Full Phase Refrigerant Liquid Subcooling as a Mean of Dehumidification & Energy Recovery

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This paper discusses the use of full phase refrigerant liquid subcooling in order to meet the dehumidification needs of a conditioned space. The moisture removal efficiency of Addison's new PR series with full phase refrigerant subcooling was estimated and presented in the tables that follow. The performance with liquid subcooling was also compared against other dehumidification & energy recovery techniques such as wrap-around heat-pipes.

Introduction

Liquid refrigerant subcooling is one of the most popular and efficient dehumidification design, in a Dedicated Outdoor Air System (DOAS), for reducing both sensible and latent loads of the incoming air. The concept is relatively simple, and while in dehumidification mode the refrigerant exiting the condenser is rerouted to a reheat coil connected with the condenser and located behind the evaporator as shown in Fig. 1.

In this configuration, cooled and dehumidified air exiting the evaporator coil is reheated, and the liquid refrigerant is subcooled. The subcooled refrigerant then enters the direct expansion coil, and because it is subcooled the latent and total capacity of the coil increases.

In Fig. 2 the compressor-condenser capacity with and without subcooling is illustrated. There are no penalties of increased refrigeration, and the expense of additional cooling energy is avoided since the reheat energy is free. This cycle has the same effect as the one of the run-around enhancements with two beneficial exceptions:

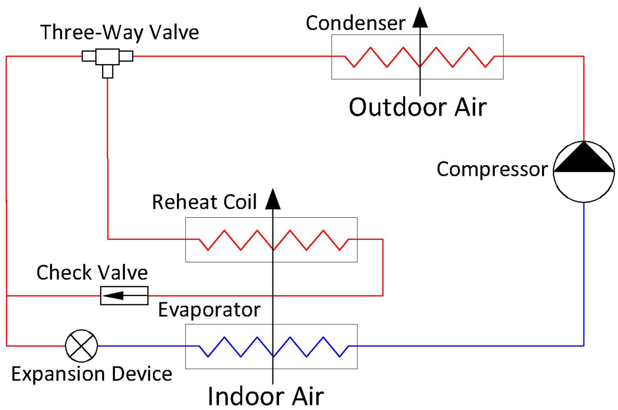

Figure 1: *Full Phase Refrigerant Liquid Subcooling-Air Reheating*

- There is no need for a precooling coil.
- The depth of the subcooling coil is less than that of the heat pipe.

This enhanced subcooling results in reducing the evaporation temperature and boosting the latent capacity of the system. The system subcooling is only limited by the size of the reheat coil and the air temperature leaving the evaporator, thus a configuration with subcooling becomes one of the most efficient technologies of increasing the dehumidification capabalities without compromising cooling performance.

The advantages of refrigerant-subcooling/air reheating are the following:

- Only a single coil is required in the air stream leaving the main coil.

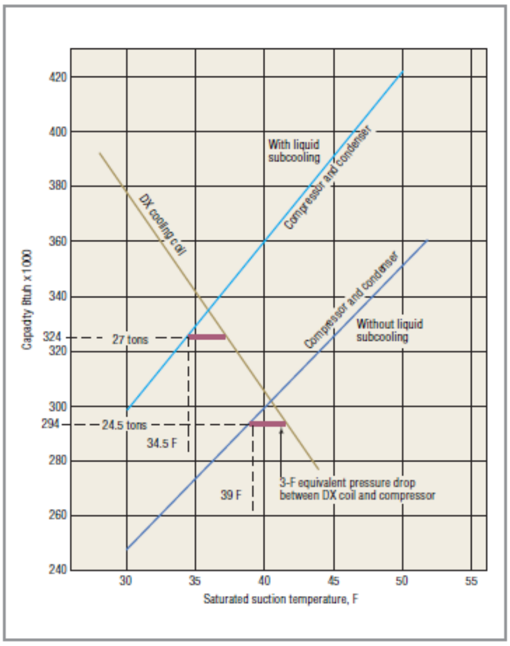

Figure 2: *Impact of Subcooling on Cooling Capacity [1]*

- Pressure drop is half of that of other dehumidification enhanacements such as heat pipes.

