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R290-cooler drying biogas

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INTRODUCTION

The lecturer:
Karl Huber, since 1987 managing shareholder of

HKT Huber-Kälte-Technik GmbH

Manufacturer and system supplier for

Goeldner-Compressors and –units

- The lecture is based on the experience in manufacturing and operation of compressors and units for HC-Refrigerants.
  - Especially many propane chillers, installed since 1998
  - This is the first publishing of the below mentioned project

If there are any further questions HKT Huber-Kälte-Technik GmbH, respectively Mr. Huber will be available at every time under tel. +49(0)8055/9187 or email technik@hkt-goeldner.de

R290-Liquid chiller for Biogas drying

The refrigeration and air-conditioning will change radically! Why is it?

Caused by the new F-gases Regulation (EU) No. 517/2014 from 16.04.2014 binding and came into force from 01.01.2015 on.

The vertices are:

- Direct prohibitions of refrigerants with a GWP > 2500 from 2020 on
- Dramatic shortage of existing refrigerants from 2015 by 2030 to 21%
- Quota system for F-Gas refrigerant manufacturers and suppliers (based on 2015 = 100% now 93% in 2018 63%)
- Expansion and intensification of the operator's obligations regarding maintenance, repair and leak tests of refrigeration and air conditioning systems

More natural refrigerants are already coming back into operation as there are HydroCarbons and mixtures of them, CO2 and Ammonia

and this will cause if applicable: other plant systems than before > rethinking is required

R290-Liquid chiller for Biogas drying

HC Refrigerant 5kg

+

With HC Propane

It‘s easy to grill
but hard to chill

Agenda

1. Refrigerant data
2. Plant design, special features
3. System design, components
4. Technical data
5. Summary and outlook

1. The refrigerant used (data)

- **Physical / Chemical Properties** (SDB-2002, GH & Co.)

Form:	compressed liquefied gas mixture		heavier than air
Color:	colorless		
Odor:	sweetish		
Aadiabatic change of condition			
Melting point	< -189,7 °C		
Boiling point	-42,1 °C		
Flash point	-104,0 °C		
Explosion limit:	lower limit 1,7 Vol. %	upper limit 10,9 Vol. %	
Flammability LFL	0,038		
Iignition temperature:	450 °C (470)		
Vapoiur pressure:	(20 °C) 8,27 bar	(30 °C) 10,8 bar	(50 °C) 17,2 bar
Gas density:	(0°C) 2,01 g/l	vapour density:	1,832
Solubility in water:	(20 °C) 8 mg/l		
pH-value aqueous solution at (17 g/l, 20 °C) -	11,6		
Viscosity:	0,102 mPa*s (bei 25 °C)		

1. The refrigerant used (Data)

- Physical / Chemical Properties comparison

	Propane	R1234ze	R134a	R407C	R410A	Unit/Reference
Chemical Formula	C3H8	C3H2F4	CH2F-CF3	CH2F2/CF3-CHF2/CF3-CH2F	CH2F2/CHF2-CF3	
Safety group	A3	A2L	A1	A1	A1	
PED Fluid group	1	1	2	2	2	
Composiotion	100%	100%	100%	R32/125/134a 23/25/52%	R32/R125 50/50%	
Mol mass	44,1	114,04	102,03	80,13	72,6	g/mol
Boiling point	-42	-19	-27	-44	-51	°C (1,013bar)
Melting point	-188	-105	-101	-111	< -100	°C (760 mm Hg)
Vapour density	1,832	1,34	4,258	3,582	3,007	kg/m3 (25°C 1,013b
ATEL ODL	0,09	0,28	0,25	0,31	0,44	kg/m3
crit.Temperature	97	110	101	87	72	°C
krit. Pressure	42,6	36,35	40,64	46,5	48,9	bar
Cond.-temperature (26bar)	70	92	79,5	60	46	°C
ODP	0	0	0	0	0	
GWP (CO2=1)	3	7	1300	1525	1725	

1. The refrigerant used (Data)

- Wherever it may be allowed by the safety regulations of hydrocarbon refrigerants (Group A3), preferably a natural refrigerant, as e.g. R290, should/can be used for water chillers.

- Caused by the positive characteristics of R290 a high efficiency will be achieved.
  The ROI will be, dependent on the design and costs of electricity, 3-5 years.
  As the cost for electricity will arise by sure, the time of amortisation will go down.
  Not to forget the costs of refrigerant in a direct exp.system compared to indirect HC-Chiller-System.

