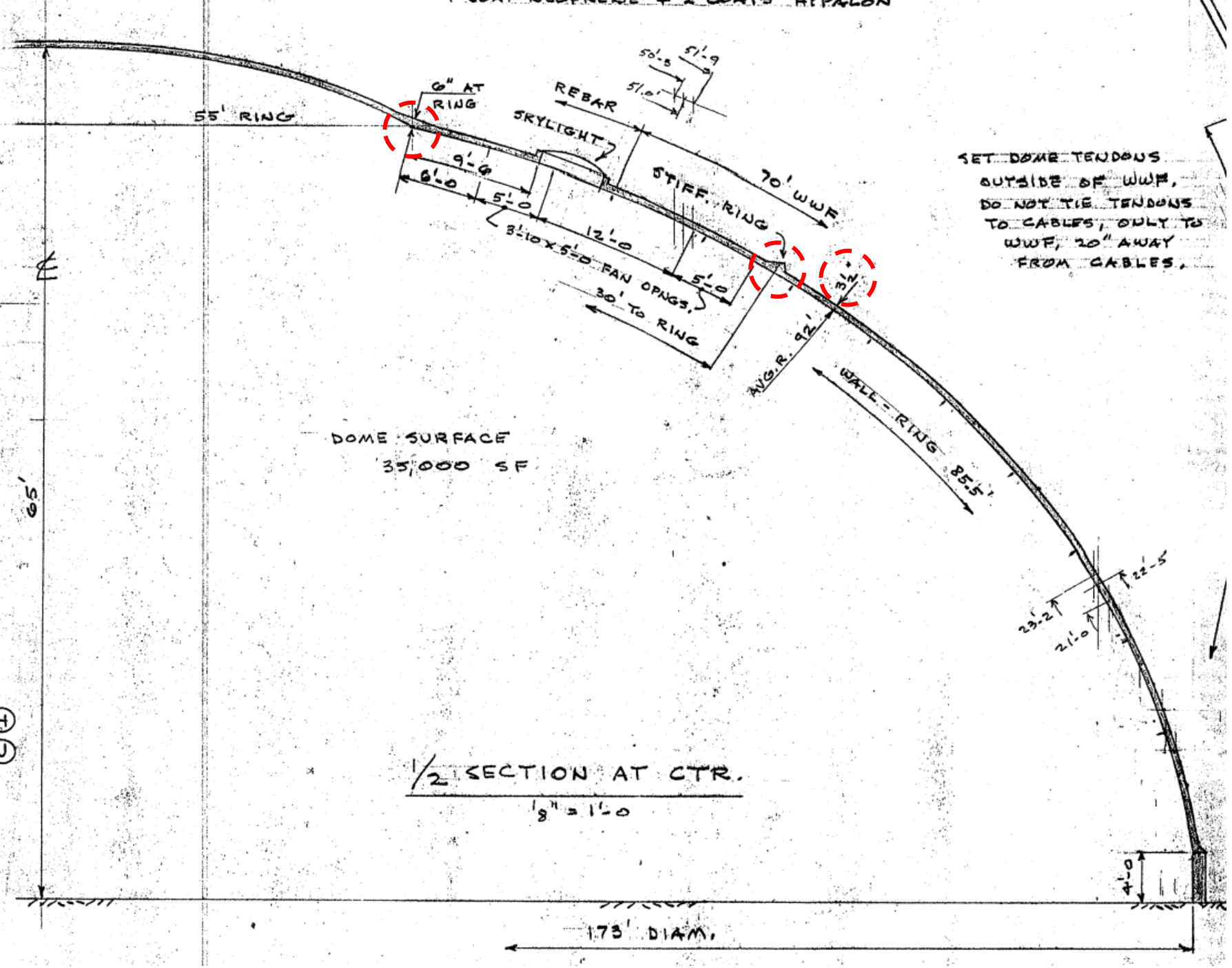
Supplemental Post-Tensioning for Concrete Dome Repairs

Travis Marman, Cody Mitchell, Josh Brewster
Vector Construction, Inc.
Fargo, ND

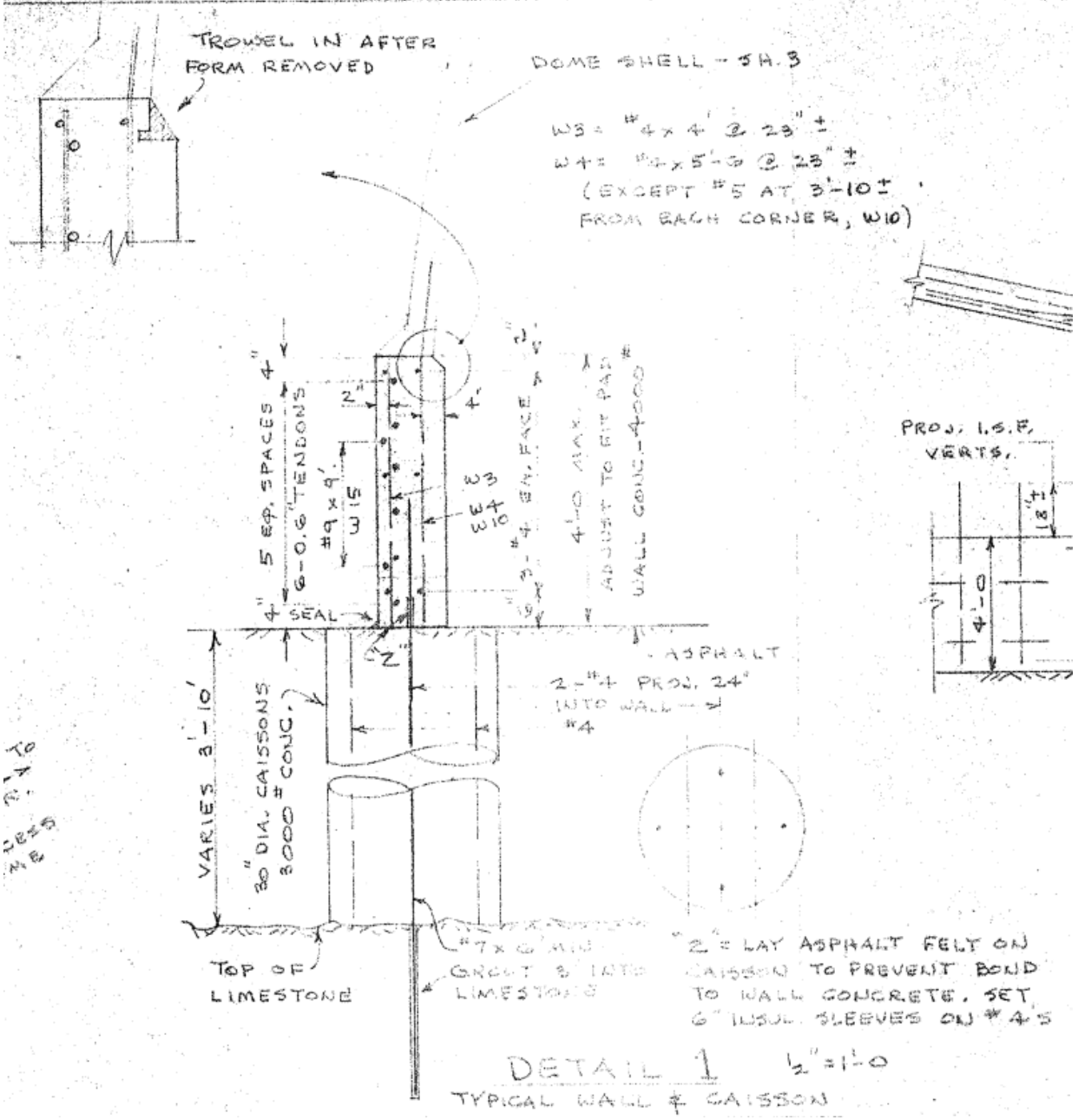
Jared Brewe, Neal Anderson
Simpson Gumpertz & Heger
Chicago, IL

Matt Miltenberger, Andrew Broecker
Vector Corrosion Services, Inc.
Tampa, FL



½ SECTION AT CTR.

