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TNER.82.029

71.4.20.700

EXPLORATION AND PRODUCTION:
GAS TESTS OFFSHORE NORWAY - GAS WELL 31/2-6

E.P. Knowles

Req. No: Telex ref. FOR 290712 d.29.7.81

SIPM/EP/23

[redacted]

EXTERNAL REPORT

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(Budget Classification 71.4.20.700)

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Reviewed by : N. Coleclough

SUMMARY

The Thornton well-head testing equipment has been used to determine the well-head fluid composition and equilibrium data of gas well 31/2-6, by split phase sampling.

Satisfactory agreement was found between phase compositions and liquid recoveries determined experimentally and those predicted by the computerised SHAMROCK flash program.

SHELL RESEARCH LIMITED

T H O R N T O N R E S E A R C H C E N T R E

Transport and Storage Division

May 1982

EXPLORATION AND PRODUCTION: GAS TESTS OFFSHORE NORWAY — GAS WELL 31/2-6

1. INTRODUCTION

In October 1981 Thornton carried out a short series of tests using the Thornton well-head testing equipment on Well 31/2-6 during production testing of the gas zone at that location.

The objective of the Thornton work was to obtain a detailed, accurate well stream composition together with gas/liquid equilibrium data.

2. EXPERIMENTAL AND RESULTS

The Thornton well-head testing equipment consists of two main sections illustrated in Figures 1 and 2. The heavy duty sampling manifold (ref. Figure 1) incorporates a mixing device and is placed in the well effluent flow line between the well-head and the choke manifold.

After thorough phase mixing a sample stream is passed isokinetically via a probe to the miniature laboratory which houses a series of small scale split phase sampling separators. These separators are maintained at carefully controlled conditions of temperature and pressure (ref. Figure 2).

Previous work[1] on the 31/2 field gas zone indicated that two stage separations would be in order and trial determinations of the condensate gas ratio prior to the main testing period confirmed this.

The conditions used for the separations performed are shown below:

		psig	°F
Test 1	1st stage	1000	32
	2nd stage	500	9
Test 2	1st stage	1000	33
	2nd stage	500	13

Following reduction to atmospheric pressure, samples of gases and condensates from these tests were analysed using standard gas chromatographic techniques. The data obtained was used in recombination

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[1] Ref. TNTR.81.014 (TNER.81.091), March 1981

calculations to produce a well steam composition together with test condition phase data for each test. In addition condensate/gas ratios at test and vented conditions were calculated.

The experimental analytical data provides an isomeric split for butane and pentane and also indicates the molar percentage of benzene, toluene and xylene. The experimentally determined phase compositions are given in Tables 1 and 2.

The resultant well-head fluid compositions obtained by recombination were flashed to the first stage test conditions using the SHAMROCK flash program. Then the predicted first stage gas composition was subsequently flashed to the second stage test conditions. The results from this exercise are shown in Tables 1a and 2a.

In addition a second series of SHAMROCK flashes were performed on the well-head fluid after re-classifying the C9+ fraction to include a 60% aromatic/naphthene content. The data produced is shown in Tables 1b and 2b. Table 3 shows the gas/liquid equilibrium data for both tests and Table 4 provides a comparison between experimental and SHAMROCK predicted mole ratios and condensate gas ratios for the respective first stage separations.

Table 5 compares recombined experimental well-head fluid compositions for easy refrence.

The gas/liquid equilibrium data for both tests is reproduced in schematic separation diagrams in Figures 3 and 4.

3. DISCUSSION

It is usual when performing SHAMROCK flash calculations to assume, as we have in these simulations, that the feed composition is predominantly paraffinic in nature, and that the boiling range of individual fractions above C9*, fall within the bounds described for the preceding n-paraffin and the n-paraffin used to identify the group. This assumption although satisfactory in many cases, will not always give truly representative predictions because, in some instances, the carbon groups will inevitably have some aromatic and/or naphthenic character. Therefore if experimental phase behaviour is to be reproduced realistically by flash procedures, then clearly it will be necessary here to allow for this aspect in the input data. We have found from experience that adjustments along these lines will, by the trial inclusion of various levels of aromaticity in the C9 to C16 fractions, result in much closer agreement between measured and

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* Benzene (C6), Toluene (C7) and Xylene (C8) were determined experimentally.

calculated results. In this respect it was especially justified to allow for aromaticity and naphthene character, because the chromatographic analysis indicated that the condensates contained only low proportions of normal straight chain paraffins and relatively high amounts of cyclic, aromatic and naphthenic components.

