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Comparison of Natural Gas Hydrocarbon Dewpointing Control Methods

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Abstract

Natural gas dew point is a very important quality parameter. It is specified in predetermined mandatory specifications for the producers through transmission and distribution companies to market. Several problems in gas transmission lines may be caused by the hydrocarbon liquid dropout. These include increase in pressure drop, line capacity reduction, and equipment problems (e.g. compressor damage). Avoiding liquid dropout, the operating current specifications of gas transmission lines require to be operated above the dew point of hydrocarbon (DPH) or cricondentherm hydrocarbon dew point (CHDP).

This paper compares the different methods for natural gas hydrocarbon dew-pointing that are widely applied in industry and choose the best method for a gas project to achieve the required hydrocarbon dew point of the export gas. These methods are Joule-Thomson expansion (J-T), turbo expansion, mechanical refrigeration, Pressure Swing Adsorption (PSA) and thermally Regenerated Adsorption (TSA). The comparison was made to choose the best applicable method needed for a gas project to achieve the required export gas specifications. It was found that the mechanical refrigeration method is preferred due to its numerous advantages.

Keyword: *Hydrocarbon dew point, Joule-Thomson expansion, turbo expander, PSA, TSA, CPF.*

1. Introduction

Natural gas dew point is an important operation parameter. Frequently, it is being used as a quality parameter. This requirement begins with the requirements of a quality product and may be at risk of losing their operating capacity if the gas quality slips [1].

Dustman et. al. state that light hydrocarbon liquids recovery from natural gas streams can range from simple dew point control to deep ethane extraction. Also, the desired degree of liquid recovery has a profound effect on process selection, complexity and cost of the processing facility [2].

Hydrocarbon dew point is the temperature at which the condensates begin to form when natural gas is cooled at constant pressure. In gas pipeline transmission, the presence of liquid hydrocarbons in grouping with traces of moisture primes to the hydrate formation as virtual solid masses [3]. Under the

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operating conditions of high flow and pressure in pipeline, these hydrates can cause harmful damage to compressors and restrict or even block pipelines [4].

There is always a hydrocarbon condensation risk in natural gas transmission pipelines. This causes an increase in pressure drop is due to the condensation of hydrocarbons and will introduce operational problems resulting from two-phase flow [5]. It is necessary to prevent condensation by keeping the temperature and pressure of natural gas above the dew point to have a single-phase region. In this context, the optimal control of the hydrocarbon dew point is necessary for economical, operational and safety reasons [6].

1.1 Objective

The main objective of this work is to compare all-natural gas hydrocarbon dewpointing control methods applied in the industry and choose the best method for the development project to achieve the export gas specifications. The process gas contains heavy components and requires hydrocarbon dewpointing facilities to be provided at the CPF to meet the gas export specification of 10.5°C at any pressure.

There exists different gas hydrocarbon dewpointing control methods available in the market to remove the heavy hydrocarbon from the feed gas and comply with the required gas specifications in terms of the required hydrocarbon dewpoint.

The available different methods for natural gas hydrocarbon dewpointing control that are widely applied in industry are Joule-Thomson expansion (J-T), turbo expansion, mechanical refrigeration, Pressure Swing Adsorption (PSA) and thermally Regenerated Adsorption (TSA)

The comparison of all these methods should be based on the following items: -

- Energy costs.
- Market conditions (materials cost, consumables costs).
- Technology evolution with time.
- Company experience with a certain technology.

2. Gas Project Description

Figure 1 reveals the major processing units which make up the central processing facility CPF. The gas project consists of eight wells, a gathering system and CPF, where the production stream from the various fields will be separated into condensate and dew pointed gas products for export. The gas processing involves inlet facilities for liquid separation, mercury removal unit, CO_2 removal unit, dehydration unit, and a hydrocarbon dew-pointing unit to meet the export gas specifications.

The condensate separated from the gas in the inlet facilities is stabilized to meet the RVP specification for export condensate. The gas will be exported via export gas pipeline and treated in a dedicated Liquefied Petroleum Gas (LPG) extraction facility to commercial specification required for end user consumption. The condensate will be exported via export pipeline to the oil terminal.

