

What is Frick's Position On CO2/R-717 Cascade?

- Not really new
- We certainly are not "against" it
- We will compress any refrigerant you want and we work hard to understand the characteristics of each refrigerant, especially it's efficiency
- One example:

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In (d) Low Temp Compressors - Large diameter screws due to R717 displacement						
2-Stage R-717	TR	BHP	BHP/TR	24/7 at \$.10/kWh	Annual Premium	20 Yr Premium
Booster	452.6	563.6	1.25			
High Stage	542.3	660.2	1.22			
System	452.6	1223.8	2.70	\$ 857,639.04	\$ -	\$ -
In (d) Low Temp Compressors - Using small diameter screws due to CO2 displacement						
CO2/R-717 Cascade	TR	BHP	BHP/TR	24/7 at \$.10/kWh	Annual Premium	20 Yr Premium
Low Side CO2	452.6	669.9	1.48			
High Side R-717	579.9	705.9	1.22			
System	452.6	1365.7	3.00	\$ 997,082.56	\$ 99,443.52	\$ 1,520,870.40
In (f) Low Temp Compressor - Using large diameter screw on CO2 for highest efficiency						
CO2/R-717 Cascade	TR	BHP	BHP/TR	24/7 at \$.10/kWh	Annual Premium	20 Yr Premium
Low Side CO2	452.6	603.3	1.37			
High Side R-717	572.9	697.4	1.22			
System	452.6	1317.7	2.91	\$ 923,444.16	\$ 65,805.12	\$ 1,316,102.40

452.6 TR @ -47 F SST/+13 F SIT/+22 F CO2 SCT (9 F TD)+95 F R717 SCT

All ratings at 0 SH, 0 SC and 0 package pressure drop and prorated using Full Load efficiencies to avoid introducing extraneous variables not related to CO2 or R-717 efficiency.

Actual differences would be less based upon run hours and plant load.

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- What about reciprocating compressors?
- With CO2, smaller displacement is needed for the same TR

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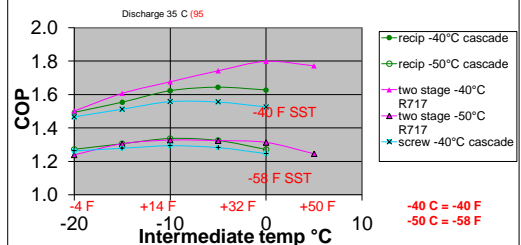
What is Frick's Position On CO2/R-717 Cascade?

- What about reciprocating compressors?
- With CO2, small displacement is needed for the same TR
- Comparison by H.Tychsen (has held R&D Engineering positions at both Sabroe and Frick)

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CO2/R717 cascade versus R717 two-stage.

Recip: Cascade 5°C (9 F) split, HPC104S and RXF39
Screw: Cascade 5°C (9 F) split, RWF 100 and RXF 39
R717 two-stage open flash, RWF177 and RXF39



This study predicts a break even on energy at -58 F SET and distinct advantage for ammonia 2-stage at -40 F SET. Frick Screw CO2 and R717 data has been confirmed via actual lab testing. All supporting rating data is available here today, for your review if desired.

What is Frick's Position On CO2/R-717 Cascade?

- What about reciprocating compressors?
- With CO2, small displacement is needed
- Comparison by H.Tychsen
- Study based on manufacturer's rating data on both the Sabroe CO2 reciprocating compressor and Frick screw compressor, both are very efficient compressors

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- What about reciprocating compressors?
- With CO2, small displacement is needed
- Comparison by H.Tychsen Study based on manufacturer's rating data on both the Sabroe CO2 reciprocating compressor and Frick screw compressor, both are very efficient compressors
- Some other studies we have seen appear to use extremely poor screw compressor ratings as basis for comparison to 2-stage ammonia

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- 10 F superheat, 0 condenser SC = combined 5%

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- Pressure Drops – valves, checks, separators (DOC)

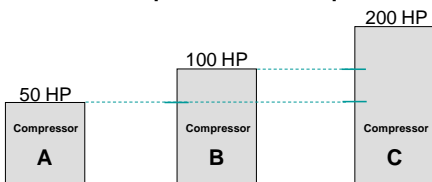
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- Pressure Drops – valves, checks, separators (DOC)
- Multiple compressor strategies – Isn't this how we do it today in R-717 systems?

