Underfloor Air Distribution:

An underfloor air distribution system utilizes a plenum space between the structural slab and the underside of a raised floor to distribute the conditioned air to the room. An underfloor air distribution system creates a stratified condition where the natural buoyancy of air removes heat and contaminates from the occupied zone. Diffusers located in the elevated floor slab distribute air to the room from the plenum. Since the diffusers are located in the floor, the supply air temperatures must be warmer then the conventional overhead air distribution systems because of the immediate proximity of the supply air to the occupied zone. For cooling the supply air temperature should range from 63°F- 68°F, this temperature range will prevent overcooling the occupants of the space.

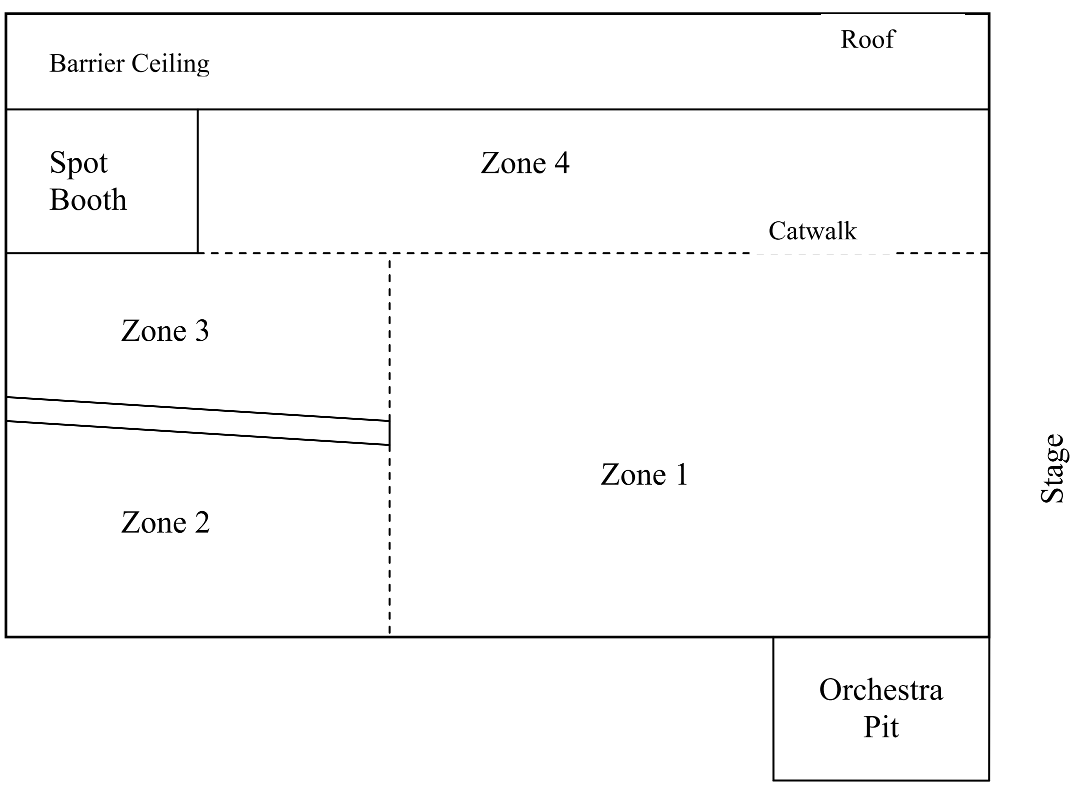
The potential benefits that occur as a result of the implementation of underfloor air distribution include increased thermal comfort, better indoor air quality, reduced outdoor airflow, reduced floor to floor heights, and reduced supply fan horsepower. The increase in thermal comfort arises from the fact that the supply air temperature is higher then conventional overhead distribution systems and the floor diffusers induce local circulation and mixing in the occupied zone to a relatively uniform temperature. The improvements in indoor air quality result from natural flow of air in the underfloor system as compared to the overhead air distribution system. In the overhead system the contaminants in the air that collect at the ceiling level, due to the natural buoyancy of air, are forced back into the breathing zone by the induced mixing of ceiling diffusers to create a uniform environment. In underfloor systems, the air supplied at the floor naturally forces the contaminants to the ceiling level where natural buoyancy and stratification keep the contaminants from re-entering the breathing zone. The air change effectiveness of underfloor systems is higher therefore; less outdoor air is needed for ventilation. This decrease in minimum required outdoor air equates to an energy savings on conditioning less outdoor air. The use of the plenum eliminates supply ducts, terminal units and diffusers in the ceiling space leaving ample room for the other trades in the ceiling space and offering the possibility of decreasing the floor-to-floor heights. The decrease in amount of supply air duct due to the use of the plenum also cuts down on the static pressure that the supply air fan must overcome. Less static pressure results in less horsepower needed to power the supply air fan.

