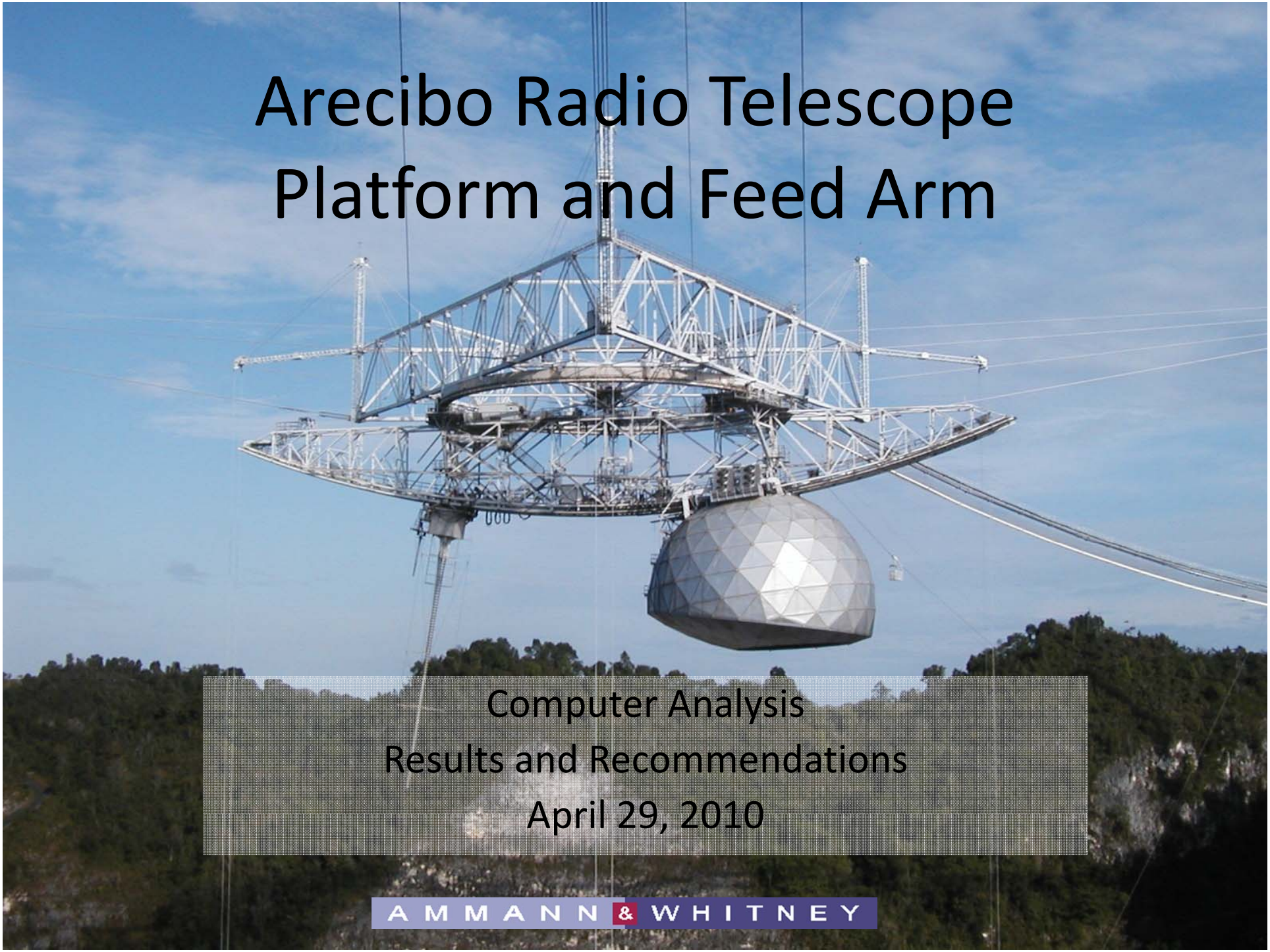


Arecibo Radio Telescope Platform and Feed Arm

Computer Analysis
Results and Recommendations
April 29, 2010

AMMANN & WHITNEY

Operational Conditions

	1963 Design	1992 Reinforcing	2010 Analysis
Unbalanced Moment	N/A	11,500 k-ft	20,000 k-ft
Tie-Down Forces		48 kips min. each	0-30-30 kips
Wind Considerations	30 mph	50 mph (5.6 psf)	28 mph (2 psf)
Gregorian Weight	N/A	180 kips	210 kips
Platform Dead Load	1250 kips (includes upgrades)	+ 472 kips - Greg. Upgrade Total **1722 kips**	**1798 kips** (2006 Sag Survey)

CABLE TENSIONS – STRENGTHENED CABLE SYSTEM

CABLES MK	101	102	103	104	301	302	303	304	305
NO.	12	5	5	5	6	2	2	2	6
DIAMETER	3"	3 1/4"	3 1/4"	3 1/4"	3 1/4"	3 5/8"	3 5/8"	3 5/8"	1 1/2"
MINIMUM BREAKING STRENGTH (KIPS)	1044	1212	1212	1212	1314	1614	1614	1614	290
TENSION PER CABLE (I) INITIAL TENSION UNDER ALL DEAD LOADS									
EXISTING *	527	593	541	566	—	—	—	—	—
INITIAL ERECTION	307	381	351	354	450	544	485	544	2.5
FINAL	480	543	503	511	602	728	662	727	21
(II) OPERATIONAL LOADS	493	561	519	530	615	746	678	743	50
(III) SURVIVAL CONDITION	498	577	532	540	622	769	698	760	2.5
DESCRIPTION	MAIN CABLES	MAIN BACKSTAY CABLES			AUX. CABLES	AUX. BACKSTAY CABLES			TIE DOWNS
	EXISTING				NEW				

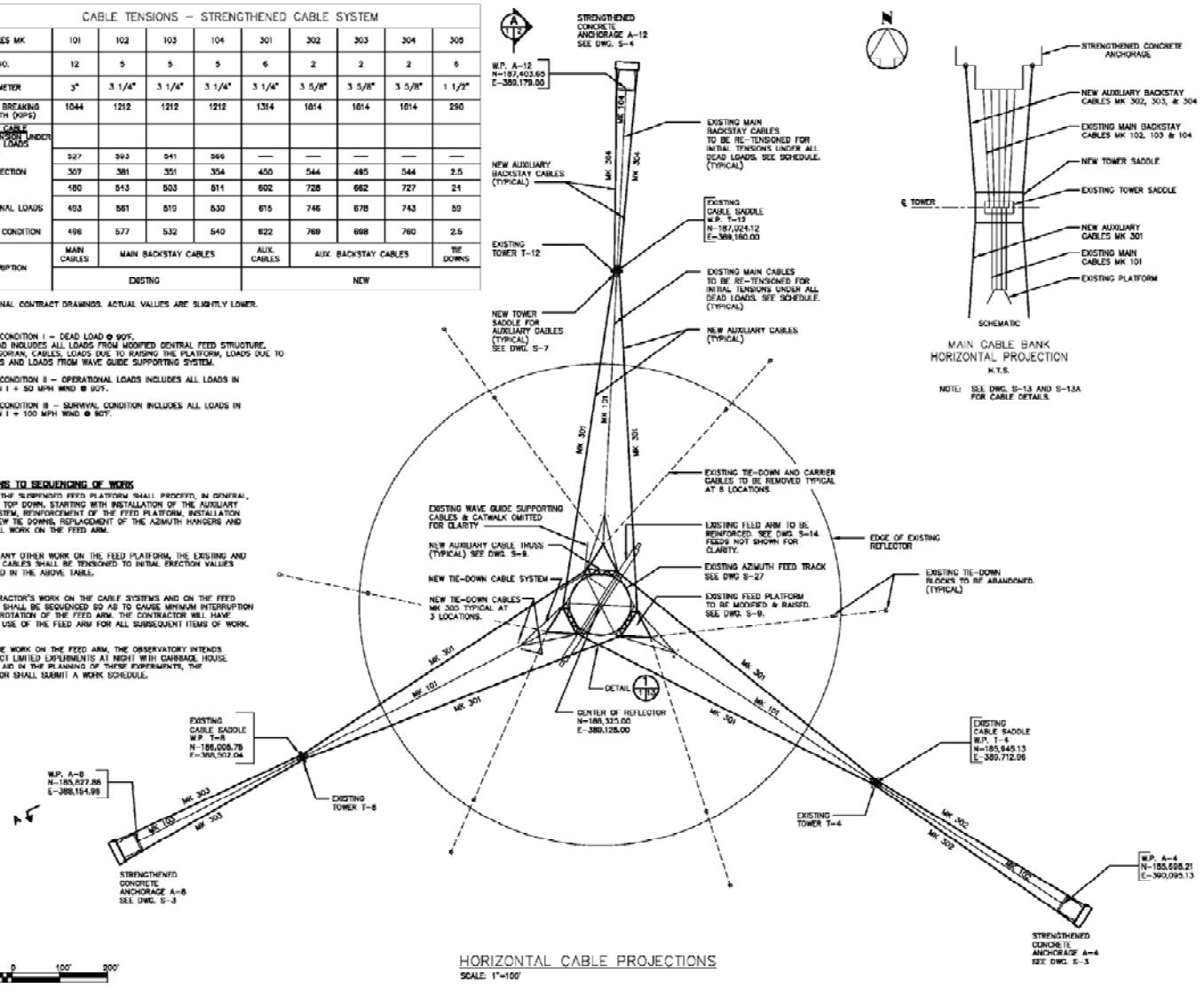
* FROM ORIGINAL CONTRACT DRAWINGS. ACTUAL VALUES ARE SLIGHTLY LOWER.

NOTES

1. LOADING CONDITION I – DEAD LOAD @ 90°F.
   DEAD LOAD INCLUDES ALL LOADS FROM MODIFIED GENTRAL FEED STRUCTURE, NEW GREGORIAN, CABLES, LOADS DUE TO RAISING THE PLATFORM, LOADS DUE TO TIE DOWNS AND LOADS FROM WAVE GUIDE SUPPORTING SYSTEM.
2. LOADING CONDITION II – OPERATIONAL LOADS INCLUDES ALL LOADS IN CONDITION I + 50 MPH WIND @ 90°F.
3. LOADING CONDITION III – SURVIVAL CONDITION INCLUDES ALL LOADS IN CONDITION I + 100 MPH WIND @ 90°F.

RESTRICTIONS TO SEQUENCING OF WORK

1. WORK ON THE SUSPENDED FEED PLATFORM SHALL PROCEED, IN GENERAL, FROM THE TOP DOWN, STARTING WITH INSTALLATION OF THE AUXILIARY CABLE SYSTEM, REINFORCEMENT OF THE FEED PLATFORM, INSTALLATION OF THE NEW TIE DOWNS, REPLACEMENT OF THE AZIMUTH HANGERS AND LASTLY ALL WORK ON THE FEED ARM.
2. PRIOR TO ANY OTHER WORK ON THE FEED PLATFORM, THE EXISTING AND AUXILIARY CABLES SHALL BE TENSIONED TO INITIAL ERECTION VALUES PRESCRIBED IN THE ABOVE TABLE.
3. THE CONTRACTOR'S WORK ON THE CABLE SYSTEMS AND ON THE FEED PLATFORM SHALL BE SEQUENCED SO AS TO CAUSE MINIMUM INTERRUPTION WITH THE ROTATION OF THE FEED ARM. THE CONTRACTOR WILL HAVE UNLIMITED USE OF THE FEED ARM FOR ALL SUBSEQUENT ITEMS OF WORK.
4. DURING THE WORK ON THE FEED ARM, THE OBSERVATORY INTENDS TO CONDUCT LIMITED EXPERIMENTS AT NIGHT WITH CARIBBEAN HOUSE NO. 1. TO AID IN THE PLANNING OF THESE EXPERIMENTS, THE CONTRACTOR SHALL SUBMIT A WORK SCHEDULE.



HORIZONTAL CABLE PROJECTIONS

SCALE: 1"=100'

MAIN CABLE BANK
HORIZONTAL PROJECTION
N.T.S.

NOTE: SEE DWG. S-13 AND S-13A FOR CABLE DETAILS.

