Design Criteria and Software Development for Finned Tube Evaporator Using R744

Friterm R&D Department has evaluated CO_2 evaporators and gas coolers used both in subcritical and transcritical refrigeration systems under the title of environmentally friendly technologies, which took place in the scope of The Scientific and Technological Research Council of Turkey (TUBITAK) Funding Program. As part of this evaluation, not only a laboratory has been constructed but also new software has been developed for finned-tube R744 (CO_2) heat exchangers. The software data have been compared to the test results so as to confirm compatibility between these two methods. The information in the following parts is aimed to address the data collected from this evaluation.

Hatice Canbaz
MSc, R&D Product Development Engineer
Friterm A.Ş.

Engin Söylemez
MSc, (PhD Candidate, Marmara University)
R&D Test Engineer
Friterm A.Ş.

Kadir Isa
Ph.D. Member ASHRAE
Assistant Professor, Istanbul University
Faculty of Engineering
Mechanical Engineering Department
isa@istanbul.edu.tr

CO_2 evaporators

Finned-tube evaporators can be employed both in subcritical and transcritical refrigeration systems. The key designing data are classified into three fundamental groups.

1. *Air side design data*
2. *CO_2 side design data*
3. *Heat exchanger design data*

Air Side Design Data

1. **Atmospheric pressure** - the atmospheric pressure must be known so that the physical properties of air relative to the pressure can be defined. The term of "altitude" is preferred instead of "atmospheric pressure".
2. **Air flow** - the amount of air flow should be known to meet required capacity.
3. **Inlet temperature** - the inlet temperature of the ambient in where the cooler run should be known.
4. **Relative humidity** - the relative humidity of the ambient in where the cooler run should also be known. Additionally, wet bulb temperature can substitute for relative humidity.

CO_2 Side Design Data

1. **Refrigerant flow** - If the refrigerant flow is known, it becomes easier to calculate the outlet conditions of the given evaporator. The superheat can be calculated according to refrigerant flow. If unknown, the following properties along with dryness fraction should be given.
2. **Evaporation temperature** – the temperature difference between ambient temperature and evaporation temperature should be determined.
3. **Dryness fraction** - the dryness fraction of the refrigerant entering the evaporator in transcritical R744 cycle must be known in order to define the inlet conditions of the refrigerant. This value is dependent on the gas cooler's operation pressure and outlet temperature. In Subcritical R744 cycle, the condensation temperature and subcooling degree should be known.

Figure 1. CO_2 evaporator testing.

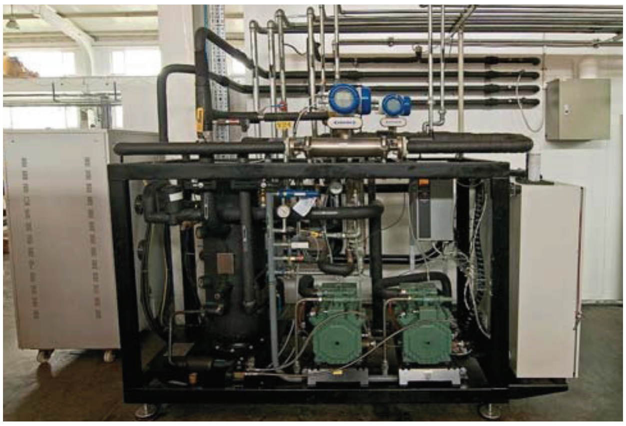


Figure 2. CO_2 refrigerant preparation unit.

4. **Superheat** - the dryness fraction should be known to define evaporator outlet conditions.
5. **Subcooling** - it is the difference between condensation temperature and the temperature before expansion valve described in subcritical R744 refrigeration cycle.

Heat Exchanger Design Data

The finned-tube heat exchanger's design data are given as follows:

> The distance between tube and rows, coil geometry, fin length, tube and row number, pass or circuit number, fin spacing, fin material and thickness, collector diameter (if known), distributor diameter and finally tube material and thickness.

In light of the data given above, the CO_2 evaporators were designed and after that they were tested in the "Calorimeter Room".

In order to test CO_2 evaporators, the given conditions are shown in **Table 1**.

