

OWNER

Fuel Gas System and Utility Consumption

Calculation

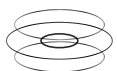


Document No.: PRO-CAL-010

Rev. A, Issued for Review

Date: September 29, 2026

Project:



TORUS

, County,

ISSUE SUMMARY AND APPROVAL

This page records each issue of PRO-CAL-010. The preparer, reviewer and approver sign for each revision.

Rev.	Date	Issue purpose	Description
A	2026-09-29	Issued for Review	First issue

Contributors

Rev.	Discipline	Prepared by	Reviewed by	Approved by
A	Process			

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1. OBJECTIVE

This calculation sets the fuel gas demand of the , sizes the two-cut fuel gas regulation on skid FG-101 and the electric fuel gas preheater E-161, checks the fuel gas lines, and summarizes the station's process utility consumption.

2. METHODOLOGY

TORUS summed the simultaneous fuel gas consumers, which occur together during a winter utility outage: the line heater at its firebox rating, its pilot, and standby generator G-101 at full load. A 10 % margin was added for sizing the regulators and fuel meter. The fuel draw in each operating case, used in the heat and material balance, is the heater's fired duty divided by the gas heating value, plus the pilot.

The temperature after each pressure cut was calculated as an isenthalpic expansion with the GERG-2008 equation of state. It was compared with the hydrate dewpoint of tariff-quality gas, the hydrocarbon dewpoint and the minimum design metal temperature. From this, the required E-161 outlet temperature and duty were found.

PCV-161 and PCV-162 were sized with the ISA-75.01.01 compressible flow equation. The expansion factor uses the isentropic exponent $\kappa = \rho c^2 / p$ from the real-gas speed of sound, which is the exponent the equation assumes. The real-gas ratio c_p / c_v would overstate it by about 12 % at the take-off pressure. The wide-open flow through PCV-161 at the maximum take-off pressure is the relief load for PSV-161, sized in PRO-CAL-007. The fuel lines were checked with the Darcy-Weisbach equation.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Fuel take-off point	V-101 outlet, upstream of the custody meters	GEN-DB-001
Take-off pressure range	897 to 1,148 psig	PRO-CAL-002, cases C5 and C1
Take-off temperature range	45 to 120 °F	GEN-DB-001 operating cases
PCV-161 and PCV-162 set pressures	150 psig and 15 psig	GEN-DB-001; second cut selected
Low-pressure fuel piping rating	285 psig (ASME Class 150)	ASME B16.5

Input	Value	Source
H-101 firebox rating and pilot	6.0 MMBtu/h and 25 scf/h	PRO-CAL-004
G-101 rating and heat rate	60 kW, 12,500 Btu/kWh	Typical, HOLD H-15
Design gas heating value	1,103.7 Btu/scf	GEN-DB-001
E-161 outlet setpoint	105 °F	Instrument and control design
Regulator x_T and candidate wide-open C_v	0.7; PCV-161 0.6, PCV-162 4.0	Typical, HOLD H-15

4. ASSUMPTIONS

1. The heater, its pilot and the generator can run together, during a winter utility outage.
2. The G-101 heat rate, the pilot flow, and the regulator C_v and x_T values are typical. *Verification required (HOLD H-15).*
3. Every component downstream of PCV-161, including those downstream of PCV-162, the burner train and the G-101 gas train inlet, is rated for at least 285 psig. PSV-161 then protects the whole low-pressure system. *Verification required from the heater and generator vendors.*
4. Nitrogen quantities assume pressure-cycle purging. The commissioning procedure may use flow-through purging instead.

5. REFERENCES

1. ANSI/ISA-75.01.01 (IEC 60534-2-1), Flow Equations for Sizing Control Valves.
2. NFPA 54, National Fuel Gas Code (2024), where applicable to fuel piping.
3. API Recommended Practice 556, Instrumentation, Control, and Protective Systems for Gas Fired Heaters.
4. GEN-DB-001, Basis of Design.
5. PRO-CAL-002, Line Sizing and Station Hydraulics; PRO-CAL-003, Hydrate and Dewpoint; PRO-CAL-004, Line Heater; PRO-CAL-007, Pressure Relief Devices.

6. CALCULATION

6.1. FUEL GAS DEMAND

Table 6-1 lists the consumers. The design flow is the sum of the heater at its rating, the pilot and the generator, plus 10 %.

