submitted to the
Milwaukee County Department of Transportation and Public Works
Architecture, Engineering and Environmental Services Division
City Campus, Room 224
2711 W. Wells Street
Milwaukee, Wisconsin 53208
Attention: Walter L. Wilson, AIA, NOMA, NCARB
County Architect

submitted by
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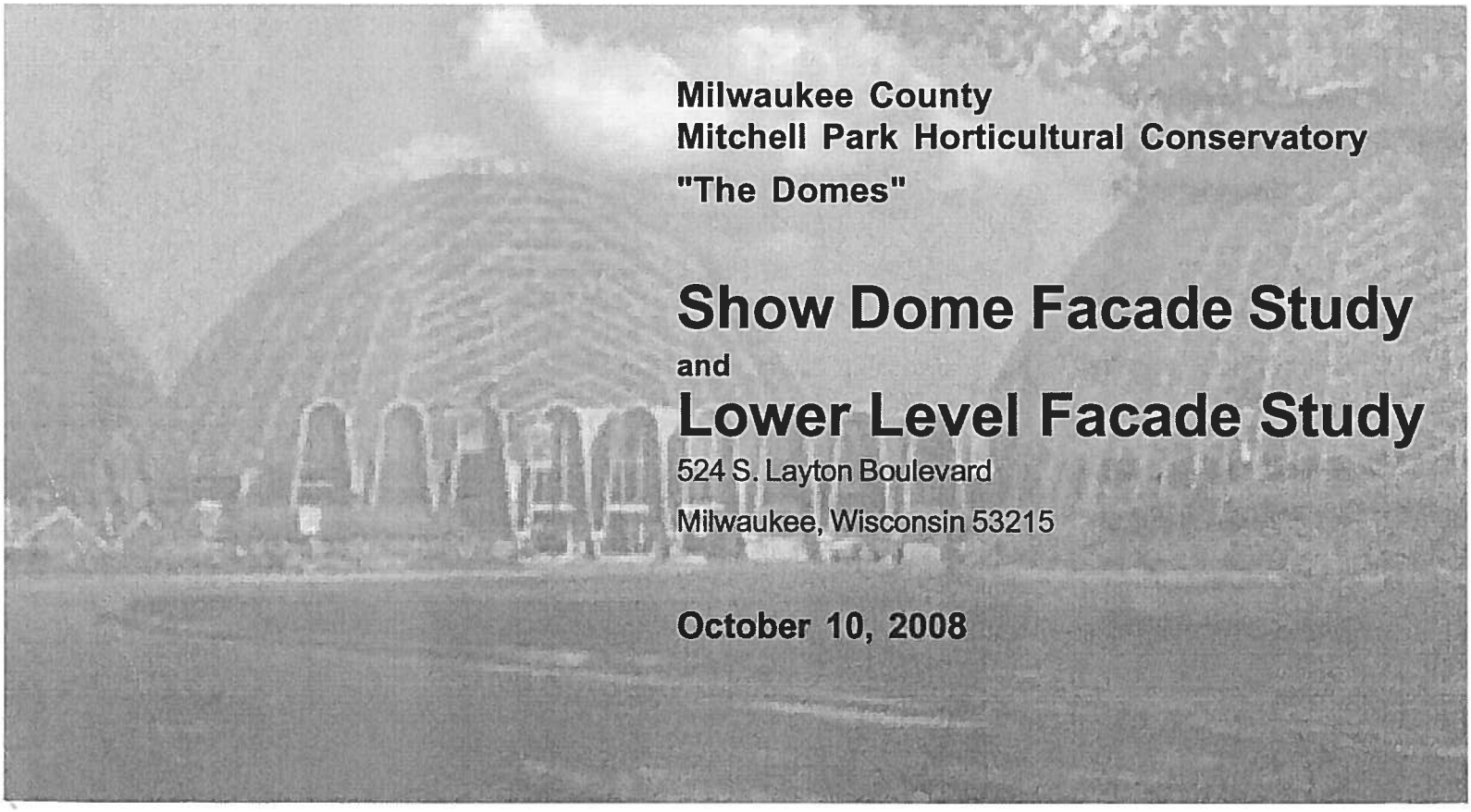
in collaboration with
PACE Architects, SC
American Design, Inc.
Agritechnove, Inc.
Construction Cost Systems, Inc.
Richard Risch



Milwaukee County
Mitchell Park Horticultural Conservatory
"The Domes"

Show Dome Facade Study
and
Lower Level Facade Study

524 S. Layton Boulevard
Milwaukee, Wisconsin 53215

October 10, 2008

Project Team Directory

September 28, 2006

Mitchell Park Domes – Structural Repair and Painting

Client	**Milwaukee County** **Department of Transportation & Public Works** Arch., Eng. and Env. Services Division Milwaukee County – City Campus 2711 W. Wells Street, 2nd Floor Milwaukee, WI 53208	**Walter Wilson** - Project Manager 414-278-4854 WWilson@milwcnty.com **Greg High** – Director 414-278-4943 GHigh@milwcnty.com
	Milwaukee County **Mitchell Park Horticultural Conservatory** 524 South Layton Boulevard Milwaukee WI 53215	**Mark Tiegs** – Director 414-649-9830 MTiegs@milwcnty.com **Wayne Majerowski** – Unit Coord 414-649-9830 WMajerowski@milwcnty.com
	Milwaukee County **Department of Parks, Recreation and Culture** 9480 Watertown Plank Road Wauwatosa, WI 53226-3560	**Chuck Ward** – Chief of Oper. 414-257-8085 CWard2@milwcnty.com **Susie Devcich** – S. Region Mgr. 414-282-5370 SDevich@milwcnty.com **Jim Ciha** – Landscape Architect 414-257-4884 JCiha@milwcnty.com
Prime Structural HVAC	**Graef, Anhalt, Schloemer & Associates, Inc.** 125 S. 84th Street, Suite 401 Milwaukee, WI 53214	**Mark Rapant** – Project Manager **John Goetter** – Principal **Ken Grebe** – Sr. Engineer **Beau Sanders** – Structural **Pete Zak** – HVAC **Mike Horne** – Structural 414-259-1500 Firstname.Lastname@GASAI.con
Architectural	**PACE Architects, SC** 233 N. Water Street, Suite 201 Milwaukee, WI 53202	**Patricia Frost** – Architect 414-273-3369 pf@pacearchitects.com **Brian Kobasick** – Architect bk@pacearchitects.com
Architectural	**American Design, Inc.** 2821 North 4th Street, Suite 500 Milwaukee, WI 53212	**John Williams** – Principal 414-263-5020 jtw@american-design.net **James Piwoni** – Architect jimp@american-design.net **John Abbott** – Technician
Conservatory Consultant	**Agritechnove** 651, route Begin St-Anselme (Quebec), Canada GOR 2NO	**Richard Denis** – Engineer 418-885-9595 r.denis@agritechnove.com
Cost Estimating Consultant	**Construction Cost Systems, Inc.** 1815 S. Meyers Road, Suite 200 Oakbrook Terrace, IL 60181	**Gavin Parr** 630-678-0808
Conservatory Consultant	**Richard Risch** 4346 South 45th Street Milwaukee, WI 53220	**Richard Risch** 414-545-7738 rwrisch@sbcglobal.net

Client-Design Team Meeting #1 Notes

Graef, Anhalt, Schloemer & Assoc, Inc.
125 South 84th Street – Milw., WI 53214

Milwaukee County
Mitchell Park Domes Façade Renovations

September 7, 2006

In Attendance:

Walter Wilson	Milwaukee County – A&E
Mark Tiegs	Milwaukee County – Mitchell Park
Wayne Majerowski	Milwaukee County – Mitchell Park
Chuck Ward	Milwaukee County – Parks
Jim Chia	Milwaukee County – Parks
Susie Devcich	Milwaukee County – Parks
Dayton Davenport	Milwaukee County – Park Maintenance
John Goetter	Graef, Anhalt, Schloemer & Associates, Inc.
Ken Grebe	Graef, Anhalt, Schloemer & Associates, Inc.
Mark Freding	Graef, Anhalt, Schloemer & Associates, Inc.
Pat Frost	PACE Architects, SC
Brian Kobasick	PACE Architects, SC
JT Williams	American Design Inc.
Jim Piwoni	American Design Inc.
Richard Denis	Agritechnove
Richard Risch	Richard Risch
Mark Rapant	Graef, Anhalt, Schloemer & Associates, Inc.

Copies To:

All in Attendance
Greg High – Milwaukee County
John Abbott – American Design Inc.
Bob Svoboda – Const. Cost Systems
Pete Zak – GASAI
Beau Sanders – GASAI
Mike Horne – GASAI

Next Client-Design Team Meeting: October 19, 2006 – 10:00am - To be Confirmed

Issues Discussed:

1. **Introductions**
   - See "Project Team Directory" for names, positions and contact information.

2. **Correspondence Routing / Chain of Command**
   - All correspondence for the Client is to be routed through Walter Wilson at the Department of Transportation and Public Works.
   - All correspondence for the Design Team is to be routed through Mark Rapant of Graef, Anhalt, Schloemer & Associates, Inc.
   - Access within the Domes is to be coordinated through Mark Tiegs or Wayne Majerowski of Mitchell Park Domes.

3. **Conservatory Video**
   - A "Domes" design and construction video, created by GAS staff in the 1990's, was reviewed.
   - A copy of the video, on DVD, will be forwarded to each firm represented.

4. **Conservatory Goals**
   - The following presumed Mitchell Park Conservatory goals were reviewed:
     - To maintain "The Domes" as a jewel of Milwaukee County Park's infrastructure.
     - To maintain the invaluable investment in horticultural species.
     - To maintain the facility as a "must see and must experience" destination for SE Wisconsin residents and visitors.
     - To increase public usage, and the use of the facility for business and private gatherings.
     - To increase revenue, decrease operating costs, and promote "The Domes" self-sufficiency.
     - To expand educational opportunities.

5. **Project Goals**
   - The following Project goals were reviewed, discussed, and roughly prioritized:
     - To eliminate the water leaks into the "Show Dome".
     - To lower the operating expenses of the facility through improvements in energy efficiency.
     - To improve the ease of enclosure maintenance, and to lower the maintenance costs of replacing and cleaning the glass.
     - To provide the most cost effective, long-term repair and/or replacement solutions.
     - To maintain the unique visual design of the facility.
     - To improve the climate within the dome for the well-being of the plants, wildlife and visitors.
     - To improve safety and security, and to reduce vandalism.
     - To design façade repairs at Transition House and Loading Dock.
     - To minimize disruption of current operations, especially facility leasing opportunities and visitor experiences.
     - To establish a paradigm for future repair work on other domes.

6. **Previous Structural Condition Study**
   - A structural condition study was completed in 1994 by Graef, Anhalt, Schloemer & Associates, Inc.
   - The study occurred in 1993/1994 with a final report dated February 7, 1994.
   - The study addressed the condition and recommended repairs of the following components:
     - the concrete frame structural condition
     - the paint on the concrete frame
     - the wire glass glazing
     - the glazing gaskets
     - the glazing fastener screws
     - the aluminum framing and drainage system
     - the lightning rods
     - the ventilation screens and louvers

7. **Previous Domes Repair Work**
   - The Show Dome has had numerous repairs completed through the years with the following major repairs within the last 10 years:
     - Glass and gasket replacement, and hub cleaning – Phase 1 – 1996
     - Glass and gasket replacement, and hub cleaning – Phase 2 – 1997
     - Glass and gasket replacement, and hub cleaning – Phase 3 – 1998
     - New personnel lift to apex
     - HVAC Retrofits – 2003 to 2005

8. **2006/2007 Project Scope and Approach Outline**
   The following Project phases were discussed:
   - <u>Phase 1 – Programming Phase</u>
     - Project Kickoff Meeting and Interviews with Project Stakeholders
     - Review Previous Reports and Work Completed
     - Complete Site Investigation and Documentation
     - Complete Structural Analysis of Existing Concrete Frame
     - Complete Energy Analysis
     - Prepare Programming Phase Report, and Review with Client

- Phase 2 – Schematic Design Development Phase
  - Develop Options for Repair and/or Replacement of the Show Dome Cladding
  - Prepare Cost Estimates
  - Prepare Schematic Design Report, and Review with Client
- Phase 3 – Design Development Phase
  - Prepare 50% Construction Documents
- Phase 4 – Construction Documents Phase
  - Prepare 100% Construction Documents
- Phase 5 – Bidding and Negotiating Phase
- Phase 6 – Construction Phase

9. 2006/2007 Project Schedule

- A proposed project schedule was distributed and discussed.
- The schedule anticipates an approximate one month time frame for each of Phases 1 through 5. This is dependent upon the decisions reached in Phases 1 and 2.
- Schedule assumes acceptance/approval of work by Owner on a timely basis.
- Mark Tiegs noted that major construction may not be able to occur in the Show Dome during the summer of 2007 due to space leasing commitments.