GENERAL NOTES

(UNLESS OTHERWISE SHOWN OR NOTED)

1. ELEVATIONS ARE IN FEET AND BASED ON THE USGS DATUM FOR PUERTO RICO, FOR WHICH MEAN SEA LEVEL IS 0.00 FT.
2. WORK POINT COORDINATES OF THE EXISTING STRUCTURE ARE IN FEET AND BASED ON THE PUERTO RICO DATUM, LAMBERT PROJECTION, PUERTO RICO ZONE.
3. STRUCTURAL STEEL SHAPES AND PLATES SHALL CONFORM TO ASTM STANDARD A572 GRADE 50.
4. SQUARE AND RECTANGULAR STRUCTURAL TUBING SHALL CONFORM TO ASTM STANDARD A500 GRADE B.
5. STRUCTURAL STEEL PIPE SHALL CONFORM TO ASTM STANDARD A501.
6. STEEL CASTINGS SHALL CONFORM TO ASTM STANDARD A148 GRADE 80-60.
7. THREADED RODS SHALL CONFORM TO ASTM STANDARD A576 GRADE 1045. NORMALIZE TO MIN. YIELD OF 50 KSI AND MIN. ULT. 90 KSI. MAGNAFLUX TO ASTM E138 (CIRCULAR AND LONGITUDINAL MAGNETIZATION REQUIRED.)
8. ALL BOLTED CONNECTIONS SHALL BE MADE OF HIGH STRENGTH STEEL BOLTS, FRICTION TYPE, TIGHTENED BY THE TURN-OF-THE-NUT METHOD. BOLTS, NUTS, AND WASHERS SHALL CONFORM TO ASTM STANDARD A325.
9. ALL HIGH STRENGTH STEEL BOLTS TO BE 7/8 INCH DIAMETER EXCEPT AS NOTED.
10. STRUCTURAL STRAND SHALL CONFORM TO ASTM STANDARD A586 PREMIUM GRADE WITH CLASS A GALVANIZED COATING ON ALL WIRES.
11. PIN HOLES SHALL BE REAMED WITH PLATES FULLY ASSEMBLED.
12. WELDING SHALL CONFORM TO AMERICAN WELDING SOCIETY STANDARD D1.1 (BRIDGE SPECIFICATIONS SHALL GOVERN.)
13. ALL FULL PENETRATION WELDS SHALL BE TESTED ULTRASONICALLY.
14. ALL CABLE END FITTINGS, END BLOCKS RODS, PINS AND ACCESSORIES SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A123 OR A153, AS APPLICABLE.
15. ALL PINS SHALL BE FORGED STEEL CONFORMING TO ASTM A521 CLASS AC. SEE TYPICAL DETAIL ON DRAWING S-13.
16. FOR ALL PAINTING SYSTEMS REFER TO SPECIFICATIONS.
17. FIELD WELDS SHALL BE MADE WITH E7018 LOW HYDROGEN ELECTRODES.
18. ALL CONCRETE SHALL BE NORMAL WEIGHT STONE CONCRETE WITH A MINIMUM COMPRESSIVE STRENGTH OF 3000 PSI AFTER 28 DAYS.
19. CONCRETE REINFORCEMENT SHALL BE GRADE 60 DEFORMED BARS CONFORMING TO ASTM STANDARD A615.
20. REINFORCING SHALL BE DETAILED ACCORDING TO THE MANUAL OF STANDARDS FOR DETAILING CONCRETE REINFORCEMENT ACI – 315.
21. CABLE END FITTINGS SHALL BE PROOF LOADED TO 50% OF THE SPECIFIED BREAKING STRENGTH.
22. THE CONTRACTOR SHALL SUBMIT FOR APPROVAL BY THE ENGINEER, WORKING DRAWINGS SHOWING ERECTION SEQUENCES AND PROCEDURES, STRUCTURAL ELEMENTS, CONNECTIONS, AND ALL RELATED DETAILS.
23. SHOP DRAWINGS OF THE EXISTING STRUCTURE WILL BE MADE AVAILABLE. THE CONTRACTOR IS EXPECTED TO WORK THESE SHOP DRAWINGS IN CONJUNCTION WITH THE CONTRACT DOCUMENTS. IT WILL BE THE CONTRACTOR'S RESPONSIBILITY TO VERIFY ALL EXISTING CONDITIONS IN THE FIELD BEFORE PROCEEDING WITH FABRICATION.
24. ALUMINUM PLATES AND SHAPES SHALL BE 6061-T6.
25. FASTENERS FOR ALUMINUM SHAPES AND PLATES SHALL CONFORM TO ASTM A193 CLASS 2, GR. B8T OR GR. B8M.
26. WELDING FOR ALUMINUM SHALL BE IN ACCORDANCE WITH THE ALUMINUM STRUCTURAL WELDING CODE ANSI/AWS D1.2-90.

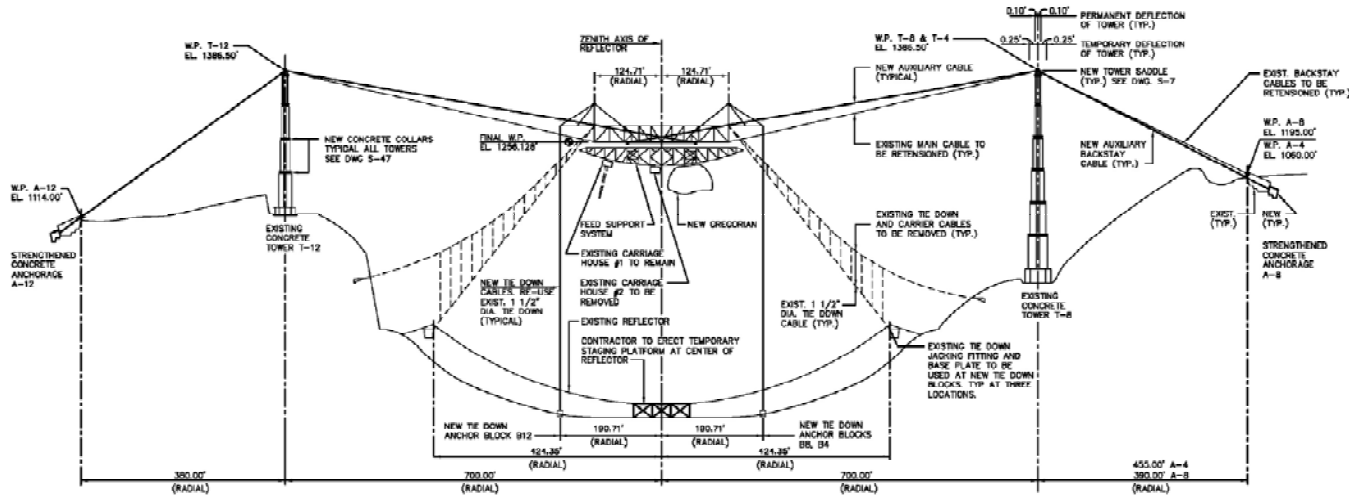
NATIONAL ASTRONOMY AND IONOSPHERE CENTER
CORNELL UNIVERSITY
ARECIBO RADIO OBSERVATORY
GREGORIAN UPGRADING

GENERAL I

AMMANN & WHITNEY, CONSULTING ENGINEERS
NEW YORK, NEW YORK

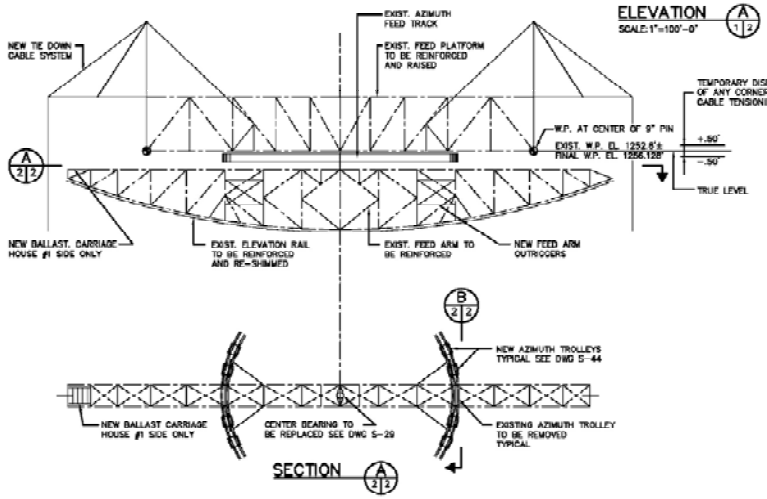
DRAWN BY:	APPROVED	DATE:
DESIGNED BY:		SCALE: 1"=100'
CHECKED BY:		DWG. NO. S-1

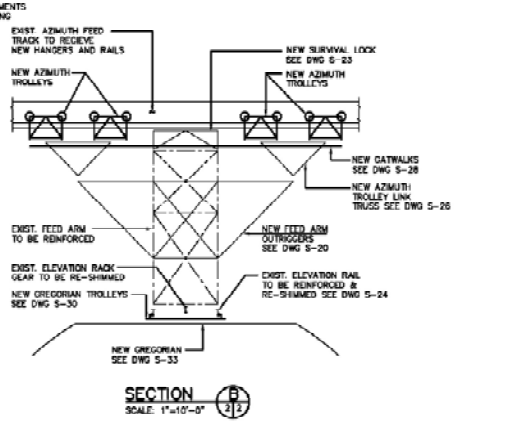
FILE @ARG1



NOTES:

1. CONTRACTOR SHALL MONITOR TOWER DEFLECTIONS DURING CONSTRUCTION TO ASSURE GIVEN TOLERANCES ARE NOT EXCEEDED.
2. DURING THE CABLE TENSIONING OPERATION CONTRACTOR SHALL MONITOR AND RECORD CABLE TENSIONS IN ALL STRANDS BY A.) DIRECT READING OF THE RAM PRESSURES IN THE JACKING SYSTEM AND B). BY A BACKUP SYSTEM CONSISTING OF EITHER OPTICAL MEASURING OF THE CABLE SAGS OR BY STRAIN GAUGES (TENSIONMETERS) ON THE STRANDS.





FEED SUPPORT SYSTEM

100' 50' 0 100' 200'

FEED SUPPORT SYSTEM BALANCING REQUIREMENTS AND USE LIMITATIONS

1- WITH EQUAL TIE DOWN TENSIONS AT EACH APEX, THE PLATFORM SHALL BE LEVEL WITH THE GREGORIAN AT 10 DEGREES APPROXIMATELY AND CARRIAGE HOUSE 1 AT 13 DEGREES APPROXIMATELY.

2- FEED ARM COUNTERWEIGHT GROSS WEIGHT SHALL NOT EXCEED 54 KIPS. FINAL COUNTERWEIGHT LOAD WILL DEPEND UPON THE FINAL WEIGHT OF THE GREGORIAN AND THE WEIGHT AND POSITION OF THE FAN COIL UNITS, PUMPS AND ARTICULATED ARM ON THE FEED ARM.

3- CARRIAGE HOUSE 1 MAY BE LOADED TO A GROSS WEIGHT OF 40 KIPS MAXIMUM. THE GROSS WEIGHT OF THE GREGORIAN SHALL NOT EXCEED 180 KIPS.

4- EXCEPT AS OTHERWISE PERMITTED BY NOTES 5 AND 6 BELOW, THE GREGORIAN AND CARRIAGE HOUSE 1 SHALL BE OPERATED IN SLAVE POSITIONS. THIS REQUIREMENT IS MANDATORY FOR STRUCTURAL SAFETY WHEN THE GREGORIAN IS BETWEEN ITS STOW POSITION (7.5 DEGREES) AND 20 DEGREES.

5- WHEN THE GREGORIAN IS STOWED, CARRIAGE HOUSE 1 MAY BE OPERATED OVER ITS NORMAL RANGE BETWEEN MINUS 2 DEGREES (SLIGHTLY ON THE GREGORIAN SIDE) AND 20 DEGREES.

6- WHEN CARRIAGE HOUSE 1 IS STOWED, MOVEMENT OF THE GREGORIAN SHALL BE RESTRICTED BETWEEN THE ZENITH AND ITS STOW POSITION.

7- DURING ACTIVE CONTROL WITH THE TIE DOWN CABLES, THE MAXIMUM TENSION IN ANY TIE DOWN SHALL NOT EXCEED 58 KIPS, BROKEN DOWN AS FOLLOWS PER CABLE:

PRESTRESS AT 90 DEGREES F	– 24 KIPS
ACTIVE PULL DOWN DUE TO 30 DEGREE TEMP DROP	– 15 KIPS
ACTIVE PULL DOWN DUE TO UNBALANCED MOMENT	– 19 KIPS

8- THE AGGREGATE TENSION IN ALL SIX TIE DOWNS SHALL NOT EXCEED 240 KIPS.

9- UNDER STOW CONDITIONS, THE TENSION IN EACH TIE DOWN CABLE SHALL BE REDUCED TO 28 KIPS.