The Proscenium Theater design will utilize a pressurized plenum with passive diffusers to supply the theater with air. When designing an underfloor air distribution system there is a choice of using a pressurized plenum or a zero-pressure plenum. With the pressurized plenum the plenum maintains a slightly higher pressure then the conditioned space usually in the magnitude of 0.05 – 0.1 in WG. The biggest problem with pressurized plenums is the issue of leakage through floor panels. In the Proscenium Theater, the diffusers will be located in the concrete slab and not in a raised access floor. Therefore air leakage through the panels or due to a panel being removed will not be a problem. In order to supply air utilizing a zero-pressure plenum the diffusers must be fan powered active diffusers. The use of fans at all the diffuser locations would introduce increased noise levels to a level above the specified limit of RC 18-22.

Proscenium Theater Load Calculations:

In order to model the Proscenium Theater and determine the ventilation and cooling load requirements Trane's Trace 700 program was used. There is not yet a program that will model a space for underfloor air distribution. Currently the Center for Built Environment at the University of California is working on developing a UFAD system simulation program. This technology is not fully developed or available to the public so Trace 700, designed to model conventional overhead systems, was used.

Since Trace 700 will not model for underfloor distribution situations when using the software for the underfloor loads, the space was broken up into zones in order to try to create a scenario similar to what actual conditions will be. One of the characteristics of underfloor distribution, as opposed to overhead distribution, is temperature stratification. In an effort to create this in the Trace program, the Proscenium Theater is broken up into five zones.



Zone 1 is the first level seating area that is not under the balcony. Zone 2 is the first level seating area under the balcony. Zone 3 is the balcony seating area. Zone 4 is the plenum above all the seating areas. Zone 5 is the orchestra pit.

