

OWNER

Lightning Risk Assessment and Protection Design

Calculation



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TORUS

[REDACTED] [REDACTED], [REDACTED] County, [REDACTED]

ISSUE SUMMARY AND APPROVAL

This page records each issue of ELE-CAL-006. The preparer, reviewer and approver sign for each revision.

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A	2026-09-29	Issued for Review	First issue

Contributors

Rev.	Discipline	Prepared by	Reviewed by	Approved by
A	Electrical			

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1. OBJECTIVE

This calculation assesses the lightning risk to each structure at the , decides which structures need a lightning protection system, and defines that system: strike termination devices, conductors, grounding, bonding and surge protection. The layout is shown on the grounding and lightning protection plan in Appendix A.

2. METHODOLOGY

TORUS used the simplified risk assessment of NFPA 780-2023 Annex L. For each structure the expected annual number of direct strikes N_d follows from the ground flash density and the structure's equivalent collection area, which extends three times the structure height beyond its outline. The tolerable number of strikes N_c follows from four coefficients for construction, contents, occupancy and consequence. Where N_d exceeds N_c , protection is recommended. The station handles flammable gas and houses the control and safety systems that keep gas deliveries safe, so TORUS provides protection wherever the assessment recommends it rather than accepting the risk.

A structure of metal at least 3/16 in thick and electrically continuous is its own strike termination and needs only grounding (NFPA 780 Chapters 4 and 7). Other structures receive air terminals laid out by the NFPA 780 spacing rules. Where a tall strike termination may shelter a lower structure, the 150 ft rolling sphere method decides whether the lower structure lies fully inside its zone of protection. Only full coverage is credited.

3. DESIGN INPUTS

The inputs in Table 3-1 govern the calculation.

Table 3-1: Design Inputs

Input	Value	Source
Ground flash density N_g	8 flashes/km ² /yr	Lightning detection network data for central ; verify at final coordinates (HOLD H-02)
Rolling sphere radius R	150 ft	NFPA 780-2023
Plan dimensions of structures	Plot plan	MEC-DWG-001
B-102 eave height	11 ft	Assumed, vendor to confirm (HOLD H-15)
B-101 roof height	10 ft	Assumed, vendor to confirm (HOLD H-15)
SK-110 canopy	52 x 18 ft roof, 14.8 ft high side	STR canopy design

Input	Value	Source
VS-101 vent stack	NPS 8 x 25 ft	GEN-DB-001
T-101 liquids tank	9.5 ft OD, 8 ft shell plus 1 ft roof	MEC-DS-004
H-101 line heater	34 x 9.5 ft, stack 20 ft	Plot plan; stack height assumed (HOLD H-15)
ANT-201 antenna monopole	50 ft breakpoint monopole at (150, 22)	INS-DWG-001
Occupancy	Unmanned station	GEN-DB-001

4. ASSUMPTIONS

1. The ground flash density of 8 flashes/km²/yr is at the upper end of published values for central and is conservative. *Verification required (HOLD H-02).*
2. Structure heights not yet fixed by vendor drawings are as listed in Table 3-1. *Verification required (HOLD H-15).*
3. The ANT-201 monopole shaft, the VS-101 stack, the T-101 shell and roof and the H-101 shell and stack are steel at least 3/16 in thick and electrically continuous. *Verification required with each vendor (HOLD H-15).*
4. The station is unoccupied. Loss of the control building, the meter canopy or the antenna would interrupt gas delivery, so continuity of service is treated as required; VS-101 and T-101 carry flammable vapor and liquid, so an environmental consequence is assumed for them.

5. REFERENCES

1. NFPA 780, Standard for the Installation of Lightning Protection Systems, 2023 Edition, including Annex L.
2. NFPA 70, National Electrical Code, 2023 Edition, Articles 242 and 250.
3. UL 96, Lightning Protection Components; UL 96A, Installation Requirements for Lightning Protection Systems.
4. API RP 545, Recommended Practice for Lightning Protection of Aboveground Storage Tanks for Flammable or Combustible Liquids, 1st Edition (2009).
5. API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, 8th Edition (2015).
6. GEN-DB-001, Basis of Design.
7. ELE-CAL-005, Station Grounding and Bonding Design.
8. ELE-RPT-001, Hazardous Area Classification.
9. MEC-DWG-001, Plot Plan.

