Schlumberger

SWTC Flow Loop
1 Benoi Crescent
Singapore 629986

Vx Spectra xx
Flow Loop Test Procedure and Report Template

MPFM Serial Number	: xxxxx
Client Tag Number	: xxxxx
Test requestor	: xxxxx
SLB Flow Operator	: xxxxx
Document Reference	: xxxxx
Revision	: xx
Release Date	: xxxxx

Table of Contents

1 Test objective and executive summary

The main objective is to demonstrate Vx Spectra xx mm performances at **flow loop conditions** are within product performance specifications.

This report presents the result from a flow loop test of Vx Spectra at Singapore Well Testing Center-Three phases flow loop facility. The Vx spectra Multiphase flowmeter will be tested at pressures and GVF ranges mentioned in the table below.

Description	Details
MPFM Serial Number	xxxxx
Client Tag Number	xxxxx
Pressure (Line)	xx barg
Gas Volume Fraction range	xx% to xx% (Refer to Test matrix for more details)

2 Abbreviations and Definitions

DAFC	Data Acquisition Flow Computer
DCS	Distributed Control System
DPV	Differential Pressure across Venturi
FLT	Flow loop test
GVF	Gas Volume Fraction
MK4	Multi-controller Kit (Version) 4
MPFM	Multiphase Flow Meter
MVT	Multivariable Transmitter
P	Pressure
PVT	Pressure-Volume-Temperature
SCADA	Supervisory Control and Data Acquisition
SI	International Standard (of Units)
T	Temperature
VFD	Vacuum Fluorescent Display
WLR	Water Liquid Ratio

3 SWTC flow loop description

3.1 Layout

SWTC flow loop is made of 4 main areas (cf. Figure 1) :

- An external STORAGE AREA where the separator and storage tanks are installed.
- An external OPEN SPACE AREA comprising the Nitrogen supply pallets and HVAC system
- A sheltered FLOW LOOP AREA where most of the piping and instrumentation is installed.
- An OPEN YARD of about 600 sqm besides the flow loop shelter.

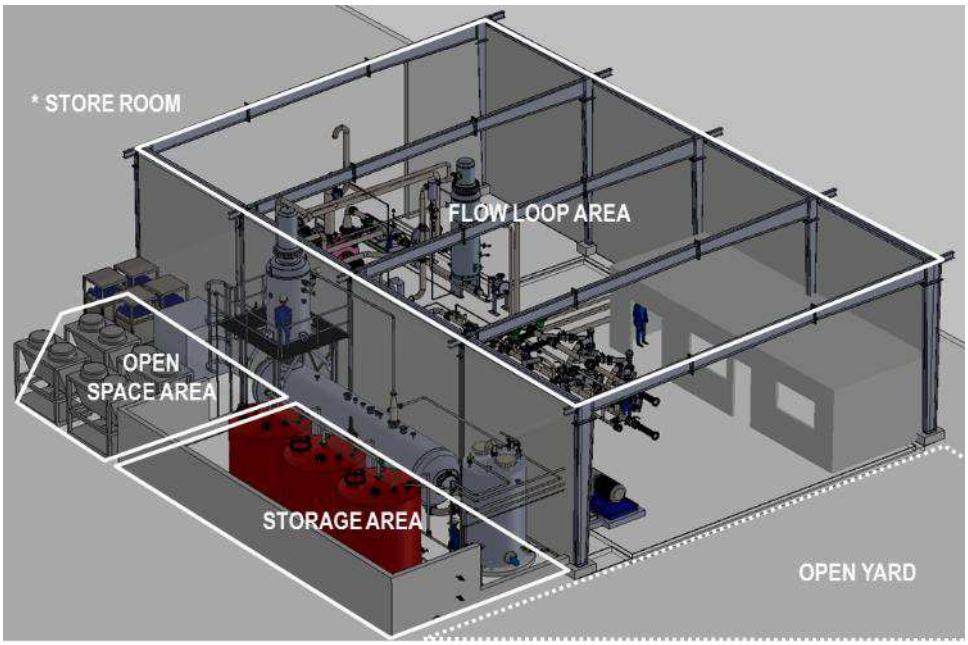

Figure 1: Flow loop layout showing the 4 main zones of the flow loop facility

The overall pipework is entirely manufactured from stainless steel that can support brine as water phase. It has been optimized so that it fits in a compact footprint (23.4m by 21.4m), so that a large portion of the available floor area is dedicated to the test section to offer a wide and safe access to the test stands. This maximizes the testing efficiency and reduces potential hazards related to the movement and rig-up of test skids.

