

Extension of ASHRAE 137 Standard for Testing Ground Source B/R Heat Pumps

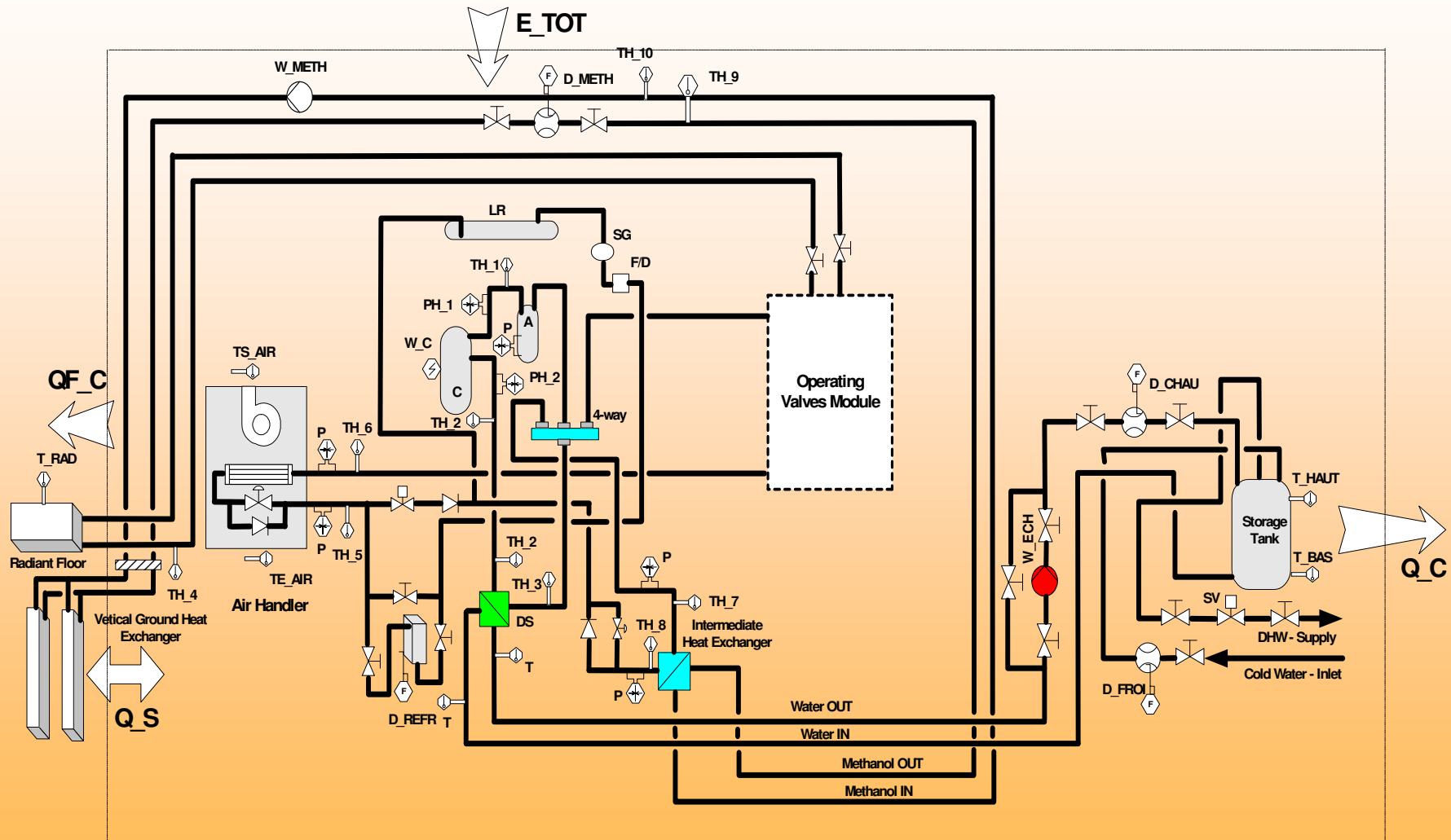
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***Hydro-Quebec Research Institute, LTE Laboratory
IEA HPP Annex 28 Workshop, Las Vegas, May 30, 2005***

Annex 28 – Canadian Contribution

- **Develop a Multi-Function Ground Source Heat Pump for Simultaneous Radiant Floor Space/DHW Heating and Space Air Cooling/DHW Production**
- **Test the first Laboratory Prototype**
- **Propose:**
 - **A Testing Procedure, and**
 - **A Calculation Method for the Simultaneous Seasonal Performance Factors**
- **By Extension of the ASHRAE 137 Standard**