Table 6-1: Fuel Gas Consumers

Consumer	Flow, scf/h	Duty cycle	Source
H-101 main burner, at the 6.0 MMBtu/h firebox rating	5,440	Intermittent, on TIC-152 demand	PRO-CAL-004
H-101 pilot	25	Continuous while the heater is in service or hot standby	Typical, HOLD H-15
G-101 standby generator, 60 kW at 12,500 Btu/kWh	680	Utility outage and weekly test	Typical, HOLD H-15
Design flow (sum x 1.10)	6,760	330 lb/h	Regulator and meter sizing

$$Q_{design} = 1.10 (5,440 + 25 + 680) = 6,760 \text{ scf/h} = 330 \text{ lb/h}$$

The fuel drawn in each operating case is given in Table 6-2. Case C1 governs at 4,820 scf/h. In the cases where the heater is bypassed it stays in hot standby on its pilot, so it can return to service without a cold start.

Table 6-2: Fuel Draw by Operating Case

Case	H-101	Absorbed duty, MMBtu/h	Burner, scf/h	Total, scf/h	Total, lb/h
C1	In service	3.96	4,790	4,820	235.5
C2	Bypassed, hot standby	0.00	0	25	1.2
C3	Bypassed, hot standby	0.00	0	25	1.2
C4	Bypassed, hot standby	0.00	0	25	1.2
C5	In service	0.03	32	57	2.8
C6	Bypassed, hot standby	0.00	0	25	1.2
C7	In service	1.52	1,740	1,760	86.3

6.2. TEMPERATURES THROUGH THE REGULATORS AND E-161 DUTY

Without preheat, the first cut from 1,148 psig at 45 °F to 150 psig in case C1 cools the gas to -36 °F. That is below the -20 °F minimum design metal temperature and below the 4 °F hydrate dewpoint of tariff gas at 150 psig, and the second cut takes it lower. The fuel gas must therefore be preheated. Table 6-3 shows the temperatures in every case, with and without E-161.

Table 6-3: Fuel Gas Temperatures Through the Regulators, °F

Case	Take-off, psig	Take-off	After PCV-161, no preheat	After PCV-162, no preheat	E-161 outlet	After PCV-161	After PCV-162
C1	1,150	45	-36	-50	105	46	36
C2	1,050	70	7	-5	105	52	42
C3	1,000	60	-3	-15	105	55	45



Case	Take-off, psig	Take-off	After PCV-161, no preheat	After PCV-162, no preheat	E-161 outlet	After PCV-161	After PCV-162
C4	1,100	120	68	59	120	68	59
C5	897	60	5	-7	105	61	52
C6	1,150	45	-36	-50	105	46	36
C7	1,100	60	-11	-23	105	49	39

E-161 must heat the gas enough to meet two criteria: the PCV-162 outlet stays at or above 20 °F, and the PCV-161 outlet stays at or above 40 °F. Table 6-4 gives the E-161 outlet temperature each criterion needs. The 105 °F setpoint covers both in every case, including rich-gas case C7. At 105 °F the hydrocarbon dewpoint (-52 °F at 15 psig) is never approached.

Table 6-4: Minimum E-161 Outlet Temperature and Duty

Case	For PCV-162 outlet 20 °F, °F	For PCV-161 outlet 40 °F, °F	E-161 duty at design flow, kW
C1	93	100	3.98
C2	88	96	2.20
C3	86	93	2.81
C4	120	98	0.00
C5	80	88	2.74
C6	93	100	3.98
C7	91	98	2.90

The duty in case C1, with the design fuel flow heated from 45 °F to 105 °F at 1,148 psig, is:

$$\dot{Q} = \dot{m}(h_{105} - h_{45}) = 330 \times 41.11 = 13,600 \text{ Btu/h} = 3.98 \text{ kW}$$

E-161 is rated 5 kW, 26 % above the 3.98 kW design duty, with its outlet controlled at 105 °F.

TORUS selected an electric heater rather than a fuel gas coil in the H-101 bath. The bath is cold at start-up and during summer hot standby, exactly when a coil could not preheat the fuel. E-161 is fed from the standby-power panel so it also serves G-101 during an outage.

6.3. PCV-161, FIRST CUT

PCV-161 is sized at the minimum take-off pressure, 897 psig in case C5, with the gas preheated. At 911.3 psia the isentropic exponent is $\kappa = 1.330$, so $F_k = 0.950$ and the flow is choked:

ISA-75.01.01, compressible flow

$$x = 0.820 > F_k x_T = 0.665, \quad Y = 0.667$$

$$C_v = \frac{W}{63.3 Y \sqrt{x P_1 \rho_1}} = \frac{330}{63.3(0.667) \sqrt{0.665(911.3)(3.172)}} = 0.179$$



PCV-161 needs $C_v = 0.18$. A 1 in pilot-operated regulator with a wide-open C_v of 0.6 runs at 30 % of capacity at the design flow.

A regulator with a smaller orifice was not chosen because the 0.6 trim already gives adequate turndown to the 25 scf/h pilot flow, and a smaller trim would leave no margin for the generator start.

6.4. PCV-162, SECOND CUT

From 150 psig at 46 °F to 15 psig the flow is also choked ($x = 0.823$, above $F_{kx_T} = 0.642$). The required C_v is 1.00.

