Assignment 02 – Heat Recovery Systems, Thermal Storage Systems, Noise and Vibration Control (2022-2023)

1. Heat Recovery Systems

1.1 Calculate the supply air conditions leaving a total heat recovery wheel with 5.6 m^3/s of outside air at 34 °C dry bulb and 25 °C wet bulb; and 5.6 m^3/s of return air at 24 °C dry bulb and 50% RH, if both the sensible and latent effectiveness of the wheel is 60%. Also, calculate the reduction in required cooling energy. Discuss the advantages and disadvantages of using total heat recovery wheel for heat recovery in buildings.

(17 marks)

1.2 Explain the working principles of a heat recovery chiller. Illustrate with diagrams. Discuss the difference between heat recovery chiller and heat pump when applied for heat recovery applications.

(16 marks)

2. Thermal Storage Systems

2.1 Discuss the benefits of thermal storage in HVAC systems. Compare the principles and major characteristics of sensible and latent thermal energy storage techniques. Explain how to consider the sizing options for thermal storage systems.

(14 marks)

2.2 A glycol-based ice thermal storage system is designed for a building. A summary of the utility period, design day cooling load profile and cooling mode is shown in Table 1. For quick sizing of chiller and storage capacity, the following equations can be used.

Nominal chiller size
= Total cooling load for 24 hours / ($H_{chrg}.CR_{chrg} + H_{DConp}.CR_{DConp} + H_{DCoffp}.CR_{DCoffp}$)

Storage capacity = Total cooling load for 24 hours – ($TC_{DConp} + TC_{DCoffp} + KH_{DCchrg}$)

where H_{chrg} = hours charging storage
CR_{chrg} = capacity ratio when charging storage
H_{DConp} = hours of direct cooling during the on-peak period
CR_{DConp} = capacity ratio when direct cooling during on-peak period
H_{DCoffp} = hours direct cooling during off-peak period
CR_{DCoffp} = capacity ratio when direct cooling during off-peak period
TC_{DConp} = total capacity when direct cooling during on-peak
TC_{DCoffp} = total capacity when direct cooling during off-peak
KH_{DCchrg} = kW-hours direct cooling while simultaneously charging

If the charging capacity ratio is 0.7 and the direct cooling capacity ratio is 1.0, calculate the nominal chiller size and storage capacity for: (a) daily full storage option where all on-peak cooling will be supplied from storage, (b) daily partial storage option with load leveling, and (c) daily partial storage option with demand limiting. Plot the graphs of

24-hour load profile to illustrate these three operation strategies or options.

(20 marks)

Table 1. Utility period, cooling load profile and cooling mode

Hour	Utility period	Load (kW)	Cooling mode
1	Off-peak	0	Charging
2	Off-peak	0	Charging
3	Off-peak	0	Charging
4	Off-peak	0	Charging
5	Off-peak	0	Charging
6	Off-peak	0	Charging
7	Off-peak	0	Charging
8	Off-peak	3020	Met while charging
9	Off-peak	9450	Discharging and direct cooling
10	Off-peak	10,500	Discharging and direct cooling
11	On-peak	11,800	Discharging and direct cooling
12	On-peak	12,850	Discharging and direct cooling
13	On-peak	13,550	Discharging and direct cooling
14	On-peak	13,300	Discharging and direct cooling
15	On-peak	13,550	Discharging and direct cooling
16	On-peak	13,000	Discharging and direct cooling
17	On-peak	12,050	Discharging and direct cooling
18	On-peak	10,700	Discharging and direct cooling
19	On-peak	0	Charging
20	On-peak	0	Charging
21	On-peak	0	Charging
22	Off-peak	0	Charging
23	Off-peak	0	Charging
24	Off-peak	0	Charging

3. Noise and Vibration Control

3.1 Describe the typical HVAC noise sources and noise transmission paths. Illustrate with diagrams. Explain the common solutions for HVAC vibration control.

(13 marks)

3.2 A 600 mm × 800 mm × 10 m long rectangular supply duct for a storeroom in a building is constructed of 0.75 mm sheet metal. Given the following information about the sound power levels produced for a 0.75 m diameter backward-curved centrifugal fan in the duct and the duct breakout transmission loss, calculate the breakout sound pressure levels at different frequencies at 3 m from the surface of the duct. From the calculated sound pressure levels, determine the total A-weighted dB level and the noise criterion (NC) level. Comment on the noise criteria for the building space.