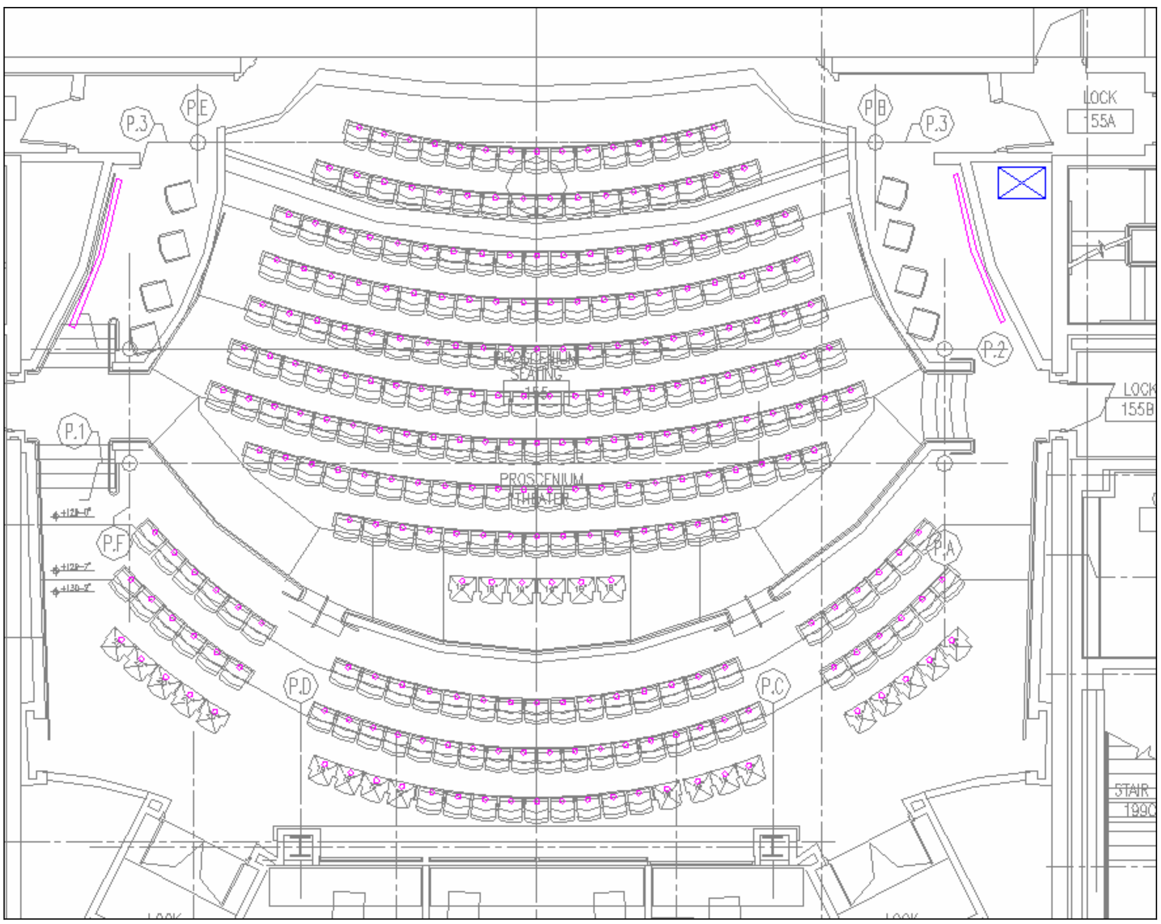
The Proscenium Theater is an interior space and the only exterior walls on the theater are once the theater reaches a height above the rest of the Center for the Arts building. Zone 4 contains the entire exterior wall load, the roof load, and the lighting load from the lights at the catwalk level. All the other zones only have the lighting load from lights located in the respective zone and the people loads. The purpose of breaking up the theater in this fashion was to determine the temperature of the air at the top of the room where the return grilles are located. If you enter the theater as one room, Trace will not account for the fact that the air is supplied at the floor and returned at the ceiling and the temperature stratification that results. The loads accounted for in zone 4 are directly routed back to the air handling unit through the return air path.

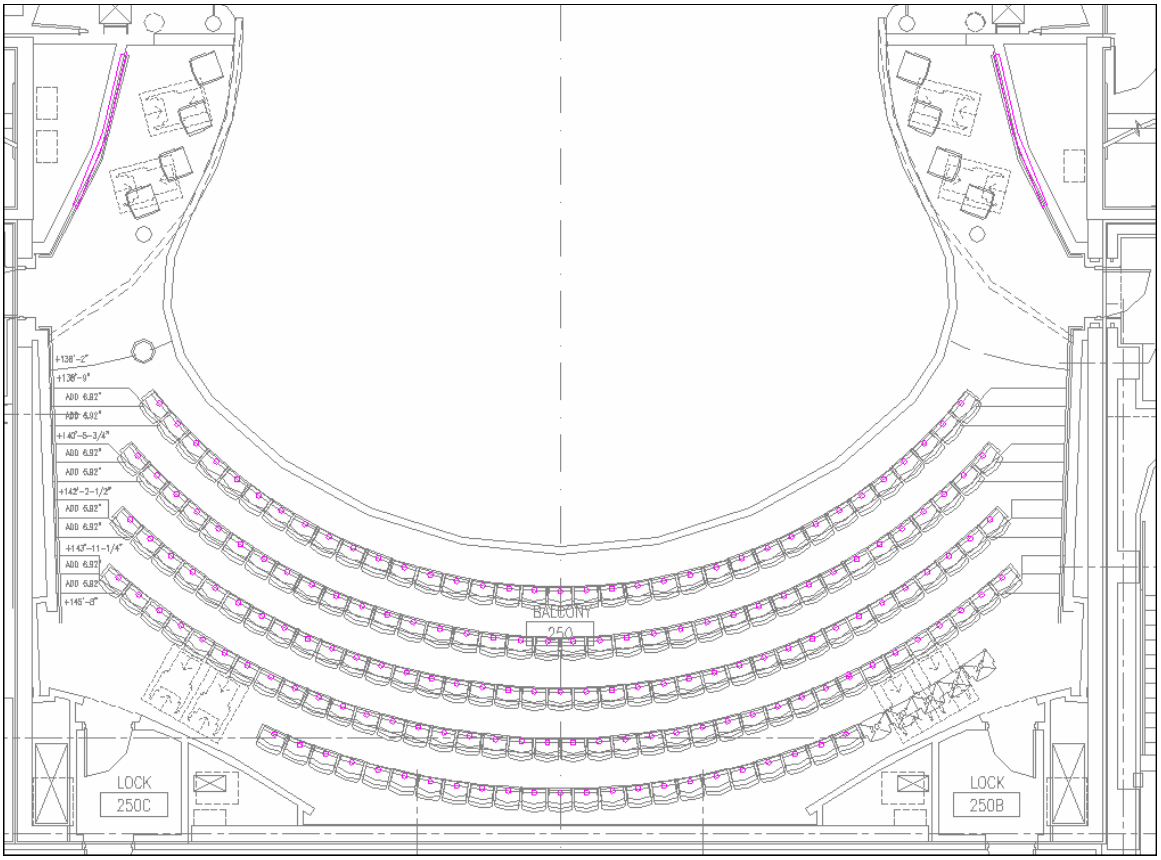
The printouts of the Trace 700 load outputs are located in Appendix A. The Trace outputs call for 14,200 cfm of supply air producing a 310Mbh total capacity of the cooling coil.

