Gas Measurement Integrity Audits

Israel Natural Gas Lines (INGL)

Leviathan Custody Transfer Gas Audit May 2022

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1 Revision Control

Rev	Issue date	Description	Prep.	App.
1	17/06/2022	Issued for comment	MM	RA
2	08/07/2022	Issued as Final	MM	DS

2 Introduction

KELTON^{tm} were approached on behalf of Israel Natural Gas Lines (INGL) to complete a gas measurement integrity audit on the Chevron Leviathan platform.

The Leviathan platform custody transfer gas measurement station comprises the boundary of this audit, which was conducted between the 23rd and 26th of May 2022 by Malcolm MacCall of KELTON Engineering Ltd.

2.1 System Description

The Leviathan custody transfer gas metering system consists of four meter runs each of which comprises of the following:

- 2 x USM (Duty and Check)
- 2 x Pressure transmitters
- 2 x Temperature transmitters
- 2 x Flow computers

Common equipment comprises of:

- 1 x C6+ Gas chromatograph (GC)
- 1 x H_2S analyser
- 1 x Moisture analyser
- 1 x Hydrocarbon Dewpoint (HDP) analyser

There is no supervisory system. The flow computers are interfaced via an Integrated Control and Safety System (ICSS) based human-machine interface (HMI).

3 Acknowledgements

The auditor would like to thank Philip Krasnopolsky (INGL) and the onsite technicians (Mark Donnelly and Steve Graham) for their invaluable assistance during the audit process.

4 Wash-up Meeting Attendees

Auditor	Mal MacCall (Kelton)
INGL Measurement Engineer	Philip Krasnopolsky (INGL)
Measurement Support Engineer	Keith Brown (Rust Resources)
Platform Measurement Technician	Mark Donnelly (Rust Resources)
Platform Analyser Technician	Steve Graham (Rust Resources)
Maintenance Forman	Mike Foreman (Chevron)
Assistant Maintenance Forman	Dennis Porsnuk (Chevron)

5 Management Summary

The Leviathan gas metering system has two Risk Factor 2 findings and eight Risk Factor 3 audit findings identified during this audit. These are:

Risk Factor2

- USM Calibration Issues: May result in a potential for flowrate bias if there are traceability issues found with the calibration curve settings.
- Dataflow Issues: May result in mis-reporting exposures.

Risk Factor 3

- USM Internal Diameter (ID) Traceability: Minor compliance issue.
- USM Spool Corrections: Small potential for flowrate bias if not applied or not applied correctly.
- Analyser Sample Conditioning Issues: Potential for heavy end component drop out, thus reducing confidence in the reported gas quality values.
- Unrepresentative Uncertainty Values: Representative uncertainty calculations are essential to ensure the system is operating within contractual limits.
- Spares Lead Times: If critical spares are not available in a timely manner confidence in the system performance may be reduced until the situation has been resolved by replacement/repair of the affected item(s).
- GC performance: Asynchronous component response factor trending can highlight component uncertainty issues and therefore reduce confidence with the reported analyses.
- Alarm and Event Handling/Monitoring: It is acknowledged that the metering department should capture most events/issues via daily checks and monitoring; however, ineffective alarm and event handling/monitoring issues could lead to situations where issues are not detected/reported in a timely manner.
- Master Parameter Lists: The site uses the latest configuration dumps; however, there are no formal revision-controlled master parameter lists. Formal, controlled master lists increase confidence in the flow computer settings by helping to reduce the potential for confusion and/or the use of unrepresentative values.

The detailed findings, significance, and recommended actions are noted in Section 14 of this document.

Additional comments were also made to highlight issues where potential for improvement and/or enhancements could be made. The main comments can be seen in Section 14 with other observations in the audit criteria.

6 Audit Point Classification

Risk Factor 1	A serious control weakness which could expose the business to a major extent to commercial and/or reputational issues and require immediate corrective action. The finding is also likely to cause a high undesirable effect on the achievement of one of the assets objectives, thus warranting immediate reporting to the auditee's management. This Risk Factor may also lead to significant mismeasurement potential or large actual
Risk Factor 2	A medium control weakness, which of itself would not be serious but could adversely impact on the business and requires, scheduled corrective action. The finding is also likely to cause a measurable undesirable effect on the achievement of one of the assets objectives. This Risk Factor may also lead to large mismeasurement potential, or medium actual.
Risk Factor 3	A minor control weakness where the impact on the business would have a low significance but scheduled corrective action is still required. This weakness is unlikely to have a measurable impact on the asset's objectives, but its correction would enhance the risk-based control framework. This Risk Factor may also lead to medium mismeasurement potential, or no actual.
Comment	An item, which does not have a significant impact on the business, but if corrected may result in improvements to the efficiency/effectiveness of the measurement integrity process.

Recommended Action Periods[1]	
Risk Factor 1	3 months
Risk Factor 2	6 months
Risk Factor 3	9 months

7 Findings Overview

	Risk Factor 1	Risk Factor 2	Risk Factor 3
Leviathan Gas Metering	0	2	7
Total	0	2	7
Open Items @ Final Report Issue	0	2	7

[1] Based on typical periods found with other global operators/pipelines

8 Audit Objectives and Scope

Objectives

a) Assess the current condition of the Metering Station(s)
b) Assess the Metering Station(s) historical performance
c) Establish if the metering station(s) have been operating to the required standards
d) Assess the integrity of the data transmitted from the metering system into the relevant allocation and accounting process
e) Follow-up previous audit action items (where applicable)
f) Review system documentation
g) Where required and information is supplied - determine metering station(s) compliance with relevant company policies, government regulations & guidelines and applicable operating, transportation & sales agreements.

Scope

The following areas to be audited/reviewed include:

System Areas

a) the total metering system(s) including primary elements
b) gas quality measurement system(s)
c) the flow of data (measured to allocated)
d) the metering system(s) calibration equipment.

Control Areas

a) the maintenance and calibration history records and schedules
b) the system uncertainty (design to actual)
c) the procedures
d) the logbooks and measurement manuals
e) the metrological certification
f) the master configuration lists and files for computers and primary elements
g) the experience and competence of staff
h) the roles and responsibilities

9 Terms of Reference

The audit was conducted against the following (where supplied):

a) Applicable Contractual Operating & Transportation Agreements
b) Applicable Governmental Guidelines and Policies
c) Applicable International Metrological Procedures and Standards

10 Common Acronyms

The following common abbreviations and acronyms are used in this document:

Acronym	Meaning
ISO	International Standards Organisation
UFM/USM	Ultrasonic Flow Meters
GC	Gas Chromatograph
OIML	The International Organisation of Legal Metrology
AGA	American Gas Association
API	American Petroleum Institute
IP	Institute of Petroleum
ICSS	Integrated Control and Safety System
CBM	Condition Based Monitoring

11 System Inventory

Primary Data

Primary Device(s)	USM (x4 duty and x4 check)		
Manufacturer of Device(s)	Caldon LEFM 380ci (Duty) Sick Maihak FlowSic600-XT Forte (Check)		
Number of Streams	4		
Redundancy of Streams		Yes	~~No~~
Proving or Verification Device(s)		Yes	~~No~~
Proving or Verification Type	Check Meters		

Secondary Data

Density Measurement Method	~~ρ Live~~	Calculated
Manufacturer of Density Device	N/A	
Density Calculation Method	AGA-8	
Relative Density Method	~~RD Live~~	Calculated
Manufacturer of Relative Density Analyser	N/A	
Standard Density Calculation Method	AGA-8 (1994)	
Energy Calculation Method	ISO-6976 (1995)	
Composition Determination Method	~~Manual Sample Analysis~~	Online Chromatograph

Manufacturer of Composition Device	Emerson		
Sampling Method	Manual Sample Analysis		Automatic Sampling
Manufacturer of Sampling Device	ZY Systems DP2010RN		
Pressure Measurement Method	~~Single~~		Redundant
Manufacturer of Pressure Device(s)	Emerson 3051 TG4A x 8		
Temperature Measurement Method	PT100	Transmitter	Redundant
Manufacturer of Temperature Device(s)	Emerson 3144P x 8		

Flow Computer System

Redundancy of Supervisory		~~Yes~~	No
Manufacturer of Supervisory	N/A		
Redundancy of Stream(s)		~~Yes~~	No
Manufacturer of Stream(s)	OMNI		
Model of Stream(s)	Model 3000 (x8)		
Other Flow Computation Device		Yes	~~No~~
Manufacturer of Other Device	ICSS		

12 Applicable Standards

Uncertainty	ISO-5168
Flow	AGA-9/ISO-17089/OIML R137-1
Density	AGA-8
Standard Density	AGA-8
Calorific Value	ISO-6976
Sampling	ISO-10715
Online analysis	ISO-6974
Calibration gas mixtures	ISO-6141/6142/6143

13 Reported Uncertainty

Uncertainty Basis	Gross Volume	Energy
Design Calculated Uncertainty	0.212%	0.331%
Contractual Limit	± 1 %	± 1 %

14 Audit Findings

Item	Findings	Significance	Recommended Action	Category
1	USM Calibration Issue It was noted that the CEESI certificates had Modbus based outputs during the USM calibrations; however, the Leviathan system uses pulse based outputs from the USMs. *Post Audit Update* From subsequent information on the Leviathan Caldon duty meters, the vendor stated that there should be no significant difference. However, they went on to state that it can be verified by initiating a data log from the USMs and comparing the data logged average flow against the totalised average flow from the flow computers. *(Criteria Reference – 14.1 Comment 9)*	As the formal traceability path to the meter output is MODBUS based, pulse output traceability is effectively unknown. Therefore, there may be a potential for flowrate bias. With regards to a precedent for this issue, another operator had a similar issue which did result in bias; however, the meter type was not specified in that instance.	a) It is recommended that the Leviathan gas metering Sick Maihak USM vendor is contacted to get a definitive written statement to the effect that there will be no bias and/or measurement integrity issues as a result of using a Modbus as opposed to pulse based output. b) To close the action with respect to the Leviathan gas metering Caldon duty meters - Verification shall be completed as per the vendors instructions on comparing data logged average flow totals from the USMs against the respective flow computer totals.	Risk Factor 2 Open

Item	Findings	Significance	Recommended Action	Category
2	**Production Dataflow Issue** From supplied hourly energy data from INGL, it was not possible to get the supplied 25th May 2022 06:00 report from the OMNI to correlate. *Post Audit Update* It was reported after the site visit that there may be a mismatch in mapping of the data. *(Criteria Reference – 14.4.3 Comment 3)*	Dataflow issues may result in mis-reporting exposures.	To ensure complete alignment of reported data - the reasons for the apparent differences in reported totals from the Leviathan gas metering computer system and the INGL hourly totals shall be established and rectified as required.	Risk Factor 2 Open
3	**USM Traceability Issues** Whilst there were stated internal diameters (ID) on the wet calibration certificates, there were no formal dry metrology documents to show traceability to the IDs of the USMs. The USM standards noted as referenced in the supplied system handbook (LPP-OP-NEM-OPS-MAN-0001 Rev C2) are – AGA-9 (2007) and ISO-17089 (2010). Both of the above standards require the ID to be determined as per Chapter 6.2 and Chapter 5.9.3.3 respectively. There were minor differences noted in flowrates used in some of the curve constants entered in the meter electronics. The error values, however, appear to be satisfactory.	USM IDs are a critical element in the determination of flowrates. It is recognised that the likelihood of the in-use values being incorrect is small, nonetheless, traceability issues with the USMs will exist until formal dry metrology documents that conform to the standards referenced in the system data book are made available. Minor traceability issues will exist to the USM calibration curve constants if the computer settings do not match their respective certificate values exactly.	a) Formal dry metrology documents shall be traced for all eight Leviathan USMs to establish a traceability path that conforms to AGA-9 (2007) Chapter 6.2 and ISO-17089 (2010) Chapter 5.9.3.3. Once the formal dry metrology showing the appropriate traceability is available, it shall be located in the site metering folder for future auditing and information purposes. *Post Audit Update* As there is now a traceable path to the USM IDs –action a) is considered closed.	Risk Factor 3 Open

Item	Findings	Significance	Recommended Action	Category
	Post Audit Update From supplied information for both duty and check meters post site visit, the USMs now have metrology information. This information was from the certification packages from the respective vendors. Whilst traceability was confirmed to the meter IDs, there was no mention of AGA-9 or ISO-17089. It was also reported that the above are now in the site measurement folder for future auditing and information purposes. *(Criteria Reference – 14.1 Comments 1 and 7)*		b) All Leviathan USM calibration curve constants shall match the certificate values as required.	

Item	Findings	Significance	Recommended Action	Category
4	**USM Spool Corrections** On the FloSic600 check meters the spool corrections appear to be applied using fixed values in the meter electronics, which are not representative of the observed conditions. It was not possible to determine from the supplied Caldon duty meter information if this function was enabled/disabled. It was not possible to determine during the site visit if implementation of this function is a contractual requirement. *(Criteria Reference – 14.1 Comment 11)*	A small flowrate bias may exist if USM spool corrections are not implemented and/or use unrepresentative pressure and temperature values.	All Leviathan gas metering system stakeholders shall be contacted to establish if USM spool corrections are required. If it is established that USM spool corrections are required, then the Leviathan gas metering system check and duty USMs shall be setup accordingly. Ideally, live pressure and temperature values should be used, which would require signals to be made available to the USMs. If this is not possible then any fixed values used shall be subject to regular review to ensure they are representative.	Risk Factor 3 Open
5	**Analyser Sample Conditioning** The analyser sample conditioning system heated regulators were not working during the site visit, and it was noted that there is evidence of some condensation on the regulators. This issue is known, and spares were reported to have been requested. The reason for the failures was reported as water leaking into the regulator terminal enclosure due to cable gland issues. *(Criteria Reference – 14.3.1 Comment 4)*	Effective heated regulators should help prevent component dropout caused by Joule-Thomson effects. If the device heaters are not working, then increased exposure to component drop out may therefore occur; however, no issues with liquids present in the system were reported. Successful calculated versus measured velocity of sound checks also carried out on a weekly basis give additional confidence in the reported GC compositions.	Whilst it is recognised that the measurement integrity impact of the unserviceable Leviathan gas metering sample conditioning system heated regulators appears to be relatively small in this instance - to increase confidence in the gas quality measurement determination, these devices shall be returned to a serviceable state as soon as possible.	Risk Factor 3 Open

