

OWNER

Ultrasonic Meter Sizing and Meter Run Design

Calculation



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TORUS

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

ISSUE SUMMARY AND APPROVAL

This page records each issue of ME-A-CAL-001. 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	Measurement			

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1. OBJECTIVE

This calculation confirms the size of the custody-transfer ultrasonic meters FE-111 and FE-121 and sets the geometry of meter runs MR-110 and MR-120. It establishes the meter velocity for every basis case, compares NPS 8, 10 and 12 meters, checks the run pressure drop against the basis allowance, fixes the straight lengths and the positions of the flow conditioner, thermowells and pressure tap, and states why the meter tubes are insulated and shaded.

2. METHODOLOGY

For each operating case of the Basis of Design, TORUS calculated the meter pressure by deducting the upstream losses from the station inlet pressure, and the meter temperature by isenthalpic expansion across those losses. The line heater is downstream of the meters, so it has no effect at the meter. One run carries the full case flow, as the design intends. Standard volume flow was converted to mass flow with the real-gas base density, and mass flow to actual flow with the flowing density. Bore velocity follows directly.

The velocity range was compared with typical ultrasonic meter limits and with the AGA Report No. 9 performance requirements. Run pressure drop was calculated from Darcy friction and fitting loss coefficients over the header-to-header length of the piping general arrangement. The meter tube layout follows the typical AGA 9 installation with a perforated-plate conditioner. Solar heating of the meter tube was screened to decide whether insulation and a sunshade are needed.

Gas properties are from the GERG-2008 equation of state (AGA Report No. 8 Part 2) as implemented in CoolProp 8.0, with the viscosity model of the same package.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Operating cases C1 to C7	Flow, inlet pressure and temperature per case	GEN-DB-001, Section 6
Gas composition	Design gas (C1 to C6), rich gas (C7)	GEN-DB-001, Section 5.1
Base conditions	14.73 psia, 60 °F	GEN-DB-001, Section 4
Local atmospheric pressure	14.10 psia	GEN-DB-001, Section 3
Filter separator loss, dirty	10 psi	GEN-DB-001, Section 6

Input	Value	Source
Inlet piping loss, IJ-101 to meter header	3 psi at 120 MMSCFD	Assumption 1
Meter bore	9.562 in (NPS 10 Sch 80)	GEN-DB-001, Section 8.1
Typical meter limits, qmin / qt / qmax	1.5 / 5.0 / 100 ft/s	Typical, HOLD H-15
Header centerline to header centerline	40.00 ft	Piping general arrangement, Volume 4
MOV face-to-face	31.0 in	MEC-LST-003, Valve List
Meter run pressure drop allowance	3 psi	GEN-DB-001, Section 6

4. ASSUMPTIONS

1. Pressure loss from the station inlet to the meter header is 3 psi at 120 MMSCFD in addition to the dirty filter, both scaled with the square of flow. *Verification required by the process hydraulic calculation.*
2. Typical meter limits are qmin 1.5 ft/s, qt 5.0 ft/s and qmax 100 ft/s for NPS 8 to 12 meters. *Verification required (HOLD H-15).*
3. The perforated-plate conditioner has a loss coefficient $K = 2.0$ on the pipe velocity head, and the meter body is 30 in long. *Verification required (HOLD H-15).*
4. Other loss coefficients: header tee entry 0.4, exit 0.9, full-bore ball valve 0.05, meter body 0.1, long-radius elbow 0.2, tee through branch 1.0; pipe roughness 0.0018 in.
5. The project limits operating velocity to 70 ft/s to keep noise, conditioner loss and thermowell loading moderate.

5. REFERENCES

1. AGA Report No. 9 (2022), Measurement of Gas by Multipath Ultrasonic Meters.
2. AGA Report No. 8 Part 2 (2017), Thermodynamic Properties of Natural Gas, GERG-2008.
3. ISO 17089-1:2019, Measurement of fluid flow in closed conduits, Ultrasonic meters for gas.
4. API MPMS Chapter 21.1 (2013), Flow Measurement Using Electronic Metering Systems.
5. ASME B36.10M, B16.5, B16.9 and B16.10.
6. GEN-DB-001, Basis of Design.
7. MEA-CAL-002, Measurement Uncertainty Analysis; MEA-CAL-004, Sampling System Design and Thermowell Evaluation.

