Twister NGL Recovery Study

Technical Note

Final Report

Genesis Job Number J-10205/A

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EXECUTIVE SUMMARY

Genesis Oil and Gas Consultants Ltd. (GOGC) has performed a third party simulation study to compare the condensate recovery performance of Twister and a conventional Joule–Thomson System. A range of compositions, feed temperatures (25-45°C), feed pressures (40-100barg) and feed water contents (bone dry, saturated plus 1-7lb/MMscf) have been employed in the study, representing the likely spread of operating parameters in different NGL recovery systems in gas plants worldwide.

The basis for the work was that no chemicals are used and the comparison is to establish the NGL recovery achievable without the risk of hydrates. (For most of the cases the gas is dehydrated upstream so this does not represent a major constraint.)

The results of the simulations have shown that the Twister scheme produces greater quantities of NGL and LPG than the conventional JT scheme consistently over the range of compositions, feed conditions, pressure drops and upstream dehydration specifications studied.

The improvement in performance is especially great at higher feed pressures and for leaner feed gas.

With a feed pressure of 100bar and downstream pressures of 55-75bar the improvement is typically around 0.8-1.0 tonnes/MMscf more LPG and 15-20bbl/MMscf greater NGL recovery. With a feed pressure of 70bar and downstream pressures of 40-50bar the improvement is typically around 0.4-0.6 tonnes/MMscf more LPG and 5-10bbl/MMscf greater NGL recovery. At low feed pressures the benefit of Twister over the JT is eroded. At a feed pressure of 40bar and downstream pressures of 20-30bar, when expansion is inefficient as outlet pressure is below the cricondentherm pressure, the NGL yields of the two processes are similar, though the Twister starts to outperform the JT for lean gas for higher pressure losses.

For lean gas, the recovery with Twister is typically five to ten times as great as with the conventional JT scheme, with the JT recovery only approaching the recovery achieved by Twister when the feed water content is very low. This compares with Twister recoveries of around double the JT recovery for a typical mean composition and 150% of the JT recovery for rich compositions, again with the difference reducing for very low water content.

1 INTRODUCTION

Genesis Oil and Gas Consultants Ltd. (GOGC) has completed a third party study to compare the condensate recovery performance of Twister and a conventional Joule–Thomson Low Temperature Separation (JT-LTS) System. A range of feed temperatures, feed pressures and water contents have been employed in the study, representing the likely spread of operating parameters in different NGL recovery systems in gas plants worldwide.

The purpose of this study was to evaluate and compare the condensate recovery of the Twister system and conventional JT-LTS facilities using Hysys models of both systems.

The Hysys models used to simulate the performance of the Twister and hydrate separator in the study were proprietary black box models provided by Twister B.V. The fidelity of these Hysys models was confirmed by comparison of test data from the Gasunie test facility at Groningen and high pressure Twister performance data from the B11 platform with the results of simulations performed using the Hysys models for the test conditions.

2 METHODOLOGY

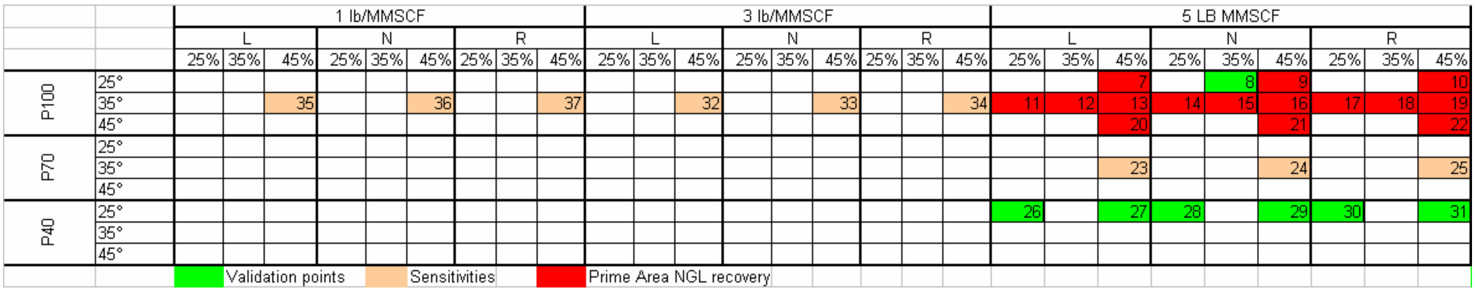
2.1 Simulation parameters

A schedule of cases were selected to be modelled using Hysys, featuring variations in the following parameters:

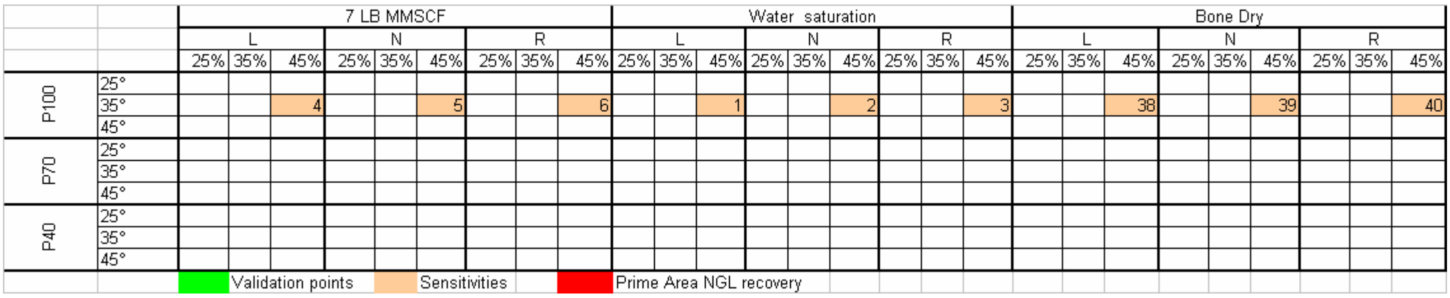
- Feed pressure: 100 bara and 70 bara, representing the normal range of feed pressures for NGL recovery systems, plus 40 bara, which is typically the minimum feed pressure at which expansion facilities are likely to be used. Feed temperature: three temperatures, 25°C, 35°C and 45°C, representing the likely range of cooler outlet temperatures in different gas plants worldwide.
- Pressure loss: three pressure loss cases, 25% of the feed pressure (minimum of Twister range), 35% of the feed pressure, and 45% of the feed pressure (maximum of Twister range).
- Feed water content: a range of feed water contents were modelled, these were:
    - saturated at the feed conditions, with no upstream dehydration;
    - 7lb/MMscf (~145ppmv) and 5lb/MMscf (~105ppmv), to represent the typical sales gas specifications for warm countries; e.g., South East Asia;

  - 3lb/MMscf (~60ppmv), 1lb/MMscf (~20ppmv), to represent the typical sales gas specifications for colder countries; e.g., Northern Europe;
  - bone dry - for example, the feed to an LNG plant.
- The cases simulated are presented in Table 2.1. Numbers in the simulation matrix are case identifiers.

Table 2.1 – Matrix of Simulation Cases



		1 lb/MMSCF									3 lb/MMSCF									5 LB MMSCF								
		L			N			R			L			N			R			L			N			R		
		25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%
P100	25°																					🟥 7		🟩 8	🟥 9			🟥 10
	35°			🟧 35			🟧 36			🟧 37			🟧 32			🟧 33			🟧 34	🟥 11	🟥 12	🟥 13	🟥 14	🟥 15	🟥 16	🟥 17	🟥 18	🟥 19
	45°																					🟥 20			🟥 21			🟥 22
P70	25°																											
	35°																					🟧 23			🟧 24			🟧 25
	45°																											
P40	25°																			🟩 26		🟩 27	🟩 28		🟩 29	🟩 30		🟩 31
	35°																											
	45°																											
		🟩	Validation points			🟧	Sensitivities			🟥	Prime Area NGL recovery																	



		7 LB MMSCF									Water saturation									Bone Dry								
		L			N			R			L			N			R			L			N			R		
		25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%	25%	35%	45%
P100	25°																											
	35°			🟧 4			🟧 5			🟧 6			🟧 1			🟧 2			🟧 3			🟧 38			🟧 39			🟧 40
	45°																											
P70	25°																											
	35°																											
	45°																											
P40	25°																											
	35°																											
	45°																											
		🟩	Validation points			🟧	Sensitivities			🟥	Prime Area NGL recovery																	

Three feed gas compositions were selected for study, ‘lean’, ‘normal’ and ‘rich’. These are presented in Table 2.2

Table 2.2 – Feed Compositions

	Lean	Normal	Rich
CO2	6.46E-03	0.018	0.030
Nitrogen	0.043	0.025	0.006
Methane	0.855	0.820	0.785
Ethane	0.052	0.069	0.086
Propane	0.025	0.035	0.045
i-Butane	6.11E-03	0.007	0.009
n-Butane	6.51E-03	0.012	0.017
i-Pentane	1.95E-03	3.97E-03	6.00E-03
n-Pentane	5.01E-04	3.30E-03	6.10E-03
n-Hexane	3.10E-03	5.16E-03	7.23E-03
n-Heptane	2.45E-04	1.32E-03	2.40E-03
n-Octane	5.51E-05	2.78E-04	5.02E-04
n-Nonane	0	5.09E-05	1.02E-04
n-Decane	0	1.06E-06	2.11E-06
H2O	-	-	-
MW	19.08	20.51	21.96

2.2 Base Assumptions

- The first assumption is that no chemicals are used and the comparison is to establish the NGL recovery achievable without the risk of hydrates. (For most of the cases the gas is dehydrated upstream so this does not represent a major constraint.)

- A pressure loss of 0.8bar was assumed across each heat exchanger, including pipework (across each side for cross-exchangers).

- The minimum temperature approach for each exchanger was assumed to be 5°C.

3 PROCESS SCHEMES SUMMARY

The basis for the process schemes for both the Twister and JT-LTS systems is to provide maximum heat recovery while remaining above the hydrate formation temperature plus a margin of 4°C (1°C for saturated feed)[1] at all points in the process. For those cases in which maximum heat integration is achieved, but the operating temperature remains above the hydrate temperature, a chiller will also be considered to increase total liquids recovery.

Figure 3.1 depicts the Twister process scheme without a chiller. The feed gas stream is cooled in the gas-gas exchanger by the cold gas stream from Twister and Hydrate Separator. A fraction of the feed gas is diverted to the gas-NGL exchanger to maximise heat integration where possible.

Liquids are removed in the Twister suction scrubber to maximise the efficiency of the Twister. After leaving the scrubber, the gas stream enters the Twister and expands to supersonic velocity in the Twister tube causing liquids drop out from the gas stream. The treated gas and the wetter gas from the Hydrate Separator are mixed and routed to the gas-gas exchanger to cool the feed stream. The Hydrate Separator, which is based on LTX technology, operates at approximately 3-5°C above the hydrate point at the bottom of the vessel to melt any hydrates. Cold liquid from the suction scrubber and Hydrate Separator may be used to cool the feed stream in the gas-NGL exchanger. The liquids from the suction scrubber may require heating against the feed stream to prevent hydrate formation downstream of the level control valve.

Figure 3.2 shows the process scheme 1 for the Twister with further cooling from propane refrigerant in an upstream chiller with an additional gas-gas exchanger for maximum heat recovery. Otherwise it is identical to the scheme depicted in Figure 3.1.

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[1] N.B. the accuracy of the Hysys hydrate prediction model is very good for water saturated gas but prediction is more difficult for low water contents so a greater margin is added.

Figures 3.3 and 3.4 are the equivalent schemes to Figures 3.1 and 3.2, each with Joule-Thomson valve and a low temperature separator in place of Twister and Hydrate Separator. Once again, these schemes employ a knockout drum upstream of the Joule-Thomson valve to remove liquids and maximise the temperature drop across the valve.

The schemes shown in Figures 3.1 to 3.4 are generic and minor modifications may have been made to optimise each case; for example, cross exchangers may be removed if the temperature approach is less than 5°C, the Hydrate Separator may be replaced by an LTS if the operating temperature is above the hydrate temperature plus margin at the combined liquid outlet stream, cases 3.2 and 3.4 also employ a knockout drum upstream of the propane chiller if the feed to the chiller contains a large quantity of liquid.

Figure 3.1 – Twister with a Gas-Gas Exchanger & Gas-NGL Exchanger

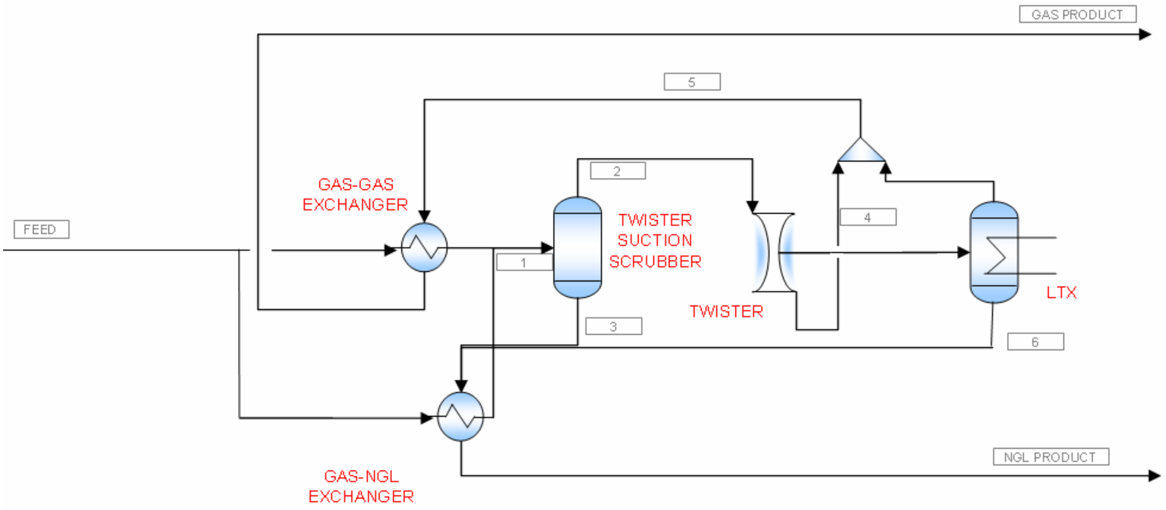


Figure 3.2 – Twister with Two Gas-Gas Exchangers, a Gas-NGL Exchanger and a Chiller

