

**Field Demonstration of a Membrane Process
to Recover Heavy Hydrocarbons and to
Remove Water from Natural Gas**

Annual Report

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by

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ABSTRACT

The objective of this project is to design, construct and field demonstrate a 3-MMscfd membrane system to recover natural gas liquids (NGL) and remove water from raw natural gas. The gas processed by the membrane system will meet pipeline specifications for dew point and Btu value, and the process is likely to be significantly less expensive than glycol dehydration followed by propane refrigeration, the principal competitive technology.

The BP-Amoco gas processing plant in Pascagoula, MS was finalized as the location for the field demonstration. Detailed drawings of the MTR membrane skid (already constructed) were submitted to the plant in February, 2000. However, problems in reaching an agreement on the specifications of the system compressor delayed the project significantly, so MTR requested (and was subsequently granted) a no-cost extension to the project. Following resolution of the compressor issues, the goal is to order the compressor during the first quarter of 2002, and to start field tests in mid-2002.

Information from potential users of the membrane separation process in the natural gas processing industry suggests that applications such as fuel gas conditioning and wellhead gas processing are the most promising initial targets. Therefore, most of our commercialization effort is focused on promoting these applications. Requests for stream evaluations and for design and price quotations have been received through MTR's web site, from direct contact with potential users, and through announcements in industry publications. To date, about 90 commercial quotes have been supplied, and orders totaling about \$1.13 million for equipment or rental of membrane units have been received.

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1. INTRODUCTION

The objective of this project is to design, construct and field demonstrate a 3-MMscfd membrane system to recover natural gas liquids (NGL) and remove water from raw natural gas. An extended field test to demonstrate system performance under real-world conditions is required to convince industry users of the efficiency and reliability of the process. The system will be designed and fabricated by Membrane Technology and Research, Inc. (MTR) and then installed and operated at British Petroleum (BP)-Amoco's Pascagoula, MS plant. The Gas Research Institute will partially support the field demonstration and BP-Amoco will help install the unit and provide onsite operators and utilities. The gas processed by the membrane system will meet pipeline specifications for dew point and Btu value and can be delivered without further treatment to the pipeline. Based on data from prior membrane module tests, the process is likely to be significantly less expensive than glycol dehydration followed by propane refrigeration, the principal competitive technology. At the end of this demonstration project the process will be ready for commercialization. The route to commercialization will be developed during this project and may involve collaboration with other companies already servicing the natural gas processing industry.

2. EXECUTIVE SUMMARY

The BP-Amoco gas processing plant in Pascagoula, MS was finalized as the location for the field demonstration. Detailed drawings of the MTR membrane skid (already constructed) were submitted to the plant in February, 2000. However, problems in reaching a decision on the specifications of the compressor to be used in the system delayed the project significantly. Due to this delay, MTR requested (and was subsequently granted) a no-cost extension to the project. Following resolution of the compressor issues, plans for the field test portion of the project are to order the compressor during the first quarter of 2002, and to start the tests later in 2002. A detailed field test plan will be developed in cooperation with the Pascagoula plant personnel during the first quarter of 2002.

Some modifications to the existing module test system were made during this reporting period in readiness for the field tests; a few others remain to be done. Changes are being kept to a minimum to avoid extensive rebuilding. Due to the ongoing delays in the compressor purchase, we will defer the planned production of all twelve modules until early April 2002; four modules will be prepared during the first quarter of 2002.

We continued to gather information on the market and applications of our technology in the natural gas industry. Information obtained from potential users of the MTR membrane separation process in the natural gas processing industry suggests that applications such as fuel gas conditioning and wellhead gas processing are the most suitable initial targets. Therefore, we are concentrating most of our effort in promoting these applications and in gaining a greater understanding of the potential market sizes and sales potential.

During this reporting period, we submitted between 85 and 90 commercial quotes related to applications of NGL removal and/or recovery from natural gas. A substantial number of requests

for evaluations and for design and price quotations were submitted through MTR's web site at www.mtrinc.com. Others resulted from direct contact with potential users and from announcements in trade publications. To date, we have received orders for equipment or rental from three companies: Statoil, Norway (U.S. \$68,000); Exxon Mobil, Gulf of Mexico (U.S. \$107,500); and UEG Araucaria, Brazil (U.S. \$950,000).

Dr. Lokhandwala, the project manager, was presented with a plaque recognizing his best-overall-presentation award (2000 GPA National Conference) at the March, 2001 GPA Conference. We will continue to make presentations at natural gas utilization meetings and at gas-turbine-related conferences to promote the fuel gas conditioning products.

3. EXPERIMENTAL

During this reporting period, no experimental work was performed because of the delay in starting the field tests, as discussed in detail in Section 4 under Task 4.0. A detailed field test plan will be developed in cooperation with personnel at the field site, the BP-Amoco gas processing plant in Pascagoula, MS, during the first quarter of 2002. The range of testing and the test duration will be determined by the total budget available at the beginning of the field testing phase.

