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NATIONAL STUDENT DESIGN COMPETITION

DESIGNING THE HVAC SYSTEM FOR A THREE SCREEN MULTIPLEX

A PROJECT DONE BY
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PRESENTED BY ISHRAE JADAVPUR UNIVERSITY STUDENT CHAPTER

ACKNOWLEDGEMENT

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ABSTRACT

Human comfort is essential now a days because of the improvement in life style and increasing atmospheric temperature. Due to rapid urbanization ,industrialization and excessive use of fossil fuels ,the air quality is rapidly falling as this generation progresses .Air pollution has become a major issue nowadays and designing a healthy and safe environment is now of utmost importance. Adequate temperature and humidity definitely necessary for different jobs as well. For example, in mint excessive humidity will cause notes to be smudgy while less humidity will cause the notes to crumble. Electrical individual air conditioning machines are not suitable for large buildings because of the higher power consumption for shorter life. Central air conditioning with proper air filtration techniques is more reliable for easy operation with lower maintenance cost. All large buildings like commercial complex,auditorium, cineplex, office buildings are provided with central air conditioning systems. The effective design of central air conditioning can provide lower power consumption, capital cost and improve aesthetics of a building. This project establishes the cooling load calculation of different climate conditions by using CLTD methods for a three screen multiplex.

Cooling load is calculated based on the heat generation due to various reasons such as people ,lighting , infiltration ,ventilation ,solar exposure , have been calculated using standard heat load calculation techniques and tabulated using MS-Excel.

A. OBJECTIVE

The objective of this project is to calculate cooling load to find exact ratings of air conditioning equipment and air handling unit to achieve comfort operation and good air distribution in the air-conditioned region.

A.1 HVAC SYSTEM DESIGN

The main objective of designing the HVAC system are as follows

- Control of temperature, humidity, air purity and correct pressurization to avoid contamination.
- Provide comfort and healthy indoor environment for the cineplex.
- Provide special air filtration to remove bacteria, maintain high indoor air quality and avoid cross contamination.

A.2 COOLING LOAD CALCULATIONS

The objectives of cooling load calculations are as follows

- To determine the optimum rate at which heat needs to be removed from space to establish thermal equilibrium and maintain a pre-determined inside condition.
- To calculate peak design loads(cooling/heating)
- To estimate capacity of equipment required

B. DATA COLLECTION AND METHODOLOGY

B.1 BASIC INFORMATION

Before estimating cooling load of any building there are some basic information necessary to design an exact HVAC system, like building orientation, weather condition, building spacing, building materials etc. The more exact the information the more accurate will be the load estimated.

B.1.1 Building Location

The three-screen multiplex considered in this study is situated in Kolkata and located at 22.5726°N latitude and 88.3639°E longitude in West Bengal, India at an elevation of about 9.1 meters above sea level.

B.1.2 Climate Condition

Kolkata has tropical wet and dry climate. The annual mean temperature is 24.8°. The highest rainfall occurs during monsoon in the month of August.

Table 1: Average high and low temperature (in °C) of Kolkata according to months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High	27	29	34	36	36	33	32	32	32	32	29	26
Average Low	13	15	21	24	25	26	26	26	26	24	18	13

Table 2: Average relative humidity according to months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average RH %	66	58	58	66	70	77	83	83	81	73	67	68

B.1.3 Building Structures

The dimensions of the cineplex which is to be air conditioned is 56m*27.35m*12.15 m in size. It has three auditoriums, two washrooms, a restaurant and a lobby. The exterior walls of buildings consist of 616.5 mm common brick+air space+616.5 mm common brick. The interior walls of the building consist of 587 mm common brick. The roof is made of fiber glass material with a gypsum false ceiling. The window consists of double glass material of 13 mm thick with frame panel.

C. LOAD COMPONENTS

The total heat required to be removed from the space in order to bring it at the desired temperature of (22°C-25°C) and relative humidity (50%) by the air conditioning equipment is known as cooling load or conditioned load. The load consists of external loads and internal loads.

C.1 Heat Gain from Occupants

The human body in a cooled space constitute cooling load of sensible and latent heat. In an air conditioned room, sensible heat load given out is due to temperature difference between body and room air. The heat gain from occupants is based on the average number of people that are expected to be present in a conditioned space. The heat load produced by each person depends upon the activity of the person. The value of the heat gain increases with increase in activity of the human being.

The heat gain from occupancy or people are calculated by the following equations.

Sensible heat gain from occupants

$$Q_{S,person} = q_{S,person} * N * CLF$$

Latent heat gain from occupants

$$Q_{L,person} = q_{L,person} * N$$

where $q_{S,person}$=sensible heat gain/person (W)

$q_{L,person}$=latent heat gain/person (W)

N=total number of people present in conditioned space

CLF=cooling load factor

Table 4: Rate of heat gain from occupants in conditioned space(W)

Degree of Activity	Type of Applications	Total Heat		Sensible Heat	Latent Heat
		Adult, Male	Adjusted		
Seated at Theater	Theater, matinee	115	95	65	30
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department store; retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurants	145	160	80	80
Light bench work	Factory	235	220	80	140
Moderate dancing	Dance hall	265	250	90	160
Bowling	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Athletics	Gymnasium	585	525	210	315

Table 5: Sensible heat cooling load factor (CLF) for people

Total Hours in space						**Hrs. after each entry into space**						
1	1	2	3	4	5	6	7	8	9	10	11	12
2	0.49	0.58	0.17	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.03
4	0.49	0.59	0.66	0.71	0.27	0.21	0.16	0.14	0.11	0.10	0.08	0.07
6	0.50	0.60	0.67	0.72	0.76	0.79	0.34	0.26	0.21	0.18	0.15	0.13
8	0.51	0.61	0.67	0.72	0.76	0.80	0.82	0.84	0.38	0.30	0.25	0.21
10	0.53	0.62	0.69	0.74	0.77	0.80	0.83	0.85	0.87	0.89	0.42	0.34
12	0.55	0.64	0.70	0.75	0.79	0.81	0.84	0.86	0.88	0.89	0.91	0.92
14	0.58	0.66	0.72	0.77	0.80	0.83	0.85	0.87	0.89	0.90	0.91	0.92
16	0.62	0.70	0.75	0.79	0.82	0.85	0.87	0.88	0.90	0.91	0.92	0.93
18	0.66	0.74	0.79	0.82	0.85	0.87	0.89	0.90	0.92	0.93	0.94	0.94

C.2 HEAT GAIN FROM ELECTRIC EQUIPMENT

The general electrical equipment and appliances such as projectors, sound box, speakers, kitchen equipment also add heat in the air conditioning space. The heat gain by the equipment is determined by the wattage of the equipment and is calculated by

$$Q_{equipment} = \text{Total wattage of equipment} * \text{Use factor} * CLF$$

C.3 SENSIBLE HEAT GAIN THROUGH OPAQUE SURFACES

C.3.1. Overall Heat Transfer Coefficient Calculation

Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation. All material has different kinds of thermo-physical properties; the thermo-physical properties of common building materials have been measured and presented in ASHRAE and other handbooks.

Thermal conductivity of brick (Kbrick) = 0.77 W/m-K
Thermal conductivity of plaster (Kplaster) = 8.65 W/m-K
Thermal conductance of air gap = 5.8 W/m²-K
Outside film coefficient = 23 W/m²-K

Inside film coefficient = 8.5 W/m²-K

Thermal conductivity of false ceiling=2.2W/mK

Thermal conductivity of window glass(13mm)=0.78W/mK

Thermal conductivity of rockwool(100mm)=0.04 W/mK

Overall heat transfer coefficient U(W/m²K)

$$\frac{1}{U} = \sum_{i=0}^{n} \frac{l(i)}{K(i)} + \sum_{j=0}^{n} \frac{1}{h(j)}$$

C.3.1..1. Overall heat transfer coefficient for inner and partition walls

Inner partition wall exists between 2 halls. Firstly we have the wall carpet of rockwool thickness of 100mm , wall thickness of 274mm, air gap , wall thickness , then carpet .

After considering all these, $U_{partition\ wall}$ =1.69W/m² K

C.3.1.2. Overall heat transfer coefficient of roof

The roof consists of indoor air film, fibre glass thickness of 22mm, air gap, false ceiling made of gypsum of thickness 12.5mm

U_{roof} =2.2W/m²K

C.3.1.3. Overall heat transfer coefficient of window glass

The window made of double glass pane of thickness 13mm.

U_{window}=60W/m²K

Table 6: Equivalent CLTD for D type walls

Wall Facing	Solar Time Hour																								Hr. of Max CLTD	Max CLTD	Min CLTD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
N	8	7	7	6	5	4	3	3	3	3	3	4	4	6	7	7	8	9	10	11	11	11	10	9	21	11	3
NE	9	8	7	6	6	4		4	6	8	9	11	12	13	13	13	13	14	14	13	13	12	11	10	19	14	4
E	11	9	8	7	6	5	4	5	7	9	12	15	17	18	18	18	18	18	17	16	16	14	13	12	16	18	4
SE	11	9	8	7	6	6	4	4	6	7	9	12	14	16	17	12	18	18	17	16	16	14	13	12	17	18	4
S	11	9	8	7	6	5	4	4	3	3	4	5	7	9	11	13	15	16	16	15	15	14	13	12	19	16	3
SW	16	14	12	11	9	8	7	6	5	4	4	4	6	7	9	12	15	18	20	21	21	21	19	17	21	21	4
W	17	15	13	12	10	8	7	6	6	5	5	5	6	6	8	10	13	17	20	23	23	22	21	19	21	23	5
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6	7	8	10	12	25	18	18	18	17	15	22	18	4

Table 6 gives values for particular latitude, time of the year, colour of the wall, temperature difference between outside design and inside design conditions and variation in outside design temperature. The values shown in Table 6 assume a mean temperature of 29.4 °C, room temperature 24.5 °C, dark surface, and a clear sky. For CLTD value of different kinds of roof and ceilings we can refer ASHRAE hand books. For different design conditions, the CLTD values given in Table 6 must be corrected before used in heat transfer equations. The following equation can be used to correct CLTD.

CLTDcorr = (CLTD + LM) K + (25.5 – Ti) + (To – 29.4)
where To = outside design temperature (°C)
Ti = inside design temperature (°C)
LM = latitude month correction given in Table 8
K = correction factor depends on building colour.
K = 1 for dark colour, 0.85 for medium colour and 0.65 for light colour.
When type of wall is thermally heavier then group A type of wall due to added insulation, then uncorrected CLTD is given in Table 7

Table 7: CLTD when wall is heavier

N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
6	9	12	12	9	12	12	9

Table 8: Latitude month correction (LM) value for 24°N

Month	N	NE/NW	E/W	SE/SW	S	HOR
Dec	-5	-8	-7	3	13	-13
Jan/Nov	-4	-9	-6	3	13	-11
Feb/Oct	-4	-6	-3	3	10	-7
March/Sept	-3	-3	-1	1	4	-3
Apr/Aug	-2	0	-1	-1	-3	0
May/Jul	1	2	0	-3	-6	1
Jun	3	3	0	-4	-6	1

C.4 HEAT GAIN THROUGH GLASS

Heat is transmitted through glass due to solar radiation. The heat gain through glass areas constitutes a major portion of the load on the cooling apparatus. This could be direct in the form of sunrays or diffused radiation due to reflection from other objects outside. Heat transmitted through a glass depends on the wavelength of radiation and physical and chemical characteristics of glass. Part of the radiation is absorbed, part is reflected and the rest is transmitted. The heat transfer of glass takes place in the two ways, transmission heat gain and solar heat gain. The following equations are used to calculate heat gain from glass areas.

Q =UA(CLTD) corr

By solar radiation:
*Q=SHGF*SC*CLF*
SHGF = maximum solar heat gain factor (W/m2)
SC = shading coefficient depends on type of shading
CLF = cooling load factor

Table 9 gives the value of sensible heat gain factor for 22 °North latitude at different orientations and months.

Table 9: $SHGF_{max}$ for 22°N latitude

Month	Maximum Solar Heat Gain Factor W/m^2					
	N	NE/NW	E/W	SE/SW	S	HOR
January	82	129	568	726	640	647
February	88	243	647	697	533	744
March	98	372	685	609	366	811
April	110	473	662	476	192	826
May	129	527	631	362	129	820
June	167	543	612	328	123	811
July	136	520	618	360	129	808
August	114	461	640	457	205	785
September	104	356	650	587	360	729
October	91	240	621	675	517	644
November	82	129	558	722	631	353
December	79	91	533	729	672	647

C.5 HEAT GAIN DUE TO INFILTRATION

Infiltration is defined as the uncontrolled entry of intreated outdoor air directly into the conditioned space. In other words infiltration is the amount of air that enters a conditioned space through window's crack and opening and closing of doors. This is caused by a pressure difference between the two sides of the windows and doors and it depends on wind velocity and its direction and difference in densities due to the temperature difference between the inside and outside air. For calculating the amount of infiltrated air , air change method is used.

Amount of infiltrated air(V_{inf})=$\frac{Volume\ of\ space*K}{60}\ m^3/min$

Where K is the number of air changes value/hour and its value is given in Table 10.

Table 10: Number of air changes per hour

Kind of room or building	Number of air changes per hour (K)
Room with no windows or outside doors	0.5 to 0.75
Room with one wall exposed	1
Room with two walls exposed	1.5
Room with three walls exposed	2
Room with four walls exposed	2
Entrance halls	2 to 3
Reception halls	2

The sensible heat gain due to infiltration is given by

$Q_{S,inf}$ =20.44*V_{inf}*(T_0-T_i) Watts

And the latent heat gain due to infiltration is given by

$Q_{L,inf}$ =50000*V_{inf}*(W_0-W_i) Watts

Where T_0 and T_i =Outside and inside design temperatures respectively (°C)

W_0 and W_i =Specific humidity of outside and inside in conditioned space (kg/kg of dry air)

C.6 HEAT GAIN DUE TO VENTILATION

Human beings inside a space require fresh air. It has been seen by the studies by the ASHRAE, that inadequate fresh air supply to a space leads to health problems for people inside it. This is called sick building syndrome. Ventilation is provided in the conditioned space to minimize odor, concentration of smoke, carbon dioxide and other undesirable gases so the that the freshness of air could be maintained. The quality of air outside air used for ventilation should provide at least one half air change per hours in building with nominal ceiling height. Also if the infiltration air quantity is larger than the ventilation quantity then the later should be decreased to at least equal to the infiltration air. The outside air adds sensible as well as latent heat.

ASHRAE gives the minimum and recommended values of fresh air per person for different applications is space.

Table 11: Required ventilation rate per person per unit area

Description	Default occupant density ppl/100 m^2	Outdoor air m^3/min/person	Outdoor air m^3/min/m^2 area
Auditorium seating area	20	0.15	0.05
Classroom(age 9 plus)	35	0.30	0.04
Computer Lab	25	0.30	0.04
Lecture classroom	65	0.23	0.02
Library	10	0.15	0.04
Lobbies	150	0.15	0.02
Office space	5	0.15	0.02
Reception area	30	0.15	0.02
Multi-purpose assembly	120	0.15	0.02

C.7 TOTAL ROOM SENSIBLE HEAT GAIN

Room sensible heat gain is a combination of all type of sensible heat gain in a conditioned space i.e,

RSH=Sensible heat gain through walls,floors,ceilings+Sensible heat gain through glasses+Sensible heat gain due to occupants+Sensible heat gain due to infiltrated air+Sensible heat gain due to ventilation+Sensible heat gain due to appliances.

C.8 TOTAL ROOM LATENT HEAT GAIN

Room latent heat gain is a combination of all types of latent heat in a conditioned space

RLHG=Latent heat gain due to infiltration+Latent heat gain due to ventilation+Latent heat gain from persons+Latent heat gain due to appliances

C.9 ROOM SENSIBLE HEAT FACTOR

Room sensible heat factor is defined as the ratio of the room sensible heat to the room total heat. Mathematically, room sensible heat factor

$$RSHF = \frac{RSH}{RSG+RLG} = \frac{RSH}{RTH}$$

C.10 TOTAL HEAT LOAD IN TONS

Total heat gain obtained by all above modes is in Watts and we can convert this value from Watts to tons with the help of the following equation

$$Total\ load\ in\ tons = \frac{Total\ load\ in\ Watts}{3500}$$

D. HEAT LOAD CALCULATIONS

In any building, heat is transmitted through external walls, roof tops, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation.

In our HVAC design we have to consider the cooling load calculations related to the cinema hall. For reference of formulas and data tables we referred to the ASHRAE handbook of Fundamentals in the year 2005. This method is called Cooling Load Temperatures Difference (CLTD) method.

The general step by step procedures for calculating the total heat load are as follows:

- Select inside design condition (Temperature, relative humidity).
- Select outside design condition (Temperature, relative humidity).
- Determine the overall heat transfer coefficient U for wall, ceiling, floor, door, windows, below grade.
- Calculate area of wall, ceiling, floor, door, windows.
- Calculate heat gain from transmission.
- Calculate solar heat gain
- Calculate sensible and latent heat gain from ventilation, infiltration and occupants
- Calculate lighting heat gain
- Calculate total heat gain and
- Calculate TR

D.1.DESIGN CONDITION

The amount of cooling that has to be accomplished to keep buildings comfortable in summer and winter depends on the desired indoor conditions and on the outdoor conditions on a given day. These conditions are, respectively, called the “indoor design condition” and the “outdoor design condition”.
For most of the comfort systems, the recommended indoor temperature and relative humidity are as follows
DBT – 22.78 °C to 26.11 °C, and RH – 50% for summer and monsoon

DBT – 22.11 °C to 22.22 °C and RH – 20 to 30% for winter

The cooling load of the theatres is based on 22 °C dry bulb temperature and 50% relative humidity Indoor design conditions.