Item	Findings	Significance	Recommended Action	Category
6	**Reported System Uncertainty Values** The quoted uncertainties for energy flow appear to be unrealistically low at 0.331% - 0.341%. *(Criteria Reference – 14.5 Comment 8)*	Representative uncertainty calculations are essential to ensure the system is operating within contractual limits.	The Leviathan uncertainty calculations shall be revisited to ensure representative of the current setup and process.	Risk Factor 3 Open
7	**Spares Lead Times** It was reported that there are issues with lead time on spares which is delaying the replacement of the heated regulators noted previously in item 5. During the wash-up meeting this issue was discussed and min/max stock levels should be set to ensure timely access to critical spares by having sufficient local availability in the first instance. Correspondence with local agents was also discussed to help source equipment quicker. *(Criteria Reference – 14.6 Comment 3)*	If critical spares are not available in a timely manner, then confidence in the system performance may be reduced until the situation has been resolved by replacement/repair of the affected item(s).	As per the wash-up discussion for the Leviathan gas metering system – appropriate measures shall be taken to ensure access to critical spares can be achieved in a timely manner, which in turn should help reduce exposures to any measurement integrity issues caused by equipment failure(s).	Risk Factor 3 Open

Item	Findings	Significance	Recommended Action	Category
8	**Gas Chromatograph (GC) Performance** From supplied GC response factor (RF) data it was noted that there are asynchronous RF trends on the i-Pentane, n-Pentane, n-Butane, and Nitrogen components. Of the trends that are deviating, most are the heavier end components which have very small concentrations and therefore measurement risks should be mitigated. (Criteria Reference – 14.3.1 Comment 8)	It is recognised that measurement risks are minor in this instance; however, asynchronous component RF trending can highlight component uncertainty issues and therefore reduce confidence with the reported analyses.	It is recommended to carry out repeatability tests on the Leviathan gas metering GC (compliance as per ASTM D1945-14 - 2019) to ensure there are no event or valve timing issues.	Risk Factor 3 Open
9	**Master Parameter Lists** The site uses the latest configuration dumps; however, there are no formal revision-controlled master parameter lists. *(Criteria Reference – 14.4.1 Comment 3)*	Formal, controlled master lists increase confidence in the flow computer settings by helping to reduce the potential for confusion and/or the use of unrepresentative values.	Formal master parameter lists should be implemented for the Leviathan gas metering system flow computers and USM transmitter settings.	Risk Factor 3 Open

Item	Findings	Significance	Recommended Action	Category
10	**GC Redundancy** The USMs, flow computers, and pressure/temperature transmitters have excellent levels of redundancy and thus high confidence in the gross volume flow indication. Gas quality determination has the same importance level as the gross volume flow; however, in this instance the system has no redundancy. No ISO-10723 GC performance evaluation data was presented during the site visit. No GC monitoring software in use. However, it was noted that spreadsheet-based response factor (RF) monitoring was in place. *(Criteria Reference – 14.6 Comment 1)*	Whilst it is appreciated that the gas composition is relatively stable, extended operation with fixed compositions if the GC fails may result in exposure to some commercial risks. An additional GC would help mitigate this risk and give increased confidence levels with the energy, mass, and standard volume flowrates. ISO-10723 GC performance evaluations and implementation of monitoring software will increase confidence in the GC output and therefore in the reported energy, mass, and standard volume readings.	a) To increase confidence in the gas quality determination and reduce exposures to operating with fixed compositional values - It is recommended that an additional GC is fitted to the Leviathan gas metering system. b) It is recommended that an ISO-10723 Performance evaluation is carried out on the Leviathan gas metering system GC along with implementation of monitoring software (for example GCAS or equivalent).	Comment

Item	Findings	Significance	Recommended Action	Category
11	**Alarm and Event Handling/Monitoring** There does not appear to be any alarm output from the USMs to the computer system. The alarm limits at the flow computers for pressure and temperature appear to be excessive at 10-150 barg and 0-150°C respectively (live values were ~81 barg and ~16°C). The gross flow high limit on the flow computer meter set-up was noted as being 707912 m^3/hr. The low limit was noted as zero (it is assumed that these units reflect standard volume flow). This limit should reflect the flow range from the meter calibration certificates. It was also reported that the alarm outputs that are part of the contractual connection agreements have still to be implemented at the HMI. *(Criteria Reference – 14.4.2 Comment 4)*	It is acknowledged that the metering department should capture most events/issues via daily checks and monitoring; however, alarm and event handling/monitoring issues could lead to situations where issues may go undetected.	a) The Leviathan gas metering computer system shall have a robust alarm/event handling system, which also indicates USM alarm situations as required. b) Operations shall be made aware of Leviathan gas metering critical alarms/events and know what action to take if an alarm is raised. c) Alarm limits shall be optimised for the Leviathan gas metering process. d) Alarm outputs that are part of the contractual connection agreements shall be implemented at the Leviathan gas metering HMI system.	Comment
12	**Dispensation Request System** There does not appear to be a formal dispensation request system/process in place. *(Criteria Reference – 14.5 Comment 10)*	A dispensation system adds a level of control to measurement issues that may be subject to delayed resolution.	An appropriate dispensation system should be implemented for the Leviathan gas metering system.	Comment

Item	Findings	Significance	Recommended Action	Category
13	**Maintenance Frequency** Given the history of calibration results noted from the supplied information, along with the levels of redundancy available with the USMs, flow computers, and pressure/temperature transmitters - the frequency of calibrations could be relaxed. However, during the site wash-up meeting it was reported that maintenance has to be completed in a period no greater than 42 days. *(Criteria Reference – 14.5 Comment 6)*	Excessive calibration frequencies result in unnecessary man-hour expenditure. Additionally, if there is too much emphasis on completing tasks that are not necessary on a monthly basis, then other important tasks may be affected.	It is recognised that the monthly calibration frequencies are a requirement, nonetheless a case should be presented to all Leviathan gas metering system stakeholders to reduce maintenance frequencies to more appropriate levels. Presentation of this case should include the excellent history of calibration results and the levels of redundancy available.	Comment
14	**Check USM Pressure Taps** The check meters (Sick Maihak) use a downstream tapping ~6D from the meter, which is slightly over the requirements of the gas USM standards (for example AGA-9 Chapter C3.2.2 states within 5D). The Sick Maihak operation manual also states in Chapter 3.3.3 that the pressure tapping should be used. *(Criteria Reference – 14.2.1 Comment 3)*	It is recognised this issue would have little effect on measurement integrity; however, the set-up is not compliant with the USM standards and the vendor recommendations.	A deviation request should be made to all system stakeholders to continue Leviathan gas metering operations without using the check USM pressure taps and being slightly over the 5D limit allowed in the standard.	Comment

Item	Findings	Significance	Recommended Action	Category
15	**Logbooks/Analyser Maintenance Histories** Whilst information was supplied for the USMs, Pressure/Temperature transmitters, and flow computer checks – the only analyser test noted was for monthly GC auto calibration checks. There is also no common equipment logbook for the system analysers. *(Criteria Reference – 14.5 Comment 2)*	Whilst not presenting a direct measurement integrity issue – a lack of a common equipment logbook and test information may lead to traceability issues.	It is recommended that information on the Leviathan gas metering analyser system maintenance is recorded and documented in the same manner as the rest of the metering system.	Comment
16	**Calibration Test Forms** The temperature transmitter test form has the error sections reflected in °C not %. The AGA-10 test form does not show the pressure and temperature used for the test. Units are missing from the totaliser test forms. The density, calorific value, and standard density test forms do not have any reference to the standard used. *(Criteria Reference – 14.4.1 Comment 7)*	Minor traceability issues with calibration test forms.	a) The Leviathan gas metering system calibration temperature transmitter test form shall have the error noted in % as opposed to °C. b) Leviathan gas metering AGA-10 test form shall show the pressure and temperature used for the test. c) The required units shall be added to the Leviathan gas metering totaliser forms. d) The Leviathan gas metering density, calorific value, and standard density test forms shall show the applicable standards used for testing.	Comment

Item	Findings	Significance	Recommended Action	Category
17	**Mismeasurement Process** It was demonstrated that a mismeasurement process is in place and the procedure was noted on the front of each report. However, there was no sign-off section from hydrocarbon accounts or INGL. It was reported that the Gas Controllers apply corrections; however, implementation in accounts was not witnessed during the site visit. *(Criteria Reference – 14.5 Comment 7)*	The audit/document trail will be incomplete If there is no sign off section to show that a correction has been implemented by hydrocarbon accounting. Any mismeasurement methodology should also be agreed with INGL.	it is recommended that a section is added to the Leviathan gas metering mismeasurement reports to show totals been amended/ implemented by accounts/ gas controllers and approved by INGL to fully close out the mismeasurement process.	Comment
18	**Meter Calibration Frequency** No definitive information on calibration frequency was supplied during the site visit; however, it was reported that the actual frequency for the above may be up to 16 years (reported frequency from a document that is still in draft form). *(Criteria Reference – 14.1 Comment 9)*	It is recognised that the duty/check meter setup should identify drift and/or other issues; however, there is a risk that any subsequent calibrations may show a shift in calibration results, which may result in a potentially complicated mismeasurment exercise and therefore exposure to commercial risks.	a) It is recommended that the Levithan gas metering system meter calibration frequency has definitive information available for future information and auditing purposes. b) To mitigate against any measurement risks associated with shifts in Leviathan meter calibration results – consideration should be given to higher calibration frequency. Any change to the frequency would also require approval from all system stakeholders.	Comment

Item	Findings	Significance	Recommended Action	Category
19	**Available Archive Data** The only parameter that appears to be stored in the archive data is hourly based energy increments. *(Criteria Reference – 14.4.2 Comment 8)*	It may not be possible for INGL to recalculate energy increments in the event of missing live data.	It is recommended that averaged pressure, temperature, heating value, base/line density, and gross/ net/mass totalisers are added to the Leviathan archived data.	Comment

Audit Criteria

14.1 UFMs

a) Check the serial number of the ultrasonic meter and cross reference to the calibration certificates and logbooks. Check that the bore size and wall thickness correspond with the manufacturer's meter dry metrology certificate.

b) Obtain measurements of upstream and downstream straight lengths of pipework ensuring the necessary straight pipe diameters are available. If a flow straightener is installed, ensure necessary diameter lengths are available upstream. Check that the meter flow orientation is correct.

c) Check that adequate insulation has been applied to the meter tubes to ensure thermal stability across the meters and associated instrumentation.

d) Check the condition of cabling associated with the meter flow sensors and comment on any damage found.

e) Observe, and comment upon any process conditions or piping configurations, which may be detrimental to the measurement integrity.

f) Check the integrity of all path signals to ensure adequate performance, for online meters - verify that that the measured VOS and calculated VOS give good agreement. Check that condition-based monitoring (CBM) is being used and that meter performance is acceptable for all key parameters such as swirl, turbulence, SNR, AGC.

g) Verify that all transducer constants entered in the associated flow computers, and the transducer serial numbers, match those on the master configuration lists and calibration certificates.

h) Confirm that the method used to correct for meter calibration performance is by linear interpolation and has been implemented in the correct manner. Any other correction method shall be highlighted.

i) Obtain a copy of the calibration certificate/s for the meter, ensuring that the agreed calibration frequency has been complied with and that the calibration was carried out by a recognised authority. Any associated "curve fit" constants within the system computers should reflect the values on the meter calibration certificate. Ensure that the meter signal output format matches that of the wet calibration certificate. Review historic shifts from the previous calibrations and comment on any shifts greater than the maximum stipulated in the relevant agreements.

j) If during the audit visit a meter is removed for recertification, check for visible damage to the meter body or transducers and for the presence of pipe scale and/or hydrocarbons in the meter and upstream/downstream pipe sections.

k) Confirm that expansion corrections, for temperature and pressure, are being applied for the meter spool in the correct manner.

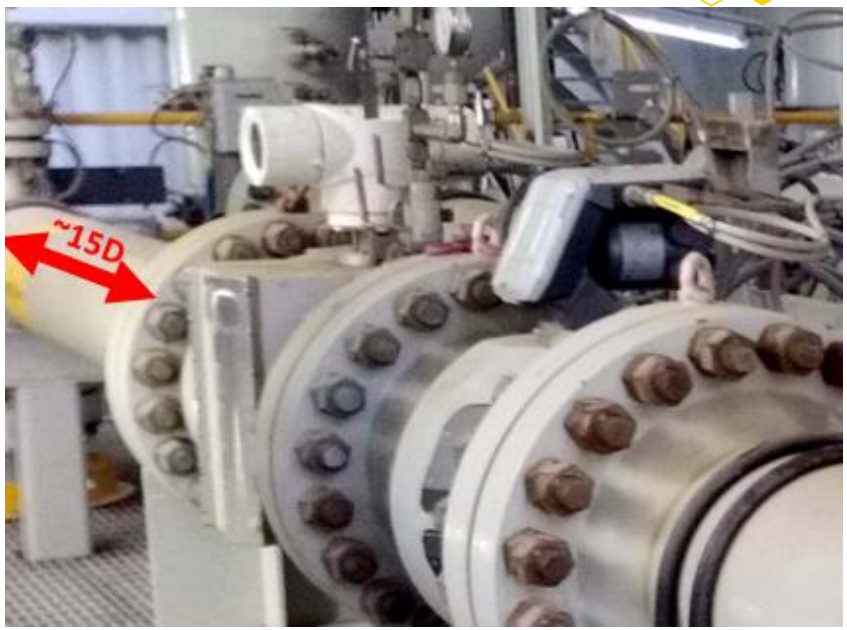
Traceability

AGA 9
BS 7965
ISO TR 12765
BS 8452
BS ISO-17089-1
API Chapter 5 Section 8

Pass (✓)		Fail (X)			Not Possible (NP)				Not Applicable (NA)			
METER STREAM	ITEM	A	B	C	D	E	F	G	H	I	J	K
Check Meters												
FT-9202	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9212	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9222	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9232	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
Custody Transfer												
FT-9204	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9214	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9224	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-9234	Pass/Fail	X	X	✓	✓	X	X	X	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11

Comments:

1. Serial numbers correlate with supplied certificates; however, whilst there were stated IDs on the wet calibration certificates, there were no formal dry metrology documents as per the requirements of the standards to show traceability to the IDs of the USMs. (Risk Factor 3)
2. ~15D from bend/blank flange to first USM (duty). This complies with vendor specifications and OIML R137, but not AGA-9. There are no flow conditioners fitted. (Comment)



3. As seen from photo above - No insulation fitted; however, the metering skid is not exposed, and the observed velocities were ~20 -24 m/sec, which should not result in any thermal gradient issues.
4. No issues visually noted with cabling.
5. See comment 2. Additionally, from the CEESI calibration certificate information it can be seen that the set up appears representative of the site configuration – see excerpt from one certificate example below:

Serial Number: 17190001

Job Number: CE26982 **Data File Number:** 17SIN-0079 17SIN-0080

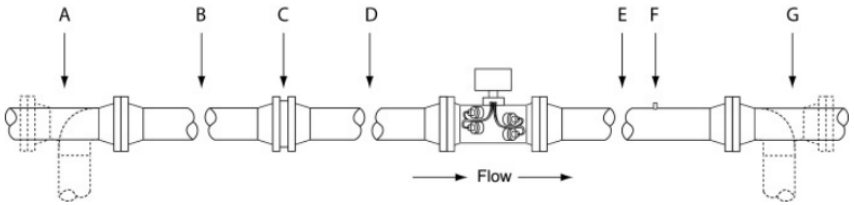


Figure 1: Piping Configuration

Meter Tube Identification:

Identifier	Length	Serial Number
B - Upstream Tube	10 Inches (254.00 mm)	TEE ASSEMBLY
D - Inlet Tube	137 Inches (3479.8 mm)	Not Present
E - Exit Tube	88.5 Inches (2247.9 mm)	Not Present

Meter Flow Conditioner Identification:

Identifier	Installed	Manufacturer	Serial Number	Flow Arrow	Top Dead Center
C - Upstream Flow Conditioner	No	Not Present	Not Present	Un-Verified	Un-Verified

Lengths B+C above result in ~15D which correlates with the upstream lengths observed during the audit. However, from the above it can be seen that only one meter is present. (Comment)

6. The diagnostics were checked, and it was noted that most parameters were within the vendor set limits - with the exception of some turbulence values. The site also records the diagnostics on a regular basis on spreadsheets.
7. Minor traceability issues - very slight differences in flowrates in some of the curve constants entered in the meters. The error values, however, appear to be satisfactory. (Risk Factor 3)
8. Linear interpolation in use on all 8 meters.
9. No historical calibration certificates available. All supplied documents were dated in November 2017.