10. Next Client-Team Meeting – October 19, 2006 – 10:00am – To be Confirmed

End of Meeting Notes

Prepared by:
Mark J. Rapant, AIA, P.E.
Graef, Anhalt, Schloemer & Associates, Inc. 414-266-9066

Project Update #1

September 29, 2006

Mitchell Park Domes – Structural Repair and Painting

Milwaukee County

Project Status

Phase I – Programming Phase / Evaluation of Existing Show Dome

Review of Previous Repair Reports	**75% Complete**
Dome Façade Evaluation and Documentation	**25% Complete**
Structural Analysis of Concrete Frame	**50% Complete**
Energy Analysis of Dome Enclosure	**5% Complete**
Brick/Concrete Façade Evaluation	**10% Complete**
Phase 1 Report	**5% Complete**

Phase 2 – Schematic Design Phase / Development of Options for Repair and/or Replacement

Repair Options Identification	**0% Complete**
Replacement Options Identification	**0% Complete**
Cost Estimates	**0% Complete**
Phase 2 Report	**0% Complete**

Future Meetings (Short-Term)

Tuesday, October 3, 2006 - **Design Team Meeting #2**
- *2:00 p.m.* at Graef, Anhalt, Schloemer & Associates, Inc.

Tuesday, October 17, 2006 - **Design Team Meeting #3**
- *2:00 p.m.* at Graef, Anhalt, Schloemer & Associates, Inc.

Thursday, October 19, 2006 - **Client / Design Team Meeting #2**
- *10:00 a.m.* (to be confirmed) at Mitchell Park Domes

Short-Term Action Items

Finalize Design Contract with County	**Complete.**	
Prepare Subconsultant Agreements	**GASAI drafting agreements.**	Rapant
Obtain Existing Facility Drawings	**Milwaukee County copying requested plans.**	
Finalize Phase 1 & 2 Project Work Plan	**GASAI updating and distributing to Design Team 10/02/06.**	Rapant
Prepare Condition Assessment Base Plans	**GASAI finalizing initial drawings 09/29/06.**	Rapant
Prepare Project Team Directory	**Completed 09/28/06.**	
Prepare 09/07/06 Meeting Notes	**GASAI to distribute 10/02/06.**	Rapant

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EXECUTIVE SUMMARY

The Mitchell Park Horticultural Conservatory consists of three conoid shaped, glass enclosed, concrete framed, structures referred to as "domes"; a central lobby; a gift shop; a transition greenhouse; and lower level mechanical rooms. The three domes contain unique microclimates including a tropical environment, an arid environment, and an environment for changing seasonal horticultural exhibits.

In August of 2006, Graef Anhalt Schloemer & Associates, Inc. was retained by Milwaukee County to perform an existing condition study of the glass façade and concrete frame of the Show Dome. Also included was an existing condition study of the masonry brick and precast concrete wall panel facades on the lower level of the Arid Dome, the Mechanical Room, and the Transition Greenhouse. The purpose of these studies was to quantify the nature and extent of the façade deterioration of the Show Dome and lower level, to determine the structural capacity and condition of the concrete frame in the Show Dome, and to recommend alternatives for repair and/or replacement of the façades and concrete frame.

Based on visual observations, the Show Dome has broken and leaking glass, faulty aluminum framing components, and a poorly functioning condensate drainage system. All of these issues have created extensive water dripping within the Show Dome. The concrete frame that supports the glass and aluminum framed façade is in fair condition, however, the paint is fading and peeling, and isolated areas of concrete cracking and deterioration are present. One failed concrete-to-aluminum hub connection should be repaired immediately.

Delayed maintenance of these systems will result in accelerated deterioration and a continuing failure of the dome components. It has been found to be very difficult and costly to repair the dome's façade components and support systems due to the difficulties of physically getting close to the skin of the dome.

Several Show Dome renovation options were developed.

- Option 1 includes replacing all damaged glass panels with similar single pane wire glass, repairing the aluminum framing components, and repairing and recoating the concrete frame, at an estimated cost of $4,000,000 to $6,000,000.

- Option 2 includes replacing all glass with double pane insulated glass, repairing the aluminum framing components, and repairing and recoating the concrete frame, at an estimated cost of $15,000,000 to $18,000,000.

- Option 3 includes replacing all glass and all aluminum framing with a new façade system. The existing concrete frame would be used to support the new glass façade, and would be repaired and recoated. This option has an estimated cost of $8,000,000 to $10,000,000.

- Option 4 includes replacing all glass and all aluminum framing with a new self supported façade system. The existing concrete frame would remain in place and would be repaired and recoated. This option has an estimated cost of $10,000,000 to $13,000,000.

- Option 5 includes replacing all glass, all aluminum framing, and all concrete framing with a new self supporting glass dome system, at an estimated cost of $8,500,000 to $10,500,000.

In general, Options 1, 2, 3 and 4 maintain the existing appearance and shape of the Show Dome, and maintain the existing concrete frame. Option 5 would be a different shape and appearance, and would eliminate the concrete frame. Options 2, 3, 4 and 5 would all have insulated glazing which would significantly reduce the facility's energy usage. Options 3, 4 and 5 would have a new aluminum façade framing system, thus eliminating the shortfalls of the existing system.

Based on visual observations, and some minor destructive testing, the lower level façade review concluded that the supports for the precast concrete panel and masonry brick cladding are failing, primarily due to rusting of the base support steel and the connection steel. Pieces of the façade have broken away from the building. Lack of repairs will result in continued corrosion and pieces of the façade will continue to break away from the building.

Lower level façade renovation options have been developed which range from short-term minor repairs, to long-term total reconstruction, to permanent façade removal. The estimated costs of the renovation options presented range from $100,000 for short-term minor repairs to $450,000 for long-term total reconstruction.

It is recommended that the long-term total reconstruction option for the lower level facades be selected. This option recommends that the current precast panels and brick veneers be completely removed and re-installed with new support angles, flashings, weep holes, anchors, and cavity wall construction techniques. This reconstruction will significantly reduce the expansion and corrosion of the systems that would continue with only a short-term partial repair. This option also maintains the historical significance of the existing facility. This total reconstruction option is estimated to cost $400,000 to $450,000.

INTRODUCTION

The Mitchell Park Horticultural Conservatory consists, in part, of three conoid glass enclosed concrete framed structures referred to as "domes," a central lobby, a gift shop, a transition greenhouse, and lower level mechanical rooms. Each of the three domes contains a different climate. The individual domes are referred to by their specific climate and include the Arid Dome, the Tropical Dome, and the Show Dome. Construction of the Mitchell Park Horticultural Conservatory began with the demolition of the previous conservatory in 1955, and proceeded in phases until final completion in 1965, at a total cost of approximately $4,200,000.

The individual domes are comprised of a precast concrete frame supporting aluminum-framed wire glass cladding and an aluminum-framed apex. Each dome is approximately 85 feet high above interior grade, and has a 140-foot base diameter. The precast concrete frame is a series of beams arranged in triangular panels which make up the conoid shape. The individual concrete sections were constructed on-site and erected over temporary steel frames. The aluminum framing, containing the glazing system, is supported by stainless steel stub posts attached to the concrete frame. The aluminum frame has an internal drainage system to channel condensation and water leaks to the base of each dome. There are a total of 3,185 panels of ¼-inch thick wire glass in the Show Dome. The apex is 37 feet in diameter and houses mechanical equipment for the air handling system.

The domes were designed and constructed in the late 1950's and early 1960's using concepts which advanced the state-of-the-art of conservatories and construction. Ideas developed from the design and construction of the domes have been studied and utilized on other projects throughout the country. The domes have performed satisfactorily for 40 years, but are continuing to show signs of age. A variety of deficiencies that affect functionality and operating costs have been identified. These deficiencies will increase and accelerate if maintenance is delayed.

PREVIOUS STUDIES & REPAIR WORK

In October 1993, Graef Anhalt Schloemer & Associates, Inc. (GAS) was retained by Milwaukee County to perform an existing condition study of the Mitchell Park Domes. The purpose of this study was to quantify the nature and extent of the deterioration, to determine feasible methods for performing repair work, and to provide data necessary to develop a reasonable plan and schedule for doing the repair work. The scope of the study included gathering available information, obtaining the observations and concerns of interested parties, visually inspecting and testing the domes to quantify the nature and extent of deterioration, researching different repair approaches, and preparing preliminary cost estimates for the repair approaches. The study was limited to the three domes above the level of the concrete foundation wall. The nature and extent of the deterioration, as it affects the structural components of the domes, was determined by visual inspections and by limited concrete and drainage system testing.

Based on the observations and tests, the 1993/1994 study found that the structures had broken and/or leaking glass, missing hub caps, broken lightning rods, and poorly functioning drainage systems. The report indicated that the concrete frame appeared to be in good condition, however, the paint was peeling and isolated areas of deterioration were present. The report also concluded that without the protection of paint, and with the poorly functioning drainage system, the concrete frame would continue to deteriorate resulting in potential major future repairs. Other maintenance items were identified such as ripped and dirty screens.

As a result of the study, façade repairs were completed on the Show Dome in the late 1990's over 3 construction periods. The repairs included the following:

- replacement of some damaged wire glass panels,
- partial replacement of rafter cap gaskets,
- partial installation of rafter cap sealants,
- partial cleaning of rafter support hubs,
- partial replacement of rafter support hub gaskets,
- partial installation of rafter support hub sealants,
- minor concrete frame repairs, and
- lightning rod repairs.

Other very limited repairs of glass panels, 10 to 20 panels, have reportedly occurred in other domes in the past 40 years, due to weather or vandalism. Repairs have been limited due to the difficultly and high cost to repair the dome's façade components and support systems, mainly due to the difficulties of physically getting close to the skin of the dome. Other major repair/renovation work have also been completed in the domes including HVAC modifications and maintenance lift replacement.

SHOW DOME FAÇADE REVIEW

In September and October of 2006, an existing condition survey was completed of the façade of the Show Dome at the Mitchell Park Horticultural Conservatory. The primary purpose of the condition survey was to determine the cause of numerous water leaks, and subsequent dripping, within the Show Dome. The survey was also conducted to identify the extent of component deterioration on the Show Dome.

The façade of the Show Dome consists of a steel reinforced concrete frame and an aluminum façade framing system supporting single pane wire glass panels. An isometric view of a typical façade hub assembly is shown in Figure 1. A cross section diagram of the concrete frame and aluminum hub assembly is shown on Exhibit SD-12 in Appendix A. (This diagram can be folded out to view as reference). From inside, the primary façade components include the concrete frame members, stainless steel connection posts, aluminum spherical hubs. aluminum façade rafters, rubber glazing strips, wire glass, aluminum rafter caps and aluminum hub covers.