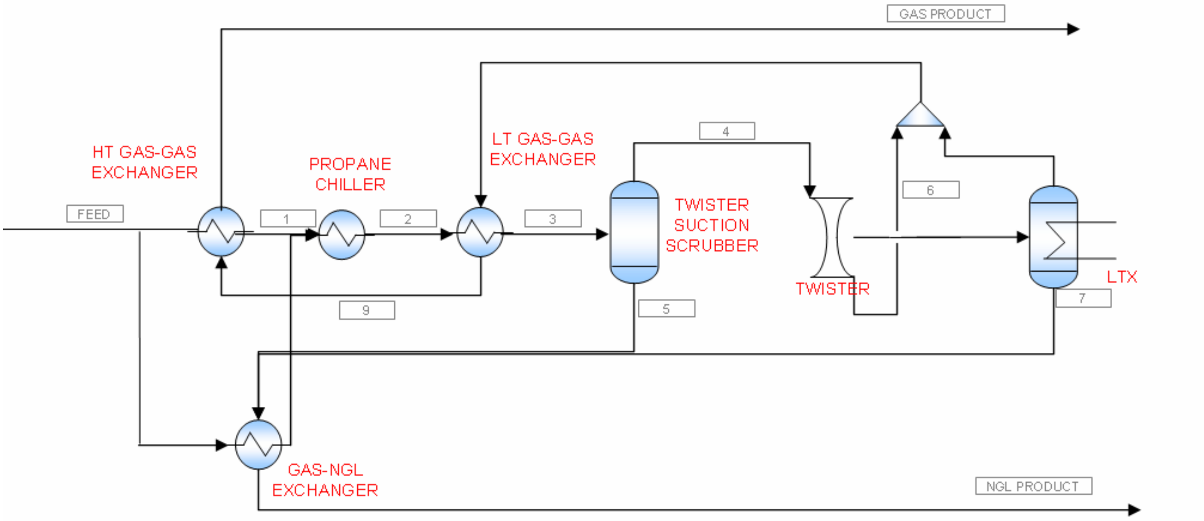


Figure 3.3 – JT with a Gas-Gas Exchanger and a Gas-NGL Exchanger

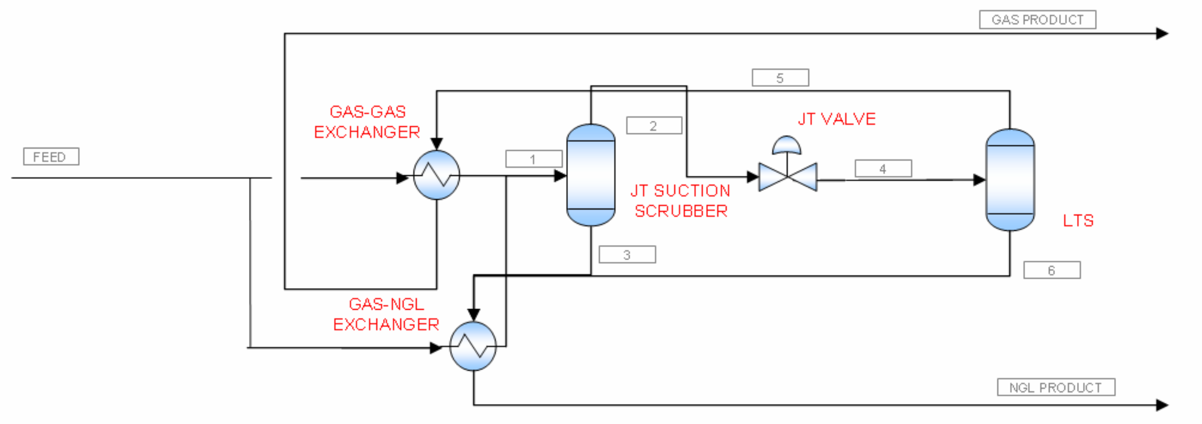
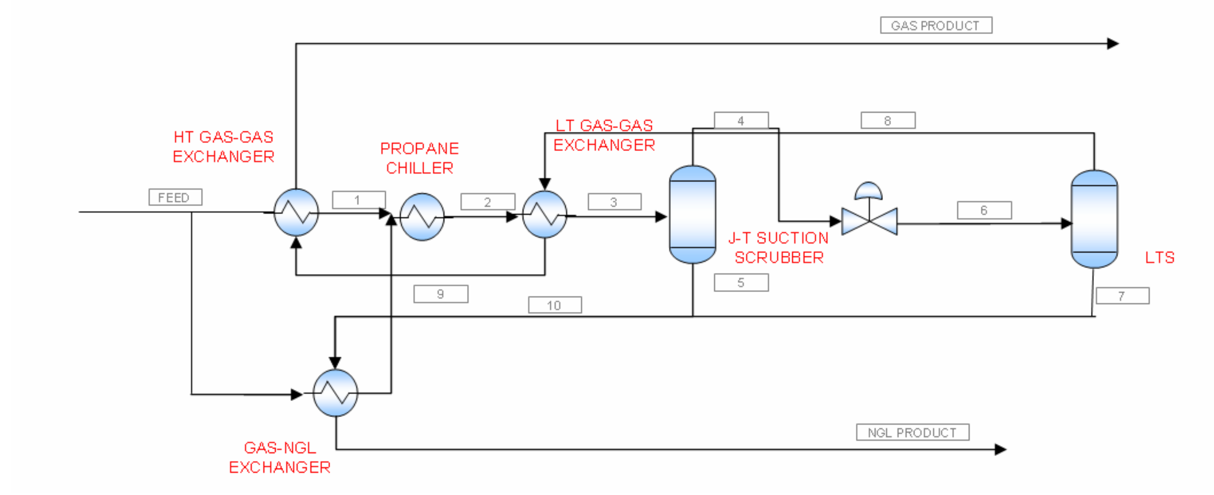


Figure 3.4 – JT with Two Gas-Gas Exchangers, a Gas-NGL Exchanger & a Chiller



4 RESULTS

4.1 Water Content

Figures 4.1 to 4.3 present the comparative results for feed conditions of 100barg and 35°C with a 45% pressure drop across the dewpointing system. Figure 4.1 shows the LPG recovery per MMscf of feed gas, Figure 4.2 shows the NGL production achieved and Figure 4.3 shows the recovery of C_{3+} as a percentage of the feed.

As the water content in the feed increases, the hydrate formation temperature rises and less heat integration is possible, this means that NGL recovery for the water saturated feed is far lower than for bone dry gas (without the use of chemicals). This has a greater impact on the JT system as the hydrate formation temperature limits the operating temperature in the LTS whereas the hydrate formation temperature only limits the Twister system at the inlet as hydrates do not form in the Twister tube due to the very short residence time and any hydrate formation in the secondary outlet of the Twister tube is managed in the Hydrate Separator. Moreover, the Twister tube has a near isentropic expansion whereas a JT valve has an isenthalpic (adiabatic) expansion. Therefore a Twister tube is able to expand deeper into the phase envelope to increase recovery.

The water saturation point on the X-axis of the figures has been moved for clarity; the actual saturation water content for the feed gas stream is 41lb of water / MMscf of gas.

Figure 4.1 – LPG Recovery versus Feed Water Content

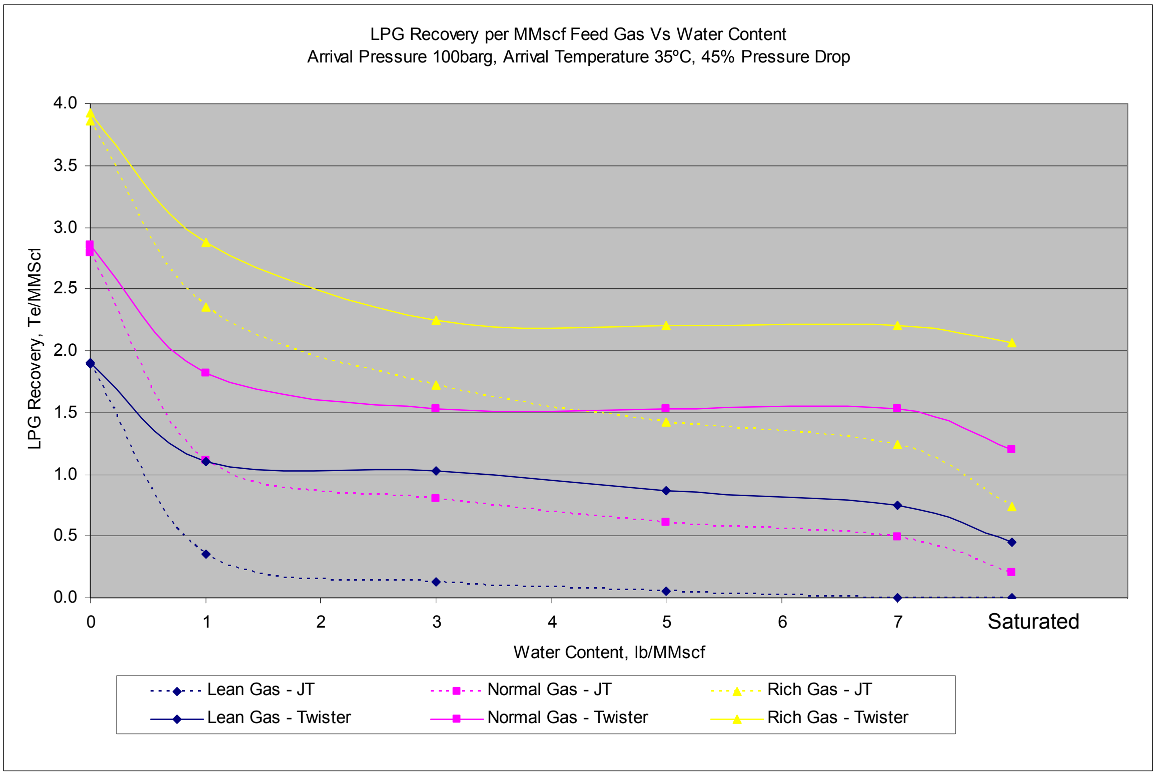


Figure 4.2 – NGL Recovery versus Feed Water Content

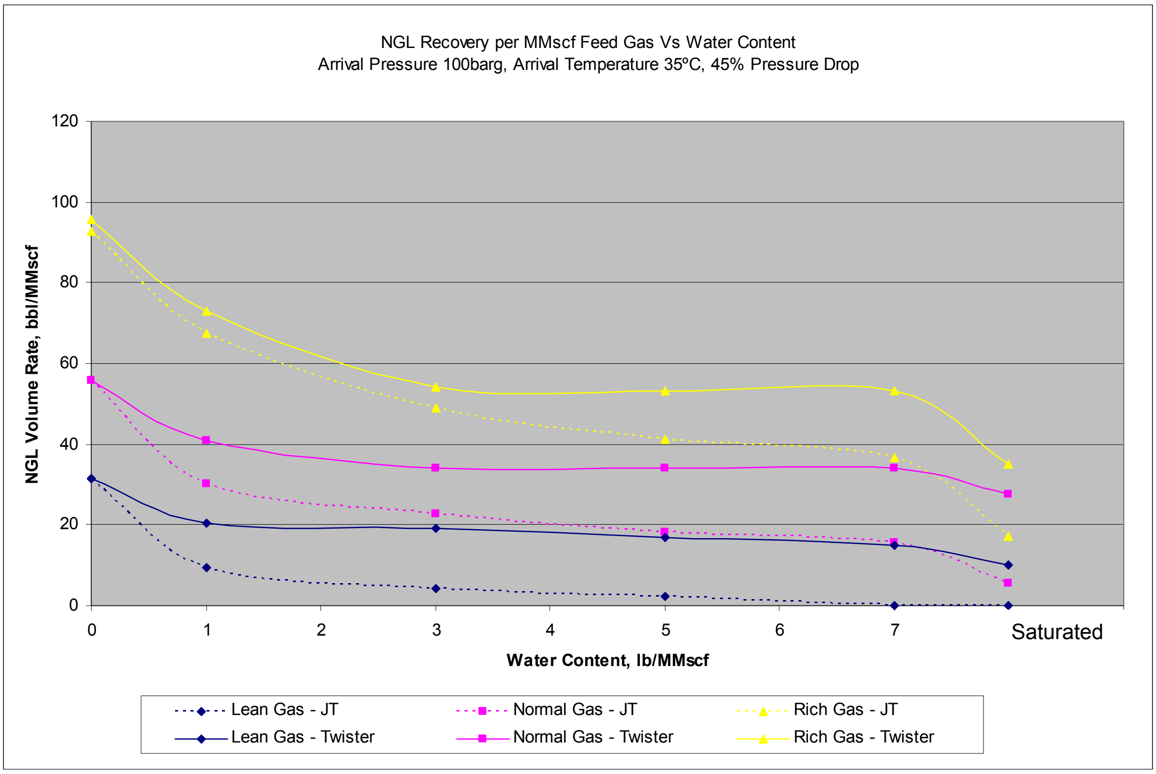


Figure 4.3 – C3+ Recovery versus Feed Water Content

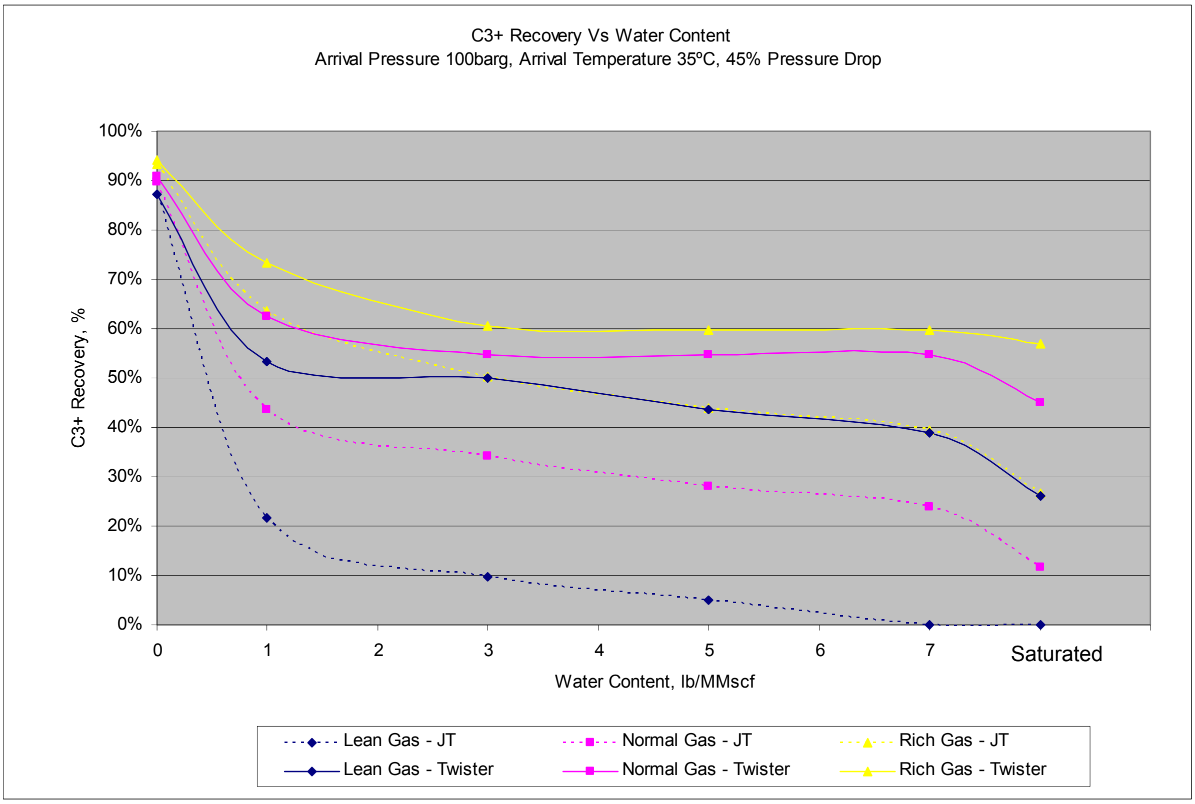


Figure 4.4 – C3+ Recovery versus Feed Water Content with Chiller

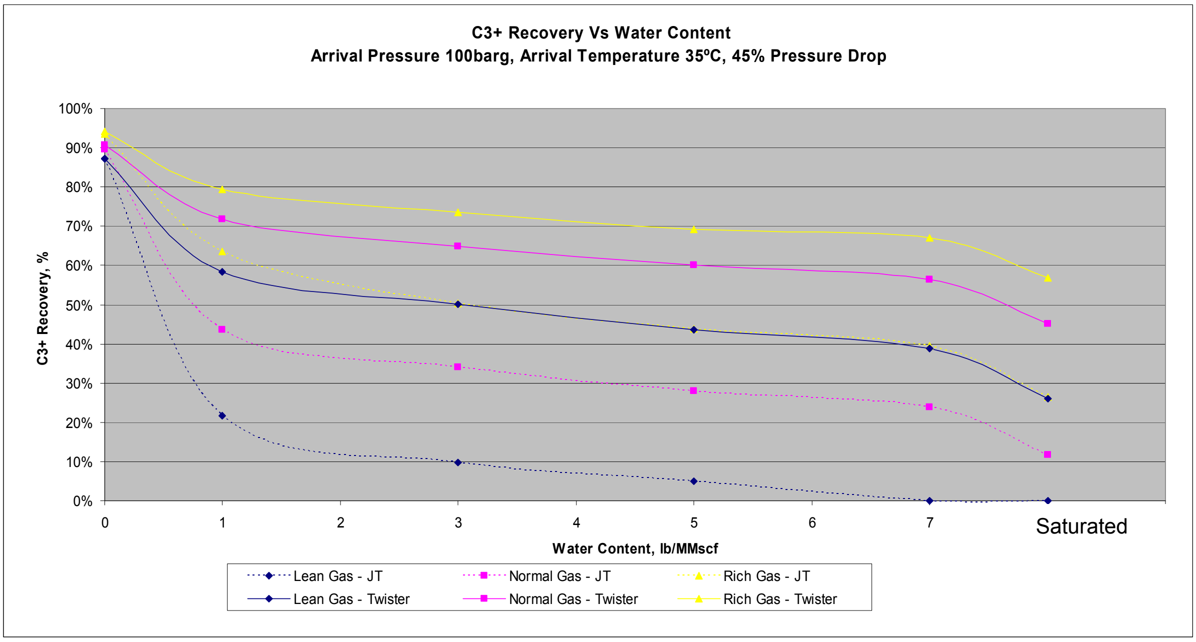


Figure 4.3 shows that the Twister scheme recovers around 30%-60% of the C3+ in the feed for saturated feed gas rising to around 50%-75% for low water content, where the hydrate temperature is lower and greater heat integration is possible. By comparison, the JT scheme recovers less than 25% of the C3+ in the feed for saturated feed gas, rising to around 20%-65% for low water content, and none at all from lean feed gas with the water content of 7lb water/MMscf or greater. The difference between the two is clearly illustrated by Figures 4.1 and 4.2, which show that LPG production with a Twister is typically 1 tonne/MMscf higher than with a JT and NGL recovery which is typically 15-20bbl/MMscf greater.

