Main Index

Norwegian
Society of
Chartered Engineers

NORTH SEA FLOW MEASUREMENT WORKSHOP

OCTOBER 22. - 24. 1991
SOLSTRAND FJORD HOTEL, BERGEN - NORWAY

TESTING OF CORIOLIS METERS FOR METERING OF OIL CONDENSATE AND GAS

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Kongsberg Offshore a.s
North Sea Flow Measurement Workshop 1991

Title

TESTING OF CORIOLIS METERS FOR METERING

OF

OIL, CONDENSATE AND GAS

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TABLE OF CONTENT

Section | Page

APPENDIX

1 INTRODUCTION

The tests described in this paper are the results of a joint venture development project to investigate and qualify the abilities of Coriolis mass flowmeters for fiscal measurement of gas and liquid.

The companies responsible for the project was:

- Autek Instrument a.s (Micro Motion representative)
- Fimas (Schlumberger representative)
- Kongsberg Offshore a.s (Project responsible, Mechanical engineering and Control System Design)
- Elf Aquitane Norge a.s
- The Norwegian Petroleum Directorate
- Phillips Petroleum Company Norway a.s (PPCON)
- Saga Petroleum a.s
- Statoil. (Den Norske Stats Oljeselskap a.s)

The project was established the 30. August 1990 and finalized on the 9. Mai 1991.

The main objectives of the project to design and test the performance of a metering station based on coriolis mass flowmeters suitable for high pressure gas application. The testing was done at the K-lab natural gas test loop.

The metering station (testrig) was designed specifically for the test and standard coriolis mass flowmeters were selected to meet the maximum test pressure of 100 Bar.

In addition Statoil provided the group with the opportunity to check the performance of the coriolis mass flowmeters in a liquid application at Kårstø NGL plant using the N-butane liquid loading facilities.

This paper has been prepared by Kongsberg Offshore a.s, Autek Instrument a.s and Fimas.

2 ABBREVIATIONS

NGL - Natural Gas Liquids
KOS - Kongsberg Offshore a.s
MM - Micro Motion Master Meter
MM1 - Micro Motion Meter 1
MM2 - Micro Motion Meter 2
NPD - The Norwegian Petroleum Directorate

3 TESTRIG DESIGN

To make the tests as realistic as possible the project decided to design a purpose made testrig. The testrig was designed to test 3 mass flowmeters, model DH300-S manufactured by Micro Motion and 1 mass flowmeter, model 7860B manufactured by Schlumberger.

The arrangement of the testrig is shown in Figure 1. Four photos that illustrate the final testrig design is included as appendices.

One of the main installation requirements for coriolis mass flowmeters are to minimize pipe stress on the sensor process connections, both axial and lateral. This was reflected in the rig design by the positioning of the Micro Motion Master Meter (MM) and the Micro Motion Meter no. 1 (MM1) in the upper positions.

The rig was designed so that each coriolis mass flowmeter could be run either separately or in series with the Master Meter. Each metering line was equipped with two downstream shutoff valves with a bleed port in between. This to ensure actual zero flow when adjusting the transmitters zero set point.

At the inlet of the testrig an extra pipe construction where made consisting of four off 90 degree bends. This pipe section could be connected to the inlet manifold by manually operating the appropriate shut off valves. The purpose of this pipe section was to test if the upstream pipe configuration influenced the mass flowmeters accuracy.

The Micro Motion Master Meter and the Schlumberger mass flowmeter was monitored for pressure drop across the flowmeters by differential pressure transmitter. In addition the rig itself was monitored for pressure drop by means of one pressure transmitter on the inlet manifold and one on the outlet manifold.

The testrig was designed according to Statoils specifications for equipment to be installed K-lab.

Size of testrig: Length = 5.9 m
Height = 2.1 m
Width = 2.5 m

Weight of testrig = approx. 2.5 tonnes

4 CORIOLIS MASS FLOWMETER SPECIFICATIONS

The manufacturers specifications given for the coriolis mass flowmeters are available only for liquid and thereby relevant only for the liquid test on N-butane. The specifications could only be used as an indication of what to expect when using the mass flowmeters in Natural Gas since no testing on these meters had been performed on natural gas before.

Micro Motion Model D300 Mass Flow and Density Sensor

Maximum Flowrate	: 200 tonnes/hour
Nominal Pipe bore	: 80 mm
Mass Accuracy	: ±0.20% of rate ± zero stability
Mass Repeatability	: ± 0.05
Mass zero stability	: ± 0.11 tonnes/hour
Max Operating pressure	: 276 Bar
Temperature range	: - 240 to +204 degree Celsius

Schlumberger Massmaster 150

Maximum Flowrate	: 150 tonnes/hour
Nominal Pipe bore	: 50 mm
Mass Accuracy	: ±0.25% of rate ± zero stability
Mass Repeatability	: ± 0.05
Mass zero stability	: ± 0.03 tonnes/hour
Max Operating pressure	: 150 Bar
Temperature range	: - 50 to +110 degree Celsius

5 CONTROL SYSTEM DESIGN

A special Control System was made by Kongsberg Offshore a.s (KOS) to sample the data from the mass flowmeters and from the instruments on the test rig.

The Control System consisted of the following main parts:

- One Computer Cabinet containing:
    - One Massmaster Flowcomputer type 7960 (Schlumberger)
    - Three RFT 9712 Mass Flow Transmitters (Micro Motion)
    - One Process Machine (Kongsberg Offshore)
- Free Standing Items
    - One VDU (Interfacing the Process Machine)
    - One PC with VDU (Data Storage)
    - One printer.

The Process Machine interfaced the instrumentation on the testrig, the Schlumberger flowcomputer and the Micro Motion Mass Flow Transmitters. For each Test run the Process Machine sampled all process data and stored them in separate files. These files could be transferred to the PC for further treatment and presentation on VDU or as printed.

See Figure 2.

6 TEST ON LIQUID

This test was performed at the Kårstø NGL plant using the N-butane Liquid loading facilities.

6.1 Aim of the Test

The aim of the test was to verify the performance of the coriolis mass flowmeters on liquid. In addition the test were to verify the functionality of the testrig, the coriolis mass flowmeters and the control system before the gas test.

The metering accuracy aimed for where ± 0.5 %.

6.1.1 Reference Conditions

6.1.1.1 Test Fluid

The test fluid was N-butane. Samples of the liquid was collected and analysed before and after the test period. The results showed that the composition could be considered as constant during the test. The tests was performed at the following conditions:

Pressure : approx. 10 Bar
Temperature : 3-5 degree Centigrade

6.1.1.2 Reference Flowmeter

The reference flowmeter for this test was a 3" Brooks turbine meter calibrated using a compact prover

The linearity of the turbine meter within the flowrange 10:1 was ± 0.15 %

6.1.1.3 Reference Density

The calculation of the liquid density was performed using the API COSTALD method. For N-butane this method will give an accuracy of ± 0.3 % or better.

6.1.2 Description of the Tests

Figure 3 is giving a representation of the practical test arrangement.

Liquid N-butane is pumped through the test setup using the pumps on the N-butane tank.

The flow rate through the test arrangement was limited by the pressure drops in the recirculation line, testrig and the calibration skid.

These operational limitations made it possible to carry out tests at only three different relatively low flowrates:

Mass flow : approx. 15, 30 and 40 tonnes/h

6.1.3 Test Procedure

Prior to the start of the test the 3" Brooks turbine reference meter was calibrated at the three different actual flowrates:

15 tonnes/h
30 tonnes/h
40 tonnes/h

An accurate meter factor was thereby established as an reference. The density of the liquid was known from the Costald calculations.

The tests were performed as follows:

1) The flow was manually started and data for the reference meter and the coriolis mass flowmeter on test was noted.

2) Pulses from the reference meter and the mass flow meter was read continously by the appropriate flowcomputers for 2 hours.

3) The flow was stopped manually and data for the reference meter and the mass flowmeter on test was noted.

4) The reference mass flow was calculated multiplying the number of pulses collected from the Brooks reference meter, dividing by the meter factor from the Brooks reference for the actual rate and multiplying by the density calculated by the Costald routine. The Brooks meter factor is the average meter factor as determined by the Con-tech´s Turbine meter calibration computer.

Two testruns were performed. The first was run with MM1 in series with [illegible] second test was run with the Schlumberger mass flow meter in serie [illegible]

6.1.4 Test Results

The results for MM1 and the Schlumberger mass flowmeter are presented in Figure 4 and Figure 5. The figures show the coriolis mass flowmeters deviation from the reference plotted for the three test flow rates.

It should be noted that the meter factor for both the Micro Motion meter and the Schlumberger meter used during the test was determined from the water calibration of the coriolis mass flowmeters.

Further the equipment used in this test are high pressure versions of the mass flowmeters.

6.1.4.1 Schlumberger

The Schlumberger mass flowmeter made a close to perfect linear relationship but were off the correct result with approximately +1%. The reason for this can be explained by a to early zero set point setting. Adjusting the straight line to an assumed correct zero set point gives a metering accuracy well within the specification of the mass flowmeter.

See Figure 4.

6.1.4.2 Micro Motion

The accuracies obtained for the Micro Motion mass flowmeter were well within the specified accuracy of the mass flowmeter. Results are only plotted for the "MM1".

During the test it became evident that the Micro Motion "Master Meter" showed abnormal behaviour. In order to confirm this, the "Master Meter" and the "MM1" was interchanged. New tests where carried out and the error with the "Master Meter" was confirmed. Stress caused by distortion between flanges are the most likely reason for the high deviation from the reference meter.

Finally the "MM2" connected in parallel with the "Master Meter" showed instability, and was subsequently disconnected". A possible reason for the instability was crosstalk.

7 TEST ON NATURAL GAS

This test was performed at K-lab using the natural gas test loop.

7.1 Aim of the test

The aim of the test was to calibrate the mass meters against the reference bank of sonic nozzles at K-lab. In addition repeatability, reproducibility and cross talk should be checked.

