byzantine fresco chapel - climatology

arch 316 with mark oberholzer: final project

allan v co - fall 2002

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figures a, b, c

the byzantine fresco chapel museum of houston, texas (29 degrees north latitude) was opened in february of 1997 at 4011 yupon at branard (see fig d), near the campus of the university of st. thomas. only four-thousand square feet, its intimate scale houses the united states' repository for the only set of intact byzantine frescoes in the western hemisphere. in thanks for rescuing the frescoes from smugglers, the church of cyprus - the rightful owners of the frescoes - are allowing a long term loan of the art in this museum specially designed by the architect francois de menil, son of the original patrons of the menil foundation, in 1994 (see fig. a-c)

the byzantine chapel is oriented to face fully in line with the cardinal points - the facades face completely north, south, east and west (see fig e). enclosed space measure approximately 116 thousand cubic feet. there are no windows on the surface area of the building, except for a a skylight of 1,012 square feet of clear, double glazed glass with an inc light diffuser (u = .70 in winter), that permits natural light to pervade the interior.

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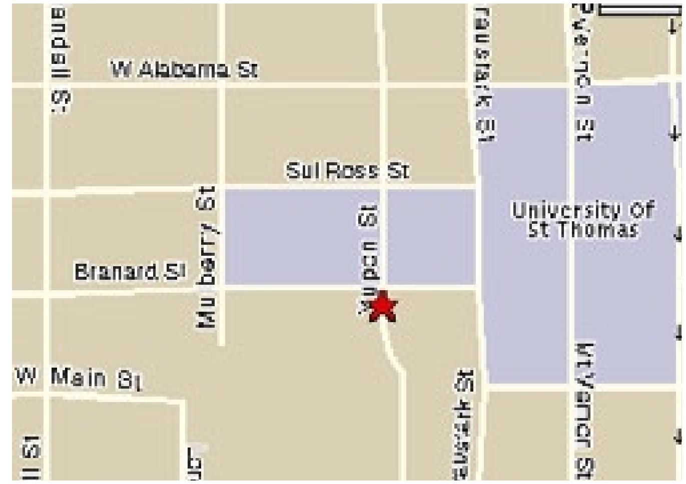

figure d

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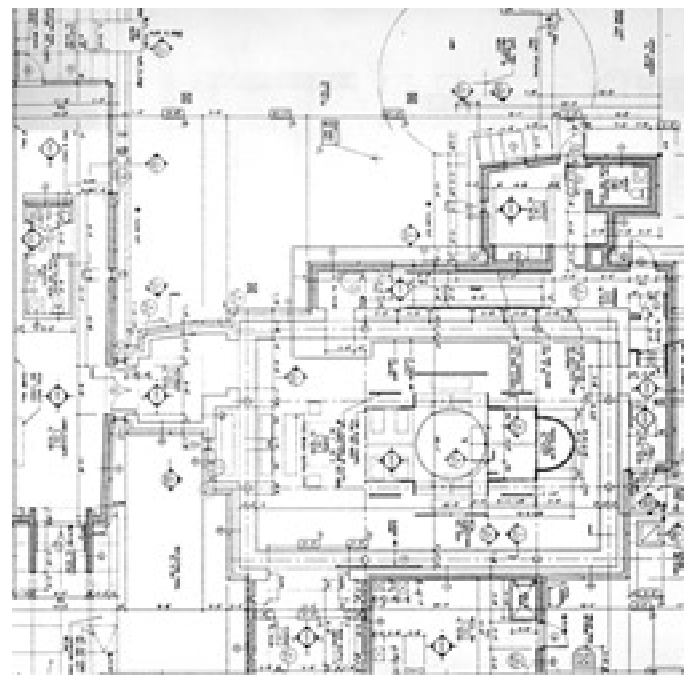

figure e

the byzantine chapel's walls are mostly steel framed concrete measuring slightly over 33 feet. large concrete panels make up most of the approximately 8,250 square feet of surface area, though two four-inch reveals of lead coated copper facing cmu pierce each elevation on the main body of the building (see fig. f & g)

there is no shading of any of the walls of the chapel.