The whole facility has been reviewed and approved by Ministry of Manpower Professional Engineers, both for process and electrical standpoints.

The equipment and piping are organized into 7 separate sections corresponding to the process P&IDs, as shown on Figure 2 :

- Separation system (PID 1101)
- Compressors section (PID 1102)
- Pumps section (PID 1103)
- Test section (PID 1104)
- Storage and transfer (PID 1105 and 1106)
- Cooling system (PID 1107)

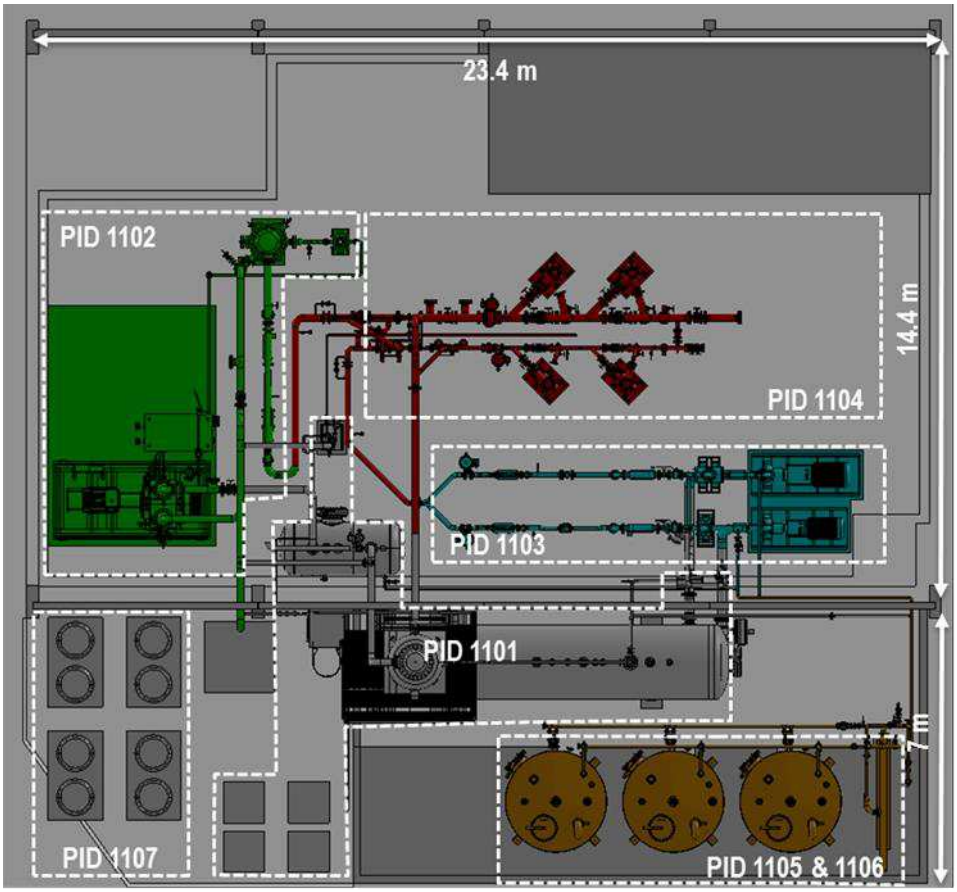

Figure 2: Top view of the SWTC flow loop

Test section is located in a central position below the shelter with the return line going straight to the separator inlet. The control room located in the top right corner offers a direct view on the test stations.

3.2 Test fluids

The gas, oil and water phases were carefully selected in order to test the meters under safe, reproducible and realistic conditions but also with a view to facilitate the three phase separation in the separator.

3.2.1 Gas phase

The flow loop is filled and pressurized with high purity Nitrogen (99.99%) but other pure gases may also be considered in the future provided that they meet the minimum safety requirements.

Gas purity ..... 99.7% min.

It must be noted that the actual gas purity accounts for the residual traces of air species left in the flow loop throughout the vacuum purging and inerting processes. Refer to the *Reference Measurement & Calculations* document **[1]** for more details on the gas composition.

3.2.2 Oil phase

The oil used for the present test is **Exxsol D80**:

Oil density @ 15.6 °C ..... 795 kg/m^3
Oil viscosity @ 25 °C ..... 2.18 cSt
Flash point ..... 82 °C

Note: the flow loop has been designed to handle different types of oil. For safety compliance, oil flash points shall always be above 63°C. The liquid pumps, heat exchangers and reference flow meters have been sized to handle fluid with densities comprises between 785 to 875 kg/m3 and viscosities between 2 to 300 cSt.

