

OWNER

Fire and Gas Detection Philosophy

Report

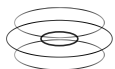


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N O T I C E

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ISSUE SUMMARY AND APPROVAL

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1. INTRODUCTION

1.1. PURPOSE

This report sets the fire and gas (F&G) detection philosophy for the (). It states what is detected, where, with which technology, at which setpoints and voting, and what the safety programmable logic controller (safety PLC) does in response. It also records the calculations that size the ventilation of analyzer shelter B-101 and limit the gas that a sample-line failure can release into it.

1.2. SCOPE

The report covers analyzer shelter B-101, control and electrical building B-102, the burner end of line heater H-101, the emergency shutdown (ESD) pushbuttons, the beacons and horn, and the portable gas monitors carried by technicians. The detector layout is drawing SAF-DWG-001, Fire and Gas Detector Layout, reproduced as Figure 3-1.

1.3. EXCLUSIONS

Area classification is covered by ELE-RPT-001, Hazardous Area Classification, and ELE-DWG-002, Hazardous Area Classification Plan. Facility spacing and the radiation from an ignited vent are covered by SAF-RPT-004, Facility Siting and Spacing Review. The burner management system (BMS) flame detectors inside the H-101 firebox belong to the heater vendor's package and are covered by SAF-SRS-001, Safety Requirements Specification. Firefighting is left to the local fire department under SAF-RPT-005, Emergency Response Plan.

2. DESIGN BASIS

2.1. OPERATING CONTEXT

The station is unmanned. A technician visits for routine work, assumed to be a few hours a week (HOLD, Owner staffing), and the Owner's gas controller monitors the station from the SCADA host. F&G detection therefore has two jobs. The first is to protect the two enclosed buildings, where gas can accumulate and where an ignition would do the most harm. The second is to start a station ESD on confirmed gas or fire, so the inventory feeding a release is isolated without waiting for a call-out.

2.2. HAZARD BASIS

The hazards that drive detection are set out in Table 2-1. The gas is dry, sweet and lighter than air, which governs where detectors are placed.

Table 2-1: Hazard Basis

Item	Value	Source
Fluid	Treated, dehydrated sweet natural gas, molecular weight 17.2 to 19.7, specific gravity 0.59 to 0.68	GEN-DB-001
Hydrogen sulfide	0.25 grain/100 scf (4.0 ppmv) tariff maximum	GEN-DB-001
Lower flammable limit (LFL), hydrocarbons only	4.56 vol % design gas, 4.83 lean, 4.33 rich	Section 5.1
Detector calibration gas	Methane; 100 % LEL taken as 5.0 vol % methane (confirm with the detector standard adopted, HOLD H-15)	INS-DS-009
Fire hazards	Jet fire from a flange or small-bore leak; flash fire; fire at the H-101 fuel train; electrical fire in B-102	SAF-RPT-001

Because the gas rises, detectors inside buildings are mounted high, at the ceiling above the leak sources, and at the B-102 air intake, where gas would be drawn in. Toxic gas detection is not provided. At the 4.0 ppmv tariff limit, hydrogen sulfide stays below the OSHA ceiling and below the usual 10 ppm alarm setpoint, and analyzer AT-143 shuts in off-specification gas before it reaches the station in quantity.

2.3. OPEN-AREA DETECTION

TORUS considered point gas detectors in the open process yard and did not adopt them. A buoyant gas released in a well-ventilated yard rises and disperses, so a point detector has a low chance of sitting in the plume. With nobody on site for most of the week, the consequence reduction a yard detector could buy is small. Outdoor releases are covered instead by the ESD pushbuttons, the technician's portable monitor, and the SCADA process alarms on pressure decay and rate of change at PT-101 and PT-172.

This follows the performance-based approach of ISA-TR84.00.07 applied qualitatively to an unmanned station, and it is to be confirmed in the formal hazard and operability study (recommendation HZ-50 of SAF-RPT-001).