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Screw Compressor Sequencing



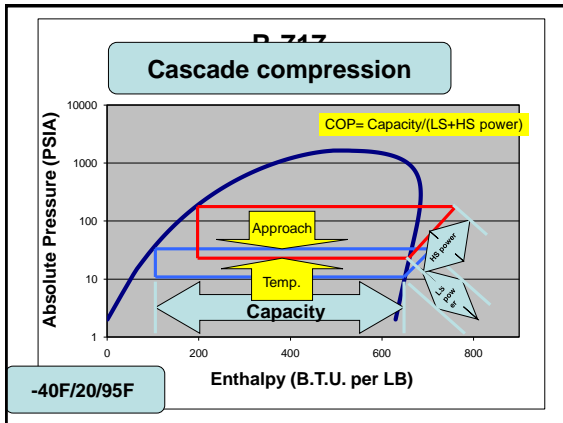
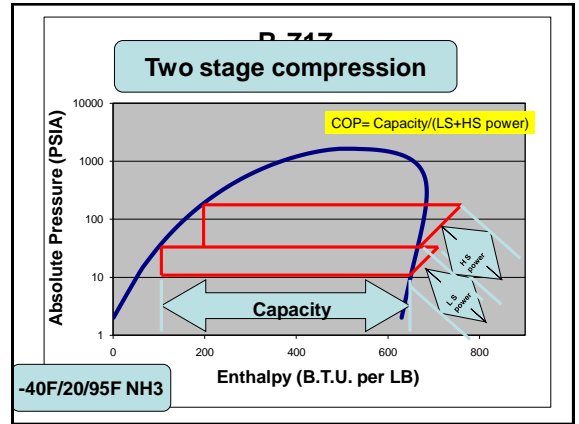
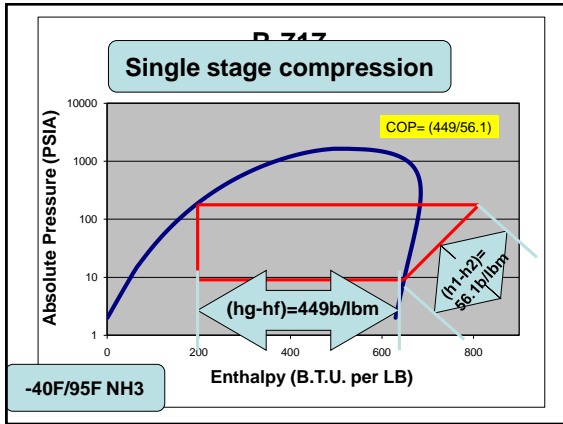
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|-----------------|----------------------|
| 1. 0 - 50 HP | Compressor A |
| 2. 50 - 100 HP | Compressor B |
| 3. 100 - 150 HP | Compressor A & B |
| 4. 150 - 200 HP | Compressor C |
| 5. 200 - 250 HP | Compressor A & C |
| 6. 250 - 300 HP | Compressor B & C |
| 7. 300 - 350 HP | Compressor A & B & C |