- The pressure level is low this preserves the machine and raises the live time of components and compressors.

- Natural refrigerants are a synonymous for safety of investment.

2. Plant design, special features

- Matrix of requirement:
  Ecology, Economy
  >>> Refrigerant (Capacity, Temperatures, Pressures, Placement)
  >>> Concept of the unit

- The refrigerant circuit is held simple related by the process,
  solutions across-the-board are possible, erecting outside is recommended
  but not always neccesary and dependent on the filling due to risk analysis
  that has to be done following Machinery Directive 2006/42/EC
  (it is law and has to be done for every machine) and/or calculation
  following Standard EN 378-2.

  Note:
  The directive is law and risk analysis has to be done for every machine,
  whereas a standard is more or less only a recommendation.

2. Plant design, special features

Calculation on filling EN378-1:2017-03:
refrigerant: A3
machinery room: entrance only authorized persons
situated: under floor

20% x LFL x room vol.
(0,2x0,008x300=2,4kg)
but maximum 1,0 kg

Erection inside under floor machine room (ca.300m^3)

- Water cooled brine cooler
- Cabinet on top
- no refrigerant receiver
- frequency controlled compressor speed control range 20...70Hz (28...100%)

2. Plant design, special features

Recomended filling (kg) for HC ref. (A3) according to standard DIN EN 378-1:2017-03 Anh.C.2

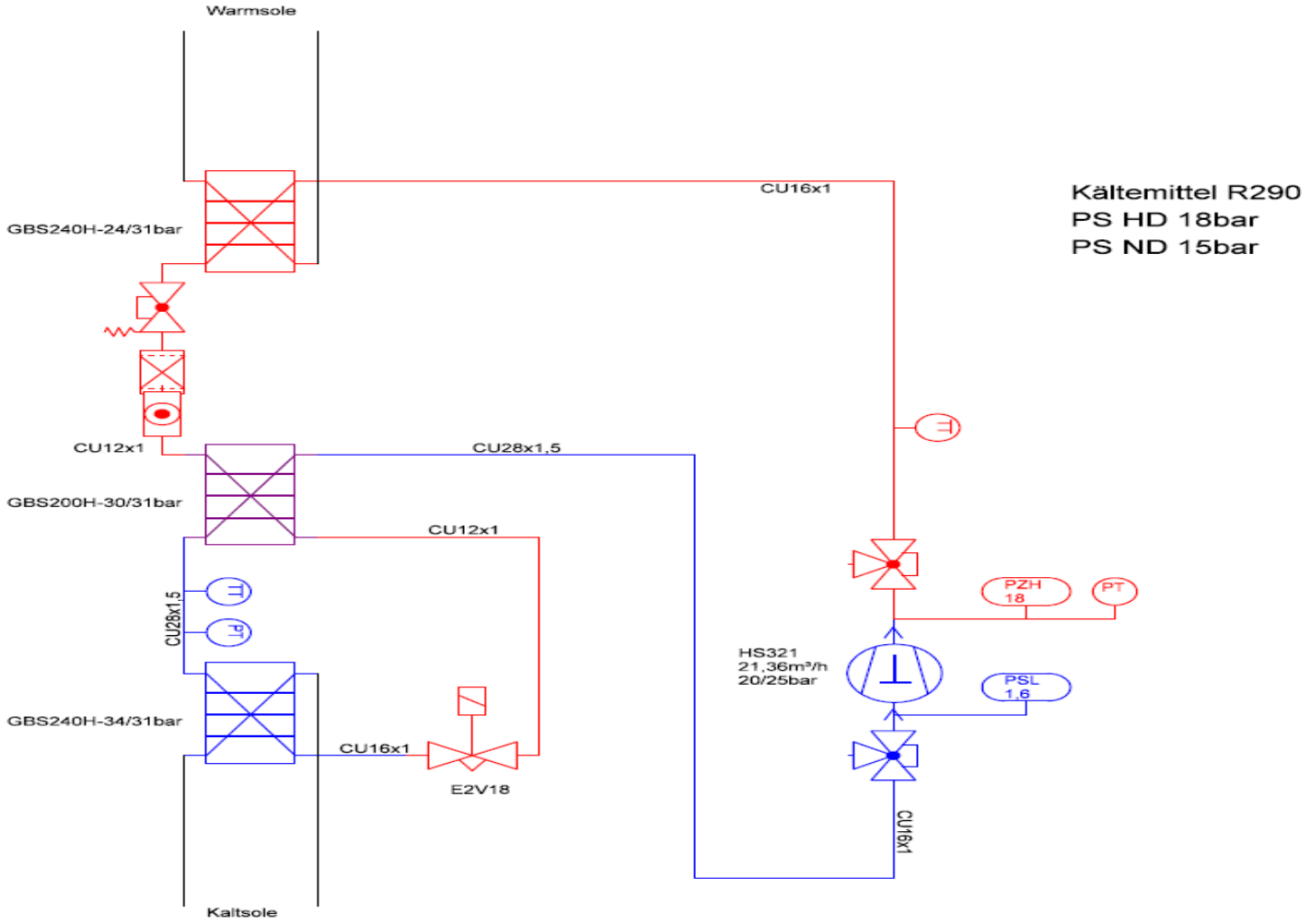
Brennbarkeits-klasse	Kategorie des Zugangsbereichs			Aufstellungsort-Klassifikation			
				I	II	III	IV
3	a	Menschlicher Komfort		Nach C.2 und nicht mehr als m_2 bzw. 1,5 kg		Nicht mehr als 5 kg [c]	Füllmenge des Kältemittels nicht mehr als m_3
		Andere Anwendungen	Unterirdisch	Nur dauerhaft geschlossene Anlagen: 20 % × LFL × Raumvolumen und nicht mehr als 1 kg			
			Oberirdisch	Nur dauerhaft geschlossene Anlagen: 20 % × LFL × Raumvolumen und nicht mehr als 1,5 kg			
	b	Menschlicher Komfort		Nach C.2 und nicht mehr als m_2 bzw. 1,5 kg		Nicht mehr als 10 kg [c]	
		Andere Anwendungen	Unterirdisch	20 % × LFL × Raumvolumen und nicht mehr als 1 kg [a]			
			Oberirdisch	20 % × LFL × Raumvolumen und nicht mehr als 2,5 kg			
	c	Menschlicher Komfort		Nach C.2 und nicht mehr als m_2 bzw. 1,5 kg		Keine Begrenzung der Füllmenge [c]	
			Unterirdisch	20 % × LFL × Raumvolumen und nicht mehr als 1 kg [c]			
		Andere Anwendungen	Oberirdisch	20 % × LFL × Raum-volumen und nicht mehr als 10 kg [c]	20 % × LFL × Raum-volumen und nicht mehr als 25 kg [c]		