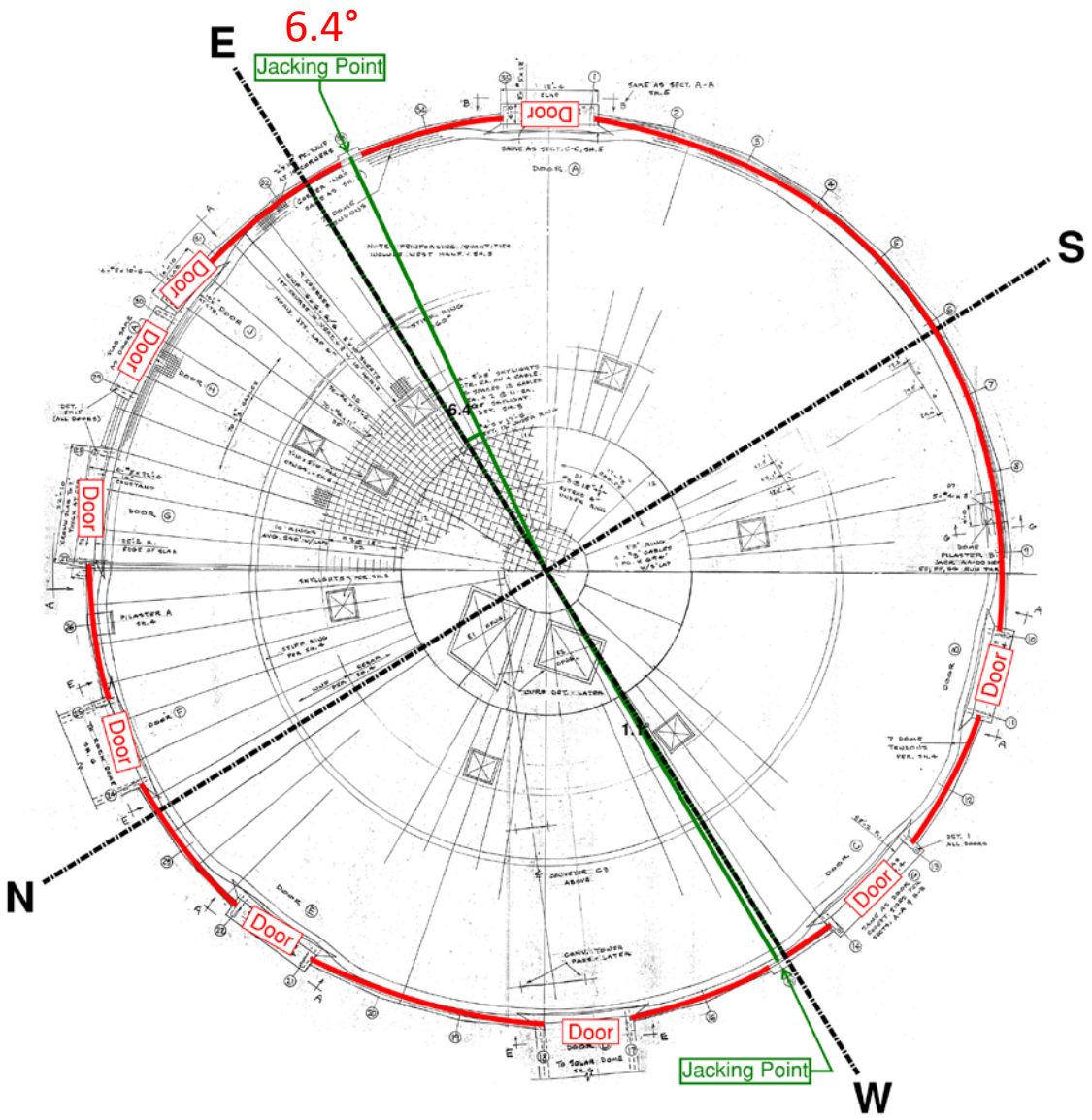
⅛" = 1'-0

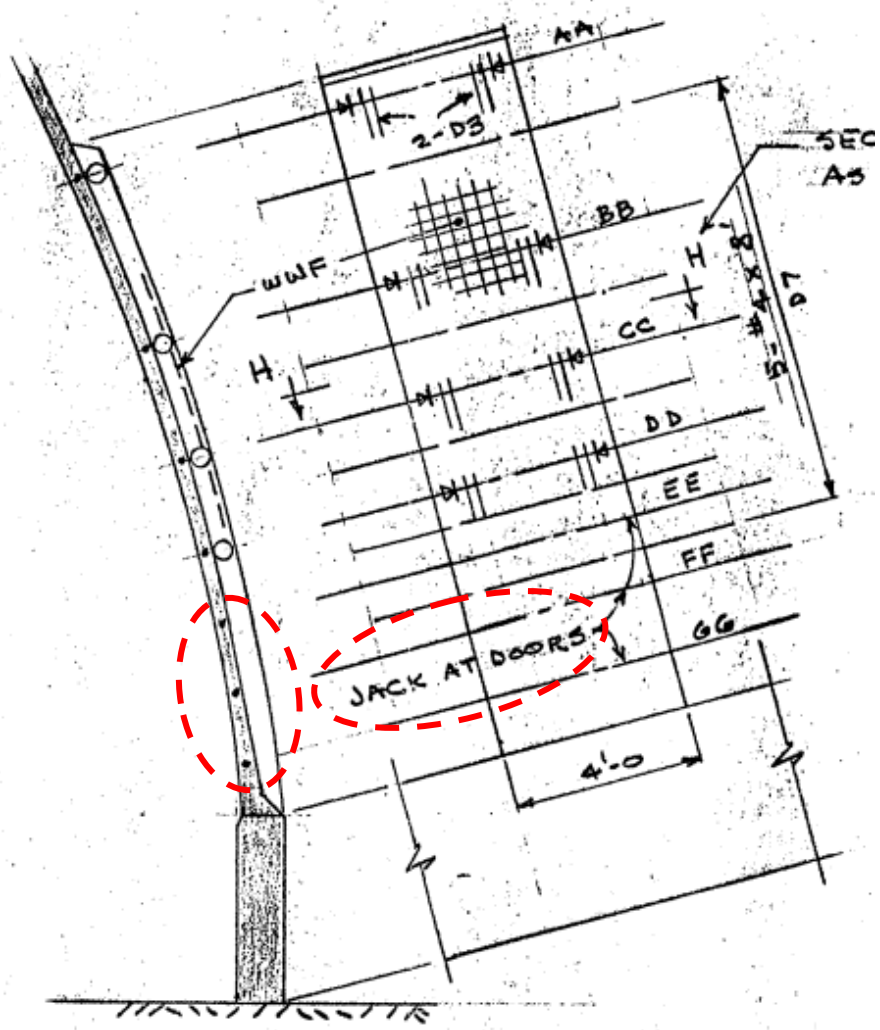


DETAIL 1 ½" = 1'-0

TYPICAL WALL & CAISSON

Location of Door Jambs



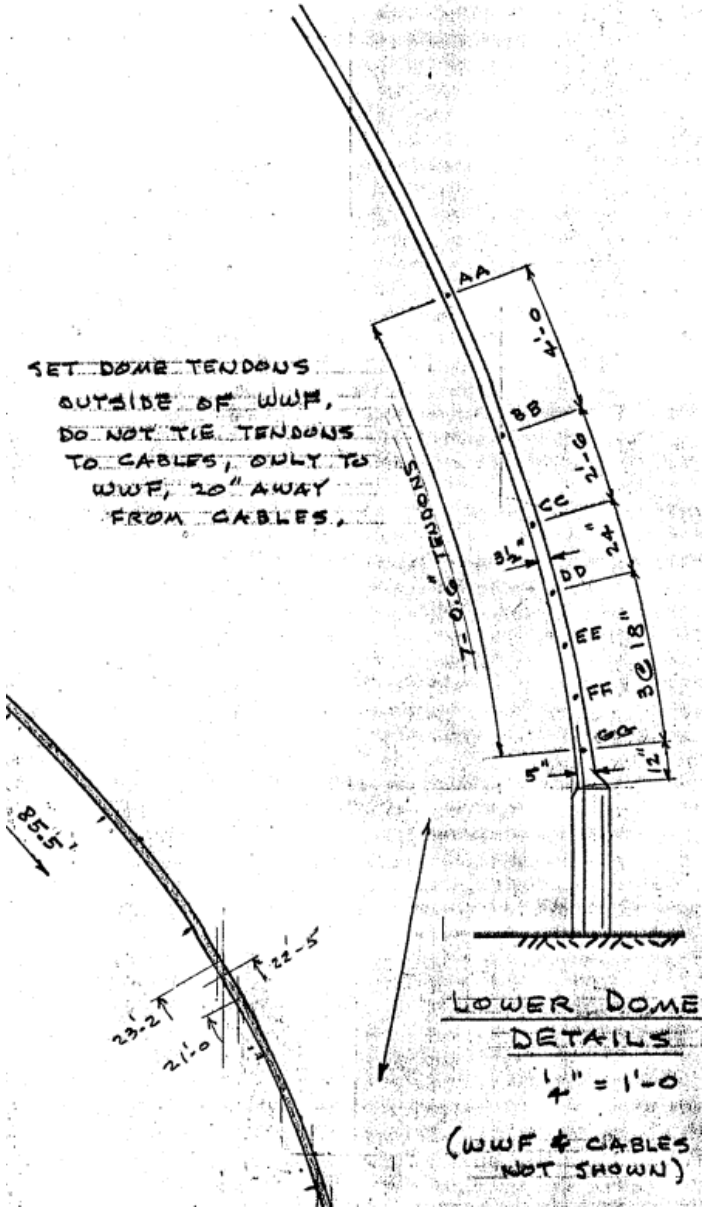


SECT. G-G

1/4" = 1'-0

PILASTERS A & B

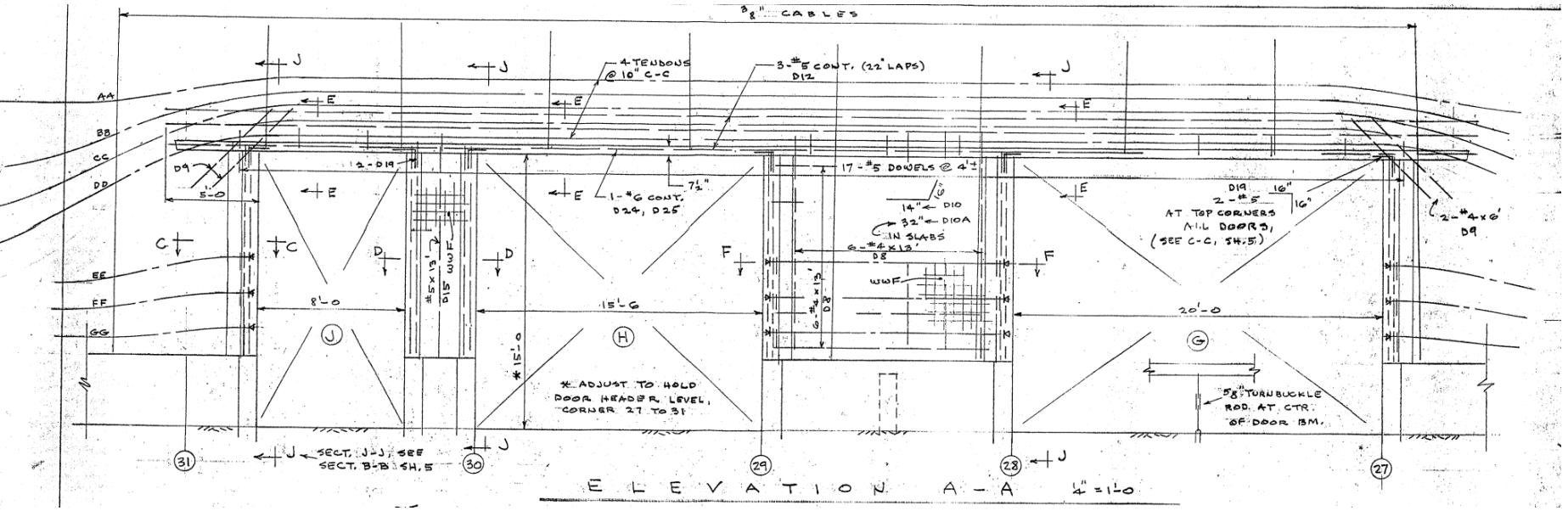
SET DOME TENDONS OUTSIDE OF WWF, DO NOT TIE TENDONS TO CABLES, ONLY TO WWF, 20" AWAY FROM CABLES.



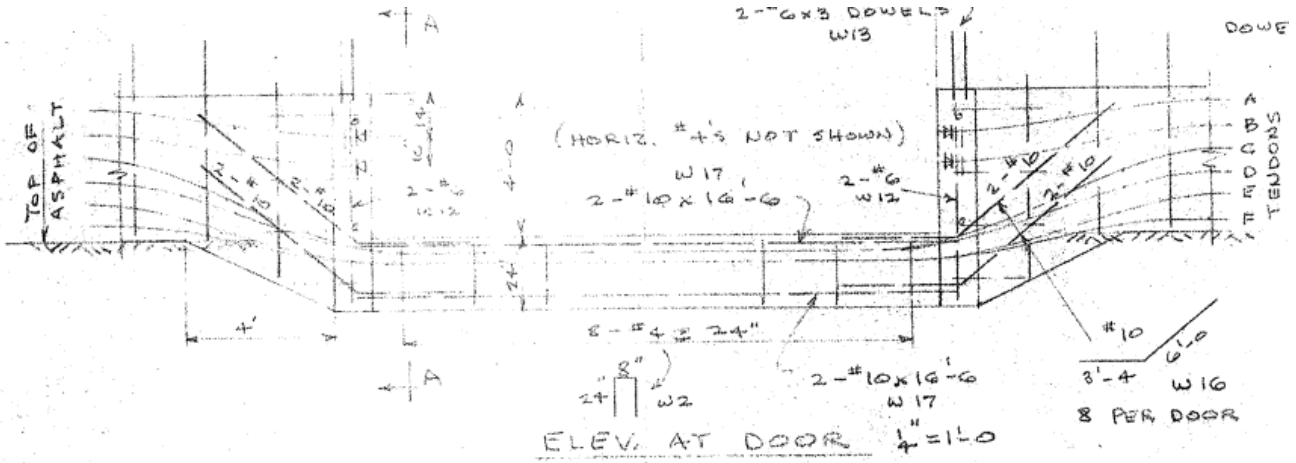
LOWER DOME DETAILS

1/4" = 1'-0

(WWF & CABLES NOT SHOWN)



ELEVATION A-A 1/4"=1'-0



ELEV. AT DOOR 1/4"=1'-0

DOOR - DETAIL 3


GENIE


CONDOR


OX

Situation

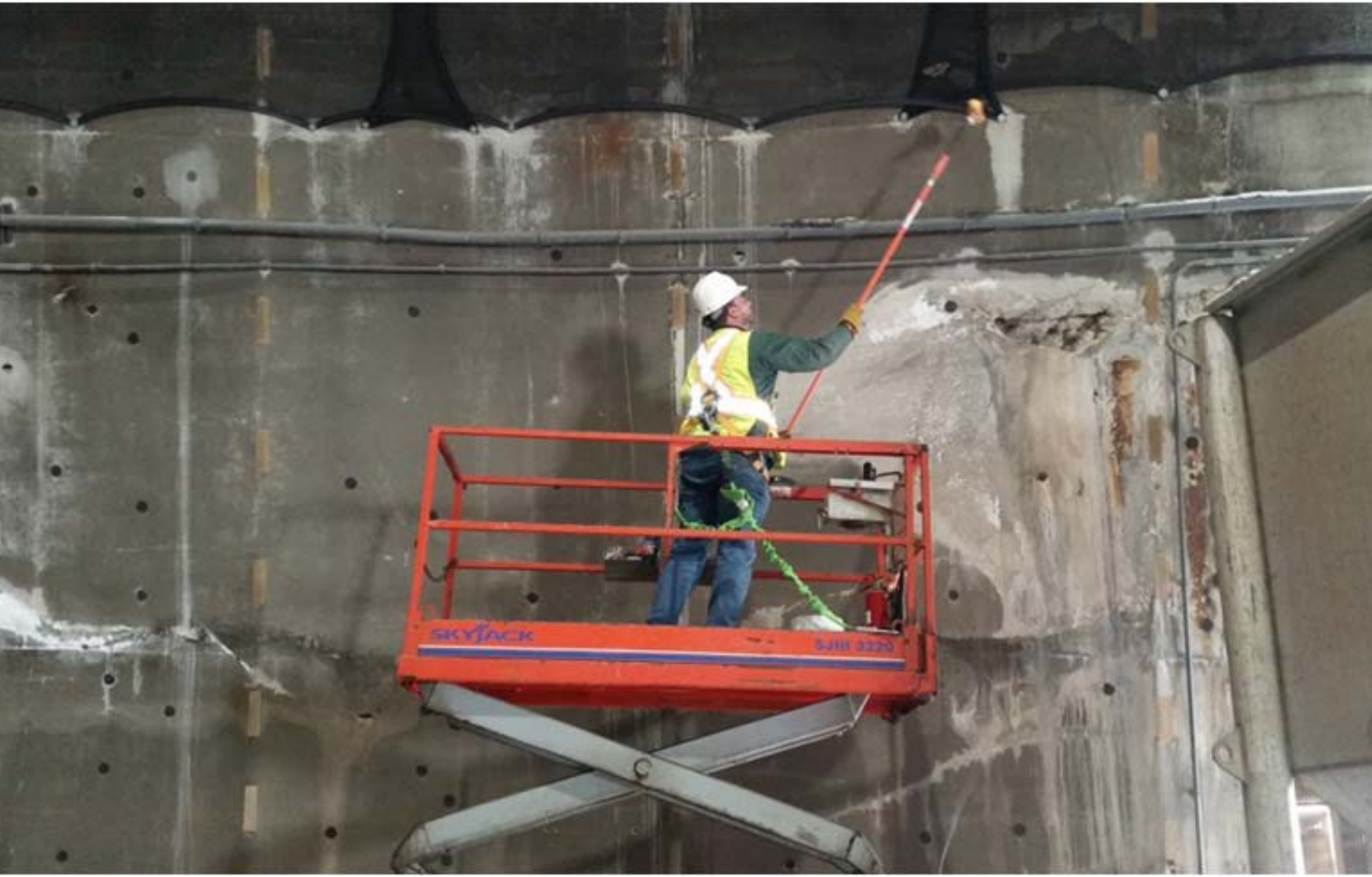
- Structure ~ 30 yr old, Owner wants 30 more yr
- 24/7 operation
- Aggressive environment
- Concerns over leaking, cracking, and deflection
- Owner weighing options to rehab or replace
- Prior evaluation
  - Sounding - identified “wide-spread delamination”
  - Corrosion potentials – identified active corrosion
  - No mention of PT system status
  - Recommended replacement
  - Installed netting inside, external foam, and waterproofing