Figure 4.4 shows the additional recovery achievable from introducing an upstream propane chiller, as depicted in Figures 3.2 and 3.4. A comparison of Figure 4.4 with Figure 4.3 suggests that adding a chiller can increases the recovery of the Twister schemes with rich and normal gas compositions by around 10% but makes no difference for lean gas or for the JT schemes, which are already limited by temperature at the JT valve inlet.

4.2 Pressure Drop

Figures 4.5 to 4.7 present the comparative results for different pressure drops for feed conditions of 100barg and 35°C with a water content of 5lb/MMscf. Figure 4.5 shows the LPG recovery per MMscf of feed gas, Figure 4.6 shows the NGL production achieved and Figure 4.7 shows the recovery of C_{3+} as a percentage of the feed.

The JT system yields barely any condensate from the lean composition, even at a 45% pressure drop across the valve. The figures show that the JT scheme is relatively insensitive to pressure drop (provided sufficient pressure drop is available to achieve the minimum approach in the cross exchangers); the pressure drop available has more impact on the size of the cross exchangers.

Figure 4.5 – LPG Recovery versus Percentage Pressure Drop

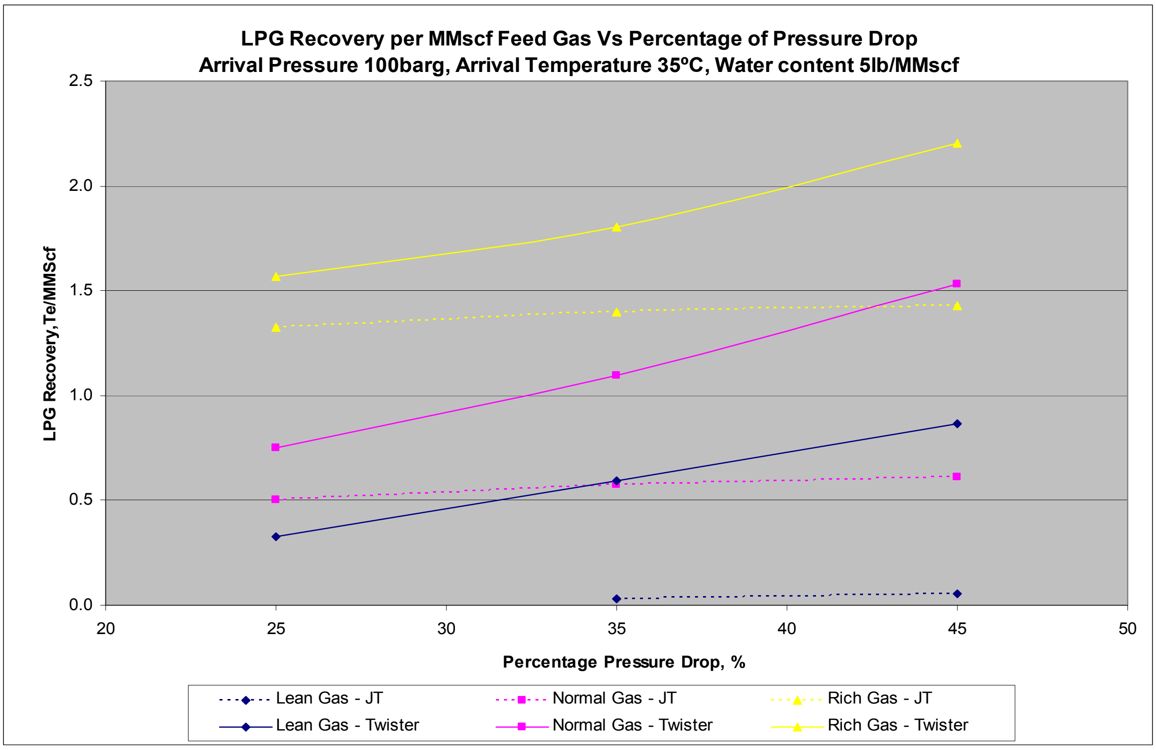


Figure 4.6 – NGL Recovery versus Percentage Pressure Drop

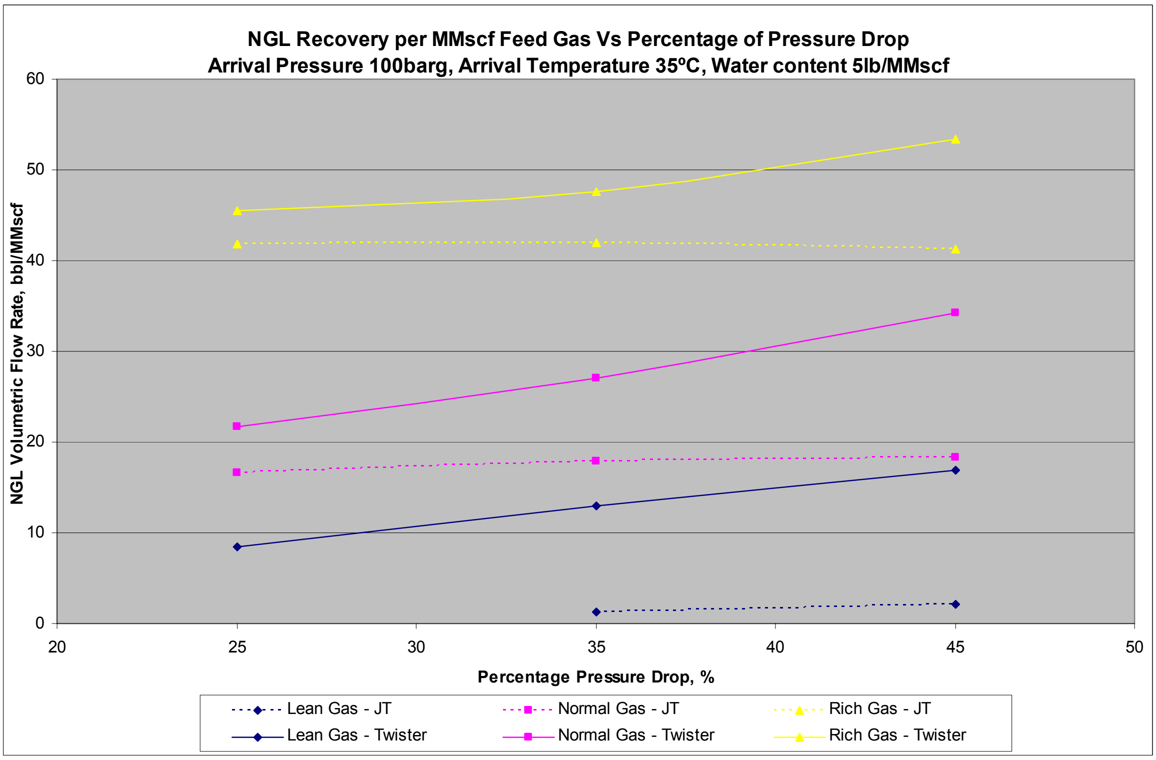
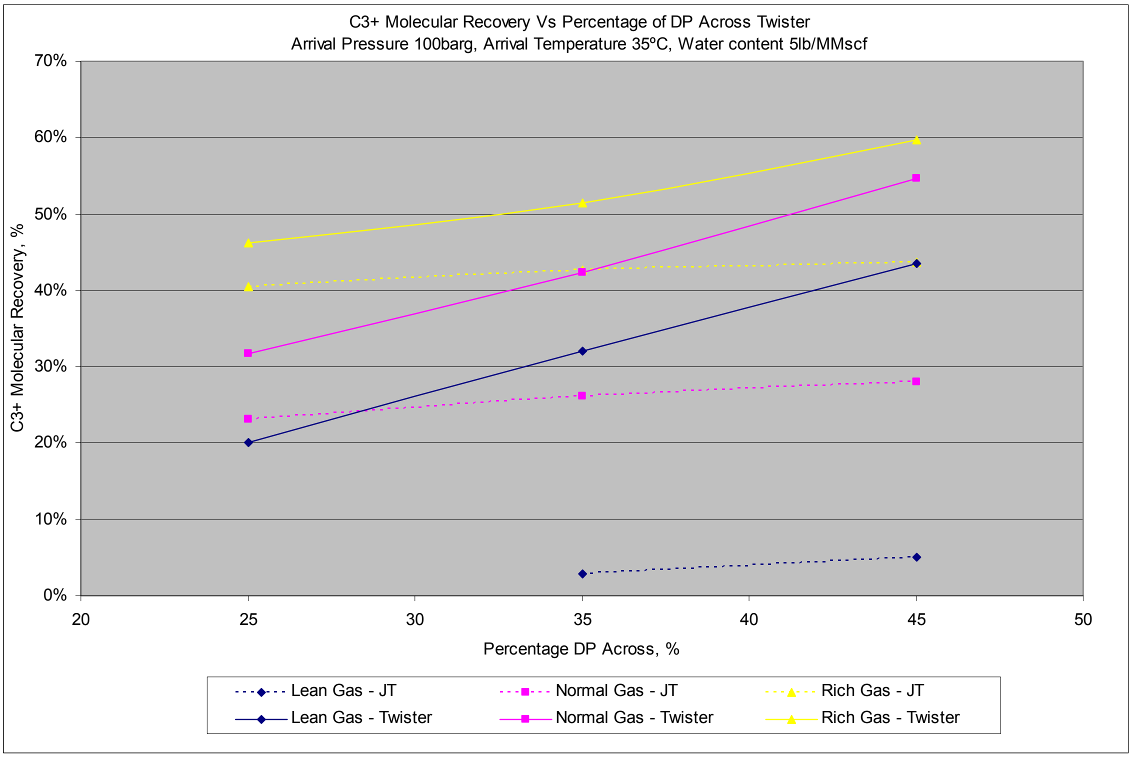


Figure 4.7 – C3+ Recovery versus Percentage Pressure Drop



As the Twister device is more efficient, the Twister results show a clear increase in recovery with increasing pressure drop. The results for Twister are consistently better than for a JT, for all compositions throughout the pressure drop range.

4.3 Feed Temperature

Figures 4.8 to 4.10 present the comparative results for different feed temperatures for a feed pressure of 100barg with a water content of 5lb/MMscf and a pressure drop of 45% across the device. Figure 4.8 shows the LPG recovery per MMscf of feed gas, Figure 4.9 shows the NGL production achieved and Figure 4.10 shows the recovery of C_{3+} as a percentage of the feed.

As one might expect, the arrival temperature does not have a great effect on condensate recovery, more so on the upstream exchanger duties. However, the Twister cases are not all limited by heat integration and some improvement in recovery can be seen at reduced feed temperatures.

Once again, the Twister scheme results show markedly better recovery for all cases, especially for lean gas where the improvement in recovery is nine-fold, 17bbl/MMscf versus 2bbl/MMscf for a JT and 44% recovery versus 5% for a JT.