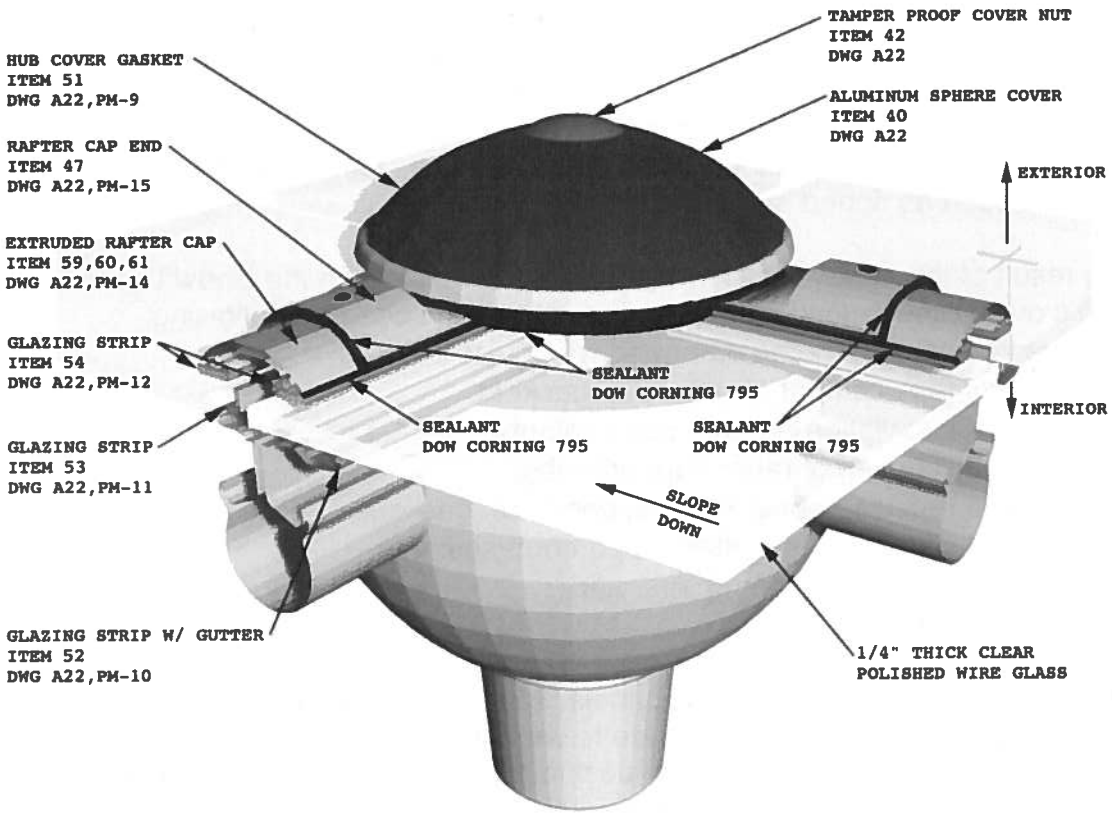

Figure 1: Isometric View of Typical Façade Hub Assembly

Each panel of glass was inspected, either close up or with binoculars, to determine its' current condition. The panels were identified as undamaged, cracked, or projectile damaged. The approximate location of the damage on each panel was also noted on the field copy of the notes. Typical glass breakage, including cracked and projectile damaged, is shown in Figure 2.

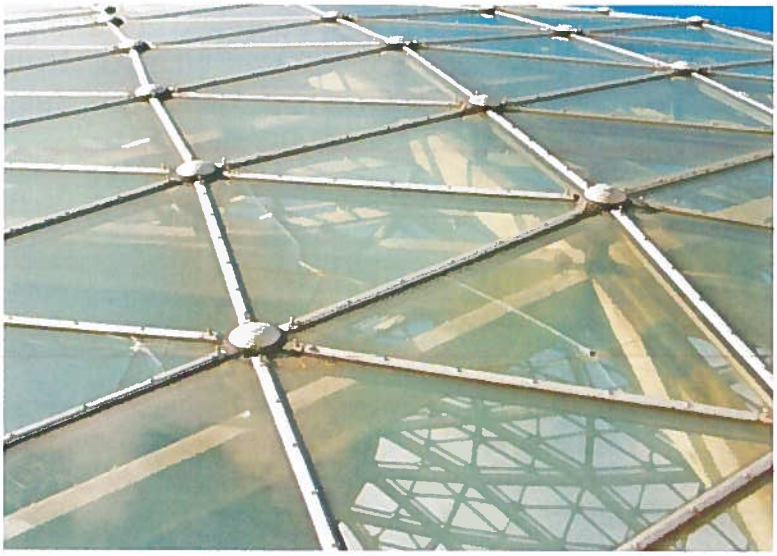

Figure 2: Typical Glass Panel Breakage

The condition of the glass panels was recorded on schematic drawings of the Show Dome facades, and designated as Exhibits SD-1 through SD-6 in Appendix A. Previous glass condition information, recorded in the 1990's, was combined to create the current glass panel condition drawings. The drawings indicate the following glass conditions:

- undamaged glass panels
- cracked glass observed in 1996 -1998
- projectile damaged glass observed in 1996-1998
- glass replaced in 1996-1998
- glass replaced in 1996-1998 and observed re-damaged in 2006
- new cracked glass observed in 2006
- new projectile damaged glass observed in 2006

A Glass Panel Condition Summary is shown in Figure 3 on the following page.

Show Dome Façade Study

The Show Dome study began with discussions with County Staff that have been closely involved with day to day operations and maintenance of the facility. The original Architect for the Domes, Donald L. Grieb, was also contacted to discuss design intent and decisions reached during the design and construction of the facility. This information was used to plan the on-site survey approach. Existing building plans were also obtained and reviewed to study the façade details and connections.

The on-site inspection of the Show Dome façade generally consisted of viewing all the components from grade level, both inside and outside the Show Dome. Binoculars were used to review all components above an elevation of approximately 15 feet. The survey was limited to the review of the following façade components:

- the wire glass panels,
- the aluminum framing,
- the facade drainage system,
- the concrete support frame, and
- the apex glass panels.

Deterioration or damage was documented, such as cracking of the glass panels, and concrete cracking and spalling. Also leaks and stains, unwanted plant growth, and peeling paint, were noted, but specific locations were not documented. In addition, the survey included a review of the condition of the façade repairs that were completed on the Show Dome in the 1990's. Following is a detailed description of the condition of the existing façade components.

Glass Panel Review

The Show Dome façade is constructed of 3,136 triangular ¼" thick clear wire glass panels below the mechanical equipment platform, at the apex of the dome. In addition, there are forty-nine (49) ¼"-thick frosted wire glass panels at the apex of the Show Dome. The choice of wire glass for the Domes facade may have been selected for fire and/or safety considerations. Unfortunately, the ¼" thickness makes this glazing very susceptible to breakage as a result of thermal stress, vandalism, use of cleaning equipment, etc. Additional stresses may also be created by structural swaying during high winds. Wire glass is about half the strength of annealed glass and cannot be tempered or otherwise heat-strengthened. This single pane glass selection also results in particularly high energy consumption, especially during winter, as the heat transmission is significant.

Show Dome Façade Study

Show Dome Façade Study

The Glass Panel Condition Summary provides the following information:

- there are 3,185 wire glass panels in the Show Dome,
- 399 panels were reportedly damaged in the 1990's,
- 165 damaged panels were replaced in the 1990's,
- 234 damaged panels were not replaced in the 1990's,
- 24 panels which were replaced in the 1990's re-cracked,
- 138 additional panels were damaged in a 14+/- year time period, and
- 396 total panels are now damaged, or 12.4% of the total.

There are numerous reasons for the damaged glass panels. The obvious projectile damaged glass appears to be mostly due to vandalism, but may also include some minimal damage from wind blown debris or hail. The majority of the cracked glass appears to be caused by the brittle nature of the ¼" wire glass, and the result of differential thermal expansion and contraction movement between the glass and the aluminum framing. Also, some breakage may have occurred as the result of built-up stresses due to fastening of the glass to the framing via the rafter caps and screws. There is also some suspicion that previous maintenance equipment, which rolled on the outside of the dome, may have cracked some of the glass, and it has never been replaced. Most of the breakage from maintenance equipment may have occurred during the first few years of the domes' existence.

Many of the water leaks within the Show Dome are a result of damaged glass. Some leaking is occurring through holes in projectile damaged glass, and there is also some leaking through cracked glass. Some cracks appear to be still tight, as a function of the wire glass, and do not appear to leak. Sealants have been used to attempt to seal some cracks or holes in the glass. The sealants are unsightly, and some appeared to have failed.

The existing glass façade system is difficult and expensive to repair, primarily because of the difficulty of obtaining access. The ¼" wire glass system has a low flexural capacity that will not support workers walking on the surface, or any other type of equipment that could potentially be used to access broken panes of glass, or to do maintenance work on the mullion systems. Therefore, it is also very difficult to replace broken panels of glass.

Due to the nature of the existing glass and glazing system, it is extremely difficult to clean the glass, both interior or exterior. Over time, as the dome glass became more dirty and stained, there was a slow degradation of the amount of available light inside the dome. Also, in areas where repairs were made to the mullion system using directly applied elastomeric sealants, the sealant has also stained the glass. This condition may have helped the cooling of the facility in summer as the solar gain was decreasing, but it most likely has also produced detrimental effects on plant growth.

Aluminum Framing Review

As discussed earlier and as shown in Figure 1, the aluminum framing system consists of stainless steel connection posts, aluminum spherical hubs, aluminum façade rafters, rubber glazing strips, wire glass, aluminum rafter caps and aluminum hub covers. In general the aluminum framing system is in good condition, with the exception of old gaskets and a malfunctioning drainage system, described later.

Failed Connection
At several locations around the perimeter of the Show Dome, rusting was observed at the steel connection plates that the aluminum framing hub posts are connected to. Some concrete spalling was also observed at some of these locations.

Although, at one aluminum spherical hub, located over an entrance door to the Show Dome, the connection of the hub to the concrete frame has completely failed. The connection plate, which was originally cast into the surface of the concrete frame, has severely rusted and has broken away from the internal steel that it was connected to. It is suspected that this connection has experienced repeated wetting and drying due to partially functioning drainage holes at this low point in the dome structure, and subsequent rusting has occurred. This condition was previously observed in 1995 by Graef, Anhalt, Schloemer engineers and a repair detail was designed and drafted. The repair has not yet been completed. The repair of this connection should be completed immediately to ensure that the structural integrity of the dome system is not compromised.

Water Test
A water test was conducted on a limited area of the Show Dome to evaluate the amount of leakage through cracked glass, the effectiveness of the façade drainage system, and the effectiveness of previous façade repairs. A controlled water spray test was selected, versus a test during a full rain event, to better identify the source of leaks.

Water was sprayed from the roof of the airlock building onto segments Q through R, and approximately across glass panels 1 through 24. There are two cracked glass panels in this area that were observed to be damaged in the 1990's, but not replaced; two glass panels that were replaced in the 1990's; and two new cracked panels that were observed in 2006. The spray from a garden hose nozzle produced a somewhat even flow of water across the façade surface for approximately a two hour period.

At the start of the test, the interior of this section was inspected and no water leaks were observed at gaskets, glass cracks, or at the hubs. After one hour of water flow, no visible interior water leaks were observed at gaskets, glass cracks, or at the hubs. After two hours of water flow, no visible interior water leaks were observed at gaskets or

glass cracks, but one dripping condition was observed at a hub, at the intersection of the hub and a lower rafter.

Gasket System
After some 40 years, the glass gasket system has "dried up" due to age, and has become more prone to water leakage, mostly from rain and snow melt seeping inside the dome. The gasket system will continue to deteriorate and more leakage inside is to be expected if nothing is done.

At the same time, the gasket system drying up results in the domes becoming less airtight. This can be a very costly effect as overall air infiltration has probably gone up significantly since the opening of the facility. In winter, this cold air needs to be warmed and increases the load on the heating system requiring more heating power to overcome the infiltration. The total energy consumption of the dome also undoubtedly increased because of air leakage.

Façade Drainage System Review

The aluminum frame has an internal drainage system intended to channel moisture to the base of the dome. The drainage system was designed to allow moisture to flow down either the neoprene gasket gutters or the aluminum rafter gutters to the hubs. See Figure 1. From the hubs, the moisture is channeled through the interior of the aluminum rafter members to the next lower hubs, until the moisture reaches the lowest hubs which have holes at the bottom. (refer to Exhibits SD-12 and SD13 in Appendix A). The water is then intended to flow down a cap flashing to the lowest point on the foundation wall where there is an embedded pipe in the concrete wall which directs the water into the basement of the dome.

