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April 16, 2004

VIA HAND DELIVERY

Ms. Deborah Taylor Tate, Chairman
TENNESSEE REGULATORY AUTHORITY
460 James Robertson Parkway
Nashville, Tennessee 37243

Re: ***Petition of Chattanooga Gas Company for Approval of Adjustment of its Rates and Charges and Revised Tariff, Docket No. 04-00034***

Dear Chairman Tate:

Enclosed please find the original and thirteen (13) copies of a Petition to Intervene, to be filed on behalf of our client, Gas Technology Institute.

Also enclosed is the original and thirteen (13) copies of Qualifications and Direct Testimony of Ronald B. Edelstein with Exhibit 1 and Exhibit 2 attached in support of the Company's Petition. Also enclosed is our check in the amount of $25.00, payable to the Tennessee Regulatory Authority for the filing fee.

Should you have any questions concerning any of the enclosed, please do not hesitate to contact me.

Thanking you in advance for your assistance with this matter, I am

Very truly yours,

R. Dale Grimes

RDG/tn
Enclosures

cc: Certificate of Service
J. Richard Collier, Esq.

2468394 1

**BEFORE THE TENNESSEE REGULATORY AUTHORITY
NASHVILLE, TENNESSEE**

IN RE:	)	
	)	
PETITION OF CHATTANOOGA	)	
GAS COMPANY FOR APPROVAL	)	**DOCKET NO. 04-00034**
OF ADJUSTMENT OF ITS RATES	)	
AND CHARGES AND REVISED TARIFF	)	
	)	
	)	
	)	

PETITION TO INTERVENE BY GAS TECHNOLOGY INSTITUTE

Gas Technology Institute (hereinafter "GTI"), pursuant to Tenn. Code Ann. § 65-2-107 and Rule 1220-1-2-.08 of the Tennessee Regulatory Authority ("TRA"), respectfully petitions to intervene in this docket in order to request the TRA to give Chattanooga Gas Company authority to collect a surcharge from its customers to fund research and development activities that provide benefits for consumers of natural gas. In support of this petition, GTI states as follows:

1. GTI is an organization, formerly known as Gas Research Institute ("GRI") that was formed in 1977 by natural gas local distribution companies and pipe line companies in agreement with the Federal Energy Regulatory Commission ("FERC"). GTI is engaged predominately in research and development activities with respect to natural gas usage and natural gas consumer benefits.

2. Gas consumer benefits research and development is that in which applicable technologies result in benefits primarily accruing to gas consumers. These benefits includes lower energy use, increased safety, enhanced deliverability, and reduced energy costs.

3. Based on a national gas consumer benefit-to-cost ratio analysis reviewed by FERC in June 2003, GTI's research and development program showed an overall national gas consumer benefit-to-cost ratio of 8 to 1.

4. In addition, GTI's research and development has residential applications, commercial applications, industrial applications, and applications related to safety and operations of gas transmission and distribution systems. GTI's research and development activities have also included projects designed to benefit low-income gas customers specifically.

5. Without an organization like GTI, it is unlikely that the private sector would have invested in much of this research and development.

6. There are many vital reasons for continuing the work GTI has begun. These include substantial remaining issues for gas supply, delivery and use that have major impacts on gas consumers, dollarized benefits, environmental benefits, and safety benefits.

7. Since it was established in 1977, GTI has been funded through a FERC-authorized surcharge on gas transported over interstate pipelines. Thus, Chattanooga Gas customers have historically supported GTI research and development through upstream suppliers' prices which were in turn charged under Chattanooga Gas' retail cost of gas. Prior to and including 1998, the FERC-approved charge was 1.74 cents per Mcf. FERC decided to discontinue the charge before the end of 2004 and to transfer the funding authority for research and development to the state jurisdiction such as the TRA.

8. In order to continue the funding of research and development activities specifically designed to benefit Chattanooga Gas' customers, GTI recommends that 1.74 cents per Mcf be collected by Chattanooga Gas from its customers. This is a conservative request given the costs of proposed gas consumer benefit projects. This is the same rate as the FERC-

approved charge for the GTI research and development program up until 1998 and is the rate that GTI has recommended in cases before other state commissions.

9. There are fifteen states currently authorizing research funding for gas consumers benefit research and development: Alabama, Delaware, Florida, Idaho, Illinois, Kentucky, Mississippi, New Hampshire, New Jersey, New York, North Dakota, Oregon, Utah, Washington, and Wyoming. One other state, Michigan, has a case pending in which the research and development surcharge is included.

10. The research and development dollars collected through this charge will not necessarily be earmarked for GTI. Chattanooga Gas, with TRA oversight, will have the ability to choose specific research and development projects that will benefit its customers, and place these research and development dollars with GTI or other research organizations for consumer benefit research and development purposes.

11. Accordingly, GTI requests to intervene and participate in this case in order to advocate the inclusion of the research and development charges requested herein.

12. If its petition to intervene is granted, all notices, correspondence, and copies of orders and other material should be addressed as follows, and the following should be placed upon the official service list in this proceeding:

R. Dale Grimes
BASS, BERRY & SIMS PLC
AmSouth Center
315 Deaderick Street, Suite 2700
Nashville, Tennessee 37238-3001
Phone Number (615) 742-6244
Fax Number (615) 742-2744
dgrimes@bassberry.com

WHEREFORE, the Gas Technology Institute respectfully requests that the TRA enter an order granting this petition to intervene allowing GTI to become an intervening party of record in this docket.

DATED: April 16, 2004.

Respectfully submitted,

R. Dale Grimes

R. Dale Grimes (#6223)
BASS, BERRY & SIMS PLC
AmSouth Center
315 Deaderick Street, Suite 2700
Nashville, Tennessee 37238
(615) 742-6244

Attorneys for Gas Technology Institute

CERTIFICATE OF SERVICE

I hereby certify that a true and exact copy of the foregoing has been served on the following person(s), via the method(s) indicated, on this the 16 day of April, 2004:

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P.G. Summers

BEFORE THE TENNESSEE REGULATORY AUTHORITY
NASHVILLE, TENNESSEE

IN RE:	)	
	)	
PETITION OF CHATTANOOGA	)	
GAS COMPANY FOR APPROVAL	)	**DOCKET NO. 04-00034**
OF ADJUSTMENT OF ITS RATES	)	
AND CHARGES AND REVISED TARIFF	)	
	)	
	)	
	)	

QUALIFICATIONS

AND

DIRECT TESTIMONY

OF

RONALD B. EDELSTEIN

Q. Please state your name and business address.

A. My name is Ronald Edelstein. My business address is 1700 South Mount Prospect Road, Chicago, IL 60618.

Q. By whom and in what capacity are you employed?

A. I am employed by the Gas Technology Institute ("GTI") as Director, State Regulatory Programs.

Q. Please describe your educational background and professional experience.

A. I graduated from the University of Florida with a BS in Aerospace Engineering (1969), Rensselaer Polytechnic Institute (RPI) with an MS in Engineering Science: Solid Mechanics (1972), and another MS from RPI in Engineering Science: Environmental Science & Technology (1977). I began my employment with Pratt & Whitney, working as a structural engineer on gas turbines for 8 years, then Planning Research Company as an engineering consultant to the U.S. Department of Energy for three years, then the Solar Energy Research Institute as an R&D planner for three years. I joined the Gas Research Institute ("GRI") (now Gas Technology Institute) in 1983 as an R&D planner. I have also held positions as Director of Planning and Director of Sales. My current position is Director of State Regulatory Programs.

Q. Have you previously filed testimony before any regulatory commission?

A. Yes. I have filed testimony in the states of Kansas, Massachusetts, Tennessee, and Michigan. I have testified before the Massachusetts Department of Telecommunications and Energy on behalf of KeySpan Energy.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to summarize the history of GTI and its predecessor, GRI, to describe the benefits that natural gas consumers receive from GTI and its gas consumer benefits research and development (R&D) program, and to request that the Tennessee Regulatory Authority ("Authority") give AGL Chattanooga Gas Company ("Chattanooga Gas") the authority to collect a surcharge from its customers to fund gas consumer benefits R&D.

Q. What is "gas consumer benefits R&D"?

A. This is a specific type of R&D, in which the applicable technologies result in benefits that primarily accrue to gas consumers. These benefits include lower energy use (through increased efficiency appliances), increased safety, enhanced deliverability, and reduced energy costs (through lowering of gas local distribution company operating & maintenances costs.)

Q. What is the GTI?

A. Natural gas local distribution companies ("LDCs") and pipeline companies, in agreement with the Federal Energy Regulatory Commission ("FERC"), formed GRI in 1977 in the midst of natural gas curtailments and a predicted gas supply shortage. That organization, now known as GTI, directed 75% of its initial research efforts toward increasing supply and lowering the cost of acquiring natural gas. This emphasis decreased in the 1980s to about one-third of our budget as a "bubble" developed in natural gas supply.