10. ELE-DWG-004, Grounding and Lightning Protection Plan (Appendix A).

6. CALCULATION

6.1. EXPECTED STRIKE FREQUENCY

For a rectangular structure the equivalent collection area is its plan area extended by three times its height. For B-102, $L = 7.32$ m, $W = 3.66$ m and $H = 3.35$ m:

NFPA 780-2023, Annex L, equivalent collection area

$$A_e = LW + 6H(L + W) + 9\pi H^2 = 7.32(3.66) + 6(3.35)(7.32 + 3.66) + 9\pi(3.35)^2 = 565 \text{ m}^2$$

B-102 has G-101 and a lighting pole within three times its height, so it is not an isolated structure and its location coefficient is $C_1 = 0.5$:

NFPA 780-2023, Annex L, expected strike frequency

$$N_d = N_g A_e C_1 \times 10^{-6} = 8(565)(0.5) \times 10^{-6} = 2.26 \times 10^{-3} \text{ per year}$$

For a slender structure such as the antenna monopole or the vent stack, the collection area is a circle of radius three times the height. For ANT-201 with $H = 15.24$ m:

$$A_e = \pi(r + 3H)^2 = \pi(0.23 + 3(15.24))^2 = 6,633 \text{ m}^2, \quad N_d = 8(6,633)(1.0) \times 10^{-6} = 53.1 \times 10^{-3}$$

6.2. TOLERABLE STRIKE FREQUENCY

Table 6-1 lists the coefficients assigned to each structure. C_2 reflects construction (0.5 for a metal structure with a metal roof, 3.0 for the combustible fiberglass analyzer shelter). C_3 is 3.0 where the structure holds electronics or flammable material. C_4 is 0.5 because the station is unmanned. C_5 is 5.0 where loss of the structure would interrupt gas delivery and 10.0 where a strike could release flammable vapor or liquid to the environment.

NFPA 780-2023, Annex L, tolerable strike frequency

$$C = C_2 C_3 C_4 C_5 = 0.5(3.0)(0.5)(5.0) = 3.75, \quad N_c = \frac{1.5 \times 10^{-3}}{C} = \frac{1.5 \times 10^{-3}}{3.75} = 0.40 \times 10^{-3}$$

Table 6-1: Annex L Coefficients

Structure	C_1	C_2	C_3	C_4	C_5	C
B-102 control / electrical building	0.5	0.5	3.0	0.5	5.0	3.75
B-101 analyzer shelter	0.5	3.0	3.0	0.5	5.0	22.50
SK-110 meter skid canopy	1.0	0.5	3.0	0.5	5.0	3.75
VS-101 vent stack	1.0	0.5	3.0	0.5	10.0	7.50
T-101 liquids tank	1.0	0.5	3.0	0.5	10.0	7.50
H-101 line heater (stack 20 ft)	1.0	0.5	3.0	0.5	5.0	3.75

Structure	C_1	C_2	C_3	C_4	C_5	C
G-101 standby generator enclosure	0.5	0.5	2.0	0.5	5.0	2.50
ANT-201 telecom antenna mast (50 ft)	1.0	0.5	3.0	0.5	5.0	3.75
Station overall (fenced area)	1.0	0.5	3.0	0.5	5.0	3.75