Thus in considering differences between the experimental determined liquid phase compositions and those predicted by SHAMROCK, the closest comparisons are those containing 60% aromatics and with the C6 and C7 fractions described as cyclohexane and methylcyclohexane for the two tests performed ref. Tables 1/1b and 2/2b respectively. There was also some improvement in the condensate gas ratio comparison on the incorporation of aromatics.

Table 1

TEST 1

Experimentally determined phase compositions (mol %)

Component	Well-head fluid	Separation 1 1000 psig/32°F		Separation 2 500 psig/9°F	
		Liquid	Gas	Liquid	Gas
C1	92.569	27.379	93.012	20.300	93.077
2	3.437	5.315	3.424	5.510	3.422
3	0.304	1.373	0.296	1.903	0.295
i4	0.342	3.158	0.323	5.579	0.318
n4	0.029	0.397	0.027	0.684	0.026
i5	0.090	1.106	0.083	4.937	0.079
n5	0.014	0.280	0.012	1.100	0.011
6	0.203	11.089	0.129	18.730	0.112
7	0.212	19.659	0.080	28.774	0.053
8	0.051	6.786	0.005	5.552	
9	0.050	6.906	0.003	3.047	
10	0.039	5.569		1.042	
11	0.021	2.998		0.308	
12	0.012	1.814		0.098	
13	0.008	1.193		0.046	
14	0.006	0.856		0.020	
15	0.004	0.627			
16	0.002	0.330			
17		0.144			
18		0.088			
19		0.072			
20		0.033			
21		0.011			
22		0.007			
23		0.006			
Toluene	0.005	0.644		0.605	
Xylene	0.009	1.312		0.673	
N_2	1.702	0.221	1.713	0.093	1.714
CO_2	0.891	0.627	0.893	0.999	0.893
Mol wt	17.85	80.46	17.43	72.97	17.38
Mole ratio		0.0068		0.0009	
CGR (bbl/MMSCF)		5.66		0.74	
C7+	0.419	49.055		40.165	

Table 1a

TEST 1

SHAMROCK predicted phase compositions (mol %)

Component	Well-head fluid	Separation 1 1000 psig/32°F		Separation 2 500 psig/9°F	
		Liquid	Gas	Liquid	Gas
C1	92.569	31.416	93.101	20.272	93.184
2	3.437	5.899	3.416	5.501	3.413
3	0.304	1.550	0.293	1.890	0.291
i4	0.342	3.630	0.313	5.421	0.308
n4	0.029	0.410	0.026	0.650	0.025
i5	0.090	2.310	0.071	4.220	0.066
n5	0.014	10.470	0.010	0.900	0.009
6	0.203	12.469	0.096	24.752	0.068
7	0.212	8.298	0.054	27.833	0.023
8	0.051	5.259	0.006	4.160	0.001
9	0.050	5.509	0.002	2.020	
10	0.039	4.430	0.001	0.650	
11	0.021	2.410		0.160	
12	0.012	1.390		0.030	
13	0.008	0.930		0.010	
14	0.006	0.690			
15	0.004	0.460			
16	0.002	0.230			
Toluene	0.005	0.490	0.001	0.500	
Xylene	0.009	0.970	0.001	0.480	
N_2	1.702	0.180	1.715	0.090	1.717
CO_2	0.891	0.600	0.894	0.460	0.894
Mol wt		72.82	17.37	71.97	17.31
Mole ratio		0.0086		0.0011	
CGR (bbl/MMSCF)		7.04		0.91	
C7+	0.405	39.606		34.863	

Table 1b

TEST 1

SHAMROCK predicted phase compositions (mol %)
assuming 60% aromatic content in C9+ fraction