3. System design, components

- The components were chosen carefully and correspond to the actual regulations for flammable refrigerants of group A3 (EN 378-1:2017-03),
  as well as Kat.I Modul A PED 2014/68/EU and MD 2006/42/EG,
  Atex 2014/34/EU which have no distinction for A2L refrigerants.
- Efficiency, reliability and with it - safety have to be raised.
  At the same time the charge of refrigerant should be as less as possible.
- In this project used main components:

  - special compressors for *R290 and speed control by inverter* *>> Efficiency*
  - *electronic expansion valve* *>> Efficiency*
  - *plate heat exchangers for less internal volume* *>> Charge*
  - *no receiver* *>> Charge*
  - *well made frame and vibration damping* *>> Safety*

R290-Liquid chiller for Biogas drying



R290-Liquid chiller for Biogas drying

GOELDNER- VERDICHTER — **Typ:**

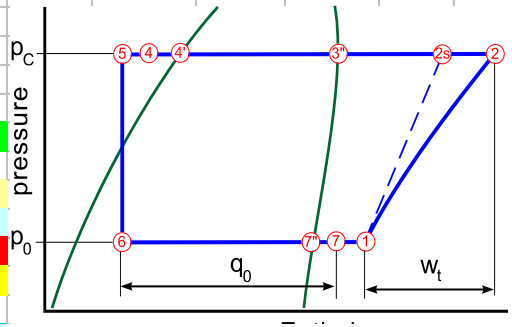
Verdichterauslegung: Einstufig — **H/O 32 1**