Q. What were the results of this effort?

A. First portrayed as a "gas bubble", the supply shortage turned into a surplus, eventually resulting in substantial savings to gas consumers. Production of coalbed methane, called "moonbeam gas" by its detractors, jumped from under 50 billion cubic feet (Bcf) /year in the 1980s to over 1,400 Bcf /year by 2002. During the same period, production of tight sands gas went from 300 Bcf /year to over 2,000 Bcf /year. R&D performed by GTI (amongst other initiatives like an investment tax credit) reduced the technical risks inherent in finding and recovering these unconventional gas resources and aided in bringing them into mainstream production.

In the area of conventional supply, GTI developed an imaging technology to produce high-resolution seismic "pictures" of subsurface features. This enables producers to find natural gas that had been overlooked between existing wells.

Q. What is GTI's emphasis on end-use R&D?

A. Initially, end-use R&D was about 20% of GTI's budget; then shifted to about half of our budget in the 1980's and 1990's, and is now about 25% of our budget. The original focus on increased-efficiency equipment like residential space heating and industrial process heating has shifted toward reduced emissions, enhanced safety, and the development of technologies such as fuel cells and combined heating/cooling/power systems which result in substantial overall efficiency increases through the combination power generation and finding uses for the waste heat.

Q. What results has GTI had with its research into residential space heating?

A. Prior to GTI, typical home furnace efficiency was in the range of 60% to 70%. With the introduction of the 96%+ efficiency fully condensing pulse combustion furnace, GTI raised the bar and encouraged manufacturers to develop options for the fully condensing furnace. Today, condensing furnaces with over 90% efficiency account for about 25% of residential furnace sales; the pulse combustion furnace and its derivatives are still among the most efficient furnaces on the market.

Q. Can you give a Tennessee-specific example?

A. In Tennessee, over 65,000 fully condensing furnaces were sold to residential consumers between 1995 and 2000 (according to Gas Appliance Manufacturers Association data) alone. These have benefited Tennessee consumers who purchased the devices by net present value of savings of $331 per furnace, even taking into account the higher capital cost of the more-efficient furnaces, compared to a 78% efficient gas furnace. This has saved Tennessee residential consumer over $21.7 million dollars, net present value. Additionally, in 2002 alone over 0.5 Bcf of reduction in gas load was achieved, resulting in savings to all Tennessee consumers because of reduction in gas demand.

Q. How do these savings compare to the cost of the GTI FERC R&D program?

A. Over the same time period, 1995 – 2000, the ***entire*** GTI FERC R&D program cost all Tennessee residential gas customers $11.71 for the six years indicated, or about $12.8 million. The benefit-to-cost ratio of just one GTI-developed technology, then, compared to the entire cost of the R&D program, was 1.7 to 1. Imagine what the benefit-to-cost ratio would be if all 500 technologies that GTI developed and brought to the marketplace were included in the analysis.

Q. Do you have any idea what this total benefit-to-cost ratio might be?

A. Yes we do. From Exhibit No. 1 to my testimony (attached hereto), a national analysis of the benefit-to-cost ratio of GTI's FERC R&D program, reviewed by FERC in June, 2003, our overall benefit-to-cost ratio is 8 to 1.

Q. Are there any projects explicitly designed for the low-income gas customer?

A. Yes, GTI is working on two projects that could directly benefit the low-income gas customer. First, we have under development a combination water heater/ space heater system for residential homes that uses a low-cost, fully condensing, high-efficiency (greater than 93%) water heater to provide both water heating and space heating needs for the home. It would eliminate the need for a space heater in smaller homes and apartments.

This project has only been tested in the laboratory, and needs additional field testing in a real-world environment to validate proof of feasibility. Second, we are working on a heating-only absorption gas heat pump that has a heating efficiency of 120-140%. If the capital cost of the unit could be significantly reduced through R&D, this unit could provide substantial energy savings to the low-income gas customer.

Q. **What about commercial applications of GTI's R&D?**

A. GTI funding has produced a new generation of natural gas engine-driven, absorption, and desiccant-based cooling systems. First-generation single-effect absorption cooling systems had coefficients of performance (COPs) of 0.6; the efficiencies of these new systems (developed as a result of GTI and other R&D) are verified for COPs ranging from 0.8 to 1.2, producing gas savings as well as lowering peak electric loads.

Q. **What about industrial applications of GTI's R&D?**

A. GTI-funded advancements in industrial combustion equipment helped increase the efficiency and lower the emissions from process heating and boiler steam production markets. For instance, in 2001, GTI demonstrated oscillating combustion on a forging furnace with a 49% decrease in NOx emissions and a 3% decrease in fuel usage, while keeping the average CO emissions below 100 ppm; this technology has applications to a wide range of high-temperature industrial furnaces.

Q. **Would the private sector have invested in this R&D without the existence of GTI?**

A. Not likely. Current laws and regulations in general require far lower efficiencies and allow higher NOx emissions. Manufacturers generally have no incentive – cost or otherwise -- to produce such efficient or environmentally friendly equipment above and beyond regulatory requirements. Unfortunately, energy efficiency in and of itself does not sell well in the U.S. market, and so is not invested in by manufacturers.

Q. How does GTI contribute to safety?

A. Typically, as new equipment is developed, systemic gaps can cause problems in the areas of safety and reliability. For example, gas furnace corrosion is dependent on vent system design and installation but, typically, the meter and upstream service is handled by the LDC, the furnace by the manufacturer, and the vent system by the installers. As manufacturers began to offer partially condensing furnace designs with 80% to 90% efficiencies, the heat exchanger and vent system began to experience corrosion problems which did not exist in the lower-efficiency furnaces sold before 1981. GRI designed improved heat exchangers and developed vent installation guidelines that minimized the amount of condensation. GRI also developed furnace installation instructions that are included in every mid-efficiency residential furnace sold in the U.S. and its vent design procedures have been incorporated into the National Fuel Gas Code.

Q. Do you have other examples of safety-related R&D?

A. Yes. Other safety-related research resulted in the elimination of "false positives" from CO monitors and developed scientific data for acceptable NOx levels for indoor air quality. In 1998, GTI introduced a test methodology to evaluate new water heater designs that could reduce or prevent flammable vapor incidents when flammable liquids are improperly stored adjacent to the heater.

Q. Would the private sector have invested in this R&D without the existence of GTI?

A. That is unlikely. The problems fell "between sectors"; that is, an ultimate problem resulted from perfectly acceptable and safe technologies not being able to co-exist in the same environment. GTI was uniquely placed to bridge that gap and provide successful solutions.

Q. What have been the results of GTI's R&D efforts to increase the safety and reduce the cost of gas transmission and distribution systems?

A. GTI research focused on the fundamentals of polyethylene (PE) pipe, especially fracture mechanics, failure analysis, and joining integrity in an effort to lower the technical risks and increase the confidence in PE pipe. When GTI was created, plastic pipe comprised about 20% of all new distribution mains; today, non-corroding PE, with a cost of about half that of coated steel pipe, comprises over 90% of all new main installations.

Q. Are there other examples of operations-related R&D?

A. Yes. Most gas mains and services installed in the 1970s used trenching tools which tore up the surface and subsurface, increasing restoration costs and risked penetrating near-surface utility lines. Six years of GTI research yielded the first set of guided horizontal boring tools which are now in general use throughout the gas industry, providing substantial O&M cost savings.

Q. Has GTI R&D improved operational safety?

A. Yes. For instance, GTI developed the optical methane detector (OMD). This device works by shining a laser beam from a vehicle to quickly and reliably scan streets for methane leakage. Many LDCs conduct required leak inspections by a walking survey; the OMD will allow LDCs to convert to driving surveys with a significant reduction in response time and reduction in labor cost. Also, GTI's gas transmission R&D introduced low-NOx controls for reciprocating engines and gas turbines used at large compressor stations.

Q. What R&D issues and challenges remain for GTI?

A. I believe there are substantial remaining issues for gas supply, delivery, and use that have major impacts on gas consumers, dollarized benefits, environmental benefits, and safety benefits. There are many vital reasons for continuing the work GTI has begun. I will describe a few of the challenges that are ahead of us.

Advanced laser-based drilling and fracturing technologies are in the basic research stage and require a substantial amount of funding to carry them forward.

Totally new sources of natural gas supply may be required to ensure domestic gas supply security. A vast supply resource may be in natural gas hydrates but DOE's basic research has not yet lowered the technical unknowns and risks to permit even exploratory production.

