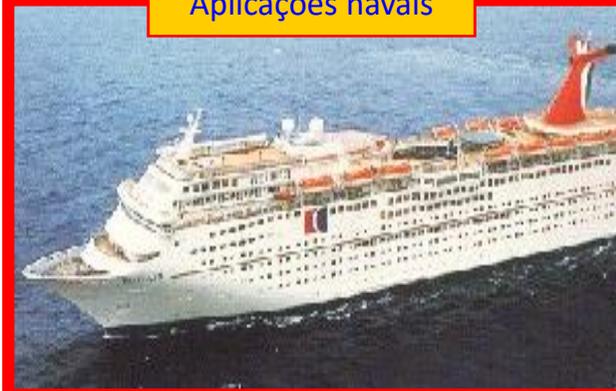
Cervejarias



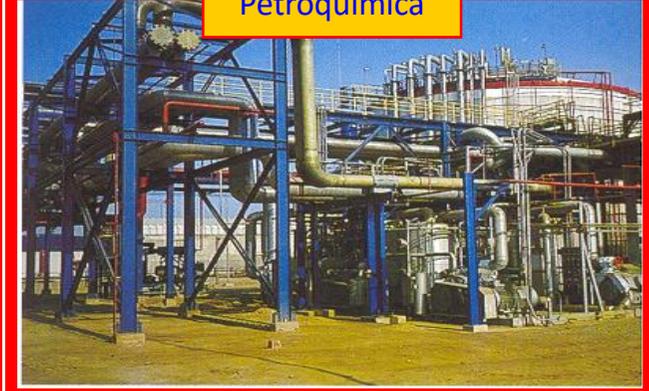
Abatedouro de frangos



Aplicações navais



Química e Petroquímica



# Chillers com trocadores de calor a placas

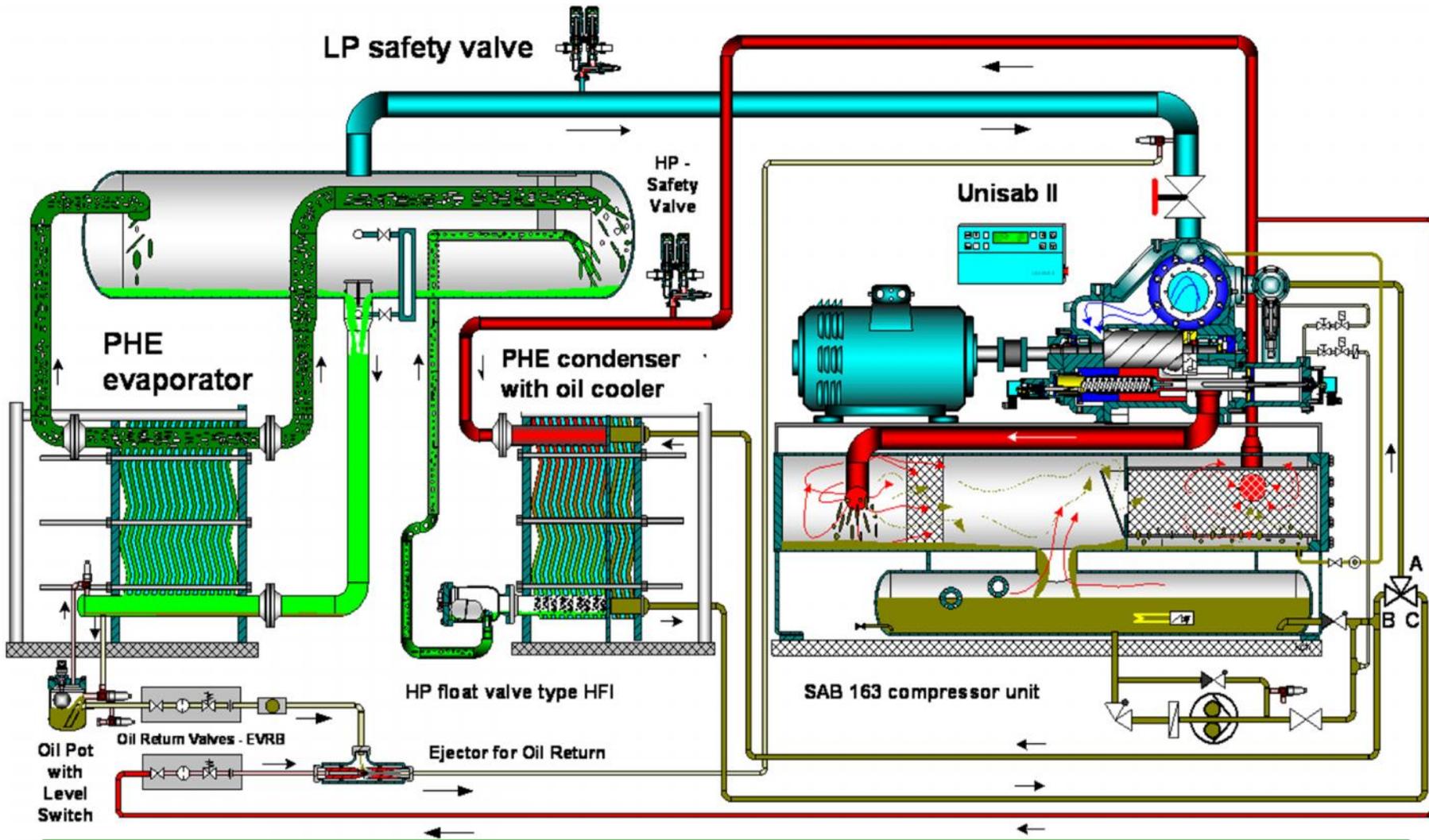


## Associação de características de otimização:

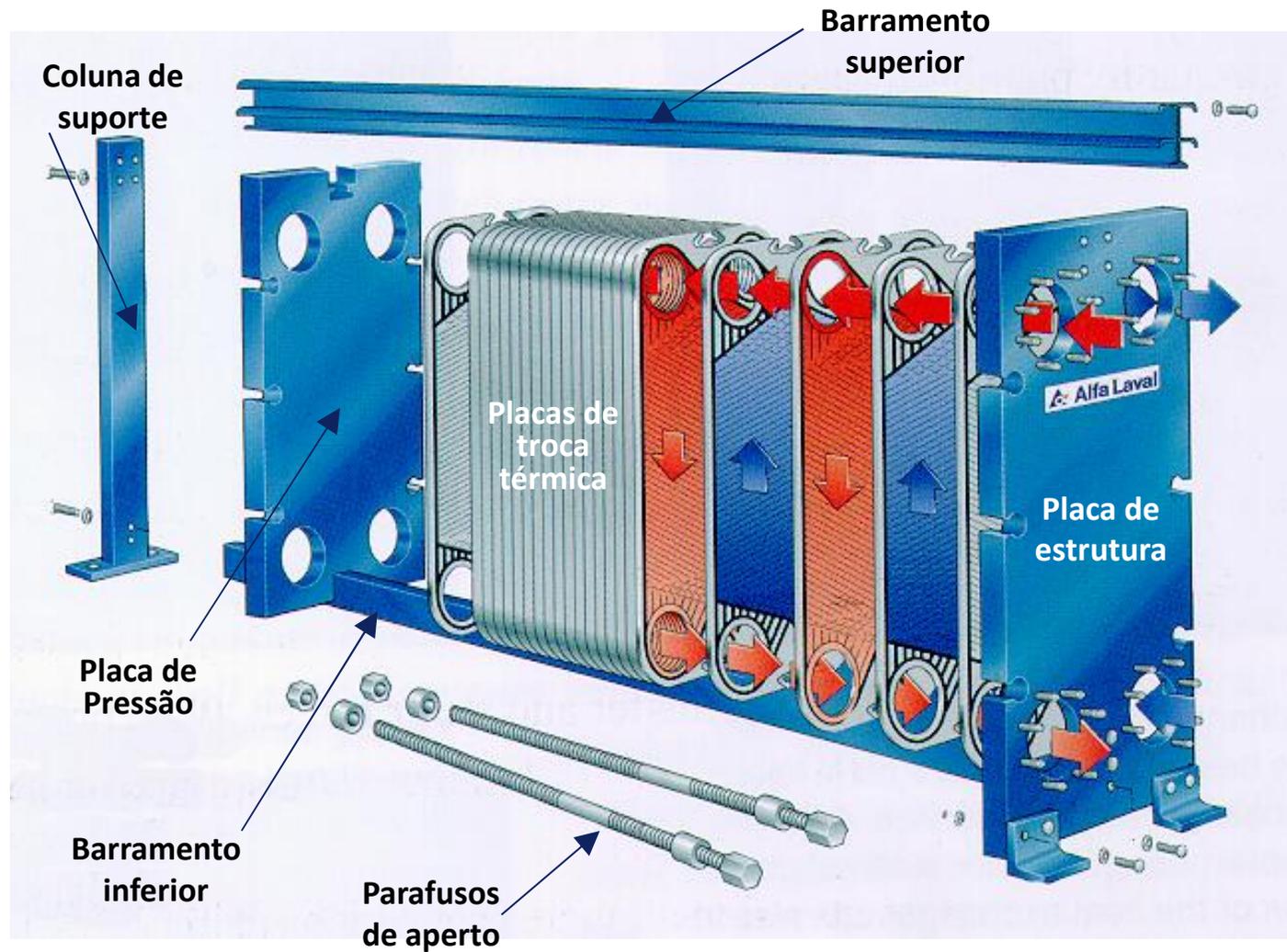


- R 717 como refrigerante:  
*carga reduzida*
- Trocadores de calor a placas:  
*aço inoxidável ou titânio*
  - Projeto compacto
- Não há conexões de R 717:  
*reduzido risco de vazamento*
- Manutenção simplificada
- Instalação: flexibilidade e rapidez
  - Alto COP

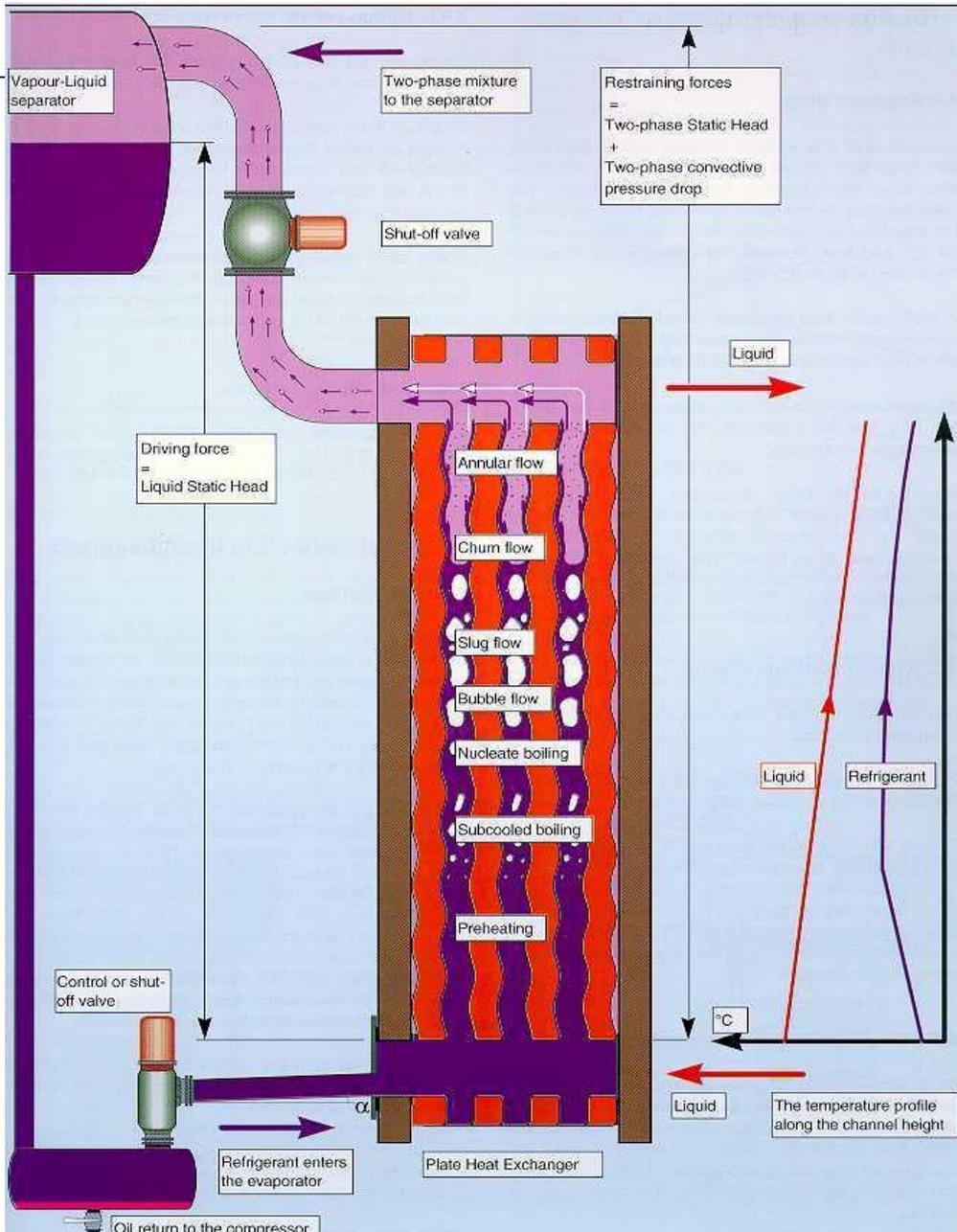
# Chiller com PHE



# PHE - Semi Soldado



# Evaporador Inundado



• Sistema auto-circulante:

Dispensa bomba  $\text{NH}_3$