	One-octave band centre frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
$L_{w(in)}$ (dB)	85	85	84	79	75	68	64	62
TL_{out} (dB)	-20	-23	-26	-29	-32	-37	-43	-45

$L_{w(out)} = L_{w(in)} + 10 \log (S/A) - TL_{out}$

$L_p = L_{w(\text{out})} - 10 \log (\pi\, r\, L)$

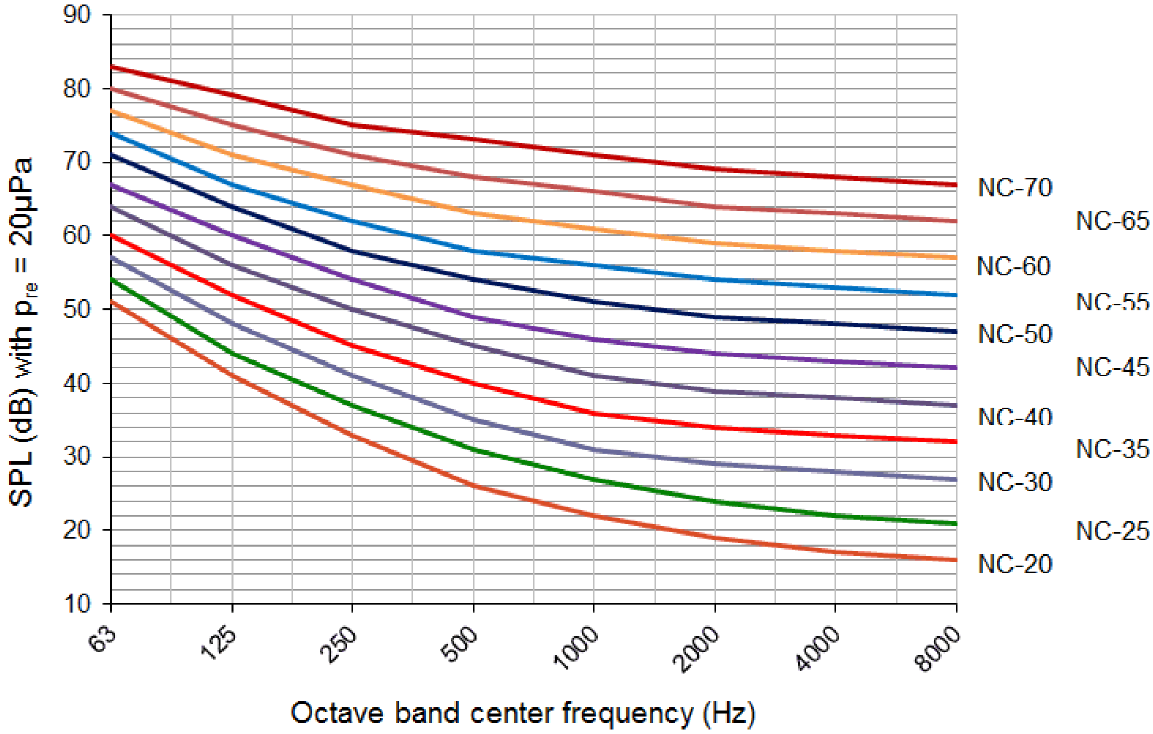
where $L_{w(in)}$ = sound power level of sound inside duct, dB
$L_{w(out)}$ = sound power level of sound radiated from the outside surface (breakout) of duct walls, dB
S = surface area of outside sound-radiating surface of duct, m^2
A = cross-section area of inside of duct, m^2
For rectangular ducts, $S = 2\,L\,(a + b)$; $A = a \times b$
L = length of the duct sound-radiating surface, m
a, b = dimensions of the rectangular duct, m
TL_{out} = normalized duct breakout transmission loss, dB
L_p = sound pressure level at a specified point in the space, dB
r = distance between duct and position for which L_p is calculated, m

A-weighting adjustment:

	One-octave band centre frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
A-weighting (dB)	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

Total sound pressure level dB = 10 log $(10^{0.1Lp1} + 10^{0.1Lp2} + \ldots + 10^{0.1Lp8})$

Noise criterion (NC) curves:



(20 marks)