Mercury has been detected up to 70 ng/Sm^3 in some well samples. Well samples are reported to contain no elemental Sulphur, no wax and no paraffin. Also, the H_2S content of the wells is zero

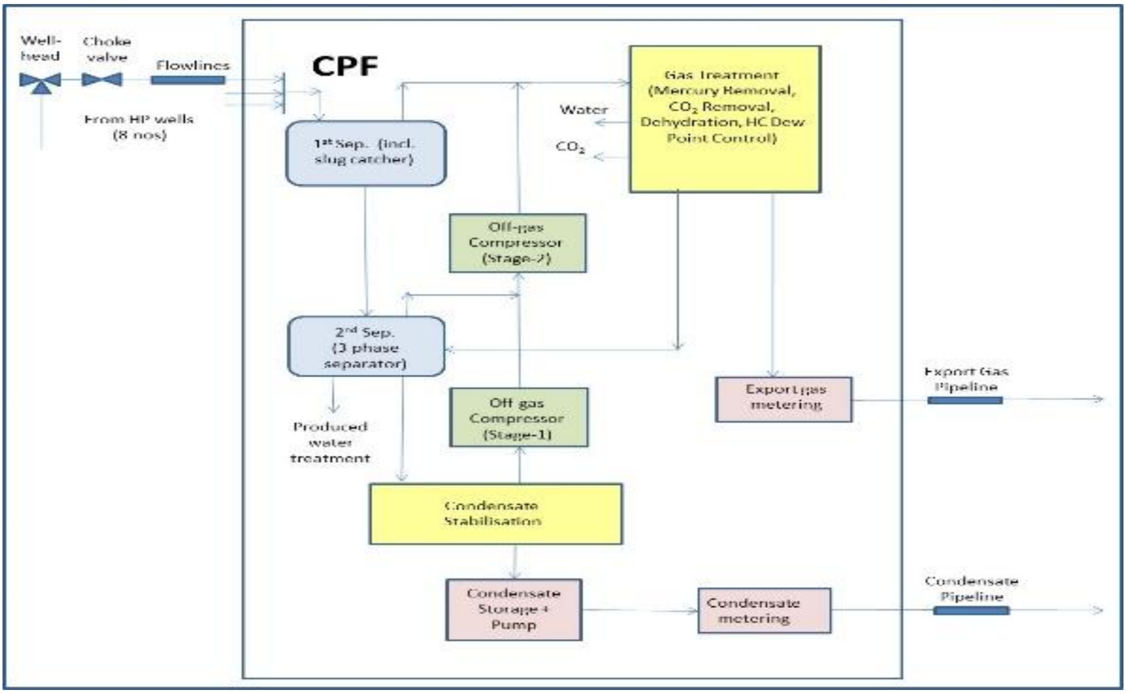

Figure 1 Schematic of the CPF Process Units

3. Gas Project Design Capacities

The gas project is designed for a production of 2.7 MSCMD export gas and 10,000 STB/d export condensate. Table 2 explore the design flowrates for the for the process facilities of the gas project.

Table 3: Flowrates Design Production

Design Capacity	Unit	Value
Production from wells (Note 1)	MSCMD	2.9 (Lean Gas) 3.3 (Rich Gas)
Gas Export (for gas pipeline design)	MSCMD	2.7
Condensate Export, maximum	STB/d	10,000
Water Production, water-cut	% Vol.	10

Note1- Includes 0.1 MSCMD of fuel gas.

3.1 Product Specifications

The following are the gas and condensate specifications for pipeline export and water specification for disposal.

The export gas specifications for gas are:

- Water dew point: -12°C.
- Hydrocarbon dew point at 35 barg: +10°C.
- CO_2 content: < 2.0 mole %.

The pressure of the export gas is 44 barg.

The condensate stabilization unit is designed to achieve a true vapor pressure (TVP) < 0.8 bara at 60°C, which gives the Reid vapor pressure (RVP) < 0.4 bara.

4. Hydrocarbon Dew pointing control methods:

The following methods are the all available methods to achieve the required hydrocarbon dew point in the export gas of the gas plant.

4.1 Joule-Thomson Expansion

Figure 1 illustrate the hydrocarbon dewpointing control by the J-T effect.

Table 1 reveals the advantages and disadvantages of the joule- Thomason (JT) expansion joint

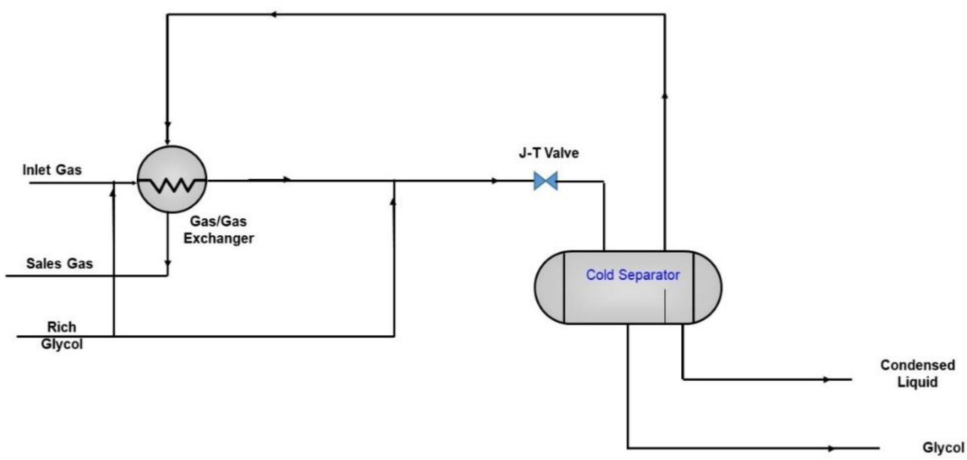

Figure 1: PFD for a typical Joule-Thomson Expansion unit [7]

