Successful Application of Light Hydrocarbon Desulfurization by Alkaline Wash in Tahe Oilfield

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ABSTRACT: In 2016, the light hydrocarbons sold by Tahe oilfield light hydrocarbon station No.2 have given off peculiar smell. After laboratory analysis, it was found that the total sulfur light hydrocarbon was beyond relevant requirements in *Stable Light Hydrocarbon 9053–2013 GB*. After analysis, it is considered that the organic sulfur, such as the organic sulfur in the light hydrocarbon, leads to excessive sulfur content. According to the fact that established mixed hydrocarbon alkali washing desulfurization device can better remove the organic sulfur, it was determined to connect the light hydrocarbon with the existing mixed hydrocarbon alkali washing desulfurization device for alkali washing. Reconstruction scheme: one is to reconstruct the inlet tube of existing alkali wash tank and water tank and add distributor; another one is to optimize alkali washing process flow, add one vertical alkali washing tank. After reconstruction was carried out, ethanethiol was removed from light hydrocarbon by alkali washing process, and the sulfur content was obviously decreased, which meets the standard requirements.

KEYWORDS: Light hydrocarbon; Alkaline washing desulfurization; Sulfur content exceeding standard; Process optimization

Leakage and Explosion Hazard Analysis of LNG Receiving Station

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ABSTRACT: LNG belongs to the inflammable and explosive goods. In case of a leakage, it might trigger hazards like jet fire, pool fire, flash fire and vapor cloud explosion. In this paper, a typical working condition of leakage accident of LNG as well as other hazards caused by leakage was selected by using DNV PHAST software to calculate and analyze the consequence. Then GIS was adopted to show the hazardous area of the diffusion gas, heat radiation ranges of jet fire and pool fire, and the influenced zone of vapor cloud explosion. Finally, some countermeasures were put forward to prevent such risks. These countermeasures can provide the basis for the establishment of fire power and the formulation of contingency plan

KEYWORDS: LNG leakage; Jet fire; Pool fire; Vapor cloud explosion; LNG receiving station safety

Comparison of Energy Consumption Between Propane–Propene Distillation Separation Process and Prospect Forecast

Li Jintao (College of Chemical and Chemical Engineering of Southwest Petroleum University, Chengdu, Sichuan, 610500, China) **NGO, 2016, 34(6):46–50**

ABSTRACT: In order to reduce the energy consumption of the propane–propene separation process effectively, a theoretical basis for the optimization have been provided by comparing several relevant distillation processes. It begun with the existing propane–propene separation process, set up feed ratio to reach high purity propene with the mass fraction of 99.6%. In this paper, the process simulation software of ASPEN PLUS V8.6 has been used to simulate the conventional distillation process, heat pump distillation, conventional extractive distillation and divided wall extractive distillation. Then, comparative study was conducted according to the stimulation result from the combination of energy consumption and equipment investment. In the case of energy conservation, the last three kinds of distillation could save consumption by 34.1%, 20.2% and 42.1% compared with conventional distillation. With the consideration of equipment investment, heat pump distillation and divided wall extractive distillation have significant advantages. So, heat pump distillation and divided wall extractive distillation could have wide industry applications and would be the focus of future study.

KEYWORDS: Propane; Propene; Heat pump distillation; Extractive distillation; Divided wall; Simulation

OIL AND GAS FIELD DEVELOPMENT

Application of Pressure Drop Method in Interwell Interference Well Group

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Zhang Xiaobin, Li Wenhong, Fan Wei, Liu Lei (National Engineering Laboratory for Low Permeability Exploration and Development, Xi'an, Shaanxi, 710021, China) **NGO, 2016, 34(6):51–54**

丙烷-丙烯精馏分离工艺能耗比较及前景展望

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摘　要: 为了降低丙烷-丙烯精馏体系的能耗，结合相关精馏分离工艺进行比较，得到优化的理论依据。从现有的丙烷-丙烯分离方式出发，规定进料比例及流量，以得到质量分数 99.6% 的高纯度丙烯为要求，采用 Aspen Plus V 8.6 将常规精馏、热泵精馏、常规萃取精馏和隔壁塔萃取精馏进行模拟，再根据模拟结果，从能源消耗及设备投资等方面进行比较。就节约能耗方面来说，后三种精馏方式相比于常规精馏分别能节省能耗 34.1%、20.2% 及 42.1%。结合各自的设备投资情况来看，热泵精馏及隔壁塔萃取精馏工艺具有明显优势。热泵精馏及隔壁塔萃取精馏工艺拥有广阔的工业应用前景，将是未来研究的重点方向。