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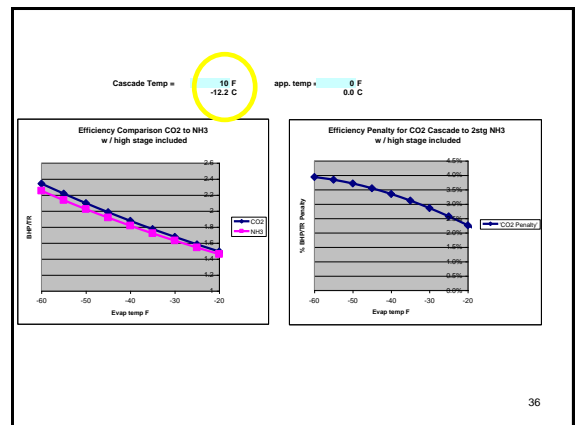
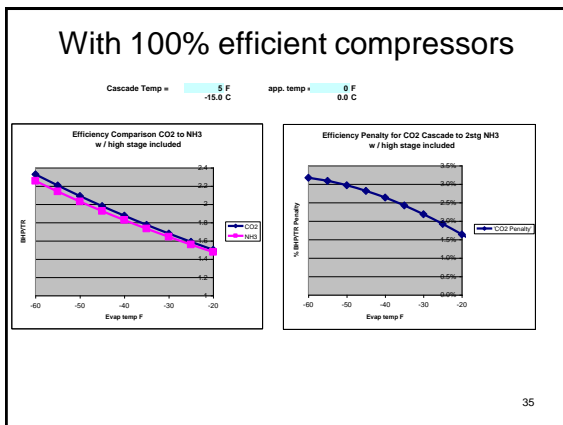
What is Frick's Position On CO₂/R-717 Cascade?

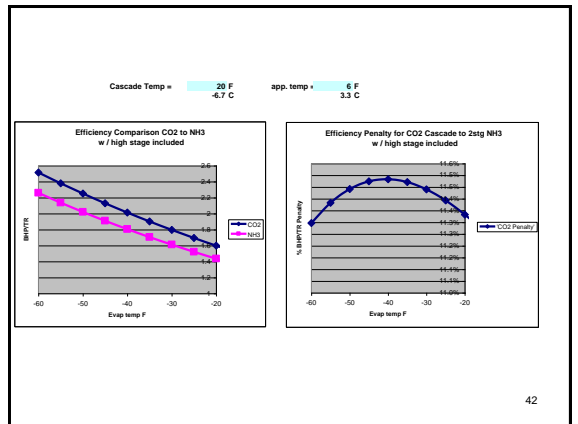
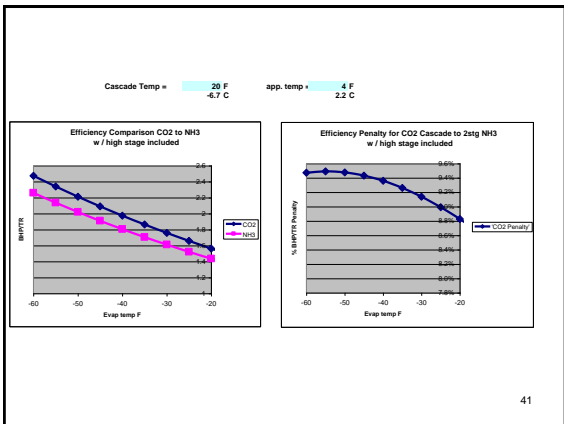
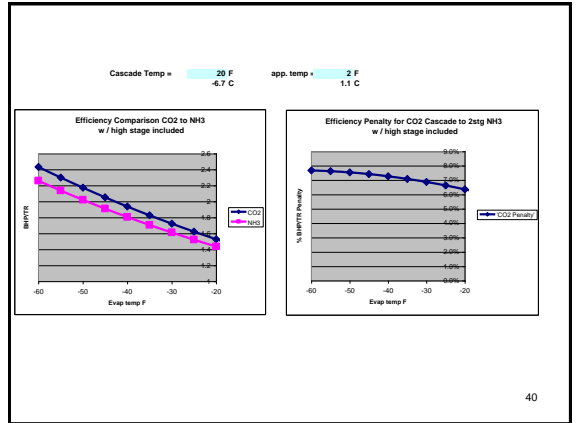
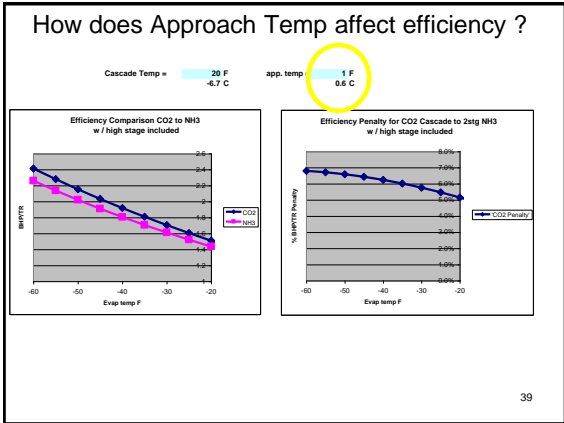
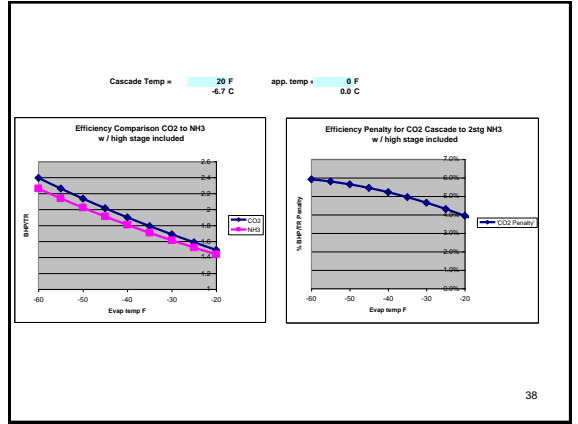
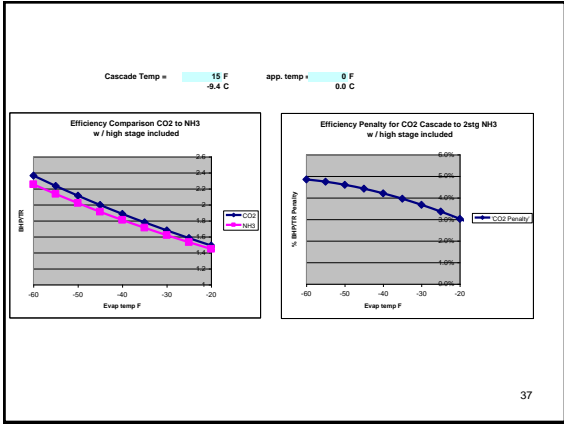
*At Part Load, temperature split at the cascade condenser will be reduced but will not disappear.