8. MEA-DWG-001, Meter Run Fabrication Drawing, and MEA-DWG-002, Meter Skid General Arrangement (Appendix A).

6. CALCULATION

6.1. METER CONDITIONS

Table 6-1 gives the meter pressure and temperature for each case, and Table 6-2 the gas properties and actual flow. Cases C1 and C6 are identical at the meter because the line heater is downstream.

Table 6-1: Meter Pressure and Temperature

Case	Flow (MMSCFD)	Inlet pressure (psig)	Meter pressure (psig)	Meter temperature (°F)
C1	120	1,150	1,137.0	44.2
C2	90	1,050	1,042.7	69.6
C3	10	1,000	999.9	60.0
C4	120	1,100	1,087.0	119.4
C5	120	900	887.0	59.2
C6	120	1,150	1,137.0	44.2
C7 (rich gas)	120	1,100	1,087.0	59.2

Table 6-2: Gas Properties and Actual Flow at the Meter

Case	Z_f	Density (lb/ft ³)	Viscosity (cP)	Speed of sound (ft/s)	Actual flow (acf/h)
C1	0.7783	5.050	0.0133	1,227	48,408
C2	0.8323	4.127	0.0131	1,276	44,423
C3	0.8259	4.065	0.0129	1,258	5,012
C4	0.8807	3.715	0.0137	1,362	65,811
C5	0.8430	3.544	0.0125	1,259	68,973
C6	0.7783	5.050	0.0133	1,227	48,408
C7	0.7750	5.023	0.0135	1,184	51,912

6.2. GOVERNING CASE C5

Case C5, the lowest metering pressure at full flow, gives the highest velocity. The upstream loss is 13.0 psi, so the meter operates at 887.0 psig (901.1 psia) and 59.2 °F. The base density is 0.04889 lb/ft³ ($Z_b = 0.99743$), which gives the mass flow:

$$\dot{m} = \frac{120 \times 10^6}{86,400} \rho_b = 1,388.9 \times 0.04889 = 67.91 \text{ lb/s}$$

At the flowing density of 3.544 lb/ft³ ($Z_f = 0.84299$) the actual flow and the bore velocity are:

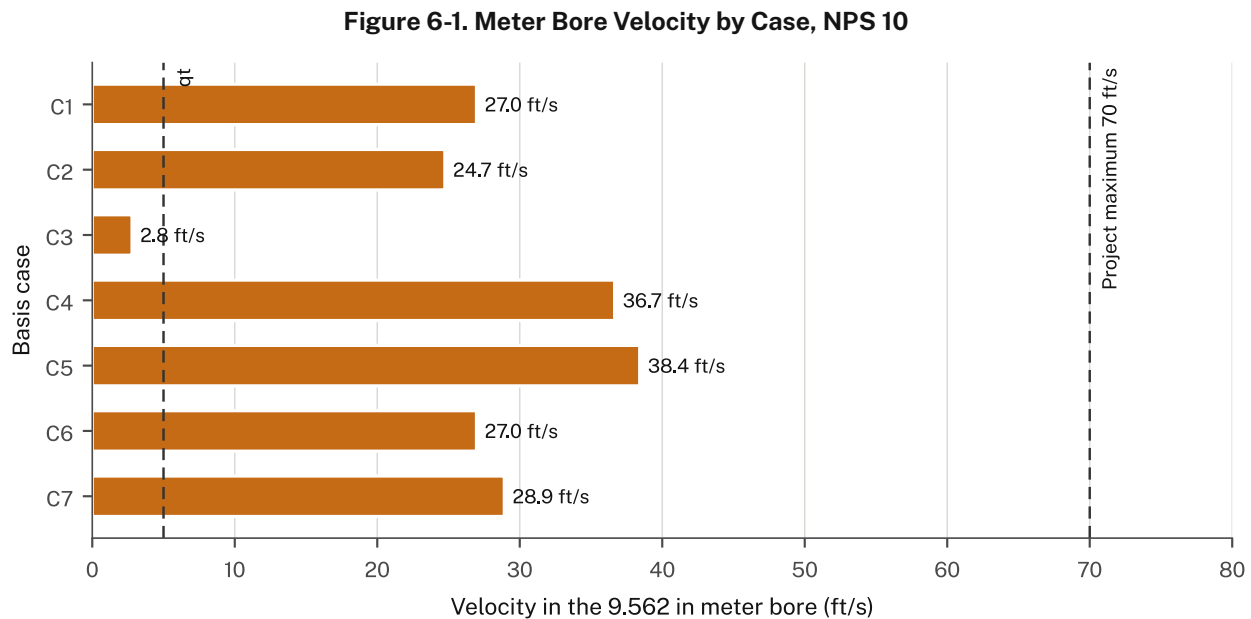
$$Q_f = \frac{\dot{m}}{\rho_f} = \frac{67.91}{3.544} = 19.16 \text{ ft}^3/\text{s} = 68,970 \text{ acf/h}$$

