



Performance testing of an advanced glycol dehydrator design showed that the unit, compared with a conventional dehydration technology, saved the equivalent of more than 35 million standard cu ft/year of natural gas valued at more than \$173,000. It also lowered hazardous air pollutant (HAP) and volatile organic compound (VOC) emissions.

During this test, the new unit produced by Engineered Concepts LLC, Farmington, NM, also reduced CO₂ emissions by nearly 3,000 tons/year.

A 1996 study of CH₄ emissions from the natural gas industry, conducted by the US Environmental Protection Agency and the Gas Research Institute, estimated that active glycol dehydrators in the US collectively emitted about 18.6 billion standard cu ft/year of CH₄.¹

These units also reportedly produced 85% and 81% of the production sector's HAP and VOC emissions, respectively.^{2,3} These considerations make dehydrators ideal candidates for both gas savings and emission reductions.

Testing of the Quantum Leap natural gas dehydration technology (QLT) occurred at the Kerr-McGee Corp. gathering station in Brighton, Colo., in April 2003.

EPA's Office of Research and Development, under its Environmental Technology Verification program, conducted the study. The program operates six centers that focus on testing technologies designed to mitigate a broad range of environmental problems.

This test was conducted by the Greenhouse Gas Technology Center that is comanaged with EPA and operated by Southern Research Institute, Research Triangle Park, NC.

Technology description

The QLT can be configured as a retrofit to, or a replacement of, existing conventional dehydrators.

Fig. 1 shows a schematic of the technology as installed at the Kerr-McGee plant and Fig. 2 shows the installed system.

In conventional dehydrators, wet

natural gas enters a two-phase separator that divides liquid hydrocarbons from the gas stream. Liquid products feed a condensate storage tank for sale and wet gas flows to an absorber.

Lean, dry triethylene glycol (TEG) directly contacts the wet gas and absorbs water vapor, methane, HAPs including benzene, toluene, ethylbenzene, and xylene (BTEX), n-hexane, and VOCs.

Dry natural gas exits the absorber as pipeline-quality gas ready for sale. The rich, wet glycol exiting the absorber feeds a regeneration reboiler that removes the absorbed constituents resulting in a lean glycol mixture suitable for reuse in the absorber.

The regeneration process is typically the primary source of emissions from a dehydrator. The process contains a process pump, reboiler still, and a variety of heat exchangers.

The process pump moves glycol through the system and is either electrical or, most commonly, a gas-assisted Kimray pump.

High-pressure natural gas powers the Kimray pumps; spent pump gas is usually dumped into the rich glycol stream, flashed off in the regenerator, and vented through the still column. Units with a glycol flash tank upstream of the reboiler can recapture some of the spent gas for reboiler fuel.

The reboiler strips absorbed water, HAPs, VOCs, and CH₄ out of the glycol and into the still column. Regenerated lean glycol exits the reboiler, is cooled via cross exchange with returning rich glycol, and enters a surge tank. From there, it is pumped to a glycol-gas heat exchanger and back to the absorber.

This heat exchanger controls the lean glycol temperature to the absorber. High glycol temperatures relative to the gas temperature reduce TEG's moisture-absorption capability. Conversely, temperatures that are too low promote glycol loss due to foaming and increase the glycol's hydrocarbon uptake and potential still-vent emissions.

Advanced dehydrator design recovers gas, reduces emissions

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The still column vent emits stripped water, methane, HAPs, and VOCs to the atmosphere unless a combustion or condensation device controls the stream. Combustion devices include flares or, in the case of the Kerr-McGee site, thermal oxidizers. Condensers include water-knockout systems and other separation systems that produce saleable condensate products.

The QLT system contains these component modifications and additions (Fig. 1): electric glycol circulation pump, eductor, still column effluent condenser, glycol cooler, three-phase vacuum separator, three-phase emissions separator, electric process pump, and two high-efficiency glycol filters.

Circulation of glycol via the circulating pump (A) through the eductor (B) creates a vacuum. This vacuum is con-



This photo shows the system's features installed at the test site in Brighton, Colo. (Fig. 2).

makeup gas, and corresponding off cycles during which the recovered fuel gas pressure would increase to a point that the eductor was unable to pull an adequate vacuum.