The accuracy aimed for was ± 1% within a operational range to be defined through the tests. This reflecting the requirements for fiscal measurment of gas from NPD.

7.2 Reference Conditions

7.2.1 Test Fluid

The test fluid was natural gas with the following composition.

C1 = 84.94
C2 = 12.10
C3 = 0.71
IC4 = 0.03
NC4 = 0.05
IC5 = 0.00
NC5 = 0.00
C6+ = 0.00

N2 = 0.93
CO2 = 1.24
H2O = 0.00
H2S = 0.00

7.2.2 Reference Flowmeter

The reference flowmeter were K-labs bank of sonic nozzles which where calibrated over the range of 20 to 100 bars absolute.

The flow computation through the nozzle bank was performed by a specially designed Scientific Data Acquisition System.

K-lab makes a statement of uncertainty using the sonic nozzles of 0.3% of the mass flowrate.

7.2.3 Reference Density

The reference density in the nozzle bank was calculated using the AGA8 equation of state.

7.3 Description of the Tests

Figure 6 is giving a representation of the practical test arrangement.

A centrifugal compressor circulates the gas around the loop. Three air coolers cool down the gas coming from the loop compressors before the gas enters the 6" test section where the testrig was installed, and finally the gas passes through the sonic nozzle section.

The tests performed can be divided in three main groups:

1) Preliminary Test:

- Crosstalk
- Repeatability

2) Main calibration Tests:

- Micro Motion 1 (MM1)
- Micro Motion Master Meter
- Schlumberger

3) Additional Tests:

- Effect of twisted bend
- Reproducibility test
- Clamp test
- Schlumberger installed directly in line
- Effect of zero adjustment

See Table 1 for a complete Test Matrix.

7.4 Test Procedure

The following procedure was used to obtain a test point.

1) The number of nozzle lines necessary to achieve the required flow through the test loop were opened.

2) The loop was flared or filled with gas until the pressure was as close as possible to the requested test pressure.

3) The pressure control set point was adjusted so that the test pressure was correct upstream the nozzles.

4) The cooling system was adjusted so the gas had the correct temperature upstream the nozzles.

5) If neseccary the flow were adjusted by opening or closing more nozzles.

6) Then the system was left alone until the pressure and temperature had stabilised.

7) Then, at the same time the flow on the SDAS and the Kongsberg Offshore a.s (KOS) data acquisition system where integrated for a period of three minutes. This was repeated until 5 test points where obtained.

7.5 Test Results

7.5.1 Preliminary Tests

The test started with a check of the repeatability of the different mass flowmeters and continued with cross talk tests. Cross talk tests where done by turning the power on and off the mass flowmeters which where not in operation.

The preliminary tests where performed at 37 degree Celsius, 70 bara and a flowrate of 30.6 tonnes/h.

Micro Motion

Three tests were done to check crosstalk effects and repeatability on the MM.

The results are given below:

Test no	Mean Dev. from Sonic Nozzles MM	Repeatability MM	Flow through Meter	Power on	Power off
1	- 0.14	± 0.95	MM	MM.	MM1&MM2
2	1.05	± 0.94	MM	MM&MM2	MM1
3	0.46	± 0.90	MM	MM&MM1	MM2

Two test were done to check crosstalk effects and repeatability on the MM2. The results are given below:

Test no	Mean Dev. from Sonic Nozzles MM2	Repeatability MM2	Flow through Meter	Power on	Power off
1	- 1.01	± 0.57	MM2	MM2	MM1&MM
2	- 3.46	± 0.26	MM2	MM2&MM	MM1

From these tests it was difficult to determine whether the deviation from the sonic nozzles were caused by crosstalk or was a result of the poor repeatability.

The only "clear" indication of a possible crosstalk effect was on the MM2 which had an clear increase in the mean deviation from the sonic nozzles. The decision was made to disconnect the MM2 and to continue testing on MM1 and the Master Meter.

In addition to these tests, the massflow displayed by the Micro Motion mass flow transmitter was observed, while the power on the MM2 and MM1 where turned on and off. The same were checked and with loose clamps and tight clamps on meter flanges. No clear change in massflow could be observed.

Schlumberger

A repeatability test was performed on the Sclumberger massmeter at 70 bar a and 37 degree Celsius at a flowrate of 2.9 kg. The repeatability of this meter was ± 0.05 %.

This is within the Schlumberger mass flowmeter specification for liquid, however here obtained using gas.

7.5.2 Main Calibration Tests

7.5.2.1 Micro Motion Meter 1

The results obtained calibrating the MM1 against the sonic nozzles are summarised in Figure 7 and Table 2.

As can be seen from the results of the Micro Motion Meter 1, the meter functioned well within the aim of the test (accurcay of ± 1% of rate) for the following conditions:

Pressure (bar)	Temp (deg C)	Flowrate (tonnes/h)
70	37	5.3 - 28.1
100	50	20.0 - 59.3
100	37	55.0 - 60.8

An additional observation is that all results are above the zero line and following the same trend as the specified accuracy curve for the meter. This could mean that the zero is not correct set on the meter. Moving the results to an assumed correct zero would bring the results within the meters specified accuracy for liquid which is given in Table 2.

7.5.2.2 Master Meter

The results obtained calibrating the Micro Motion Master Meter against the sonic Nozzles are summarised in Figure 8 and 9 and Table 3 and 4.

Worth noticing is that this is the meter which was installed with a certain amount of stress on the process connections.

The results obtained at 70 bar are not within aim of the test but the results are following the same trend as the specified accuracy curve of the meter. The deviation from the correct result are increasing with decreasing flowrate.

The results within the aim of the test (± 1% of rate) obtained at 100 bars are summarised below:

Pressure (bar)	Temp (deg C)	Flowrate (tonnes/h)
100	37	7.8 - 23.1
100	50	22.4 - 40.5

The results which were within the aim of the test were obtained when the MM was connected in series with the MM1. When connecting the Schlumberger meter in series with the MM the values obtained from the Meter tended to shift to an higher uncertainty but still following the specified trend of the accuracy curve. To find the reason to this trend more tests will have to be performed.

7.5.2.3 Schlumberger Mass meter

The results obtained when calibrating the Sclumberger meter against the sonic nozzles are summarised in Figure 10 and Table 5.

The results obtained within the aim of the test (accuracy of ±1% of rate) are summarised below.

Pressure (bar)	Temp (deg C)	Flowrate (tonnes/h)
70	37	7.8 - 15.6
70	50	2.5 - 15.1
100	50	11.2 - 29.4
100	37	4.0 - 30.3
20	40	2.1 - 4.2
55	37	2.1 - 5.5

The results obtained from the Schlumberger meter are as for the Micro Motion meters, following the same trend as the specified accuracy curves of the Meter. The maximum flowrate obtained through the Schlumberger meter is lower than the corresponding maximum value of the Micro Motion meter. This is due to the different diameter of the Meters.

7.5.3 Additional Tests

Effect of twisted bend

The idea was to see if the accuracy of the meters changed if the twisted bend upstream the inlet manifold was connected or not.

Several tests where run but no influence on the accuracy could be observed.

Reproducibility test

Several tests where run confirming that the results where reproducible.

Clamp test

This test was run for Micro Motion meters only.

The aim of this test was to see the influence of a "bad" installation. First a test where run with the clamps tight. Then the clamps where loosened and a new test where run.

This procedure introduced a shift in the metering accuracy of approximately 2%. This confirming the importance of installing the meters according the manufacturers requirements.

Effect of zero adjustment

After the clamp test the clamps were tightened and the meters zero point were adjusted. The accuracy of MM1 after this procedure was + 0.5 % of the correct result when running at 70 bara, 50 degree Celsius and a flowrate of 27 tonnes/hour. This underlining the importance of adjusting the zero set point of the Micro Motion meters whenever changes has been made.

Schlumberger meter Installed directly in the line

The Schlumberger meter was installed directly in the test loop to quantify the effect of the Test rig when it comes to limitations in the flowrate.

In the testrig the Schlumberger meter could measure 20.52 tonnes/hour before the measurment error became to large. Installed directly in the loop the maximum flowrate was increased to 25.92 tonnes/hour (26% increase).

It is worth notizing that the change in location from the testrig to the test loop was done without resetting the zero. The metering accurcay of the meter was not influenced by the change in process and installation conditions.