The results collected from the tests have been analyzed in detail by means of FRTCOILS and are shown in **Table 2**.

Test results were in comply with the calculation of software. In other terms, the software calculations have been supported by the test results. Consequently, a new software has been built which enables the designing of finned-tube CO_2 evaporators and gas coolers.

Conclusion

So far it has been seen that a system choice which is in line with the designing conditions is crucial. The needed software evaluation has been carried out for the evaporators and gas coolers - the most important components of the system. In this brief paper, only the studies carried out for the evaporators are considered. The software efforts have been supported by the test results of the prototypes. It is concluded that test results are in comply with the calculations of the software. In conclusion, FRTCOILS has been developed for the finned-tube CO_2 heat exchangers.

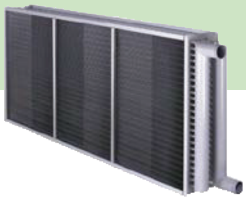
Table 1. Evaporator test conditions

Test	Tested Products	CO_2 Evaporation Temperature (°C)	CO_2 Mass Flow (kg/h)	Inlet air Temperature (°C)	Air Relative Humidity (%)
1	Prototype 1	1,58	193,11	12,02	45,17
2	Prototype 2	1,25	164,068	10	48,79
3	Prototype 2	-7,08	122,829	-0,01	50,20
4	Prototype 3	-12,39	76,492	-0,01	41,50
5	Prototype 4	-2,74	110,705	15,03	27,70

Table 2. CO_2 Evaporator testing results.

Test	Tested Products	Results Capacity (kW)
1	Prototype 1	11,503
2	Prototype 2	9,667
3	Prototype 2	7,684
4	Prototype 3	4,665
5	Prototype 4	6,989

Cooling & Heating Coils



Heating Cooling Coils (HCCs) which enable the conditioning of different zones and flexibility in application in buildings are generally employed in compact and central station AHU. To meet the required extra capacity in various processes, they are also used as heating or cooling devices.

With the application of these coils to high energy efficient heat recovery systems, the entire system becomes more compact as well as it avoids occupation of large spaces. Besides, they can be applied to Variable Air Volume (VAV) systems used for conditioning of hospitals, shopping centers and convention facilities.

The Certification programme for the HCCs has increased integrity and accuracy of the industrial performance ratings which provides clear benefits for end users who can be confident that the product will operate in accordance with design specifications. Also, by means of this certification programme users can collect reference data on the fundamental characteristics of the HCCs, such as capacity, pressure drop, mass flow complying with the standard of EN 1216.

Committee chair:
Engin Söylemez
R&D Test Engineer, Friterm A.Ş

Scope of certification

The rating standard applies to ranges of forced circulation air cooling and air heating coils as defined in ENV1216.

Certification requirements

- Qualification and repetition procedures: units declared will be selected and tested by an independent laboratory.
- The number of units will depend on the variety of coil material configurations and their applications for the applied range.
- The selection software will be verified in comparison with the test results.

Certified characteristics & tolerances

- Capacity: –15%
- Air side pressure drop: +20%
- Liquid side pressure drop: +20%

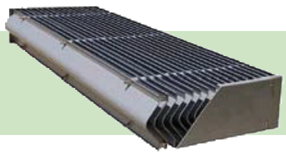
ECC Reference documents

- OM-9
- RS 7/C/005

Testing standards

- ENV 1216

Drift Eliminators



Scope of certification

The Eurovent Certification Programme for Drift Eliminators applies to Drift Eliminators used for evaporative water-cooling equipment.

Certified characteristics & tolerances

The following characteristics of Drift Eliminators shall be certified by tests:

- For counter-flow and cross-flow film fill, the average drift losses of the two tests at 3.5 m/s are less than 0.007% of circulating water flow rate.
- For cross-flow splash fill, the average drift losses of the two tests at 3 m/s are less than 0.007% of circulating water flow rate.

No tolerance will be applied on the average drift losses.

ECC Reference documents

- Certification manual
- Operational Manual OM-14
- Rating Standard RS 9/C/003

Testing standards

- Eurovent Rating Standard 9/C/003
- CTI ATC-140