AIRFLOOR™

The Forced Air Radiant
Cooling & Heating System

AIRFLOOR™ Design Guide

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Preliminary Design

1.1 Applications

The first step is to determine the areas or zones in which the Airfloor™ system will be applied

The most common application for the Airfloor™ system is to provide general space heating, ventilation and air conditioning (HVAC) to occupied spaces within buildings. The range of heating and cooling capacity which can be achieved by the Airfloor™ system means that it can be applied to virtually any type of space. The particular characteristics of Airfloor™ make it especially suitable in instances which require:

- The removal of overhead ductwork and discrete air delivery
- Enhanced thermal comfort and indoor air quality (IAQ)
- A reduced HVAC zone
- Improved acoustics
- Reduced energy consumption

The Airfloor™ system can be, and has been, applied to residential, commercial, main lobbies, restaurants, multi-storey buildings, renovations and new-build developments.

Additionally there are a number of special applications for Airfloor™ which include computer rooms and return or exhaust air pathways. This document provides design guidance in relation to the most common applications.

1.2 Heating and Cooling Loads

Space Thermal Loads

Once the zones of application have been determined the next step is to determine the zone heating and cooling loads. These values form the basis of the system airflow sizing and determination of supply air temperature (SAT). These can be determined several ways:

A. Dynamic simulation modelling

Typically used by professional engineering consultants. Simulation software may include HAP, eQuest, DOE 2, Trane Trace, Hevacomp, IES-VE. These tools should be used only by qualified professionals

B. Manual Hand Calculation

Various methodologies exist to determine space heating and cooling loads including the ASHRAE Heat Balance method (HBM)[A], the Radiant Time Series (RTS) Method[A] and the CIBSE Admittance Method[B]. Any of these methods may be used at the discretion of the designer.

C. Rule of Thumb Estimation

Various rule of thumb data exist for the estimation of heating and cooling loads for different building types and different climate zones.

While this may be useful as means of preliminary system sizing it is recommended that loads are validated using one of the methods above.

Once the space heating and cooling loads have been determined losses and dynamic effects must be considered.

Allowance for Losses and Dynamic Effects

In addition to the space heating and cooling loads, allowance needs to be made for heat losses and gains in distribution. For intermediate floors in which spaces are conditioned or tempered both above and below the Airfloor™ distribution system the distribution losses are negligible. In slab on grade applications heat losses can average 10-15% without slab insulation but this can be reduced below 10% by using foundation wall insulation. A similar allowance should also be considered in instances where the Airfloor™ slab is above an unheated space, for example with overhung or cantilevered slabs. However, it is recommended to apply insulation beneath the Airfloor™ system in these instances, either within or beneath the slab, to minimise uncontrolled heat loss.

Finally, a provision is required for initial heat-up/cool-down. The extent of this depends upon both the desired pre-conditioning period, setback temperatures and thermal response of the space. More detailed guidance on this topic is provided elsewhere in this guide. However, a minimum of 10% of the combined space load and heat losses is recommended.

The following equation may then be used to determine the sensible design loads, h_s

$$h_s = h_{space} + h_{dist.} + h_{margin}$$

Where:

h_{space} = space heating / cooling load
$h_{dist.}$ = distribution losses / gains
h_{margin} = margin for preconditioning

1.3 Design Temperatures

Room Air Temperature

Suitable room temperature for thermal comfort varies depending upon the type of activities performed and the clothing typically worn by the occupants. As a result, design temperatures for the same type of space can also vary seasonally due to the changing clothing of the occupants. Consequently, it is recommended to set both summer and winter room design temperatures.

ASHRAE 55[C] provides guidance on thermal comfort and appropriate temperature setpoints in different types of spaces based on either Predicted Mean Vote (PMV) or Adaptive methods. The Adaptive method is only applicable for building without mechanical cooling systems and therorefore is not applicable to the Airfloor™ system. It should be noted that Ashrae 55[C] is also referenced by LEED and WELL building standards.

Elsewhere EN 16798[D] provides similar guidance based upon ISO 7730[E], also identifying different categories of thermal environment.

The UC Berkley Center for the Built Environment (CBE) provide a useful online calculator to allow assessment of different conditions and their impact upon thermal comfort https://comfort.cbe.berkeley.edu/EN

CIBSE Guide A[B] also proposes design temperatures for common space typologies.

Supply Air Temperature (SAT)

In order to determine bulk airflow requirements to each zone it is necessary to set an initial supply air temperature (SAT).

In heating mode in temperate climates (ASHRAE climate zones 1-4[F]), a SAT of 90-105degF (32-41degC) is typical. In colder climates (ASHRAE climate zones 5-6[F]) a SAT up to 125degF (52degC) may be considered. These values are typically adequate to meet heating demand in most spaces. However, in very cold climates or in highly glazed spaces the heating output of the system can be enhanced further by the provision of a finned tube convector within the supply air register to re-heat the supply air before it enters the space.

In cooling mode, a SAT in the range 50-60degF (10-16degC) is typical and adequate to serve most applications. It will be noted by HVAC engineers that this is lower than industry guidance provided by ASHRAE and CIBSE for displacement applications who typically recommend supply air temperatures in the range 63-68degF (17-20degC) in order to ensure acceptable comfort. However, as the cool air circulates through the Airfloor™ void, heat is transferred to the air stream from the topping slab above such that when the air enters the space at the floor grille it is typically within this recommended comfort range. Consequently, the Airfloor™ system may be more energy efficient than conventional underfloor air distribution (UFAD) and displacement ventilation (DV) systems in humid climates because there is a reduced requirement for reheat at the air handling unit after the dehumidification cycle.

For best efficiency and effectiveness of the radiant floor it is recommended that the supply airflow volume on the heating and cooling cycles are approximately balanced. Therefore, the final determination of both heating and cooling SAT is typically an iterative process to balance the airflow. Designers are therefore advised to start somewhere in the middle of the ranges given here and then adjust as necessary to achieve equivalent airflow on both cycles.

1.4 Airflow for Heating, Cooling and Ventilation

Simple Method

In single height spaces up to 12' (3.7m) it is possible to calculate airflow values for heating and cooling in the same manner as a conventional overhead HVAC system, i.e. based upon the sensible heat balance equation. Airflow for sensible heat can be determined using the formulae below:

IP Units

$$V_{SENS} = h_s / (1.08*dT)$$

Where:

h_s = sensible heat (BTU/hr)

V_{SENS} = air volume flow for sensible heat (CFM)

dT = Temperature difference between supply air and room temperature (degF)

SI Units

$$V_{SENS} = h_s / (c_p*\rho*dT)$$

Where:

h_s = sensible heat (kW)

V_{SENS} = air volume flow for sensible heat (m^3/s)

dT = Temperature difference between supply air and room temperature (degC)

ρ = density of air (kg/m3)

c_p = specific heat of air (kJ/kg.K)

This method may be used for determination of both airflow for heating (V_{HEAT}) and cooling (V_{COOL}).

As with a conventional system, it also necessary for designers to perform proper psychrometric checks on the cooling cycle especially, to ensure that latent heat is addressed, and humidity levels are controlled to acceptable levels.

Minimum Outdoor Air (OA)

Supply air may be either 100% outdoor air or a mix of outdoor air (OA) and recirculated return air depending upon the application. Minimum outdoor air requirements for different types of spaces and occupancies are often prescribed by local building codes as either a flow rate per person, per unit of area, as an air change rate or a combination. These requirements are usually mandatory and vary between cities, states and countries and should be used as a starting point for determination of minimum outdoor airflow requirements.

In the absence of mandatory guidance reference can be made to International Mechanical Code, ASHRAE Standard 62.1[I] for commercial buildings and ASHRAE Standard 62.2[J] for residential buildings.

ASHRAE Standard 62.1[I] provides default values for ventilation effectiveness and the following equation to determine breathing zone outdoor air flow:

$$V_{OZ} = (R_P*P_Z + R_A*A_Z) / E_Z$$

Where:

V_{OZ} = required volume of outdoor air to zone

R_P = outdoor air flow rate required per person, cfm/person (l/s per person)

R_A = outdoor air flow rate per unit area, cfm/sq.ft (l/s per sq.m)

P_Z = zone population, i.e. the largest number of people expected to occupy the zone during typical usage, persons

A_Z = zone floor area, sq.ft (sq.m)

E_Z = ventilation effectiveness

Due to the air supply being at floor level the ventilation effectiveness of the Airfloor™ system should be taken as 1.05 – 1.5 depending upon the discharge velocity and throw of the floor supply grille. The Airfloor™ system therefore typically requires less outdoor air than a conventional overhead HVAC system to achieve the same level of ventilation. This can yield significant energy savings in both hot and cold climates.

1.4 Airflow for Heating, Cooling and Ventilation

AIRFLOOR™

Design Air Flow Rate

The design supply airflow rate (V_S) of the system is the greater of the outdoor airflow rate, the heating airflow rate and the cooling airflow rate as

$$V_S = Max\ [V_{OZ}, V_{HEAT}, V_{COOL}]$$

Where:
V_{OZ} = required volume of outdoor air to zone
V_{HEAT} = required airflow for heating
V_{COOL} = required airflow for cooling

In temperate climates there is usually be a significant energy benefit in the application of an airside economizer (or free cooling) system. To maximize the benefit of this control function it is recommended that the outdoor air intake is sized to match the design supply airflow rate (V_S) of the system.

Rule of Thumb Values

Clearly, the required airflow will vary based upon the design of the space, the prevailing climate and the internal heat gains (i.e. occupancy, lighting and equipment). However, typical values of Airflow for different types of spaces are provided in the table below as a benchmark for validation of calculated values.

Type of Space	**Typical Airflow (CFM/ft^2)**	**Typical Airflow (l/s per m^2)**
Office	1.0 - 1.5	5.1 – 7.6
Residential	0.75 - 1.0	3.8 – 5.1
School	1.2 - 2.0	6.1 – 10.2
Auditoria/Theatre	2.0	10.2

Other Methods

A. Advanced Manual Calculation

It is possible to determine via hand calculation the thermal operating characteristics of an Airfloor™ system under steady state operating conditions; including the relative proportions of heating and cooling accomplished by radiant and convective heat transfer and the temperature of air discharged into the room from the floor. This approach requires calculation of the thermal resistance of both upper and lower slabs plus the determination of the surface coefficient of the floor.

B. Displacement Calculation

In taller or double height spaces it may also be possible at the designer's discretion to calculate required airflow for heating and cooling by considering the stratified and occupied zones separately or by using a displacement ventilation calculation methodology.

Several displacement ventilation calculation methods existing including the ASHRAE[G] method and the REHVA[H] method developed by the Federation of European Heating and air-conditioning Associations. While these methods are similar, they make slightly different assumptions. Therefore, the designer must ensure to select the most appropriate method and ensure that the specific pre-requisites of the selected method are met by the usage case.

C. Computational Modelling

All these procedures rely on assumptions and so should be used with care when applied to large spaces such as theatres or atria. A computational fluid dynamics (CFD) of large spaces is recommended to determine and optimize the airflow in large and complex spaces.