A pressure-relief valve and fuel accumulator were installed to prevent this pressure buildup and to enable proper burner control.

Pressure relief valve

A pressure-relief valve (PRV) was installed in the vacuum separator. It would open to atmosphere when the recovered fuel gas pressure reached 30 psig and close when the pressure was less than 30 psig.

The PRV is a safety device. The system uses this feature only during initial system start-up; the vent remains

closed during normal operations.

Fuel accumulator vessel

A 430-gal accumulator vessel was installed to dampen the effects of large swings in reboiler temperature.

The accumulator vessel increased the fuel gas system's reserve volume during high-recovery periods. This allowed the burner to fire with small amounts of makeup fuel during high-firing cycles and provided a pressure cushion to accumulate fuel during low-firing periods.

A pressure-activated valve would open to the atmosphere if the gas pressure in the vessel exceeded 28 psig. This could produce air emissions, but this PRV is a safety device that would actuate during abnormal conditions only. It

remained closed during the tests.

Gas processed in the dehydrator had an unusually high btu content. Consequently, the process occasionally recovered more high-btu vapors than it could consume during normal operations. This resulted in a higher fuel pressure and subsequent problems in maintaining an adequate vacuum.

The accumulator helped dampen the system response; but as an added measure, Kerr-McGee installed a water-injection system.

Water-injection system

A compressed-air-driven pump was installed to inject some of the vacuum separator's recovered waste water back into the reboiler. This would increase the reboiler load when necessary, which enabled the burner to de-

mand more fuel.

The fuel-gas pressure and effluent condenser temperature control this pump. The effluent condenser temperature is a key control point because hot vapors cause inefficient hydrocarbon condensation.

The pump operates when the fuel-gas pressure is 20 psig or more and the overhead temperature is 120° F. or less; otherwise, the pump automatically shuts down. The water pump was designed with a reserve capacity sufficient to handle all reasonably expected gas compositions at the test facility.

Performance verification

We verified the operational performance for sales-gas moisture and production rate, glycol circulation rate, and

makeup natural-gas fuel flow rate. We also verified the environmental performance of reboiler-stack emission rates and HAP destruction efficiency.

Sales gas

Kerr-McGee continuously monitors sales-gas moisture using a GE Panametrics meter with a moisture measurement range of 0-20 lb H₂O/MMscf, a lower detection limit of 0.2 lb H₂O/MMscf, and a rated accuracy of $\pm 5\%$ of reading.

Panametrics calibrated the meter before installation. We used the 1-min average moisture data.

Kerr-McGee uses an Emerson MVS205 multivariable-sensor orifice meter to document sales-gas production. The sales-gas meter contains a 4-in. orifice plate and is temperature and pressure compensated to 60° F. and 14.7 psia (gas industry standard conditions).

The meter's operating range is 0-2 million standard cu ft/hr with a rated accuracy of $\pm 1\%$ of reading. Site personnel calibrated the flowmeter before testing. We used the meter's 1-min averages.

Glycol circulation

A Controlotron Corp. 1010EP1 ultrasonic meter measured the glycol circulation rate. The meter is a digitally integrated flowmetering system that consists of a portable computer and ultrasonic fluid flow transmitters.

The meter determines fluid velocity by measuring ultrasonic pulse transit times between the transducers. A precision-mounting jig secures the transducers to the pipe at a known distance.

The operator enters the fluid composition (100% TEG for this test), pipe diameter, material, wall thickness, and expected sonic velocity into the meter's

computer.

The flowmeter determines sonic velocity based on the known distance between the transducers for zero-flow conditions with the pipe full of fluid. It multiplies fluid velocity by the internal pipe area, and reports 1-min average volumetric flow rates.