Component	Well-head fluid	Separation 1 1000 psig/32°F	
		Liquid	Gas
C1	92.569	28.216	93.120
2	3.437	5.479	3.419
3	0.304	1.480	0.294
i4	0.342	3.550	0.314
n4	0.029	0.410	0.026
i5	0.090	2.310	0.071
n5	0.014	0.470	0.010
*6N	0.203	15.258	0.072
7N	0.212	19.238	0.046
8	0.051	5.299	0.005
9	0.020	2.210	0.001
9A	0.030	3.370	0.001
10	0.016	1.780	
10A	0.023	2.680	
11	0.008	0.960	
11A	0.013	1.450	
12	0.005	0.550	
12A	0.007	0.830	
13	0.003	0.370	
13A	0.005	0.550	
14	0.002	0.280	
14A	0.004	0.420	
15	0.002	0.190	
15A	0.002	0.280	
16	0.002	0.230	
Toluene	0.005	0.490	0.001
Xylene	0.009	0.980	0.001
N_2	1.702	0.150	1.716
CO_2	0.891	0.520	0.894
Mol wt	17.83	74.10	17.34
Mole ratio		0.0086	
CGR (bbl/MMSCF)		6.62	

* 6N = cyclohexane 7N = methyl cyclohexane 9A etc. = aromatic components

Table 2

TEST 2

Experimentally determined phase compositions (mol %)

Component	Well-head fluid	Separation 1 1000 psig/33°F		Separation 2 500 psig/13°F	
		Liquid	Gas	Liquid	Gas
C1	92.695	25.614	93.150	19.845	93.194
2	3.456	5.219	3.444	5.338	3.443
3	0.304	1.363	0.297	1.827	0.296
i4	0.339	3.144	0.320	5.283	0.317
n4	0.028	0.401	0.025	0.610	0.025
i5	0.057	1.129	0.050	2.824	0.048
n5	0.009	0.284	0.007	0.700	0.007
6	0.161	11.401	0.085	18.405	0.073
7	0.182	20.225	0.046	31.153	0.026
8	0.053	7.214	0.004	6.408	
9	0.050	7.079	0.002	3.686	
10	0.040	5.804		1.400	
11	0.020	2.929		0.363	
12	0.013	1.903		0.098	
13	0.009	1.322		0.022	
14	0.005	0.785			
15	0.005	0.709			
16	0.002	0.294			
17		0.125			
18		0.095			
19		0.071			
20		0.016			
21		0.010			
22					
Benzene					
Toluene	0.005	0.677		0.691	
Xylene	0.009	1.329		0.821	
N_2	1.678	0.245	1.688	0.090	1.689
CO_2	0.880	0.612	0.882	0.436	0.882
Mol wt	17.78	82.20	17.34	75.18	17.31
Mole ratio		0.0067		0.006	
CGR (bbl/MMSCF)		6.12		0.53	
C7+	0.393	50.586		44.642	

Table 2a

TEST 2

SHAMROCK predicted phase compositions (mol %)

Component	Well-head fluid	Separation 1 1000 psig/33°F		Separation 2 500 psig/13°F	
		Liquid	Gas	Liquid	Gas
C1	92.695	31.049	93.155	19.672	93.214
2	3.456	5.881	3.438	5.291	3.437
3	0.304	1.540	0.295	1.800	0.294
i4	0.339	3.601	0.315	5.111	0.311
n4	0.028	0.400	0.025	0.600	0.025
i5	0.057	1.500	0.046	2.610	0.044
n5	0.009	0.310	0.007	0.570	0.006
6	0.161	10.642	0.083	21.482	0.065
7	0.182	17.443	0.052	30.093	0.028
8	0.053	6.261	0.007	6.311	0.002
9	0.050	6.381	0.003	3.150	
10	0.040	5.291	0.001	1.070	
11	0.020	2.681		0.240	
12	0.013	1.750		0.060	
13	0.009	1.220		0.020	
14	0.005	0.680			
15	0.005	0.680			
16	0.002	0.270			
Benzene					
Toluene	0.005	0.550	0.001	0.680	
Xylene	0.009	1.120	0.001	0.720	
N_2	1.678	0.170	1.689	0.090	1.691
CO_2	0.880	0.580	0.882	0.430	0.883
Mol wt	17.78	75.40	17.35	74.71	17.30
Mole ratio		0.0074		0.0008	
CGR (bbl/MMSCF)		6.19		0.70	
C7+	0.393	44.327		42.29	