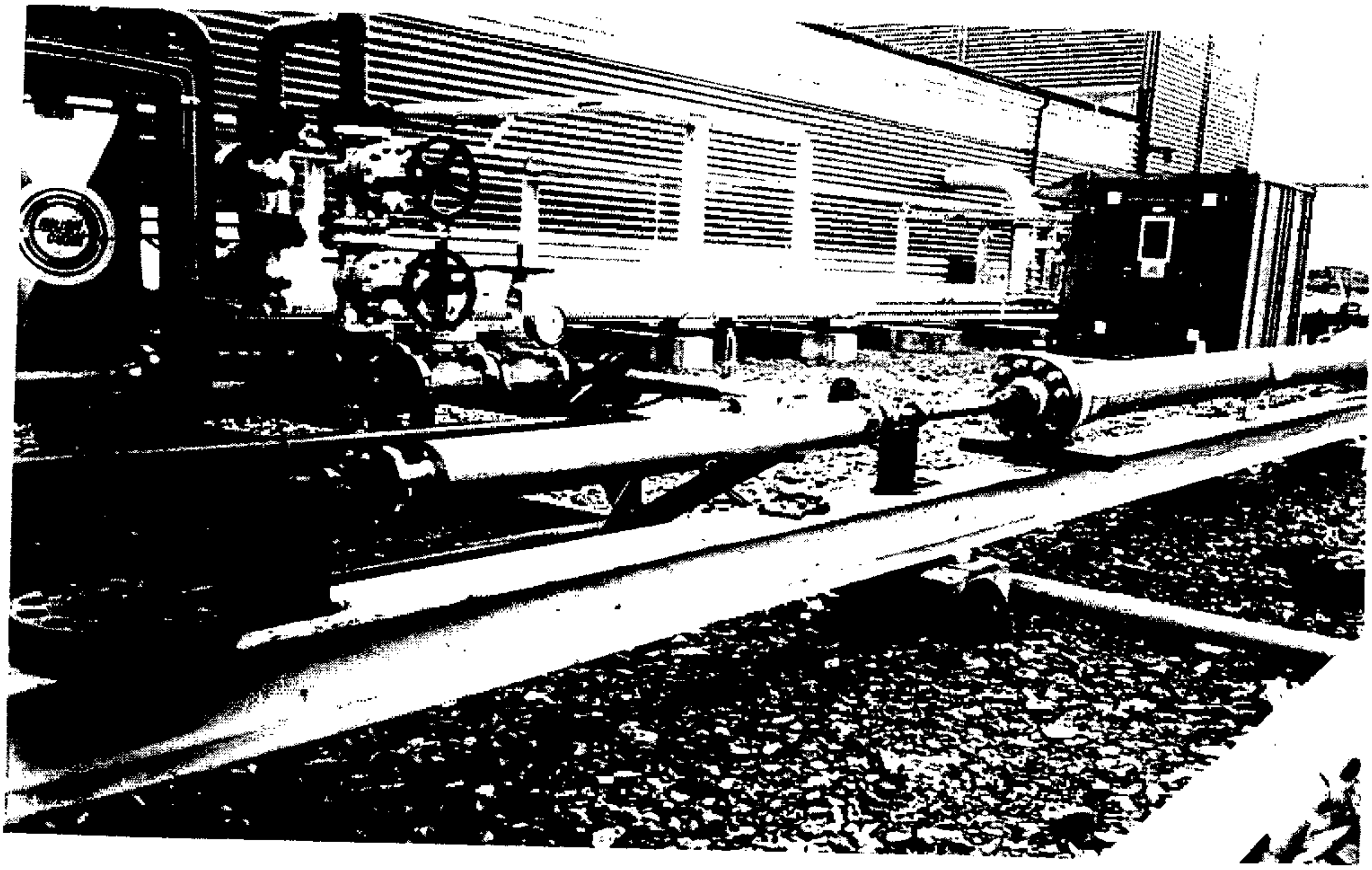
This indicating that more consideration must be put into minimizing the pressure drop when designing Coriolis Metering Skids.

8 LESSONS LEARNED

- The importance of a correct zero point setting whenever a change in temperature or pressure has occured for Micro Motion mass flowmeters
- The importance of correct installation of the coriolis mass flow meters.
- Calibration of the coriolis meters should if possible be performed on the fluid which they are to be used.
- Selection of the coriolis mass flowmeters must carefully consider the process conditions which they are to meet