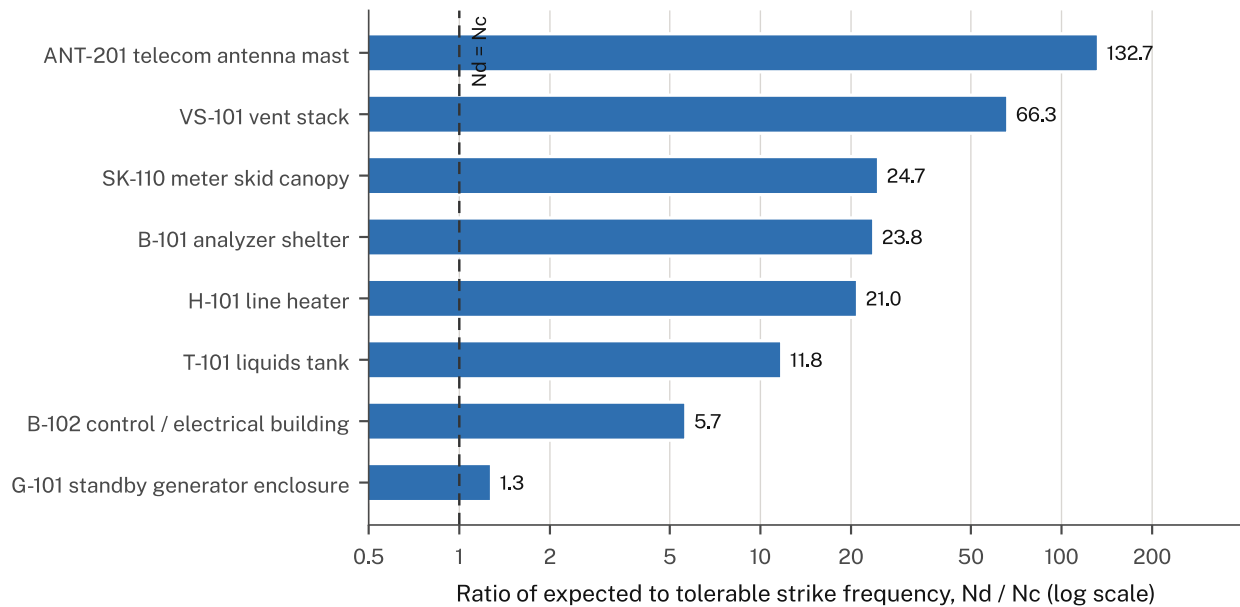
6.3. RISK RESULTS

Table 6-2 compares the expected and tolerable strike frequencies. Every structure exceeds its tolerable frequency, and the station as a whole can expect a direct strike about once every 10 years. Figure 6-1 shows the ratio for each structure.

Table 6-2: Expected and Tolerable Strike Frequencies

Structure	L x W x H, ft	A_e , m ²	N_d , per year	N_c , per year	N_d / N_c	Protection
B-102 control / electrical building	24 x 12 x 11	565	2.26e-03	4.00e-04	5.7	Recommended
B-101 analyzer shelter	12 x 10 x 10	396	1.59e-03	6.67e-05	23.8	Recommended
SK-110 meter skid canopy	52 x 18 x 15	1,234	9.87e-03	4.00e-04	24.7	Recommended
VS-101 vent stack	1 x 1 x 25	1,658	1.33e-02	2.00e-04	66.3	Recommended
T-101 liquids tank	10 x 10 x 9	294	2.35e-03	2.00e-04	11.8	Recommended
H-101 line heater (stack 20 ft)	34 x 10 x 20	1,051	8.41e-03	4.00e-04	21.0	Recommended
G-101 standby generator enclosure	10 x 5 x 7	192	7.68e-04	6.00e-04	1.3	Recommended
ANT-201 telecom antenna mast (50 ft)	2 x 2 x 50	6,633	5.31e-02	4.00e-04	132.7	Recommended
Station overall (fenced area)	250 x 200 x 25	12,558	1.00e-01	4.00e-04	251.2	Recommended

Figure 6-1. Ratio of Expected to Tolerable Strike Frequency



Lightning protection is recommended for every structure assessed.

6.4. ZONES OF PROTECTION

The ANT-201 monopole, with its air terminal 2 ft above the highest antenna, is the tallest strike termination on the site. The horizontal distance it protects at the height h_p of a lower structure is:

NFPA 780-2023, rolling sphere method

$$d = \sqrt{h(2R - h)} - \sqrt{h_p(2R - h_p)} = \sqrt{52(300 - 52)} - \sqrt{7(300 - 7)} = 68.3 \text{ ft}$$

A structure is fully protected only if its farthest corner lies within that distance. Table 6-3 gives the check for the structures near the monopole and for B-101 near the canopy.