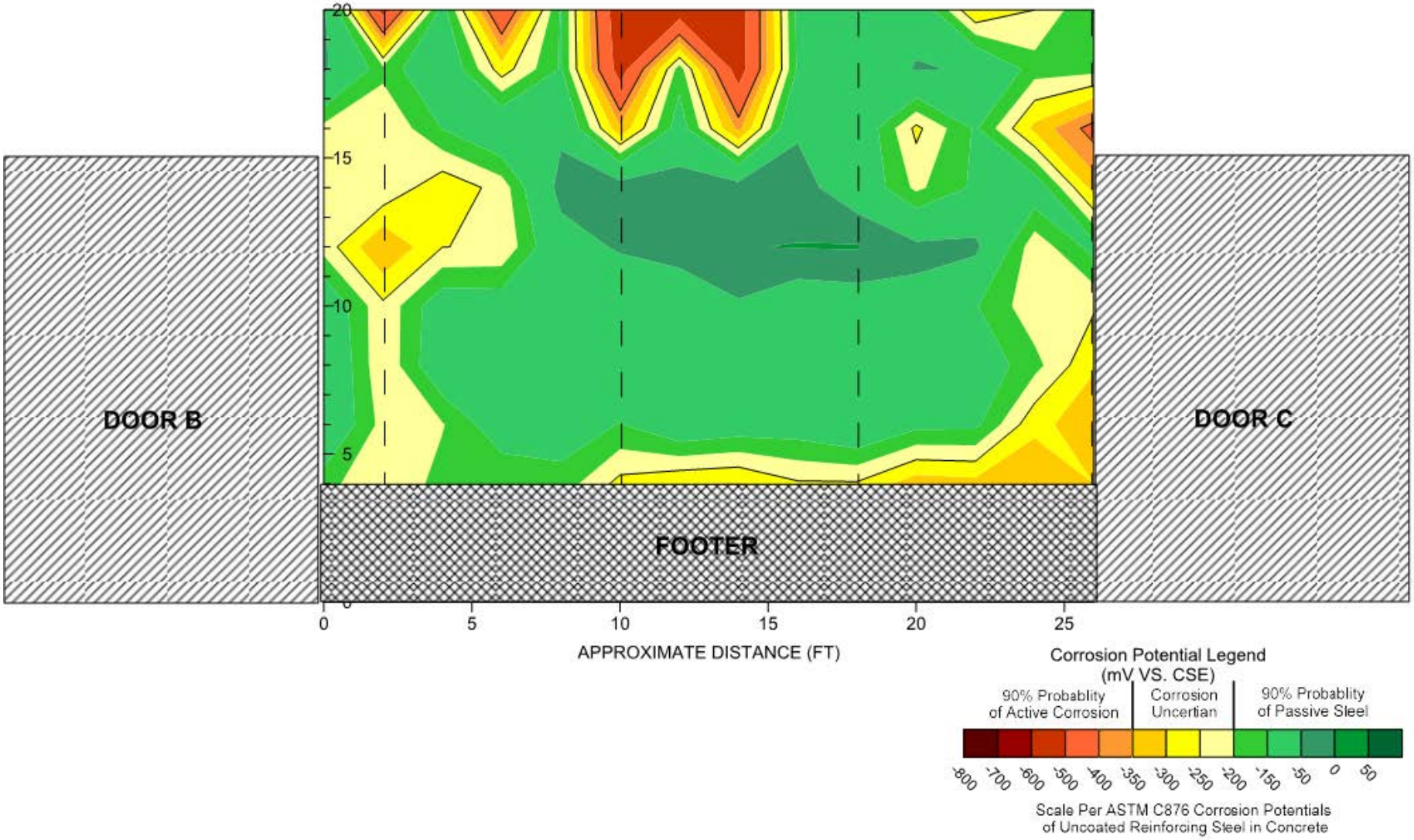
Investigation Phase

- Document Review
- Interviews with maintenance personnel
- Visual assessment
- Corrosion potential survey
- Chloride, carbonation, strength sampling
- PT evaluation
- LIDAR shape survey

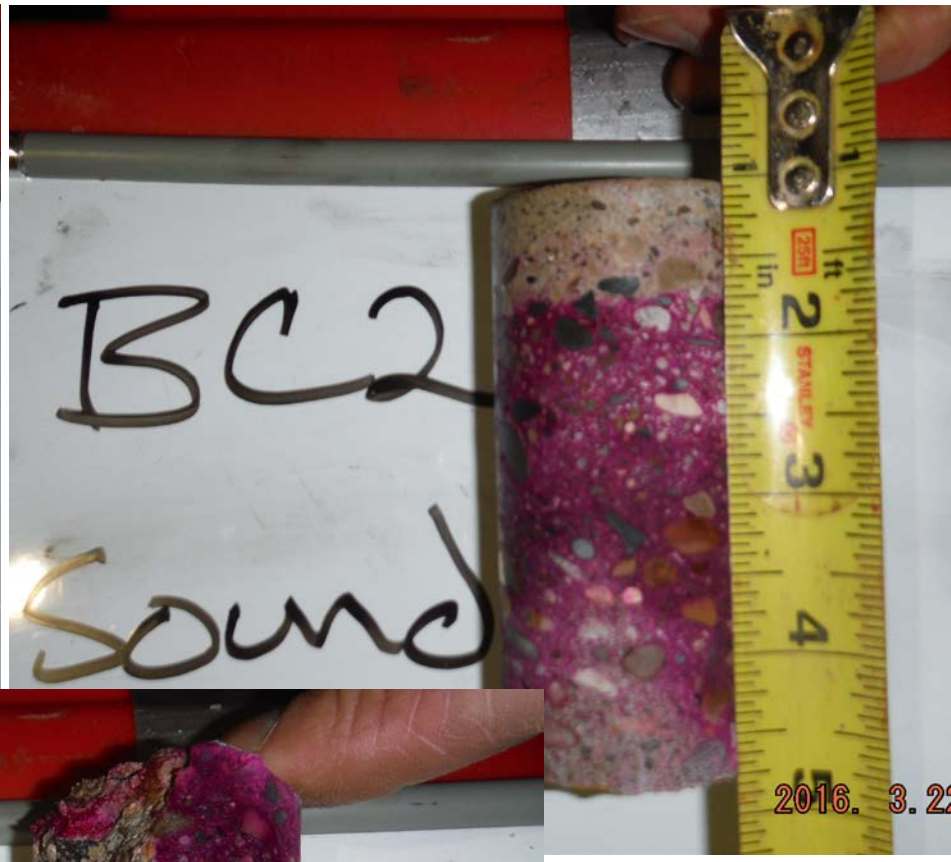

B C2


E F H

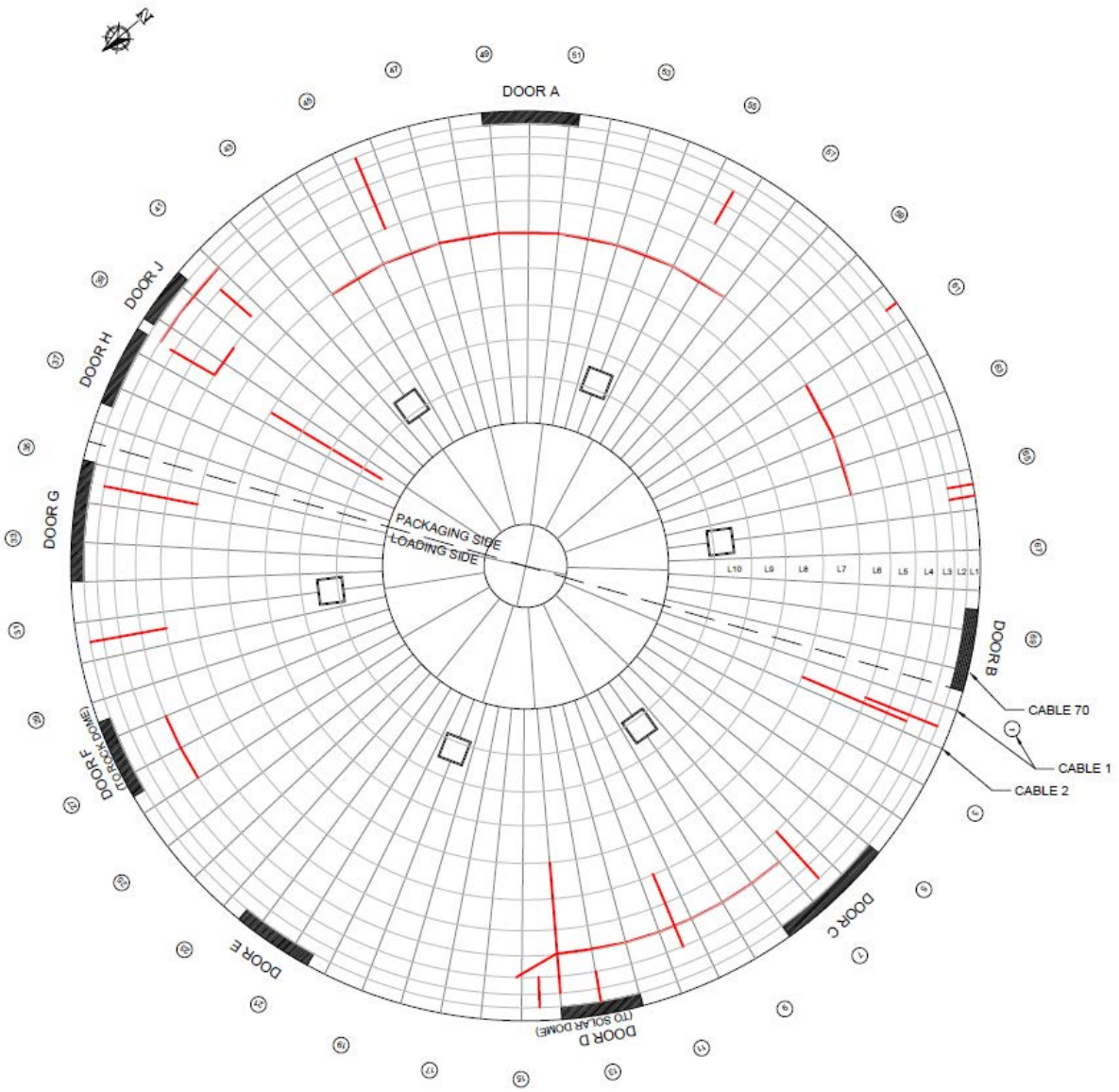

SKYJACK


20
15
10
5
0
DOOR B
DOOR C
FOOTER
0
5
10
15
20
25
APPROXIMATE DISTANCE (FT)
Corrosion Potential Legend
(mV VS. CSE)
90% Probablity
of Active Corrosion
Corrosion
Uncertian
90% Probablity
of Passive Steel
-800
-700
-600
-500
-400
-350
-300
-250
-200
-150
-50
0
50
Scale Per ASTM C876 Corrosion Potentials
of Uncoated Reinforcing Steel in Concrete


BC 1
CRACK

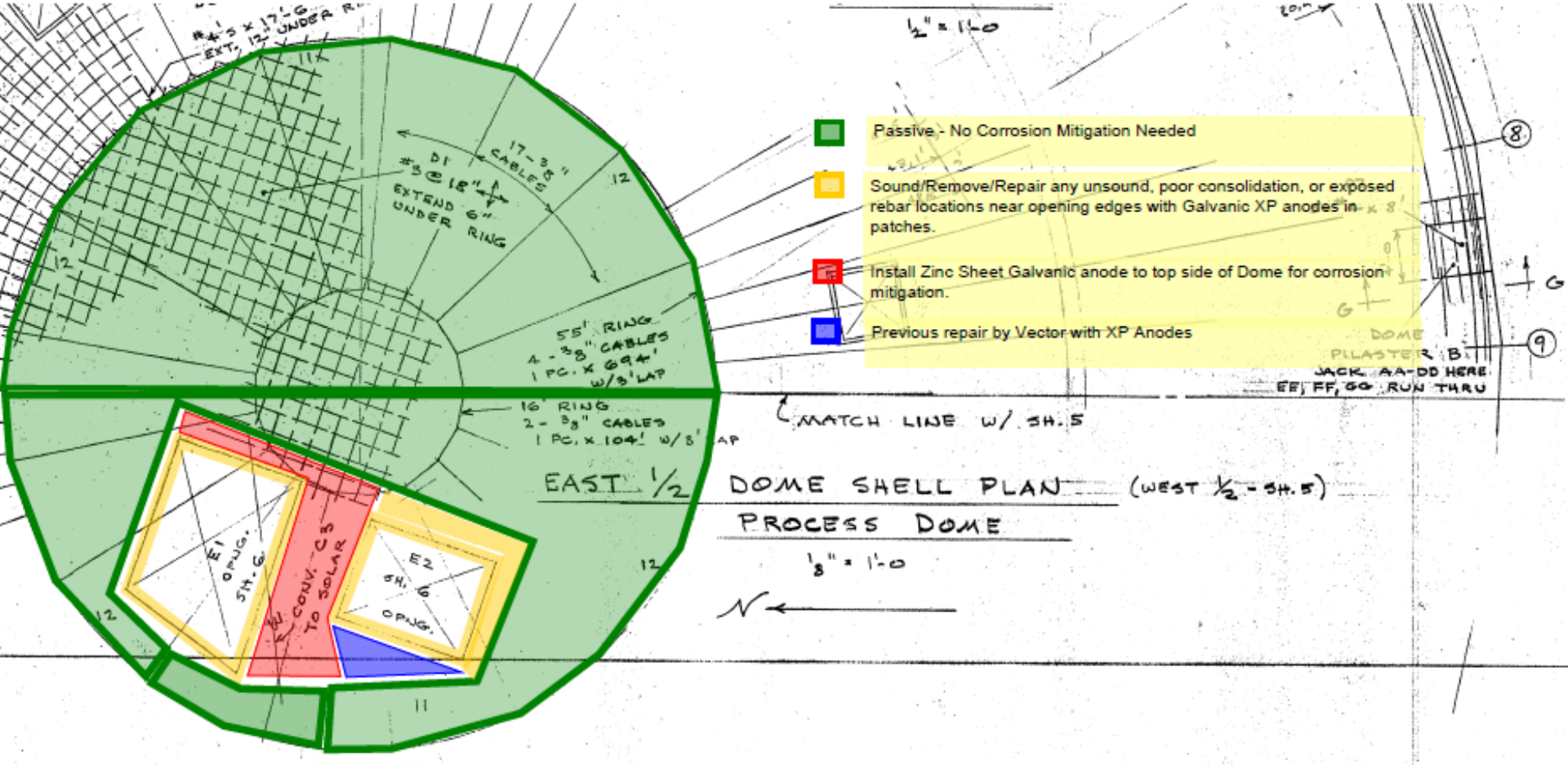

BC2
Sound
2016. 3. 22


BC 1
CRACK
2016. 3. 22 11:38


N
DOOR A
DOOR B
DOOR C
DOOR D
(TO SOLAR DOME)
DOOR E
DOOR F
(TO SOLAR DOME)
DOOR G
DOOR H
DOOR J
PACKAGING SIDE
LOADING SIDE
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
CABLE 70
CABLE 1
CABLE 2