关键词: 丙烷; 丙烯; 热泵精馏; 萃取精馏; 隔壁塔; 模拟

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0　前言

丙烯是化工过程中用途十分广泛的中间物，能用于生产三大合成材料。丙烯主要来源于石油精炼所得的副产品，常常与氢气、乙烯、乙烷和丙烷等混合在一起。随着丙烯的需求不断上升以及催化剂研究在选择性及收率上的突破，由价格低廉的丙烷脱氢制丙烯得到了推广[1]。在丙烯精制过程中，其与较轻组分如氢气、乙烷和乙烯等采用深冷分离及常规精馏都能较好分离，而与和丙烯沸点、相对分子质量等性质都很接近的丙烷，采用常规的精馏方法分离难度大，并需要消耗大量的能源[2]。

目前，有学者提出变压吸附法、变真空吸附法等在理论上能达到降低能耗效果，使用多孔物质进行吸附分离或是膜分离也是当下研究热门的分离方法，但材料开发、生产能力与操作时间在实际生产中都会有所限制[3]。目前，工业上精馏仍是大量分离丙烷-丙烯的首选。

分析丙烷-丙烯的物性参数及主要能耗，结合分离过程的理论，选择热耦合精馏或者萃取精馏来代替常规精馏能有效降低能耗，但同时会增加设备投资及操作费用。而到底采用哪种精馏方式是由能量消耗、设备投资与操作费用共同决定的。

本文通过规定工业级别量的丙烷-丙烯分离任务，借助流程模拟软件 Aspen Plus V 8.6 模拟三种工艺过程，在确保丙烯产品质量达到要求的基础上确定能耗。再根据流程特点估算设备投资费，为工艺上的丙烷-丙烯分离过程优化提供理论依据。

1　精馏工艺简述

1.1　常规精馏

丙烷-丙烯在常温、常压下很难分离。如果使用常规精馏，实际工业生产中往往采用高压条件[4]。常规精馏流程简单，但回流比太大，往往达到 20 左右，同时塔板数也较多，常采用上下塔的形式[5]，见图 1。即便如此，因其一次投资较少，操作稳定，检修方便，目前仍是丙烷-丙烯分离所采用的主流工艺。如在 2014 年投产的宁波海越丙烷脱氢制丙烯(60×10^4 t/a)装置中，丙烯产品分离塔共包括 290 块逆流塔盘，分为上下塔，塔盘数占产品

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精制段总数的 68 %。塔顶冷却器与塔釜再沸器会消耗大量能源。在丙烷脱氢工艺中，一般情况下塔顶的高纯度液态丙烯向下游或罐区输送，塔釜得到的丙烷则循环至反应单元继续反应。