Table 2b

TEST 2

SHAMROCK predicted phase compositions (mol %)
assuming 60% aromatic content in C9+ fraction

Component	Well-head fluid	Separation 1 1000 psig/33°F	
		Liquid	Gas
C1	92.695	27.980	93.178
2	3.456	5.470	3.442
3	0.304	1.470	0.295
i4	0.339	3.510	0.315
n4	0.028	0.400	0.025
i5	0.057	1.490	0.046
n5	0.009	0.310	0.007
*6N	0.161	13.270	0.063
7N	0.182	18.500	0.045
8	0.053	6.290	0.006
9	0.020	2.550	0.001
9A	0.030	3.890	0.001
10	0.016	2.110	
10A	0.024	3.190	
11	0.008	1.070	
11A	0.012	1.600	
12	0.005	0.700	
12A	0.008	1.050	
13	0.004	0.480	
13A	0.005	0.730	
14	0.002	0.270	
14A	0.003	0.400	
15	0.002	0.270	
15A	0.003	0.400	
16	0.002	0.270	
Toluene	0.005	0.550	0.001
Xylene	0.009	1.120	0.001
N_2	1.678	0.150	1.690
CO_2	0.880	0.510	0.883
Mol wt	17.76	76.45	17.32
Mole ratio		0.0074	
CGR (bbl/MMSCF)		5.84	

* 6N = cyclohexane 7N = methyl cyclohexane 9A etc. = aromatic components

Table 3

Condensate gas ratios

Test	Date/time	Separation conditions psig/°F	Measured CGR's			
			At test conditions		At 1 Atm/63°F	
			Kg/10^6 NM^3	bbl/MMSCF	Kg/10^6 NM^3	bbl/MMSCF
1	7/10/81	1000/32	23132	5.66	20451	4.56
	1242 h	500/9	2998	0.74	2998	0.62
2	7/10/81	1000/33	25010	6.12	22143	4.68
	1545 h	500/13	2138	0.53	1716	0.42

Table 4

Comparison of experimental and SHAMROCK predicted equilibrium data

Test	EXPERIMENTAL		SHAMROCK 1*		SHAMROCK 2*	
	Liquid mole ratio	CGR bbl/MMSCF	Liquid mole ratio	CGR bbl/MMSCF	Liquid mole ratio	CGR bbl/MMSCF
1	0.0068	5.66	0.0086	7.04	0.0086	6.62
2	0.0067	6.12	0.0074	6.19	0.0074	5.84

* SHAMROCK 1 using experimental well-head fluid

SHAMROCK 2 using 60% aromatic content in C9+ fraction

Table 5

Comparison of experimentally determined well-head fluid compositions (mol %)

Component	TEST 1	TEST 2
C1	92.569	92.695
2	3.437	3.456
3	0.304	0.304
i4	0.342	0.339
n4	0.029	0.028
i5	0.090	0.057
n5	0.014	0.009
6	0.203	0.161
7	0.212	0.182
8	0.051	0.053
9	0.050	0.050
10	0.039	0.040
11	0.021	0.020
12	0.012	0.013
13	0.008	0.009
14	0.006	0.005
15	0.004	0.005
16	0.002	0.002
Toluene	0.005	0.005
Xylene	0.009	0.009
N_2	1.702	1.678
CO_2	0.891	0.880
C7+	0.419	0.393