$$A = \frac{\pi \left(\frac{9.562}{12} \right)^2}{4} = 0.4987 \text{ ft}^2, \quad V = \frac{19.16}{0.4987} = 38.4 \text{ ft/s}$$

The Reynolds number is 1.3×10^7 ; every case is fully turbulent, from 1.0×10^6 at C3 upward.

6.3. METER SIZE

Figure 6-1 shows the bore velocity for each case against the typical transition flow rate and the project maximum. The highest velocity, 38.4 ft/s, is 38 % of the typical qmax and 55 % of the 70 ft/s project limit.



Note 1: Typical qmin 1.5 ft/s and qmax 100 ft/s (HOLD H-15). One run carries the full case flow.

Table 6-3 compares the three candidate sizes. NPS 8 would run at 60.4 ft/s at C5, and its run loss of 6.14 psi (conditioner alone 2.79 psi) would break the 3 psi allowance. NPS 12 adds cost and pushes the turndown case further below qt without any benefit. NPS 10 with the Sch 80 bore is therefore confirmed. An NPS 10 Sch 40 bore would lower the velocity by 9 %, which is not needed.

Table 6-3: Bore Velocity by Meter Size (ft/s)

Case	NPS 8 Sch 80	NPS 10 Sch 40	NPS 10 Sch 80	NPS 12 Sch 80
C1	42.4	24.6	27.0	19.1
C2	38.9	22.5	24.7	17.5

Case	NPS 8 Sch 80	NPS 10 Sch 40	NPS 10 Sch 80	NPS 12 Sch 80
C3	4.4	2.5	2.8	2.0
C4	57.6	33.4	36.7	25.9
C5	60.4	35.0	38.4	27.2
C7	45.5	26.3	28.9	20.4

The turndown case C3 runs at 2.8 ft/s, between qmin and qt for any practical size. AGA 9 allows a wider error band between qmin and qt. The flow calibration will therefore include two points in the 1.5 to 5 ft/s band, and MEA-CAL-002 carries an additional low-flow term. At C3 pressure the meter reaches qt at 17.9 MMSCFD, which is the reason the uncertainty targets are stated from 20 to 120 MMSCFD.

A single run carries every basis case. The second run would only be needed for capacity above about 250 MMSCFD, where one run reaches 80 % of qmax at C5 density.

6.4. RUN PRESSURE DROP

The loss from header to header is the Darcy friction over the 40.00 ft run plus the fitting losses. At C5 the velocity head is 0.565 psi and the Darcy friction factor 0.0137:

$$\Delta P = \left(f \frac{L}{D} + \sum K \right) \frac{\rho V^2}{2g_c} = \left(0.0137 \frac{40.00}{0.7968} + 3.5 \right) 0.565 = 0.388 + 1.98 = 2.36 \text{ psi}$$

Table 6-4 gives the result for each case. The 3 psi allowance holds with 0.64 psi margin.

Table 6-4: Meter Run Pressure Drop, Header to Header

Case	Velocity (ft/s)	Velocity head (psi)	Friction (psi)	Conditioner (psi)	Total (psi)
C1	27.0	0.396	0.272	0.793	1.66
C2	24.7	0.273	0.188	0.545	1.14
C3	2.8	0.003	0.003	0.007	0.01
C4	36.7	0.539	0.370	1.077	2.26
C5	38.4	0.565	0.388	1.129	2.36
C7	28.9	0.453	0.311	0.907	1.90

In series verification the gas passes both runs and the 33.1 ft crossover. The added loss is 1.97 psi at 90 MMSCFD and 4.07 psi at 120 MMSCFD. The loss is upstream of the flow control valves, so it reduces delivery capacity at low inlet pressure but does not affect overpressure protection. Series verification will therefore be run at the C2 rate of 90 MMSCFD or lower. The Joule-Thomson cooling between the two meters in series is 0.11 °F at 90 MMSCFD; each meter uses its own temperature, so no correction is required.