Substantial research is needed to enhance the confidence in current nondestructive evaluation (NDE) techniques used to inspect natural gas pipelines. A substantial portion of the national pipeline system is not "piggable"; that is, valves, bends, turns, reduced-diameter pipe sections, or other obstructions prohibit internal inspection by moving a mechanical device, or "pig", through the pipe. Further, current NDE tools and technologies can detect pipe wall thinning and circumferential flaws but other types of flaws, such as stress corrosion cracking and axial flaws, are very difficult to detect. Only additional R&D can ameliorate these and other issues such as pipeline coatings lifetime determination and microbiologically influenced corrosion. Additionally, Office of Pipeline Safety rulings are applying similar inspection requirements to high-pressure distribution mains.

Despite 20 years of research, we are still unable to reliably locate buried plastic pipe under all types of soil and moisture conditions. Tracer wire laid above the pipe is helpful but, since it can corrode or break, locating plastic pipe by tracer wire is not always reliable.

The guided horizontal boring tools described earlier are guidable from point to point as well as steerable; however, they still cannot "see" in front of themselves underground. The ability to locate sewer pipes, utilities and other obstacles is still an important and unresolved safety issue.

Infrastructure Security is at the forefront of national attention following the events of 9/11. R&D in this area is still uncharted; yet the "cyber" and physical security of our natural gas infrastructure is critical to gas consumers and the national interests.

Environmental issues surrounding old manufactured gas plant sites will cost millions of dollars to clean up. Environmental research, beginning with the determination of environmentally acceptable endpoints ("how clean is clean?"), is still required to minimize environmental compliance costs and yet still answer regulatory concerns. The PCB "Megarule" promulgated by the U.S. Environmental Protection Agency requires that gas mains be inspected for PCB's, yet standard protocols have not yet been developed and accepted by all parties for such procedures.

End-use programs that are under development but which will not be able to proceed without continued funding include a low-cost, fully condensing residential water heater which is over 92% efficient, a residential heating-only absorption-based gas heat pump with a heating COP of 1.4, and an industrial super-boiler with efficiencies over 96% currently being funded by DOE as a laboratory sub-scale pilot project.

A low-cost residential/commercial fuel cell is still not on the horizon. The private sector and DOE are developing a host of technologies for distributed generation, including larger fuel cells, reciprocating engines, and microturbines. However, their successful integration into the gas distribution system and electric grid is still not assured, emissions and costs (compared to central station generation and electric T&D system upgrades) need to be analyzed, their integration with combined heating, cooling and power systems to ensure maximum overall efficiency, and their impact on the reliability of the gas and electric infrastructure has not yet been documented.

Q. What specific types of research projects is GTI expecting to research on behalf of Chattanooga Gas and its customers?

A. There are at least fifteen research projects GTI is planning that support Chattanooga Gas's gas customers and other gas customers in Tennessee. The objectives of the end-use projects are to increase energy efficiency and so lower retail customers' gas bills. The objectives of the operations projects are to increase safety and reduce operating costs.

Q. What are the End-Use Projects Chattanooga Gas is planning to fund?

A. These projects are: **(1) Combination Residential Space/Water Heater:** GTI is seeking to assess the performance via field testing of an optimized condensing water heater in combination space/ water heater applications. The system will eliminate the need for a space heater, using the water heater for both water and space heating, and should aid low-income customers by reducing the first cost and operating cost of buying a space and water heater at the same time. The U.S. DOE and GTI are currently cofunding technology development of the condensing water heater. The high-efficiency, condensing water heater uses porcelain coating on both sides of the heat exchanger to avoid corrosion and keep manufacturing costs down (by avoiding the use of stainless steel). It has an extremely high Energy Factor of 0.77 and a heat exchanger efficiency of over 90%. However, field testing and system design in a real-world environment is critical to minimizing the technical risk on this project.

Condensing water heaters have Energy Factors approaching the high .70's, however; often, the increased cost in production and installation outweighs the cost saved from energy. Producing condensing water heaters that are efficient and more cost effective would greatly benefit the consumer, manufacturer and nation. The cost of a condensing water heater can be reduced (possibly by as much as 30%) by coating a standard heat exchanger with porcelain. Presently condensing heat exchangers use stainless steel.

In Phase 1, the existing furnace and water heater are replaced with a power vent water heater combination heating system. Baseline data is gathered on the performance and energy consumption of the power vent combo system until April 2004. At that time Phase 2 will commence and a high-efficiency, optimized, condensing water heater will replace the power vent water heater. The performance and energy consumption of the condensing water heater will be closely monitored for a 12-month period.

The field test will validate superior operational performance and comfort as well as any economic benefits associated with the utilization of a low-cost condensing water heater for space and water heat in various climates throughout North America. In addition, the field test will validate to the utility and homeowner the value of combination systems in new and retrofit heating applications.

(2) Residential/Commercial Codes & Standards Program: The gas industry recognizes the importance of ensuring that gas technologies comply with appropriate codes and standards, and that natural gas receives equitable treatment in the creation or revision of these rules. Maintaining the option for cost-effective gas technologies is a critical, but often unseen, element of the broader product development and deployment process. Working closely with the gas industry and research partners, this task area will develop and present in-depth scientific data and technical information needed by codes and standards organizations and regulatory bodies, so that codes & standards can be developed based on scientific data and quantified benefit/cost analysis. In addition to developing data for specific gas technologies, broader whole-house and building system issues will be addressed. These issues include depressurization of new "tight" homes and its impact on ventilation of appliances, pollutant evaluation within homes (indoor air quality), and mold formation, abatement, and prevention.

(3) Advanced Gas Water Heater Assessment project: Several regulatory and codes issues are converging to impact the continued viability of gas-fired residential water heaters. These include design changes to accommodate efficiency, emissions, and safety programs. Compounding the risk associated with these enhanced product requirements is the uncertainty associated with fluctuating gas and electric prices. This project will initiate a comprehensive evaluation of the need for new gas water heater designs that address these and other issues. The evaluation will include an update to the gas industry and gas consumers on new technologies entering the market as well as the magnitude of the ongoing risk to the industry and consumers of losing the gas water heating option and potential approaches to mitigating that risk. Depending on the outcome of this evaluation, novel technologies and system-based approaches may be assessed, leading towards advanced product concepts for consideration in future product development efforts.

(4) Combined Gas Heat Pump/Generator for Combined Heat and Power (CHP): This project will develop a unitary natural gas engine-driven combination heat pump and standby generator for the residential and small commercial market. The appliance comprises a low-emission natural gas engine-driven generator set that supplies electricity to a standard hermetically sealed compressor or pre-selected standby electrical loads. The proposed appliance will benefit gas consumers by providing higher efficiency heating, lower operating costs, lower cost cooling, and greater electric reliability than currently available options. The project that would encompass design finalization, including DFMA (design for manufacturing and assembly) analysis, control application and refinement (including a staged or modulated combustion system), integration of a heat recovery option, full ASHRAE/ARI (American Society of Heating, Refrigeration and Air Conditioning Engineers/Air Conditioning and Refrigeration Institute) characterization of the unit, and ANSI (American National Standard Institute) certification testing. The second phase of this program would be a field demonstration phase that would prove the various model configurations in field application.

(5) Superboiler for Commercial/industrial Applications: An ultra-low NOx (<5 ppm) and super-high efficiency (>94 %) boiler in the range 5 to 20 MMBtu/hr is planned to be ready for field demonstration by the end of 2004. This project would support site selection and cofunding for installation and long-term field testing. As commercial and industrial boilers are substantial gas energy users, increasing efficiency from the current 85-88% to the proposed 94% would have a major impact on natural gas use.

Q. What are the Operations Projects Chattanooga Gas is planning to fund?

A. These projects are: **(1) Miniature Methane/Ethane Detector for Leak Surveys**: Previous gas-industry-sponsored work has resulted in the development of optical methods of finding gas leaks by detecting methane and, more recently, ethane. The presence of ethane in gas leak positively confirms that the leak is related to natural gas, and not "swamp gas" or other sources of methane. This confirmation eliminates the cost of gas sampling and analysis, minimizes multi-party discussions and time for the gas industry, thus reducing the cost of operations. However, detection of very low levels of ethane in natural gas leaks is very challenging. Initial experiments conducted with the previously developed Proof-of-Concept system for ethane have demonstrated the viability of detection of ethane content in natural gas plumes under realistic leak conditions. The proof-of-concept tests were successful in detection of ethane presence in low concentration (30 ppm methane) natural gas plumes. The best sensitivity of these tests showed the detection capability of ethane to 200 ppb. These Concept Evaluation Unit tests used an optical modulator for ethane detection which was too large to be integrated into a Portable Methane Detector (PMD) being developed under a separate project.

