



faster to Europe

natural refrigerants

11-12 October 2011 in Brussels

By KLAAS VISSER

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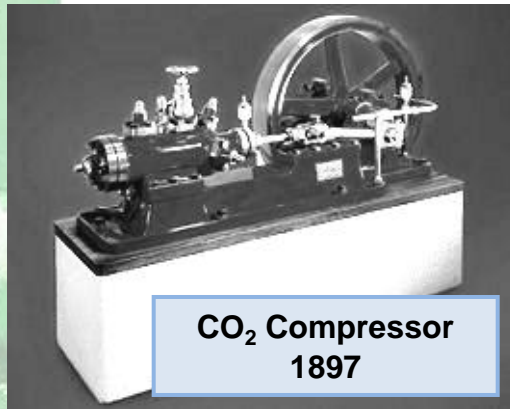
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**THE WORLD'S FIRST
MULTIFUNCTION
TWO STAGE
TRANSCRITICAL
CO₂ REFRIGERATION
SYSTEM AT A FOOD
PROCESSING PLANT
IN MELBOURNE,
AUSTRALIA**

KAV CONSULTING PTY LTD

Advisers to the Refrigerated Food Industries

History: CO₂ utilized as refrigerant in sub- and transcritical refrigeration systems

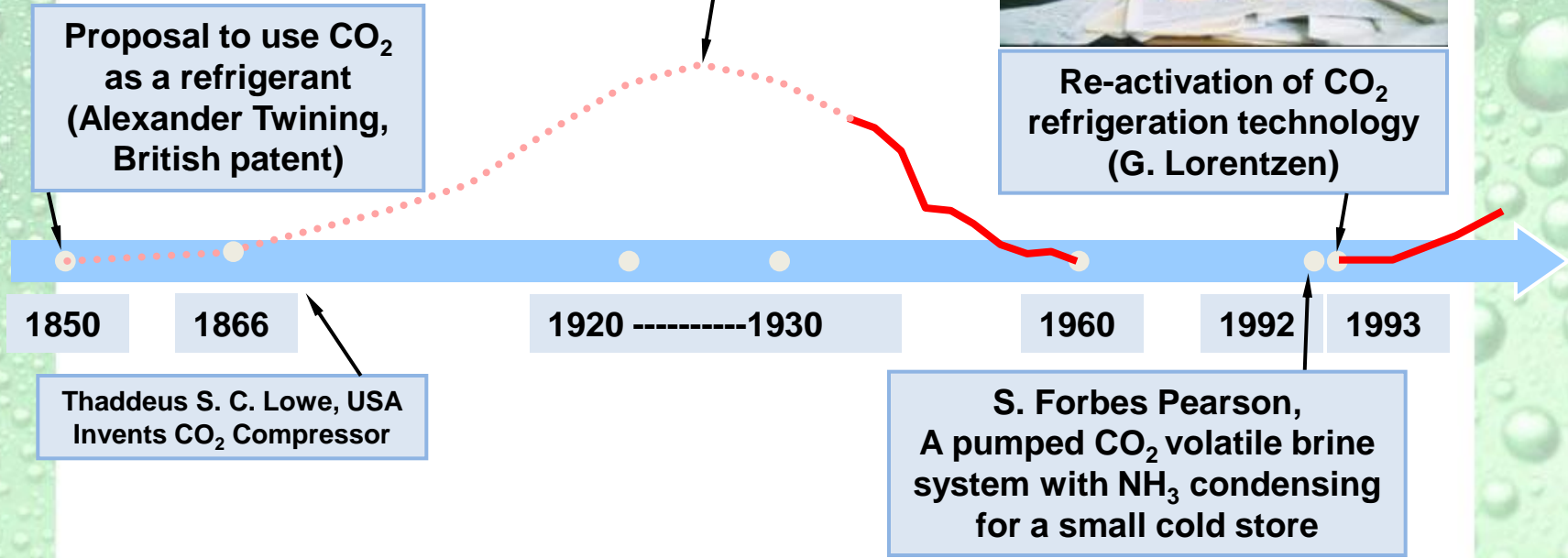


**CO₂ Compressor
1897**

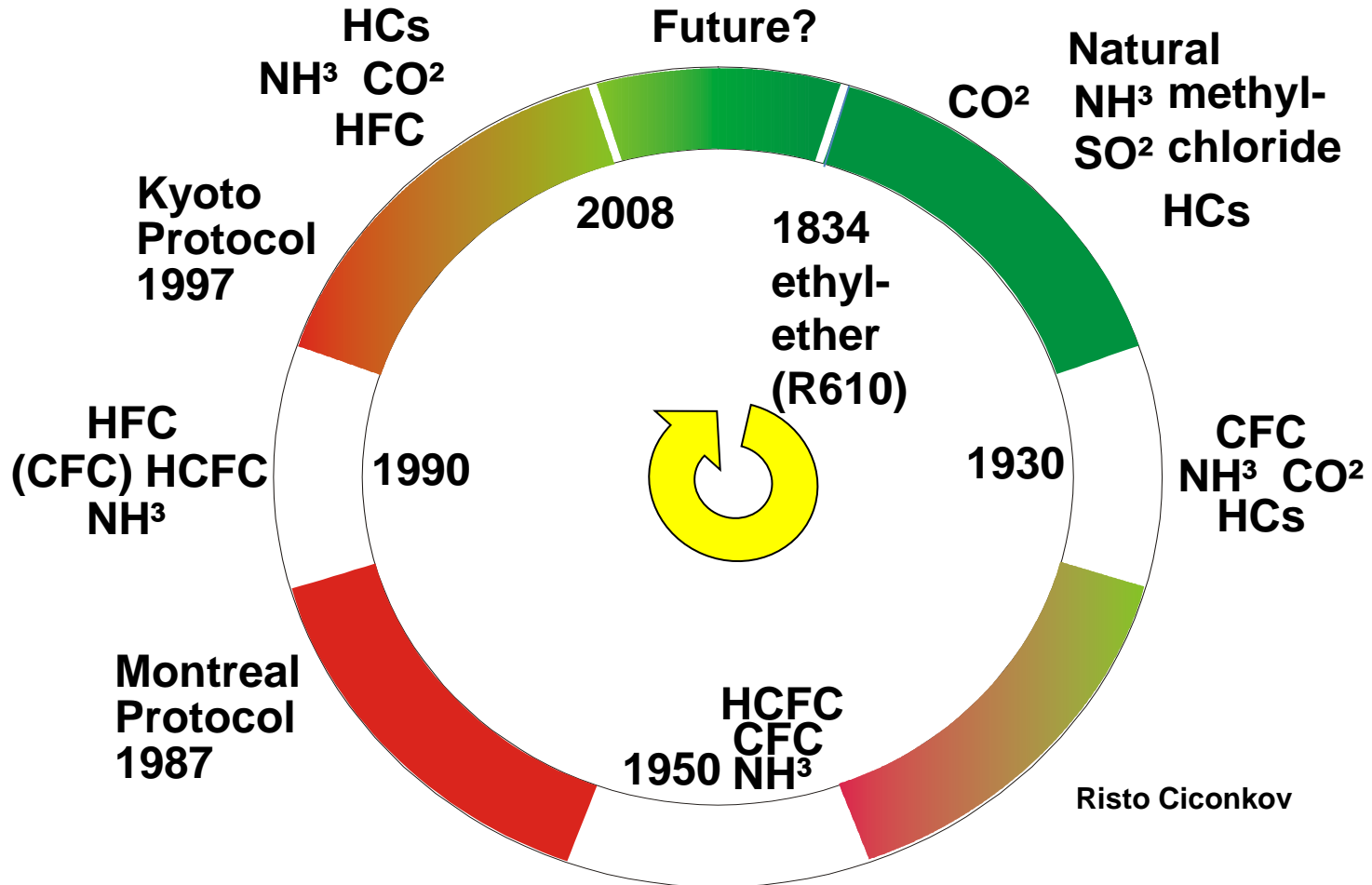
Prof. Dr. Gustav Lorentzen



**Re-activation of CO₂
refrigeration technology
(G. Lorentzen)**



Short History of Refrigerants



TJISADANE



Introduction

- EXQUISINE Pty Ltd needed to increase in Blast Freezing and Cold Storage Capacity.
- Natural Refrigerants were chosen because:
 - Mr. David Rose, CEO of Exquisite wanted a green image for his business.
 - High Global Warming Impact of HFC's.
 - HFC's likely to become controlled substances and subject to a carbon price. This has happened.
 - High price of HFC's and much higher with carbon price.
 - Possible future phase out of HFC's by regulation.