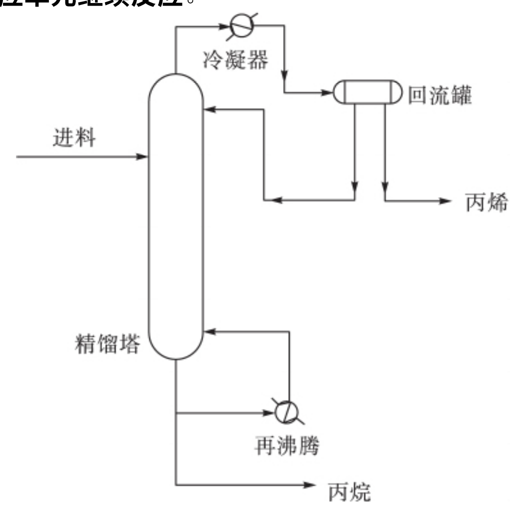

图 1　常规精馏流程

1.2　热耦合精馏

热耦合精馏是指将精馏中需要加热和冷却的物质进行换热，以达到节省能耗的目的。随着能源问题日益受到重视，能够回收部分热量节能的工艺引起了广泛的关注。热泵精馏是一种典型的热耦合精馏，将塔顶的高温蒸汽作为塔釜再沸器的热源，用塔顶高温气体的热量与塔釜低温液体的冷量，提高能量利用率[6]。适用于塔顶、塔釜沸点差较小，在换热网络分析时还应满足塔顶、塔底温差跨越夹点。对于丙烷-丙烯体系，可满足上述要求。热泵精馏大致分为塔顶压缩型和塔釜节流型两类[7]，见图 2～3。在处理量、产品质量指标及操作压力均相同的情况下，采用两种热泵精馏流程的能源消耗都比采用常规精馏流程低。综合考虑传热温差以及压缩机可能存在的工质泄露等情况，就丙烷-丙烯体系来说，塔釜节流型热泵精馏流程更适合。

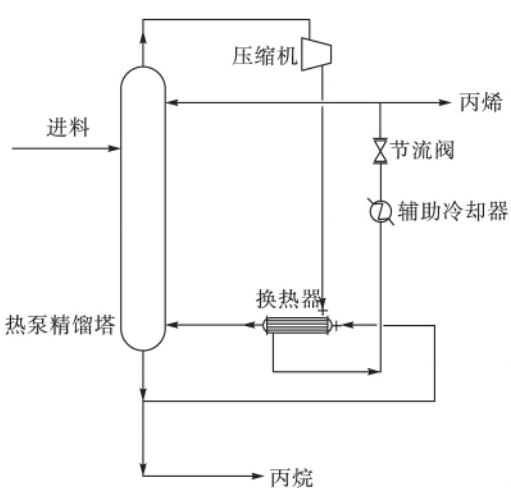

图 2　塔顶压缩型热泵精馏

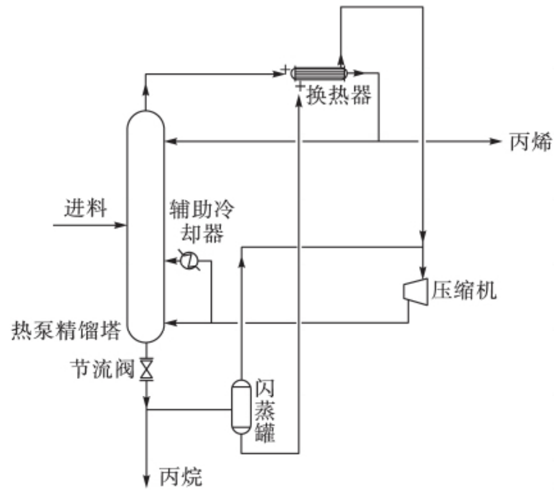

图 3　塔釜节流型热泵精馏

目前，丙烷-丙烯热泵精馏已实现工业化。镇海石化总厂的丙烷-丙烯分离使用塔釜节流型热泵系统投产顺利，产品丙烯质量浓度达到 99.72 %[8]。与常规精馏与萃取精馏不同的是，热泵精馏在设备安装及相关控制方案方面更加复杂，因为不设再沸器与冷却器，故塔顶高温气体与塔釜低温液体之间交换热量的换热器显得尤为重要，在实际热泵精馏中通常考虑增设一个辅助冷却器，保证塔顶高温气体换热后完全冷却。同时，经过换热管网的工艺气体、液体量往往很大[9]。但热泵精馏在节能方面却有很大的潜力，单从体系内部节能效果上考虑，采用热泵精馏的丙烷-丙烯体系节能理论上可到 90 %，十分可观。考虑设备投资及操作成本等，总体上依然能有较大的节约。目前国内外许多学者致力于热泵精馏的优化及相关技术的改进，提出了热声热泵、吸附热泵、侧热泵等针对不同体系所设计的热泵精馏技术[10-11]。