It was decided that the first step towards a practical ethane instrument would be to develop a miniaturized ethane modulator, the main component of the PMD. This miniaturized Ethane/Methane Detector (EMD) project is now coming to a successful conclusion. Although the work is not yet fully complete, an ethane capable modulator (approximately one cubic inch in size) has been developed. Thermal testing under controlled, laboratory conditions showed that ethane detection would be much more difficult (approximately three times more demanding than methane-only detection). Preliminary tests have shown that the miniature EMD modulator is capable of operating at or near the same sensitivity level as the much larger unit used in the concept evaluation tests.

The next logical step in the EMD development is to miniaturize other components of ethane detection and integrate the ethane system into the PMD unit. The specific tasks for the proposed project are: (1) Receiver Design and Prototyping, (2) Methane Filtering, (3) Software Development, (4) Display Options and Integration with PMD and Testing, and (5) Prepare Final Report.

(2) Hand-Held Acoustic system for Plastic Pipe Location: Past GTI-sponsored research has successfully demonstrated that active pulsed-echo sonic technology can detect and locate small-diameter pipes, including polyethylene (PE) pipes, to the depth of 5 feet in a laboratory environment. In addition, attenuation measurement data sets collected by a third party from soils around the United States were applied to the current system to perform mathematical analysis on the applicability of the system. This analysis showed that a laboratory-grade acoustic system has the potential for detecting 1.5 and 4-inch diameter pipes at a depth of 3 ft for 50% and 100% of soils in the United States, respectively.

In this project, the laboratory-grade pulse-echo pipe location system will be designed into a hand-held system for application to buried pipe detection. The system will include data acquisition and processing boards powered by a battery, transducer and receiver arrays in a cane-like setup, and data display system. The system will be tested with participating utilities for detecting buried pipes, 1 to 6 inches in diameter at depths from 6 inches to 10 feet. The data collected at each location will require less than two minutes and the analyzed data will be displayed to the system operator.

The following tasks are included in the project: (1) Planning Meetings. GTI and its subcontractor will meet with industry representatives and present the initial work plan for the proposed effort. This plan will define pipe sizes to be detected, soil conditions, and system approach and cost. The plan will also determine the field evaluation site(s) and test time frame. (2) Design Electrical and Electronic System. Under this task, electrical and electronic components will be designed, tested and built. The power requirement for the system will be defined and appropriate battery needs will be procured. (3) Develop System Software. The objectives of this task are to develop the data acquisition system, signal processing, and user interface. The past knowledge of interactions of various acoustic waves and methods to avoid interactions of these acoustic waves will be used to improve data analysis packages. (4) Design Transmit-Receive Set. As indicated before, the project calls for a miniaturization of the current hardware for the hand-held pipe detection system application. In this task, two pairs of sensors, each consisting of two receivers and a transmitter, will be designed and build. These pairs of sensors will be integrated into a cane-like structure for hand-held application. (5) Integrate System. The electrical and electronic system, transmit-receive set, and software for data analysis will be integrated. Two sets of a identical systems will be manufactured. The system weight, size, and cost will be determined, (6) System Evaluations. The complete system will be evaluated for its ability to detect buried pipes. This task will confirm the system's capabilities and field evaluation needs. Based on these initial evaluations, the system will be improved, if required. The final system will be tested in the field at two locations with the participating utilities, and (7) Final Report.

(3) Remote Laser Leak Surveys: Current leak surveys of natural gas distribution systems involve use of "flame packs" and the mobile Optical Methane Detector (OMD). Both of these leak location technologies require that the detector be brought in contact with the gas leakage plume, a very labor-intensive effort. The Laser Line-scan Camera (LLC) technology being developed under the on-going GTI-managed, utility-sponsored project with Laser Imaging Systems, Inc. (LIS) and AVISYS, Inc. allows "stand-off" inspection of both mains and service lines out to distances of 30 meters from a moving vehicle. The initial results of the on-going project are very encouraging. However, the detection limit, inspection speed, operator interface and packaging of the system will require further evaluations/improvements to make the LLC an attractive alternative to the current leak survey practices.

The primary objective of the proposed project is to evaluate/improve the detection limit and inspection speed of the LLC, and to make the system more user-friendly. This will be accomplished by conducting additional testing in laboratory, in field, and upgrading various components of the current LLC design.

In the current, on-going project, a prototype LLC was designed and built. This system used two semi-conductor lasers, one at a wavelength strongly absorbed by methane and the other at a wavelength for which the gas is essentially transparent. These two lasers are scanned across the field-of-view of a 32-element detector array that is projected from a turret atop a van.

The line scan field-of-view of the detector array is displayed on a conventional video image of the area being inspected. The operator controls the direction of the LLC field-of-view. When the line scan passes over an area on the surface where there is methane gas, an upward deflection of the line occurs. The higher the gas concentration, the higher is the line-scan deflection. By orienting the viewing direction of the LLC to maximize the line scan deflection, the operator is able to pinpoint the location of the leakage plume.

The specific technical issues to be resolved in the proposed project are: (1) Evaluation of detection limit and improvements: Studies involving the effect of laser pulse width and signal processing sample rates on the leak detection limit will be conducted. Improvements to the detection limit will be implemented, (2) Range limitations: Various designs of the collection optics will be investigated to increase the detection range of the LLC system, (3) Establish maximum survey speed: Trade-offs between line-scan frequency and detection sensitivity will be performed to determine the maximum survey speed for the LLC, (4) Packaging/operator interface improvements: Special attention will be directed towards reducing the size and power requirements of the LLC system. The system package will be hardened for routine field application, and the operator interface will be simplified.

(4) Integration of Electromagnetic and Acoustic Obstacle Detection Systems for Utility Construction Operations: This project focuses on integrating the drill-head mounted electromagnetic (EM) obstacle detection sensors under development at Maurer Technology, Inc. (MTI) with the surface deployed acoustic sensors being developed by Folsom Research, Inc. (FRI). The objective of these projects is to provide real-time detection of underground utilities during horizontal directional drilling (HDD) operations during installation of pipes. The current technology development is funded by GTI with cofunding from several utilities. Together, these technologies have the potential to prevent striking and damaging buried utilities during creation of the pilot hole or during back reaming operations. The warning and detection circuitry would be electronically tied to the drill string rotation and forward advance controls so the drill string can be automatically stopped before a strike can occur. By combining these two technologies into a single, integrated display it would be possible to successfully detect buried, energized cables, as well as steel, plastic, clay and concrete pipes.

The specific objectives of this project will be to: (1) Improve the noise generation capability for acoustic technology, (2) Design a wireless radio link between the matrix of acoustic sensors and their processor to simplify field operation, (3) Reduce the size of the EM electronics and sensors mounted in the jet head for use in smaller utility directional drilling rigs (4) Integrate the data acquisition, processing and display of the acoustic and EM sensors, (5) Work with leading drill rig manufacturers to incorporate automatic stoppage of drill string rotation and advance when obstacles are detected within a few feet of the boring head, and (6) Conduct field trials of the integrated obstacle detection system in support of commercialization.

(5) Product Development of an Obstacle Detection System Using Ground Penetrating Radar (GPR): Currently there are no commercial instruments available to sense the presence of obstacles in the vicinity of a horizontal directional drilling (HDD) bore used for installation of pipes. In the on-going project with Vermeer Manufacturing Company under the sponsorship of GTI, a new advanced GPR system, mounted on the drill head of an HDD that is capable of detecting obstacles in the proximity of the bore is being developed. It is expected that this initial on-going project will provide a pre-production system suitable for only one size HDD machine. This new GPR offers a step forward in the detection of obstacles in the HDD operations. However, this system will require further enhancements to be suitable as a commercially acceptable product from it current pre-production status.

The objective of the proposed work is to produce a fully commercial version of the drill head mounted GPR applying the results of the past developments. The program plan will address the tasks of (1) additional field testing to determine optimal hardware configuration, (2) further ruggedize the downhole components, (3) investigate optimal means of data transmission from the antenna to the surface, (4) continue software and data presentation development, and (5) address issues of integrating the GPR with HDD controls.

(6) Inspection Platforms for Unpiggable Lines: In response to a number of significant pipeline incidents in recent years, the federal government has imposed new requirements on gas transmission pipeline operators to assess the condition of their facilities. One of the methods used to examine a trans-mission pipeline is in-line inspection (ILI), also known as "smart pigging." Many transmission pipelines are designed to accommodate pigs. Similar requirements are expected within the next few years for LDC-owned transmission pipelines. Unfortunately, the majority of LDC-owned transmission or higher pressure lines contain short-radius bends, plug valves and other obstacles that render them unpiggable with traditional pigging devices.