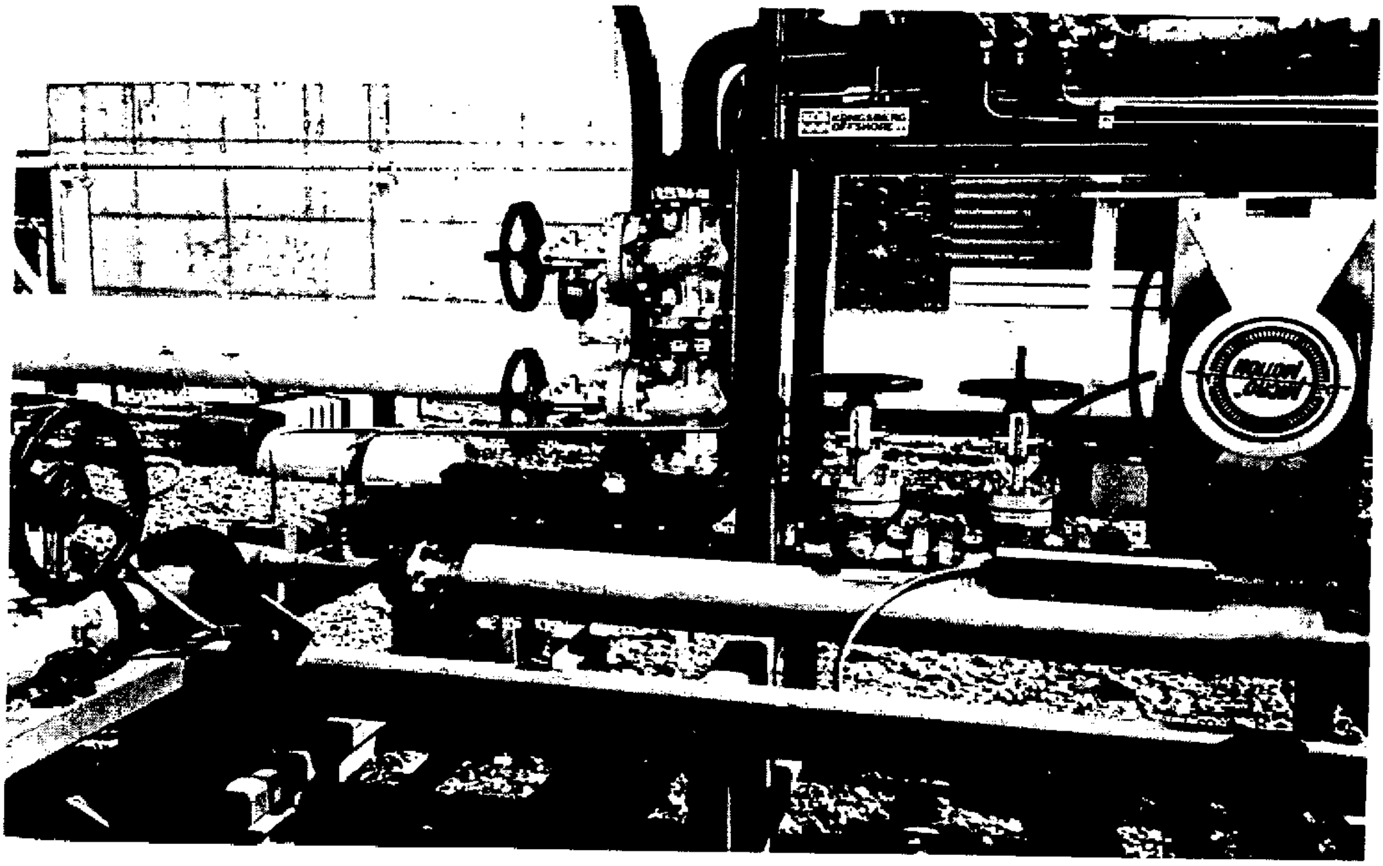
APPENDIX A

PHOTOS



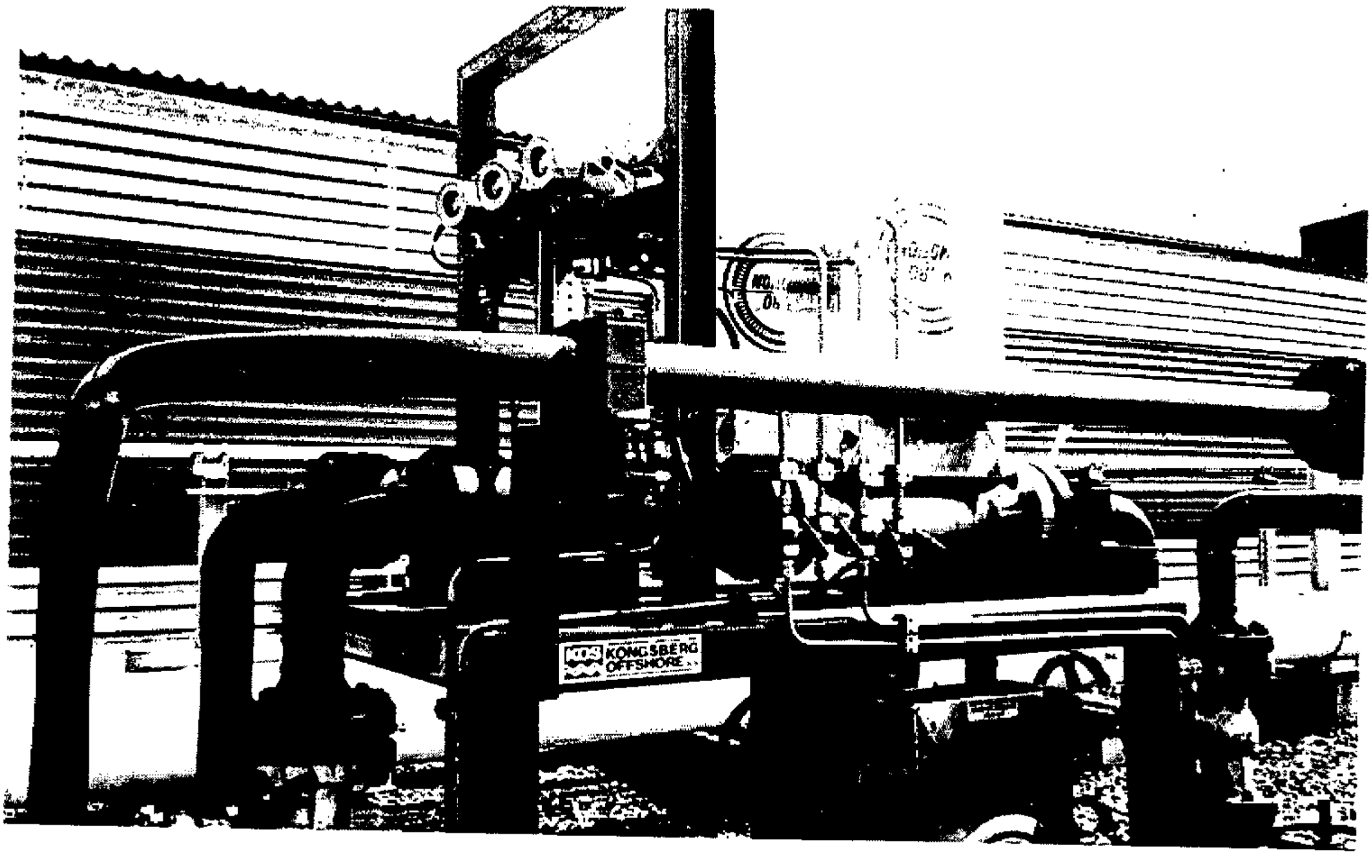
DETAILS OF THE SCHLUMBERGER MASS FLOW METER
INSTALLED DIRECTLY IN THE TESTLOOP

PHOTO 4



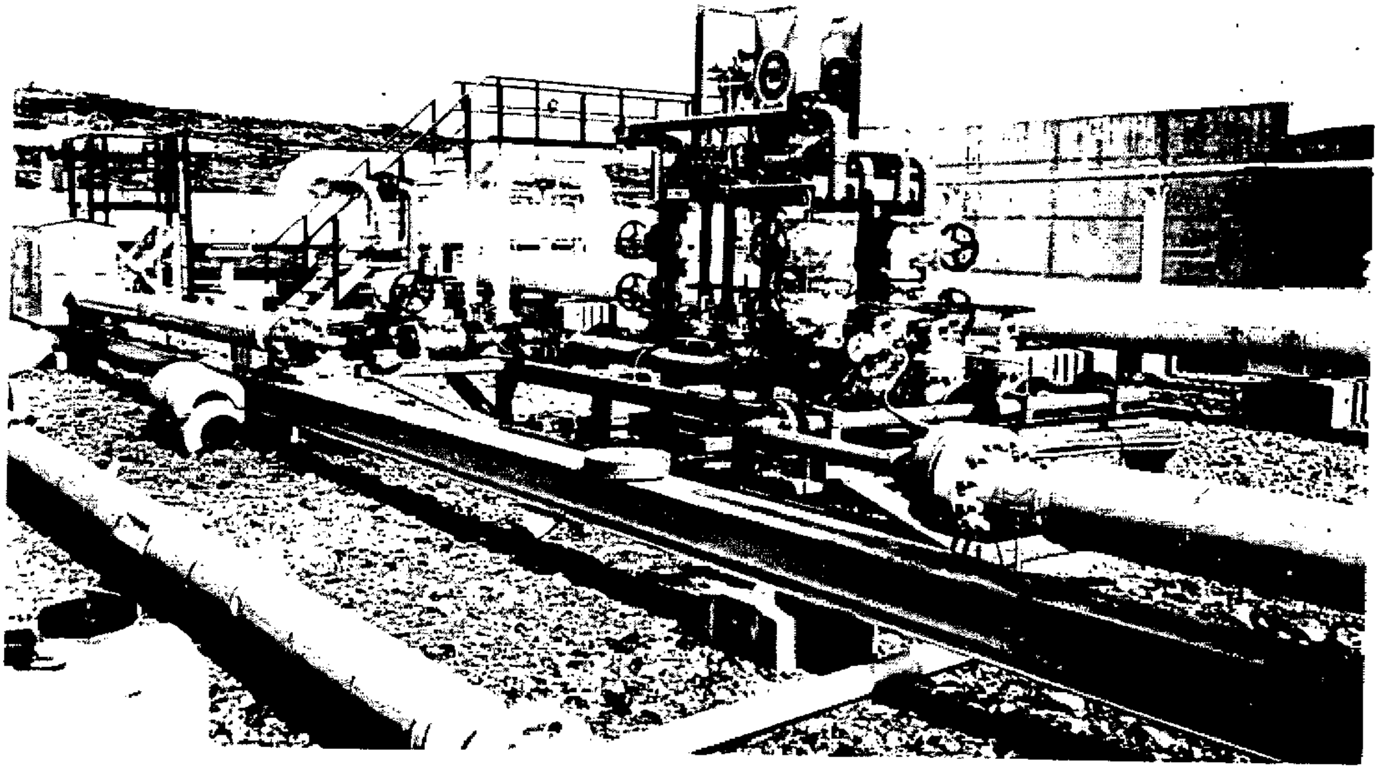
DETAILS OF THE SCHLUMBERGER MASS FLOW METER
INSTALLED IN THE TESTRIG

PHOTO 3



DETAILS OF THE MICRO MOTION MASS FLOW METER
INSTALLED IN THE TESTRIG

PHOTO 2



TESTRIG INSTALLED IN THE NATURAL GAS TEST LOOP
AT K-LAB

PHOTO 1

A P P E N D I X B

FIGURES