1.3　萃取精馏

相同碳原子数目的烷烃、烯烃通常因理化性质相似而采用萃取精馏，以被分离物质在萃取剂中不同的溶解度差异进行分离，在解决沸点接近和恒沸物体系的分离过程中具有很大优势。目前，针对四个碳原子的丁烷-丁烯的萃取精馏技术已相当成熟，其两塔流程萃取精馏提纯正丁烯的技术具有高选择性、热稳定性及化学稳定性，在工业上得到进一步推广[12]。丙烷-丙烯萃取精馏虽尚未工业化，但其研究已经有一定深度。常规萃取精馏由萃取塔与萃取剂再生塔组成，具有装置简单、处理量大等优势，见图 4。使用萃取剂改变料液中被分离组分间的相对挥发度，使常规精馏需要耗费大量能量才能分离的液体混合物变得易于分离。

萃取精馏相比于常规精馏能有效降低热负荷，减少塔板数及回流比，但会增加一个塔及相应的管路。有研

究人员通过对常规萃取精馏工艺进行改进，使萃取精馏工艺更具有竞争力。随着隔壁塔的工业化普及，使用隔壁塔进行萃取精馏理论上的研究已有进展，此塔能在控制设备投资的前提下达到节约能耗的目的，仅需要一个塔就能完成分离以及萃取剂再生任务的隔壁萃取精馏塔[13]，因减少了一个塔的设置，相比于传统萃取精馏降低了设备投资，得到了广泛关注。隔壁精馏塔是在塔内部设置隔板，是具有两塔功能的一种热耦合塔的特殊结构，见图 5。隔壁塔可实现多组分的分离，仅由一塔即可完成常规精馏需要两个塔才能完成的分离任务，可大幅减少设备投资费用，近年来已广泛应用于工业领域。已有的研究表明，隔壁塔萃取精馏塔将隔壁塔与萃取精馏工艺有效融合，吸收两种工艺技术的优点，在控制设备投资成本的同时进一步降低能耗。此外，还有学者提出了变压热耦合萃取精馏，能够进一步降低公用工程的消耗，达到节能目的[14]。

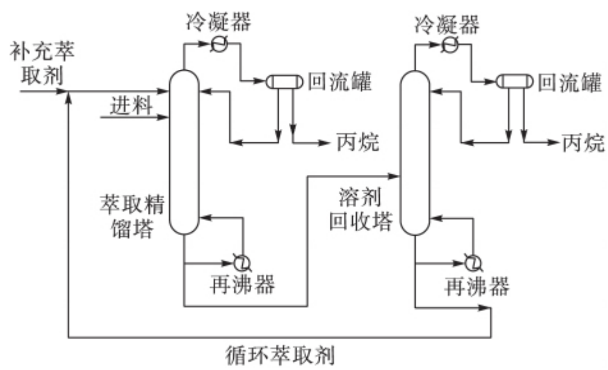

图 4　常规萃取精馏

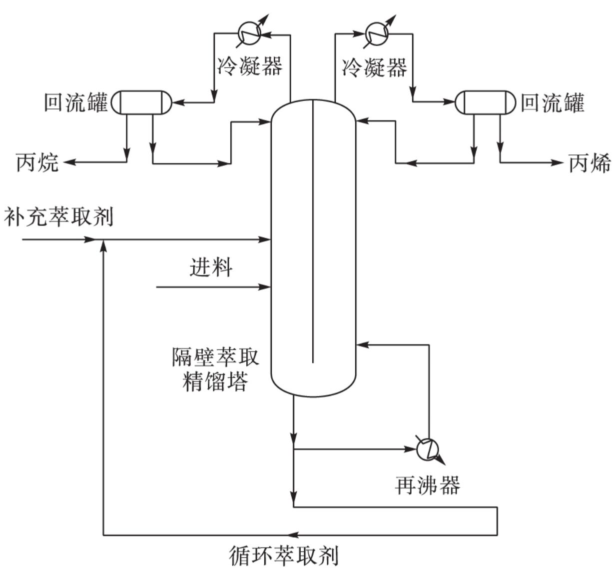

图 5　隔壁塔萃取精馏

2　流程模拟

使用 Aspen Plus V 8.6 对三种分离工艺流程进行模拟，以得到相应的工艺参数，为后续能耗估算提供理论数据。

根据丙烷脱氢工艺流程中丙烷-丙烯分离中的大致流量比例，规定待分离物进料量以及丙烷、丙烯的比例[15]。考虑到丙烯下游产品线对丙烯浓度的要求以及交通运输的因素，规定产品丙烯的质量纯度为 99.6 %，而塔釜中丙烯的浓度不超过 5 % 为分离要求，相关条件见表 1。