Table 1: Joule-Thomson Expansion Advantages / Disadvantages [8, 9]

Advantages	Disadvantages

Self-refrigeration process, no external cooling medium required.	High pressure drop.
Outlet gas can achieve hydrocarbon and water dew point.	Sales gas may require additional recompression to meet export pressure.
Has a high flow turndown and ease of operation.	

4.2 Mechanical Refrigeration

Figure 2 illustrate the hydrocarbon dewpointing controlling by mechanical refrigeration process. glycol (MEG) injection at the inlet of the gas-gas heat exchanger and/or chiller is the most cost-effective means of preventing hydrate formation in a mechanical refrigeration process. [10].

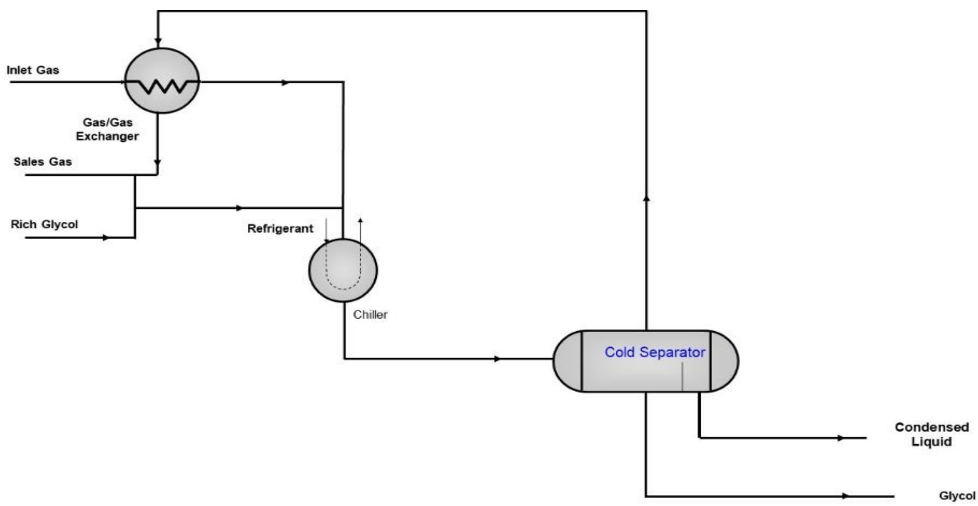

Figure 2: PFD for a Basic Mechanical Refrigeration unit [10]

Table 2 reveals the advantages and disadvantages of the mechanical refrigeration

Table 2: Mechanical Refrigeration Advantages / Disadvantages [11,12]

Advantages	Disadvantages
Low-pressure drop, sales gas	A refrigeration cycle is required,

recompressor not required.	including refrigerant compressor.
Outlet gas can achieve hydrocarbon and water dewpoint.	Source of refrigerant and on-site storage and disposal.

4.3 Turbo expansion

The turbo-expansion process utilizes a turbo-expander to reduce the gas pressure with expansion following a near isentropic path. A typical expansion process for hydrocarbon dewpoint control is shown in figure 3[13].

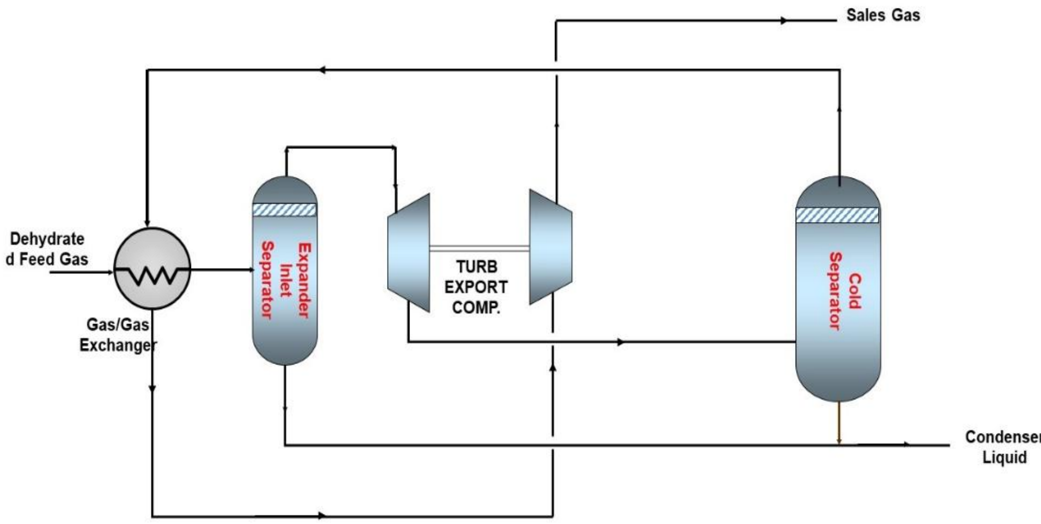

Figure 3: PFD for a Typical Turbo-Expansion Unit [13]