The outdoor design conditions are determined from published data for the specific location, based on weather bureau or airport records. The outdoor design conditions of Kolkata is 36 °C DBT and Relative Humidity 46% for summer (month of May) and 32°C DBT and 84 % RH for monsoon (month of July).

Cooling Load Calculation for Theatre 1

Job No.	1	Coordinates	22.5726° N, 88.3639° E
		City	Kolkata
Project	Theatre 1,Restaurant, Washroom Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	19.435	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width(m):	18.745	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Height(m):	5.7095	Inside	22	15.42	50	0.0082	22	15.42	50	0.0082
Area(m²):	370	Difference	12	13.9	21	0.0159	10	13.9	32	0.0167
Volume(m³):	2567.83									

BPF: 0.12 NO. OF AIR CHANGES/HOUR: 0.62 FILTERED AIR(m³/min):13.187 25.18

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	SUMMER W/m²	W	MONSOON W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAIN FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	0	1.69	********	0	********	0
Wall(NE)	0	*******	********	0	********	0
Wall(E)	0	1.69	********	0	********	0
Wall(SE)	0	*******	********	0	********	0
Wall(S)	0	1.69	********	0	********	0
Wall(SW)	0	*******	********	0	********	0
Wall(W)	0	1.69	********	0	********	0
Wall(WN)	0	*******	********	0	********	0
Roof Sun	0	4.16	********	0	********	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All glass	0	Calculate	********	0	********	0
Partition 1	137	1.69	2	463.1	2	463.1
Partition 2	80.9	0.32	2	51.78	2	51.78
Partition 3	132.5	1.69	2	447.8	2	447.8
Partition 4	137	1.69	0	0	0	0
Ceiling	364.3	2.2	6	4808.8	5	4007.4
Floor	235.57	1.685	2	793.8	2	793.8

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
25.18	1	20.44	2	1029.35	2	1029.35

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	200	45	********	9000	********	9000
Lights	****	0.6	********	155.4	********	155.4
Sound Box	1	1	********	2000	********	2000
Projector	1	1	********	4000	********	4000
Others			********	500	********	500
		ROOM SENSIBLE HEAT SUBTOTAL:		19637		19637
		S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):		1963.7		1963.7
		ROOM SENSIBLE HEAT (R.S.H):		21600.7		21600.7

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
25.18	1	50000	0.0011	1384.9	0.0011	1384.9
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of	200	30	********	6000	********	6000

people						
Lights	259	*******	********	0	********	0
Sound Box	1	*******	********	0	********	0

	Summer	Monsoon
S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	738.5	738.5
ROOM LATENT HEAT(R.L.H):	8123.4	8123.4
ROOM TOTAL HEAT (R.T.H):	29724.1	29724.1

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.5	0.88	20.44	11	3660.39	6.25	2079.77

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.5	0.88	50000	0.014	11396	0.0103	8384.2

	Summer	Monsoon
R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):	752.82	521.1
SUB TOTAL:	15809	10987.17
GRAND TOTAL:	45533.1	40711.3
TONS=W/3500:	13.0	11.63
SENSIBLE HEAT FACTOR=RSH/RTH:	0.55	0.58

COOLING LOAD FOR THEATER 1 PROJECTION ROOM

INTERNAL GAIN

				Summer		Monsoon
Projection Machine				4000		4000
Items	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Partition 1	9.8	0.32	4	12.544	4	12.544
All glass	4.168	0.72	6	18	6	18
Partition 3	9.8	0.32	6	18.82	6	18.82
Partition 4	4.168	0.32	6	8	6	8
		TOTAL		4057.37		4057.37
		TONS		1.16		1.16

Cooling Load Calculation for Theatre 2

		Coordinates	22.5726° N, 88.3639° E
Job No.	2	City	Kolkata
Project	Theatre 2 Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
		CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Length(m):	24.411									
Width(m):	14.821									
Height(m):	5.397	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	370	Inside	22	15.42	50	0.0082	22	15.42	50	0.0082
Volume(m³):	1582.44	Difference	12	13.9	21	0.0159	10	13.9	32	0.0167

BPF: 0.12 NO. OF AIR CHANGES PER HOUR: 0.62 INFILTRATED AIR: 16.352

SOLAR HEAT GAIN FOR GLASS

			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	95.43	0.33	18	566.854	8.5	267.68
Wall(NE)	0		**********	0	**********	0
Wall(E)	0		**********	0	**********	0
Wall(SE)	0		**********	0	**********	0
Wall(S)	0		**********	0	**********	0
Wall(SW)	0		**********	0	**********	0
Wall(W)	0		**********	0	**********	0
Wall(WN)	0		**********	0	**********	0
Roof Sun	0	4.16	**********	0	**********	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All glass	0	********	**********	0	**********	0
Partition 1	106.7	1.69	0	0	0	0
Partition 2	47.44	0.32	2	30.4	2	30.4
Partition 3	106.77	1.69	0	0	0	0
Ceiling	362.48	2.75	6	5980.9	5	4984.1
Floor	307.6	1.85	2	1138.1	2	1138.1

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
16.352	1	20.432	2	668.2	2	668.2

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	300	45	**********	13500	**********	13500
Lights	***	0.6	**********	155.4	**********	155.4
Sound Box	1	1	**********	2000	**********	2000
Others(screen emission,seat emission)			**********	500	**********	500

ROOM SENSIBLE HEAT SUBTOTAL:	26796	26496.87
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	2679.6	2649.69
ROOM SENSIBLE HEAT (R.S.H):	29475.65	29146.56

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
16.35	1	50000	0.0011	899.25	0.0011	899.25

Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	300	30	**********	9000	**********	9000
Lights		********	**********	0	**********	0
Sound Box	1	********	**********	0	**********	0
			**********	0	**********	0

S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	989.93	989.93
ROOM LATENT HEAT(R.L.H):	10889.18	10889.18
ROOM TOTAL HEAT (R.T.H):	40364.8	40035.74

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.5	0.88	20.44	11	3660.39	6.25	2079.77

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.5	0.88	50000	0.014	11396	0.0103	8384.2

R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):	752.82	521.1
SUB TOTAL:	15809.2	10987.17
GRAND TOTAL:	56174	51023
TONS=W/3500:	16.05	14.58
SENSIBLE HEAT FACTOR=RSH/RTH:	0.73	0.728

COOLING LOAD FOR THEATRE 2 PROJECTION ROOM

INTERNAL GAIN

Projection Machine	4000	4000

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Partition 1	9.8	0.32	4	12.544	4	12.544
All glass	4.168	0.72	6	18	6	18
Partition 3	9.8	0.32	6	18.82	6	18.82
Partition 4	4.168	0.32	6	8	6	8
		TOTAL		4057.37		4057.37
		TONS		1.16		1.16

Cooling Load Calculation for Theatre 3

		Coordinates	22.5726° N, 88.3639° E
Job No.	3	City	Kolkata
Project	Theatre 3 Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	24.411	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width(m):	15.217	Outside	34	29.33	71	0.0241	32	29.3	82	0.02
Height(m):	5.397	Inside	22	15.42	50	0.0082	22	15.42	50	0.01
Area(m²):	371.46	Difference	12	13.9	21	0.0159	10	13.9	32	0.02
Volume(m³):	1624.72									

BPF: 0.12 | NO. OF AIR CHANGES PER HOUR: 0.62 | INFILTRATED AIR 18.96

SOLAR HEAT GAIN FOR GLASS

			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	97.98	0.33	18	582	8.5	274.83
Wall(NE)	0	2.81	*******	0	******	0
Wall(E)	0	2.81	*******	0	******	0
Wall(SE)	0	2.81	*******	0	******	0
Wall(S)	0	2.81	*******	0	******	0
Wall(SW)	0	2.81	*******	0	******	0
Wall(W)	0	2.81	*******	0	******	0
Wall(WN)	0	2.81	*******	0	******	0
Roof Sun	0	4.16	*******	0	******	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All glass	0	******	*******	0	******	0
Partition 1	106.7	1.69	0	0	0	0
Partition 2	50.7	0.32	2	32.45	2	32.45
Partition 3	106.7	1.69	2	360.65	2	360.65
Ceiling	371.87	2.75	6	6152.3	5	5130.3
Floor	310.5	1.85	2	1148.3	2	1102.3

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
20.3	1	20.44	2	829.86	2	829.86

INTERNAL GAIN

Item			Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People		300	45	*******	13500	******	13500
Lights		***	0.6	*******	155.4	******	155.4
Sound Box		1	1	*******	2000	******	2000
Others				*******	500	******	500
			ROOM SENSIBLE HEAT SUBTOTAL:		27574.96		27267.8
			S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):		2757.5		2726.8
			ROOM SENSIBLE HEAT (R.S.H):		30332.5		29994.6

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass		Factor	Diff kg/kg	W	Diff kg/kg	W
18.96		1	50000	0.0011	1042.8	0.0011	1042.8
Item			Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people		300	30	*******	9000	*******	9000
lights		259		*******	0	*******	0
Sound Box		1		*******	0	*******	0
Projector		1		*******	0	*******	0
			S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):		1004.3		1004.3
			ROOM LATENT HEAT(R.L.H):		11047.08		11047.08
			ROOM TOTAL HEAT (R.T.H):		41379.6		41041.7

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF		Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.96		0.88	20.44	11	3751.41	6.25	2131.48

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF		Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.96		0.88	50000	0.014	11679.36	0.0103	8592.672
			R.A. HEAT,LEAK GAIN & SAFETY FACTOR (5%):		771.538		536.2
			SUBTOTAL:		15430.77		10724.15
			GRAND TOTAL:		56810.4		51765.85
			TONS=W/3500:		16.23		14.79
			SENSIBLE HEAT FACTOR=RSH/RTH:		0.733		0.731

COOLING LOAD FOR THEATRE 3 PROJECTION ROOM

INTERNAL GAIN

Item	Area(m²)		Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Projection Machine					4000		4000
Partition 1		9.8	0.32	4	12.544	4	12.544
All glass		4.168	0.72	6	18	6	18
Partition 3		9.8	0.32	6	18.82	6	18.82
Partition 4		4.168	0.32	6	8	6	8
			TOTAL		4057.37		4057.37
			TONS		1.16		1.16
Partition 1		9.8	0.32	4	12.544	4	12.544
Air glass		4.168	0.72	6	18	6	18
Partition 3		9.8	0.32	6	18.82	6	18.82
PARTITION 4		4.168	0.32	6	8	6	8
			TOTAL		4057.37		4057.37
			TONS		1.16		1.16

Cooling Load Calculation for Lobby

Job No.	4	Coordinates	22.5726° N, 88.3639° E
		City	Kolkata
Project	Lobby cooling load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	48.783									
Width(m):	10.55	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height(m):	4.05	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	514.66	Inside	24	15.42	50	0.0082	24	15.42	50	0.0082
Volume(m³):	2084.375	Difference	10	13.9	21	0.0159	8	13.9	32	0.0167

BPF:	0.12	NO. OF AIR CHANGES PER HOUR:	0.5	FILTERED AIR(m³/min):13.187	17.37

SOLAR HEAT GAIN FOR GLASS

			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff(°C)	W	Temp Diff(°C)	W
Wall(N)	0	2.81	0	0	0	0
Wall(NE)	0	2.81	0	0		0
Wall(E)	0	2.81	0	0	0	0
Wall(SE)	0	2.81		0		0
Wall(S)	0	2.81	0	0	0	0
Wall(SW)	0	2.81		0		0
Wall(W)	0	2.81	0	0	0	0
Wall(WN)	0	2.81		0		0
Roof Sun	0	4.16	0	0		0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff(°C)	W	Temp Diff(°C)	W
Air glass	0					
Partition	0					
Ceiling	514.66					
Floor	514.66					

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
17.37	1	20.44	0	0	0	0

INTERNAL GAIN

Item		Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
People	50	68.25		3412.5		3412.5
Lights	******	0.86		1429.62		1439.62
Sound Box	1			2000		2000
Projector	0			0		0
		ROOM SENSIBLE HEAT SUBTOTAL:		6852.12		6852.12
		S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):		685.2		685.2
		ROOM SENSIBLE HEAT (R.S.H):		7537.33		7537.33

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
25.18	1	50000	0	0	0	0
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	50	70		3500		3500
Lights	0	0		0		0
Sound Box	0			0		0
Projector	0			0		0
		S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):		350		350
		ROOM LATENT HEAT(R.L.H):		3850		3850

		ROOM TOTAL HEAT (R.T.H):		11387.33			11387.33

OUTSIDE AIR HEAT

				OUTSIDE AIR SENSIBLE HEAT (OASH)				
Outside air	1-BPF		Factor	Temp Diff(°C)	W		Temp Diff(°C)	W
41.6875		0.88	20.44	0	0		0	0
				OUTSIDE AIR LATENT HEAT (OALH)				
Outside air	1-BPF		Factor	Diff kg/kg	W		Diff kg/kg	W
41.6875		0.88	50000	0	0		0	0
	R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):				0			0
			GRAND TOTAL:		11387.33			11387.33
			TONS=W/3500:		3.25			3.25
			SENSIBLE HEAT FACTOR=RSH/RTH:		0.662			0.662

Cooling Load Calculation for Restaurant

		Coordinates	22.5726° N, 88.3639° E
Job No.	5	City	Kolkata
Project	Restaurant Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
		CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Length(m):	7.41									
Width(m):	4.697									
Height(m):	4.05	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	34.8	Inside	24	15.42	50	0.0082	24	15.42	50	0.0082
Volume(m³):	140.96	Difference	10	13.9	21	0.0159	8	13.9	32	0.0167

BPF:	0.12	NO. OF AIR CHANGES PER HOUR:	2	FILTERED AIR(m³/min):13.187	4.699

SOLAR HEAT GAIN FOR GLASS			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	1.96	0.72	167	235.67	136	191.92
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS						
Item	Area(m²)	Factor(W/m²-°C)	Temp Diff(°C)	W	Temp Diff(°C)	W
Wall(N)	28.1	1.04	10	292.24	8	233.79
Wall(NE)	0	2.81	**************	0	**************	0
Wall(E)	34.8	2.81	0	0	0	0
Wall(SE)	0	2.81	**************	0	**************	0
Wall(S)	28.1	2.81	0	0	0	0
Wall(SW)	0	2.81	**************	0	**************	0
Wall(W)	34.8	2.81	0	0	0	0
Wall(WN)	0	2.81	**************	0	**************	0
Roof Sun	34.8	4.16	**************	0	**************	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF						
Item	Area(m²)	Factor(W/m²-°C)	Temp Diff(°C)	W	Temp Diff(°C)	W
All glass	0		*************	0	***********	0
Partition	0		*************	0	***********	0
Ceiling	365.53		*************	0	***********	0
Floor	370		*************	0	***********	0

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
4.699	1	20.44	10	960.475	8	768.38

INTERNAL GAIN

Item		Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
People	20	71.2	**************	1424	**************	1424
Lights	******	0.86	**************	48.79	**************	48.79
Electrical Appliances	*************		**************	2000	**************	2000

ROOM SENSIBLE HEAT SUBTOTAL:	4961.75	4666.88
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	496.1	466.68
ROOM SENSIBLE HEAT (R.S.H):	5457.93	5133.57

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
4.699	1	50000	0.0159	3735.7	0.0167	3923.67
Item		Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
No. of people	20	80	**************	1600	**************	1600
Lights	0	0	**************	0	**************	0

S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	533.57	552.37
ROOM LATENT HEAT(R.L.H):	5869.27	6076
ROOM TOTAL HEAT (R.T.H):	9126.57	9009.57

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
5.67	0.88	20.44	10	1019.87	8	815.9

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
5.67	0.88	50000	0.0159	3966.7	0.0167	3166.32

R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):	249.33	199.11
GRAND TOTAL:	14362.47	13190.9
TONS=W/3500:	4.1	3.77
SENSIBLE HEAT FACTOR=RSH/RTH:	0.357	0.326

Cooling Load Calculation for Exit Passage

		Coordinates	22.5726° N, 88.3639° E
Job No.	1	City	Kolkata
Project	COOLING LOAD EXIT PASSAGE	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	51.485									
Width(m):	Theatre 2 & 3 3.43									
	Theatre 1 2.7	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height(m):	2.85	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	159.3	Inside	24	15.42	50	0.0082	24	15.42	50	0.0082
Volume(m³):	515	Difference	10	13.9	21	0.0159	8	13.9	32	0.0167

BPF:	1	NO. OF AIR CHANGES PER HOUR:	2	INFILTRATED AIR(m³/min):13.187	17.168

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	SUMMER W/m²	W	MONSOON W/m²	W
Glass (N)	1.92	0.72	129	178.3	136	188
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	131	0.33	10	518	8	431
Wall(NE)	0	0	***********	0	***********	0
Wall(E)	12.9	0	0	0	0	0
Wall(SE)	0	0	***********	0	***********	0
Wall(S)	131	0	0	0	0	0
Wall(SW)	0	0	***********	0	***********	0
Wall(W)	12.9	0	0	0	0	0
Wall(WN)	0	0	***********	0	***********	0
Roof Sun	0	0	***********	0	***********	0

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
17.168	1	20.44	10	3509.14	8	2807.3

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	0	0	***********	0	***********	0
Lights	****	0.8	***********	411.6	***********	411.6

	Summer	Monsoon
ROOM SENSIBLE HEAT SUBTOTAL:	4617.04	3837.9
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	461.7	383.7
ROOM SENSIBLE HEAT (R.S.H):	5078.74	4221.7

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
17.168	1	50000	0.0078	6695.52	0.0082	7038.88
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	0	0	***********	0	***********	0
Lights	****		***********	0	***********	0