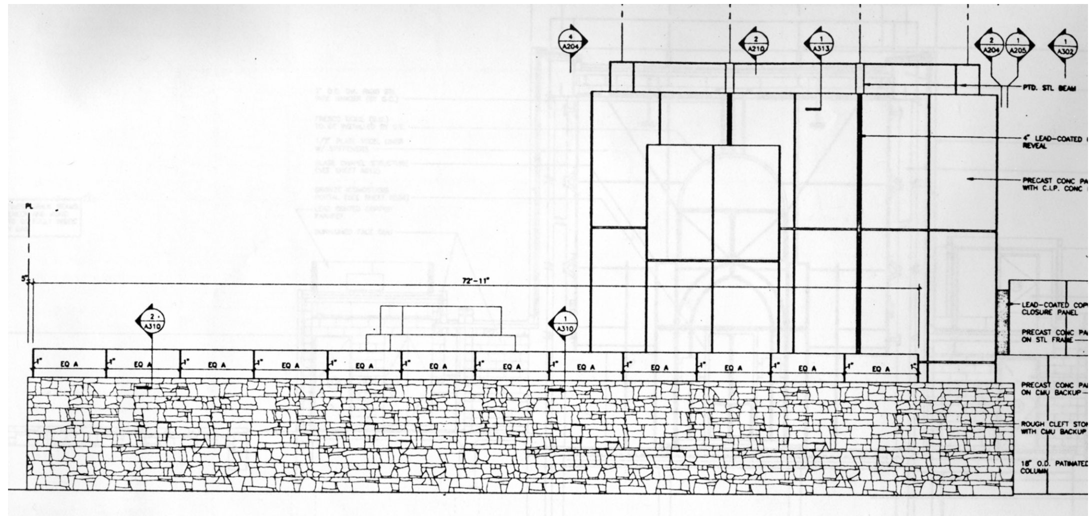

figure f: west elevation

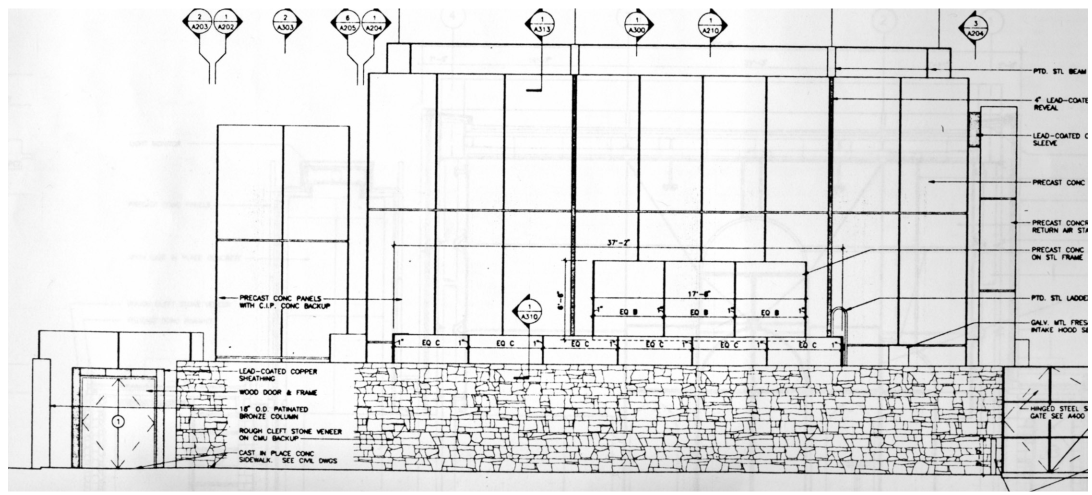

figure g: south elevation

over a dozen different wall sections were applied to the building in order to create the atmosphere that de Menil desired.

de Menil encloses the frescoes (see fig f & g) and creates a mystifying aura using a variety of materials including concrete, concrete masonry unit (CMU), stone, rigid insulation, batt insulation, plywood, steel, lead coated copper, and others.

only four wall types, however, make up a majority of the walling system of the chapel. resistance and conductance of aforementioned walls is documented on the next page.