 - Desire to reduce specific energy consumption and emissions per kg of product produced.
- CO₂ was chosen because NH₃ considered too risky with a residence 30 metres from the plant room. In Transcritical mode CO₂ is used to heat process water and potable water for domestic and cleaning purposes.

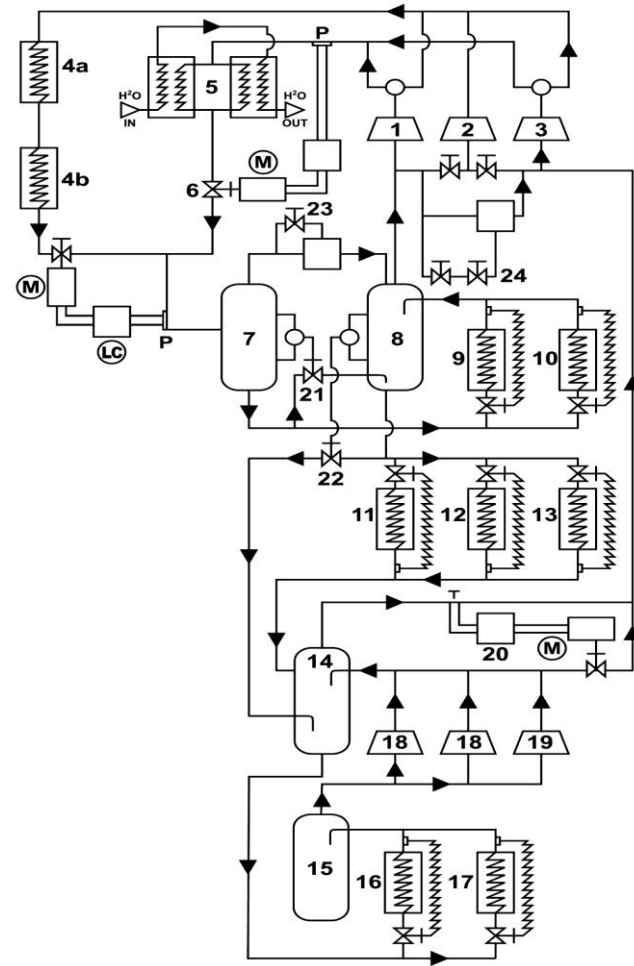
Introduction *Continued*

- The original time frame was mid September 2009 – end May 2010, but the project was eight months late for various reasons.
- Project capacity and scope definition, followed by an analysis of the local climate, detail design, specifications and drawings, and tendering. Decision to project manage to reduce costs after all tenders over budget.
- Australian Federal Government Funding of \$472,000.00 (50% of budgeted costs) obtained under its “Re-Tooling for Climate Change” Program.
- The major equipment suppliers Bitzer Australia and Guentner Australia were selected as partners, a sound decision.
- Two small contractors were chosen as partners in an effort to start an industry. This was a serious mistake. Significant cost over runs were experienced.

Schematic of two stage transcritical CO₂ refrigeration system with heat recovery and AC/economiser compressors.