PLAN VIEW


2016. 3.23 11:13



Notes:

- The majority of corrosion potentials taken at the top of the dome showed very passive conditions at the reinforcing steel. There were a select few localized active areas of corrosion indicated in the area between the two openings. This area is exposed from above and below with no waterproofing on top and is exposed to the humidity from outside the top penthouse. This entire area will be treated with a corrosion mitigation system to prevent against future corrosion.

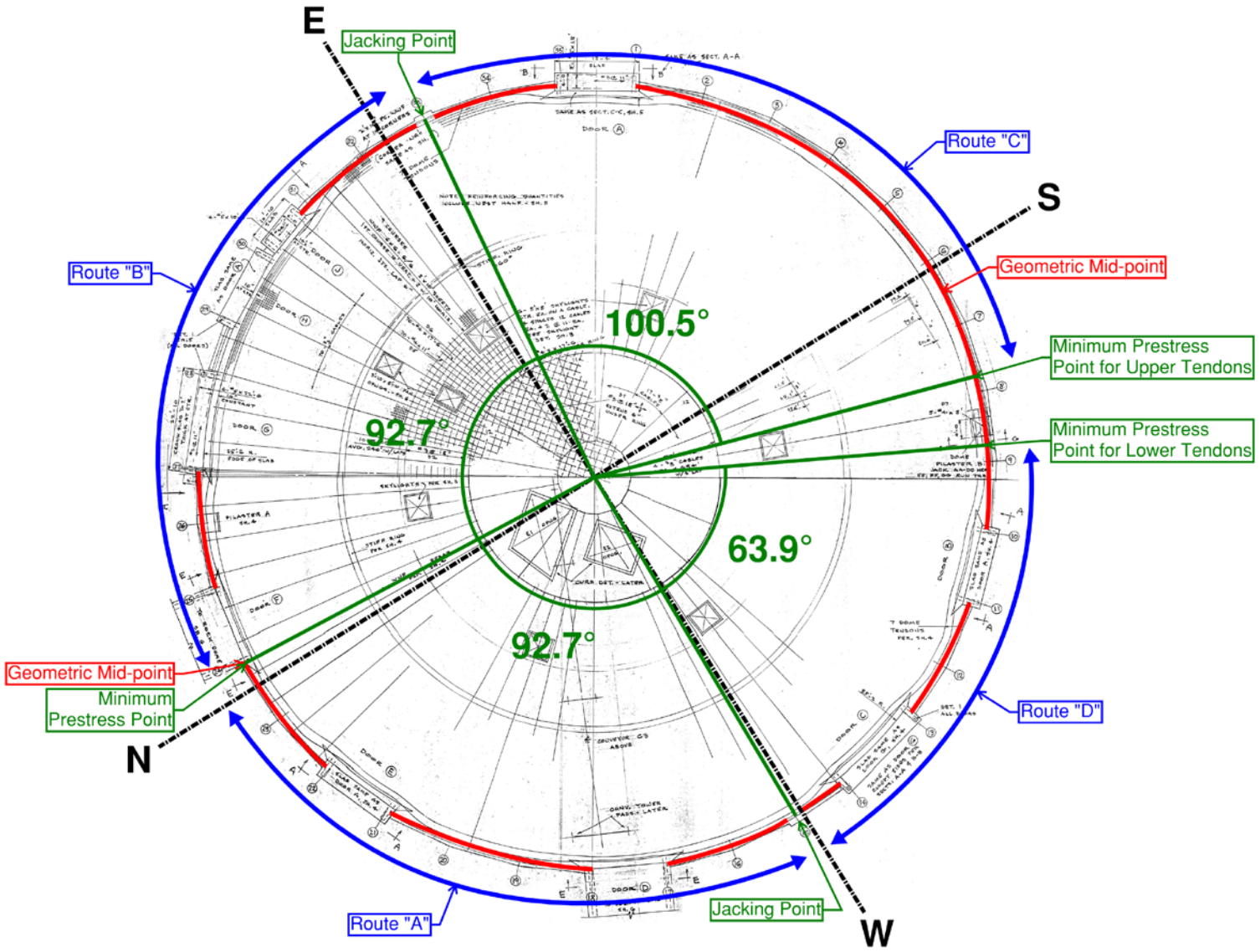
Findings

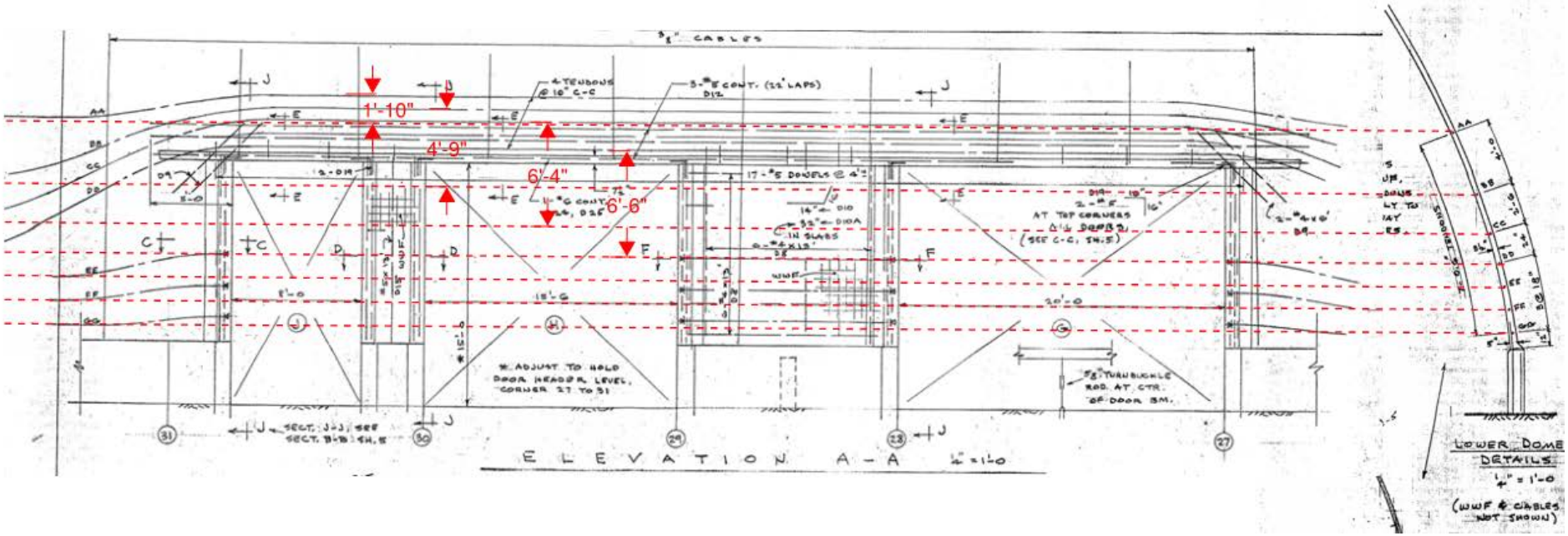
- Widespread shadowing behind reinforcing
- Reinforcement was severed at leaking cracks
- Corrosion damage around skylights
- No prestress in any tendon tested
- PT anchors exposed, corroding
- Poor consolidation behind some PT anchors
- Carbonation & chloride progressed along cracks
- Concrete strength >7000 psi where consolidated