A computational method has also been proposed to allow dynamic assessment of the system behaviour combining dynamic simulation modelling (DSM) and computational fluid dynamics (CFD).

1.5 Preliminary Design Overview

Step 1 – Identify Zones
This includes spaces to be served with the Airfloor™ and also the thermal zoning therein

Step 2 – Calculate Heating and Cooling Loads
Specifically space heating and cooling loads as these are required to determine supply air temperatures and air volumes in both heating and cooling cycles

Step 3 – Select Initial Design Temperatures
Follow the guidance elsewhere in this section regarding typical heating and cooling supply air temperatures

Step 4 – Determine Initial Heating and Cooling Airflow Rate
Follow a suitable approved methodology for preliminary determination for heating and cooling airflow rate as described elsewhere in this section

Step 5 – Evaluate and Adjust Initial Design Temperatures
The goal in this step is to ensure that the airflow volume across both heating and cooling cycles is approximately equal

Step 6 – Re-Calculate Heating and Cooling Airflow Rate
Re-calculate final airflow rates based upon new design conditions. Repeat steps 5 and 6 until heating and cooling airflow rates are approximately equal

Step 7 – Determine Outdoor Airflow Rate
Determine the required minimum outdoor air flow required to each zone served by the system based upon local building code, client requirement or industry guidance as appropriate. This provides the designer with the information required to determine coil conditions for all zones.

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Contents:

Detailed Design

2.1 Ductwork Distribution

Method I: Ducted Beneath Splash Box

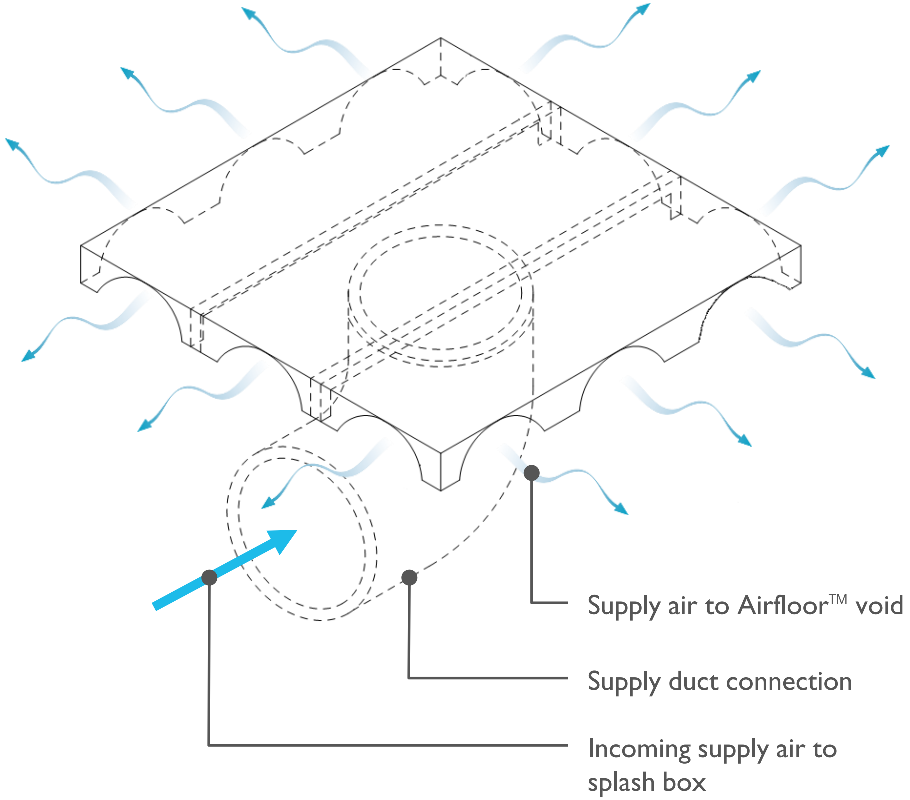
Description

The most common method of ductwork distribution is to form ducted connections to splash boxes from beneath. In this approach, air is circulated to splash boxes via rectangular or circular ductwork which runs either beneath the structural slab for upper levels, or within a chase or trench for slab on grade applications. Circular spigot connections are then made to each splash box from beneath as per the sizing guidance elsewhere in this document.

Spigot connections to splash boxes should be circular and made into the centre of the splash box to ensure even air distribution into the Airfloor™ labyrinth on all four sides. The sizes of spigot connections and the splash boxes themselves will vary depending upon the airflow handled by each splash box and the static pressure limits of the system. Detailed guidance on this is provided subsequently in this document.

Where duct connections are made through the structural slab, it is important that these openings are coordinated with the structural engineer and sleeved or protected with an approved detail if required to maintain the fire separation between floors.

Splash Box Connection



Typical Installation

2.1 Ductwork Distribution

Method 2: In-Floor Ducting

Description

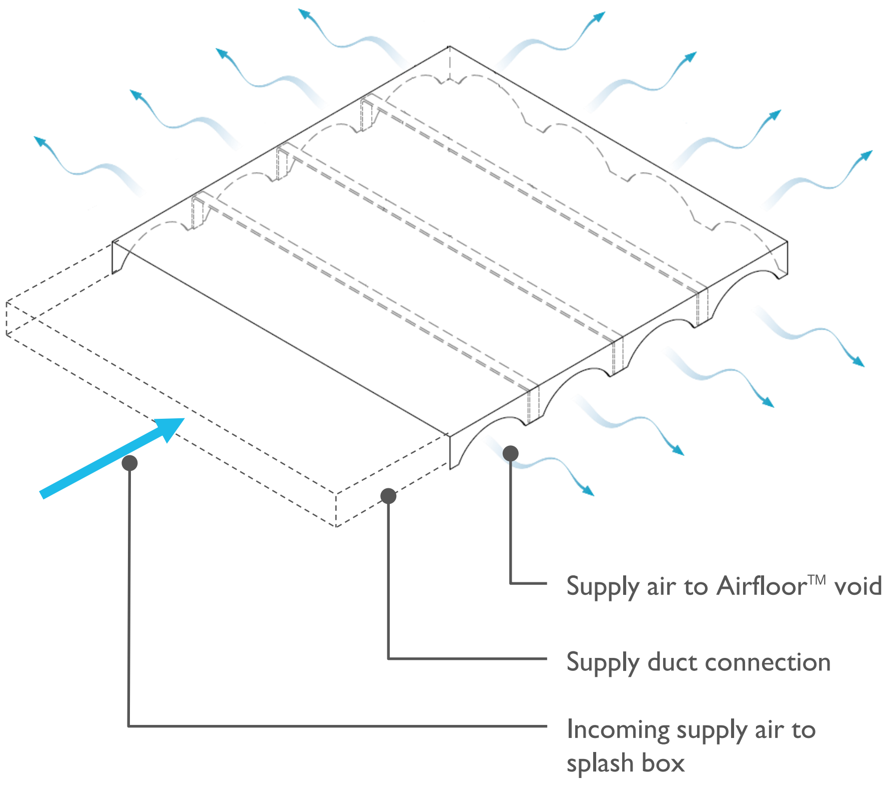
The alternative method is in-floor ducting. In this method ductwork connections to splash boxes are formed via flat and wide duct sections running within the same zone as the Airfloor™ forms themselves.

In this style of distribution the ductwork runs above the structural slab and connects into splash boxes from the side meaning that one side of the splash box acts as the inlet with up to 3 sides acting as outlets. As a result, the airflow handled by each splash box may be reduced.

Ductwork is typically fed from above in this approach and due to the reduced handling capacity of each splash box multiple supply points may be required to each room.

As the ductwork runs above the structural slab it must be protected with bridging plates to spread the weight of both the topping slab and the eventual live load to prevent the duct from being crushed.

Splash Box Connection



Typical Installation

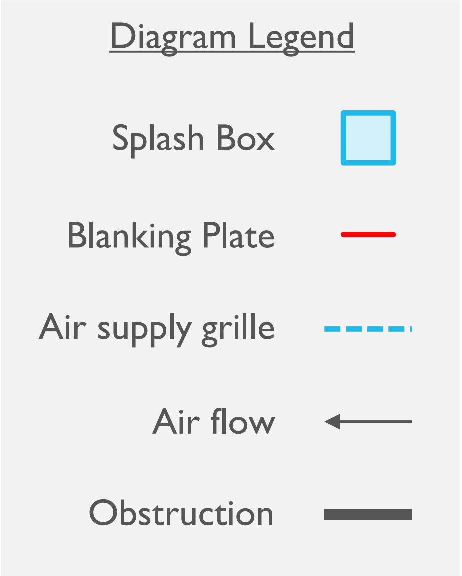
2.2 Splash Box Layout

Good Practice Principles

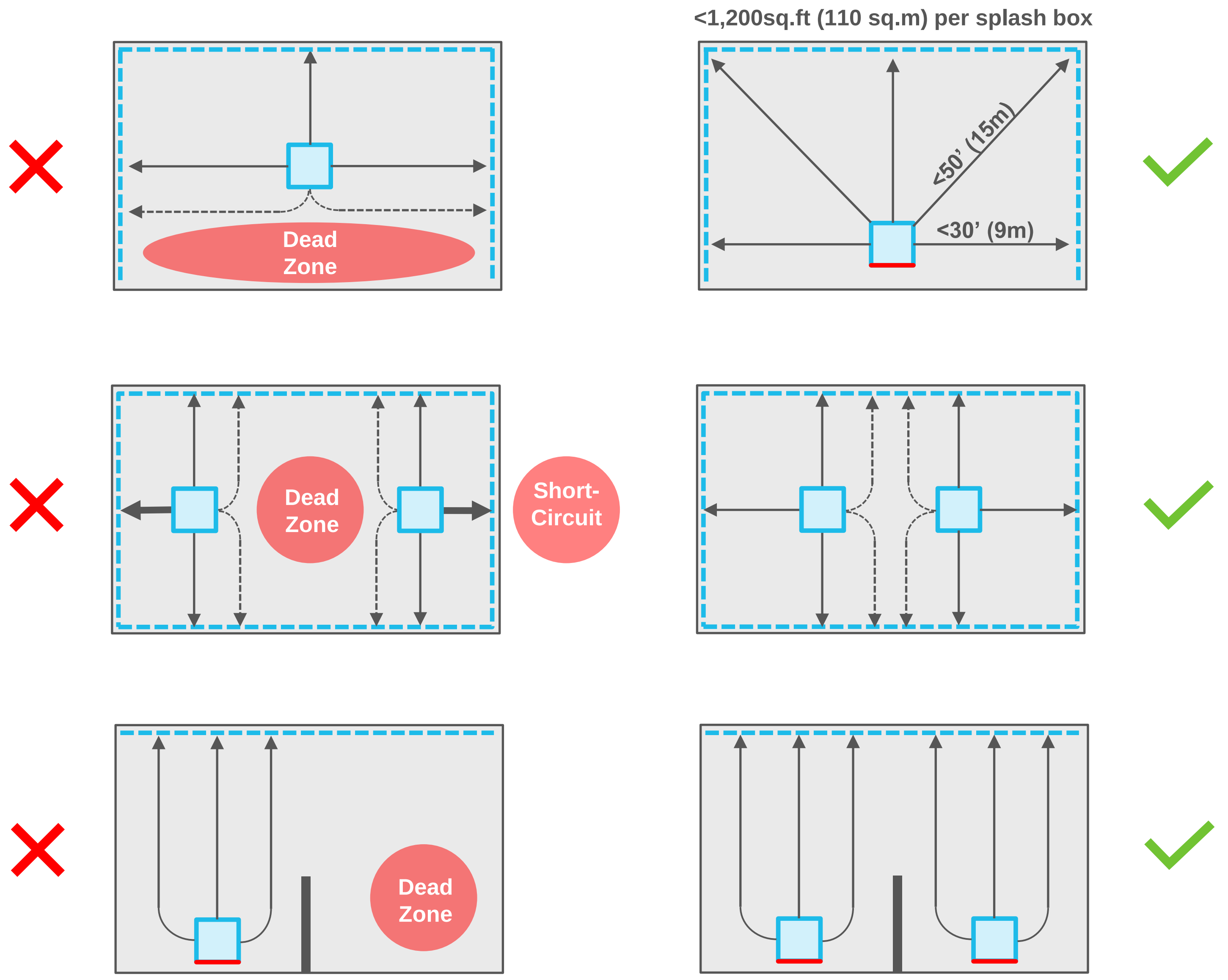
Setting out of splash boxes is important to ensuring good airflow throughout the Airfloor™ void in order to achieve well developed airflow and consistent heat transfer via the floor surface. It also helps to ensure even distribution of air at the supply air outlets.