N.B. Oil recovery & management not shown

Item No.	Description	No Off
1	AC and economiser compressor	2
2	Standby for 1 and 3	1
3	High stage and chiller comp.	3
4a	First stage gas cooler – air cooled	1
4b	Second stage gas cooler – air cooled Adiabatically assisted – 10% of time	1
5	water heaters – SWEP	2
6	CO ₂ expansion valves – ICMT	2
7	+10°C (44 barg) expansion vessel	1
8	+5°C (39 barg) suction trap	1
9	Factory cooling evaporator	1
10	Office AC evaporator	1
11	Packing area evaporator	1
12	Ingredient chiller evaporator	1
13	Ingredient for process chilled H ₂ O	1
14	-5°C LPR/de-superheater	1
15	-40°C suction trap with boil off coil	1
16	Blast freezer evaporator – ETX	1
17	Cold store evaporator – ETX	1
18	CO ₂ booster compressors	2
19	Standby CO ₂ booster compressor	1
20	Super-heat regulator compressor suction	1
21	High side float with DP sensor maintains level in 7	1
22	High side float with DP sensor maintains level in 8	1
23	BP regulator for 44 bar in 7	1
24	BR regulator for 39 bar in 8 when CO ₂ compressors 1 are stopped at light load	1
P =	Pressure transducer	
T =	Temperature transducer	
M =	Valve modulating motor	
LC =	PLC Control	

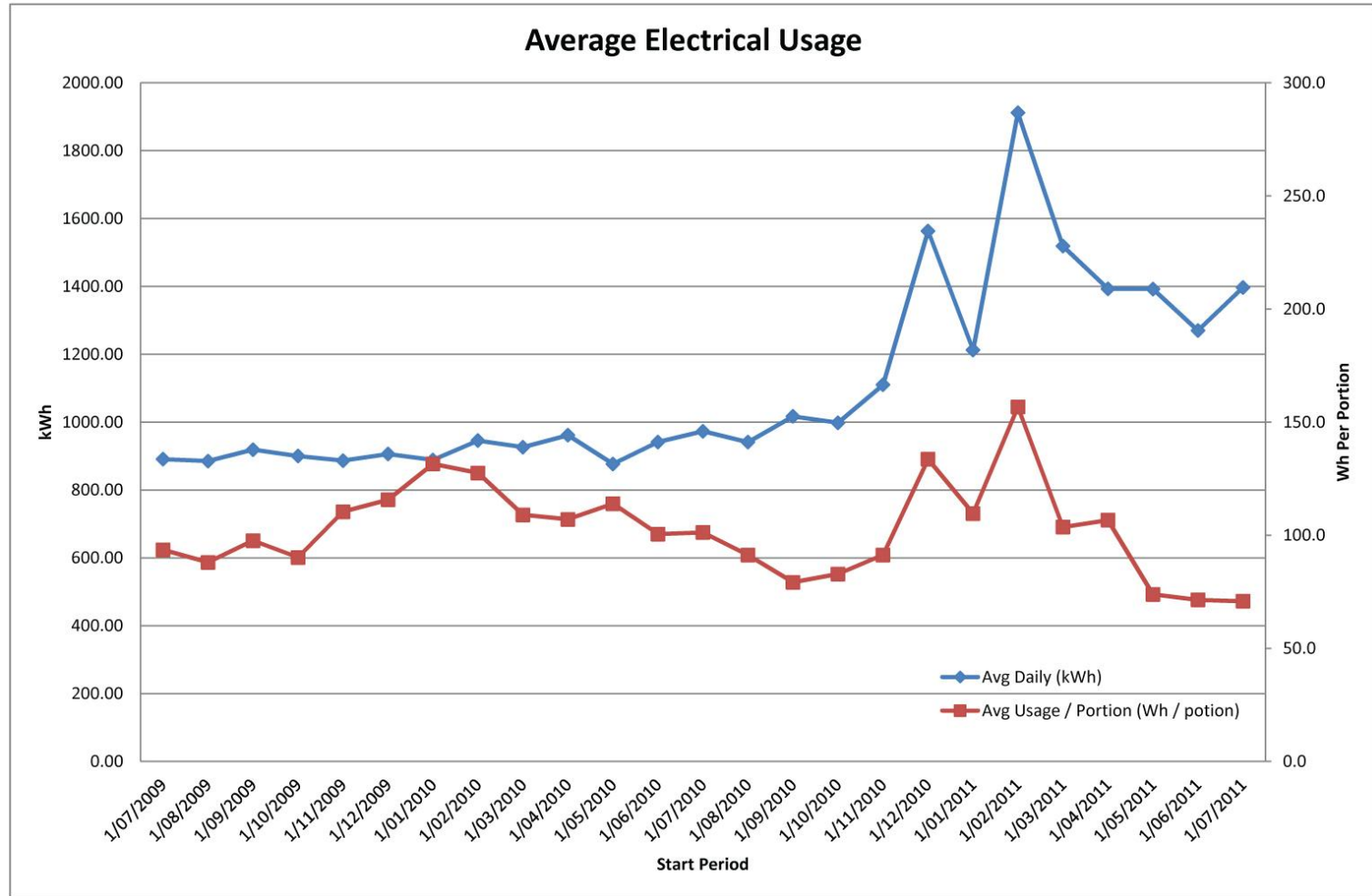


Existing Factory Cooling & Heating Systems & Duties at Exquisite Pty Ltd. Replaced by the new two stage transcritical CO₂

	SYSTEM DETAILS	NO OFF
No	DESCRIPTION	
1	Blast Freezer R502 Single Stage	1
2	Cold Store R22 Single Stage	1
3	Chiller Holding R22 Single Stage	1
4	Ingredient Chiller R22 Single Stage	1
5	Water Chiller R22 Single Stage	1
6	Air to Water Heat Pumps R134a	6
7	Office AC Reverse Cycle R134a	4
8	Factory Cooling Evaporative Cooling	1
9	Under Floor Heating BF & Cold Store	2
10	Domestic and Factory Hot Water	3
11	Factory Air Exhaust	1
12	Total Existing Systems	22

Electrical Energy Efficiency

Figure Courtesy Mr David Rose, CEO Exquisite Pty Ltd.



Electrical Energy Efficiency *Cont.*

Specific Electrical Energy Analysis derived from previous slide.