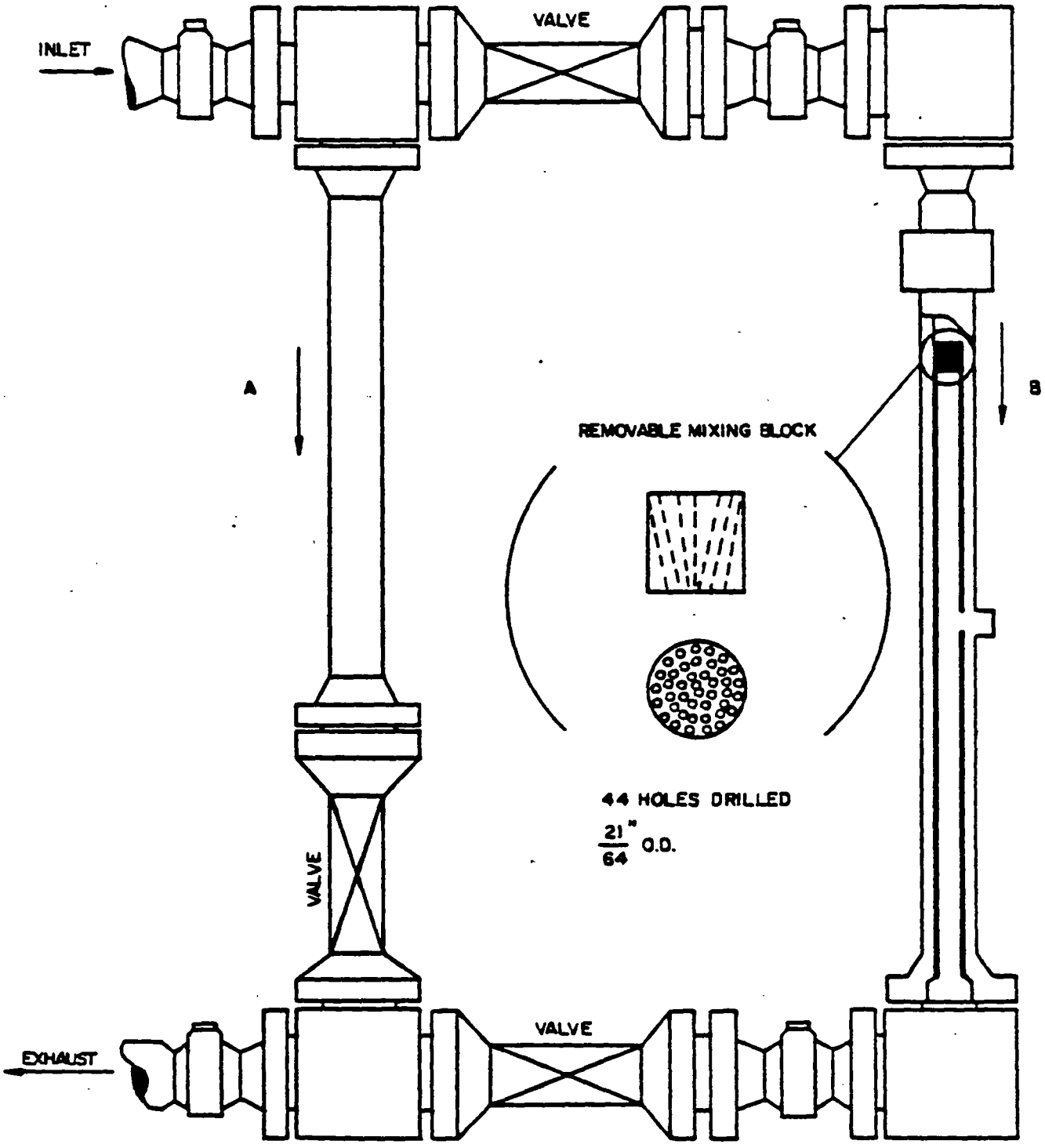


FIG. 1 – Mixing manifold