The flowmeter's overall rated accuracy

TEST SITE DESIGN, OPERATING CONDITIONS

Table 1

Natural gas production, MMscfd at 14.7 psia, 60° F.	26
Sales gas moisture content, lb H ₂ O/MMscfd gas	<7
Electric 5-hp motor pump circulation rate, gpm	
Glycol for absorption, regeneration	5
Glycol for condensation, eductor power	72
Glycol-glycol heat exchanger	
Duty, 1,000 btu	325
Shell operating conditions (lean glycol)	Atmospheric pressure, 400° F.
Tube operating conditions (rich glycol)	30 psig, 300° F.
Reboiler still	
Duty, 1,000 btu/hr	600
Operating conditions	0-2 in. WC (vacuum)
Reboiler burner	
Total heat input required, MMbtu/hr	1.2
Fuel gas from emissions separator	~233-388 scfh (70-80 vol %) Specific gravity = 0.75 Lower heating value = 1,410 btu/scf
Makeup natural gas	~0-166 scfh (0-30 vol %) Specific gravity = 0.65 Lower heating value = 950 btu/scf
Stack dimensions	10-in. diameter, 20-ft high
Glycol condenser, glycol-air heat exchanger	
Duty, 1,000 btu/hr	225
Rich glycol operating conditions	30 psig, 150° F.
Emissions separator	
Dimensions	30-in. diameter, 6.5-ft high
Operating pressure, psig	15
Vacuum separator	
Dimensions	20-in. diameter, 5.5-ft high
Operating pressure, in. WC (vacuum)	0-5
Water discharge rate, gal/1.5-in. change in liquid level	~1.89
Condensate discharge rate, gal/1.5-in. change in liquid level	~1.89
Effluent condenser, vapor-glycol heat exchanger	
Duty, 1,000 btu/hr	100
Tube operating conditions (still vapors)	0-5 in. WC (vacuum), 212° F.
Shell operating conditions (rich glycol)	30 psig, 110° F.

EMISSIONS TESTING

Table 2

Measured variable	US EPA reference method	Analyzer type	Instrument range
NO _x	7E	Chemiluminescence	0-100 ppm
CO	10	Nondispersive infrared	0-100 ppm
Total hydrocarbons	25A	Flame ionization detector	0-100 ppm
O ₂	3A	Paramagnetic	0-25%
CO ₂	3A	Nondispersive infrared	0-20%
CH ₄	18	Gas chromatograph, flame ionization detector	0-100 ppm
BTEX,* n-Hexane	18	Gas chromatograph, flame ionization detector	0-100 ppm
Exhaust gas volumetric flow rate	1A and 2C (modified)	Differential pressure	9,000-11,000 scfh
Moisture	4	Gravimetric	0-100%

*Includes separate benzene, toluene, ethylbenzene, and xylene quantification.

is $\pm 1.0\%$ of reading and can be used on 0.25-360 in. diameter pipes with fluid flow rates of 0-60 fps.

Makeup natural gas

The new reboiler burner can accept up to 166 scfh of makeup natural gas as supplemental fuel.

A Halliburton Co. MC-II EXP turbine meter installed on the 1-in. ID gas line upstream of the reboiler measured makeup gas flow. The meter includes an integral-signal display and transmitter with a linear flow range sufficient to measure gas flows if the reboiler operates on makeup gas only (0-600 scfh).

The manufacturer used a piston-type volume prover to calibrate the meter. It is temperature and pressure-compensated, and provided a mass flow output accurate to 1% at standard conditions. We used the 1-min average data from this meter.

Reboiler stack emissions

Cubix Corp., an independent stack testing contractor in Austin, performed reboiler stack emissions testing to determine concentrations and emission rates for: CO, total hydrocarbons, greenhouse gases (CO₂, NO_x, and CH₄), BTEX, and total HAPs, which are BTEX plus n-hexane.

Cubix conducted three 90-min (nominal duration) test runs for each parameter while the system was operating at normal conditions.

Emission rates reported in ppm (vol) dry (ppmvd) are correlated with the stack volumetric flow rates in dry standard cu ft/min to yield lb/hr emission rates for NO_x, CO, CH₄, VOC, hexane, BTEX, and HAPs.