表 1　进料组成及流量

项目	丙烷	丙烯	合计
组成 w/(%)	61.1	38.9	100
流量/($kmol \cdot h^{-1}$)	2 700	1 800	4 500

2.1　常规精馏

在常规精馏中因涉及到高压，故采用适合于高温、高压下非极性混合体系的 RK-SOAVE 状态方程为物性方法，能够使模拟结果接近实际情况[16]。

常规精馏方法的模拟与优化比较普遍，先选取 DSTWU(简捷设计)模型进行计算，只需确定加料条件及精馏要求即可算出最小理论板数及最小回流比等塔的基本操作参数[17]。通过 DST-WU 模型计算达到精馏要求及产品规格以后，还需在此基础上使用 RadFrac(严格计算)模块进行核算，使用模型分析工具，如灵敏度分析及设计规定等来优化塔的参数并得到优化的工艺操作条件，具体数据见表 2。

表 2　常规精馏工艺操作条件

塔顶压力/MPa	全塔压降/MPa	最少理论板数/个	实际板数/个	最小回流比	实际回流比
2.0	0.15	104	180	20.81	30.17

从表 2 数据可以看出，即使在优化参数条件下，为了得到高纯度的产品，常规精馏的塔板数及回流比仍较大，能耗难以得到有效控制。

2.2　热泵精馏

在对热泵精馏进行模拟时，与常规精馏条件有所不同，此时塔可在更低的压力下操作，采用 SRK 状态方程能够更准确地模拟实际情况。

在常规精馏模拟的基础上，去掉再沸器及冷却器，塔釜产物经节流冷却后与塔顶的高温蒸汽换热使蒸汽冷凝，再经过压缩机压缩后进入闪蒸罐，上升气相返回塔釜，下降液体作为丙烷采出，经过冷却的蒸汽冷凝液再经过分离器分出部分丙烯产品后循环至塔顶，回到塔顶的部分与作为产品采出的部分流量之比则相当于理论上的回流比。此时理论上不需要外加蒸汽。模拟得到的数据见表 3。

表 3　热泵精馏工艺操作条件

塔顶压力/MPa	全塔压降/MPa	塔板数/个	理论回流比	节流阀压力/MPa
1.5	0.1	112	24.77	0.25

2.3　萃取精馏

在萃取精馏体系中涉及到液液平衡，根据相关研究，使用 UNIFAC 基团贡献法活度计算模型可以很好预测本体系[18]。

因涉及原料及萃取剂两股进料，故选用 RadFrac(严格计算)模块进行模拟。以得到符合要求的产品为目标进行调试。先单独模拟萃取塔，使用设计规定模块及产品分离要求，计算萃取塔的理论板数和回流比，调试相关参数，使结果准确，确定萃取塔理论板数为 69，回流比为 8.2。使用灵敏度分析确定原料及萃取剂进料位置，得到优化数据。再将萃取塔塔釜的物流作为萃取剂再生塔的进料，使用设计规定及灵敏度分析确定该塔的相关优化工艺参数，使塔顶丙烯质量分数达到要求。再将再生塔塔釜得到的萃取剂经换热后与补加的萃取剂混合加至萃取塔，经过调试，达到期望的产物要求[19]。

目前国内外关于隔壁塔的研究越发深入，将隔壁塔萃取精馏工业化是未来研究的一个重点方向。在 Aspen Plus V 8.6 中采用主塔与侧塔的形式可达到隔壁塔的模拟效果，见图 6。同时根据常规萃取精馏的结果确定主塔与侧塔的精馏产品。模拟时先从主塔入手，参考常规萃取的结果，确定最佳理论板数、进料板数据后，单独模拟侧塔至丙烯产品质量符合要求，再将循环的萃取剂接回主塔，并调整新加入萃取剂的量至结果收敛，将相关参数与常规萃取精馏对比，结果见表 4。

