

OWNER

Lighting Design

Calculation

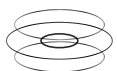


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TORUS

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

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1. OBJECTIVE

This calculation sets the exterior and interior lighting for the . It selects luminaires suitable for the classified areas, fixes the pole locations, and confirms by calculation that the maintained illuminance meets the target in each operating area and in the two buildings. The lighting loads carried in ELE-CAL-001, Electrical Load Analysis, and the layout on ELE-DWG-005, Lighting Plan (Appendix A), follow from it.

2. METHODOLOGY

The station is normally unattended. Lighting is needed for night maintenance, for emergency response, for truck loading at liquids tank T-101 and for security at the main gate. TORUS therefore set targets by task rather than a single yard value: 5 fc average where operators work at valves, closures and instruments, 10 fc on the meter skid where instruments are read, and lower values around the buildings and the gate. The targets follow the guidance of API RP 540 and ANSI/IES RP-7 for comparable process areas.

Exterior illuminance was calculated point by point. The maintained horizontal illuminance at grade was summed from every pole and canopy luminaire on a 2 ft grid over each target area, and on a 5 ft grid over the whole fenced yard. Light from the poles is treated as fully blocked under the meter skid canopy roof, so the skid is lit by its own canopy luminaires only. The four wall packs were left out of the sum, which understates the illuminance near the buildings slightly.

Vendor photometric (IES) files are not yet available (HOLD H-15). Until they are, each luminaire is represented by a symmetric intensity distribution normalized so that it delivers its rated lumens times the light loss factor. The pole heads use a wide Type V shape, with intensity rising toward 62 degrees from nadir and a full cutoff at 75 degrees. This shape was chosen over a simple uniform cone because an area luminaire concentrates its output at high angles to spread light between poles; a cone would overstate the illuminance under the pole and understate it between poles. The canopy luminaires use a uniform cone to 55 degrees with cutoff at 70 degrees, typical of a low-bay optic.

Interior illuminance was calculated by the lumen (zonal cavity) method, using the room cavity ratio and a coefficient of utilization for enclosed linear LED luminaires at 70/50/20 % ceiling, wall and floor reflectances.

3. DESIGN INPUTS

The luminaire data and loss factors in Table 3-1 govern the calculation.

Table 3-1: Design Inputs

Input	Value	Source
Pole luminaire (type LA)	LED area luminaire, 150 W, 19,500 lm, 4000 K, Type V, Class I Div 2 Groups C and D, T4	Typical, vendor to confirm (HOLD H-15)
Canopy luminaire (type LB)	LED low-bay, 60 W, 7,800 lm, Class I Div 2, T4	Typical, vendor to confirm (HOLD H-15)
Wall pack (type LC)	LED, 30 W, 3,600 lm, Class I Div 2, T4	Typical, vendor to confirm (HOLD H-15)
B-102 luminaire (type LD)	LED 4 ft enclosed linear, 40 W, 5,000 lm	Typical, vendor to confirm (HOLD H-15)
B-101 luminaire (type LE)	LED 4 ft linear, 40 W, 4,600 lm, Class I Div 2, T4	Typical, vendor to confirm (HOLD H-15)
Pole mounting height	25 ft above finished grade	Selected, Section 6.3
Canopy luminaire mounting height	13 ft (canopy eave 14 ft)	STR-CAL-003, Meter Skid Canopy
Lamp lumen depreciation, LLD	0.90	LED L90 rating at end of design life
Luminaire dirt depreciation, LDD	0.90	Enclosed luminaire, dusty rural site
Light loss factor, LLF	0.81	LLD x LDD
Equipment, roads and canopy layout	Plot plan coordinates	MEC-DWG-001, Plot Plan
Area classification	Division 1 and Division 2 envelopes	ELE-RPT-001, Hazardous Area Classification