	Summer	Monsoon
TOTAL	6695.52	7033.88
S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):		
ROOM LATENT HEAT(R.L.H):	7365.1	7737.27
ROOM TOTAL HEAT (R.T.H):	12443.84	11958.97
GRAND TOTAL:	12443.8	11958.97
TONS=W/3500:	3.55	3.417
SENSIBLE HEAT FACTOR=RSH/RTH:	0.408	0.353

Cooling Load Calculation for Wash Room

		Coordinates	22.5726° N, 88.3639° E
Job No.	7	City	Kolkata
Project	Wash room Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	7.41	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width(m):	4.697									
Height(m):	4.05	Outside	34	29.32	71	0.0241	32	29.3	82	0.024
Area(m²):	34.8	Inside	24	15.42	50	0.0082	24	15.42	50	0.008
Volume(m³):	140.96	Difference	10	13.9	21	0.0159	8	13.9	32	0.016

BPF: 0.12 NO. OF AIR CHANGES PER HOUR: 2 FILTERED AIR(m³/min):13.187 4.699

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	SUMMER W/m²	W	MONSOON W/m²	W
Glass (N)	1.96	0.72	167	235.67	136	191.92
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Wall(N)	28.1	1.04	10	292.24	8	233.79
Wall(NE)	0	2.81	************* *	0	************* *	0
Wall(E)	34.8	2.81	0	0	0	0
Wall(SE)	0	2.81	************* *	0	************* *	0
Wall(S)	28.1	2.81	0	0	0	0
Wall(SW)	0	2.81	************* *	0	************* *	0
Wall(W)	34.8	2.81	0	0	0	0
Wall(WN)	0	2.81	************* *	0	************* *	0
Roof Sun	34.8	4.16	************* *	0	************* *	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Air glass	0		************* *	0	**********	0
Partition	0		************* *	0	**********	0
Ceiling	365.53		************* *	0	**********	0
Floor	370		************* *	0	**********	0

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Facto r	Temp Diff (°C)	W	Temp Diff (°C)	W
4.699	1	20.44	10	960.475	8	768.38

INTERNAL GAIN

Item		Facto r	Temp Diff (°C)	W	Temp Diff (°C)	W
People	0	0	************* *	0	**********	0
Lights	****	0.86	************* *	48.79	**********	48.79

ROOM SENSIBLE HEAT SUBTOTAL:	1780.62 5	4666.88
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	178.1	466.68
ROOM SENSIBLE HEAT (R.S.H):	1958.68 8	5133.57

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Facto r	Diff kg/kg	W	Diff kg/kg	W
4.699	1	5000 0	0.0159	3735.7	0.0167	3923.67

Item		Facto r	Diff kg/kg	W	Diff kg/kg	W
No. of people	20	80	**********	1600	**********	1600
Lights	0	0	**********	0	**********	0

S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	533.57	552.37
ROOM LATENT HEAT(R.L.H):	5869.27	6076
ROOM TOTAL HEAT (R.T.H):	9126.57	9009.57

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Facto r	Temp Diff (°C)	W	Temp Diff (°C)	W
5.67	0.88	20.44	10	549.572	8	408.5

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Facto r	Diff kg/kg	W	Diff kg/kg	W
5.67	0.88	5000 0	0.0159	3966.7	0.0167	3166.32

R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):	249.33	199.11
GRAND TOTAL:	13642.8	13190.9

TONS=W/3500:	3.8	3.77
SENSIBLE HEAT FACTOR=RSH/RTH:	0.333	0.326

D.2. ASSUMPTIONS

The following assumptions were considered while calculating the cooling load for the seven zones.

- Indoor and outdoor conditions remain steady
- Design outside conditions are selected from a long term statistical database. The conditions will not necessarily represent any actual year but are representative of the location of the building.
- The load on the building due to solar radiations is estimated for clear sky conditions.
- The building occupancy has been assumed to be at full design capacity
- All building equipment and appliances are considered to be operating at a reasonably representative capacity
- BPF has been assumed to be 0.12
- Walls have been considered to be colored with medium color
- Building orientation has been fixed so that the entrance of the building faces South
- Fresh air is brought into the building at outdoor temperature
- Indoor air is exhausted from the building at the indoor temperature

E. AIR FLOW CALCULATION

The flow rate of air is given by

$Q_{sensible}= \rho*V*C_P*(T_{in}- T_{supp})$

P=Density of air=1.2 kg/m^3

V=Volume of air movement per second(m^3/s)

C_P= Specific heat of air=1.0216 KJ/kg-K

T_{In}= Temperature inside the hall=22°C

T_{Supp}=Supply air temperature=13°C

E.1.DUCT DESIGN

There are many theories which define the size of the duct system including

- equal friction
- static regains
- total pressure
- velocity reduction
- constant velocity

From these methods, we elect to use the equal friction method because it gives us more correct values to keep the discharge constant. In the equal friction method, the system is sized for a constant pressure loss per unit length of duct. The equal friction method can be used for the design of supply and extract the resulting duct systems.

For the branch design arrangement, there are mainly two types of methods

_ Reducing plenum method
_ Reducing trunk method
The reducing plenum method is widely used. In the reducing plenum method, a single plenum will have extended up to 15 to 20 feet. Branching is done on the plenum with no plenum reduction being done after a branch. It is easier to install and provides a cost reduction. However, there are some problems such as a lack in the proper arrangement leading to a chance of discomfort because the discharge and velocity cannot remain the same as the calculation due to the constant plenum. In addition, there will be a chance of a reverse effective pressure, which could result in a negative pressure that will create at branching instead of discharge it and will suck the indoor air.

In the reduction duct diameter, we keep the air velocity as 6 m/s.

Fritzche equation is given as:

$P_f = \frac{0.01422*L*v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

The pressure loss due to friction will be same as the above for all branches according to the equal frictional pressure drop method.

E.2.RETURN DUCT

by The return duct is required in every HVAC system maintains both the indoor pressure and the air quality. We located the return duct only at the auditorium and not in the other locations. Because the main requirement of the air is only for the auditorium and to maintain a good quality of the air wasted, the air must be constantly ejected from the indoor environment. **According to the ASHRAE handbook, the required fresh air flow per person is 17 CFM(0.00802 m^3/s).**

We fixed the velocity of the main return duct at 6 m/s. Using the Fritzche equation we determined the main return duct diameter and calculated associated divided branches.

As shown in the table, we have tabulated the data for the return duct as shown below, which was acquired the same way as supply duct using Fritzche equation.

The air which is not being taken out from the theatre is assumed to be lost due to infiltration through theatre doors and other undesired areas.

E.3.FAN POWER

As we can see from the supply and return duct sizing data, the fan must be designed for the supply air conditioning. Therefore the power required for the fan is given by

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate

η= Efficiency of fan=0.85

E.4.THEATER 1+RESTAURANT+WASHROOM

Total sensible heat = 32255.2 W

The volume of air that passes through the duct work: V=2.911 m^3/s

E.4.1.Supply Duct Design

Fritzche equation is given as:

$P_f = \frac{0.01422 * L * v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 2.911 m^3/s

V = inlet velocity= 6 m/s

D = main duct diameter (m)

D=0.786
P_f/L = 0.629 N/m^3

Pressure Loss due to friction= 62.10 N/m^2
Loss due to joints= 266.98 N/m^2

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate =2.911 m^3/s

η= Efficiency of fan=0.85

P_s=1127 W

E.4.2.Return Duct Design

Total air to be removed= No.of people * Fresh air requirement per person on average
= 220* 0.008 m^3/s
= 1.76 m^3/s.

Fritzche equation is given as:

$P_f = \frac{0.01422 * L * v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 1.76 m3/s

V = inlet velocity =6 m/s

D = main RETURN duct diameter (m)

D = 0.583 m
P_f/L = 0.777 N/m^3

Pressure Loss due to friction= 90.4 N/m^2
Loss due to joints= 220.02 N/m^2

P_s = Δp_s*Q/η

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate =1.76 m^3/s

η= Efficiency of fan=0.85

P_s=642.76 W

E.5. THEATER 2+ EXIT PASSAGE

Total sensible heat= 35423.8 W

The volume of the air per second that passes through the duct work is:

V=3.12 m^3/s

E.5.1.Supply Duct Design

Fritzche equation is given as:

$P_f = \frac{0.01422 * L * v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 3.12 m^3/s

V = inlet velocity =6 m/s

D = main duct diameter (m)

D = 0.814 m
P_f/L = 0.509 N/m^3

Pressure Loss due to friction= 72.74 N/m^2
Loss due to joints= 203.22 N/m^2

P_s = Δp_s*Q/η

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate =3.12 m^3/s

η= Efficiency of fan=0.85

P_s=1012.9 W

E.5.2. Return Duct Design

Total air to be removed= No. of people * Fresh air requirement per person on average
= 300* 0.008 m^3/s
= 2.4 m^3/s.

Fritzche equation is given as:

$P_f = \frac{0.01422*L*v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 2.4 m^3/s

V = inlet velocity =6 m/s

D = main RETURN duct diameter (m)

D = 0.714m
P_f/L = 0.601 N/m^3

Pressure Loss due to friction= 41.1 N/m^2
Loss due to joints= 138.8 N/m^2

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate =2.4 m^3/s

η= Efficiency of fan=0.85

P_s=507.9 W

E.6.THEATER 3 + LOBBY

Total sensible heat= 41621.3 W

The volume of the air per second that passes through the duct
work is:

V=4.097 m^3/s

E.6.1.Supply Duct Design

Fritzche equation is given as:

$P_f = \frac{0.01422*L*v^{1.852}}{D^{1.269}}$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 4.097 m^3/s

V = inlet velocity =6 m/s

D = main duct diameter (m)

D = 0.913 m
P_f/L = 0.475 N/m^3

Pressure Loss due to friction= 127.75 N/m^2
Loss due to joints= 313.63 N/m^2

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate =4.097m^3/s

η= Efficiency of fan=0.85

P_s=2127 W

E.6.2. Return Duct Design

Total air to be removed= No.of people * Fresh air requirement per person on average
= 300* 0.008 m^3/s
= 2.4 m^3/s.

Fritzche equation is given as:

$$P_f = \frac{0.01422 * L * v^{1.852}}{D^{1.269}}$$

V=Q/A where A=π/4*D^2

v=6 m/s

$$D^{3.704} = 1.5642 * \left(\frac{Q}{v}\right)^{1.852}$$

So, for the main duct

Q = inlet discharge = 2.4 m^3/s

V = inlet velocity =6 m/s

D = main RETURN duct diameter (m)

D = 0.714m
P_f/L = 0.601 N/m^3

Pressure Loss due to friction= 62.10 N/m^2
Loss due to joints= 266.98 N/m^2

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan

Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints

Q=Discharge rate = 2.4 m^3/s

η= Efficiency of fan=0.85

P_s=507.95 W

***(Duct Design of all theatres have been added at the end of the pdf) ***

Supply and Return Duct Sizing for Theatre 1

SUPPLY DUCT SIZING

Branch No.	Discharge(m^3/s)	PF/L	D(m)	V(m/s)	L(m)	PF(N/m^2)	Velocity Pressure(N/m^2)	Friction factor(f)	Joint constant K	Loss due to joints(N/m^2)
1(M)	2.911	0.629	0.786	6	2.298	1.445	21.6	0.008	0.05	1.08
2L	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
3L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
4L	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
5L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
6L	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
7L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
8L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18
2R	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
3R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
4R	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
5R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
6R	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
7R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
8R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18

9(M)	2.055	0.629	0.661	5.988	5.133	3.229	21.5	0.002	0.08	1.72
10L	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
11L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
12L	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
13L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
14L	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
15L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
16L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18
10R	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
11R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
12R	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
13R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
14R	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
15R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
16R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18
17(M)	1.199	0.629	0.505	5.96	5.133	3.229	21.3	0.002	0.08	1.705
18L	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
19L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
20L	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
21L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
22L	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
23L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
24L	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18
18R	0.428	0.629	0.359	4.25	2.25	1.415	10.84	0.008	0.51	5.527
19R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
20R	0.32	0.629	0.321	3.964	2.25	1.415	9.428	0.01	0.59	5.562
21R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
22R	0.214	0.629	0.274	3.629	2.25	1.415	7.9	0.008	0.73	5.768
23R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	1.03	5.898
24R	0.107	0.629	0.21	3.089	0.5	0.3145	5.726	0.017	0.73	4.18
25(M)	0.343	0.629	0.27	5.998	11.604	4.86	21.3	0.002	0.08	1.704
26L	0.18	0.629	0.267	3.572	4.5	2.83	7.66	0.039	0.73	5.59
27L	0.09	0.629	0.196	2.97	4.5	2.83	5.297	0.009	0.73	3.867
26R	0.09	0.629	0.196	2.97	4.5	2.83	5.297	0.009	0.73	3.867
28(M)	0.073	0.629	0.181	2.837	2.3	1.447	4.829	0.002	1.03	4.974
29(M)	0.073	0.629	0.181	2.837	4.55	2.862	4.829	0.002	1.03	4.974
30(M)	0.0365	0.629	0.139	2.42	4.1	2.5789	3.514	0.002	0.73	2.565
31S	0.0365	0.629	0.139	2.42	1.5	0.9435	3.514	0.002	0.73	2.565
	TOTAL				102.62	62.1024	427.072			266.997

PRESSURE LOSS(N/m^2	271.5268
POWER(W)	715.55

RETURN DUCT

Branch No.	Discharge(m^3/s)	PF/L	D(m)	V(m/s)	L(m)	PF(N/m^2)	Velocity Pressure(N/m^2)	Friction factor(f)	Joint constant K	Loss due to joints(N/m^2)
1(M)	1.6	0.777	0.583	6	3	2.331	21.6	0.005	0.05	1.08
2(M)	1.52	0.777	0.57200	5.91496	3	2.331	20.99205682	0.008	0.51	10.70594898
3(M)	1.44	0.777	0.56060	5.83391	4.57	3.55089	20.42073064	0.017	1.03	21.03335256
4R	0.16	0.777	0.24733	3.33010	3.5	2.7195	6.653772706	0.01	0.59	3.925725896
5R	0.08	0.777	0.19106	2.79024	3.5	2.7195	4.671275915	0.017	1.03	4.811414192
6(M)	1.28	0.777	0.53654	5.66118	5.133	3.988341	19.2293801	0.008	0.73	14.03744748
7R	0.16	0.777	0.24733	3.33010	3.5	2.7195	6.653772706	0.017	1.03	6.853385887
8R	0.08	0.777	0.19106	2.79024	3.5	2.7195	4.671275915	0.017	0.73	3.410031418
9(M)	1.12	0.777	0.51051	5.47153	5.133	3.988341	17.96258146	0.008	0.51	9.160916543
10(M)	1.12	0.777	0.51051	5.47153	2.793	2.170161	17.96258146	0.017	1.03	18.5014589
11(M)	1.04	0.777	0.49661	5.36903	2.793	2.170161	17.29589766	0.01	0.59	10.20457962
12(M)	0.96	0.777	0.48203	5.26048	0.9	0.6993	16.60359227	0.017	1.03	17.10170004
13(M)	0.64	0.777	0.41447	4.74341	6	4.662	13.49997124	0.008	0.73	9.854979002
14(M)	0.56	0.777	0.39436	4.58450	4	3.108	12.61061624	0.017	1.03	12.98893473
15(M)	0.48	0.777	0.37236	4.40767	5.133	3.988341	11.65653895	0.017	0.73	8.50927343
16L	0.16	0.777	0.24733	3.33010	3.5	2.7195	6.653772706	0.002	0.08	0.532301816
17L	0.08	0.777	0.19106	2.790244	3.5	2.7195	4.671275915	0.008	0.51	2.382350717
18(M)	0.32	0.777	0.320178	3.974427	5.133	3.988341	9.477644229	0.017	1.03	9.761973556
19L	0.16	0.777	0.247334	3.330108	3.5	2.7195	6.653772706	0.01	0.59	3.925725896
20L	0.08	0.777	0.191063	2.790244	3.5	2.7195	4.671275915	0.017	1.03	4.811414192
21(M)	0.16	0.777	0.247334	3.330108	4.57	3.55089	6.653772706	0.008	0.73	4.857254075
22L	0.16	0.777	0.247334	3.330108	3.5	2.7195	6.653772706	0.017	1.03	6.853385887

23L	0.08	0.777	0.191063	2.790244	3.5	2.7195	4.671275915	0.017	0.73	3.410031418
24(M)	0.32	0.777	0.320178	3.974427	2	1.554	9.477644229	0.008	0.51	4.833598557
25R	0.08	0.777	0.191063	2.790244	5	3.885	4.671275915	0.017	1.03	4.811414192
26L	0.08	0.777	0.191063	2.790244	4.5	3.4965	4.671275915	0.01	0.59	2.75605279
27(M)	0.16	0.777	0.247334	3.330108	2.69	2.09013	6.653772706	0.017	1.03	6.853385887
28(M)	0.16	0.777	0.247334	3.330108	6	4.662	6.653772706	0.008	0.73	4.857254075
29R	0.08	0.777	0.191063	2.790244	4	3.108	4.671275915	0.017	0.51	2.382350717
30L	0.08	0.777	0.191063	2.790244	5	3.885	4.671275915	0.017	1.03	4.811414192
			TOTAL		116.3	90.40239	304.0609002			220.0190566