Table 3 shows the advantages and disadvantages of the turbo-expander

Table 3: Turbo-expansion Advantages / Disadvantages [14,15]

Advantages	**Disadvantages**
Expander mechanical energy stream recovered for sales gas compression.	Outlet gas may require an additional compressor for export.
Lower hydrocarbon dewpoint can be obtained.	Stringent upstream dehydration required.

4.4 Swing Adsorption

Adsorption systems for dewpoint control take advantage of the fact that hydrocarbon adsorption follows the molecular weight of the hydrocarbon; higher molecular weight hydrocarbons are preferentially adsorbed while lighter hydrocarbons pass through the adsorbent bed and are available as sales gas [16].

Swing adsorption processes are described by the method of bed regeneration:

- Pressure swing adsorption (PSA)
- Temperature swing adsorption (TSA)

4.4.1 Pressure Swing Adsorption (PSA)

PSA systems typically operate at relatively low pressure; in the range of 4.5 to 28.5 bar. The heavy hydrocarbons are removed onto adsorbent bed producing sales gas at feed pressure. The regeneration saturated bed is done by pressure reduction eliminating the heavier hydrocarbons from the adsorbent. In most cases, PSA systems consist of three to four adsorber vessels [17].

Sulan Xia et al. [18] investigated PSA removing C_{+2} from natural gas as raw material for thermal chlorination. They obtained the optimal condition of PSA purification for removing C_{+2} components from natural gas as raw material for chloride methane manufactured by thermal chlorination. It has been confirmed in practice that the PSA natural

4.4.2 Temperature Swing Adsorption (TSA)

TSA systems normally operate at pressures greater than 28.5 bara. Water and heavier hydrocarbons are adsorbed on a bed of adsorbent, which becomes saturated after a period of operation ranging from 15 minutes to several hours. The saturated bed is regenerated by heating to desorb the water and heavy hydrocarbons. A typical TSA process is shown on figure (4) [19].

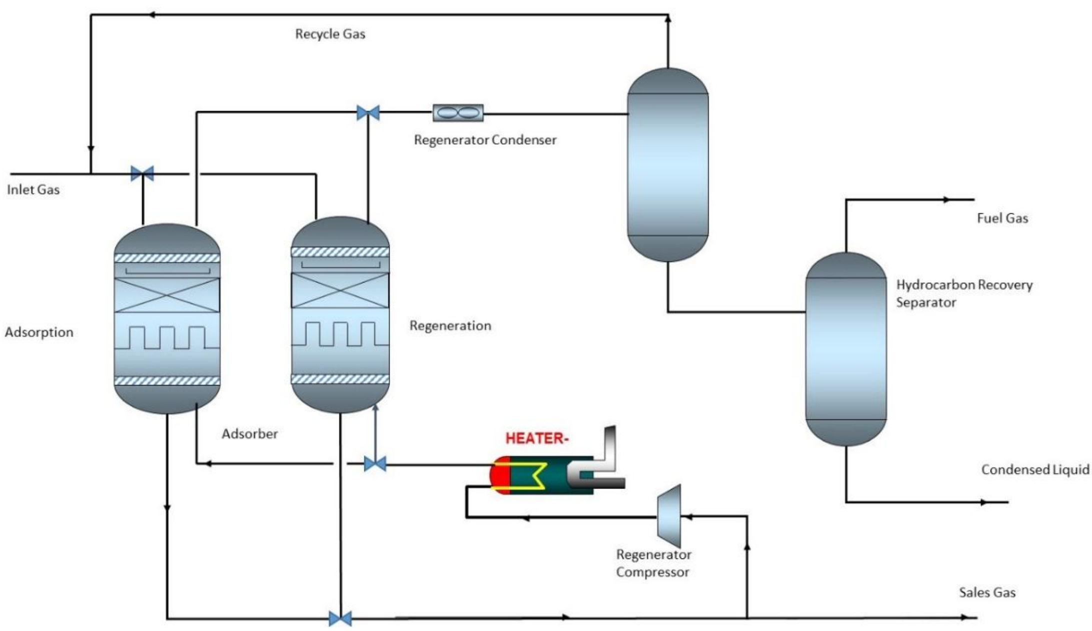

Figure 4: PFD for a Typical TSA Unit [19]

Table 4 illustrates the advantages and disadvantages of the swing adsorption method

Table 4: Swing Adsorption Advantages / Disadvantages [20,21]

Advantages	Disadvantages
Low pressure drop compared with Joule-Thomson or Turbo-Expander processes.	Exhausted adsorbent requires disposal using an approved environmental method and high pressure drop compared to refrigeration system
High operating flexibility.	Complex controls for batch type regeneration process.
Water and hydrocarbon dew point control not sensitive to feed gas composition.	Feed gas temperature required to be less than 45°C at inlet.