Hub caps were removed to determine the cause of water dripping from the hubs on the inside of the Show Dome. The hub covers came off easily after removing the retaining nut. Sealant was not apparent around the gasket. The gasket was brittle and cracked easily, and appeared to be permanently compressed. Each hub that was opened was filled with approximately a 1/2" of water and black debris. The debris included dirt and, in some cases, dead plant matter. Water can accumulate in the hubs due to their construction. The rafters at the bottom of the hubs are connected to the hubs with spherical bolts, compression collars, compression nuts, and inner and outer gaskets, as shown in Exhibit SD-12 in Appendix A. These components extend about a ½" into each hub. The condensate and leakage water cannot drain into the lower rafters until it reaches a depth equal to the height of the rafter connection components. The inner and outer rafter connection gaskets appear to have failed, allowing the stored water in each hub to slowly drip into the dome.

A horizontal aluminum plate diverter was observed across the center of the hub. The diverter appears to catch water from the three upper rafters and direct the water to the back of the hub. The diverter may also keep water away from the hub cover.

There was also both plant and root growth observed inside the façade rafters. Insects can crawl inside the rafters and nest there. Over time, the accumulation of debris may have partially or completely plugged the condensation and rain run-off waterways. This has resulted in water seeping out of the façade drainage system and dripping on the floor below.

At the lowest hubs on the façade, there is a drain hole in the bottom of each hub. The drainage water drips out of these hubs and onto the top of the concrete foundation wall. This condition is diagramed on Exhibit SD-13 in Appendix A. The water is intended to drain down the sloped concrete foundation wall to an embedded drainage pipe in the foundation wall. Unfortunately, only some of the water reaches this drainage pipe. The foundation wall is constructed of a poured-in-place concrete wall, a grouted cavity, and a precast concrete exterior panel. The grouted cavity has become deteriorated due to freeze-thaw conditions. It appears that some of the drainage water flows into the cavity behind the precast concrete panels, and some of it flows out over the top of the precast panels and flows down the face of the panels. There is evidence of staining and some concrete spalling on the face of the panels where water leakage has occurred. In several cases it also appeared as though the embedded drainage pipe seemed to be partially plugged.

Above the doorways, no drainage pipe appears to have been placed to direct the water to interior drains. Water is channeled inside the dome and collects at the low point on the ledge above the doorways. When the water reaches a certain level, it flows to the canopy above the door. The canopy is sloped inward to the center and water ultimately drips onto the floor directly in the path of dome visitors.

Concrete Support Frame Review

Concrete Condition Survey

The dome's structural framework was constructed of concrete members arranged in a generally triangular pattern to form the conoid shape. The members were cast on-site, hoisted into place, and temporarily supported by interior shoring until the entire frame was erected and fastened together. The members range in size from 3 inches x 6 inches, up to 6 inches x 8 inches. The individual members range in length from 6 to 10 feet, and are connected to other members by a welded connection of the internal steel reinforcement to steel connection plates. There are 1,255 precast concrete beam members in the Show Dome. The precast concrete frame is supported by a cast-in-place concrete foundation wall.

Show Dome Façade Study

A number of concrete cracks were observed in the precast concrete beam frame in the Show Dome. The cracks typically appear where two separate precast pieces were connected during construction. There was also visible cracking between the concrete foundation walls and the precast frame members. These cracks generally appear to be due to concrete shrinkage. The cracks, although unsightly, appear to be only superficial in nature. The cracks, however, give access points for moisture to come in contact with the cast-in reinforcing steel and steel connection hardware. This will lead to rusting of the internal reinforcing steel and deterioration of the concrete frame.

There were also approximately 20 small concrete spalls observed in the Show Dome concrete frame. The locations of the observed spalls are shown on Exhibits SD-7 through SD-11 in Appendix A. A spall is a form of concrete deterioration, most often caused by corrosion of embedded steel. As the steel corrodes and rusts, the corrosion products take up more volume than the original steel, causing outward pressure against the concrete. This pressure cracks the concrete between the steel and the concrete surface, often causing a piece of concrete, or spall, to fall away from the structure. The observed spalls typically occur at the embedded steel plate where the aluminum hub assembly is attached to the concrete frame. Additional concrete spalls may be present where not readily observable from ground level, and/or where only a hairline crack exists. During the concrete paint removal phase, if selected, the concrete will need to be closely inspected for loose pieces, and spalls will need to be removed.

The exposed rusting steel at the spall locations should be cleaned to the base metal. The bare steel should then be coated with two coats of corrosion resistant paint. The spalls are not typically visible to visitors and they only need to be painted to match the surrounding concrete frame. Patching with grout is not recommended as the grout may shrink and crack, or fall off, causing further problems.

Currently, the concrete appears to be in good condition based on the visual observations, but without an adequate protective coating, the concrete will continue to deteriorate causing structural problems in the future.

Structural Analysis

A structural analysis of the concrete frame in the Show Dome was undertaken to investigate the structural adequacy of the frame based on loading requirements of the current codes. The analysis was also taken one step further to investigate if the concrete frame could support additional dead loads and additional snow loads if the current glass was changed from single pane glass to double pane insulated glass.

For the structural analysis, a three dimensional model was developed, and each concrete element was given its actual size and properties as shown on the existing building plans. The model was loaded with four load types: dead loads, live loads, snow

loads, and wind loads. The dead loads included the weight of the concrete, the weight of the glass, the weight of the aluminum framing which supports the glass, the weight of the aluminum framing at the apex which supports the mechanical equipment, and the weight of the mechanical equipment itself. The snow load was determined by using the American Society of Civil Engineers (ASCE) Standard 7-2005, Minimum Design Loads for Buildings and Other Structures. There were two separate snow loading requirements: balanced and unbalanced. The wind load was determined from ASCE 7-2005, as well.

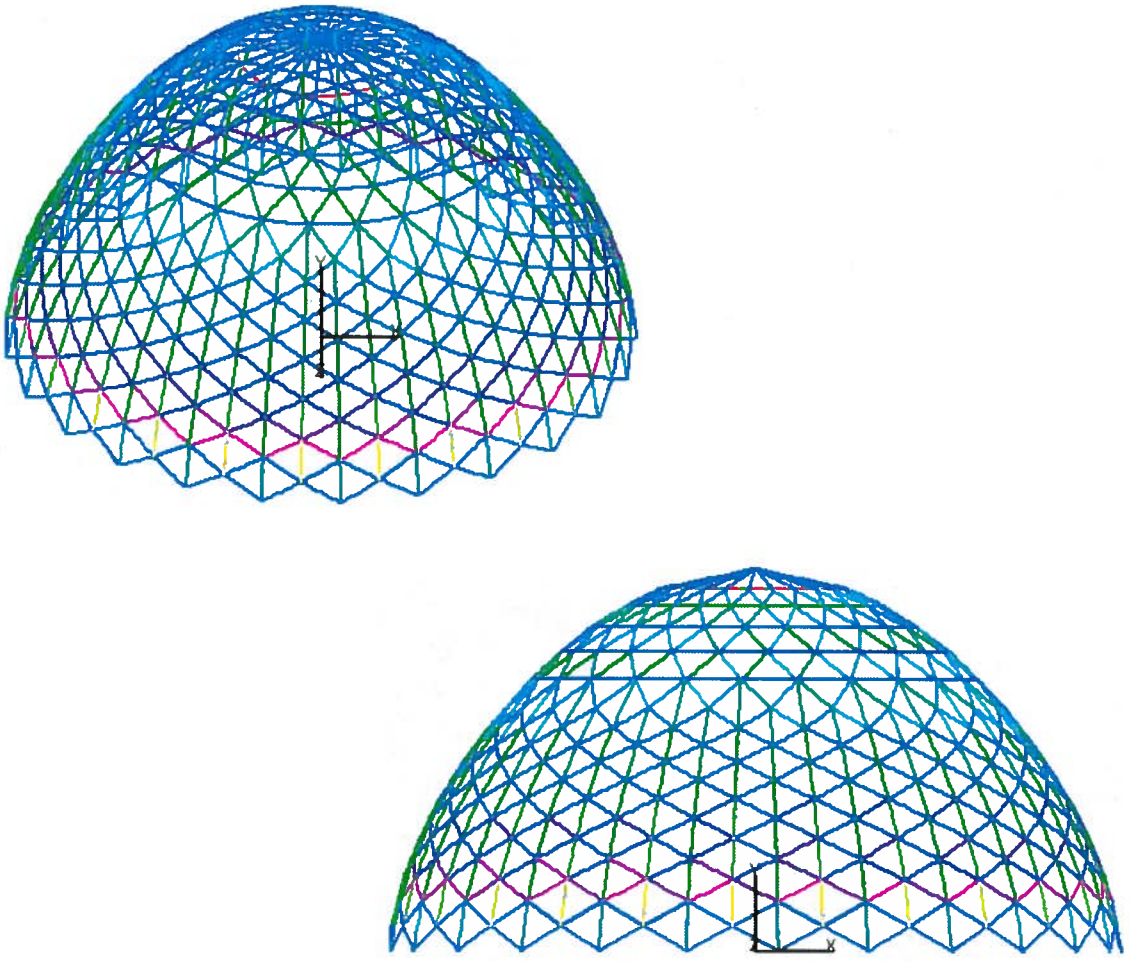

Figure 4: Structural Analysis Model of the Show Dome Concrete Frame (representing varying levels of tension and compression forces in concrete members under dead plus live loads, magenta = tension and blue = compression)

After analyzing the model based on multiple load combinations, the maximum forces in each individual member were compared to the allowable forces that each member could support. The highest stressed elements of the dome under current dead load and live load conditions are at about 68% of their capacity. The highest stressed elements of the dome with the single pane glass being replaced with double pane insulated glass would be at about 77% of their capacity. After this preliminary initial investigation, it appears that the Show Dome is structurally adequate to support the current dead loads and the current code required live loads.

Further investigations will need to be performed during the design development phase of the project if changes are proposed which would increase the dead loads on the structure. These investigations may include, but are not limited to, model refinements, verification of equipment loads, wind tunnel testing, material testing, and further site investigations of the structure including elements such as the foundations and the precast element connections.

Protective Coating

The concrete frame was originally painted with two coats of epoxy paint. This paint was specified to have a life expectancy of 10 to 15 years. The paint has been in service for approximately 40 years, and is fading, chalking and peeling in the Show Dome, as shown in Figure 5. There is also visible dirt streaking on the paint in the Show Dome as shown in Figure 6. Dust propagation from the walkways is believed to be partially responsible for the amount of dust. Water dripping from the façade is believed to be causing the streaking.

Figure 5: Typical Paint Peeling and Staining on Concrete Frame

There currently is no easy way to wash the interior of the structure. To reach the upper sections of the domes, either a lift or lightweight rigging will be required. Also, available lifts have a wider wheel base than some of the designated walkways. Some of the existing plants would need to be removed during the refurbishing. The weight of a lift may also cause damage to the paved walkways, requiring repairs.

The concrete frame needs to be recoated after leakage problems from the drainage system are fixed and all the damaged glass has been replaced, so that paint work is not immediately stained. Additional temporary air handling equipment may be required to improve air circulation and air quality during recoating. Drop cloths would also be required to keep paint chips from contaminating the soil as the existing paint is removed, and to protect the plants during recoating.

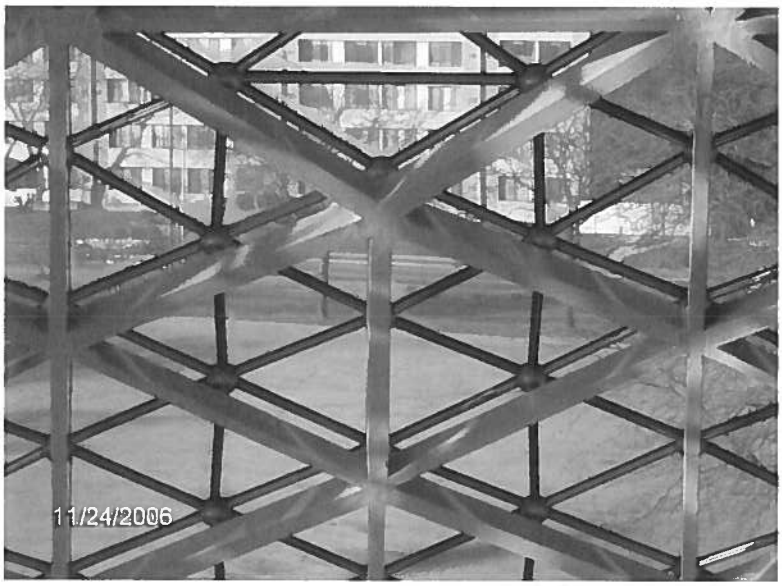

Figure 6: Dirt Streaking on Concrete Frame in Show Dome

Apex Review

An inspection was conducted of the construction and condition at the apex area of the Show Dome. Access to the apex and mechanical equipment platform was gained via the vertical man lift basket at the center of the dome. Access to the exterior of the apex was gained via a roof hatch located within the exhaust fan plenum.