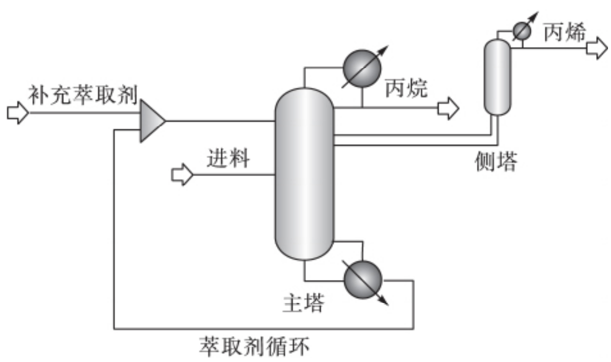

图 6　隔壁塔萃取精馏 Aspen Plus V 8.6 模拟流程

表 4　萃取精馏工艺操作条件

项目	常规萃取精馏		隔壁塔萃取精馏	
	萃取塔	再生塔	主塔	侧塔
溶剂含水量/(%)	13.8			
溶剂比	5.3		5.2	
塔板数	69	18	58	12
回流比	8.2	0.5	4.9	0.4

3　能耗比较

根据以上模拟结果，确定不用精馏工艺的能耗工质消耗量，见表 5。依据 GB/T 50441-2007《石油化工设计能耗计算标准》，得出能耗工质与折能指标的对应关系表，见表 6。再结合表 5 进行比较分析，得出折能后的合计能耗，见表 7。

表 5　精馏工艺消耗工质对比

能耗工质	吨产品耗能			
	常规精馏	热泵精馏	常规萃取精馏	隔壁萃取精馏
3.5 MPa 蒸汽/t	-	1.82	-	-
0.3 MPa 蒸汽/t	4.07	-	3.31	2.42
循环水/t	424.59	199.1	297.05	204.52
电量/(kW·h)		113.44		

表 6　能耗工质对应折能指标关系

能耗工质	折能指标/MJ
3.5 MPa 蒸汽/t	3 684
0.3 MPa 蒸汽/t	2 763
循环水/t	4.19
电量/(kW·h)	9.21

表 7　精馏工艺折能能耗对比

能耗工质	常规精馏折能/MJ	热泵精馏折能/MJ	常规萃取精馏折能/MJ	隔壁萃取精馏折能/MJ
3.5 MPa 蒸汽/t	-	6 704.88	-	-
0.3 MPa 蒸汽/t	11 245.41	-	9 145.53	6 686.46
循环水/t	1 779.03	834.229	1 244.64	856.94
电量/(kW·h)	-	1 044.782 4	-	-
合计	13 024.44	8 583.891 4	10 390.17	7 543.4

采用热泵精馏及萃取精馏均可降低能耗，从表 5~7 数据可知，与常规精馏相比，常规萃取精馏节能 20.2%，热泵精馏节能 34.1%，隔壁塔萃取精馏节能 42.1%，与相关研究报道数据较一致，说明本次模拟结果可信。

在设备投资方面，常规萃取精馏需要两个塔及相应的管设施，产品成本难以得到有效控制。热泵精馏不设塔顶冷却器及回流罐，但会增设闪蒸罐、换热器，虽然热泵精馏的控制方案、操作维修等方面较复杂，但整体设备投资成本与常规萃取精馏较接近，且在工业化中已经证明了其降低能耗的可行性[20]。隔壁塔萃取精馏采用隔壁塔，有效减小了装置体积，既吸取了萃取精馏的优势，又能有效降低能耗，同时随着隔壁塔技术的成熟，隔

壁塔萃取精馏将成为未来丙烷-丙烯分离优化的一个重点方向。

4 结论

1) 仅仅从能耗问题角度出发，对于丙烷-丙烯体系，常规精馏虽然操作简单、运行稳定，但其热力学效率低、能耗极高，使其在能源问题日益凸显的今天竞争力下降。相比之下，热泵精馏能有效回收利用低品味能量，提高能量利用率，工业应用前景广阔。萃取精馏通过添加萃取剂改变相对挥发度降低精馏分离的难度，同时采用隔壁塔萃取精馏集成了隔壁塔自身结构的特点，在常规萃取精馏的基础上进一步降低了能耗，是极有潜力的精馏方式。