It was noted that the CEESI certificates had Modbus based outputs during the calibrations; however, the Leviathan system uses pulse-based outputs – see excerpt from calibration certificate below:

Meter Output:	Modbus

The impact of this is unknown at the moment; however, another operator had a similar issue which resulted in a bias. It is recommended that the Sick Maihak and Caldon meter vendors are contacted to get definitive statements that there will be no bias and/or measurement integrity issues in this instance. (Category 2)

10. Not applicable – no meters removed. It was reported that meter calibrations may be as much as 16 years. This length of time between calibrations may present a risk if it is found that a meter has had a calibration shift, which may lead to a complicated mismeasurement investigation/report and the resultant commercial exposure. (Comment)
11. On the FloSic600 check meters the spool corrections appear to be applied using fixed values, which are not representative of the observed conditions. This may lead to a small bias if not representative of actual conditions. It was not possible to determine from the supplied Caldon duty meter information if this function was enabled. (Risk Factor 3)

14.2 Secondary Equipment

14.2.1 Pressure Measurement

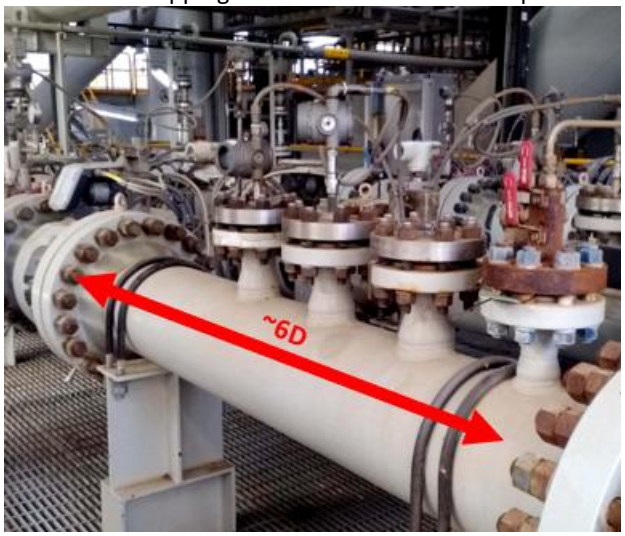
a) Check the serial numbers of the pressure transmitters and cross reference to the calibration certificates or logbooks.
b) Check the condition of the pressure transmitter enclosure and heater, if fitted, and ensure that the enclosure temperature is thermostatically controlled.
c) Observe pressure tapping's and pressure transmitters are in an appropriate location for the type of installation, ensuring that gas turbine and USM installations utilise the reference tapping. Ensure impulse lines are in good condition and as short as possible.
d) Witness the calibration check on the pressure transmitter, referring to the detailed calibration procedures. Confirm that the pressure transmitter calibrates satisfactory.
e) Witness re-instatement of the pressure transmitters and ensure the impulse lines are secured and leak tight.
f) Ensure that corrections for local gravity, calibration temperature and gauge/absolute pressure, where required, are being applied correctly.
g) Check maintenance records. Highlight any maintenance faults or discrepancies, which may have affected the pressure reported and subsequently used in the flow calculation.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)		
METER STREAM	ITEM	A	B	C	D	E	F	G
Check Meters								
PT-9202	Pass/Fail	✓	NA	X	✓	✓	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9212	Pass/Fail	✓	NA	X	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9222	Pass/Fail	✓	NA	X	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9232	Pass/Fail	✓	NA	X	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
Custody Transfer Meters								
PT-9204	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9214	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9224	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-9234	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7

Traceability
BS7965
AGA 9
EN 1776

Comments:

1. Serial numbers correlate with supplied calibration data.
2. Not applicable – devices have no enclosures.
3. Duty meters (Caldon) use reference tapping. Check meters (Sick Maihak) use a downstream tapping ~6D from the meter – see photo below:



This is slightly over the requirements of the gas USM standards. The Sick Maihak operation manual also states in Chapter 3.3.3 that the pressure tapping be used – see excerpt from chapter below. It is, however, likely that this issue will have a negligible effect on measurement integrity.

- Pressure measuring devices must be connected to the pressure tap provided. The pressure inlet nozzle is marked with p_m.

It was reported that this was implemented due to site safety requirements. It is recommended that a deviation request is raised with all affected stakeholders to grant approval to continue operations with the above set-up. (Comment)

4. FT-9202 pressure transmitter calibration witnessed successfully.
5. No issues noted on reinstatement.
6. Not applicable – BEAMEX calibrators used.
7. Monthly checks all show AF/AL since start up.

14.2.2 Temperature Measurement

a) Check the calibration certificates or logbooks to see if there have been any changes made to the temperature measurement equipment.
b) Ensure that any possibility of thermal gradients – for example between the primary elements and temperature elements have been minimised by application of appropriate insulation.
c) Check the temperature element is installed in the correct location in relation to the primary element and that a suitable thermal conductivity medium is used.
d) Check the availability of a thermowell adjacent to PRT to perform spot checks using a certified temperature indicator, if a test thermowell is not available ensure that a suitable alternative method exists for carrying out a loop check.
e) Witness a functional check of each complete temperature measurement loop, referring to the detailed calibration procedures.
f) Check maintenance records. Highlight any maintenance faults or discrepancies, which may have affected the temperature used in calculation and reported.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)	
METER STREAM	ITEM	A	B	C	D	E	F
Check Meters							
TT-9202	Pass/Fail	✓	✓	✓	✓	✓	✓
	Comment No.	1	2	3	4	5	6
TT-9212	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-9222	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-9232	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
Custody Transfer Meters							
TT-9204	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-9214	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-9224	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-9234	Pass/Fail	✓	✓	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6

Traceability
BS 7965
EN 1776

Comments:

1. Serial numbers correlate with supplied calibration certificates.
2. Skid not exposed and velocities of gas sufficiently high enough to mitigate against thermal gradients.
3. No issues noted.
4. Spare thermowell fitted.
5. FT-9202 temperature transmitter calibration witnessed satisfactorily. However, it was noted there was a 0.4 Deg C difference between TT-9212 and TT-9214 on the local indicators. Whilst within a 0.5 Deg C tolerance this may lead to a small bias in indicated flows if the device which is least representative is in use. (Comment)
6. Monthly checks on transmitters and elements since all show AF/AL start up. Devices noted to be setup with a large range – 0 to 150 Deg C, whereas the observed operating temperature was~16 Deg C. (Comment)

14.3 Gas Quality Measurement

14.3.1 GC

a) Check the serial number of the GC and cross reference to the calibration certificates or logbooks.
b) Ensure that the sample probe is located in an area of turbulence and that the sample obtained is representative of operating conditions. Ensure probe has been inspected on at least a five-yearly basis
c) Check that the sample lines are as short as possible, and heat traced (if required) and/or insulated to prevent liquid dropout from the gas sample. The sample lines should slope upwards away from the sample point.
d) Confirm that the heating system of the sample-conditioning system is functioning and that the pressures, temperatures and flowrates are set to their design values.
e) Witness a calibration of the GC and check all functions with reference to the calibration procedures. Review copies of the calibration records and comment on any irregularities.
f) Review calibration gas certificates, checking the location where testing and certification was carried out, the suitability and source of the calibration gas, and the representivity compared with flowing gas.
g) If applicable, check the ISO 10723 performance evaluation for the analyser.
h) Verify that the chromatograph response factors are being monitored via control charts and that action is taken when the response factor deviation is excessive or when response factor correlation is poor. Check if repeatability / reproducibility checks have been completed.
i) Verify all calculations, density, relative density, calorific value and compressibility, carried out by the GC using the analysed data, ensuring that all calculations comply with the system design standards. Ensure that the total un-normalised concentration is within the agreed tolerances.
j) Ensure that all the analysis data is communicated correctly to the appropriate flow computers.

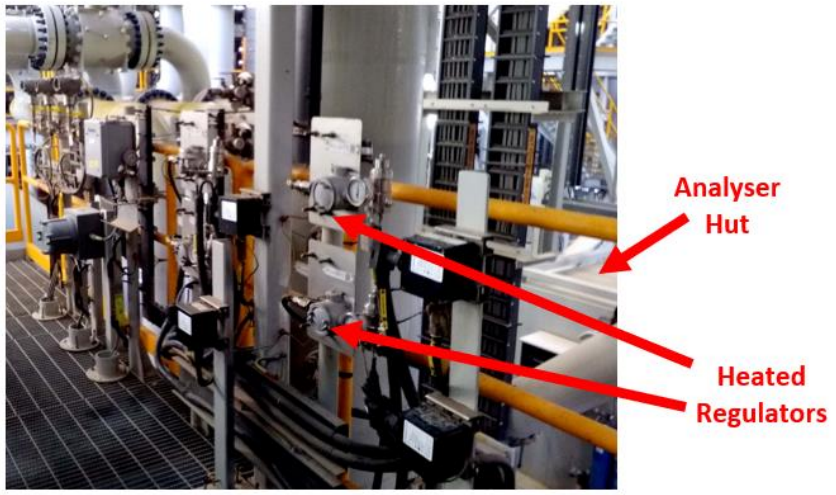
Traceability
ISO 10723:2002 Section 5

EN 1776:1998 Section 6.2.4, 6.3.2

Pass (✓)		Fail (X)		Not Possible (NP)				Not Applicable (NA)			
GC	ITEM	A	B	C	D	E	F	G	H	I	J
AT-8011	Pass/Fail	✓	✓	X	X	✓	✓	NA	X	✓	✓
	Comment No.	1	2	3	4	5	6	7	8	9	10

Comments:

1. Serial number correlates with supplied information.
2. No issues noted. Site has not yet been in operation for more than 5 years so inspection not yet required. Oracle maint system not checked to verify if this task is scheduled at 5 yearly. (Comment)
3. See photo below of sample conditioning and analyser hut. As the probes and sample conditioning are above the analyser hut it is not compliant with ISO-10715. It was reported however, that there have been no issues with component drop-out. Sample lead time reported as estimated as ~10 minutes. (Comment)



4. Flows and pressures appear to be satisfactory during site visit. However, the sample conditioning system heated regulators not working, this issue is known,

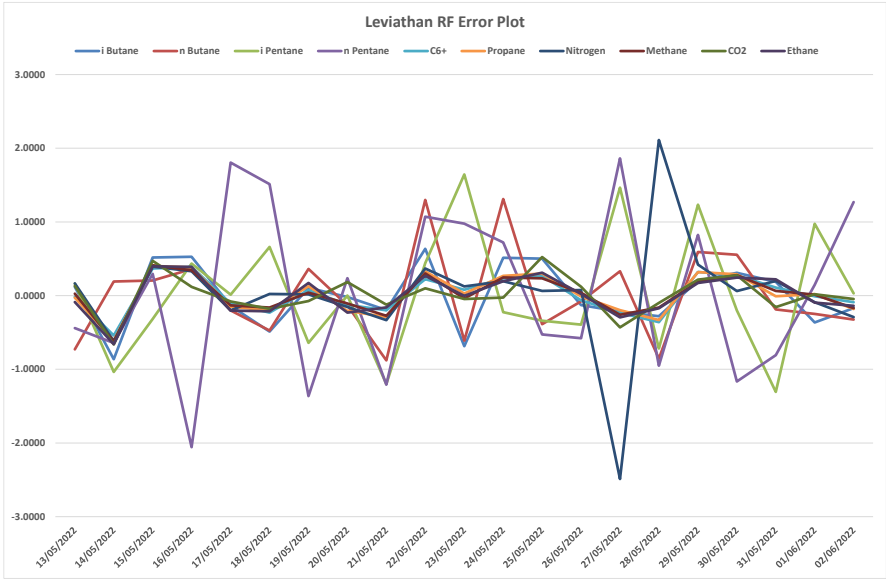
and spares requested. The reason for the failures was reported as water leaking into the regulator terminal enclosure due to cable gland issues.
There was evidence of condensation on the affected devices.
It was reported that there are issues with lead time on spares which is delaying the replacement of the devices. (Risk Factor 3)
5. No issues noted during auto calibration.
6. Effectech gas in use and supplied certificate data correlates with Component Table 1 in MON2020. Representivity appears to be satisfactory. The in-use gas expiry date is in July 2022; however, a spare bottle is available. See photo of calibration gas and carrier gas setup below. Helium carrier gas bottles 99.9995% purity.

Calibration & Carrier Gases

Carrier Gas Changeover Setup

7. Not applicable – not completed. The site may benefit from a performance evaluation to give added confidence in the GC output and to identify any weaknesses in GC, sample conditioning performance, and calibration gas suitability. Whilst it is appreciated that the gas composition is relatively stable, it is also recommended that consideration to adopting a condition-based monitoring package is given (for example GCAS), which further ensures confidence and can highlight issues before failure. In turn this could help prevent any excessive downtime issues on a system with no redundancy, and therefore reduce any commercial exposures that may result with fixed composition operation. (Comment)

8. No repeatability tests noted; however, RF is being monitored regularly via charting functions – see GCAS comment above. It can be seen from the graph of RF errors below that there are some asynchronous trends for some components. The trends that are deviating most are the heavier end components which have very small concentrations and therefore measurement risks should be mitigated. However, it is recommended to carry out some repeatability tests (compliance as per ASTM D1945-14 - 2019) to ensure there are no event or valve timing issues. (Risk Factor 3)



9. Calculations completed at OMNI computers. Un-normalised % noted as being within 98% - 102% during site visit.
10. No issues noted.