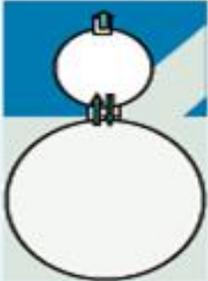
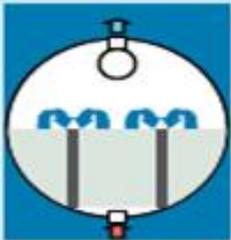
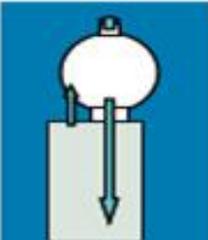
• Melhores coeficientes de

troca térmica:

Superfícies sempre molhadas

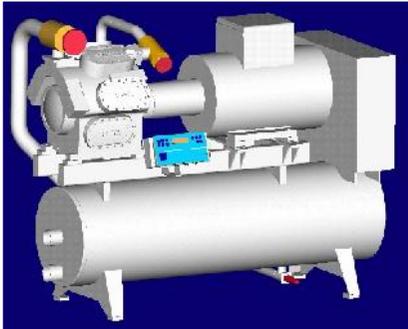
# Comparativo entre trocadores de calor de calor



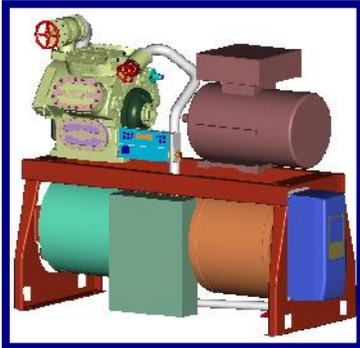
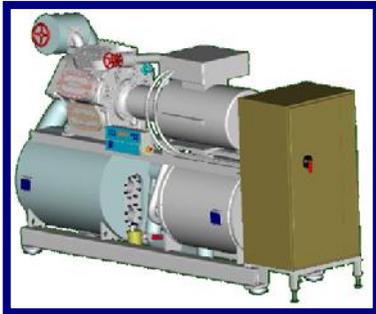
Modelo/Tipo do Evaporador	Carga de R-717 (100%)
 <p>EOSB 415004 Inundado (Shell &amp; Tube)</p>	210 kg
 <p>ESSM 5040B3 Inundado (Shell &amp; Tube)</p>	120 kg
 <p>EPHE 100 (M10) Inundado (PHE)</p>	45 kg
 <p>ESRA 70 Inundado (Shell &amp; Plate)</p>	20 kg

Ref. Carga: capacidade = 500 kW

# ChilIPAC



**Product development process**



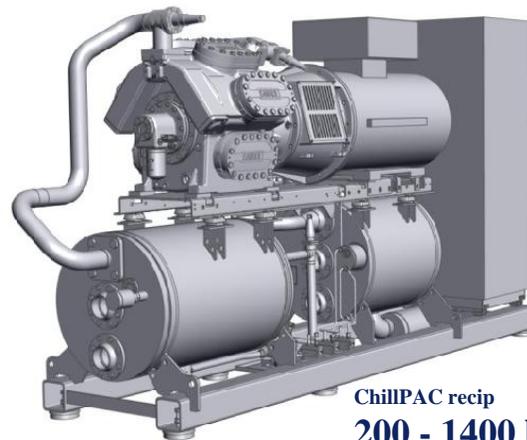
# Sabroe chillers – a clear product profile