3. DETECTION COVERAGE

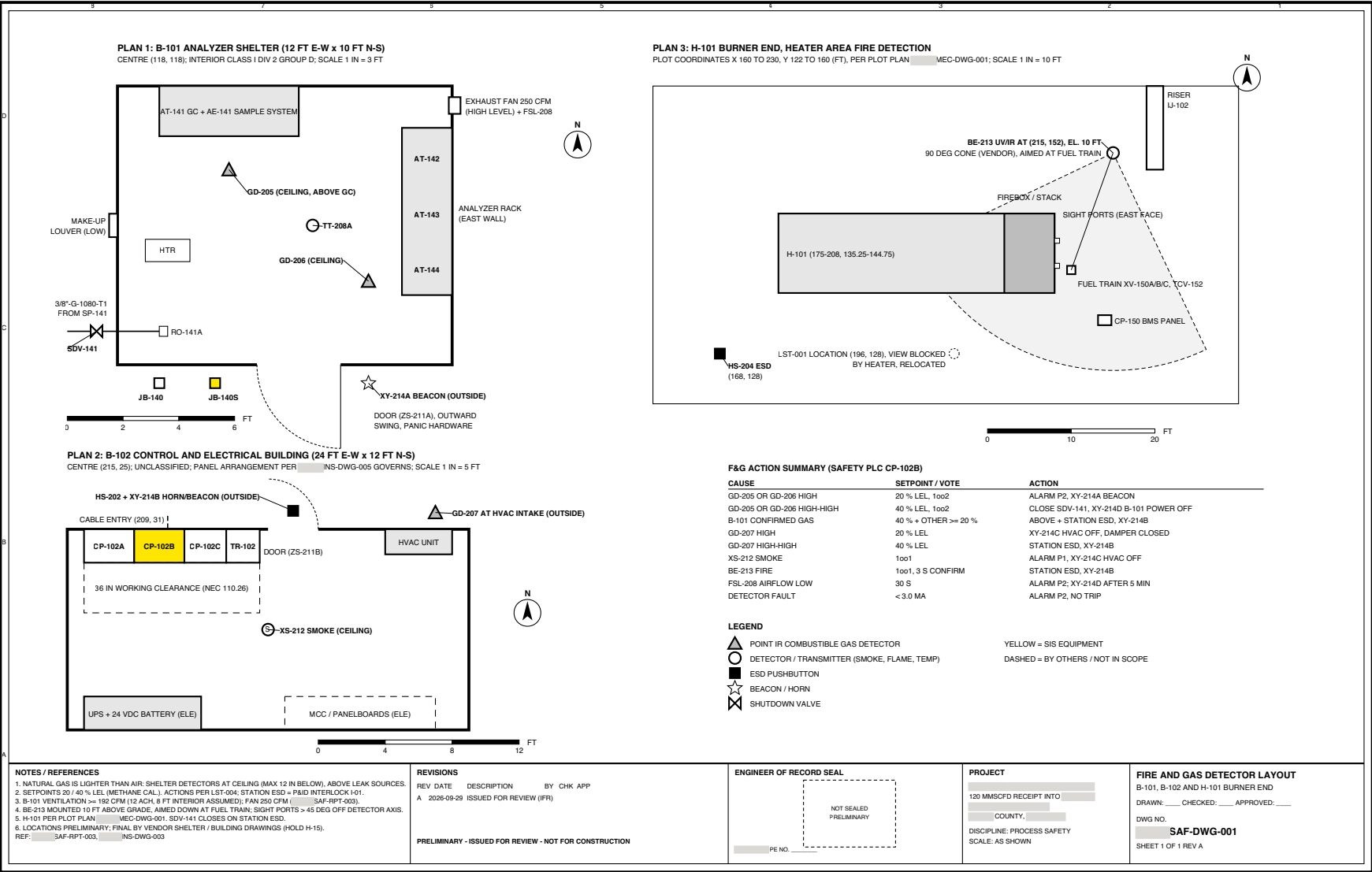
3.1. SUMMARY

Table 3-1 summarizes the detection at each area, and Figure 3-1 shows where each device is mounted.