FEED SUPPORT SYSTEM WEIGHT INCREASE TABLE

	(KIPS)
1.0 FEED PLATFORM	
1.1 MAINTRUSS REINFORCEMENT, AUXILIARY CABLE TRUSSES AND CONNECTIONS	70.0
1.2 NEW TIE DOWN CABLE SYSTEM	48.0
1.3 NEW TIE DOWN CABLE PRESTRESS: OPERATIONAL	144.0
SURVIVAL	15.0
OPERATIONAL	262.0
SURVIVAL	148.0
2.0 AZIMUTH FEED TRACK	
2.1 ADDITIONAL AZIMUTH TROLLEYS INCL. DRIVES	53.0
2.2 NEW HANGERS (NET INCREASE)	3.3
2.3 LINK TRUSSES	22.0
	78.3
3.0 FEED ARM	
3.1 REINFORCEMENT	52.0
3.2 OUTRIGGERS	48.0
3.3 ELEVATION RAIL AND RACK GEAR SHIM BLOCKS (NET INCREASE)	5.0
3.4 ELEVATION RAIL GUIDE ANGLES	1.0
3.5 BALLAST PLATFORM AND BALLAST	54.0
3.6 TRANSMITTER EQUIPMENT INCLUD. HEAT EXCHANGERS PUMPS, ARTICULATED ARM, PIPING, CONDUIT, WATER, ETC. (NET INCREASE)	19.0
3.7 CATWALKS AND PLATFORMS (NET INCREASE)	5
3.8 CARRIAGE HOUSE NO. 2 REMOVED	-33.0
	155.5
4.0 EXISTING TIEDOWN CABLES REMOVED	-90.0
5.0 GREGORIAN	
5.1 ALUMINUM DOME INCLUD. BOTT. CAP AND ROOF	42.0
5.2 SECONDARY REFLECTOR INCLUD. BACKUP TRUSSES	26.0
5.3 TERTIARY REFLECTOR	2.0
5.4 GREGORIAN TROLLEYS	11.0
5.5 ELEVATION DRIVE SYSTEM INCLUD. HYDRAULICS	18.0
5.6 SUPERSTRUCTURE INCLUD. LONGITUDINAL TRUSSES, TRANSVERSE BEAMS, COLLAR TRUSS, DRAG LINK BEAMS, GUIDE ROLLERS	37.0
5.7 FEED MODULE INCLUD. FRAMING, WALLS, ROTATING FEED FLOOR, KLYSTRON FLOOR, SERVICE PLATFORM STAIRS AND CATWALKS	12.0
5.8 FEEDS	6.0
5.9 TRANSMITTER EQUIPMENT INCLUD. KLYSTRONS, ELECTRONICS, SWITCH GEAR, CONSOLES, PIPING AND WATER	15.0
5.10 VENTS, FANS, AIRCONDITIONERS	2.0
	170.0
TOTAL INCREASE OPERATIONAL	815.5
TOTAL INCREASE SURVIVAL	496.8

NOTE: CONTRACTOR SHALL PROVIDE OWNER WITH A FINALIZED FEED SUPPORT SYSTEM WEIGHT INVENTORY TO INCLUDE ALL ITEMS ADDED AND ALL ITEMS REMOVED FROM FEED SUPPORT SYSTEM.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER
CORNELL UNIVERSITY
ARECIBO RADIO OBSERVATORY
GREGORIAN UPGRADING

GENERAL II

AMMANN & WHITNEY, CONSULTING ENGINEERS
NEW YORK, NEW YORK

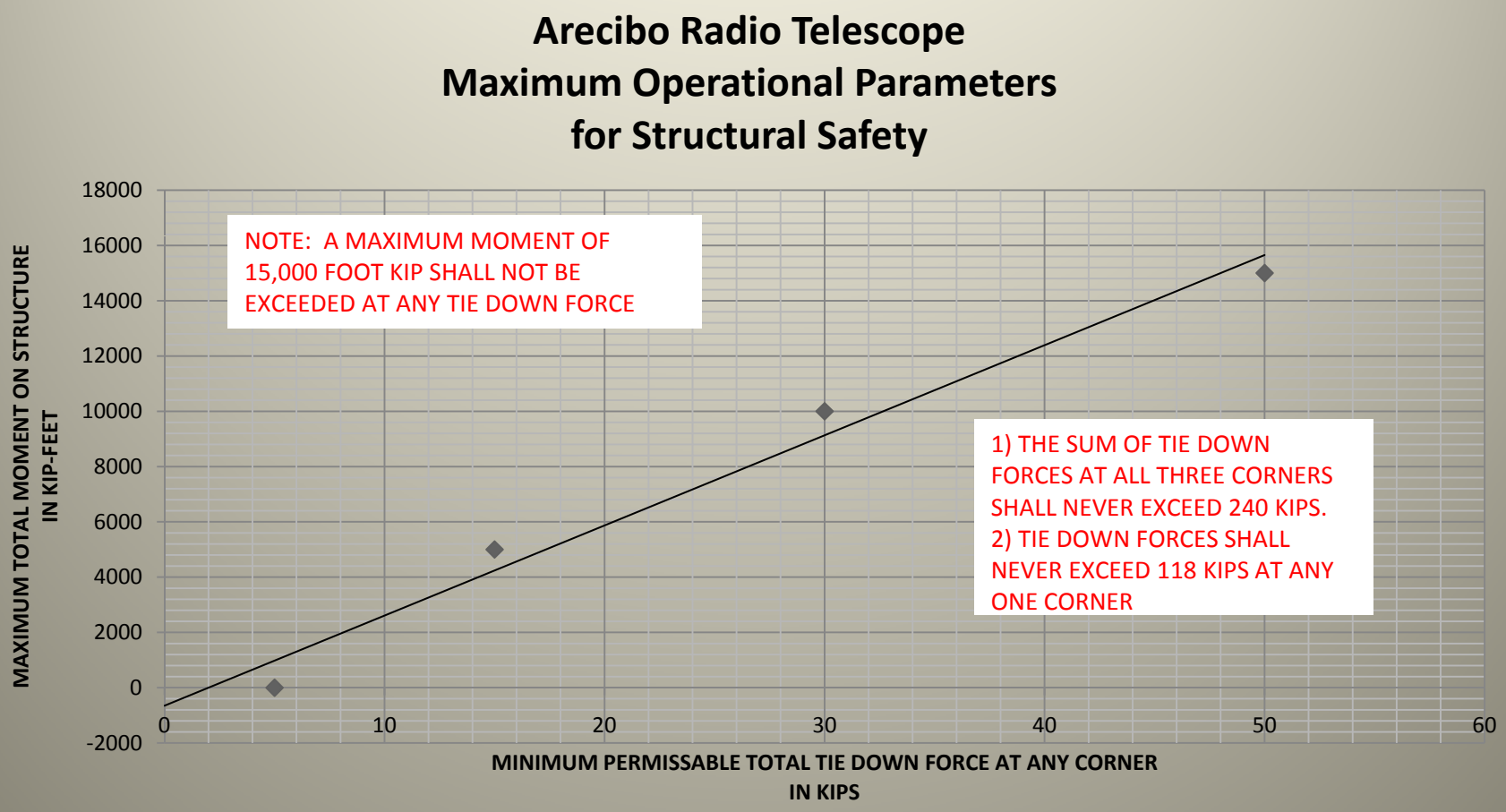
DRAWN BY:	APPROVED	DATE:
DESIGNED BY:		SCALE: AS NOTED
CHECKED BY:		DWG. NO. S-2

FILE BARC2

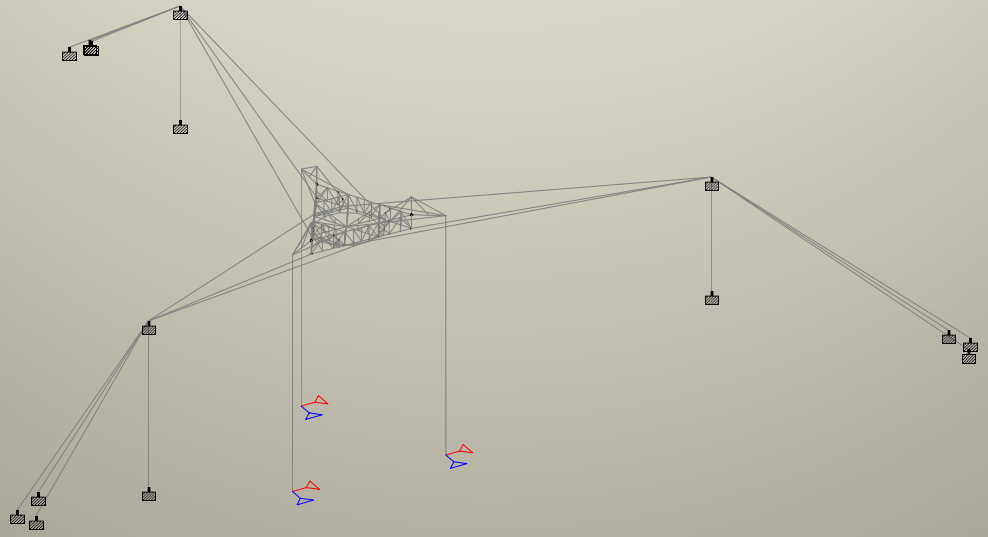

02/03/2010

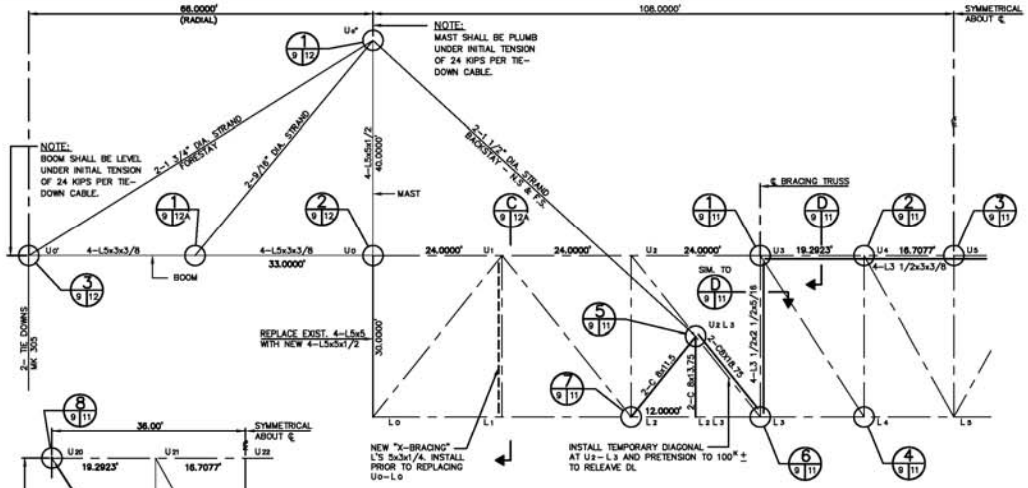

02/03/2010

April 2010 Safe Operating Parameters

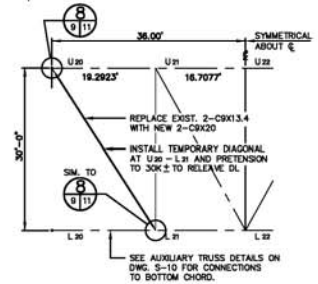


2010 Analysis

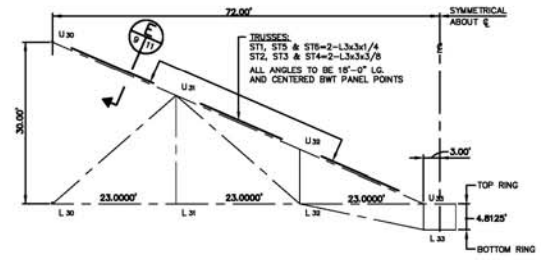




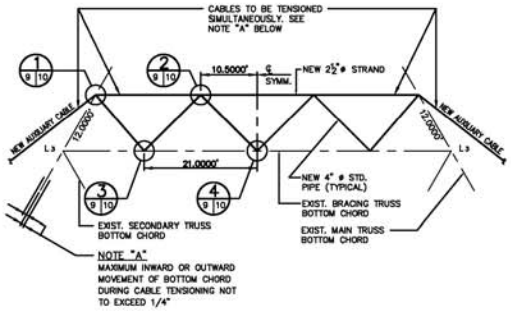
MAIN TRUSS
SCALE: 1"=10'-0"



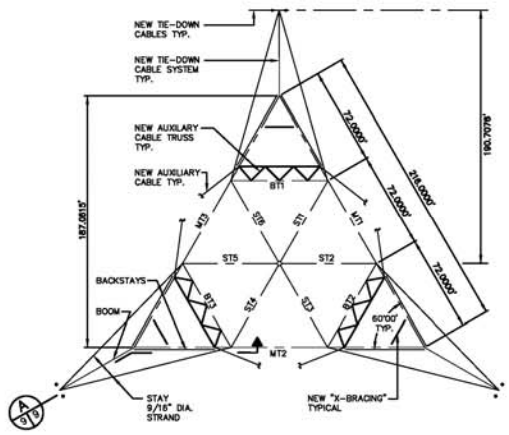
BRACING TRUSS
SCALE: 1"=10'-0"



SECONDARY BRACING TRUSS
SCALE: 1"=10'-0"



NEW AUXILIARY CABLE TRUSS
SCALE: 1"=10'-0"



FEED PLATFORM PLAN
SCALE: 1"=40'-0"

LEGEND

MT – EXISTING MAIN TRUSS

BT – EXISTING BRACING TRUSS

ST – EXISTING SECONDARY BRACING TRUSS

REINFORCED FEED PLATFORM FORCE TABLE

	MEMBER	OPERATIONAL	SURVIVAL
MAIN TRUSS	Uo' – Uo	-185	-62
	Uo – U1	-104	-30
	U1 – U2	-365	-401
	U2 – U3	-592	-811
	U3 – U4	-778	-735
	U4 – U5	-770	-922
	Lo – L1	+1301	+1274
	L1 – L2	+1301	+1274
	L2 – L2,3	+1430	+1469
	L2,3 – L3	+1430	+1469
	L3 – L4	+1689	+1645
	L4 – L5	+1570	+1548
	Uo' – Uo	-319	-105
	Uo – Lo	-302	-98
	U1 – L1	0	0
	U2 – L2	-292	-287
	U2,3 – L2,3	-104	-105
	U3 – L3	+85 / -307	-282
	U4 – L4	-108	+191 / -173
	U5 – L5	0	0
	U1 – Lo	-232	+323
	U1 – L2	+283	+302
	U2,3 – L3	+318	+332
	L2,3 – L3	+410	+381
	U3 – L4	+312 / -29	+297 / -36
	U4 – L5	+115 / -102	+158 / -125
BRACING TRUSS	U20 – U21	-151	-172
	U21 – U22	-154	-165
	U20 – L21	+41 / -58	+98 / -48
	U21 – L22	+7 / -59	+100 / -15
	U21 – L21	+36 / -23	+53 / -66
	U22 – L22	0	0
	U20 – L21	+304	+271
	U21 – L22	+41 / -29	+74 / -54
SECONDARY TRUSS	U30 – U31	+23 / -61	+30 / -43
	U31 – U32	+23 / -61	+22 / -34
	U32 – U33	+23 / -61	+22 / -34
	L30 – L31	+74	+100
	L31 – L32	+74	+100
	U32 – U33	+59 / -12	+70 / -12
	U31 – L31	0	0
	U32 – L32	0	0
	U33 – L33	-27	-28
	U30 – U31	+21 / -13	+20 / -11
	U31 – U32	+21 / -13	+20 / -11
	U32 – L33	+42	+42

NOTES: 1) ALL FORCES IN KIPS. TENSION DENOTED +, COMPRESSION DENOTED -.