14.3.2 Dew Point Measurement

a) Check the serial number of the dew point analyser and cross reference to the calibration certificates or logbooks.
b) Inspect sample conditioning system. Check for signs of contamination to the sensing elements that will result in slow response time or affect its accuracy.
c) Where applicable, inspect the configuration of the sensor controller and ensure all parameters are configured according to the manufacturer's literature and sensor calibration data.
d) Witness a calibration check on the dew point analyser referring to detailed calibration procedures.
e) Review records for the dew point analyser calibrations ensuring that there are no irregularities.
f) Review physical position of sensing probe with respect to pipeline entry / exit point.

Pass (✓)	Fail (X)			Not Possible (NP)		Not Applicable (NA)	
DEWPOINT	ITEM	A	B	C	D	E	F
AT-9172	Pass/Fail	NP	X	NP	NP	X	X
	Comment No.	1	2	3	4	5	6

Comments:

1. Serial number – 10221775.
2. Same setup as GC – heated regulators not working.
3. Not witnessed.
4. Not witnessed.
5. Records reported as entered in Oracle and not checked during site visit. No common equipment logbook. (Comment)
6. Same issues as GC system. (Comment)
7. There is also a hydrocarbon dewpoint (HDP) analyser fitted (serial number ZW-24110961-2). As with the moisture and H2S the same issues exist in terms of maint records and logbook. (Comment)

14.3.3 H_2S Measurement

a) Check the serial number of the H_2S analyser and cross reference to the certification or logbooks.
b) Witness the calibration of the H_2S analyser referring to detailed calibration procedures and verify range and sensitivity of the instrument.
c) Ensure that the calibration gas range is suitable for the analyser.
d) Review records for the H_2S analyser calibrations ensuring that there are no irregularities

Pass (✓)		Fail (X)		Not Possible (NP)	Not Applicable (NA)
H_2S	ITEM	A	B	C	D
AT-9171	Pass/Fail	NP	NP	✓	X
	Comment No.	1	2	3	4

Comments:

1. Serial number ZW93310961-13 fitted. Test sheets not supplied as such not verified.
2. Not witnessed.
3. 10 ppmv gas in use. It was noted that there was zero H2S indicated during the audit.
4. Same issues as other analysers in that records in Oracle and not checked during site visit. (Comment)

14.3.4 Sampling

14.3.4.1 Automatic Sampling (Gas)

a) Check records for sample probe type and assess the installation in relation to the representivity of the sample extracted. Ensure probe has been inspected on at least a five-yearly basis

b) Ensure sample lines are heat traced, insulated, slope upwards from the sample point and are as short as possible.

c) Ensure that the sampler is operating flow proportionally and that the sample cans are changed over at the correct time.

d) Ensure that periodic checks carried out by the operator to verify that the sampler is operating correctly.

e) Ensure that the storage area for unused cylinders is suitable and prevents contamination of the cylinders.

f) Verify that the samples have been collected at the agreed frequency. Check that updates of reference composition and gas dependent parameters have been carried out at the agreed frequency.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)	
SAMPLER	ITEM	A	B	C	D	E	F
AK-9001	Pass/Fail	NA	NA	NA	NA	NA	NA
	Comment No.	1					

Comments:

1. No longer in operation.

Traceability

API Chapter 14 Sections 1

ISO 10715

14.3.4.2 Manual Sampling (Gas)

a) Ensure sample lines are heat traced, insulated, slope upwards from the sample point and are as short as possible. Ensure probe has been inspected on at least a five-yearly basis
b) Check records for sample probe type and assess the installation in relation to the representivity of the sample extracted.
c) Witness a sample being taken referring to the specific sampling procedure.
d) Ensure sampling containers are in good condition and appropriately labelled.
e) Verify that the samples have been collected at the agreed frequency. Check that updates of reference composition and gas dependent parameters have been carried out at the agreed frequency.

Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

SAMPLER	ITEM	A	B	C	D	E
	Pass/Fail	X	X	NP	NP	NP
	Comment No.	1	2	3	4	5

Comments:

1. Same sample lines as analysers assumed – as such same issues.
2. Same as analyser system.
3. Not witnessed.
4. Not witnessed.
5. Not witnessed.

Traceability
API Chapter 14 Sections 1
ISO 10715

14.4 Flow Computers

14.4.1 Gas Flow Computer

a) Check the serial number of the flow computers and cross reference to the certification or logbooks. Ensure that all changes to flow computer software have been recorded and checked appropriately after installation.

b) Where relevant - verify the computation of all gas composition derived parameters, as detailed below, using fixed composition, temperature and pressure are carried out within the agreed tolerance. Ensure that the correct values are entered on the master configuration list.
   - Density
   - Standard Density
   - GHV

c) Obtain the approved flow computer 'Master Configuration List' and confirm the flow computer configurable locations are in agreement with the list. If the configuration lists references calibration certificates, these should be obtained to ensure correct values are entered in the flow computer.

d) Verify the computation of density using the certified density constants and fixed, temperature and pressure is carried out within the agreed tolerance.

e) Verify the computation of flow-rate, for mass, standard volume and energy, is carried out within the agreed tolerance.

f) Verify the totalisation of mass, standard volume and energy is carried out within the agreed tolerance.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)	
METER STREAM	ITEM	A	B	C	D	E	F
Check Meters							
FQI-9202	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9212	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9222	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9232	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
Custody Transfer Meters							
FQI-9204	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9214	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9224	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-9234	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6

Comments:

1. Not witnessed.
2. Test results from January 2020 all AF/AL.
3. No formal master parameter list is in use. The site uses the latest parameter dumps from the OMNIs as the master lists. (Risk Factor 3)
4. No densitometers – not applicable.
5. Flow tests witnessed satisfactorily on stream 1. Test results from January 2020 all AF/AL.
6. Totaliser test witnessed satisfactorily on stream 1. Test results from January 2020 all AF/AL.

7. The temperature transmitter test form has the error sections reflected in °C not %.
The AGA-10 test form does not show the pressure and temperature used for the test.
Units are missing from the totaliser test forms.
The density, calorific value, and standard density test forms do not have any reference to the standard used. (Comment)

14.4.2 Supervisory Computer/ICSS/CBM

a) Check the serial number of the supervisory/DCS/CBM computers and cross reference to the certification or logbooks.
b) Obtain the approved supervisory computer/DCS/CBM 'Master Configuration Lists' and confirm the computer configurable locations are in agreement with the list. If the configuration lists references calibration certificates, these should be obtained to ensure correct values are entered in the flow computer.
c) Check and confirm that the stream summation is carried out correctly.
d) Check that priority alarms are operational and confirm that alarms are handled and stored adequately. Verify that limits are appropriate and representative. Ensure that the occurrence of nuisance alarms is mitigated as far as possible.
e) Check that all calculations carried out by the supervisory/CBM computers are carried out to the agreed tolerance.
f) In the case of DCS based systems verify the following as applicable:
   - The validity and representivity of all critical constants and/or Compterms.
   - Check flowrate calculations against offline methods, and that totaliser tests are carried out to within the agreed tolerance
g) Where CBM facilities are being used – verify that comprehensive procedures are in place to ensure appropriate operation, monitoring, and application.

Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

METER STREAM	ITEM	A	B	C	D	E	F	G
1	Pass/Fail	NA	NA	NA	X	NA	NA	X
	Comment No.	1	2	3	4	5	6	7

Comments:

1. Not applicable.
2. Not applicable.
3. Not applicable – system has individual lines. Summation not done in OMNI/HMI system.
4. There does not appear to be any alarm output from the USMs to the computer system. The alarm limits at the flow computers for pressure and temperature appear to be excessive at 10-150 barg and 0-150°C respectively (live values were ~81 barg and ~16°C). The gross flow high limit on the flow computer meter set-up was noted as being 707912 m^3/hr. The low limit was noted as zero (it is assumed that these units reflect standard volume flow). This limit should reflect the flow range from the meter calibration certificates. It was also reported that the alarm outputs that are part of the contractual connection agreements have still to be implemented at the HMI. (Risk Factor 3)
5. Not applicable.
6. Not applicable.
7. Calculated vs measured VOS checks completed once per week. This is based on taking the AGA-10 VOS values from the OMNIs and checking against the measured VOS from the USMs using the meter diagnostics. The diagnostic data is also downloaded to a spreadsheet and checked by the metering technician. Further CBM could be adopted by comparing pressure and temperature values. Given the level of redundancy in this system, the CBM capabilities of this system could be used to justify a reduction in maintenance. (Comment)
8. The only parameter that appears to be stored in the archive data is hourly based increments. (Comment)

14.4.3 Data Transmission

a) Confirm that metering data is transmitted correctly from the flow computer system to the installation control system
b) Confirm that metering data is transmitted correctly from the flow computer system to the main control centre, for example: Flowrates, flow totals, temperatures, pressures, densities, compositions, dew points.
c) Confirm that the daily reported quantities, and gas composition, are correctly entered in the operational allocation system. Record the data for three random production days in the tables below. For systems where gas composition is used in the allocation, the daily composition should also be recorded.
d) Confirm that the flow computer system time is synchronised with the installation control system.

Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

ITEM	A	B	C	D
Pass/Fail	✓	NP	X	X
Comment No.	1	2	3	4

Comments:

1. System ICSS used as HMI.
2. Not witnessed.
3. When the 06:00 OMNI report for the 25th May 2022 for FQI-9202 and FQI-9204 was compared against the reported hourly figures supplied by INGL, the energy figures did not correlate closely. (Category 2)
4. There is no clock pulse from the ICSS to the OMNIs. One computer was selected at random and was noted to be ~ 2 minutes slow. The OMNIs themselves are also 1hour behind actual time until October when the clocks go forward. It was reported that this is to prevent complications with clock changes – i.e., with a 23 hour day and a 25 hour day. (Comment)

14.5 Documentation

a) Ensure that a system measurement manual exists for the metering station and that it contents are representative and correct.
b) Ensure that logbooks, electronic or handwritten, exist for the metering system and confirm that totaliser stop and start figures are entered into logbooks when a stream is taken on or offline, together with the date and time and reason for the stream change.
c) Check that all major events are logged, including details of any equipment replaced and the reason for their replacement. Issues that are likely to have caused measurement errors should be investigated.
d) Ensure that suitable procedures exist for the operation of the metering system. Review the procedures to confirm that they contain sufficient detail and indicate the roles and responsibilities of everyone involved with the operation of the system.
e) Review the approved maintenance/calibration procedures and confirm suitability.
f) Review the maintenance/calibration records and confirm if the results are considered acceptable, with minimal failures to achieve the agreed tolerances.
g) Review the documentation and procedures for capturing mis-measurements. Evaluate the cause of any mis-measurements since the previous audit. Check some examples to ensure correct and timely application in the accounts system.
h) Review the approved uncertainty calculations and confirm suitability.
i) Review the calibration test equipment certification and confirm the suitability of the equipment for this application. Ensure that the test equipment is dedicated to the calibration of metering equipment only.
j) Review the documentation and procedures for obtaining dispensations. Ensure dispensations and appropriate action plans were requested where necessary. Evaluate the cause of any dispensations over the audit period.

Pass (✓)	Fail (X)	Not Possible (NP)					Not Applicable (NA)				
DOCUMENTATION	ITEM	A	B	C	D	E	F	G	H	I	J
1	Pass/Fail	✓	X	✓	NP	✓	✓	NP	X	✓	X
	Comment No.	1	2	3	4	5	6	7	8	9	10

Comments:

1. Measurement manual supplied (Doc Number LPP-OP-NEM-OPS-MAN-0001 Rev C2 Oct '19).
2. No common equipment logbook for the analyser systems. (Comment)
3. See above comment 2. No issues that may have resulted in mismeasurement noted from the start of the logbooks.
4. Operational procedures not supplied during site visit.
5. Maintenance procedures part of above measurement manual – noted to be satisfactory.
6. No failures noted in maint history from January 2020.
Given level of redundancy with the USMs, flow computers, and pressure/temperature transmitters, along with the calibration history – the frequency of calibrations could be relaxed. If calibration frequencies cannot be relaxed, then an additional experienced technician resource should be considered.
7. It was demonstrated that a mismeasurement process is in place; however, the procedure was not supplied and there were no outstanding or historical mismeasurements. (Comment)
8. The reported energy uncertainty does not appear to be representative. (Risk Factor 3)
9. No issues noted. It was reported that there is a two yearly calibration interval. However, yearly calibrations are applied. See details in table below:

Equipment	Serial Number	Certificate Date	Certificate Number
Beamex MC6	702361	20/03/2022	2033166/2-3-4
Beamex EXT250	74292	20/03/2022	2203166/5
Beamex Probe	06458	06/06/2021	2105332/6

The EXT250 above is the external pressure module used for pressure transmitter calibrations. Historical certificates also supplied, which matched the serial numbers on the supplied April 2022 test sheets.
10. There does not appear to be a dispensation process in place. (Comment)

14.6 Metering Management

a) Confirm that the metering system is being operated and maintained as indicated in the pertaining commercial agreements.
b) Ensure that all personnel involved with the operation and maintenance of the metering and sampling systems display sufficient competency on the system.
c) Ensure that sufficient spares are available and not subject to excessive expediting delays - to minimise downtime and errors due to equipment failures.
d) Ensure that any modifications, or changes, made to the system since the last audit have been recorded and that the relevant interested parties have been informed of the changes.

Pass (✓)	Fail (X)	Not Possible (NP)		Not Applicable (NA)	
DOCUMENTATION	ITEM	A	B	C	D
1	Pass/Fail	✓	✓	X	NA
	Comment No.	1	2	3	4

Comments:

1. Given the levels of redundancy and equipment performance demonstrated via observed and supplied data it would be unlikely if the system was non-compliant. However, the system, whilst having excellent levels of redundancy for the meter runs, does not have the same level of capability for the gas quality determination. It Is recognised that the gas composition is relatively stable and that having only one GC does not result in a measurement integrity issue, nonetheless a lack of redundancy could lead to potential exposure to commercial/reputational risk if the GC fails and results in the use of "Fixed" compositions for extended periods. (Comment)
2. No issues noted.
3. As seen from the issue with expediting the analyser sample conditioning heated regular – there appears to be issues with timely supply of critical spares. (Risk Factor 3)
4. Not applicable – initial audit.

Gas Measurement Integrity Audits

Israel Natural Gas Lines (INGL)

AOT Custody Transfer Gas Audit May 2022

Document Reference: MK4266 - 002

Client Reference: 334782

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Contents

1 Revision Control

Rev	Issue date	Description	Prep.	App.
1	17/06/2022	Issued for comment	MM	RA
2	08/07/2022	Issued as Final	MM	DS

2 Introduction

KELTON[tm] were approached on behalf of Israel Natural Gas Lines (INGL) to complete a gas measurement integrity audit on the Ashdod Onshore Terminal (AOT) site.