A major concern with multiple coil systems is refrigerant migration that occurs when not all of the coils are always active. A system with liquid subcooling is free of such concerns as it it always filled with liquid refrigerant, regardless of the operating mode.

Performance Characterization

In 2015, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) introduced a performance rating for DOAS units. In the sections that follow we compare the performance rating of Addison's DOAS systems with liquid subcooling against the performance with a heat pipe, per AHRI standard 920 recommendations.

Integrated Seasonal Ratings

The AHRI committee [2] provided a weighted value moisture removal efficiency that puts emphasis on the part load values in calculating the integrated seasonal ratings. The following table lists the weighted percentage values.

The integrated seasonal values are a weighted average of the the individual rating values that are expressed in pounds of moisture removal per kilowatt (MRE) in dehumidification mode.

Rating Points(°Fdb/°Fwb)	Weight (%)
A : 95/78	12
B : 80/73	28
C : 68/66	36
D : 60/58	24

Table 1: *Weighting Percentages for Integrated Ratings*

$$ISMRE = MRE_A \cdot 0.12 + MRE_B \cdot 0.28 + \\ + MRE_C \cdot 0.36 + MRE_D \cdot 0.24 \quad (1)$$

where MRE_A, MRE_B, MRE_C, and MRE_D are the Standard Rating Conditions at point A, B, C, and D respectively.

The minimum $ISMRE$ values, for air cooled equipment, in dehumidification mode are $ISMRE = 4.0$ without energy recovery, and $ISMRE = 5.2$ with energy recovery.

Case I

We estimated the MRE performance of Addison's PROA036 unit with liquid subcooling at 450 SCFM and the performance with a 6-row heat pipe for the same volume of air. Table 2 summarizes our findings. It is apparent that liquid subcooling outpeforms heat pipes not only on an average basis but also at each individual rating point, other than design conditions, i.e. Condition A. Clearly, the values also exceed the threshold, i.e. $ISMRE = 5.2$, for a unit with energy recovery

Condition	Subcooling MRE	Heat Pipe MRE
A	5.6	6.1
B	7.3	6.9
C	7.5	6.8
D	6.3	6.1
ISMRE	**7.0**	**6.6**

Table 2: *MRE values for PROA036 with subcooling VS a heat pipe*

Case II

Similar trend was depicted by Addison's PROA240 with liquid subcooling at 2000 SCFM in one case, and a 6-row heat pipe for the same volume of air in the other case. Table 3 summarizes the our results. The configuration with liquid subcooling has higher

MRE and ISMRE at every rating point other than the design conditions. In addition, the estimated values exceed the minimum value for energy recovery in this case as well.

Condition	Subcooling MRE	Heat Pipe MRE
A	5.6	6.2
B	8.1	8.2
C	8.9	8.2
D	7.6	7.5
ISMRE	**8.0**	**7.8**

Table 3: *MRE values for PROA240 with subcooling VS a heat pipe*

Conclusions

In this paper we discussed the use of full phase refrigerant liquid subcooling in order to meet the sensible and latent requirement of a conditioned space. The moisture removal efficiency of Addison's PR series with liquid subcooling and with a wrap-around heat pipe was estimated in terms of MRE, per AHRI standard 920.

Two different cases were examined, Case I at 450 SCFM and Case II at 2000 SCFM, and the integrated seasonal values were estimated for using full phase liquid subcooling and with a heat pipe. In both cases liquid subcooling outperformed the wrap-around heat pipe and exceeded the minimum value set by AHRI for a unit with energy recovery.

In addition to performance, there are several other drawbacks when considering heat pipes. The latter are associated with significant pressure drop and increased blower size in order to compensate for that. Also, heat pipe coils are more expensive as each of the many refrigeration circuits in heat pipes must be individually evacuated and charged. Finally, the physical arrangement of the coils must enable gravity drainage or capillary transfer of the condensed refrigerant from the heating coil to the precooling coil [1].

References

[1] D. P. Gatley, "Dehumidification enchancements for 100-percent-outside-air ahus," *HPAC Heating/Piping/AirConditioning Engineering*, 2000.

[2] AHRI, "2015 standard for performance rating of dx-dedicated outdoor air system units," tech. rep., AHRI, 2015.