POWER RETURN FAN (W)	421.06

Supply and Return Duct Sizing for Theatre 2 and Exit Passage

SUPPLY DUCT SIZING

Branch No.	Discharge(m^3/s)	PF/L	D(m)	V(m/s)	L(m)	PF(N/m^2)	Velocity Pressure(N/m^2)	Friction factor(f)	Joint constant K	Joint Loss(N/m^2)
1(M) ROW1	3.12		0.814		3.05	1.55245	21.6		0.05	1.08
2L	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4L	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023
5L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6L	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8L	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
2R	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4R	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023
5R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6R	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8R	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
2(M) ROW2	2.248	0.509	0.72	5.51	6.137	3.124	18.216	0.002	0.08	1.457
2L	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4L	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023
5L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6L	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8L	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
2R	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4R	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023
5R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6R	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8R	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
3(M) ROW3	1.376	0.509	0.6	4.86	6.137	3.124	14.172	0.002	0.08	1.134
2L	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4L	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023
5L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6L	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7L	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8L	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
2R	0.436	0.509	0.391	3.63	1.75	0.891	7.91	0.008	0.51	4.034
3R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
4R	0.327	0.509	0.351	3.37	1.75	0.891	6.819	0.01	0.59	4.023

5R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
6R	0.218	0.509	0.302	3.04	1.75	0.891	5.544	0.008	0.73	4.047
7R	0.109	0.509	0.233	2.55	0.5	0.255	3.894	0.017	1.03	4.011
8R	0.109	0.509	0.233	2.55	2.133	1.086	3.894	0.017	0.73	2.842
4(M)	0.504	0.509	0.413	3.76	8.207	4.177	8.483	0.002	0.18	1.527
6S	0.055	0.509	0.181	2.13	0.7	0.306	2.741	0.039	2.33	6.342
5(M)	0.449	0.509	0.395	3.66	9.094	4.629	8.037	0.009	0.08	0.643
7(M)	0.449	0.509	0.395	3.66	0.87	0.443	8.037	0.017	0.51	4.1
E0D	0.0497	0.509	0.174	2.09	5.72	2.912	2.62	0.002	0.08	0.207
E1D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E1	0.0994	0.509	0.225	2.49	5.72	2.912	3.714	0.002	0.08	0.297
E2D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E2	0.149	0.509	0.262	2.76	5.72	2.912	4.584	0.002	0.08	0.367
E3D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E3	0.1988	0.509	0.292	2.97	5.72	2.912	5.289	0.002	0.08	0.423
E4D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E4	0.2485	0.509	0.317	3.14	3.51	1.786	5.927	0.002	0.08	0.476
E5D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E5	0.2485	0.509	0.317	3.14	2.21	1.125	5.927	0.002	0.08	0.476
E6D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E6	0.1988	0.509	0.292	2.97	5.72	2.912	5.289	0.002	0.08	0.423
E7D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E7	0.149	0.509	0.262	2.76	5.72	2.912	4.584	0.002	0.08	0.367
E8D	0.0497	0.509	0.174	2.09	0.5	0.254	2.62	0.017	1.03	2.69
E8	0.0994	0.509	0.225	2.49	5.72	2.912	3.714	0.002	0.08	0.297
E9D	0.0497	0.509	0.174	2.09	5.72	2.912	2.62	0.002	0.08	0.207
TOTAL						72.738	361.608			203.22
STATIC PRESSURE LOSS										275.96
POWER=			1012.9							

RETURN DUCT SIZING

R1M	2.4	0.601	0.714	6	6.12	3.678	21.6	0.007	0.05	1.08
ROW1										
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2M	1.6	0.601	0.614	5.405	6.137	3.688	17.527	0.002	0.08	1.402
ROW2										
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R3M	0.8	0.601	0.474	4.528	6.137	3.688	12.305	0.007	0.15	1.846
ROW3										
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08

R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
TOTAL						41.1				138.8
POWER						507.6				
PR1M	0.205	0.514	0.295	3	1.35	0.694	5.4	0.008	0	0
PR1R	0.205	0.514	0.295	3	1.35	0.694	5.4	0.008	0	0

Supply and Return Duct Sizing for Theatre 3 and Lobby

SUPPLY DUCT SIZING

Branch No.	Discharge(m^3/s)	PF/L	D(m)	V(m/s)	L(m)	PF(N/m^2)	Velocity Pressure(N/m^2)	Friction factor(f)	Joint constant(K)	Loss due to joints(N/m^2)
1(M)	4.097	0.475	0.913	6.261	1.2655	0.601113	23.52006549	0.005	0.05	1.176003275
2(L)	0.218	0.475	0.397	1.762	3.4215	1.625213	1.862690369	0.008	0.51	0.949972088
3(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
4(L)	0.109	0.475	0.2367	2.4784	4.9385	2.345788	3.685610564	0.01	0.59	2.174510233
5(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
7(R)	0.436	0.475	0.3966	3.5303	6.948	3.3003	7.477808276	0.008	0.73	5.458800042
8(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
9(R)	0.327	0.475	0.3563	3.2804	7.1645	3.403138	6.456707342	0.017	0.73	4.71339636
10(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.51	1.879661388
11(R)	0.218	0.475	0.3064	2.958	7.1645	3.403138	5.249789442	0.017	1.03	5.407283125
12(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.01	0.59	2.174510233
13(R)	0.109	0.475	0.2367	2.4784	9.1265	4.335088	3.685610564	0.017	1.03	3.796178881
14(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.73	2.690495712
16(M)	3.443	0.475	0.855	6	4.079	1.937525	21.6	0.017	0.73	15.768
17(L)	0.545	0.475	0.431	3.7372	1.5	0.7125	8.379785946	0.002	0.08	0.670382876
18(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.51	1.879661388
19(L)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.017	1.03	7.702142525
20(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.01	0.59	2.174510233
21(L)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.017	1.03	6.650408563
22(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.73	2.690495712
23(L)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.017	1.03	5.407283125
24(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	0.73	2.690495712
25(L)	0.109	0.475	0.2367	2.4784	1.678	0.79705	3.685610564	0.008	0.51	1.879661388
26(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
27(R)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.01	0.59	4.411906883
28(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
29(R)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.008	0.73	4.71339636
30(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	0.51	1.879661388
31(R)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.017	1.03	5.407283125
32(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.007	0.08	0.294848845
33(R)	0.109	0.475	0.2367	2.4784	1.5	0.7125	3.685610564	0.008	0.51	1.879661388
34(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
35(M)	2.462	0.475	0.7557	5.491	6.137	2.915075	18.09092212	0.017	1.03	18.63364978
36(L)	0.545	0.475	0.431	3.7372	1.5	0.7125	8.379785946	0.008	0.73	6.117243741
37(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
38(L)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.017	0.73	5.458800042
39(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.51	1.879661388
40(L)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.017	1.03	6.650408563
41(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.01	0.59	2.174510233
42(L)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.017	1.03	5.407283125
43(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.73	2.690495712
44(L)	0.109	0.475	0.2367	2.4784	1.678	0.79705	3.685610564	0.017	1.03	3.796178881
45(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	0.73	2.690495712
46(R)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.008	0.51	3.813682221
47(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.51	1.879661388

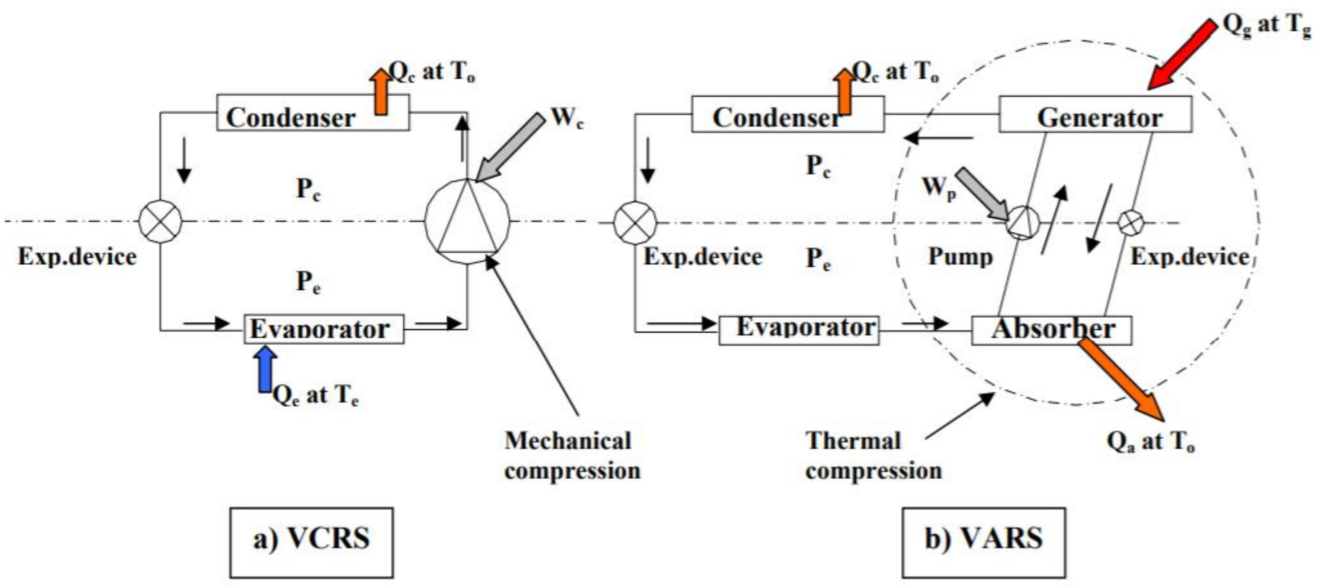
48(R)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.017	1.03	6.650408563
49(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.01	0.59	2.174510233
50(R)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.017	1.03	5.407283125
51(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.73	2.690495712
52(R)	0.109	0.475	0.2367	2.4784	1.5	0.7125	3.685610564	0.017	1.03	3.796178881
53(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	0.73	2.690495712
54(M)	1.481	0.475	0.6254	4.8231	6.137	2.915075	13.95752182	0.017	1.03	14.37624747
55(L)	0.545	0.475	0.431	3.7372	1.5	0.7125	8.379785946	0.01	0.59	4.944073708
56(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
57(L)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.008	0.73	5.458800042
58(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
59(L)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.017	0.73	4.71339636
60(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.009	0.48	1.769093071
61(L)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.017	1.03	5.407283125
62(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.73	2.690495712
63(L)	0.109	0.475	0.2367	2.4784	1.678	0.79705	3.685610564	0.017	1.03	3.796178881
64(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	0.73	2.690495712
65(L)	0.436	0.475	0.3966	3.5303	1.5	0.7125	7.477808276	0.008	0.51	3.813682221
66(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
67(R)	0.327	0.475	0.3563	3.2804	1.5	0.7125	6.456707342	0.01	0.59	3.809457332
68(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
69(R)	0.218	0.475	0.3064	2.958	1.5	0.7125	5.249789442	0.008	0.73	3.832346292
70(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
71(R)	0.109	0.475	0.2367	2.4784	1.5	0.7125	3.685610564	0.017	0.73	2.690495712
72(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.008	0.51	1.879661388
73(M)	0.5	0.475	0.4174	3.6559	4.082	1.93895	8.019219301	0.017	1.03	8.25979588
74(L)	0.109	0.475	0.2367	2.4784	2.563	1.217425	3.685610564	0.01	0.59	2.174510233
75(L)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
76(R)	0.109	0.475	0.2367	2.4784	2.563	1.217425	3.685610564	0.008	0.73	2.690495712
77(R)	0.109	0.475	0.2367	2.4784	0.5	0.2375	3.685610564	0.017	1.03	3.796178881
78(M)	0.282	0.475	0.3372	3.1588	3.63	1.72425	5.986815964	0.017	0.73	4.370375654
		TOTAL			127.754	60.68315	418.3192037			313.6354427
	FAN POWER(W)	1536.382								
RETURN DUCT SIZING										
R1M	2.4	0.601	0.714	6	6.12	3.678	21.6	0.007	0.05	1.08
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2M	1.6	0.601	0.614	5.405	6.137	3.688	17.527	0.002	0.08	1.402
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
R3M	0.8	0.601	0.474	4.528	6.137	3.688	12.305	0.007	0.15	1.846
R2L	0.4	0.601	0.366	3.794	2.93	1.761	8.636	0.008	0.51	4.405
R3L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4L	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5L	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6L	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6

R2R	0.4	0.601	0.366	3.794	1.38	0.829	8.636	0.008	0.51	4.405
R3R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R4R	0.2667	0.601	0.315	3.422	1.75	1.578	7.024		0.59	4.144
R5R	0.1334	0.601	0.243	2.867	0.5	0.301	4.932	0.03	1.03	5.08
R6R	0.1334	0.601	0.243	2.867	2.25	1.352	4.932	0.017	0.73	3.6
		TOTAL				41.1				138.8
		POWER				507.6				

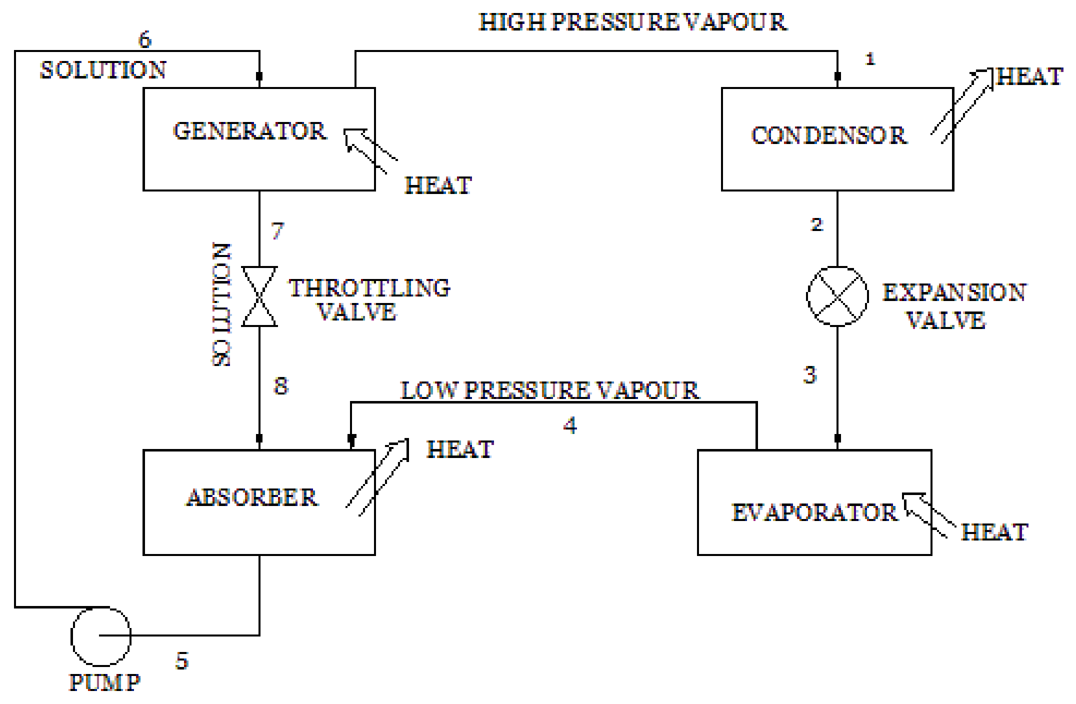
F. AIR-CONDITIONING SYSTEM DESIGN

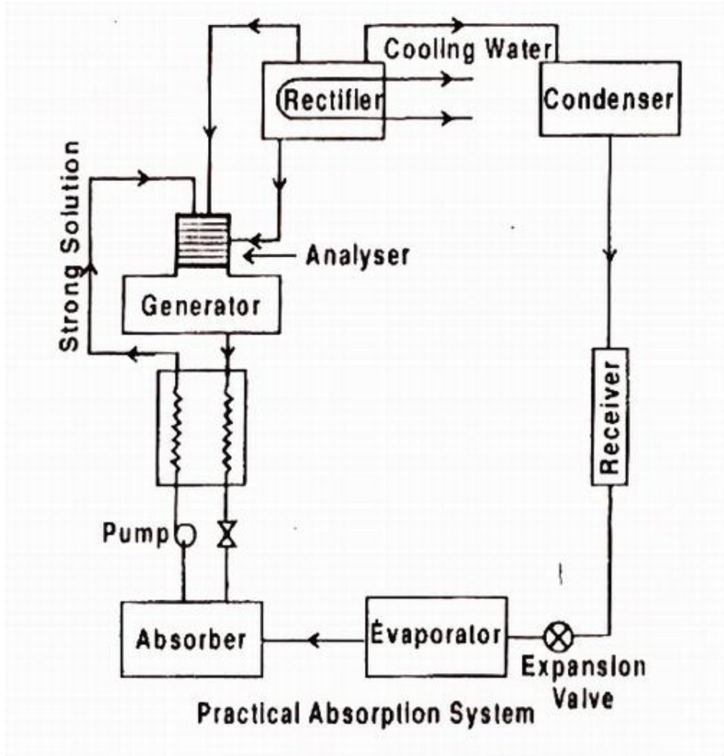
For our air conditioning system, we have used the vapour absorption refrigeration cycle using ammonia water mixture

Compression systems	Absorption systems
Work operated	Heat operated
High COP	Low COP (currently maximum ≈ 1.4)
Performance (COP and capacity) very sensitive to evaporator temperatures	Performance not very sensitive to evaporator temperatures
System COP reduces considerably at part loads	COP does not reduce significantly with load
Liquid at the exit of evaporator may damage compressor	Presence of liquid at evaporator exit is not a serious problem
Performance is sensitive to evaporator superheat	Evaporator superheat is not very important
Many moving parts	Very few moving parts
Regular maintenance required	Very low maintenance required
Higher noise and vibration	Less noise and vibration
Small systems are compact and large systems are bulky	Small systems are bulky and large systems are compact
Economical when electricity is available	Economical where low-cost fuels or waste heat is available



***Figs.14.2**: a) Vapour compression refrigeration system (VCRS)*
b) Vapour Absorption Refrigeration System (VARS)





<u>For the sake of simplified calculations we have based our analysis on the approximate(simplified) VAR system as shown in the figure on the left</u>

THIS DESIGN HAS BEEN DONE SOLELY FOR THEATER 2 AND THE EXIT PASSAGE

SINCE THE COOLING REQUIREMENTS OF THEATER 3 & LOBBY AND THEATER 1 & RESTAURANT & WASHROOM ARE NEARLY EQUAL TO THAT OF THEATER 2 & THE EXIT PASSAGE, THE SAME DESIGN PARAMETERS AND SAME RATED EQUIPMENTS ARE USED.