3.2.3 Water phase

The flow loop aqueous phase for the present test is **xxxxx** with **xxxxx** (mass concentration)

Brine density @ 30 °C ..... 999 to 1010 kg/m^3

Note: Salts may possibly be diluted in real-time into the water phase at up to 90% of the corresponding salt saturation to avoid solids precipitations. The flow loop pumps, heat exchanger and reference flow meters have been sized to handle fluids with density between 996 to 1280 kg/m^3 and conductivity up to 222 mS/cm.

3.3 Operating envelope

3.3.1 3” test line

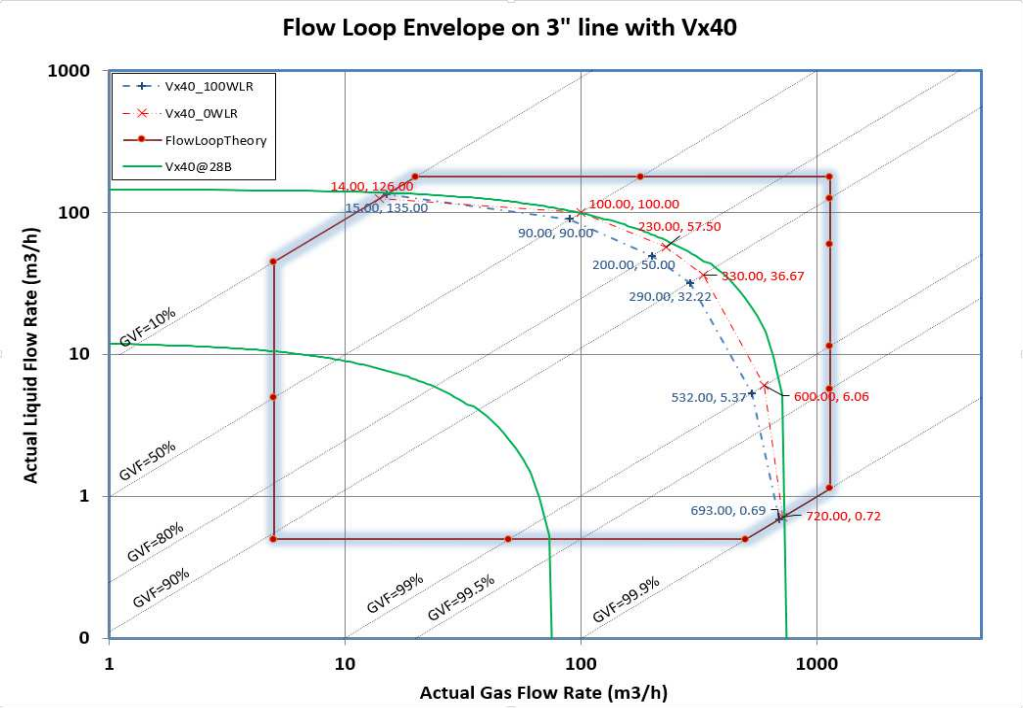

Figure 3 Operating envelope of 3” test line in SWTC flow loop

3.3.2 6” test line

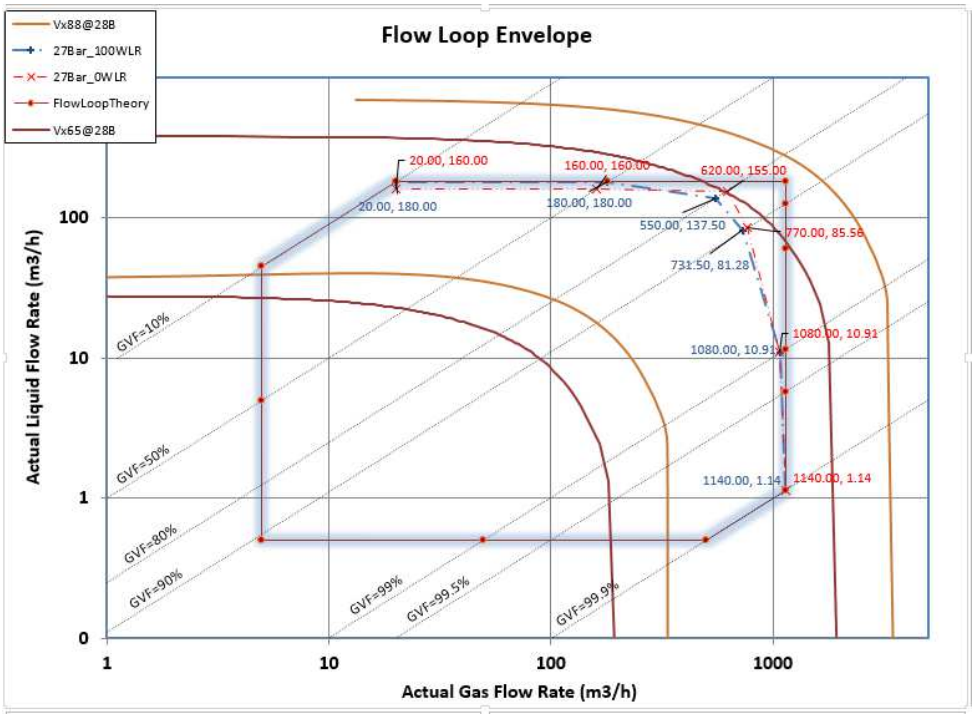

Figure 4 Operating envelope of 6” test line in SWTC flow loop

Operating envelop summary table

Fluids	**Flow rates**
Water	Up to 180 m^3/h
Oil	Up to 160 m^3/h
Total liquid	200 m^3/h
Nitrogen gas	1140 Am^3/h
GVF	0% - 100%

Operating Conditions

Line pressure	3-28 barg
Line temperature	30°C to 60°C

3.4 Reference metering

Nitrogen Coriolis Meter	**Flow rate range @ 30 bar**
1/2-inch	5 to 15 Am^3/h
1 1/5-inch	15 to 90 Am^3/h
3-inch	90 to 1200 Am^3/h

Oil Coriolis Meter	**Flow rate range**
1-inch	0.5 to 10 m^3/h
3-inch	10 to 200 m^3/h

Water Coriolis Meter	**Flow rate range**
1-inch	0.5 to 10 m^3/h
3-inch	10 to 200 m^3/h

4 Test setup and procedures

4.1 Meter setup

Vx Spectra is connected to test station #xx of xx-inch test line (

Figure 5). Connection to flow loop is done via SWTC standard xx-inch skid with integrated crossover between xx inch to xx inch at both inlet and outlet.

Figure 5 Illustration of Vx Spectra 40 mm assembly on flow loop (For Reference)