5. Implementation

The feed composition of the central process facilities in the gas project will be a mixture of the production from 8 gas wells. The composition reaching the central process facilities will be a mixture of production from each well and may be a combination of rich fluids from one well and lean from another well.

Since each well has different composition in each zone so the mixed composition must achieve the export gas and condensate required flowrates.

Aspen HYSYS steady state simulation software version 10.1 was used to simulate the all hydrocarbon dewpointing control method in the gas plant at different compositions [22]. Rich gas and lean gas compassions from the gas wells were used for the simulation

The selected physical property package for the HYSYS model developed for the gas Project is the Peng-Robinson Equation-of-State with modified interaction parameters fluid package.

In order to provide confidence in the design to achieve the above specifications some margin has been assumed for each parameter i.e. water dew point -15°C, HC dew point 6.5°C and CO_2 content 1.8% vol. These design margins will allow gas export to continue in the event of off-specification gas production. The online gas chromatograph, part of the fiscal metering unit, will be used to assess the off-specification gas.

Since the export gas specification requires the water dewpoint (< -12°C) lower than the hydrocarbon dewpoint (< 10.5°C), gas dehydration is required prior to hydrocarbon dewpointing using the J-T expansion, turbo-expansion or mechanical refrigeration systems.

In addition, the limits on the CPF arrival pressure and the gas delivery pressure at the LPG demands minimum pressure drop across the CPF.

The four methods for achieving the required hydrocarbon dew point in the export gas were simulated by HYSYS steady state software. The required energy for each method was extracted from the simulation software. Also, the availability and subtility in the North African countries were highlighted. Finally, the capital cost for each method was mentioned

Finally, a comparison was made to choose the best method to achieve the required export gas specifications

6. Results

6.1 Phase Envelop

HYSYS simulation steady state software was used to simulate the gas plant based on the rich and lean compositions of the gas wells in the summer case

Figure 5 reveals the phase envelop for the lean gas case while Figure 6 shows the phase envelop for the rich gas case. The phase envelops in Figure 5 & 6 compare between the bubble points, dewpoint and the possibility of hydrate formation at different pressures & temperatures in the gas pretreatment stage and the export gas stage. The gas pretreatment step include separation, gas dehydration, gas sweetening and hydrocarbon dewpointing control.