6.5. METER TUBE GEOMETRY

The meter tube follows the typical AGA 9 installation with a tested perforated-plate conditioner: 10D of straight pipe upstream of the meter with the plate 5D from the meter, and 5D downstream. TORUS selected this arrangement for four reasons. The upstream disturbance is a single header tee and a full-bore ball valve, which a tested plate handles with 10D. The whole tube, conditioner and meter are flow calibrated as one unit, so the plate-meter interaction is removed by calibration and only the header difference remains as an installation term. The header tee is 18.3D from the meter inlet, well beyond the 10D minimum. And the 5D downstream spool keeps both thermowells inside the calibrated assembly and meets the basis requirement for TT-111 at 2 to 5D downstream.

The skid piping (headers, valves and crossover) follows the piping general arrangement. The calibrated assembly is placed within that run as Table 6-5 shows.

Table 6-5: Meter Run Geometry, D = 9.562 in

Segment	Length (in)	Length (D)	Plot X at end (ft)
Inlet header centerline to MOV-111 inlet face	20.50	2.14	65.71
MOV-111	31.00	3.24	68.29
Spool SP-1 (crossover tee on MR-120)	26.60	2.78	70.51
Upstream spool U1, inlet flange to conditioner	47.75	4.99	74.49
Flow conditioner with gaskets	1.50	0.16	74.61
Upstream spool U2, conditioner to meter	47.75	4.99	78.59
Meter body (typical, HOLD H-15)	30.00	3.14	81.09
Downstream spool DS	47.75	4.99	85.07
Spool SP-2 (crossover tee on MR-110)	163.65	17.11	98.71
MOV-112	31.00	3.24	101.29
MOV-112 outlet face to outlet header centerline	32.50	3.40	104.00
Header to header	480.00	50.20	

Note 1: The calibrated assembly (U1, conditioner, U2, meter, DS) is 174.75 in long, from plot X 70.51 to 85.07 ft.

Thermowell TW-111 (TT-111) is 3.0D (28.69 in) and test well TW-112 is 4.0D (38.25 in) downstream of the meter outlet face, both at 12 o'clock. PT-111 connects to the meter body pressure tap, which is the pressure reference the meter's calibration uses. Run 2 is identical.

The piping general arrangement currently shows the conditioner 4.4D from the tube inlet flange and the meter 4.0D from the conditioner, with a 42.4 in meter body. That is 9.7D of upstream length, short of the 10.1D this calculation requires. The positions in Table 6-5 govern, and the piping general arrangement will be revised to match. A longer meter body shifts the downstream spool and thermowells by the difference and still fits the run.

6.6. BORE MATCHING

AGA 9 limits the meter tube bore to within 1 % of the meter bore, as Table 6-6 shows. MEA-SPC-001 sets tighter project limits: tube bore within 0.5 % of the meter bore, no step greater than 0.029 in (0.3 % D) at any joint, alignment by dowel pins, and internal welds ground flush within 10D upstream of the meter. The tighter limits cost little at fabrication and remove a source of drift if a spool is ever replaced.

Table 6-6: Bore Tolerances, D = 9.562 in

Requirement	AGA 9 limit	Project limit
Tube bore vs meter bore	±1 % (9.466 to 9.658 in)	±0.5 % (9.514 to 9.610 in)
Step at any joint	1 % D (0.096 in)	0.3 % D (0.029 in)
Out of round	1 % of mean bore	1 % of mean bore
Conditioner bore vs pipe bore	Within 1 %	Within 1 %

6.7. INSULATION AND SUNSHADE

Solar heating of a bare meter tube was screened with 1,000 W/m² on a 10 ft exposed length, absorptivity 0.6. Table 6-7 shows that at design flows the bulk temperature rise is negligible, but the pipe wall runs 3.5 °F above the gas at C3 and 6 to 22 °F above it between 5 and 1 MMSCFD. Above a Richardson number of about 0.1 the warm layer stratifies at the top of the pipe, where the thermowells are. A well conducting heat from a sun-heated wall reads high by a similar margin, and each 1 °F is 0.34 % of volume at C5 (MEA-CAL-002).