Glass Panels

The apex is constructed of aluminum framing components, including I-beam sections, plates, grating, and pipe. All of the framing appeared to be in good condition. The exterior of the apex is enclosed with frosted wire glass and aluminum sheets. There are forty-nine (49) glass panels and one (1) aluminum access hatch. Fifteen (15) glass panels were observed to be cracked; most of the cracks had been previously sealed with a surface applied sealant. See Figure 8. (The locations of the cracked glass panels at the apex are shown on Exhibit SD-6 in Appendix A).

Below the upper ring of 25 glass panels, an additional layer of translucent plastic panels is installed about 8" below the glass as shown in Figure 9. The plastic panels are very dirty on the inside (top) surface. Sections of several plastic panels have been cut out to allow for access to hoist beam connection bolts. It is assumed that these translucent panels were installed to reduce the direct sunlight and heat gain on the apex mechanical equipment.

Figure 7: Underside of Show Dome Apex

Figure 8: Damaged Glass Panels at Show Dome Apex

Figure 9: Stained Translucent Panels above Mechanical Equipment

Exhaust Fan Plenums

There are ten (10) exhaust fans and twenty-five (25) motorized dampers at the apex level. The fans and dampers were reportedly upgraded as part of the mechanical system renovations completed in approximately 2003 or 2004. There is a plenum space between the fans and the louvers. Within this plenum space there are five (5) plenum drains. These drains are connected to a pipe loop under the deck grating, and then to two (2) pumps, as shown in Figure 7, which are connected to two of the aluminum hubs on the perimeter of the apex. It is assumed that the intent of this system is to collect water which gets into the plenum through the louvers, and convey it through the pumps, and into the dome façade drainage system. It appeared as though very little water gets into this system, and it is unknown if this drainage system is operable.

Drainage System Flushing Valves

Adjacent to the top corner of each motorized damper, there exists a gate valve with a male garden hose fitting as shown in Figure 10. Flexible rubber hoses, are connected to one end of each valve, and extend down adjacent to each rafter towards the aluminum façade hubs at the perimeter of the apex. (Existing building drawings indicated that a stainless steel hose coupling was to be installed at each upper level hub. This connection is not visible). It is assumed that these valves, hoses and connections were meant to allow for periodic flushing of the aluminum façade drainage system. It is unknown if this has ever been completed. It is also unknown if flushing water can reach the apex of the dome without auxiliary pumping equipment.

Figure 10: Drainage System Flushing Valve at Apex Louvers

HVAC System Description

The Show Dome has a mechanical system designed for summer ventilation and winter heating, with minimal ventilation in the heating mode. (An evaluation of the condition and functional design of the mechanical system equipment was not a part of the scope of this project).

The ventilation system consists of air supply units, summer air intakes, wall exhaust fans, and apex exhaust fans. There are ten (10) air supply units (ASU) located around the perimeter of the dome with outside air intake louvers, dampers, mixing plenums, steam heating coils, and supply fans with ductwork at each location discharging air into the building through grilles. Twenty-one (21) summer air intakes (SAI) with dampers and louvers are spaced around the perimeter as well. Specific sets of these louvers and dampers serve ventilation requirements in winter mode, and all outside air intakes serve ventilation requirements in summer mode. Five (5) wall exhaust fans (WEF) with variable speed drives are also located along the lower level of the dome, approximately 5'-0" above grade. These fans are cycled on during summer ventilation mode through a pressure sensor, to control pressurization of the dome by exhausting air from the space. Ten (10) apex exhaust fans (AEF) are located at the top of the dome, which cycle with the supply fans during full ventilation mode, and exhaust with the supply fans off during winter heating mode to provide minimum ventilation in the space. The entire ventilation system is controlled through a space temperature sensor which opens SAI and AEF dampers, followed by cycling AEF on, and finally ASU fans on for maximum ventilation of the dome.

The heating system consists of steam finned tube convectors routed around the perimeter of the dome, below the catwalk at grade level. The finned tube system is divided into multiple zones controlled by local temperature sensors throughout the space. The ten ASU located around the perimeter of the dome, with steam heating coils, also provide heat to the domes. Specific SAI dampers are opened in heating mode for minimum ventilation settings.

Figure 11: Typical Summer Air Intake (SAI)

Equipment Components

Air Supply Units	Supply Fan - (10) 3,300 cfm, 1.5 hp Heating Coil - steam heating coil at discharge of each unit Ductwork - 15"x15" non-insulated sheet metal at each unit Damper - return air dampers and outside air insulated blade dampers at each unit
Summer Air Intakes	Louver - typically size of 2-3 glass panels Damper - insulated blade type, (13) 60"x36", (8) 60"X24", (28) 60"x12", (34) 18"x12" Actuator - direct coupled for each damper
Wall Exhaust Fans	Exhaust Fan - (5) 48"x48" centrifugal fan Damper - insulated blade type Actuator -direct coupled for each damper
Apex Exhaust Fans	Exhaust Fan - (10) 36"x36" centrifugal fan Louver - (25) size of fan discharge Damper - insulated blade type Actuator - direct coupled for each damper

Figure 12: Wall Exhaust Fans for Summer Ventilation

Energy Use Evaluation

The energy consumption calculations for this project were performed using an analysis program called Trane Trace 700. This program calculated the heating and ventilation load on the existing central plant and included electrical energy used to condition the zone. The method used to calculate the energy consumption is the Total Equivalent Temperature Difference method with Time Averaging (TETD/TA), which is one of the recommended calculation methods of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The scope of the calculations included the area of the Show Dome only.

Items considered in the energy analysis include area of existing glass façade, existing gas-fired steam boiler central plant, summer and winter ventilation system in Show Dome, and glass replacement options. The glass options used for the calculations are listed below, with Option #1 being the existing construction baseline.

Show Dome Façade Study

Glass Option #1	
Construction:	Single Pane Glazing - ¼" clear pane
U-value:	0.95 btu/hr·ft^2·°F
Shading Coefficient:	0.95*
Glass Option #2	
Construction:	Insulated Glazing - ¼" clear pane, ½" air space, ¼" clear pane
U-value:	0.31 btu/hr·ft^2·°F
Shading Coefficient:	0.64*
Glass Option #3	
Construction:	Insulated Glazing - ¼" clear pane, ½" argon filled space, ¼" clear pane
U-value:	0.27 btu/hr·ft^2·°F
Shading Coefficient:	0.64*

*The shading coefficient defines shading properties and effects the solar radiation transferred through the glass. As the value nears 1.0, the shading effect is lessened. The shading coefficient is equal to the solar heat gain coefficient (SHGC), at normal incidence, divided by 0.87.

The exterior façade of the dome was divided into multiple areas and multiple angles to achieve an accurate model of the geometry for the calculations. Due to the fact that the area of the mullions (aluminum framing) is extremely minimal, this area was not included in the calculations. The whole exterior of the dome was considered glass for the purpose of this analysis.

In order to create the various alternatives, the base line energy consumption was calculated through the energy analysis program. This value was compared with a degree-day analysis calculation. The calculations produced a value of fuel required to heat the dome. Both methods produced approximately the same results, verifying the analysis program's economic results.

These resultants were then compared with a simple U x A x ΔT energy use calculation. This simplified calculation compares the glass U-value (U), area of façade(A), and temperature difference between inside and outside the dome(ΔT). Using this equation, the percentage of savings for each option was verified.

The results of two glass options were compared with the current calculated energy use of the dome. The results indicate that an approximate energy savings of $55,000 to $65,000 per year can be achieved with the insulated glass replacement option #2. An approximate energy savings of $60,000 to $70,000 per year can be achieved with the argon filled insulated glass replacement option #3.

Based on the energy analysis calculations the results represent a large savings in yearly energy consumption and would increase the efficiency and lifespan of existing equipment.

Related Façade Maintenance Needs

There are approximately 28 screens in the Show Dome in need of repair or cleaning. Some screens are ripped and some have debris trapped between the screen and louver. This debris includes old leaves and plant growth. The ripped screens allow bugs and animals access to the domes. The debris prevents the louvers from drawing in the required air which causes the air handling system to run inefficiently. The ripped screens should be removed and repaired. The debris between the screen and louver should be removed and the screens replaced.

SHOW DOME FAÇADE RENOVATION OPTIONS

Option 1 –
Repair of Existing Façade and Concrete Frame

This option is the repair of the existing Show Dome façade and concrete frame to generally the original as-built conditions. The general work items for this option include the following:

- **1A.** Replacing all damaged glass panels with the same wire glass.
- **1B.** Replacing top side glass gaskets where not previously replaced.
- **1C.** Cleaning and modifying the condensate/leak drainage system.
- **1D.** Removing and reinstalling mechanical equipment.
- **1E.** Cleaning, repairing and installing a protective coating on the concrete frame.
- **1F.** Repairing exterior screens.
- **1G.** Installing new foundation wall flashing.
- **1H.** Cleaning interior and exterior of all wire glass panels.
- **1J.** Providing protection of the existing vegetation.

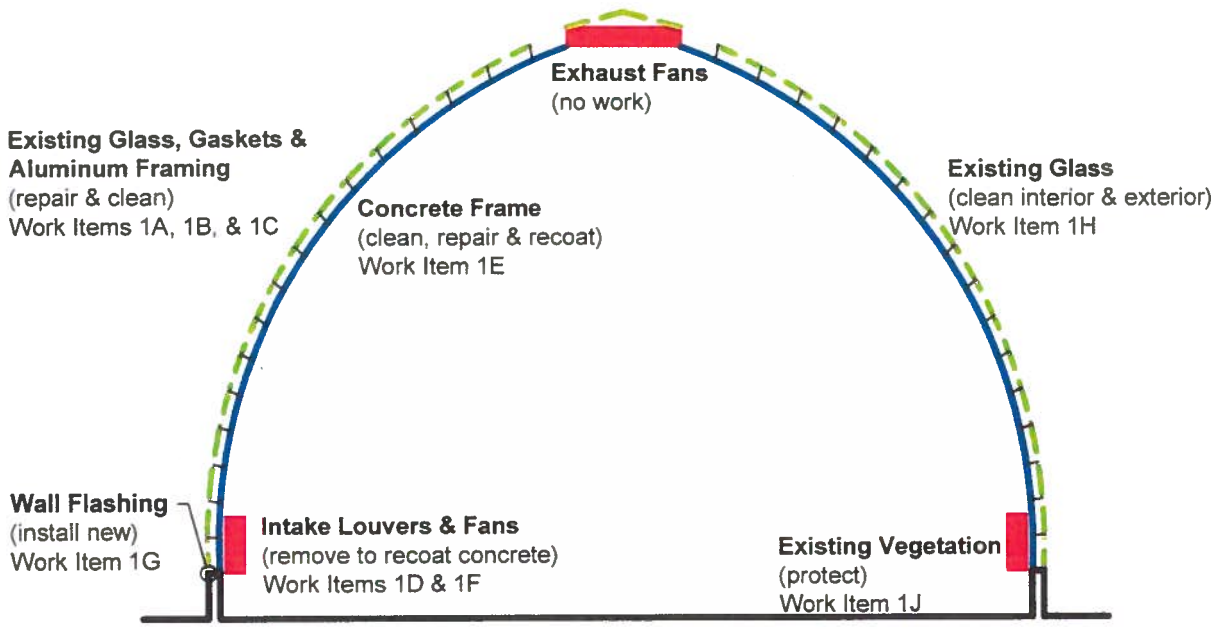

Figure 13: Schematic Representation of Option 1

Work Item 1A – Replace Damaged Glass

Work item 1A in this option is to replace all the damaged wire glass in the Show Dome. As noted earlier in this report, 396 panels of glass are damaged. Work would include the following:

- Removing all rafter caps at damaged glass panels.
- Removing and discarding gaskets and damaged glass panels.
- Installing new wire glass.
- Installing new gaskets.
- Re-installing rafter caps with new screw fasteners.
- Installing a bead of sealant over the gasket, between the glass surface and the aluminum rafter cap.