Key principles:

1. Observe maximum zone sizes and separation distances
2. Keep a consistent distance between splash boxes and supply grilles to prevent short-circuiting
3. Place splash boxes to avoid the creation of dead zones with no air flow
4. Use blanking plates to block exits from splash boxes which are not required to be active
5. Consider the impact of physical obstructions on airflow



Do's and Don'ts



2.3 Fan Static Pressure

Overview

As with all HVAC systems, the system external static pressure (ESP) is a combination of the friction loss of all of the components which form part of the index run. This includes the ductwork, the splash box, the Airfloor™ void and the air supply grille. This combined static pressure loss is a key determinant in the overall fan energy consumption of the system. The Airfloor™ system is designed to be a low-pressure system when compared to a conventional HVAC system, therefore correctly sizing the various components is important.

The following equation may then be used to determine the design external static pressure for fan sizing, P_{ESP}

$$P_{ESP} = P_{Duct} + P_{Splash} + P_{Void} + P_{Connector} + P_{Grille}$$

Where:

P_{ESP} = Combined external static pressure
P_{Duct} = Ductwork static pressure loss
P_{Splash} = Splash box static pressure loss
P_{Void} = Airfloor™ void static pressure loss
$P_{Connector}$ = Airfloor™ connector pressure loss
P_{Grille} = Grille static pressure loss

Elements of Static Pressure Calculation

1. Ductwork

Guidance on ductwork design is provided by various industry bodies like ASHRAE and CIBSE covering a number of methods exist including constant friction, constant velocity and static regain methods. Any method may be used at the designer's discretion, however, as a low-pressure system the default recommendation is to use the constant friction method. Further details on this can be found in ASHRAE Fundamentals[A] and CIBSE Guide C4[H].

2. Splash Boxes

As a potential pinch point, the correct sizing of splash boxes is important to limiting the overall static pressure of the system. Guidance on the correct sizing of splash boxes is provided in subsequent pages.

3. Airfloor™ Void

Air movement within the Airfloor™ void is generally slow and friction loss correspondingly low. However, this should also be assessed as part of the overall system static pressure as set out in subsequent pages.

4. Connectors

Connectors are the fabricated parts used to either connect riser ducts to the Airfloor™ void from above or to form connections from the void to the supply registers. This involves turning air through 90 degrees so it is important to capture this pressure loss.

5. Grilles and Registers

The Airfloor™ system is extremely flexible when it comes to delivery of supply air. Many methods can be adopted, and guidance is provided elsewhere in this document. Generally, static pressure for grilles should be determined based upon manufacturer's data. Custom arrangements should be assessed by the design engineer and suitable allowance made for friction loss.

2.4 Splash Box Design

Splash Box Sizing Procedure

Objective

As a potential pinch point, the sizing of splash boxes is therefore important to controlling this. The Airfloor™ system is designed to be a low static pressure system when compared to a conventional HVAC system.

Selection Process

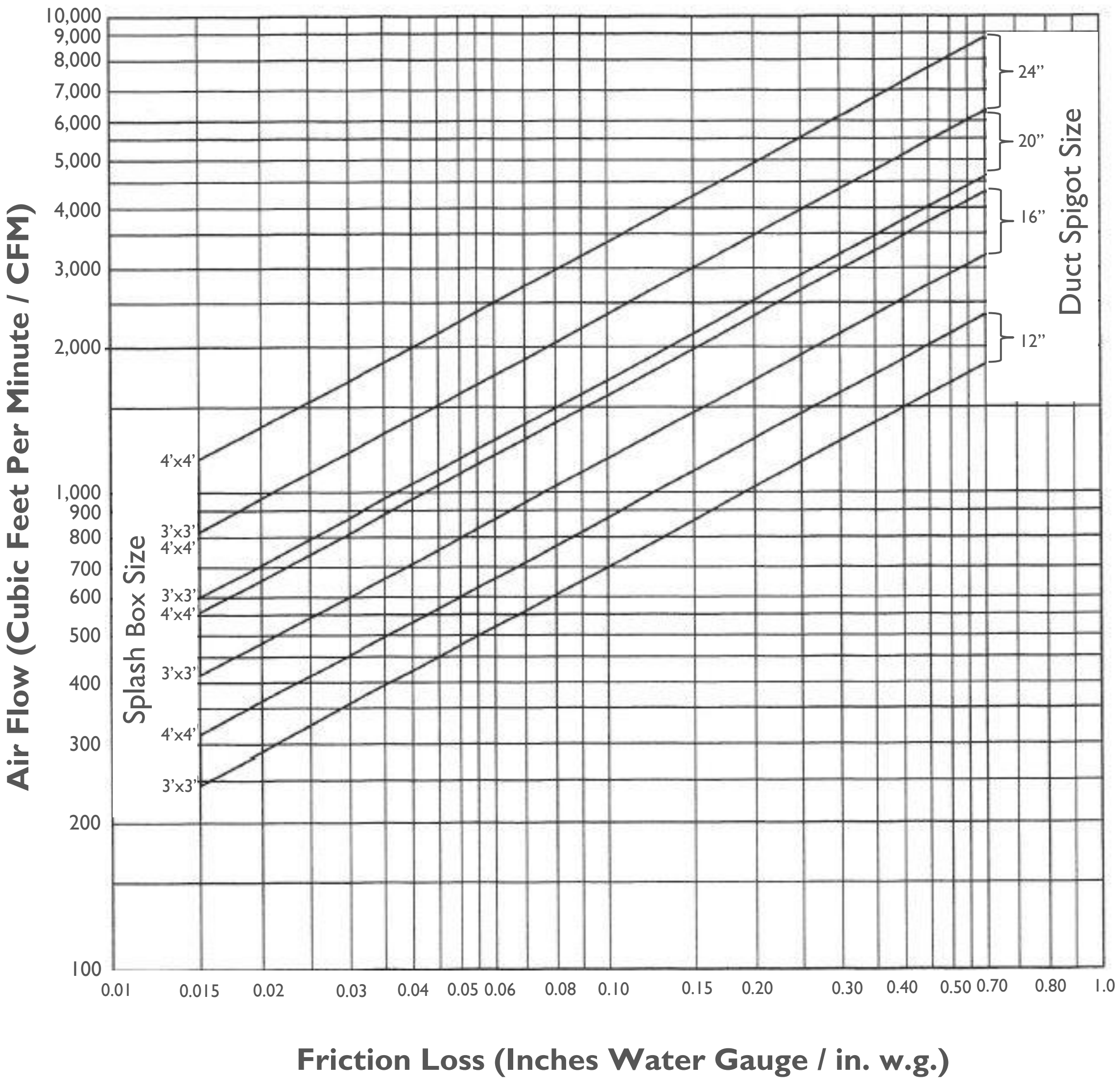
Typically, one splash box is adequate to serve zones up to 1,200 sq.ft (~110 sq.m) in area. For larger zones multiple splash boxes may be used served from the same common duct for simplicity of control.

Sizing Criteria

When sizing splash boxes it is recommended to limit the friction pressure loss to <0.10" w.g. (25 Pa).

It is also required to ensure that net free area of the splash box outlets is greater than the net free area of the duct or trench supplying the splash box. This is to avoid acceleration of the airflow as it travels through the system and associated static pressure loss.

Splash Box Sizing Nomogram



2.4 Splash Box Design

AIRFLOOR™

Splash Box Sizing Tables: Static Pressure Loss (in. w.g.)

CFM	Supply Duct Dia. (Inches)	Supply Duct Velocity (FPM)	2' x 2'	3' x 3'	3' x 4'	4' x 4'
400	10"	735	0.03	0.024	0.020	0.018
600	10"	1100	0.068	0.048	0.040	0.040
800	10"	1468	0.14	0.074	0.07	0.065
1000	10"	1835	0.18	0.10	0.10	0.10
	12"	1275	0.23	0.18	0.16	0.12
	16"	717		0.07	0.06	0.05
1200	12"	1529	0.29	0.26	0.21	0.17
	16"	860		0.11	0.09	0.06
	20"	550		0.05	0.040	0.02
1400	12"	1784	0.42	0.36	0.30	0.23
	16"	1005		0.14	0.11	0.08
	20"	642		0.07	0.06	0.04
1600	12"	2040		0.49	0.38	0.29
	16"	1147		0.18	0.14	0.11
	20"	734		0.09	0.07	0.05
1800	12"	2290		0.58	0.46	0.37
	16"	1290		0.22	0.18	0.13
	20"	825		0.11	0.07	0.06
2000	16"	1432		0.27	0.22	0.16
	20"	918		0.18	0.10	0.09
	24"	637		0.08	0.06	0.040
2200	16"	1575		0.32	0.28	0.19
	20"	1010		0.16	0.12	0.10
	24"	700		0.09	0.08	0.05

CFM	Supply Duct Dia. (Inches)	Supply Duct Velocity (FPM)	2' x 2'	3' x 3'	3' x 4'	4' x 4'
2400	16"	1720		0.38	0.30	0.22
	20"	1100		0.19	0.15	0.10
	24"	760		0.13	0.09	0.06
2600	16"	1865		0.43	0.35	0.29
	20"	1190		0.20	0.16	0.12
	24"	830		0.12	0.10	0.06
2800	16"	1935		0.50	0.40	0.30
	20"	1285		0.26	0.19	0.14
	24"	890		0.13	0.13	0.08
3000	16"	2150		0.54	0.44	0.33
	20"	1375		0.28	0.22	0.16
	24"	955		0.18	0.14	0.09
3200	16"	2290		0.66	0.50	0.38
	20"	1470		0.30	0.24	0.19
	24"	1020		0.19	0.14	0.10
3400	20"	1560		0.35	0.25	0.20
	24"	1090		0.20	0.15	0.11
3600	20"	1650		0.40	0.30	0.22
	24"	1145		0.22	0.18	0.12
3800	20"	1745		0.42	0.32	0.26
	24"	1200		0.24	0.21	0.14
4000	20"	1846		0.49	0.35	0.28
	24"	1275		0.25	0.20	0.15
4500	20"	2100		0.61	0.45	0.34
	24"	1460		0.29	0.23	0.18
	30"	940		0.13	0.08	0.07
5000	24"	1600		0.38	0.27	0.22
	30"	1050		0.22	0.14	0.12

2.5 Airfloor™ Void Design

Airfloor™ Void Static Pressure Calculation

Resistance within Airfloor™ void itself is nominal. The friction loss through the floor was scientifically tested by California Testing Laboratories and the findings of their analysis are summarised in the nomogram opposite (original test report is provided in the reference information). This shows the friction loss in inches of water per 50' (15m) rather than per 100' because it is recommended to have a maximum distance of 50' (15m) from the main supply to the outlet.