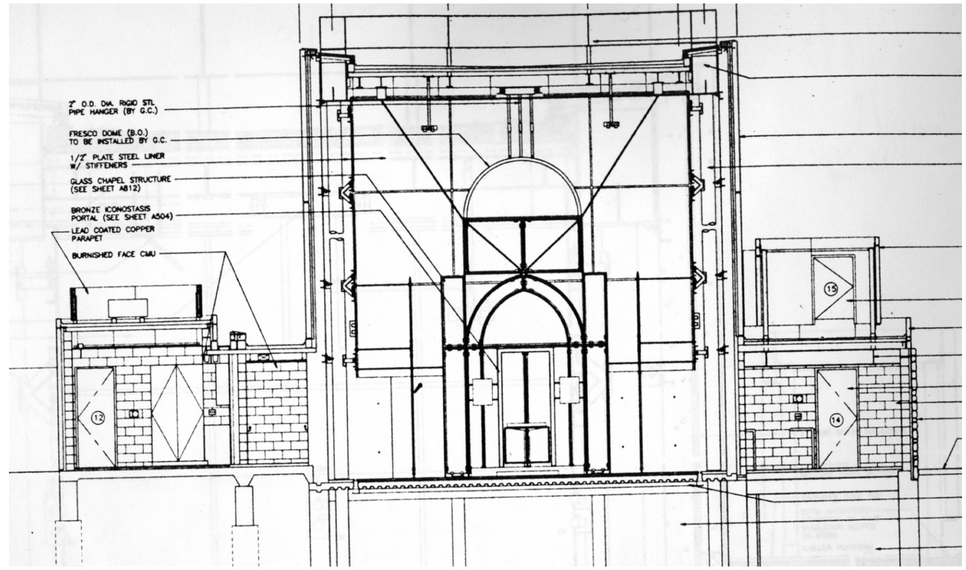

figure h: north/south section through main body

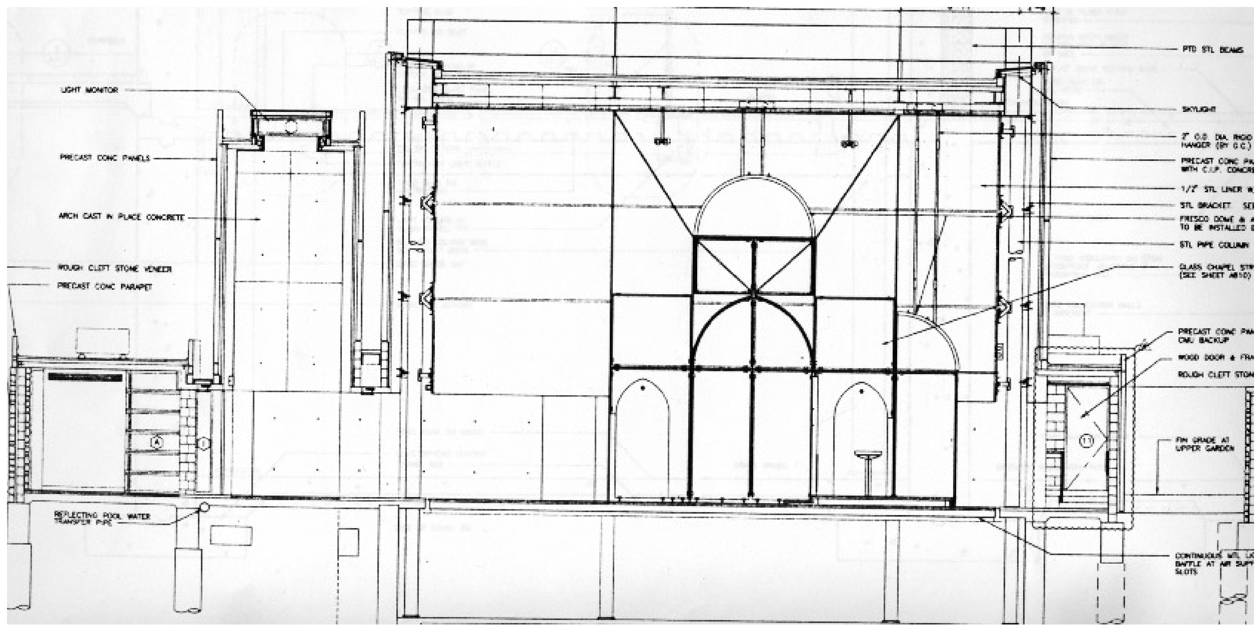

figure i: east/west section through main body although over a dozen different wall sections exist within the chapel, four types make up a majority of the walls. concrete, cmu, and rigid board makes up most of these walls.

wall section a	
total wall r value:	12.6
r value w/ air films:	13.45
u value (with air films):	.074

wall section b	
total wall r value:	10.11
r value w/ air films:	10.96
u value:	.091

wall section c	
total wall r value:	11.63
r value w/ air films:	12.48
u value:	.080

wall section d	
total wall r value:	9.47
r value w/ air fims:	10.32
u value:	.097

exterior walls are faced with 5 inch pre-cast concrete panels that run on most of the 8,250 square feet of the building. panels are of varying sizes.

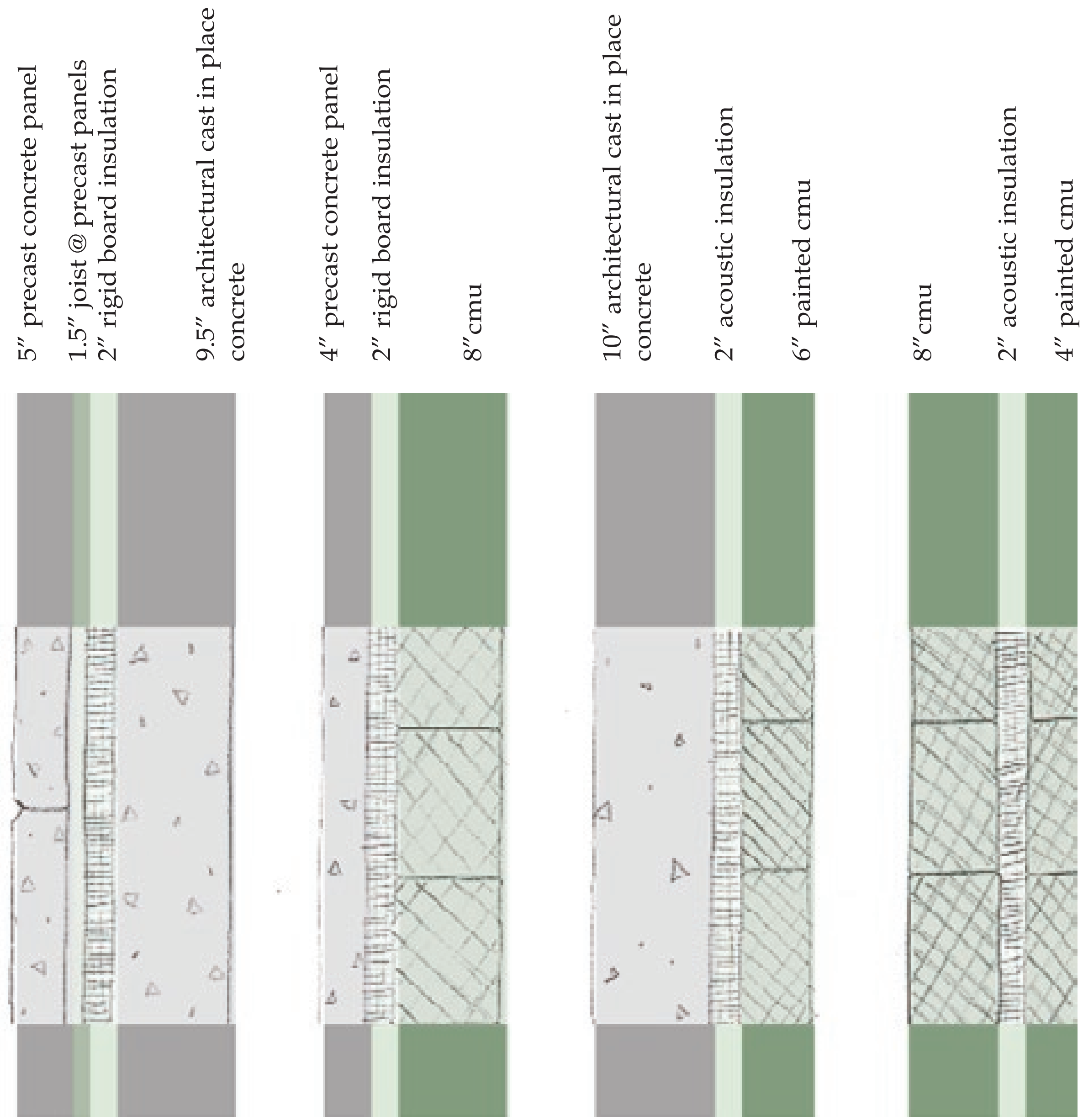

figure j: most typical wall sections; wall section a, b, c, d (left to right) the menil's byzantine chapel uses mechanical systems to control the environment of the building to exactly as it wants it. using a split DX (direct exchange) system (see fig. k) with vapor compression chiller for cooling purposes in conjunction with a heat pump for heat recovery and a humidifier for control of the chapel, the building is rather efficient. the vapor compression chiller unit is mounted on the roof of the mechanical room, adjacent to the main body of the chapel. the roof of the mechanical room is lower than that of the main body of the museum - that which houses the frescoes (see fig. k; refer to next few pages for more graphical information regarding mechanical systems).