Table 6-7: Solar Heating of the Meter Tube

Flow	Velocity (ft/s)	Bulk rise, bare (°F)	Wall above gas, bare (°F)	Richardson number	Bulk rise, insulated and shaded (°F)
C5, 120 MMSCFD	38.4	0.011	0.47	1.6×10^{-5}	0.002
C2, 90 MMSCFD	24.7	0.014	0.60	4.8×10^{-5}	0.002
C3, 10 MMSCFD	2.8	0.125	3.45	0.022	0.022
5 MMSCFD	1.4	0.25	6.0	0.15	
2 MMSCFD	0.6	0.63	12.5	2.0	

Insulating the tube from U1 through the thermowells with 2 in of mineral wool, and shading the skid with a canopy, reduces the bulk effect to 0.02 °F at C3 and removes the wall-to-gas driving force. The insulation and canopy are therefore required. Flanges of the calibrated assembly are left under removable covers so they can be inspected without disturbing the tube.

7. RESULTS AND CONCLUSIONS

1. The NPS 10 Class 600 meter with a 9.562 in bore is confirmed. The maximum velocity is 38.4 ft/s at C5, 38 % of the typical q_{max} .
2. The turndown case C3 runs below the typical q_t . The flow calibration shall include two points between 1.5 and 5 ft/s.
3. The run pressure drop is 2.36 psi at C5, within the 3 psi allowance. Series verification shall be run at 90 MMSCFD or lower.
4. The meter tube is 5D + conditioner + 5D upstream and 5D downstream, placed at plot X 70.51 to 85.07 ft. The piping general arrangement will be revised to these positions.
5. The meter tubes shall be insulated and the skid shaded.

The next step is to confirm the meter limits, body length and conditioner loss with the selected vendor (HOLD H-15) and rerun this calculation with the vendor data.

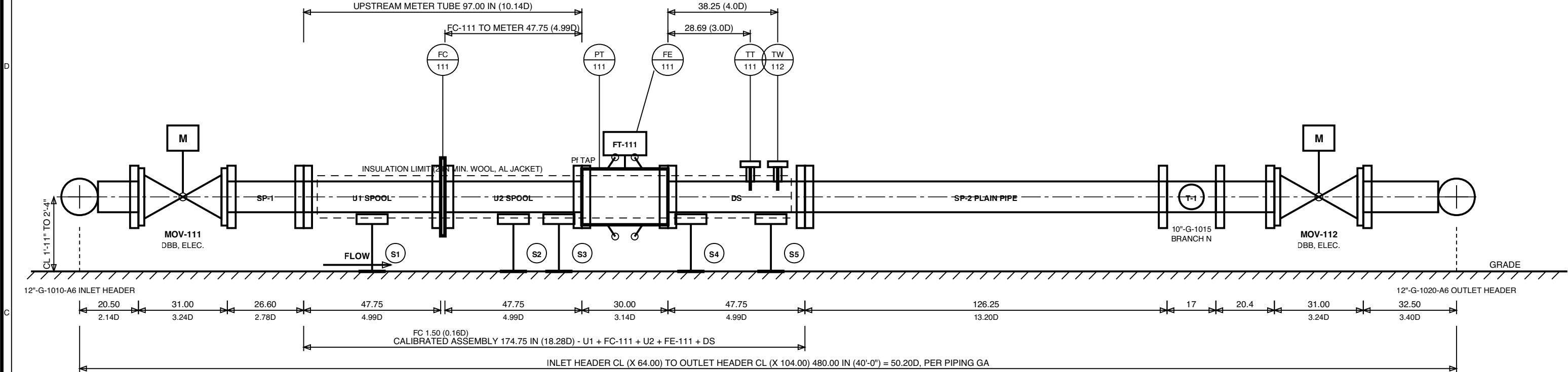


APPENDIX A. METER RUN AND SKID DRAWINGS

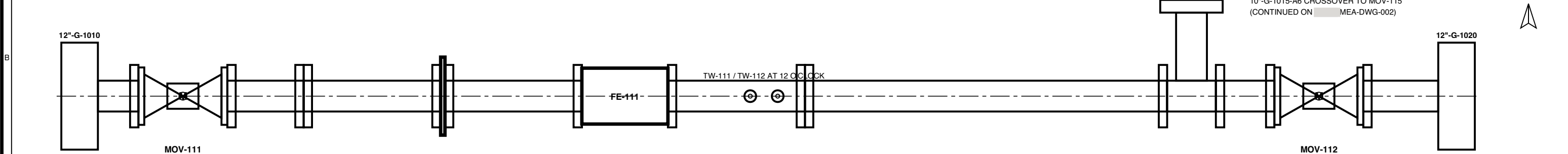


ELEVATION A - METER RUN MR-110 (RUN 1, LINE 10"-G-1011-A6), LOOKING NORTH

MR-120 (RUN 2, 10"-G-1012-A6) IS IDENTICAL EXCEPT THAT ITS CROSSOVER TEE IS IN SP-1 (CL AT X 69.80) AND T-1 IS PLAIN PIPE (NOTE 6). PLOT X PER PIPING GA (VOLUME 4).



