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ACOUSTICS OF EPCOT

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EPCOT, the Experimental Prototype Community of Tomorrow and the last grand vision of Walt Disney, has been recently carried to fruition by the Disney Organization and their engineering arm WED Enterprises. I would like to share with you today some of the acoustical highlights of EPCOT from my perspective as consultant on many of the pavilions that were built. I would like not to slight others who have worked on these projects as well, let me mention then among the others who have worked on various pavilions, Paul Veneklasen Associates did the Transarama 2000, Purcell-Noppe Associates did Canada and portions of Communicore, Charles Salter Associates did Spaceship Earth, and Wilfred Malmund did American Adventure. Marshall Long/Acoustics did Energy, Horizons, Imagination, Land, Seas, Mexico, China, Africa, Germany, Italy, Japan, France, United Kingdom and the portion of West Communicore under development now. We have also been asked to assist with some problems that arose in Canada, Spaceship Earth and American Adventure.

All who worked on the project I am sure will agree that there were enormous challenges involved. The types of problems go well beyond the normal acoustical problems which you might expect from any building. The difficulty with these types of applications are that first of all there is a tremendous amount of traffic and any materials that are used are subject to incredible abuse. The typical animated figures in the rides are inspected every night to see whether they need a change of clothes. Anything within reach of people will be destroyed on a regular basis and most things that are within projectile range will undergo periodic damage. Secondly

you have problems of safety especially where you have ride vehicles. There is a tremendous effort expended in keeping people from hurting themselves. You have the problem of people who will get out of vehicles or maintenance people who have to be protected from hurting themselves by vehicles, turntables or whatever. An additional problem is that anything that is difficulty to maintain, hard to access or generally a nusiance will be quickly discarded by the maintenance personnel. Thus box tops for enclosures or anything that is a trouble will find itself no longer in use.

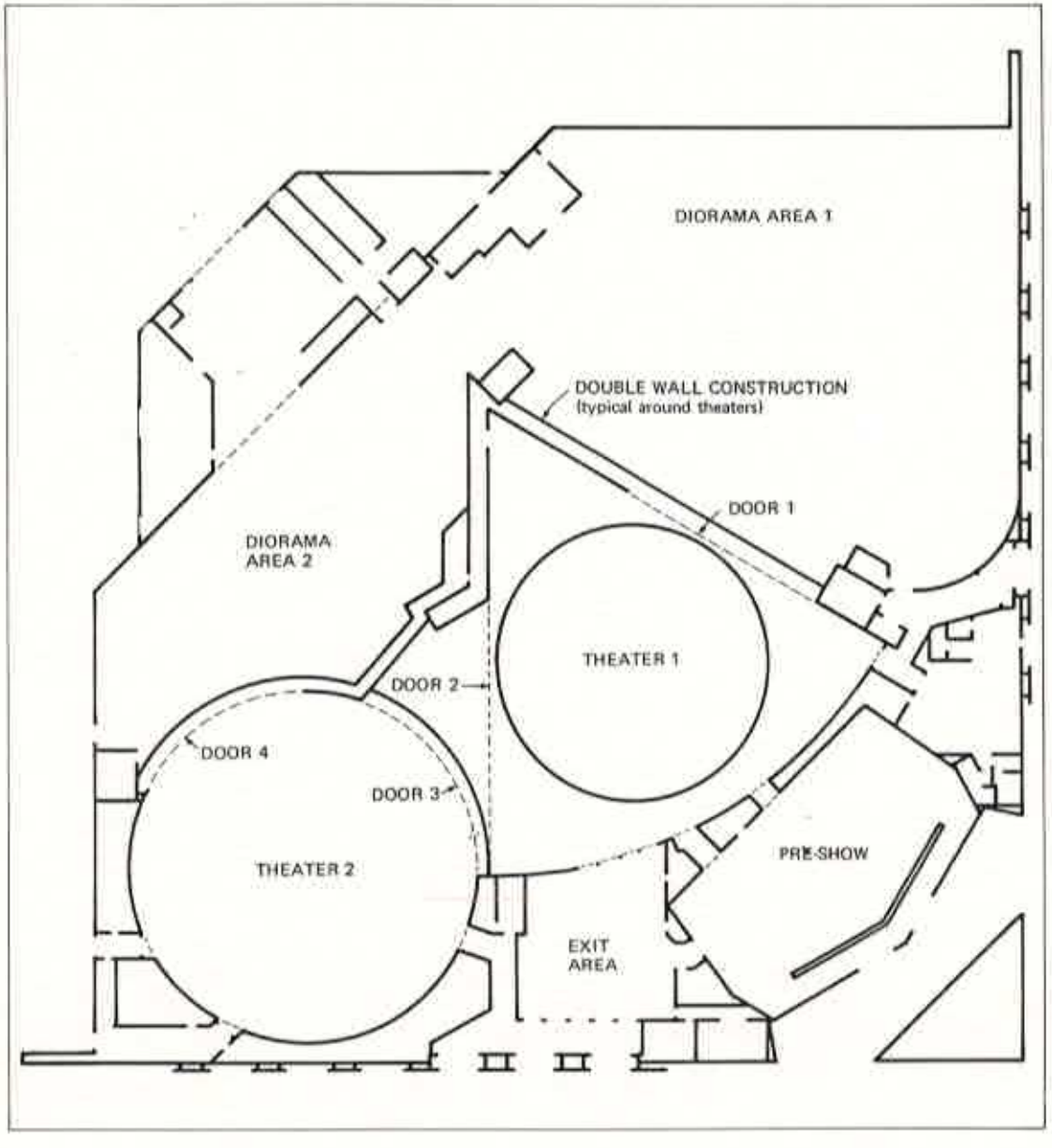
The ultimate problem perhaps in any project is that it is financially a zero sum game. Every dollar that goes into acoustical treatment must be weighed against the additional revenue that it will produce. Time and time again I was asked what will the consequences in terms of decibels be if we don't do what you ask. Thus we spent as much time calculating for alternatives as what we wanted to see. The question which had to be weighed was what is the impact on the attendance at the park of this particular dollar spent. How many more people will come to the park or come back to the park if we put in a door or add absorption or quiet a noise source. This is due to the fact that a dollar spent on acoustics is a dollar not spent on something else which might be more productive.

The final problem was tied up with the overwhelming scope of the project. This is a billion dollar project which has been built in essentially two years. Although planning has been underway for several years, the main thrust has been in the last two years.

Disney committed to opening the park on a given day and has sacrificed enormously to achieve that end both in the work that has been done, the extra money that has been spent in order to meet the deadline and the things that have been left out in the rush to get everything built.