Figure 6 Vx Spectra 40 mm Name Plate (For Reference)

4.2 Data logging

4.2.1 Uncertainty analysis

4.2.1.1 Flow loop reference measurement uncertainty

Over the majority of the operating envelope of SWTC flow loop the combined uncertainties on mass flow rates are:

- Gas uncertainty < 0.81 %
- Oil uncertainty < 0.59 %
- Water uncertainty < 0.42 %

4.2.1.2 Vx Spectra xx 's specification

Table 1 shows the performance specifications of Vx Spectra xx for liquid flow rate, gas flow rate and WLR with 95% confidence interval.

Table 2 Typical performance of Vx Spectra 40 (Vx 40 is used for reference)

Vx Spectra 40 Performance (95% confidence level)		Unit	Gas Volume Fraction or GVF					
		[%]	0-20	20-90	90-95	95-98	98-99	99-100
Liquid	Relative	[%]	1.75	2.75	5.0	9.0	25.0	(35)
	Absolute	[m^3/h]	1.0	1.0	0.75	0.75	0.5	0.5
WLR	Absolute	[%]	1.25	2.75	3.75	8.5	10	-
WVF	Absolute	[%]	-	-	0.50	0.35	0.20	0.10
Gas	Relative >20bar	[%]	**	5.0	5.5	5.0	5.0	5.0
	Relative <20bar		**	8.5	9.0	8.0	8.5	6.5
	Absolute	[m^3/h]	1.5	8.5	-	-	-	-

**at GVF below 20%, an absolute uncertainty of 1.5 am3/h is considered due to the low quantity of gas

4.2.2 Validation on test matrix

The test matrix consists of flow periods (FP) that are within the working envelope of the flow loop instrumentation. These Flow Periods are selected to cover a wide range of flow situations in a short period of time. At the same time, the flow loop instrumentation deviation is minimized. This will ensure a true assessment of the Vx Spectra performance. The test matrix is detailed in the table below:

Table 3: Agreed Test Matrix flow points and diagram (For reference)