Table 3-1: Detection Coverage

Area	Hazard	Device	Technology and location	Setpoints	Voting
B-101 analyzer shelter (Class I Division 2 inside)	Sample gas leak from the chromatograph, analyzers or sample system	GD-205, GD-206	Point infrared, 0 to 100 % LEL; at the ceiling, within 12 in of the roof, above the chromatograph and above the analyzer rack	20 % and 40 % LEL	One at 40 % and the other at 20 %
B-102 control building (unclassified)	Gas drawn in by the HVAC unit	GD-207	Point infrared, at the HVAC outside-air intake on the north wall	20 % and 40 % LEL	1oo1
B-102	Electrical fire	XS-212	Photoelectric smoke, ceiling center	Alarm	1oo1
H-101 burner end	Fuel train fire, burner-front fire	BE-213	Ultraviolet and infrared flame detector, explosion-proof; at (215, 152), 10 ft above grade, aimed at the fuel train	Fire output	1oo1, 3 s confirmation
Whole station	Any release	Portable monitor	Four-gas (LEL, oxygen, carbon monoxide, hydrogen sulfide), worn in the breathing zone	10 % and 20 % LEL	Personal
Whole station	Any emergency	HS-201 to HS-204	ESD pushbuttons at the main gate, B-102, the meter skid and the heater	Manual	1oo1

Figure 3-1. Fire and Gas Detector Layout, SAF-DWG-001



3.2. B-101 ANALYZER SHELTER

Two point infrared detectors are installed rather than one. The pair allows a confirmed vote, so a single spurious reading does not trip the station, while a single high-high reading still closes the sample shutoff and isolates the shelter power at once. Those two actions do not stop delivery and need no confirmation. Infrared detectors were chosen over catalytic bead because they do not poison, fail to a detectable fault state, and need no oxygen to read.

The shelter is 12 ft east-west by 10 ft north-south. Each detector covers about half of the 120 ft² roof, and no tubing fitting on the chromatograph or analyzer panels is more than about 6 ft horizontally from the nearer detector.

The sample line enters at the south-west corner through SDV-141, a fail-closed solenoid valve on the safety PLC, and restriction orifice RO-141A downstream of it. SDV-141 closes on every station ESD. RO-141A has a 1/32 in bore. At the 25 psig regulated sample pressure it limits a full tubing break inside the shelter to 32 scfh. That is a quarter of the ventilation's dilution capacity, so the shelter stays below 25 % LEL without any detector acting (Section 5.3).

If the probe regulator at SP-141 fails open, relief valve PSV-141B at the regulator outlet holds the RO-141A inlet at or below 55 psig. PSV-141B is outside the shelter, upstream of SDV-141, set at 50 psig, and discharges to the valve bleed header. At 55 psig, RO-141A passes 57 scfh, still inside the dilution capacity. Without PSV-141B, the failed-open case would pass about 1,100 scfh through RO-141A, nine times the dilution capacity, and the sample components upstream of PCV-141E would see line pressure. The probe vendor is to confirm the relief capacity of PSV-141B for the failed-open regulator (HOLD H-15).

Exhaust fans EF-101A and EF-101B, 250 cfm each, run duty and standby at high level with a low-level make-up louver. They give at least 12 air changes per hour for an interior height of 8 or 9 ft. Airflow switch FSL-208 in the duct is wired to the safety PLC; if airflow is lost for 5 min, the PLC isolates the non-rated power in the shelter through XY-214D. Analyzer and chromatograph vents and sample bypass flows are piped outside to a point above the roof, so they are not leak sources inside.

Beacon XY-214A is mounted outside the shelter door so that a technician sees a gas condition before opening it. The detector displays can be read through the door window.