PAC recip  
**100 - 1400 kW**



PAC screw  
**200 - 8000 kW**

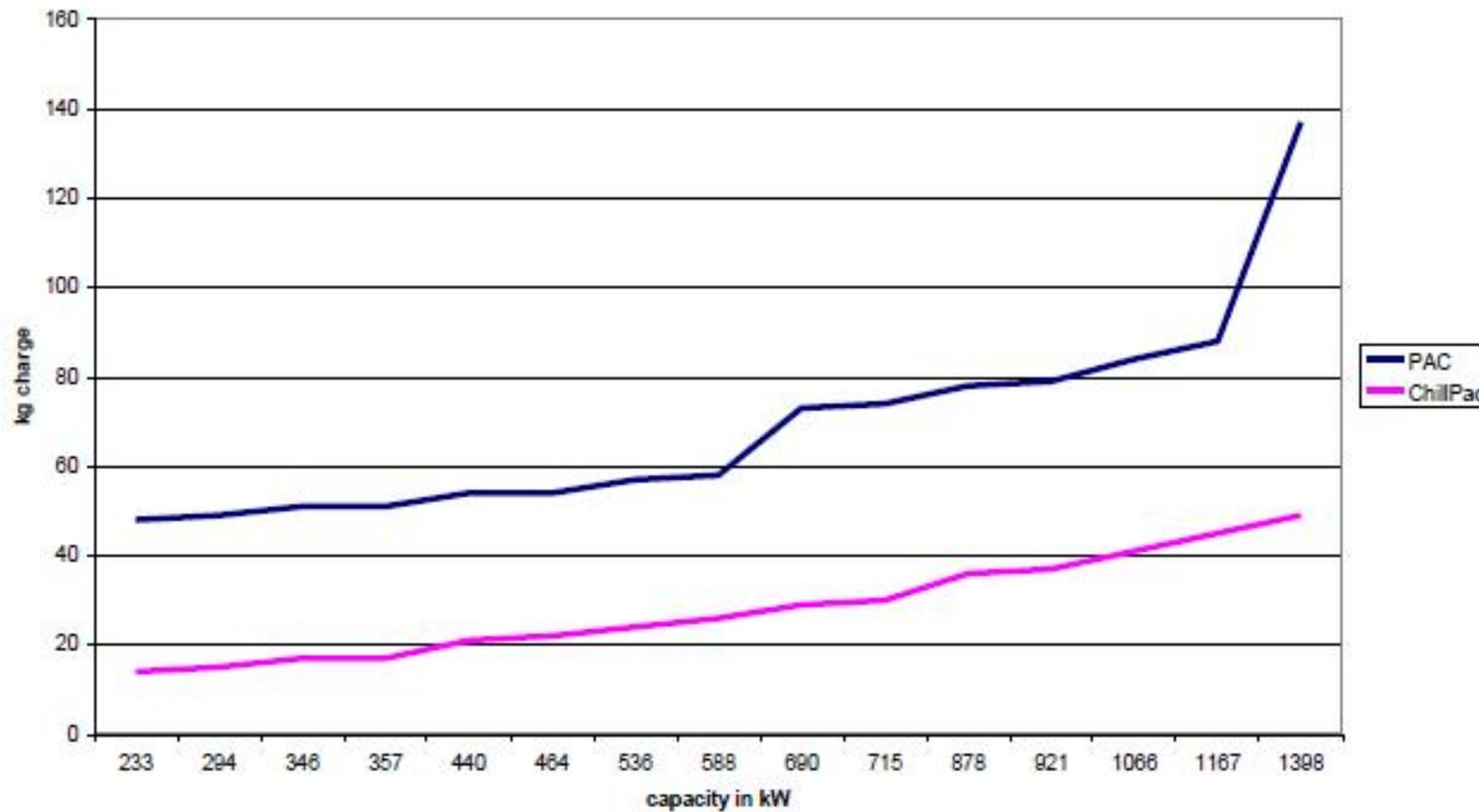


ChillPAC recip  
**200 - 1400 kW**

# Comparação entre chillers



Charge in old and new ammonia chillers

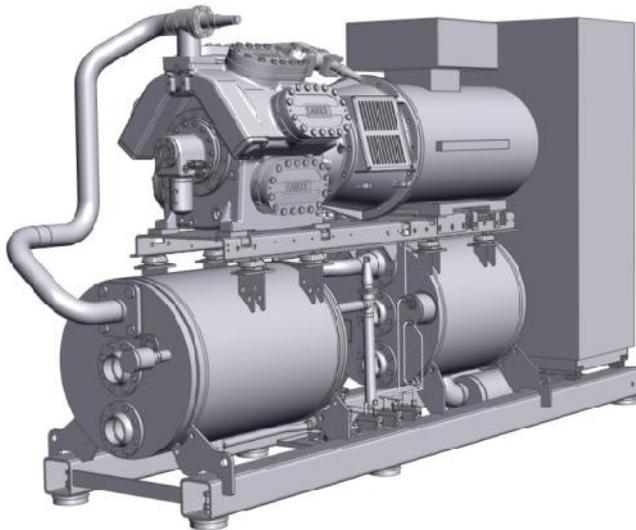


# ChillPAC

## Important features demanded by the market



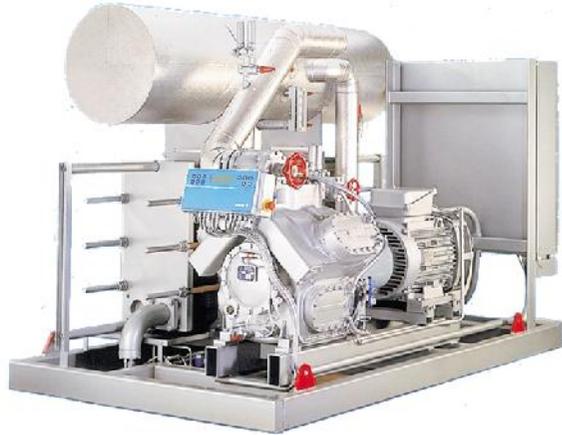
- Future-safe refrigerant (ammonia)
- High COP even at part load (flooded evaporation)
- **Lowest possible refrigerant charge** (plate heat exchanger technology)
- Compactness (door size)



- Application:
- process water cooling
  - air conditioning
  - Retrofit in old R-22 installations

# PAC x ChiIPAC

## Features



**Conventional chiller**

- Semi-welded plate heat exchangers
- Traditional design of plates/cassettes
- External liquid separator
- External oil separator
- External high-pressure float valve