As the glazing is replaced, the gasket material and seals should be replaced with new gasket material and sealant. The missing hub cap assemblies should also be replaced during reglazing.

Work Item 1B – Replace Gaskets

Work item 1B in this option is to replace the top side glass gaskets in the areas of the Show Dome where this was not done in the 1990's repair work. This would be in segments F through P. Work would include the following:

- Removing all rafter caps around 1,112 pieces of glass (188 damaged pieces of glass are already included for replacement in Work Item 1A above).
- Removing and discarding top side gaskets.
- Installing new top side gaskets.
- Re-installing rafter caps with new screw fasteners.
- Installing a bead of sealant over the gasket, between the glass surface and the aluminum rafter cap.

Work Item 1C – Clean and Modify Drainage System

Work item 1C in this option is to clean and modify the interior condensate/leak drainage system. As noted earlier in this report, the major detriments to the proper functioning of this system include debris collection in the hubs, leaking rafter gaskets at the hubs, and faulty drainage channels at the base of the dome. Work would include the following:

- Removing all 1,725 aluminum hub covers.
- Cleaning the debris and standing water out of all hubs.
- Installing a flowable sealant into each hub.
- Reinstalling the hub covers with new gaskets and sealant.

The purpose of the flowable sealant in each hub is to provide a seal around each lower rafter-to-hub connection, and to fill the void in each hub where water and debris collects. The sealant will be installed to the level of the lowest rafter drain connection. The connection between the lower rafters and the hub could also be tightened at some locations. This will compress the neoprene seals which may have taken a compression set over the years.

Work Item 1D – Remove and Reinstall Mechanical Equipment

Work item 1D in this option is to remove the mechanical system equipment at the base of the Show Dome to allow for concrete repairing and concrete protective coating installation. This same equipment will need to be reinstalled after completion of the concrete repair work. Work would include the following:

- Removing and reinstalling 5 wall exhaust fans, including dampers and louvers.
- Removing and reinstalling 13 summer air intakes, including dampers and louvers.

Work Item 1E – Clean, Repair and Recoat Concrete Frame

Work item 1E in this option is to clean, repair and recoat the concrete frame. Work would include the following:

- Preparing the existing concrete frame surfaces for recoating.
- Repairing the damaged concrete surfaces.
- Recoating the concrete frame surfaces to the top of the foundation wall.

Recommendations for Preparing the Existing Concrete Surfaces

[Important Note: The existing paint in the Show Dome should be tested by the Owner for lead, prior to concluding or advancing contract documents for any of the project design options.]

Preparing the coating substrate correctly is always critical to the final success of any coating system. Although the overcoat nature of a urethane-enamel, an epoxy, or an acrylic-solid systems allows for the possibility of not completely removing the existing paint coats, an acrylic-stain system requires complete removal in order to allow the new stain to penetrate the concrete surfaces.

A couple of cleaning methods have been considered for this project. One is a water/sand pressure wash method; and the other is a controlled chemical-stripping method which is neutralized by a final water wash or wipe.

Each of the re-coating manufacturers consulted has initially suggested various water-sand pressure washes in order to thoroughly remove the existing paint. Although a water-sand type wash is environmentally benign, the pressure wash has the complications of needing to mask any glass or glazing, and of cleaning up large volumes of water and sand residue. These tasks ultimately increase the surface preparation costs. In addition, if the Owner's field test shows that lead is present in the existing finish, the need to control any dispersion of airborne or waterborne lead residue would be difficult and costly.

An alternate controlled chemical-stripping method has also been researched. (A local manufacturer of chemical stripping products is Diedrich Technologies in Oak Creek, WI). This method would allow application of the cleaning product onto the various faces of the concrete structural members via hand troweling, brushing, or roller, and therefore would require much less masking. The old epoxy paint system would be incrementally scraped or wiped off, and immediately placed into containers. This eliminates the need to clean up dispersed materials and assists with controlled disposal from the site, so it can also directly address removal of lead residue if necessary. This method can be easily site tested prior to any final specification.

It should be stated in conclusion, that to consider any cost savings by not completely removing the existing paint system would result in a warranty reduction for any of the new re-coat systems. Minimizing surface preparation will result in not providing the long term solution security that the Owner seeks. Therefore, it is strongly recommended that all existing coatings be removed to the concrete substrate no matter what protective re-coating system is eventually selected.

Protective Coating Options Review Process
The following procedure was used to analyze options for protective coatings systems for the re-coating of the Show Dome concrete structural frame:

1. The following qualified protective coating system manufacturers were identified based upon available products and technical support within the Milwaukee County construction market:
   - Tnemec Coating Specialists, Inc.; Garland TX
   - ICI Paints (Devoe High Performance Coatings); Cleveland OH
   - PPG Architectural Finishes, Inc. (Pittsburgh Paints); Pittsburgh PA
   - Sherwin-Williams (Industrial & Marine Coatings); Cleveland OH

2. Meetings were held with manufacturer representatives to give an overview of this Dome study, to discuss the Owner's particular concerns related to the renovations, and to review the schematic design options being considered. A partial copy of the Domes 1994 Conditions Study, including the original epoxy-

paint coating specifications, was given to each representative. The need for a system that could be applied incrementally under interior/exterior weather conditions was discussed, including the need for local Contractors to be familiar with applying the coatings, and the desire to maintain best product warranty. The requirement for obtaining a uniform look of the final coat was stressed, whether applying over the existing concrete substrate or over new concrete patches at previously cracked or spalled areas. The need to also provide surface preparation and recoating of all embedded steel connector plates at the aluminum glazing system attachment points was also explained.

3. The manufacturer representatives visited the project site and visually assessed conditions of the original coating and the concrete frame surfaces. The Domes on-site facilities contact was consulted to obtain additional information regarding the County's past or standard maintenance of surfaces. The manufacturer's preferred surface preparation method was requested based upon the representative's site observations.

4. The manufacturer's recommendations and specifications for a new coating system, the necessary surface preparation, the performance attributes of their product, and the current material-only costs were received and reviewed.

5. A matrix report chart as shown in Appendix B was prepared to assist in comparing the product data. A simplified rating system (1 low – 3 high) was established for each system attribute with the intent to focus more clearly on which coating(s) ranked higher in meeting overall project goals. This type of presentation helps to better clarify particular features of the coatings reviewed, and will assist in discussions regarding the re-coat application methods, re-coat long-term performance, and final selections.

Coating System Recommendations
The following are some of the more recognizable features of the various systems:

1. All of the systems offer color representation that matches the original coating color.

2. All of the systems are sustainable due to topcoat reparability over the maintenance life.

3. The epoxy coating installation would have greater out-gassing than the other solid overcoat systems; but a much longer thirty-year life expectancy could offset this initial issue.

4. The acrylic-stain coating penetrates the concrete surface and offers a lower life cycle cost due to needing only maintenance touch-ups; but the finish can express more variations in look than the solid overcoat systems, and the original coating must be completely removed.

5. All of the systems offered some degree of initial resistance to organic growth; although all the manufacturers stated that the long-term performance was a more difficult factor to assess. The urethane-enamel or the epoxy systems would definitely create a harder surface and thus be more scrubbable, and more resistant to dirt collection which encourages organic growth.

Therefore, in consideration of the manufacturers' product recommendations and based upon the data requested and reviewed, the best choices for product consideration and for field demonstration testing are as follows:

- PPG Paints – Pitt -Guard 95-245 Series, Polyamide-Epoxy
  - No primer coat required.
  - System warranty of 20-30 years if surfaced prepped and (2) finish coats.
  - Higher 2.50 overall rating

- Tnemec – Conformal Stain 607, Acrylic Polymer Stain
  - Unique option verses overcoat, offering long-term sustainability of low maintenance.
  - No primer coat required.
  - Lower 2.13 overall rating (due to need for complete removal existing finish)

It is suggested that minimally these two systems be on-site tested during the next stages of design option development.

Work Item 1F – Repair Exterior Screens
Work item 1F in this option is to replace the damaged exterior screens at mechanical louvers. Work would include the following:
- Removing 28 existing damaged screens.
- Installing 28 new screens.

Work Item 1G – Install New Foundation Wall Flashing
Work item 1G in this option is to install new metal flashing on top of the existing foundation wall. Work would include the following:
- Removing 440 feet of existing flashing at the base of the dome.
- Installing 440 feet of new drainage and closure flashing at the base of the dome.

Work Item 1H – Clean All Wire Glass Panels

Work item 1H in this option is to clean all wire glass panels.

Work Item 1J – Provide Vegetation Protection

Work item 1J in this option is to install protective enclosures to protect the existing vegetation during construction.

Conceptual Estimates of Project Costs for Option 1

Work Item 1A =	$ 1,100,000	Replace Damaged Glass
Work Item 1B =	$ 260,000	Replace Gaskets
Work Item 1C =	$ 730,000	Repair Drainage System
Work Item 1D =	$ 30,000	Remove and Reinstall Mech. Equipment
Work Item 1E =	$ 1,380,000	Clean, Repair and Recoat Concrete Frame
Work Item 1F =	$ 10,000	Repair Exterior Screens
Work Item 1G =	$ 50,000	Install New Foundation Wall Flashing
Work Item 1H =	$ 70,000	Clean All Wire Glass Panels
Work Item 1J =	$ 100,000	Provide Vegetation Protection
Subtotal =	$ 3,730,000	
Contingency - 20%	$ 750,000	
Design Fee - 10%	$ 370,000	
County Admin. Fee	$ 370,000	
Total =	**$ 5,220,000**	

Option 2 –
Replace Existing Glass and Repair Concrete Frame

This option is the replacement of the existing Show Dome glass with insulated glazing, utilizing the existing aluminum façade framing; and repair of the concrete frame to generally the original as-built conditions. The general work items for this option include the following:

- **2A.** Replacing all glass with insulated glazing.
- **2B.** Cleaning and modifying the condensate/leak drainage system.
- **2C.** Removing and reinstalling mechanical equipment.
- **2D.** Cleaning, repairing and installing a protective coating on the concrete frame.
- **2E.** Repairing exterior screens.
- **2F.** Installing new foundation wall flashing.
- **2G.** Providing protection of the existing vegetation.