TESTRIG LAYOUT

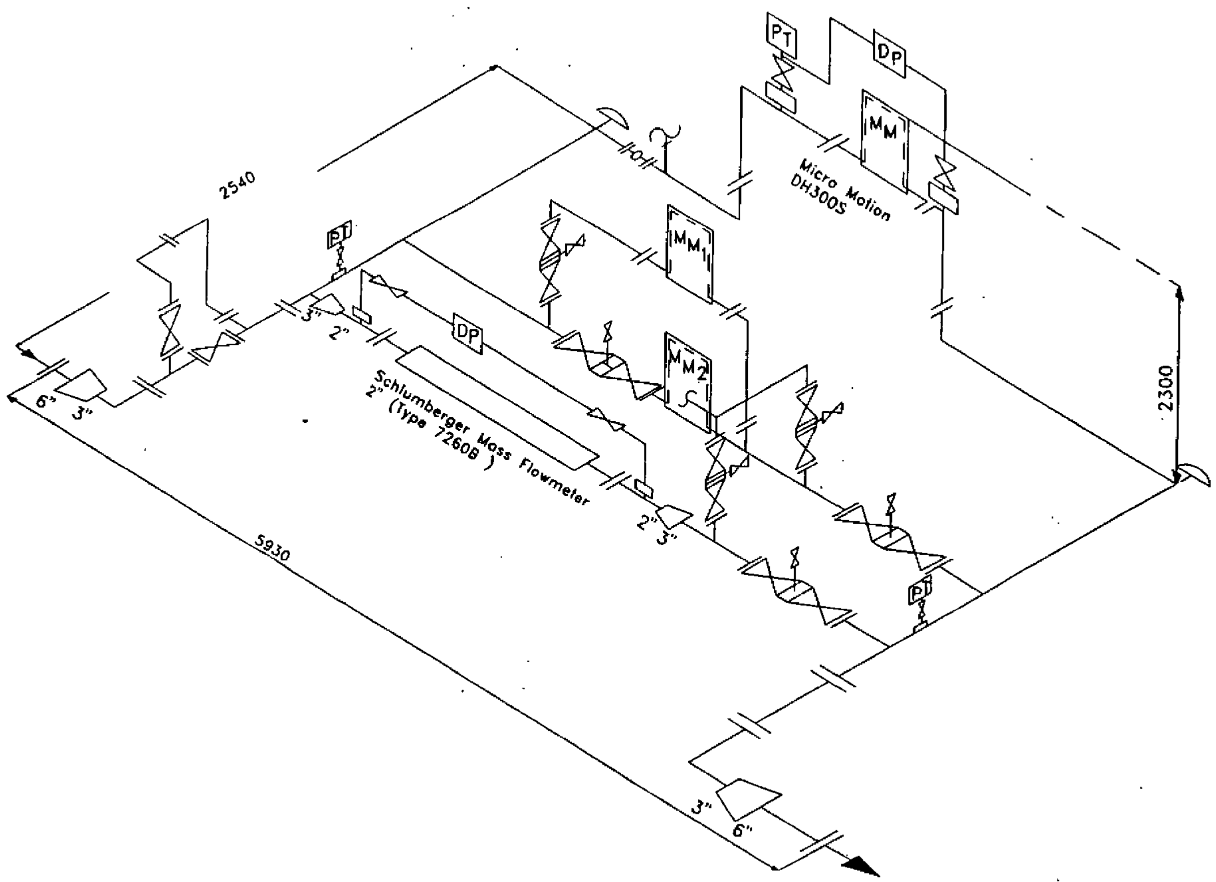


FIGURE 1

CORIOLIS TEST CONTROL SYSTEM

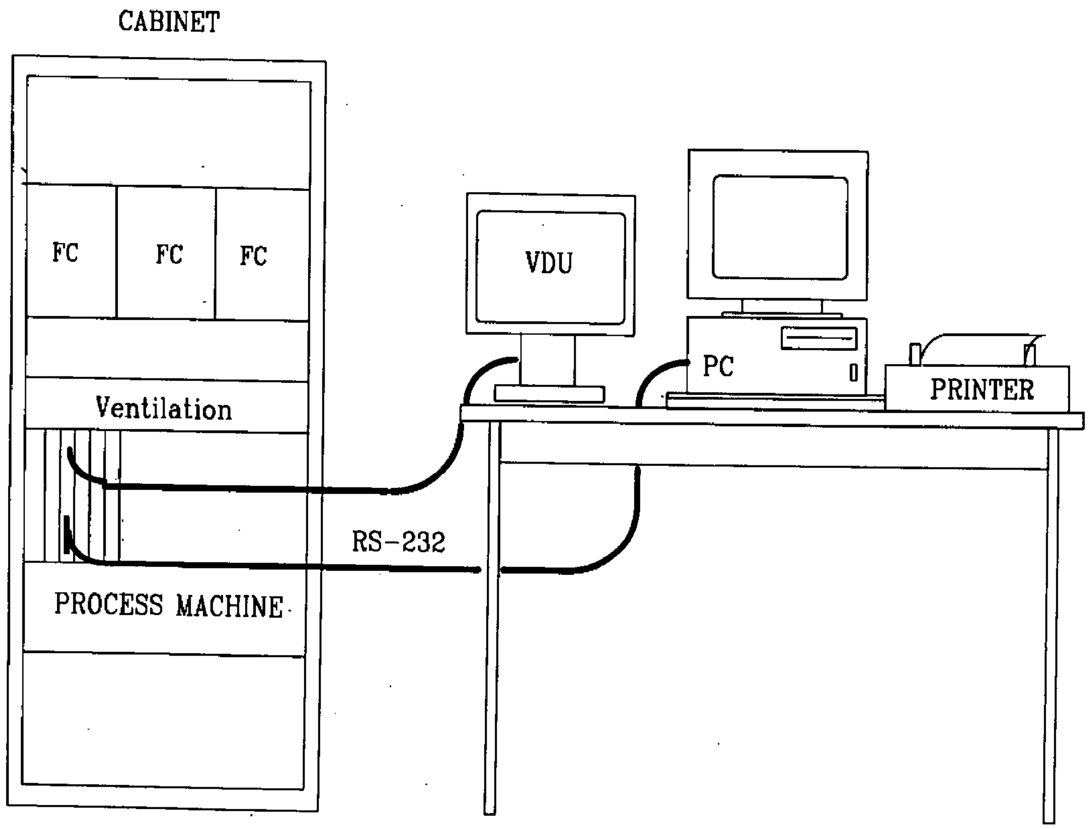


FIGURE 2

ARRANGEMENT FOR TESTING MASS FLOWMETERS IN LIQUID

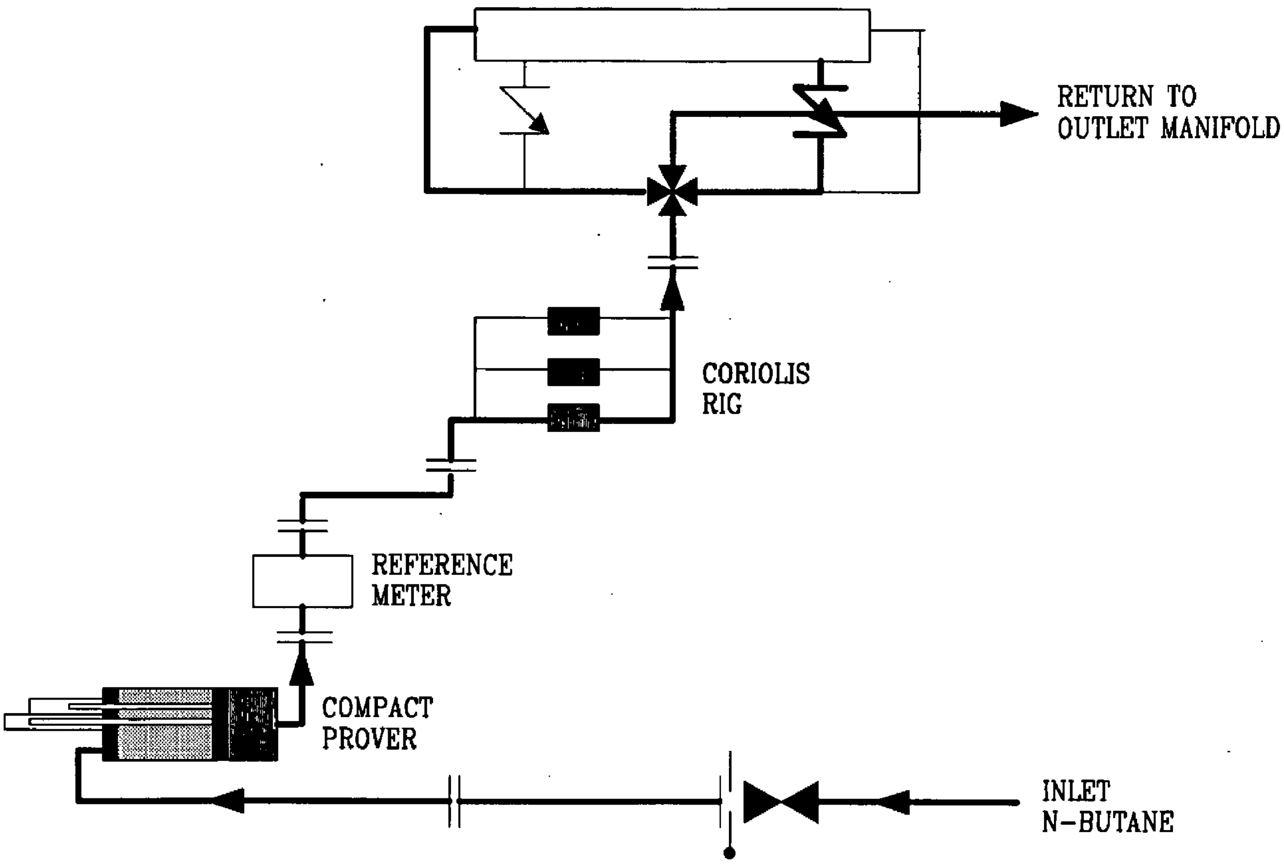


FIGURE 3

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN REFERENCE METER AND SCHLUMBERGER MASS FLOWMETER

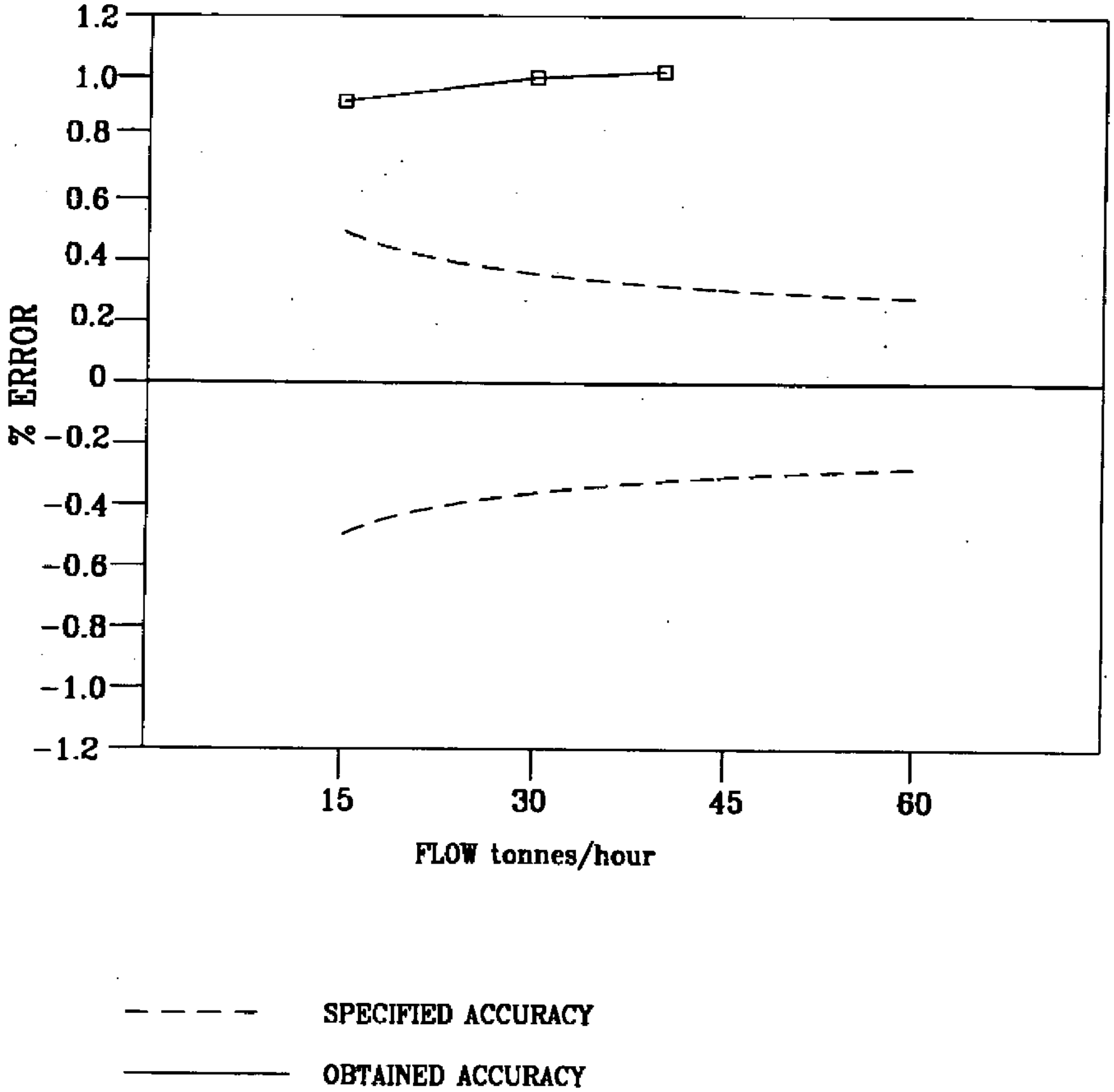


FIGURE 4

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN REFERENCE METER AND MICRO MOTION MASS FLOWMETER