The range of acoustical problems encountered runs from the mundane to the impossible. The overall noise level criteria was set for all guest areas in EPCOT at an NC 35. This was a compromise value between a lower criteria that was considered more desirable for theaters and a higher criteria that was considered probably more practical for rides. Reverberation times in the show spaces depended on the size of the room and what could be achieved in the size of the individual theaters. In general we were trying to achieve a reverberation times below a second at 70% of the theater capacity and typically about .8 seconds at full capacity in the mid frequencies.

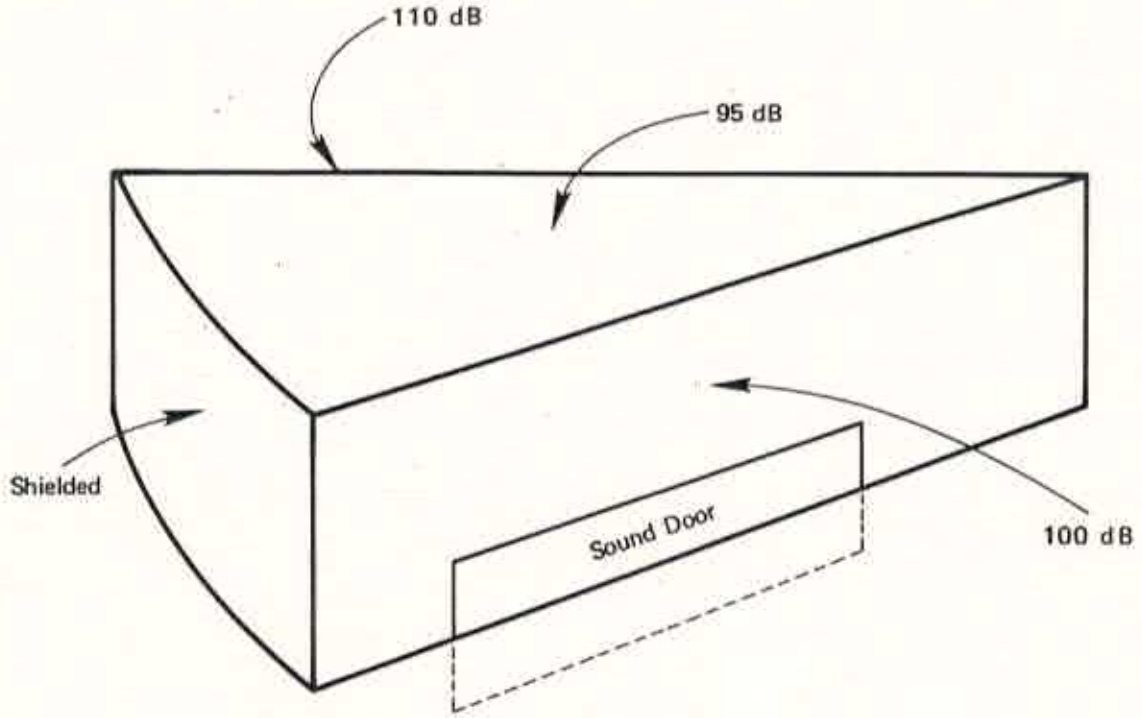
But to take specific examples lets take a look at one typical pavilion, Energy Pavilion, the earliest pavilion in which we were involved. First slide shows its basic concept which is three separate theater areas where simultaneous shows are to take place. Theater 1 and Theater 2 are shows for film and the Diorama Area is the large set piece portraying the prehistoric world, in full scale. The adjacent theater areas presented the initial problem of isolation between the areas. We had in addition some reverberation problems for example in the Diorama area, which is the largest room in EPCOT at some 1.6 million cubic feet. This needed to be isolated acoustically from Theater 1 which was next door, the main problem was a thunder effect at 100 dB at 100 Hz plus of course the



ENERGY PAVILION PLAN SHOWING SOUND DOORS

reverberant sound in the room of that size. Theater 1 next door has a unique pie shape design 153 feet on the side making it at a half million cubic feet not particularly small. The reverberation there is made more interesting by the fact that all the straight walls were to have mirrors on them. Theater 2 at only 400 thousand cubic feet is round but otherwise inoffensive. It has the takeoff noise from the space shuttle at 110 dB at 100 Hz which needed to be isolated from Theater 1.

There were a couple of complicating factors, first of all the people are not seated in these theaters in the normal sense but rather carried on vehicles which are built to carry approximately 100 people each. The vehicles themselves have no operators but are computer controlled and the're driven by a pulsed dc motors and so you have a considerable vehicle associated noise problem. So that the people can fully appreciate the spectical these vehicles are driven into the theaters and sit on turntables which rotate around at various parts of the show. The turntables themselves are supported on a system of air bearings. These bearings had their own interesting acoustical properties which we will see in a few minutes. To top it all off of course you had to get the six vehicles from one theater to another and you in addition had to acoustically isolate these two areas. Thus we were required to design acoustical doors approximately 90 feet long and 10 feet high which dropped down into the floor. The doors then had to be able to withstand the vehicles driving over them at some 40,000 pounds of vehicles and load.