The AOT site custody transfer gas measurement station comprises the boundary of this audit, which was conducted between the 29th and 30th of May 2022 by Malcolm MacCall of KELTON Engineering Ltd.

2.1 System Description

The AOT custody transfer gas metering system consists of three meter runs each of which comprises of the following:

- 1 x USM (Duty)
- 1 x Turbine Meter (Check)
- 4 x Pressure transmitters
- 4 x Temperature transmitters

Common equipment comprises of:

- 1 x C6+ Gas chromatograph (GC)
- 1 x H_2S analyser
- 1 x Moisture analyser
- 1 x Hydrocarbon Dewpoint (HDP) analyser
- 8 x Multi-Stream Flow Computers (quadruple redundant)

There is no supervisory system. The flow computers are interfaced via an Integrated Control and Safety System (ICSS) based human-machine interface (HMI).

3 Acknowledgements

The auditor would like to thank Philip Krasnopolsky (INGL) and the AOT technicians (Mark Donnelly – Rust Resources and Dan Teterson and Ofer Einav - Chevron) for their invaluable assistance during the audit process.

4 Wash-up Meeting Attendees

Auditor	Mal MacCall (Kelton)
INGL Measurement Engineer	Philip Krasnopolsky (INGL)
Measurement Support Engineer	Keith Brown (Rust Resources Ltd)
Site Measurement Technician	Mark Donnelly (Rust Resources Ltd)

5 Management Summary

The AOT gas metering system has two Risk Factor 2 findings and seven Risk Factor 3 audit findings identified during this audit. These are:

Risk Factor2

- USM Calibration Issues: May result in a potential for flowrate bias if there are traceability issues found with the calibration curve settings.
- Dataflow Issues: May result in mis-reporting exposures.

Risk Factor 3

- USM Internal Diameter (ID) Traceability: Minor compliance issue.
- USM Spool Corrections: Small potential for flowrate bias if not applied or not applied correctly.
- Unrepresentative Uncertainty Values: Representative uncertainty calculations are essential to ensure the system is operating within contractual limits.
- Spares Lead Times: If critical spares are not available in a timely manner, then confidence in the system performance may be reduced until the situation has been resolved by replacement/repair of the affected item(s).
- GC performance: Response factor (RF) benchmark and asynchronous component response factor trending can highlight component uncertainty issues and therefore reduce confidence with the reported analyses.
- Alarm and Event Handling/Monitoring: It is acknowledged that the metering department should capture most events/issues via daily checks and monitoring; however, ineffective alarm and event handling/monitoring issues could lead to situations where issues are not detected/reported in a timely manner.
- Master Parameter Lists: The site uses the latest configuration dumps; however, there are no formal revision controlled master parameter lists. Formal, controlled master lists increase confidence in the flow computer settings by helping to reduce the potential for confusion and/or the use of unrepresentative values.

The detailed findings, significance, and recommended actions are noted in Section 14 of this document.

Additional comments were also made to highlight issues where potential for improvement and/or enhancements could be made. The main comments can be seen in Section 14 with other observations in the audit criteria.

6 Audit Point Classification

Risk Factor 1	A serious control weakness that could expose the business to a major risk and that requires immediate corrective action. It will impair the achievement of business objectives.
Risk Factor 2	A medium control weakness which of itself would not be serious but could adversely impact the business and requires scheduled corrective action.
Risk Factor 3	A minor control weakness where the impact on the business would have a low significance but scheduled corrective action is still required.
Comment	An item, which does not have a significant impact on the business, but if corrected may result in improvements to the efficiency/effectiveness of the measurement integrity process.

Recommended Action Periods[1]	
Risk Factor 1	3 months
Risk Factor 2	6 months
Risk Factor 3	9 months

7 Findings Summary

	Risk Factor 1	Risk Factor 2	Risk Factor 3
Ashdod AOT Site	0	1	5
Total	0	1	5
Open Items @ Final Report Issue	0	1	5

[1] Based on typical periods found with other global operators/pipelines

8 Audit Objectives and Scope

Objectives

a) Assess the current condition of the Metering Station(s)
b) Assess the Metering Station(s) historical performance
c) Establish if the metering station(s) have been operating to the required standards
d) Assess the integrity of the data transmitted from the metering system into the relevant allocation and accounting process
e) Follow-up previous audit action items (where applicable)
f) Review system documentation
g) Where required and information is supplied - determine metering station(s) compliance with relevant company policies, government regulations & guidelines and applicable operating, transportation & sales agreements.

Scope

The following areas to be audited/reviewed include:

System Areas

a) the total metering system(s) including primary elements
b) gas quality measurement system(s)
c) the flow of data (measured to allocated)
d) the metering system(s) calibration equipment.

Control Areas

a) the maintenance and calibration history records and schedules
b) the system uncertainty (design to actual)
c) the procedures
d) the logbooks and measurement manuals
e) the metrological certification
f) the master configuration lists and files for computers and primary elements
g) the experience and competence of staff
h) the roles and responsibilities

9 Terms of Reference

The audit was conducted against the following (where supplied):

a) Applicable Contractual Operating & Transportation Agreements
b) Applicable Governmental Guidelines and Policies
c) Applicable International Metrological Procedures and Standards

10 Common Acronyms

The following common abbreviations and acronyms are used in this document:

Acronym	Meaning
ISO	International Standards Organisation
UFM/USM	Ultrasonic Flow Meters
GC	Gas Chromatograph
OIML	The International Organisation of Legal Metrology
AGA	American Gas Association
API	American Petroleum Institute
IP	Institute of Petroleum
ICSS	Integrated Control and Safety System
CBM	Condition Based Monitoring

11 System Inventory

Primary Data

Primary Device(s)	3 x USM (Duty), 3 x Turbine (Check)		
Manufacturer of Device(s)	Instromet (QSonic5 USM) Instromet (QIC Turbine Meter)		
Number of Streams	3		
Redundancy of Streams		Yes	~~No~~
Proving or Verification Device(s)		Yes	~~No~~
Proving or Verification Type	Check meters		

Secondary Data

Density Measurement Method	~~ρ Live~~	Calculated
Manufacturer of Density Device	N/A	
Density Calculation Method	AGA-8 (1994)	
Relative Density Method	~~RD Live~~	Calculated
Manufacturer of Relative Density Analyser	N/A	
Standard Density Calculation Method	AGA-8 (1994)	
Energy Calculation Method	ISO-6976 (1995)	
Composition Determination Method	~~Manual Sample Analysis~~	Online Chromatograph

Manufacturer of Composition Device	Emerson 700XA x 1		
Sampling Method	Manual Sample Analysis		~~Automatic Sampling~~
Pressure Measurement Method	~~Single~~		Redundant
Manufacturer of Pressure Device(s)	Emerson 3051S2TG x 12		
Temperature Measurement Method	PT100	Transmitter	Redundant
Manufacturer of Temperature Device(s)	Emerson 3144P x12		

Flow Computer System

Redundancy of Supervisory		~~Yes~~	No
Manufacturer of Supervisory	N/A		
Redundancy of Stream(s)		~~Yes~~	No
Manufacturer of Stream(s)	OMNI		
Model of Stream(s)	6000 x 8		
Other Flow Computation Device		Yes	~~No~~
Manufacturer of Other Device	ICSS		

12 Applicable Standards

Uncertainty	ISO-5168
Flow	AGA-9/ISO-17089/OIMLR-137/ ISO-9951
Density	AGA-8
Standard Density	AGA-8
Calorific Value	ISO-6976
Sampling	ISO-10715
Online analysis	ISO-6974
Calibration gas mixtures	ISO-6141/6142/6143

13 Reported Uncertainty

Uncertainty Basis	Gross Volume	Energy
Design Calculated Uncertainty	0.232%	0.525%
Contractual Limit	± 1 %	± 1 %

14 Audit Findings

Item	Findings	Significance	Agreed Recommended Action	Category
1	**Production Dataflow Issue** When the 06:00 OMNI reports for the 1st May 2022, 14th May 2022, and 28th May 2022 were compared against the reported hourly figures supplied by INGL, the energy figures did not correlate exactly. The figures for the 1st May appear to be out for one hour and this was confirmed by comparing the one hour OMNI totals. However, on the 14th May and the 28th May there were -0.35% and -0.005% differences respectively, which cannot currently be explained by a one hour difference. It was also noted that duplicate values from the supplied hour totals and .xml files were evident – some examples are: On the 2nd May 2022 the 18:00 total was 40029.16 MMBtu, it was exactly the same total again at 03:00 on the 15th May 2022. Again on the 28th May 2022 at 06:00 the total was 45417.5 MMBtu and exactly the same value again on the 29th May 2022 at 00:00. *Post Audit Update* It was reported that a contributory reason for the above could be that the	Dataflow issues may result in mis-reporting exposures.	To ensure complete alignment of reported data - the reasons for the apparent differences in reported totals from the AOT gas metering computer system and the INGL hourly totals shall be established and rectified as required.	Risk Factor 2 Open

Item	Findings	Significance	Agreed Recommended Action	Category
	values at the OMNI are integers and the flows are very stable, which may result in flows that are the same as a previous hour. However, it does not explain why the same numbers appear some days later. *(Criteria Reference – 14.5.3 Comment 3)*			
2	**USM Traceability Issues** Whilst there were stated internal diameters (ID) on the wet calibration certificates, there were no formal dry metrology documents to show traceability to the IDs of the USMs. The USM standards noted as referenced in the supplied system handbook (AOT-OP-HMS-OPS-MAN-0001 Rev C1 Nov '14) are – AGA-9 (2007) and ISO-17089 (2010). Both of the above standards require the ID to be determined as per Chapter 6.2 and Chapter 5.9.3.3. *(Criteria Reference – 14.1 Comments 1 and 7)*	USM IDs are a critical element in the determination of flowrates. It is recognised that the likelihood of the in use values being incorrect is small, nonetheless, traceability issues with the USMs will exist until formal dry metrology documents that conform to the standards referenced in the system databook are made available.	Formal dry metrology documents shall be traced for all three AOT USMs to establish a traceability path that conforms to AGA-9 (2007) Chapter 6.2 and ISO-17089 (2010) Chapter 5.9.3.3. Once the formal dry metrology showing the appropriate traceability is available, it shall be located in the site metering folder for future auditing and information purposes.	Risk Factor 3 Open

Item	Findings	Significance	Agreed Recommended Action	Category
5	**USM Spool Corrections** On the Instromet QSonic5 duty USMs it was not possible to determine if the above corrections are applied. It was also not possible to determine during the site visit if implementation of this function is a contractual requirement. *(Criteria Reference – 14.1 Comment 11)*	A small flowrate bias may exist if USM spool corrections are not implemented.	All AOT gas metering system stakeholders shall be contacted to establish if USM spool corrections are required. If it is established that USM spool corrections are required, then the AOT gas metering system duty USMs shall be setup accordingly. Ideally, live pressure and temperature values should be used, which would require signals to be made available to the USMs. If this is not possible then any fixed values used shall be subject to regular review to ensure they are representative.	Risk Factor 3 Open
6	**Reported System Uncertainty Values** The quoted uncertainty for energy flow appear to be unrealistically low at 0.525%. *(Criteria Reference – 14.6 Comment 8)*	Representative uncertainty calculations are essential to ensure the system is operating within contractual limits.	The AOT uncertainty calculations shall be revisited to ensure representative of the current setup and process.	Risk Factor 3 Open
7	**Gas Chromatograph (GC) Performance** From the sites response factor (RF) monitoring facility, it was noted that there is step change in the C6+ benchmark value. The current data set is based on RF information from 2018. When more recent data was used the benchmark trend shows better results.	The RF trending facility is a useful indicator of GC performance and requires representative benchmark data to be an effective monitoring tool.	a) The AOT gas metering GC RF benchmark data set should be updated to ensure the data set is representative. b) It is recommended to carry out repeatability tests on the AOT gas	Risk Factor 3 Open