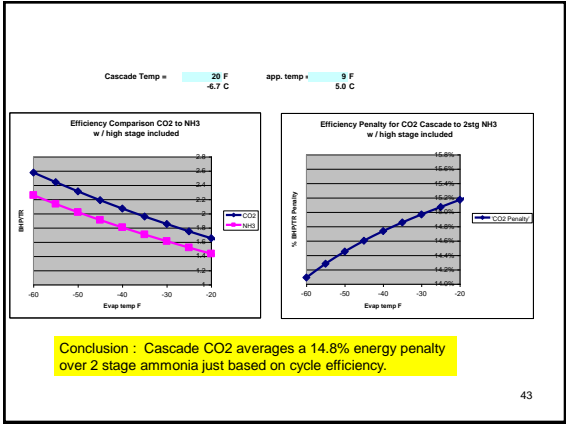
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- ## Cycle Comparisons
- Give the limit of Maximum efficiency possible with 100% compressor efficiency.
 - Give real world comparisons with real compressor efficiency.
 - Ammonia high stage assumed the same in both cases.
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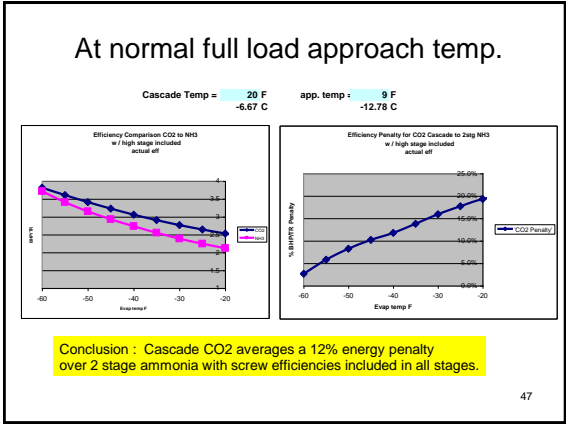
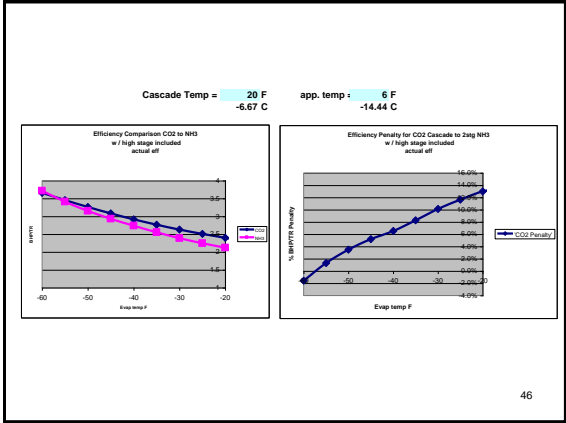
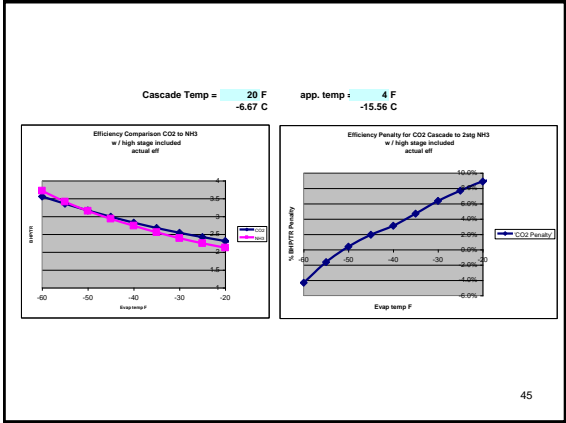