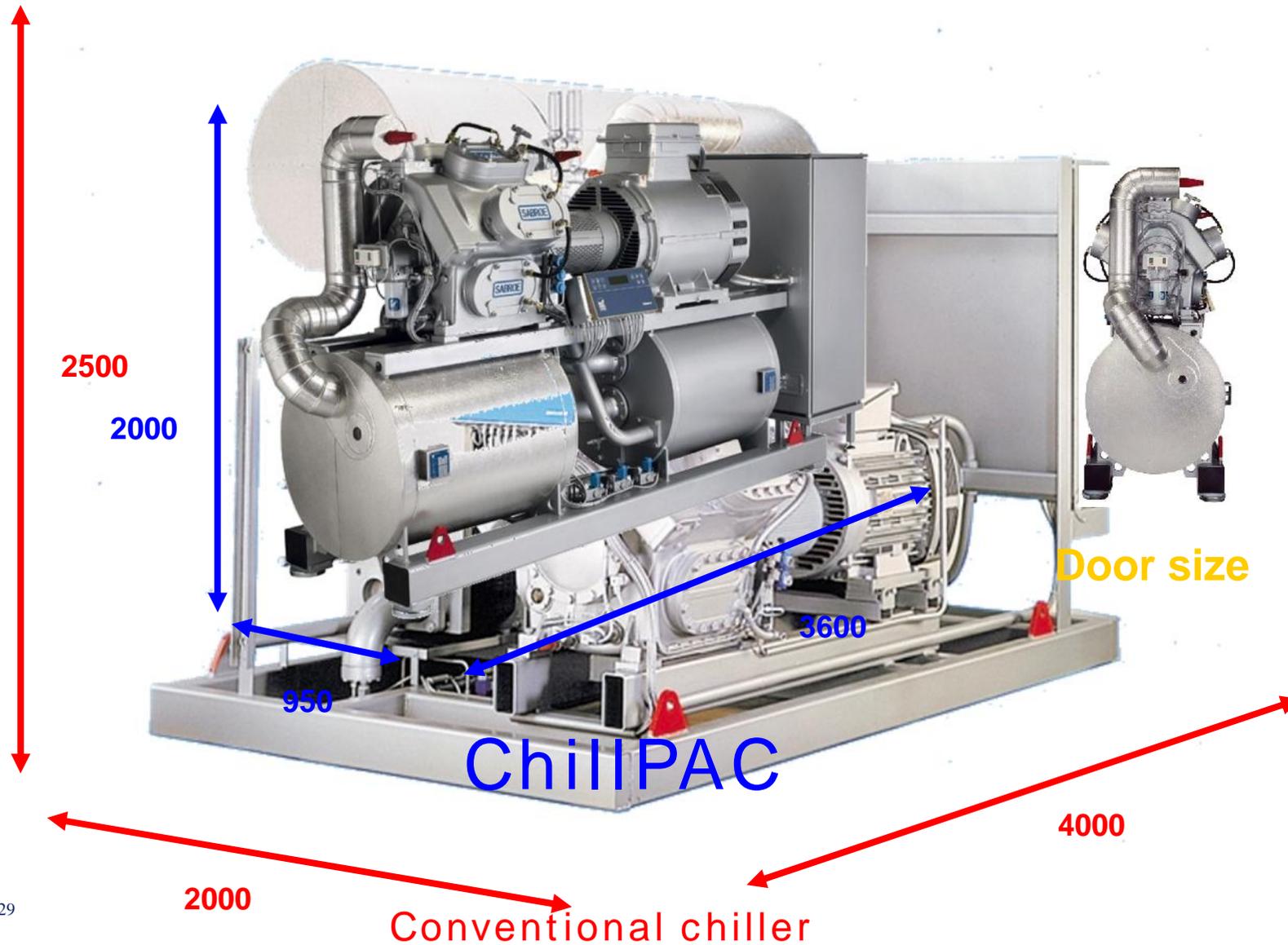


**ChiIPAC**

- Fully welded plate heat exchangers
- New patented plate/cassette design
- Built-in liquid separator (into evaporator)
- Built-in oil separator (into condenser)
- Built-in high pressure float valve (into condenser)

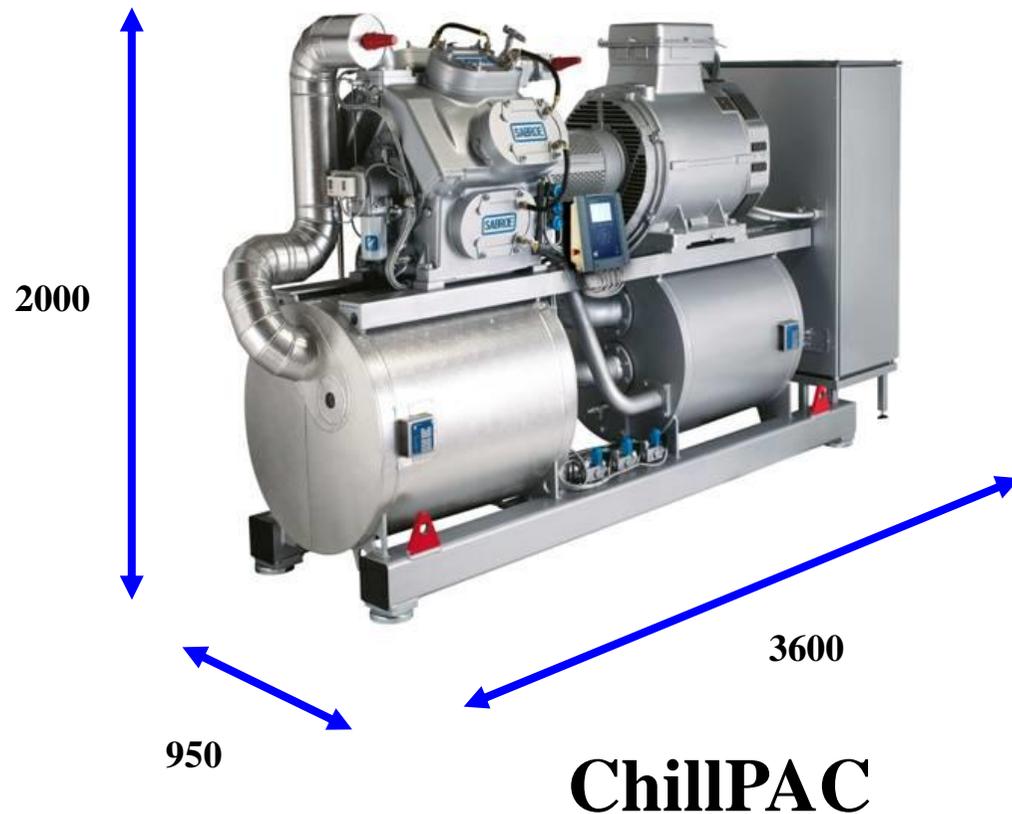
# ChilPAC

Very compact ammonia chiller



# ChillPAC

Compact, low weight and small refrigerant charge



**Sabroe type:**  
**ChillPAC 108 E-A**

**Cooling capacity: 700 kW**

**Conditions water:**  
**+12/+7°C and +30/+35°C**

**Drive system: 132 kW Y/D or VSD**  
**(Data from brochure)**

**Refrigerant charge: 35 kg**

# ChilIPAC

Low weight and very low charge



ChilIPAC 108 E-A

Cooling capacity: 700 kW, E-water +12/+7°C, C-water +25/+30°C & E-motor 132 kW



Conventional chiller



Approx. unit weight: 4300 kg

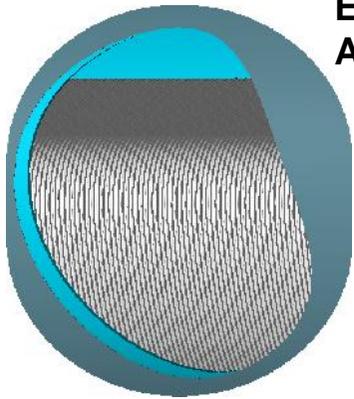
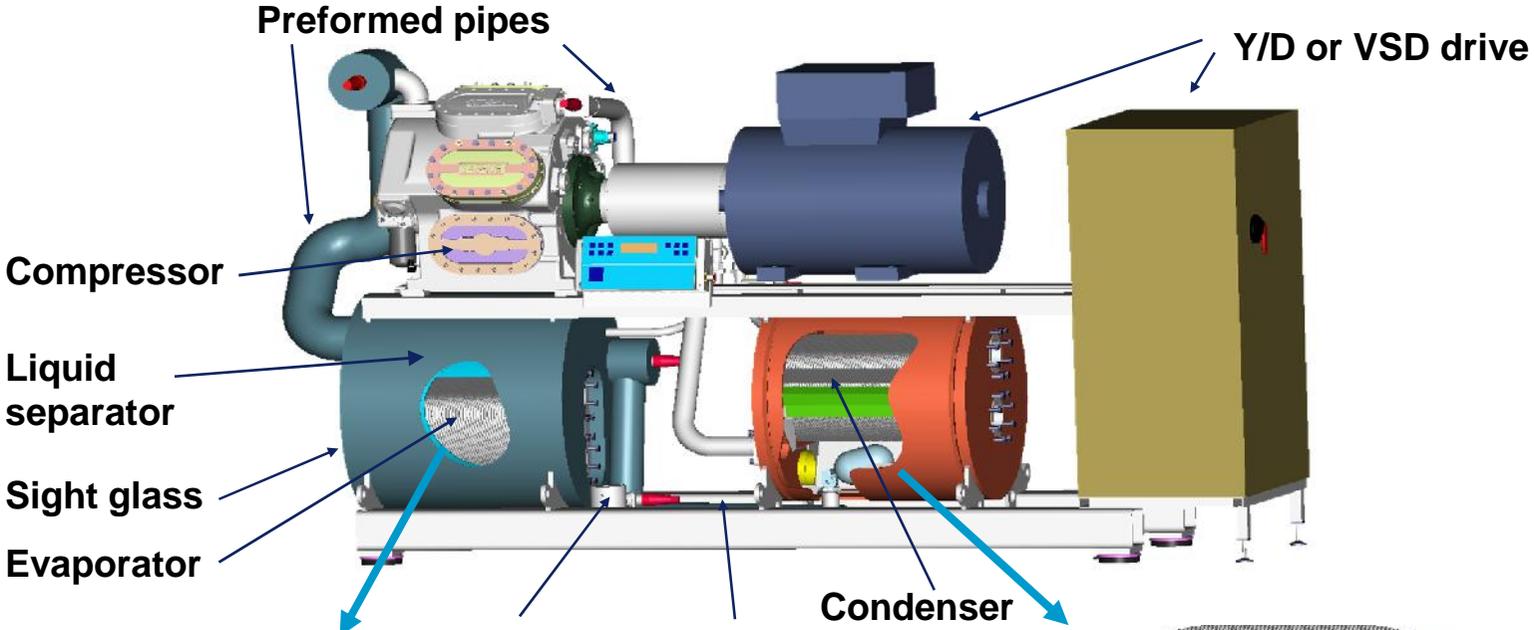