Period under consideration	Variable		
	No of Units produced daily.	Total average daily energy consumption	Average energy consumption
	Average	kWh	Wh / Unit
1/7/2009 – 30/6/2010 Before New Plant (BNP)	9,483	993	104.7
1/2/2010 – 30/6/2010 (BNP)	8,877	940	105.9
1/2/2011 – 30/6/2011 New Plant (NP)	16,897	1,394	82.5
Increase/Decrease Quantity	+ 8,020	+454	-23.4
% Increase/Decrease	+ 90.3	+48.3	-22.1
1/4/2010 – 30/6/2010 (BNP)	8,821	925	104.9
1/4/2011 – 30/6/2011 (NP)	18,832	1,349	71.6
Increase/Decrease Quantity	+10,011	+424	-33.3
% Increase/Decrease	+113.5	+45.8	-31.7
Final Target	+37,932 (+400%)	+210 (+21.1%)	-79.3 (-75.7%)

Energy Efficiency Analysis

Difference in planned and actual results in energy efficiency.

1. The Blast Freezer fans have been running @ 100% speed rather than 80% for low freezing capacity.
2. Compressor discharge pressures are higher than they should be due to algorithm for subcritical operations not being fully developed due to a shortage of funds.
3. Lower than design Blast Freezing air temperatures because of unfounded fear of large ice crystal growth during slow freezing.
4. Initially water heating at 80 bar rather than 90 – 100 bar.
5. Old systems were running during commissioning of new system.
6. Some old systems like electrical underfloor heating in the old cold store and Blast Freezer continued to operate.
7. Some extra process equipment and pumps not taken into account during design.
8. Warm Glycol defrost not as efficient as thought.
9. Attempts to operate at one third Blast Freezer evaporator capacity proved unwise and was energy intensive.

10. People object to work in the new refrigerated packing room. It is too cold and doors are left open.
11. Significant infiltration into cold store. The general air tightness of the panel construction -23°C cold store and -30°C to -35°C Blast Freezer is suspect.
12. Notwithstanding the preceding litany of woes in not achieving planned energy efficiency, a 31.7% reduction in specific energy consumption has been achieved when increasing production 113.5%, which increased energy consumption 45.8%. This was considerably more than predicted.
13. Efforts to reduce the energy consumption are continuing by tuning the systems and more is learned about its peculiarities.
14. The reduction in gas consumption for water heating has not yet been evaluated.

N.B. Items 2 and 9 are also design errors.

Capital Cost Analysis

- Alternative systems like Ammonia, HFC's and HC's were not considered, either as total systems or as CO₂ /NH₃, CO₂/HFC and CO₂/HC cascades.
- The new system had to be efficient to avoid having to upgrade the electricity supply capacity. This provided a significant capital offset of around \$300,000.
- When the lowest tender of AU\$1.3 million was received, the client requested that the project would be project managed, which would save an estimated AU\$350,000.
- The project was supported by AUSIndustry to the tune of AU\$472,000 (50% of the estimated cost) under the "Retooling for Climate Change" program.
- Estimated cost savings were not achieved and the final project cost exceeded the originally tendered price plus an 8 month delay.

Operating Cost Analysis

- May, June, July 2010 compared with May, June July 2011
 1. Increase in factory production +113.5%
 2. Increase in daily energy consumption +45.8%
 3. Decrease in specific electrical energy consumption per unit production and attendant indirect Global Warming Emissions (GWE) -31.7%

N.B. No figures available yet on gas consumption reduction and attendant GWE.
- The above figures are a long way below the following forecast figures for the reasons stated previously.
 1. Increase in factory production 400%
 2. Increase in electrical energy consumption 21.1%
 3. Decrease in gas consumption 60%
 4. Decrease in specific electrical energy consumption 75.7%
 5. Decrease in direct (HFC HCFC) and indirect GWE 40%

Potential Savings in the Future

- The CO₂ plant is built to increase freezing capacity by 400%. This takes care of not having to spend any more capital for a long time.
- No more replacement cost for HFC losses which are becoming very costly now that a carbon tax is levied on HFC at the point of entry into our country.
- Specific energy cost reductions per unit production will continue to increase. Every effort will be made to reach the forecast figures.
- Forecast expectations were not met for reasons explained previously, some of which are outside our control.

Lessons Learned

- The mechanical constant pressure regulators on the +10°C +5°C vessels hunted and were replaced with ICM type electronic regulators which respond much quicker and are more stable.
- The oil still on the -5°C low pressure receiver/high stage compressor suction trap/booster discharge desuperheater does not work and is completely useless. This is likely due to the high miscibility of CO₂ and POE oils.
- We did not install a suction heat exchanger in the suction lines to the AC & high stage compressors. To achieve a high COP we try to work with a virtual gas cooler exit temperature of +5°C.
- This gives the disadvantage of low suction super heat on the high stage and AC compressors, resulting in low discharge temperatures and difficulty reaching high water temperatures.

Lessons Learned *Cont.*

- We had to change cold store and chill store evaporator circuiting on site and were lucky to find a very skilled welder tradesman who was capable of doing this.
- A liquid receiver with constant level control is required for subcritical operations to take advantage of low discharge pressures giving high COPs during cool periods. The subcritical liquid receiver would work in parallel with the 1st stage transcritical expansion vessel when some compressors are operating transcritically with other running subcritically. When all compressors are running subcritically, the two vessels operate in series, i.e. The pilot receiver is filled from the gas cooler, which expands into the 1st stage expansion vessel.
- We will endeavour not to repeat the design errors made in this first project.

Lessons Learned *Cont.*

- In particular, we will ensure to have suction heat exchangers in the suction to the compressors at each evaporating level, i.e. three in this case.
- In the next project we will ensure to have a large capacity, mainly thermodynamically neutral oil distilling system.
- The next system will definitely not be project managed.
- Other than the above, designing and building these systems is not a whole lot different from designing a two stage industrial ammonia plant with a Low Pressure receiver.
- Everything we learned will be taken into account in the next project, i.e. the good, the bad and the ugly.