Table 6-3: Rolling Sphere Checks, R = 150 ft

Structure and strike point	Strike point height, ft	Structure height, ft	Protected distance, ft	Distance to structure, ft	Result
B-102 (11 ft) from ANT-201 at (150, 22)	52	11	57.2	53.0 to 77.5 ft	Partial
G-101 (7 ft) from ANT-201 at (150, 22)	52	7	68.3	30.0 to 40.1 ft	Protected
XF-101 (5 ft) from ANT-201 at (150, 22)	52	5	75.2	87.7 to 94.5 ft	Outside
B-101 (10 ft) from ANT-201 at (150, 22)	52	10	59.7	94.6 to 107.9 ft	Outside

Structure and strike point	Strike point height, ft	Structure height, ft	Protected distance, ft	Distance to structure, ft	Result
V-101 (8 ft) from ANT-201 at (150, 22)	52	8	65.2	58.2 to 77.6 ft	Partial
FG-101 (8 ft) from ANT-201 at (150, 22)	52	8	65.2	59.2 to 69.1 ft	Partial
SDV-101 (6 ft) from ANT-201 at (150, 22)	52	6	71.6	82.4 to 86.3 ft	Outside
PR-101 (5 ft) from ANT-201 at (150, 22)	52	5	75.2	105.4 to 127.4 ft	Outside
FCV (8 ft) from ANT-201 at (150, 22)	52	8	65.2	62.0 to 74.8 ft	Partial
SK-110 (15 ft) from ANT-201 at (150, 22)	52	15	48.2	79.9 to 121.8 ft	Outside
XF-101 (5 ft) from B-102 SE air terminal	13	5	22.7	up to 23.1 ft	Partial
B-101 (10 ft) from canopy corner terminal	17	10	15.0	7.3 to 22.0 ft	Partial

Only G-101 lies fully inside the monopole's zone, so G-101 needs no air terminals of its own. B-102 is only partly covered and receives its own air terminals. The monopole's 30 ft breakpoint limits its fall radius to 20 ft, which clears G-101 (30 ft away) and B-102 (53 ft away). B-101 is only partly inside the canopy's zone and also receives its own air terminals. XF-101 is utility equipment protected by the utility's arresters; it lies partly inside the B-102 zone.

6.5. PROTECTION BY STRUCTURE

Table 6-4 sets the protection for each structure.

Table 6-4: Lightning Protection by Structure

Structure	Strike termination	Qty	Layout	Conductors and grounding
ANT-201	Air terminal 3/8 x 24 in on the mast top, 2 ft above the highest antenna; the steel shaft is the down conductor	1	Tip at 52 ft	Base plate to own ring with four rods; ring bonded to the process ring
B-102	Air terminals 24 in along both long roof edges	4	20 ft spacing, 2 ft from ends; roof 12 ft wide, so no mid-roof terminals	Roof conductor loop 72 ft; two down conductors at opposite corners
G-101	None; inside the ANT-201 zone of protection	0	Rolling sphere, 150 ft	Enclosure frame grounded at two corners

Structure	Strike termination	Qty	Layout	Conductors and grounding
B-101	Air terminals 24 in at the roof corners; the FRP roof is not a conductor	4	10 x 8 ft pattern, within 20 ft	Roof conductor loop 44 ft; two down conductors at opposite corners in PVC guards
SK-110 canopy	Air terminals 24 in on the perimeter of the 52 x 18 ft roof	8	16 ft spacing on the 52 ft edges; 18 ft ends need none between corners	Roof loop 140 ft bonded to the steel frame; the 8 steel columns are the down conductors
VS-101	None; the stack wall is at least 3/16 in and is its own strike termination	0	NFPA 780, metal 3/16 in or thicker	Base plate grounded at two points; nothing placed in the vent's Division 1 envelope
T-101	None; steel shell and roof at least 3/16 in (9.5 ft OD x 8 ft)	0	NFPA 780, Chapter 7 metallic tanks	Shell grounded at two points (30 ft circumference); vents fitted with flame arrestor and gasketed covers
H-101	None; steel shell, firetube and stack at least 3/16 in (34 x 9.5 ft)	0	NFPA 780, metal 3/16 in or thicker	Skid grounded at two corners; burner management panel bonded

Air terminals are 3/8 in solid copper, 24 in high, at no more than 20 ft spacing and within 2 ft of roof ends and corners. Roofs narrower than 50 ft need no mid-roof terminals. Materials are NFPA 780 Class I because no structure exceeds 75 ft: the main conductor is copper of 57,400 cmil and bonding conductors are 26,240 cmil, all listed to UL 96 and installed to UL 96A. Each structure has at least two down conductors, as far apart as practicable, each ending at a ground rod bonded to the station grid with exothermic connections (ELE-CAL-005). The canopy's steel columns are electrically continuous and at least 3/16 in thick, so they serve as its down conductors and no separate conductors are run.