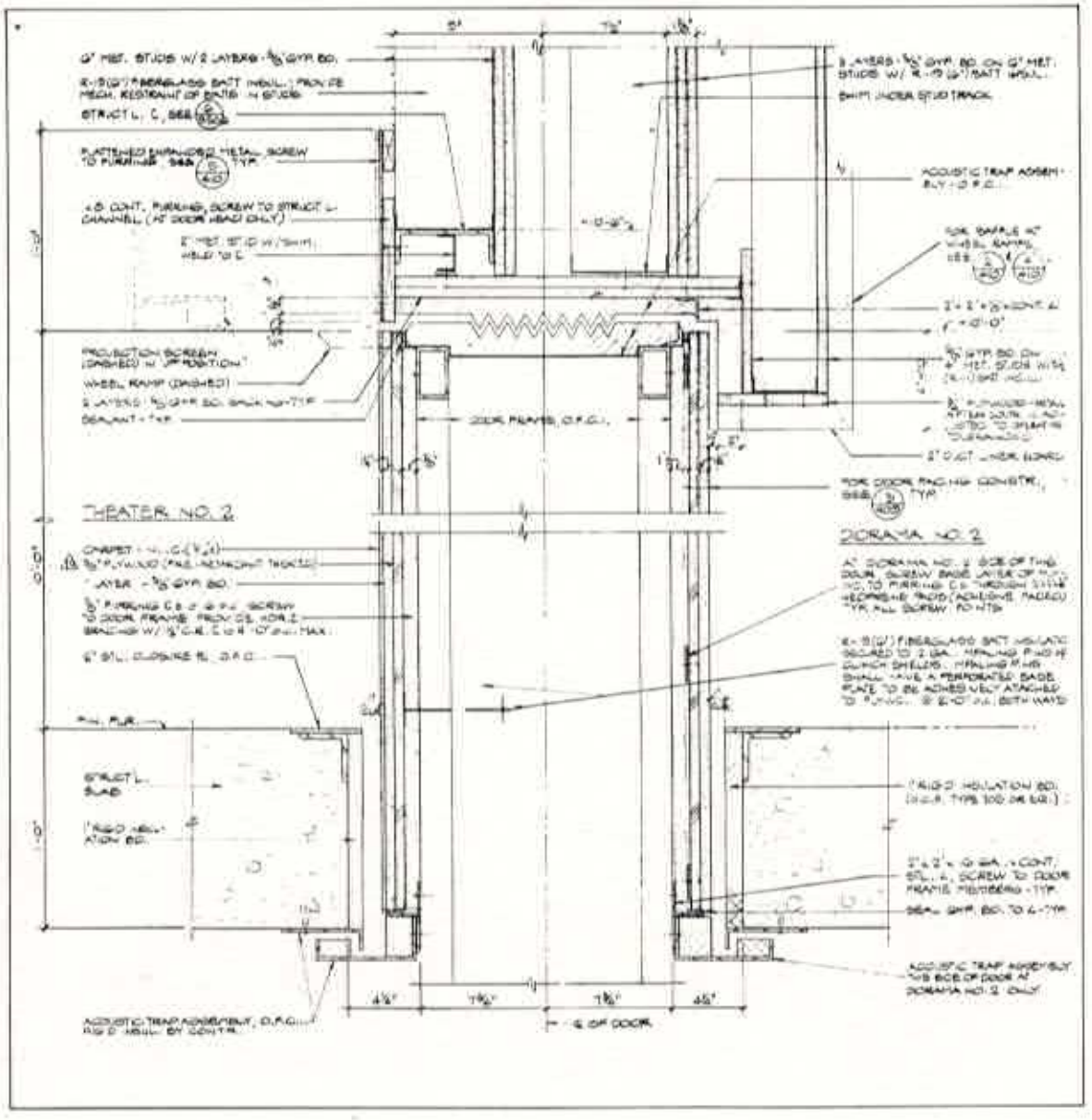
ENERGY PAVILION - THEATER I

Assumed Sound Field Distribution
Levels at 100 Hz

In addition to all this there was the normal special effects including fans, pumps, steam jets, winches, lifts and other Disney paraphanalia. The design of all these factors is sort of like trying to play the violin while hopping on one foot it's not so much the problem of doing one individual thing as it is the problem of combining all the conflicting problems.

First of all the theater separation problem was tackled by designing a double wall all around, this was reasonably straight forward and the problem became concentrated on the door design. Due to the weight of the door the hydraulics could not lift them and they had to be counter balanced. Each door weighed about 25,000 pounds with the exterior skin panels negotiated down to about 5 lbs/ft^2 each. The point mounting technique of Ben Sharp used to advantage to decouple the doors from the interior frame. The design was complicated somewhat by the fact that in being counter balanced there could be no compressive seals in the entire design. Since all seals had to be passive then all were designed as labyrinths at the top, bottom, sides and in addition in a center where two doors meet. It was quickly discovered that this was an area where little technical research had been done. The theory of acoustical transmission through labyrinths is not something that is easy to find.

In addition there are a number of problems associated with merely in field type difficulties. When you have that much steel in the air we had a variation of as much as an inch in the top seals so the seals had to be able to accommodate that kind of mis-