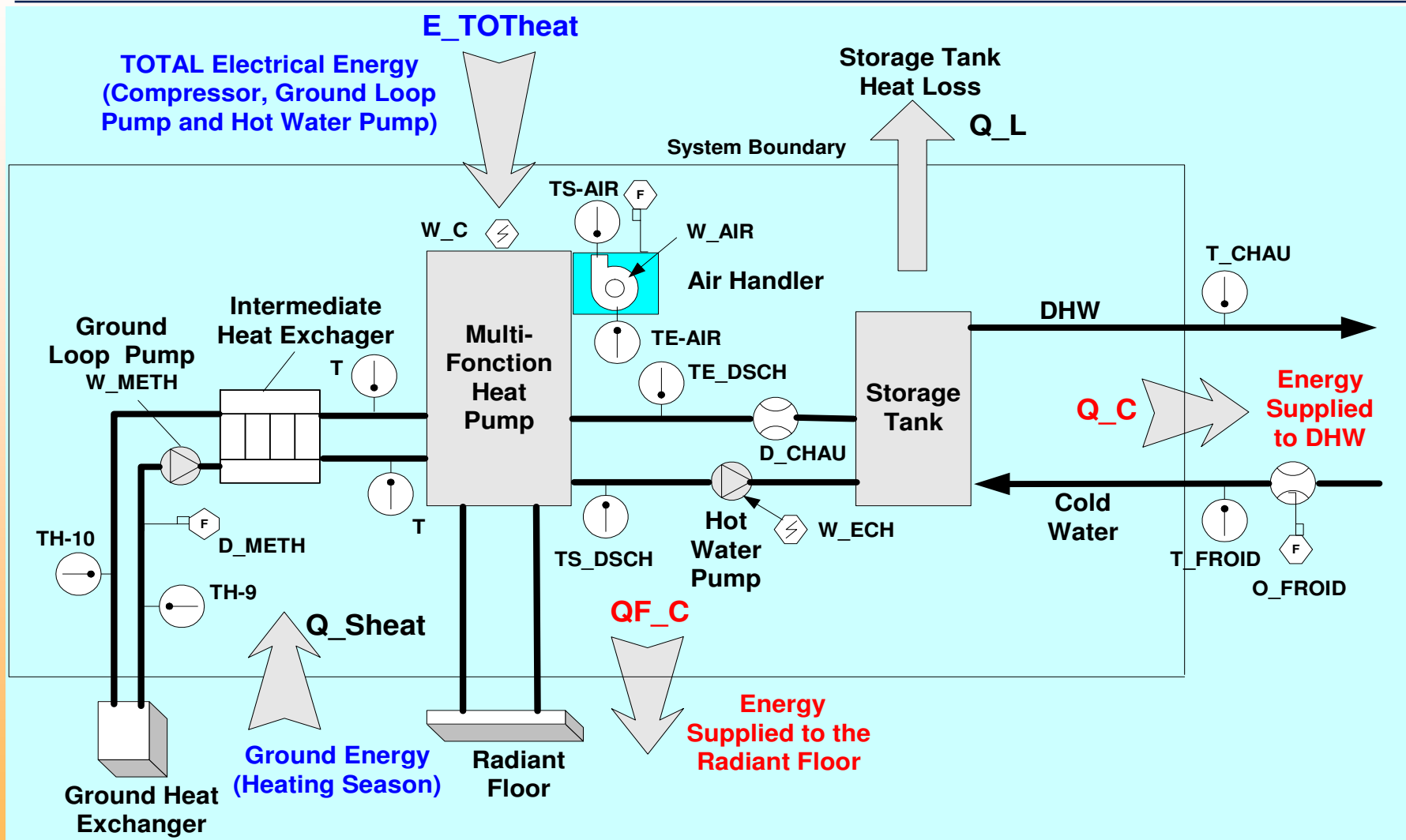
Multi-Function Ground Source Heat Pump (GEO-PAC)