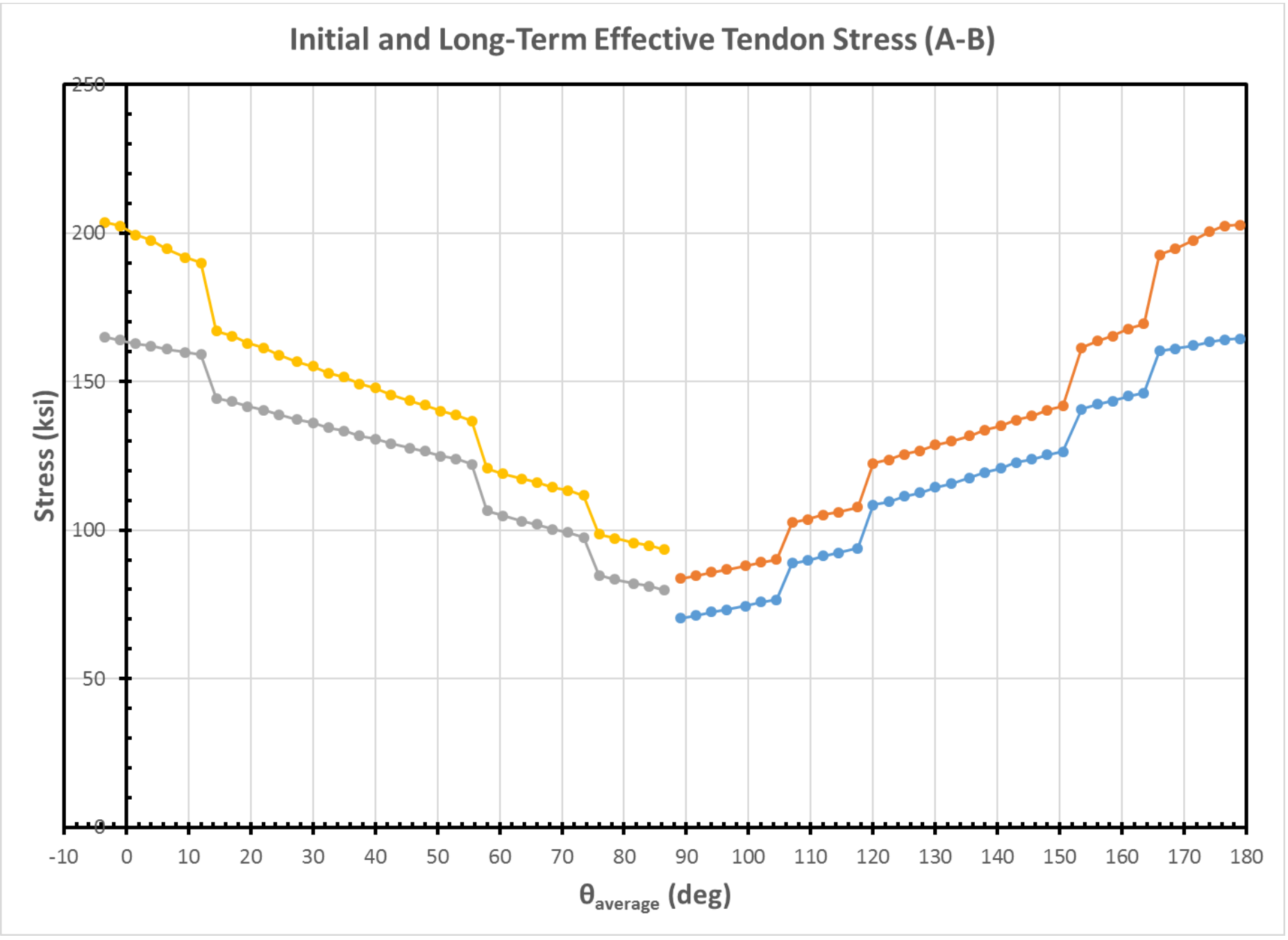
Rehabilitation Strategy

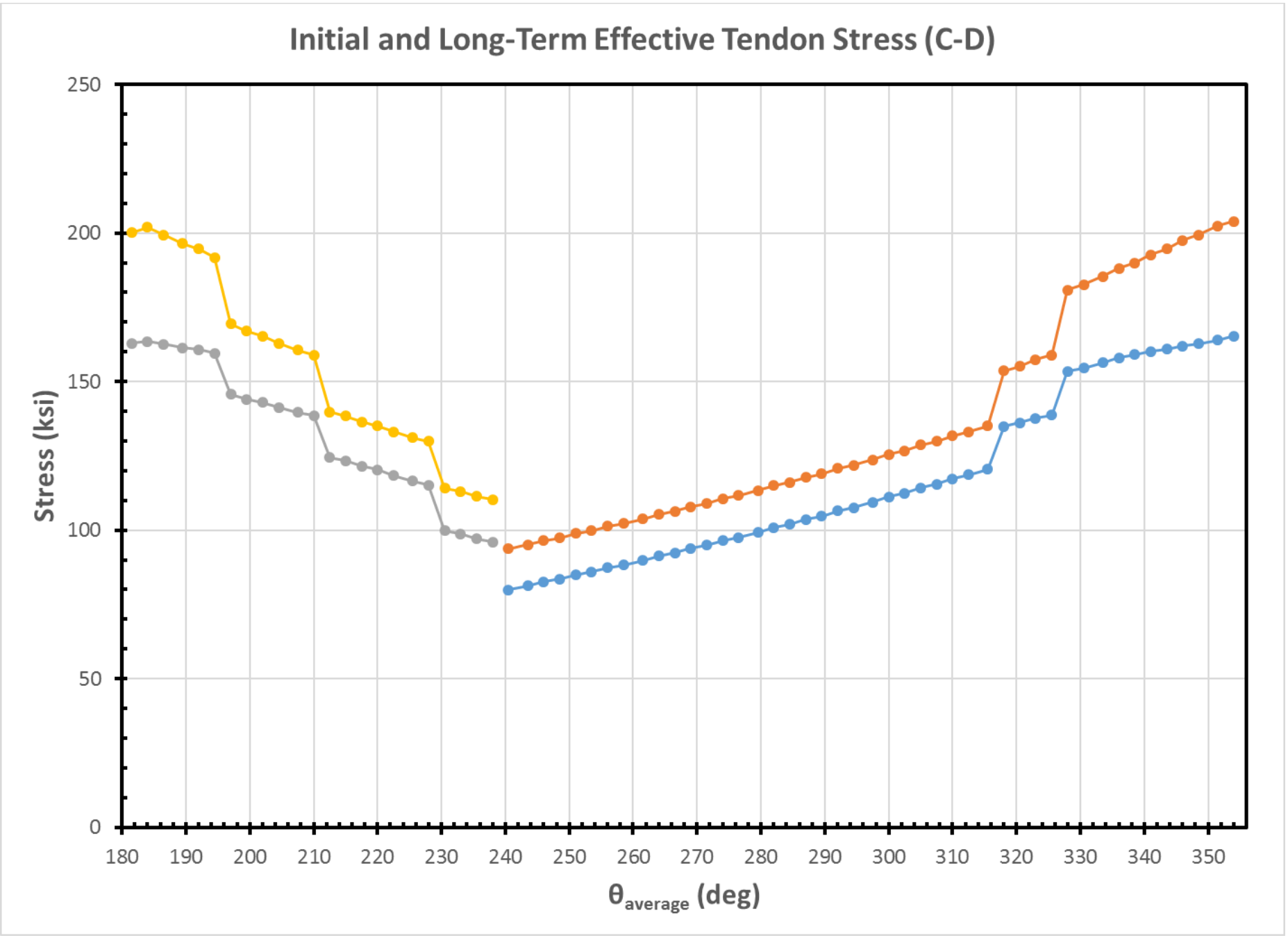
- Structural analysis required (FEM analysis)
- Remove conveyor support loads
- Infill skylights
- Restring PT between doors
- Cast new door jambs and eyebrows
- External PT above eyebrows
- GFRP strengthening at top stiffening ring
- Inject/seal cracks with epoxy
- Corrosion mitigation at cracks and as needed

Schematic Jacking Stress Location Plan

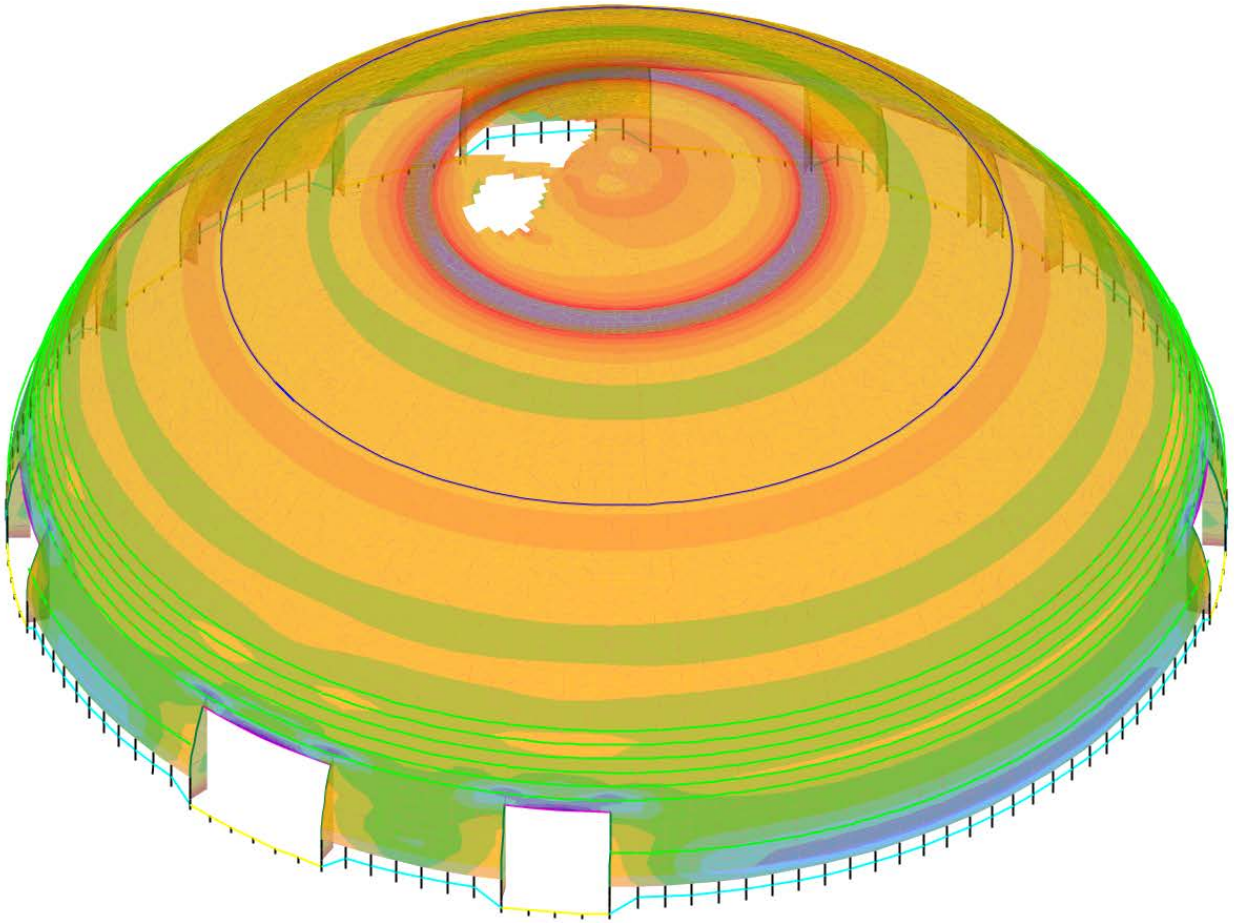


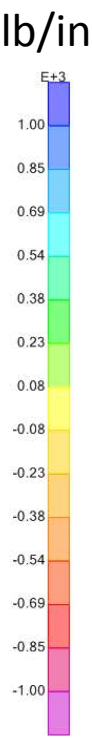

1'-10"
4'-9"
6'-4"
6'-6"
ELEVATION A-A
LOWER DOME DETAILS


Initial and Long-Term Effective Tendon Stress (A-B)
Stress (ksi)
250
200
150
100
50
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
θaverage (deg)

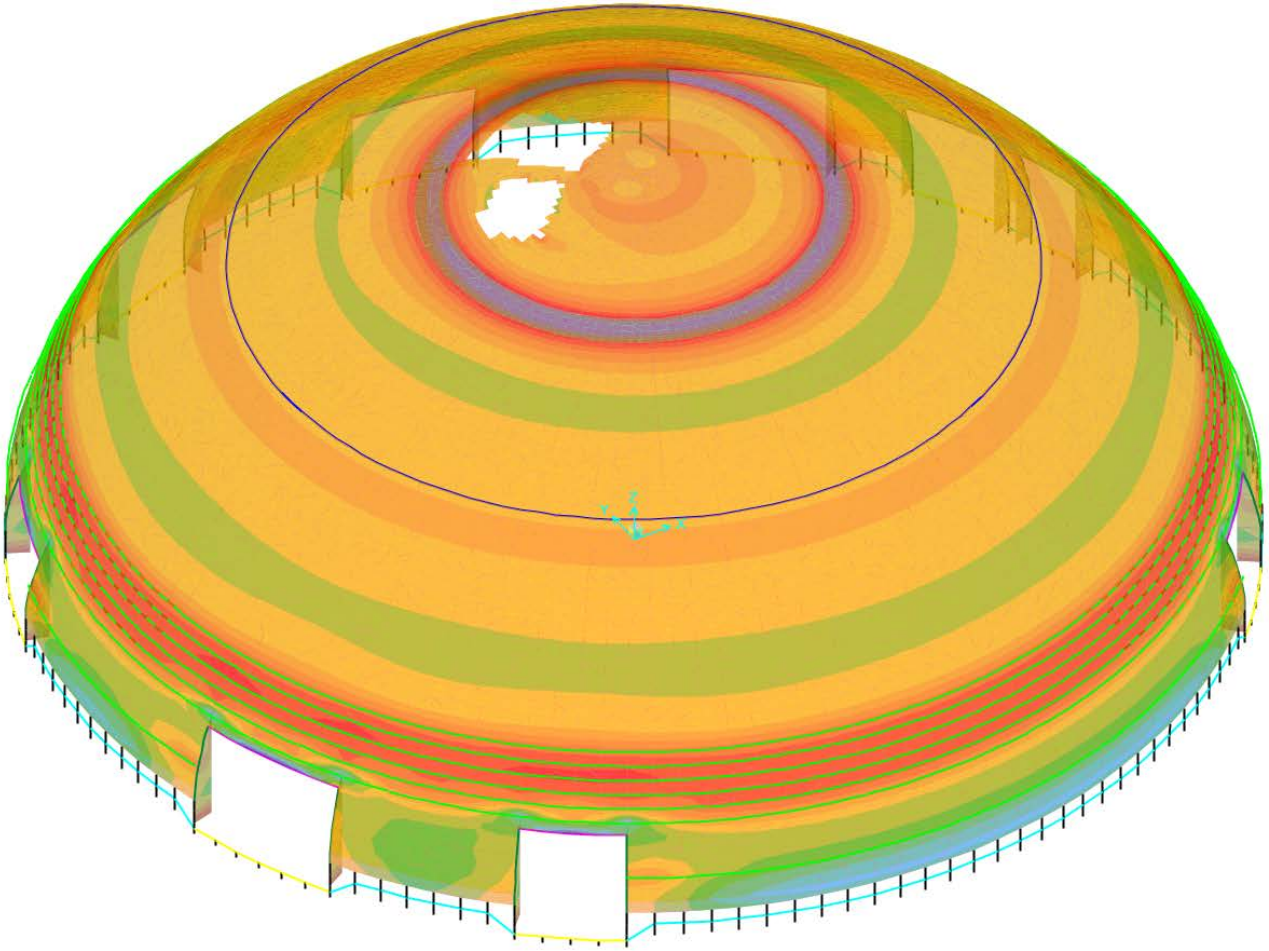

Initial and Long-Term Effective Tendon Stress (C-D)
Stress (ksi)
250
200
150
100
50
0
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
θaverage (deg)

DL — Circumferential Force, F11 (+ = tension)