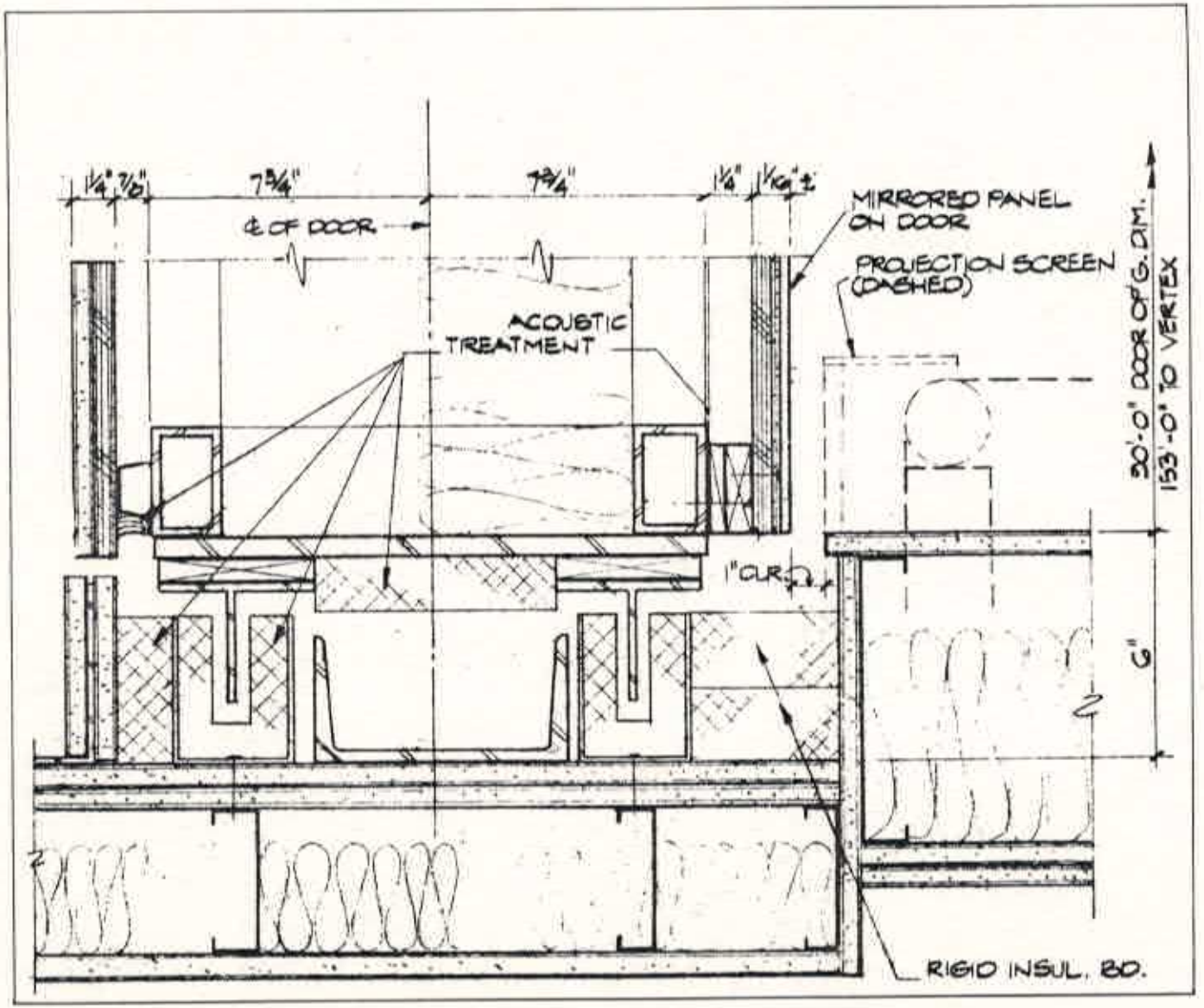
ENERGY PAVILION SOUND DOORS / SECTION THROUGH DOOR NO. 4

alignment. The design is shown in the slide and includes overlapping passive seals. At the top we used 20 pounds per cubic foot closed cell foam which had some transmission loss value as well as absorption value. At the bottom and sides we used more conventional labyrinth design.

The overall result was reasonably satisfactory. The theaters are isolated sufficiently that you can not hear from one to another except near the doors where some of the seals have been removed. Right now we are trying to lobby to get some of the seals put back in.

The second significant problem was control of reverberation in these very large rooms. The Diorama in particular was an interesting challenge of its very large volume and the fact that we were only able to treat selected surfaces. Floor is concrete, the murals were to be applied on gypsum board and there was considerable rock work.

Since the primary absorptive surface was the ceiling then the room height controlled the reverberation time. In this simplified approach the reverberation time is 1/20th of the room height. Thus the first step was to lower the volume of the room by lowering the ceiling to a height of about 35 feet resulting in a reverberation time of about 1.7 seconds. This then brought us to an interesting theoretical question. That is what constitutes the volume of the room for low frequency sound. If for example we took the absorption and hung it in a T-bar frame the low frequency



ENERGY PAVILION SOUND DOORS / LABYRINTH SEAL DESIGN

sound would tend to pass through the absorption and strike the roof above and be reflected. Thus we would be dealing with a volume which extended from the floor to the roof without making much note of the ceiling's presence. If we change the ceiling material by making very heavy,such as plaster ceiling with absorption on it then we would decrease our reverberation time by decreasing the volume, however we might offset that effect by the reduced efficiency at low frequencies of abosrption that we put on the ceiling. Finally it was decided that we would construct the ceiling out of a relatively thin layer of drywall covered with 3" of absorption which was later cut back to 2". This would allow the bass frequencies at 60 to 100 Hz to pass through into the space above and provide additional absorption by diaphramatic action while leaving the higher frequencies a smaller volume to rattle around in. The question of what constitutes volume in a room where you have a ceiling suspended away from reflecting surface as a function of ceiling mass is an interesting theoretical problem.

The final results were actually a little better than we expected. The rock work provided us with a great deal of diffusion and so the high frequency sounds are quite adequately absorbed. There is still some low frequency reverberation in the room, however it is we think due to the cavities which are formed by the hollow rock work and we are seeking to treat the back of the rock work to take care of the problem.

The next major problem in Energy Pavilion is caused by the turntables themselves. The turntables are supported by a unique system of air bearings. An air bearings which is shown in the slide is a saucer like device which has a vinyl bag attached to the bottom. The air is ejected through holes near the center and travels out radially. This forms a thin sheet of air on which the bearing rests and then the plate in turn supports a steel frame structure. In theory rather substantial loads can be supported with very nominal air pressures.

The problem which we encountered was that this air flow was occasionally modulated by vibrations in the vinyl. The vinyl would encounter a small imperfection in the floor which would allow the air to escape out periodically causing the vinyl to vibrate. This resulted in a siren effect which produced levels of as much as 110 dBA at 5 feet. The effect was most pronounced when the bearings were in their unloaded condition or at very high air pressures or when there was a small tilt to the air bearings. Likewise when there were any small pockets of grit or debris or indentations in the floor the air bearings tended to siren. As a result it made control rather difficult and tenuous. The only solution found was to control the flatness and the smoothness of the floor. Thus for the 90 foot diameter turntable the floor flatness spec was written to a 1/4 of an inch tolerance over the 90 feet plus smoothness requirement in addition to that. Several problems were encountered in achieving this. First of all when concrete was used on the

floor, in order to achieve the smoothness, the concrete had to be machine trowelled and ground. So much trowelling was required that the agitation caused the lime in the concrete to rise to the surface weakening the surface. When the turntable was placed on the concrete surface the enormous weight of the turntable caused small flakes of concrete to chip and flake off leaving small pits which exacerbated the problem. A concrete guru was brought in and a solution was attempted by jackhammering out a layer of concrete and replacing it with more concrete bolted back in to the previous slab. This however proved no better. The third approach was to install steel plates over the concrete and bolt them to the floor. In order to achieve the necessary smoothness special welding equipment was used which was guided on rails in order to achieve the necessary alignment of the weld. The welds were then ground and polished in order to obtain the overall smoothness necessary. Remember that everytime the pit was changed a 90' diameter steel turntable had to be disassembled and removed and then reinstalled.

The final solution resulted in a reasonable amount of success although there is still variation in the response of the system to different load conditions. When the turntables are unloaded there is a greater tendency for the air bearing to siren. This is complicated somewhat by the fact that the air bearings are being fed with air at a pressure of approximately 3 times that which was originally anticipated in order to carry the load of the table. Fortunately in the unloaded condition the patrons are into the next scene and the problem is not very pronounced. When the table

is loaded with vehicles and people then the sirening is infrequent, however there is some difficulty in controlling the load distribution on the table since people are allowed to enter the vehicles at random and distribute themselves among the vehicles in a random fashion then occasionally we get an unloaded condition. In order to try to minimize the difference between loaded and unloaded conditions one set of air bearings is used when the table is unloaded and a second set is used when the table is loaded with the air pressure adjusted accordingly. In addition the top of the turntable is covered over with a 1/4" steel plate which serves to attenuate the noise, however the plate is not continuous and there are a number of holes which have not yet been taken care of.

The final challenge of the Energy Pavilion were the vehicles themselves. Three major sources of noise were associated with the vehicles. First was the drive motors which were operated to propel the vehicles, the second are the front and rear steering motors which control the steering system to follow a guide wire in the floor. The third is the recharge plates which are located near the underside of the vehicle and replenish the power to the batteries. The vehicle is battery powered, however there is not sufficient life in the batteries to drive the vehicle for a full day of operation, consequently the batteries are recharged by a magnetic coupler during each performance while the vehicles sit on the turntable.

