EVAPORATORS FOR CHILLING - A REVIEW ON HEAT LOADS, PULLDOWN AND WEIGHT LOSS

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The following section generally discusses industrially accepted methods of chiller design and selecting evaporators for chilling, and compares some results to see how appropriate they are.

Several computer programs were used to help generate data for the discussion. However, these programs have not been used to the ultimate degree, as general data were adequate for this discussion of significant factors.

1. Heat Loads

To calculate the heat load, the industry commonly uses data as illustrated in Tables 1 and 2.

Carcass Weight 205 kg/body (Table 1)

The parameters presented commonly represent chillers designed in the '60s and '70s; carcass weight chosen at 205 kg per body (total weight for 100 bodies = 20,500 kg).

The most significant load in a chiller is the product load, and it is extremely important to have this part correct. The other loads are less significant.

Carcass Weight 350 kg/body (Table 2)

The parameters have been upgraded for product from 205 kg in Table 1 to 350 kg (total weight for 100 bodies = 35,000 kg). Note that the product load has increased dramatically. This illustrates that a chiller designed for 205 kg bodies will generally be inadequate for today's larger bodies.

Table 1: Heat load for chiller for 100 bodies @ 205 kg

Type of load		Sensible heat loss (kW)	Latent heat loss (kW)	Total heat loss (kW)	% of total
Conduction	- Walls	1.9	-	1.9	2.8
	- Ceiling	1.8	-	1.8	2.7
	- Floor	2.5		2.5	3.7
	Total:	6.3	- -	6.3	9.2
People		0.0	0.0	0.0	0.0
Lighting		1.1	-	1.1	1.6
Product		48.6	-	48.6	71.5
Motors	- Forklifts	0.0	-	0.0	0.0
	- Conveyors	0.0	-	0.0	0.0
	- Fans	12.0	-	12.0	17.7
Infiltration		0.0	0.0	0.0	0.0
Safety Factor		0.0	0.0	0.0	0.0
Overall Heat Losses		**68.0**	**0.0**	**68.0**	**100.0**

Heat Loss per Cubic Meter (W/m³) – 111.8299

Input Specifications

Dimensions (m)	Length	17	
	Width	6.5	
	Height	5.5	
Temperatures (°C)	Ambient/Room	40°C	1°C
Humidities (%)	Ambient/Room	30%	90%
Conduction	Insulating Material / Conductivity (W/m.K)	Styrene	.035
	Thickness of Styrene (m)	.1	
	Heat Transfer Coeff. (W/m².K) Walls/Floor	0.338	1.200
	Ground Temperature (°C)	20	
	Non-Standard Floor Construction Used		
People	No. of People in Room	0	
Lighting	Lighting Load per Area (W/m²)	10	
Ventilation	No. of Air Changes per 24 hours	0	
Product	Material to be cooled	Meat	
	Initial/Final Temperatures (°C)	39	7
	Heat Capacity (kJ/kg.K)	T> -2=3.2	T< -2=1.7
	Latent Heat (kJ/kg)	250	
	Mass in Room (kg)	20500	
	Cooling Time (Hours)	12	
Forklifts	No. in Use * Power Rating/Forklift (W)	0 * 0	
Conveyors	No. in Use * Power Rating/Conveyor (W)	0 * 0	
Fans	No. in Use * Power Rating/Fan (W)	0 * 0	
Infiltration		0	
Safety Factor (%)		0	

Table 2: Heat load for chiller for 100 bodies @ 350 kg

Type of load		Sensible heat loss (kW)	Latent heat loss (kW)	Total heat loss (kW)	% of total
Conduction	- Wall	1.9	-	1.9	1.9
	- Ceiling	1.8	-	1.8	1.8
	- Floor	2.5		2.5	2.5
	Total:	6.3	- -	6.3	6.1
People		0.0	0.0	0.0	0.0
Lighting		1.1	-	1.1	1.1
Product		83.0	-	83.0	81.1
Motors	- Forklifts	0.0	-	0.0	0.0
	- Conveyors	0.0	-	0.0	0.0
	- Fans	12.0	-	12.0	11.7
Infiltration		0.0	0.0	0.0	0.0
Safety Factor		0.0	0.0	0.0	0.0
Overall Heat Losses		**102.3**	**0.0**	**102.3**	**100.0**