Nb	Qliq	Qoil	Qwat	Qgas	WLR	GVF(*)	Recording time	PL
1	42	10.5	31.5	17.9	74.9	29.89	15	27
2	26.4	11	15.4	21.5	58.3	44.9	15	27
3	93.3	0	93.3	39.7	100	29.9	15	27
4	6.2	6.2	0	55.1	0	89.8	25	27
5	22	4.4	17.6	65.6	79.9	74.9	15	27
6	80.1	80.1	0	119.2	0	59.8	15	27
7	26.4	13.2	13.2	148.7	50	84.9	25	27
8	30.8	8.8	22	275.7	71.4	89.9	25	27
9	15.8	0	15.8	298.2	100	95	25	27
10	19	5.7	13.3	380.0	70	95	25	27
11	21	6.3	14.7	397.7	70	95	25	27
FL / Pt	**m3/h**	**m3/h**	**m3/h**	**m3/h**	**%**	**%**	**min**	**bar**

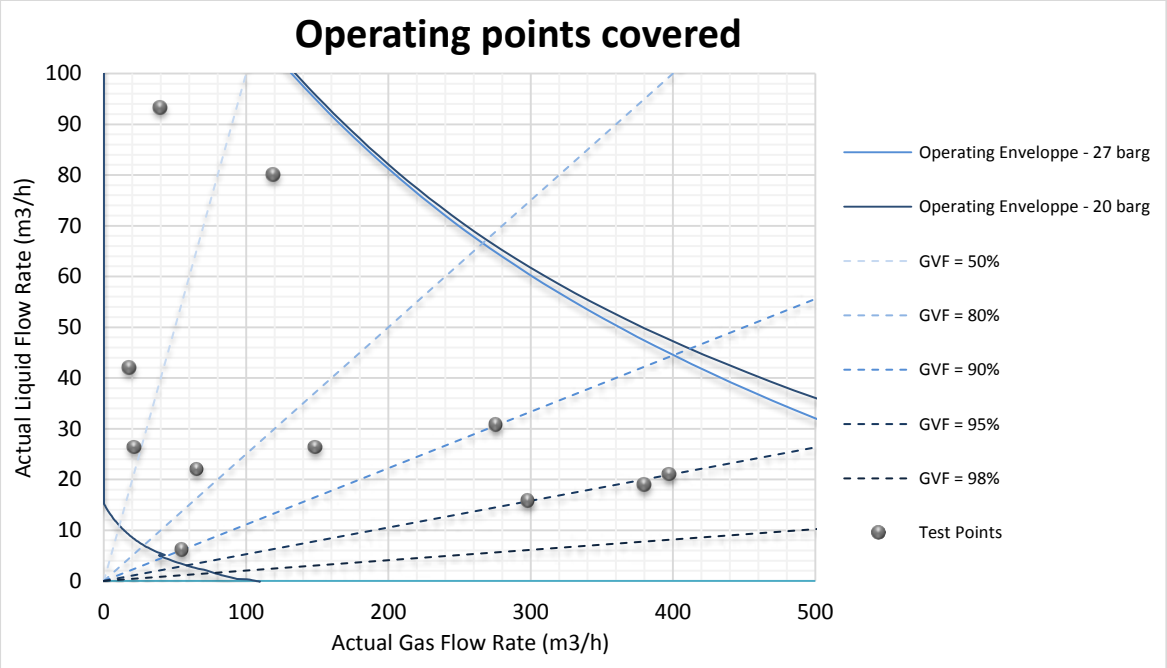

Figure 7 Test matrix- Operating points in Vx Spectra operating envelope. **(For Reference)**

4.2.3 Test acceptance

Vx Spectra performance are determined with 95% confidence interval. This statistical definition is valid on a large amount of flow periods, above hundreds. In the case of a flow loop test with a limited number of flow periods, the number of FP allowable outside of performance specification must be translated as follows:

- 8 to 17 FP allowable FP outside spec: **2**
- 18 to 29 FP allowable FP outside spec: **3**
- 30 to 44 FP allowable FP outside spec: **4**

4.2.4 Fluid In situ reference

Empty pipe count rates (EP) is acquired at atmospheric pressure in air. Mass attenuation of oil and water are measured in situ prior to start the test. Below table summarizes nuclear count rates obtained for each in situ measurement performed:

Table 4: Count rate of EP and IS for Vx Spectra 40 **(For reference)**

	Duration (s)	LE (cps)	HE (cps)	356(cps)
EP	16:49:10	38283	16388	34069
Water In Situ	00:20:40	8999.7	7937.3	21240
Oil In Situ	00:30:10	17033	9264.4	23251

5 Results and discussion

5.1 Test numerical results

In Table 5 below, presents Vx Spectra performance or relative deviation versus measures flow loop reference flow rates. Volumetric flow rates are given at Vx throat conditions of pressure and temperature.