PLAN B - METER RUN MR-110 (NORTH UP)



DETAIL C - THERMOWELL TW-111/112/121/122 (NTS)

BORE AND ALIGNMENT TOLERANCES (D = 9.562 IN)

REQUIREMENT	PROJECT	AGA 9 LIMIT
TUBE ID VS METER BORE	+/-0.5 % (9.514-9.610)	+/-1 % (9.466-9.658)
STEP AT ANY JOINT	0.029 IN (0.3 % D)	1 % D
OUT-OF-ROUND	1 % OF MEAN ID	1 %
FC BORE VS PIPE ID	WITHIN 1 %	WITHIN 1 %
FLANGE CONCENTRICITY	0.02 IN, 2 DOWELS	-
FACE PERPENDICULARITY	0.5 DEG MAX	-
SPOOL LENGTH	+/-0.06 IN	-

NOTES

- ALL DIMENSIONS IN INCHES UNLESS NOTED; D = METER BORE 9.562 IN (NPS 10 SCH 80). DRAWN NTS, PROPORTIONAL.
- DESIGN 1,440 PSIG / -20 TO 150 F; ASME B16.5 CLASS 600 RF WN FLANGES BORED TO D; API 5L X52 PSL2.
- U1 + FC-111 + U2 + FE-111 + DS FLOW CALIBRATED AS ONE ASSEMBLY (MEA-SPC-001); MATCH-MARK AND DOWEL EVERY JOINT; NO WELDING, GRINDING OR DRILLING AFTER CALIBRATION.
- INTERNAL WELDS GROUND FLUSH; NO PROTRUSION INTO BORE WITHIN U1, U2, DS.
- SUPPORTS S1-S5: CLAMP SADDLES, NOT WELDED TO CALIBRATED SPOOLS; S3/S4 WITHIN 12 IN OF METER FLANGES.
- MR-110: SP-1 PLAIN, T-1 = 10 IN TEE (CL X 96.30) BRANCH NORTH TO 10"-G-1015; POSITIONS PER PIPING GA.
- MR-120: SP-1 HAS 10 IN TEE (CL X 69.80) BRANCH SOUTH FROM 10"-G-1015, T-1 PLAIN. CAL. ASSY X 70.51-85.07.
- HYDROTEST 2,160 PSIG 8 H BEFORE CALIBRATION; 100 % RT/AUT BUTT WELDS, 100 % MT FILLETS.
- MOV FACE-TO-FACE AND METER LENGTH TYPICAL, CONFIRM WITH VENDOR DATA (HOLD H-15).
- INSULATE U1 TO DS (2 IN), REMOVABLE COVERS AT FLANGES; SKID CANOPY PER DWG-002.
- PT-111 ON METER BODY Pf TAP; TT-111 IN TW-111 (3.0D); TW-112 TEST WELL (4.0D).

NOTES / REFERENCES

- DIMENSIONS IN INCHES AND PIPE DIAMETERS D (D = 9.562 IN).
 - GEOMETRY PER MEA-CAL-001 SECTION 7.7.
 - THERMOWELLS PER MEA-CAL-004 AND DS-010.
- REF: MEA-SPC-001
- REF: MEA-DS-001/002/010
- REF: MEA-DWG-002

REVISIONS

REV DATE DESCRIPTION BY CHK APP

A 2026-09-29 ISSUED FOR REVIEW (IFR)