Item	Findings	Significance	Agreed Recommended Action	Category
	From supplied GC response factor (RF) data it was also noted that there are asynchronous RF trends on the i-Butane, and n-Butane components. *(Criteria Reference – 14.4.1 Comment 8)*	It is recognised that measurement risks are minor in this instance; however, asynchronous component RF trending can highlight component uncertainty issues and therefore reduce confidence with the reported analyses.	metering GC (compliance as per ASTM D1945-14 - 2019) to ensure there are no event or valve timing issues.	
8	**Master Parameter Lists** The site uses the latest configuration dumps; however, there are no formal revision controlled master parameter lists. *(Criteria Reference – 14.5.1 Comment 3)*	Formal, controlled master lists increase confidence in the flow computer settings by helping to reduce the potential for confusion and/or the use of unrepresentative values.	Formal master parameter lists should be implemented for the AOT gas metering system flow computers and USM transmitter settings.	Risk Factor 3 Open
9	**Spares Lead Times** A lack of spare USMs and associated components was reported at AOT. This may become more of an issue as the 2006 meters are now “legacy” items and as such may be subject to support and/or component supply issues. *(Criteria Reference – 14.7 Comment 3)*	If critical spares are not available in a timely manner, then confidence in the system performance may be reduced until the situation has been resolved by replacement/repair of the affected item(s).	Appropriate measures shall be taken to ensure access to critical spares for the AOT gas metering system can be achieved in a timely manner, which in turn should help reduce exposures to any measurement integrity issues caused by equipment failure(s).	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
10	**Alarm and Event Handling/Monitoring** Alarm functions reported as set up in the HMI. From the connection agreement the following are configured in the HMI to alarm: Pressure and temperature, H_2S, HCDP, WDP, Gas Flow off spec (CH_4, N_2, CO_2, Wobbe, CV, and difference between duty/check meters). It is not clear if USM diagnostic alarms are available to the HMI alarm system. A document was also supplied which is to provide operations guidance on OMNI alarms for out of hours cover. However, it is not clear from the supplied information on how/when operations respond to these alarms. *(Criteria Reference – 14.5.2 Comment 4)*	It is acknowledged that the metering department should capture most events/issues via daily checks and monitoring; however, alarm and event handling/monitoring issues could lead to situations where issues may go undetected.	It should be demonstrated that the AOT gas metering computer system has a robust alarm/event handling system. This should include how operations respond and handle critical metering alarms and events, and also indication of critical USM alarm situations.	Comment
11	**Dispensation Request System** There does not appear to be a formal dispensation request system/process in place. *(Criteria Reference – 14.6 Comment 10)*	A dispensation system adds a level of control to measurement issues that may be subject to delayed resolution.	An appropriate dispensation system and procedure should be implemented for the AOT gas metering system	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
12	**Maintenance Frequency** Given the history of calibration results noted from the supplied information, along with the levels of redundancy available with the turbine meters, USMs, flow computers, and pressure/temperature transmitters - the frequency of calibrations could be relaxed. However, during the site wash-up meeting it was reported that maintenance has to be completed in a period no greater than 42 days. *(Criteria Reference – 14.6 Comment 6)*	Excessive calibration frequencies result in unnecessary man-hour expenditure. Additionally, if there is too much emphasis on completing tasks that are not necessary on a monthly basis, then other important tasks may be affected.	It is recognised that the monthly calibration frequencies are a requirement, nonetheless a case should be presented to all AOT gas metering system stakeholders to reduce maintenance frequencies to more appropriate levels. Presentation of this case should include the excellent history of calibration results and the levels of redundancy available.	Comment
13	**Logbooks/Analyser Maintenance Histories** Whilst information was supplied for the turbine meters, USMs, Pressure/Temperature transmitters, and flow computer checks – the only analyser test noted was for monthly GC auto calibration checks. There is also no common equipment logbook for the system analysers. *(Criteria Reference – 14.6 Comment 2)*	Whilst not presenting a direct measurement integrity issue – a lack of a common equipment logbook and test information may lead to traceability issues.	It is recommended that information on the AOT gas metering analyser system maintenance is recorded and documented in the same manner as the rest of the metering system.	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
14	**Calibration Test Forms** The temperature transmitter test form has the error sections reflected in °C not %. The AGA-10 test form does not show the pressure and temperature used for the test. Units are missing from the totaliser test forms. The density, calorific value, and standard density test forms do not have any reference to the standard used. *(Criteria Reference – 14.5.1 Comment 7)*	Minor traceability issues with calibration test forms.	a) The AOT gas metering system calibration temperature transmitter test form shall have the error noted in % as opposed to °C. b) AOT gas metering AGA-10 test form shall show the pressure and temperature used for the test. c) The required units shall be added to the AOT gas metering totaliser forms. d) The AOT gas metering density, calorific value, and standard density test forms shall show the applicable standards used for testing.	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
15	**Mismeasurement Process** It was demonstrated that a mismeasurement process is in place and the procedure was noted on the front of each report. AOT had 15 mismeasurements completed from May 2019 to July 2021. Most appear to be for USM flow when offline, with others noted for USM signal dropout. It was reported that the Gas Controllers apply corrections; however, implementation in accounts was not witnessed during the site visit. However, there was no sign-off section from hydrocarbon accounts or INGL. *(Criteria Reference – 14.6 Comment 7)*	The audit/document trail will be incomplete If there is no sign off section to show that a correction has been implemented by hydrocarbon accounting. Any mismeasurment methodology should also be agreed with INGL.	it is recommended that a section is added to the AOT gas metering mismeasurement reports to show totals have been amended/ implemented by accounts/ gas controllers and approved by INGL to fully close out the mismeasurement process.	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
16	AOT Meter Calibration Certificates The turbine meter and USM calibration certificates for FT-1441 shows the pipework set-up at CEESI; however, the older certificates for FT-1401, FT-1411, FT-1421, FT-1431, and FT-1451 do not show a calibration set-up. The correct calibration curve values were noted in the flow computers when checked against the respective calibration certificates. However, the traceability was based on historical calibration curve conversion spreadsheet documents that were not supplied during the site visit. *(Criteria References – 14.1 Comments 2 & 8 and 14.2 Comment 5)*	If it cannot be determined if the turbine meters and USMs had the appropriate spools during calibrations, then it is not possible to verify if the calibration set-ups were representative of the set-up at AOT. If all critical calibration curve information is not readily available for information and auditing purposes, then it may introduce confusion and traceability issues.	a) The calibration set-ups for AOT gas metering system turbine meter and USM tag numbers FT-1401, FT-1411, FT-1421, FT-1431, and FT-1451 should be checked/verified. If not representative of the respective meter run set-ups at AOT, then approval to continue operations with the existing calibration curves until the meters are due re-calibration should be sought from all relevant system stakeholders. b) All AOT gas metering system turbine meter and USM calibration curve information (including conversion spreadsheets) shall be made available in the AOT metering folder for future information and auditing purposes.	Comment

Item	Findings	Significance	Agreed Recommended Action	Category
17	**Meter Calibration Frequency** No definitive information on calibration frequency was supplied during the site visit; however, it was reported that the actual frequency for the above may be up to 16 years (reported frequency from a document that is still in draft form). *(Criteria Reference – 14.1 Comment 9)*	It is recognised that the duty/check meter setup should identify drift and/or other issues; however, there is a risk that any subsequent calibrations may show a shift in calibration results, which may result in a potentially complicated mismeasurment exercise and therefore exposure to commercial risks.	a) It is recommended that the AOT gas metering system meter calibration frequency has definitive information available for future information and auditing purposes. b) To mitigate against any measurement risks associated with shifts in AOT meter calibration results – consideration should be given to higher calibration frequency. Any change to the meter calibration frequency would also require approval from all system stakeholders.	Comment
18	**Available Archive Data** The only parameter that appears to be stored in the archive data is hourly based energy increments. *(Criteria Reference – 14.5.2 Comment 8)*	It may not be possible for INGL to recalculate energy increments in the event of missing live data.	It is recommended that averaged pressure, temperature, heating value, base/line density, and gross/ net/mass totalisers are added to the AOT archived data.	Comment

Audit Criteria

14.1 UFMs

a) Check the serial number of the ultrasonic meter and cross reference to the calibration certificates and logbooks. Check that the bore size and wall thickness correspond with the manufacturer's meter dry metrology certificate.

b) Obtain measurements of upstream and downstream straight lengths of pipework ensuring the necessary straight pipe diameters are available. If a flow straightener is installed, ensure necessary diameter lengths are available upstream. Check that the meter flow orientation is correct.

c) Check that adequate insulation has been applied to the meter tubes to ensure thermal stability across the meters and associated instrumentation.

d) Check the condition of cabling associated with the meter flow sensors and comment on any damage found.

e) Observe, and comment upon any process conditions or piping configurations, which may be detrimental to the measurement integrity.

f) Check the integrity of all path signals to ensure adequate performance, for online meters - verify that that the measured VOS and calculated VOS give good agreement. Check that condition-based monitoring (CBM) is being used and that meter performance is acceptable for all key parameters such as swirl, turbulence, SNR, AGC.

g) Verify that all transducer constants entered in the associated flow computers, and the transducer serial numbers, match those on the master configuration lists and calibration certificates.

h) Confirm that the method used to correct for meter calibration performance is by linear interpolation and has been implemented in the correct manner. Any other correction method shall be highlighted.

i) Obtain a copy of the calibration certificate/s for the meter, ensuring that the agreed calibration frequency has been complied with and that the calibration was carried out by a recognised authority. Any associated "curve fit" constants within the system computers should reflect the values on the meter calibration certificate. Ensure that the meter signal output format matches that of the wet calibration certificate. Review historic shifts from the previous calibrations and comment on any shifts greater than the maximum stipulated in the relevant agreements.

j) If during the audit visit a meter is removed for recertification, check for visible damage to the meter body or transducers and for the presence of pipe scale and/or hydrocarbons in the meter and upstream/downstream pipe sections.

k) Confirm that expansion corrections, for temperature and pressure, are being applied for the meter spool in the correct manner.

Traceability

AGA 9

BS 7965

ISO TR 12765

BS 8452

BS ISO-17089-1

API Chapter 5 Section 8

Pass (✓)		Fail (X)			Not Possible (NP)				Not Applicable (NA)			
METER STREAM	ITEM	A	B	C	D	E	F	G	H	I	J	K
FT-1401	Pass/Fail	X	X	X	✓	X	✓	✓	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-1411	Pass/Fail	X	X	X	✓	X	✓	✓	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11
FT-1441	Pass/Fail	X	X	X	✓	X	✓	✓	✓	X	NA	X
	Comment No.	1	2	3	4	5	6	7	8	9	10	11

Comments:

1. Serial numbers correlate with supplied certificates; however, whilst there were stated IDs on the wet calibration certificates, there were no formal dry metrology documents as per the requirements of the standards to show traceability to the IDs of the USMs. (Risk Factor 3)

2. All three meters have a flow conditioner which is compliant with the standards at 10D. However, the pipework upstream of the flow conditioners is not

compliant with AGA-9 (2007). FT-1401 has a reverse calibration and was confirmed as installed in reverse.

The excerpt below from the calibration cert for FT-1441 shows the set-up at CEESI.

Uni-Directional Calibration Configuration Details

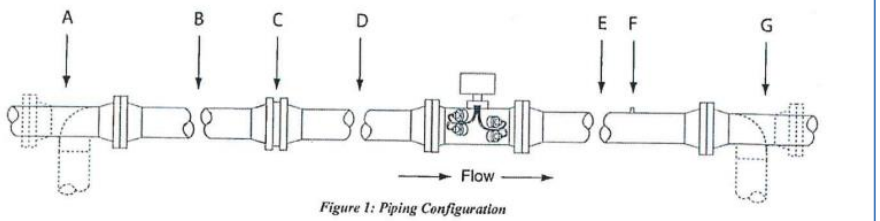


Figure 1: Piping Configuration

Meter Tube Identification:

Identifier	Length	Serial Number
B - Upstream Tube	120.0 Inches	Not Present
D - Inlet Tube	240.0 Inches	Not Present
E - Exit Tube	135.0 Inches	Not Present

Meter Flow Conditioner Identification:

Identifier	Installed	Manufacturer	Serial Number	Flow Arrow	Top Dead Center
C - Upstream Flow Conditioner	Yes	CPA 50E	1619-2	Verified	Verified

Meter Thermowell Identification:

Identifier	Distance to Closest Meter Flange Face	Quantity
F - Exit Thermowell	86.0 Inches	2

Fitting Identification:

Identifier	Type
A - Entrance Fitting	Straight Pipe
G - Exit Fitting	Straight Pipe

The older certificates associated with FT-1401 and FT-1411 did not show the calibration set-up as such it was not possible to determine if their respective calibrations had the appropriate spools and as such if they were representative. (Comment)

3. No insulation on meter runs. There was condensation noted on the online runs; however, given the gas velocity there should not be an issue with thermal gradients. It was reported that a roof structure is proposed for this system as there has been historical failure of the USM electronics due to excessive temperature build up. (Comment)
4. No issues visually noted.
5. See comment 2.
6. Diagnostics print out supplied – it was noted that path performance on all meters was 100%.
7. Curve constants were correct as per the supplied information.
8. Method by linear interpolation. FT-1401/1411 are implemented in the OMNIs, whilst FT-1441 has the settings in the USM electronics. The correct values were noted in the OMNIs when checked against the respective calibration certificates. However, the traceability was based on historical documents that were not supplied during the site visit and which should be part of the document package for this system and made available or future information auditing purposes. (Comment)
9. Unlike the EMG and Leviathan sites the supplied CEESI data for AOT shows that the calibrations were pulse based for both USMs and Turbine meters. FT-1401 calibration date – 05/10/06, FT-1411 calibration date – 04/10/06, FT-1441 calibration date – 16/12/11. The supplied maintenance verification log shows 5 years – see excerpt below:

Run 1 USM	KAU 1400	N/A	Laboratory Calibration	N/A	5 yearly
Run 2 USM	KAU 1410	N/A	Laboratory Calibration	N/A	5 yearly
Run 3 Turbine meter	KAU 1420	N/A	Laboratory Calibration	N/A	5 yearly
Run 4 Turbine meter	KAU 1430	N/A	Laboratory Calibration	N/A	5 yearly
Run 5 USM	KAU 1440	N/A	Laboratory Calibration	N/A	5 yearly
Run 6 Turbine meter	KAU 1450	N/A	Laboratory Calibration	N/A	5 yearly

If 5 years is the requirement, then the calibration dates on all three meter runs exceed the above requirement. It was reported that due to the master check set-up, the frequency may be much lower than the above. It was reported that a draft document is in progress to show a calibration frequency up to 16 years; however, there was no definitive information regarding calibration frequencies available at the time of the site visits. (Comment)
10. No meters removed during site visit.
11. No spool corrections applied. (Risk Factor 3)

14.2 Turbine Meters

a) Record the meter manufacturer, model and meter serial numbers and compare these against previous records/logbooks.
b) Obtain measurements of upstream and downstream straight lengths of pipework ensuring the necessary straight pipe diameters are available. If a flow straightener is installed, ensure necessary diameter lengths are available upstream. Check that the meter flow orientation is correct.
c) Check that adequate insulation has been applied to the meter tubes to ensure thermal stability across the meters and associated instrumentation.
d) If during the audit visit a meter is removed for recertification, check for visible damage to the meter body or impeller and for the presence of pipe scale and/or hydrocarbons in the meter and upstream/downstream pipe sections.
e) Check the type of meter correction being applied (single offset/correction, linear interpolation, or polynomial correction) and ensure the correct calibration parameters are recorded on the master configuration list.
f) Obtain a copy of the calibration certificate/s for the meter, ensuring that the agreed calibration frequency has been complied with and that the calibration was carried out by a recognised authority. Review historic shifts from the previous calibrations and comment on any shifts greater than the maximum stipulated in the relevant agreements.
g) Ensure that a suitable method exists for checking error pulses and check the recorded error pulse counts. Investigate the cause of any excessive levels found.
h) Inspect the maintenance records and indicate any maintenance actions, e.g. meter lubrication, which are out with the planned maintenance schedule.