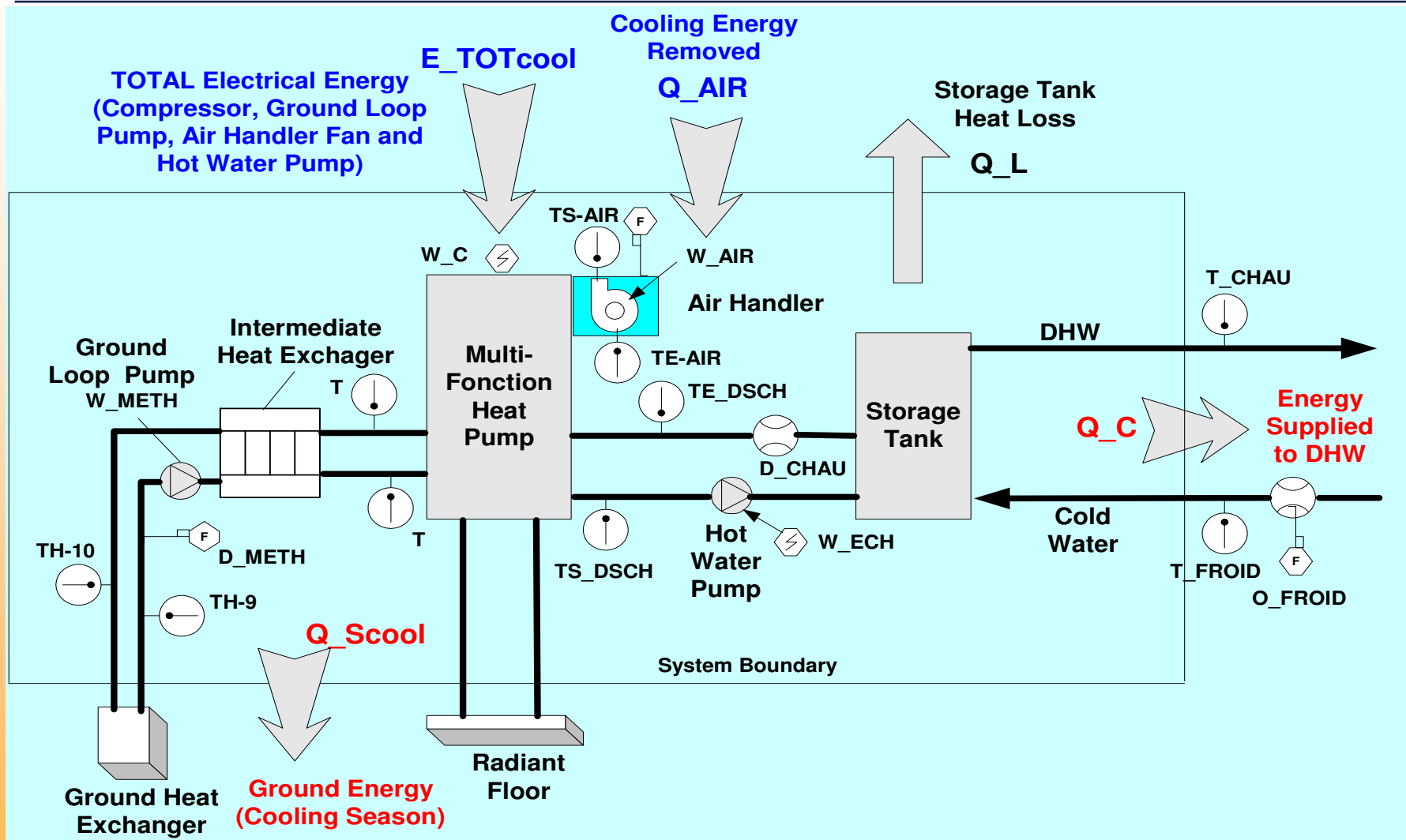
GEO-PAC



System Boundary – HEAT&DHW Mode



System Boundary – COOL&DHW Mode



Laboratory Test Procedure

- **Data acquisition (14/37 Parameters) - only when the compressor is running and all measured parameters are stable**
- **Data recording – at 15-second intervals and averaged at each 2-minute period**
- **The liquid pumps (DSH Water and Ground Brine) are not operating during the stand-by periods**
- **In HEAT&DHW mode, the system is regulated to keep the setting indoor temperature by Compressor ON/OFF or Fan ON/OFF methods**
- **In COOL&DHW mode, the system is regulated to keep the setting indoor temperature by Compressor ON/OFF method**

Performance Factors Calculation

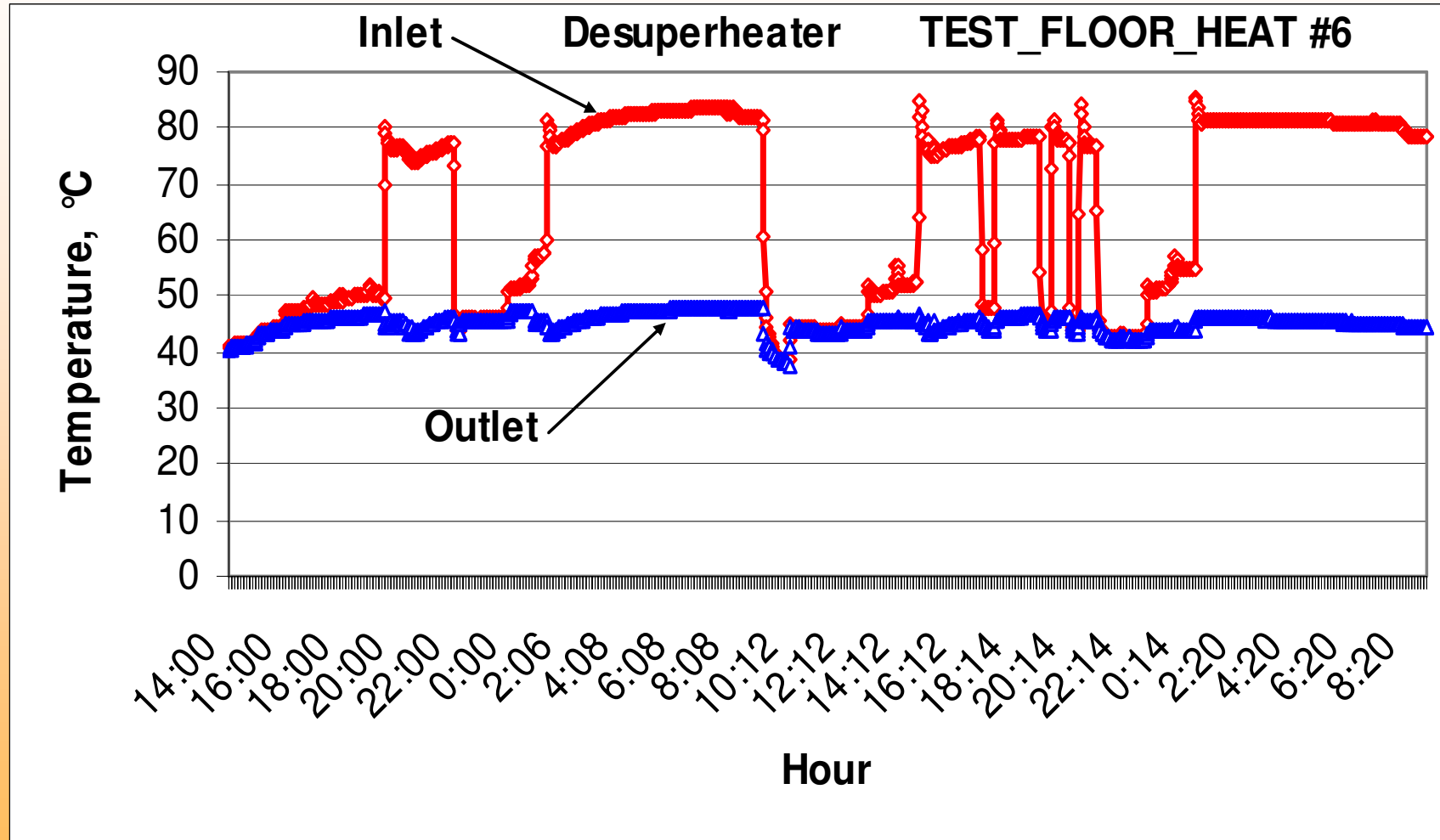
	SEER	HSPF	Simultaneous Performance Factor (SPF)	Equation
Space Cooling Only	ASHRAE 116-1995	-	-	-
Space Heating Only	-	ASHRAE 116-1995	-	-
Simultaneous Space-Floor Heating and Domestic Hot Water-Heating	-	-	$\text{SPF}^{\text{HEAT}} = \frac{\sum_{j=1}^n \left[\frac{q(t_j)}{N} + \frac{q_w(t_j)}{N} \right]}{3.413 \frac{\text{Btu/h}}{W} \sum_{j=1}^n \left[\frac{E(t_j)}{N} + \frac{ER(t_j)}{N} + \frac{RH(t_j)}{N} \right]}$	Equation 1
Simultaneous Space-Air Cooling and Domestic Hot Water-Heating	-	-	$\text{SPF}^{\text{COOL}} = \frac{\sum_{j=1}^n \left[\frac{q(t_j)}{N} + \frac{q_w(t_j)}{N} \right]}{3.413 \frac{\text{Btu/h}}{W} \sum_{j=1}^n \left[\frac{E(t_j)}{N} + \frac{ER(t_j)}{N} \right]}$	Equation 2
Water-Heating Only Season	-	-	$\text{SPF}^{\text{HEAT}} = \text{EF}$ <p>(Energy Factor "EF" determined as specified in ANSI/ASHRAE 118.2-2002)</p>	Equation 3

Results - Floor HEAT&DHW Mode

Test	Cold and DHW			W_C	DSH pump		W_METH	TH_9	TH_10	D_METH
HEAT	O_FROID	T_FROID	T_CHAU	-	W_ECH	-	-	-	-	-
-	Litres	°C	°C	kW	kW	L/min	kW	°C	°C	L/min
#4	23	17.3	35.8	1.06	0.088	3	0.22	9.8	3.5	10.2
#6	656	22.9	41.2	1.15	0.095	1	0.22	7.9	-0.4	10.3

Test	ON/OFF	PH_1	T_EVAP	PH_2	D_REF	TH_2	TH_3	T_COND	TH_4
HEAT	-	°C	°C	°C	kg/h	°C	°C	°C	°C
#4	COMP	100.3	-0.31	359.4	96	88.6	45.1	42.6	42
#6	FAN	103.4	0.1	388.3	96	90.9	65.4	45.9	41

Desuperheater - Refrigerant Temperatures



Floor HEAT&DHW Mode

Simultaneous Performance Factors

Test	Duration		QF_C	Q_D	η_H	E_C	EP_E	EP_M	Q_S ^H	Heat Loss	CPF ^H	ϵ_H
	Cycle	COMP										
.	Hrs	hrs	kWh	kWh	%	kWh	kWh	kWh	kWh	kWh	.	%
#4	1.5	1.44	7.0	1.76	20	1.6	0.13	0.33	6.6	0.08	4.29	6.83
#6	43.0	41.47	220	45.7	17	47.5	4.05	9.26	233	2.07	4.39	5.65

Results - Air COOL&DHW Mode

Test	Cold and DHW			W_C	DSH pump		W_METH	TH_9	TH_10	D_METH
COOL	O_FROID	T_FROID	T_CHAU		W_ECH					
-	Litres	°C	°C	kW	kW	L/min	kW	°C	°C	GPM
#09	412	14.0	34.5	0.50	0.087	3	0.21	11.2	19.2	10.5
#10	407	13.8	33.7	0.56	0.095	3	0.23	11.6	19.2	10.5
#11	405	13.6	22.8	0.47	0.089	3	0.22	11.4	19.2	10.3
#12	366	13.1	25.6	0.48	0.091	1	0.22	11.3	18.7	10.5
#13	387	8.0	21.3	0.42	0.092	1	0.22	9.9	15.9	10.3

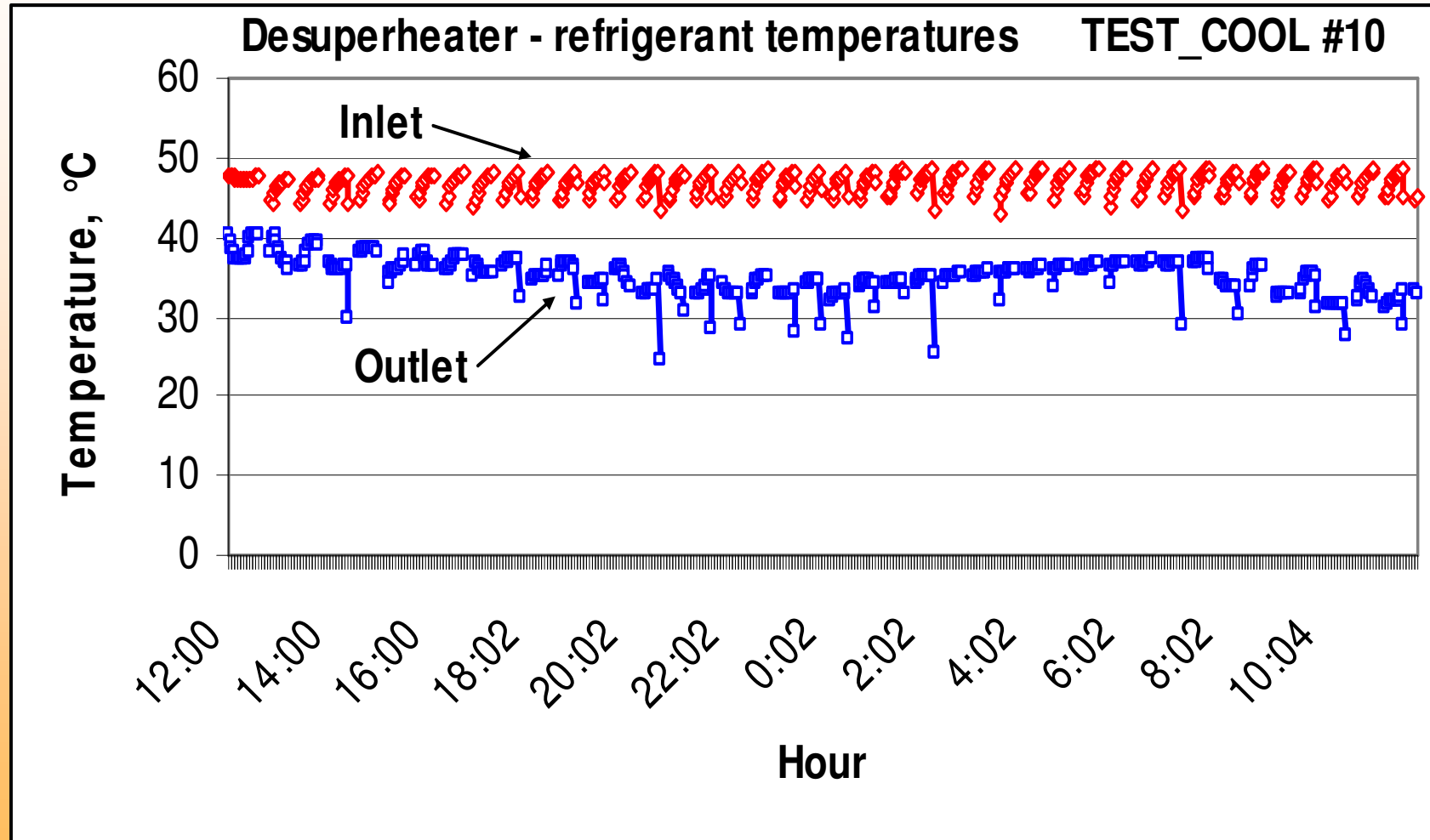
Test	TH_2	TH_3	TE_AIR	TS_AIR	T_EVAP	T_COND
COOL	°C	°C	°C	°C	°C	°C
#09	47.2	35.8	24	9	1.3	23.6
#10	46.9	35.1	23.8	9.5	1.3	23.6
#11	43.9	27.9	24	9.4	0.5	23.7
#12	46.7	28.4	23.8	8.3	0.2	23,2
#13	46.3	22.7	16	3.8	-3.6	19.8

Air COOL&DHW Mode

Simultaneous Performance Factors

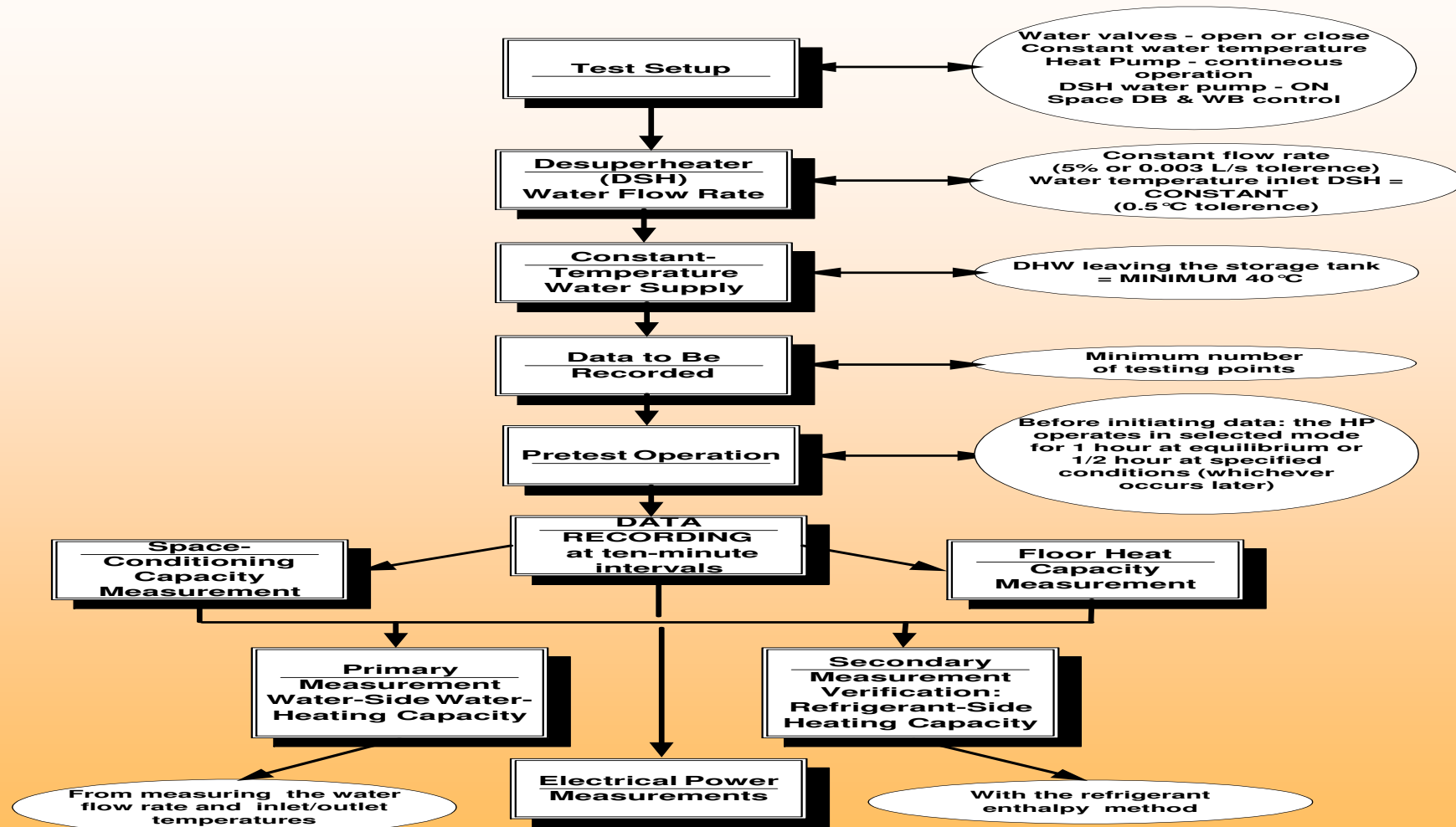
Test	Duration		Q_S ^C	Q_D	η_c	E_C	EP_E	EP_M	EV_A	Q_A	Q_L	CPF ^C	ε_c
COOL	Cycle	COMP
.	Hrs	Hrs	kWh	kWh	%	kWh	kWh	kWh	kWh	kWh	kWh	.	%
#09	24	17.7	103	14	12	8.7	1.61	3.9	4.38	104	0.7	6.36	4
#10	24	16	109	11.9	9.9	8.1	1.5	3.7	4.2	107	0.64	6.81	5
#11	24	17	94	11.9	11.2	7.9	1.5	3.7	4.1	102	0.7	6.62	3.7
#12	24	17.6	102	13.4	11.6	8.4	1.6	3.9	4.4	114	0.7	6.96	6
#13	24	15.8	66	12	15.4	6.5	1.45	3.6	4.0	75	0.61	5.62	4.5

Desuperheater - Refrigerant Temperatures



Extension of ASHRAE 137 Standard

Proposed Testing Method



Proposed Test Conditions

ST #	Inlet BRINE Temperature*	Brine Flow Rate	Refrigerant Direct Condensing Temperature (FLOOR)	Simultaneous Operating Mode (Conditions)	Minimum Water Tapping Temperature	Air Surrounding Indoor Unit (Dry bulb)
-	°C	L/s	°C	-	°C	°C
1	-5	Manufacturer	45	Floor HEAT&DHW (Low Temperature)	40	21.1
2	0	Manufacturer	45	Floor HEAT&DHW (Standard)	40	21.1
3	+5	Manufacturer	45	Floor HEAT&DHW (High Temperature)	40	21.1
4	+10	Manufacturer	35	Air COOL&DHW	30	26.7

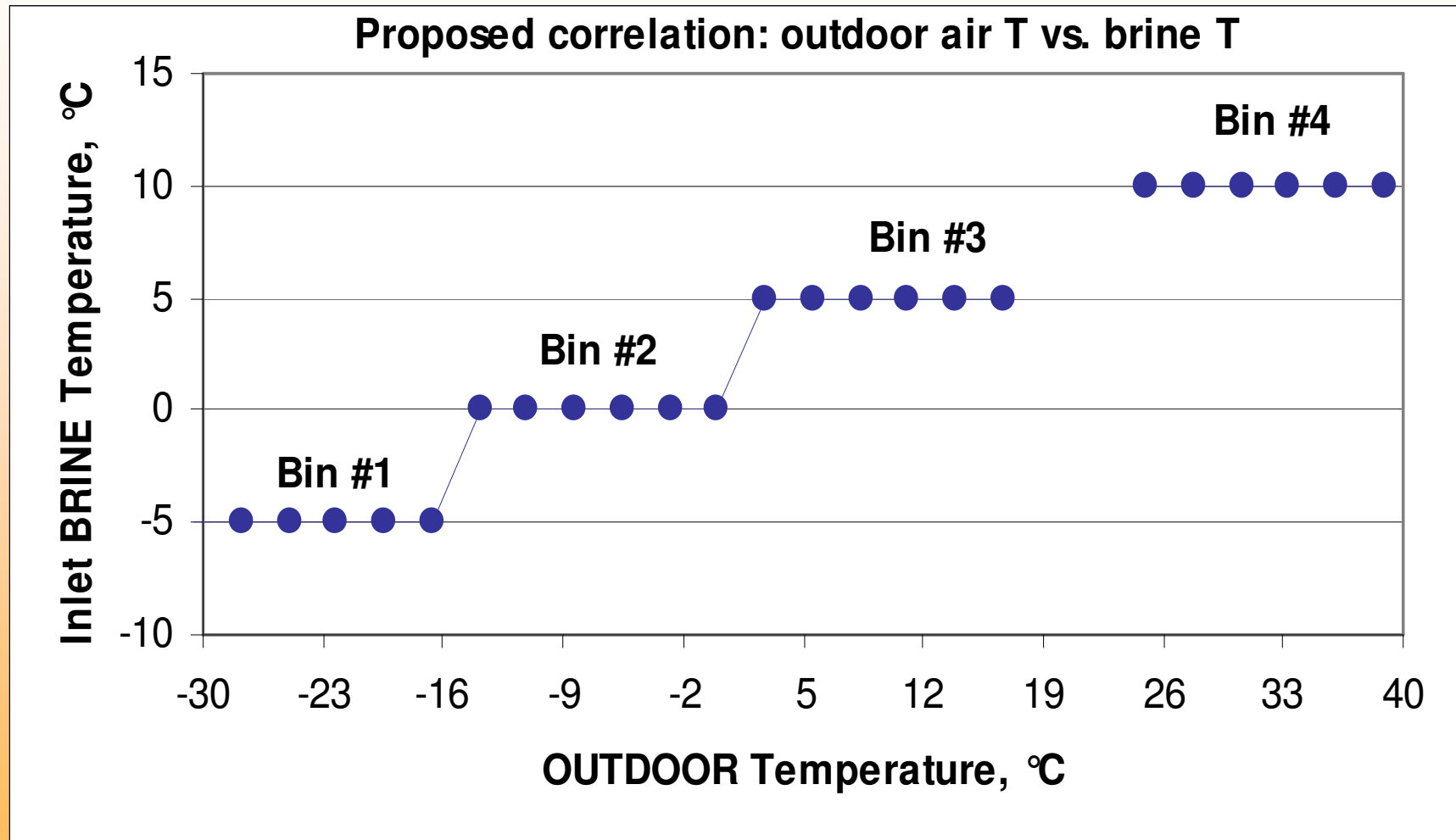
Proposed Calculation Method

(according with the ASHRAE 137 Standard)

Proposed Tests Number and Fractional BIN Hours

TEST #	Outdoor Bin Temperature	Corresponding Fractional Bin Hours	BRINE Inlet Temperature	Simultaneous Operating Mode	Season and Test Conditions
	t_j	n_j/N^*	$t_{b,inlet}$	-	-
-	°C	-	°C	-	-
#1	-30.5 to -16.6	0.065	- 5	Floor HEAT&DHW	Winter Low Temperature
#2	-13.8 to 0	0.41	0	Floor HEAT&DHW	Winter Standard Conditions
#3	2.7 to 16.6	0.525	+5	Floor HEAT&DHW	Transition High Temperature
-	19.4 to 22.2	0.445	-	-	Thermal Equilibrium
#4	25 to 38.8	0.555	+ 10	Air COOL&DHW	Summer

Proposed Correlation between the Outdoor Air and Inlet Brine Temperatures



Proposed Distribution of the Fractional BIN Hours as Function of the BIN's Brine Inlet Temperature