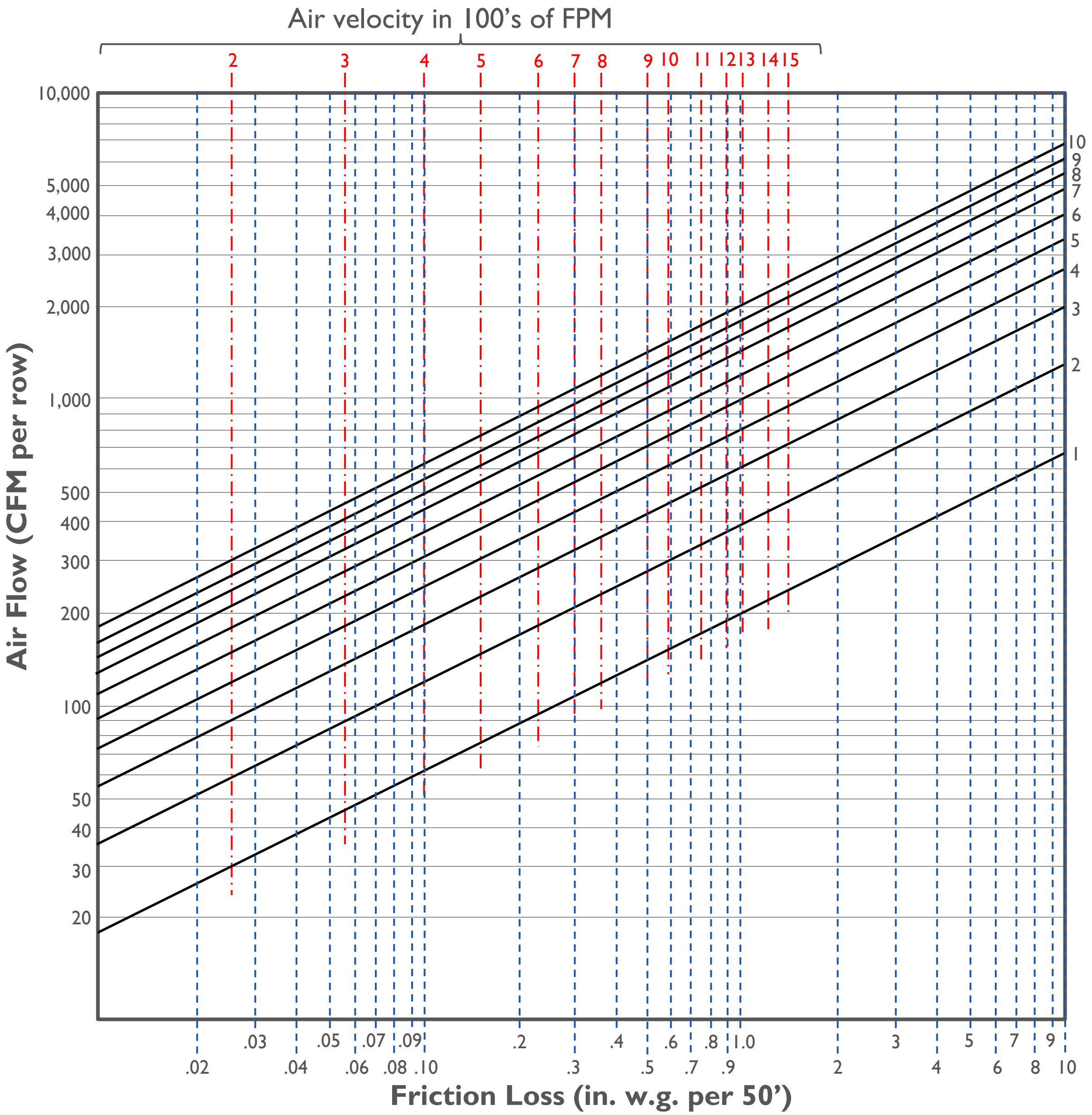
Using this chart requires the calculation of airflow (CFM) per row. To do this divide the CFM required for the area to be supplied by the number of linear feet along the section of the Airfloor supplying that area. For example, in a room 40' long x 30' wide supplied by 1600 CFM; dividing 1600 by 40' gives 40 CFM per row through a 30 ft. run across the width of the room.

The cross-sectional free area of the Airfloor forms is 22 sq.in or 0.1524 sq.ft per linear foot. Dividing 40 CFM by 0.1524 sq.ft gives a velocity of approximately 262 FPM per row. Reading from the chart gives the corresponding friction loss per 50' run which can then be adjusted to reflect the actual length of the run.

As mentioned elsewhere in this guide, divider pieces may be used to direct air flow and prevent short circuiting to the outlets nearest to splash boxes. Typically, these are located halfway between the splash box and the closest wall where the registers are located. A divider piece is placed in every other row of forms about 60% of the way across the width of the room. The use of dividers in this application will add 0.01-0.02" in. w.g. of friction loss.

No. Rows	Area (sq.in)	Area (sq.ft)	No. Rows	Area (sq.in)	Area (sq.ft)
1	22	0.1524	6	132	0.9167
2	44	0.3056	7	154	1.0694.
3	66	0.4583	8	176	1.2222
4	88	0.6111	9	198	1.3750
5	110	0.7639	10	220	1.5278

Airfloor™ Void Static Pressure Nomogram



2.6 Connector Design

Connector Static Pressure Calculation

The term 'connector' refers to any custom fabricated parts used to either connect riser ducts to the Airfloor™ void from above or to form connections from the void to supply registers located above finished floor level.

As a restriction often with a reduced cross-sectional area or orifice the associated pressure loss of this must be considered.

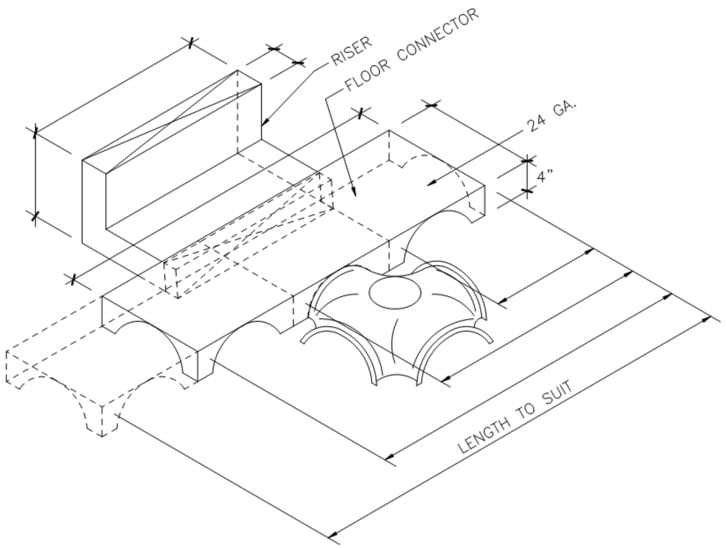
The following formula can be used assuming that the connector piece is turning the airflow through 90 degrees:

$$P_{CONNECTOR} = 1.5 * (V / 4005)^2$$

Where:

$P_{Connector}$ = Pressure loss through connector (in. w.g.)
V = Velocity through orifice (FPM)

Connector Example



2.7 Grille and Register Design

Supply Grille Style

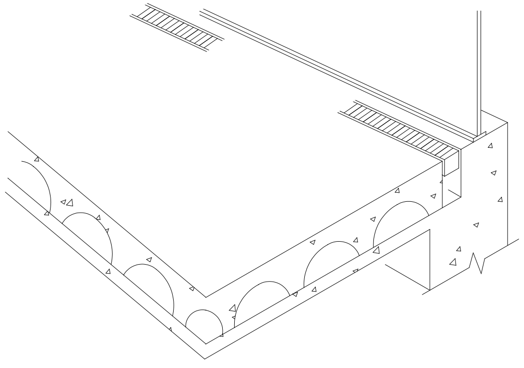
Many different air supply styles can be integrated with the Airfloor™ system offering significant flexibility in the delivery and concealment of air supply to suit the application. A number of these styles are shown in the sketch diagrams opposite, however, others are also possible.

Supply Grilles and Return Register Placement

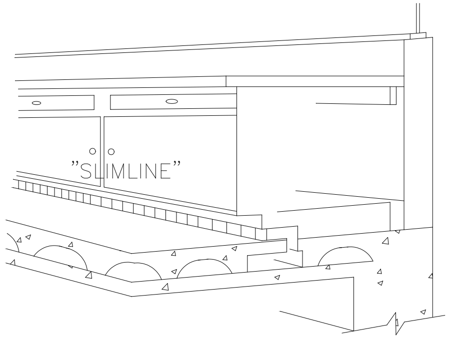
As with any HVAC system, supply grilles should be located to ensure good distribution of air within the space served. The placement of return air registers should also be considered and where possible placed in opposition to supply air points to prevent short-circuiting. In spaces with glazed facades it is recommended to ensure air supply grilles are located at the façade line to mitigate environmental heating/cooling loads from the glass.

Supply Grille Sizing

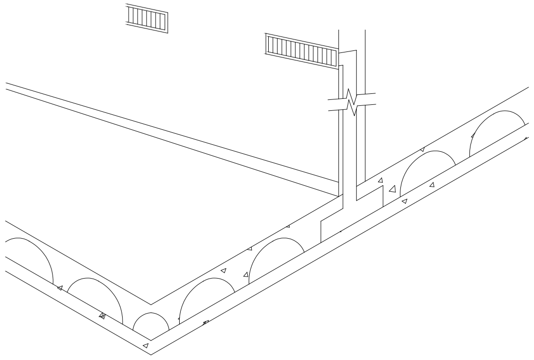
Sizing of air supply grilles should generally be conducted in accordance with good engineering practice. In order to maximise the ventilation effectiveness benefits of supplying air directly into the breathing zone it is recommended to supply air at a maximum velocity of 150FPM (0.8m/s) for supply grilles located in the perimeter zone of the room served (i.e. outside the occupied zone). Floor grilles located within the occupied portion of the floor plan should be sized in accordance with displacement ventilation best-practice to ensure occupant comfort is not compromised. A diffuser face velocity of 40FPM[i] (0.2m/s) is recommended.