PRELIMINARY - ISSUED FOR REVIEW - NOT FOR CONSTRUCTION

ENGINEER OF RECORD SEAL

NOT SEALED
PRELIMINARY

PE NO. _____

PROJECT

120 MMSCFD RECEIPT INTO _____

COUNTY, _____

DISCIPLINE: MEASUREMENT

SCALE: NTS

METER RUN FABRICATION DRAWING

MR-110 / MR-120, NPS 10 CLASS 600 USM RUN

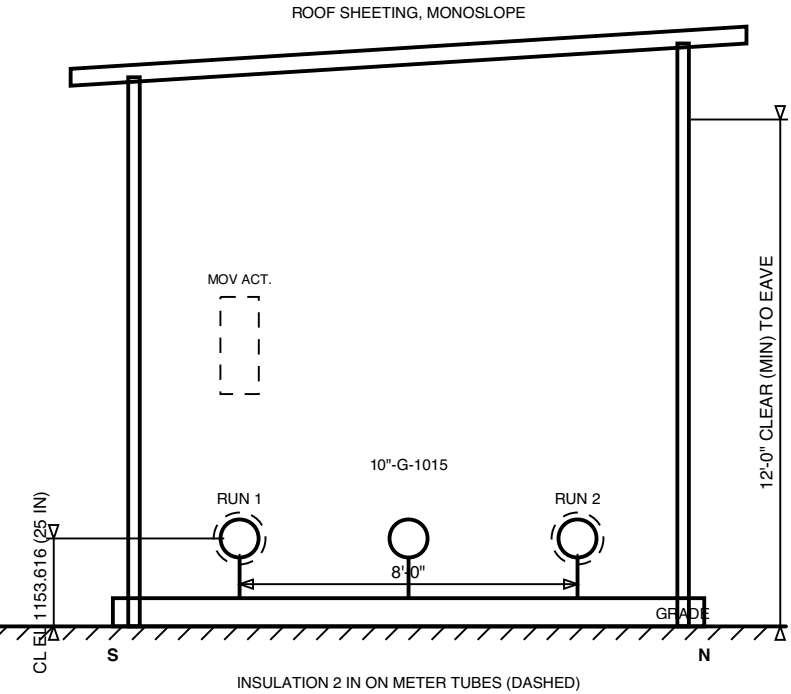
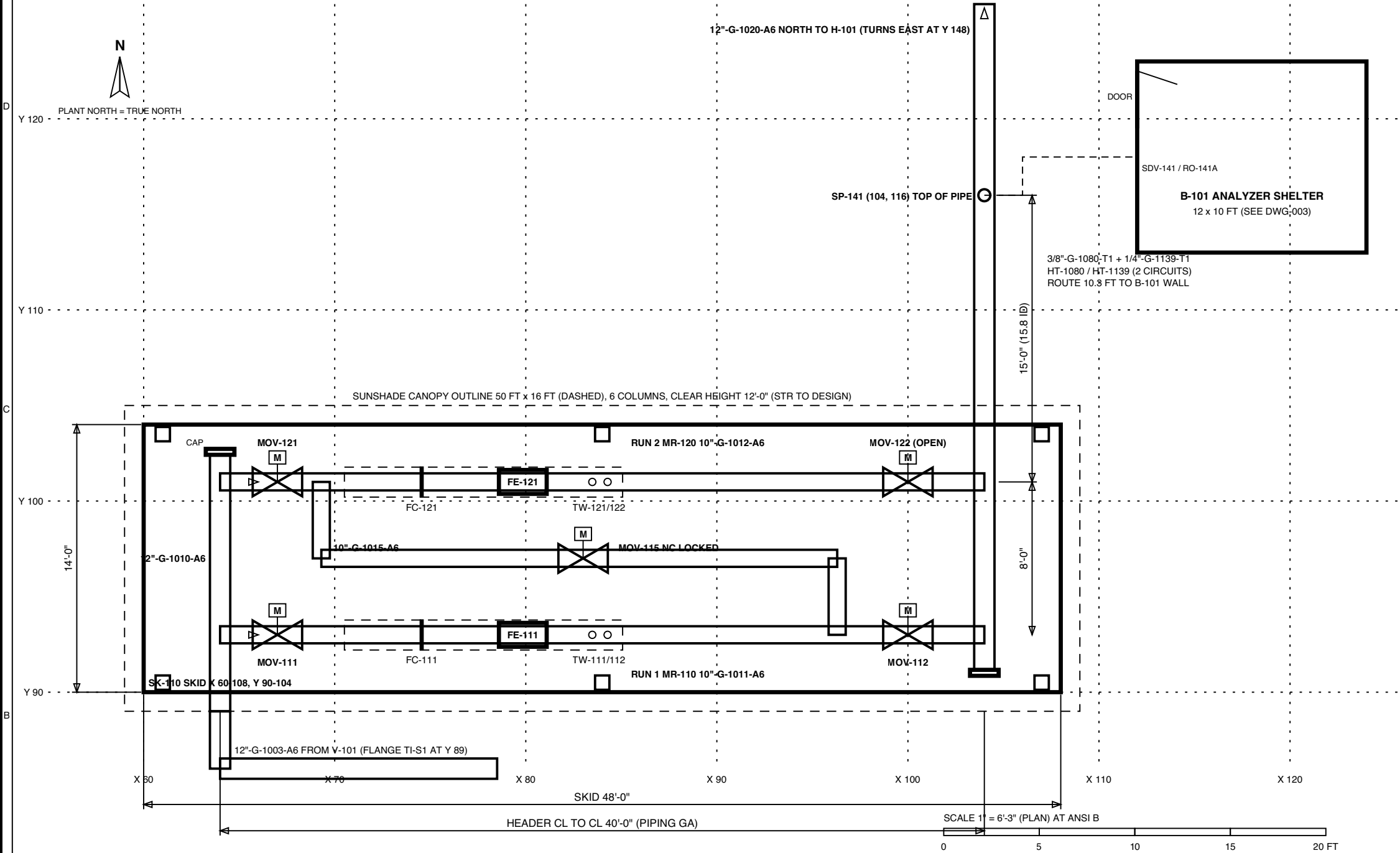
DRAWN: _____ CHECKED: _____ APPROVED: _____