Figure 4.8 – LPG Recovery versus Feed Temperature

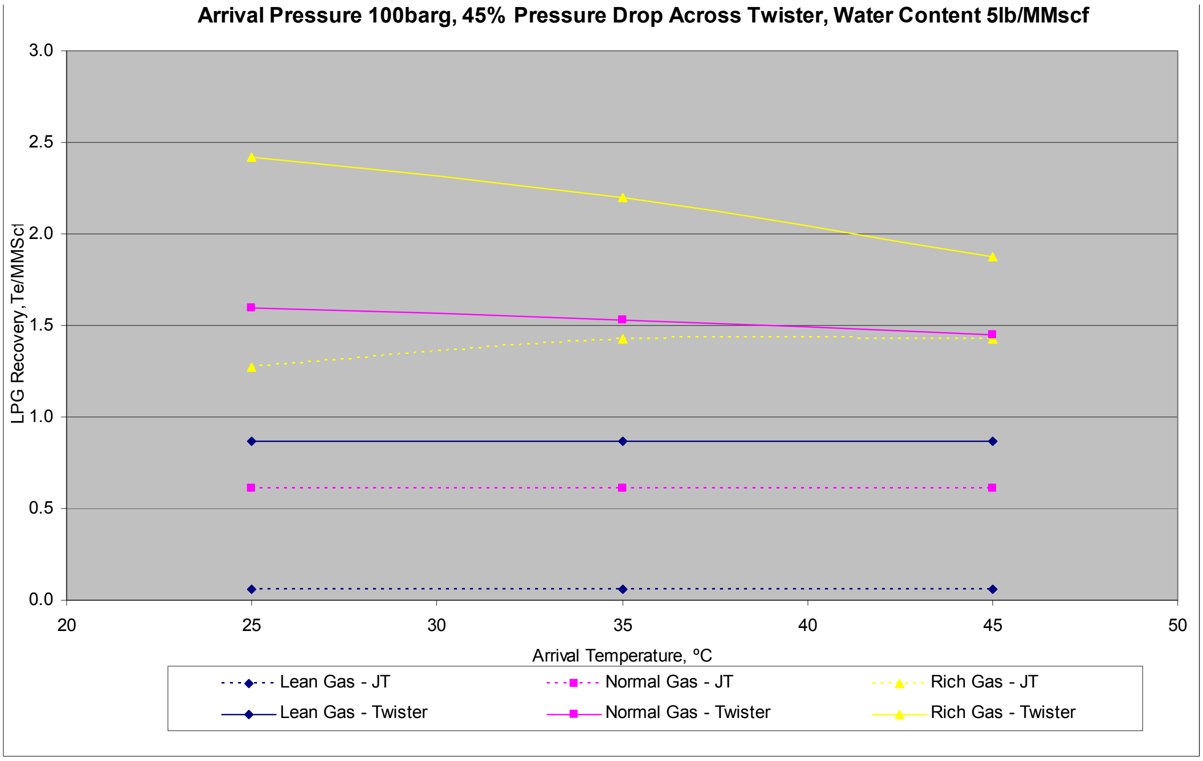


Figure 4.9 – NGL Recovery versus Feed Temperature

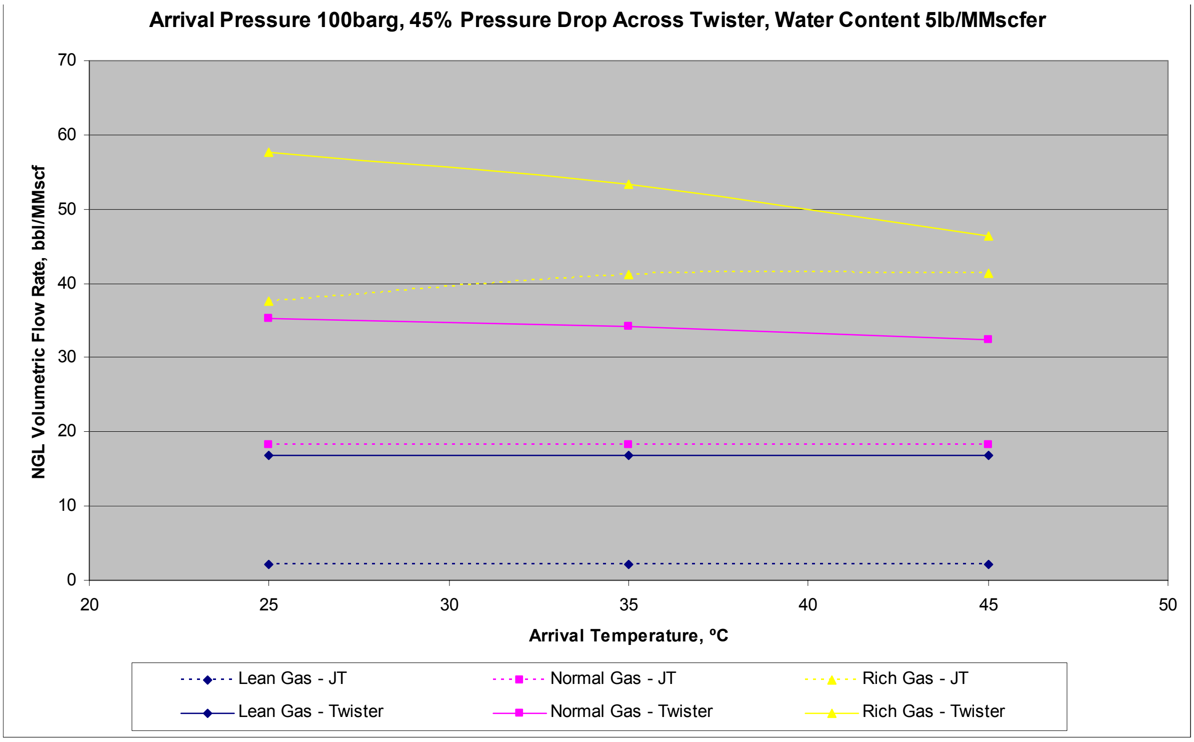
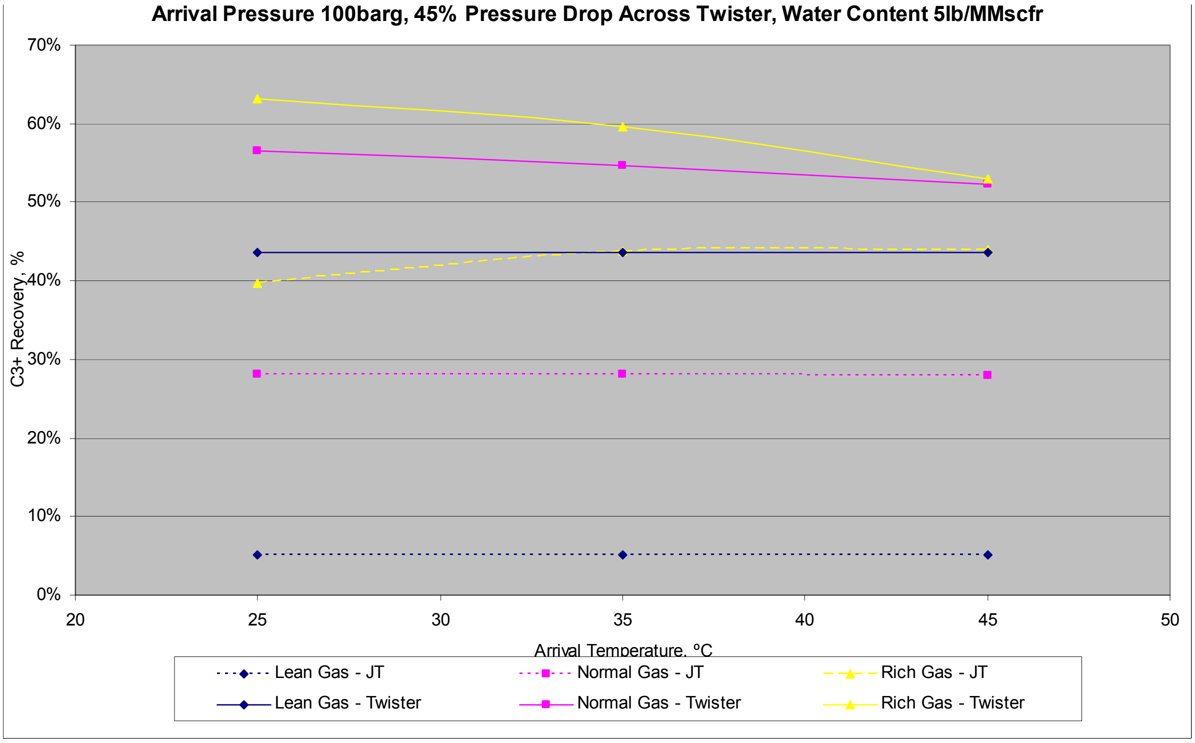


Figure 4.10 – C3+ Recovery versus Feed Temperature



4.4 Feed Gas Composition

Figures 4.11 to 4.13 present the comparative results for different feed compositions for feed conditions of 100barg and 35°C with a water content of 5lb/MMscf and a pressure drop of 45% across the device. Figure 4.11 shows the LPG recovery per MMscf of feed gas, Figure 4.12 shows the NGL production achieved and Figure 4.13 shows the recovery of C_{3+} as a percentage of the feed.

Once again, the Twister scheme results show markedly better recovery for all cases, with the JT scheme producing barely any liquids for the lean composition and the Twister scheme consistently producing around 1 tonne/MMscf more than the JT scheme in Figure 4.11 and around 15bbl/MMscf more in Figure 4.12. With the lower molecular weight ‘lean’ gas there is limited heat recovery in the cross exchangers and little or no liquid knock out in the scrubber and LTS.

Figure 4.11 – LPG Recovery versus Feed Gas Composition

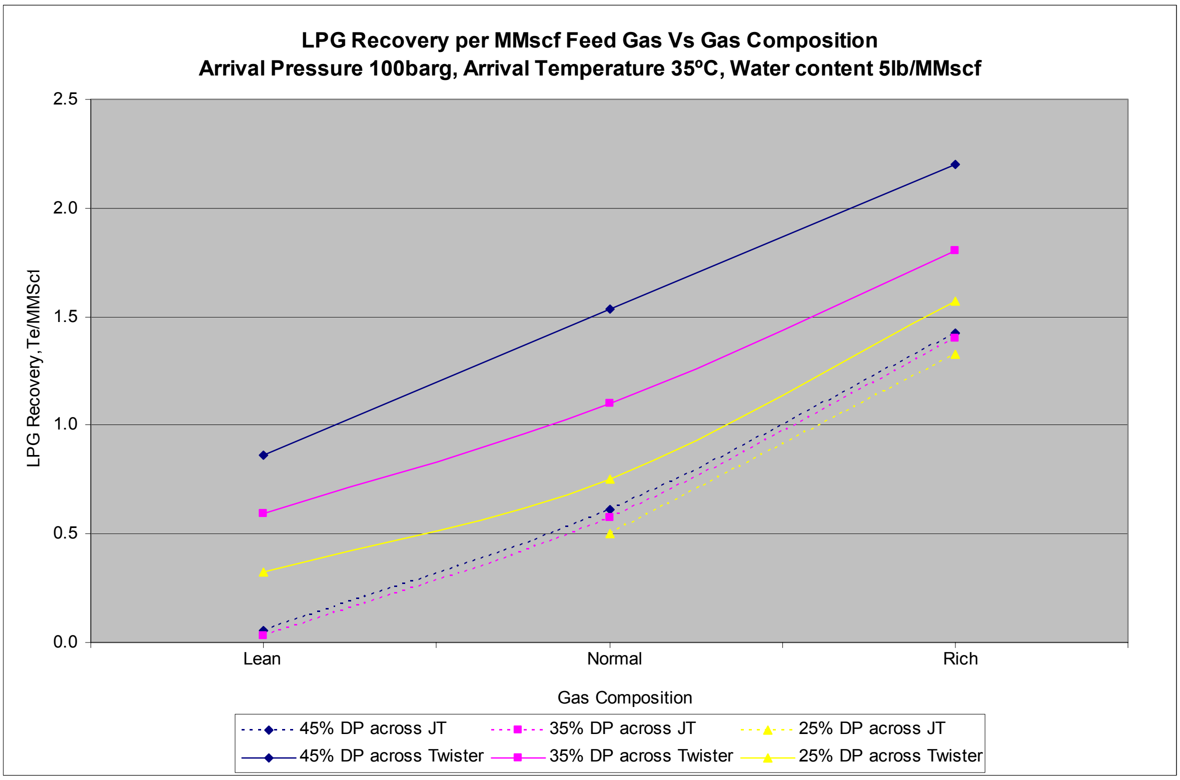


Figure 4.12 – NGL Recovery versus Feed Gas Composition

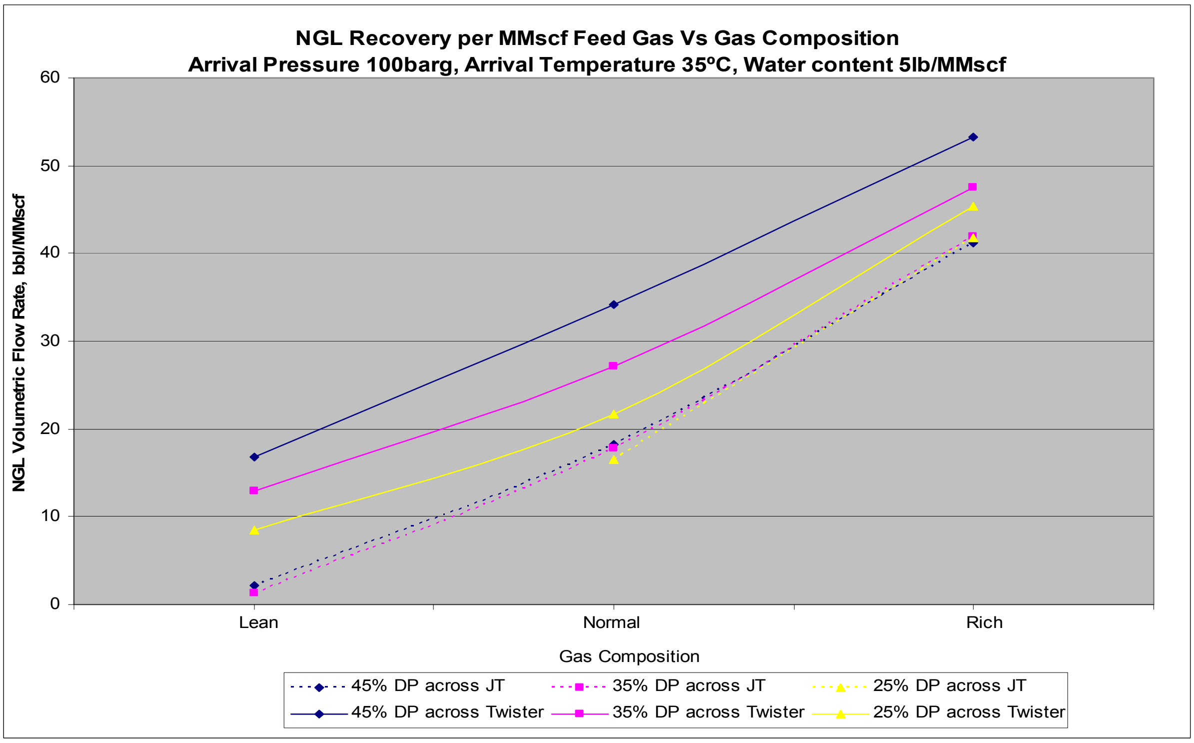
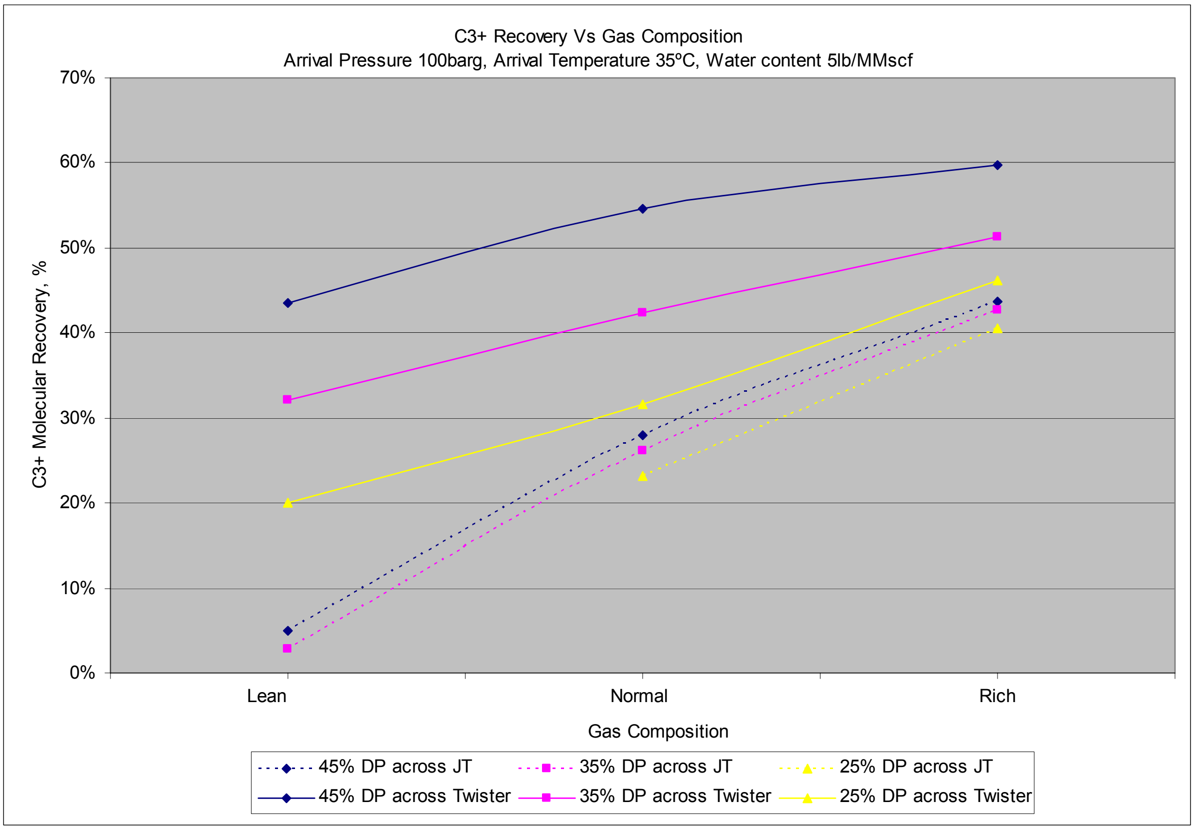


Figure 4.13 – C3+ Recovery % versus Feed Gas Composition



4.5 Feed Pressure

Figures 4.14 and 4.15 present the comparative results for different feed compositions for feed conditions of 40barg and 25°C with a water content of 5lb/MMscf and pressure drops of 25% and 45% across the device. Figures 4.16 and 4.17 present similar results feed pressures of 70barg and 100barg with an arrival temperature of 35°C, a water content of 5lb/MMscf and a pressure drop of 45% across the device.

The 40barg simulations were selected to benchmark the results, rather than as a typical pressure for either Twister or JT expansion. At 40barg and low feed temperature, there is little difference between the performance of the Twister and the JT valve with the difference between the two remaining less than 5bbl/MMScf NGL recovery for different feed compositions and pressure drops. For these cases, the Twister outlet temperature is similar to the feed temperature and the potential for heat integration is limited. The isentropic expansion of Twister will generate more liquids inside the Twister tube than a JT. However, the amount of liquids which have been formed is too small to saturate the secondary gas stream. Therefore no liquids will be produced form the Hydrate Separator which in turn has a negative impact on the heat integration potential.