Barriers and Solutions

- Difficulties were experienced obtaining parts like high pressure leak proof valves for the transcritical discharge side.
- We hired a commissioning engineer out of Denmark, who proved very valuable even though he had never seen a multifunction system of this complexity.
- In this case the management of EXQUISINE wanted to do the project, whilst this presenter was initially reluctant, particularly with a project management approach.
- We did not experience any safety problems or legislative barriers. However, having the duty of care, and in the absence of an Australian CO₂ Safety Code, we arranged with the UK Institute of Refrigeration to use their CO₂ Safety Code, an excellent and comprehensive document.
- Initially cost differences were not a concern but when cost overruns occurred they became, and still are, a concern for management.

- Rapid implementation of these systems will be held back by a shortage of application engineers.
- This presenter discerns that there is too much emphasis on the **“WHY”** of CO₂ and not nearly enough on the **“HOW”** of CO₂ systems.
- My dear late friend Gustav Lorentzen told me once and I quote:

“Visser, we have done enough research to find applications for a hundred years.”

It is becoming apparent that history is repeating itself.

Future Plans

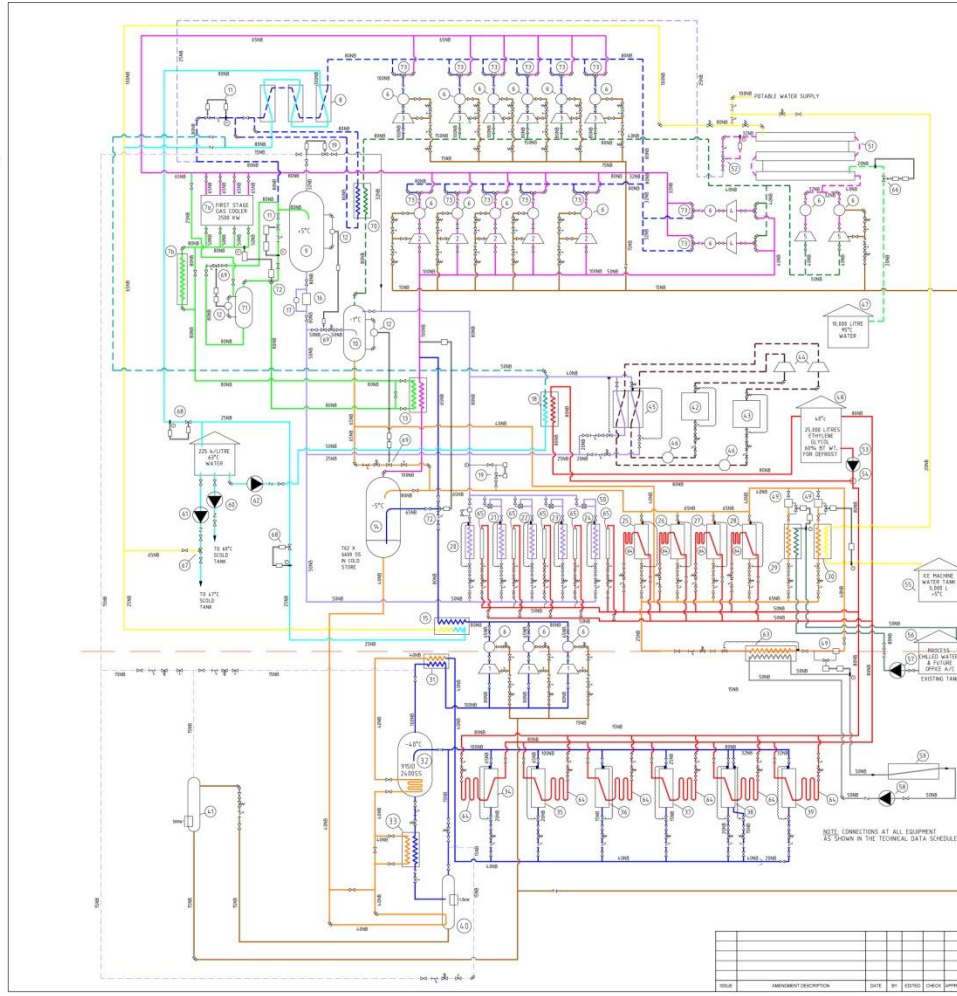
- Our office has recently completed the design and documentation for a much larger project. We were pleased and grateful that, Mr David Rose, the CEO of EXQUISINE, told our new client that he was pleased with the final system, notwithstanding the trials and tribulations experienced with the Exquisite plant, the first of its type in the world.
- As for designing a system, one should in general follow the rules and practices of industrial ammonia refrigeration system design obeying several simple guidelines.
 - Ensure that no liquid can enter any of the compressors at any time.
 - Ensure there is a good deal of superheat on the suction gas to the compressors achieved by liquid subcooling in a suction heat exchanger. This will enhance the COP and facilitates water heating in a gas cooler.
 - Where heat recovery is incorporated, ensure there is an air cooled gas cooler to handle the heat rejection where no heat recovery is required.
 - Ensure that the CO₂ vapour velocity through the cross section of any vessel in the suction of any compressors does not exceed 0.2 m/sec. This is because the high density CO₂ vapour exerts a much greater drag force on a small CO₂ droplet requiring much lower separation velocities than is the case with ammonia plants.

Future Plans *Cont.*

- Do not design piping systems too small in the belief that high pressure drops can be tolerated. Low piping pressure losses are always beneficial!
- Ensure that any evaporator circuit exit velocities do not exceed about 7 m/sec @ $T_0 = -40^\circ\text{C}$ and 10 m/sec @ $T_0 = 0^\circ\text{C}$ to ensure high circuit pressure drops do not occur with attendant boiling point suppression.
- Slope return header piping downward from the evaporators to the compressor suction trap where substantial heat load variations occur. This is similar to NH_3 systems.
- Carry out an analysis of the local climate and estimate the annual performance.
- Similar to NH_3 practice collect the oil from the lowest point of a suction trap in the lowest temperature DX circuit and ensure there is sufficient heat available to boil any CO_2 off distilling only oil.
- Locate the Low Pressure Receiver in a Cold Store to ensure no CO_2 blow off during a prolonged stoppage of the plant.