F.1.DESIGN PARAMETERS

The pressure to be maintained in the condenser for changing the phase of ammonia vapours into ammonia liquid depends on type and temperature of the condensing medium used .In this system, forced air is used as a condensing medium. **<u>Water is available at a temperature of 25°C i.e., condensing temperature is Tc = 25°C</u>**. For condensing ammonia vapours at 25°C, the corresponding pressure required can be noted from the refrigeration table of ammonia.

In this way, the condenser pressure is fixed at (pc) = 10.03 bar.

Concentration of NH_3 in refrigerant, X_r = 0.10
Concentration of NH_3 in Solution, X_s = 0.50
Concentration of NH_3 in absorbent, X_w = 0.38
Temperature of the evaporator, T_E = 4°C
Condenser pressure, P_C = 1003.2 kPa
Condenser Temperature = 25°C.
Evaporator pressure, P_L = 497.5 KPa
Temperature of the Condenser, T_C= 25
Temperature of the Generator, T_G = 120°C

F.1.1. EVAPORATOR DESIGN

Total cooling load = 21 tons = 21*3.5 kW = 73.5 kW
Let Air inlet temperature = 30°C
Supply air temperature = 13°C

ΔT_1 = 30 – 4 = 26°C
ΔT_2 = 13 – 4= 9°C

LMTD:

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

LMTD (ΔT_m) = (26 – 9)/ ln(26/9) = 16.024°C

Heat to be removed = Q_E = 73.5 kW

$Q_E = F*U*A*\Delta T_m$
Assuming correction factor to be 1
Taking U = 900 W/m²/°C

Area of heat transfer associated with the evaporator = 5.096 ≈ 5.1 m²
Now, Area = π*d*L
Considering the diameter on the basis of availability in the market = 0.02 m
Length = 81.2 m

Taking no of passes to be 80, length of each evaporator tube = 1.015 m

STATE POINT 4:

Temperature= 4^{o}C
Pressure= 497.5 KPa
Specific enthalpy= h_4 = 1609 KJ/kg

STATE POINT 3:

Temperature= 4^{o}C
Pressure= 497.5 KPa
Specific enthalpy= h_3 =361.71 KJ/kg

From 1st law of thermodynamics ,
$Q_E = m_r*(h4 – h_3)$ m_r = mass flow rate of refrigerant into the evaporator

m_r = 73.5/(1609 – 361.71) = 0.0589 kg/s

Using mass balance equation for ammonia

Mass of solution (m_s)= Mass of refrigerant(m_r) +Mass of absorbent[water](m_w)

$m_s = m_r + m_w$
$m_sX_s = m_rX_r + m_wX_w$
$(m_r + m_w) X_s = m_rX_r + m_wX_w$

Concentration of NH_3 in refrigerant, Xr = 0.99
Concentration of NH_3 in Solution, Xs = 0.50
Concentration of NH_3 in absorbent, Xw = 0.38

m_w = 0.236 kg/s

m_s = 0.295 kg/s

F.1.2.CONDENSER DESIGN

STATE POINT 1:
Temperature= 25^{o}C
Pressure= 1003.2 KPa
Specific enthalpy= h_1 =1626.6 KJ/kg

STATE POINT 2:
Temperature= 25^{o}C
Pressure= 1003.2 KPa
Specific enthalpy= h_2 =361.71 KJ/kg

Cooling medium is water

Air inlet temperature = 30^{o}C
Air outlet temperature = 45^{o}C

ΔT_1 = 30 – 25 = 5^{o}C
ΔT_2 = 45– 25= 20^{o}C

LMTD:

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

LMTD (ΔT_m) = (5 – 20)/ ln(5/20) = 10.82°C

Mass flow rate of refrigerant = 0.0589 kg/s

From 1st law of thermodynamics ,
$Q_C = m_r*(h_1 – h_2)$ m_r = mass flow rate of refrigerant into the evaporator

Q_C = 74.5 kW

$Q_C = F*U*A*\Delta T_m$
Assuming correction factor to be 1
Taking U = 1000 W/m^2/^{o}C

Area of heat transfer associated with the evaporator = 6.885 ≈ 6.9 m^2
Now, Area = π*d*L
Considering the diameter on the basis of availability in the market = 0.02 m

Length = 109.8 m

F.1.3.ABSORBER DESIGN

STATE POINT 5:
Specific enthalpy= h_1 =90 KJ/kg

STATE POINT 8:
Specific enthalpy= h_2 =260 KJ/kg

Heat rejected in the absorber $Q_A = m_W h_8 + m_R h_4 - m_S h_5$

$Q_A = (0.236 \times 260) + (0.0589 \times 1609) - (0.295 \times 90)$
$Q_A = 129.58$ kW
Considering the absorber to be direct contact heat exchanger in which the weak solution from the generator mixes with the ammonia gas from the evaporator and due to the direct mixing the heat is rejected. Air is used as cooling medium.

F.1.5.GENERATOR DESIGN

STATE POINT 7:
Temperature= 120°C
Pressure= 1070 kPa
Specific enthalpy= h_7 =255 KJ/kg
Xw = 0.38

STATE POINT 6:
Temperature= 25°C
Pressure= 1003.2 KPa
Specific enthalpy= h_6 =90 KJ/kg
Xs = 0.50

Q_G is the heat supplied to the generator and Qd is the heat

removed from water. Therefore,

$Q_G - Q_D = m_R (h_1 - h_6)$

And $Q_D = m_R (h_4 - h_7)$

$Q_G = m_R h_1 + m_W h_7 - m_S h_6$
Therefore;
$Q_G = 129.4$ kW.

The required heat to the generator is provided with solar energy.

The energy absorbed by the collector plate is given by

Q= K*S*A

Where,

K = efficiency of the collector plate = 0.8

S = average solar heat falling on Earth's Surface (for Kolkata) = 240 W/m^2 http://solarelectricityhandbook.com/solar-irradiance.html

A = Area of collector plates

Q_G = 129400 W/s = 0.8*240*A

A=673.96 m^2

Hence, the solar collectors are to be installed with area = 673.96 m^2.

For the three different cooling systems to be installed, the total area required is around 2010 m^2.
<u>The total roof area (slanted section of the roof) available for solar panel installation is around 1200 m^2</u>. So the entire slanting portion of the roof is utilized for solar panels, hence preventing direct sun exposure on the roofs of the theatres. The solar energy generated is stored in a battery and fed to the generator during operation where an internal irradiative heater heats the solution. The energy required for running the remaining generators is taken from an electric source (heater), or a diesel powered generator which runs alongside the solar plant if required and can take up the task of providing the entire heating load in case of a failure. <u>(If surrounding areas are available within the building compound, then that area can be utilized for setting up the remaining necessary solar panels).</u>
3 separate dedicated generators are installed each having the capability to provide the maximum required heat load for each generator.

F.2. COP OF SYSTEM

COP = Q_E / Q_G (neglecting pump work)

$Q_E = 73.5$ kW

$Q_G = 129.4$ kW.

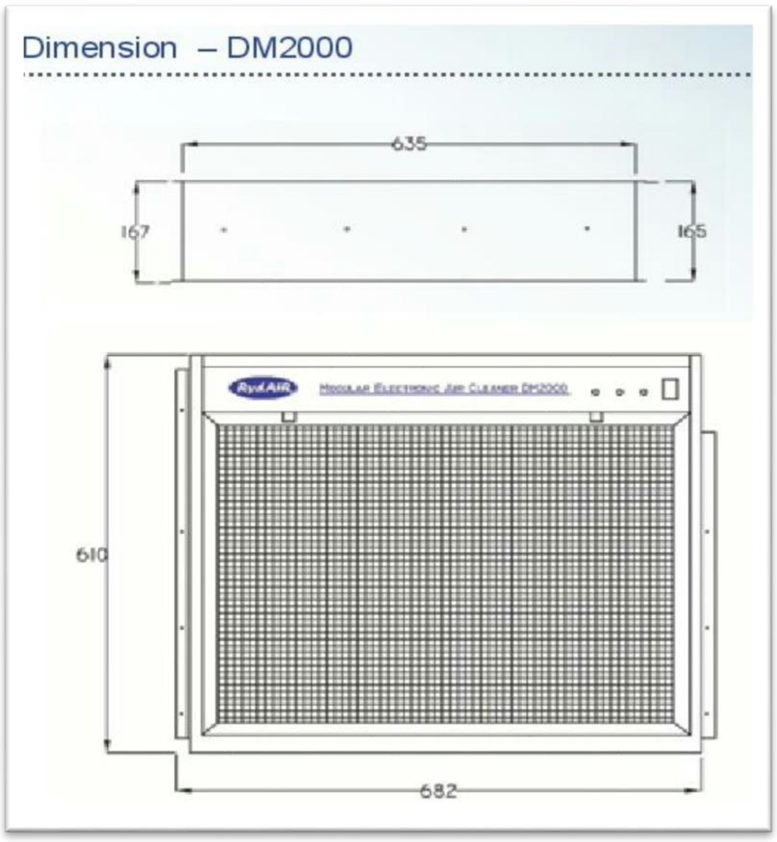
COP/ Energy Efficiency Ratio= 0.568

F.3.AIR FILTER

For our purpose we have used electronic air filters by RYDAIR.

F.3.1.SPECIFICATIONS

Voltage & Frequency	220/240 VAC 50/60 hz
Power Consumption	36 watts
Ionizer Voltage	8.1KV
Collector Voltage	4.1KV
Accessories	Mesh Pre filter
Option	Charcoal Filter.
Weight of unit	17Kg
Shipping weight	19KG
Cell Weight	5.5Kg (each)
No of Cells	2
Cell Materials	Aluminium
Cell Loading	Front Loaded
Installation	Mounted in front of Return Air Plenum of Air Handling Unit



G. PART LOAD EFFICIENCY CALCULATION

Part-load efficiency refers to the ability of a system to handle part-load energy use and it should be taken into consideration when specifying an HVAC system. Systems generally operate at their peak efficiency when they are working at their maximum capacity and most systems are sized to meet heating and cooling conditions that occur only 1% to 2.5% of the time. Because of this, systems are often oversized, rarely operate at full load, and thus do not operate efficiently.

The following calculations have been made based on survey made on several cinema halls at Kolkata.
It has been that during weekdays cinema halls have 50% occupancy and at weekend 75%-80% occupancy. So taking mean value we have considered 50% occupancy for part load. The following table shows the cooling load calculations for part load:

Part Load Calculation for Theatre 1

		Coordinates	22.5726° N, 88.3639° E
Job No.	1	City	Kolkata
Project	Theatre 1 Part Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
		CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Length(m):	19.435									
Width(m):	18.745									
Height(m):	5.7095	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	370	Inside	22	15.42	50	0.0082	22	15.42	50	0.0082
Volume(m³):	2436.85	Difference	12	13.9	21	0.0159	10	13.9	32	0.0167

BPF:	0.12	NO. OF AIR CHANGES/HOUR:	0.62	FILTERED AIR(m³/min):13.187	25.18

SOLAR HEAT GAIN FOR GLASS			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAIN FOR WALLS AND ROOF						
Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	0	1.69	********	0	********	0
Wall(NE)	0	*******	********	0	********	0

Wall(E)	0	1.69	********	0	********	0
Wall(SE)	0	*******	********	0	********	0
Wall(S)	0	1.69	********	0	********	0
Wall(SW)	0	*******	********	0	********	0
Wall(W)	0	Calculate	********	0	********	0
Wall(WN)	0	*******	********	0	********	0
Roof Sun	0	4.16	********	0	********	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All glass	0	Calculate	********	0	********	0
Partition 1	137	1.69	2	463.1	2	463.1
Partition 2	132.5	0.33	2	87.4	0	87.4
Ceiling	365.53	2.2	2	1608.33		
Floor	235.57	1.685	2	793.8	3	793.8

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
25.18	1	20.44	2	1029.35	2	1029.35

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	100	45	********	4500	********	4500
Lights	***	0.6	********	155.4	********	155.4
Sound Box	1	1	********	2000	********	2000
Projector	1	1	********	4000	********	4000
ROOM SENSIBLE HEAT SUBTOTAL:				14637.38		13029.05
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):				1463		1302.9
ROOM SENSIBLE HEAT (R.S.H):				16101.12		14331.96

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
25.18	1	50000	0.0011	1384.9	0.0011	1384.9
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	100	30	********	3000	********	3000
Lights	***		********	0	********	0
Sound Box	1		********	0	********	0
Projector	1		********	0	********	0
S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):				438.5		438.5
ROOM LATENT HEAT(R.L.H):				4823.39		4823.39
ROOM TOTAL HEAT (R.T.H):				20924.51		19155.35

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.5	0.88	20.44	11	3660.39	6.25	2079.77

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.5	0.88	50000	0.014	11396	0.0103	8384.2
R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):				752.82		523.2
SUBTOTAL				15809.21		10987.17
GRAND TOTAL:				36733.72		30142.52
TONS=W/3500:				10.5		8.61
SENSIBLE HEAT FACTOR=RSH/RTH:				0.769		0.748

Part Load Calculation for Theatre 2

Job No.	2	Coordinates	22.5726° N, 88.3639° E
Project	Theater 2 Part Load	City	Kolkata
		Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	24.411									
Width(m):	14.821	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height(m):	5.397	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m²):	370	Inside	22	15.42	50	0.0082	22	15.42	50	0.0082
Volume(m³):	1582.44	Difference	12	13.9	21	0.0159	10	13.9	32	0.0167

BPF:	1	NO. OF AIR CHANGES PER HOUR:	0.62	INFILTRATED AIR:	16.352

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	SUMMER W/m²	SUMMER W	MONSOON W/m²	MONSOON W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	95.43	0.33	18	566.854	8.5	267.68
Wall(NE)	0			0		0
Wall(E)	0		0	0	0	0
Wall(SE)	0			0		0
Wall(S)	0		0	0	0	0
Wall(SW)	0			0		0
Wall(W)	0		0	0	0	0
Wall(WN)	0			0		0
Roof Sun	0	4.16	47	0		0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Air glass	0					
Partition 1	106.7	1.69	0	0	0	0
Partition 2	47.44	0.32	4	60.723	4	60.723
Partition 3	106.77	1.69	0	0	0	0
Ceiling	351.48	3.32	8	9344.87	6.6	7709.52

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
16.352	1	20.432	2	668.2	2	668.2

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	150	45		6750		6750
Lights	***	0.6		155.4		155.4
Sound Box	1	1		2000		2000
Others(screen emission,seat emission)				500		500

ROOM SENSIBLE HEAT SUBTOTAL:	20046.1	18050.8
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):		
ROOM SENSIBLE HEAT (R.S.H):	22050.71	19855.9

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
16.35	1	50000	0.0011	899.25	0.0011	899.25

Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	150	30		4500		4500
Lights	***			0		0

Sound Box	1	0	0
Projector	1	0	0

S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	539.25	539.93
ROOM LATENT HEAT(R.L.H):	5939.18	5939.18
ROOM TOTAL HEAT (R.T.H):	27989.89	25795.08

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.5	0.88	20.44	11	3660.39	6.25	2079.77

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.5	0.88	50000	0.014	11396	0.0103	8384.2

R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):	15809.2	10987.17
GRAND TOTAL:	43799.1	36782.25
TONS=W/3500:	12.51	16.09
SENSIBLE HEAT FACTOR=RSH/RTH:	0.639	0.701

Part Load Calculation for Theatre 3

Job No.	3	Coordinates	22.5726° N, 88.3639° E
		City	Kolkata
Project	Theater 3 Cooling Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
		CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Length(m):	19.435	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Width(m):	18.745	Inside	22	15.42	50	0.0082	22	15.42	50	0.0082
Height(m):	5.7095	Difference	12	13.9	21	0.0159	10	13.9	32	0.0167
Area(m²):	370									
Volume(m³):	2436.85									

BPF: 0.12 NO. OF AIR CHANGES/HOUR: 0.62 FILTERED AIR(m³/min):13.187 25.18

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	SUMMER W/m²	W	MONSOON W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAIN FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	97.98	0.33	18	582	8.5	274.83
Wall(NE)	0	2.81	*******	0	******	0
Wall(E)	0	2.81	*******	0	******	0
Wall(SE)	0	2.81	*******	0	******	0
Wall(S)	0	2.81	*******	0	******	0
Wall(SW)	0	2.81	*******	0	******	0
Wall(W)	0	2.81	*******	0	******	0
Wall(WN)	0	2.81	*******	0	******	0
Roof Sun	0	4.16	*******	0	******	0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
All glass	0	******	*******	0	******	0
Partition 1	106.7	1.69	0	0	0	0

Partition 2	48.71	0.32	4	62.35	4	62.35
Partition 3	106.7	1.69	2	360.65	2	360.65
Ceiling	360.87	3.32	8	9584.7	8	9584.7

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
20.3		1	20.44	2	829.86	2	829.86

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	150	45	*******	6750	******	6750
Lights	***	0.6	*******	155.4	******	155.4
Sound Box	1	1	*******	2000	******	2000
Others			*******	500	******	500

ROOM SENSIBLE HEAT SUBTOTAL:	20824.96	20517.8
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	2082.5	2051.78
ROOM SENSIBLE HEAT (R.S.H):	22907.46	22569.58

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass		Factor	Diff kg/kg	W	Diff kg/kg	W
18.96		1	50000	0.0011	1042.8	0.0011	1042.8

Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	150	30	********	4500	********	4500
Lights	***		********	0	********	0
Sound Box	1		********	0	********	0