The results of the 70barg simulations show that, although the NGL recovery performance of the Twister is poorer at 70barg than at 100barg (by around 10bbl/MMscf from Figure 4.17), it remains consistently better than the performance of the equivalent JT scheme (by around 5-10bbl/MMscf).

Figure 4.14 – NGL Recovery vs Feed Gas Composition – 40bar Feed

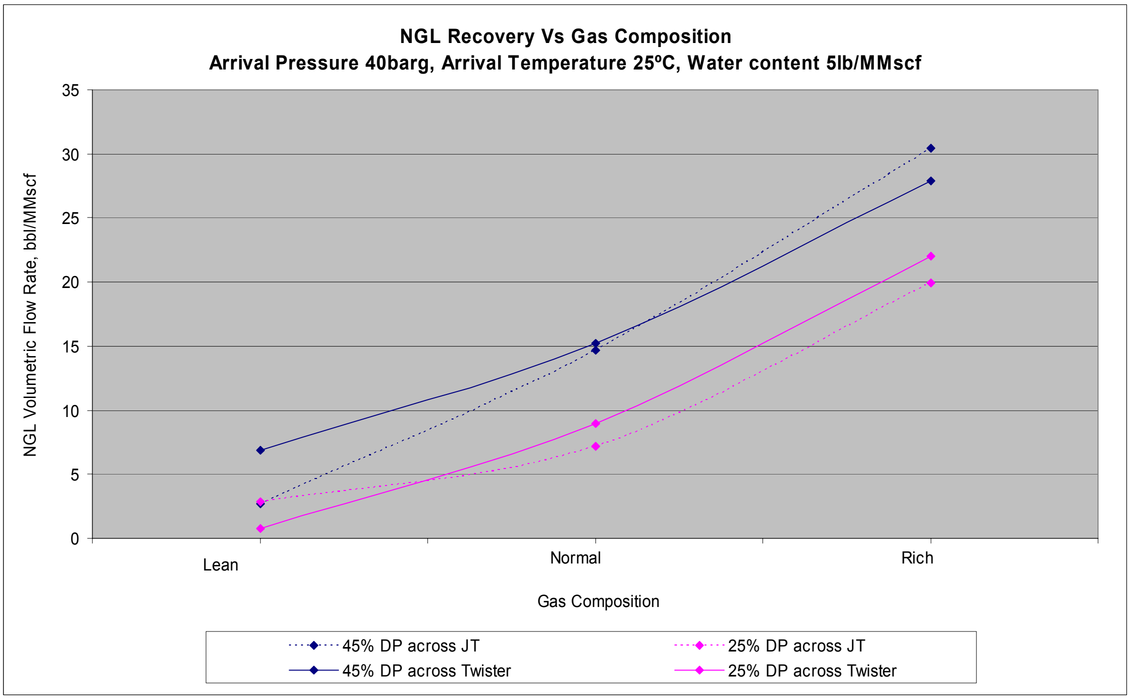


Figure 4.15 – C3+ Recovery % versus Feed Gas Composition – 40bar Feed

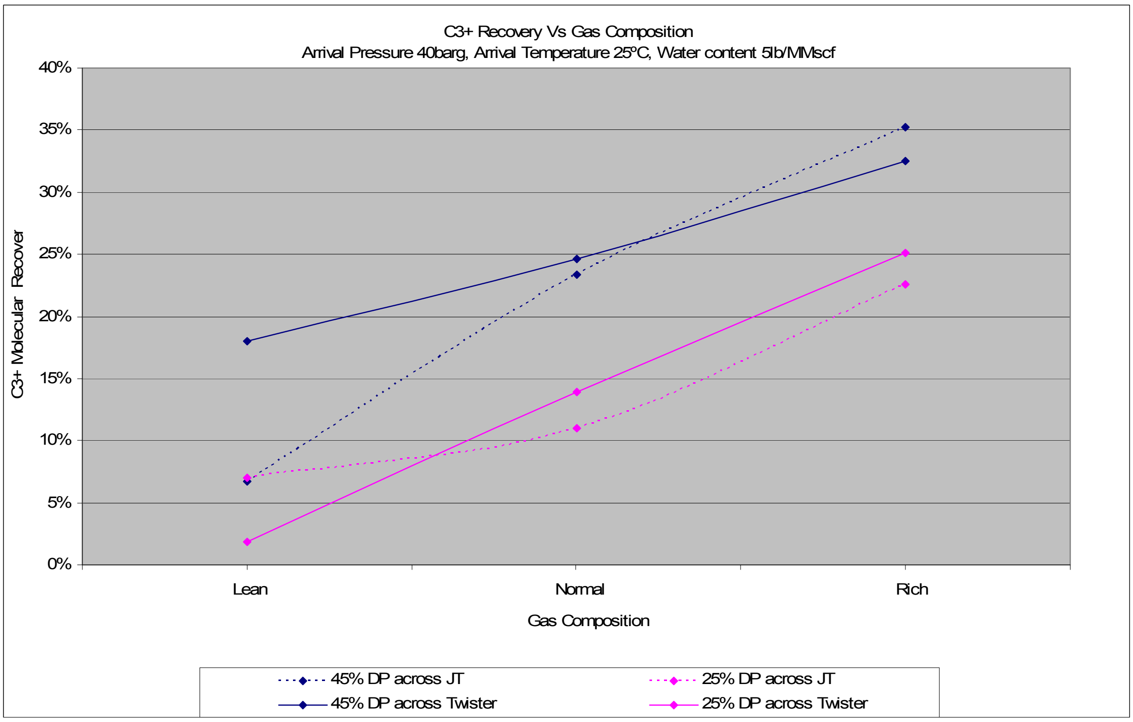


Figure 4.16– NGL Recovery versus Feed Gas Composition – 70 & 100bar

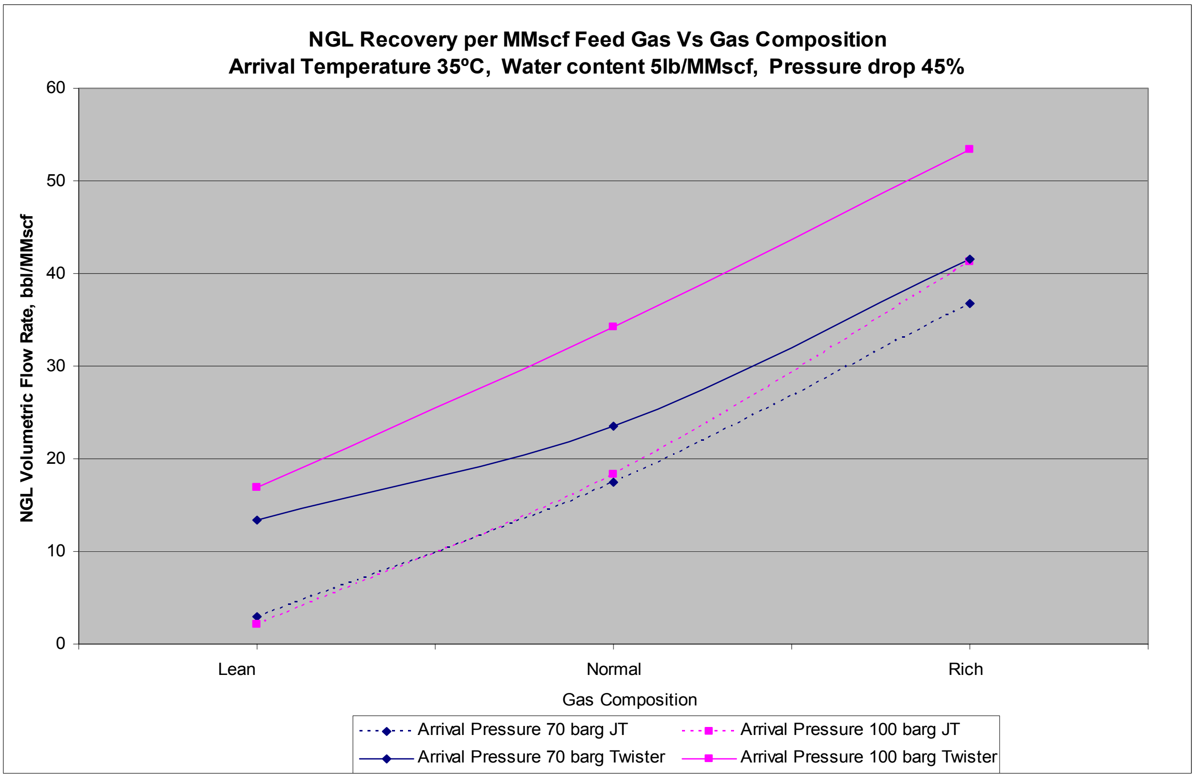
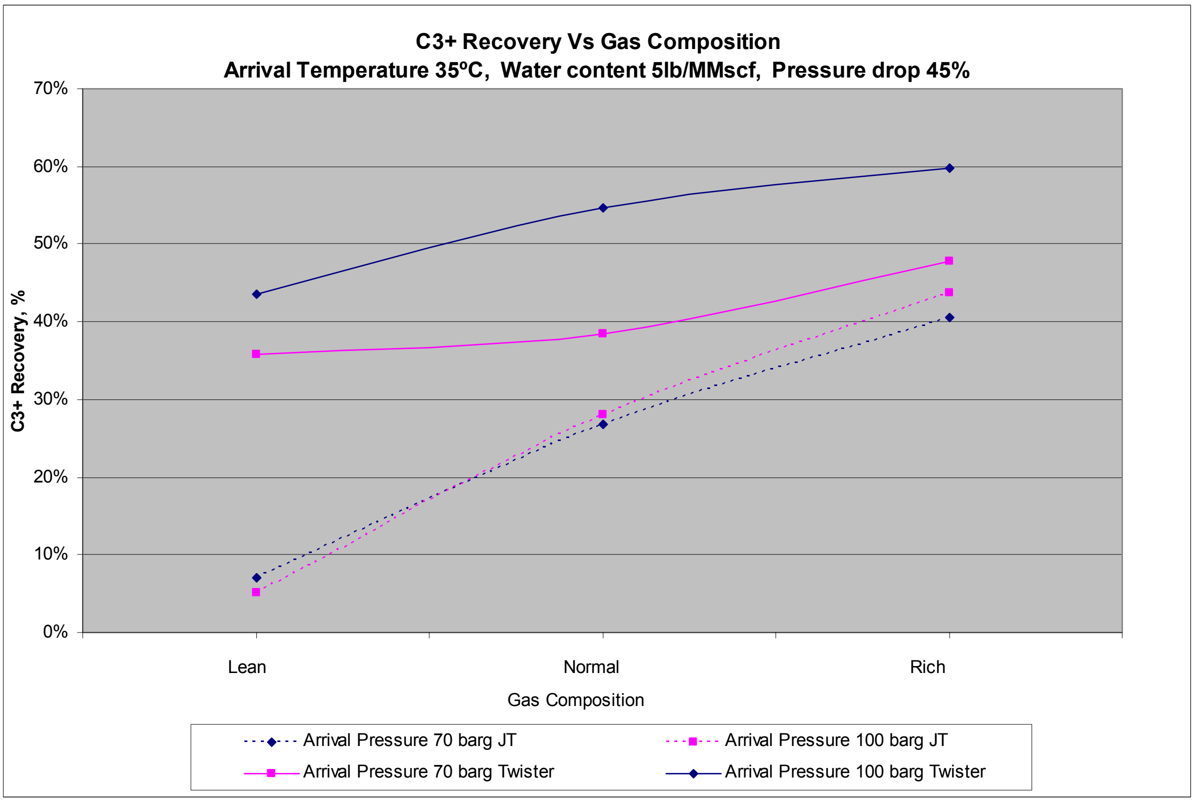


Figure 4.17 – C3+ Recovery % versus Feed Gas composition – 70 and 100barg



5 CONCLUSIONS

The Twister scheme has been shown to produce greater quantities of NGL and LPG than the conventional JT scheme consistently over the range of compositions, feed conditions, pressure drops and upstream dehydration specifications studied. The Twister scheme has also been shown to have a wider operating envelope than the JT scheme.

The improvement in performance is especially great at higher feed pressures and for leaner feed gas.

With a feed pressure of 100bar and downstream pressures of 55-75bar the improvement is typically around 0.8-1.0 tonnes/MMscf more LPG and 15-20bbl/MMscf greater NGL recovery.

With a feed pressure of 70bar and downstream pressures of 40-50bar the improvement is typically around 0.4-0.6 tonnes/MMscf more LPG and 5-10bbl/MMscf greater NGL recovery.

At low feed pressures the benefit of Twister (without chiller) over a JT is eroded as the higher outlet temperature affords only limited heat integration. At a feed pressure of 40bar and downstream pressures of 20-30bar, when expansion is inefficient as outlet pressure is below the cricondentherm pressure, the NGL yields of the two processes are similar.

For lean gas (mol. weight of 19), the recovery with Twister is typically five to ten times as great as with the conventional JT scheme, with the JT recovery only approaching the recovery achieved by Twister when the feed water content is very low. This compares with Twister recoveries of around double the JT recovery for a mean composition (mol. weight of 20.5) and 150% of the JT recovery for rich compositions (mol. weight of 22), again with the difference reducing for very low water content.

APPENDIX ‘A’ – TABULATED RESULTS FROM SECTION 4.0

Summary of LPG, NGL and C3+ Molar Recovery with Different Water Contents

		Twister System			JT-LTS					
Water Content, lb/MMscf	Gas Type	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery Factor: Relative to JT-LTS	NGL Recovery Factor: Relative to JT-LTS	C3+ Recovery Factor: Relative to JT-LTS
0	Lean	1.91	31.37	87%	1.90	31.35	87%	1.0	1.0	1.0
1	Lean	1.10	20.51	53%	0.35	9.29	22%	3.2	2.2	2.5
3	Lean	1.02	19.26	50%	0.13	4.14	10%	8.2	4.7	5.1
5	Lean	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
7	Lean	0.75	15.05	39%	-	-	-	-	-	-
Saturated	Lean	0.45	10.09	26%	-	-	-	-	-	-
0	Normal	2.86	55.78	91%	2.79	55.64	90%	1.0	1.0	1.0
1	Normal	1.82	40.91	63%	1.11	30.27	44%	1.6	1.4	1.4
3	Normal	1.53	34.20	55%	0.80	22.77	34%	1.9	1.5	1.6
5	Normal	1.53	34.20	55%	0.61	18.30	28%	2.5	1.9	2.0
7	Normal	1.53	34.11	55%	0.50	15.55	24%	3.1	2.2	2.3
Saturated	Normal	1.20	27.53	45%	0.20	5.54	12%	6.0	5.0	3.9
0	Rich	3.92	89.34	94%	3.86	92.73	93%	1.0	1.0	1.0
1	Rich	2.88	72.84	73%	2.36	67.51	64%	1.2	1.1	1.2
3	Rich	2.24	54.22	61%	1.73	48.94	50%	1.3	1.1	1.2
5	Rich	2.20	53.32	60%	1.43	41.21	44%	1.5	1.3	1.4
7	Rich	2.20	53.25	60%	1.24	36.64	39%	1.8	1.5	1.5
Saturated	Rich	2.06	35.08	57%	0.73	17.12	27%	2.8	2.0	2.1

Summary of LPG, NGL and C3+ Molar Recovery with Different Pressure Drops

		Twister System			JT-LTS					
DP across Device, %	Gas Type	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery Factor: Relative to JT-LTS	NGL Recovery Factor: Relative to JT-LTS	C3+ Recovery Factor: Relative to JT-LTS
25	Lean	0.33	8.46	20%	-	-	-	-	-	-
35	Lean	0.60	12.91	32%	0.03	1.24	3%	18.5	10.4	11.4
45	Lean	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
25	Normal	0.75	21.63	32%	0.50	16.58	23%	1.5	1.3	1.4
35	Normal	1.10	27.11	42%	0.57	17.82	26%	1.9	1.5	1.6
45	Normal	1.53	34.20	55%	0.61	18.30	28%	2.5	1.9	2.0
25	Rich	1.57	45.43	46%	1.33	41.81	40%	1.2	1.1	1.1
35	Rich	1.81	47.58	51%	1.40	41.97	43%	1.3	1.1	1.2
45	Rich	2.20	53.32	60%	1.43	41.21	44%	1.5	1.3	1.4