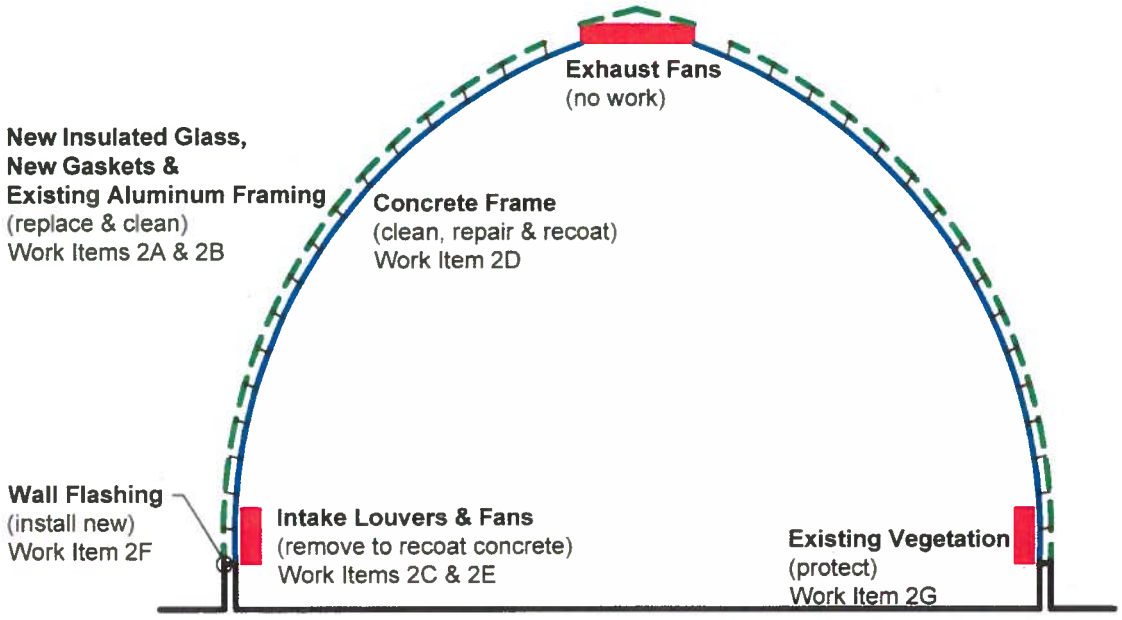

Figure 14: Schematic Representation of Option 2

Advantages of New Glazing

a. The use of insulating glass will drastically reduce the net energy needed to maintain inside temperatures. The lower solar energy transmittance of the insulated glazing units will also reduce the total exhaust fan-hours needed to maintain temperatures in

the warm season. (See 'Energy Use Evaluation' under the Show Dome Façade Study section).

b. The use of a new gasket system will also allow for selection of gasket material of a more recent technology, presumably longer lasting and less prone to becoming brittle after a few years. This should ensure a more airtight facility, which will be easier and less costly to heat.

c. The light transmittance will be better using the insulated glazing units compared to the current stained wire glass. This will result in faster growth inside the domes as a result of the higher light level. This, in turn, will need adjustment from the gardeners as the plants will react differently, probably needing adjustments in fertilization, changed flowering regime, additional trimming, etc.

d. The overall aesthetics of the domes will be significantly improved when looking from the street or from the gardens. Up close, the transparency of the glass wall will be better, allowing a better look inside from the outside.

Work Item 2A – Replace All Glass with Insulated Glass

Work item 2A in this option is to replace all 3,185 panels of wire glass in the Show Dome with insulated glazing. Work would include the following:

- Removing all rafter caps
- Removing and discarding all wire glass
- Removing and discarding all top side and bottom side gaskets
- Installing all new bottom side and top side gaskets
- Installing new insulated glazing panels
- Re-installing rafter caps with new screw fasteners
- Installing a bead of sealant over the gasket, between the glass surface and the aluminum rafter cap

Recommendations on Glass Options

Both the Show Dome and the Arid Dome are "High-Light" areas as desert plants are typically very high intensity light plants with dry environment. The Show Dome is almost similar in the sense that it is used for a variety of rotating displays that sometimes do require very high light levels.

The Tropical Dome has a lower requirement for lighting intensity as tropical plants are shade lovers in general. Therefore, a lower light transmittance (if accompanied by higher energy savings) would be acceptable for this zone, provided aesthetics of all 3 domes are taken into consideration.

It should be mentioned that the dome structure always presents a fraction of its outside wall perpendicular to the sun angle. Although a specific study was not conducted, it is believed that this dome shape favors light energy accumulation throughout the day, and allows some leeway in reducing the insulated glass units' light transmittance to save energy. Measurements of simultaneous existing light levels inside and outside the dome under sunny and cloudy conditions would allow the variation of lighting levels to be quantified once the new glass is in place.

Assuming that the concrete structure can accept the additional weight, insulating glass units (IGU) are the best option to reducing the operating costs of the facility, to provide the needed resistance to damage on the outside, and to provide the safety aspects required on the inside.

TYPES OF GLASS	Thickness (in)	Transmission %			U-Value (BTU/h-sf-F)	
		Visible Light	Solar Energy	U-V	Night	Day
Uncoated Monolithic Glass	1/4	88	77	63	1.02	0.92
Viracon VE 6-85 Coated Laminated Glass	1/4-.030-1/4	70	34	<1	0.97	0.88
Viracon VE 1-2M IGU	1/4-1/2-1/4	70	33	10	0.29	0.26
Viracon VE 1-2M Laminated IGU	1/4-1/2-1/4-.030-1/4	67	29	<1	0.29	0.26
Viracon VE 1-85 IGU	1/4-1/2-1/4	76	47	26	0.31	0.29
Viracon VE 1-85 Laminated IGU	1/4-1/2-1/4-.030-1/4	72	40	<1	0.31	0.28
Uncoated Clear IGU	1/4-1/2-1/4	79	61	46	0.47	0.49
Uncoated Clear Laminated IGU	1/4-1/2-1/4-.030-1/4	75	50	<1	0.46	0.48

The above table compares light transmission and insulation values for different types of glass. The existing wire glass was probably close to the "uncoated monolithic glass" originally when the system was put in place. The transmission is probably slightly lower due to the wires embedded in the glass. Coating glass with metal oxide produces an average reduction in the visible light transmission but an important reduction in the solar energy. Therefore, such coatings have an important impact on the solar gain (protection against overheating during the day). The coating doesn't change the insulation factor as much as one would expect, and therefore is not a considerable gain from the existing situation with uncoated glass.

Lamination has an important impact on the ultraviolet (UV) light transmission. The laminating film almost completely cuts out the UV being allowed within the enclosure. Typically UV is detrimental to plants and therefore the lamination would have a positive impact on the plant life within the domes. Lack of UV inside would also protect paint color and slow down considerably the deterioration of interior plastic material under the sun.

Looking at the IGU options, the laminating film cuts very little visible light or solar energy. Its effect, as mentioned above, is mostly on the UV wavelengths. Visible light reduction between laminated and non-laminated IGUs are mostly due to the thicker pane of glass. The film does not have a significant effect on cutting the solar energy.

The IGU's interior lite will need to be laminated glass per Code requirements. The outer lite should be heat strengthened or tempered to provide more resistance to shocks, especially in the lower portions of the dome. Considering the difficulty of reaching individual IGUs on this special structure, our recommendation is to go with tempered glass. Tempered glass would provide about 8 times more resistance to breakage. Considerations should be given to the maintenance system that will be used in the future to clean and maintain the glazing system. If a cart of some sort is used to roll over glass, the pane should have the resistance calculated accordingly. Glass should preferably allow one person to walk on the exterior surface without breakage.

The recommendation is to use an outer pane of minimum 1/4 inch tempered glass and an interior lite created of 2 panes of 1/4" annealed glass laminated with a polyvinyl butyl film of thickness 0.030 inch. The resulting weight would be approximately 10.5 pounds per square foot, about 3 times that of the existing wire glass. Thickness of the air space shall be based on the curtain wall system. Thicker is better from an insulation standpoint. Clear IGU's are preferred although tinting could be considered for the Tropical Dome, knowing that an identical outside appearance of all 3 domes is a factor. The low-e coating should be applied on the #2 surface, which is the inside surface of the exterior pane, as is commonly done.

The target light transmittance factor should be 70% or higher for the Show Dome and Arid Dome, while it can be somewhat lower (55%-60%) for the Tropical Dome. Uncoated laminated clear insulating glass has a visible light transmittance of 75%, solar energy transmittance of 50%, and U-Value of 0.47 (night). The IGUs can be coated with a layer of metal oxide (Low-E) that changes these parameters. The goal is to pick an acceptable IGU make-up that decreases the U-Value while maintaining light transmittance. Products should be such as Viracon Solarscreen Low-E (VE) Insulating Glass (VE- 1-85) with light transmittance of 76% and U-Value of 0.31 (winter), or Guardian Sunguard SN-68 Low-E coated product that shows light transmittance of 68% and U-Value of 0.29.

Final glass selection shall be based on costs of the IGU's versus incremental energy savings. Light transmittance is a critical parameter as well. It may be worth looking at argon filling of the IGU as it would generate additional energy savings. However, the argon-filling process is expensive and the additional results depend on the integrity of the IGU seals over time.

Other factors that will influence the choice of IGU's include:

a. The triangular shapes of the current glass panels should be investigated to ensure the feasibility of constructing insulated glass units of such shapes.

b. The very high number of different glass shapes over the entire structure makes it difficult and, at the very least, more costly than usual for IGU's. This should be closely looked at with the Vendors as the regularity of the glass panes throughout will have a very significant price impact. IGU's are rarely fabricated on site. They are done in shops under controlled conditions.

c. The question of the IGU warranty should be discussed completely with the chosen glass Vendors. Typically, IGU's are not warranted at all when installed as sloped glass for greenhouse (high humidity) applications.

Work Item 2B – Clean and Modify Drainage System
Work item 2B in this option is to clean and modify the interior condensate/leak drainage system. This work item is the same as described in Work Item 1C as described in Option 1.

Work Item 2C – Remove and Reinstall Mechanical Equipment
Work item 2C in this option is to remove mechanical system equipment at the base of the Show Dome to allow for concrete repairing and concrete protective coating installation. This same equipment will need to be reinstalled after completion of the concrete repair work. This work item is the same as described in Work Item 1D as described in Option 1.

Work Item 2D – Clean, Repair and Recoat Concrete Frame
Work item 2D in this option is to clean, repair and recoat the concrete frame. This work item is the same as described in Work Item 1E as described in Option 1.

Work Item 2E – Repair Exterior Screens
Work item 2E in this option is to replace the damaged exterior screens. This work item is the same as described in Work Item 1F as described in Option 1.

Work Item 2F – Install New Foundation Wall Flashing
Work item 2F in this option is to install new metal flashing on top of the existing foundation wall. This work item is the same as described in Work Item 1G as described in Option 1.

Work Item 2G – Provide Vegetation Protection
Work item 2G in this option is to install protective enclosures to protect the existing vegetation during construction.

Conceptual Estimates of Project Costs for Option 2

Work Item 2A =	$ 9,560,000	Replace All Glass
Work Item 2B =	$ 730,000	Repair Drainage System
Work Item 2C =	$ 30,000	Remove and Reinstall Mech. Equipment
Work Item 2D =	$ 1,380,000	Clean, Repair and Recoat Concrete Frame
Work Item 2E =	$ 10,000	Repair Exterior Screens
Work Item 2F =	$ 50,000	Install Foundation Wall Flashing
Work Item 2G =	$ 100,000	Provide Vegetation Protection
Subtotal =	$ 11,860,000	
Contingency - 20%	$ 2,370,000	
Design Fee - 10%	$ 1,190,000	
County Admin. Fee	$ 1,190,000	
Total =	**$ 16,610,000**	

Option 3 –
Replace Existing Facade and Repair Concrete Frame

This option is the complete replacement of the existing Show Dome façade, and repair of the concrete frame to generally the original as-built conditions. The general work items for this option include the following:

- **3A.** Removing and discarding the existing glass and aluminum façade framing.
- **3B.** Installing a new aluminum framing and glass façade system.
- **3C.** Removing and reinstalling some existing mechanical equipment, and installing new louvers, mixing plenums, and screens.
- **3D.** Cleaning, repairing and installing a protective coating on the concrete frame.
- **3E.** Providing protection of the existing vegetation.