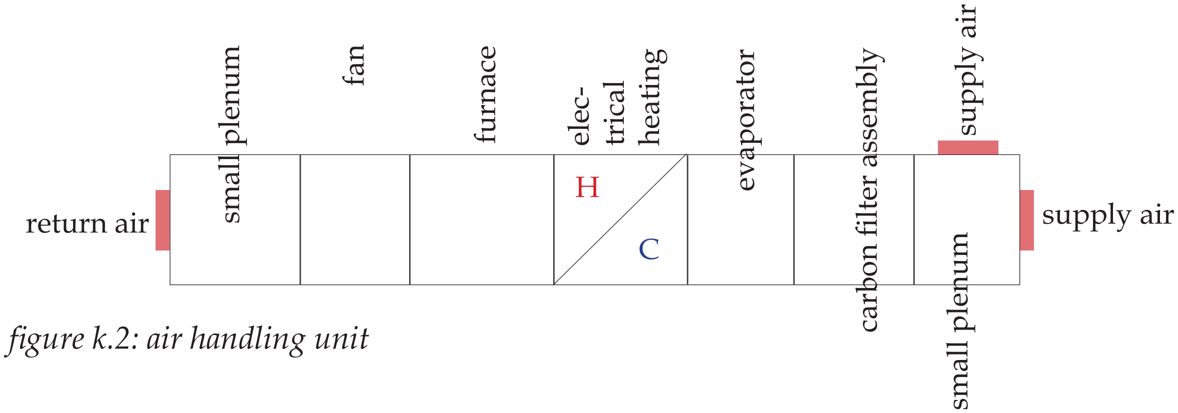

figure k.2: air handling unit

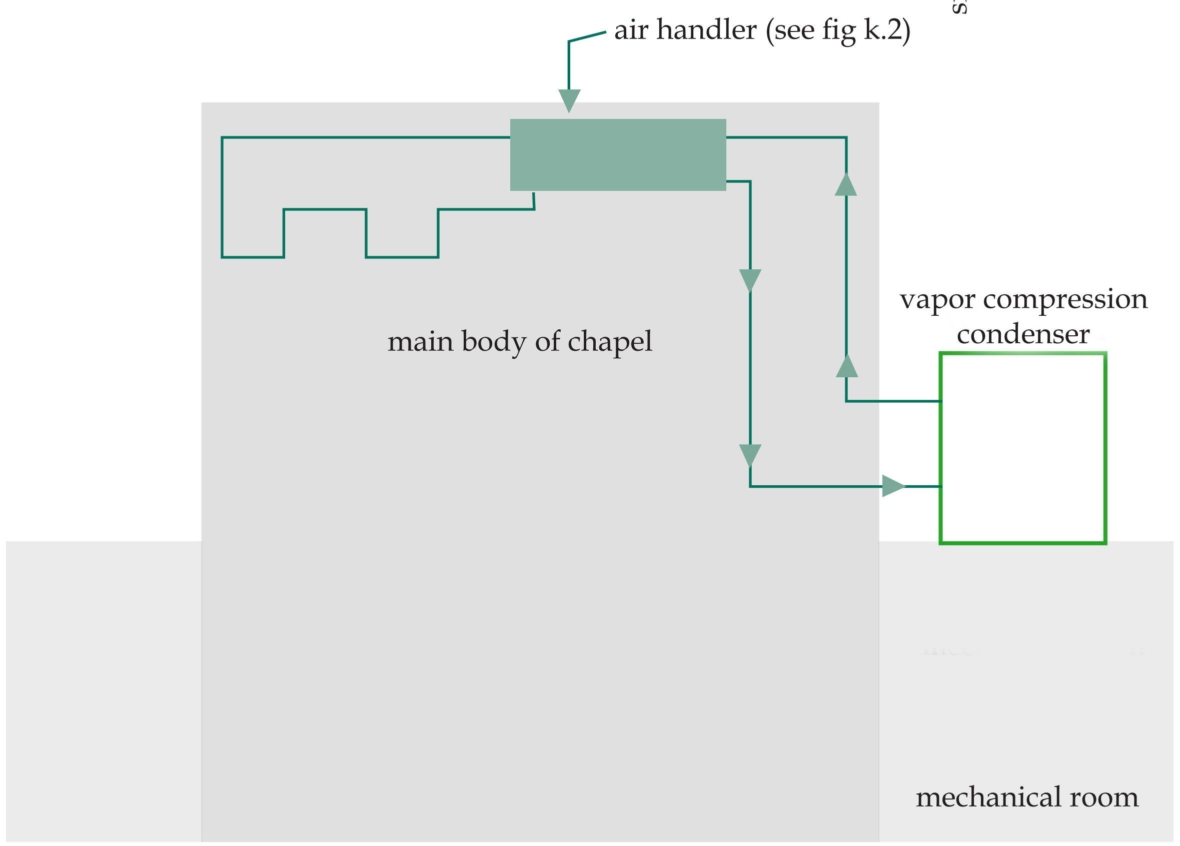

figure k.1: vapor compression condenser above mechanical room

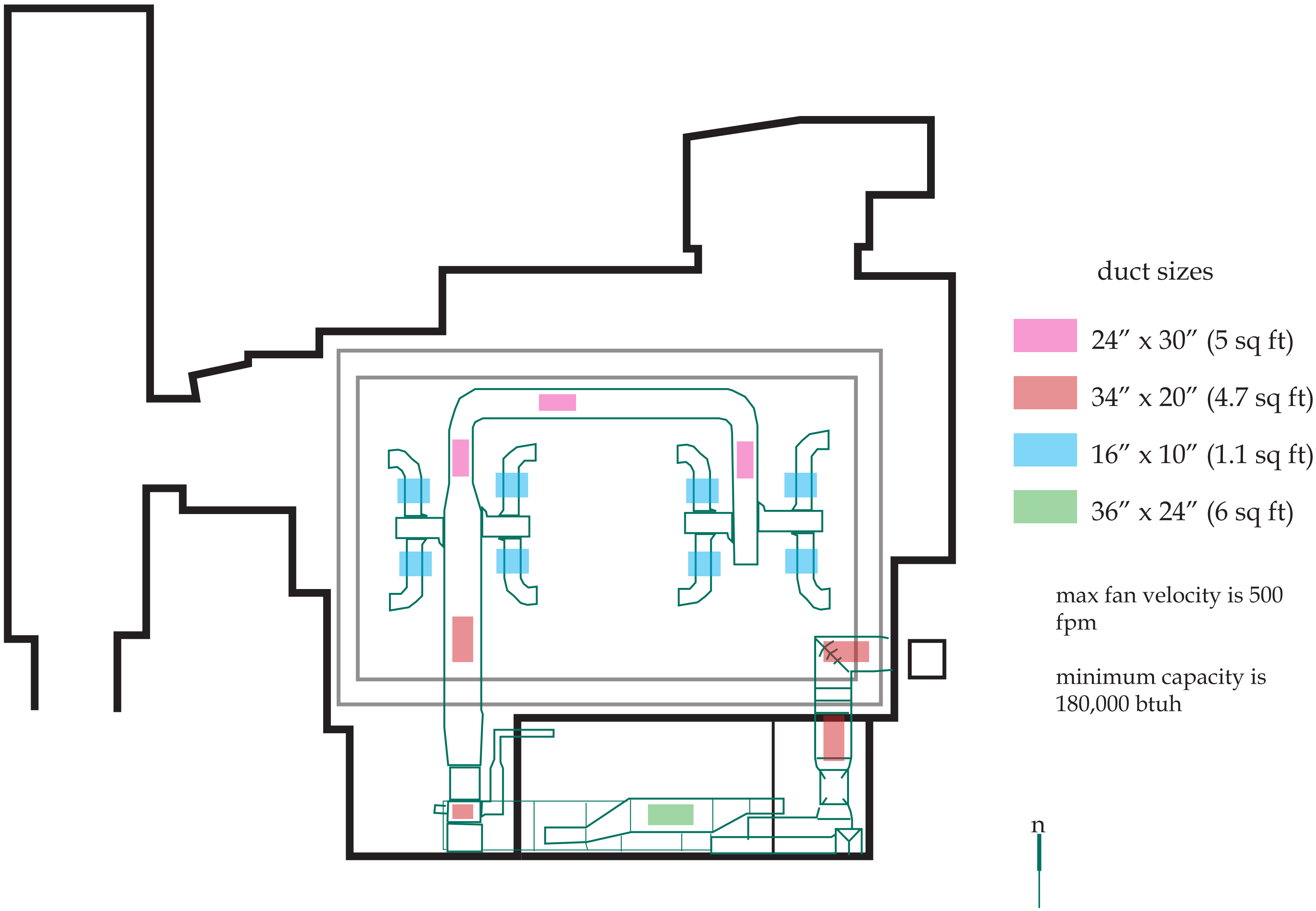

figure l: air distribution through main body of building in analyzing the byzantine fresco chapel museum in such a fashion, it is important to understand that the building was designed not only with visitors in mind, but with the concern of preserving the arts as well. consequently, much attention was paid to the efficiency of the building, in order to assure the well being of the works. despite the efficiency that was attempted for when designing the mechanical systems of the building, the byzantine chapel is still subject to heat gain and loss (see fig m):

heat loss analysis — *inside:* *75 degrees F*; *outside:* *20 degrees F*

source	*load (btuh)*
total transmission losses:	*387,724*
infiltration losses:	*294,030*
supply duct heat loss:	*586,087*
ventilation:	*39,023*
humidification load:	*589,789*
total load:	*1,344,652*

heat gain analysis — *inside:* *75 degrees F*; *outside:* *95 degrees F*

source	*load (btuh)* *sensible*	*latent*
solar radiation heat gain through glass:	*61,479*	
transmission gains:	*112,301*	
internal heat gain:		
occupants:	*9,890*	*8,170*
lights:	*3,641*	
infiltration:	*97,200*	*194,400*
supply duct heat gain:	*72,318*	*2,451*
room, zone or block design load:	*259,629*	*8,170*
ventilation:	*330*	*408*
return air load from lighting and roof:	*-171,247*	
total load:	*402,659*	*232,390*

annual energy use of the building amounted to over 70 million kbtu, with total electric equal to 17 million kwh.