VOC emissions are all organic compounds minus methane and ethane emissions according to Colorado Department of Public Health and Environ-

OPERATING DATA, NORMAL CONDITIONS¹

Table 3

Date in 2003	Valid data, hr	Sales gas moisture content, ² lb H ₂ O/MMscf		Sales gas flow rate, ² MMscfd		Makeup natural gas flow rate, ² scfh		Glycol circulation rate, gpm	
		Range	Average	Range	Average	Range	Average	Range	Average
Apr. 23	15.05	0.80-1.69	1.02	28.67-31.39	29.31	0.11-345.98	16.32	1.55-6.04	3.63
Apr. 24	24.00	0.79-1.03	0.89	26.18-32.02	28.63	0-220.19	1.22	1.47-4.00	3.30
Apr. 25	20.73	0.91-1.44	1.12	26.09-29.96	28.38	0-190.44	0.63	0-4.71	3.00
Apr. 26	24.00	0.73-1.99	1.28	26.13-29.97	28.15	0-317.04	1.68	0.64-5.34	3.21
Apr. 27	23.95	0.95-1.69	1.27	25.69-28.83	26.88	0-3.92	0.83	1.79-4.23	3.67
Apr. 28	24.00	0.85-1.76	1.24	23.13-29.96	26.81	0-706.33	5.41	1.68-4.61	3.68
Apr. 29	24.00	0.89-1.64	1.18	25.20-29.96	27.38	0-3.61	0.83	1.87-4.43	3.77
Overall average			1.14		27.90		3.85		3.47
Normal operating conditions ¹		0.89-1.50		26.54-29.26		0-1.76		3.14-3.93	

¹Normal operating conditions is the range represented by 75% of individual 1-min measurement values. ²Source: Kerr-McGee operations. ³The flowmeter occasionally reported zero on this date due to aeration in the pipeline. When the operator added makeup TEG to the system, the aeration ceased and the flowmeter resumed normal operations.

ment regulations.

All the test procedures are documented Title 40 CFR 60 Appendix A reference methods.

Table 2 summarizes reference methods performed for emissions testing supporting this verification.

HAP destruction efficiency

Destruction efficiency is the net HAPs entering the system from the glycol minus those leaving the system in emissions sources divided by the net HAPs entering the system.

Testers determined the HAPs inputs via the Atmospheric Rich-Lean Method for Determining Glycol Dehydrator Emissions.⁴

HAP emission sources at this site include: fugitive leaks, reboiler burner exhaust, waste water, and PRVs. We determined that fugitive leaks are negligible because the fabricator certified the system to be leaktight. The burner stack may emit unburned HAPs to the atmosphere; HAPs dissolved in waste water can release during disposal.

Consistent with 40 CFR Part 63,5

REBOILER STACK EMISSIONS

Table 4

	Test run			Average
	1	2	3	
Exhaust O ₂ , %	6.4	6.7	6.8	6.6
Stack gas velocity, fps	23.64	23.72	24.27	23.87
Stack flow rate, dscfh	10,793	10,369	10,359	10,507
Emissions				
NO _x , ppmvd	67.8	66.0	61.6	65.1
NO _x , lb/hr	0.0873	0.0817	0.0761	0.0817
CO, ppmvd	0.3	1.0	0.6	0.6
CO, lb/hr	0.0003	0.0007	0.0004	0.0005
VOCs, ppmvd	0.4	0.8	0.5	0.6
VOCs, lb/hr	0.0002	0.0004	0.0002	0.0003
CH ₄ , ppmvd	<0.1	<0.1	<0.1	<0.1
CH ₄ , lb/hr	<0.00004	<0.00004	<0.00004	<0.00004
CO ₂ , %	9.5	9.2	9.1	9.3
CO ₂ , lb/hr	117	108	107	111
Total HAPs, ppmvd	<0.6	<0.6	<0.6	<0.6
Total HAPs, lb/hr	<0.0016	<0.0016	<0.0015	<0.0016

HAPs dissolved in the condensate stream are considered to be “controlled” or “sequestered” and not emissions.

We conducted performance testing in two stages: operational testing occurred over 7 days both to obtain reportable flow rate data and to ensure that the plant was operating normally; environmental testing occurred on the following day in three test runs of 70-85 min each.

Test results

Table 3 shows the operational results. Makeup natural gas flow rates are

particularly interesting.

We expected the new reboiler to use up to 166 scfh of makeup gas to supplement its fuel supply, but the overall average flow rate was 3.85 scfh. This showed that the unit could use high-btu, wet hydrocarbon vapors as a primary fuel.