Heat Loss per Cubic Meter (W/m³) – 168.3834

Input Specifications

Dimensions (m)	Length	17	
	Width	6.5	
	Height	5.5	
Temperatures (°C)	Ambient/Room	40°C	1°C
Humidities (%)	Ambient/Room	30%	90%
Conduction	Insulating Material / Conductivity (W/m.K)	Styrene	.035
	Thickness of Styrene (m)	.1	
	Heat Transfer Coeff. (W/m².K) Walls/Floor	0.338	1.200
	Ground Temperature (°C)	20°C	
	Non-Standard Floor Construction Used		
People	No. of People in Room	0	
Lighting	Lighting Load per Area (W/m²)	10	
Ventilation	No. of Air Changes per 24 hours	0	
Product	Material to be cooled	Meat	
	Initial/Final Temperatures (°C)	39	7
	Heat Capacity (kJ/kg.K)	T> -2=3.2	T< -2=1.7
	Latent Heat (kJ/kg)	250	
	Mass in Room (kg)	35000	
	Cooling Time (Hours)	12	
Forklifts	No. in Use * Power Rating/Forklift (W)	0 * 0	
Conveyors	No. in Use * Power Rating/Conveyor (W)	0 * 0	
Fans	No. in Use * Power Rating/Fan (W)	0 * 0	
Infiltration		0	
Safety Factor (%)		0	

Carcass Pulldown

What is expected, when one specifies a pulldown from +39°C to 7°C?

What has been calculated, in the heat loads above, is the overall pulldown or the **mass average** pulldown of the total product, **not** the deep-butt.

Is it realistic to pull down deep-butt to +7°C in 12 hours? The major factors include body weight and fat cover.

Fig. No.	0°C Air Temperature Air Velocity [m/s]	39°C to 7°C for 400 kg Bodies	
		Lean Beef Hours	Heavy Fat Hours
2.1	0.5	28	36
2.2	1.0	26	34
2.3	2.0	25	32

The above data is generated from Figures 2.1, 2.2 and 2.3. It shows that deep-butt pulldown to 7°C in 12 hours is not practical. It also shows that air velocity has only a small effect on final deep-butt temperature.

However, even with only 0.5 m/sec air velocity at 0°C air temperature, 350 kg carcasses should comply to EMO250 (to +20°C in 20 hours). To obtain +17°C to +18°C in 16 hours is much more practical. Hence, the mass average carcass temperature is generally +12°C for the 350 kg carcass. Therefore, the assumption in Tables 1 and 2 for the pulldown of 39°C to +7°C in 12 hours is somewhat unrealistic.

The sensible product load for Table 2, should be calculated from 39°C to +12°C in 16 hours (52.5 kW in lieu of 83 kW).

Latent Heat from Product

The analysis in Tables 1 and 2 is conservative in sensible heat allowance, however, there is no latent heat allowance. We know this is not possible; there is always some drying of the sides, hence weight loss.

Considering a weight of 1.3% (hot dry to cold dry) on a total of 35,000 kg of product relates to 455 kg loss weight through the chilling process. Assuming the weight loss is pure water and a chilling duration of 16 hours, the **average product** latent load is approximately 19.7 kW. [This assumption is not strictly correct, the fluid would comprise some salts and organics in small quantities.]

Heat Load Profile

What is commonly calculated for a chiller heat load is the **average summary and cycle load** only. The actual cycle load profile would exceed this load in the first half of the cycle and lessen in the latter half of the cycle as the carcass temperature cools and approaches that of the chiller air temperatures.

A typical load profile for the 350 kg bodies has been presented in Figure 1.