4. ASSUMPTIONS

1. The symmetric luminaire model represents the selected products closely enough for layout. The calculation shall be repeated with the vendor's IES files before the next issue. *Verification required (HOLD H-15).*
2. The illuminance targets are taken from API RP 540 and IES RP-7 guidance. The table values shall be confirmed against the editions in force. *Verification required.*
3. Interior reflectances are 70 % ceiling, 50 % walls and 20 % floor, for white interior finishes in both buildings.
4. Shadowing by equipment other than the meter skid canopy is not modeled. Local shadowed spots behind vessels are covered by portable lighting during maintenance.
5. The poles and their foundations suit the site wind speed of 108 mph, Exposure C; the pole vendor shall confirm this. *Verification required (HOLD H-06).*
6. Dusk-to-dawn operation is 4,300 h/yr at the site latitude.

5. REFERENCES

1. API Recommended Practice 540, Electrical Installations in Petroleum Processing Plants, 4th Edition (1999).
2. ANSI/IES RP-7-21, Recommended Practice: Lighting Industrial Facilities (2021).
3. IES Lighting Handbook, 10th Edition (2011): point-by-point and zonal cavity methods.
4. NFPA 70, National Electrical Code (2023): Articles 500 and 501, including 501.130(B) luminaires in Class I Division 2 and 500.8 temperature class.
5. NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors (2024): autoignition temperatures.
6. API Recommended Practice 500, Classification of Locations for Electrical Installations at Petroleum Facilities, 3rd Edition (2012).
7. NFPA 101, Life Safety Code (2024): Section 7.9, emergency lighting, and Section 7.10, marking of means of egress.
8. GEN-DB-001, Basis of Design.
9. MEC-DWG-001, Plot Plan.
10. ELE-RPT-001, Hazardous Area Classification; ELE-CAL-001, Electrical Load Analysis; ELE-LST-001, Cable Schedule.
11. ELE-DWG-005, Lighting Plan (Appendix A); ELE-DWG-007, Typical Installation Details.

6. CALCULATION

6.1. ILLUMINANCE TARGETS

Table 6-1 sets the target for each area. Each area is the footprint of the equipment it serves, extended by a working margin of 3 to 6 ft, taken from the plot plan.

Table 6-1: Illuminance Targets

Area	Target average, fc	Target minimum, fc	Task
A1 Inlet: PR-101, SDV-101, V-101 (incl. closures)	5.0	1.0	Valves, closures, manifolds
A2 Fuel gas skid FG-101 (incl. E-161)	5.0	1.0	Regulators, gauges
A3 Meter skid SK-110 (under canopy)	10.0	5.0	Instrument reading, meter work
A4 T-101 truck loadout connection	5.0	1.0	Truck loading
A5 Control valves, SDV-102, CKV-171, SDV-103	5.0	1.0	Valves, manifolds



Area	Target average, fc	Target minimum, fc	Task
A6 H-101 line heater and burner front	5.0	1.0	Fired equipment, burner front
A7 B-101 analyzer shelter approach	2.0	0.5	Building approach
A8 B-102, G-101, XF-101 electrical area	2.0	0.5	Electrical equipment exterior
A9 Main vehicle gate	1.0	0.2	Gate, entrance
A10 T-101 containment	1.0	0.2	Tank, containment
B-102 control and electrical room	50		Control room and electrical equipment
B-101 analyzer shelter	30		Analyzer house, general

Note 1: Targets are maintained horizontal illuminance at grade outdoors and at the work plane indoors. Analyzer vendors provide local task lighting at the analyzer faces.

6.2. LUMINAIRE SELECTION FOR CLASSIFIED AREAS

Every exterior luminaire is listed for Class I Division 2, Groups C and D, as NEC 501.130(B) requires for luminaires in Division 2 locations. Poles LP-P1, LP-P2, LP-P4, LP-P8 stand at grade inside Division 2 envelopes of ELE-RPT-001, so their in-pole fuse holders and wiring follow Division 2 methods. No pole or head is in a Division 1 location. The heads at 25 ft are outside every envelope. TORUS still specified one Division 2 luminaire type for every pole, because a head lowered for maintenance enters the envelope, the other poles stand within a few feet of Division 2 envelopes, a single type keeps one spare on the shelf, and the cost premium for a Division 2 LED area luminaire is small.