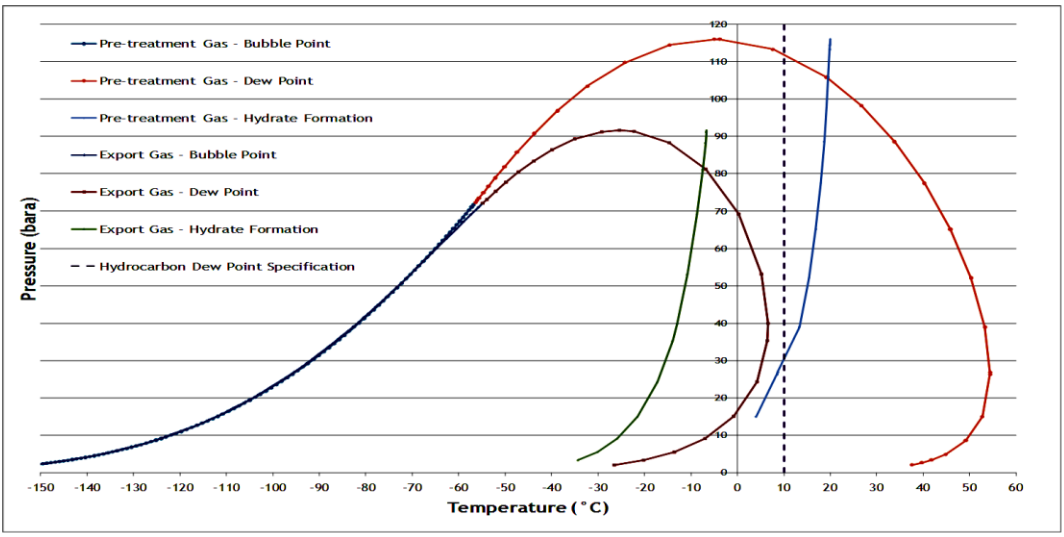

Figure 5 Lean Gas Composition Phase Envelope

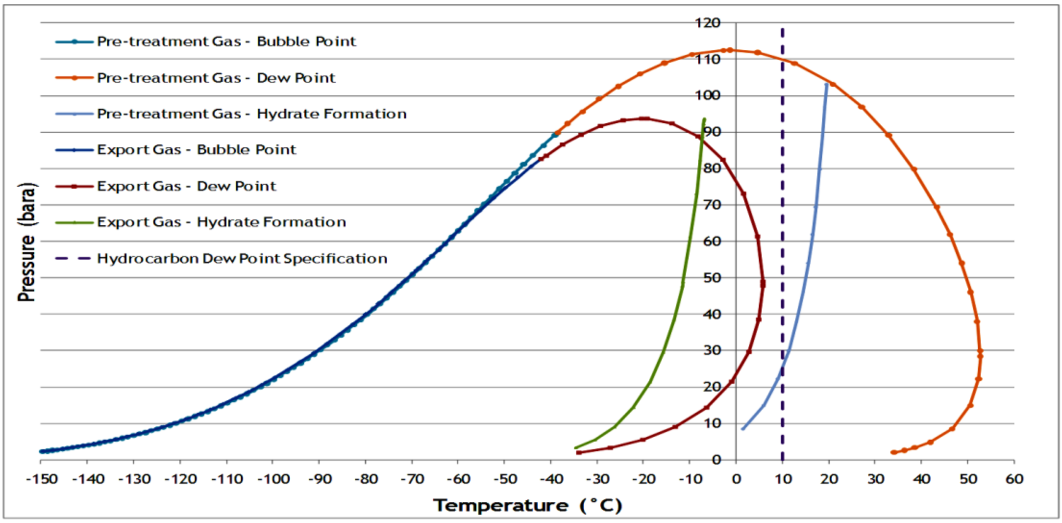

Figure 6 Rich Gas Composition Phase Envelope

6.2 Technical comparison between Hydrocarbon dewpointing control methods

6.2.1 J-T expansion

However, the J-T design is less efficient per unit of energy expended. Since a large letdown of pressure from 55 barg to ~20 barg is anticipated to achieve the HC dewpoint specification which would also require an additional compressor of substantial size.

This process is well suited to a high-pressure reservoir where the ratio between inlet pressure and sales gas pressure is approximately 1.5; i.e. no sales gas compression is required. However, although this is initially the case for the gas project, it is expected that the reservoir pressures will decline quickly and will be insufficient for J-T expansion after only a short period of operation.

The J-T expansion has the largest recompression duty and makes this system least attractive. The J-T expansion method is not technically suitable for the gas project

6.2.2 Turbo-expander

The turbo-expander also needs additional compression requirements to achieve the required export pressure, as the recompression is not 100% efficient. The turbo-expander with the additional compressor increases the CAPEX and OPEX by an amount dependent on the extent of recompression required downstream. For the gas project, the extra cost may be around 10% for the relatively relaxed dew point required, but for a more onerous specification, it can be much higher.

The turbo-expansion process is often the preferred solution when the inlet pressure is provided by compression or when the ratio of inlet to sales gas pressure is approximately 1.1 to 1.5

In the case of gas projects, the limits for the CPF arrival pressure and the gas delivery pressure at LPG plant require having a minimum pressure drop across the CPF. A Turbo-expander based dewpoint control would require an additional compressor to meet the export gas delivery pressure at the end.

The turboexpander method is not technically suitable for the gas project

6.2.3 Mechanical Refrigeration

Similarly, the mechanical refrigeration system also involves additional CAPEX and OPEX for the external refrigeration plant; the high ambient temperatures also result in larger air cooler sizes. A source of refrigerant is required for first fill and make-up due to losses from the system. However, pressure drop is the least of all the options evaluated and export gas compression is not required.

The mechanical refrigeration method is technically suitable for the gas project

6.2.4 Swing Adsorption

The swing adsorption system is not suited to high inlet gas temperatures and complex controls for batch type regeneration.

The swing adsorption method is technically not suitable for the gas project

Table 5 displays the main technical differences between each method used to achieve the required hydrocarbon dew point in the gas plant