Table 4 shows the reboiler stack emissions results for the three test runs. A continuously extracted stack-gas sample periodically injected into a gas chromatograph provided the material for organic (CH₄, HAPs) concentration determinations.

Test personnel performed six injections, each about 15 min apart, during each test run.

The analyst determined that each HAP constituent was consistently below the instrument’s detection limit of <0.1 ppmvd. This equates to an average emission rate of <0.0016 lb/hr, which is well below the site’s permit requirement.

All CH₄ results were also below the gas chromatograph, flame ionization detector’s detection limit of <0.1 ppmvd.

Table 5 summarizes HAP destruction efficiency for each test run and the overall average. The calculation method for total HAP destruction efficiency to sum HAPs in the waste water (Table 6) and reboiler exhaust (Table 7) and divide by HAPs inputs from glycol streams (Table 8).

The operational performance data showed that:

- The moisture content of dry natural gas was well below the 7 lb H₂O/MMscf limit that the operator required

HAP DESTRUCTION EFFICIENCY

Table 5

	Test run			Average	90% confidence interval
	1	2	3		
HAPs in, lb/hr					
Rich glycol	9.83	8.37	10.19	9.46	1.62
Lean glycol	0.33	0.37	0.4	0.37	0.06
Net inflows	9.50	8.00	9.79	9.09	1.62
HAPs out, lb/hr					
Waste water	0.0209	0.0220	0.0232	0.0220	0.0020
Stack	<0.0016	<0.0016	<0.0015	0.0016	0.00015
Vented	0	0	0	0	—
Net emissions	0.0226	0.0236	0.0245	0.0236	0.002
Destruction efficiency, %	99.76	99.70	99.75	99.74	0.01

HAPs IN WASTE WATER

Table 6

	Concentration in waste water, µg/ml				Average		Waste water production, gpm	HAP in waste water, lb/hr
	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	ppg		
Run 1								
n-Hexane	0.801 (ND)	1.001 (ND)	1.001 (ND)	1.001 (ND)	0.951	0.000008	0.101	0.00005
Benzene	200.489	227.145	313.737	289.688	257.764	0.002151	0.101	0.01298
Toluene	104.976	113.377	175.446	157.164	137.741	0.001150	0.101	0.00693
Ethylbenzene	0.971 (J)	1.279 (J)	1.918 (J)	1.642 (J)	1.453	0.000012	0.101	0.00007
m- and p-Xylene	8.352	9.058	16.928	15.516	12.463	0.000104	0.101	0.00063
o-Xylene	2.829 (J)	3.434 (J)	5.570	5.212	4.261	0.000036	0.101	0.00021
Total HAPs	318.417	355.294	514.600	470.223	414.634	0.003460	0.101	0.0209
Run 2								
n-Hexane	0.400 (ND)	1.001 (ND)	1.464 (J)	1.001 (ND)	0.967	0.000008	0.119	0.00006
Benzene	186.603	271.942	146.598	284.810	222.488	0.001857	0.119	0.01328
Toluene	96.426	165.647	78.479	168.820	127.343	0.001063	0.119	0.00760
Ethylbenzene	0.855 (J)	1.635 (J)	1.001 (ND)	1.803 (J)	1.324	0.000011	0.119	0.00008
m- and p-Xylene	8.629	15.951	7.379	16.304	12.066	0.000101	0.119	0.00072
o-Xylene	2.671	5.173	2.485 (J)	5.408	3.934	0.000033	0.119	0.00023
Total HAP	295.584	461.350	237.407	478.147	368.122	0.003072	0.119	0.0220
Run 3								
n-Hexane	1.001 (ND)	1.001 (ND)	1.001 (ND)	1.001 (ND)	1.001	0.000008	0.098	0.00005
Benzene	275.285	272.485	291.060	307.250	286.520	0.002391	0.098	0.01407
Toluene	156.729	157.039	165.044	168.717	161.882	0.001351	0.098	0.00795
Ethylbenzene	1.609 (J)	1.555 (J)	1.706 (J)	1.677 (J)	1.637	0.000014	0.098	0.00008
m- and p-Xylene	15.815	15.510	16.673	16.276	16.068	0.000134	0.098	0.00079
o-Xylene	5.391	5.090	5.367	5.323	5.293	0.000044	0.098	0.00026
Total HAP	455.829	452.680	480.850	500.245	472.401	0.003942	0.098	0.0232
Overall average total HAPs	356.610	423.108	410.952	482.871	418.386	0.003	0.106	0.0220

ND = nondetect or the analytical result is below the minimum detection limit (MDL). J = analytical result is between the MDL and the limit of quantification.

throughout the monitoring period. Actual daily averages were 0.89-1.28 lb H₂O/MMscf.