Table 5: Test results (For reference)

FP no.	Ref GVF	Reference			Vx Spectra					
		Qliq	Qgas	WLR	Qliq	Rel. Liq. Dev.	Qgas	Rel. Gas. Dev.	WLR	Abs. WLR Dev
	(%)	(m^3/h)	(m^3/h)	(%)	(m^3/h)	(%)	(m^3/h)	(%)	(%)	(%)
1	31.9	41.9	19.6	75.0	42.1	0.4	19.5	-0.7	74.3	-0.8
2	47.1	26.4	23.4	58.4	26.6	0.9	23.1	-1.3	56.3	-2.0
3	35.8	93.3	52.1	99.9	93.5	0.2	53.4	2.5	99.1	-0.7
4	90.6	6.2	59.9	0.0	6.3	1.7	62.1	3.6	-0.5	-0.5
5	77.0	22.0	73.7	80.0	22.3	1.5	74.5	1.2	78.2	-1.8
6	65.3	80.0	150.7	0.0	79.5	-0.7	154.0	2.2	-0.5	-0.5
7	86.2	26.3	164.5	50.1	26.9	2.1	160.5	-2.4	48.2	-1.9
8	91.5	30.7	329.7	71.5	30.0	-2.3	329.5	-0.1	70.2	-1.3
9	95.5	15.9	336.4	99.3	15.3	-4.0	348.3	3.5	96.0	-3.2
10	96.0	19.0	450.2	70.0	18.5	-2.3	458.2	1.8	65.4	-4.7
11	95.7	21.0	470.1	70.0	20.7	-1.4	475.1	1.1	64.5	-5.5

5.2 Test results graphic presentation

5.2.1 Liquid flow performance

Figure 8 shows the relative deviation of liquid flow rate versus reference GVF. This agrees with the acceptance criterion stated in section 4.2.1.

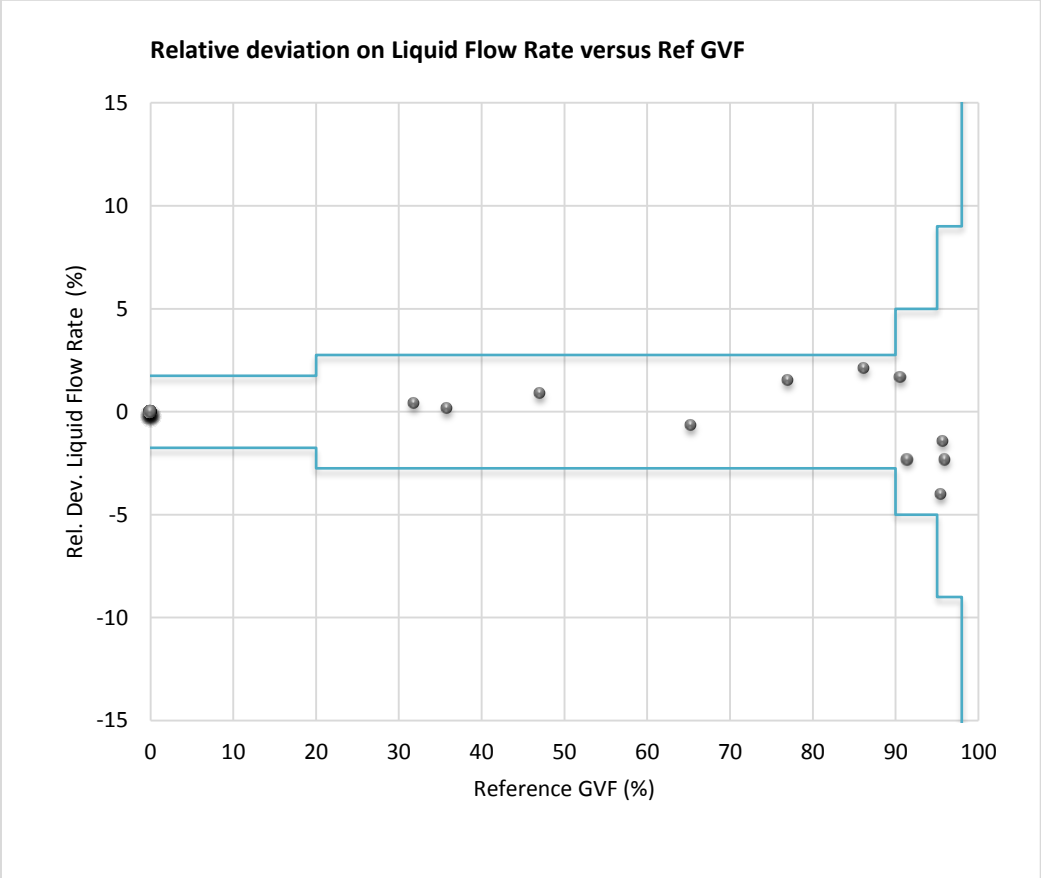

Figure 8 Relative deviation of liquid flow rate versus reference GVF (For reference)**.**