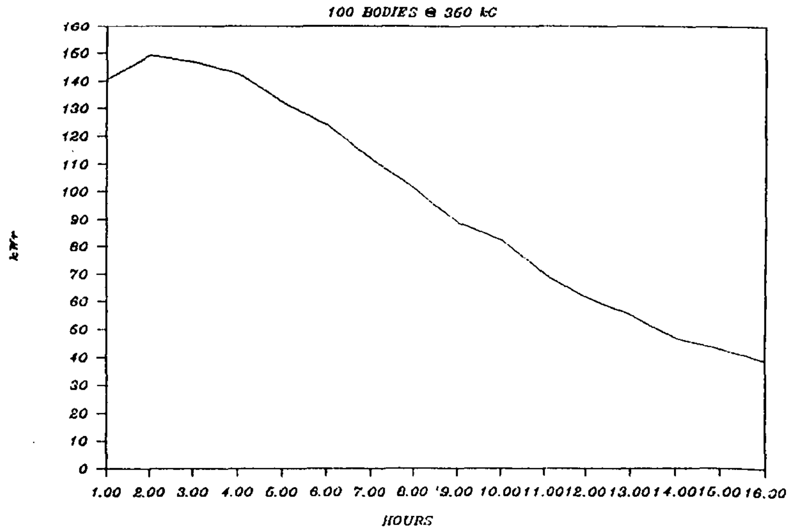

Figure 1: Chilling load profile

unit and generally not depth, as the deeper the coil, the more moisture it removes. In general it is unwise to use 'old' air coolers from general storage facilities for carcass chilling, as it is usually a deep coil.]

A **modulating** suction pressure regulator is also desirable, to allow the air coolers to always operate at the highest possible suction condition as the heat load drops.

3. Weight Loss

Vapour Pressure

Weight loss can be simply described as the evaporation of the moisture from the wet body surface to the surrounding air.

The potential to lose weight is the difference between the surface water vapour pressure and the partial pressure of the surrounding air. The larger the difference, the larger the potential.

Vapour pressure, in turn, is related to temperature. The larger the difference, the larger the potential. Hence, it is especially important to reduce the surface temperature of the bodies as soon as it is practicable, to minimise weight loss.

Figures 3 and 4, illustrate the difference between designing at the cycle average and above the average. The difference in area between the curves provides an indication of the potential to save weight, which is 30%.

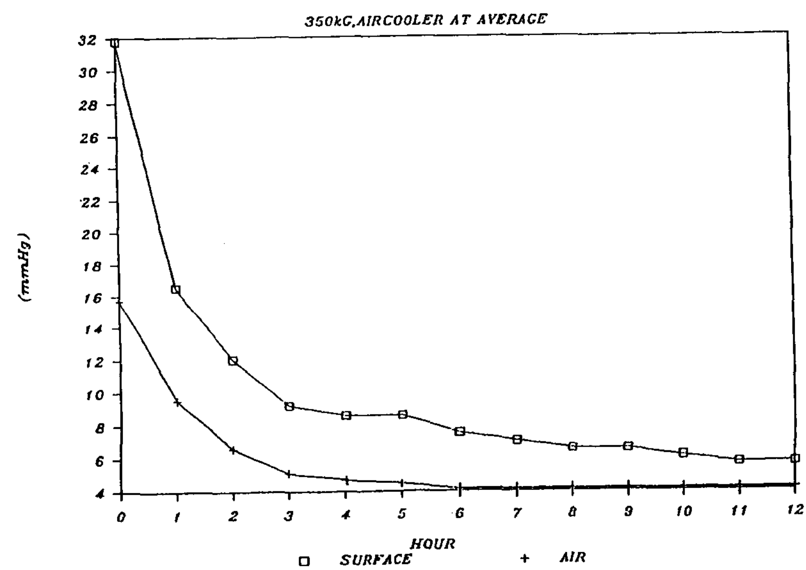

Figure 3: Vapour pressure difference - fast pulldown

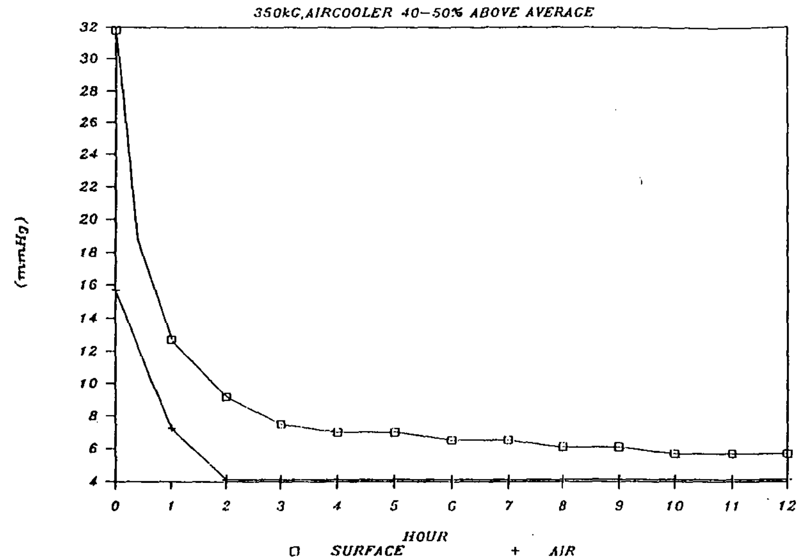

Figure 4: Vapour pressure difference – slow pulldown

Air Velocity Consideration

It is important to have good air velocity and air distribution within a chiller, however, equipment layout has not been covered within the scope of this discussion.