Using Real compressor efficiency Applies to Apples

- Using same type of compressor (Frick screw compressors) on both systems
-compares refrigerants, not compressor brands

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Using Recip efficiency on CO2 and Screw on NH3

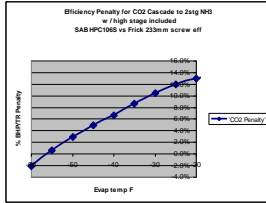
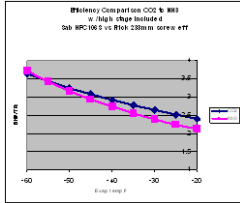
- Taken from Sabroe Comp1 rating program for recip. HPC 106 S
- Frick Coolware for Screw rating RWF-177

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Using Recip efficiency on CO2 low stage and Screw efficiency on NH3 Boosters

Cascade Temp = 20 F
-6.67 C

app. temp = 6 F
-14.44 C

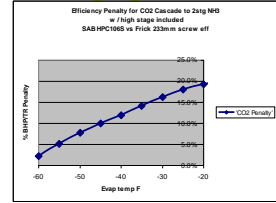
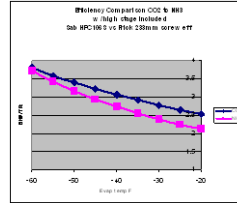


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Using Recip Efficiencies at normal full load approach temp.

Cascade Temp = 20 F
-6.67 C

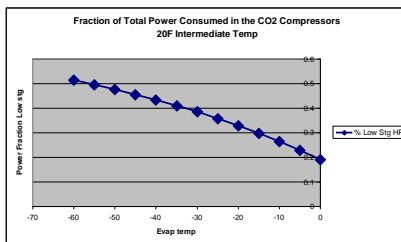
app. temp = 9 F
-12.78 C



Conclusion : Cascade CO2 averages a 12% energy penalty over 2 stage ammonia with recip. efficiencies included.