The propulsion system motor, a rather straightforward noise control problem, causes a level of 66 dBA in the rear seats.

Solutions have been proposed to enclose the motor and within the existing fiberglass enclosure. Due to the problems in getting the ride system to operate consistantly this has not yet been implemented, however it is scheduled for implementation.

The second difficulty is a 56 dB 4 KHz tone which is produced by the control pulse for the steering motors. This 4 KHz pulse controls the right and left steering system by varying the pulse width. If you could envision a square wave at 4 KHz then the distribution of current between the positive and negative sides of this wave can be varied by moving the position of the transition between positive and negative. As the transition point is moved leftward then more energy is transferred to the negative side of the wave. As it is moved rightward more current is transferred to the positive side of the wave. When the cars are steering straight there is an even distribution of current. While for left or right more positive or negative current is fed. Since the steering motors undergo a DC torque there is no possibility of decoupling them from the vehicle itself. It was however found that by shifting the pulsing frequency to 7 KHz a 20 dB attenuation could be achieved. Unfortunately this required a derating in power of the servo amplifiers which decreased the mean time before failure of these units. To date the solution of the 4 KHz tone problem has not been implemented, however it is scheduled for an experimental test at some future time.

The final problem occurred with the magnetic couplers. These were large flat plates which have a pole piece imbedded in them and windings on each side of the plate. The large currents involved produced a noise level of about 55 dBA centered around 120 cycles. Since the level is linearly dependent upon flux density and flux density on the conduction medium area, it was decided the most expediant way to treat the problem was to redesign the interior pole pieces by increasing the size of the steel core. Since flux density is one of the few functions which is linear with sound level a considerable decrease in noise was achieved by this technique. Current levels are something under 40 dBA.

One interesting note in passing, there is a large transformer which was associated with smoothing the charging circuit and was located in a typical electrical enclosure for this vehicle. Outside the enclosure it was found to create a noise of some 84 dB in the 125 Hz octave band which was reduced to 78 dB when placed in a steel enclosure. After some experimentation it was discovered that the top of the box was being included in the magnetic field produced by the transformer itself and thus was being caused to reradiate sound as the transformer was cycled. A 10 dB decrease was achieved by placing a spacer material between the transformer and the top of the box so as to maintain the spacing and reduce the magnetic gap between the transformer and the plate itself. The spacer also acted as a half wave rectifier and damper for the plate by not allowing it to move in a downward direction. The box was then located beneath the vehicle and thus the floor of the vehicle provided the additional attenuation needed to get the vehicle down to the criteria level.

Energy Pavilion has been one of the most challenging and frustrating of the pavilions. The solutions to the problems encountered have had to be very unique. Very few of the problems have yeilded to the straightforward solutions. There is still a ways to go in several instances but progress is being made.

Mexico Pavilion was a much less complicated although there were unique material problems involved here. This was much more a traditional architectural acoustics problem. The concept in general is that there is an overall open air plaza which is lit at dusk with live entertainment in the plaza. Second feature of the pavilion is the boat ride. The overriding problem involved the plaza which had to be a simulated open air environment thus be acoustically dead. The entertainment stage was located at the center of a circular area approximately 60 feet in diameter. There was in addition the usual noise control problems in the ride, control of reverberant sound, and scene to scene isolation.

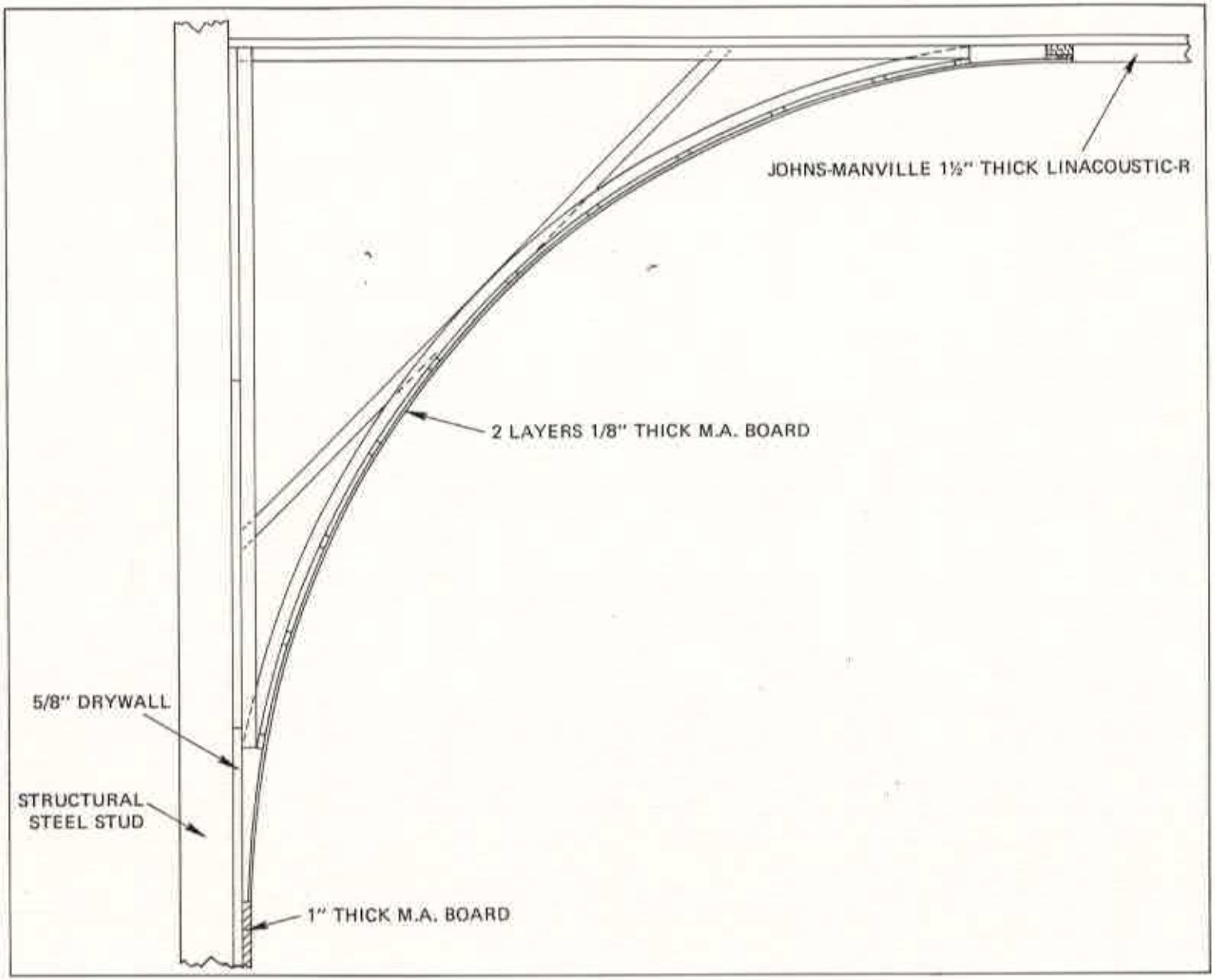
The absorption problem was attacked in a number of ways. The murals themselves are painted on a muslin which is sized and glued to a drywall wall. We sought a way to make a typical mural absorptive by placing it over a relatively hard fiberglass board. We chose a fiberglass board having a density of 10 pounds per cubic foot and did a number of experiments where the mural was glued to the board. The process was such that we had to first seal the surface of the board with an oil base sealant and then to glue the mural to that with a water base glue. The sealant had to be of a