Kältemittel:		R290		Prozeßdaten				
Verdampfungstemperatur	t''_0:	-4	°C	p_0 =	418,9	kPa	t_{Om} =	-4,00 °C
Überhitzung Verdampfer	$\Delta t_{ÜO}$:	5	K	p_C =	1433,2	kPa	t_{Cm} =	42,00 °C
Überhitzung Saugleitung	$\Delta t_{ÜS}$:	15	K	π =	3,4	-	Δt_O =	0,00 K
Kondensationstemperatur	t''_C:	42	°C	q_O =	301,5	kJ/kg	Δt_C =	0,00 K
Unterkühlung Verflüssiger	Δt_{UC}:	0	K	w_t =	74,7	kJ/kg		
Unterkühlung Flüss.-leitg.	Δt_{UF}:	13	K	ε =	4,0	-		
Isentroper Gütegrad	η_i:	0,85	-	q_{OV}=	2521,8	kJ/m³		
Liefergrad	λ :	0,82	-					

Verdichterdaten:							mittl.			
	Kolben-	Kolben-	Zylinder-	Drehzahl			Kolben-	Hubraum	spez.Ansaugvol.	
	durchmess	hub	anzahl		geom.Hubvol.		geschw.	gesamt	v1	v1
Typ	d	h	i	n	Vg		wm		*dm3/kg*	*m3/kg*
	mm	*mm*		*U/min*	*m3/h*	*m3/s*	*m/s*	*ccm*		
H/O 32 1	65	37	2	1450	21,36	0,005934	1,788333333	245,55	119,55078	0,11955

Wärmestrom Verdampfer		h0	=	301,5	*kJ/kg*
Wärmestrom Verflüss.		hc	=	355,6	*kJ/kg*
Spez.Verdichterarbeit		ws	=	63,7	*kJ/kg*
Volum.Kälteleistung		q0vh	=	2747	*kJ/m3*
Saugdampf Vol.strom		Vs	=	17,5	*m3/h*
Kältemittelmassenstrom		mk	=	0,04	*kg/s*
			=	146,2	*kg/h*
Verdichtungs-Enthalpie		h2	=	678,3	*kJ/kg*
Leistungsaufnahme		Pe	=	4,32	*kW*
Verdichter Kälteleistung:		Q0	=	13,34	*kW*
Verdampferleistung		Q00	=	12,25	*kW*
Verflüssigerleistung		Qc	=	15,45	*kW*
COP			=	3,09	
Verdichtungsendtemp.		th2	=	77	*°C*

Frequenz:	**50**	**Hz**
Drehzahl:	**1450**	**rpm**



3. System design, components

Heat exchanger for biogas

The installed chiller at DKV exkursion

Mechanical condensate floating separator

4. Technical data

Technical data of the chiller:

- Refrigerant R290
- Goeldner-semi-hermetic-compressor,
  Propane model range, Type HS 32 1/6P
- Cooling capacity 14,5kW
- Primary side Propane 2°C <> 9°C
- Secondary cold side brine Monoethylene-glycol (30 Vol. %) 1°C <> 6°C
- Secondary warm side brine Monoethylene-glycol (30 Vol. %) 30°C <> 40°C
- Heat exchangers tube design
- Electronic expansion valve
- Refrigerant charge 1 kg

5. Summary and outlook

- Liquid coolers e.g. for production are playing a key role in recent and future processes.
  The less secondary energy consumption (operating expense) of the machines used for, the better.
- Minimization of running cost are to achieved with natural refrigerants.
  This not only causes ecological winnings for the environment,
  it also makes economically sense for the enterprises running such machines.
- As the costs of electricity won‘t go down, the cost saving potential through efficient chillers with natural refrigerants are braking the way for this technology.

Conclusion:

R290 chillers are not only better for our environment they are also likely to bring down the running costs for cooling.

5. Summary and outlook

- Natural refrigerant are justifiably coming into foreground (see F-Gas-Regulation etc.).
- Ecology (CO_2-Emmisions reduction) in combination with safety of investment (Nat.refrigerants <>Legislation) are the tenor for chillers running with Hydro Carbons.
- The project mentioned in this presetation shows that it is feasible to build and run Propane-Chillers.

Now it is up to us to spread the awareness for these technologies and to use it increasingly.