Our Action Plan

1. Actions in Hand – A current design ready for tendering.



Item No.	Description
1	Blast freezing & cold storage 540kW @ $T_0 = -40^{\circ}\text{C}$
2	Factory cooling 707kW @ $T_0 = 0^{\circ}\text{C}$
3	High stage and chiller load 900kW @ $T_0 = -5^{\circ}\text{C}$
4	Process water heating 1.370kW to heat 382,000 litres of water from 20 to 63°C
5	Heat 10,000 litres of water from 20 to 95°C 60 to 100kW

LEGEND - UNITS ARE:

REF VALVE	STOP VALVE	STOP PRESSURE RELIEF	COMP	CONDENSER	EVAPORATOR	SEPARATOR	RECYCLE VALVE
MANUAL EXP. VALVE	PROTECTIVE RELIEF VALVE	STOP	REF	CONDENSER	EVAPORATOR	SEPARATOR	RECYCLE VALVE
SHUT OFF VALVE	STOP PRESSURE RELIEF	STOP	REF	CONDENSER	EVAPORATOR	SEPARATOR	RECYCLE VALVE
SHUT OFF VALVE	STOP PRESSURE RELIEF	STOP	REF	CONDENSER	EVAPORATOR	SEPARATOR	RECYCLE VALVE

2011
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PROJECT: PROPOSED REFRIGERATION SCHEMATIC FOR A MULTIFUNCTION 2 STAGE TRANSCRITICAL CO₂ REFRIGERATION SYSTEM WITH HEAT RECOVERY

DESIGNED: L. GIBSON DRAWN: F. J. B. SCALE: DRAWING: VIC-103-005

Our Action Plan *Cont.*

- We have done a considerable amount of work on applying both CO₂ and ammonia, separately or in combination, to the built environment, both by retrofitting into existing buildings and applying these Natural Refrigerants to new buildings.

Our Action Plan *Cont.*

Comparison of total energy CO₂ and ammonia refrigeration systems for the cooling and heating of office buildings and hospitals in Washington DC.

Building type and location		Seasonally Weighted Compressor COP		Performance/ft ² of building ⁽¹⁾						% water savings	
				Electrical energy		Primary energy		Emissions ⁽²⁾			
No	Description	Cooling only	Combine d Heating & Cooling	kWh	% Red.	BTU	% Red.	lbs	% Red.	At building	At power station
				1	.1 Office buildings Existing USA	3.22	-	7.04	0		
	.2 CO ₂ retrofit	5.29	7.95	5.64	19.8	51,669	50.0	7.7	41.2	80	19.8
	.3 NH ₃ retrofit ⁽³⁾	8.49	7.23	5.9	16.2	64,793	37.3	8.0	38.9	46	16.3
	.4 CO ₂ purpose built	6.9	10.6	3.46	50.8	46,865	54.6	4.7	64.1	80	53.4
	.5 NH ₃ purpose built ⁽³⁾	8.49	7.06	4.05	42.4	44,580	56.6	5.5	58.0	53	42.4
2	.1 Hospitals Existing USA	3.35	-	13.8	0	218,390	0	26.8	0	0	0
	.2 CO ₂ retrofit	5.37	7.99	10.8	21.7	117,700	46.1	14.7	45.1	88	21.7
	.3 NH ₃ retrofit ⁽³⁾	9.04	8.18	11.0	20.3	121,379	44.4	15.1	43.6	45	20.0
	.4 CO ₂ purpose built	7.0	10.68	6.5	52.9	77,701	64.4	8.8	67.1	88	55.0
	.5 NH ₃ purpose built ⁽³⁾	9.04	7.94	8.05	41.6	88,736	59.4	10.9	59.3	52	41.7

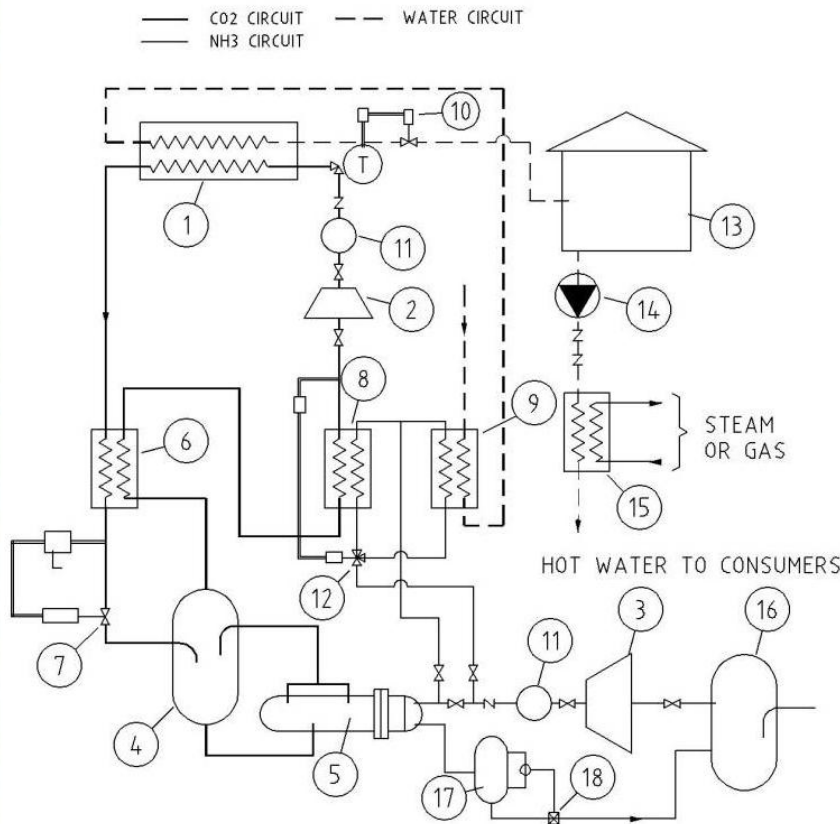
⁽¹⁾ Please note much larger reductions in electrical, primary energy and water consumption, and emissions would be possible with energy recovery from exhaust air, ambient air economizing and pre-cooling cycles, different methods of air distribution and chilled beams technology for example.