5.2.2 Gas flow performance

As shown in the figure below, gas flow rate uncertainties of all the tested FPs are within specification.

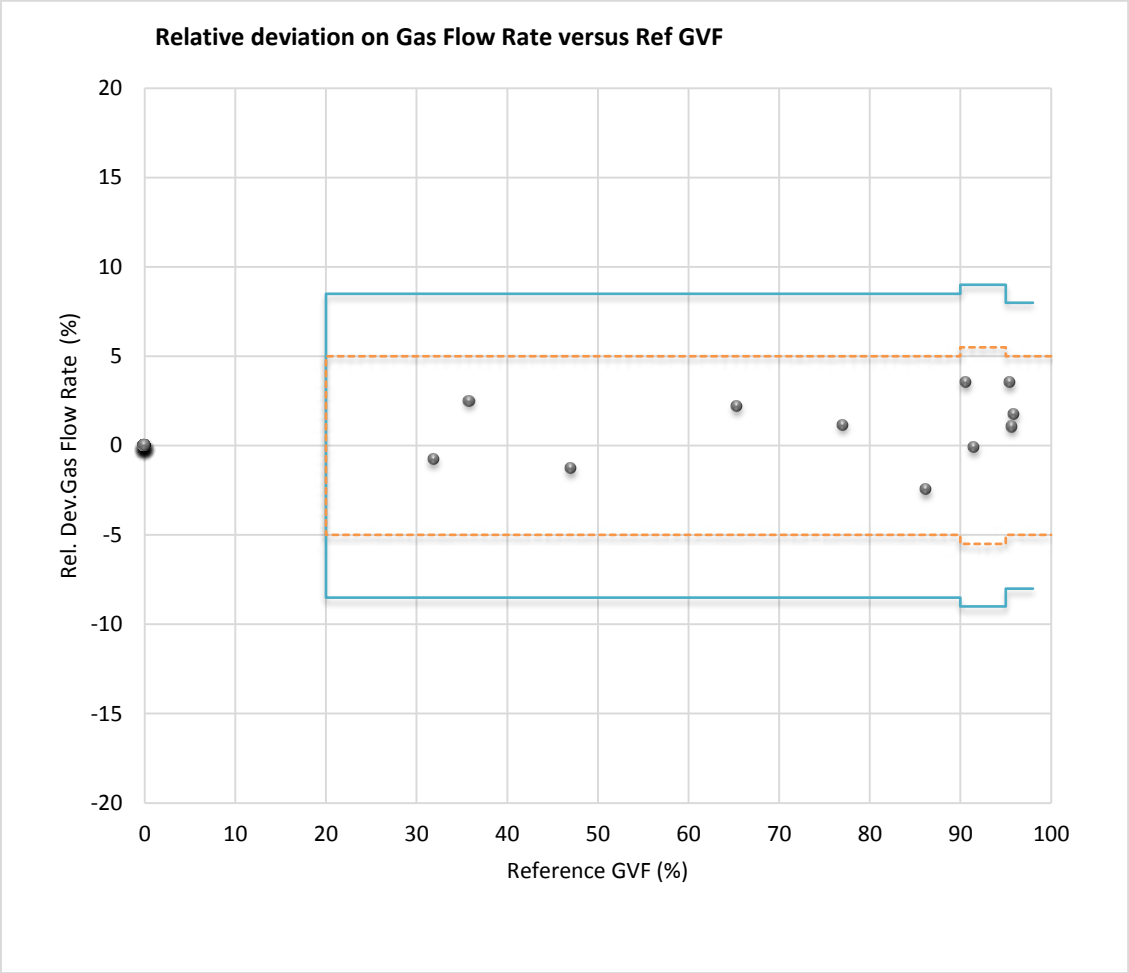

Figure 9 Relative deviation of gas flow rate versus reference GVF (For reference)**.**