The following system requirements were identified:

- 12" to 24" diameter; up to 0/5" wall thickness
- Five mile run length
- Self-powered
- Operate in gas flow velocities of 25 feet per second to 150 feet per second
- Able to negotiate plug valves, mitered bends, compound 90 degree bends, and diameter reductions of at least two sizes
- Detect defects resulting from both internal and external corrosion through the use of MFL sensors
- Minimize the number of hot taps
- Minimize extent of excavations needed for launching

In 2002, a preliminary investigation was conducted into the feasibility of developing integrated locomotor/sensor robotic system for the inspection of presently unpiggable LDC-owned pipelines. Two proposals were funded, from Foster-Miller/PII and Automatika/Maurer Engineering. Each of these teams produced preliminary designs. Additional R&D is required to further develop the systems.

This R&D will involve a Phase II effort to develop and test the following:

- Foster-Miller/PII System
- Locomotor and inspection sensor application

- Performance testing
- Automatika/Maurer Engineering System
- Test critical technologies
- Wireless
- Locomotor
- In-pipe battery recharge
- Inspections sensor application

(7) Safe Reliable Operation and Maintenance of Aldyl A Plastic Gas Pipe Systems: Plastic pipe was introduced to the natural gas industry in the early 1960's. With its many advantages over steel pipe (including lower cost, lighter weight, easier handling, speedier installation and joining, no corrosion problems, and no welding), it quickly became the material of choice for gas distribution systems. Some of these early materials have, and continue to, perform well. However, significant technology improvements since the 1960's have made the current generation of plastic piping materials highly rugged and reliable, with many types of plastic piping having estimated life expectancies in excess of fifty years. While the new plastic perform very well, some of the early materials were problematic.

This project has as its intent the identification of specific problems and issues associated with the use of Aldyl-A pipe systems (pipe and fittings). The objectives of this project are to:

- Determine the performance characteristics of Aldyl-A materials, by year of manufacture, through laboratory testing of samples and feedback provided by participants

- Determine the estimated remaining useful life of the product materials by year of manufacture, including the influence of such factors as operating pressure, temperature, surface scratches, defects, type of backfill, and other conditions that may impact on life expectancy.

(8) Alternative Methods for Pavement Cutting: Most of the current pavement cutting and restoration procedures use jackhammers, pavement saws, and backhoes for cutting and moving the asphalt and concrete layers. These methods are noisy, restricted to daylight operation, produce a risk of injury, and can cause damage to adjacent uncut pavement.

This project focuses on evaluating alternatives to these methods with the objectives of eliminating the drawbacks of existing methods and presenting improvements in efficiency and cost-effectiveness. The proposed work consists of two phases:

- Phase I: Evaluate several alternative technologies. These technologies will include laser cutting devices, thermal cutting methods, microwave devices, water jets, and the latest developments in mechanical cutters such as pavement breakers and diamond saws. These methods have varying degrees of efficiency and operating costs. The work of this phase will define the parameters associated with the cost and further development needs of these technologies. It will also include laboratory evaluation and specification development for the most promising technology.

- Phase II: Acquire, design, and implement engineering modifications to produce a prototype of the selected method which meets the specifications and requirements of Phase I. Coordinate field tests with the participating utilities for evaluating the performance of the device under realistic operating conditions.

(9) Micro-Excavation System Applications: This project has as its intent the development of equipment, tools, sensors, materials, and procedures to access, examine, and maintain buried pipe through two, two-inch diameter excavations. The objectives of this project are to:

- Develop a prototype articulating device to hold sensors, toos, and light sources, and to successfully deliver them through a two-inch opening down to a buried pipe.
- Evaluate prototype sensors to examine a section of pipe through a micro-excavation opening to inspect for corrosion, coating conditions, and wall thinning.
- Evaluate the effects of creating small voids around the pipe during micro-excavation, and determine methods to sufficiently backfill and compact micro-excavation openings.
- Evaluate existing anaerobic sealing tools and procedures for use in micro-excavations.
- Develop methods to install anodes on pipes for cathodic protection through micro-excavations.
- Evaluate methods to abandon gas services through micro-excavations.

(10) Service Applied Main Stopper: This project focuses on lowering the costs associated with emergency gas shut-off due to third-party damage, through the development of an innovative tool and method of use. Current field practices to isolate the damaged section of pipe involve multiple excavations to set stopping or squeeze-off equipment as well as multiple customer shut-offs. The Service Applied Main Stopper (SAMS) project objectives are to: (1) Develop technology and the necessary tools that will utilize existing customer service lines and meter sets to isolate pipe ruptures and stop the flow of gas, (2) Reduce costs by minimizing excavations through the use of the SAMS "no-dig" technology, and (3) Decrease the isolation area, which will reduce customer outages and impact due to third-party main damage

Service lines allow safe entry to the gas main. By inserting a stopping device through the customer's meter valve, crews can isolate the damaged section between neighboring customer service lines and stop the flow of gas.

Developing this technology will resolve two major issues: (1.) the costs associated with third-party damage repairs and (2.) the ability to isolate and stop a ruptured gas main. The costs involved with third-party damages are high due to the labor associated with the number of excavations required to isolate the damaged area. Addressing the ruptured main, without having to make any excavations, would allow crews to decrease the time required to stop the blowing gas, decrease total repair allocations and substantially minimize the costs in restoration of pavement and landscaping. All of this will be performed remotely, at the customer's meter, which also increases crew safety. Under many circumstances, the ideal location to isolate a damaged section of main cannot be utilized due to a number of complications (other existing utility lines, pavement issues, etc.); however, this device does not discriminate against surrounding factors because the existing service line acts as a safe conduit to the main.

Q **How will the projects be chosen?**

CHATTANOOGA GAS, with Authority oversight, will provide the final authorization as to where their research-funding dollars are applied from the list of candidate projects.

Q. How is GTI currently funded?

A. Since it was established in 1977, GTI has been funded through a FERC-authorized surcharge on gas transported over the interstate pipelines. Chattanooga Gas customers have supported GTI R&D through upstream suppliers prices which were in turn charged under Chattanooga Gas's retail cost of gas. The FERC has decided to discontinue that charge before the end of 2004 and transfer the funding authority to the state jurisdiction.

Q. What level of funding is GTI seeking from local distribution companies that are coming before their state jurisdictions in request of general base rate changes?

A. GTI has performed an analysis of needed distribution operations and increased efficiency R&D only (*not* including needed supply and transmission R&D). Given the projects just discussed and the budgets of $390,000 indicated in Exhibit 2 to my direct testimony (attached hereto), and the Chattanooga Gas load of about 20 Bcf per year, a funding unit of 1.95 cents per Mcf would be required to support this R&D. However, GTI is recommending only 1.74 cents per Mcf be collected from Chattanooga Gas's customers. This would be a conservative goal for the R&D surcharge, given the costs of the proposed projects. The 1.74 cents per Mcf is also consistent with the Federal Energy Regulatory Commission (FERC) approved charge from the GTI R&D program up until 1998 (when parties agreed to reduce and then eliminate the FERC-approved charge). This is also the rate GTI has recommended in cases before other state commissions.

Q. What other states are already participating in GTI's state funding program?

A. There are 15 states currently authorizing research funding for gas-consumer-interest R&D.

These are Alabama, Delaware, Florida, Idaho, Illinois, Kentucky, Mississippi, Hampshire, New Jersey, New York, North Dakota, Oregon, Utah, Washington, and Wyoming. One other state, Michigan, has a case pending in which the R&D surcharge is included.

Q. Would you expect the dollars collected to be earmarked for GTI?

A. Not necessarily. Chattanooga Gas, with Authority oversight, will have the ability to (1) choose specific R&D projects that will benefit its customers and (2) place these R&D dollars with GTI or other research organizations for consumer-interest R&D purposes.

Q. Is there any chance that the FERC-approved program will be continued beyond the end of 2004?

A. There is an initiative just started in 2004 to establish a national FERC II program at a funding level of 0.56 cents/Mcf. It has a very difficult national approval process. In the event that the FERC II surcharge is approved, GTI recommends that the Chattanooga Gas R&D surcharge be reduced to 1.18 cents/Mcf, so the Tennessee gas consumer is never charged more than 1.74 cents/Mcf, the historic FERC surcharge from 1998 and prior years.

Q. What do you have to say in conclusion?

A. Over the past twenty-five years, gas consumers have realized billions of dollars of benefits from GTI's R&D. Our overall consumer benefit-to-cost ratio is 8/1, including all R&D costs and benefits from commercialized products and services. Based on our over twenty-year track record of maintaining benefit-cost ratios of over 8:1, I believe that in the future GTI can sustain this benefit-to-cost ratio for Tennessee gas consumers.