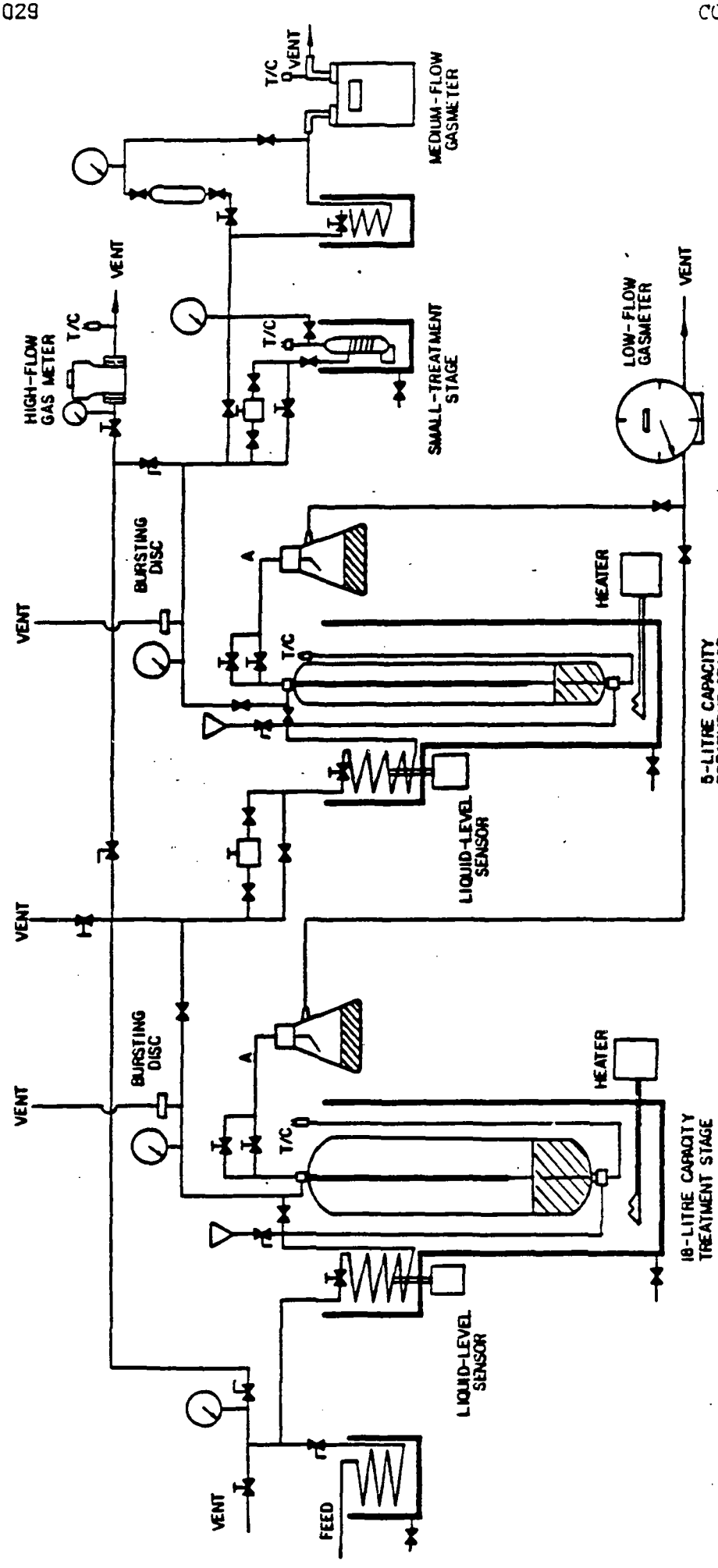
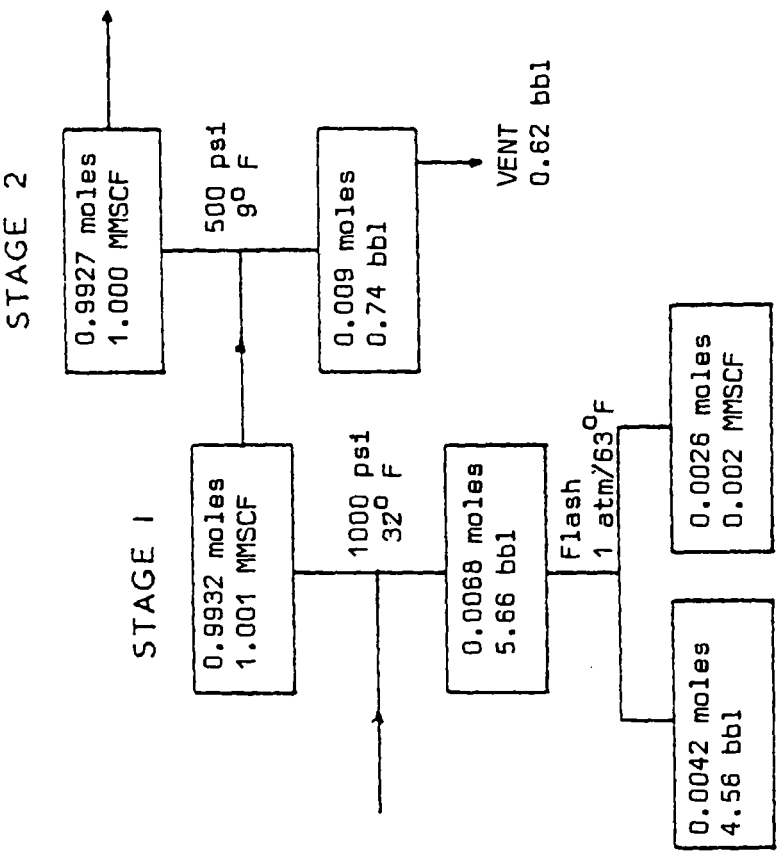