- Average sales-gas flow rates were 26.8-29.3 MMscfd.
- The system burned all noncondensable hydrocarbon vapors without venting them to the atmosphere and used little or no makeup gas. Average flow rates of makeup natural gas were 0.63-16.32 scfh with an overall average of 3.85 scfh.

- Daily average glycol circulation rates were 3.0-3.77 gpm.

The environmental testing proved that:

- Overall average emission rates for NO_x, CO, CO₂, and VOCs from the reboiler stack were 0.0817, 0.0005, 111, and 0.0003 lb/hr, respectively.

- HAP and CH₄ concentrations in the reboiler stack were undetectable. Maximum HAPs leaving the system in the reboiler exhaust and waste water were 0.0016 and 0.022 lb/hr, respectively.

- HAP destruction efficiency was greater than 99.74% ± 0.01%.

- PRVs did not operate at any time during the entire test. No releases are anticipated during normal operations; therefore, no expected emissions were assigned to PRV operations.

- Average waste water and condensate-production rates were 6.36 and

REBOILER EXHAUST STREAM

Table 7

Run		HAP, lb/hr
1	n-Hexane	<0.000241
	Benzene	<0.000218
	Toluene	<0.000258
	Ethylbenzene	<0.000297
	p-Xylene	<0.000297
	o-Xylene	<0.000297
2	Total HAP	<0.00161
	n-Hexane	<0.000232
	Benzene	<0.000210
	Toluene	<0.000247
	Ethylbenzene	<0.000286
	p-Xylene	<0.000286
3	o-Xylene	<0.000286
	Total HAP	<0.00155
	n-Hexane	<0.000232
	Benzene	<0.000210
	Toluene	<0.000247
	Ethylbenzene	<0.000285
Overall average	p-Xylene	<0.000285
	o-Xylene	<0.000285
	Total HAP	<0.00154
		0.00157

2.88 gph, respectively.

Cost savings, emission reductions

The four main sources of cost savings for the new dehydrator result from replacing the Kimray pump, eliminating gas stripping, reducing still column overhead emissions, and lowering thermal oxidizer fuel use.

Kimray pump

An electric pump in the QLT replaced the Kimray pump, which is pressurized with natural gas in typical dehydrators.

The Kimray pump developed a pres-

sure load of 1,070 psig, which worked against the absorber and the glycol flash separator. Kimray literature indicates that, at this pressure, the pump consumes 5.95 scf/gal of glycol pumped or a total of 34,200 scfd based on a 4 gpm glycol circulation rate.

The reboiler in the original configuration consumed some of this gas. It burned about 520,000 btu/hr assuming a 50% efficiency.

The approximate net heating value of gas from the glycol-gas separator was about 1,160 btu/scf according to a process model. This is higher than the plant fuel gas value of 1,107 btu/scf because the gas contained some of the heavier components absorbed by the glycol.

The reboiler therefore consumed 448 scfh and the rest was vented to the thermal oxidizer. Total gas no longer wasted is 34,300 - 448(24) = 23,500 scfd. At 1,160 btu/scf this equals 1.14 MMbtu/hr.

Gas stripping

Because a condensing water exhauster was incorporated into the new design, the gas stripping system (sparger) was no longer needed. The minimum design consumption rate using a sparger was 4 scf of gas/gal of glycol circulated; we assumed that consumption rate for these tests.