⁽²⁾ Emissions do not take into account any reduction in direct emissions from Fugitive HFC Refrigerant Gases.

⁽³⁾ In all ammonia cases a separate compressor is required as a heat pump compressor.

Inverse Ammonia CO₂ Cascade Heat Pump

We are keen to develop an inverse NH₃/CO₂ cascade heat pump by retrofitting a transcritical CO₂ compressor to the high stage of an existing two stage NH₃ plant.

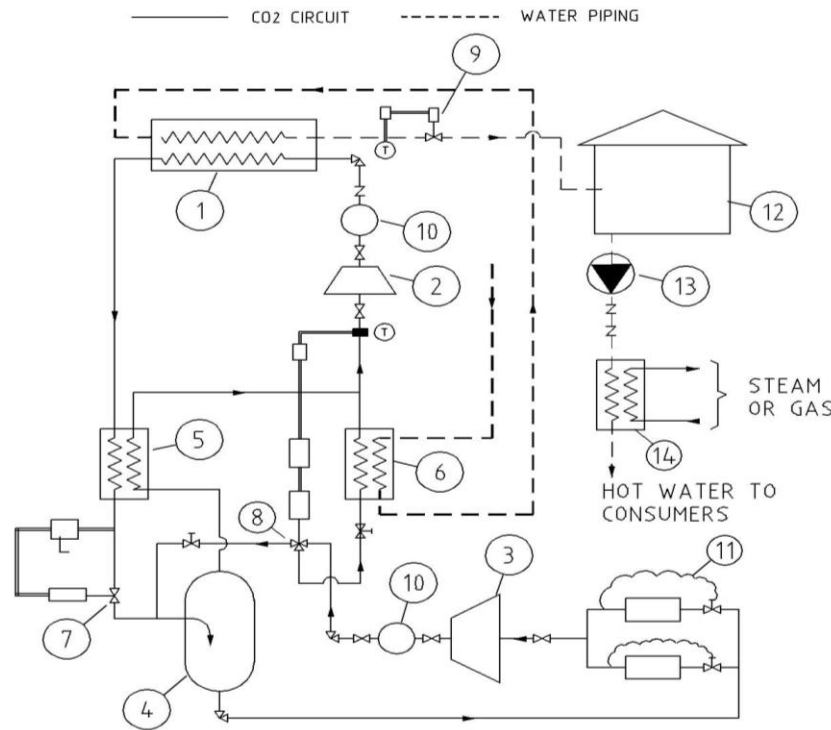


Legend

1. CO₂ gas cooler/water heater – 80 bar to 140 bar
2. Transcritical CO₂ compressor – 80 bar to 140 bar +15° SST
3. High stage ammonia compressor, –10°C SST / +20°C SCT
4. CO₂ expansion vessel / surge drum +15°C inverse NH₃/CO₂
5. Inverse NH₃/CO₂ cascade NH₃ condenser CO₂ evap. t = +15°C, NH₃ cond. t = +20°C
6. CO₂ suction Heat Exchanger
7. Discharge pressure controlled CO₂ expansion valve
8. CO₂ compressor suction superheat regulator using ammonia hot gas
9. Water heater using ammonia hot gas as heat source
10. Water temp controlled regulating valve
11. Oil separators
12. Three way NH₃ valve controlled by suction superheat to the transcritical CO₂ compressor 2
13. Hot water storage tank - 70°C to 85°C
14. Hot water circulating pump
15. Steam or gas heated water heater standby or top up
16. High stage (-10°C) pump accumulator for NH₃ plant
17. Control vessel
18. High side float

High Efficiency Two Stage CO₂ Heat Pump

We are also working on the concept of a high capacity two stage heat pump with CO₂



Legend

1. CO₂ gas cooler/water heater – 80 bar to 140 bar
2. Transcritical CO₂ compressor – 80 bar to 140 bar +15° SST
3. Subcritical CO₂ compressor, -5°C SST / +15°C SCT
4. +15°C CO₂ expansion vessel
5. Suction Heat Exchanger compressor 2
6. Desuperheater water heater
7. Discharge pressure controlled CO₂ expansion valve
8. CO₂ discharge gas diverting valve superheat controller
9. Water flow regulating valve controlled by gas cooler exit temperature
10. Oil separators
11. -5°C CO₂ evaporators
12. Hot water storage tank - 70°C to 95°C
13. Hot water circulating pump
14. Steam or gas water heater – standby and top up

Needed Action

- **Technology**

- There is a need for larger two stage reciprocating compressors with high suction pressure ability. Such compressors would very likely have both higher volumetric and isentropic efficiencies, thereby enhancing the COPs.
- Valves and controls with the correct pressure ratings for transcritical CO₂ operations are a need to enable larger plants to be built. The oil and gas industry are worth looking at.
- A CO₂ expander compressor to assist compression of the CO₂ to enhance the COP is a must. We believe that the unit developed at TU Dresden by Professor Hans Quack and his team is readily developed further. Their findings should not be ignored but commercialised with a simplified design.

- **Training**
- There is a dire need for the development of a nuts and bolts CO₂ design manual. Industrial ammonia designers would have little or no difficulty adapting to this quickly and competently once basic design parameters are formulated.
- Any training must concentrate on the custom design of systems and components like evaporators, rather than the design of packaged equipment for specific duties.
- Training at all levels from design engineers to technicians, mechanics and pipe welders is essential. The electrical and control engineers also need to be brought up to speed quickly.
- **Safety**
- We do not see any major safety issues with NH₃ and CO₂ with which we are familiar.
- We are not familiar with the requirements of the safe use and handling of HCs.