different base than the glue so that when the mural was applied it would not dissolve the sealant underneath. In testing this configuration it yielded absorption coefficients which as one might expect were not particularly good on the order of .3 in the mid frequencies. This was considered an insufficient result to warrant the expense of doing the treatment.

In a further experiment we perforated the surface of the mural and the underlying board. The perforating of course had to be done after the mural was glued up and painted. This was somewhat more successful yielding coefficients on the order of .7 at the mid frequencies. The tricky part of this procedure was that a perforation method had to be developed which could be used on a reasonably large scale with the mural in place. The fastest way of perforating the mural was found to use a hand held saber saw with a triangular sewing needle clamped into the saw blade position. The depth and speed at which the saw was moved had to be carefully controlled in order not to tear the mural. Test murals were painted and perforated and lit with show lighting and approved by art direction for various distances and lighting conditions. Once the program was completed there was a decision not to proceed with implementation in the field due to the experimental nature of the process and since there was no clear cut guarantee that the method would survive a test of longevity in the Florida climate. As a result although Mexico Pavilion was not significantly affected there was a considerable loss of absorption in the Land Pavilion Farmers Market area where this process was countered on to achieve approximately 10,000 sabins.

The second large area of concern in the plaza of Mexico Pavilion was to achieve an absorptive ceiling which could be painted out to look like the sky at dusk and transitioned into a compound curved cove and finally into a curved mural. Conventional absorbant materials simply could not take the curve and the transition to a plaster cove was deemed less than satisfactory from the standpoint of both acoustics and appearance. The final solution utilized was to use a duct liner board, manufactured by Manville Corporation, called Linacoustic-R. This material has a flat black surface which takes painting well and still retained its absorptive properties. The curved coves which were compounded with an 8' radius in one dimension and a 56' radius in the other dimension were built of two layers of 18 pound per cubic foot pressed fiberglass board which was 1/8" thick with 2 layers glued together. In order to retain the same surface texture untreated Linacoustic surface material from Manville was applied over the cove glasstrate board and these materials transitioned up into the ceiling area. In the critical areas where the seams were likely to show they were also covered over with this cloth material and the whole area was painted with a non bridging latex light spray paint.

The base material, the Linacoustic-R was an excellent choice since it was relatively inexpensive when compared to conventional finish materials and it also could be glued and screw attached to the drywall ceiling. The murals on the wall behind the pyramid in Mexico were then brought up and overlapped onto the cove area and painted out so that the transition is quite smooth and undetectable.



MEXICO PAVILION PLAZA AREA / ABSORBANT COVE DESIGN

The same Linacoustic material was used on the sidewalls in the blacked out areas of the rides. In the ride portion of Mexico and other ride areas scene to scene isolation was maintained by division of walls in which the entrance and exit areas were made as small as possible. Additional absorption was picked up in scenes where there was very little absorption in the set work by building sets out of Tectum. The sets themselves where they were designed to look like adobe houses for example were constructed of acoustical plaster trowelled over Tectum and then textured with regular plaster.

The other noise control treatments in the Mexico Pavilion are relatively straight forward some of which are being implemented at this time. Standard enclosures have been designed for the pumps and the projection booths. We are still in negotiation on use of glass in some of the projection booth windows.

Land Pavilion is the largest pavilion which has been built to date in EPCOT. The main problem involved in Land were by and large due to it's scale. There are two sit down theaters, one for film and one for animated figures. There is a very large eating area called the Farmers Market which has about 1.3 million cubic feet. In addition there is a boat ride involving a number of different types of show areas, plus a revolving restaurant set on a turntable which overlooks part of the ride area.

In Land Pavilion the theaters are a good example of what we sought to achieve in the theater design. First the theaters are separated from adjacent areas by double walls and double sets of doors. Due to the problems of maintenance and operational considerations, no drop closures or bottom seals were used on the doors. Isolation was calculated by taking a composite transmission loss for the doors and the crack openings, however the crack openings were not assumed to have a zero transmission loss as is normally done. Rather they were assumed to have a loss equal to end reflection that you would get from the open area in any conventional duct transmission problem. This is another area where there is not a very good theory available for calculation of losses through composite surfaces with holes in them.

The Symbiosis theater in Land Pavilion is designed for film. Since the walls were originally parallel a zigzag pattern was designed and covered over with grille cloth which was then protected with wood slats. Behind the grille cloth there is 3" of fiberglass batt on surfaces facing the screen so that a side reflection are minimized. In addition the area behind the screen is completely covered with absorptive material as well as the back wall. Here again there was another theoretical problem with calculating the reverberation time with a material which was placed behind a large perforated screen. We found very little data on the effects of such screens and there were particular problems with unperforated screens which we had to use in some theaters.

The projection booths presented an additional problem and one that we are still trying to work out. Projection at Disney is a sacred art and responsibly is vested in the studio rather than being associated with the engineering arm. At first the projection department was unwilling to consider any glass in any of the projection ports at EPCOT. We went through a number of meetings to try to change this view. Finally it was agreed that a standard port would be designed and the projection department would design the port assembly which would include a 1/4" piece of glass in it. Unfortunately the port assembly ended up having a number of openings and is now being modified to reduce the transmission of sound through the assembly to the audience.

In this regard a unique problem arose in the Circlevision theaters. Projection is done between the screens so that when a glass assembly is placed over the lens between the screens there is a glow from the light reflecting off the glass. After seeing this all the glass was removed from the projection covers in the Circlevision theaters. Recently we have designed an enclosure which does not require glass and we are hoping that this will be implemented in the circlevision projection booths.