4. RESULTS AND DISCUSSION

The project started on September 30, 1999. The work accomplished during the annual project period ending September 31, 2001 is summarized by task below.

Task 4.0 Develop Field Test Plan

The BP-Amoco gas processing plant in Pascagoula, MS was finalized as the location for the field demonstration. We submitted detailed drawings of the MTR membrane skid (already constructed) to the plant in February, 2000. However, problems in reaching a decision acceptable to BP-Amoco on the specifications of the compressor to be used in the system delayed the project significantly. (These issues were finally resolved towards the end of 2001, and MTR held a two-day Hazop meeting at the BP-Amoco facility in Pascagoula. As a result of various issues discussed there, some further documentation and control issues had to be resolved before the compressor order could be placed. Resolution was completed in December 2001.) The compressor will be on order during the first quarter of 2002, and we expect the field test to begin later in 2002.

A detailed field test plan will be developed in cooperation with the Pascagoula plant personnel during the first quarter of 2002. The range of testing and also the test duration will be determined by the total budget available at the beginning of the testing phase.

Task 5.1 Prepare Membranes and Modules

The membrane sheets required for this project were first manufactured in 2000. While making modules we encountered some problems due to the sheets curling, which caused difficulties in the module manufacturing process. To address this issue, the formulation of the poly(ether imide) [PEI] support was modified, resulting in a membrane less prone to curling.

Due to the ongoing delays in the compressor purchase, we have delayed the production of all twelve modules until early April 2002. Four modules will be prepared in readiness for the field test during the next quarter.

Task 5.2 Design and Construct Field Demonstration System

After reviewing the changes required in the system, we decided to make some modifications, but to keep these to a minimum to avoid extensive rebuilding. The changes that have already been made or are planned or in progress include:

- Remove feed flow control needle valves - completed
- Upgrade flow monitoring instrumentation - under review, to be completed before shipment
- Modify level gauges on two-phase separator to allow control of liquids discharge - completed
- Fix auto drain on coalescer into skid - in progress
- Tie in heat tracing to allow single connection from site - in progress
- System cleaned with solvent and internal rust sanded out - completed
- System repainted - completed
- Inlet flow restriction valves removed - completed
- Check valves cleaned - completed
- Inlet three-phase separator cleaned - completed

The changes that will not be made are:

- Change piping to move module housing inlet close to coalescer
- Incorporate particulate filter on skid - will not be done because inlet gas is clean

(Note: The finalized gas compressor supplier is ENERFLEX, Calgary, Canada. We anticipate the compressor pricing, including the change order and shipping etc., to be in the U.S. \$300,000 range.)

Task 5.3 Install System at Site/Initial Evaluation

Activity on this task is planned to begin in May or June, 2002.

Task 5.4 Operate System Continuously

Activity on this task is planned to begin in July 2002.

Task 5.5 Survey Industry Users/Analyze Economics

We continue to gather information on the market and applications of our technology in the natural gas industry. During this reporting period, we submitted about 85-90 commercial quotes related to applications of NGL removal and/or recovery from natural gas. Based on the large numbers of process design calculations and first-hand customer contacts, we have concluded that MTR systems are best suited for the following broad application classes:

- Fuel Gas Conditioning (gas engines and turbines)
- NGL Recovery from rich associated gas streams (up to 15 MMscfd)
- Gas Processing for dew-point control (up to 20 MMscfd)

In general, we believe that applications such as fuel gas conditioning and wellhead gas processing are the most suitable for MTR's technologies. Therefore, we are targeting most of our effort in promoting these applications to gain greater understanding of the potential market sizes and sales potential. A summary of this activity is given in Table 1.

Table 1. Selected List of Companies Contacted by MTR to Introduce MTR Natural Gas Products Related to This Project.

