CONF-9605212--1

Paper Number:
DOE/METC/C-96/7242

Title:
An Acid-Gas Removal System for Upgrading Subquality Natural Gas

Authors:
Nagaraju Palla (Institute of Gas Technology)
Anthony L. Lee (Institute of Gas Technology)
Dennis Leppin (Gas Research Institute)
Harold D. Shoemaker (METC)
H. Max Hooper (Krupp Koppers GmbH)
Gerd Emmrich (Krupp Koppers GmbH)
Tom F. Moore (Moore Environmental Resources)

RECEIVED
SEP 1 1 1996
OSTI

Conference:
XII Jornadas de Gas

Conference Location:
Puerto La Cruz, Venezuela

Conference Dates:
May 8-11, 1996

Conference Sponsor:
Association of Venezuela Gas Processors

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
VM

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Summary

The objective of this project is to develop systems to reduce the cost of treating subquality natural gas. The team members and their functions are described as follows:

Funding Organizations:

Gas Research Institute
Department of Energy — Morgantown Energy Technology Center
Institute of Gas Technology's Sustaining Membership Program.

In-Kind Funding Organizations:

Huntsman Specialty Chemical Corporation provides solvents and engineering assistance.
Koch Engineering Co., Inc., provides structured packings and engineering assistance.
Shell Oil Company provides host-sites and field assistance.
Michigan Consolidated Gas Company provides host-site and field assistance.
Krupp Koppers GmbH is the commercial developer of this technology.

Based on over 1000 laboratory experiments on vapor-liquid equilibria and mass transfer and simulation studies, the use of N-Formyl Morpholine as a solvent together with structured packings has the following advantages:

- High capacity for H_2S and CO_2 removal
- Little or no refrigeration required
- Less loss of hydrocarbons (CH_4, C_2-C_6...)
- Dehydration potential.

The process implications are —

- More hydrocarbons in the product gas
- 15% savings in plant construction costs
- 40% savings in plant operating costs.

The implications for the gas industry are —

- Increased production
- Reduced cost of upgrading subquality natural gas.

To verify these findings and to obtain additional data base for scale-up, a field test unit capable of processing 1MMSCF/d of natural gas has been installed at the Shell Western E&P Inc. (SWEPI) Fandango processing plant site. The results of the testing at the Fandango site will be presented when available.

IGT's Current Acid-Gas Removal System

The Institute of Gas Technology (IGT) is developing technology that will reduce gas processing costs for current production and allow subquality gas to be economically produced that would have been, otherwise, not produced. The experimental program discussed in this paper has been in progress since 1990. It has focused primarily on the evaluation of N-Formyl Morpholine (NFM), shown in Figure 1, as a physical solvent for the cost-effective upgrading of subquality natural gas to pipeline quality gas. The selection of NFM for this program was based on previous work conducted by IGT on the selective removal of hydrogen sulfide and carbon dioxide from coal gasifier effluents. That work showed that the use of NFM resulted in a significant cost advantage over 107 other solvents for that application.

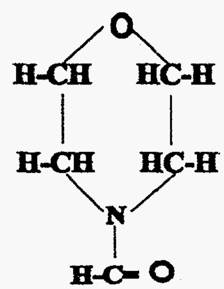

Figure 1. N-FORMYL MORPHOLINE ($C_5H_9O_2N$)

NFM has been used successfully in the recovery of high-purity aromatics since 1968 by both Huntsman Specialty Chemical Corporation and Krupp Koppers GmbH, the major German engineering contractor with worldwide experience in the field of process plants for refineries and petrochemicals, coal gasification facilities, coking plants, and coke oven gas processing. Some of the 25 applications developed by Krupp Koppers are Morphylane®, Morphylex®, Butenex®, and Octenar®.

NFM, a derivative of morpholine, exhibits very high selectivity with good solvency, is environmentally compatible, is nontoxic and biologically degradable, and is widely known in refinery technology. Now its application is being extended to gas sweetening.

Laboratory Vapor-Liquid Equilibrium (VLE) Studies

The VLE apparatus developed at IGT, is capable of handling all sulfur species present in natural gas and operating at pressures from 25 to 3000 psia and temperatures from 60° to 300°F.

Over 1000 data points were collected for mixtures of NFM and water, MEA, DGA, MDEA, NMM, and NEM over the following ranges of conditions:

Temperature, °F	60-300
Pressure, psia	25-1150
Gas Components	
Single Component	CO_2, H_2S, COS, C_3H_8, to C_6's
Mixtures	CH_4, CO_2, H_2S, C_2H_6, C_3H_8, to C_6's, BTEX.