Even though the required airflow increased from 7900 cfm to 14,200 cfm the ASHRAE Standard 62.1 minimum required outdoor air quantity decreases. Underfloor air distribution allows the zone air distribution effectiveness to increase from 1.0 to 1.2 because there is a floor supply of cool air and ceiling return. The increase in zone air distribution effectiveness results in a 17% decrease in the zone outdoor airflow value, V_{oz}. The system ventilation efficiency increases from 0.8 to 0.9 for the underfloor system because the maximum outdoor air fraction decreases to 0.16 for the Theater under the new underfloor system. The net result of these changes is a 50% reduction in minimum required outdoor air from 44% for the overhead distribution to 22 % for the underfloor distribution. See Appendix B for a comparison of ASHRAE Standard 62.1 of the two systems.

Diffuser Selection and Layout:

The plenums in the Proscenium Theater, first level and balcony level, are four feet deep and there are 8in swirl diffusers for the air to be supplied through. The swirl diffusers will be Nailor Industries Inc. Floor "Swirl" Diffusers model NFD. (Specification in Appendix C) One swirl diffuser will be located under ever seat in the Proscenium Theater. In order to ensure that the location of the diffusers does not conflict with the placement of the seats in the Theater the seats will be installed before the holes are bored into the concrete elevated slab. Since the placement of the holes in the slab for the diffusers is occurring after the pouring of the concrete it is crucial for the structural stability if the slab that the diffuser holes not cut through the rebar reinforcing.





In order to fill the plenum with conditioned air, the air is ducted from the air-handling unit in the second floor mechanical room to the plenums. All of the ducts in the plenum will sit on duct stands and not the concrete slab. Once in the plenum the duct branches out throughout the plenum to bellmouth openings where the air is supplied to the plenum at 200 fpm.   The diffusers will be permanently set to supply the specified amount of air as determined through from the Trace loads; plans in Appendix D specify cfm levels per zone.

Air Handling Unit Changes:

With the use of underfloor air distribution, the ductwork in the gallery catwalk ceiling area is eliminated. There is only one occupied space on gallery (third) level of the theater, the Spot Booth; the same air handler that serves the Proscenium Theater cannot feasibly supply this room. This room is better served off the air-handling unit that supplies the public lobby (AHU-1). In order to supply the Spot Booth, a 740cfm tap is required off the branch duct that runs the length of the second floor circulation hallway. The tap goes up the mechanical shaft in the northeast corner of the balcony.

The underfloor air distribution decreases the load on the cooling coil from 420Mbh to 315Mbh while increasing the airflow from 7,900cfm to 14,200cfm. The increase in airflow results from the increase in the supply air temperature from 55°F to 68°F. The decrease in the load on the cooling coil is a result of the decrease in required outdoor air. The static pressure in the supply air ductwork decreases dramatically in the underfloor air distribution system because for acoustical reasons the flow of the air in the ducts is kept between 200-400 feet per minute. This low air velocity keeps the static pressure on supply air side at 2.5in down from the overhead system that requires 5in of static pressure.