Summary of LPG, NGL and C3+ % Recovery with Different Feed Temperatures

		Twister System			JT-LTS					
Arrival Temperature, C	Gas Type	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery Factor: Relative to JT-LTS	NGL Recovery Factor: Relativeve to JT-LTS	C3+ Recovery Factor: Relative to JT-LTS
25	Lean	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
35	Lean	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
45	Lean	0.87	16.87	44%	0.06	2.14	5%	15.2	7.9	8.7
25	Normal	1.60	35.34	56%	0.61	18.30	28%	2.6	1.9	2.0
35	Normal	1.53	34.20	55%	0.61	18.30	28%	2.5	1.9	2.0
45	Normal	1.45	32.48	52%	0.61	18.29	28%	2.4	1.8	1.9
25	Rich	2.42	57.64	63%	1.27	37.52	40%	1.9	1.5	1.6
35	Rich	2.20	53.32	60%	1.43	41.21	44%	1.5	1.3	1.4
45	Rich	1.87	46.30	53%	1.43	41.32	44%	1.3	1.1	1.2

Summary of LPG, NGL and C3+ % Recovery with Different Feed Compositions

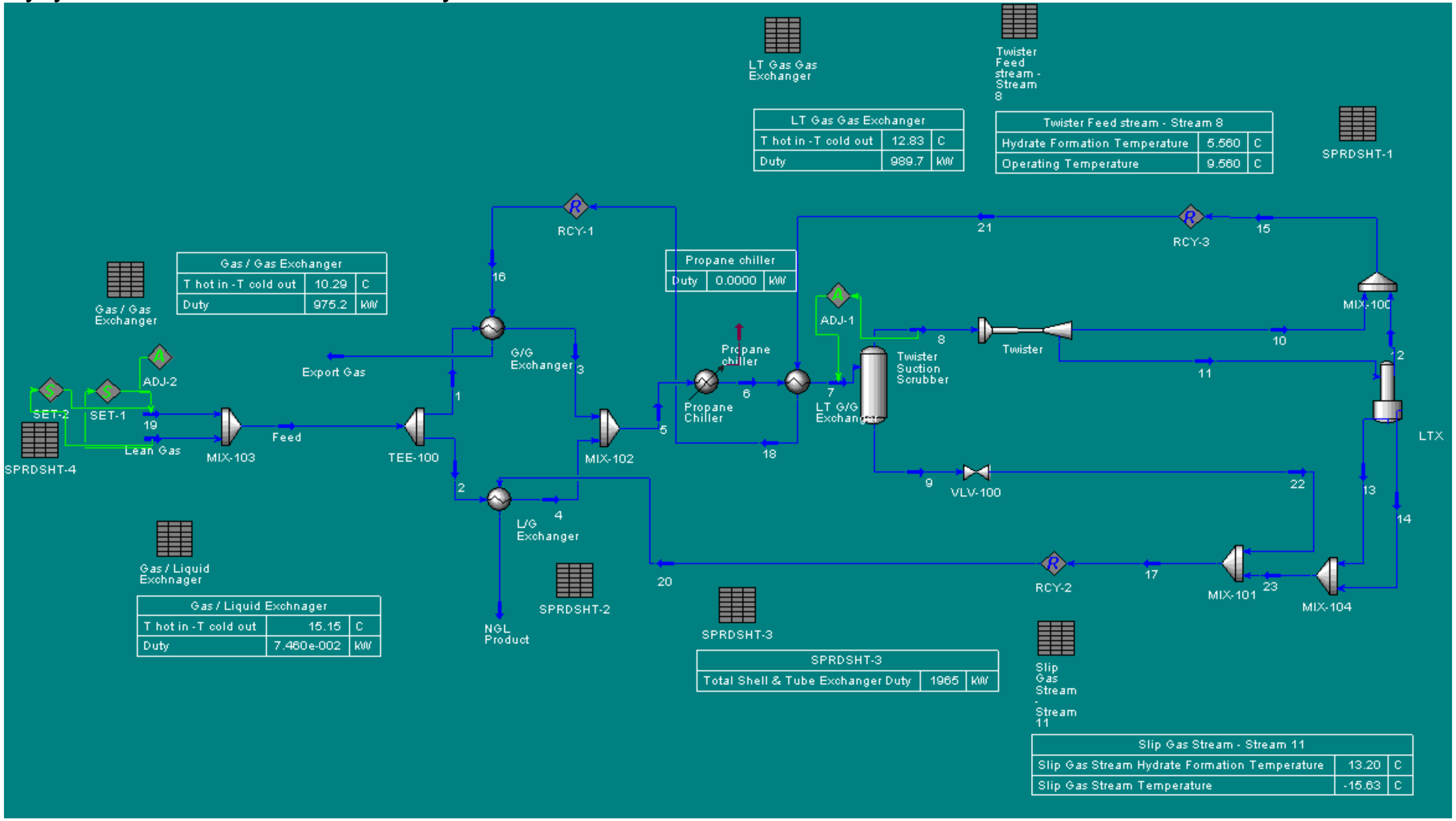
		Twister System			JT-LTS					
Gas Type	DP across Device , %	LPG Recovery , e/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery , te/MMscf	NGL Recovery, bbl/MMscf	C3+ Recovery, mol%	LPG Recovery Factor: Relative to JT-LTS	NGL Recovery Factor: Relativeve to JT-LTS	C3+ Recovery Factor: Relative to JT-LTS
Lean	45	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
Lean	35	0.60	12.91	32%	0.03	1.24	3%	18.5	10.4	11.4
Lean	25	0.33	8.46	20%	-	-	-	-	-	-
Normal	45	1.53	34.20	55%	0.61	18.30	28%	2.5	1.9	2.0
Normal	35	1.10	27.11	42%	0.57	17.82	26%	1.9	1.5	1.6
Normal	25	0.75	21.63	32%	0.50	16.58	23%	1.5	1.3	1.4
Rich	45	2.20	53.32	60%	1.43	41.21	44%	1.5	1.3	1.4
Rich	35	1.81	47.58	51%	1.40	41.97	43%	1.3	1.1	1.2
Rich	25	1.57	45.43	46%	1.33	41.81	40%	1.2	1.1	1.1

Summary of LPG, NGL and C3+ Molar Recovery with Different Feed Pressures

		Twister system			JT-LTS System					
	Arrival Pressure, barg	Total LPG Recovery, te/MMscf	NGL Vol Rate, bbl/MMscf	C3+ NGL Molar recovery, %	Total LPG Recovery, te/MMscf	NGL Vol Rate, bbl/MMscf	C3+ NGL Molar recovery, %	LPG Recovery Factor: Relative to JT-LTS	NGL Recovery Factor: Relativeve to JT-LTS	C3+ Recovery Factor: Relative to JT-LTS
Lean	100	0.86	16.85	44%	0.06	2.14	5%	15.2	7.9	8.7
Normal	100	1.53	34.20	55%	0.61	18.30	28%	2.5	1.9	2.0
Rich	100	2.20	53.32	60%	1.43	41.21	44%	1.5	1.3	1.4
Lean	70	0.67	13.34	36%	0.08	2.90	7%	8.9	4.6	5.1
Normal	70	0.92	23.57	38%	0.54	17.46	27%	1.7	1.4	1.4
Rich	70	1.60	41.48	48%	1.25	36.69	41%	1.3	1.1	1.2

APPENDIX ‘B’ HYSYS PFDS

Hysys simulation PFD for Twister system



LT Gas Gas Exchanger		
T hot in -T cold out	12.83	C
Duty	989.7	kW

Twister Feed stream - Stream 8		
Hydrate Formation Temperature	5.560	C
Operating Temperature	9.560	C

Gas / Gas Exchanger		
T hot in -T cold out	10.29	C
Duty	975.2	kW

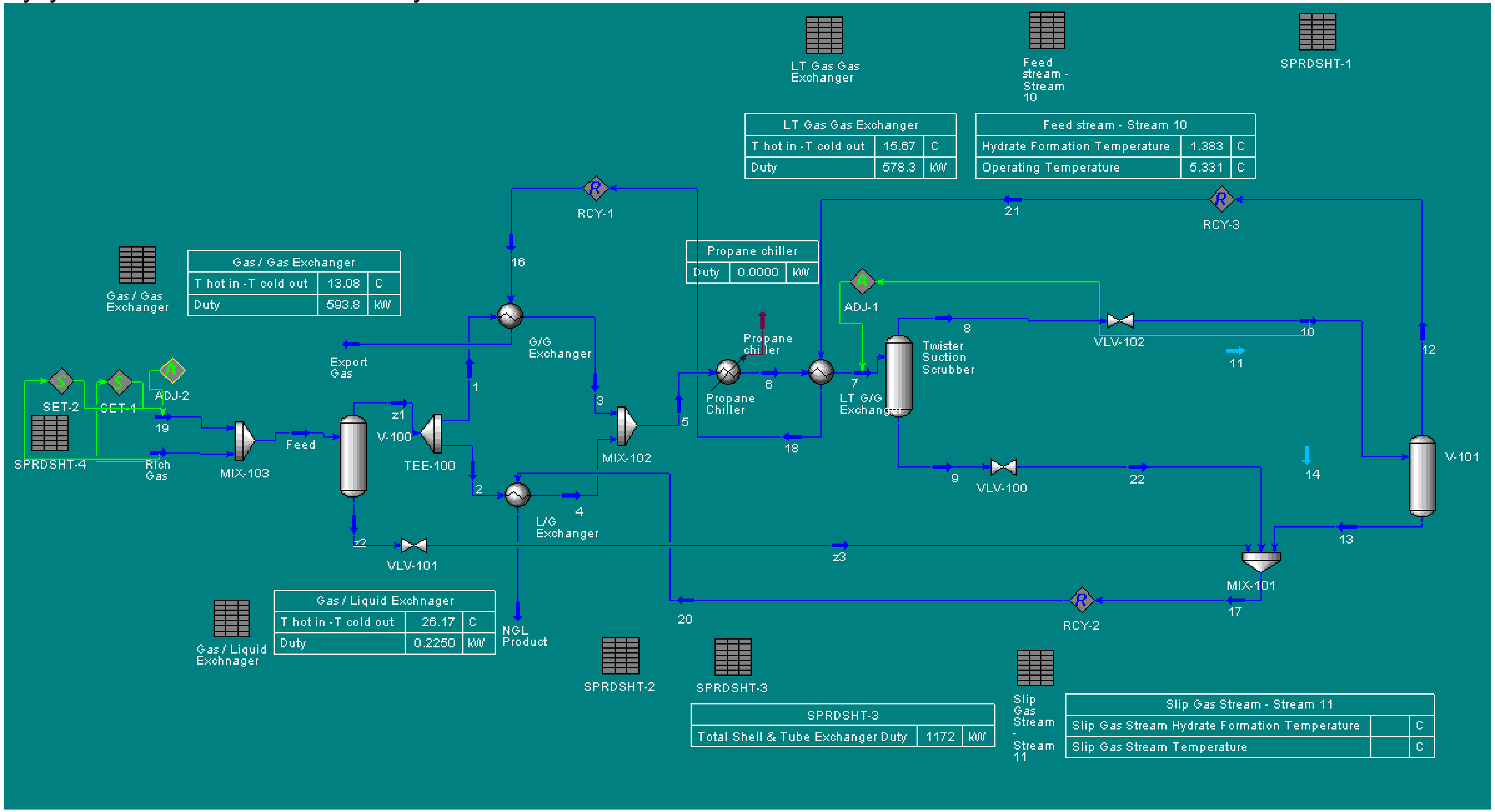
Propane chiller		
Duty	0.0000	kW

Gas / Liquid Exchnager		
T hot in -T cold out	15.15	C
Duty	7.460e-002	kW

SPRDSHT-3		
Total Shell & Tube Exchanger Duty	1965	kW

Slip Gas Stream - Stream 11		
Slip Gas Stream Hydrate Formation Temperature	13.20	C
Slip Gas Stream Temperature	-15.63	C

Hysys simulation PFD for JT-LTS system



LT Gas Gas Exchanger		
T hot in - T cold out	15.67	C
Duty	578.3	kW

Feed stream - Stream 10		
Hydrate Formation Temperature	1.383	C
Operating Temperature	5.331	C

Gas / Gas Exchanger		
T hot in - T cold out	13.08	C
Duty	593.8	kW

Propane chiller		
Duty	0.0000	kW

Gas / Liquid Exchnager		
T hot in - T cold out	26.17	C
Duty	0.2250	kW

SPRDSHT-3		
Total Shell & Tube Exchanger Duty	1172	kW

Slip Gas Stream - Stream 11		
Slip Gas Stream Hydrate Formation Temperature		C
Slip Gas Stream Temperature		C

APPENDIX ‘C’ – FULL TABULATION OF SIMULATION RESULTS

Simulation results for JT-LTS system without chiller

Option	Water Content, lb/MMscf	Composition	DP across Twister, %	Arrival Pressure, barg	Arrival Temperature	LPG Recovery (C3 & C4)	C5+ Recovery	C3+ Recovery (NGL)	Total LPG Recovery	NGL Vol Rate	Total Heat Exchangers Duty	C3+ Recovery	Inlet temp to JT	Outlet temp from JT
1	saturated	L	45	100	35	0%	0%	0%	0te/MMscf	0	0KW/ MMscf	0.0%	35.0C	17.7C
2	saturated	N	45	100	35	6%	36%	15%	0.2te/MMscf	5.5bbl/MMscf	0.0KW/MMscf	11.7%	35.0C	18.3C
3	saturated	R	45	100	35	18%	60%	32%	0.7te/MMscf	17.1bbl/MMscf	0.0KW/MMscf	26.5%	35.0C	18.3C
4	7	L	45	100	35	-	-	-	-	-	-	-	-	-
5	7	N	45	100	35	16%	61%	29%	0.5te/MMscf	15.5bbl/MMscf	9.4KW/MMscf	23.9%	23.5C	5.3C
6	7	R	45	100	35	30%	77%	46%	1.2te/MMscf	36.6bbl/MMscf	11.7KW/MMscf	39.5%	23.4C	5.3C
7	5	L	45	100	25	3%	23%	7%	0.1te/MMscf	2.1bbl/MMscf	2.1KW/MMscf	5.0%	21.7C	1.3C
8	5	N	35	100	25	18%	62%	31%	0.6te/MMscf	17.9bbl/MMscf	7.4KW/MMscf	26.2%	16.3C	2.5C
9	5	N	45	100	25	19%	67%	34%	0.6te/MMscf	18.3bbl/MMscf	4.4KW/MMscf	28.0%	19.5C	1.3C
10	5	R	45	100	25	30%	77%	46%	1.3te/MMscf	37.5bbl/MMscf	1.2KW/MMscf	39.6%	23.3C	5.3C
11	5	L	25	100	35	-	-	-	-	-	-	-	-	-
12	5	L	35	100	35	1%	13%	4%	0.0te/MMscf	1.2bbl/MMscf	12.6KW/MMscf	2.8%	18.2C	2.6C
13	5	L	45	100	35	3%	23%	7%	0.1te/MMscf	2.1bbl/MMscf	9.8KW/MMscf	5.0%	21.7C	1.3C
14	5	N	25	100	35	16%	56%	28%	0.5te/MMscf	16.6bbl/MMscf	19.2KW/MMscf	23.1%	13.2C	3.6C
15	5	N	35	100	35	18%	62%	31%	0.6te/MMscf	17.8bbl/MMscf	16.1KW/MMscf	26.1%	16.4C	2.6C
16	5	N	45	100	35	19%	67%	34%	0.6te/MMscf	18.3bbl/MMscf	13.0KW/MMscf	28.0%	19.5C	1.3C
17	5	R	25	100	35	32%	74%	46%	1.3te/MMscf	41.8bbl/MMscf	23.0KW/MMscf	40.5%	13.3C	3.5C
18	5	R	35	100	35	33%	78%	48%	1.4te/MMscf	42.0bbl/MMscf	19.3KW/MMscf	42.7%	16.5C	2.6C
19	5	R	45	100	35	34%	81%	50%	1.4te/MMs	41.2bbl/	15.8KW/	43.8%	19.7C	1.3C