DWG NO.
MEA-DWG-001

SHEET 1 OF 1 REV A

PLAN - METER SKID SK-110 AND ANALYZER SHELTER B-101 (PLOT COORDINATES, FT)

SECTION A-A (LOOKING EAST AT X = 80)



MOV LINE-UP BY MODE (MEA-RPT-001)

MODE	111	112	121	122	115
RUN 1 DUTY	O	O	C	O	C
RUN 2 DUTY	C	O	O	O	C
PARALLEL (>80 FT/S)	O	O	O	O	C
SERIES 1 -> 2	O	C	C	O	O
RUN 1 MAINT.	C/B	C/B	O	O	C

O OPEN, C CLOSED, C/B CLOSED AND BLED (DEPRESSURED). STANDBY RUN OUTLET MOV KEPT OPEN.

- COORDINATES ARE PLOT COORDINATES (FT), GEN-DB-001 SECTION 10.1. SKID PIPING PER PIPING GA (VOLUME 4).
- CALIBRATED METER TUBE ASSEMBLY PER MEA-DWG-001 AND MEA-CAL-001 (X 70.51 TO 85.07).
- RUN CL EL 1153.616; FINISHED GRADE PER CIV-CAL-001.
- SERIES MODE AT C2 RATE (90 MMSCFD) OR LOWER: ADDED LOSS 1.97 PSI AT 90 MMSCFD, 4.07 PSI AT 120 MMSCFD.
- SP-141 AT PLOT (104, 116): 12 O'CLOCK ON 1020, 15.8 ID DOWNSTREAM OF RUN 2 TEE; TIP 4.5 IN.
- STANDBY RUN OUTLET MOV ALWAYS OPEN (BLOCKED-IN RUN IN SUN REACHES ABOUT 1,570 PSIG); A RUN IS BLOCKED IN AT BOTH ENDS ONLY WHEN DEPRESSURED.
- CANOPY BY STR/CIV; FULL SHADE OF METER TUBES, 12 FT CLEAR. MOV DATA PER MEC-LST-003 (HOLD H-15).

NOTES / REFERENCES

- SEE DRAWING NOTES ON SHEET.
 - PLAN SCALE BASED ON ANSI B PRINT (16 UNITS PER FT).
- REF: MEA-DWG-001
REF: MEA-DWG-003
REF: MEA-RPT-001
REF: MEA-CAL-001/004

REVISIONS

REV	DATE	DESCRIPTION	BY	CHK	APP
A	2026-09-29	ISSUED FOR REVIEW (IFR)			

PRELIMINARY - ISSUED FOR REVIEW - NOT FOR CONSTRUCTION

ENGINEER OF RECORD SEAL

NOT SEALED
PRELIMINARY

PE NO. _____

PROJECT

120 MMSCFD RECEIPT INTO _____
COUNTY, _____
DISCIPLINE: MEASUREMENT
SCALE: PLAN 1" = 6'-3"; SECTION NTS

METER SKID GENERAL ARRANGEMENT

SK-110 PLAN, SECTION A-A, MOV LINE-UP
DRAWN: _____ CHECKED: _____ APPROVED: _____
DWG NO. MEA-DWG-002
SHEET 1 OF 1 REV A