5. Summary and outlook

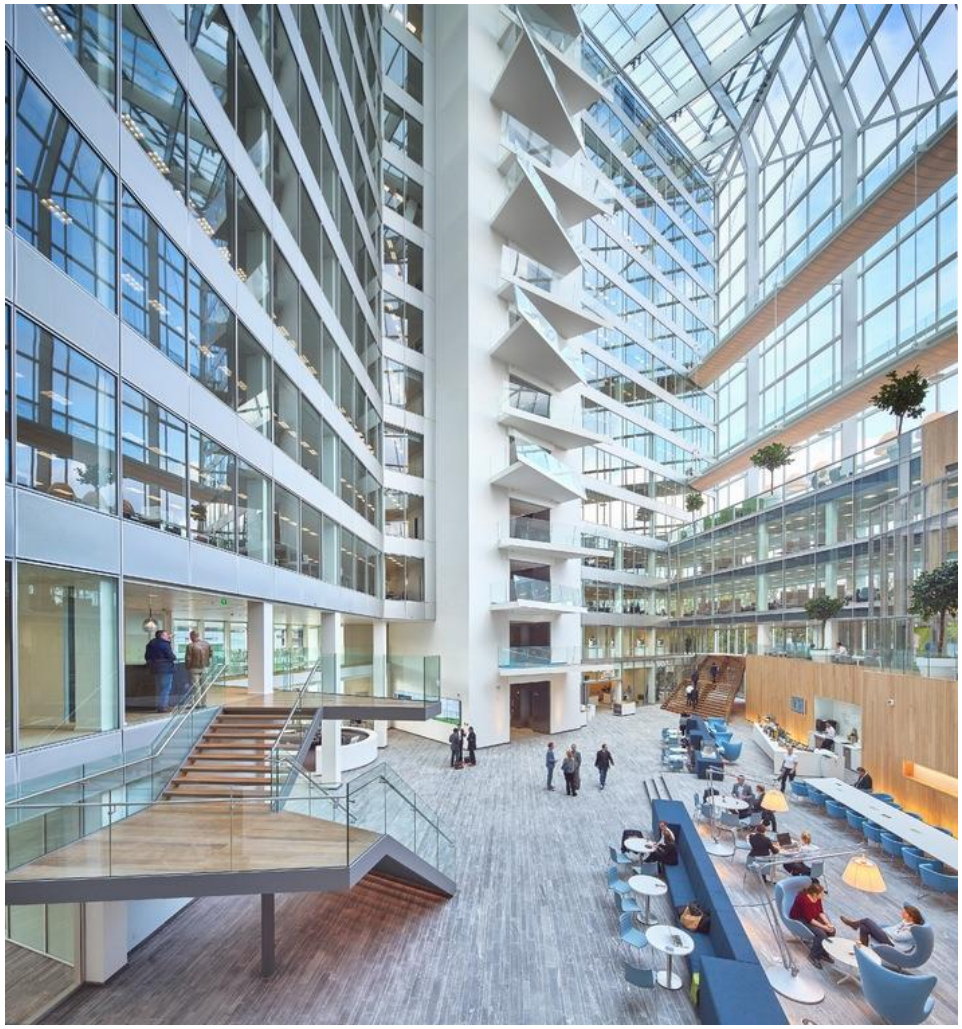
Chillers:

- Breweries
- Production in food industry
- Secondary cooling generally (e.g. plastic moulding)
- chemical Industry
- and much more.....

Heat pumps:

- Heating of old and new buildings
- Process water heating, domestic warm water generating
- District heating system
- Greenhouses
- and much more .....

R290-Liquid chiller for Biogas drying



Examples for Propane in practice:

A small
HKT PROPANE chiller
at the most sustainable
office building in the world
„The Edge“ in Amsterdam.

The picture:
Atrium The Edge / OVG Real Estate
and Deloitte realised the most sustainable
office building in the world
/ "The Edge" in Amsterdam received
the highest BREEAM-Rating any times
/ More text about OTS and
www.presseportal.de/pm/115520 /

R290-Liquid chiller for Biogas drying

➢ Some more samples applied 1-2

(2017) Small chiller (40kW) for plastic production cooling. An assesment of efficiency is just at work and will show very good figures.

(2011) Small heat pump 6kW for a house in austria, working with CO_2 heat-pipe

R290-Liquid chiller for Biogas drying

➢ Some more samples applied 3-4

(2012) Small twin-compressor frequency controlled HP (14kW) for a house.

(2007) Big heat pump 6 compressors (2x 300kW) for a hard ware store in austria.

R290-Liquid chiller for Biogas drying

- **Some more samples applied 5-6**

(2003) Small 3 compressor rack frequency controlled HP (4,5-28kW) for a small bio supermarket.