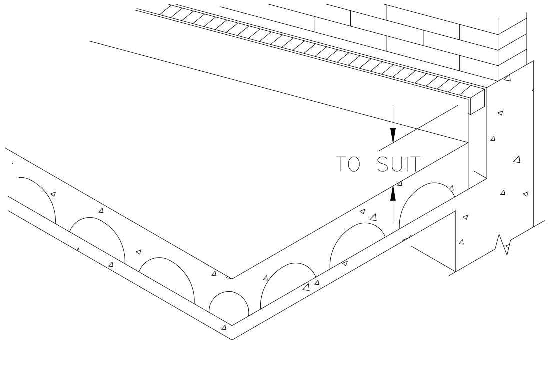
A. Typical floor grille



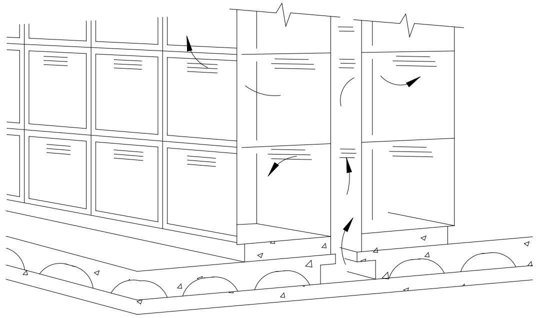
B. Toe space register



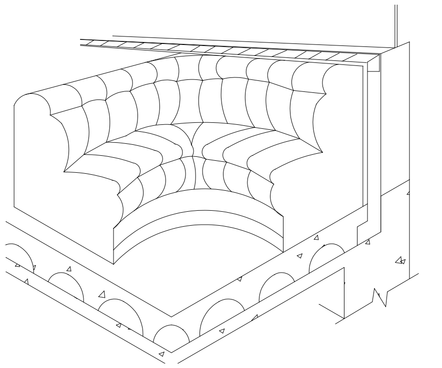
C. Low or high partition register



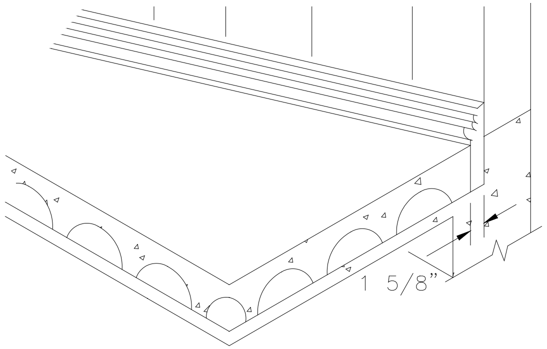
D. Raised floor grille



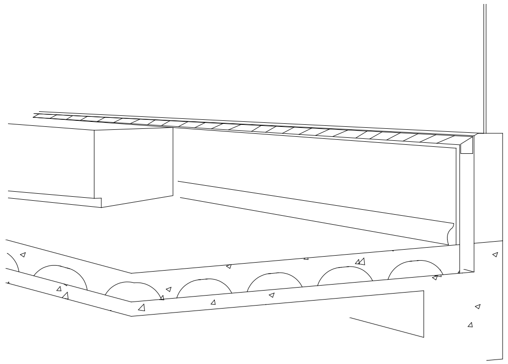
E. Locker room supply



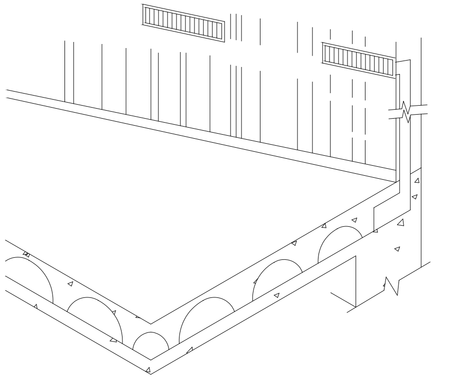
F. Concealed booth supply



G. Baseboard register



H. Window sill register



I. Low or high exterior wall register

2.8 Detailed Design Overview

Step 1 – Determine number and size of Splash Boxes required

Consider maximum zone sizes and also maximum recommended friction loss per splash box based on guidance in this document.

Step 2 – Locate Splash Boxes on Plan

Consider guidance on maximum and minimum separation distances provided in this document.

Step 3 – Select and Locate Supply Grilles and Registers

Following industry guidance and recommendations elsewhere in this document in selection and placement. Calculate friction loss.

Step 4 – Calculate Friction Loss for Airfloor™ Void and Connectors

Following recommendations elsewhere in this document.

Step 5 – Design Supply Ductwork

Following industry guidance and recommendations in this document, take the most efficient route possible to connect the supply system to all splash boxes. Care should be taken in the sizing of ductwork to ensure that the velocity of supply air is always decreasing in the direction of flow.

Step 6 – Determine Combined External Static Pressure

Combine friction loss for all elements on the index run of the system to determine the required external static pressure of the fan.

3

Controls Design

Contents:

3.1 Basic Control Modes

AIRFLOOR™

General Modes of Operation

Simple Controls

For domestic and small commercial applications it is possible to operate Airfloor™ with no modulating controls based upon a simple timeclock and thermostat.

Advanced Controls

For commercial applications, the Airfloor™ system can work equally well in both constant air volume (CAV) and variable air volume (VAV) applications with VAV operation offering attendant savings on fan energy.

In either case it may be beneficial to specify variable speed blowers / fans equipped with inverters to allow accurate commissioning of the system and to reduce energy consumption, however, this is not a requirement for CAV operation.

For commercial applications, a well written sequence of operation is recommended for effective commissioning of the Airfloor™ system. Example sequences of operation are provided elsewhere in this section as a starting point for designers to develop their own control sequences to suit particular project requirements.

Simple Controls (Domestic/Small Commercial Applications)

In its most simple application, the Airfloor system can be operated with no modulating controls and a simple program clock used to determine the operation of the system. The clock should be set to energize the fan or blower before the controls begin to function. Continuous circulation during the occupied period is strongly recommended.

Depending upon the size and type of building, the program clock should start the system approximately 2 to 3 hours before occupancy, with the fan going into operation first before the controls activate the heating or cooling equipment. 1 hour will usually provide sufficient time to build up the storage capacity of the concrete, so that with proper air volumes the floor surface temperature will be at the desired level upon occupancy.

Similarly, the controls may be configured to shut off the heating and cooling equipment approximately 1 hour before the end of the occupancy, as the thermal capacity of the concrete and air circulation alone will be sufficient to maintain comfort conditions for the last hour.

In this control mode, the heating or cooling should come on at full capacity on demand of the thermostat because of the mass of the concrete floor itself acts as the modulating control.

3.2 Advanced Control Modes

Advanced Controls (Large Commercial Applications)

Constant Air Volume (CAV) Systems

In CAV systems, temperature reset should be used to modulate the temperature control.

CAV systems can also incorporate the special functions described in this section.

Where a large system serves multiple splash boxes it is advised to either provide volume control dampers (VCDs) on sub-branches to each box to facilitate air balancing or to design ductwork to be self-balancing.

VAV Systems

In VAV systems it is important to note that heat transfer to the slab is most effective when the supply airflow is close to its maximum volume. Therefore it is recommended to prioritize temperature reset over volume reset, with volume reset effectively acting as a dead band when the space setpoint is satisfied.

Where a system serves multiple thermal zones with differing thermal profiles, it may be necessary to provide VAV boxes to each thermal zone for control purposes.

In order to ensure heat exchange with the upper slab during volume reset it is recommended that the maximum turn down per zone is limited to 50%.

Special Functions

Airside Economizer

As an all-air system, Airfloor™ offers great potential for airside economizer. In effect this means circulating 100% outdoor air when the system is operating in cooling mode and outdoor air conditions are favourable.

For this application, a comparative dry-bulb economizer based upon return air temperature and outdoor air temperature is recommended to maximize energy savings. However, if a return air temperature sensor is not provided, then a simple dry bulb economizer control based upon outdoor air temperature will also offer energy benefits in most climates.

Night Purge Free-Cooling

The circulation of 100% outdoor air outside of occupied hours when it is cooler can be used to build up a storage capacity of cooling potential in the slab that can then be used the following day. This application may be used to either reduce energy usage in systems with cooling or to improve comfort where no mechanical cooling is provided.

Demand Controlled Ventilation (DCV)

This mean modulating the amount of outdoor air to match the occupancy which is usually determined by a CO_2 sensor using measured CO_2 level as a proxy for occupancy. In spaces with variable occupancy this can yield significant energy savings in either hot and humid or cold climates by reducing the energy expended in treating outdoor air.

3.3 Sensors and Controllers

Temperature Sensors

Temperature sensors should be provided as follows to facilitate proper system control:

- A space temperature sensor or thermostat is required for each thermal control zone. It is recommended to provide this within the occupied zone of the space served, i.e. wall mounted ~4-5' above finished floor level. This is preferred to a temperature sensor within the return air duct as it provides a more accurate measurement of space temperature.
- A supply air temperature sensor is required at the discharge of each air handling unit.
- An external temperature sensor is required to facilitate airside economizer operation
- Due to temperature stratification, the return air temperature in double and triple height spaces may differ somewhat from that in the occupied zone, therefore in this case it is recommended to also provide a return air temperature sensor for best control of comparative economizer functionality.

Other Sensors and Controllers

Other sensors and controllers may be provided as follows:

- CO2 sensors located either within occupied areas or within return air ducts are required to facilitate demand controlled ventilation if this function is to be used.
- User controllers or thermostats may be provided at the designer's discretion but are not always required. It should be noted that due to the thermal mass effect of the slab the response time to user changes of setpoint is somewhat slower then with a conventional system, however, the provision of a radiant cooling generally ensures occupant comfort is better than a conventional system.
- Within highly glazed spaces subject to high solar radiation, a radiant temperature sensor to accurately determine the operative temperature may be provided at the designer's discretion but is not required.
- Floor temperature sensors or temperature sensors inside the Airfloor™ void or at the supply grille are not required.