Table 5: Technical Comparison between Hydrocarbon Dewpointing control Methods

Item	Joule-Thomson Expansion	Mechanical Refrigeration	Turbo expansion	Temperature Swing Adsorption	Pressure Swing Adsorption
Hydrocarbon dew point achievement	Yes	Yes	Yes	Yes	Yes
Pressure Drop	High	Low	High	Low	Low
Recompression requirements	Yes	No	Yes	No	No
Design Simplicity	Yes	Yes	No	No	No
Turndown stage	Yes	Yes	No	No	No
Refrigeration	No	Yes	No	No	No

cycle requirements					
upstream dehydration required	No	Yes	Yes	No	No
Feed gas requirements	Wide range of flow rate, lower flowrate	Wide range of flow rate, lower flowrate	High flowrate only	Inlet pressure above 28.5 bar Sensitive to gas composition, Feed temperature less than 45 C	Inlet pressure from 4.5 to 28.5 bar Sensitive to gas composition, Feed temperature less than 45 C
Operation flexibility	Flexible	Flexible	Complicated	Flexible	Flexible
Control System	Simple	Simple	Simple	Complex	Complex
Regeneration system Requirements	No	No	No	Yes	Yes
Refrigeration Cycle	No	Yes	No	No	No
Environmental impact	No	No	No	Yes	Yes
Proven Technology	Yes	Yes	Yes	Yes	Yes

From table 5 it can be noticed that the best method for the gas plant is the mechanical refrigeration method as it has lower pressure drop. simple in operation, simple control system and no need for any compression package.

6.2 Economical comparison between Hydrocarbon dewpointing control methods

Aspen HYSYS steady state simulation software version 10.1 was used to simulate the all hydrocarbon dewpointing control methods to achieve the required hydrocarbon dew point in the gas plant. The required energy for each method was taken from the simulation of each method

Figure 7 displays the required energy for each hydrocarbon dew pointing control method for the gas project.

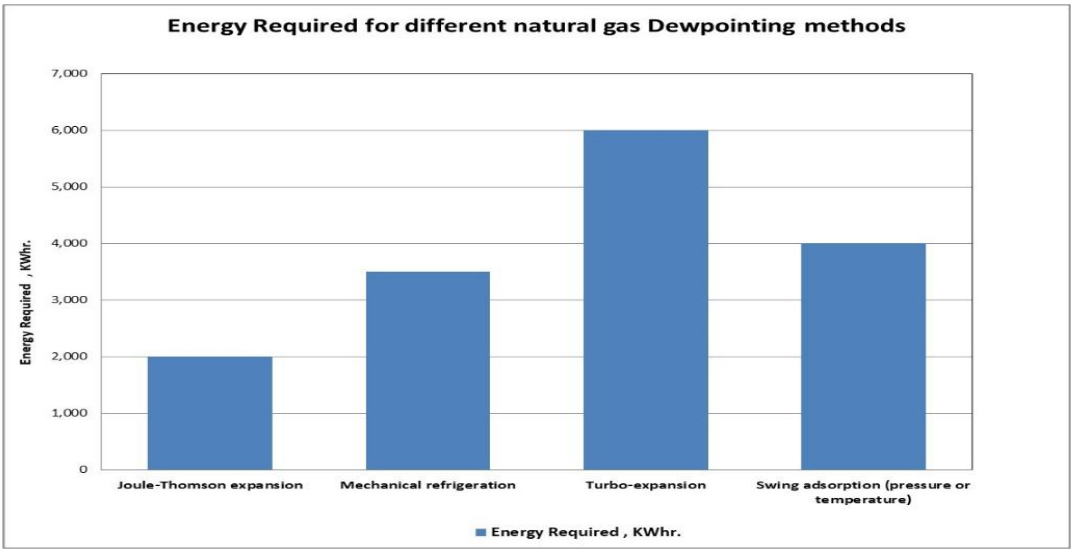

Figure 7: Energy Required for different Natural Gas Hydrocarbon Dewpointing Control Methods

The capital cost of each method required to achieve the hydrocarbon dew point in the gas plant was taken from the HYSY simulation program and from different vendors all over the world. Figure 8 illustrates the capital cost in million USD for each hydrocarbon dew pointing control method for the gas project