S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):	554.28	554.28
ROOM LATENT HEAT(R.L.H):	6097.08	6097.08
ROOM TOTAL HEAT (R.T.H):	29004.54	28666.66

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
18.96	0.88	20.44	11	3751.41	6.25	2131.48

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
18.96	0.88	50000	0.014	11679.36	0.0103	8592.672

R.A. HEAT,LEAK GAIN & SAFETY FACTOR (5%):	771.538	536.2
SUBTOTAL:	15430.77	10724.15
GRAND TOTAL:	44435.31	39390.81
TONS=W/3500:	12.69	11.25
SENSIBLE HEAT FACTOR=RSH/RTH:	0.789	0.787

Part Load Calculation for Lobby

		Coordinates	22.5726° N, 88.3639° E
Job No.	4	City	Kolkata
Project	Lobby part load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	48.783									
Width(m):	10.55	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Height(m):	4.05	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Area(m^2):	514.66	Inside	24	15.42	50	0.0082	24	15.42	50	0.0082
Volume(m^3):	2084.375	Difference	10	13.9	21	0.0159	8	13.9	32	0.0167

BPF:	0.12	NO. OF AIR CHANGES PER HOUR:	0.5	FILTERED AIR(m^3/min):13.187	17.37

SUMMER MONSOON

SOLAR HEAT GAIN FOR GLASS

Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	0	0.72	129	0	136	0
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	0	2.81	0	0	0	0
Wall(NE)	0	2.81	0	0		0
Wall(E)	0	2.81	0	0	0	0
Wall(SE)	0	2.81		0		0
Wall(S)	0	2.81	0	0	0	0
Wall(SW)	0	2.81		0		0
Wall(W)	0	2.81	0	0	0	0
Wall(WN)	0	2.81		0		0
Roof Sun	0	4.16	0	0		0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF

Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Air glass	0					
Partition	0					
Ceiling	514.66					
Floor	514.66					

HEAT GAIN DUE TO INFILTRATION

Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
17.37	1	20.44	0	0	0	0

INTERNAL GAIN

Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	20	68.25		1365		1365
Lights	****	0.86		1429.62		1439.62
Sound Box	1			2000		2000
Projector	0			0		0
ROOM SENSIBLE HEAT SUBTOTAL:				4804.62		4802.62
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):				480.02		480.02
ROOM SENSIBLE HEAT (R.S.H):				5285.08		5285.08

ROOM LATENT HEAT CALCULATIONS

Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
25.18	1	50000	0	0	0	0
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	20	70		1400		1400
Lights	0	0		0		0
Sound Box	0			0		0
Projector	0			0		0
S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):				140		140
ROOM LATENT HEAT(R.L.H):				1540		1540
ROOM TOTAL HEAT (R.T.H):				6825.08		6825.08

OUTSIDE AIR HEAT

OUTSIDE AIR SENSIBLE HEAT (OASH)

Outside air	1-BPF	Factor	Temp Diff(°C)	W	Temp Diff(°C)	W
41.6875	0.88	20.44	0	0	0	0

OUTSIDE AIR LATENT HEAT (OALH)

Outside air	1-BPF	Factor	Diff(kg/kg)	W	Diff(kg/kg)	W
41.6875	0.88	50000	0	0	0	0
R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):				0		0
GRAND TOTAL:				6825.08		6825.08

TONS=W/3500:	1.95	1.95
SENSIBLE HEAT FACTOR=RSH/RTH:	0.774	0.774

Part Load Calculation for Restaurant

		Coordinates	22.5726° N, 88.3639° E
Job No.	5	City	Kolkata
Project	Restaurant part Load	Month	May for summer July for monsoon

			SUMMER				MONSOON			
Length(m):	7.41	CONDITION	DBT	WBT	%RH	kg/kg	DBT	WBT	%RH	kg/kg
Width(m):	4.697	Outside	34	29.32	71	0.0241	32	29.3	82	0.0249
Height(m):	4.05	Inside	24	15.42	50	0.0082	24	15.42	50	0.0082
Area(m²):	34.8	Difference	10	13.9	21	0.0159	8	13.9	32	0.0167
Volume(m³):	140.96									

BPF:	0.12	NO. OF AIR CHANGES PER HOUR:	2	FILTERED AIR(m³/min):13.187	4.699

SOLAR HEAT GAIN FOR GLASS			SUMMER		MONSOON	
Item	Area(m²)	Factor	W/m²	W	W/m²	W
Glass (N)	1.96	0.72	167	235.67	136	191.92
Glass (NE)	0	0.33	527	0	520	0
Glass (E)	0	0.59	631	0	618	0
Glass (SE)	0	0.71	372	0	360	0
Glass (S)	0	0.52	129	0	129	0
Glass (SW)	0	0.17	372	0	360	0
Glass (W)	0	0.13	631	0	618	0
Glass (NW)	0	0.17	527	0	520	0

SOLAR AND TRANSMISSION HEAT GAINS FOR WALLS AND ROOFS						
Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff(°C)	W
Wall(N)	28.1	1.04	10	292.24	8	233.79
Wall(NE)	0	2.81		0		0
Wall(E)	34.8	2.81	0	0	0	0
Wall(SE)	0	2.81		0		0
Wall(S)	28.1	2.81	0	0	0	0
Wall(SW)	0	2.81		0		0
Wall(W)	34.8	2.81	0	0	0	0
Wall(WN)	0	2.81		0		0
Roof Sun	34.8	4.16		0		0

TRANSMISSION HEAT EXCEPT FOR WALLS AND ROOF						
Item	Area(m²)	Factor(W/m²-°C)	Temp Diff (°C)	W	Temp Diff (°C)	W
Air glass	0					
Partition	0					
Ceiling	365.53					
Floor	370					

HEAT GAIN DUE TO INFILTRATION						
Infiltrated Air	Bypass	Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
4.699	1	20.44	10	960.475	8	768.38

INTERNAL GAIN						
Item		Factor	Temp Diff (°C)	W	Temp Diff (°C)	W
People	10	71.2		712		712
Lights	**	0.86		48.79		48.79
electrical appliances	0			2000		2000

ROOM SENSIBLE HEAT SUBTOTAL:	4249.75	4249.75
S.A. HEAT GAIN,LEAK LOSS & SAFETY FACTOR(10%):	424.98	424.98
ROOM SENSIBLE HEAT (R.S.H):	4674.72	4674.72

ROOM LATENT HEAT CALCULATIONS						
Infiltrated Air	Bypass	Factor	Diff kg/kg	W	Diff kg/kg	W
4.699	1	50000	0.0159	3735.7	0.0167	3923.67
Item		Factor	Diff kg/kg	W	Diff kg/kg	W
No. of people	10	80		800		800
Lights	0	0		0		0
Sound Box	0			0		0
Projector	0			0		0

		S.A. HEAT GAIN,LEAK LOSS,SAFETY FACTOR(10%):		453.57			472.37
		ROOM LATENT HEAT(R.L.H):		4989.27			5196.04
		ROOM TOTAL HEAT (R.T.H):		8663.99			8863.99

OUTSIDE AIR HEAT

			OUTSIDE AIR SENSIBLE HEAT (OASH)				
Outside air	1-BPF	Factor	Temp Diff(°C)	W		Temp Diff(°C)	W
5.67	0.88	20.44	10	1019.87		8	815.9
			OUTSIDE AIR LATENT HEAT (OALH)				
Outside air	1-BPF	Factor	Diff(kg/kg)	W		Diff(kg/kg)	W
5.67	0.88	50000	0.0159	3966.7		0.0167	3166.32
		R.A. HEAT,LEAK GAIN & SAFETY FACTOR(5%):		249.33			199.11
		GRAND TOTAL:		13899.89			13045.32
		TONS=W/3500:		3.97			3.72
		SENSIBLE HEAT FACTOR=RSH/RTH:		0.424			0.414

G.1. THEATRE 1+RESTAURANT+WASHROOM

Total sensible heat = 22734.52 W
Part load is 78.3% of the full load
The volume of air that passes through the duct work: V=1.854 m^3/s

$v = \frac{Q}{A}$ where $A = \frac{\pi}{4} * D^2$

D=.786m

v=3.82 m/s

Pressure Loss due to friction= 62.10 N/m^2
Loss due to joints= 266.98 N/m^2

$P_s = \Delta p_s * Q/\eta$

P_s= Power required by fan
Δp_s= Static pressure loss = pressure loss due to friction + Loss due to joints
Q=Discharge rate =1.854 m^3/s
η= Efficiency of fan=0.85

P_s=592.25W

G.2. THEATRE 2+EXIT PASSAGE

Total sensible heat = 27129.45 W
Part load is 78.5% of the full load
The volume of air that passes through the duct work: V=2.213 m^3/s

$V = \frac{Q}{A} \quad where\ A = \frac{\pi}{4} * D^2$
D=0.814m
v=4.25 m/s
Similarly,
P_s=718.5W

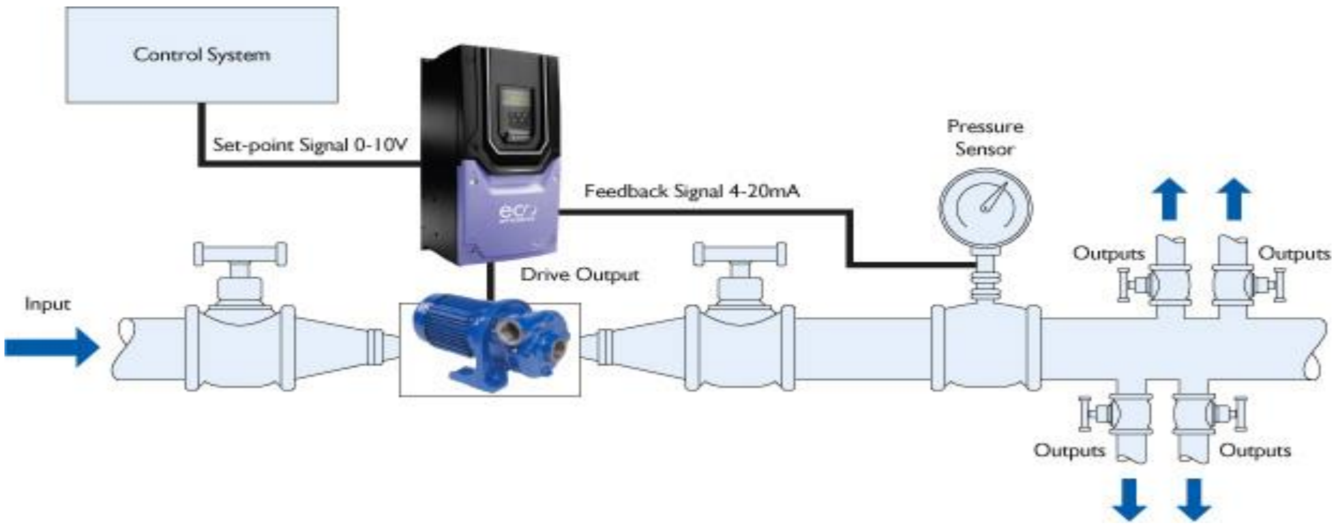
G.3. THEATRE 3+LOBBY

Total sensible heat = 28192.54 W
Part load is 74.4% of the full load
The volume of air that passes through the duct work: V=2.3 m^3/s
$V = \frac{Q}{A} \quad where\ A = \frac{\pi}{4} * D^2$
D=.913m
v=3.513 m/s
Similarly,
P_s=1012.86W

G.4. VFD DRIVE (VARIABLE FREQUENCY DRIVE)

This can be used to change the fan speed from full load to part load.

The following circuit shows the VFD drive:



G.5. PART LOAD EFFICIENCY OF GENERATOR

Total cooling load Q_E = 60.3 kW

Considering all other design conditions same for part load,

m_r = mass flow rate of refrigerant into the evaporator

m_r = 73.5/(1609 – 361.71) = 0.0483 kg/s

therefore, m_w=0.197kg/s m_s=0.245kg/s

$Q_G = m_r h_1 + m_W h_7 - m_S h_6$ =106.7kW

COP/Energy efficiency ratio=Q_E/Q_G=0.565

H. LIFE CYCLE COST ANALYSIS FOR ENTIRE CINEPLEX

For the life cycle cost analysis of the HVAC system, we are considering a 25 year life cycle. The life cycle cost analysis includes the **installation cost, maintenance cost, annual electricity cost, replacement cost, and salvage cost.**

H.1. INSTALLATION COST

As per market conditions, we have derived the approximate installation cost for the whole HVAC system as shown in

S No.	UNIT	No. of units	UNIT COST in Rs.
1	Machine Cost + Fabrication Cost	3	3*3000000 = 9000000
2	Cooling tower	3	3*9000 = 27000
3	Cooling water pump	3	3*100000 = 300000
4	Chilled water pump	3	3*15000 = 45000
5	LT hot water pump	3	3*7000= 21000
6	HT hot water pump	3	3*7000= 21000
7	Solar Plant	2	2*2500000 = 5000000
8	Fire dampers	101	101*6000= 606000
9	Others(electric heater,battery)	----	100000
TOTAL			1,51,20,000 (One crore sixty-nine lakhs and fourteen thousand)

If a diesel-powered generator instead of direct electricity supply to the heater is used then the

INSTALLATION COST REQUIRED FOR EACH GENERATOR IS AROUND RS.2,00,000

H.2. ELECTRICITY COST

For electricity cost analysis,

- We consider **6 operational days in a week**.
- We considered **10 working hours and 200 operational days for the COOLING APPLIANCES and 300 operational days (since during winters the cooling system is not functional) for the FANS and AIR FILTER in a year** tabulated as follows.

S No.	APPLIANCE	No. of units used	Power (kW)	hour	Days	kWh/year	price rate (in Rs./kWh)	TOTAL COST (in 1 year)	TOTAL COST FOR 25 YEARS in Rs.
1	Refrigerator pump	3	3*0.1 = 0.3	10	200	600	5	3000	75000
2	Solution pump	3	3*0.45 = 1.35	10	200	2700	5	13500	337500
3	Cooling water pump	3	3*1.3 = 3.9	10	200	7800	5	39000	975000
4	Chilled water pump	3	3*1.3 = 3.9	10	200	7800	5	39000	975000
5	LT hot water pump	3	3*0.3= 0.9	10	200	1800	5	9000	225000
6	HT hot water pump	3	3*0.3= 0.9	10	200	1800	5	9000	225000
7	Fan (Supply + Return)	6	5.93	10	300	17790	5	88950	2223750
8	Electric heater/generator	1	1*129=129	10	200	258000	5	1290000	32250000
9	Air Filter	3	0.36*3 = 1.08	10	300	3240	5	16200	405000
TOTAL									3,76,91,250 (Six crore ninety nine lakhs forty one thousand two hundred and fifty)

In case the solar power plant is unable to provide the requisite power, the generators substitute them thereby increasing electricity consumption.

IF WE ASSUME THAT ANOTHER GENERATOR IS PRESSED INTO SERVICE FOR 200 DAYS 5 HOURS A DAY THEN THE TOTAL RUNNING COST (FOR 25 YEARS) BECOMES RS. 5,38,16,250.

H.3. MAINTENANCE COST

Maintenance costs of the VARS are the labour and material expense required to maintain the system in suitable use condition. The total annual maintenance cost of VAR is around Rs.1,00,000 leading to Rs.25,00,000 over 25 years of operation.

H.4. REPLACEMENT COST

For the entire life cycle, there is no consideration for cooling towers and chillers in the replacement cost because the lifetime of

these are same as the analysis period. The service life for all the pumps is 10 years. There will be a replacement twice during the 25 year operation. The total cost has been tabulated as follows-

S No.	APPLIANCE	No. of units used	TOTAL COST FOR 10 YEARS in Rs.	TOTAL COST FOR 25 YEARS in Rs.
1	Refrigerator pump	3	3*1500 = 4500	9000
2	Solution pump	3	3*9000 = 27000	54000
3	Cooling water pump	3	3*20000 = 60000	120000
4	Chilled water pump	3	3*15000 = 45000	90000
5	LT hot water pump	3	3*7000= 21000	42000
6	HT hot water pump	3	3*7000= 21000	42000
7	Fan (Supply + Return)	6	90000	180000
8	Air Filter	3	3*18000 = 54000	108000
	TOTAL			645000 (Six lakhs forty-five thousand)

H.5. TOTAL LIFE CYCLE COST (LCC)

LCC = Installation cost + Electricity cost (+42% may be incurred) + Maintenance cost + Replacement cost

LCC = Rs.5,59,56,250

I. FIRE AND SAFETY

Our plan is to install fire dampers along with smoke and fire sensors at the opening of each supply duct release.

I.1.THERMOELECTRIC WITH SPRING RETURN ACTUATOR

Motorised fire dampers contain thermoelectric release mechanisms and a spring return actuator. When the release temperature is reached (72°C or 95°C), the temperature sensor in the airstream interrupts the supply voltage to the spring return actuator, and the spring return in the actuator causes the fire damper to close. A second temperature sensor monitors the ambient temperature. Since the supply duct gets closed the circulation of harmful gases and supply of oxygen is prevented and return ducts draws out the smoke from the region.


I.1.1. Cost of Installation:

Cost of each damper: Rs6000

Total supply duct opening: 101

Total cost: Rs 6,06, 000

I.1.2. Replacement Cost

These dampers have long life time efficiency of around 25 years.

I.2. AUTOMATIC SPRINKLER SYSTEM

It is an active fire protection method, consisting of a water supply system, providing adequate pressure and flowrate to a water distribution piping system, onto which fire sprinklers are connected.

I.2.1. Cost of Installation:

An approximate cost of installing a new sprinkler system is Rs 36 per square feet.