3.3. B-102 CONTROL BUILDING

B-102 is outside all classified areas. Its nearest release source, SDV-103 and CKV-171, is 57.9 ft away (SAF-RPT-004). The building holds non-rated equipment, so the credible path for gas to reach an ignition source is through the HVAC outside-air intake. GD-207 is mounted at the intake. At 20 % LEL the safety PLC stops the HVAC unit and closes the outside-air damper through XY-214C, before gas enters. At 40 % LEL a station ESD follows.

Smoke detector XS-212 at the ceiling center covers the 288 ft² room within the listed spacing of a typical photoelectric detector (NFPA 72; confirm with the listed device). Smoke stops the HVAC unit, so a fire is not fed or spread, and raises a P1 alarm. It does not start a station ESD, because a fire in B-102 is not a process release. If a fire disables the safety PLC, all its outputs are de-energize-to-trip and the station shuts down anyway.

A fixed clean-agent suppression system is not proposed for B-102. The building is small, unmanned and holds no critical record that cannot be restored from backup, and a fail-safe safety PLC makes suppression unnecessary for process safety. A 10 lb carbon dioxide extinguisher and a 20 lb ABC extinguisher are provided inside the door. The Owner's insurer is to confirm that no fixed suppression is required (HOLD, Owner).

3.4. H-101 HEATER AREA

A fire at H-101 is a station ESD cause in GEN-DB-001. The BMS flame detectors BE-153A and BE-153B look into the firebox and cannot see an external fire, so a separate ultraviolet and infrared flame detector, BE-213, watches the burner end.

BE-213 stands at (215, 152), 10 ft above grade, aimed down and to the south-west at the fuel train. The fuel train is 14.9 ft away and burner panel CP-150 is 21.0 ft away, both well inside the typical 50 ft range for a 1 ft² hydrocarbon fire (vendor to confirm, HOLD H-15). An earlier location south-west of the heater, at (196, 128), was rejected because the heater body blocks the line of sight to the fuel train: the sight line crosses the burner end at Y = 136.6 ft, inside the heater footprint.

The burner flame itself must not trip BE-213. It is visible only through the sight ports on the east face. The line from the center of the burner face to BE-213 is 63.4° off the sight-port axis, while a sight tube with a length-to-diameter ratio of 2 or more shows the flame only within 26.6° of its axis. BE-213 therefore cannot see the burner flame. Sight-port covers are kept closed except during inspection, and the inspection procedure places BE-213 in maintenance bypass (Section 6.2). A 3 s confirmation delay rejects transients such as lightning and reflected welding arcs.

3.5. PORTABLE GAS MONITORS

Every person who enters the fence carries a calibrated, bump-tested four-gas monitor, switched on before entry. Portable monitors are the only detection for yard work (opening the pig receiver, changing filter elements, meter inspection, heater light-off), and the procedures for those tasks require a continuous LEL reading at the work point. Hydrogen sulfide is included because contractor crews may come from sour systems elsewhere; the Owner's program may omit it for its own staff. The alarm setpoints are 10 % and 20 % LEL, oxygen 19.5 % and 23.5 %, carbon monoxide 35 ppm and hydrogen sulfide 10 ppm. Before opening B-101, the technician checks beacon XY-214A and the SCADA reading and samples at the door gap. Two monitors and a docking station are kept at the Owner's field office rather than on site, to avoid unattended temperature exposure.

4. SETPOINTS, VOTING AND ACTIONS

4.1. SETPOINTS AND VOTING

Table 4-1 sets the setpoints and voting of each fixed detector.