NOTES

1. DURING REINFORCING OPERATIONS THE FEED ARM SHALL BE PARKED IN A POSITION PARALLEL TO THE TRUSS BEING REINFORCED.
2. REPLACEMENT MEMBERS SHALL BE IDENTICAL TO EXISTING MEMBERS EXCEPT AS SHOWN.
3. ALL BOLTS IN FEED PLATFORM CONNECTIONS ARE 1" DIAMETER UNLESS SHOWN OTHERWISE.
4. APPROXIMATELY 500 BOLTS IN FEED PLATFORM ARE TO BE REPLACED . LOCATION OF BOLTS TO BE PROVIDED BY OWNER.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER
CORNELL UNIVERSITY
ARECIBO RADIO OBSERVATORY
GREGORIAN UPGRADING

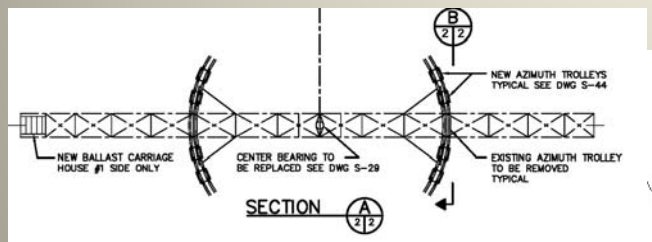
FEED PLATFORM I

AMMANN & WHITNEY, CONSULTING ENGINEERS
NEW YORK, NEW YORK

DRAWN BY:	APPROVED	DATE:
DESIGNED BY:		SCALE: AS NOTED
CHECKED BY:		DWG. NO. S-9

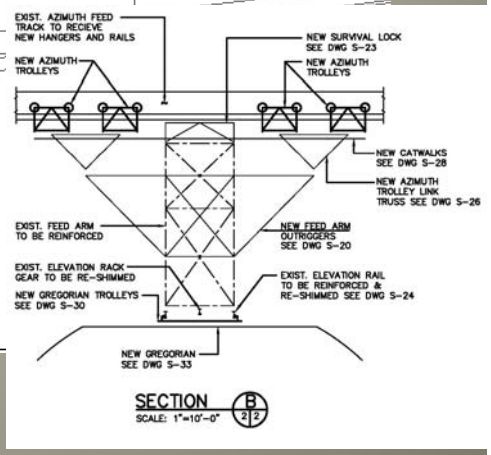
FILE #ARC7

Main Platform Loading



43.1 kip/wheel
-19.5 kip/wheel
23.6 kip/wheel

43.1 kip/wheel
+19.5 kip/wheel
62.6 kip/wheel



1963 Materials Specification

		incl.										
A441 - 63T High strength low alloy structural steel shapes, plates and bars for welded, riveted or bolted construction but intended primarily for use in welded bridges and buildings where saving in weight or added durability are important. The atmospheric corrosion resistance of this steel is approximately twice that of structural carbon steel. This specification is limited to material up to 8 in. inclusive in thickness.	[c]Shapes	I	70 min.	50	18	...	.22	1.25 max.	.30 max.	.05	.04	Chemical requirements include also copper, Cu = 0.20% min. and vanadium, V = 0.02% min.
		II	67 min.	46	19	...						
		III	63 min.	42	16	24						
	Plates and bars	To ¾ thk. incl.	70 min.	50	18	...						
		Over ¾ to 1½ incl.	67 min.	46	19	...						
		Over 1½ to 4 incl.	63 min.	42	16	24						
		Over 4 to 8 incl.	60 min.	40	...	24						

[a] Values represent ladle analysis.

[b] See individual ASTM specifications for deduction from percentages for increments of diameter or thickness.

[c] See table below.

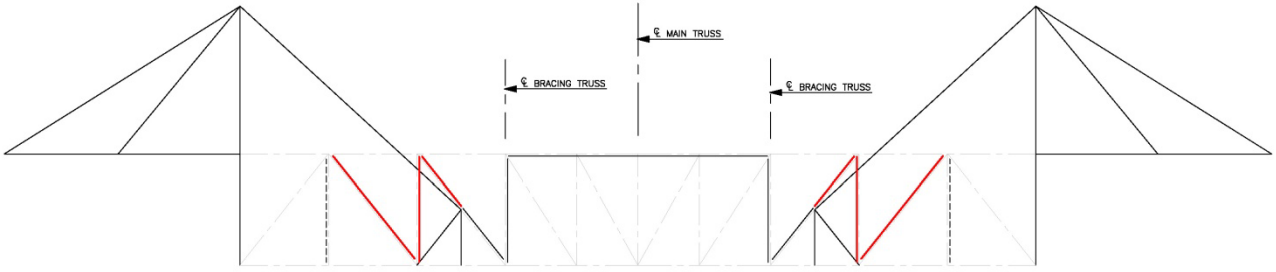
Group I	Group II		Group III	
	Wide Flange Shapes		Wide Flange Shapes	
	Nom. Size	Weight per ft.	Nom. Size	Weight per ft.
All shapes except those listed in Groups II and III	36 × 16½	All weights	14 × 16	219 to 426, incl.
	33 × 15¾	All weights		
	14 × 16	142 to 211, incl.		
	12 × 12	120 to 190, incl.		
	Angles over ¾ in. in thickness			

[d] Group A includes WF shapes as follows: All 36, 33 and 30, 27 × 14, 24 × 14, 21 × 13, 14 × 16, 14 × 14½, 12 × 12 and 10 × 10.

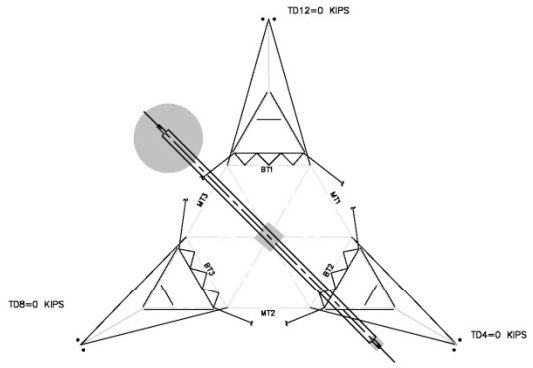
Main Platform Forces

						Italic Members Fy = 36 ksi		Bottom Chord Flanges:	Fy =	46	ksi		U = 0.85			Other:	Fy =	50	ksi	k =	1.00				
MAIN TRUSS					(-) Compression				Fu =	67	ksi						Fu =	70	ksi	4.71√(E/Fy)	113.43				
					(+) Tension																				
										Tension Limited Members							**Compression Limited Members**								
Member	Original Member	Area	1992 Reinforcement	Area	1963 Force Table	1992 Operational	1992 Survival	2010 STAAD Forces (20000)	Length	Gross Area	0.6FyAg	Anet	0.5FuAe	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio	I	r	kL/r	Fcr	Pn/Ω	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio
		[in²]		[in²]	[kip]	[kip]	[kip]	[kip]	[ft]	[in²]	[kip]	[in²]	[kip]	Operational	Operational	Survival	(20000 ft-k)	[in⁴]	[in]		[ksi]	[kip]	Operational	Operational	Survival	(20000 ft-k)
Top Chords																										
Uo'-Uo			4-L5x3x3/8	11.44		-185	-62		33	11.44								1606	10.55	37.54	45.11	308.99		59.87%	20.07%	
Uo-U1	4-L3.5x3.5x5/16	8.36			20	-104	-30	-34.5	72	8.36								1011	11	78.55	31.85	159.42		65.23%	18.82%	21.64%
U1-U2	2-C18x42.7	25.2			-376	-395	-401	-443.5	72	25.2								3146.5	11.17	77.35	32.28	487.15	77.18%	81.08%	82.31%	**91.04%**
U2-U3	2-C18x51.9	30.6			-557	-592	-611	-688.1	72	30.6								3831.6	11.19	77.21	32.33	592.47	**94.01%**	**99.92%**	**103.13%**	**116.14%**
U3-U4	2-C18x58	34.2	4-L3.5x3x3/8	9.2	-663	-778	-735	-859.6	72	43.4								5793	11.55	74.81	33.21	863.08	76.82%	**90.14%**	85.16%	**99.60%**
U4-U5	2-C18x58	34.2	4-L3.5x3x3/8	9.2	-654	-770	-722	-831.1	72	43.4								5793	11.55	74.81	33.21	863.08	75.78%	89.22%	83.65%	96.29%
Bottom Chords																										
Lo-L1	2-18x1 1/16 + 21 7/8x1/2	49.1875			1362	1301	1274	1398.4	24	49.1875	1357.58	52.19	1486.04	**100.33%**	**95.83%**	**93.84%**	**103.01%**									
L1-L2	2-18x1 1/16 + 21 7/8x1/2	49.1875			1362	1301	1274	1400.6	24	49.1875	1357.58	44.49	1490.42	**100.33%**	**95.83%**	**93.84%**	**103.17%**									
L2-L23	2-18x1 1/4 + 21 1/2x1/2	55.75			1553	1430	1469	1548.6	24	55.75	1538.70			**100.93%**	**92.94%**	**95.47%**	**100.64%**									
L23-L3	2-18x1 1/4 + 21 1/2x1/2	55.75			1553	1430	1469	972.9	24	55.75	1538.70			**100.93%**	**92.94%**	**95.47%**	63.23%									
L3-L4	2-18x1 7/16 + 21 1/8x1/2	62.3125			1736	1689	1645	1191.6	24	62.3125	1719.83			**100.94%**	**98.21%**	**95.65%**	69.29%									
L4-L5	2-18x1 1/2 + 21x9/16	65.8125			1825	1510	1548	1339.5	24	65.8125	1816.43	56.94	1907.41	**100.47%**	83.13%	85.22%	73.74%									
Verticals																										
Uo-Lo	*4-L5x5x3/8*	~~14.44~~	4-L5x5x1/2	19	-44	-302	-96	-95.2	30	19								2204	10.77	33.43	46.08	524.24	8.39%	57.61%	18.31%	18.16%
U1-L1	*2-L5x3x5/16*	4.8			0	0	0	6.4	30	4.8	103.68			0.00%			6.17%									
U2-L2	2-C12x25	14.68			-238	-252	-267	-313.7	30	14.68								288	4.43	81.26	30.85	271.19	87.76%	**92.92%**	**98.45%**	**115.67%**
U2L3-L23			2-C8x13.75	8.08		-104	-105	-117.2	12	8.08								72.2	2.99	48.16	42.20	204.18		50.94%	51.43%	57.40%
U3-L3	2-C12x25	14.68	4-L3.5x2.5x5/16	7.12	-221	85/-307	-282	-354.3	30	21.8	654.00				13.00%			438.7	4.48	80.36	31.18	407.06	54.29%	75.42%	69.28%	87.04%
U4-L4	2-C12x25	14.68			-103	-108	151/-173	103.1/-136	30	14.68	440.40					34.29%	23.41%	288	4.43	81.26	30.85	271.19	37.98%	39.82%	63.79%	50.15%
U5-L5	*2-L6x3.5x5/16*	5.74			-8	0	0	-11.7	30	5.74																
Diagonals																										
U1-Lo	2-C15x33.9	20			-319	-232	-323	-362.1	38.4	20								630	5.62	81.99	30.58	366.27	87.09%	63.34%	88.19%	**98.86%**
U1-L2	2-C8x18.75	11.02			305	285	302	336.4	38.4	11.02	330.60	15.04	447.56	**92.26%**	86.21%	**91.35%**	**101.75%**									
U2-U2L3	2-C8x18.75	11.02			291	316	332	391.4	17.2	11.02	330.60	8.95	313.25	88.02%	**95.58%**	**100.42%**	**124.95%**									
U2L3-L2			2-C8x11.5	6.74				71.7	17.2	6.74	202.20						35.46%									
U2L3-L3	2-C8x18.75	11.02	2-C8x18.75	11.02	291	410	381	460.1	17.2	22.04	661.20	17.90	532.53	44.01%	62.01%	57.62%	86.40%									
U3-L4	2-C10x20	11.74			196	312/-23	297/-36	300.3	38.4	11.74	352.20	10.13	301.34	55.65%	88.59%	84.33%	**99.66%**									
U4-L5	2-C12x25	14.68			106/-100	115/-102	138/-125	153.2/-123.8	38.4	14.68	440.40			24.07%	26.11%	31.34%	34.79%	182.4	3.52	130.91	14.65	128.76	77.67%	79.22%	97.08%	96.15%