FIG.2-Well-head testing unit



TEST NO. 1

Fig. 3

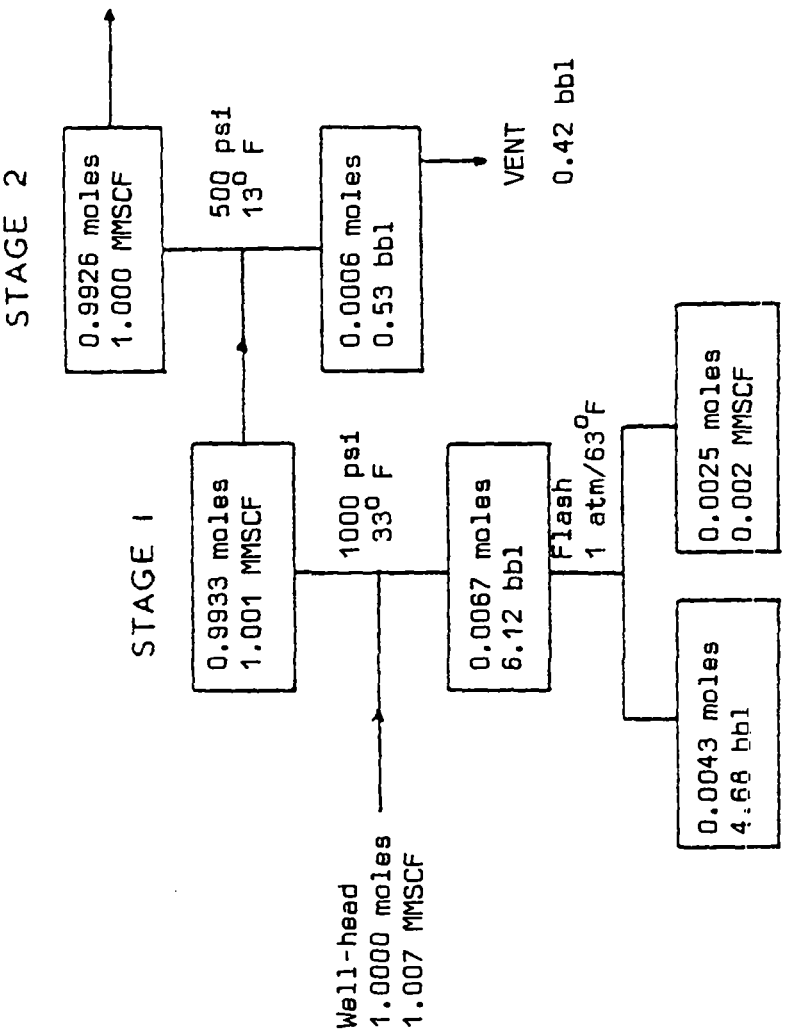

TEST NO. 2
Well-head
1.0000 moles
1.007 MMSCF
1000 psi
33° F
STAGE 1
0.9933 moles
1.001 MMSCF
500 psi
13° F
STAGE 2
0.9926 moles
1.000 MMSCF
0.0067 moles
6.12 bbl
Flash
1 atm/63°F
0.0043 moles
4.68 bbl
0.0025 moles
0.002 MMSCF
0.0006 moles
0.53 bbl
VENT
0.42 bbl

Fig. 4

Distribution

SIPM, The Hague

EP/0 (22)

KSEPL, Rijswijk (2)