									cf	MMscf	MMscf			
20	5	L	45	100	45	3%	23%	7%	0.1te/MMscf	2.1bbl/MMscf	17.3KW/MMscf	5.0%	21.7C	1.3C
21	5	N	45	100	45	19%	67%	34%	0.6te/MMscf	18.3bbl/MMscf	21.3KW/MMscf	28.0%	19.5C	1.3C
22	5	R	45	100	45	34%	81%	50%	1.4te/MMscf	41.3bbl/MMscf	25.4KW/MMscf	43.9%	19.7C	1.3C
23	5	L	45	70	35	3%	34%	10%	0.1te/MMscf	2.9bbl/MMscf	13.9KW/MMscf	7.1%	14.3C	-1.7C
24	5	N	45	70	35	17%	70%	33%	0.5te/MMscf	17.5bbl/MMscf	17.7KW/MMscf	26.8%	13.8C	-1.7C
25	5	R	45	70	35	29%	82%	47%	1.3te/MMscf	36.7bbl/MMscf	19.3KW/MMscf	40.6%	14.4C	-1.7C
26	5	L	25	40	25	3%	35%	10%	0.1te/MMscf	2.9bbl/MMscf	14.6KW/MMscf	7.0%	1.7C	-3.9C
27	5	L	45	40	25	3%	35%	9%	0.1te/MMscf	2.7bbl/MMscf	13.2KW/MMscf	6.7%	3.6C	-6.7C
28	5	N	25	40	25	5%	39%	15%	0.2te/MMscf	7.2bbl/MMscf	4.5KW/MMscf	11.0%	18.2C	12.7C
29	5	N	45	40	25	13%	68%	30%	0.4te/MMscf	14.7bbl/MMscf	15.9KW/MMscf	23.3%	4.3C	-6.7C
30	5	R	25	40	25	12%	60%	29%	0.5te/MMscf	19.9bbl/MMscf	4.7KW/MMscf	22.6%	18.8C	12.9C
31	5	R	45	40	25	23%	80%	42%	1.0te/MMscf	30.4bbl/MMscf	16.7KW/MMscf	35.2%	4.9C	-6.6C
32	3	L	45	100	35	6%	40%	13%	0.1te/MMscf	4.1bbl/MMscf	14.4KW/MMscf	9.8%	15.9C	-4.6C
33	3	N	45	100	35	25%	75%	40%	0.8te/MMscf	22.8bbl/MMscf	18.4KW/MMscf	34.1%	14.0C	-4.6C
34	3	R	45	100	35	41%	86%	56%	1.7te/MMscf	48.9bbl/MMscf	22.1KW/MMscf	50.4%	14.2C	-4.6C
35	1	L	45	100	35	16%	67%	26%	0.3te/MMscf	9.3bbl/MMscf	24.2KW/MMscf	21.7%	4.3C	-16.6C
36	1	N	45	100	35	35%	84%	50%	1.1te/MMscf	30.3bbl/MMscf	26.5KW/MMscf	43.6%	6.2C	-13.2C
37	1	R	45	100	35	56%	93%	69%	2.4te/MMscf	67.5bbl/MMscf	35.3KW/MMscf	63.5%	3.0C	-16.8C
38	0	L	45	100	35	86%	98%	89%	1.9te/MMscf	31.3bbl/MMscf	84.1KW/MMscf	87.3%	-46.4C	-66.1C
39	0	N	45	100	35	88%	99%	91%	2.8te/MMscf	55.6bbl/MMscf	80.0KW/MMscf	89.6%	-35.5C	-56.7C
40	0	R	45	100	35	92%	99%	95%	3.9te/MMscf	92.7bbl/MMscf	80.2KW/MMscf	93.4%	-28.8C	-50.1C

Simulation results for Twister system without chiller

Option	Water Content, lb/MMscf	Composition	% DP across Twister,	Arrival Pressure, barg	Arrival Temp, C	LPG Recovery (C3 & C4)	C5+ Recovery	C3+ Recovery (NGL)	Total LPG Recovery	NGL Vol Rate	Total Heat Exchangers Duty	C3+ Recovery	Inlet temp to twister	Outlet temp from twister Slip Gas
1	Fully saturated	L	45	100	35	21%	71%	31%	0.5te/MMscf	10.1bbl/MMscf	11.0KW/MMscf	26.0%	20.5C	-4.5C
2	Fully saturated	N	45	100	35	38%	81%	51%	1.2te/MMscf	27.5bbl/MMscf	12.0KW/MMscf	45.1%	20.9C	-2.2C
3	Fully saturated	R	45	100	35	49%	88%	62%	2.1te/MMscf	35.1bbl/MMscf	14.2KW/MMscf	56.9%	21.1C	-1.7C
4	7	L	45	100	35	34%	80%	44%	0.8te/MMscf	15.1bbl/MMscf	19.6KW/MMscf	38.8%	9.6C	-15.6C
5	7	N	45	100	35	48%	86%	60%	1.5te/MMscf	34.1bbl/MMscf	20.7KW/MMscf	54.6%	11.5C	-12.2C
6	7	R	45	100	35	52%	89%	65%	2.2te/MMscf	53.2bbl/MMscf	16.8KW/MMscf	59.6%	18.4C	-4.6C
7	5	L	45	100	25	39%	82%	48%	0.9te/MMscf	16.8bbl/MMscf	15.4KW/MMscf	43.5%	5.5C	-19.8C
8	5	N	35	100	25	41%	83%	53%	1.3te/MMscf	31.1bbl/MMscf	13.7KW/MMscf	47.8%	10.1C	-7.4C
9	5	N	45	100	25	50%	87%	61%	1.6te/MMscf	35.3bbl/MMscf	15.0KW/MMscf	56.5%	9.2C	-14.7C
10	5	R	45	100	25	56%	90%	68%	2.4te/MMscf	57.6bbl/MMscf	11.5KW/MMscf	63.1%	13.9C	-9.4C
11	5	L	25	100	35	15%	61%	24%	0.3te/MMscf	8.5bbl/MMscf	23.2KW/MMscf	20.1%	5.4C	-7.3C
12	5	L	35	100	35	27%	75%	37%	0.6te/MMscf	12.9bbl/MMscf	23.2KW/MMscf	32.1%	5.4C	-13.3C
13	5	L	45	100	35	39%	82%	48%	0.9te/MMscf	16.8bbl/MMscf	23.1KW/MMscf	43.5%	5.5C	-19.8C
14	5	N	25	100	35	24%	68%	37%	0.7te/MMscf	21.6bbl/MMscf	15.3KW/MMscf	31.6%	17.2C	5.8C
15	5	N	35	100	35	35%	79%	48%	1.1te/MMscf	27.1bbl/MMscf	16.8KW/MMscf	42.3%	15.7C	-1.7C
16	5	N	45	100	35	48%	87%	60%	1.5te/MMscf	34.2bbl/MMscf	20.7KW/MMscf	54.7%	11.5C	-12.2C
17	5	R	25	100	35	37%	80%	52%	1.6te/MMscf	45.4bbl/MMscf	16.0KW/MMscf	46.2%	19.5C	8.2C
18	5	R	35	100	35	43%	84%	57%	1.8te/MMscf	47.6bbl/MMscf	14.8KW/MMscf	51.4%	20.9C	3.8C

19	5	R	45	100	35	52%	89%	65%	2.2te/MMscf	53.3bbl/MMscf	16.8KW/MMscf	59.7%	18.5C	-4.6C
20	5	L	45	100	45	39%	82%	48%	0.9te/MMscf	16.9bbl/MMscf	30.7KW/MMscf	43.6%	5.4C	-19.9C
21	5	N	45	100	45	46%	85%	58%	1.4te/MMscf	32.5bbl/MMscf	26.7KW/MMscf	52.3%	14.0C	-9.7C
22	5	R	45	100	45	45%	85%	59%	1.9te/MMscf	46.3bbl/MMscf	19.0KW/MMscf	52.9%	25.3C	2.7C
23	5	L	45	70	35	31%	82%	41%	0.7te/MMscf	13.3bbl/MMscf	22.0KW/MMscf	35.9%	3.1C	-17.4C
24	5	N	45	70	35	29%	82%	45%	0.9te/MMscf	23.6bbl/MMscf	13.8KW/MMscf	38.5%	18.2C	-1.4C
25	5	R	45	70	35	38%	88%	55%	1.6te/MMscf	41.5bbl/MMscf	12.8KW/MMscf	47.8%	20.9C	1.7C
26	5	L	25	40	25	1%	12%	3%	0.0te/MMscf	0.8bbl/MMscf	0.4KW/MMscf	1.9%	23.9C	16.9C
27	5	L	45	40	25	11%	70%	23%	0.2te/MMscf	6.8bbl/MMscf	12.3KW/MMscf	18.0%	4.9C	-10.7C
28	5	N	25	40	25	6%	49%	19%	0.2te/MMscf	8.9bbl/MMscf	0.0KW/MMscf	13.9%	24.9C	18.6C
29	5	N	45	40	25	14%	73%	31%	0.4te/MMscf	15.2bbl/MMscf	4.7KW/MMscf	24.7%	18.5C	3.5C
30	5	R	25	40	25	14%	66%	32%	0.6te/MMscf	22.0bbl/MMscf	0.0KW/MMscf	25.1%	24.9C	18.1C
31	5	R	45	40	25	20%	79%	40%	0.8te/MMscf	27.9bbl/MMscf	1.7KW/MMscf	32.5%	22.4C	7.4C
32	3	L	45	100	35	46%	84%	54%	1.0te/MMscf	19.3bbl/MMscf	28.5KW/MMscf	50.07%	-0.5C	-26.3C
33	3	N	45	100	35	48%	86%	60%	1.5te/MMscf	34.2bbl/MMscf	20.8KW/MMscf	54.7%	11.4C	-12.3C
34	3	R	45	100	35	53%	89%	66%	2.2te/MMscf	54.2bbl/MMscf	18.0KW/MMscf	60.5%	17.7C	-5.5C
35	1	L	45	100	35	50%	85%	57%	1.1te/MMscf	20.5bbl/MMscf	31.9KW/MMscf	53.4%	-4.5C	-30.0C
36	1	N	45	100	35	57%	90%	67%	1.8te/MMscf	40.9bbl/MMscf	28.0KW/MMscf	62.5%	4.7C	-19.5C
37	1	R	45	100	35	69%	94%	77%	2.9te/MMscf	72.8bbl/MMscf	32.4KW/MMscf	73%	5.2C	-18.6C
38	0	L	45	100	35	87%	92%	88%	1.9te/MMscf	31.9bbl/MMscf	73.6KW/MMscf	87.2%	-39.4C	5.0C
39	0	N	45	100	35	90%	94%	91%	2.9te/MMscf	60.8bbl/MMscf	78.7KW/MMscf	90.7%	-34.7C	5.0C
40	0	R	45	100	35	93%	97%	95%	3.9te/MMs	95.8bbl/MMs	79.8KW/	94.1%	-28.3C	5.0C

									cf	cf	MMscf			

Simulation results for JT-LTS system with chiller

Option	Water Content, lb/MMscf	Composition	DP across Twister, %	Arrival Pressure, barg	Arrival Temperature	LPG Recovery (C3 & C4)	C5+ Recovery	C3+ Recovery (NGL)	Propane Chiller Outlet temperature	Total LPG Recovery	NGL Vol Rate	Total Heat Exchangers Duty	Chiller Duty	C3+ Recovery	Inlet temp to JT
1	Fully saturated	L	45	100	35	0%	0%	0%	35.0C	0.00te/MMscf	0.0bbl/MMscf	0KW	0KW	0.0%	35.0C
2	Fully saturated	N	45	100	35	6%	36%	15%	35.0C	0.20te/MMscf	5.5bbl/MMscf	0KW	0KW	11.7%	35.0C
3	Fully saturated	R	45	100	35	18%	60%	32%	35.0C	0.73te/MMscf	17.1bbl/MMscf	0KW	0KW	26.5%	35.0C
4	7	L	45	100	35	-	-	-	-	-	-	-	-	-	-
5	7	N	45	100	35	16%	61%	29%	29.0C	0.50te/MMscf	15.5bbl/MMscf	938.4KW	0KW	23.9%	23.5C
6	7	R	45	100	35	30%	77%	46%	29.0C	1.24te/MMscf	36.6bbl/MMscf	1,172.4KW	0KW	39.5%	23.4C
7	5	L	45	100	25	3%	23%	7%	23.0C	0.06te/MMscf	2.1bbl/MMscf	206.7KW	0KW	5.0%	21.7C
8	5	N	35	100	25	18%	62%	31%	20.0C	0.57te/MMscf	17.9bbl/MMscf	744.9KW	0KW	26.2%	16.3C
9	5	N	45	100	25	19%	67%	34%	22.0C	0.61te/MMscf	18.3bbl/MMscf	435.2KW	0KW	28.0%	19.5C
10	5	R	45	100	25	30%	77%	46%	24.0C	1.27te/MMscf	37.5bbl/MMscf	115.4KW	0KW	39.6%	23.3C
11	5	L	25	100	35	-	-	-	-	-	-	-	-	-	-
12	5	L	35	100	35	1%	13%	4%	26.0C	0.03te/MMscf	1.2bbl/MMscf	1,257.4KW	0KW	2.8%	18.2C
13	5	L	45	100	35	3%	23%	7%	28.0C	0.06te/MMscf	2.1bbl/MMscf	977.6KW	0KW	5.0%	21.7C
14	5	N	25	100	35	16%	56%	28%	23.0C	0.50te/MMscf	16.6bbl/MMscf	1,921.7KW	0KW	23.1%	13.2C
15	5	N	35	100	35	18%	62%	31%	25.0C	0.57te/MMscf	17.8bbl/MMscf	1,607.7KW	0KW	26.1%	16.4C
16	5	N	45	100	35	19%	67%	34%	27.0C	0.61te/MMscf	18.3bbl/MMscf	1,302.4KW	0KW	28.0%	19.5C
17	5	R	25	100	35	32%	74%	46%	25.3C	1.33te/MMscf	41.8bbl/MMscf	2,298.0KW	0KW	40.5%	13.3C
18	5	R	35	100	35	33%	78%	48%	25.0C	1.40te/MMscf	42.0bbl/MMscf	1,933.8KW	0KW	42.7%	16.5C
19	5	R	45	100	35	34%	81%	50%	27.0C	1.43te/MMscf	41.2bbl/MMscf	1,578.9KW	0KW	43.8%	19.7C
20	5	L	45	100	45	3%	23%	7%	33.0C	0.06te/MMscf	2.1bbl/MMscf	1,725.6KW	0KW	5.0%	21.7C
21	5	N	45	100	45	19%	67%	34%	31.0C	0.61te/MMscf	18.3bbl/MMscf	2,134.0KW	0KW	28.0%	19.5C
22	5	R	45	100	45	34%	81%	50%	31.0C	1.43te/MMscf	41.3bbl/MMscf	2,544.6KW	0KW	43.9%	19.7C
23	5	L	45	70	35	3%	34%	10%	25.0C	0.08te/MMscf	2.9bbl/MMscf	1,391.4KW	0KW	7.1%	14.3C
24	5	N	45	70	35	17%	70%	33%	24.0C	0.54te/MMscf	17.5bbl/MMscf	1,774.0KW	0KW	26.8%	13.8C
25	5	R	45	70	35	29%	82%	47%	24.0C	1.25te/MMscf	36.7bbl/MMscf	1,931.3KW	0KW	40.6%	14.4C