The other theater in Land called Kitchen Kabaret features the show of animated figures portraying the basic food groups. In all animation of this type there are considerable problems associated with the activation of this animation. Each AA Figure is activated by pneumatic or hydraulic cylinders to control its motion.

Hydraulics are used generally where precise control is required since with hydraulics you can stop a motion at anywhere along the stroke. Pneumatic actuators are used where binary motion is used where there is full limit stop on each side. The hydraulic noise comes from the attachment of piping to the sets. For example, in the Pirate ride in both Disneyland and Disney World background levels are in the mid 70's due to the humming of the wood sets with the hydraulic lines clamped down to them.

Where pneumatic actuators are used there is noise both from the actuating valves and from the piston actuators. The actuator design was modified slightly to allow the collection of exhaust air into a common blow-off silencer. It is interesting we obtained about 5 to 10 dB of improvement by using a length of flexible air hose between the exhaust from the valve and the muffler itself. The hose slowed down the flow, increased the volume into which the air expands and changed the leading edge of the wave shape so that a smoother shape was achieved and consequently resulted in a lower sound level. Retrofit of all A-A figures in EPCOT with the modified parts is still underway.

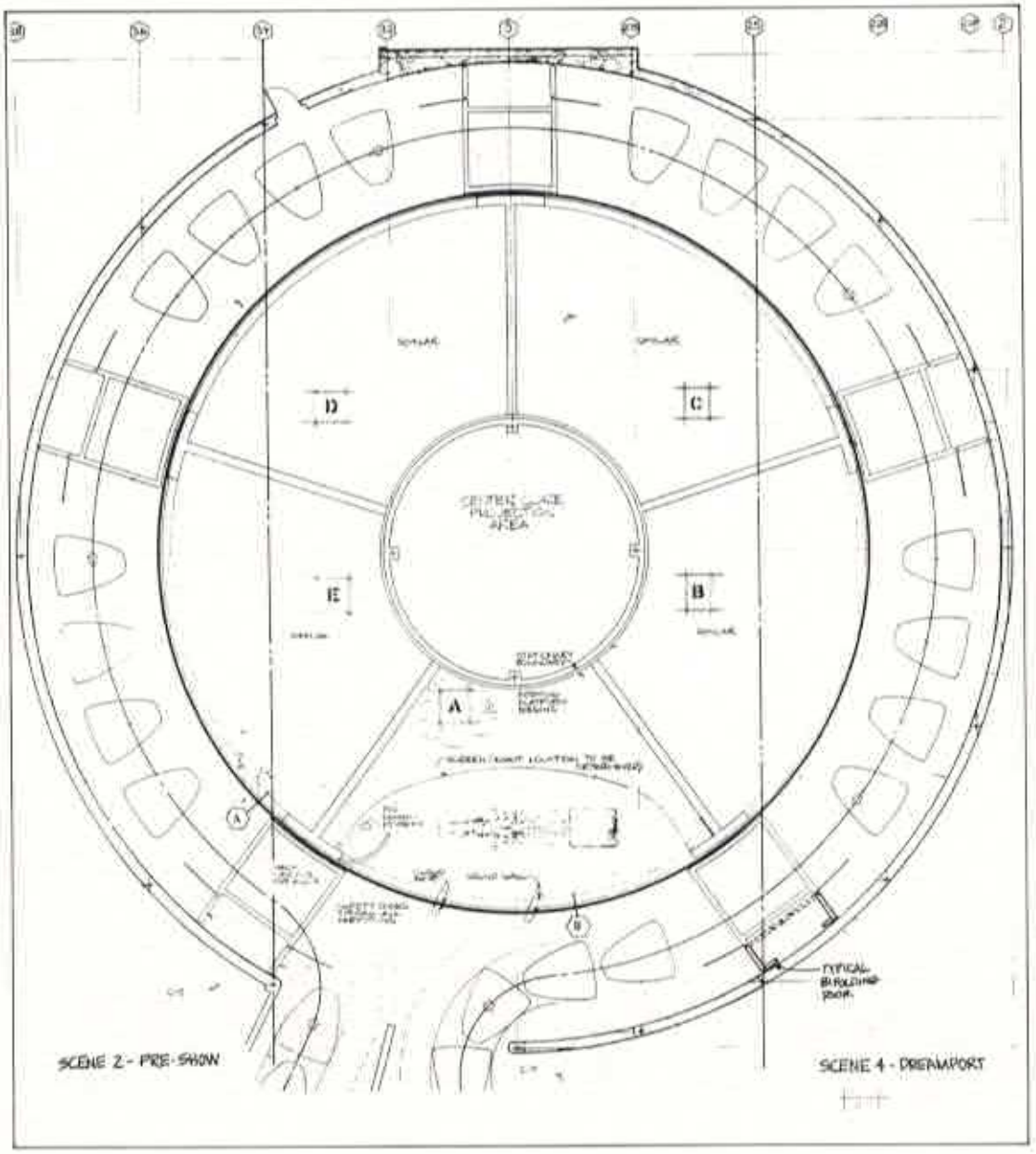
The Farmers Market area in Land was one challenge where we were not successful in getting a satisfactory solution. This room which is about 1.3 million cubic feet has a glass ceiling and painted murals on a large portion of the side walls. We had hoped to be able to use the perforated mural technique here to achieve reverberation time which while not short might be considered tolerable.

Unfortunately when we could not use the perforated murals the results were less than satisfactory.

One additional area of interest in the Land Pavilion is the Barn Theater which is a theater for film within the ride itself. We needed some absorption on the walls which were suspose to look like wood. This is one place that Disney really excells. All the walls in that theater are painted to look like wood and it is very very difficult to tell even within a few feet whether or not the walls are painted.

Finally I would like to talk a little bit about one of the most interesting pavilions if not the most interesting, which is Imagination Pavilion. The concept here is that there are three separate areas, first the Magic Eye Theater, a 3D movie theater, second the Image Works which is a participatory game area where patrons interact with the games. The third is the large Imagination Ride.

The ride, while containing the typical ride problems of vehicle noise isolation, special effects, scene to scene isolation, projectors and the other kinds of problems, has one of the most interesting special problems in EPCOT. This problem is that of a revolving turntable theater. Unlike most other revolving theaters which stop when the scenes are being played this never stops. The vehicles enter the theater in groups of four and are rotated around the theater while the show is underway. The obvious problem here is scene to scene isolation which has to be achieved for a moving wall, something that I have really never seen or heard of before.