4

Contents:

Components, Materials and Dimensions

4.1 Airfloor™ Components

Parts List

The Airfloor™ system comprises several proprietary components which can be assembled to create a fully functioning HVAC distribution system. The key parts are listed below

Part Name

I. Airfloor™ Form
II. Locking Clip
III. Form Closure / Divider Piece
IV. Splash Box: Ducted From Beneath
V. Splash Box: In-Floor Ducting
VI. Form Extension

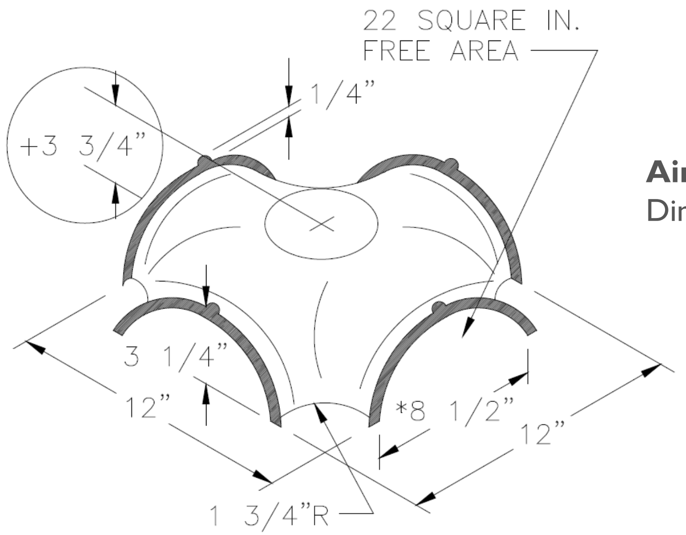
I. Airfloor™ Form

Purpose: To compose a strong, structurally sound, arch-hollowed and air ventilated concrete floor slab constructed in place

Material: 22-gauge press-formed galvanized steel

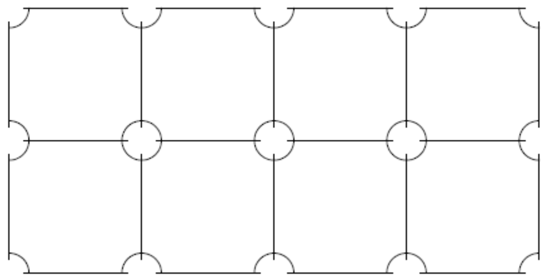
Dimensions: Rise = 3 ¾" (95mm), span = 8 ½" (216mm), width = 12" (305mm)

Weight: 1.2 lbs (0.54kg)



Airfloor™ Form
Dimensions

Assembled Airfloor™ Section
8 forms, 4'x2' (1219x610mm)
weight = 9.6lbs (4.35kg)
(Plan view)



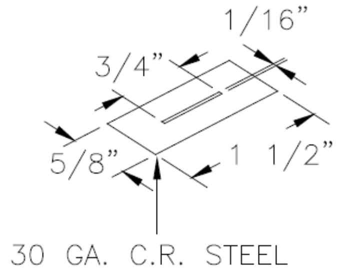
4.1 Airfloor™ Components

II. Locking Clip

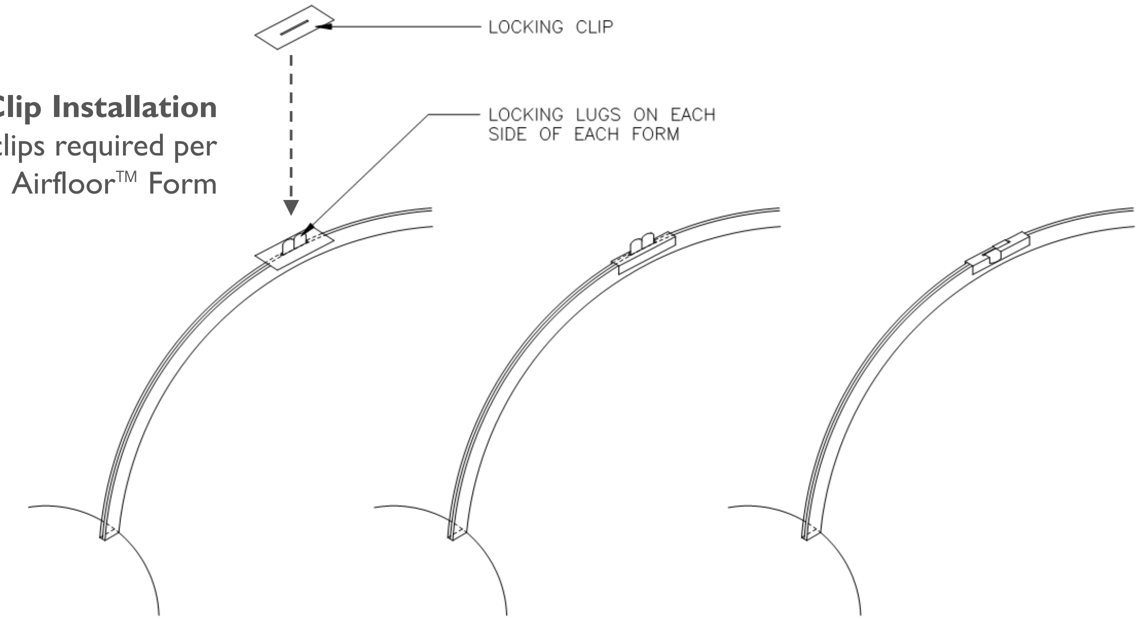
Purpose: Locking forms together to create a continuous, water-tight floor void to facilitate concrete pour

Material: 30-gauge cold rolled steel

Dimensions: Length = 1 ½” (38mm), width = $^{5}/_{8}$” (16mm)



Airfloor™ Locking Clip
Dimensions



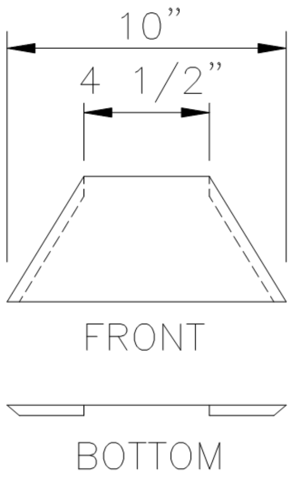
Clip Installation
Two clips required per Airfloor™ Form

III. Form Closure / Divider Piece

Purpose: to seal open archways around perimeter of Airfloor™ to prevent from pouring under forms during final concrete pour and to turn and channel air through the floor void

Material: 22-gauge galvanized steel sheet

Dimensions: Width = 10” (254mm)



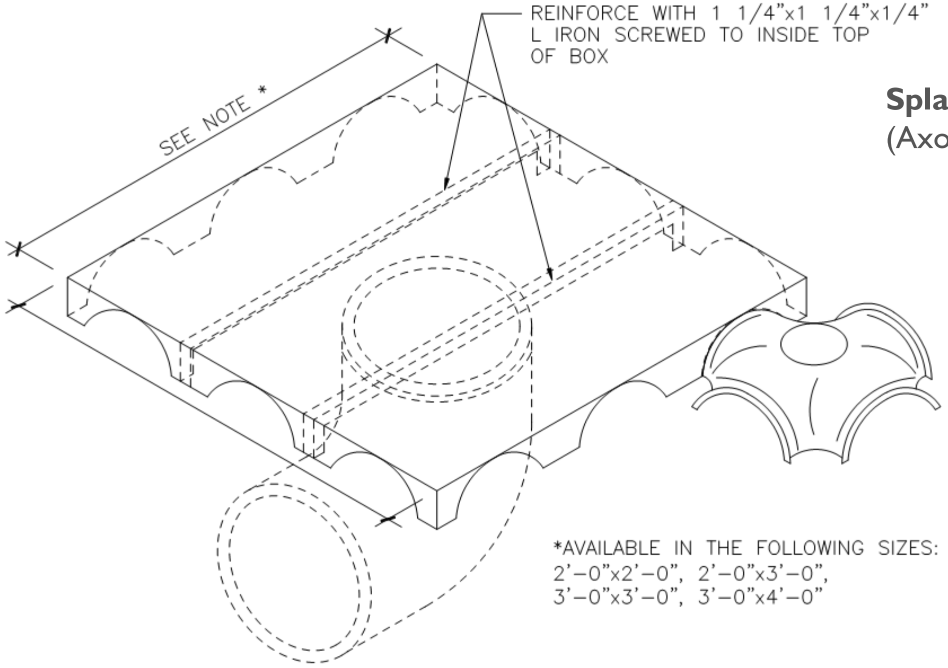
4.1 Airfloor™ Components

IV. Splash Box: Ducted from Beneath

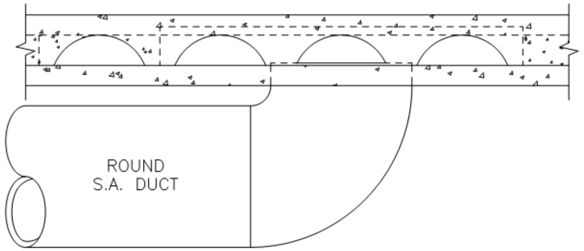
Purpose: to connect ductwork to Airfloor™ void and distribute air evenly

Material: 22-gauge cold-rolled galvanized steel sheet

Dimensions: Various sizes – 2'x2', 2'x3', 3'x3', 3'x4', 4'x4' (610x610mm, 610x914mm, 914x914mm, 914x1219mm, 1219x1219mm)



Splash box
(Axonometric view)



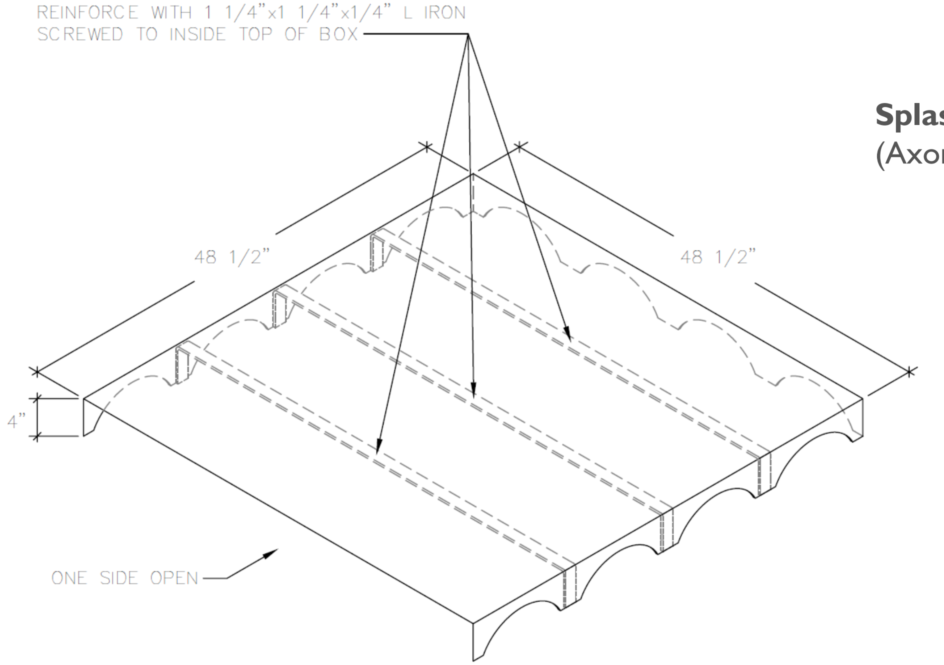
Splash box
(Section view)

V. Splash Box: In-Floor Ducting

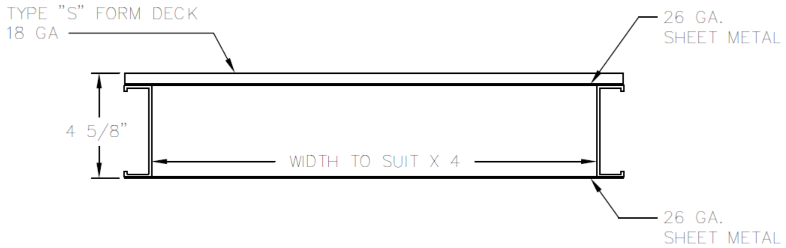
Purpose: to connect in-floor ductwork to Airfloor™ void and distribute air evenly