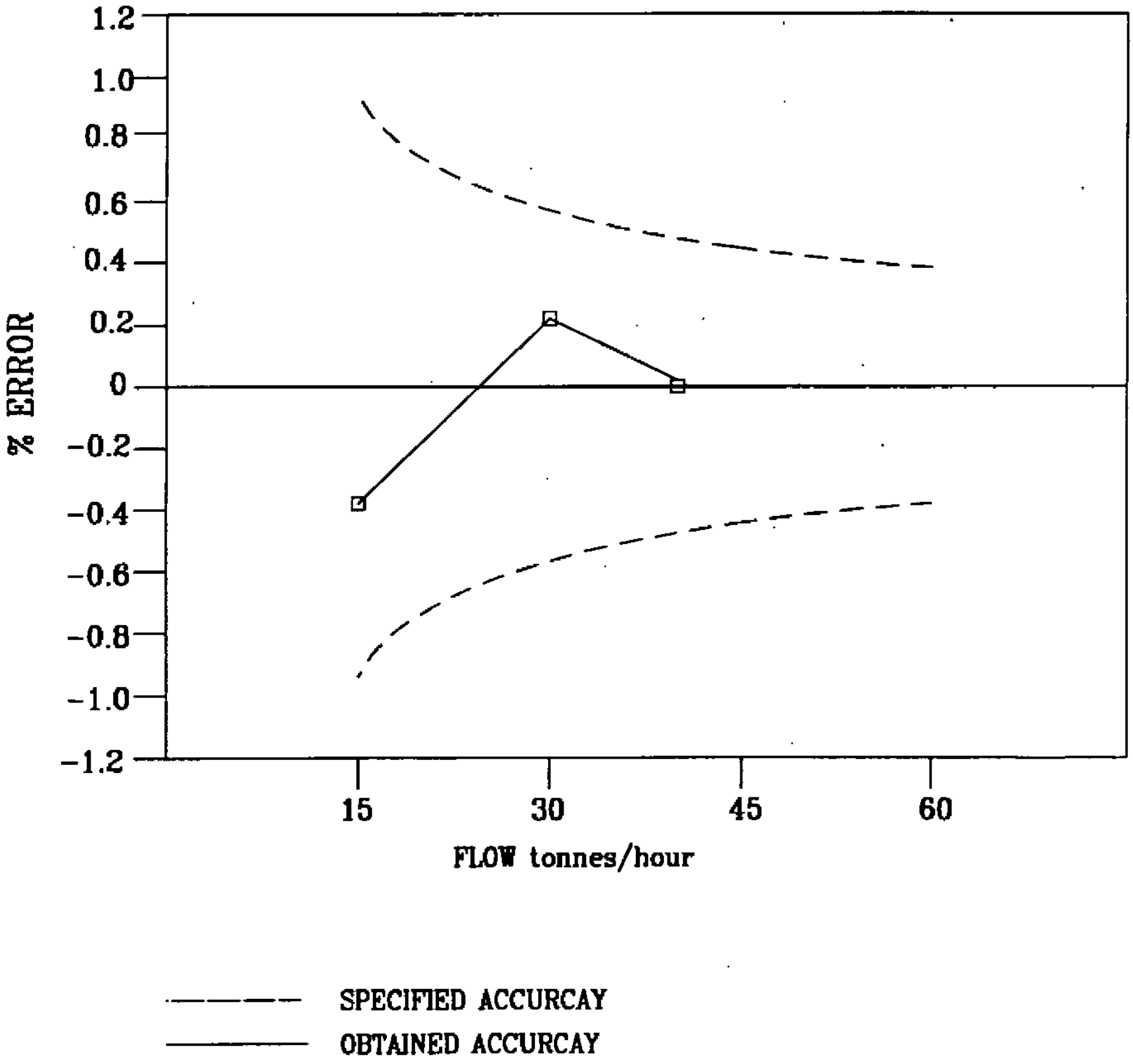


FIGURE 5

SCHEMATIC LAYOUT OF THE K-LAB TEST LOOP

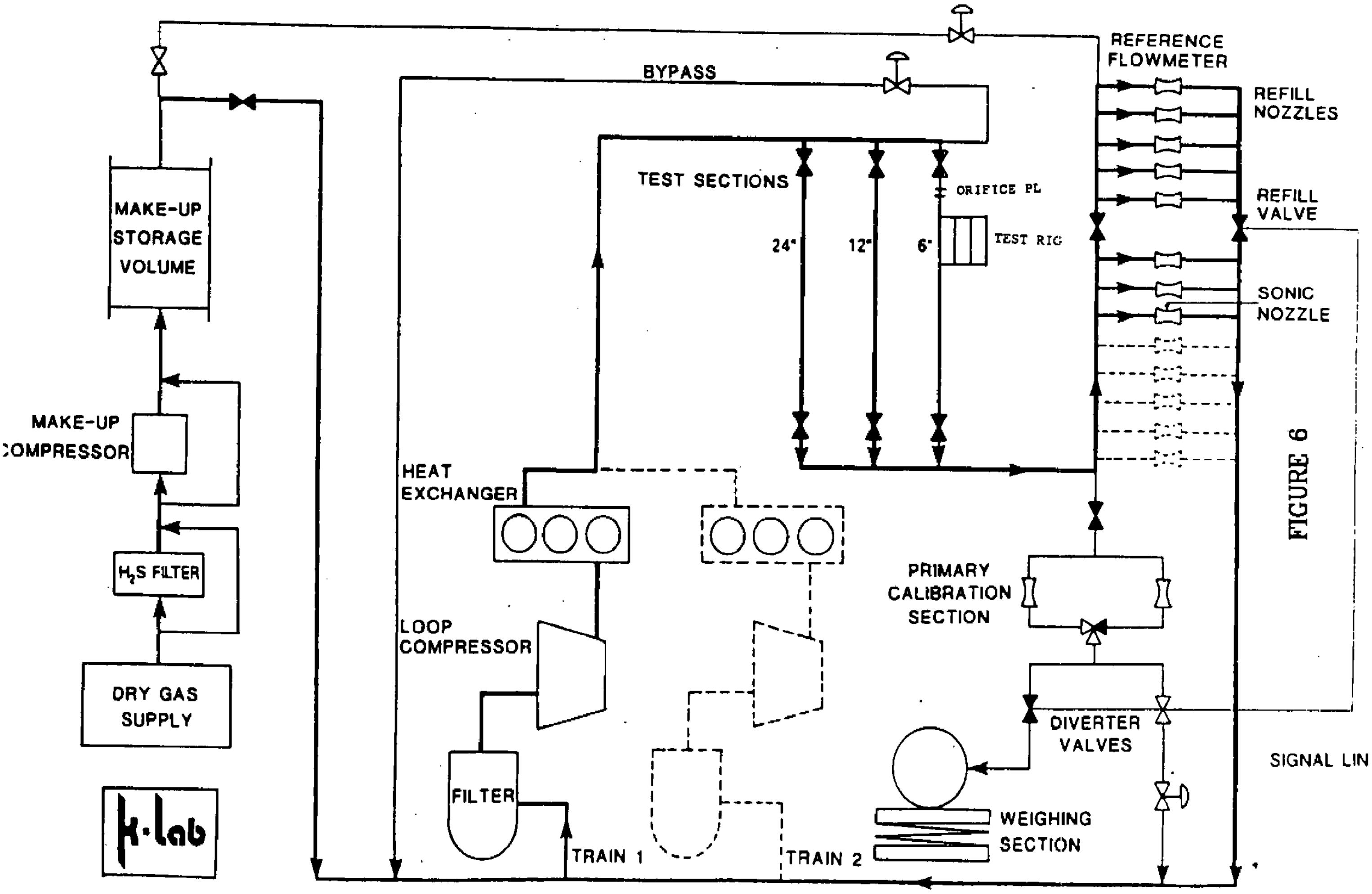


FIGURE 6

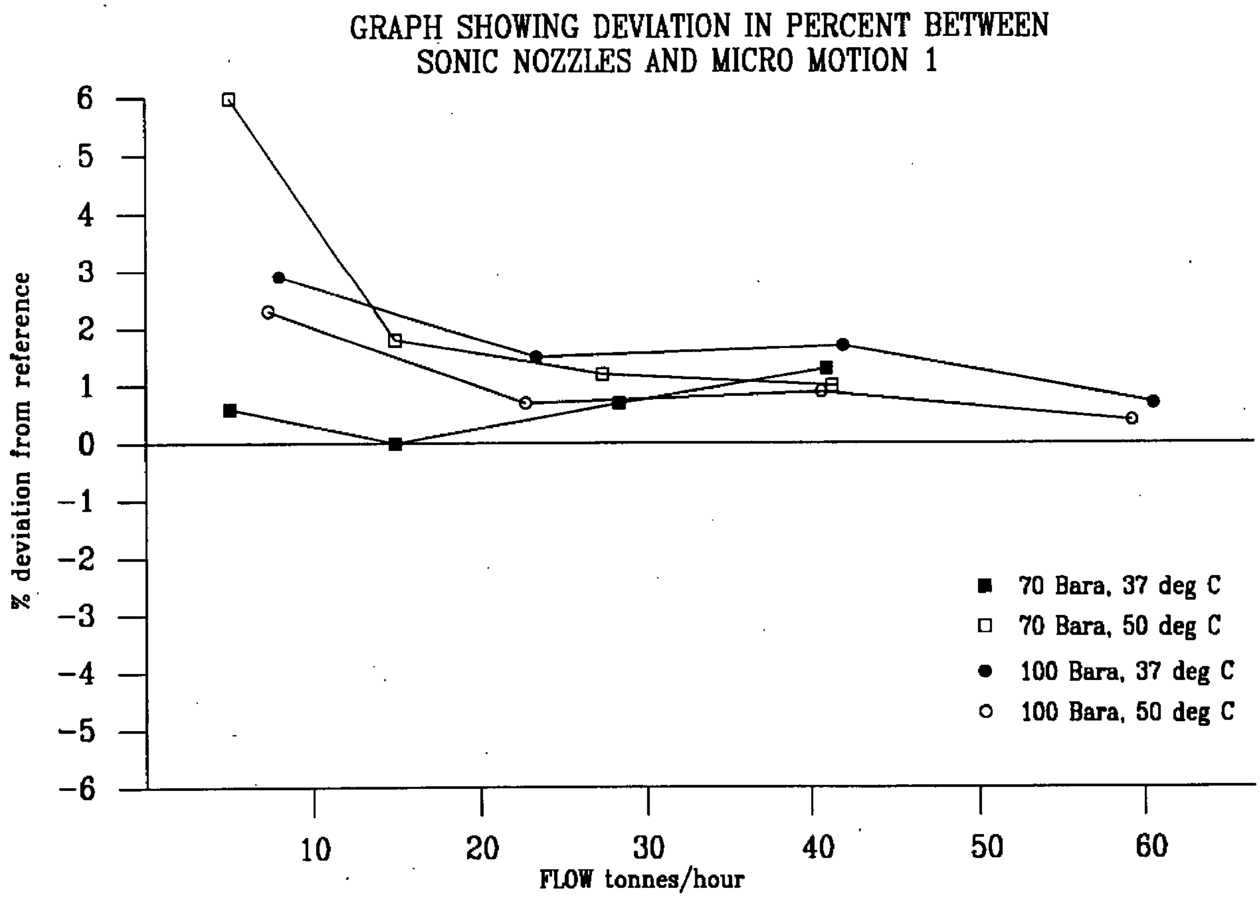

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN
SONIC NOZZLES AND MICRO MOTION 1
% deviation from reference
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
10
20
30
40
50
60
FLOW tonnes/hour
70 Bara, 37 deg C
70 Bara, 50 deg C
100 Bara, 37 deg C
100 Bara, 50 deg C