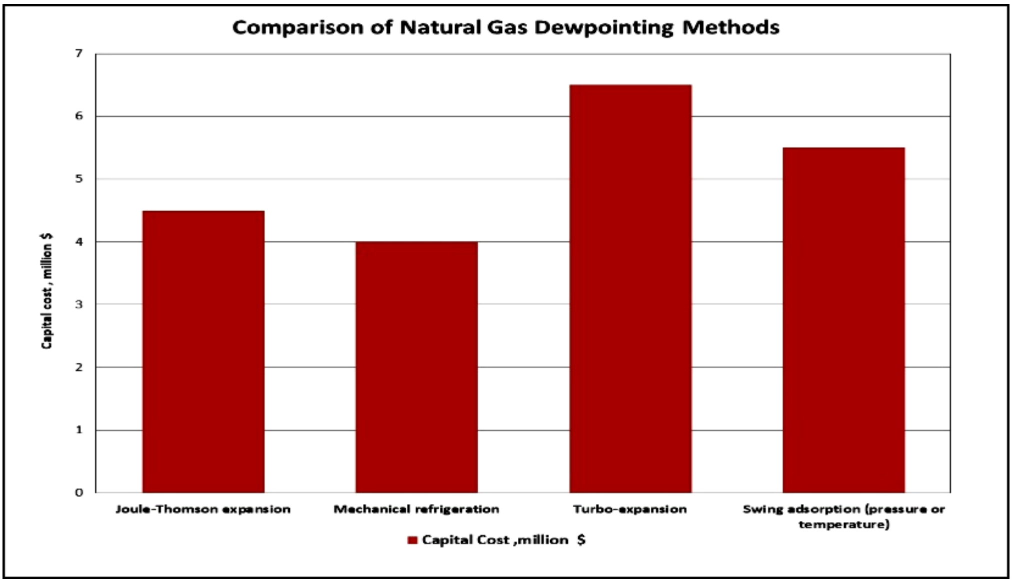

Figure 8: Capital Cost for different natural gas hydrocarbon dew pointing control methods

6.3 Comparison Summary between Hydrocarbon dewpointing control methods

Table 6 summarizes the main technical and commercial differences between the hydrocarbon dew pointing control methods needed to achieve the required hydrocarbon dew point in the export gas of the gas plant.

The comparison in this table is based on the capital cost for each method, the availability & suitability in the North African countries, energy required for each method and the limitations for each method.

From the table, it can be noticed that the best method technical and economically is the mechanical refrigeration method

Comparison between Hydrocarbon Dew pointing control methods					
Technology	Joule-Thomson expansion	Mechanical refrigeration	Turbo-expansion	Swing adsorption (pressure or temperature)	Remarks
Energy Required , KWhr.	2,000	3,500	6,000	4,000	
Suitability in North African countries	No	Yes	Yes	No	
Design Limitation	Feed Pressure	external refrigeration plant is needed	• Feed Pressure • Complex Operation	• Complex controls for batch type regeneration • Feed inlet temperature • Environmental problems	• Joule Thomson Requires gas export compressor to increase the export gas pressure and used only for short period of operation(startup) • Turbo expander Requires gas export compressor to increase the export gas
North Africa Reference	No	Yes	Yes	NA	
Capital Cost ,million $	4.5	4	6.5	5.5	The Capital cost include the cost of the export compressor needed for the turbo expander and joule Thomson methods.

Table 6: Comparison between hydrocarbon dew pointing control methods

Conclusions & recommendations

Based on the technical and commercial comparison between the all available methods in the international market to achieve the required hydrocarbon dew point of the export gas in the gas project , it is confirmed that mechanical refrigeration is the best option for controlling the hydrocarbon dewpoint in the gas project.

Nomenclature:

Abbreviation	Description
CAPEX	Capital Expenditure
CHDP	Cricondentherm
	hydrocarbon dew point
CPF	Central Processing Facility
HDP	Hydrocarbon dew point
J-T	Joule-Thomson
LPG	Liquefied Petroleum Gas
MEG	Monoethylene Glycol
OPEX	Operating Expenditure
PSA	Pressure Swing Adsorption
ROI	return on investment
TSA	Temperature Swing Adsorption

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الملخص العربي:

تعتبر نقطة التكثف للغاز الطبيعي من العوامل الهامة جدًا. وهي محددة بمواصفات محددة سلفا وإلزامية لجميع أنحاء المنتجين من خلال شركات النقل والتوزيع في السوق. قد ينجم عن وجود السائل الهيدروكربوني عدد من المشاكل في خطوط نقل الغاز. وتشمل تزايد انخفاض الضغط ، وقلة سعة الخط ، و أيضا مشاكل في المعدات مثل تلف الضواغط. ولتجنب المشاكل الناجمة عن تكثف الغاز يتطلب ذلك مواصفات التشغيلية الحالية لخطوط نقل الغاز أن يتم تشغيلها فوق نقطة الندى في الهيدروكربون (DPH) أو نقطة الندى الهيدروكربونية الحلقية (CHDP) .

يقارن هذا البحث الطرق المختلفة لنقط الندي الغاز الطبيعي للهيدروكربوني والتي يتم تطبيقها على نطاق واسع في الصناعة واختيار أفضل طريقة لها لمشروع الغاز لتحقيق نقطة الندى الهيدروكربونية المطلوبة لغاز التصدير . هذه الطرق هي توسعة Joule-Thomson (J-T)، والتوسع التوربيني ، والتبريد الميكانيكي ، وامتصاص تأرجح الضغط (PSA) ، والامتزاز المتولد حرارياً .(TSA) تم إجراء المقارنة لاختيار أفضل طريقة قابلة للتطبيق مطلوبة لمشروع الغاز لتحقيق المواصفات المطلوبة لغاز التصدير ووجدت أنه من المستحسن استخدام طريقة التبريد الميكانيكية بسبب مزايا عديدة