The temperature class is T4, a maximum surface temperature of 275 °F (135 °C). The design gas is mostly methane, which autoignites at 1,112 °F (NFPA 497), but it carries small fractions of heavier hydrocarbons down to n-hexane, which autoignites at 437 °F. T4 stays below the lowest of these with margin, and it also covers the heavier vapors present at the T-101 vent and truck loadout. T3 (392 °F) would also have been acceptable; T4 was chosen because it is the standard rating of Division 2 LED luminaires and costs nothing extra.

Luminaires inside analyzer shelter B-101, whose interior is Class I Division 2, are Division 2 T4. Control building B-102 is unclassified and uses general-purpose enclosed luminaires.

6.3. LUMINAIRE INTENSITY MODEL

The peak intensity I_0 of each pole head was found by setting the flux of the modeled distribution equal to the delivered lumens. For the Type V shape $f(\theta) = \cos^{-1.5} \theta$ up to 62 degrees, falling linearly to zero at 75 degrees:

IES Lighting Handbook, luminous flux of a symmetric distribution

$$I_0 = \frac{\Phi \cdot LLF}{\int_0^{\pi/2} f(\theta) 2\pi \sin \theta d\theta} = \frac{19,500 \times 0.81}{7.801} = 2,025 \text{ cd}$$

The same normalization gives $I_0 = 1,864$ cd for each canopy luminaire. A numerical check confirmed that the illuminance of one head, integrated over the ground plane, returns the delivered 15,795 lm.

6.4. POINT-BY-POINT, WORKED EXAMPLE

The worked point is (75, 40), the west end of filter separator V-101, where operators open the quick-opening closure to change elements. It lies in area A1. The nearest pole, LP-P2, is 25.3 ft away horizontally and carries two heads, so the intensity toward the point is twice the single-head value:

IES Lighting Handbook, point-by-point method

$$\theta = \arctan \frac{r}{h} = \arctan \frac{25.3}{25} = 45.4^\circ, \quad I = 2I_0 f(\theta) = 6,876 \text{ cd}$$

IES Lighting Handbook, inverse square and cosine law

$$E = \frac{I \cos^3 \theta}{h^2} = \frac{6,876 \times \cos^3(45.4^\circ)}{25^2} = 3.82 \text{ fc}$$

The other poles add 2.80 fc (LP-P1 2.69 fc at 37 ft; LP-P3 0.09 fc at 80 ft; LP-P4 0.02 fc at 89 ft). The canopy luminaires contribute nothing at this distance. The total is:

$$E_{point} = \sum E_i = 3.82 + 2.80 = 6.62 \text{ fc}$$

The V-101 closure receives 6.6 fc, above the 5 fc average target for the inlet area, so element changes can be done at night without portable lighting at the closure.

6.5. EXTERIOR AREAS

Table 6-2 gives the results for every area and Figure 6-1 compares them with the targets. All ten areas meet both the average and the minimum. The tightest margins are the T-101 loadout (5.1 fc against 5 fc) and the electrical area minimum (0.51 fc against 0.5 fc) at the south-east corner behind transformer XF-101, where no work is done at night. The meter skid is lit well above its target because six canopy luminaires were needed for uniformity along the 48 ft skid, not for level.