Material: 22-gauge cold-rolled galvanized steel sheet

Dimensions: Various sizes – 2'x2', 2'x3', 3'x3', 3'x4', 4'x4' (610x610mm, 610x914mm, 914x914mm, 914x1219mm, 1219x1219mm)



Splash box
(Axonometric view)



Splash box
(End view)

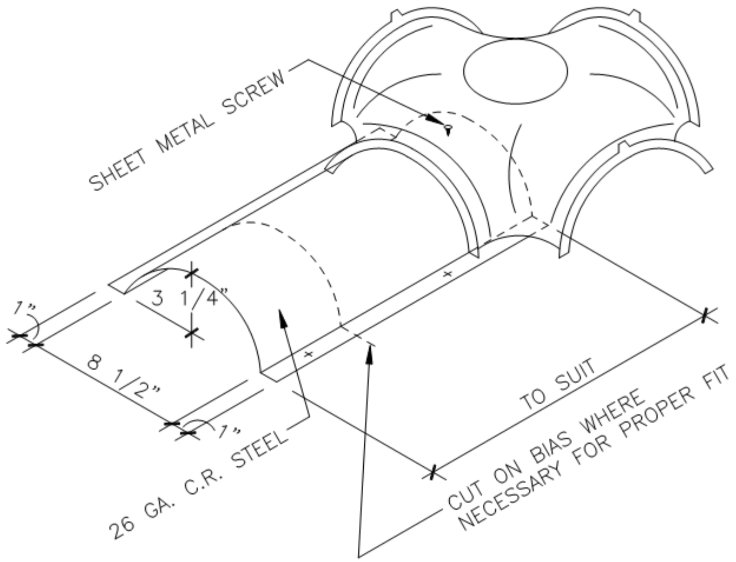
4.1 Airfloor™ Components

VI. Form Extension

Purpose: to extend Airfloor™ void up to floor connectors and registers

Material: 22-gauge cold-rolled galvanized steel sheet

Dimensions: Span = 8 ½" (216mm), Height = 3 ¼" (83mm), length to suit requirement



4.2 Typical Dimensions

Slab Thickness

The depth of concrete topping slab varies depending upon the application. The table below provides a guide to recommended minimum concrete cover thicknesses over the Airfloor™ forms in common applications. Additional concrete may also be added to increase the thermal storage capacity of the floor as required. In instances where a setting bed is used, guidance on the required thickness should be sought from the vendor of the floor system.

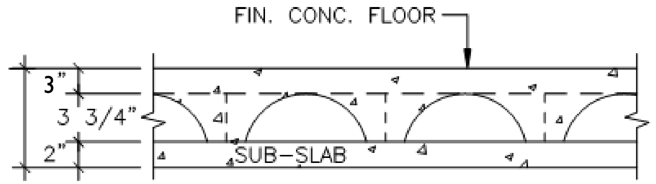
For slab on grade applications a minimum thickness of 2" (51mm) is recommended for the sub-slab, however, required thickness of both the sub-slab and the topping slab for the application and loading should be determined by the structural engineer. The foundation around the perimeter of the sub slab should extend to a depth below the frost line and this foundation should be insulated, preferably by applying insulation on the interior of the foundation wall. In addition, in areas where there are extremely cold winters, the sub slab should be poured of insulating concrete or have a layer of insulation placed under it.

Specific requirements for compliance with local energy code should be determined by the project mechanical engineer.

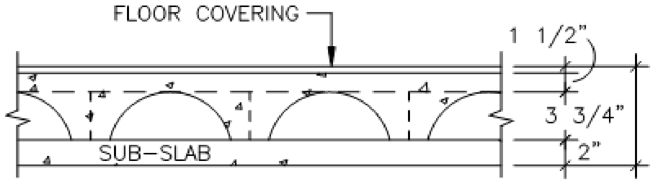
Application	Recommended Minimum Cover*	Notes
Exposed Concrete	3" (76mm) cover	
Covered Floor	1-1½" (25-38mm) cover	For example, vinyl or carpet floor covering
Terrazzo (opt 1)	¾" (19mm) cover + 1½" (38mm) setting bed	Using 15lb felt membrane between the Airfloor™ cover and the setting bed.
Terrazzo (opt 2)	¾" (19mm) cover + 2$^1/_8$" (38mm) setting bed	Using sand cushion between the Airfloor™ cover and the setting bed. Sand cushion laid beneath felt paper membrane. Setting bed is reinforced.
Slabs	¾" (19mm) cover + Grout as required	For example, stone or slate

*Indicative guidance to be adjusted to suit application/field conditions

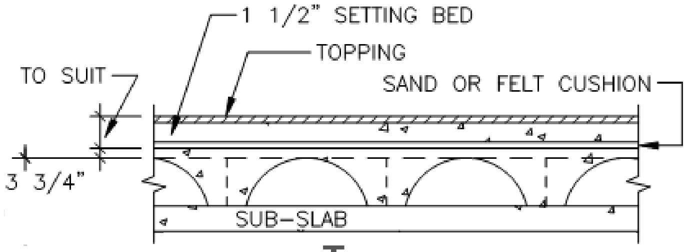
Typical Applications



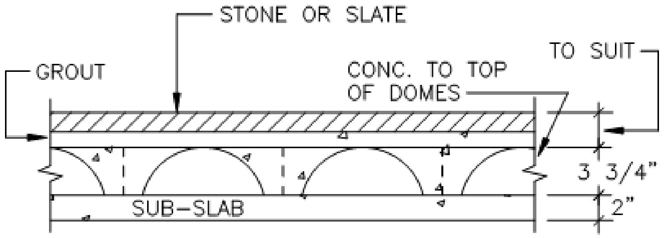
Exposed Concrete



Covered Floor



Terrazzo



Slabs

4.3 Slab Requirements

Typical Concrete Mix and Preparation*

Concrete Mix

A degree of cracking of the topping slab is inevitable, however, a relatively dry mix is recommended to minimize this. The concrete used should be low slump type with maximum 3½" (89mm) of slump. Minimum 2,500 PSI (17,240 kPa) strength. A wire reinforcement mesh is typically not required in the topping slab, and load testing of the system has been conducted without a mesh in place.

Prevent Concrete Ingress

The clips between the Airfloor™ forms create a tight seal and prevent concrete seeping into the void. Form closures must also be applied around the perimeter of the Airfloor™ void to prevent concrete ingress wherever registers are not present.

Provide for Registers

For continuous perimeter registers or slots, use 1" (25mm) x 6" (152mm) shutter boards against the end of the Airfloor™ forms where the registers are to be located. The exact distance from the wall should be determined by using wedges or wood spacers about 24"(610mm) apart. The use of these spacers also facilitates the easy removal of the wood after the upper pour has been made by knocking out the spacers.

For typical registers, an opening may be cut in the top of the Airfloor™ forms and a forming box dropped in the opening.

For outlets above the finished floor level, for example partition mounted registers or raised floor grilles, a sheet metal riser should be installed by the contractor to connect the airfloor void to the outlet.

Concrete Pour Recommendations*

Pour Size

In order to limit cracking, it is recommended that each pour section is 400-1,000sq.ft (37-93sq.m). In areas with large daily temperature variation, it is recommended to provide expansion joints between each pour section.

Pour Procedure

1. Sub-slab needs only to be rough finished and reasonably level. This does not have to be a smooth trowel finish, but it should be given at least a "bull float" finish: too rough a sub-slab surface could increase the static pressure resistance to the air stream going through the void.
2. Sub-slab must be swept clean before laying of forms.
3. Keep the Forms cool with water spray until they are covered with concrete, if the sun has heated them. Wet them in any event.
4. Provide suitable control joints in the slab to allow for shrinkage.
5. Screeding is done with an adjustable type stake screed held in place by puddle at corner of forms. Stake screeds can also be driven through the sub-slab.

Additional step applicable to exposed slab and terrazzo applications only:

6. After placement and tamping of the final floor pour, float finish smooth and trowel in the usual way.

*Indicative guidance to be adjusted to suit application/field conditions

5

Contents:

Reference Information

5.1 References and Glossary

References

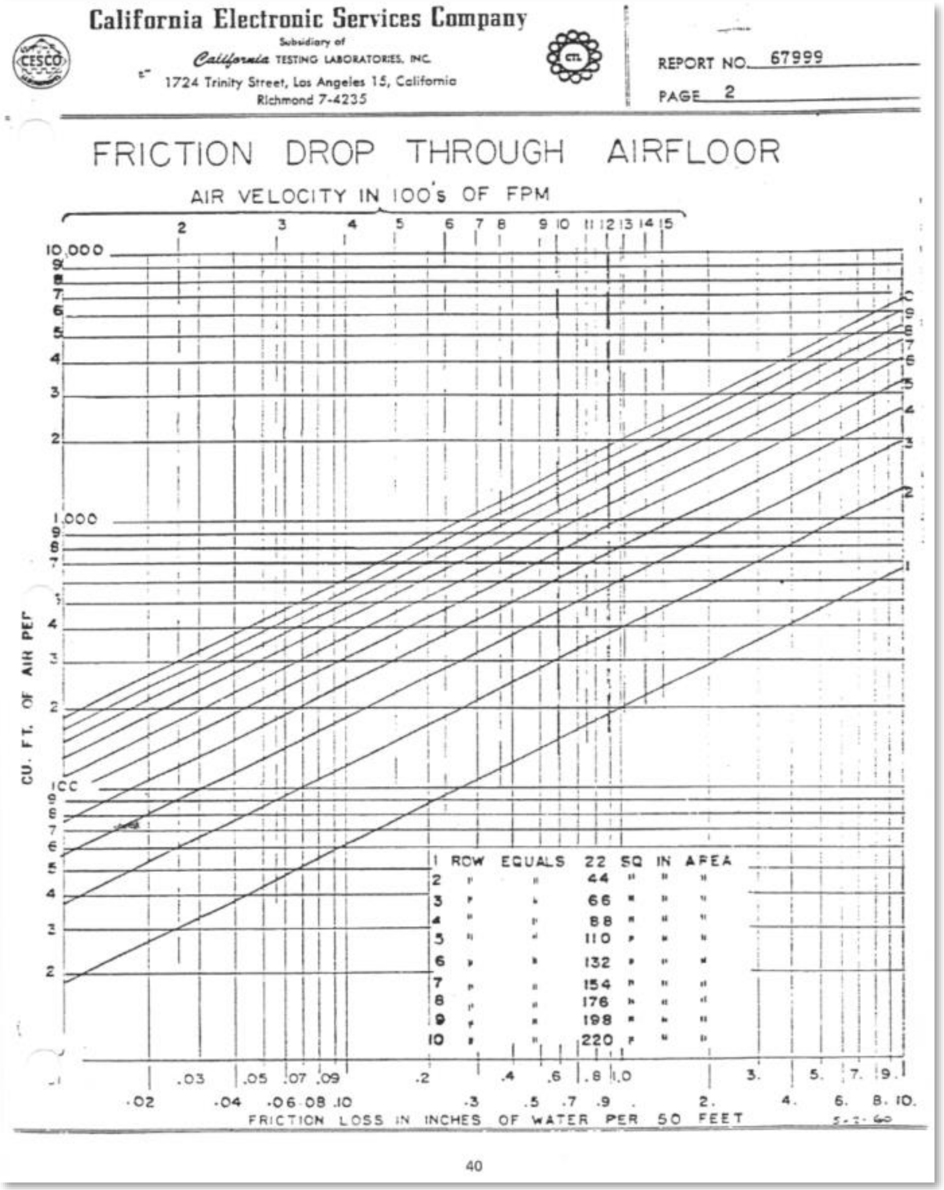
A, Ashrae Fundamentals Handbook (2017)
B, CIBSE Guide A – Environmental Design (2015)
C, Ashrae Standard 55 – Thermal Environmental Conditions for Human Occupancy (2020)
D, EN 16789-1 Energy Performance of Buildings (2019)
E, ISO 7730 – Ergonomics of the Thermal Environment (2015)
F, ASHRAE 169 – Climatic Data for Building Design Standards (2013)
G, ASHRAE System Performance Evaluation and Design. Guidelines for Displacement Ventilation' (2003)
H, REHVA Guidebook No. 23 – Displacement Ventilation
I, ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality (2019)
J, ASHRAE Standard 62.2 Ventilation and Acceptable Indoor Air Quality in Residential Buildings (2019)
H, CIBSE Guide C4 – Flow of Fluids in Pipes and Ducts (2007)
I, Price Industries Engineering Guide Section J – Displacement Ventilation
J, ASHRAE Guide: Sequences of Operation for Common HVAC Systems (2005)