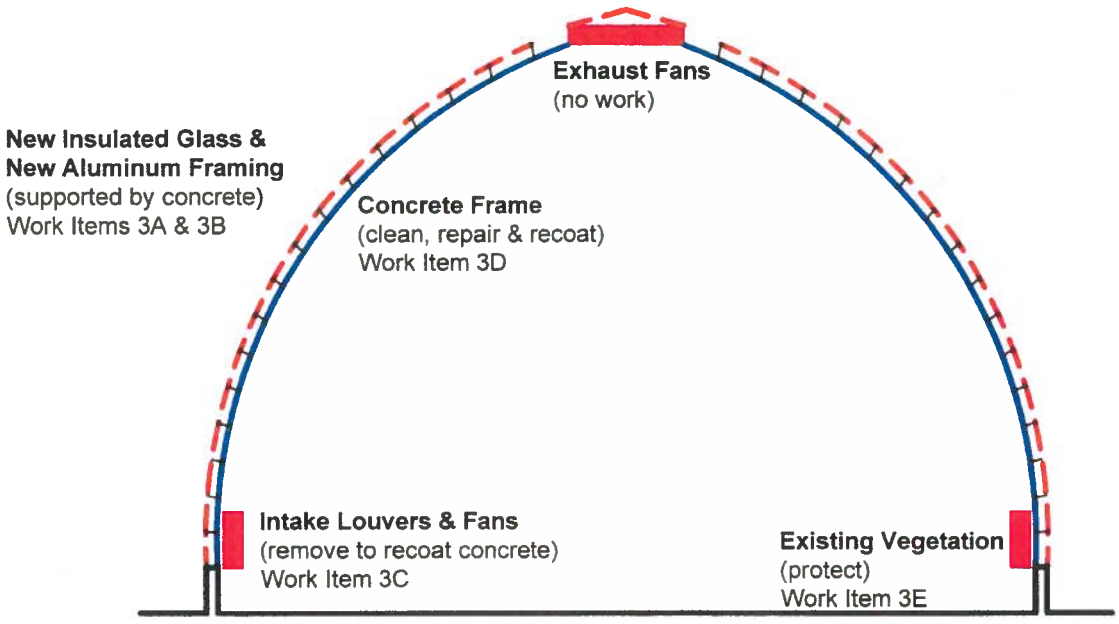

Figure 15: Schematic Representation of Option 3

Work Item 3A – Remove Existing Facade

Work item 3A in this option is to fully remove and discard the existing wire glass and aluminum framing façade system.

Work Item 3B – Install New Façade on Existing Concrete Frame
Work item 3B in this option is to install a complete new aluminum framing façade system with new insulated glass panels. This system would connect to, and be supported by the existing concrete frame.

Work Item 3C – Remove and Reinstall Existing and New Mechanical Equipment
Work item 3C in this option is to remove and reinstall existing, and some new, mechanical system equipment at the base of the Show Dome to allow for concrete repairing and concrete protective coating installation; and to allow for the installation of a new façade system. Work would include the following:

- Removing 5 wall exhaust fans, including dampers, louvers and screens.
- Removing 13 summer air intakes, including dampers, louvers and screens.
- Reinstalling 5 wall exhaust fans and dampers, with new mixing plenums/ductwork, louvers and screens.
- Reinstalling 13 summer air intakes and dampers, with new mixing plenums/ductwork, louvers and screens.

Work Item 3D – Clean, Repair and Recoat Concrete Frame
Work item 3D in this option is to clean, repair and recoat the concrete frame. This work item is the same as described in Work Item 1E as described in Option 1 above.

Work Item 3E – Provide Vegetation Protection
Work item 3E in this option is to install protective enclosures to protect the existing vegetation during construction.

Conceptual Estimates of Project Costs for Option 3

Work Item 3A =	$ 230,000	Remove Existing Façade
Work Item 3B =	$ 4,530,000	Install New Façade with New Flashings
Work Item 3C =	$ 60,000	Remove and Reinstall Mech. Equipment
Work Item 3D =	$ 1,380,000	Clean, Repair & Recoat Concrete Frame
Work Item 3E =	$ 200,000	Provide Vegetation Protection
Subtotal =	$ 6,400,000	
Contingency – 20%	$ 1,280,000	
Design Fee – 10%	$ 640,000	
County Admin. Fee	$ 640,000	
Total =	**$ 8,960,000**	

Option 4 –
Replace Existing Facade and Repair Concrete Frame

This option is the complete replacement of the existing Show Dome façade, and repair of the concrete frame to generally the original as-built conditions. The general work items for this option include the following:

- **4A.** Removing and discarding the existing glass and aluminum façade framing.
- **4B.** Installing a new aluminum framing and glass façade system.
- **4C.** Removing and reinstalling some existing mechanical equipment, and installing new louvers, mixing plenums, and screens.
- **4D.** Cleaning, repairing and installing a protective coating on the concrete frame.
- **4E.** Providing protection of the existing vegetation.

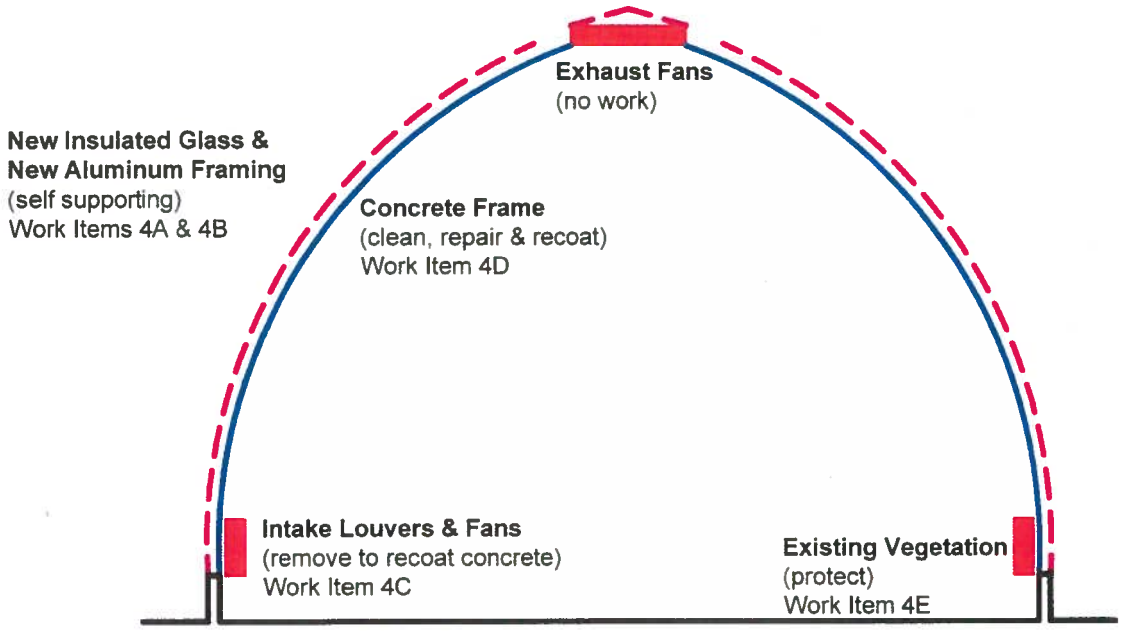

Figure 16: Schematic Representation of Option 4

Work Item 4A – Remove Existing Facade

Work item 4A in this option is to fully remove and discard the existing wire glass and aluminum framing façade system.

Work Item 4B – Install New Self-Supported Façade
Work item 4B in this option is to install a complete new aluminum framing façade system with new insulated glass panels. This system will not connect to the existing concrete frame, but will be self-supporting.

Work Item 4C – Remove and Reinstall Existing and New Mechanical Equipment
Work item 4C in this option is to remove and reinstall existing, and some new, mechanical system equipment at the base of the Show Dome to allow for concrete repairing and concrete protective coating installation; and to allow for the installation of a new façade system. Work would include the following:

- Removing 5 wall exhaust fans, including dampers, louvers and screens.
- Removing 13 summer air intakes, including dampers, louvers and screens.
- Reinstalling 5 wall exhaust fans and dampers, with new mixing plenums/ductwork, louvers and screens.
- Reinstalling 13 summer air intakes and dampers, with new mixing plenums/ductwork, louvers and screens.

Work Item 4D – Clean, Repair and Recoat Concrete Frame
Work item 4D in this option is to clean, repair and recoat the concrete frame. This work item is the same as described in Work Item 1E as described in Option 1.

Work Item 4E – Provide Vegetation Protection
Work item 4E in this option is to install protective enclosures to protect the existing vegetation during construction.

Conceptual Estimates of Project Costs for Option 4

Work Item 4A =	$ 230,000	Remove Existing Façade
Work Item 4B =	$ 6,540,000	Install New Façade with New Flashings
Work Item 4C =	$ 60,000	Remove and Reinstall Mech. Equipment
Work Item 4D =	$ 1,380,000	Clean, Repair & Recoat Conc. Frame
Work Item 4E =	$ 200,000	Provide Vegetation Protection
Subtotal =	$ 8,410,000	
Contingency – 20%	$ 1,680,000	
Design Fee – 10%	$ 840,000	
County Admin. Fee	$ 840,000	
Total =	**$11,770,000**	

Option 5 –
Replace Existing Facade and Remove Concrete Frame

This option is the complete replacement of the existing Show Dome façade, and removal of the concrete frame. The general work items for this option include the following:

- **5A.** Removing and discarding the existing glass and aluminum façade framing.
- **5B.** Removing and discarding the existing concrete frame.
- **5C.** Removing existing mechanical equipment.
- **5D.** Installing a new aluminum framing and glass façade system.
- **5E.** Installing new mechanical equipment, including louvers, mixing plenums and screens.
- **5F.** Providing protection of the existing vegetation.

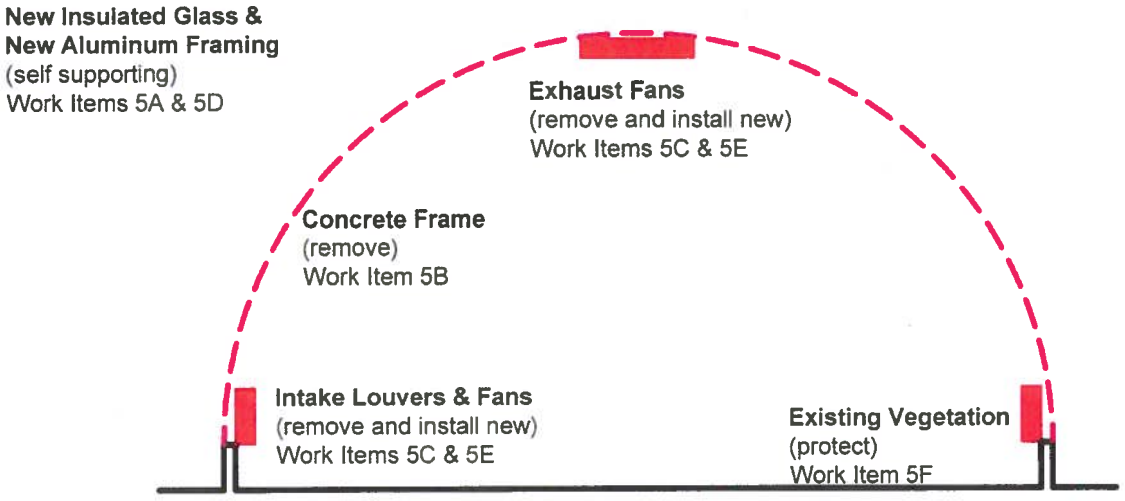

Figure 17: Schematic Representation of Option 5

Work Item 5A – Remove Existing Facade

Work item 5A in this option is to fully remove and discard the existing wire glass and aluminum framing façade system.

Work Item 5B – Remove Existing Concrete Frame
Work item 5B in this option is to fully remove and discard the existing concrete frame system, including the apex framing.

Work Item 5C – Remove Existing Mechanical Equipment
Work item 5C in this option is to fully remove all existing mechanical equipment, including all equipment at the apex.

Work Item 5D – Install New Self-Supported Façade
Work item 5D in this option is to install a complete new aluminum framing façade system with new insulated glass panels.

Work Item 5E – Install New Mechanical Equipment
Work item 5E in this option is to install new mechanical system equipment at the base of the Show Dome and at the dome apex.

Work Item 5F – Remove and Replace Vegetation
Work item 5F in this option is to remove existing vegetation and replace the vegetation after construction.

Conceptual Estimates of Project Costs for Option 5

Work Item 5A =	$ 230,000	Remove Existing Façade
Work Item 5B =	$ 200,000	Remove Concrete Frame
Work Item 5C =	$ 20,000	Remove Mechanical Equipment
Work Item 5D =	$ 4,200,000	Install New Façade with New Flashings
Work Item 5E =	$ 1,600,000	Install New Mechanical Equipment
Work Item 5F =	$ 500,000	Remove Vegetation and Reinstall
Subtotal =	$ 6,750,000	
Contingency - 20%	$ 1,350,000	
Design Fee -10%	$ 680,000	
County Admin. Fee	$ 680,000	
Total =	**$ 9,460,000**	