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At -20/+20/95F, CO2 Cascade, 32% of the total compression power is consumed in the CO2 compressors



Conclusion : In order to save 32% in energy, the CO2 compressors would have to consume ZERO power..! In order to save 20% energy the CO2 compressors have to consume one third of rated power. NOT POSSIBLE

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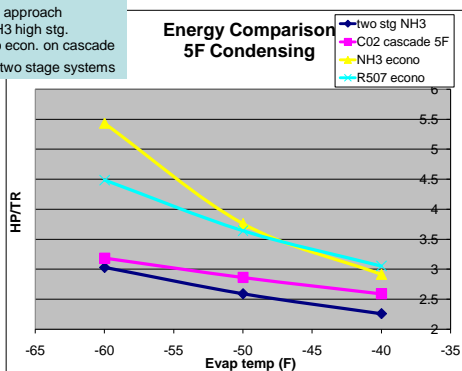
Conclusion

- There may be reasons to use CO2 cascade in refrigeration systems,
- BUT, energy savings is not one of them.

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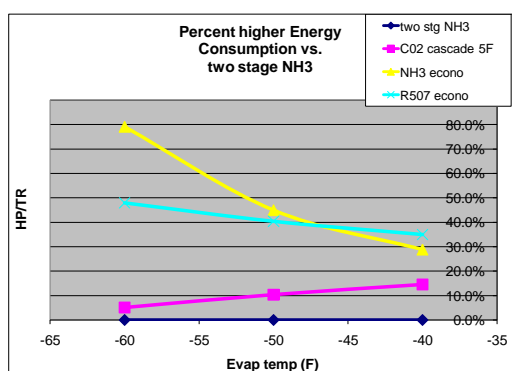
5F approach
NH3 high stg.
No econ. on cascade
or two stage systems

Energy Comparison 5F Condensing



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Percent higher Energy Consumption vs. two stage NH3



Oils

- Miscible oils help evap., but may hurt compressor performance.
- PAO - proven stability, immiscible, separates good, OK in compressor.
- POE - miscible, OK in compressor. Hygroscopic. Wet CO2 forms acid that destroys compressors.

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CO2 as a Cascade Refrigerant - the Good

- Allows greatly reduced size of low stage compressors.
- Environmentally friendly.
- -65F with no risk of air ingress (positive pressure, not in a vacuum).
- No ammonia in the room.
- Reduced risk of ammonia damage to products people or fire.

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CO2 as a Cascade Refrigerant - the Bad

- Added cost and complexity of cascade system. Smaller doesn't mean cheaper.
- Much higher pressures:
 - 20 F = 407 PSIG
 - 95 F = 1043 PSIG
- Defrost issues. H.G., water, electric.
- CO2 Cascade not yet recognized in Safety or building codes.
 - DWP 80F for lowside (954psig)
 - Compressor DWP 3x954psig = 2860psig

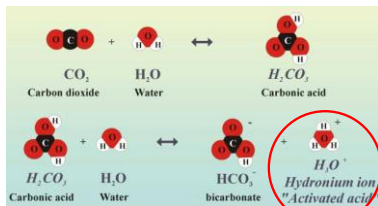
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CO2 Cascade - the Bad

- Compressor life is reduced.
- Efficiency not as good as 2-stg ammonia > -60F
- Oil is expensive and troublesome.
- Must refrigerate the CO2 to avoid loss of charge during power failure or relieve gas.
- Safety valve placement is important to avoid plugging from dry ice.
- Charging systems or changing filters requires caution to avoid dry ice formation blocking flow.
- Trapped liquid expands much more than NH3 or R134a. (4-10 times)
- Water in CO2 forms acid. Be careful with oil.