Total area to be sprinkled is 12895.16 sq.ft

Total installation cost=Rs 464226

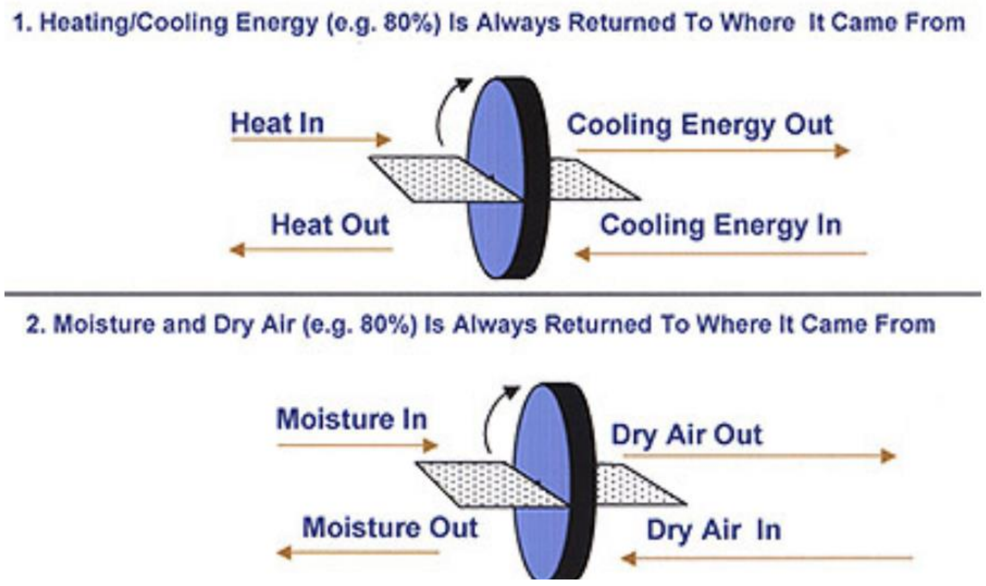
J. A Special Attention to Indoor Air Quality

- Using eco friendly Carpets on The Floor
- Paint and furniture should be V.O.C free
- Taking free air through heat recovery wheel
- Almost half an hour before opening of building all the windows should be opened so that there is a circulation of fresh air
- Proper HVAC system should be installed in food court to remove smell of food
- Proper ventilation should be given to the building and special attention should be given to the restrooms.

K. FUTURE PROSPECT

K.1. USING HEAT RECOVERY WHEEL

In a typical installation, the wheel is positioned in the AHU so that it is divided into two half-moon sections. Stale exhaust air is drawn through one half and outdoor air through the other in a counter flow pattern. At the same time the wheel is rotated. Sensible heat is transferred as the metallic substrate picks up and stores heat from the warmer air stream and gives it up to the cooler one. Latent heat is transferred as the desiccant coating on the metallic substrate adsorbs moisture from the air stream that has the higher humidity ratio and releases the moisture into the air stream that has the lower humidity ratio.



K.1.1. Benefits of Heat Recovery Wheels

- Pre-conditions incoming fresh air
- Easily integrated/retrofitted into new/existing ventilation systems
- Delivers fresh air throughout the year at conditions very near inside conditions.
- Helps to meet ventilation standards without raising energy costs
- Maintains humidity conditions at no additional cost
- Allows reduction in system capacity by 30 to 65%

K.2. USING SOLAR BLINDS

Blinds can be set to actively respond to the environment in 2 ways, with closed blind angle as specified by the user

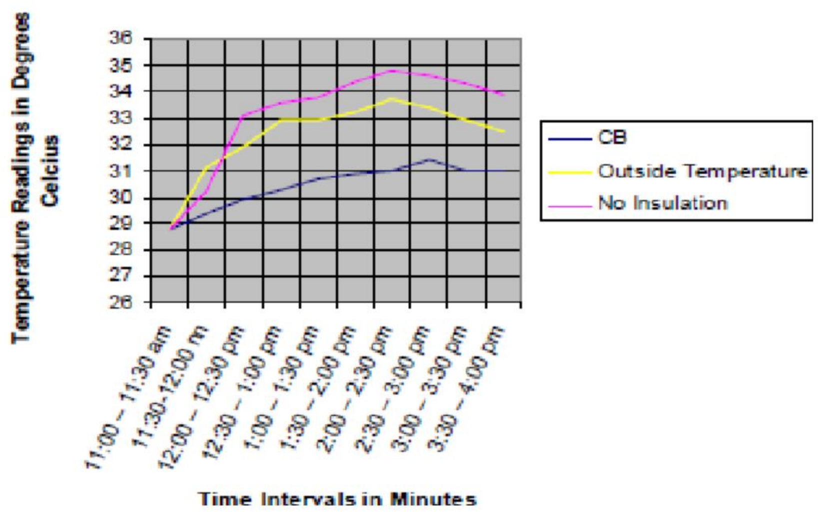
- Temperature Sensitive: Blinds open/close when they cross the upper alert temperature threshold (too hot)
- Solar intensity Sensitive: Blinds close when the direct normal illuminance is more than the normal amount (glare)

K.3. SHIFTING OR SHAVING LOADS DURING PEAK DEMAND PERIODS

Many electricity distribution companies offer cheaper rates during off peak periods that typically occur during the night. energy management systems can shed non-critical loads at peak periods to prevent short duration electrical demands from affecting energy bills for the entire year. The number of shows during peak periods can be reduced so that the electricity consumption from critical loads are reduced during this time. At the same time, the number of shows during off peak periods can be increased.

K.4. USING SPECIAL INSULATING MATERIALS TO REDUCE HEAT LOAD

To reduce the heat load on the building we propose to use a unique insulation material **Coco Coir Polypropylene** as a thermal insulator. The following figure shows the heat insulation performance of CCP



K.5. USING MEDICINAL PLANTS TO DETOXIFY AIR

In our project we have used special air filters to filter in incoming air. As an alternative we could use medicinal plants that remove toxicants from the air. A few example of such plants are Mother in Law's Tongue (*Sansevieria trifasciata)*, Money Plant (*Epipremnum aureum),* Peace Lily(*Spathiphyllum),* Bamboo Palm (*Chrysalidocarpus lutescens).* Using these medical plants will reduce the cost of installation to a great extent

K.6. SMART BUILDINGS

Provisions could be made to minimize energy usage whenever there is an opportunity. Elevators should have sensors installed that will detect occupancy. If the elevator is unoccupied then it will go to sleep mode by turning off all its light and music. Also, elevators/escalators could have regenerative drive which converts excess mechanical energy into electrical energy.

K.7. SUSTAINABLE ENERGY FLOOR

Sustainable Energy Floor can be used in high footfall areas. The floor modules flex slightly when stepped on. Inside each tile is an electromechanical system, which transforms the small vertical movement produced by pedestrians into a rotating movement that drives a generator. Each module by the size of 115 mm can produce up to 30 watt of continuous output. Typical power output for continuous stepping by a person lies between 1 and 10W nominal output per module.

K.8. VIVACE(VORTEX INDUCED VIBRATION FOR AQUATIC CLEAN ENERGY)

The device designed to capture and convert energy from ocean and river currents has been developed to provide a source of clean and renewable energy. The energy produced by this device will be cheaper than that produced from either solar or wind power and offer distinct advantages over standard hydropower technologies.

K.9. TRANSPARENT SOLAR CELLS

MIT researchers are making transparent solar cells that could turn everyday products such as windows and electronic devices into power generators—without altering how they look or function today. The solar cells absorb only infrared and ultraviolet light. Visible light passes through the cells unimpeded, so our eyes don't know they're there. Using simple room-temperature methods, the researchers have deposited coatings of their solar cells on various materials and have used them to run electronic displays using ambient light

L. CONCLUSION

Since, we have used a solar collector water heater to run the generator, there are no direct emissions from this system, so it is completely eco-friendly. The only leakage would be that of our refrigerant is NH_3. Since this leakage is negligible, it can be neglected and the ODP (Ozone Depletion Potential) and GWP (Global Warming Potential) of NH_3 is very low, so that it would not adversely affect the environment.

The only electricity that we are using in our system is for the pumps and fans and a generator. The total units consumed by these fans and pumps per year are **301530 UNITS**.
FOR 1 UNIT, 6.89551X10^{-4} METRIC TONS OF CO_2 ARE EMITTED IN THE ATMOSPHERE. HENCE, THE TOTAL INDIRECT EMISSION IS AROUND 200 METRIC TONS OF CO2. Otherwise, there is not any indirect emission.

M. REFERENCES

The following HVAC design has been made based on

ANSI/ASHRAE Standard 62.1-2007

(Supersedes ANSI/ASHRAE Standard 62.1-2004)

Includes ANSI/ASHRAE Addenda listed in Appendix I(reference ASHRAE STANDARDS)

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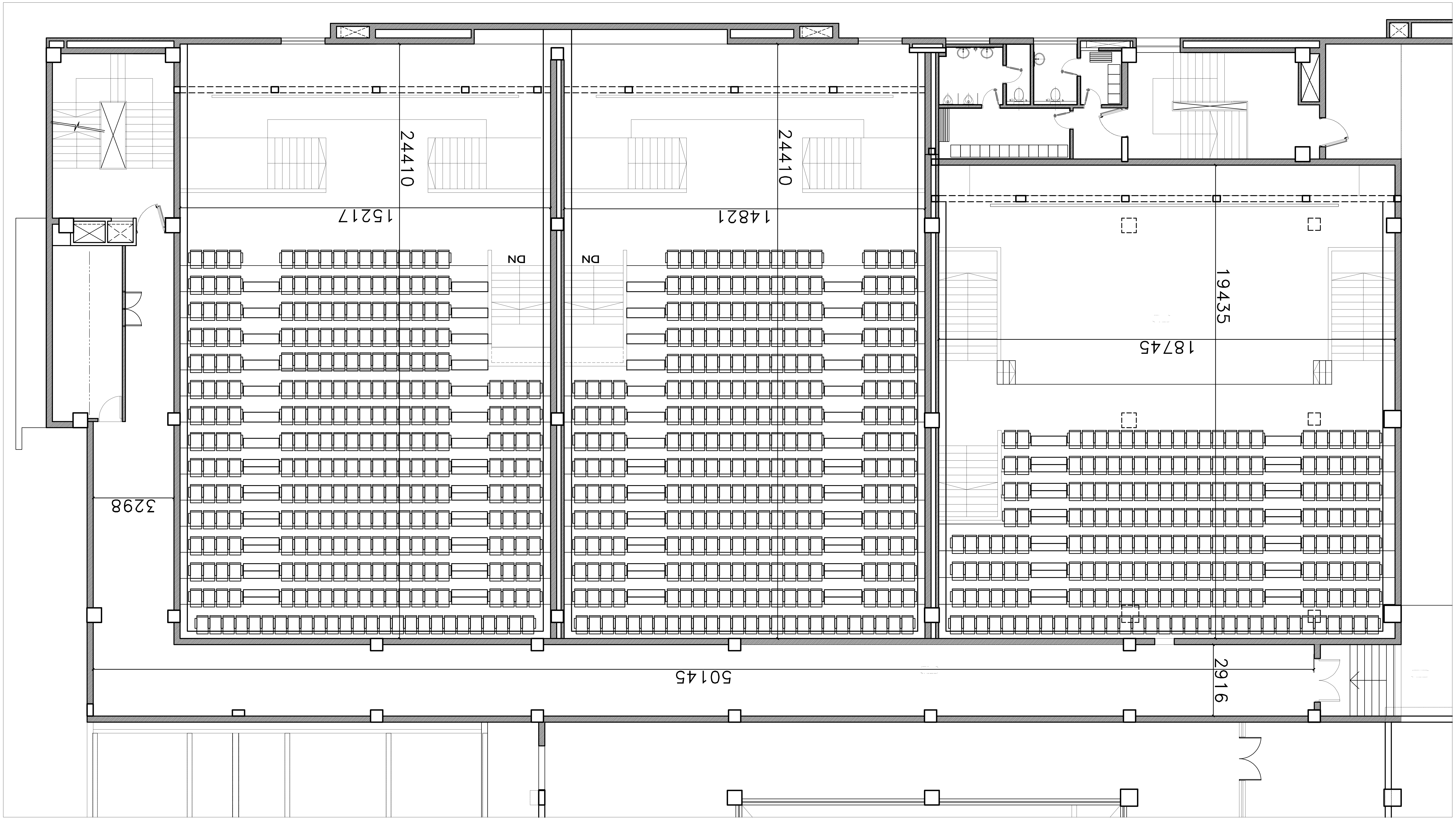
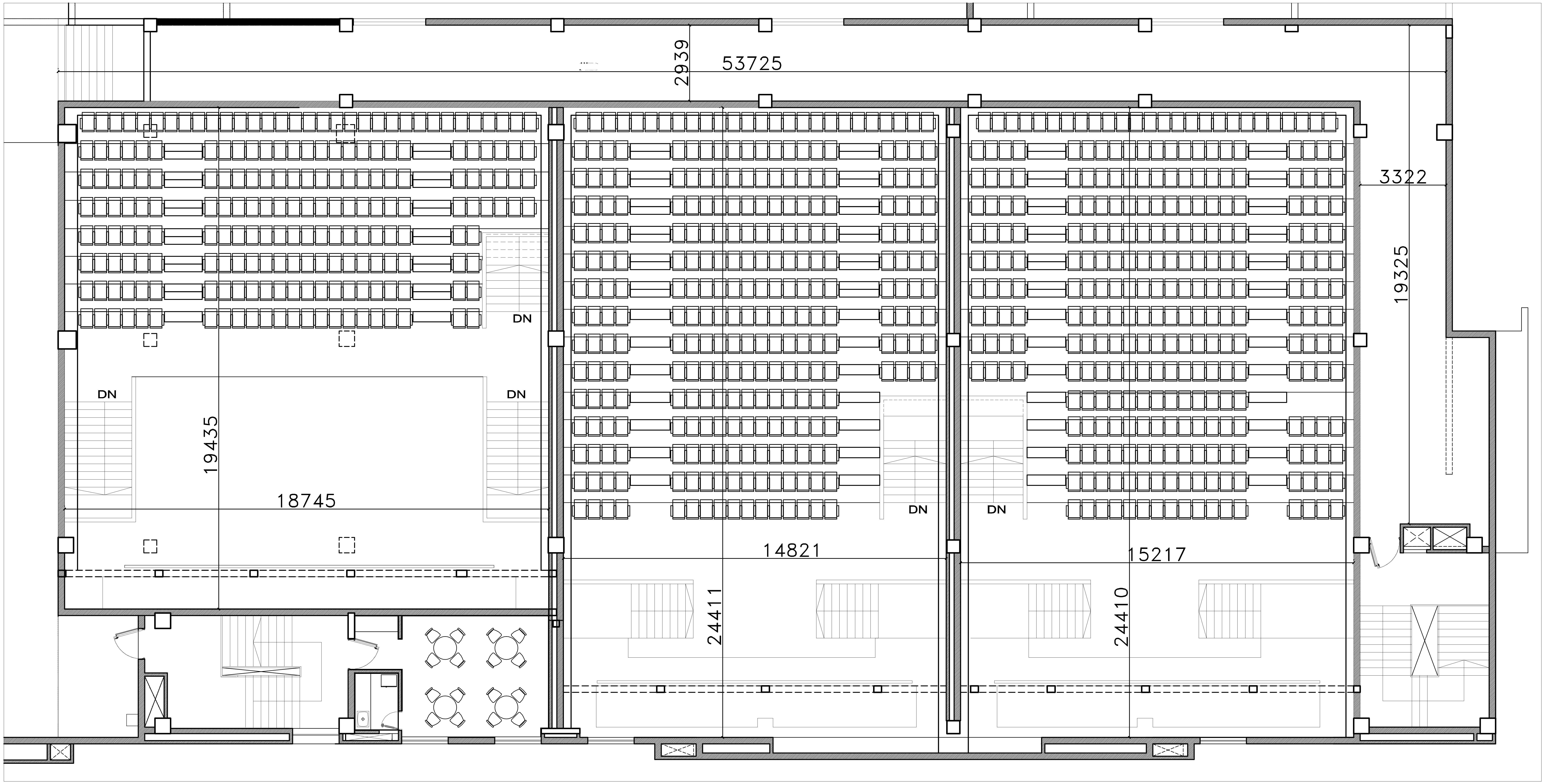