The guidance from public utility commissions and LDCs as well as others (such as consumer advocates and environmental groups) will ensure the selection of specific R&D projects that are appropriate to and offer benefits for Tennessee gas consumers.

Continuation of GTI's R&D programs is absolutely critical for the continued supply, transport, and use of natural gas as a current and future environmentally benign, domestically produced energy source for Tennessee and for the United States.

Q. Does this conclude your prefiled testimony?

A. Yes it does.

EXHIBIT 1

TO QUALIFICATIONS AND

DIRECT TESTIMONY

OF RONALD B. EDELSTEIN

GRI-03/0106

Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1998 Through 2002

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May 2003

Abstract

This report provides brief descriptions for twenty-eight new GRI RD&D products commercialized in 2002 and three enhancements of previously introduced products. The economic benefits are quantified for ninety-eight items commercialized between 1998 and 2002 that are known to have produced significant economic benefits for their users. The calculated ratio of the benefits to gas customers to total GRI costs incurred in 1998 through the end of 2002 was 8 to 1.

Acknowledgments

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Introduction

Between January 1, 2002 and December 31, 2002, twenty-eight GRI RD&D results were placed in commercial service. In addition, enhanced versions of three previously commercialized items were placed in use* Those items are listed in Table 1, and brief descriptions of the thirty-one items are included in Appendix A. With these new additions, some 153 GRI RD&D results have entered the commercial marketplace during the 5-year period between January 1998 and December 2002 The full list of the 153 items is included in Appendix B. As one measure of the value of the GRI RD&D program, the economic benefits accruing to users of 98 out of the 153 products can be compared to the total outlays of GRI during the past five years. This paper highlights the new GRI products that have entered the market during the past year and presents the results of the benefit-to-cost analysis of GRI's RD&D results during the past five years.

Notable additions to the list of GRI RD&D results placed in commercial service in 2002 are

- A summary report of GRI's research on condensate-induced corrosion pertaining to mid- and high-efficiency gas furnaces and boilers, condensing heat exchangers, and venting guidelines for higher efficiency gas appliances,
- A gas heating system for a gas-fired commercial steam cooker that enables multi-point heating,
- Development of advanced U-shaped Si-SiC radiant tubes,
- A patented Forced Internal Recirculation burner that combines staged combustion with internal recirculation of partial combustion products to reduce the formation of both thermal and prompt NO_x,
- A low-cost advanced NGV fueling dispenser,
- Efficiency improvements for the John Deere PowerTech 8.1L and the Mack Truck E7G natural gas engines used in many medium-duty NGVs,
- A tool for splitting old service lines to allow larger plastic pipe to be inserted,
- Techniques to predict and model stress behavior and rock slippage to predict the integrity of gas storage caverns in thin salt beds,
- A manual of best environmental management practices to serve as a reference document and field guide for pipeline construction,
- A more accurate seismic signal analysis method for identifying potential gas reservoirs, and
- Screening criteria for evaluating the ecological impacts at E&P sites.

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* For tangible products (hardware, software) we interpret "commercialized" to mean that the product is commercially available, economically viable without subsidies, and has been sold in meaningful quantities. For the less tangible reports and other information products, we require that the products have been used in a commercial enterprise and have generated demonstrable economic benefits to the users. "Enhanced" products have been augmented in a commercially significant way, with or without GRI support. The augmentation may be a technical improvement in a product line, expansion of a product catalog, or expansion of the product market into new areas not available to the original product at its time of introduction

Table 1. GRI RD&D Results That Have Been Placed in Commercial Use in 2002

RESIDENTIAL

1. Summary Report of GRI's Venting Research
2. Gas Venting Safety Assessment
3. Accurate Assessment of Heat Pump Efficiency

COMMERCIAL

4. Comparison of Radiant and Convective Unit Heaters
5. Gas-Fired Commercial Steam Cooker

INDUSTRIAL

6. Advanced U-Shaped Radiant Tubes *
7. Low-NO_x Retrofit Burners for Fire-Tube Boilers
8. Low-Cost Multi-Gas Continuous Emissions Monitor

TRANSPORTATION

9 Advanced NGV Fueling Dispenser
10. Reference Guide of Best Practices for Medium-and Heavy-Duty NGV Fuel System Design
11. Clean Cities Initiative to Evaluate NGV Technology
12. Resource Guide for Heavy-Duty LNG Vehicles
13. Regional Natural Gas Vehicle Fueling Infrastructure Standards
14. Heavy-Duty Engine Efficiency Improvements (Deere 8 1L and Mack Truck E7G) *

DISTRIBUTION

15. Pipe Splitting Tool *
16. Gas Distribution Cost Database
17. Effect of Bomb Blasts on Gas Distribution Equipment
18 Assessment of PVC Pipe
19. Effect of Utility Cuts on Pavement Quality
20. Plastic Pipe Informational Web Site
21. Evaluation of the Performance of Carbon Monoxide Alarms
22. Worker Exposure to Hazardous Substances Database

PIPELINE

23. Predicting the Integrity of Storage Caverns in Thin Salt Beds
24. ASME Standard for Pipeline Integrity Management
25 NACE Standard for Direct Assessment of Pipeline Corrosion
26. Revegetation of Rights-of-Way in Wetlands
27. Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effect in Wetlands
28. Best Environmental Practices for Pipeline Construction
29. Integrated Vegetation Management

EXPLORATION AND PRODUCTION

30. Enhanced Seismic Spectral Processor
31. Evaluating Ecological Impacts at E&P Sites

* Enhancement to a previous product.

Benefits Results

The full list of the 153 items placed in commercial use between January 1998 and December 2002 is included in Appendix B, but we chose to focus the benefits analysis of GRI's RD&D on 98 of the 153 items that are known to have produced significant *quantifiable economic* benefits for their users. The 98 items are listed in Table 2. Benefits to product users in typical applications were calculated by comparing the economics of the GRI-sponsored products with the economics of products that would have been used in the absence of the GRI product. Product cost and performance data were obtained from product vendors, from field test results, or from product users. The measure of product benefit is the net present value of the incremental cash flow to the user (cost savings minus incremental cost) over the product lifetime using a real discount rate of 5% (above inflation) The GRI Baseline [1] national average projections of energy prices were used, when appropriate, to estimate cost savings Total benefits were calculated by multiplying the unit benefits by the sales projected by product vendors from the first year in which the product was sold through 2007. The results are shown in Table 2. A range of product sales is shown to protect proprietary vendor sales projections.

As shown in Table 2, calculated economic benefits for the 98 items are estimated to be between $4.0 and $7 1 billion. Table 3 shows the expected value of benefits, at about $5 5 billion, and the breakdown of the economic benefits by sector We estimate that the 98 items account for most of the economic benefits that would be calculated for the entire set of 153 products. Omitted items often offer significant benefits to their users, but have not achieved widespread use as have the 98 high impact items. In addition, some of the omitted items are designed to produce benefits that are not easily expressed in economic terms. For example, RD&D results provide test methods for new gas equipment, technologies to meet existing or anticipated air emissions requirements, and information that is useful to the gas industry in developing the gas resources and delivering them to consumers.

Table 2. Summary of Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1998 Through 2002