FIGURE 7

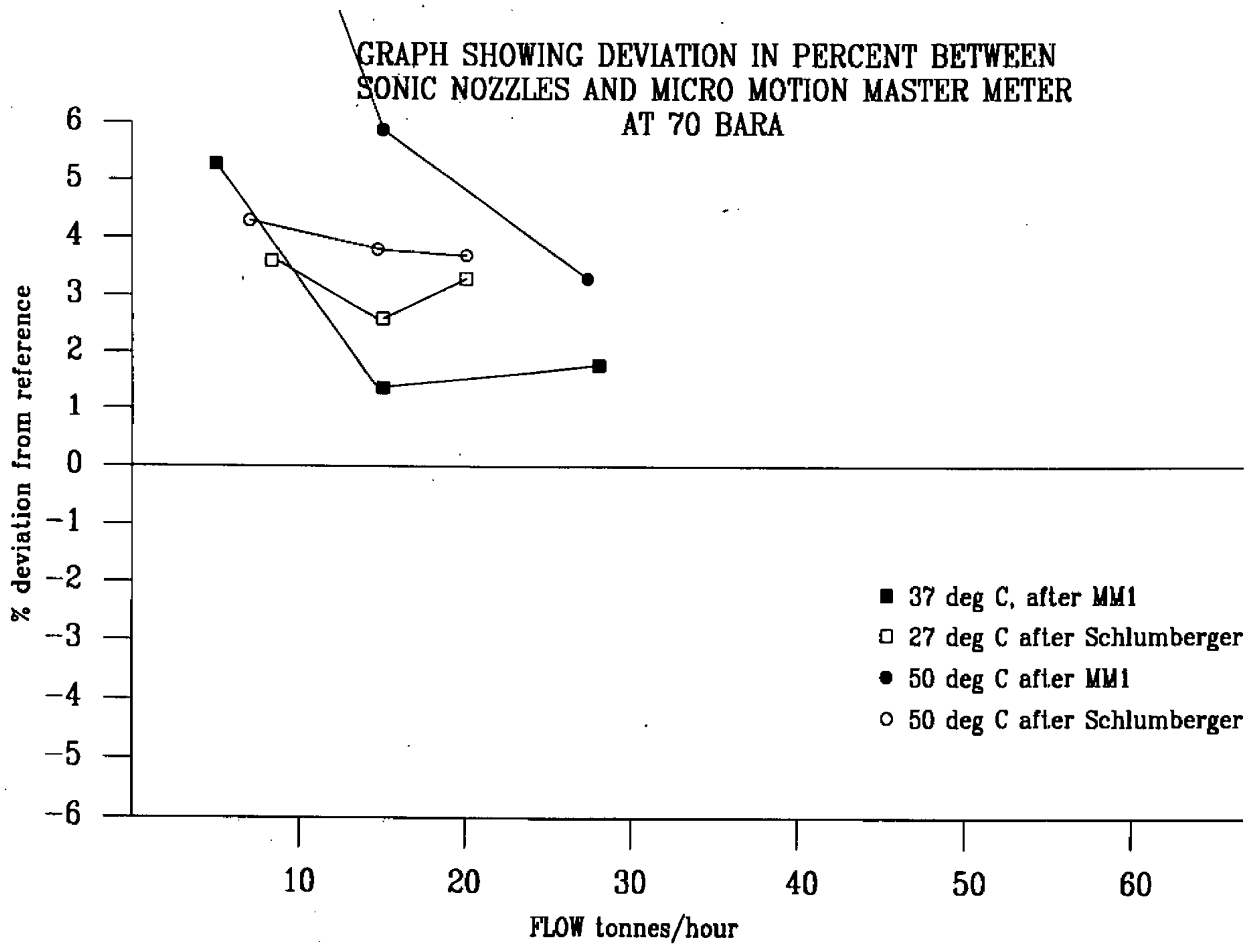

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN
SONIC NOZZLES AND MICRO MOTION MASTER METER
AT 70 BARA
% deviation from reference
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
10
20
30
40
50
60
FLOW tonnes/hour
37 deg C, after MM1
27 deg C after Schlumberger
50 deg C after MM1
50 deg C after Schlumberger

FIGURE 8

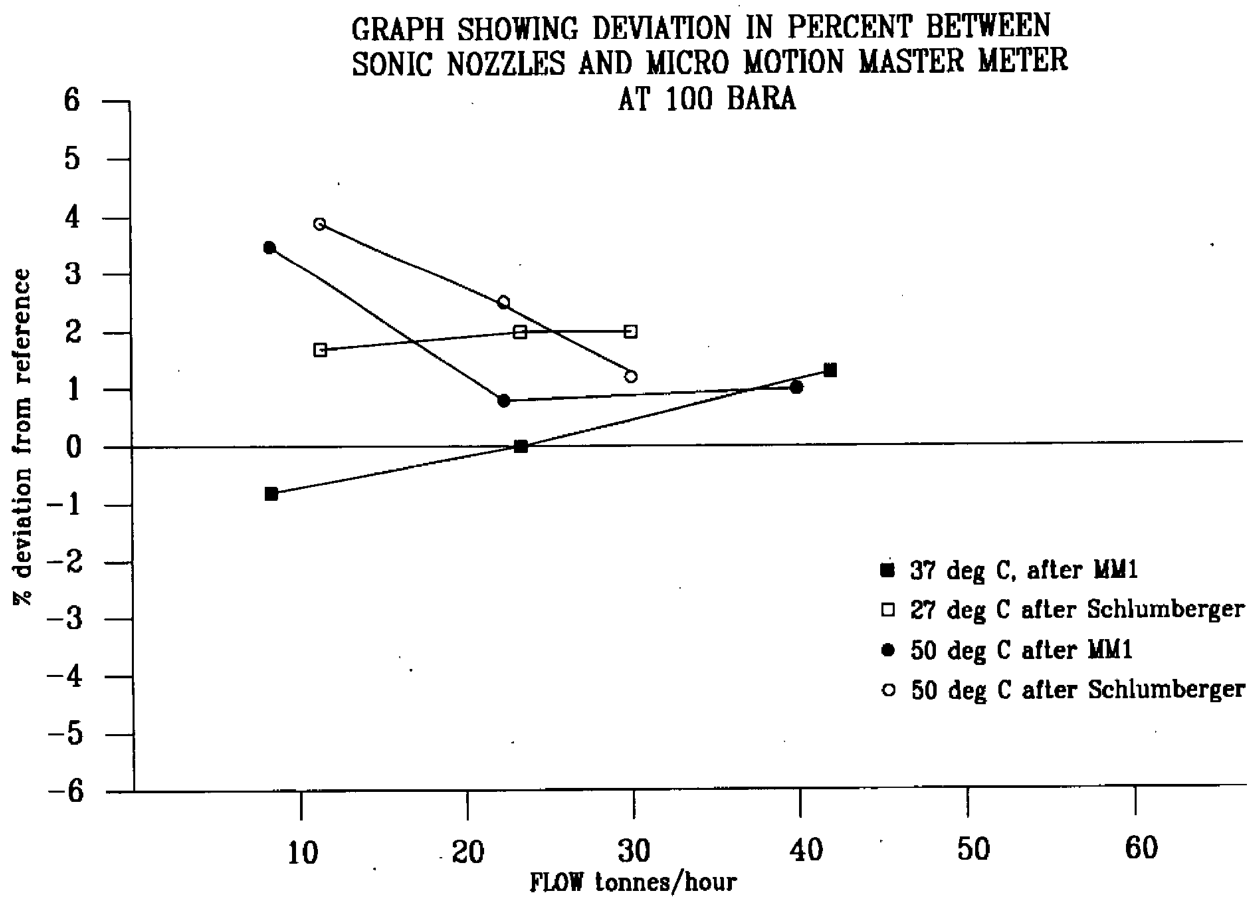

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN
SONIC NOZZLES AND MICRO MOTION MASTER METER
AT 100 BARA
% deviation from reference
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
10
20
30
40
50
60
FLOW tonnes/hour
37 deg C, after MM1
27 deg C after Schlumberger
50 deg C after MM1
50 deg C after Schlumberger