VS-101 and T-101 contain or release flammable vapor. No air terminal or conductor is placed inside a Division 1 envelope (ELE-RPT-001). The T-101 vent carries a flame arrestor and its emergency vent a gasketed cover, so that a strike on the shell cannot ignite vapor inside the tank. Manual blowdown to VS-101 shall not be performed when lightning is within 10 miles; this is an operating rule in the station procedures.

Lighting poles are not credited as strike terminations, because their walls are thinner than 3/16 in; each pole base is grounded to the grid.

6.6. SURGE PROTECTION

A strike on or near the station induces surges on every conductor entering B-102. Surge protective devices are therefore provided at each entry (NFPA 780 and NEC Article 242): a Type 1 device at the service disconnect MCB-101, Type 2 devices at DP-101, LP-101 and UP-101, coaxial arrestors where the buried antenna cables from ANT-201 enter B-102, and a data-line protector on the RS-485 circuit to the

receiving pipeline operator's demarcation panel. The coaxial shields are bonded at the top and base of the monopole and at the B-102 entry. Decouplers across the insulating joints protect the joints themselves (CP-CAL-001).

7. RESULTS AND CONCLUSIONS

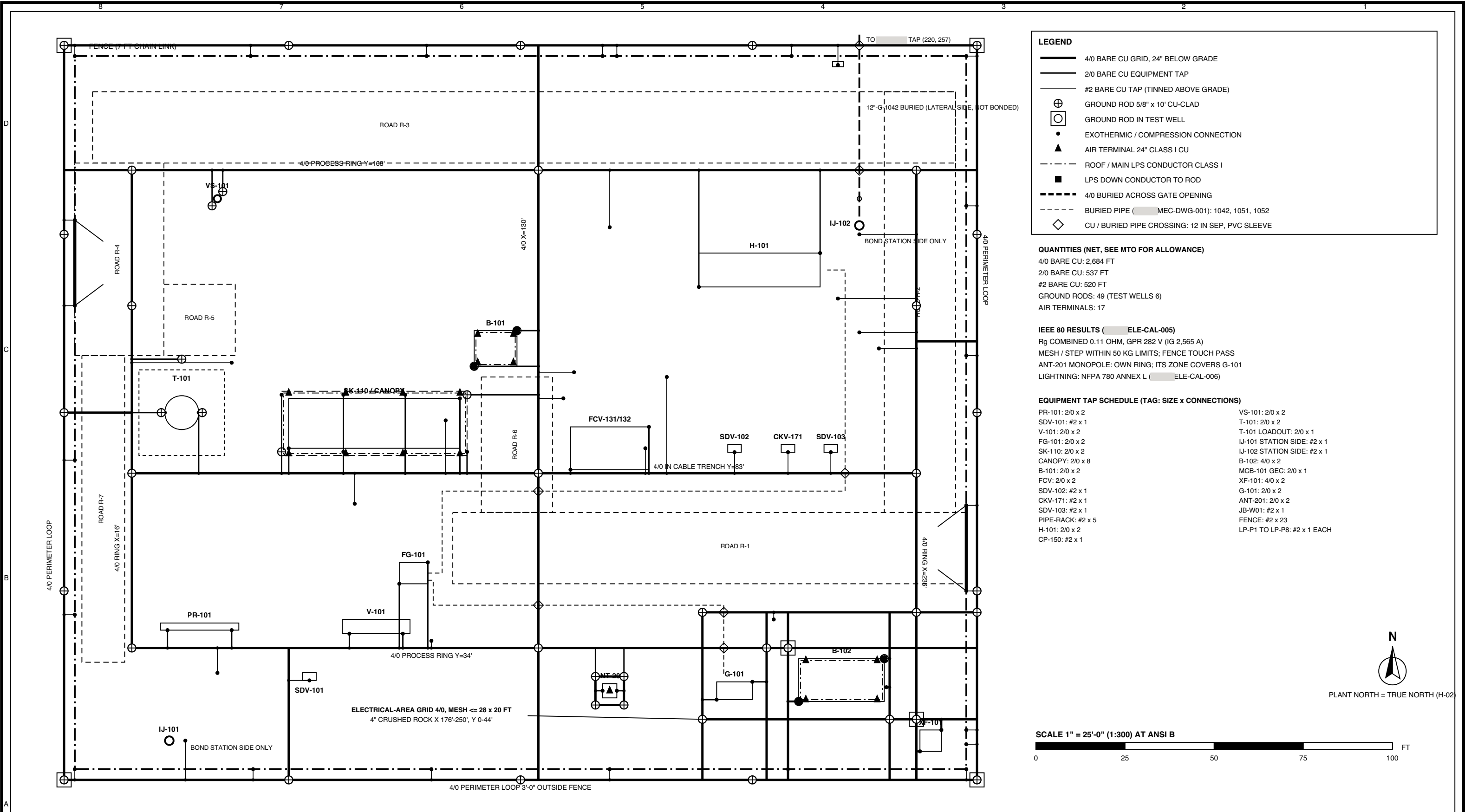
TORUS draws the following conclusions:

1. Every structure assessed exceeds its tolerable strike frequency, and lightning protection is provided for each.
2. ANT-201, VS-101, T-101 and H-101 are steel at least 3/16 in thick and are their own strike terminations; ANT-201 also carries an air terminal above its antennas. Each is grounded at two points.
3. B-102, B-101 and the SK-110 canopy receive air terminal systems bonded to the station grid. G-101 lies inside the monopole's zone of protection and needs none.
4. Surge protective devices shall be installed at every service, power and signal entry to B-102.
5. The ground flash density, structure heights and steel thicknesses shall be confirmed before the design is issued for construction.

The following items remain open: the ground flash density at the final coordinates (HOLD H-02), and vendor confirmation of structure heights and steel thicknesses (HOLD H-15).

APPENDIX A. GROUNDING AND LIGHTNING PROTECTION PLAN





NOTES / REFERENCES

- GRID: BARE STRANDED CU 24 IN BELOW GRADE; BURIED JOINTS EXOTHERMIC (DWG-007).
- FENCE POSTS (≤ 50 FT) BONDED #2 TO LOOP; GATE LEAVES FLEXIBLE BRAID JUMPERS.
- GROUND STATION SIDE OF IJ-101/102 ONLY; NOTHING MAY BRIDGE AN IJ (CP-DWG-002).
- G-101 NOT SEPARATELY DERIVED; N-G BOND AT MCB-101 ONLY. XF-101 BY UTILITY.
- T-101 LOADOUT STATIC GROUND MONITOR (NFPA 77). VS-101/T-101/H-101 SELF-PROT.
- SOIL (H-08) AND FAULT DATA (H-10) ASSUMED. FALL-OF-POTENTIAL TEST ≤ 1.0 OHM.

REF: ELE-CAL-005, -CAL-006, -DWG-007; CP-DWG-001

REVISIONS			
REV	DATE	DESCRIPTION	BY
A	2026-09-29	ISSUED FOR REVIEW (IFR)	CHK APP
PRELIMINARY - ISSUED FOR REVIEW - NOT FOR CONSTRUCTION			

ENGINEER OF RECORD SEAL

NOT SEALED
PRELIMINARY

PE NO. _____

PROJECT

120 MMSCFD RECEIPT INTO _____

COUNTY, _____

DISCIPLINE: ELECTRICAL
SCALE: 1" = 25'-0"

GROUNDING AND LIGHTNING PROTECTION PLAN

STATION GROUNDING SYSTEM

DRAWN: _____ CHECKED: _____ APPROVED: _____

DWG NO.
ELE-DWG-004

SHEET 1 OF 1 REV A