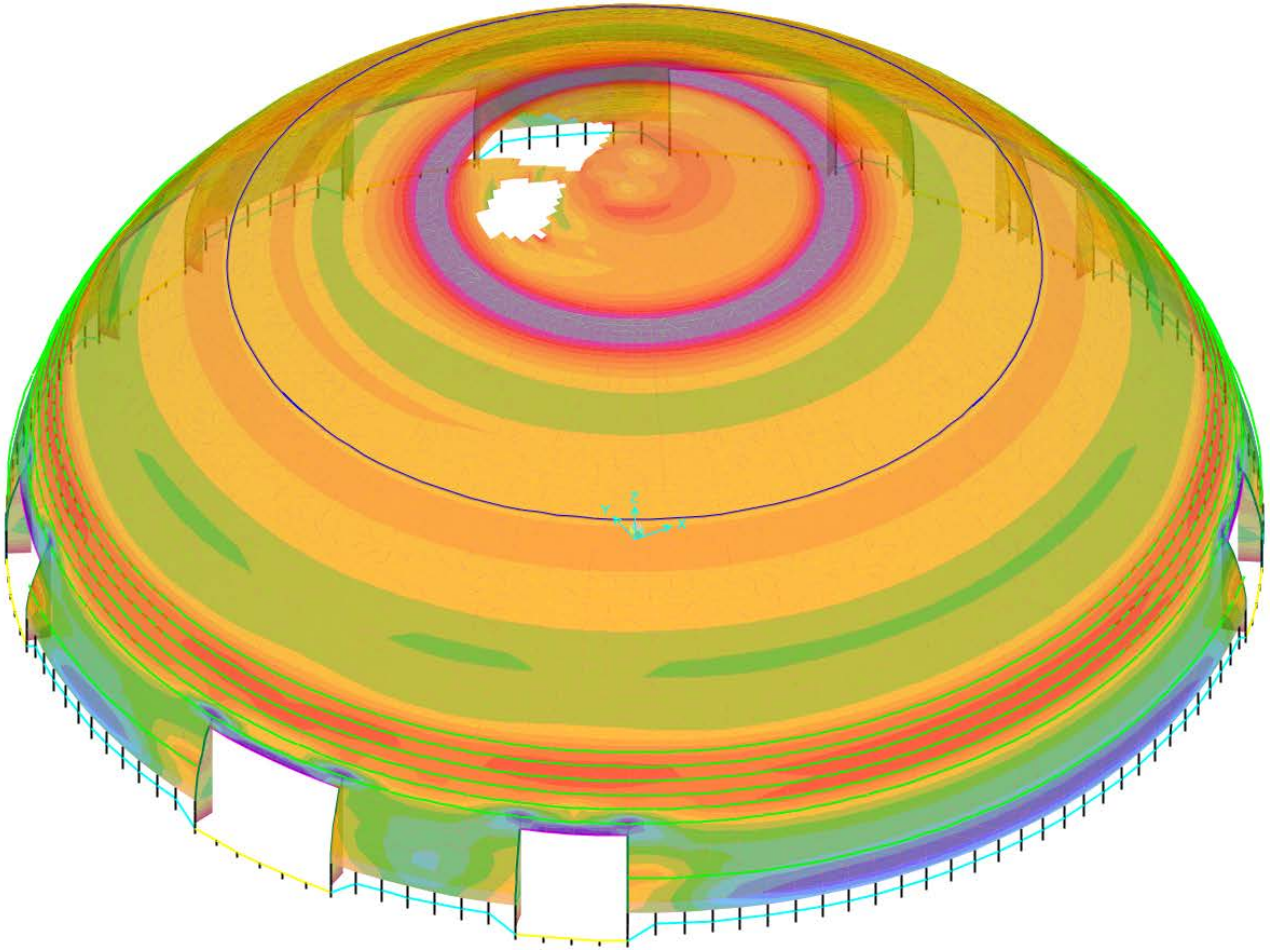
DL + PT — Circumferential Force, F11 (+ = tension)

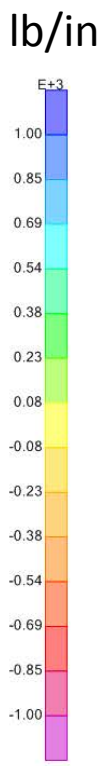


lb/in

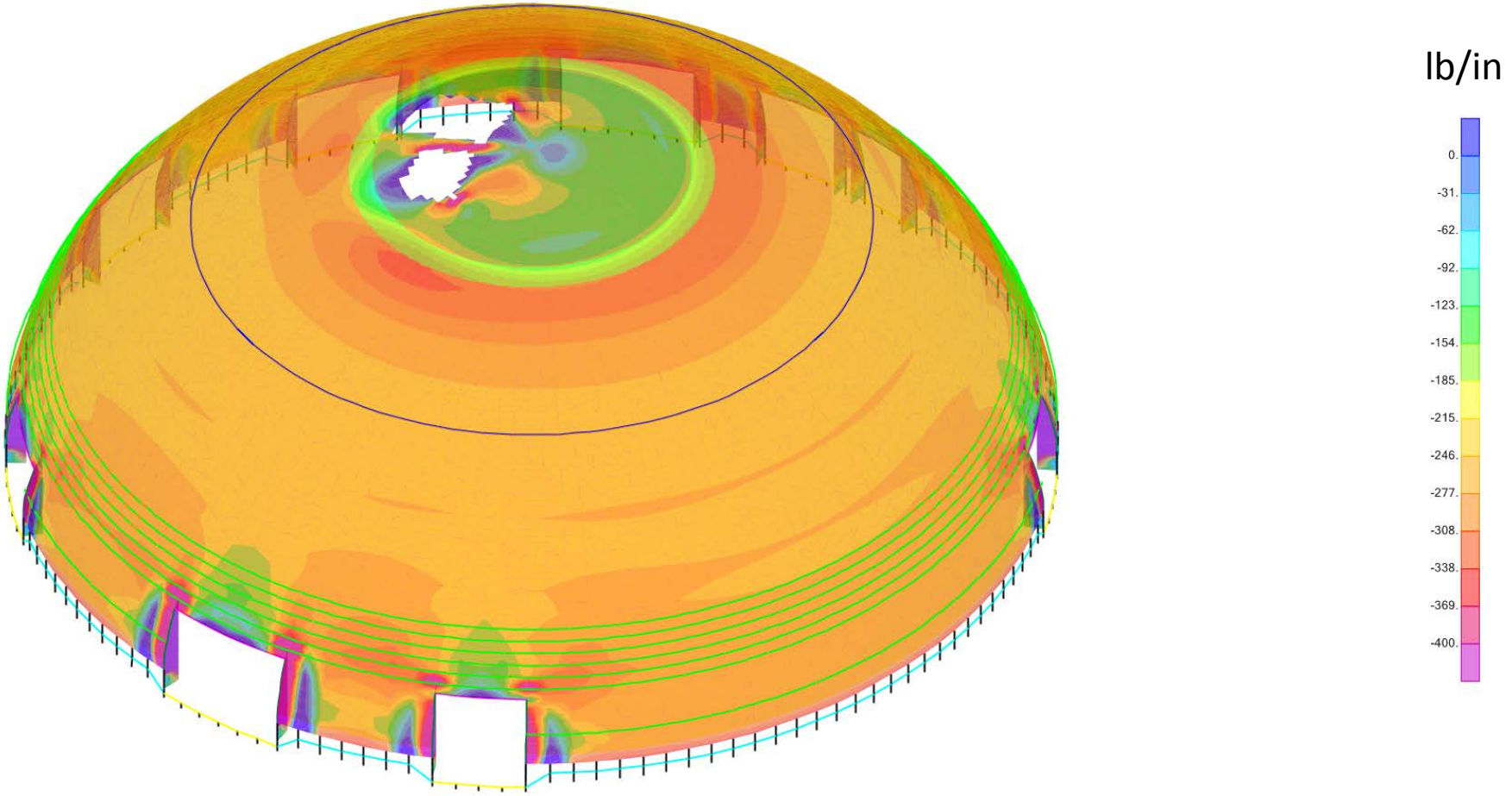
E+3
1.00
0.85
0.69
0.54
0.38
0.23
0.08
-0.08
-0.23
-0.38
-0.54
-0.69
-0.85
-1.00

DL + PT + SL (Bal) — Circumferential Force, F11 (+ = tension)

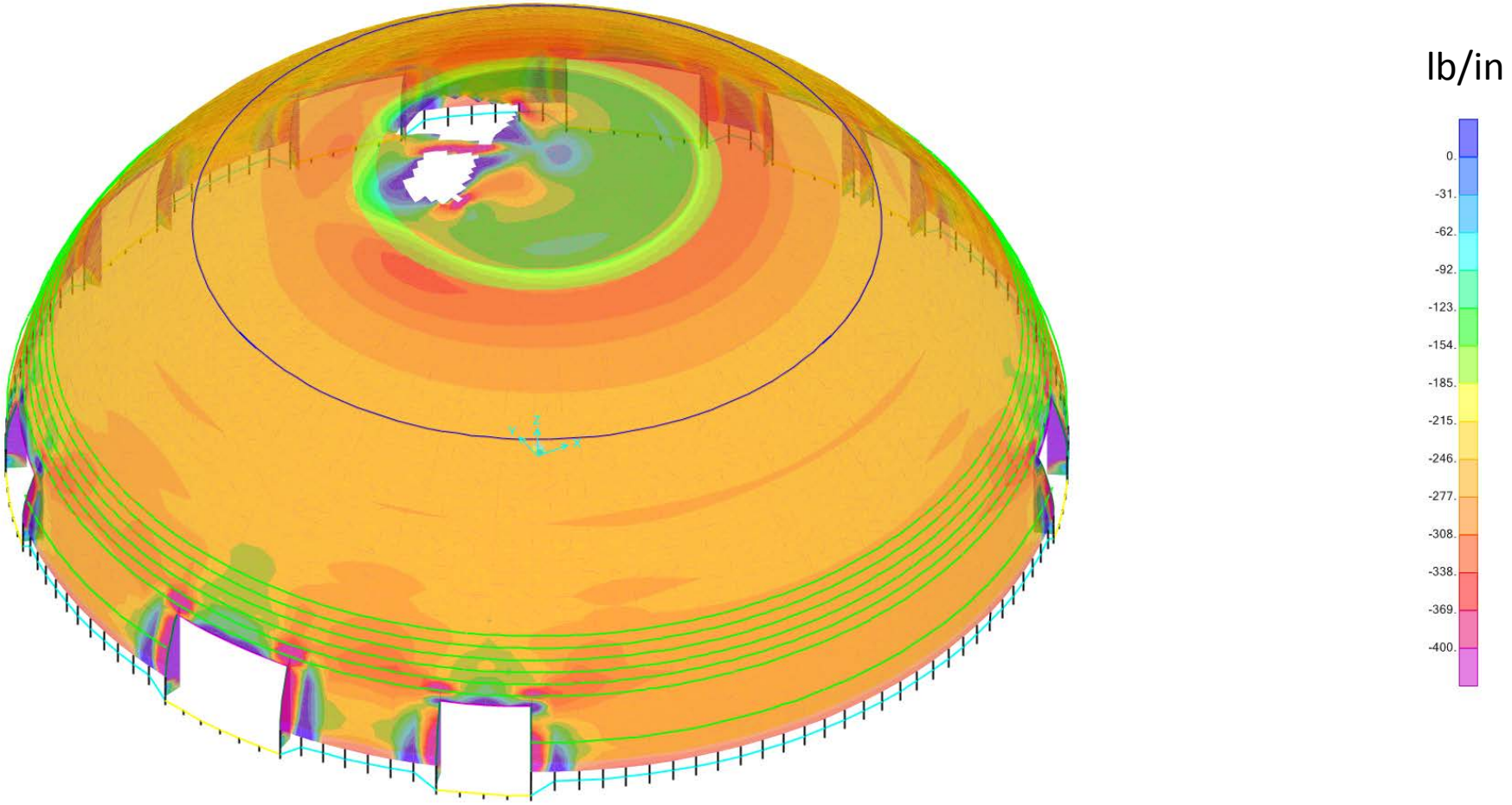




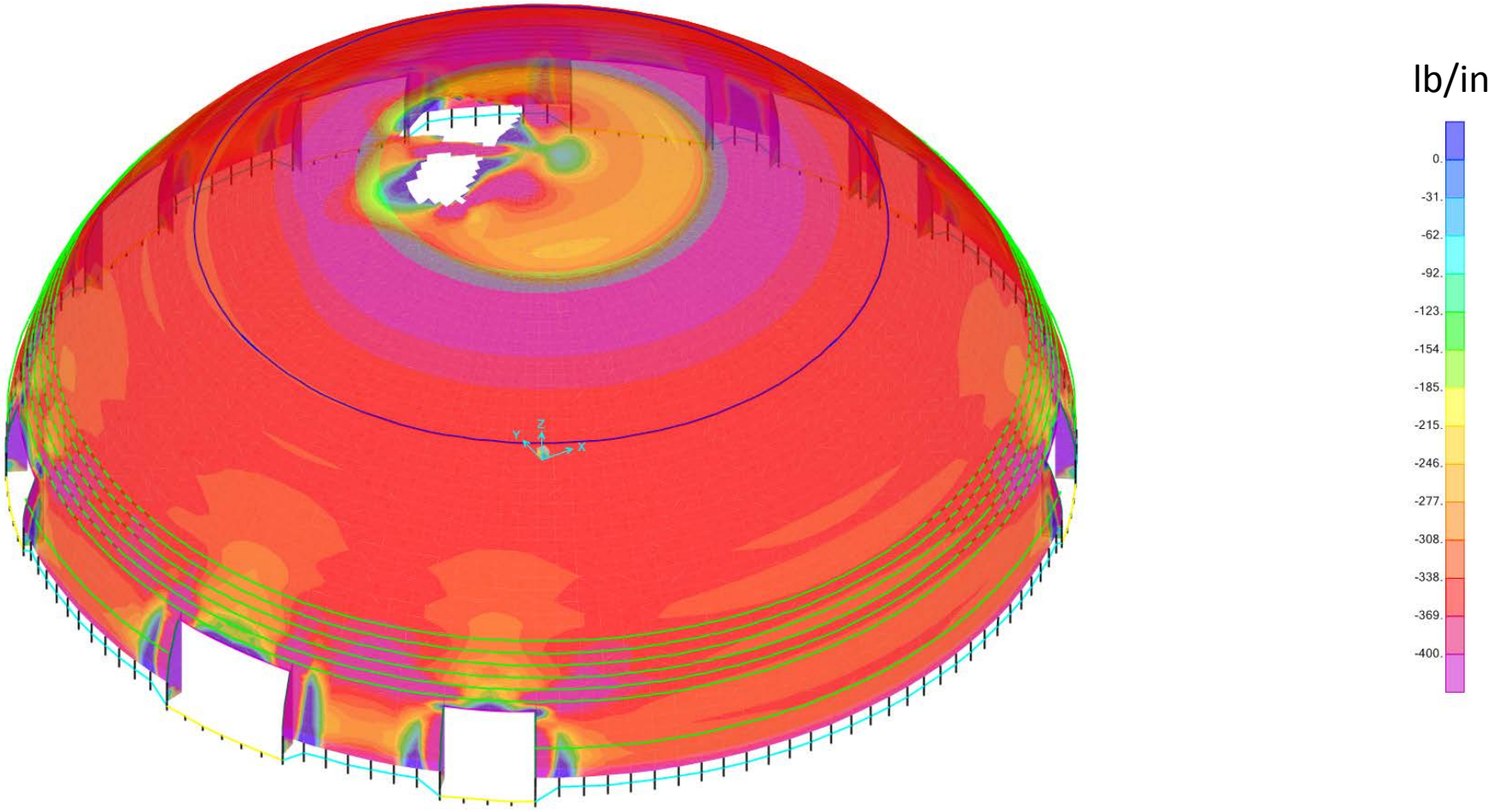
DL — Meridional Force, F22 (+ = tension)