PROJECTION LEVEL

AHU LEVEL



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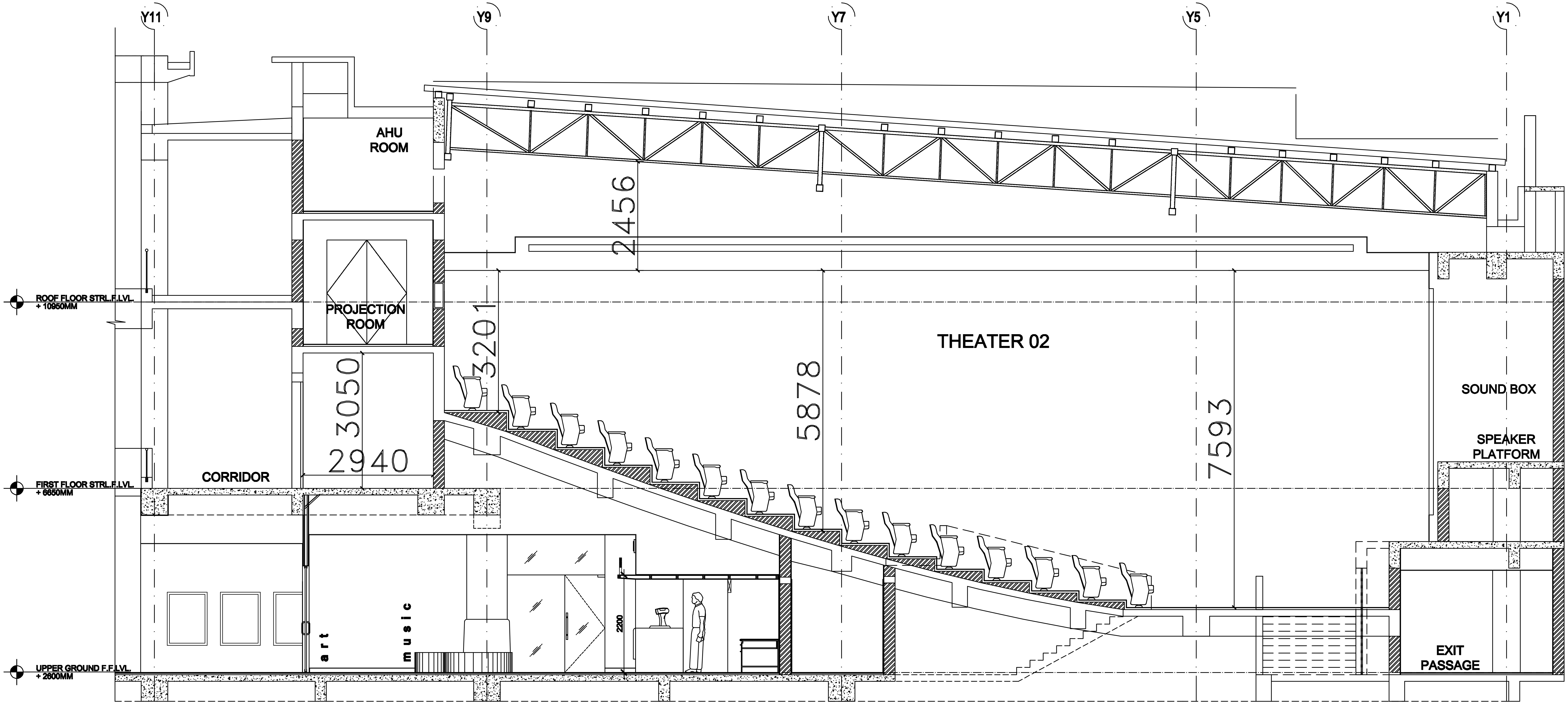

SECTION C

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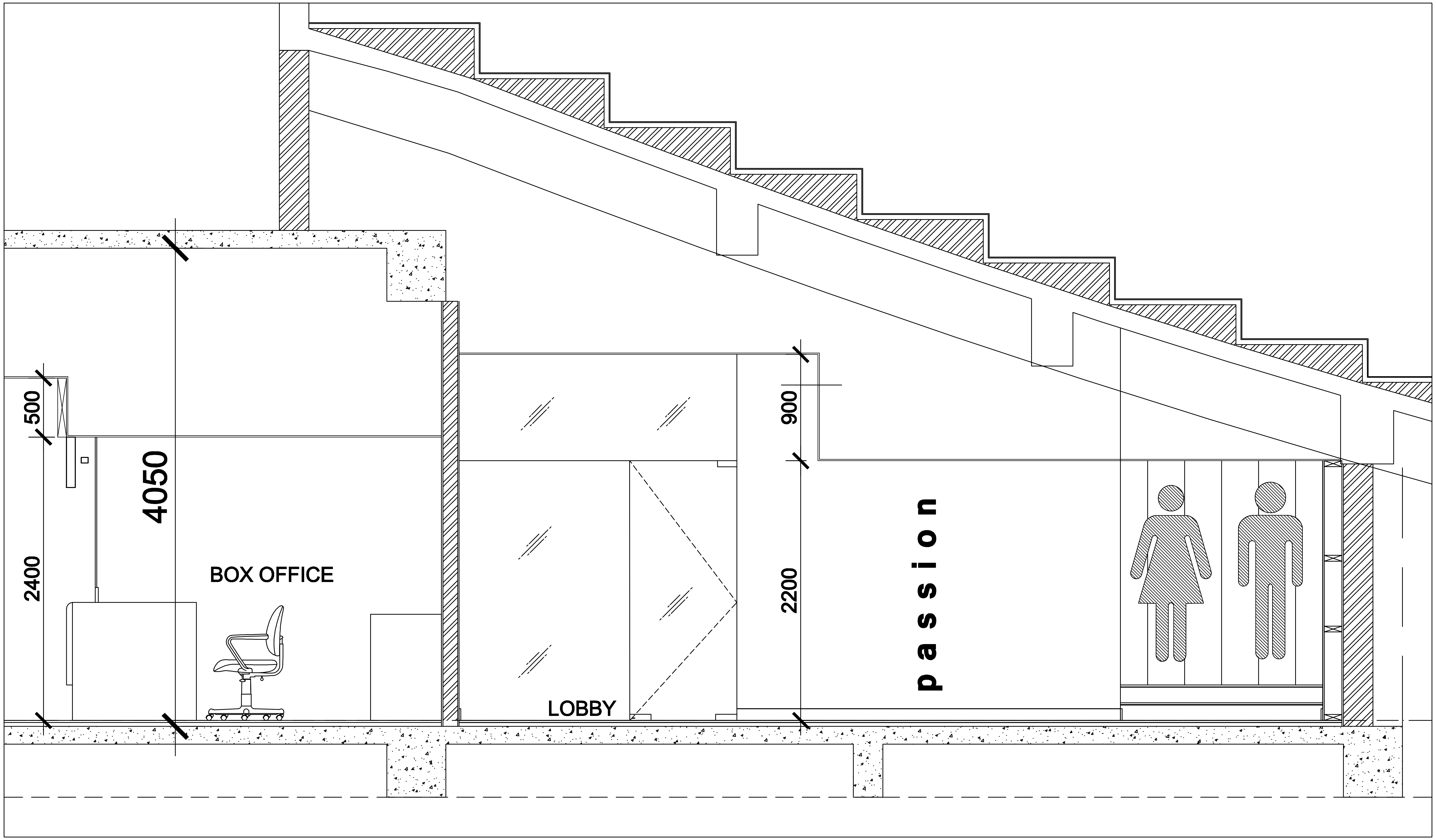
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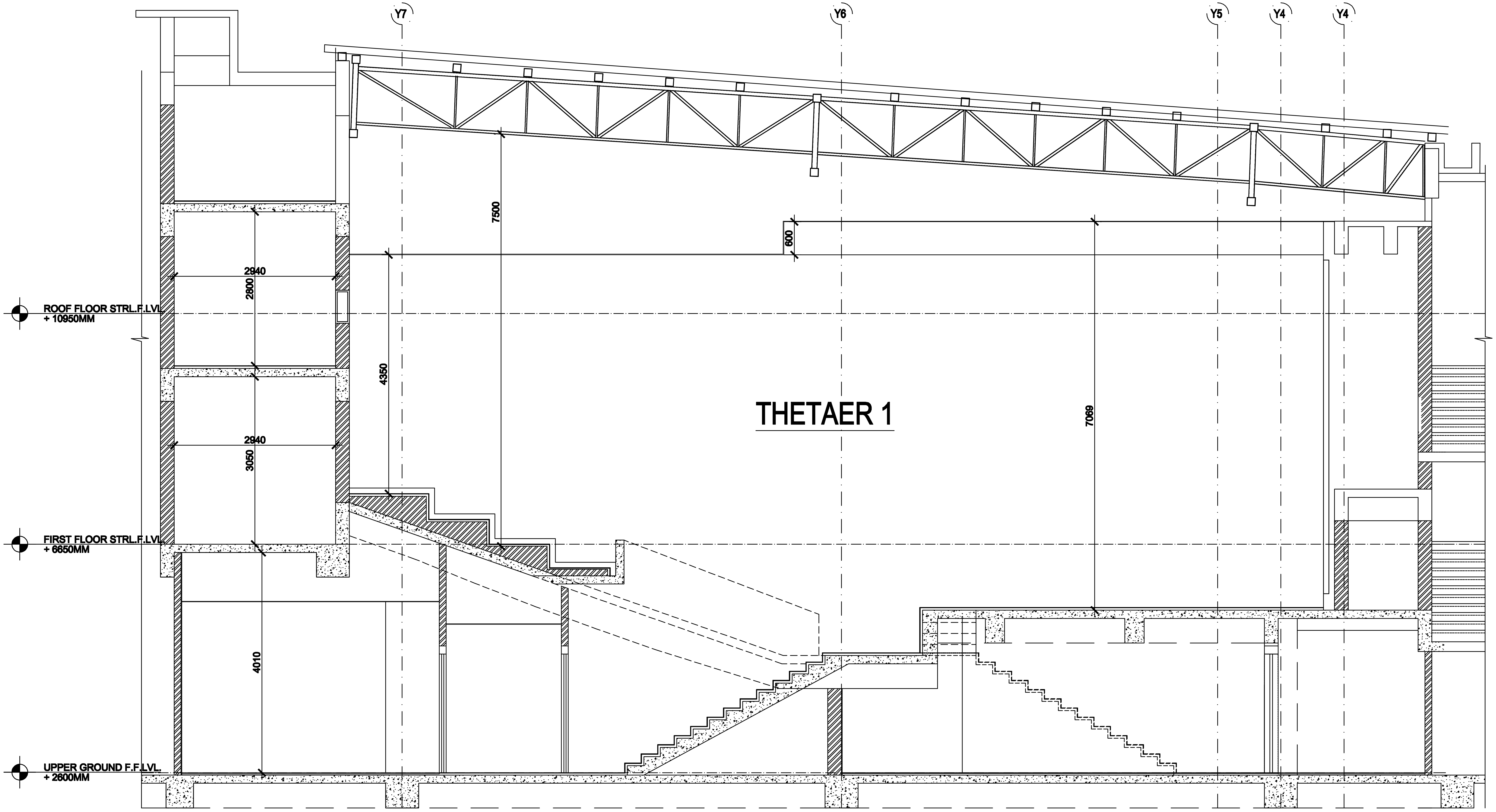
passion


Y7
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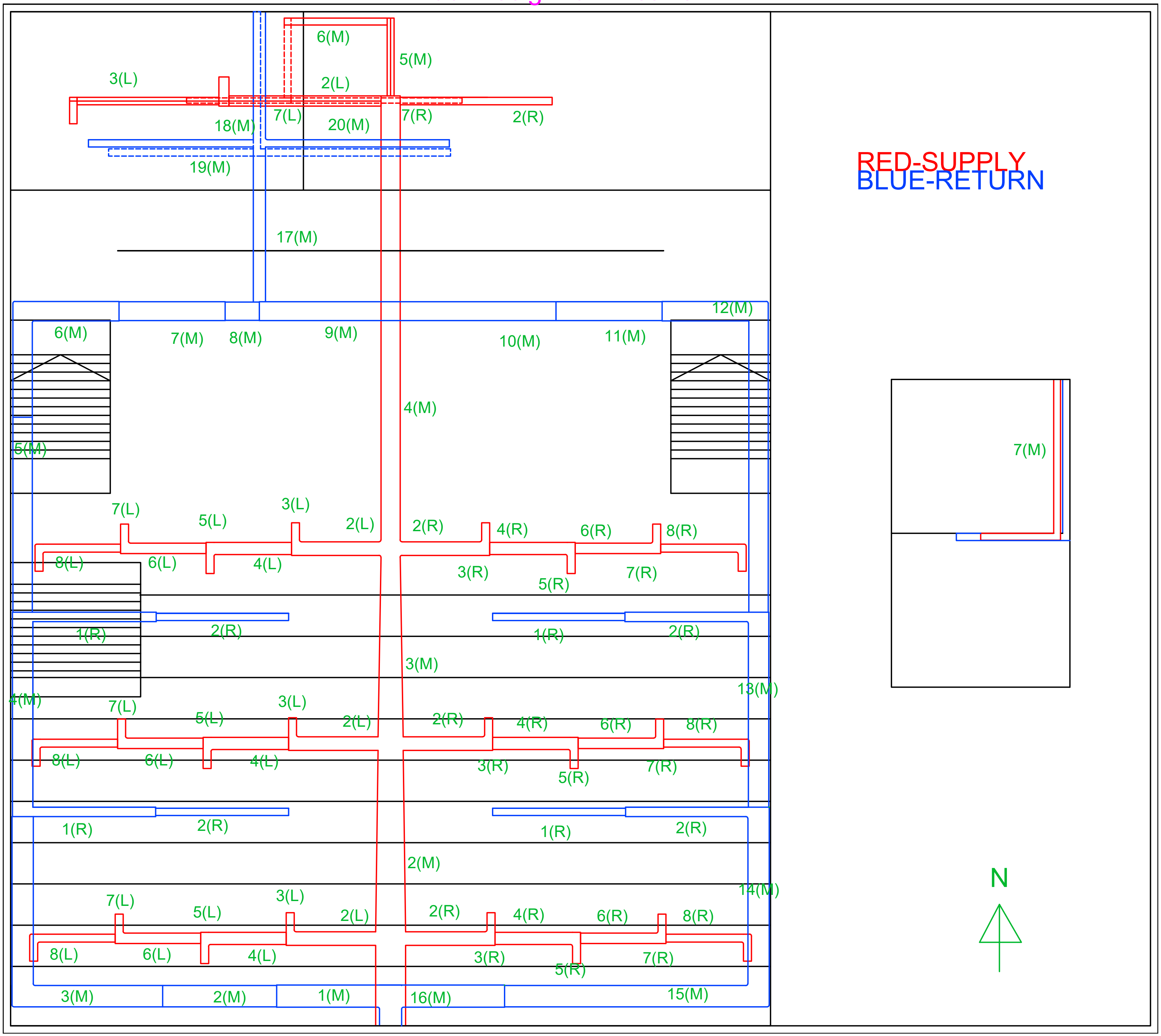
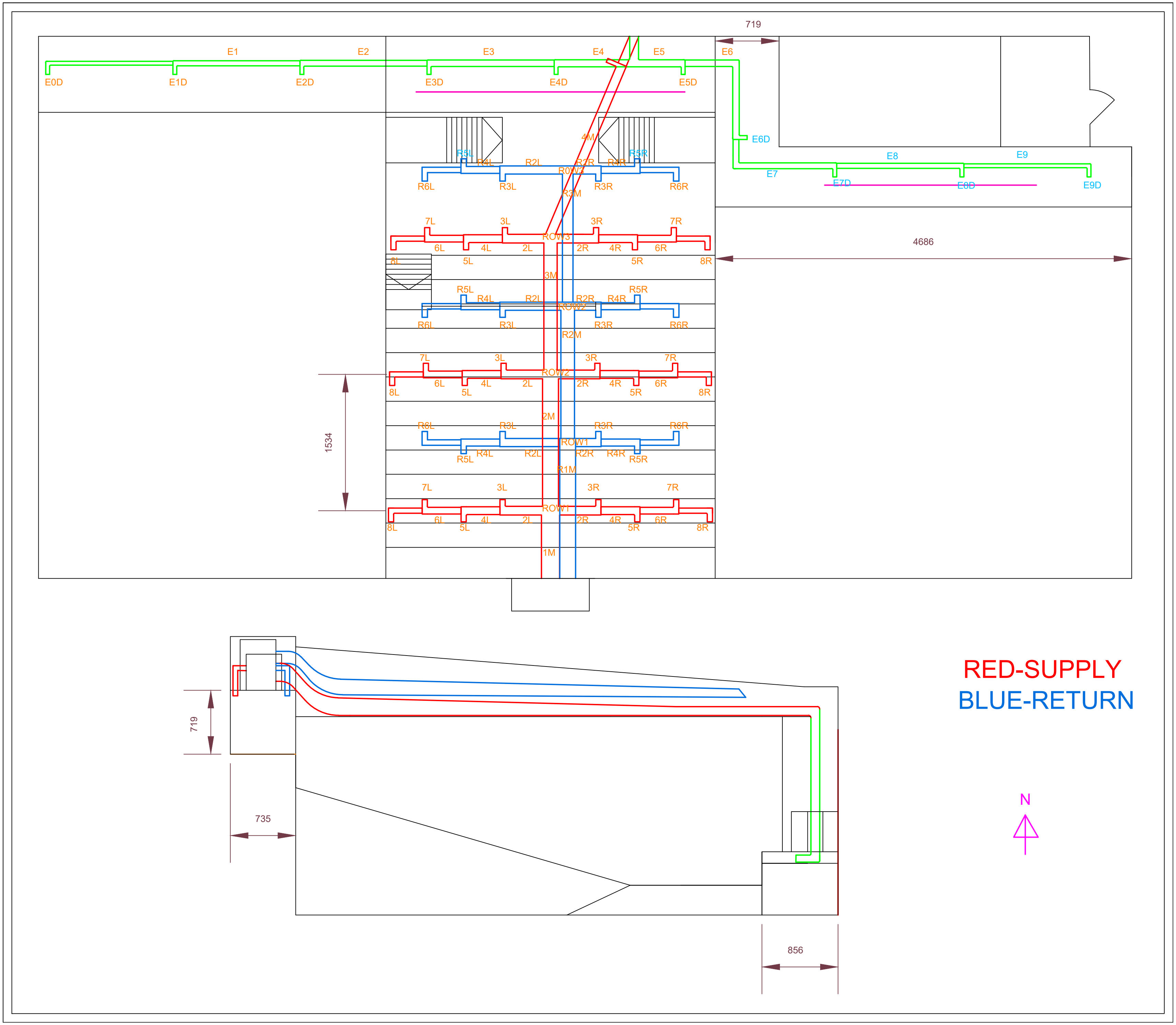
ROOF FLOOR STRL.F.LVL.
+ 10950MM
4350
THETAER 1
7069
2940
3050
FIRST FLOOR STRL.F.LVL.
+ 6650MM
4010
UPPER GROUND F.F.LVL.
+ 2600MM

SECTION A

Duct Design for Theatre 1



Duct Design For Theatre 2



Duct Design for Theatre 3