At this rate, the sparger used 23,040

HAPs IN GLYCOL STREAMS

Table 8

Run 1 Lean 1	Concentration, µg/ml					Average µg/ml	Average ppg	Lean glycol flow, gpm	HAP, lb/hr	Difference in net HAPs lb/hr
	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml					
n-Hexane	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.769	0.01		
Benzene	69.4	54.0	68.2	59.1	62.66	0.0005229	3.769	0.12		
Toluene	89.6	66.5	87.6	69.4	78.26	0.0006531	3.769	0.15		
Ethylbenzene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.769	0.01		
p-Xylene	16.6	15.6	14.8	19.9	16.73	0.0001396	3.769	0.03		
o-Xylene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.769	0.01		
Total HAP	193.58	154.14	188.63	166.28	175.66	0.0014659	3.769	0.33		
Rich 1	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	Average ppg	Rich glycol flow, gpm	HAP	Difference in net HAPs lb/hr	
n-Hexane	140.13	107.27	144.50	137.00	132.22	0.0011034	3.916	0.26	0.25	
Benzene	1,660.5	1,424.8	1,704.8	1,394.5	1,546.13	0.0129031	3.916	3.03	2.91	
Toluene	2,744.7	2,393.9	2,843.6	2,293.2	2,568.85	0.0214381	3.916	5.04	4.89	
Ethylbenzene	58.98	51.47	62.31	48.01	55.19	0.0004606	3.916	0.11	0.10	
p-Xylene	614.6	545.7	647.7	511.2	579.80	0.0048386	3.916	1.14	1.11	
o-Xylene	137.67	120.91	144.49	113.18	129.06	0.0010771	3.916	0.25	0.24	
Total HAP	5,356.52	4,644.02	5,547.40	4,497.10	5,011.26	0.0418210	3.916	9.83	9.50	
Run 2 Lean 2	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	Average ppg	Lean glycol flow, gpm	HAP, lb/hr	Difference in net HAPs lb/hr	
n-Hexane	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.604	0.01		
Benzene	82.5	74.4	68.6	75.5	75.25	0.0006280	3.604	0.14		
Toluene	102.5	94.5	86.6	92.8	94.11	0.0007853	3.604	0.17		
Ethylbenzene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.604	0.01		
p-Xylene	20.6	16.1	24.8	14.3	18.96	0.0001582	3.604	0.03		
o-Xylene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.604	0.01		
Total HAP	223.66	202.98	197.99	200.64	206.32	0.0017218	3.604	0.37		
Rich 2	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	Average ppg	Rich glycol flow, gpm	HAP	Difference in net HAPs lb/hr	
n-Hexane	135.27	122.23	119.66	134.68	127.96	0.0010679	3.772	0.24	0.23	
Benzene	1,476.1	1,461.7	1,332.5	1,467.7	1,434.50	0.0119715	3.772	2.71	2.57	
Toluene	2,197.3	2,355.2	2,133.1	2,275.6	2,240.32	0.0186964	3.772	4.23	4.06	
Ethylbenzene	44.96	47.96	42.70	43.75	44.84	0.0003742	3.772	0.08	0.07	
p-Xylene	474.4	508.0	458.7	470.2	477.84	0.0039878	3.772	0.90	0.87	
o-Xylene	106.65	112.41	100.60	103.05	105.68	0.0008819	3.772	0.20	0.19	
Total HAP	4,434.72	4,607.53	4,187.29	4,495.03	4,431.14	0.0369797	3.772	8.37	8.00	
Run 3 Lean 3	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	Average ppg	Lean glycol flow, gpm	HAP, lb/hr	Difference in net HAPs lb/hr	
n-Hexane	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.887	0.01		
Benzene	74.3	74.3	71.6	86.0	76.57	0.0006390	3.887	0.15		
Toluene	91.1	88.7	86.5	105.6	92.98	0.0007760	3.887	0.18		
Ethylbenzene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.887	0.01		
p-Xylene	17.1	21.6	16.5	18.4	18.41	0.0001536	3.887	0.04		
o-Xylene	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00 (ND)	6.00	0.0000501	3.887	0.01		
Total HAP	200.51	202.67	192.57	228.09	205.96	0.0017188	3.887	0.40		
Rich 3	Sample 1	Sample 2	Sample 2a	Sample 3	µg/ml	Average ppg	Rich glycol flow, gpm	HAP	Difference in net HAPs lb/hr	
n-Hexane	144.62	128.69	144.76	135.22	138.32	0.0011544	4.047	0.28	0.27	
Benzene	1,652.1	1,566.6	1,576.0	1,592.6	1,596.84	0.0133263	4.047	3.24	3.09	
Toluene	2,609.8	2,517.0	2,529.8	2,665.7	2,580.59	0.0215361	4.047	5.23	5.05	
Ethylbenzene	50.25	51.93	51.89	53.51	51.90	0.0004331	4.047	0.11	0.09	
p-Xylene	524.0	542.0	544.3	550.5	540.19	0.0045081	4.047	1.09	1.06	
o-Xylene	115.01	121.90	121.59	120.08	119.64	0.0009985	4.047	0.24	0.23	
Total HAP	5,095.74	4,928.21	4,968.39	5,117.57	5,027.48	0.0419563	4.047	10.19	9.79	
Overall average	Sample 1, µg/ml	Sample 2, µg/ml	Sample 2a, µg/ml	Sample 3, µg/ml	µg/ml	Average ppg	Avg. flow rate, gpm	Avg. mass rate	Difference in net HAPs lb/hr	
Lean total HAP	205.92	186.60	193.06	198.33	195.98	0.0016355	3.753	0.37		
Rich total HAP	4,962.33	4,726.59	4,901.03	4,703.23	4,823.29	0.0402523	3.912	9.46	9.09	