Main Platform Forces – Web Members



MAIN TRUSS 3
VERTICALS & DIAGONALS
MEMBERS U2–L2/U1–U2L3/U1–L2

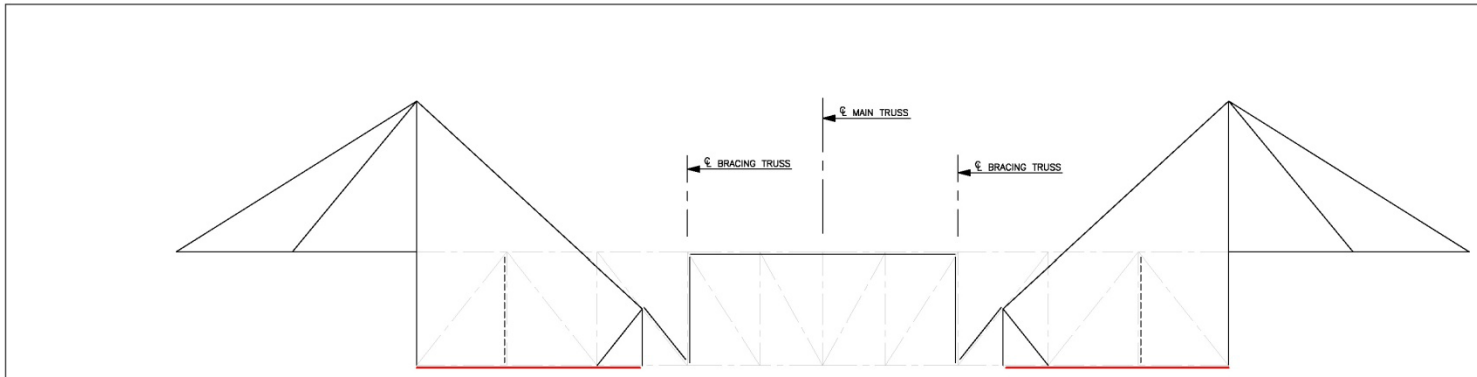


AZIMUTH 315°
20,000 KIP-FT MOMENT

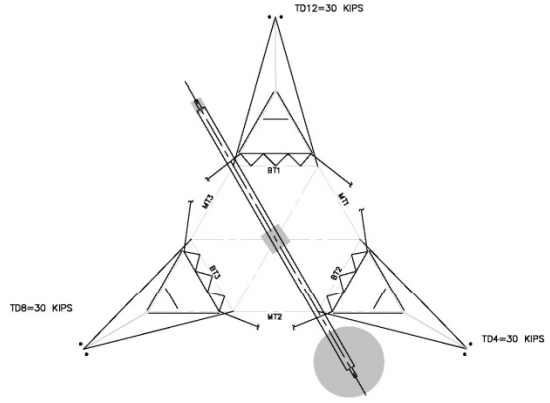
LEGEND:

- EXISTING 1963 STRUCTURAL MEMBERS UNCHANGED
- 1992 REINFORCED MEMBERS
- 2010 OVERSTRESSED MEMBERS

Main Platform Truss – Chord Members



MAIN TRUSS 2
BOTTOM CHORD
MEMBERS L0–L1/L1–L2/L2–L2L3



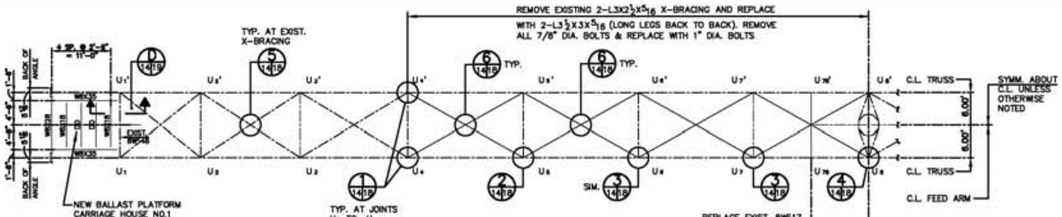
AZIMUTH 150°
20,000 KIP-FT MOMENT

LEGEND:

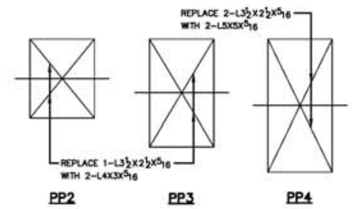
- EXISTING 1963 STRUCTURAL MEMBERS UNCHANGED
- 1992 REINFORCED MEMBERS
- 2010 OVERSTRESSED MEMBERS

Bracing Truss Forces

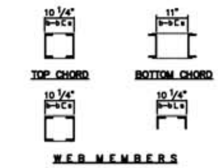
											Tension Limited Members							**Compression Limited Members**								
Member	Original Member	Area	1992 Reinforcement	Area	1963 Force Table	1992 Operational	1992 Survival	2010 STAAD Forces (20000)	Length	Gross Area	0.6FyAg	Anet	0.5FuAe	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio	I	r	kL/r	Fcr	Pn/Ω	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio
		[in^2]		[in^2]	[kip]	[kip]	[kip]	[kip]	[ft]	[in^2]	[kip]	[in^2]	[kip]	Operational	Operational	Survival	(20000 ft-k)	[in^4]	[in]		[ksi]	[kip]	Operational	Operational	Survival	(20000 ft-k)
Top Chords																										
U20-U21	2-C10x15.3	8.96			-135	-151	-172	-153.2	72	8.96								1327	12.17	71.00	34.59	185.57	72.75%	81.37%	92.69%	82.56%
U21-U22	2-C10x15.3	8.96			-121	-154	-165	-143.2	72	8.96								1327	12.17	71.00	34.59	185.57	65.20%	82.99%	88.92%	77.17%
Bottom Chords																										
L20-L21	2-16x1/2 + 23x7/16	26.0625			12	41/-59	98/-49	15.1/-62.3	19.29	26.0625	719.33			1.67%	5.70%	13.62%	2.10%	2653	10.09	22.94	48.11	750.85		7.86%	6.53%	8.30%
L21-L22	2-16x1/2 + 23x7/16	26.0625			119	7/-59	105/-45	196.5	16.71	26.0625	719.33			16.54%	0.97%	14.60%	27.32%	2654	10.09	19.87	48.58	758.11		7.78%	5.94%	
Verticals																										
U21-L21	2-C10x15.3	8.96			40/-50	36/-23	53/-66	48.5/-53	30	8.96	268.80			14.88%	13.39%	19.72%	18.04%	1327	12.17	29.58	46.90	251.64	19.87%	9.14%	26.23%	21.06%
U22-L22	*2-L6x3.5x5/16*	5.74			-2	0	0	-1.7	30	5.74																
Diagonals																										
U20-L21	2-C9x13.4	~~7.88~~	2-C9x20	11.74	222	304	271	314.9	35.67	11.74	352.20	11.44	340.38	63.03%	86.31%	76.94%	**92.51%**									
U21-L22	2-C10x15.3	8.96			55/-49	41/-29	74/-64	62/-54.2	34.34	8.96	268.80			20.46%	20.46%	27.53%	23.07%	1327	3.52	117.06	18.32	98.28	49.86%	29.51%	65.12%	55.15%



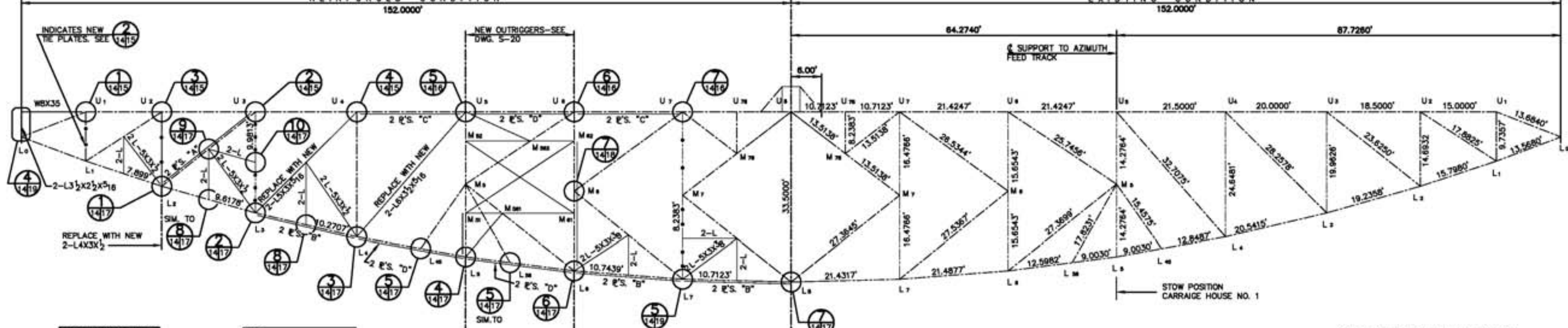
TOP LATERAL BRACING
SCALE: 1"=10'-0"



SWAY FRAMES AT PANEL POINTS
SCALE: 1"=10'-0"



TYPICAL EXISTING FEED ARM MEMBERS



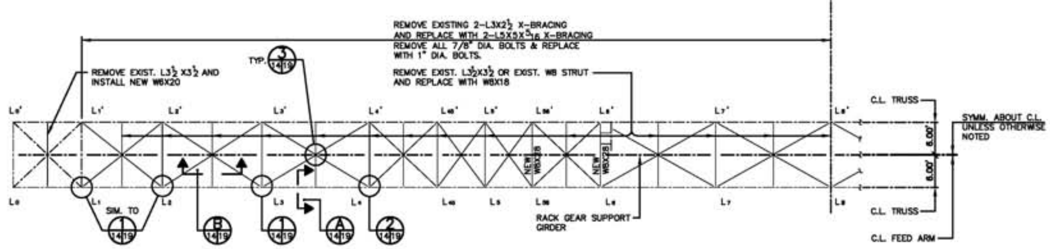
REINFORCING PLATE SCHEDULE
℄ "A" - 4" X 1/2"
℄ "B" - 6" X 3/8"
℄ "C" - 6" X 1/2"
℄ "D" - 6" X 3/4"

NOTE
ALL 2-L TO BE 4X3X3/8 UNLESS OTHERWISE NOTED

NOTE:
ALL FIELD WELDS ON DRAWINGS S-14 THRU S-19 INDICATED AS NOTE #1 SHALL BE PERFORMED PRIOR TO ALL OTHER WORK AT THE CONNECTION.

REINFORCED AND EXISTING CONDITIONS SYMMETRICAL ABOUT ℄ UNLESS OTHERWISE NOTED

FEED ARM ELEVATION
SCALE: 1"=10'-0"



BOTTOM LATERAL BRACING
SCALE: 1"=10'-0"

REINFORCED FEED ARM FORCE TABLE

MEMBER NO.	OPERATIONAL LOADS (KIPS) T	OPERATIONAL LOADS (KIPS) C	SURVIVAL LOADS (KIPS) T	SURVIVAL LOADS (KIPS) C
TOP CHORD				
U1-U2	53		12	
U2-U3	107		48	3
U3-U4	178		118	12
U4-U5	239		194	30
U5-U6	276		228	31
U6-U7	250		176	
U7-U8	185		106	
BOTTOM CHORD				
L0-L1		54		13
L1-L2		106		47
L2-L3		153		106
L3-L4		231		179
L4-L5		[illegible]		[illegible]
L5-L6		[illegible]	3	277
L6-L7		[illegible]		179
L7-L8		214		172
VERTICAL MEMBERS				
U1-L1		23		11
U2-L2		47		41
U3-L3		67		[illegible]
U4-L4		67		[illegible]
[illegible]		[illegible]	89	[illegible]
[illegible]		97	49	134
[illegible]		110		[illegible]
[illegible]	71		243	[illegible]
[illegible]		12	[illegible]	[illegible]
[illegible]	33		44	[illegible]
[illegible]	2	26	[illegible]	[illegible]
[illegible]	17		114	[illegible]
U7-M7	37		[illegible]	[illegible]
M7-L7	13	16	17	[illegible]
U78-M78		0		0
U8-L8	30		4	5
DIAGONALS				
L0-U1	67		14	
L1-U2	88		[illegible]	
L2-U3	117		[illegible]	
L3-U4	105		[illegible]	
L4-U5	115		[illegible]	
[illegible]	3		[illegible]	[illegible]
[illegible]	44		[illegible]	[illegible]
[illegible]	29		[illegible]	[illegible]
[illegible]	11	22	[illegible]	[illegible]
[illegible]		40	[illegible]	40
[illegible]	33		[illegible]	40
[illegible]		79	[illegible]	[illegible]
[illegible]	81		[illegible]	[illegible]
U7-M78	2		2	
[illegible]	4	38	37	41
[illegible]	38		41	[illegible]

NOTES: (UNLESS OTHERWISE NOTED)

1. FEED ARM REINFORCING DRAWINGS SHALL BE WORKED WITH EXISTING SHOP DRAWINGS. NEW REPLACEMENT MEMBERS SHALL BE IDENTICAL TO EXISTING MEMBERS EXCEPT AS SHOWN.
2. THE OPERATION OF REMOVING AND REPLACING ANY MEMBER SHALL BE COMPLETED BEFORE REMOVING ANY OTHER MEMBER.
3. AT ANY CONNECTION THE OPERATION OF REMOVING AND REPLACING A BOLT SHALL BE COMPLETED BEFORE REMOVING ANOTHER BOLT.
4. CARRIAGE HOUSE NO. 2 SHALL BE REMOVED PRIOR TO REINFORCING FEED ARM.
5. CARRIAGE HOUSE NO. 1 SHALL BE PARKED AT STOW POSITION ON FAR SIDE OF FEED ARM AWAY FROM ANY REINFORCING OPERATIONS.
6. FOR NEW WORK, BOLT SPACING SHALL BE A MINIMUM OF 3" AND AN EDGE DISTANCE OF 2".
7. SHORING IS REQUIRED WHILE REPLACING MEMBERS IN FEED ARM TRUSSES. SHORING DESIGN SHALL CONSIDER LOADS IN ADJACENT TABLE.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER
CORNELL UNIVERSITY
ARECIBO RADIO OBSERVATORY
GREGORIAN UPGRADING