5.2.3 Water cut performance

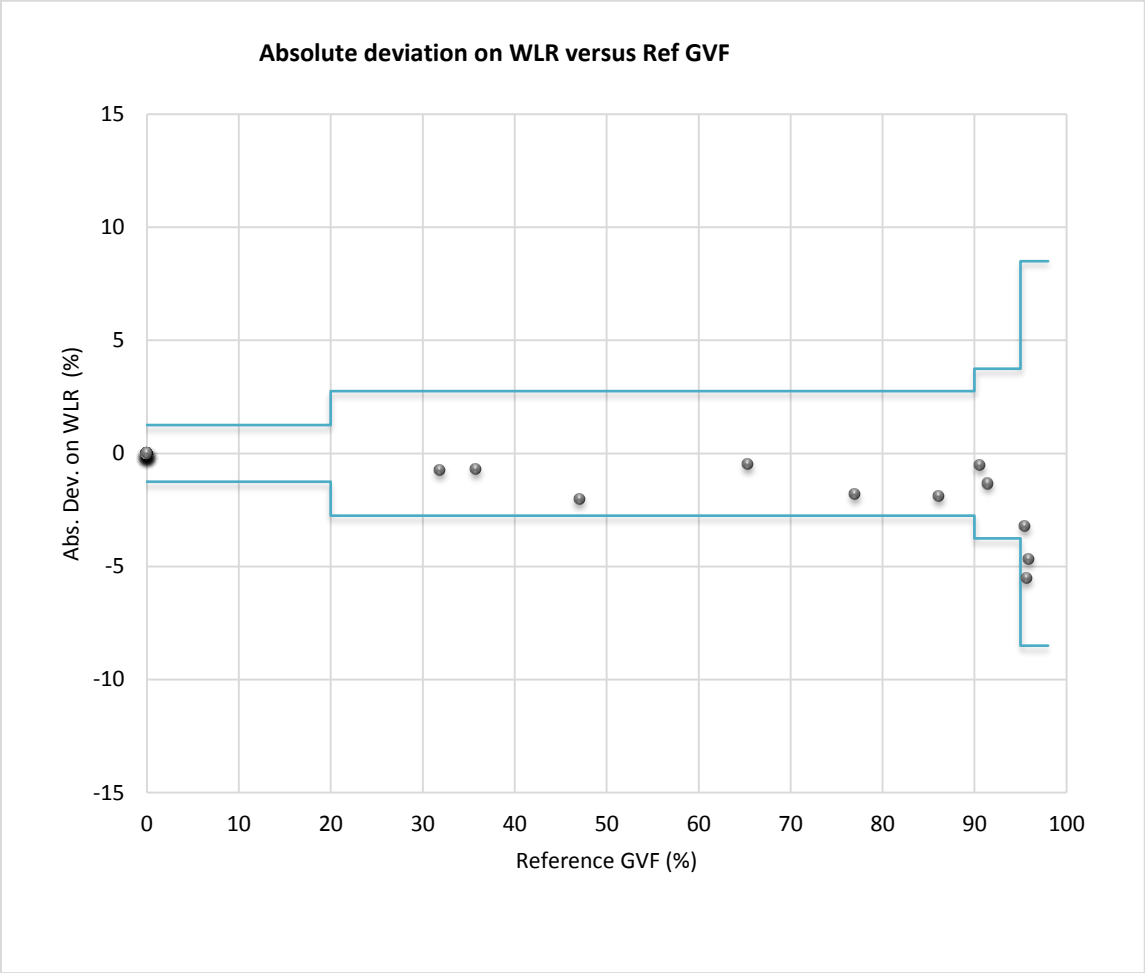

Figure 10 Absolute deviation of WLR versus reference GVF (For reference)**.**

5.3 Conclusion

The xx mm Vx Spectra- Serial number: xxxxx was subjected to a flow loop test, defined in section 4.2.2 and is performing within/outside the product performance criteria defined in section 4.2.3.

Flow Loop Operator	Test Result Reviewer
X Ritesh Munjal Flow Loop Leader	X xxxxxx

6 References

6.1 Normative References

Title	Document Number
1. SWTC Flow loop – Reference Measurement & Calculations	DMS# 102673252
2. SWTC Flow loop – Test Streamlined Procedure	DMS# 102879705

A Appendices

A-1 Flow loop test witness sign off sheet

Client witness sign off sheet will be attached to this report.

A-2 Flow meters, Pressure & Temperature calibration certificates

Calibration certificates for the reference meters used in the SWTC Flow Loop will be provided separately