ChilIPAC

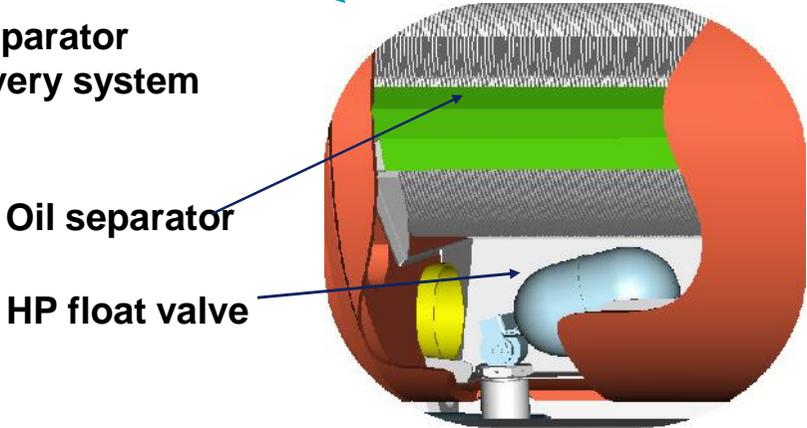


Approx. unit weight: 3500 kg

# ChillPAC integrated design in detail



Evaporator & oil separator  
Automatic oil recovery system



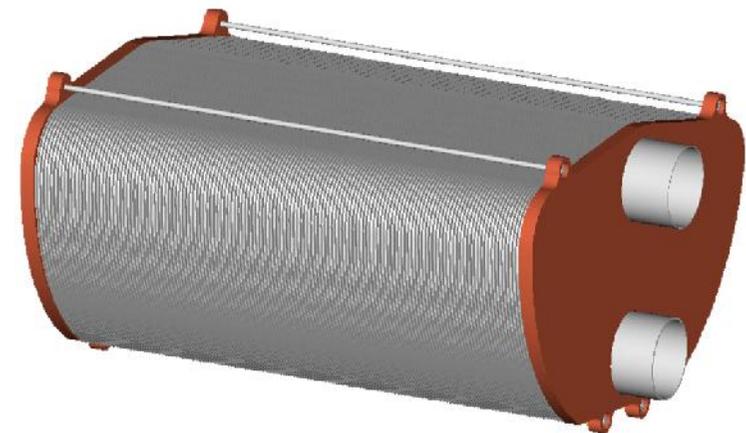
# ChillPAC plate stack

Plate heat exchanger for compact ammonia chiller

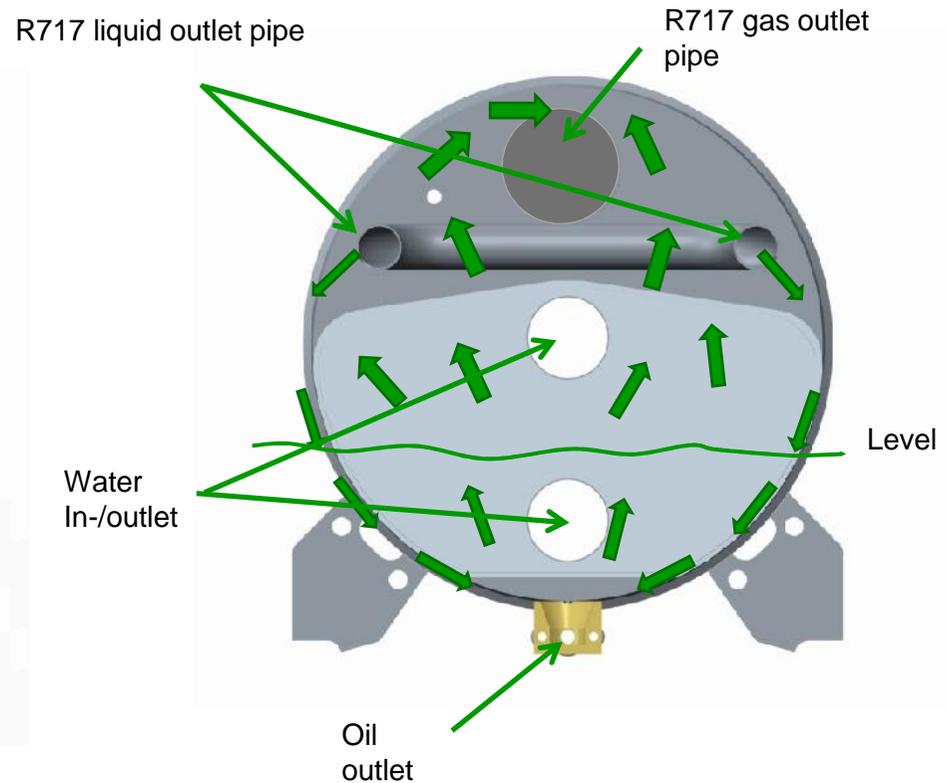
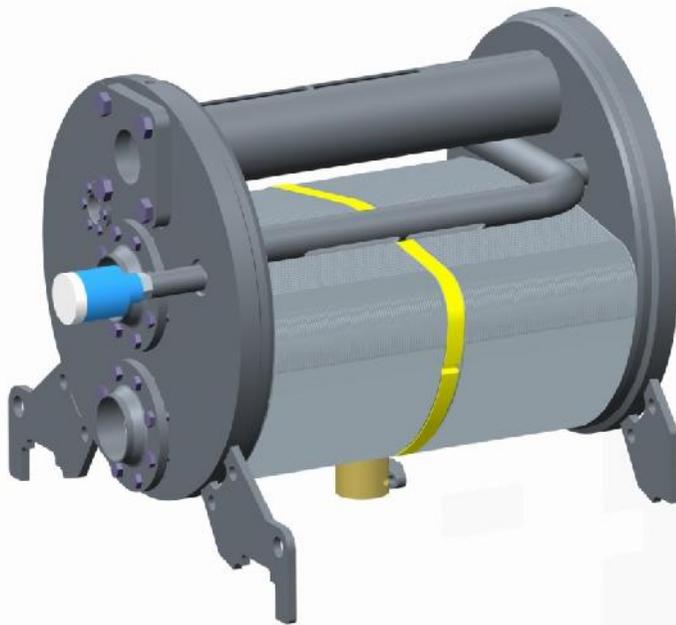