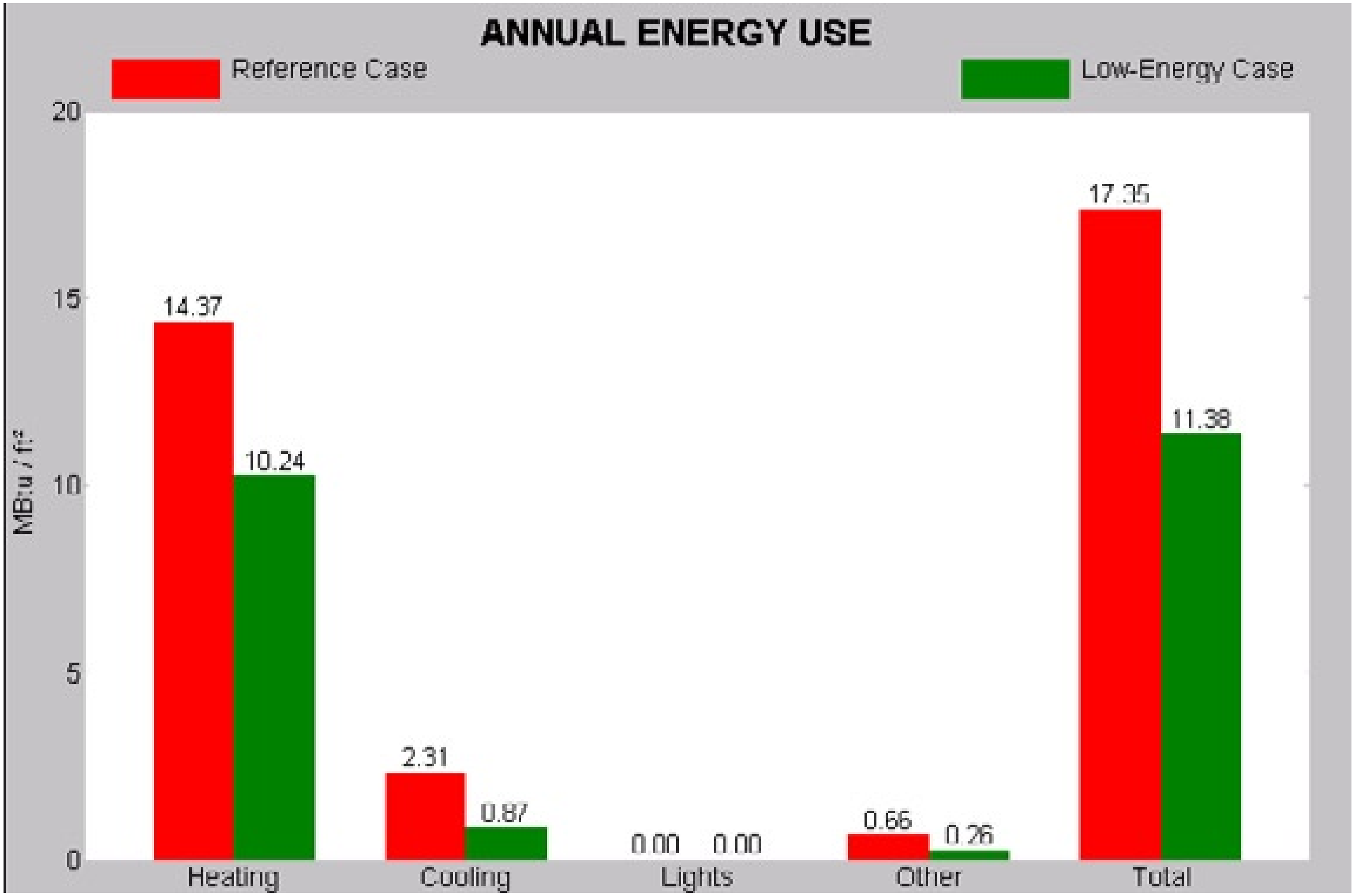

figure m: annual energy use of the building plus a lower energy alternative as mentioned before, the chapel is subject to heat gains and losses, which ultimately effect how efficient it is. most of the heat loss occurs because of infiltration and transmission. several energy saving strategies may be employed to increase the efficiency of the building (see fig n).

clearly, hvac controls and duct leakage could be improved in order to increase the energy-efficiency of the byzantine chapel.

while it is important to research the different ways the chapel may increase its efficiency, it has already cut down many unneccessay extremities by utilizing such techniques as very little glazed surface area, light grey paint, evaporative cooling by means of reflective pools, and minimal electrical lighting. with this in mind it is easy to see why hvac controls and duct leakages are ranked higher. obviously, a higher efficiency hvac system would also improve the building's effectiveness, as that is what it is meant to do.