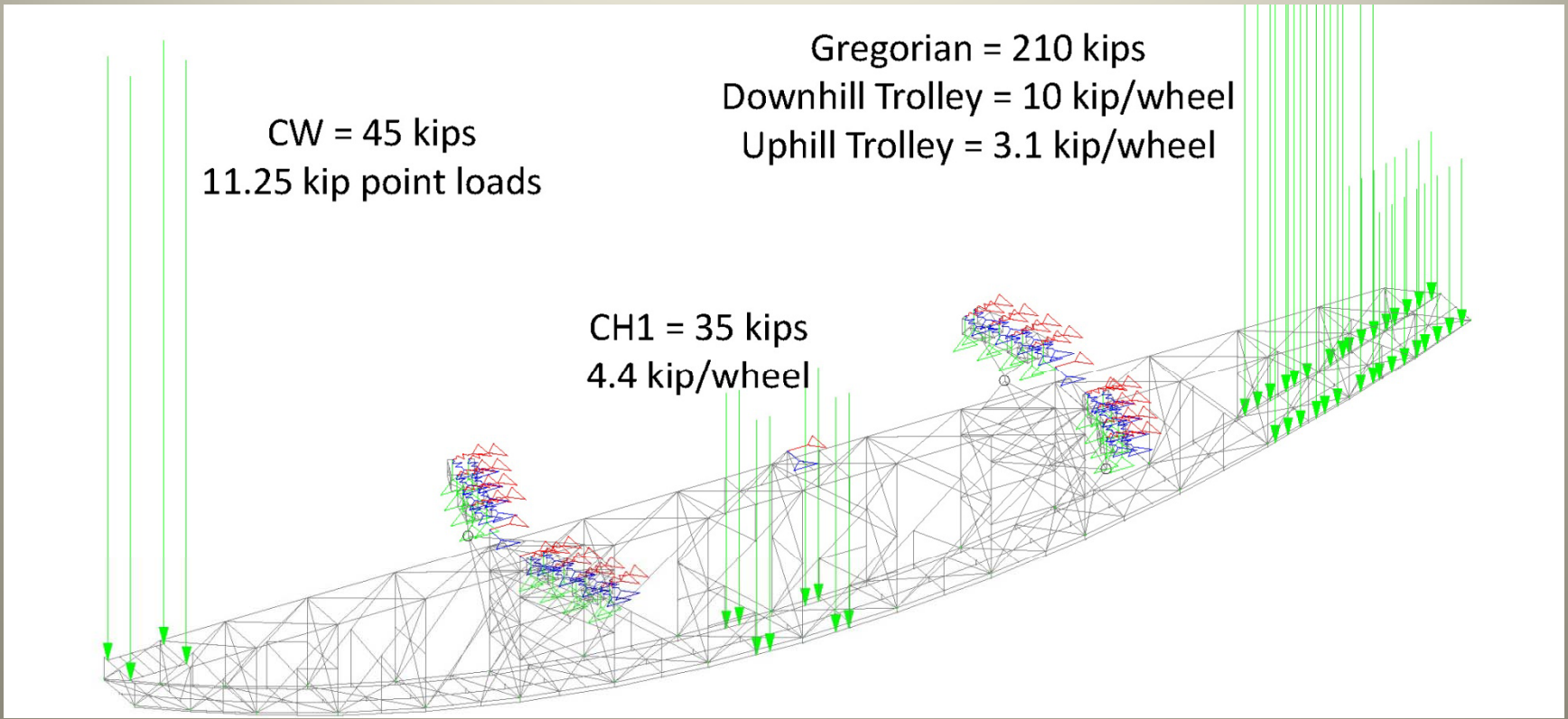
FEED ARM REINFORCING I

AMMANN & WHITNEY, CONSULTING ENGINEERS
NEW YORK, NEW YORK

DRAWN BY:	APPROVED	DATE:
DESIGNED BY:		SCALE:
CHECKED BY:		DWG. NO. S-14

FILE #ARC9

Feed Arm Loading



Feed Arm Forces

						(-) Compression		Fy =	50	ksi						*Italic Members Fy = 36 ksi*				
FEED ARM TRUSS						(+) Tension		Fu =	70	ksi										
											Tension Limited Members					**Compression Limited Members**				
Member	Original Member	Area	1992 Reinforcement	Area	1963 Force Table	1992 Operational	1992 Survival	2010 STAAD Forces (no WL)	Length	Gross Area	0.6FyAg	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio	Capacity	1963 Ratio	1992 Ratio	1992 Ratio	2010 Ratio
		[in²]		[in²]	[kip]	[kip]	[kip]	[kip]	[ft]	[in²]	[kip]	Operational	Operational	Survival	Operational	[kip]	Operational	Operational	Survival	Operational
Top Chords																				
U1-U2	2-C8x11.5	6.74			33	53	12	25	15	6.74	202.20	16.32%	26.21%	5.93%	12.36%					
U2-U3	2-C8x11.5	6.74			71	107	46/-3	55	18.5	6.74	202.20	35.11%	52.92%	22.75%	27.20%					
U3-U4	2-C8x11.5	6.74			99	178	116/-12	97	20	6.74	202.20	48.96%	88.03%	57.37%	47.97%					
U4-U5	2-C8x11.5	6.74	2-6"x1/2"	6	129	239	194/-30	176	21.5	12.74	382.20	33.75%	62.53%	50.76%	46.05%					
U5-U6	2-C8x13.75	8.08	2-6"x3/4"	9	174	276	228/-21	182	21.425	17.08	512.40	33.96%	53.86%	44.50%	35.52%					
U6-U7	2-C8x13.75	8.08	2-6"x1/2"	6	155/-37	250	176	167	21.425	14.08	422.40	36.70%	59.19%	41.67%	39.54%					
U7-U8	2-C8x13.75	8.08			156/-91	185	106	106/-23	21.425	8.08	242.40	64.36%	76.32%	43.73%	43.73%					
Bottom Chords																				
Lo-L1	2-C8x11.5	6.74			-34	-54	-13	-28	13.568	6.74						-165.05	20.60%	32.72%	7.88%	16.96%
L1-L2	2-C8x11.5	6.74			-72	-106	-47	-49	15.798	6.74						-188.05	38.29%	56.37%	24.99%	26.06%
L2-L3	2-C8x11.5	6.74			-97	-153	-107	-75	19.236	6.74						-181.76	53.37%	84.18%	58.87%	41.26%
L3-L4	2-C8x13.75	8.08	2-6"x3/8"	4.5	-120	-231	-179	-167	10.27	12.58						-319.99	37.50%	72.19%	55.94%	52.19%
L4-L5	2-C8x13.75	8.08	2-6"x3/4"	9	-149	-355	-296	-287	21.852	17.08						-379.13	39.30%	93.64%	78.07%	75.70%
L5-L6	2-C8x13.75	8.08	2-6"x3/4"	9	-172	-336	3/-277	-267	21.601	17.08						-383.52	44.85%	87.61%	72.23%	69.62%
L6-L7	2-C8x13.75	8.08	2-6"x3/8"	4.5	12/-134	-252	-179	-182	21.488	12.58	377.40	3.18%				-315.14	42.52%	79.96%	56.80%	57.75%
L7-L8	2-C8x13.75	8.08	2-6"x3/8"	9	46/-113	-214	-122	26/-153	21.432	17.08	512.40	8.98%			5.07%	-428.23	26.39%	49.97%	28.49%	35.73%
Verticals																				
U1-L1	*2-L3.5x2.5x5/16*	3.56			-35	-23	-11	-22	9.7357	3.56						-47.42	73.81%	48.51%	23.20%	46.40%
U2-L2	*2-L4x3x7/16*	5.74			-35	-47	-41	-23	14.693	5.74						-59.72	58.60%	78.70%	68.65%	38.51%
U3-L3	*2-L5x3x1/2*	7.5			-41	-67	-52	-48	19.963	7.5						-118.00	34.75%	56.78%	44.07%	40.68%
U4-L4	2-C8x11.5	6.74			-48	-67	-50	-56	24.648	6.74						-103.96	46.17%	64.45%	48.10%	53.87%
U5-M52	W10x60 + 2-9.25"x1/2"	26.85			88	-80	89/-160	-94	5.7764	26.85	579.96	15.17%		15.35%						
M52-M5	W10x60 + 2-9.25"x1/2"	26.85			88	-97	49/-134	-97	8.5322	26.85	579.96	15.17%		8.45%						
M5-M51	*W10x39*	11.5			27	-110	-155	-130	5.7764	11.5	248.40	10.87%				-208.00	-12.98%	52.88%	74.52%	62.50%
M51-L5	*W10x39*	11.5	2-8"x1/2"	8	27	71	243/-196	62		19.5	488.40	5.53%	14.54%	49.75%	12.69%					
U6-M62	*2-L4x3x3/8*	4.96			31/-4	-12	25/-30	25/-9	5.7764	4.96	107.14	28.94%		23.33%	23.33%					
M62-M6	*2-L4x3x3/8*	~~4.96~~	2-L4x3x3/8	4.96	31/-4	33	44/-32	59		4.96	148.80	20.83%	22.18%	29.57%	39.65%					
M6-M61	*2-L4x3x3/8*	~~4.96~~	2-L4x3x3/8	4.96	-31	2/-26	91/-63	35/-49	5.7442	4.96	148.80			61.16%		-67.94	45.63%	38.27%	**92.73%**	72.13%
M61-L6	*2-L4x3x3/8*	~~4.96~~	2-L4x3x3/8	4.96	-31	17	114/-71	50/-7		4.96	148.80			76.61%						
U7-M7	*2-L4x3x3/8*	4.96			17/-9	37	25/-18	44/-5	16.477	4.96	107.14	15.87%	34.54%	23.33%	41.07%	-30.00	30.00%		60.00%	16.67%
M7-L7	*2-L4x3x3/8*	4.96			10/-19	13/-18	12/-20	48/-18	16.479	4.96	107.14	9.33%	12.13%	11.20%	44.80%	-30.00	63.33%	60.00%	66.67%	60.00%
U78-M78	*2-L3.5x2.5x5/16*	3.56			-17	0	0	0	8.2383	3.56										
U8-L8	2-C8x11.5	6.74			7/-12	30	4/-5	19	33.5	6.74	202.20	3.46%	14.84%	1.98%	9.40%					
Diagonals																				
L0-U1	*2-L3.5x2.5x5/16*	3.56			35	67	14	32		3.56	76.90	45.52%	87.13%	18.21%	41.61%					
L1-U2	*2-L4x3x5/16*	4.18			51	89	39	47		4.18	90.29	56.49%	**98.57%**	43.20%	52.06%					
L2-U3	*2-L4x3x5/16*	4.18	2-4"x1/2"	4	55	117	80	98		8.18	210.29	26.15%	55.64%	38.04%	46.60%					
L3-U4	*2-L5x3x5/16*	~~4.8~~	2-L5x3x5/16	4.8	58	105	84	125		4.8	144.00	40.28%	72.92%	58.33%	86.81%					
L4-U5	*2-L6x3.5x5/16*	~~5.74~~	2-L6x3.5x5/16	5.74	65	116	108	123		5.74	172.20	37.75%	67.36%	62.72%	71.43%					
L45-M5	2-C8x11.5	6.74			19	3	88/-29	33		6.74	202.20	9.40%	1.48%	43.52%	16.32%					
M5-L56	2-C8x11.5	6.74			20	44	76/-10	30		6.74	202.20	9.89%	21.76%	37.59%	14.84%					
M5-M562	2-C8x11.5	6.74			-66	29	26/-29	9/-36	15.328	6.74	202.20		14.34%	12.86%	4.45%	-156.14	42.27%		18.57%	23.06%
M562-U6	2-C8x11.5	6.74			-66	11/-22	39/-31	14/-55	10.417	6.74	202.20		5.44%	19.29%	6.92%	-179.25	36.82%	12.27%	17.29%	30.68%
M5-M561	2-C8x11.5	6.74			70	-40	40/-40	30/-7	9.2824	6.74	202.20	34.62%		19.78%	14.84%	-183.68		21.78%	21.78%	3.81%
M561-L6	2-C8x11.5	6.74			70	33	50/-40	65/-2	18.088	6.74	202.20	34.62%	16.32%	24.73%	32.15%	-141.18			28.33%	1.42%
M6-U7	2-C8x11.5	6.74			-49	-79	26/-58	-90	26.53	6.74	202.20			12.86%		-93.58	52.36%	84.42%	61.98%	**96.17%**
M6-L7	2-C8x11.5	6.74			52	81	60/-15	94/-24	27.536	6.74	202.20	25.72%	40.06%	29.67%	46.49%	-88.19			17.01%	27.22%
U7-M78	*2-L3.5x2.5x5/16*	3.56			15	2	2	5		3.56	76.90	19.51%	2.60%	2.60%	6.50%					
M7-U8	2-C8x11.5	6.74			6/-30	4/-38	32/-41	34/-53	27.028	6.74	202.20	2.97%	1.98%	15.83%	16.82%	-90.90	33.00%	41.81%	45.11%	58.31%
M7-L8	2-C8x11.5	6.74			30	38	41/-31	53/-48	27.365	6.74	202.20	14.84%	18.79%	20.28%	26.21%	-89.10			34.79%	53.87%
Outriggers																				
O5-M52			2-C10x25	14.68		-199	-291	-218		14.68						-362.60		54.88%	80.25%	60.12%
M52-M52'			2-C10x20	11.74		-190	-248	-177		11.74						-331.66		57.29%	74.78%	53.37%
05-M51			2-C10x20 +2-C10x15.3	20.7		296	413	336		20.7	621.00		47.67%	66.51%	54.11%					
M51-M51'			2-C10x25	14.68		212	285	239		14.68	440.40		48.14%	64.71%	54.27%					
M52-M51'			2-C10x15.3	8.96		-17	45/-85	-28		8.96	268.80			16.74%		-177.00		9.60%	48.02%	15.82%
M51-M52'			2-C10x15.3	8.96		-17	45/-85	-28		8.96	268.80			16.74%		-177.00		9.60%	48.02%	15.82%
M52-M562			2-C8x11.5	6.74		16/-9	34/-10	28		6.74	202.20		7.91%	16.82%	13.85%					
M562-M62			2-C8x11.5	6.74		60	60	48		6.74	202.20		29.67%	29.67%	23.74%					
M51-M561			2-C8x11.5	6.74		15	15/-31	-18		6.74	202.20		7.42%	7.42%						
M561-M61			2-C8x11.5	6.74		-44	-50	-46	14.159	6.74						-162.13		27.14%	30.84%	28.37%
M51-M62			2-C8x11.5	6.74		-65	-73	-63	25.746	6.74						-97.87		66.42%	74.59%	64.37%
M61-M52			2-C8x11.5	6.74		53	60	54		6.74	202.20		26.21%	29.67%	26.71%					
U5-M562			2-L4x3x1/4	3.38		46	38/-4	20		3.38	101.40		45.36%	37.48%	19.72%					
L5-M561			2-L4x3x1/4	3.38		-35	37/-5	-29		3.38	101.40			36.49%						
A			2-L4x3x1/4	3.38				-6		3.38						-35.05				17.12%
B			2-L4x3x1/4	3.38				7		3.38	101.40				6.90%					
C			2-L3x2x1/4	2.38				3		2.38										
D			2-L3x2x1/4	2.38				-2		2.38										