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Water in CO₂ systems



If water is present in CO₂ systems, water reacts with CO₂ and creates **Carbonic acid.**

The concentration is depending on the water content

Strong acid

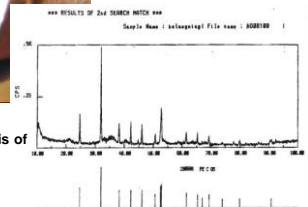
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Water in CO₂ systems

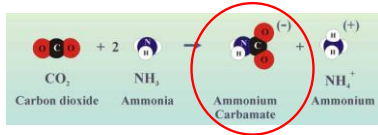


Heavy corrosion in a steel pipe from a CO₂ **production** system caused by Carbonic acid.
Corrosion **will not** take place in a well maintained CO₂ refrigeration system.

X-ray diffraction:
Crystal structure analysis of the steel pipe.



Ammonia in CO₂ systems



- The solid substance **Ammonium Carbamate** is formed immediately if CO₂ gets in contact with ammonia.
- Ammonium Carbamate is a **corrosive** substance (white powder)
- Ammonium Carbamate will dissolve, if it is heating up to a temperature higher than approx. 60 Deg. C

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Frick's Position On CO₂/R-717 Conclusions

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Frick's Position On CO₂/R-717 Conclusions

- CO₂/Cascade may be the right answer for some owners at some locations, but not for others

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Frick's Position On CO₂/R-717 Conclusions

- Do you operate mostly at temperatures that favor CO₂ efficiency?

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Frick's Position On CO₂/R-717 Conclusions

- Do you operate mostly at temperatures that favor CO₂ efficiency?
- Do you operate mostly at temperatures that favor 2-stage ammonia (or other refrigerants)?

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Frick's Position On CO₂/R-717 Conclusions

- CO₂ and ammonia are only two of forty refrigerants that can be rated by Frick's standard rating programs (many other specials).

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Frick's Position On CO2/R-717 Conclusions

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- We are not emotionally attached to any refrigerant.

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- CO2 and ammonia are only two of forty refrigerants that can be rated by Frick's standard rating programs (many other specials).
- We are not emotionally attached to any refrigerant.
- We are committed only to making accurate selections and correct recommendations.

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Frick's Position On CO2/R-717 Conclusions

- Cascade condensing (regardless of refrigerants selected) will always suffer some TD penalty

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- Cascade condensing (regardless of refrigerants selected) will always involve some risk of cross-contamination

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Frick's Position On CO2/R-717 Conclusions

- Cascade condensing (regardless of refrigerants selected) will always suffer some TD penalty
- Cascade condensing (regardless of refrigerants selected) will always involve some risk of cross-contamination
- Measures are available to minimize risk of cross-contamination but add cost and performance penalties (TD and pressure drop)

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Frick's Position On CO2/R-717 Conclusions

- Conservation strategies can be employed to optimize the energy performance of a facility using cascade condensing, but they should be employed regardless of refrigerants selected

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Frick's Position On CO2/R-717 Conclusions

- There is no guarantee that the government will not lower the threshold on ammonia below 10,000# or enact stricter measures on CO2 in the future

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Frick's Position On CO2/R-717 Conclusions

- Are you comfortable with R717, PSM, RMP, risk of leaks in the occupied space?

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- Are you comfortable with R717, PSM, RMP, risk of leaks in the occupied space?
- Are you comfortable with the issues of using CO2 such as high pressures, triple point, sensitivity to moisture, corrosion, exotic oils, etc?

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Frick's Position On CO2/R-717 Conclusions

- Are you comfortable with R717, PSM, RMP, risk of leaks in the occupied space?
- Are you comfortable with the issues of using CO2 such as high pressures, triple point, sensitivity to moisture, corrosion, exotic oils, etc?
- Carefully evaluate ALL of the issues, then do what is right for your business.
- But energy savings is NOT the reason to chose CO2 Cascade.

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THANK YOU to

**2008 Assembly of Committees
Refrigeration and Energy Committee
CO2/R717 Cascade Panel**

from

Joe Pillis
Dave Murphy

Frick