Computer Modeling

The ASPEN™ Plus process simulation software package was used to regress VLE and mass transfer data to obtain the appropriate equation-of-state coefficients. Peng-Robinson, Redlich-Kwong-Soave, Redlich-Kwong-ASPEN™, and Redlich-Kwong-UNIFAC thermodynamic models were investigated.

As a reality check, a solvent manufacturer conducted simulations of the same cases and conditions using their proprietary models for a commercial physical solvent. Table 1 shows a comparison between NFM and the commercial solvent where the requirements of the commercial physical solvent are referenced as 100%. According to the models, there would be substantial savings in plant operating costs (40% to 50%), as well as in capital costs (15% to 30%).

Table 1. COMPARISON BETWEEN A COMMERCIAL SOLVENT AND NFM

Solvent	Commercial Solvent Case A and B	IGT's NFM Case A	IGT's NFM Case B
Circulation Rate	100%	94%	75%
Total Power Required	100%	70%	37%
Total Refrigeration Duty	100%	58%	55%
Total Heat Duty	100%	68%	57%
Total Construction Costs	100%	85%	70%
Total Operating Costs	100%	60%	47%

Based on this comparison, operating cost savings of $29 million/year were estimated for the existing U.S. plants (see Table 2). The projected market potential for NFM is shown below. These data were based on GRI Topical Report GRI-93/0342, "Business Characteristics of the Natural Gas Conditioning Industry," by Purvin & Gertz, Inc., May 1993.

Table 2. POTENTIAL OPERATING COST SAVINGS WITH USE OF N-FORMYL MORPHOLINE FOR NATURAL GAS PURIFICATION

Process	Number of Plants	Avg. Plant Size	Total Gas Capacity, MMCF/d	Plants Changed Over, %	Operating Cost Savings, $/MCF	Total Annual Savings, $million/yr
Selexol	5	205	1020	80	0.04	10.7
Sulfinol	57	85	4678	30	0.03	13.8
Chemical	394	85	34295	2	0.02	4.5
Total	456	375	39993			29.0

PROJECTED MARKET POTENTIAL OF NFM

- Anticipated new plants by the year 2000:
  - — 175 for CO_2 removal
  - — 233 for H_2S removal

- Existing plants:
  - — 5 Selexol plants producing 1020 MMCF/d
  - — 57 Sulfinol plants producing 4678 MMCF/d
  - — 394 chemical solvent plants producing 34,259 MMCF/d

- Estimated NFM impact at 1988 production levels:
  - — $29 million/yr savings

Structured Packing Technology

The use of structured packing is well established and has been used successfully in distillation columns, specifically in low-pressure and vacuum distillation, because of its high efficiency, low pressure drop, low "height equivalent to a theoretical plate" (HETP) and high capacity. This technology has also shown excellent performance in natural gas dehydration at pressures of 1000 psig and above.

To illustrate the success of this technology in natural gas dehydration, a report (March 1991) by ARCO Oil & Gas Company on the performance of a structured packing in a triethylene glycol dehydration column showed that, for the same process conditions, the structured packing was able to reduce the column size by 260%, vessel weight by 200%, internals by 200%, and cost by 30%.

Surprisingly, this technology has not been popular in natural gas sweetening, and there is very little documented experience reported. The process conditions for natural gas sweetening are closer to natural gas dehydration than high-pressure distillation, and both natural gas sweetening and natural gas dehydration are absorption-type systems. Potentially, benefits such as increased capacity, increased efficiency, lower pressure drop, and lower residence time (which may translate into increased selectivity) may be realized by using this technology in natural gas sweetening.

Field Studies

In conjunction with a program to evaluate structured packing contactors for gas sweetening applications, IGT has initiated a series of tests to evaluate NFM under field conditions. Although NFM VLE and computer modeling results were very encouraging, it was necessary to test NFM on a large scale. IGT is planning to conduct tests at three different sites to determine NFM's performance in processing subquality natural gas streams with low (5% to 8%), medium (8% to 15%), and high (15% to 35%%) total acid gas concentrations. The following sites, given in Table 3, have been chosen for conducting field tests. A map of the site locations is given in Figure 2. The schedule for the field tests at these three locations is given in Figure 3.