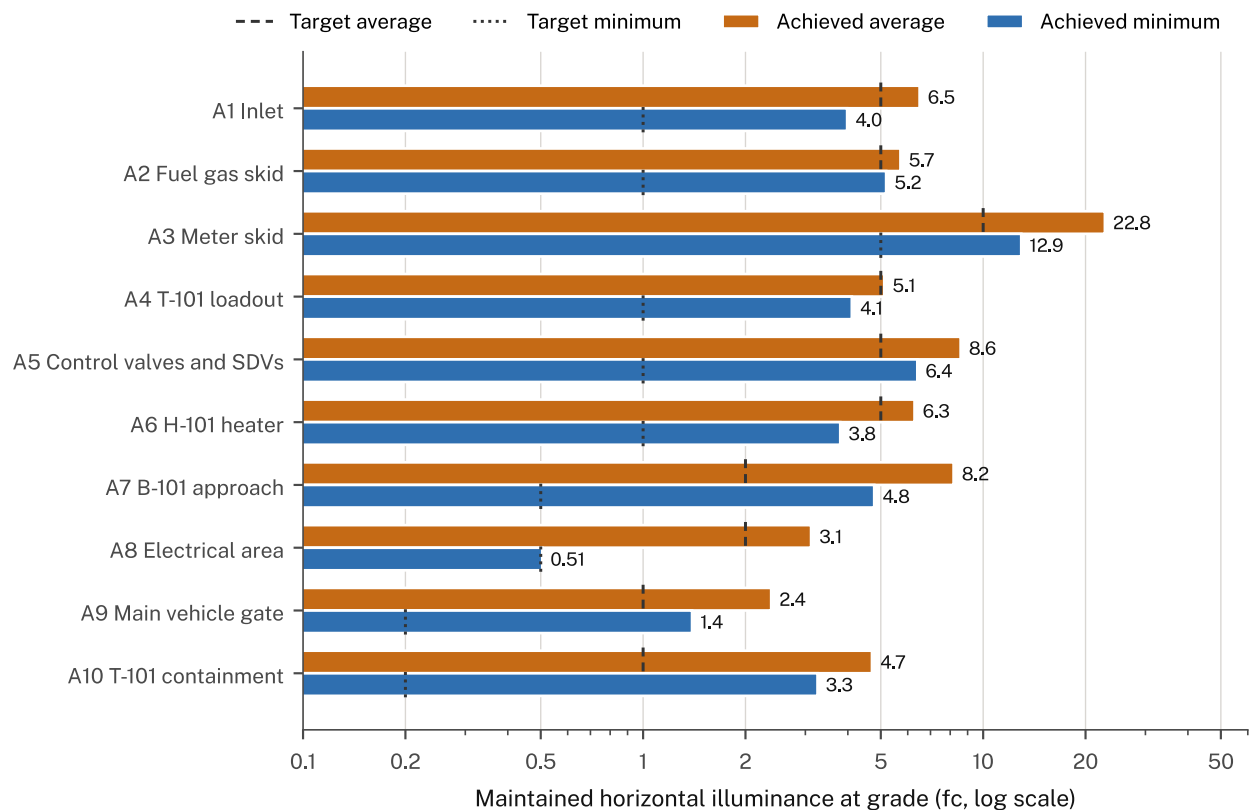
Table 6-2: Exterior Illuminance Results

Area	Target avg / min, fc	Average, fc	Minimum, fc	Maximum, fc	Avg / min	Result
A1 Inlet: PR-101, SDV-101, V-101 (incl. closures)	5.0 / 1.0	6.5	4.0	7.4	1.6	Meets
A2 Fuel gas skid FG-101 (incl. E-161)	5.0 / 1.0	5.7	5.2	6.3	1.1	Meets

Area	Target avg / min, fc	Average, fc	Minimum, fc	Maximum, fc	Avg / min	Result
A3 Meter skid SK-110 (under canopy)	10.0 / 5.0	22.8	12.9	29.6	1.8	Meets
A4 T-101 truck loadout connection	5.0 / 1.0	5.1	4.1	6.2	1.2	Meets
A5 Control valves, SDV-102, CKV-171, SDV-103	5.0 / 1.0	8.6	6.4	10.2	1.3	Meets
A6 H-101 line heater and burner front	5.0 / 1.0	6.3	3.8	9.1	1.7	Meets
A7 B-101 analyzer shelter approach	2.0 / 0.5	8.2	4.8	14.2	1.7	Meets
A8 B-102, G-101, XF-101 electrical area	2.0 / 0.5	3.1	0.51	6.1	6.2	Meets
A9 Main vehicle gate	1.0 / 0.2	2.4	1.4	3.6	1.7	Meets
A10 T-101 containment	1.0 / 0.2	4.7	3.3	6.7	1.4	Meets

Note 1: Maintained illuminance at grade, light loss factor 0.81, 2 ft calculation grid.