IMAGINATION PAVILION REVOLVING THEATER

The design is complicated further by the fact that the first scene as the vehicles enter is blocked with a permanent cloud so that the guests do not see the Dream Machine which is a feature of the show and the Dream Finder who narrates the show sitting on the machine. As the vehicles proceed around the theater the Dream Machine comes out from behind the cloud and the Dream Finder talks to the guests about what they are going to see. Thus the cloud must pass like a knife through the sound isolating wall. In addition the wall must be able to enter and exit the theater without the turntable walls running into it.

An additional problem occurs because of the need to avoid pinch points. A pinch point is a point where a moving wall meets another wall. If a person were caught in between they could be severly hurt. Thus at the pinch point at the entrance to this scene there is a requirement that there be doors there and that they be able to open up while the wall passes the pinch point and closes back after the pinch point has past.

The scene to scene isolation solution was to make a small room between each of the separate areas which would allow a double door arrangement. The doors were then hinged to a bi-folding configuration so that we created duct spaces between the rear of the door and the perforated metal skin on the back wall of the theater. A similar flap is provided at the floor of the door which is withdrawn as the door is opened. The sound is attenuated by a duct then a lined plenum and finally another duct. The areas under the tracks, under the rooms were treated with absorbant material making all openings into ducts.

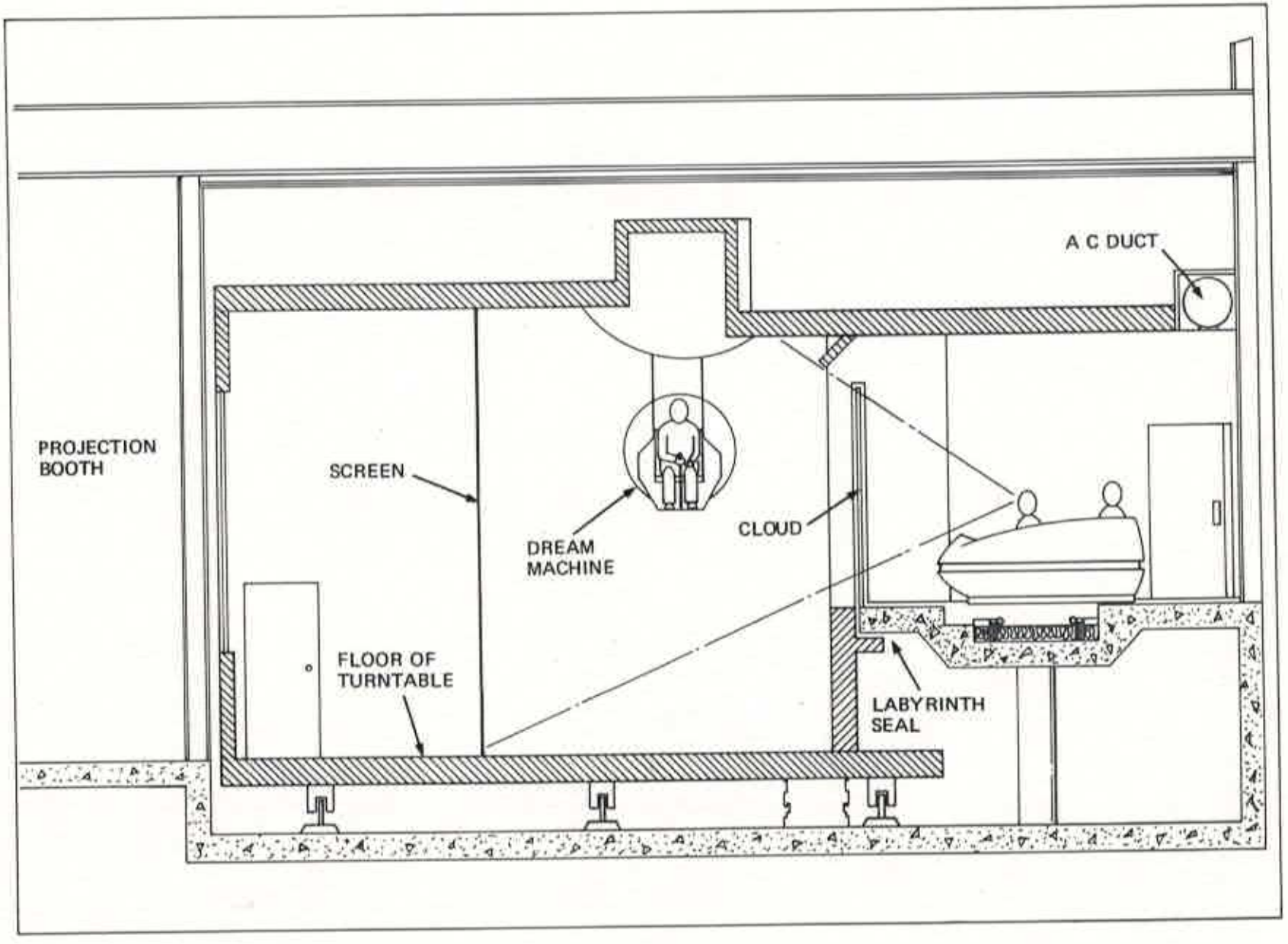
The need for vehicle drive motors complicated the turntable design process and for this and other reasons the turntable is used to push the vehicle train along as it moves through the theater. This means that there are large bumpers at either end of the room which touch the vehicle train. These bumpers effectively lengthen the duct path which allows us to achieve a slightly better attenuation through the track opening.

The cloud needed so much clearance because of the run in and run out of the turntable mechanism and the cloud itself that we could not treat it passively and had to work out an active seal which is activated by cam in the track.

There was in addition a separate noise path due to the linear diffusers which went around the outside of the room. This path was treated by inserting blocks of foam into the ducts at about 4' intervals which is equal to the normal air bar length and spacing between air feeds.

Sound isolation between the guest areas and the drive mechanisms and hydraulics located on the turntable underneath the platform was achieved by another labyrinth.

The problems involved in this particular theater are very unique. We know of no other problem of this type. It also pointed out to us another difficulty in theory of ducts, which is that for ducts which have a very long narrow openings such as that created by the door and outside wall, the theory is very poorly defined.



IMAGINATION PAVILION REVOLVING THEATER / CROSS SECTION SHOWING ACOUSTICAL DETAILS

Probably because the need for such a theory has to wait for an EPCOT to come along because no one else is crazy enough to build ducts that way.

My overall impression of the job is it has been an enormous privilege to work with the Disney Organization on this project. New ground in almost every field has been broken and acoustics is no exception. Disney has come a very long way from its previous park facilities and is beginning to appreciate the importance of acoustics in some of its new projects.

I have only been able to cover a small fraction of the work done and there are still a number of ongoing problems to clean up. I hope you will visit EPCOT and see for yourselves the remarkable achievement that has been accomplished.