Gordon Brothers Industries

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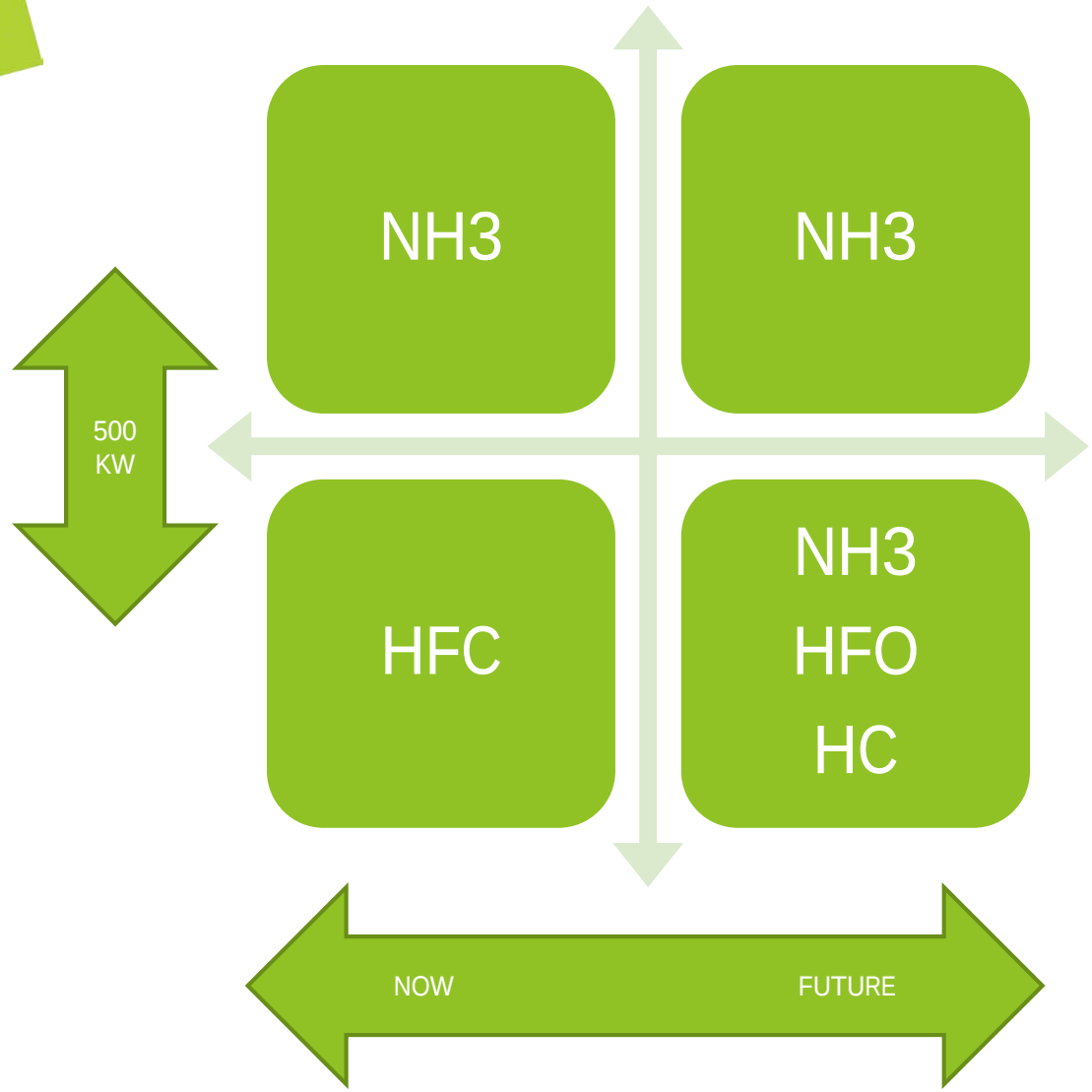
at WineEng 2017

Natural Refrigerant Chillers

- Phase-out of Hydro Fluoro Carbons (HFCs) starts in 2018
- 2% of global warming due to synthetic refrigerants in refrigeration and air-conditioning systems
- October 2016 the Kigali Amendment was signed
- March 2017 the Turnbull government introduced bill to amend OPSGGMA
- Includes all HFCs: R134a, R404A, R407C, R410A
- Sliding scale reduction from 2018 to 2036
- Quota program for the importers, based on GWP
- Resulting in price increase of HFCs