Table 4-1: Detector Setpoints and Voting

Detector	High (P2)	High-high	Vote for station ESD	Fault
GD-205, GD-206	20 % LEL, 5 s	40 % LEL, 5 s	One at 40 % and the other at 20 %	Below 3.0 mA: P2 alarm, not a trip vote
GD-207	20 % LEL, 5 s	40 % LEL, 5 s	1oo1 at 40 %	Below 3.0 mA: P2 alarm
BE-213	None	Fire output, 3 s	1oo1	Fault output: P2 alarm
XS-212	Smoke, no delay	None	No ESD	Trouble contact: P2 alarm

The 20 % and 40 % LEL values are those of GEN-DB-001. In this gas (LFL 4.33 vol %, rich case) they equal 0.87 and 1.73 vol %. Infrared detectors calibrated on methane read higher than the true % LEL for gas containing ethane and propane, so methane calibration errs toward an earlier alarm (response factors to be confirmed by the vendor). With one B-101 detector in fault, the healthy detector at 40 % LEL alone starts the confirmed action; this degraded 1oo1 mode is programmed as described in INS-RPT-001, Control Philosophy and Functional Narrative. Detector outputs are 4 to 20 mA, with fault below 3.0 mA and over-range above 20 mA.

4.2. CAUSE AND EFFECT

Table 4-2 summarizes the F&G actions. The governing matrix is INS-LST-004, Cause and Effect Matrix. “Station ESD” means P&ID interlock I-01, which closes SDV-101, SDV-102, SDV-103, SDV-106, SDV-141 and SDV-165, trips the BMS to close burner shutoff valves XV-150A/B/C, and drives the flow control valves to 0 %. SDV-165 is on the heater fuel branch only; the generator fuel branch stays live after an ESD, so standby power remains available to the UPS, the remote terminal unit and the safety PLC.

Table 4-2: Fire and Gas Cause and Effect Summary

Cause	Station ESD	SDV-141	XY-214A	XY-214B	XY-214C	XY-214D	Alarm
GD-205 or GD-206 at 20 % LEL	No	None	On	None	None	None	P2
One B-101 detector at 40 %, other below 20 %	No	Close	On	None	None	Off	P2
B-101 confirmed (one at 40 %, other at 20 %)	Yes	Close	On	On	None	Off	P1

Cause	Station ESD	SDV-141	XY-214A	XY-214B	XY-214C	XY-214D	Alarm
GD-207 at 20 % LEL	No	None	None	On	Off	None	P2
GD-207 at 40 % LEL	Yes	Close	None	On	Off	None	P1
BE-213 fire, 3 s	Yes	Close	None	On	None	None	P1
XS-212 smoke	No	None	None	On	Off	None	P1
FSL-208 airflow low for 5 min	No	None	None	None	None	Off	P2 at 30 s
Detector fault	No	None	None	None	None	None	P2

Note 1: XY-214A is the B-101 beacon, XY-214B the B-102 beacon and horn, XY-214C the B-102 HVAC stop and damper, XY-214D the B-101 non-rated power isolation. “On” and “Off” are the commanded states; “None” means no action.

All F&G actions latch in the safety PLC and are reset locally at panel CP-102B once the cause has cleared. No automatic blowdown follows an F&G shutdown, because a manual blowdown one section at a time keeps the vent radiation within limits (PRO-CAL-008, Blowdown, Vent Header and Vent Stack Calculation). The B-101 fans run continuously at a single speed and are not changed by the F&G system.

4.3. BEACONS, HORN AND SIGNS

Beacon XY-214A outside the B-101 door shows gas in the shelter. Beacon and horn XY-214B at the B-102 door signal an ESD, fire or gas anywhere on site; the horn is silenced from CP-102B or from SCADA. Signs at each gate and building door read “Natural gas facility, no smoking or open flame” and “Do not enter when beacon is on” and give the emergency numbers. Muster point signs are posted at MP-1 and MP-2 (SAF-RPT-005), and two windsocks, on B-102 and near the west emergency gate, let the technician choose the upwind muster point.

5. CALCULATIONS

5.1. LOWER FLAMMABLE LIMIT

The LFL of each gas case was calculated by Le Chatelier's rule over the hydrocarbon components only, with nitrogen and carbon dioxide left out. Leaving out the inerts gives a lower, and therefore conservative, limit. The lowest value, 4.33 vol %, for the rich case, is used throughout.