ND = nondetect or analytical result below the minimum detection limit.

scfd of 1,107 btu/scf gas or 1.06 MMbtu/hr. All of this gas was routed to the thermal oxidizer.

Still column overhead emissions

During testing, the new dehydrator recovered 2.88 gph of condensate con-

sisting mostly of HAPs valued at about 0.13 MMbtu/gal, or 0.375 MMbtu/hr. All these condensates previously went to the thermal oxidizer.

Additionally, the still column overhead emissions provided all the process fuel for the new system. The Kimray pump calculation already accounts for

this fuel because that is where the old dehydrator obtained it; therefore, 0.52 MMbtu must be added back into the still column calculation.

Total still column overhead emissions no longer wasted is 0.375 + 0.520 = 0.895 MMbtu/hr.

Thermal oxidizer fuel

We did not meter the fuel flow to the thermal oxidizer on the tested unit; however, a parallel dehydrator similarly equipped with a thermal oxidizer that processed the identical gas stream was metered. That dehydrator circulated 6 gpm of glycol. We assumed that the hydrocarbon pickup is similar and that the thermal oxidizer duty is directly proportional.

Fuel consumption in the metered thermal oxidizer, according to Kerr-McGee, is 34,700 scfd of 1,107 btu/scf gas. Fuel for the thermal oxidizer that the new system replaced was therefore $(34.7/6) \times 4 = 23,100$ scfd or 1.067 MMbtu/hr.

The total previously wasted gas in the pumps, gas stripping, still column overheads, and thermal oxidizer fuel is $1.14 + 1.06 + 0.895 + 1.07 = 4.16$ MMbtu/hr.

At a value of \$5.00/MMbtu, the gas saved is worth more than \$182,000/year.

Electric utility costs

The new process required 11.9 kw of electricity to drive the motors for the process pump, circulation pump, and glycol cooler. The conventional dehydrator required 0.8 kw of electricity to power the blower on the thermal oxidizer.

At \$0.09/kw-hr, the additional electric consumption of the new process was about \$8,800/year.

Payback

Overall savings attributable to the QLT process is about \$173,000/year. The process cost about \$300,000 but replaced equipment valued at about \$225,000. The payback on the incremental difference in capital cost is therefore less than 6 months.

CO₂ emissions

The new reboiler consumes about 0.520 MMbtu/hr of a high btu, mixed-hydrocarbon stream and produces 111 lb/hr of CO₂. If the thermal oxidizer on the old dehydrator consumed 4.16 MMbtu/hr of a similar mixture of high-btu hydrocarbon fuels, it would proportionally produce about 888 lb/hr CO₂.

About 60% of the vapors burned in the thermal oxidizer, however, were methane from gas used by the Kimray pump, gas stripping, and fuel for the thermal oxidizer.

CO₂ emissions from the methane portion of the incinerated gas are less than that for higher-btu gas components. Less CO₂ emissions to account for the methane yields a value of about 680 lb/hr, or a reduction of about 2,980 tonnes/year. ♦

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