Half pipe plate stack  
32 – 125 cassettes

Plate design by Alfa Laval



# ChillPAC flooded evaporator with integrated liquid separator



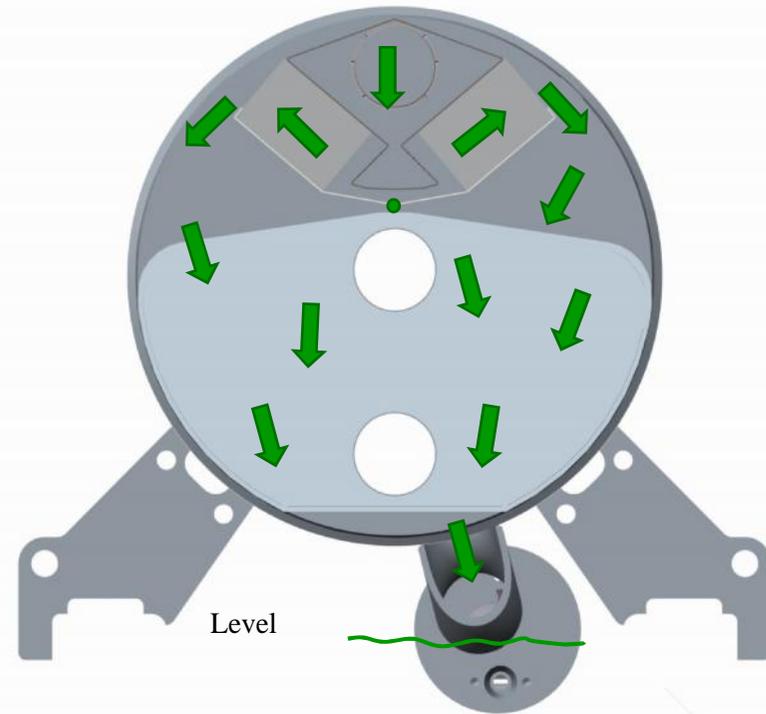
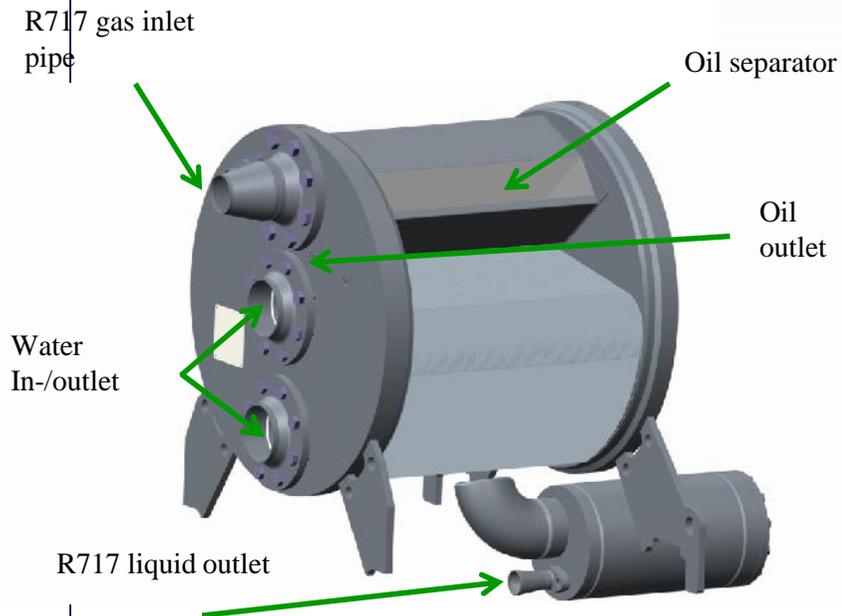
# ChillPAC condenser

with integrated oil separator, receiver and expansion valve

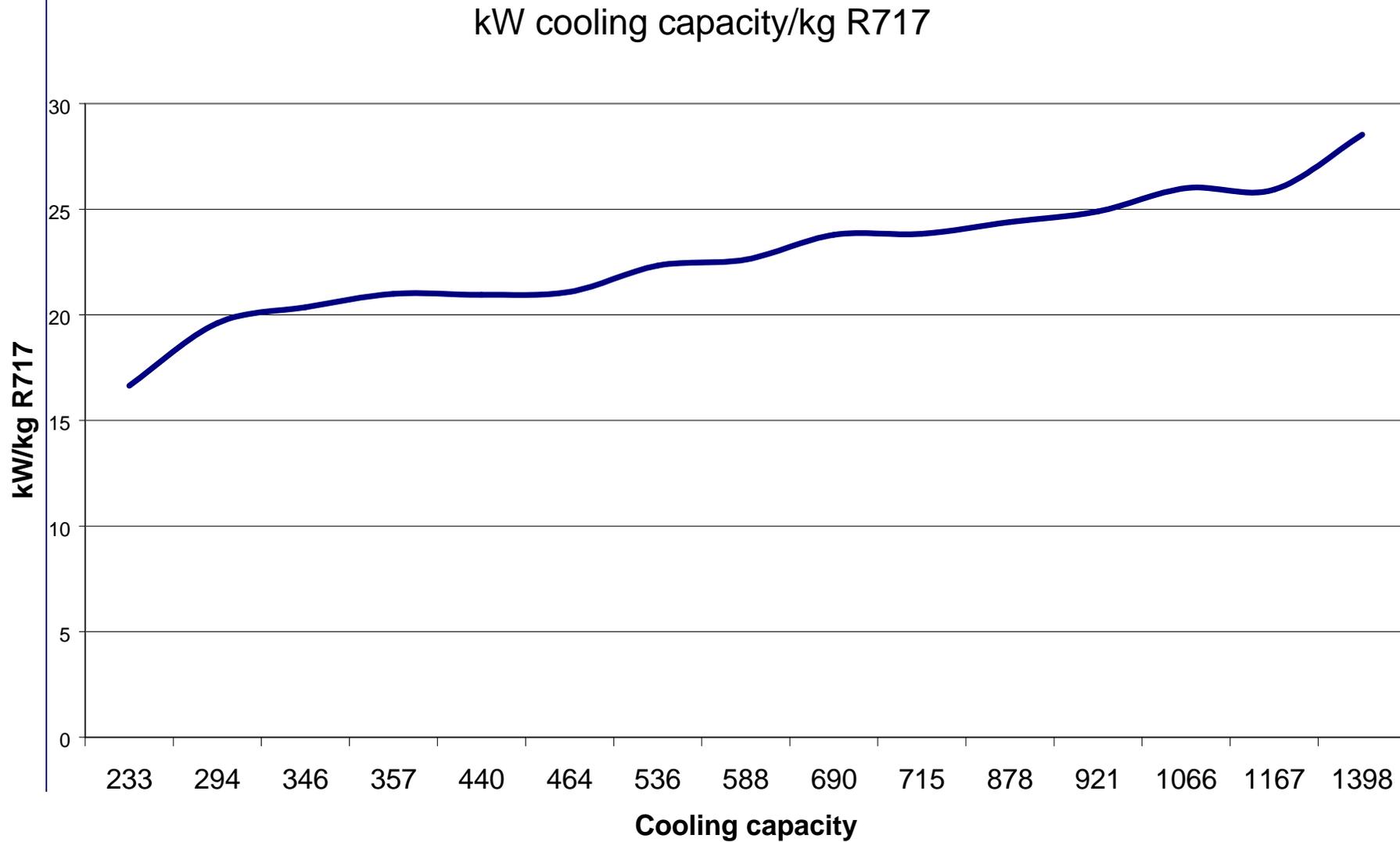


## Condenser

- Compact design
- Very low refrigerant charge
- 150 -1600 kW

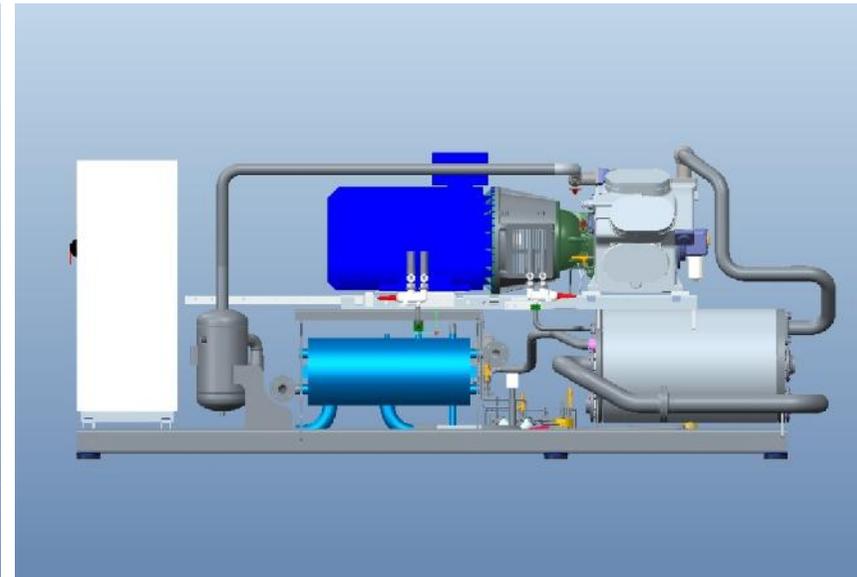
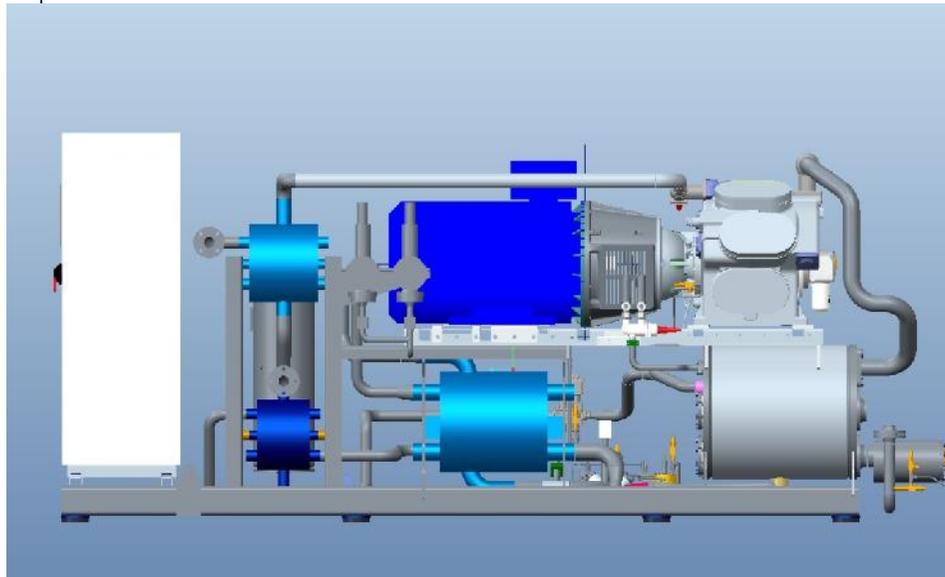