Natural Refrigerant Chillers



Natural Refrigerant Chillers

Comparative Refrigerant Cycle Analysis (Theoretical)

SST (°C)	SH (°C)	SC (°C)	SCT (°C)	Δ S * (kJ/kg.K)	η vol	Q (kWR)
-10	5	0	45	0	0.9	500

	R717 (Ammonia)	R22	R32	R134a	R1233zd E	R1234yf	R1234ze E	R290 (Propane)	R600a ** (Isobutane)	R744 *** (CO_2 Transcritcial)	
SST (kPa)	1594	355	583	201	30	222	147	345	108	2649	5729
SCT (kPa)	1783	1729	2795	1160	252	1154	876	1534	604	12000	12000
hg (kJ/kg)	1606	405	519	397	432	361	382	572	557	443	410
hf (kJ/kg)	559	256	286	264	286	262	262	322	309	256	340
hfg (kJ/kg)	1048	148	232	133	146	99	119	250	248	187	70
ṁ (kg/s)	0.48	3.37	2.15	3.76	3.43	5.06	4.19	2.00	2.02	2.67	3.21
Density (kg/m³)	2.34	14.94	15.39	9.80	1.81	12.25	7.95	7.44	2.89	67.90	194.20
Specific Volume (m³/kg)	0.428	0.067	0.065	0.102	0.553	0.082	0.126	0.134	0.347	0.015	0.005
Volumetric Flow (m³/h)	736	812	504	1381	6834	1486	1899	967	2519	142	59
Swept Volume (m³/h)	817	903	560	1535	7593	1652	2110	1074	2799	158	66
Swept Volume (ft³/min)	481	531	329	903	4469	972	1242	632	1648	93	39
h_discharge (kJ/kg)	1884	446	587	434	470	391	416	644	624	510	435
Δ h_comp (kJ/kg)	278	41	68	38	38	30	34	72	67	67	25
Absorbed Power (bkW)	133	140	146	141	131	151	143	144	136	179	80
COP	3.77	3.58	3.42	3.54	3.83	3.31	3.51	3.48	3.68	1.93	
COP diff to R717 (%)	0.00%	-5.13%	-9.20%	-5.98%	1.60%	-12.21%	-6.93%	-7.62%	-2.35%	-48.84%	

* Isentropic Compression
** Superheat SH = 10°C
*** Parallel Compression at +20°C SST

Natural Refrigerant Chillers

- Ammonia Chillers
  - Proven technology, has been around for 150 yrs
  - Zero GWP
  - Excellent thermodynamic properties and heat transfer coefficient result in high energy efficiency
  - Toxic and lower flammability (B2L ASHREA designation)
  - Low charge systems available
  - Construction of plant room or enclosure, leak detection and alarm, ventilation, electrical works, training and emergency planning
  - Available equipment ranges from 250 to 1500 kW

Natural Refrigerant Chillers

- Propane Chillers (R290)
  - Refrigerant as been around for a long time and applied in petrochemical application
  - Low GWP
  - Good heat transfer coefficient result in good energy efficiency
  - Higher flammability (A3 ASHREA designation)
  - Low charge systems
  - Installation outdoors, integrated leak detection and alarm, ventilation, electrical works for the hazardous zone, training and emergency planning
  - Available equipment ranges from 20 to 300 kW

Natural Refrigerant Chillers

- Comparison of a 250 kW (at 0/-6°C) for Ammonia, Hydrocarbon and R134a

FLUID	R134a	NH3	PROPANE
CAPITAL COST	$ 270,000	$ 320,000	$ 280,000
ANNUM ENERGY COST	$ 95,000	$ 71,000	$ 96,000
GWP	~1400	0	0
COP	2.15	2.5	2.12
TOXICITY	NON	TOXIC	NON
FLAMMABILITY	NON	LOW	HIGH

Natural Refrigerant Chillers

- HFC based chillers will be available for a number of years, but:
  - Increased cost of refrigerants
  - Poor energy efficiencies
  - No cheap drop-ins available, so conversion later expensive
- HFO refrigerants are an option, but:
  - Longevity is questionable
  - Safety
  - Still have a GWP
- Natural refrigerants are a compromise between:
  - Cost
  - Safety
  - Excellent energy efficiency and no GWP
  - Longevity