The field test unit is shown schematically in Figure 4; Figure 5 is a photograph of the unit presently installed beside a Shell Western E&P, Inc. (SWEPI) processing plant located 20 miles east of Zapata, Texas. The Shell plant processes gas from 18 wells located on the premises, and it has an operating capacity of 70 MMSCF/d. The IGT field test unit operates on a closed-loop principle and does not discharge any gases directly into the atmosphere. The feed gas for IGT's field test unit is drawn from Shell's Fandango plant, and the processed gas from IGT's test unit will be returned to the suction side of Shell's recycle compressor. A schematic diagram of the connection between the two plants is given in Figure 6. Flash gas and acid gas from IGT's skid-mounted unit will be combined and returned to Shell's vent system.

Conclusions

The use of N-Formyl Morpholine and structured packing shows promise for reducing the cost of upgrading subquality natural gas. The estimated savings are 15% in construction costs and 40% in operating costs over comparable commercial physical solvents.

Table 3. FIELD TEST SITES AND FEED GAS COMPOSITIONS

Site:	**Fandango (SWEPI)**	**Terrell (SWEPI)**	**MichCon**
Location	South Texas	Southwest Texas	Michigan
Current Solvent	Selexol	Propylene Carbonate	MDEA
Gas Flow Rate, MMCF/d	40	180 to 220	30
Temperature, °F	100	70 to 110	80 to 90
Pressure, psig	1,000	750 (compressed to 750 psig from 300 psig)	975
Feed Gas Composition, mol %			
CH_4	85.7	63	91.88
CO_2	14.0	36	7.90
C_2H_6	0.1	0.5	0.06
C3+		0.04	0.05
N_2	0.2	0.8	0.11
H_2S, ppm	50 to 75	60	
H_2O	(saturated)		(saturated)
Clean Gas Spec			
CO_2, mol %	<2	<3.5	<2
H_2S, ppm	<4	<6	<4
H_2O, lb/MMSCF	<7	<7	<7