	Sales or Applications Projected Through 2007 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2002$)		
RESIDENTIAL							
Flammable Vapors	12,900	to	20,300	1998	$127 6	to	$200 5
COMMERCIAL							
Alturdyne Hybrid Electric/Gas Engine Chiller	183	to	336	1998	$186.1	to	$341.1
kitchenCOST™ Software	545	to	1,000	1998/99	$35 0	to	$64.2
DesiCalc™ Software	340	to	620	1998	$3.7	to	$6.8
Low-NO_x Power Burner	1,770	to	3,100	1998	$16.3	to	$28 5
ASHRAE Standard 155P for Boilers	3,530	to	7,400	1998	$49.4	to	$103.7
Modulating Indirect-Fired Make-Up Air Unit with Clean Modulation	1,570	to	2,880	1999	$5.5	to	$10.1
GATC: AERCO Benchmark Boiler	1,200	to	2,400	1999	$22.0	to	$44.1
PITCO Gas Fryers	66,200	to	121,800	1999	$38 4	to	$72.7
AUTOFRY™ Deep Fat Fryer	1,890	to	3,780	1999	$6.9	to	$13.8
York 600 RT 134a Chiller	53	to	83	2000	$28.3	to	$44 4
Tecogen 150 RT 134a Chiller	56	to	91	2000	$2 0	to	$3.3
INDUSTRIAL							
Process Application of Composite Radiant Tubes	30,600	to	53,000	1994/99	$28.3	to	$49 1
Multi-Variable Controls (MVC® for Industrial Applications)	16	to	30	1998	$153.2	to	$280.9
RAPIDFIRE™ Products	13	to	23	1998	$120.5	to	$210 8
Natural Gas Cofiring in Biomass-Fueled Stoker Boilers	13	to	20	1999	$105.1	to	$165.2
Ultra-Low-NO_x Boiler Burner	120	to	180	1999	$56.5	to	$84.8
METHANE de-NOX® Reburn Technology	6	to	11	1999	$132 1	to	$226.5
Forced Convection Heater (FCH) Systems - Automotive	11	to	19	2000	$13.8	to	$23 0
Oscillating Combustion Burner	125	to	225	2001	$15.7	to	$28 1
POWER GENERATION							
SOAPP Modules	900	to	1,900	1998	$22.1	to	$46.4
IR PowerWorks Microturbine Cogeneration Systems	2,080	to	3,270	2000	$38.0	to	$59.8
Advanced High-Output Gas Engine-Generator (Caterpillar 3500® Series)	30	to	52	2001	$30.8	to	$52.9
TRANSPORTATION							
CNG Cylinder Maintenance Handbook	243,000	to	510,500	1998	$31 6	to	$66 5
Ford Crown Victoria Natural Gas Vehicle - Extended Range Package	1,180	to	3,500	1998	$5.4	to	$16 1
Risk Management Program for Liquid Natural Gas Vehicle Refueling Stations	49	to	85	1998	$22 9	to	$40.1

	Sales or Applications Projected Through 2007 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2002$)		
NGV Cylinders Types 1 and 2	24,000	to	58,700	1999	$4.5	to	$10.9
Advanced NGV Fueling Dispenser	63	to	138	2002	$0.9	to	$2.1
DISTRIBUTION							
Plastic Pipe Across (and on) Bridges	3,700	to	7,900	1995/99	$56.0	to	$117.6
Pipe Hawk™ (Buried Pipe Locator)	56	to	99	1998	$12.9	to	$22.6
Optical Methane Detector (OMD)	137	to	206	1998	$31.5	to	$47.3
Predictive Control District Regulators	260	to	470	1998	$68.0	to	$124.7
Main/Services Tester	675	to	1,240	1998	$129.4	to	$237.3
Distribution Internal Inspection System - Magnetic Flux Leakage (MFL)	14	to	25	1998	$21.6	to	$39.5
TUBIS™ Software for Repair/Replace Decisions	10	to	19	1999	$18.1	to	$33.2
DrillPath™ Software for Directional Drilling Operations	460	to	690	1996/99	$1.9	to	$2.8
Starline® 2000 Renewal Technology	54,900	to	100,600	1999	$0.8	to	$1.5
Guided Mole	40	to	70	1999	$4.3	to	$7.5
Gas Holder Manual of Practice	7	to	12	1999	$6.0	to	$11.0
One-Step Paving	250	to	450	2000	$2.0	to	$4.0
Soil Compaction Supervisor	390	to	680	2000	$7.4	to	$13.0
Self-Loading, High-Efficiency Trailer for Coiled PE Pipe	17	to	43	2001	$41.7	to	$108.5
Cold-Mix Restoration of Pavement Cuts	88	to	230	2001	$6.6	to	$17.1
Imaging Underground Utility Structures	240	to	450	2001	$5.3	to	$9.7
Comparative Evaluation of PE Pipe Materials	49	to	98	2001	$45.2	to	$90.3
Directional Drilling for Plastic Pipe under Railroad Crossings	34	to	74	2001	$9.5	to	$20.6
PE LIFESPAN FORECASTING™	111	to	205	1994/01	$85.5	to	$158.3
Pipe Splitting Tool	7	to	14	1998/02	$7.1	to	$14.2
Gas Distribution Cost Database	450	to	800	2002	$11.4	to	$20.3
Assessment of PVC Pipe	4,000	to	8,000	2002	$18.1	to	$36.2
Worker Exposure to Hazardous Substances	***			2002	$8.4	to	$25.3
PIPELINE							
NO_x Portable Analyzer Operator Guidelines	130	to	200	1998	$27.6	to	$43.4
Oxidation Catalyst Costs for Aldehyde Control	106	to	186	1998	$23.7	to	$41.4
TurboCharger Testing Facility	590	to	1,040	1998	$5.7	to	$10.0
Magnetostrictive Sensor	440	to	770	1998	$7.5	to	$13.1
Breeze Haz™ Environment and Safety Offsite Consequence Modeling Software	3,040	to	5,340	1999	$13.3	to	$23.3
Emeritus Report B31.8 Code, Federal Pipeline Safety Regulations	***			2000	$18.4	to	$55.2
Elastic Wave Vehicle Tool	***			2000	$64.6	to	$139.9
Advanced Leak Detection and Repair at Gas Processing Plants – Hi-Flow™ Sampler	370	to	660	2000	$155.0	to	$276.8
API 14.1 Gas Sampling Standard.	5	to	11	2001	$4.8	to	$10.4

	Sales or Applications Projected Through 2007 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2002$)		
Ultrasonic Meter Installation Effects	2,500	to	5,000	2001	$62.7	to	$125.5
Orifice Meter Operational Effects	23	to	43	2001	$36 2	to	$67.3
DamageExpert™ Software	31	to	66	2001	$51.9	to	$112.5
Satellite Radar Interferometry Measurement of Slope Movement	17	to	38	2001	$40.6	to	$88.0
AIRCalc™ Software	146	to	268	2001	$75 4	to	$138.3
Predicting the Integrity of Storage Caverns in Thin Salt Beds	3	to	12	2002	$0.4	to	$1 5
ASME Standard for Pipeline Integrity Management	189,000	to	389,000	2002	$3.2	to	$6.7
NACE Standard for Direct Assessment of Pipeline Corrosion	100,000	to	350,000	2002	$0 3	to	$1.0
Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effects in Wetlands	75	to	250	2002	$1 9	to	$6.2
Best Environmental Practices for Pipeline Construction	600	to	1,200	2002	$2.5	to	$4.9
EXPLORATION AND PRODUCTION							
Offshore Atlas, Vol 2.	192	to	313	1998	$13 3	to	$21.6
Coalbed Methane Reservoir Gas-In-Place Analytical Techniques	150	to	270	1999	$49.7	to	$90.5
GRI Sulfur Recovery Workshop Proceedings	295	to	440	1998	$3.0	to	$4.4
Calcite Scale Handbook/ASTM Standards	1,300	to	2,040	1998	$32 7	to	$51.3
Drill String Safety Valves (DSSVs)	4,310	to	6,470	1998	$43 4	to	$65.0
Mesa-GRIP Seismic Survey Design Software	136	to	187	1998	$57.4	to	$78 9
Crosswell Seismic Imaging	190	to	300	1998	$150.1	to	$235.9
Fracturing Information and Diagnostics • M-Site Advanced Diagnostics Insights • Hydraulic Fracture Mapping System • Downhole Tiltmeters • Fracture Fluid Characterization Facility (FFCF) Insights	12,600	to	19,800	1998	$211.3	to	$332.0
Unconventional Natural Gas Database	111	to	196	1999/01	$10.2	to	$18.0
Downhole Gas/Water Separation CD-ROM	75	to	130	1999	$8.3	to	$14.4
Advanced Crosswell Seismic Source	200	to	400	1999	$32.1	to	$63.6
High Power VSP Mechanical Seismic Source	520	to	755	1999	$24 2	to	$35.3
Advanced Stimulation Technologies CD-ROM	45	to	83	1999	$5.5	to	$10 0
Coiled Tubing Standards	3	to	5	1999	$14 9	to	$28.8
GRI-MSTR™ Software and Report to Predict Toxicity of Produced Water Discharged to the Marine Environment	275	to	435	1999	$12 0	to	$18.9
Glycol Dehydrator Emissions Calculation Program - GLYCalc 4 0	760	to	1,400	1992/00	$72.4	to	$134.0
ProTreat™ Software for Amine Gas Treating Applications	45	to	75	2000	$129 7	to	$216 2
Cased Hole Resistivity Tool	800	to	1,300	2000	$11 7	to	$19.0
Cased Hole Pressure Tool	725	to	1,245	2000	$101.5	to	$173 9

	Sales or Applications Projected Through 2007 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2002$)		
Well Siting in Carbonates – EGI Report	92	to	138	2000	$68.7	to	$103.1
Portfolio of Emerging Natural Gas Resources – Rocky Mountain Basins	630	to	950	2000	$143.1	to	$214.6
Mercury Contamination Training Workshop	300	to	500	2000	$2.9	to	$4.8
New Gas Exploration Concepts	52	to	81	2001	$219 2	to	$344 4
StreamAnalyzer™ Software	330	to	720	2001	$69.6	to	$153.1
Enhanced Seismic Spectral Processor	200	to	370	2002	$25.6	to	$47.4
TOTAL (million of 2002 dollars, 5% discount rate)					$4,010	to	$7,103