FIGURE 9

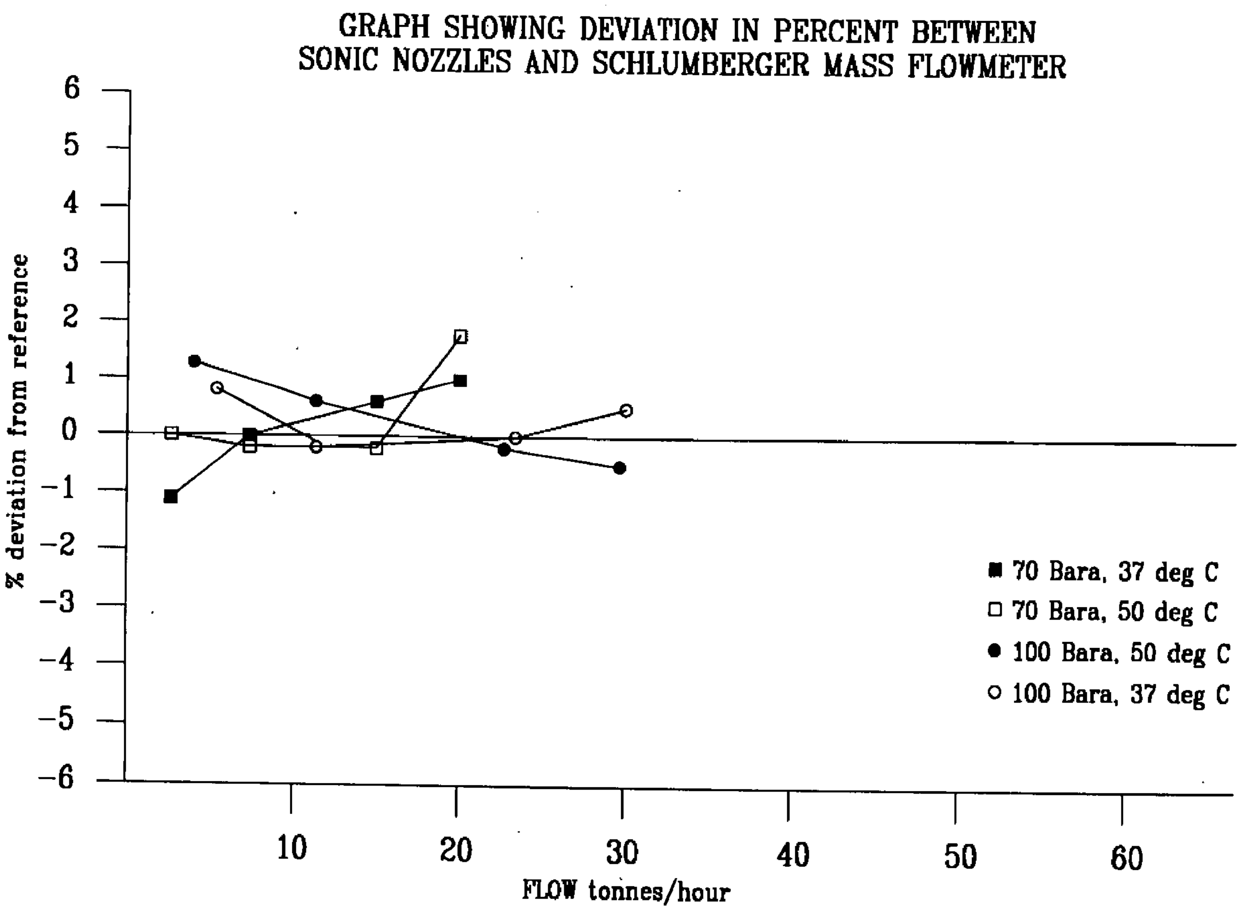

GRAPH SHOWING DEVIATION IN PERCENT BETWEEN
SONIC NOZZLES AND SCHLUMBERGER MASS FLOWMETER
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
% deviation from reference
70 Bara, 37 deg C
70 Bara, 50 deg C
100 Bara, 50 deg C
100 Bara, 37 deg C
10
20
30
40
50
60
FLOW tonnes/hour

FIGURE 10

APPENDIX C

TABLES

TABLE 1

TEST MATRIX

TEST NO	SENSOR	PRESS (BAR)	TEMP. (C)	FLOWRATE (TONN/H)			
0–146	ALL	70	37	31.0			PRELIMINARY TESTS
146–150	MM1	70	37	41.0			
151–165	MM1+MASTER	70	37		28.1	15.5	5.3
166–185	SCH +MASTER	70	37	20.4	15.6	7.8	2.6
186–190	MM1	70	50	39.9			
191–205	MM1+MASTER	70	50		27.4	15.1	5.1
207–225	SCH–MASTER	70	50	20.4	15.1	7.6	2.5
226–230	MM1	100	50	59.3			
231–245	MM1+MASTER	100	50		40.5	22.4	7.6
246–265	SCH+MASTER	100	50	29.4	22.4	11.2	3.7
266–270	MM1	100	37	60.6			
271–285	MM1+MASTER	100	37		42.1	23.1	7.8
286–305	SCH+MASTER	100	37	30.3	23.2	11.6	4.0
306–310	MM1	20	40	11.2			
311–325	MM1+MASTER	20	40		7.6	4.3	1.5
326–347	SCH+MASTER	20	40	5.5	4.2	2.1	0.7
353–372	SCH+MASTER	55	37	15.7	11.9	6.0	2.0
373–380	SCH+MASTER	55	37	15.7	6.0		TWISTED BEND
381–391	MM1+MASTER	70	50	27.1	15.0	5.4	REP. TEST
392–401	MM1+MASTER	70	50	27.2 1)	27.2 2)	27.2 3)	
402–404	MM1+MASTER	70	50	27.2 4)			
405–408	MM1+MASTER	70	50	27.2 5)			
409–411	SCH+MASTER	70	50	19.7			REP. TEST
413–425	SCH	70	37	10.4	20.5	25.6	5.1

1) LOOSE CLAMPS MM1

2) TIGHT CLAMPS MM1

3) MM1 ZERO ADJUSTED

4) TWISTED BEND

5) POWER OFF ON ALL OTHER METERS

TABLE 2

CALIBRATION RESULTS
MICRO MOTION METER 1

PRES (bar)	TEMP (deg C)	FLOWRATE (tonnes/h)	SPECIFIED ACCURACY	AIM OF TEST ACCURACY	OBTAINED ACCURACY
70	37	41.0	± 0.47	± 1.00	1.70
		28.1	± 0.59	± 1.00	0.90
		15.5	± 0.90	± 1.00	-0.07
		5.3	± 2.26	± 1.00	0.70
70	50	39.9	± 0.47	± 1.00	1.12
		27.4	± 0.60	± 1.00	1.21
		15.1	± 0.92	± 1.00	1.86
		5.1	± 2.33	± 1.00	5.97
100	50	59.3	± 0.38	± 1.00	0.39
		40.5	± 0.47	± 1.00	0.95
		22.4	± 0.69	± 1.00	0.72
		7.6	± 1.64	± 1.00	2.28
100	37	60.8	± 0.38	± 1.00	0.70
		42.1	± 0.46	± 1.00	1.65
		23.1	± 0.67	± 1.00	1.56
		7.8	± 1.60	± 1.00	2.95

Note: All accuracies are given in percent of mass flowrate.
The specified accuracies are for the mass flowmeter used for metering liquid.

TABLE 3

CALIBRATION RESULTS
MICRO MOTION MASTER METER AT 100 BARS

AFTER SENSOR:	TEMP (deg C)	FLOWRATE (tonnes/h)	SPECIFIED ACCURACY	AIM OF TEST ACCURCAY	OBTAINED ACCURACY
MM1	37	42.1	± 0.46	± 1.00	1.33
MM1	37	23.1	± 0.67	± 1.00	0.03
MM1	37	7.8	± 1.60	± 1.00	0.61
SCH	37	30.3	± 0.56	± 1.00	2.08
SCH	37	23.2	± 0.67	± 1.00	1.99
SCH	37	11.6	± 1.14	± 1.00	1.69
MM1	50	40.5	± 0.47	± 1.00	0.99
MM1	50	22.4	± 0.69	± 1.00	0.81
MM1	50	7.8	± 1.60	± 1.00	3.51
SCH	50	29.4	± 0.57	± 1.00	1.26
SCH	50	22.4	± 0.69	± 1.00	2.47
SCH	50	11.2	± 1.17	± 1.00	3.90

Note: All accuracies are given in percent of mass flowrate.
The specified accuracies are for the mass flowmeter used for metering liquid.

TABLE 4

CALIBRATION RESULTS
MICRO MOTION MASTER METER AT 70 BARS

AFTER SENSOR:	TEMP (deg C)	FLOWRATE (tonnes/h)	SPECIFIED ACCURACY	AIM OF TEST ACCURACY	OBTAINED ACCURACY
MM1	37	28.1	± 0.59	± 1.00	1.78
MM1	37	15.5	± 0.90	± 1.00	1.37
MM1	37	5.3	± 2.26	± 1.00	5.35
SCH	37	20.4	± 0.73	± 1.00	3.32
SCH	37	15.6	± 0.92	± 1.00	2.52
SCH	37	7.8	± 1.60	± 1.00	3.59
MM1	50	27.4	± 0.60	± 1.00	3.36
MM1	50	15.1	± 0.92	± 1.00	5.92
MM1	50	5.1	± 2.33	± 1.00	16.67
SCH	50	20.4	± 0.73	± 1.00	3.73
SCH	50	15.1	± 0.92	± 1.00	3.71
SCH	50	7.6	± 1.64	± 1.00	4.32

Note: All accuracies are given in percent of mass flowrate.
The specified accuracies are for the mass flowmeter used for metering liquid.

TABLE 5

CALIBRATION RESULTS
SCHLUMBERGER MASSMASTER 150

PRES (bar)	TEMP (deg C)	FLOWRATE (tonnes/h)	SPECIFIED ACCURACY	AIM OF TEST ACCURACY	OBTAINED ACCURACY
70	37	20.4	± 0.40	± 1.00	1.09
		15.6	± 0.44	± 1.00	0.66
		7.8	± 0.63	± 1.00	0.08
		2.6	± 1.40	± 1.00	-1.18
70	50	20.4	± 0.40	± 1.00	1.82
		15.1	± 0.45	± 1.00	-0.19
		7.6	± 0.64	± 1.00	-0.23
		2.5	± 1.45	± 1.00	-0.06
100	50	29.4	± 0.35	± 1.00	-0.46
		22.4	± 0.38	± 1.00	-0.19
		11.2	± 0.51	± 1.00	0.66
		3.7	± 1.06	± 1.00	1.32
100	37	30.3	± 0.35	± 1.00	0.51
		23.2	± 0.38	± 1.00	-0.06
		11.6	± 0.51	± 1.00	-0.22
		4.0	± 1.00	± 1.00	0.80
20	40	5.5	± 0.79	± 1.00	1.04
		4.2	± 0.96	± 1.00	0.36
		2.1	± 1.68	± 1.00	-0.34
		0.7	± 4.62	± 1.00	-5.22
55	37	5.5	± 0.79	± 1.00	-0.02
		4.2	± 0.96	± 1.00	-0.39
		2.1	± 1.68	± 1.00	-0.48
		0.7	± 4.62	± 1.00	-1.14

Note: All accuracies are given in percent of mass flowrate.
The specified accuracies are for the mass flowmeter used for metering liquid.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.