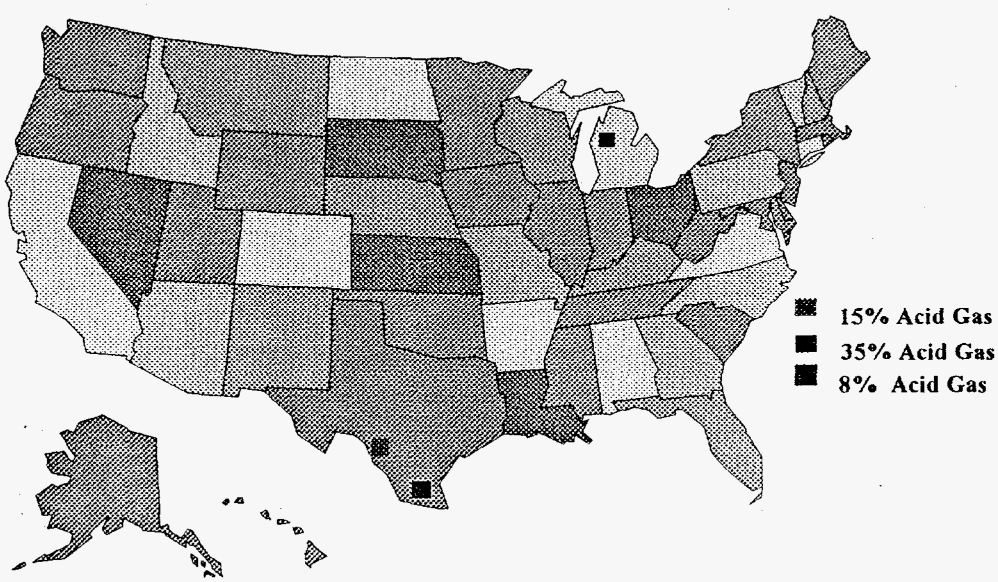

Figure 2. SELECTED FIELD TEST SITE LOCATIONS

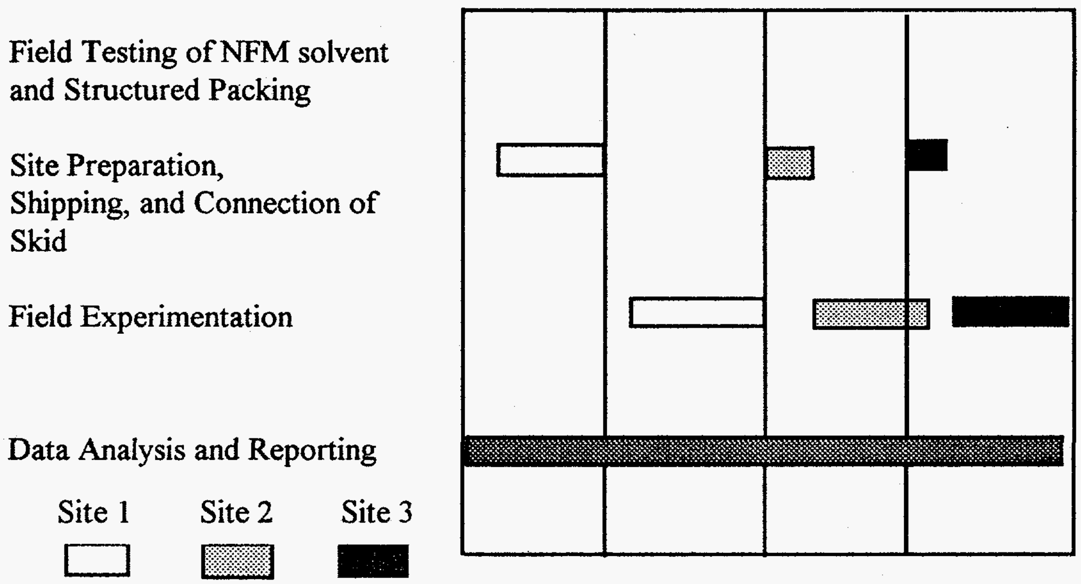

Figure 3. FIELD TEST PROGRAM SCHEDULE

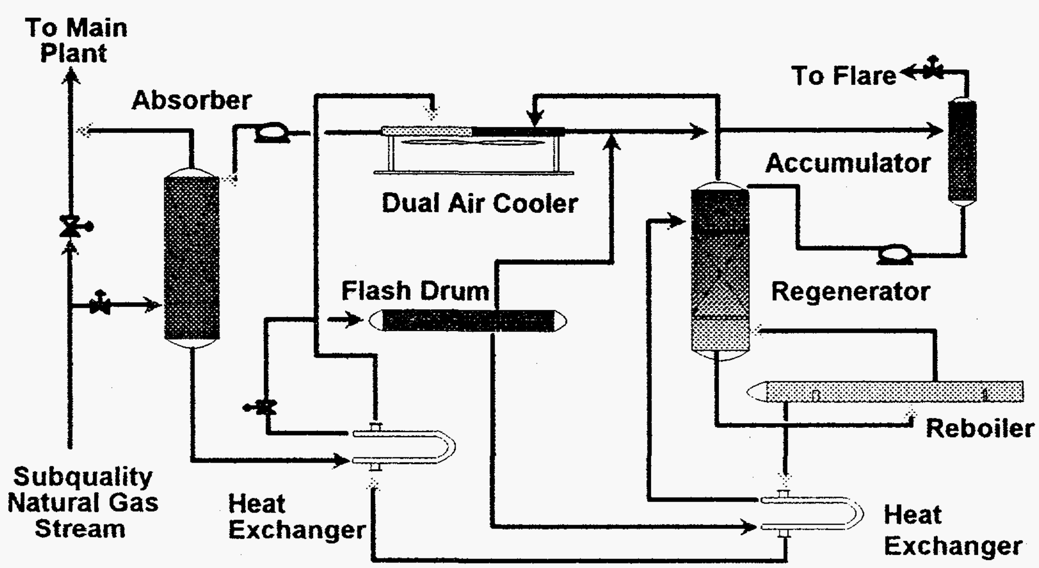

Figure 4. SCHEMATIC DIAGRAM OF FIELD TEST UNIT

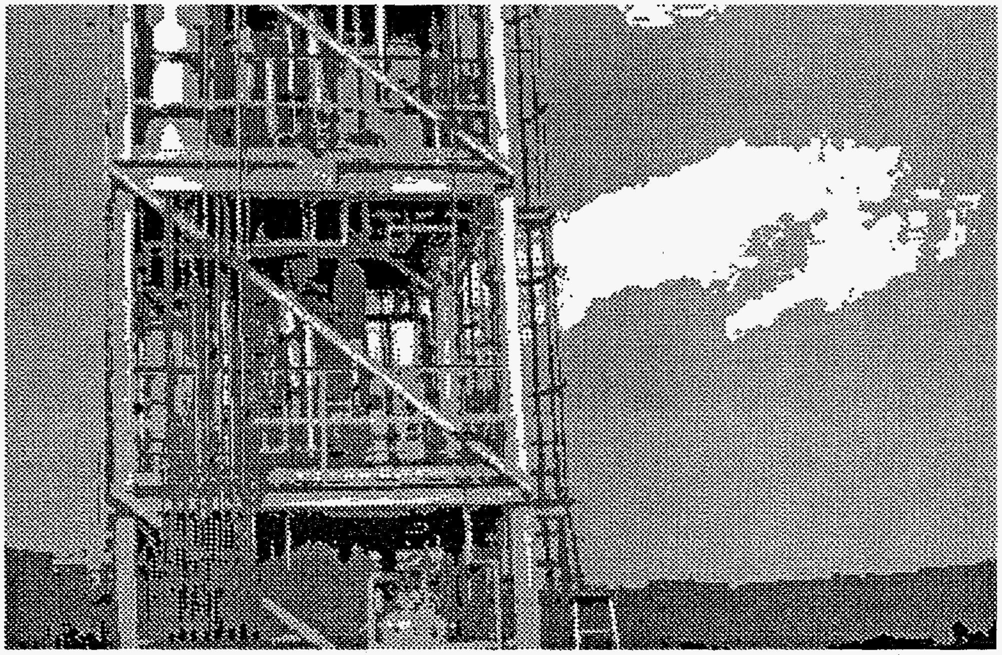

Figure 5. FIELD TEST UNIT

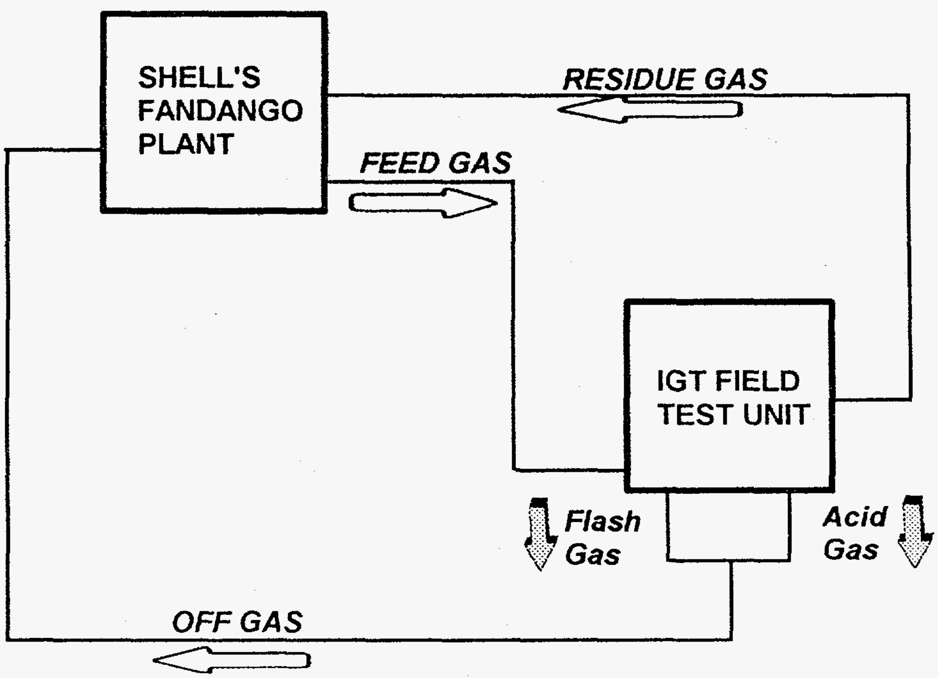

Figure 6. PROCESS FLOW DIAGRAM AT
SHELL'S FANDANGO PLANT

Acknowledgment

Financial support from the Gas Research Institute, Department of Energy-Morgantown Energy Technology Center, and the Sustaining Membership Program of the Institute of Gas Technology is greatly appreciated. Technical guidance, during various phases of this project, was provided by Howard S. Meyer of GRI; Thomas Kresse and James Frazier of NGPL; Jim Critchfield and Vicki Anderson of Huntsman; Jim Baker and Larry Gretak of Koch Engineering; Charles Wallace, Tom Fowler, and Dan Alcott of Shell; and Steve Kurmas, John Emory, and Kayode Dawodu of MichCon. Assistance in data collection and analysis was provided by John DeSando, Harlan Feldkirchner, Jim Semrau, Louis Diaz, and Ghenet Aberra.