With regard to weight loss, there is evidence that the most economical air velocity is between 0.7 to 1.3 m/sec for carcass weight between 250 to 350 kg. Furthermore, there is almost no real change in evaporative weight loss with increasing air velocity over the above values. The main reason for this is the balance between heat transfer and mass transfer. The two are inter-related, that is:

1. The higher the velocity, the higher the heat transfer, hence quicker pulldowns, lower vapour pressure difference, a lower weight loss potential on one hand,

   but,

2. The higher the air velocity, the higher the potential for mass transfer (evaporation), hence a higher potential to lose weight on the other hand.

The latter is less significant with velocity less than 1.5 m/sec and good air temperature, generally of 0°C (Figure 6 shows the typical relationship described above).

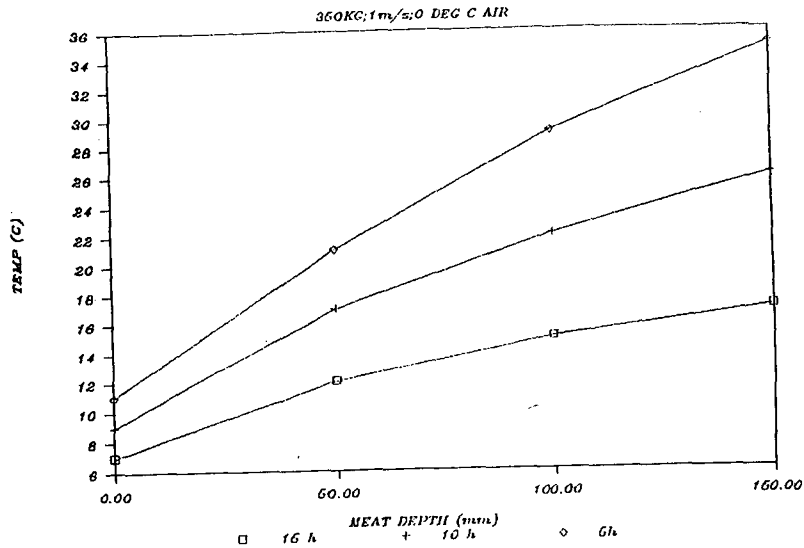

Figure 5: Deep leg temperature

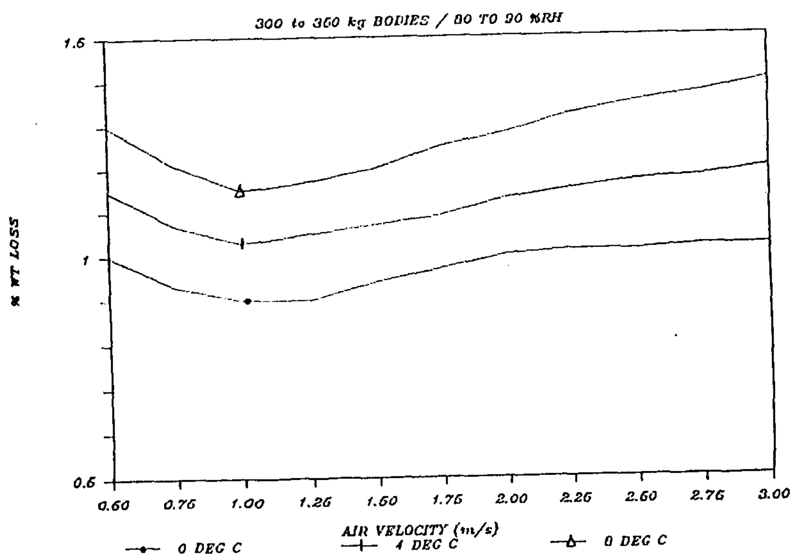

Figure 6: Weight loss versus air velocity

4. Conclusion

The main conclusion, without going into detail, can be put simply, as:

The more "appropriate" the surface area (capacity), the higher the product quality and lower the weight loss.

However, finding the "balance" which is economical and suits your requirements is also important. Hence, knowing specifically what the realistic goals are, and knowing what factors are significant, will assist.

5. References

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