Member Stresses

Member	Original Member	1992 Reinforcement	Gross Area	1992 Reinforcement	2010 STAAD Forces (20000)	Minimum STAAD Forces	Stress		
							Min.	Max.	Range
			[in^2]		[kip]	[kip]	[ksi]	[ksi]	
Uo'-Uo		4-L5x3x3/8	11.44	4-L5x3x3/8					
Uo-U1	4-L3.5x3.5x5/16		8.36		-34.5		-4.13		
U1-U2	2-C18x42.7		25.2		-443.5		-17.60		
U2-U3	2-C18x51.9		30.6		-688.1		-22.49		
U3-U4	2-C18x58	4-L3.5x3x3/8	43.4	4-L3.5x3x3/8	-859.6		-19.81		
U4-U5	2-C18x58	4-L3.5x3x3/8	43.4	4-L3.5x3x3/8	-831.1		-19.15		
Lo-L1	2-18x1 1/16 + 21 7/8x1/2		49.1875		1398.4	901.4	18.33	28.43	10.10
L1-L2	2-18x1 1/16 + 21 7/8x1/2		49.1875		1400.6	902.7	18.35	28.47	10.12
L2-L23	2-18x1 1/4 + 21 1/2x1/2		55.75		1548.6	960.9	17.24	27.78	10.54
L23-L3	2-18x1 1/4 + 21 1/2x1/2		55.75		972.9			17.45	
L3-L4	2-18x1 7/16 + 21 1/8x1/2		62.3125		1191.6			19.12	
L4-L5	2-18x1 1/2 + 21x9/16		65.8125		1339.5			20.35	
Uo-Lo	*4-L5x5x3/8*	4-L5x5x1/2	19	4-L5x5x1/2	-95.2		-5.01		
U1-L1	*2-L5x3x5/16*		4.8		6.4			1.33	
U2-L2	2-C12x25		14.68		-313.7	-94.6	-21.37	-6.44	14.93
U2L3-L23		2-C8x13.75	8.08	2-C8x13.75	-117.2		-14.50		
U3-L3	2-C12x25	4-L3.5x2.5x5/16	21.8	4-L3.5x2.5x5/16	-354.3		-16.25		
U4-L4	2-C12x25		14.68		103.1/-136		-9.26	7.02	
U5-L5	*2-L6x3.5x5/16*		5.74		-11.7		-2.04		
U1-Lo	2-C15x33.9		20		-362.1		-18.11		
U1-L2	2-C8x18.75		11.02		336.4	66.2	6.01	30.53	24.52
U2-U2L3	2-C8x18.75		11.02		391.4	109	9.89	35.52	25.63
U2L3-L2		2-C8x11.5	6.74	2-C8x11.5	71.7			10.64	
U2L3-L3	2-C8x18.75	2-C8x18.75	22.04	2-C8x18.75	460.1			20.88	
U3-L4	2-C10x20		11.74		300.3			25.58	
U4-L5	2-C12x25		14.68		153.2/-123.8		-8.43	10.44	

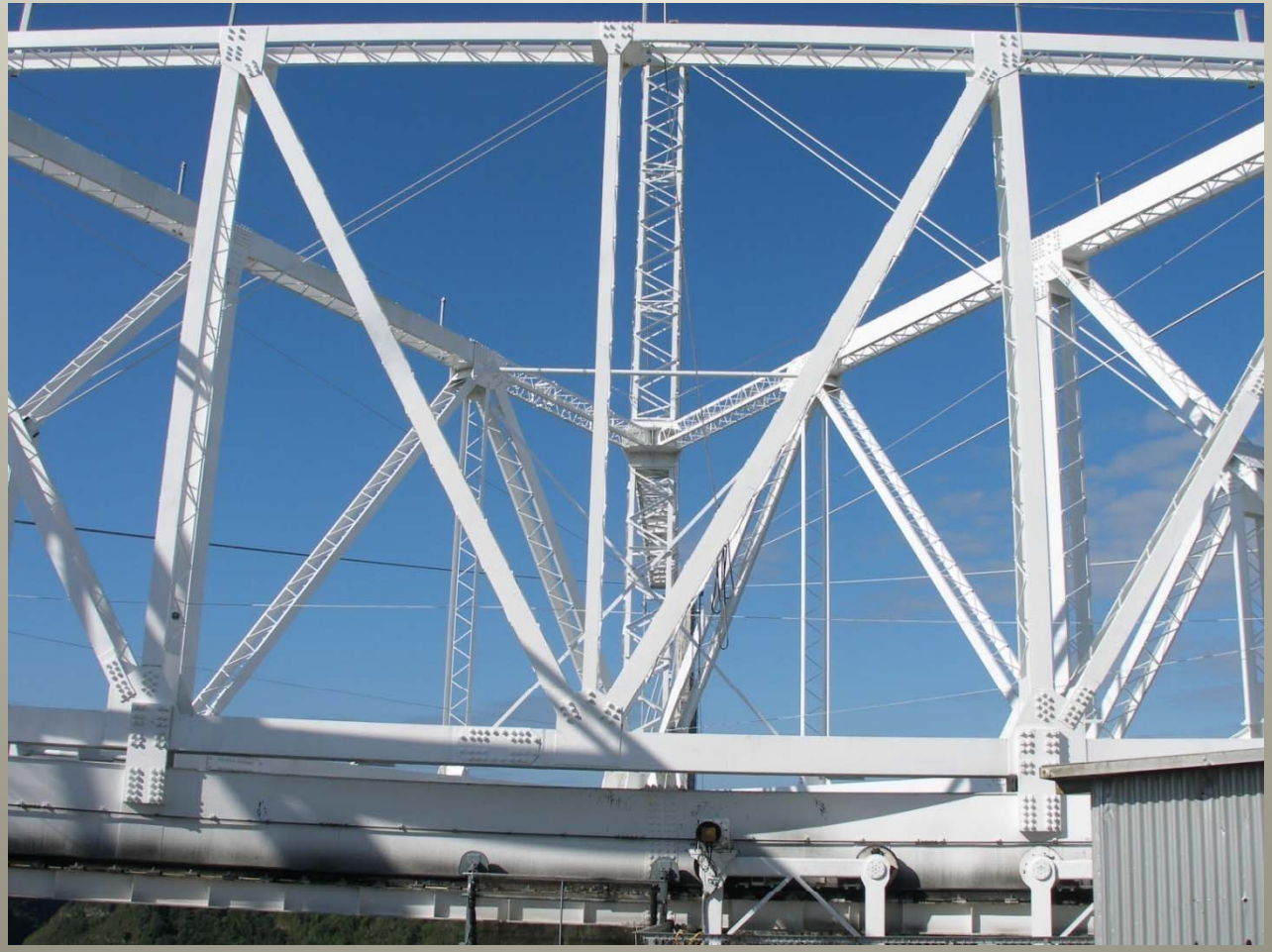
Truss Member Reinforcement

- Ammann & Whitney recommends that no members be allowed to operate at over 100% allowable design load
- Reinforcement of truss web members seems to be possible without major shutdowns
- Reinforcement of upper chord members can be accomplished by providing out of plane buckling restraint

U2-U2L3 Lower Joint

U2-U2L3 Upper Joint

U1-L2, U2-L2



U1-U2 Out of Plane Bracing

Truss Lower Chord Members

- Reinforcement of the lower truss chord will be difficult to accomplish
- Calculated overstresses in the lower chord are relatively minor
- Ammann & Whitney recommends operational modifications (reduction in moment) to reduce lower chord forces to maintain operating stresses at less than 100% of allowable

Main Truss Lower Chord

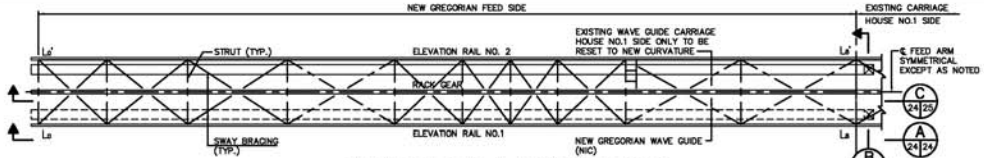
Operational Changes

- Reinforcement of the Main Truss lower chords will be problematic and difficult
- Preliminary results from the linear analysis model indicate that there may be cable factor of safety issues at 20,000 kip-ft
- Cable stresses will be investigated using a non-linear analysis program

Increase tie down force

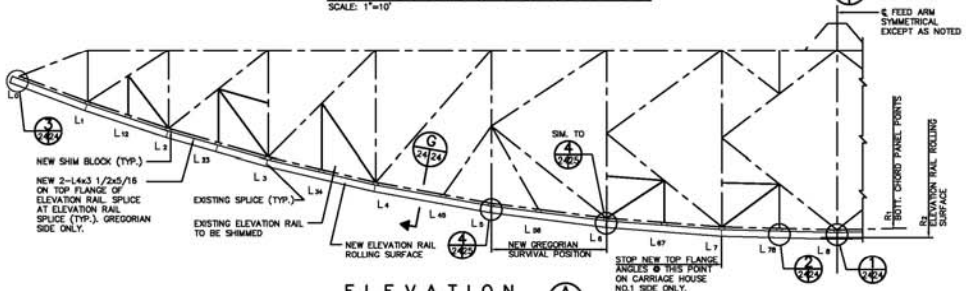
- Increasing tie down forces would reduce web forces but not outer bottom chord forces
- Cable factor of safety may likely be an issue and will require further study
- Structural modifications will be required to raise the position of the dome
  - Re-shim Rail Girder (with re-profiling of feed arm)
  - Tilt Feed Arm (by adjusting link truss attachment)
  - Reduce Weight (remove CH1)

Re-shim Rail Girder



ELEVATION RAIL & RACK GEAR PLAN

SCALE: 1"=10'



ELEVATION A

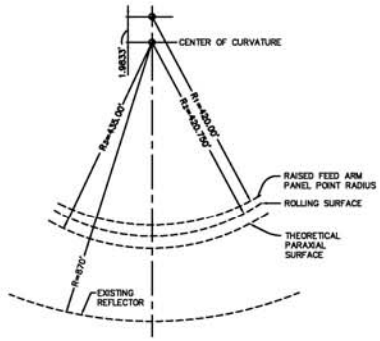
SCALE: 1"=10'

ELEVATION RAIL SHIM BLOCKS

FEED ARM PANEL POINT	SHIM BLOCK THICKNESS "t" (inches) NOTE #1	4	BLOCK TYPE	
L0		3.5	7.5	A	B
L1		4.0	8	B	B
L12		5.5	10	A	A
L2		6.5	10	B	B
L23		8.0	10	A	A
L3		9.0	10	B	B
L34		10	12	A	A
L4		11	12	A	A
L45		12	12	SEE DET	A
L5		12	12	A	A
L56		12	12	SEE DET	A
L6		12.5	12.5	B	B
L67		12.5	12.5	A	A
L7		13	13	B	B
L78		13	13	A	A
L8		14	14	A	A
	GREGORIAN FEED SIDE	CARRIAGE HOUSE NO.1 SIDE	GREGORIAN FEED SIDE	CARRIAGE HOUSE NO.1 SIDE

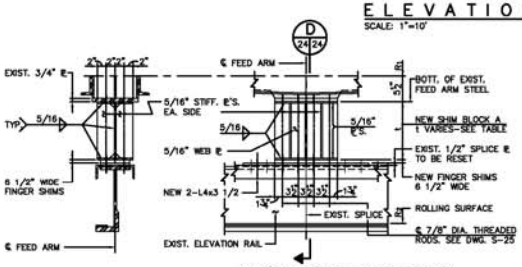
NOTES:

1. WHERE FINGER SHIMS ONLY ARE REQUIRED BLOCK TYPE REPRESENTS HOLE LAYOUT FOR FINGER SHIMS.



SCHEMATIC ELEVATION

N.T.S.