# How low charge can be achieved?



# Heat exchangers systems

## Combined Subcooler-condenser-desuperheater



Compact



Very compact

# ChillPAC - water

## Using Sabroe SMC 100 reciprocating compressors



### Selection guide - ChillPAC

Water chillers (Water: inlet 12°C, outlet 7°C)								
Type	Cooling capacity kW	E-motor kW	R717 charge kg	Dry weight kg	Dimensions			Sound level *) dB(A)
					L mm	W mm	H mm	
CPAC 104S-A	233	45	14	2301	2900	1000	2000	78
CPAC 104L-A	294	55	15	2410	2900	1000	2000	79
CPAC 106S-A	346	75	17	2727	2900	1000	2000	79
CPAC 104E-A	357	75	17	2652	2900	1000	2000	79
CPAC 106L-A	440	90	21	2950	2900	1000	2000	80
CPAC 108S-A	464	90	22	3060	2900	1000	2000	80
CPAC 106E-A	536	110	24	3225	3100	1000	2000	81
CPAC 108L-A	588	110	26	3526	3100	1000	2000	82
CPAC 112S-A	690	132	29	4315	4000	1000	2200	82
CPAC 108E-A	715	132	30	3880	3300	1000	2000	82
CPAC 112L-A	878	160	36	4738	4500	1000	2200	83
CPAC 116S-A	921	200	37	5044	4500	1000	2200	83
CPAC 112E-A	1066	200	41	5196	4600	1000	2200	83
CPAC 116L-A	1167	250	45	5556	4700	1000	2200	83
CPAC 116E-A	1398	315	49	5878	5000	1000	2200	84

Condenser: Water inlet 30°C, outlet 35°C Motor: 3 x 400V, 50Hz, 1460 rpm

# ChillPAC - water

## Using Sabroe SMC 100 reciprocating compressors



### Selection guide - ChillPAC

**Brine chillers (Ethylene glycol 30%: inlet -4°C, outlet -8°C)**

Type	Cooling capacity	E-motor	R717 charge	Dry weight	Dimensions			Sound level *) dB(A)
	kW	kW	kg	kg	L mm	W mm	H mm	
CPAC 104S-C	116	37	13	2253	2700	1000	2000	78
CPAC 104L-C	150	55	15	2378	2900	1000	2000	79
CPAC 106S-C	172	55	15	2505	2900	1000	2000	79
CPAC 104E-C	185	75	17	2586	2900	1000	2000	79
CPAC 106L-C	222	75	18	2701	2900	1000	2000	80
CPAC 108S-C	227	75	18	2766	2900	1000	2000	80
CPAC 106E-C	272	90	20	2866	2900	1000	2000	80
CPAC 108L-C	295	110	22	3091	3100	1000	2000	82
CPAC 112S-C	339	110	24	3696	3800	1000	2200	82
CPAC 108E-C	363	132	25	3523	3300	1000	2000	82
CPAC 112L-C	440	160	29	4290	4200	1000	2200	83
CPAC 116S-C	450	160	29	4390	4200	1000	2200	83
CPAC 112E-C	544	200	35	4733	4300	1000	2200	83
CPAC 116L-C	586	200	37	4898	4300	1000	2200	83
CPAC 116E-C	718	250	43	5322	4300	1000	2200	83

Condenser: Water inlet 30°C, outlet 35°C Motor: 3 x 400V, 50Hz, 1460 rpm

# ChillPAC

## Compared with a conventional chiller



- Highly efficient solution
- 60% smaller footprint
- Max. width is 1.0 m, max. height is 2.15 m
- 20% lower weight
- 60% lower refrigerant charge
- Dimensions as HCFC/HFC chillers
- Fully welded plate heat exchangers
- Built-in functions to reduce size and improve reliability and safety

# ChillPAC competitiveness



- Simple and VERY compact construction
- Very high COP and future safe refrigerants
- VERY low refrigerant charge
- Reliable and stable operation
- Only high-quality components
- R717 chiller benchmarking
- Test run facilities

# Heat Pumps



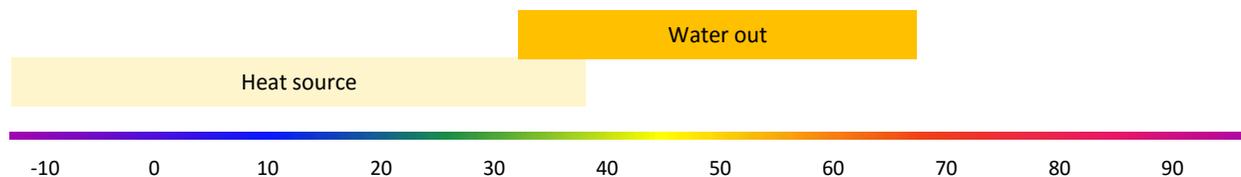
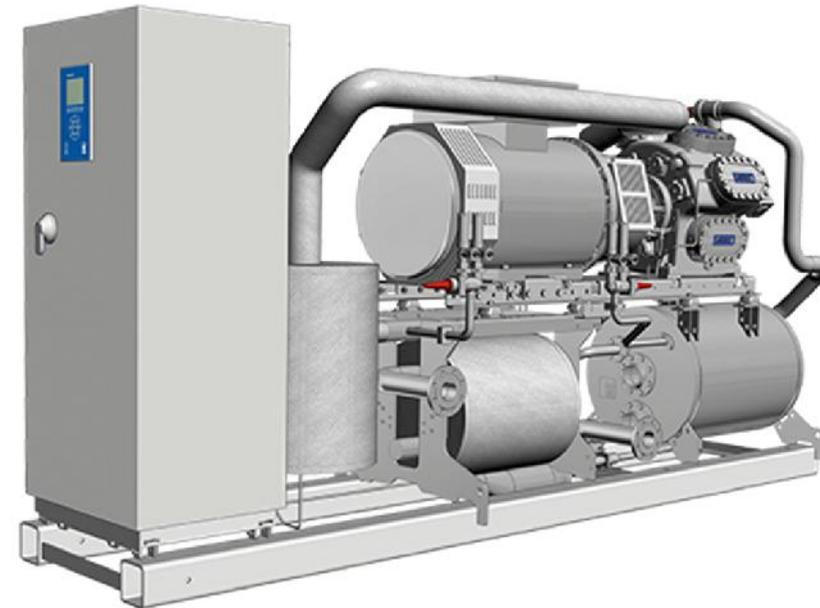
# HeatPAC 100 series

## ... for 70°C applications



### Standard NH<sub>3</sub> industrial heat pump unit

- Range consists of 6 models: 240 kW up to 1150 kW
- Max. outgoing water temperature: 70°C
- Small refrigerant charge: ~50 kg for largest unit
  
- Max. heating capacity: 1150 kW (40°C /70°C)
  - Cooling capacity: 965 kW
  - Power consumption: 186 kW
  - COP heat pump = 6.2
  
- One-stage compression only **limited lift**
- Cascade evaporator version available
  
- Application: Brewery, dairy, abattoir, fish processing etc.