Policy, Standards and Regulations

- **Policy**
 - Policy makers must be proactive in encouraging the use of Natural Refrigerants by all means available to them such as punitive tariffs or levies on the use of HFCs, accelerated phase out of HFCs, funding for demonstration projects in government buildings, funding for APPLIED R & D like, for example, modifying high pressure CNG compressor technology for transcritical CO₂ applications, funding for education and training, etc.
 - Accelerated depreciation of existing HFC equipment manufacturing facilities plus financial incentives to compressor manufacturers to invest in manufacturing plant for high suction pressure ability single and two stage transcritical reciprocating compressors with swept volumes up to say 1,000 m³/hr to start with.
 - Offer incentives to the end user industry to invest in these new technologies such as grants, accumulative depreciation, low interest long term loans etc.

Policy, Standards and Regulations

- **Standards**
 - To facilitate free and unencumbered distribution of suitable products around the world one common International Standard should be adopted.
 - In Australia, the National Refrigeration Standards Committee is working hard to adopt ISO817 and ISO 5149 and adapt them to Australian legislation and regulation.
 - National Standards are too often used as non-tariff barriers, a frequent cause of action before the WTO tribunal.

Policy, Standards and Regulations

- **Regulation**
 - Minimum regulations consistent with the highest safety standards should be implemented.
 - Any barriers against the use of NH₃ in the built environment should be removed consistent with the highest safety standards.
 - Multinational corporations with vested interests should be prevented from lobbying.
 - Abolish carbon trading and change to a carbon tax in such a manner that the polluter pays and has no opportunity to purchase carbon credits, which are essentially a licence to pollute. Carbon trading is a first order obscenity and a bigger hoax than the millennium bug.

Markets, Costs, End Users

- Government financial incentives to invest in using this revising technology should be provided to the end users in all forms like accelerated depreciation of old plant and equipment, investment bonuses and accelerated depreciation for new plant and equipment, extension of carbon taxes to the reduction in emissions resulting from the use of natural refrigerants, additional training opportunities for reskilling of a workforce, etc., etc.

Conclusions

- This plant is a major breakthrough in applying CO₂ refrigeration technology in many of its individual applications in one integrated system, including potable and process water heating for space heating, tap water and cleaning.
- Reductions in electrical energy consumption, direct and indirect global warming emissions, gas and cooling water consumption are targeted at 33%, 40%, 60% and 44% respectively. Present indicators are that the targets will not be met for a number of reasons. Some of which are design related.
- It is a challenge to make the plant run efficiently at only 20 to 40% of its design capacity. To that end extensive use is made of variable speed drives (VSD's) for all compressors, blast freezer, air cooled gas cooler and AC fans.

Conclusions *continued*

- Two stage CO₂ transcritical systems used for simultaneous cooling and heating are viable in relatively warm climates like Melbourne.
- None of the problems encountered were beyond solution. Lessons learned by both the designer and commissioning technicians are valuable and need to be published widely to prevent them from being repeated in future projects.
- The total integration of all cooling and heating functions into single and two stage transcritical refrigeration systems holds a lot of promise to significantly reduce the total energy consumption and attendant emissions plus the elimination of direct fugitive HFC emissions.
- Transcritical CO₂ refrigeration cooling and heating systems offer a great opportunity to reduce the heating and cooling costs in existing buildings and such systems are readily retrofitted into a lot of buildings.

Conclusions *continued*

- Purpose built CO₂ systems for building heating and cooling in new buildings offer even greater opportunities in reducing energy consumption and attendant emissions particularly if coupled with other strategies.
- CO₂ is a suitable refrigerant for very small to the largest designed heating and cooling systems. However, large scale development will only happen if much larger single and two stage transcritical CO₂ compressors with high suction pressure ability become available. Adaptation of compressed natural gas (CNG) reciprocating compressors with suction pressures of 60 bar and discharge pressures of up to 750 bar would be one avenue worth exploring.

Acknowledgements

Mr David Rose, the Managing Director of Exquisine, has the author's undying gratitude for his courage to try this unproven application of CO₂ refrigeration and heating into one working prototype. He has done society at large a great favour, somewhat at his own expense.

AusIndustry's financial support is gratefully acknowledged. It is unlikely the project would have been able to proceed without the substantial support.

The help and assistance of the following people are also gratefully acknowledged.

Dr Petter Neksa, Senior Research Scientist, SINTEF, Trondheim, Norway, for supporting the idea of the first fully integrated CO₂ plant in the world.

Mr Sergio Giroto, Managing Director of Enex srl, out of Treviso, Italy, for checking our design and suggesting modifications.

Dr Andy Pearson, Managing Director of Star Refrigeration out of Glasgow, Scotland, for reviewing the installation and suggesting modifications.

Mr Ruediger Rudischhauser, Managing Director of Bitzer Australia (BA) for breaking BA's policy by selling the two compressor racks to the end user direct to assist getting this project off the ground.

Mr Glen Wiles, General Manager, Guenter Australia, also for selling the evaporators and gas cooler to the end user, direct to facilitate this unique demonstration project getting off the ground.

Mr Murray Carter, Project Manager, who took firm control of the project when it was necessary to create some order out of the chaos which developed during the installation phase.

Mr Kristian Sorensen out of Denmark for assisting the local refrigeration contractors with the commissioning between the end of November and mid December last year.

Vision

- Heavier-than-air flying machines are impossible.
LORD KELVIN, *president of the British Royal Society, 1895.*
- There is no likelihood man can ever tap the power of the atom.
ROBERT MILLIKAN, *Nobel Prize winner for physics, 1923.*
- I think there is a world market for about five computers.
THOMAS WATSON SR., *founder of IBM, 1943.*
- 640K of computer memory ought to be enough for anybody.
BILL GATES, *cofounder and CEO of Microsoft, 1981.*
- There is no reason why anyone would want a computer in their home.
KENNETH OLSEN, *founder of the computer firm Digital Equipment Corporation, 1977.*
- We don't like their sound and guitar music is on the way out.
The record company **DECCA**, *rejecting the Beatles, 1962.*
- A pessimist sees a difficulty in every opportunity:
An optimist sees an opportunity in every difficulty.
WINSTON CHURCHILL, *the great English lion.*

The *Gun* Gun Salesman



**“No! – I can’t be bothered to see any crazy salesman –
we’ve got a battle to fight!”**