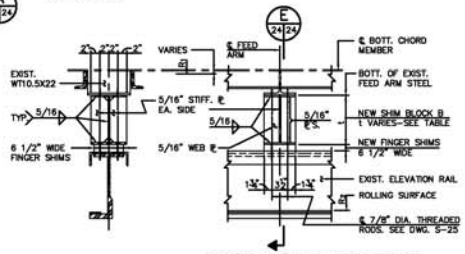
TYPICAL SEGMENT OF ELEVATION RAIL AT SHIM BLOCK A

SECTION D

SCALE: 1"=1'-0"

DETAIL 1

SCALE: 1"=1'-0"



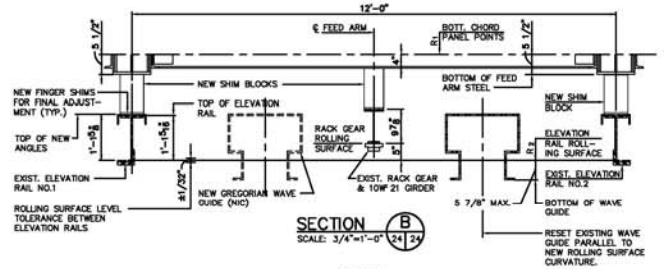
TYPICAL SEGMENT OF ELEVATION RAIL AT SHIM BLOCK B

SECTION E

SCALE: 1"=1'-0"

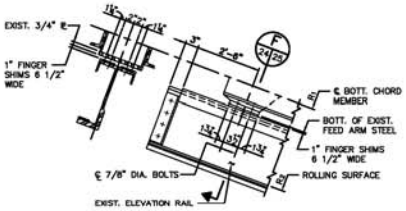
DETAIL 2

SCALE: 1"=1'-0"



SECTION B

SCALE: 3/4"=1'-0"

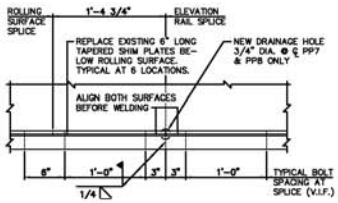


SECTION F

SCALE: 1"=1'-0"

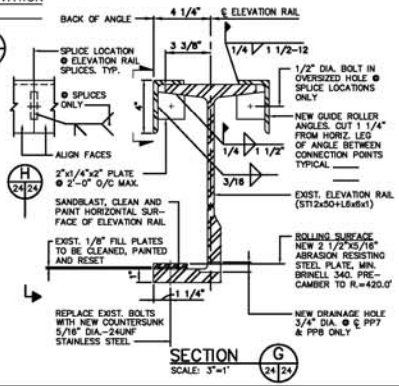
DETAIL 3

SCALE: 1"=1'-0"



SECTION H

N.T.S.



SECTION G

SCALE: 3"=1'

NOTES:

1. FINGER SHIMS SHALL BE STAINLESS STEEL.
2. THE THICKNESS OF FINGER SHIMS SHALL BE DETERMINED BY LOADING EACH PANEL POINT WITH APPROPIATE FEED SYSTEM, TO FORM THE REQUIRED ROLLING SURFACE. HOWEVER, THE THICKNESS SHALL NOT EXCEED 1". IF NECESSARY INCREASE BLOCK SIZE.
3. THE ROLLING SURFACE R3 SHALL MEET A TOLERANCE OF ±.01" WITH THE UPHILL ROLLERS, OF EITHER FEED SYSTEM, CENTERED ON EACH SHIM PACK.
4. ALL THREADED RODS SHALL CONFORM TO ASTM A354 GR. BC.
5. NEW ELEVATION RAIL CURVATURE MAY CAUSE EXISTING HOLES IN TOP FLANGE OF RAIL TO MISALIGN WITH HOLES IN BOTTOM OF FEED ARM. HOLES IN TOP FLANGE OF RAIL SHOULD BE REAMED IF REQUIRED.
3. CONTRACTOR SHALL SUBMIT HIS PROCEDURE FOR SETTING THE ELEVATION RAIL CURVATURE AND MEETING THE LEVEL TOLERANCE BETWEEN RAILS.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER
CORNELL UNIVERSITY
ARECIBO RADIO OBSERVATORY
GREGORIAN UPGRADING

ELEVATION RAIL & RACK GEAR I

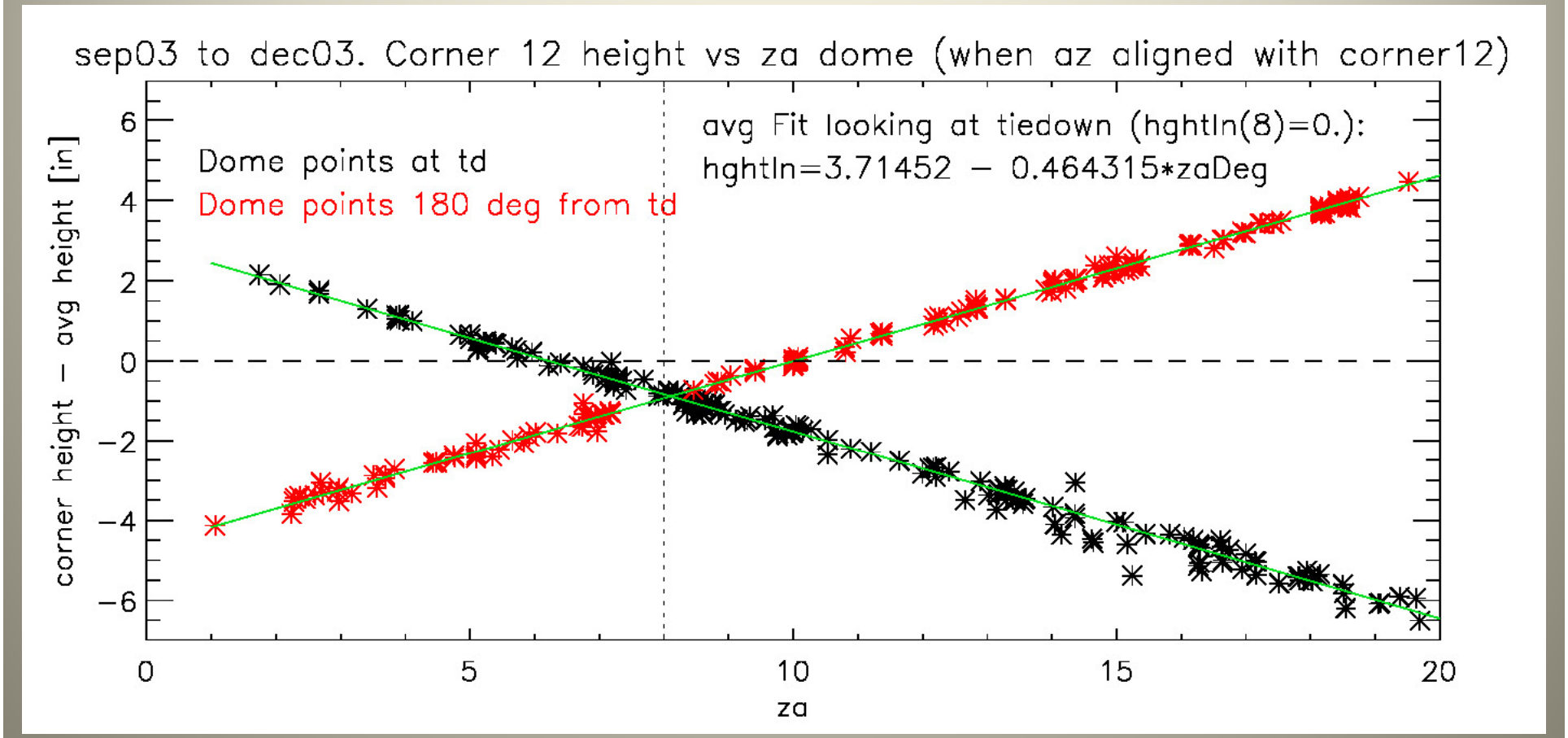
AMMANN & WHITNEY, CONSULTING ENGINEERS
NEW YORK, NEW YORK

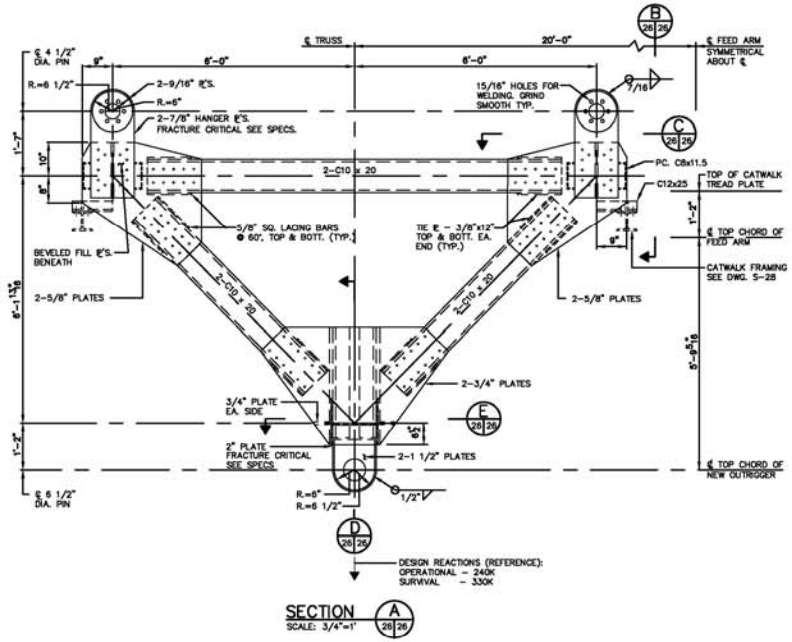
DRAWN BY:	APPROVED	DATE:
DESIGNED BY:		SCALE: AS NOTED
CHECKED BY:		DWG. NO. S-24

FILE #ARC24

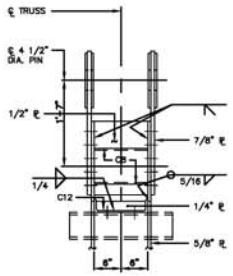
Tilt Feed Arm

- Feed arm tilts as dome moves out
- Adjustments to the link truss attachment can provide up to 5 inches of opposite tilt
- There is excess capacity in the attachment of the tang plate to the link truss so not all bolt rows are required

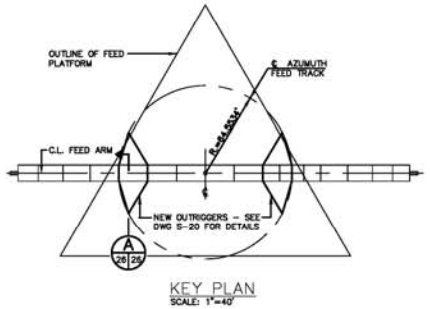

sep03 to dec03. Corner 12 height vs za dome (when az aligned with corner12)
Dome points at td
Dome points 180 deg from td
avg Fit looking at tiedown (hghtIn(8)=0.):
hghtIn=3.71452 − 0.464315*zaDeg
corner height − avg height [in]
6
4
2
0
−2
−4
−6
0
5
10
15
20
za



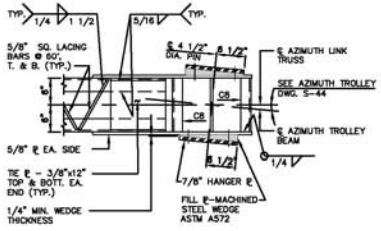
SECTION A
SCALE: 3/4"=1'



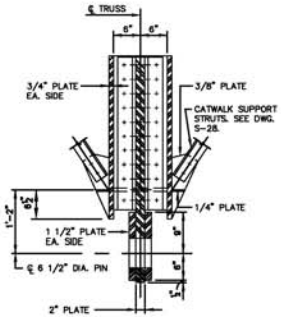
SECTION B
SCALE: 1"=1'-0"



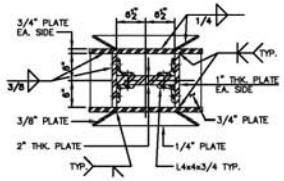
KEY PLAN
SCALE: 1"=40'



SECTION C
SCALE: 1"=1'-0"



SECTION D
SCALE: 1"=1'-0"



SECTION E
SCALE: 1"=1'-0"

NATIONAL ASTRONOMY AND IONOSPHERE CENTER CORNELL UNIVERSITY ARECIBO RADIO OBSERVATORY GREGORIAN UPGRADING	
AZIMUTH TROLLEY LINK TRUSS	
AMMANN & WHITNEY, CONSULTING ENGINEERS NEW YORK, NEW YORK	
DRAWN BY: R.C. / APPROVED / DATE:	
DESIGNED BY: J.G.	SCALE: AS NOTED
CHECKED BY: J.V.	DWG. NO. S-26

FILE #ARC20

Reduce Moment

- Add counterweight force
- Reduce Dome Weight
  - Move Mechanicals to feed arm
- Slave Carriage House 1