26	5	L	25	40	25	3%	35%	10%	9.8C	0.07te/MMscf	2.9bbl/MMscf	1,455.8KW	0KW	7.0%	1.7C
27	5	L	45	40	25	3%	35%	9%	14.0C	0.06te/MMscf	2.7bbl/MMscf	1,315.3KW	0KW	6.7%	3.6C
28	5	N	25	40	25	13%	68%	30%	6.4C	0.41te/MMscf	14.7bbl/MMscf	1,530.5KW	208KW	23.2%	1.5C
29	5	N	45	40	25	13%	68%	30%	14.0C	0.42te/MMscf	14.7bbl/MMscf	1,586.9KW	0KW	23.3%	4.3C
30	5	R	25	40	25	23%	81%	43%	7.5C	0.99te/MMscf	30.8bbl/MMscf	1,551.0KW	305KW	35.6%	2.3C
31	5	R	45	40	25	23%	80%	42%	14.0C	0.98te/MMscf	30.4bbl/MMscf	1,674.2KW	0KW	35.2%	4.9C
32	3	L	45	100	35	6%	40%	13%	25.0C	0.13te/MMscf	4.1bbl/MMscf	1,442.8KW	0KW	9.8%	15.9C
33	3	N	45	100	35	25%	75%	40%	24.0C	0.80te/MMscf	22.8bbl/MMscf	1,842.0KW	0KW	34.1%	14.0C
34	3	R	45	100	35	41%	86%	56%	24.0C	1.73te/MMscf	48.9bbl/MMscf	2,211.7KW	0KW	50.4%	14.2C
35	1	L	45	100	35	16%	67%	26%	19.0C	0.35te/MMscf	9.3bbl/MMscf	2,424.8KW	0KW	21.7%	4.3C
36	1	N	45	100	35	35%	84%	50%	18.0C	1.11te/MMscf	30.3bbl/MMscf	2,647.1KW	0KW	43.6%	6.2C
37	1	R	45	100	35	56%	93%	69%	15.0C	2.36te/MMscf	67.3bbl/MMscf	3,511.3KW	0KW	63.5%	3.2C
38	0	L	45	100	35	86%	98%	89%	-46.4C	1.90te/MMscf	31.3bbl/MMscf	8,407.8KW	0KW	87.3%	-46.4C
39	0	N	45	100	35	88%	99%	91%	-25.4C	2.79te/MMscf	55.6bbl/MMscf	8,003.6KW	0KW	89.6%	-35.5C
40	0	R	45	100	35	92%	99%	95%	-23.1C	3.86te/MMscf	92.7bbl/MMscf	8,018.3KW	0KW	93.4%	-28.8C

Simulation results for Twister system with chiller

Option	Water Content, lb/MMscf	Composition	DP across Twister, %	Arrival Pressure, barg	Arrival Temperature	LPG Recovery (C3 & C4)	C5+ Recovery	C3+ Recovery (NGL)	Propane Chiller Outlet temperature	Total LPG Recovery	NGL Vol Rate	Total Heat Exchangers Duty	Chiller Duty	C3+ Recovery	Inlet temp to twister
1	Fully saturated	L	45	100	35	21%	71%	31%	28.0C	0.5te/MMscf	10.1bbl/MMscf	1,104.4KW	0KW	26.0%	20.5C
2	Fully saturated	N	45	100	35	38%	81%	51%	28.0C	1.2te/MMscf	27.5bbl/MMscf	1,203.3KW	0KW	45.1%	20.9C
3	Fully saturated	R	45	100	35	49%	88%	62%	30.6C	2.1te/MMscf	35.1bbl/MMscf	1,714.3KW	0KW	56.9%	21.1C
4	7	L	45	100	35	34%	80%	44%	22.0C	0.8te/MMscf	15.1bbl/MMscf	1,964.9KW	0KW	38.8%	9.6C
5	7	N	45	100	35	50%	88%	62%	24.6C	1.6te/MMscf	35.5bbl/MMscf	2,208.9KW	46.4KW	56.5%	9.3C
6	7	R	45	100	35	61%	92%	72%	19.2C	2.6te/MMscf	61.1bbl/MMscf	2,299.1KW	318.6KW	67.1%	9.3C
7	5	L	45	100	25	39%	82%	48%	10.0C	0.9te/MMscf	16.8bbl/MMscf	1,544.3KW	0KW	43.5%	5.5C
8	5	N	35	100	25	45%	86%	58%	16.7C	1.4te/MMscf	34.5bbl/MMscf	1,721.8KW	114.9KW	52.3%	5.3C

9	5	N	45	100	25	54%	89%	64%	19.3C	1.7te/MMscf	37.9bbl/MMscf	1,794.2KW	60.9KW	59.7%	5.3C
10	5	R	45	100	25	63%	93%	73%	14.7C	2.7te/MMscf	64.8bbl/MMscf	1,699.5KW	330.6KW	69.1%	5.2C
11	5	L	25	100	35	15%	61%	24%	20.0C	0.3te/MMscf	8.5bbl/MMscf	2,319.1KW	0KW	20.1%	5.4C
12	5	L	35	100	35	27%	75%	37%	20.0C	0.6te/MMscf	12.9bbl/MMscf	2,319.1KW	0KW	32.1%	5.4C
13	5	L	45	100	35	39%	82%	48%	20.0C	0.9te/MMscf	16.8bbl/MMscf	2,314.9KW	0KW	43.5%	5.5C
14	5	N	25	100	35	35%	80%	48%	12.7C	1.1te/MMscf	29.4bbl/MMscf	2,351.2KW	315.5KW	42.8%	5.3C
15	5	N	35	100	35	45%	86%	58%	16.5C	1.4te/MMscf	34.5bbl/MMscf	2,389.2KW	287.4KW	52.3%	5.3C
16	5	N	45	100	35	54%	89%	65%	19.3C	1.7te/MMscf	38.4bbl/MMscf	2,512.3KW	162.4KW	60.2%	5.3C
17	5	R	25	100	35	49%	88%	63%	10.5C	2.1te/MMscf	56.6bbl/MMscf	2,432.7KW	650.3KW	57.2%	5.1C
18	5	R	35	100	35	57%	91%	69%	12.7C	2.4te/MMscf	61.1bbl/MMscf	2,456.5KW	624.4KW	64.1%	5.1C
19	5	R	45	100	35	64%	93%	73%	14.0C	2.7te/MMscf	63.8bbl/MMscf	2,516.2KW	593.9KW	69.2%	5.2C
20	5	L	45	100	45	39%	82%	48%	24.0C	0.9te/MMscf	16.9bbl/MMscf	3,067.1KW	0KW	43.6%	5.4C
21	5	N	45	100	45	55%	89%	65%	19.2C	1.7te/MMscf	38.5bbl/MMscf	3,226.3KW	291.8KW	60.3%	5.2C
22	5	R	45	100	45	64%	93%	74%	14.8C	2.7te/MMscf	64.8bbl/MMscf	3,341.7KW	699.0KW	70.1%	5.2C
23	5	L	45	70	35	31%	82%	41%	32.4C	0.7te/MMscf	13.3bbl/MMscf	2,195.1KW	0KW	35.9%	3.1C
24	5	N	45	70	35	46%	92%	60%	13.2C	1.5te/MMscf	32.9bbl/MMscf	2,320.1KW	346.7KW	53.8%	2.9C
25	5	R	45	70	35	57%	96%	70%	9.9C	2.4te/MMscf	55.7bbl/MMscf	2,343.0KW	583.2KW	64.3%	3.0C
26	5	L	25	40	25	8%	66%	20%	-1.6C	0.2te/MMscf	6.0bbl/MMscf	1,487.4KW	178.7KW	15.1%	-1.6C
27	5	L	45	40	25	16%	80%	29%	5.8C	0.4te/MMscf	8.9bbl/MMscf	1,607.8KW	59.0KW	23.6%	-1.6C
28	5	N	25	40	25	22%	85%	41%	-1.5C	0.7te/MMscf	20.6bbl/MMscf	1,479.1KW	542.5KW	33.5%	-1.5C
29	5	N	45	40	25	31%	91%	49%	-1.6C	1.0te/MMscf	24.7bbl/MMscf	1,541.3KW	471.7KW	41.4%	-1.6C
30	5	R	25	40	25	33%	92%	53%	-1.6C	1.4te/MMscf	38.7bbl/MMscf	1,474.8KW	705.7KW	45.6%	-1.6C
31	5	R	45	40	25	43%	95%	61%	-1.4C	1.9te/MMscf	44.9bbl/MMscf	1,550.1KW	719.1KW	53.8%	-1.4C
32	3	L	45	100	35	46%	84%	54%	20.0C	1.0te/MMscf	19.3bbl/MMscf	2,850.9KW	0KW	50.07%	-0.5C
33	3	N	45	100	35	60%	91%	69%	12.4C	1.9te/MMscf	42.3bbl/MMscf	2,900.6KW	405.3KW	64.9%	-0.7C
34	3	R	45	100	35	69%	94%	77%	8.2C	2.9te/MMscf	70.0bbl/MMscf	3,006.5KW	797.8KW	73.5%	-0.9C
35	1	L	45	100	35	56%	86%	62%	10.4C	1.2te/MMscf	22.4bbl/MMscf	3,672.7KW	339.3KW	58.3%	-12.9C
36	1	N	45	100	35	68%	93%	75%	-2.4C	2.1te/MMscf	50.2bbl/MMscf	3,783.1KW	897.0KW	71.9%	-13.2C
37	1	R	45	100	35	76%	95%	82%	-6.1C	3.2te/MMscf	83.5bbl/MMscf	3,967.2KW	1,351.7KW	79.5%	-13.4C
38	0	L	45	100	35	87%	92%	88%	-29.3C	1.9te/MMscf	31.9bbl/MMscf	7,360.7KW	0KW	87.2%	-39.4C
39	0	N	45	100	35	90%	94%	91%	-28.5C	2.9te/MMscf	60.8bbl/MMscf	7,871.7KW	0KW	90.7%	-34.7C
40	0	R	45	100	35	93%	97%	95%	-25.1C	3.9te/MMscf	95.8bbl/MMscf	7,980.8KW	0KW	94.1%	-28.3C

APPENDIX 'D' TWISTER DESCRIPTION

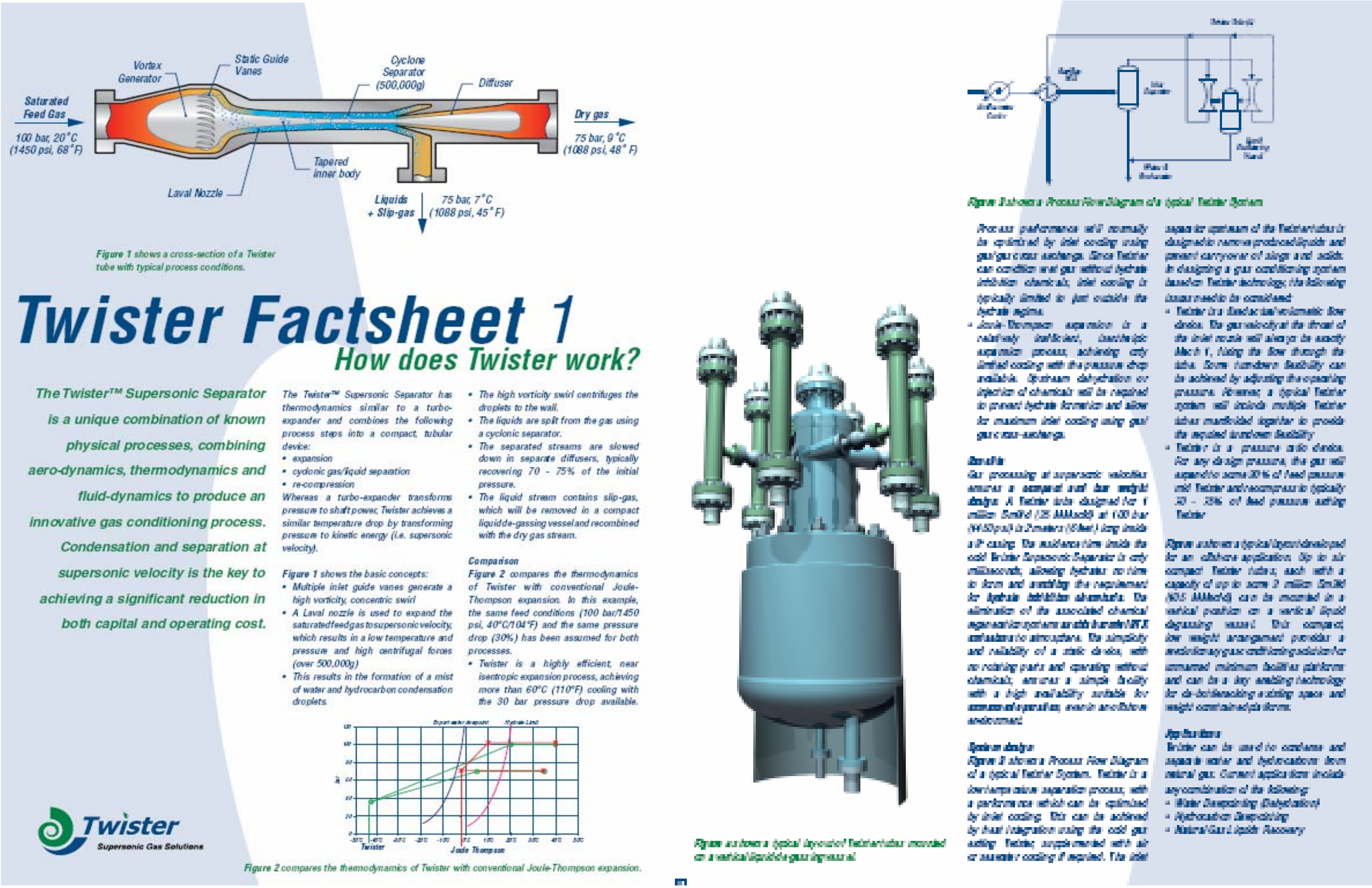


Figure 1 shows a cross-section of a Twister tube with typical process conditions.

Twister Factsheet 1

How does Twister work?

The Twister™ Supersonic Separator is a unique combination of known physical processes, combining aero-dynamics, thermodynamics and fluid-dynamics to produce an innovative gas conditioning process. Condensation and separation at supersonic velocity is the key to achieving a significant reduction in both capital and operating cost.

The Twister™ Supersonic Separator has thermodynamics similar to a turbo-expander and combines the following process steps into a compact, tubular device:

- *expansion*
- *cyclonic gas/liquid separation*
- *re-compression*

Whereas a turbo-expander transforms pressure to shaft power, Twister achieves a similar temperature drop by transforming pressure to kinetic energy (i.e. supersonic velocity).

***Figure 1** shows the basic concepts:*

- *Multiple inlet guide vanes generate a high vorticity, concentric swirl*
- *A Laval nozzle is used to expand the saturated feed gas to supersonic velocity, which results in a low temperature and pressure and high centrifugal forces (over 500,000g)*
- *This results in the formation of a mist of water and hydrocarbon condensation droplets.*
- *The high vorticity swirl centrifuges the droplets to the wall.*
- *The liquids are split from the gas using a cyclonic separator.*
- *The separated streams are slowed down in separate diffusers, typically recovering 70 - 75% of the initial pressure.*
- *The liquid stream contains slip-gas, which will be removed in a compact liquid de-gassing vessel and recombined with the dry gas stream.*

Comparison

***Figure 2** compares the thermodynamics of Twister with conventional Joule-Thompson expansion. In this example, the same feed conditions (100 bar/1450 psi, 40°C/104°F) and the same pressure drop (30%) has been assumed for both processes.*

- *Twister is a highly efficient, near isentropic expansion process, achieving more than 60°C (110°F) cooling with the 30 bar pressure drop available.*

Figure 2 compares the thermodynamics of Twister with conventional Joule-Thompson expansion.

Twister
Supersonic Gas Solutions