* Enhancement to a previous product for a new market application

** Net present value calculations based on a real discount rate of 5% (excluding inflation), stated in 2002 dollars.

*** Benefits are based on user feedback about technical and market influence of the group of the information items

Table 3. Total Expected Benefits by Sector	Quantified GRI RD&D Results	Net Present Value of Benefits (Million 2002$)
• Residential	1	$128
• Commercial	11	$541
• Industrial	8	$884
• Power Generation	3	$143
• Transportation	5	$129
• Distribution	23	$1,025
• Pipeline	19	$790
• Exploration and Production	28	$1,869
TOTAL	98	$5,509

GRI RD&D Costs

Between January 1998 and December 2002, GRI outlays totaled $592 million For comparison to the RD&D benefits calculated above, the cost cash flow stream was converted to an equivalent net present value lump sum expenditure at the beginning of 2002 As with the benefits calculation, a 5% real discount rate was used in the net present value calculation. The calculated equivalent cost was $690 million. These costs include all outlays made by GRI during the past 5-year period, not just the costs incurred to produce the 153 RD&D products Consequently, a portion of the calculated cost will yet generate benefits as additional products are commercialized in the future.

Benefit-to-Cost Ratio

Dividing the calculated benefits by the costs results in a calculated benefit-to-cost ratio range of 5.8 : 1 to 10.3 1 (benefits of $4.0 to $7 1 billion divided by outlays of $690 million) with an expected value of 8.0 : 1 ($5 5 billion divided by $690 million). In a similar analysis carried out in 2002 for RD&D items placed in commercial use between 1997 and 2001, the calculated ratio of the benefits to gas customers to total GRI costs incurred during the same period was 9.2 to 1 [Reference 2].

Conclusions

GRI's planning and budget allocation process strives to put in place a program with the maximum ratio of benefits to RD&D costs for the mutual benefit of the gas customer and the gas industry. The economic evaluation of GRI's commercially successful RD&D results have consistently shown that benefits far exceed the costs of the RD&D program.

Analysis of the benefits of approximately 98 of the 153 GRI RD&D items placed in commercial service between January 1998 and December 2002 shows that GRI RD&D will return about $8 0 for every dollar invested in GRI during the same period. In addition to the fact that only a portion of GRI's commercialized RD&D items are included in the benefits calculation, all of the costs of GRI's operations during the 1998 to 2002 period have been included in the calculation of the benefit-to-cost ratio.

References

1. P D. Holtberg, J.C. Cochener, "Baseline Projection Data Book: 2001 Edition of the GRI Baseline Projection of U.S. Energy Supply and Demand to 2020," GRI-01/0002.1 and GRI-01/0002.2, GRI, March 2001

2 A D Bournakis, and G.D. Pine, " Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1997 Through 2000," Gas Research Institute, May 2002, GRI-02/0074.

Appendix A
GRI RD&D Results That Have Been Placed in Commercial Use in 2002

RESIDENTIAL

Summary Report of GRI's Venting Research. High-efficiency gas space-heating furnaces offer the attraction of saving consumers energy costs and conserving U.S. energy resources. However, moisture condensation from the flue gases leads to corrosion of furnace heat exchangers and gas vents and to other venting problems. GRI RD&D, conducted over many years, comprehensively characterized and addressed these problems. However, continuing efforts by DOE to conserve fuels has led to recurring attempts to increase furnace efficiency, even though it is inescapable that high-efficiency furnaces cause moisture to condense. To insure that the results of GRI's RD&D on condensing furnaces and their venting are widely available for future policy decisions, GRI offered testimony and comments at the DOE Venting Workshop, held May 8, 2002 GRI also published a report, summarizing the RD&D results on which the testimony and comments were based. The summary report lists the GRI reports with abstracts pertaining to mid- and high-efficiency gas furnaces and boilers dealing with condensate-induced corrosion, condensing heat exchangers, and venting guidelines for higher efficiency gas appliances The report provides a historical perspective of the issues and research that led to the development of the gas vent design tables and identifies the assumptions made in formulating the tables. It discusses the factors that influence condensation and corrosion in appliances and vents and the benefits and problems of stainless steel and high-temperature plastic vents and masonry chimneys It also discusses the effects of expected contaminants in combustion gases.

Gas Venting Safety Assessment. Gas furnaces and water heaters rely on the buoyancy of warm combustion products to carry the combustion products up through the gas vent and out of homes At the same time, outdoor air infiltrates through many small openings in the home to replaces the air and combustion products that leave the home through the gas vent. As homes have become tighter to save energy, there is increased concern that combustion products will not vent properly but will, instead, spill into the home, leading to undesirable indoor concentrations of moisture, carbon monoxide, and nitrogen oxides. When kitchen exhaust fans, fireplaces, or similar devices are operated, outdoor air can actually be pulled down the gas vent, preventing any combustion products from leaving the home This situation is called backdrafting when the gas appliance is operating and downdrafting when it is not operating GRI investigated gas venting in detail, and found that the customary quick tests for gas vent spillage do not adequately assess whether a problem exists in a given residence. Longer-term tests are required because gas vent spillage is an intermittent phenomenon that can occur in some homes only under certain combinations of outdoor temperature and wind conditions. American Society for Testing and Materials Standard E 1998 summarizes different methods for assessing backdrafting and spillage from vented combustion appliances. It describes the equipment needed, test procedures, data reporting, results and interpretation, and technician and test time required for each method. It also discusses the advantages and uncertainties of each method. In 2002, as a result of GRI's research, ASTM modified the standard to recognize the importance of longer-term tests and recommend how those test should be performed The modified standard, issued as ASTM E 1998-02, recognizes that longer-term monitoring of gas vent spillage can provide more definitive results than short-term testing, lead to better assessment of spillage problems, and ultimately provide a greater margin of safety for building occupants.

Accurate Assessment of Heat Pump Efficiency. In the late 1990s, devices called comfort controllers became available in the market for use with electric heat pumps. Comfort controllers are resistance heaters that boost the heating capacity of heat pumps and provide delivered air temperatures higher than typically produced by the heat pump alone, creating a feeling of warmth or comfort. Because resistance heaters are not nearly as energy efficient as heat pumps, their use could degrade efficiency below the

NAECA minimum efficiency levels mandated by federal law. In 2001, DOE published a notice of proposed rulemaking for heat pump test procedures seeking to modify its standard test procedure for heat pump efficiency to account for such devices as comfort controllers GRI RD&D reviewed the proposed rules and found that the assumptions and approaches specified would not fully account for all of the energy used by heat pumps that incorporate comfort controllers. In 2001, GRI published a report of its findings and identified modifications in the test procedures that would properly evaluate the energy consumption and performance of heat pumps with comfort controllers. Because the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) maintains Standard 90 1, which regulates energy use in buildings, attention focused on insuring that ASHRAE 90.1 contained appropriate language In 2002, ASHRAE changed the standard to include language requiring that energy supplied to comfort controllers be counted as input energy to the heat pump.

COMMERCIAL

Comparison of Radiant and Convective Unit Heaters. Radiant infrared heater manufacturers claim that radiant heaters mounted near the ceiling with the radiant output directed toward the floor can maintain comfort conditions for occupants with much less fuel consumption than warm-air type space heating equipment, particularly in industrial and commercial spaces that have high ceilings. A plausible explanation is that radiant heaters warm the floor and other surfaces near the floor, and these surfaces re-radiate heat to the occupants and warm the air near the floor. In contrast, warm-air heating equipment, such as unit heaters, heat a space unevenly, with much of the warm air output rising to the ceiling, increasing heat loss through the roof, and with significantly less of the heat being available to the occupants. No known established testing substantiates this reasoning. Although warm-air heating systems do have a tendency to create a vertical temperature gradient with warmer air at ceiling level, tubular infrared heaters also appreciably heat the air around themselves and, to some degree, they also warm the ceiling-level air in addition to contributing to floor level comfort conditions. To provide definitive information, GRI RD&D compared the actual performance of a typical warm-air unit heater used in high ceiling areas with the performance of a typical tubular infrared heater. The tests assessed fuel consumption and other key performance attributes, including differences in vertical temperature gradients, response to thermostat controls, and user comfort. GRI published the results of these tests in 2002. The report presents test data and conclusions about the performance of radiant heaters relative to warm-air unit heaters It was found that each type of heater has advantages and disadvantages. