DETAILED HEAT RECOVERY SYSTEM CALCULATION PROCEDURE

- The following procedue is extracted from ASHRAE 2008 Handbook - HVAC Systems and Equipment - Chapter 25 (Air-to-Air Energy Recovery Equipment**), and it is generic for all energy recovery system types (**Liquid coupled, energy wheel, and plate heat exchanger**)**

$$\varepsilon = \frac{\text{Actual transfer of moisture or energy}}{\text{Maximum possible transfer between airstreams}} \quad (1)$$

$$\varepsilon_s = \frac{q_s}{q_{s,max}} = \frac{m_s c_{ps}(t_2 - t_1)}{C_{min}(t_3 - t_1)} = \frac{m_s c_{pe}(t_3 - t_4)}{C_{min}(t_3 - t_1)} \quad (2a)$$

where q_s is the actual sensible heat transfer rate given by

where $q_{s,max}$ is the maximum sensible heat transfer rate given by

$$q_{s,max} = 60C_{min}(t_3 - t_1) \quad (2c)$$

where

ε_s = sensible effectiveness
t_1 = dry-bulb temperature at location 1 in Figure 1, °F
m_s = supply dry air mass flow rate, lb/min
m_e = exhaust dry air mass flow rate, lb/min
C_{min} = smaller of $c_{ps}m_s$ and $c_{pe}m_e$
c_{ps} = supply moist air specific heat at constant pressure, Btu/lb·°F
c_{pe} = exhaust moist air specific heat at constant pressure, Btu/lb·°F

Assuming no water vapor condensation in the HRV, the leaving supply air condition is

$$t_2 = t_1 - \varepsilon_s \frac{C_{min}}{m_s c_{ps}}(t_1 - t_3) \quad (3a)$$

and the leaving exhaust air condition is

$$t_4 = t_3 + \varepsilon_s \frac{C_{min}}{m_e c_{pe}}(t_1 - t_3) \quad (3b)$$

$$\varepsilon_L = \frac{q_L}{q_{L,max}} = \frac{m_s h_{fg}(w_1 - w_2)}{m_{min} h_{fg}(w_1 - w_3)} = \frac{m_e h_{fg}(w_4 - w_3)}{m_{min} h_{fg}(w_1 - w_3)} \quad (4a)$$

where q_L is the actual latent heat transfer rate given by

$$q_L = \varepsilon_L q_{L,max} \quad (4b)$$

where $q_{L,max}$ is the maximum heat transfer rate given by

$$q_{L,max} = 60 m_{min} h_{fg}(w_1 - w_3) \quad (4c)$$

where

ε_L = latent effectiveness
h_{fg} = enthalpy of vaporization, Btu/lb
w = humidity ratios at locations indicated in Figure 1
m_s = supply dry air mass flow rate, lb/min
m_e = exhaust dry air mass flow rate, lb/min
m_{min} = smaller of m_s and m_e

Assuming no water vapor condensation in the ERV, the leaving humidity ratios can be given as follows. The supply air leaving humidity ratio is

$$w_2 = w_1 - \varepsilon_L \frac{m_{w,min}}{m_s}(w_1 - w_3) \quad (5a)$$

and the leaving exhaust air humidity ratio is

$$w_4 = w_3 + \varepsilon_L \frac{m_{w,min}}{m_s}(w_1 - w_3) \quad (5b)$$

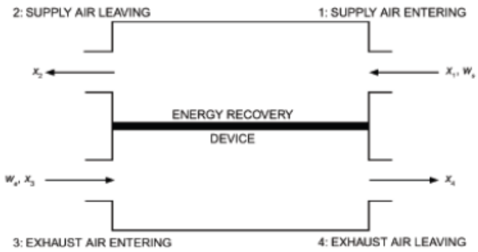


Fig. 1 Airstream Numbering Convention

The total effectiveness ε_t of an energy recovery ventilator is given as

$$\varepsilon_t = \frac{q_t}{q_{t,max}} = \frac{m_s(h_2 - h_1)}{m_{min}(h_3 - h_1)} = \frac{m_e(h_3 - h_4)}{m_{min}(h_3 - h_1)} \quad (6a)$$

where q_t is the actual total heat transfer rate given by

$$q_t = \varepsilon_t q_{t,max} \quad (6b)$$

where $q_{t,max}$ is the maximum total heat transfer rate given by

$$q_{t,max} = 60 m_{min}(h_1 - h_3) \quad (6c)$$

where

ε_t = total effectiveness
h = enthalpy at locations indicated in Figure 1, Btu/lb
m_s = supply dry air mass flow rate, lb/min
m_e = exhaust dry air mass flow rate, lb/min
m_{min} = smaller of m_s and m_e

The leaving supply air condition is

$$h_2 = h_1 - \varepsilon_t \frac{m_{min}}{m_s}(h_1 - h_3) \quad (7a)$$

and the leaving exhaust air condition is

$$h_4 = h_3 + \varepsilon_t \frac{m_{min}}{m_e}(h_1 - h_3) \quad (7b)$$

DETAILED HEAT RECOVERY CALCULATION

LIQUID COUPLED HEAT RECOVERY SYSTEM

FOR : AHU-P-1 Arrangement 2

, and EX.FAN-P-1 Arrangement 2

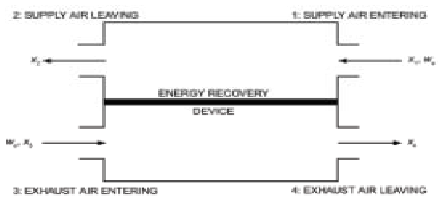
A: Input Data

ITEM	OUTSIDE AIR STREAM INLET CONDITIONS (1)				EXHAUST AIR STREAM INLET CONDITIONS (3)			
Air flow rate	V_s	=	24000	CFM	V_e	=	24000	CFM
Dry Bulb Temp.	$T_{db,1}$	=	113	F	$T_{db,3}$	=	78.8	F
Wet Bulb Temp	$Tw_{b,1}$	=	68.99	F	$Tw_{b,3}$	=	66.66	F
Relative Humidity	$RH_1\%$	=	8.62		$RH_2\%$	=	50	
Density	ρ_1	=	0.0686	lb/ft^3	ρ_3	=	0.0722	lb/ft^3
Humidity Ratio	x_1	=	0.00512	lb/lb	x_3	=	0.01094	lb/lb
Enthalpy	h_1	=	32.81	BTU/lb	h3	=	31.19	BTU/lb
Specific Heat	$C_{p,s}$	=	0.24	BTU/lb.F	$C_{p,e}$	=	0.24	BTU/lb.F

B: Calculation

- Refer to the introduction page for calculation procedure and equations.

Effectiveness of sensible heat	ξ_s	=	0.65	
	$m_s \cdot C_{p,s}$	=	395.14	BTU/min.F
	$m_e \cdot C_{p,e}$	=	415.58	BTU/min.F
Smaller of $m_s.Cp_s$, and $m_e.Cp_e$	C_{min}	=	395.14	BTU/min.F
Max heat transfer	$q_{s, max}$	=	810,819.07	BTU/hr
Actual heat treansfer	q_s	=	527,032.40	BTU/hr



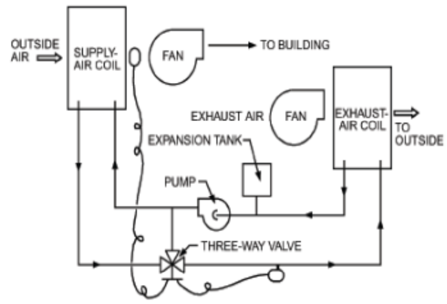


Fig. 8 Coil Energy Recovery Loop

C: Output Data

OUTSIDE AIR STREAM OUTLET CONDITIONS (2)	$T_{db,2}$	=	90.77	F
	x_2	=	0.0051	lb/lb
	h_2	=	32.81	BTU/lb

EXHAUST AIR STREAM OUTLET CONDITIONS (4)	$T_{db,4}$	=	99.94	F
	x_4	=	0.0109	lb/lb
	h_4	=	31.19	BTU/lb

SENSIBLE HEAT REDUTION	q_s	=	**527,032.40**	BTU/hr

Heat recovery coil:Water inlet Temp.	T_{wi}	=	89.37	F
Heat recovery coil:Water outlet Temp.	T_{wo}	=	101.89	F
Heat recovery coil:Water Temp. dff.	ΔT_w	=	13	F
Heat recovery coil: Water Flow Rate	Q_w	=	84.21	US GPM
Heat Recovery Pump Absorbed Power	P	=	0.71	HP
Heat Recovery Pump Motor Power	P	=	1	HP

HVAC WORKS - HEAT RECOVERY EFFECT

LIQUID COUPLED TYPE

AHU	FAN	COOLING LOAD BEFORE HEAT RECOVERY, MBH	COOLING LOAD AFTER APLYING HEAT RECOVERY, MBH	AMOUNT OF COOLING LOAD REDUCTION		
				MBH	TR	kW
AHU-1	EX.FAN-1	1,503.4	927.2	576.2	48.0	168.9
AHU-2	EX.FAN-2	563.8	347.7	216.1	18.0	63.3
AHU-3	EX.FAN-3	1,046.1	645.1	400.9	33.4	117.5
AHU-4	EX.FAN-4	814.3	502.2	312.1	26.0	91.5
AHU-G-1	EX.FAN-G-1	1,127.5	695.4	432.2	36.0	126.7
AHU-1-4	EX.FAN-1-1	3,132.0	1,931.6	1,200.4	100.0	351.8
AHU-1-5	EX.FAN-1-2	1,378.1	849.9	528.2	44.0	154.8
AHU-2-4	EX.FAN-2-4	375.8	231.8	144.1	12.0	42.2
AHU-2-5	EX.FAN-2-5	3,132.0	1,931.6	1,200.4	100.0	351.8
AHU-2-6	EX.FAN-2-6	1,879.2	1,158.9	720.3	60.0	211.1
AHU-2-7	EX.FAN-2-7	1,879.2	1,158.9	720.3	60.0	211.1
AHU-2-8	EX.FAN-2-8	877.0	540.8	336.1	28.0	98.5
AHU-5-1	EX.FAN-5-1	2,944.1	1,815.7	1,128.4	94.0	330.7
AHU-5-2	EX.FAN-5-2	2,630.9	1,622.5	1,008.4	84.0	295.5
AHU-5-3	EX.FAN-5-3	375.8	231.8	144.1	12.0	42.2
Total		**32,303.4**	**19,922.3**	**12,381.1**	**1,031.8**	**3,628.7**

DETAILED ENERGY RECOVERY CALCULATION

ROTARY WHEEL (ENTHALPY WHEEL) ENERGY RECOVERY SYSTEM

FOR : AHU-GR-2 Arrangement 3

, and EX.FAN-GR-1 Arrangement 3

A: Input Data

ITEM	SUPPLY AIR STREAM INLET CONDITIONS (1)				EXHAUST AIR STREAM INLET CONDITIONS (3)			
Air flow rate	V_s	=	40000	CFM	V_e	=	40000	CFM
Dry Bulb Temp.	$T_{db,1}$	=	113	F	$T_{db,3}$	=	80	F
Wet Bulb Temp	$T_{wb,1}$	=	68.99	F	$T_{wb,3}$	=	66.66	F
Relative Humidity	RH_1	=	8.62	%	RH_2	=	50	%
Density	ρ_1	=	0.0686	lb/ft^3	ρ_3	=	0.0722	lb/ft^3
Humidity Ratio	x_1	=	0.00512	lb/lb	x_3	=	0.01094	lb/lb
Enthalpy	h_1	=	32.81	BTU/lb	h_3	=	31.19	BTU/lb
Specific Heat	$C_{p,s}$	=	0.24	BTU/lb.F	$C_{p,e}$	=	0.24	BTU/lb.F

B: Calculation

- Refer to the introduction page for calculation procedure and equations.

Effectiveness of sensible heat transfer	ξ_s	=	0.65	
	$m_s . C_{p,s}$	=	658.56	BTU/min.F
	$m_e . C_{p,e}$	=	692.64	BTU/min.F
Smaller of $m_s.Cp_s$, and $m_e.Cp_e$	C_{min}	=	658.56	BTU/min.F
Max heat transfer	$q_{s, max}$	=	1,303,948.80	BTU/hr
Actual heat treansfer	q_s	=	847,567	BTU/hr
Effectiveness of latent heat	ξ_L	=	0.65	
	q_L	=	-685,116	BTU/hr
Effectiveness of total heat	ξ_T	=	0.65	
SAVING IN TOTAL LOAD	q_T	=	847,567	BTU/hr

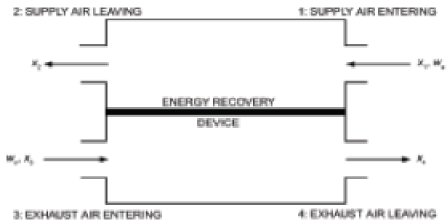


Fig. 1 Airstream Numbering Convention

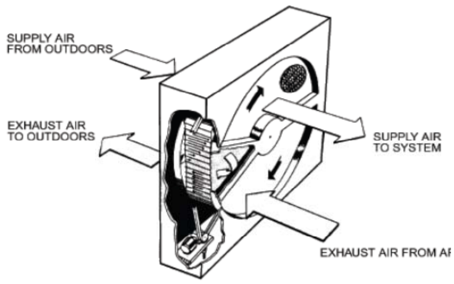


Fig. 6 Rotary Air-to-Air Energy Exchanger

C: Output Data

OUTSIDE AIR STREAM OUTLET CONDITIONS (2)	$T_{db,2}$	=	91.55	F
	x_2	=	0.0089	lb/lb
	h_2	=	31.76	BTU/lb

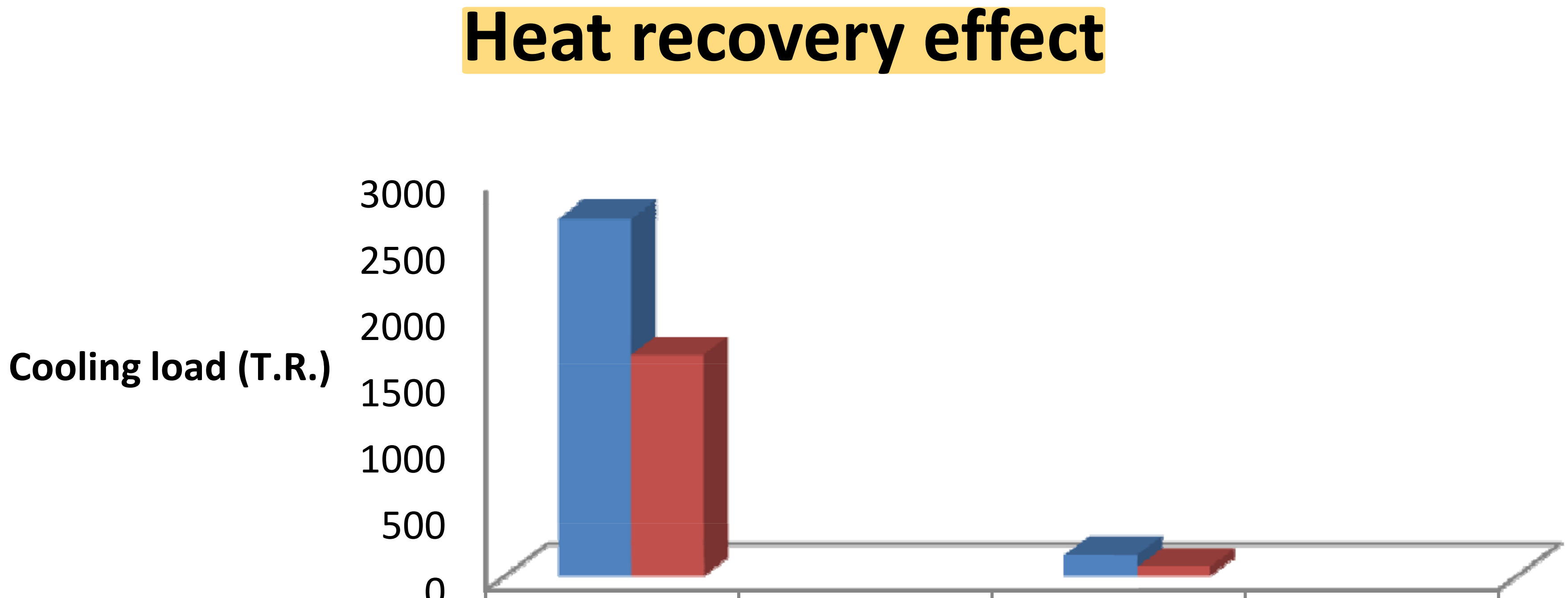
EXHAUST AIR STREAM OUTLET CONDITIONS (4)	$T_{db,4}$	=	100.39	F
	x_4	=	0.0072	lb/lb
	h_4	=	32.24	BTU/lb

SENSIBLE HEAT REDUTION	q_s	=	847,566.72	BTU/hr
LATENT HEAT REDUCTION	q_L	=	-685,116.43	BTU/hr
TOTAL LOAD REDUCTION	➡ q_T	=	847,566.72	BTU/hr

HVAC WORKS - HEAT RECOVERY EFFECT

ROTARY ENERGY WHEEL TYPE

AHU	FAN	COOLING LOAD BEFORE HEAT RECOVERY, MBH	COOLING LOAD AFTER APLYING HEAT RECOVERY, MBH	AMOUNT OF COOLING LOAD REDUCTION		
				MBH	TR	kW
AHU-P-6	EX.FAN-P-6	307.8	134	173.8	14.5	50.9
AHU-G-2	EX.FAN-G-1	1641.36	714.96	926.4	77.2	271.5
Total		**1,949.2**	**849.0**	**1,100.2**	**91.7**	**322.5**



	Liquid coupled effect (T.R.)		Energy wheel effect (T.R.)	
Before Heat Recovey	2692		162	
After Heat Recovery	1660		71	