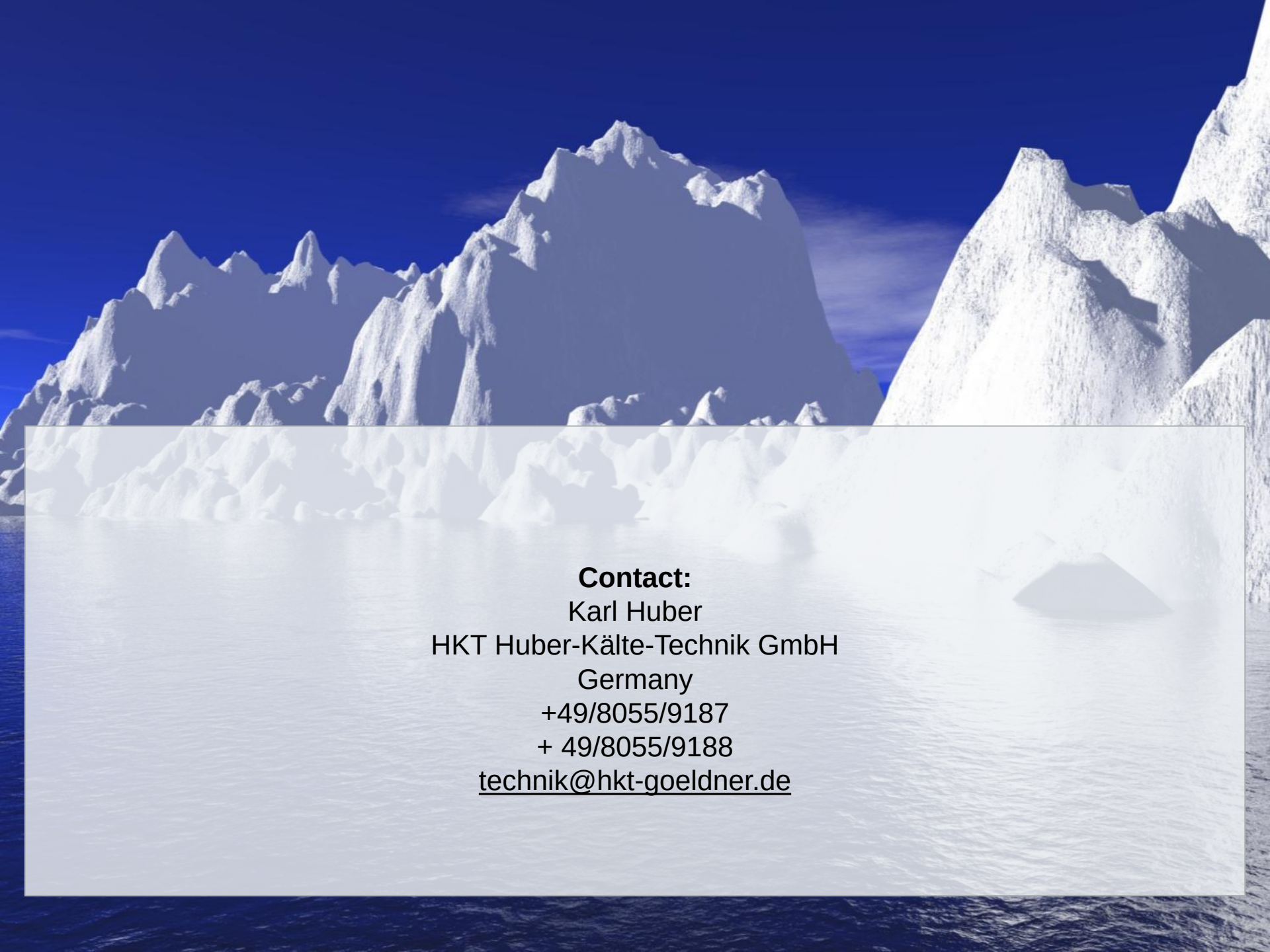
(2011) HKT first high temp. R600a heat pump (44kW) achieving 125°C.

Thank you for your attention!

R290-Liquid chiller for Biogas drying

- **http://www.eurammon.com**
  Association of companies, institutions and individuals to promote nat. refrigerant
- **http://www.hydrocarbons21.com**
  Site relating to the application and dissemination of HC as refrigerant
- **http://www.ammonia21.com**
  Site relating to the application and dissemination of NH3 as refrigerant
- **http://www.R744.com**
  Site relating to the application and dissemination of CO2 as refrigerant

- **http://www.hkt-goeldner.de**
  Manufacturer of Goeldner-Compressors for nat. refrigerants HC‘s, NH3, R717
- **http://www.bafa.de/bafa/de/energie/kaelteanlagen**
  Promotion guidelines for refrigeration systems using natural refrigerants



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