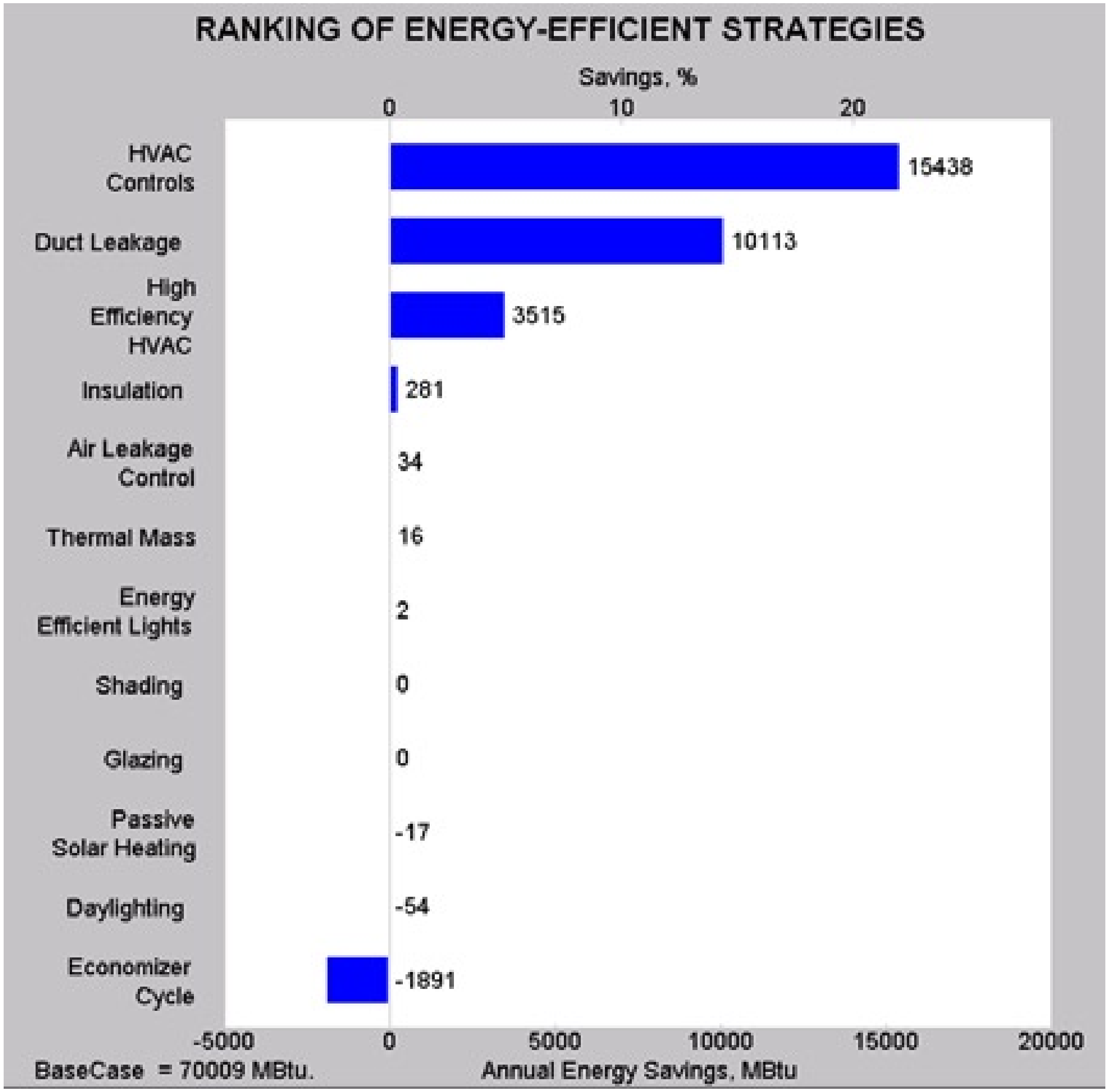

figure n: ranking of energy-efficient strategies de Menil specifically designed everything about the byzantine fresco chapel museum: from the orientation of the building, to the methods by which he chose to light and cool the building. however, he also took careful precautions to assure that the pieces of art were able to withstand the changing houston climate out past the concrete walls of the establishment. if different conditions did exist for the chapel, the heating and cooling loads as well as the energy efficiency. four scenarios are discussed here (and were, for the most part, verified through the computer).

figure p: change of percentage of glazing ▼

because so little glazed surfaces exist on the chapel's surfaces at all, increasing the percentage of these kinds of surfaces would have a drastic effect on the building. increasing the amount of windows would increase the heat lost and gained through transmission, since the conductance value of glass is higher than that of the average wall of the chapel. consequently, loads would be greater and energy use would be higher,. also, the art work would be subjected to harsher elements.

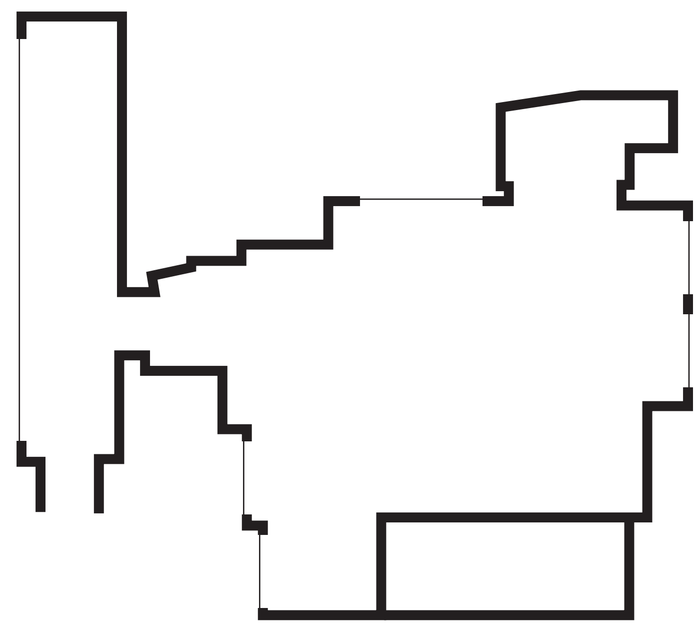

figure o: change of orientation ▲

the chapel is set normal to the cardinal points and has wall sections generally the same throughout. since there is no glass on any side of the building, glazing does not come into effect. heat gain is from a source (the sun) at a different angle and the subsequent increase or decrease in transmission would depend on the angle. thus, changes in efficiency would depend as well.