PCV-162 is a 1 in regulator with a wide-open C_v of 4.0, running at 25 % of capacity. The final burner and generator supply pressures are set by the packaged regulators on the H-101 burner train and G-101.

6.5. PCV-161 FAILED OPEN

If PCV-161 fails wide open at the maximum take-off pressure of 1,148 psig with E-161 off (45 °F gas), the flow into the low-pressure system held at the PSV-161 relieving pressure of 275 psig is:

ISA-75.01.01, compressible flow

$$W = 63.3 C_v Y \sqrt{x P_1 \rho_1} = 63.3(0.6)(0.667) \sqrt{F_{kx_T} (1162.1)(5.093)} = 1,650 \text{ lb/h}$$

This is the PSV-161 relief load used in PRO-CAL-007.

6.6. FUEL GAS LINES

Table 6-5 gives the velocity and pressure drop in each fuel line at its design flow. The lengths are the routed lengths from the piping model.

Table 6-5: Fuel Gas Line Hydraulics

Line	Service	Flow, lb/h	Pressure, psig	Length, ft	Velocity, ft/s	Pressure drop, psi	Mach
2"-F-1050-A6	V-101 outlet take-off to FG-101 / E-161 / PCV-161	330	897	15	1	0.00	0.00
2" FG-101 internal, A1	PCV-161 to PCV-162	330	150	15	7	0.01	0.01
1"-F-1051-A1, NPS 1 alternative	PCV-162 to H-101 burner	294	15	222	155	19.39	0.12
2"-F-1051-A1, as designed	PCV-162 to H-101 burner	294	15	222	38	0.56	0.03

Line	Service	Flow, lb/h	Pressure, psig	Length, ft	Velocity, ft/s	Pressure drop, psi	Mach
1"-F-1052-A1	PCV-162 to G-101	36	15	124	19	0.20	0.02

Note 1: Fittings are three to six socket-weld elbows at $K = 30 f_T$ each, plus 0.5 for the entrance or tee.

At the 15 psig burner supply pressure an NPS 1 line to H-101 would run at 155 ft/s and lose 19.4 psi, which would starve the burner. Line 1051 is therefore NPS 2, which runs at 38 ft/s and loses 0.56 psi. Moving PCV-162 to the heater, so that the long run is at 150 psig, was considered and rejected because it would split the fuel gas skid and put a regulator vent point in the heater area. Line 1052 to G-101 is adequate at NPS 1.

6.7. PROCESS UTILITY SUMMARY

Table 6-6 summarizes the process utilities.

Table 6-6: Process Utility Consumption

Utility	Quantity	Notes
Fuel gas	Design 6,760 scf/h; case C1 4,820 scf/h; hot standby 25 scf/h	Annual heater fuel about 5.2 MMscf (PRO-CAL-004)
Electric power, fuel gas preheat	E-161, 5 kW rated, 3.98 kW at design flow in case C1	Standby-power panel
Electric power, process actuators	SDV power units, MOVs, FCV actuators, LCV-104, SDV-106 and BMS: about 5 kW connected, under 1.5 kW running	Typical; electrical load study governs
Nitrogen, commissioning	8,590 scf for three pressure cycles to 30 psig (956 ft ³ internal volume); 7,410 scf more for a 100 psig leak test	Portable supply
Nitrogen, maintenance	About 2,560 scf per purge of the inlet section (two cycles to 30 psig)	Per event
Natural gas, initial pack	93,800 scf to pressurize the station to 1,150 psig	Excludes the Owner lateral
H-101 bath fluid	About 4,000 gal of 50 wt % ethylene glycol and water	Indicative, HOLD H-15
Instrument air, water, chemicals	None	Electric actuation throughout

7. RESULTS AND CONCLUSIONS

TORUS draws the following conclusions:

1. The fuel gas design flow is 6,760 scf/h (330 lb/h). Case C1 draws 4,820 scf/h.

2. Fuel gas shall be preheated before PCV-161. E-161 is rated 5 kW and set at 105 °F, which keeps the PCV-161 outlet at or above 40 °F and the PCV-162 outlet at or above 20 °F in every case.
3. PCV-161 is a 1 in regulator with C_v 0.6, set at 150 psig. PCV-162 is a 1 in regulator with C_v 4.0, set at 15 psig. PCV-161 failed open passes 1,650 lb/h, the PSV-161 relief load.
4. Line 1051 to the H-101 burner shall be NPS 2. Line 1052 to G-101 remains NPS 1.
5. FT-163 shall be ranged 0 to 350 lb/h. SDV-165 closes on station ESD and on a burner management trip.

The following items remain open: vendor ratings of the burner train and G-101 gas train components (at least 285 psig), the G-101 heat rate, and the regulator trims (HOLD H-15).