Traceability
AGA No 7
ISO 9951
BS 4161 Part 6

Pass (✓)		Fail (X)		Not Possible (NP)			Not Applicable (NA)		
METER STREAM	ITEM	A	B	C	D	E	F	G	H
FT-1421	Pass/Fail	✓	✓	X	NA	X	X	X	X
10519017	Comment No.	1	2	3	4	5	6	7	8
FT-1431	Pass/Fail	✓	✓	X	NA	X	X	X	X
10505518	Comment No.	1	2	3	4	5	6	7	8
FT-1451	Pass/Fail	X	✓	X	NA	X	X	X	X
10505519	Comment No.	1	2	3	4	5	6	7	8

Comments:
1. Serial numbers correlated with supplied certification; however, from the supplied OMNI configurations some serial numbers appear to be wrong for example on FQIY-8959B FT-1451 serial number is 10517023, whereas the actual serial number is 10505519. (Comment)
2. Meters installed in correct orientation. All three runs have flow conditioners installed 10D upstream from the meters. ISO-9951 suggests 5D; however, it is unlikely if this would have any measurement integrity impact.
3. As per the USM runs - No insulation on meter runs. There was condensation noted on the online runs; however, given the gas velocity there should not be an issue with thermal gradients. It was reported that a roof structure is proposed for this system as there has been historical failure of the USM electronics due to excessive temperature build up. (Comment)
4. No meters removed during site visit.
5. Linear interpolation in use. The correct values were noted in the OMNIs when checked against the respective calibration certificates. However, the traceability was based on historical documents that were not supplied during the site visit and which should be part of the document package for this system and made available or future information auditing purposes. (Comment)

6. FT-1421 calibration date - 11/07/14, FT-1431 calibration date – 05/11/15, FT-1451 calibration date – 08/03/16. The supplied maintenance verification log shows 5 years – see excerpt below:

Run 1 USM	KAU 1400	N/A	Laboratory Calibration	N/A	5 yearly
Run 2 USM	KAU 1410	N/A	Laboratory Calibration	N/A	5 yearly
Run 3 Turbine meter	KAU 1420	N/A	Laboratory Calibration	N/A	5 yearly
Run 4 Turbine meter	KAU 1430	N/A	Laboratory Calibration	N/A	5 yearly
Run 5 USM	KAU 1440	N/A	Laboratory Calibration	N/A	5 yearly
Run 6 Turbine meter	KAU 1450	N/A	Laboratory Calibration	N/A	5 yearly

If 5 years is the requirement, then the calibration dates on all three meter runs exceed the above requirement. (Comment)

7. Successful monthly pulse integrity checks noted on supplied maintenance data from January 2021. From the OMNI parameter list the following was noted – Error threshold –10 hz, Max error counts/batch 50 counts. However, from supplied information there does not appear to be any bad pulse recording. As such it was not possible to determine any increments. (Comment)

8. There does not appear to be evidence of spin checks on the check meters. It was reported that this is due to process isolation issues. However, given that these meters are checking devices of a different operating methodology, then any performance issues would be identified by excessive shifts against the duty USM. (Comment)

14.3 Secondary Equipment

14.3.1 Pressure Measurement

a) Check the serial numbers of the pressure transmitters and cross reference to the calibration certificates or logbooks.
b) Check the condition of the pressure transmitter enclosure and heater, if fitted, and ensure that the enclosure temperature is thermostatically controlled.
c) Observe pressure tapping's and pressure transmitters are in an appropriate location for the type of installation, ensuring that gas turbine and USM installations utilise the reference tapping. Ensure impulse lines are in good condition and as short as possible.
d) Witness the calibration check on the pressure transmitter, referring to the detailed calibration procedures. Confirm that the pressure transmitter calibrates satisfactory.
e) Witness re-instatement of the pressure transmitters and ensure the impulse lines are secured and leak tight.
f) Ensure that corrections for local gravity, calibration temperature and gauge/absolute pressure, where required, are being applied correctly.
g) Check maintenance records. Highlight any maintenance faults or discrepancies, which may have affected the pressure reported and subsequently used in the flow calculation.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)		
METER STREAM	ITEM	A	B	C	D	E	F	G
PT-1401	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1402	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1411	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1412	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1421	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1422	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1431	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1432	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1441	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1442	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1451	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7
PT-1452	Pass/Fail	✓	NA	✓	NP	NP	NA	✓
	Comment No.	1	2	3	4	5	6	7

Traceability
BS7965
AGA 9
EN 1776

Comments:

1. Serial numbers correlate on supplied test sheet data.
2. Not applicable – no enclosures.
3. No issues noted.
4. Not possible during this site visit.
5. Not possible during this site visit.
6. Not applicable – pneumatic tester in use.
7. All records from Jan 2021 AF/AL.

14.3.2 Temperature Measurement

a) Check the calibration certificates or logbooks to see if there have been any changes made to the temperature measurement equipment.
b) Ensure that any possibility of thermal gradients – for example between the primary elements and temperature elements have been minimised by application of appropriate insulation.
c) Check the temperature element is installed in the correct location in relation to the primary element and that a suitable thermal conductivity medium is used.
d) Check the availability of a thermowell adjacent to PRT to perform spot checks using a certified temperature indicator, if a test thermowell is not available ensure that a suitable alternative method exists for carrying out a loop check.
e) Witness a functional check of each complete temperature measurement loop, referring to the detailed calibration procedures.
f) Check maintenance records. Highlight any maintenance faults or discrepancies, which may have affected the temperature used in calculation and reported.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)	
METER STREAM	ITEM	A	B	C	D	E	F
TT-1401	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1402	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1411	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1412	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1421	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1422	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1431	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1432	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1441	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1442	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1451	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6
TT-1452	Pass/Fail	✓	X	✓	✓	NP	✓
	Comment No.	1	2	3	4	5	6

Traceability
BS 7965
EN 1776

Comments:

1. Serial numbers correlate on supplied test sheet data.
2. No insulation fitted – see photo below: (Comment)

Given the observed gas velocity there should be no issues with thermal gradients

3. No issues noted.
4. Test thermowells available
5. Not possible during this site visit.
6. All records from Jan 2021 AF/AL.

14.4 Quality Measurement

14.4.1 GC

a) Check the serial number of the GC and cross reference to the calibration certificates or logbooks.
b) Ensure that the sample probe is located in an area of turbulence and that the sample obtained is representative of operating conditions. Ensure probe has been inspected on at least a five-yearly basis
c) Check that the sample lines are as short as possible, and heat traced (if required) and/or insulated to prevent liquid dropout from the gas sample. The sample lines should slope upwards away from the sample point.
d) Confirm that the heating system of the sample-conditioning system is functioning and that the pressures, temperatures and flowrates are set to their design values.
e) Witness a calibration of the GC and check all functions with reference to the calibration procedures. Review copies of the calibration records and comment on any irregularities.
f) Review calibration gas certificates, checking the location where testing and certification was carried out, the suitability and source of the calibration gas, and the representivity compared with flowing gas.
g) If applicable, check the ISO 10723 performance evaluation for the analyser.
h) Verify that the chromatograph response factors are being monitored via control charts and that action is taken when the response factor deviation is excessive or when response factor correlation is poor. Check if repeatability / reproducibility checks have been completed.
i) Verify all calculations, density, relative density, calorific value and compressibility, carried out by the GC using the analysed data, ensuring that all calculations comply with the system design standards. Ensure that the total un-normalised concentration is within the agreed tolerances.
j) Ensure that all the analysis data is communicated correctly to the appropriate flow computers.

Traceability

ISO 10723:2002 Section 5
EN 1776:1998 Section 6.2.4, 6.3.2

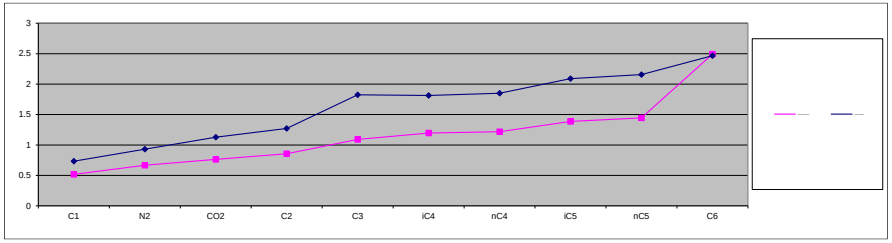
Pass (✓)		Fail (X)		Not Possible (NP)				Not Applicable (NA)			
GC	ITEM	A	B	C	D	E	F	G	H	I	J
AY-1407	Pass/Fail	✓	✓	✓	✓	NP	✓	X	X	NA	✓
	Comment No.	1	2	3	4	5	6	7	8	9	10

Comments:

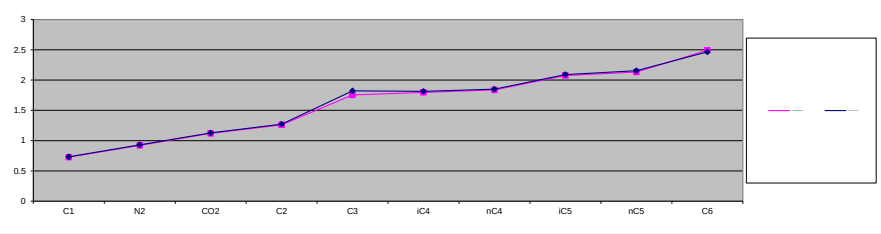
1. Serial number correlates with supplied data. A second GC was noted at the metering system, which is awaiting fitting in the near future. This should give increased gas quality measurement confidence due to increased redundancy. (Comment)
2. It is not clear if probe has been inspected. This task is typically set at a 5 year frequency. (Comment)
3. Some low points, as such not fully compliant with ISO-10715. However, no issue with drop out reported. See photos of set-up below:

4. No issues noted. Indicator covers starting to get opaque and after time it may not be possible to see values. No condensation/icing noted on sample conditioning. (Comment)

5. Physically not witnessed; however, supplied results satisfactory.
6. No issues noted with cal gas. Component Table 1 values correlate with supplied data.
7. Not completed. The site may benefit from a performance evaluation to give added confidence in the GC output and to identify any weaknesses in GC, sample conditioning performance, and calibration gas suitability. Whilst it is appreciated that the gas composition is relatively stable, it is also recommended that consideration to adopting a condition based monitoring package is given (for example GCAS), which further ensures confidence and can highlight issues before failure. In turn this could help prevent any excessive downtime issues on a system with no redundancy, and therefore reduce any commercial exposures that may result with fixed composition operation. (Comment)
8. RF is being monitored regularly via charting functions; however, see GCAS comment above.
From the above facility it was noted that there was a step change in the C6+ element benchmark – see below:

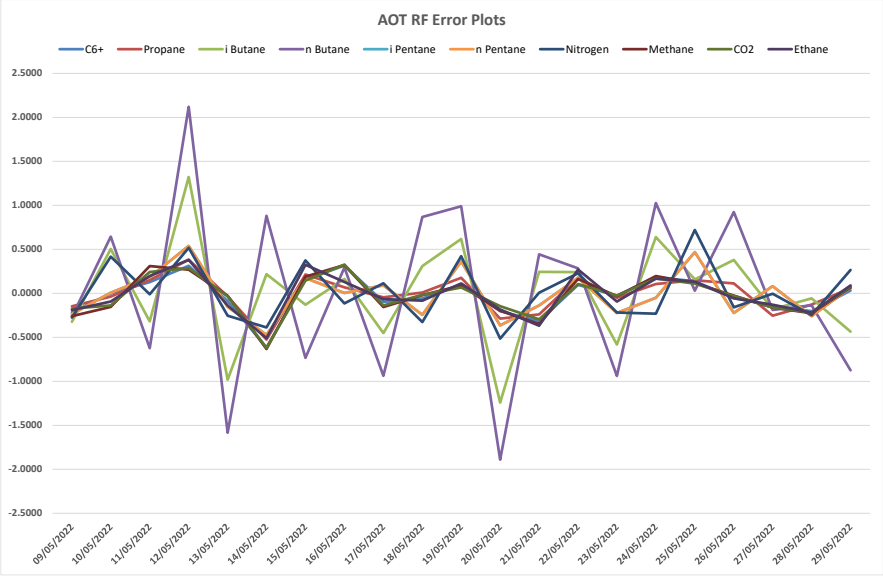


However, if more recent data than the 2018 data than that used in the example above, the benchmark trend shows better results. See below results using data from June 2021:



Therefore the in use GC RF benchmark plot is unrepresentative.

It can be seen from the graph of RF errors below that there are some asynchronous trends for some components. The trends that are deviating most are the heavier end components which have very small concentrations and therefore measurement risks should be mitigated. However, it is recommended to carry out some repeatability tests (compliance as per ASTM D1945-14 - 2019) to ensure there are no event or valve timing issues. (Risk Factor 3)



9. Calculations completed at OMNI computers. Un-normalised % noted as being within 98% - 102% during site visit.
10. No issues noted. No alarms noted on local GC display.

14.4.2 Dew Point Measurement

a) Check the serial number of the dew point analyser and cross reference to the calibration certificates or logbooks.
b) Inspect sample conditioning system. Check for signs of contamination to the sensing elements that will result in slow response time or affect its accuracy.
c) Where applicable, inspect the configuration of the sensor controller and ensure all parameters are configured according to the manufacturer's literature and sensor calibration data.
d) Witness a calibration check on the dew point analyser referring to detailed calibration procedures.
e) Review records for the dew point analyser calibrations ensuring that there are no irregularities.
f) Review physical position of sensing probe with respect to pipeline entry / exit point.

Pass (✓)	Fail (X)			Not Possible (NP)		Not Applicable (NA)	
DEWPOINT	ITEM	A	B	C	D	E	F
AI-1218	Pass/Fail	NP	✓	NP	NP	X	✓
	Comment No.	1	2	3	4	5	6

Comments:

1. Serial number – 10219584. - not possible to check against supplied information. Test sheets not supplied as such not verified.
2. See photos of set up from GC section.
3. Not witnessed.
4. Not witnessed.
5. Records reported as entered in Oracle and not checked during site visit. No common equipment logbook. (Comment)
6. Same issues as GC system. (Comment)
7. There is also a hydrocarbon dewpoint analyser fitted (AI-1217 serial number ZC-241-31124). As with the moisture and H_2S the same issues exist in terms of maint records and logbook. (Comment)

14.4.3 H_2S Measurement

a) Check the serial number of the H_2S analyser and cross reference to the certification or logbooks.
b) Witness the calibration of the H_2S analyser referring to detailed calibration procedures and verify range and sensitivity of the instrument.
c) Ensure that the calibration gas range is suitable for the analyser.
d) Review records for the H_2S analyser calibrations ensuring that there are no irregularities

Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

H_2S	ITEM	A	B	C	D
	Pass/Fail	NP	NP	✓	X
	Comment No.	1	2	3	4

Comments:

1. Serial number ZB93310542 fitted - not possible to check against supplied information. Test sheets not supplied as such not verified.
2. Not witnessed.
3. 10 ppmv gas in use.
4. Same issues as other analysers with records in Oracle and not checked during site visit. (Comment)

14.4.4 Sampling

14.4.4.1 Manual Sampling (Gas)

a) Ensure sample lines are heat traced, insulated, slope upwards from the sample point and are as short as possible. Ensure probe has been inspected on at least a five-yearly basis
b) Check records for sample probe type and assess the installation in relation to the representivity of the sample extracted.
c) Witness a sample being taken referring to the specific sampling procedure.
d) Ensure sampling containers are in good condition and appropriately labelled.
e) Verify that the samples have been collected at the agreed frequency. Check that updates of reference composition and gas dependent parameters have been carried out at the agreed frequency.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)
SAMPLER	ITEM	A	B	C	D	E
	Pass/Fail	X	X	NP	NP	NP
	Comment No.	1	2	3	4	5

Comments:

1. Same sample lines as analysers assumed – as such same issues.
2. Same as analyser system.
3. Not witnessed.
4. Not witnessed.
5. Not witnessed.