2) 设备投资方面，常规精馏虽然理论上单塔即可完成分离，但工艺中常常采用双塔串联模型，一定程度上增大了设备投资。热泵精馏能节省塔顶冷却器及回流罐，但增设压缩机等设施，设备投资相比传统精馏没有较大涨幅。常规萃取精馏因需增设一个萃取剂再生塔，故设备投资方面难以得到有效控制，而采用隔壁塔萃取精馏因单塔即能完成多组分的分离，既保留了萃取精馏的优势又节省了设备投资。

3) 目前热泵精馏在工业领域已得到广泛应用。常规萃取精馏虽能降低能耗，但增加的设备投资使其难以工业化。随着隔壁塔技术的日益成熟以及隔壁塔萃取精馏研究的不断发展，相信隔壁塔萃取精馏会有不错的应用前景。

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Successful Application of Light Hydrocarbon Desulfurization by Alkaline Wash in Tahe Oilfield

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ABSTRACT: In 2016, the light hydrocarbons sold by Tahe oilfield light hydrocarbon station No.2 have given off peculiar smell. After laboratory analysis, it was found that the total sulfur light hydrocarbon was beyond relevant requirements in *Stable Light Hydrocarbon 9053–2013 GB*. After analysis, it is considered that the organic sulfur, such as the organic sulfur in the light hydrocarbon, leads to excessive sulfur content. According to the fact that established mixed hydrocarbon alkali washing desulfurization device can better remove the organic sulfur, it was determined to connect the light hydrocarbon with the existing mixed hydrocarbon alkali washing desulfurization device for alkali washing. Reconstruction scheme: one is to reconstruct the inlet tube of existing alkali wash tank and water tank and add distributor; another one is to optimize alkali washing process flow, add one vertical alkali washing tank. After reconstruction was carried out, ethanethiol was removed from light hydrocarbon by alkali washing process, and the sulfur content was obviously decreased, which meets the standard requirements.

KEYWORDS: Light hydrocarbon; Alkaline washing desulfurization; Sulfur content exceeding standard; Process optimization

Leakage and Explosion Hazard Analysis of LNG Receiving Station

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ABSTRACT: LNG belongs to the inflammable and explosive goods. In case of a leakage, it might trigger hazards like jet fire, pool fire, flash fire and vapor cloud explosion. In this paper, a typical working condition of leakage accident of LNG as well as other hazards caused by leakage was selected by using DNV PHAST software to calculate and analyze the consequence. Then GIS was adopted to show the hazardous area of the diffusion gas, heat radiation ranges of jet fire and pool fire, and the influenced zone of vapor cloud explosion. Finally, some countermeasures were put forward to prevent such risks. These countermeasures can provide the basis for the establishment of fire power and the formulation of contingency plan

KEYWORDS: LNG leakage; Jet fire; Pool fire; Vapor cloud explosion; LNG receiving station safety

Comparison of Energy Consumption Between Propane–Propene Distillation Separation Process and Prospect Forecast

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ABSTRACT: In order to reduce the energy consumption of the propane–propene separation process effectively, a theoretical basis for the optimization have been provided by comparing several relevant distillation processes. It begun with the existing propane–propene separation process, set up feed ratio to reach high purity propene with the mass fraction of 99.6%. In this paper, the process simulation software of ASPEN PLUS V8.6 has been used to simulate the conventional distillation process, heat pump distillation, conventional extractive distillation and divided wall extractive distillation. Then, comparative study was conducted according to the stimulation result from the combination of energy consumption and equipment investment. In the case of energy conservation, the last three kinds of distillation could save consumption by 34.1%, 20.2% and 42.1% compared with conventional distillation. With the consideration of equipment investment, heat pump distillation and divided wall extractive distillation have significant advantages. So, heat pump distillation and divided wall extractive distillation could have wide industry applications and would be the focus of future study.

KEYWORDS: Propane; Propene; Heat pump distillation; Extractive distillation; Divided wall; Simulation

OIL AND GAS FIELD DEVELOPMENT

Application of Pressure Drop Method in Interwell Interference Well Group

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