Le Chatelier's mixing rule

$$LFL = \left(\sum_i \frac{y_i}{LFL_i} \right)^{-1} = \frac{1}{0.2309} = 4.33 \text{ vol \%}$$

5.2. B-101 VENTILATION

TORUS took the interior height of B-101 as 8 ft, the lower bound, because a lower height gives the smaller air volume and the lower dilution capacity. ELE-RPT-001 uses 9 ft clear. Twelve air changes an hour was adopted as the adequate-ventilation rate, because it exceeds the alternative floor-area criterion of 1 cfm/ft² (120 cfm) and is common practice for analyzer shelters.

$$Q_{min} = \frac{12 \times (12 \times 10 \times 8)}{60} = 192 \text{ cfm}$$

The selected fans deliver 250 cfm each, which gives 15.6 air changes an hour at 8 ft and 13.9 at 9 ft. If the vendor shelter is taller than 10 ft, the fans shall be re-sized to hold 12 air changes an hour.

5.3. DILUTION CAPACITY

The largest continuous release that the ventilation keeps at or below 25 % LEL, assuming the shelter air is well mixed, was calculated at the minimum airflow. The mole fraction at 25 % LEL is $x = 0.25 \times 0.0433 = 0.01083$.

$$q_{gas} = \frac{xQ}{1-x} = \frac{0.01083 \times 192}{0.98917} = 2.10 \text{ cfm} = 126 \text{ scfh}$$

At the 250 cfm fan rate the capacity is 164 scfh. The 126 scfh value is used as the acceptance limit.

5.4. SAMPLE-LINE RELEASES

The flow from a full-bore break of the 3/8 in sample tubing (0.305 in bore) and through RO-141A was calculated with the choked-flow equation for a real gas. The isentropic exponent $\kappa = \rho c^2 / p$ from the GERG-2008 equation of state is used, not the real-gas ratio c_p / c_v , because at pipeline pressure c_p / c_v overstates the exponent (1.71 against 1.41 at 1,150 psig) and with it the flow.

Choked flow of a real gas through an orifice

$$\dot{m} = C_d A p \sqrt{\frac{\kappa M}{ZRT} \left(\frac{2}{\kappa + 1} \right)^{\frac{\kappa + 1}{\kappa - 1}}}$$

Table 5-1 compares each release with the 126 scfh dilution capacity. Without isolation, a tubing break at the regulated pressure is 19 times the dilution capacity, which is why the shelter needs both the orifice and the detection. RO-141A alone brings the regulated-pressure case and the failed-regulator case with PSV-141B inside the capacity. Flows through RO-141A are those of PRO-CAL-007, Pressure Relief Devices and Tank Venting, with a discharge coefficient of 0.80; TORUS reproduced them independently to within 0.1 %.

Table 5-1: Sample-Line Releases into B-101

Case	Upstream pressure, psig	Flow into B-101, scfh	Ratio to dilution capacity
Full tubing break, no orifice, regulated pressure	25	2,360	19
Full tubing break, no orifice, regulator failed open	1,150	80,900	640
Break downstream of RO-141A, regulated pressure	25	32	0.25
Break downstream of RO-141A, regulator failed open, PSV-141B relieving	55	57	0.45
Break downstream of RO-141A, regulator failed open, no PSV-141B	1,150	1,100	8.7

Note 1: Full-bore break flows use a discharge coefficient of 0.62; RO-141A flows use 0.80, as PRO-CAL-007.

The largest orifice bore that keeps a break inside the dilution capacity is 0.070 in at 25 psig and 0.053 in at 55 psig. The selected 1/32 in bore (0.031 in) is inside both limits and still passes the analyzer demand. At full line pressure the bore would have to be 0.012 in, which is impractically small, so PSV-141B is required.