Traceability
API Chapter 14 Sections 1
ISO 10715

14.5 Flow Computers

14.5.1 Gas Flow Computer

a) Check the serial number of the flow computers and cross reference to the certification or logbooks. Ensure that all changes to flow computer software have been recorded and checked appropriately after installation.

b) Where relevant - verify the computation of all gas composition derived parameters, as detailed below, using fixed composition, temperature and pressure are carried out within the agreed tolerance. Ensure that the correct values are entered on the master configuration list.
   - Density
   - Standard Density
   - GHV

c) Obtain the approved flow computer 'Master Configuration List' and confirm the flow computer configurable locations are in agreement with the list. If the configuration lists references calibration certificates, these should be obtained to ensure correct values are entered in the flow computer.

d) Verify the computation of density using the certified density constants and fixed, temperature and pressure is carried out within the agreed tolerance.

e) Verify the computation of flow-rate, for mass, standard volume and energy is carried out within the agreed tolerance.

f) Verify the totalisation of mass, standard volume and energy is carried out within the agreed tolerance.

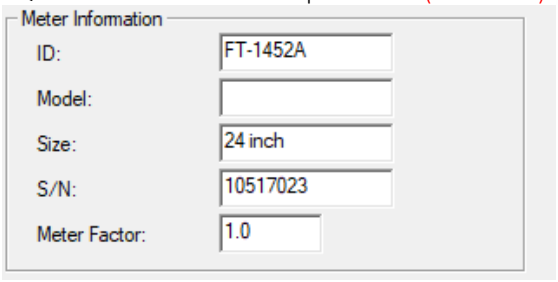
Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

METER STREAM	ITEM	A	B	C	D	E	F
FQI-8918A	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8918B	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8919A	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8919B	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8959A	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8959B	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8960A	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6
FQI-8960B	Pass/Fail	NP	✓	X	NA	✓	✓
	Comment No.	1	2	3	4	5	6

Comments:

1. Not witnessed.
2. Test results from January 2021 all AF/AL.
3. No formal master parameter list is in use. The site uses the latest parameter dumps from the OMNIs as the master lists. Given the issues with confirming the meter calibration constants – implementation of master lists would help to control the situation and avoid confusion. (Risk Factor 3)

Serial numbers for FT-1452A noted to be 10517023 in OMNI configurations for FQI8960 A and B – see example below: (Comment)



4. No densitometers – not applicable.
5. Flow tests not witnessed; however, test results from January 2021 all AF/AL.
6. Totaliser test not witnessed; however, test results from January 2021 all AF/AL.

14.5.2 Supervisory Computer/DCS/CBM

a) Check the serial number of the supervisory/DCS/CBM computers and cross reference to the certification or logbooks.
b) Obtain the approved supervisory computer/DCS/CBM 'Master Configuration Lists' and confirm the computer configurable locations are in agreement with the list. If the configuration lists references calibration certificates, these should be obtained to ensure correct values are entered in the flow computer.
c) Check and confirm that the stream summation is carried out correctly.
d) Check that priority alarms are operational and confirm that alarms are handled and stored adequately. Verify that limits are appropriate and representative. Ensure that the occurrence of nuisance alarms is mitigated as far as possible.
e) Check that all calculations carried out by the supervisory/CBM computers are carried out to the agreed tolerance.
f) In the case of DCS based systems verify the following as applicable:
   - The validity and representivity of all critical constants and/or Compterms.
   - Check flowrate calculations against offline methods, and that totaliser tests are carried out to within the agreed tolerance
g) Where CBM facilities are being used – verify that comprehensive procedures are in place to ensure appropriate operation, monitoring, and application.

Pass (✓)		Fail (X)		Not Possible (NP)		Not Applicable (NA)		
METER STREAM	ITEM	A	B	C	D	E	F	G
1	Pass/Fail	NA	NA	✓	X	NA	NA	X
	Comment No.	1	2	3	4	5	6	7

Comments:
1. Not applicable.
2. Not applicable.
3. Noted as satisfactory from supplied OMNI 06:00 reports.
4. Alarm functions reported as set up in the HMI.
From the connection agreement the following are configured in the HMI to alarm:
- Pressure and temperature,
- H2S, HCDP, WDP,
- Gas Flow off spec – CH4, N2, CO2, Wobbe, CV, and difference between duty/check meters

A document was supplied which was to provide ops guidance on OMNI alarm for out of hours cover. However, it was reported that the alarms at the OMNI flow computers are typically ignored by Ops.
It is also not clear if USM alarms from the diagnostics are available. (Risk Factor 3)
5. Not applicable.
6. Not applicable.
7. Calculated vs measured VOS checks completed once per week. This is based on taking the AGA-10 VOS values from the OMNIs and checking against the measured VOS from the USMs using the meter diagnostics. The diagnostic data is also downloaded to a spreadsheet and checked by the metering technician. Further CBM could be adopted by comparing pressure and temperature values. Given the level of redundancy in this system, the CBM capabilities of this system could be used to justify a reduction in maintenance. (Comment)
8. The only parameter that appears to be stored in the archive data is hourly based increments. (Comment)

14.5.3 Data Transmission

a) Confirm that metering data is transmitted correctly from the flow computer system to the installation control system

b) Confirm that metering data is transmitted correctly from the flow computer system to the main control centre, for example:
   - Liquid systems - flowrates, flow totals, temperatures, pressures, densities, water cuts,
   - Gas systems - flowrates, flow totals, temperatures, pressures, densities, compositions, dew points.

c) Confirm that the daily reported quantities, and gas composition, are correctly entered in the operational allocation system. Record the data for three random production days in the tables below. For systems where gas composition is used in the allocation, the daily composition should also be recorded.

d) Confirm that the flow computer system time is synchronised with the installation control system.

Pass (✓)	Fail (X)	Not Possible (NP)	Not Applicable (NA)

ITEM	A	B	C	D
Pass/Fail	✓	NP	X	NP
Comment No.	1	2	3	4

Comments:

1. System ICSS used as HMI.
2. Not witnessed.
3. When the 06:00 OMNI reports for the 1st May 2022, 14th May 2022, and 28th May 2022 were compared against the reported hourly figures supplied by INGL, the energy figures did not correlate closely. The figures for the 1st May appear to be out for one hour and this was confirmed by comparing the one hour OMNI totals. However, on the 14th May and the 28th May there were -0.35% and -0.005% differences respectively, which currently cannot be explained by an hour difference. . It was also noted that duplicate values from the supplied hour totals and .xml files were evident – some examples are: On the 2nd May 2022 the 18:00 total was 40029.16 MMBtu, it was exactly the same total again at 03:00 on the 15th May 2022. Again on the 28th May 2022 at 06:00 the total was 45417.5 MMBtu and exactly the same value again on the 29th May 2022 at 00:00. See table below: (Category 2)

02.05.2022	Energy	14.05.2022	Energy	15.05.2022	Energy	16.05.2022	Energy	28.05.2022	Energy	29.05.2022	Energy	30.05.2022	Energy
06:00	41131.47	06:00	42595.84	06:00	39366.63	06:00	40643.34	06:00	45417.5	06:00	45358.73	06:00	44933.16
07:00	41128.63	07:00	45164.43	07:00	41081.23	07:00	41946.59	07:00	45445.93	07:00	45426.98	07:00	44929.37
08:00	42712.43	08:00	44057.38	08:00	41720.06	08:00	43121.88	08:00	45471.52	08:00	45366.31	08:00	44937.9
09:00	42264.11	09:00	41132.41	09:00	41891.62	09:00	41149.48	09:00	45615.59	09:00	45400.44	09:00	44990.03
10:00	42167.43	10:00	37162.01	10:00	38167.64	10:00	41019.63	10:00	45114.2	10:00	45427.92	10:00	44998.56
11:00	42159.85	11:00	36928.84	11:00	35192.45	11:00	41024.36	11:00	45053.54	11:00	45415.6	11:00	45008.04
12:00	39348.63	12:00	38631.13	12:00	33721.43	12:00	41026.26	12:00	44747.39	12:00	45408.97	12:00	44997.61
13:00	39847.18	13:00	40849.02	13:00	37841.59	13:00	41040.48	13:00	45493.32	13:00	45223.19	13:00	44979.6
14:00	44365.42	14:00	43745.55	14:00	39983.66	14:00	41034.79	14:00	45501.85	14:00	45398.54	14:00	
15:00	45170.12	15:00	44061.17	15:00	36545.93	15:00	41068.91	15:00	45489.53	15:00	45335.04	15:00	
16:00	45571.99	16:00	44076.34	16:00	33096.82	16:00	42843.23	16:00	45462.05	16:00	45299.02	16:00	
17:00	45525.55	17:00	45530.29	17:00	35885.3	17:00	41683.1	17:00	45408.97	17:00	45302.81	17:00	
18:00	40029.16	18:00	45600.42	18:00	41722.91	18:00	38901.25	18:00	45258.27	18:00	45335.04	18:00	
19:00	39915.42	19:00	42700.11	19:00	44611.85	19:00	38520.23	19:00	45272.48	19:00	45342.62	19:00	
20:00	39908.78	20:00	35683.41	20:00	42184.49	20:00	41052.8	20:00	45278.16	20:00	45376.74	20:00	
21:00	37974.29	21:00	30204.09	21:00	42092.55	21:00	39776.09	21:00	44211.88	21:00	45433.61	21:00	
22:00	37977.13	22:00	31828.64	22:00	42090.66	22:00	39001.72	22:00	38914.52	22:00	45435.51	22:00	
23:00	43615.7	23:00	30271.38	23:00	41791.15	23:00	39008.36	23:00	42207.24	23:00	45426.02	23:00	
00:00	39980.82	00:00	29966.18	00:00	42090.66	00:00	39987.45	00:00	45345.46	00:00	45417.5	00:00	
01:00	39943.85	01:00	34906.21	01:00	40139.1	01:00	40359	01:00	45433.61	01:00	45403.28	01:00	
02:00	39934.38	02:00	35104.3	02:00	40020.63	02:00	38300.34	02:00	45478.16	02:00	45438.35	02:00	
03:00	41780.72	03:00	34977.29	03:00	40029.16	03:00	38051.06	03:00	45523.65	03:00	45414.65	03:00	
04:00	43803.36	04:00	35577.26	04:00	40017.78	04:00	38029.26	04:00	45502.8	04:00	45152.11	04:00	
05:00	43919	05:00	36290.02	05:00	40027.26	05:00	38033.05	05:00	45102.82	05:00	44974.87	05:00	

4. Not witnessed.

14.6 Documentation

a) Ensure that a system measurement manual exists for the metering station and that it contents are representative and correct.
b) Ensure that logbooks, electronic or handwritten, exist for the metering system and confirm that totaliser stop and start figures are entered into logbooks when a stream is taken on or offline, together with the date and time and reason for the stream change.
c) Check that all major events are logged, including details of any equipment replaced and the reason for their replacement. Issues that are likely to have caused measurement errors should be investigated.
d) Ensure that suitable procedures exist for the operation of the metering system. Review the procedures to confirm that they contain sufficient detail and indicate the roles and responsibilities of everyone involved with the operation of the system.
e) Review the approved maintenance/calibration procedures and confirm suitability.
f) Review the maintenance/calibration records and confirm if the results are considered acceptable, with minimal failures to achieve the agreed tolerances.
g) Review the documentation and procedures for capturing mis-measurements. Evaluate the cause of any mis-measurements since the previous audit. Check some examples to ensure correct and timely application in the accounts system.
h) Review the approved uncertainty calculations and confirm suitability.
i) Review the calibration test equipment certification and confirm the suitability of the equipment for this application. Ensure that the test equipment is dedicated to the calibration of metering equipment only.
j) Review the documentation and procedures for obtaining dispensations. Ensure dispensations and appropriate action plans were requested where necessary. Evaluate the cause of any dispensations over the audit period.

Pass (✓)	Fail (X)	Not Possible (NP)					Not Applicable (NA)				
DOCUMENTATION	ITEM	A	B	C	D	E	F	G	H	I	J
1	Pass/Fail	✓	X	✓	NP	✓	✓	X	X	✓	X
	Comment No.	1	2	3	4	5	6	7	8	9	10

Comments:

1. Measurement manual supplied (Doc Number AOT-OP-HMS-OPS-MAN-0001 Rev C1 Nov '14).
2. No common equipment logbook for the analyser systems. (Comment)
3. See above comment 2. No issues that may have resulted in mismeasurment noted from the start of the logbooks.
4. Operational procedures not supplied during site visit.
5. Maintenance procedures part of above measurement manual – noted to be satisfactory.
6. No failures noted in maint history from January 2021.
Given level of redundancy with the primary elements, flow computers, and pressure/temperature transmitters, along with the calibration history – the frequency of calibrations could be relaxed. If calibration frequencies cannot be relaxed, then an additional experienced technician resource should be considered.
7. It was demonstrated that a mismeasurement process is in place; however, unlike the Leviathan reports, there is no procedural information on the front of the reports. 15 mismeasurements completed from May 2019 to July 2021. Most appear to be for USM flow when offline, and others for USM signal dropout. It was reported that the Gas Controllers adjust the figures as required; however implementation in accounts was not witnessed;. It is recommended that a section is added to show totals have been amended/implemented by the accounts/gas controllers to fully close out the mismeasurement process. (Comment)
8. The current energy uncertainty does not appear to be representative. (Risk Factor 3)

9. No issues noted. It was reported that there is a two yearly calibration interval.
See supplied details in table below:

Equipment	Serial Number	Certificate Date	Certificate Number
Beamex MC6-Ex	701980	26/05/2021	2105332/1
Beamex EXT250	76710	06/06/2021	2105332/5
Beamex Probe	06458	06/06/2021	2105332/6
Beamex Bara Module	701980/2	06/06/2021	2105332/3

The EXT250 above is the external pressure module used for pressure transmitter calibrations. Serial numbers on the supplied April 2022 test sheets match the above table.

10. There does not appear to be a dispensation process in place. (Comment)

14.7 Metering Management

a) Confirm that the metering system is being operated and maintained as indicated in the pertaining commercial agreements.
b) Ensure that all personnel involved with the operation and maintenance of the metering and sampling systems display sufficient competency on the system.
c) Ensure that sufficient spares are available and not subject to excessive expediting delays - to minimise downtime and errors due to equipment failures.
d) Ensure that any modifications, or changes, made to the system since the last audit have been recorded and that the relevant interested parties have been informed of the changes.

Pass (✓)	Fail (X)	Not Possible (NP)		Not Applicable (NA)	
DOCUMENTATION	ITEM	A	B	C	D
1	Pass/Fail	✓	✓	X	NA
	Comment No.	1	2	3	4

Comments:

1. Given the levels of redundancy and equipment performance demonstrated via observed and supplied data it would be likely the system was compliant.
2. No issues noted.
3. A lack of USM spares was reported at AOT. This may become more of an issue as the 2006 meters are now “legacy” items. (Comment)
4. Not applicable – initial audit.