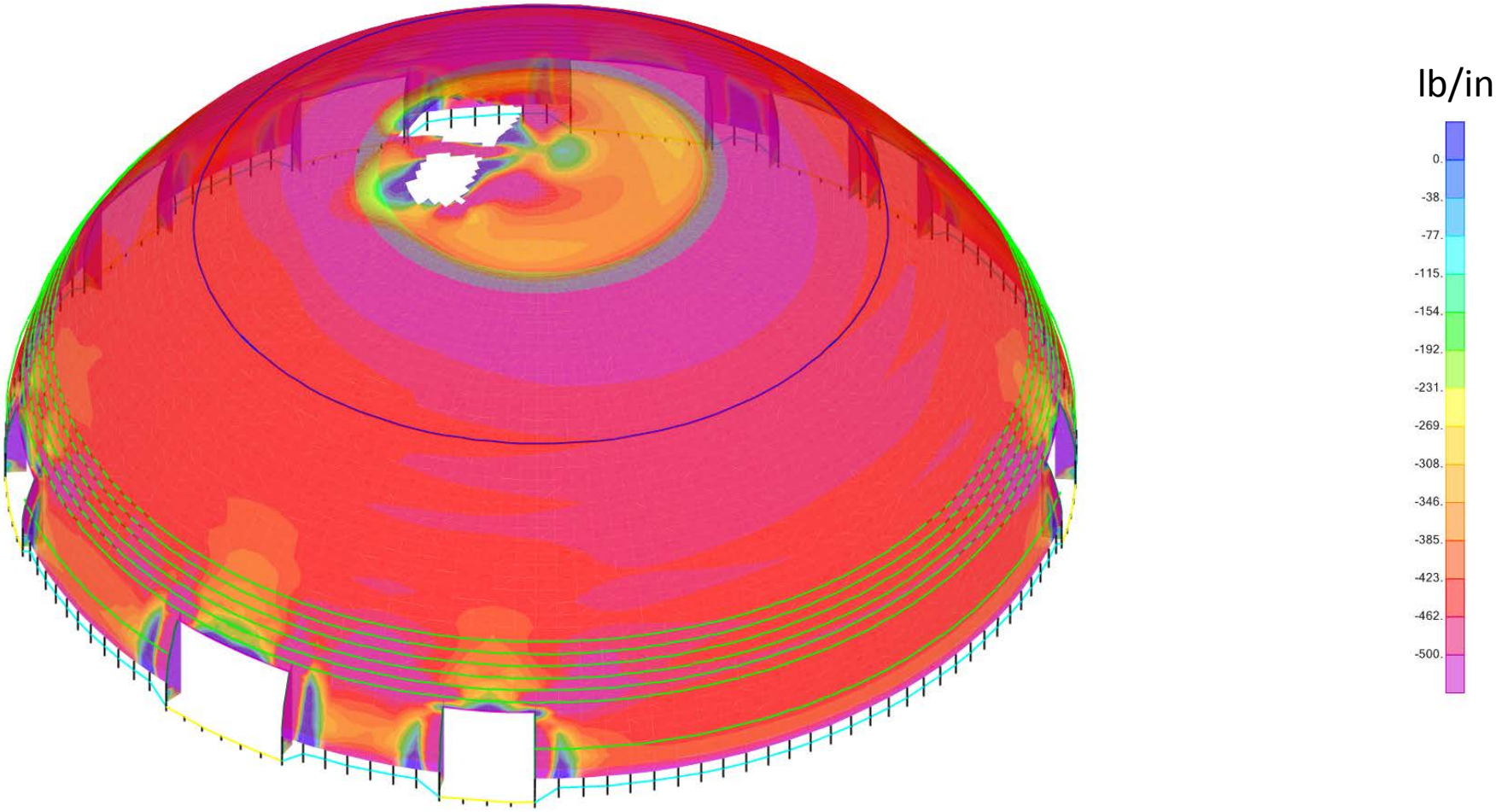
DL + PT — Meridional Force, F22 (+ = tension)

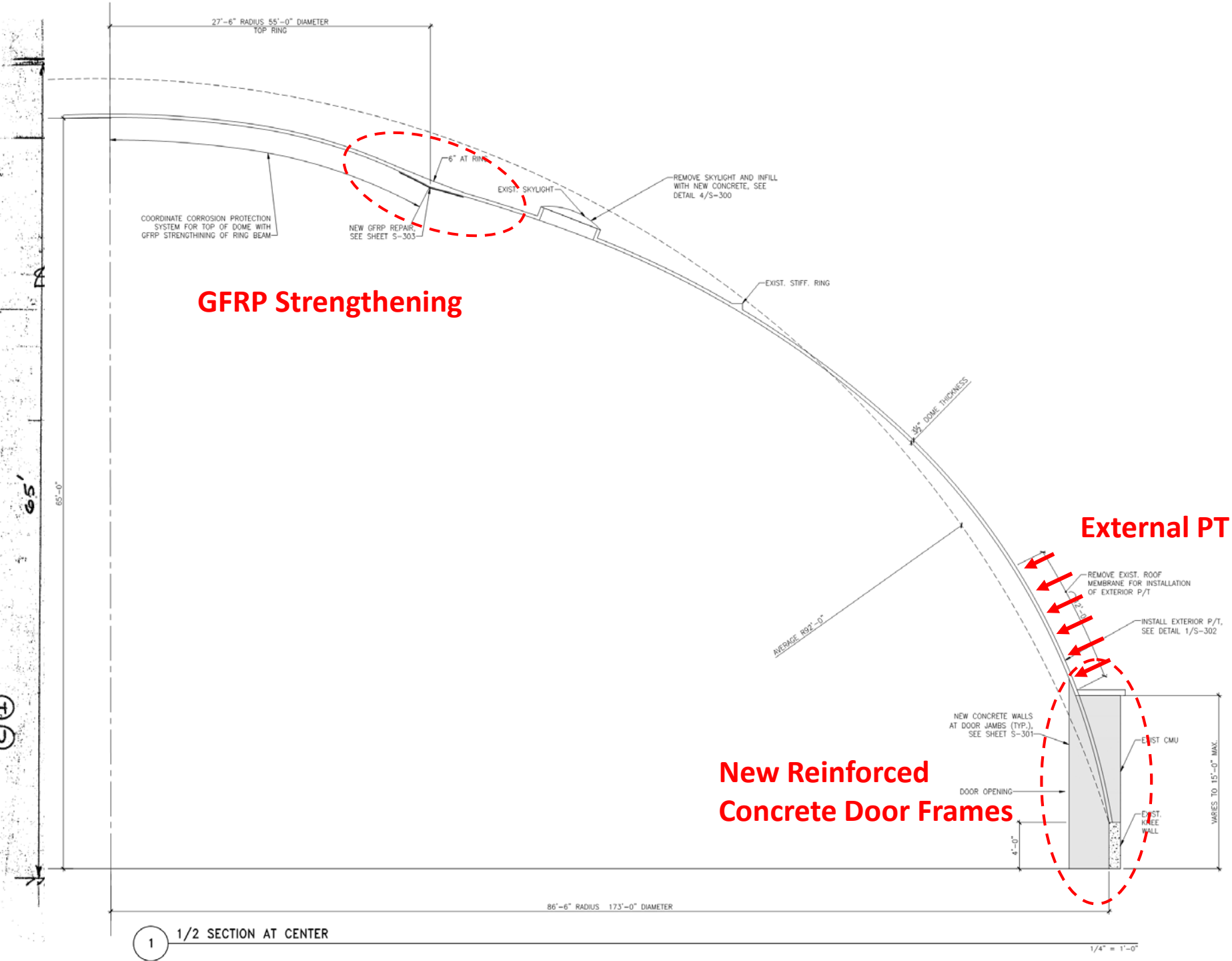


DL + PT + SL (Bal) — Meridional Force, F22 (+ = tension)

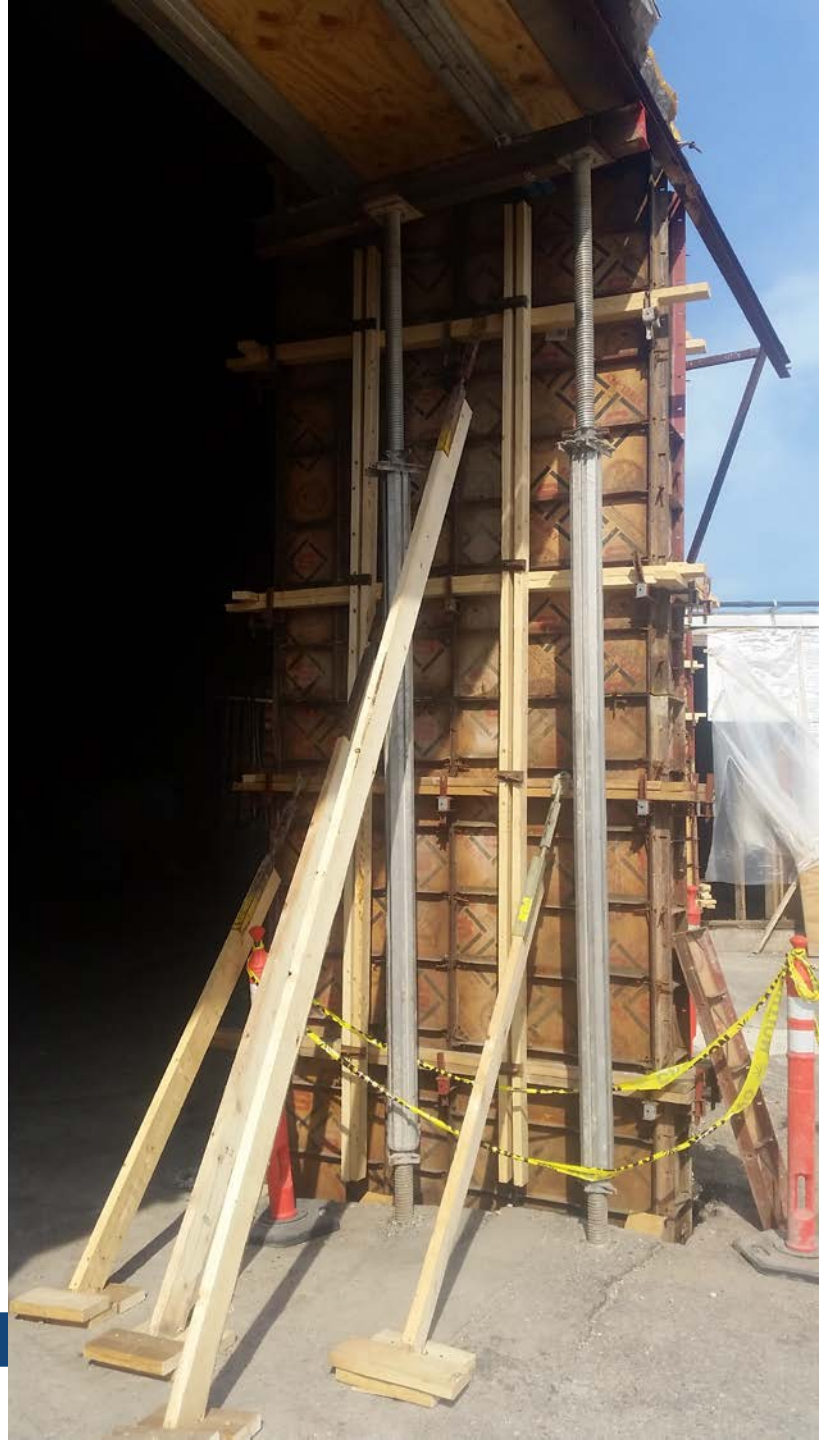


1.2DL+1.0PT+1.6SL(Bal)+0.5WL — Meridional Force, F22 (+ = tension)




27'-6" RADIUS 55'-0" DIAMETER
TOP RING
6" AT RING
EXIST. SKYLIGHT
REMOVE SKYLIGHT AND INFILL WITH NEW CONCRETE, SEE DETAIL 4/S-300
COORDINATE CORROSION PROTECTION SYSTEM FOR TOP OF DOME WITH GFRP STRENGTHINING OF RING BEAM
NEW GFRP REPAIR, SEE SHEET S-303
EXIST. STIFF. RING
GFRP Strengthening
9½" DOME THICKNESS
AVERAGE R92'-0"
External PT
REMOVE EXIST. ROOF MEMBRANE FOR INSTALLATION OF EXTERIOR P/T
INSTALL EXTERIOR P/T, SEE DETAIL 1/S-302
NEW CONCRETE WALLS AT DOOR JAMBS (TYP.), SEE SHEET S-301
EXIST CMU
DOOR OPENING
EXIST. KNEE WALL
4'-0"
VARIES TO 15'-0" MAX.
New Reinforced Concrete Door Frames
65'-0"
86'-6" RADIUS 173'-0" DIAMETER
1 1/2 SECTION AT CENTER
1/4" = 1'-0"