Glossary of Terms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CFM	Cubic feet per minute
CIBSE	Chartered Institution of Building Services Engineers
FPM	Feet per minute
HVAC	Heating, ventilation and air conditioning
In. w.g.	Inches water gauge
REHVA	Representatives of European Heating and Ventilation Associations

5.2 California Testing Laboratories Report No. 67999 – Friction Loss Through Airfloor

AIRFLOOR™



5.3 City of Los Angeles, Research Report 25679

CITY OF LOS ANGELES
CALIFORNIA

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MAYOR

DEPARTMENT OF
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OSAMA YOUNAN, P.E.
GENERAL MANAGER
SUPERINTENDENT OF BUILDING

JOHN WEIGHT
EXECUTIVE OFFICER

Airfloor, Inc.
7451 Spring Grove Ave.
Spring Grove, IL 60081

Attn: Matt O'Dwyer
(847) 459-6080

RESEARCH REPORT: RR 25679

Expires: November 01, 2022
Issued Date: May 01, 2022
Code: 2017 LABC

GENERAL APPROVAL – Renewal - Airfloor - Forms used to create hollow concrete floors for air distribution.

DETAILS
Airfloor is a system of hollow, interlocking metal forms and air registers that are placed on top of a building floor system and then covered with a concrete topping slab. The floor then becomes a plenum through which heating and cooling air flows, resulting in a radiant floor and ventilating system. The 12" square by approximately 4" thick Airfloor forms are shaped out of 26-gauge steel to resemble a groined vault having 8.5" wide by 3.75" tall arches on each side. Airfloor connecting details to concrete slab (SX-1), concrete slab with metal deck (SX-3), and wood floor (SX-2), are provided in the attachment.

The approval is subject to the following conditions:

1. Not more than 2" and not less than 1" of minimum 2,500 psi normal weight or sand-lightweight concrete topping shall be placed above the top of the forms.
2. Airfloor shall be anchored to the building floor system. See Table-1 for detail.

Table-1

Material	Detail Attachment	# of Bolts (diameter)	Bolt Material	Embedment	Spacing
Concrete[1]	SX - 1	1 (5/8)	A307/A36	4.5 in.	10'-0"
Wood	SX - 2	2 (3/4)	A307/A36	Thru	6"-0"
Metal Deck with Concrete	SX - 3	1 (5/8)	A307/A36	Thru	10'-0"

[1] Anchor bolts shall be approved with an LARR.

3. When placed over a wood floor system, a minimum of 23/32" plywood or OSB shall be used and 26-gauge galvanized sheet metal shall be provided between the Airfloor forms and the sheathing.
4. When used on a project that is located on site class F, the engineer of record shall provide analysis and design for the lateral attachment of the Airfloor system.
5. The Airfloor system shall not be used to transfer structural loads between floors. Where column and bearing walls occur, the Airfloor forms are to be omitted to allow direct load transfer of walls and columns through the structural floor system.
6. The concrete structural floor supporting the Airfloor system must be designed by an engineer registered in the State of California, and must have a minimum thickness of 8 inches. Calculations must be presented to the plan check engineer. See detail SX-1 of the attachment.
7. The Airfloor shall be installed per the manufactures' instructions and this report.
8. Slab on grade does not require any additional action other than slab on grade construction in accordance with the 2017 Los Angeles City Building Code.

DISCUSSION

The report is in compliance with the 2017 Los Angeles City Building Code.

This approval is based on tests and analyses.

Addressee to whom this Research Report is issued is responsible for providing copies of it, complete with any attachments indicated, to architects, engineers and builders using items approved herein in design or construction which must be approved by Department of Building and Safety Engineers and Inspectors.

This general approval of an equivalent alternate to the Code is only valid where an engineer and/or inspector of this Department has determined that all conditions of this approval have been met for the project in which it is to be used.

EUGENE BARBEAU, Chief
Engineering Research Section
201 N. Figueroa St., Room 880
Los Angeles, CA 90012
Phone- 213-202-9814
Email – engineering-research@lacity.org

EB
RR25679
TLB2200061
R04/15/2022
ACI 318-14

Attachments: Details and Specifications (3 Pages)

5.4 California Electronic Services Company Compression Test

LABORATORY CERTIFICATE

California Electronic Services Company

CTL
CHEMISTS AND ENGINEERS

Subsidiary of
TWINING LABORATORIES
Long Beach, CA 90806 Tele 562-426-3355

Laboratory No. 42288

Sample Airfloor Forms *Marked*

Submitted By AIRFLOOR COMPANY

REPORT

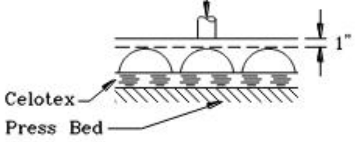
In accordance with your instructions a compression test has been applied to a typical floor specimen submitted and described as follows:

"Airfloor forms (the basic shape of the Airfloor form is a groined vault) with the height of their domes being 3-3/4" above the base. 2000 pound mix concrete was poured over the forms providing 3 1/2" diameter piers at 12" spacings each way, and one inch thickness of concrete over the summit of the domes. No reinforcing was used in the concrete".

The test specimen was placed between the heads of a testing machine and a compression load was applied to a six inch diameter (0.196 square foot) disc which centered over the one inch thickness of concrete at the center of the form.

The following tabulation gives the results of this test:

Compression Load pounds	Result
9,250	No cracks appeared until failure which fractured the concrete by punching shear at the edge of the disc.



Respectfully submitted,

CALIFORNIA TESTING LABORATORIES, INC.

DETAIL 118

5.5 Eclipse Engineering – InsulFoam® Test Certificates

Over Insulation Application

AIRFLOOR™

ECLIPSE ENGINEERING — ECLIPSE-ENGINEERING.COM

Date: November 7, 2014

To: Airfloor®

RE: Allowable Use of the Airfloor® system over Insulfoam® products

To Whom It May Concern:

We have completed the review of the Airfloor® system in order to determine the appropriate use of the form system over InsulFoam® products (including InsulGrade, R-Tech, and GF Geofoam). The InsulFoam® products are intended to be used in lieu of the concrete base slab and will be covered with a non-structural sheet steel for ducting purposes. Compressive resistance values for the foam products have been limited to a 1% deformation (strain) limit to ensure elastic behavior of the foam under loading conditions.

This review was based on the following provided reference data:

1. Airfloor®. *Concrete Calculations.* Project Number 111114C: March 23, 2011.
2. California Electronic Services Company. *Airfloor Forms.* Laboratory Number 42288: 2000.
3. InsulFoam®. *InsulGrade Below Grade Insulation Systems.* Brochure #6066-0414.
4. InsulFoam®. *InsulFoam® GF.* Brochure #10002: April 1, 2011.

Appropriate use of the Airfloor® form system over InsulFoam® products is dependent on the code required load combinations of dead and live loads. Dead loads in this case are listed by the required concrete depth over the top of the Airfloor dome. Additional dead load considerations (heavy tile, mortar set flooring, etc) should be considered by the designer when choosing the appropriate dead load value in the following chart:

Compatibility of Airfloor® form system and InsulFoam® products based on required Dead and Live Load

Concrete Depth over Airfloor dome	Live Load 40 psf	Live Load 50 psf	Live Load 60 psf	Live Load 100 psf
1 ½-inches (dead load = 36.25 psf)[1]	InsulGrade IX R-Tech IV XPS Type IV EPS29	InsulGrade IX R-Tech IV XPS Type IV EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS39
2-inches (dead load = 42.5 psf)[1]	InsulGrade IX R-Tech IV XPS Type IV EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS39
3-inches (dead load = 55 psf)[1]	InsulGrade XIV R-Tech VI XPS Type VI EPS29	InsulGrade XIV R-Tech VI XPS Type VI EPS39	InsulGrade XIV R-Tech VI XPS Type VI EPS39	InsulGrade XV R-Tech VII XPS Type VII EPS46

1. Dead load calculations include concrete depth over dome, concrete required to fill form voids to top of dome, and 5 psf floor covering allowance. Concrete weight of 150 pcf was used.

Please call with any questions.

Sincerely,
Eclipse Engineering, Inc.

Gretchen Iman, P.E.
Principal Engineer

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Digitally signed by troyL@eeimt.com
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Reason: I agree to the terms defined by the placement of my signature in this document
Location:
Date: 2014/11/07 08:57:50 -07'00'

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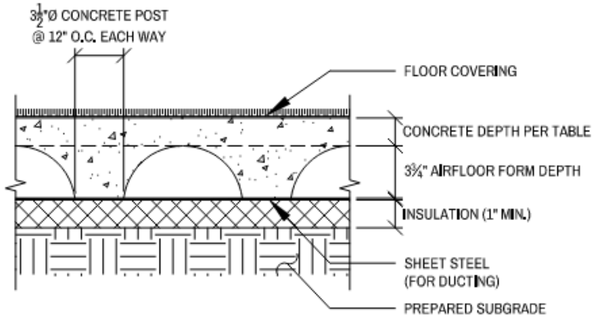
ECLIPSE ENGINEERING

AIRFLOOR CONCRETE FORM
Installation over InsulFoam Products

1 / 1

DATE: 11/07/14

DESIGN BY: GI



AIRFLOOR FORM OVER INSULFOAM

SCALE: 1 1/2" = 1'-0"

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