Figure 6-1. Achieved Illuminance Against Target by Area



Over the whole fenced yard the average is 5.0 fc. Of the 2,000 points on the 5 ft grid, 78 fall below 0.2 fc, all north of Y = 178 ft, in the strip along the north fence beyond the north road. That strip has no equipment and no night task. The west emergency gate receives 0.8 to 2.2 fc from the nearby poles, which is adequate for emergency vehicle use without a dedicated pole. Fence-line security lighting is not required by the Basis of Design.

6.6. POLE LOCATIONS

Eight 25 ft poles light the yard, as listed in Table 6-3. TORUS placed each pole beside the cable trench that feeds it, clear of the internal road and its crane paths, and outside every Division 1 envelope. A 25 ft mounting height was chosen over 30 ft because it can be relamped from a pickup-mounted platform rather than a crane, and because the yard is compact enough that the lower height gives the required uniformity with the same number of poles. Seven poles carry twin heads on an east-west arm; pole LP-P8, north of the control valves, needs only one head.

Table 6-3: Pole Schedule

Pole	X, Y, ft	Height, ft	Heads	Load, W	Circuit	Location at grade	Location at heads
LP-P1	40, 27	25	2	300	LTG-1	Div 2	Unclassified
LP-P2	100, 36	25	2	300	LTG-1	Div 2	Unclassified
LP-P3	44, 114	25	2	300	LTG-2	Unclassified	Unclassified
LP-P4	137, 104	25	2	300	LTG-2	Div 2	Unclassified
LP-P5	166, 110	25	2	300	LTG-3	Unclassified	Unclassified
LP-P6	226, 118	25	2	300	LTG-3	Unclassified	Unclassified
LP-P7	196, 42	25	2	300	LTG-1	Unclassified	Unclassified
LP-P8	150, 152	25	1	150	LTG-3	Div 2	Unclassified

Note 1: Coordinates are plot plan feet from the south-west fence corner. Heads are horizontal (no tilt). Pole bases, drilled pier foundations, in-pole fusing and grounding are detailed on ELE-DWG-007.

6.7. INTERIOR LIGHTING

For B-102, a room 24 ft by 12 ft with a 10 ft ceiling and the work plane at 2.5 ft, the room cavity ratio is:

IES Lighting Handbook, zonal cavity method

$$RCR = \frac{5 h_{rc}(L + W)}{L W} = \frac{5(7.5)(24 + 12)}{24 \times 12} = 4.69$$

which gives a coefficient of utilization $CU = 0.599$. The number of luminaires for 50 fc is:

IES Lighting Handbook, lumen method

$$N = \frac{EA}{\Phi CULLF} = \frac{50 \times 288}{5,000 \times 0.599 \times 0.81} = 5.94 \rightarrow 6$$



$$E = \frac{6 \times 5,000 \times 0.599 \times 0.81}{288} = 50.5 \text{ fc}$$

The same method for B-101 (room cavity ratio 5.50, $CU = 0.550$) requires 1.76 luminaires; two give 34 fc. Table 6-4 summarizes both buildings.

Table 6-4: Interior Lighting

Room	Size, ft	RCR	CU	Target, fc	Luminaires	Achieved, fc	Load, W
B-102 control and electrical room	24 x 12 x 10	4.69	0.599	50	6	50.5	240
B-101 analyzer shelter	12 x 10 x 9	5.50	0.550	30	2	34.2	80

B-102 requires 6 luminaires of 40 W (50.5 fc). B-101 requires 2 Class I Division 2 luminaires of 40 W (34 fc).