Company	Application	Contact Level
Texas Systems and Controls, Houston	Fuel Gas Conditioning	Active
BP-Alaska, Anchorage	Fuel Gas Conditioning	Active
Phillips, Oklahoma	NGL Recovery	Moderate
Caterpillar India	Fuel Gas Conditioning	Active
Solar Turbines, Houston	Fuel Gas Conditioning	Moderate
Statoil	Dewpoint Control	Active
The Gas Company, Los Angeles	Fuel Gas Conditioning	Moderate
Air Liquide, Houston	NGL Recovery	Low
Exxon Mobil, Virginia	NGL Recovery	Active
PDVSA, Venezuela	Fuel Gas Conditioning	Low
Wartsila-Finland	Fuel Gas Conditioning	Active
Axsia Howmar, England	Fuel Gas Conditioning	Active
Technip, Houston	NGL Recovery	Low
Chaparral Energy, Oklahoma	Dewpoint Control	Moderate
Tractebel, France	NGL Recovery	Low
Exxon Mobil- West	Fuel Gas Conditioning	Active
Wartsila-Netherlands	Fuel Gas Conditioning	Active
Ludan Engg, Romania	NGL Recovery	Low
Hanover Maloney, Houston	Fuel Gas Conditioning	Active
Texaco Pipeline, Houston	Dewpoint Control	Low
Chevron Overseas, Houston	NGL Recovery	Active
Howell Petroleum, Wyoming	Fuel Gas Conditioning	Active
Costain Oil and Gas, England	NGL Recovery	Moderate
Exxon Mobil, South Texas	Fuel Gas Conditioning	Active
Chevron Thailand-Worley Alliance, Australia	Fuel Gas Conditioning	Moderate
Advantica, England	NGL Recovery	Moderate
WS Atkins, Sharjah, UAE	NGL Recovery	Low
Althom Group, Germany	Fuel Gas Conditioning	Active
Sade Skanska, Buenos Aires	Fuel Gas Conditioning	Moderate
Bowman Engineering, Bakersfield	Fuel Gas Conditioning	Active
CSO Aker, Houston	Fuel Gas Conditioning	Active
Kvarner Engg, Houston	NGL Recovery	Active
Muruggam Group, India	Fuel Gas Conditioning	Active
Alaska Anvil, Alaska	Fuel Gas Conditioning	Low
BP-Pakistan	Fuel Gas Conditioning	Active
Caterpillar Egypt	Fuel Gas Conditioning	Active
BDR Engg, Calgary, Canada	Fuel Gas Conditioning	Active
Agiba, Alexandria, Egypt	NGL Recovery	Active
Durango Pipeline, Texas	Dewpoint Control	Active
Unigas, Australia	Fuel Gas Conditioning	Active
Colt Resources, Louisiana	NGL Recovery	Moderate

Task 5.6 Develop Commercialization Plan

As described under Task 5.5, we continued to accumulate valuable information on potential applications of the MTR membrane separation process in the natural gas processing industry. Between 80 and 90 design and price quotations and evaluations have been submitted to various companies in this industry. To date, we have received orders for equipment or rental from the following companies during this project:

- | | |
|-------------------------------|----------------|
| • Statoil, Norway | U.S. \$68,000 |
| • Exxon Mobil, Gulf of Mexico | U.S. \$107,500 |
| • UEG Araucaria, Brazil | U.S. \$950,000 |

We have focused on marketing MTR's system through our web site at www.mtrinc.com. Since our natural gas products were listed there, we have seen regular increases in traffic to the web site and an increase in the number of application submissions. During this period, we received between 15 and 20 new application submissions related to natural gas through our web site. Based on web-site access statistics, some of the most viewed pages are those related to fuel gas conditioning and NGL recovery. We will continue to update our web site with the latest developments in this area to further promote the technology being developed in this project.

During this period we made a new product announcement in the *Oil and Gas Equipment Magazine* and in *Compressor Tech Magazine*. This resulted in almost 100 leads requesting additional information and four or five application submissions. We also published our first article in Chinese on Fuel Gas Conditioning in the China edition of *Compressor Tech Magazine*.

Further marketing efforts will include:

- Selective ad placements on other web sites frequented by natural gas professionals
- New-product releases in at least two or three natural-gas-related publications
- Publication of two new articles in the *Oil and Gas Journal* and other natural-gas-related magazines
- Development and dispatch of targeted direct-mail pieces to natural gas professionals
- Publishing an online newsletter on membrane technology and its use in the natural gas industry

Task 6.0 Final Report/Conference Presentation

As reported previously, we received one of the three best-overall-presentation awards at the GPA National Conference in 2000. A plaque was presented to Dr. Lokhandwala at the March, 2001 GPA Conference. Future plans under this task include making presentations at natural gas utilization meetings, such as Powergen, and at gas-turbine-related conferences to promote the fuel gas conditioning products.

5. CONCLUSIONS/FUTURE PLANS

The BP-Amoco gas processing plant in Pascagoula, MS was finalized as the location for the field demonstration. We submitted detailed drawings of the MTR membrane skid (already constructed) to the plant in February, 2000. However, problems in reaching a decision on the specifications of the compressor to be used in the system delayed the project significantly. Due to this delay, MTR requested (and was subsequently granted) a no-cost extension to the project during 2001. Following resolution of the compressor issues, plans for the field test portion of the project are to order the compressor during the first quarter of 2002, and to start the testing in 2002.

Based on information obtained from potential users of the MTR membrane separation process in the natural gas processing industry, we have concluded that applications such as fuel gas conditioning and wellhead gas processing are the most suitable initial targets. As part of the continuing commercialization effort, we will continue to accumulate information on potential applications of the technology, and to respond to requests for evaluations and for design and price quotations. We conclude from the level of interest in the technology, as evidenced by the number of commercial quotes supplied and sales to date of over one million dollars, that the technology is likely to be commercially successful.

MTR's web site has proved to be effective in generating interest in the product, as have direct contact with potential users and announcements in industry publications. We will also continue to make presentations at natural gas utilization meetings and at gas-turbine-related conferences to promote the fuel gas conditioning products.

REFERENCES

None cited in this progress report.