Emulsified grease
Rust between wires
Anchor Corrosion
Broken wires
Pitting behind anchor

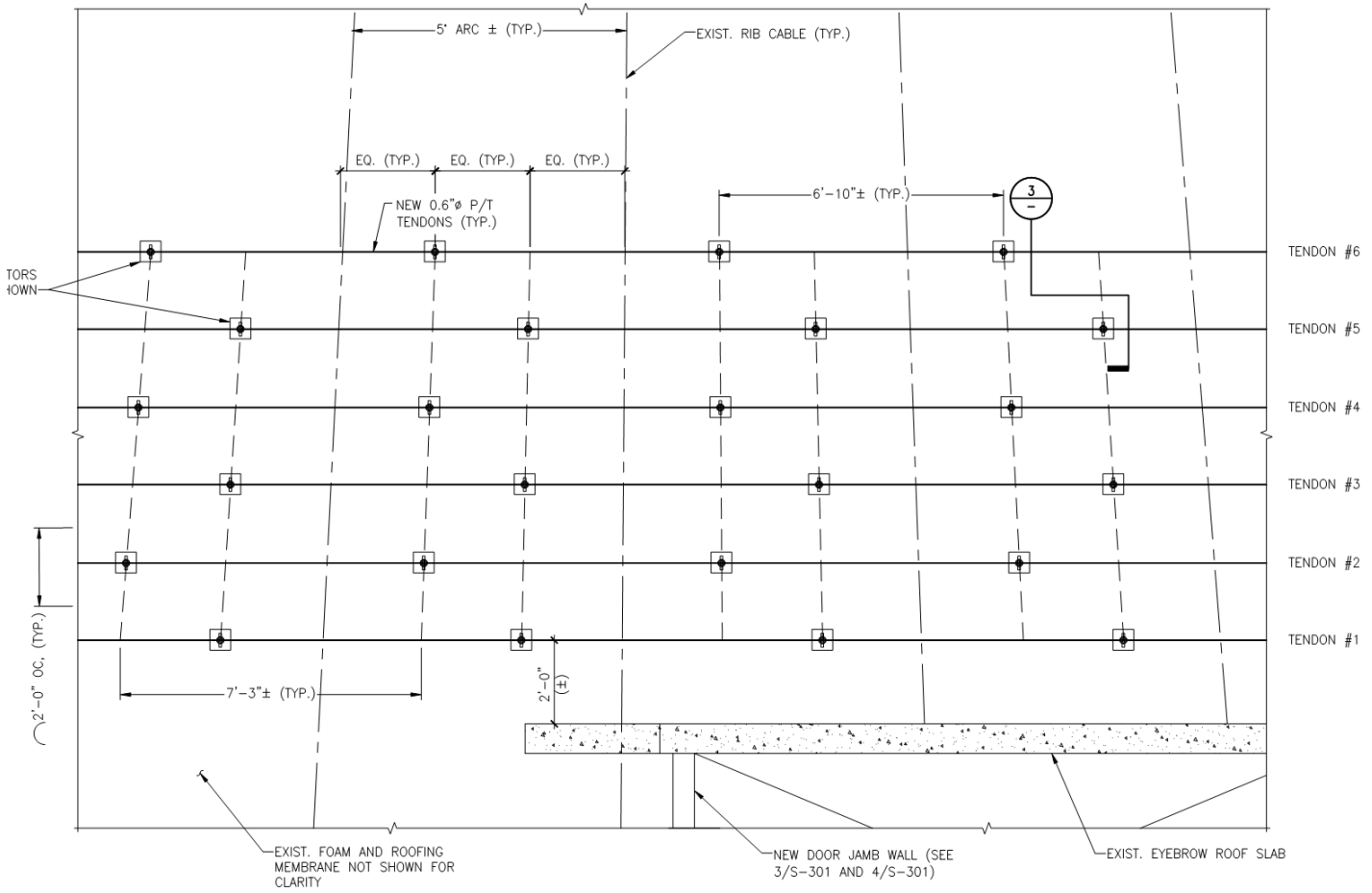


Infill Skylights

Epoxy Injection

GFRP Strengthening

External PT



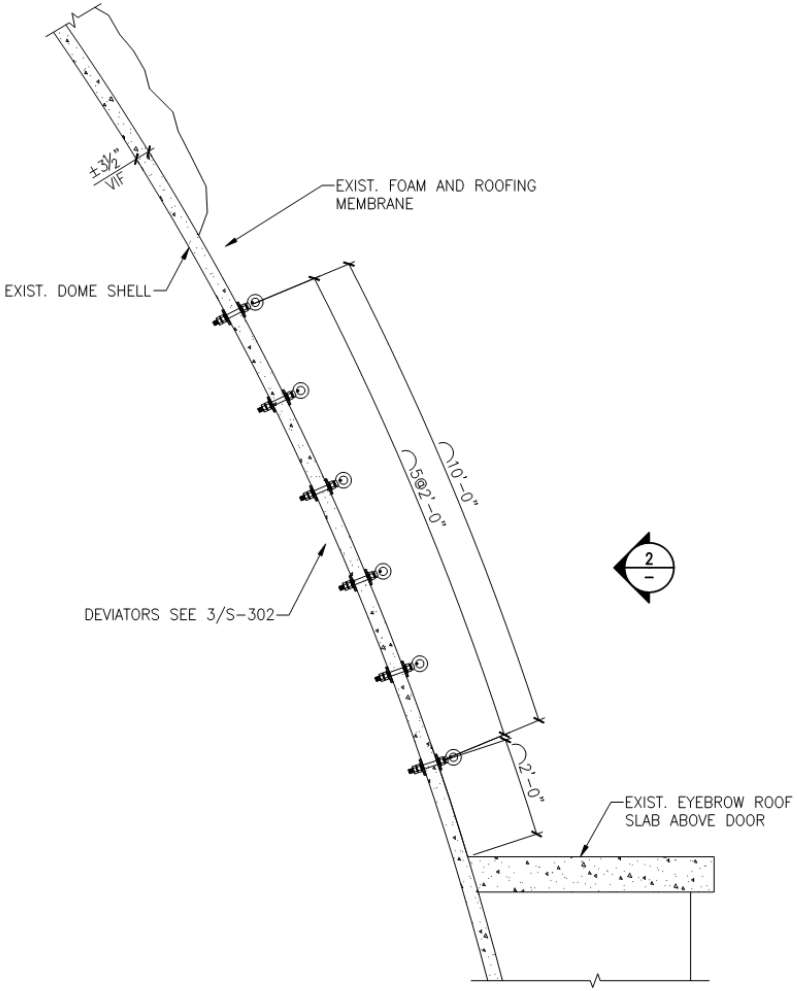
TENDON STRESSING PATTERN			
TENDON NUMBER	% OF MAXIMUM JACKING STRESS		
	STAGE 1	STAGE 2	STAGE 3
1	(1) 50%		(9) 100%
2		(6) 100%	
3	(2) 50%		(8) 100%
4		(5) 100%	
5	(3) 50%		(7) 100%
6		(4) 100%	

NOTES:

1. (#) = ORDER OF TENDON STRESSING

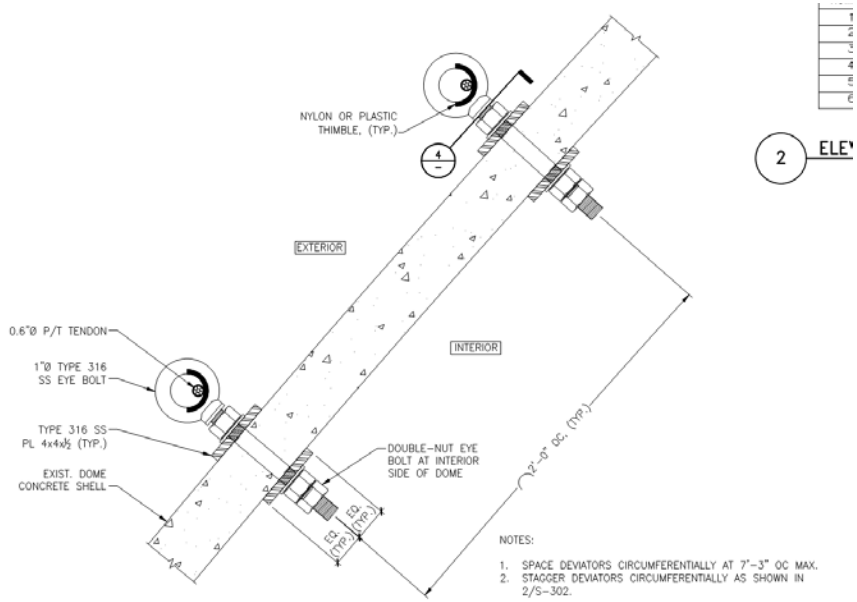
2 ELEVATION OF DEVIATOR LAYOUT

1/2" = 1'-0"



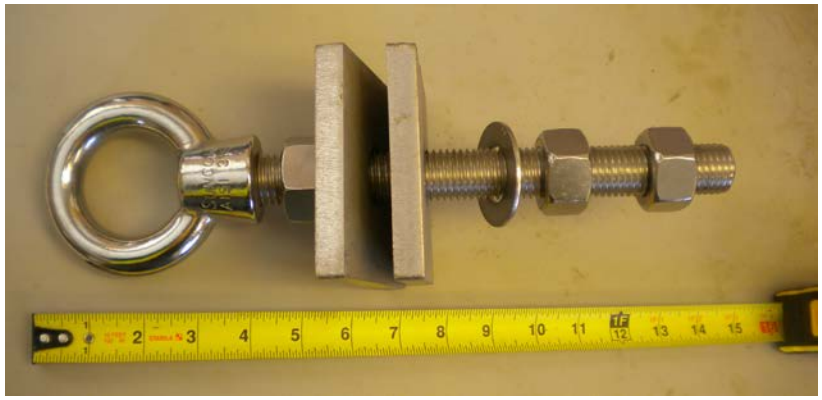
1 SECTION AT DOME (SHOWING NEW DEVIATORS)

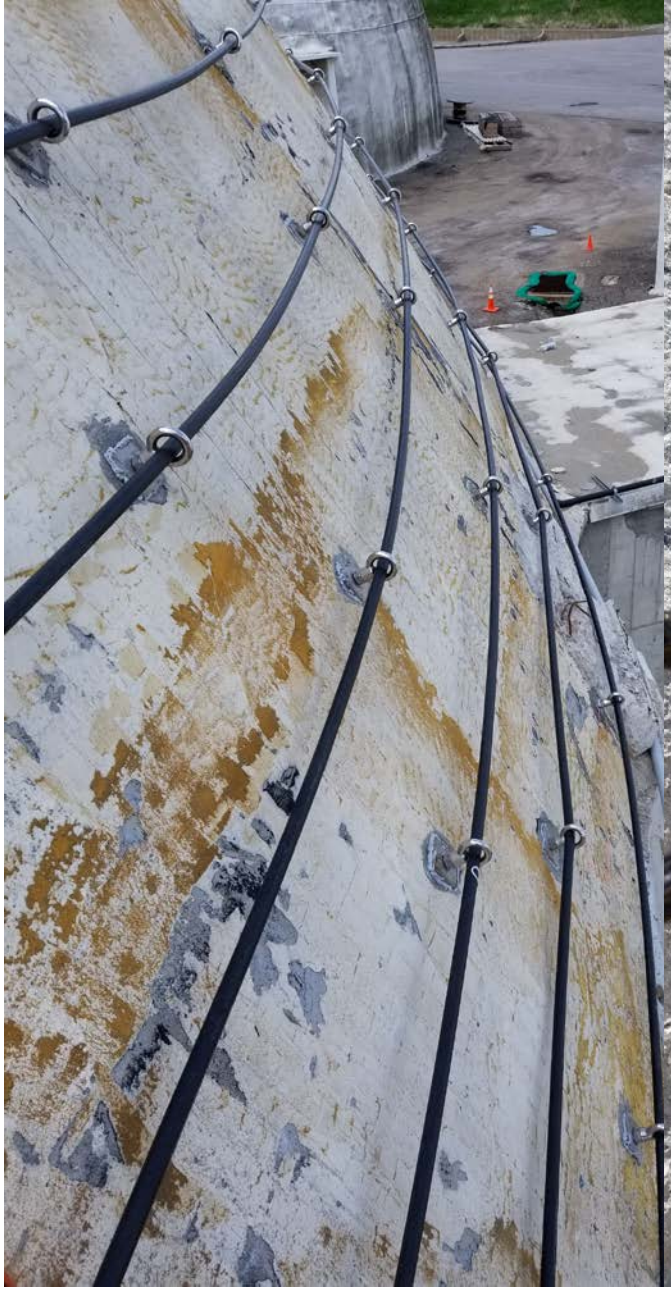
1/2" = 1'-0"



3 P/T DEVIATOR DETAIL

3" = 1'-0"






JLG LIFT
United Rentals


VOID


United Rentals
1-800-UR-RENTS

Keys to Success

- Teamwork
  - Owner
  - Production staff
  - Structural engineer staff
  - Construction team
  - Suppliers
- Evaluation to identify root cause of distress
- Proper structural analysis and design
- Constructability review during design phase
- Industrial safety mentality

Questions?

Matt Miltenberger, P.E.
Vector Corrosion Services, Inc.
(813) 501-0050
mattm@vcservices.com