6.8. EMERGENCY AND EGRESS LIGHTING

B-102 gets two self-contained emergency lighting units and two exit signs with integral 90 minute batteries, one of each at the personnel door and at the equipment door. They are connected to the unswitched leg of the B-102 lighting circuit, so they charge continuously and light on loss of that circuit. Following NFPA 101, the units provide at least 1 fc average along the egress path for 90 minutes. Self-contained units were chosen over feeding emergency lighting from the station UPS because they keep working if the UPS or its distribution fails, and because they add nothing to the 8 hour UPS battery. B-101 is a small single-door shelter that is entered only with a portable light, so it has no emergency unit.

6.9. CIRCUITS, CONTROLS AND ENERGY

Table 6-5 lists the lighting circuits. The exterior circuits run at 277 V from distribution panel DP-101 rather than at 120 V, because the longest runs exceed 250 ft and the higher voltage keeps voltage drop within 3 % on 12 AWG conductors.

Table 6-5: Lighting Circuits

Circuit	Source	Luminaires	Load, W	Current, A
LTG-1	277 V, 1-phase, via LC-101	LP-P1, LP-P2, LP-P7, B-102 D1, B-102 D2, G-101	990	3.57
LTG-2	277 V, 1-phase, via LC-101	LP-P3, LP-P4, 6 canopy luminaires	960	3.47
LTG-3	277 V, 1-phase, via LC-101	LP-P5, LP-P6, LP-P8, B-101 door	780	2.82

Circuit	Source	Luminaires	Load, W	Current, A
LTG-B102	120 V, 1-phase, LP-101	6 interior luminaires, 2 emergency units, 2 exit signs	256	2.13
LTG-B101	120 V, 1-phase, LP-101	2 Class I Division 2 luminaires	80	0.67

A photocell on the north wall of B-102 closes lighting contactor LC-101 at dusk. A hand-off-auto selector on the contactor lets the operator force the lights on for maintenance, and an auxiliary contact is available for status to the RTU. The yard lighting stays on after a station emergency shutdown because it supports emergency response. Gas detection in B-101 isolates only the non-rated equipment in the shelter; the Division 2 luminaires stay energized. All lighting is backed by standby generator G-101 through the automatic transfer switch, but not by the UPS. The B-102 interior lighting has a vacancy sensor at the personnel door, and B-101 a Division 2 switch outside its door.

The exterior connected load is 2.73 kW. At 4,300 h/yr dusk to dawn, the annual energy is:

$$E_{yr} = P \times t = 2.73 \text{ kW} \times 4,300 \text{ h} = 11,700 \text{ kWh/yr}$$

7. RESULTS AND CONCLUSIONS

Table 7-1 gives the luminaires required for the station.

Table 7-1: Luminaire Summary

Type	Description	Quantity	Watts each	Location
LA	LED area luminaire 150 W, Type V, Class I Div 2 T4	15	150	8 poles, 25 ft
LB	LED canopy luminaire 60 W, Class I Div 2 T4	6	60	Meter skid canopy
LC	LED wall pack 30 W, Class I Div 2 T4	4	30	B-102 doors, B-101 door, G-101
LD	LED 4 ft enclosed linear 40 W	6	40	B-102
LE	LED 4 ft linear 40 W, Class I Div 2 T4	2	40	B-101
EM	Emergency lighting unit, 90 min battery	2	5	B-102 doors
EX	Exit sign, 90 min battery	2	3	B-102 doors

TORUS draws the following conclusions:

- Eight 25 ft poles carrying 15 Class I Division 2 T4 area luminaires (7 twin-head poles and one single-head pole), six canopy luminaires and four wall packs meet every exterior target. The exterior connected load is 2.73 kW at 277 V, which ELE-CAL-001 carries.
- B-102 requires 6 and B-101 requires 2 40 W LED luminaires.

3. The operating areas with a 5 fc target are lit 2 % to 72 % above it. This margin covers the difference between the symmetric model and the vendor's photometry, and should be preserved when the luminaire is purchased.

The next step is to repeat the point-by-point calculation with the selected vendor's IES files and confirm the pole design for the site wind speed. The following items remain open: vendor photometry and luminaire data (HOLD H-15) and the site-specific wind data for the poles (HOLD H-06).



APPENDIX A. LIGHTING PLAN