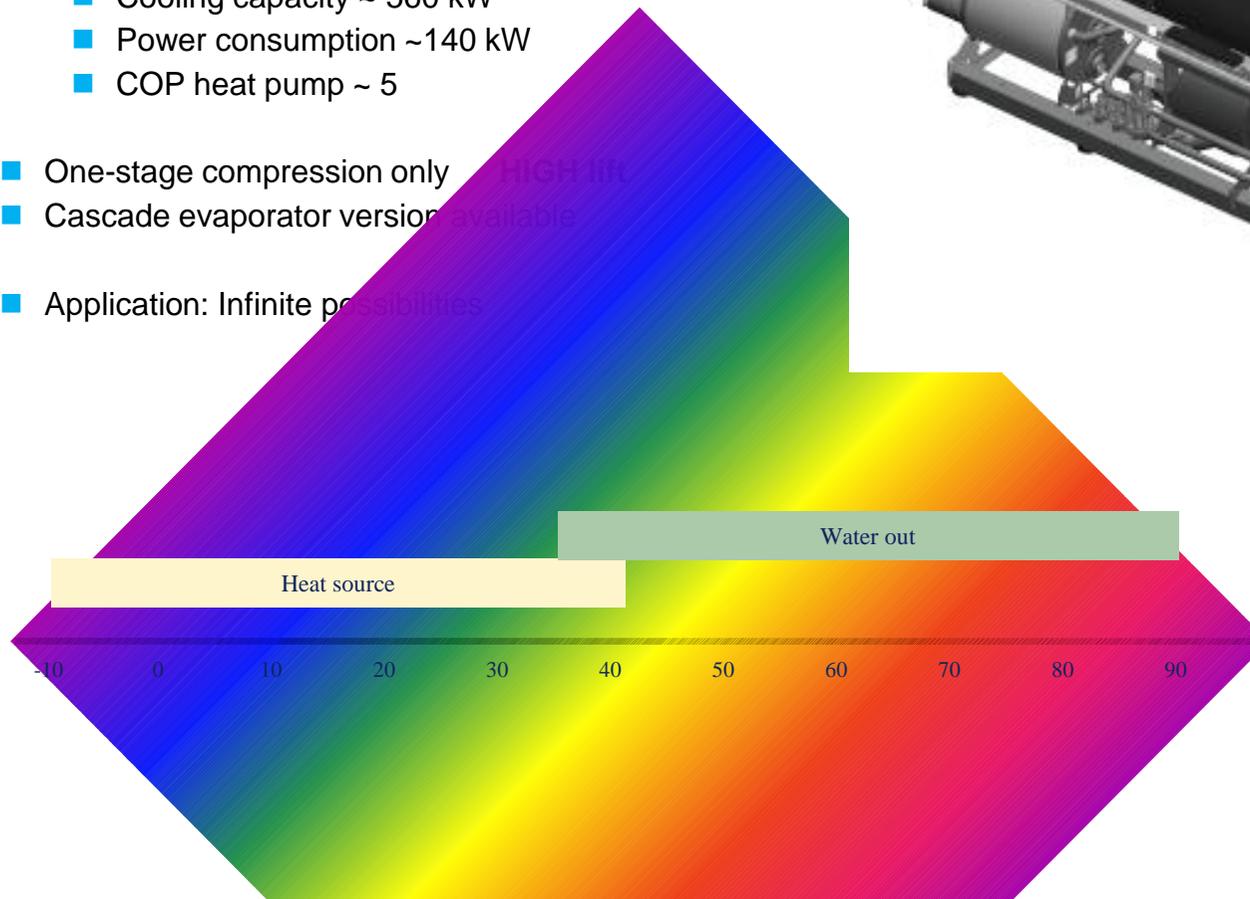
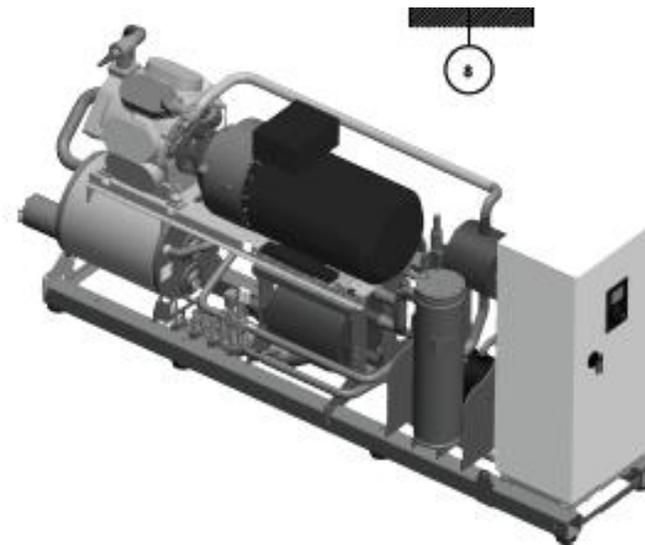


# New HeatPAC 70 series for 90°C applications



## Standard NH<sub>3</sub> industrial heat pump unit

- Range consists of 3 models: 230 to >700 kW
- Max. outgoing water temperature: 90°C
- Small refrigerant charge: ~45 kg for largest unit
  
- Max. heating capacity: > 700 kW (40°C /90°C)
  - Cooling capacity ~ 560 kW
  - Power consumption ~140 kW
  - COP heat pump ~ 5
  
- One-stage compression only
- Cascade evaporator version available
  
- Application: Infinite possibilities

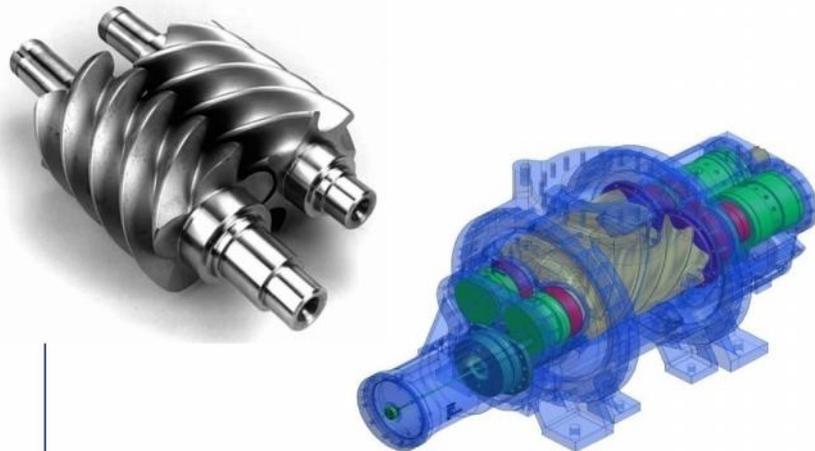
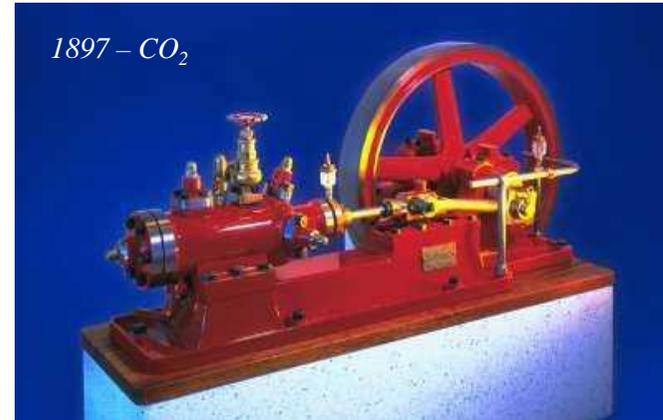


# Low Charge Heat Pumps



HPAC	Heating cap [kW]	Charge [kg]	kg/kW heat
20-W	240	20	0.083
26-W	359	23	0.064
28-W	484	25	0.052
104-W	570	28	0.049
106-W	852	37	0.043
108-W	1149	48	0.042

Muito obrigada pela atenção!



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# SISTEMAS DE ÁGUA GELADA



PROGRAMA  
BRASILEIRO DE  
ELIMINAÇÃO DOS

**HCFCs**  
Projeto para o Cumprimento de CILIBERS

Apoio Institucional:



Execução



Implementação



Empoderando vidas.  
Fazendo a diferença.

Realização

Ministério do  
Meio Ambiente