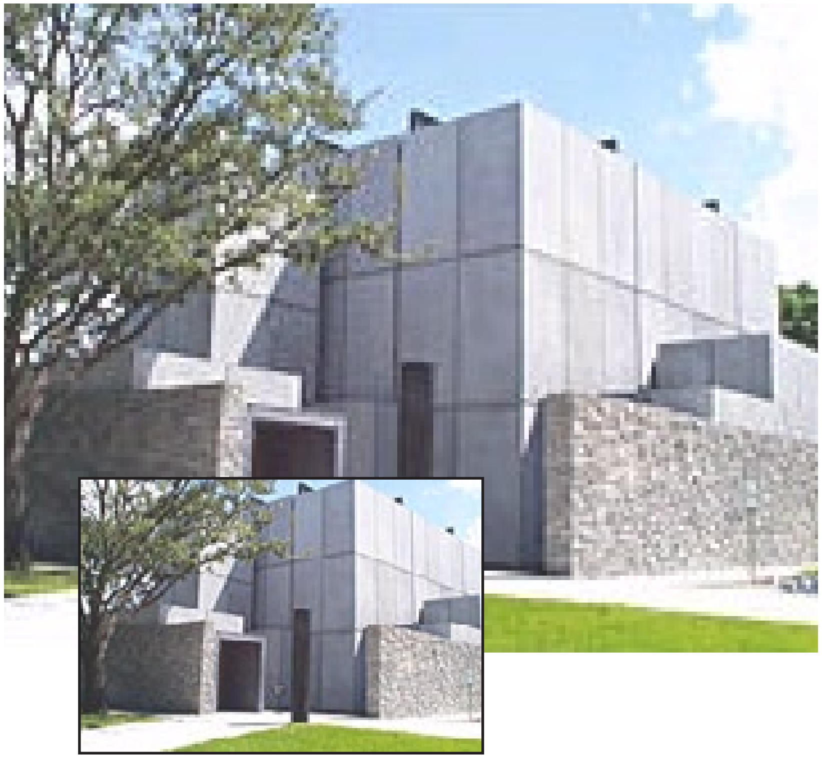

figure q: change in mass of building ◄

increasing and decreasing the volume of the byzantine chapel would also have a noticeable effect on it. changing the volume of the building would cause a change in both the surface areas of the walls and the volume of air (not to mention subsequent changes to the air handling systems, lighting, and other mechanical systems that would need to change to function for a greater sized building). wall surface area and volume of air both have a direct relationship with the heating loss and gain calculations of a building (as one increases, the other will; though it may not be linear - as it is in this case). of course the consequential change on the cooling/heating loads and therefore the energy use would change respectively - it's a direct relationship as well.

figure r: change in temperature settings of building ►

changing the temperature setting of the chapel could have, potentially, the greatest effect on the energy use of the building. since the temperature difference between the outside and that desired indoors is a factor in heat losses and gains due to transmission, infiltration and ventilation, setting the thermostat to a different desired level changes things. if the new temperature setting is closer to that of the outdoor temperature, than heating/cooling loads would decrease, as would energy use; if it was further from the outdoor temperature than loads would increase and energy use would too.

in order to make changes (presumably for the better), a number of steps could be made. without major renovation (such as changing the volume of the building or adding windows) to the building, changes to decrease the amount of energy used throughout the year are listed below.

increasing the efficiency of the air conditioning unit always helps. though the SEER of the system used at the chapel is not known, it is presumed that it can always be more efficient.

passive cooling methods could be further employed - the reflective pool may be extended to increase evaporative cooling, the concrete facing could be painted freshly white, and shading techniques could be utilized

the glass of the skylight could be changed to diffuse light more, thereby lowering the heat gain/loss from the skylight and lowering the energy use

setting the desired interior temperature closer to that of the outside temperature would lower heat gain/loss from transmission, infiltration, and ventilation, thereby lowering energy use

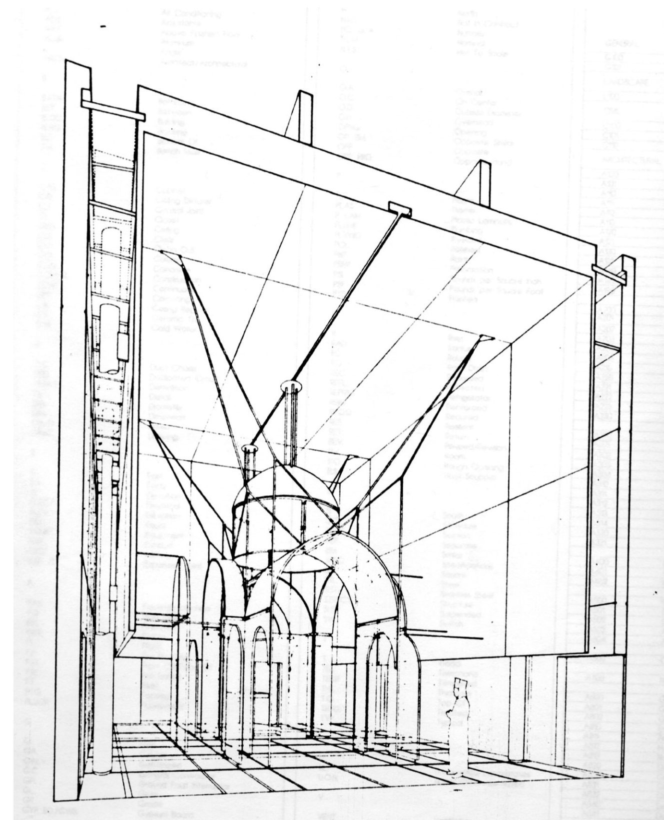

figure s: axonometric drawing

as mentioned earlier, francois de Menil painstakingly planned and redrew the design for the byzantine fresco chapel museum. working for nearly four years from start to finish - for such a small building - de Menil paid careful attention to almost every aspect of the environment that he wanted to create. the climatology of the building was just as important, and the architect made sure that it, too, was fitting.

special thanks to Francois de Menil and the Menil Foundation for their cooperation and help throughout this study.

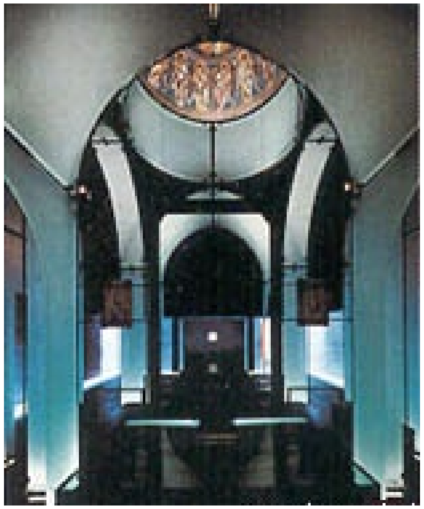

figure t: inside the chapel, looking within the steel framed, frosted glass of the remakings of a byzantine chapel from centuries ago houses frescoes from equally as far away