5.5. BE-213 VIEWING GEOMETRY

The detector position was checked in plan against the heater footprint on plot plan MEC-DWG-001: H-101 spans X 175 to 209 ft and Y 135.25 to 144.75 ft, with the burner face at X = 209 ft. From BE-213 at (215, 152) the burner face center at (209, 140) lies $\arctan(12/6) = 63.4^\circ$ off the sight-port axis. A sight tube with a length-to-diameter ratio of 2 limits the visible cone to $\arctan(1/2) = 26.6^\circ$, and a ratio of 3 to 18.4° , so the flame is not visible from BE-213 in either case.

6. TESTING, CALIBRATION AND BYPASS

6.1. TEST INTERVALS

Table 6-1 sets the test and calibration intervals. The annual functional test is done with the proof test of the safety instrumented functions, so the F&G actions are proven with the same final elements.

Table 6-1: Test and Calibration Intervals

Device	Bump test	Calibration	Functional test, cause to effect	Reference
GD-205, GD-206, GD-207	Monthly with 50 % LEL methane, on the routine visit	Every 6 months or per the vendor	Annually, including SDV-141, XY-214C, XY-214D and the station ESD	IEC 60079-29-2
BE-213	Monthly check of the optical integrity self-test	Per the vendor	Annually with an ultraviolet and infrared test lamp at the fuel train	Vendor manual
XS-212	Not applicable	Sensitivity test per NFPA 72	Annually	NFPA 72 Chapter 14
Portable monitors	Before each day of use	Per the vendor, typically monthly to 6-monthly	Not applicable	Owner program

6.2. BYPASS

Bypassing any F&G input in the safety PLC requires the maintenance override key HS-200B. A bypass is time-limited to 8 h by default, is recorded in the event log, raises a P3 alarm at SCADA, and requires a portable monitor in use in the affected area for its whole duration.

7. CONCLUSIONS AND NEXT STEP

TORUS draws the following conclusions:

1. Fixed detection is limited to the two enclosed buildings and the heater burner end, where gas can accumulate or where a fire is a basis ESD cause. Open-yard point detection is not provided, for the reasons given in Section 2.3.
2. The B-101 ventilation of 192 cfm minimum, provided by 250 cfm fans, dilutes up to 126 scfh of gas to 25 % LEL. RO-141A (1/32 in) with PSV-141B keeps every credible sample-line release inside that capacity, and detection with SDV-141 is the second layer.
3. BE-213 at (215, 152) sees the fuel train and burner panel, and it cannot see the burner flame through the sight ports.
4. The sample-line release estimates were corrected to use the isentropic exponent; the full-line-pressure break is 80,900 scfh, not 86,300 scfh. The conclusions do not change.

The actions in Table 7-1 remain before the design is issued for construction. The next step is to confirm the vendor data and include the F&G functional tests in the pre-startup safety review, SAF-LST-001.

Table 7-1: Actions

No.	Action	By
FG-01	Locate BE-213 at (215, 152), 10 ft above grade, aimed at the fuel train; carry the location onto INS-LST-001 and INS-DWG-003	TORUS Instrumentation
FG-02	Confirm the PSV-141B relief capacity for a failed-open probe regulator (HOLD H-15)	Probe vendor
FG-03	Confirm the B-101 interior height; supply EF-101A and EF-101B at 250 cfm each, duty and standby, with FSL-208 in the duct	Shelter vendor, TORUS Electrical
FG-04	Supply sight tubes with a length-to-diameter ratio of 2 or more and hinged covers on the burner face	Heater vendor
FG-05	Confirm that no fixed suppression is required in B-102	Owner's insurer
FG-06	Add F&G functional tests and detector calibration to the maintenance program and to SAF-LST-001	Owner operations
FG-07	Confirm detector ranges, cone angles and methane response factors (HOLD H-15)	Detector vendor

The station staffing assumed in Section 2.1 is to be confirmed by the Owner.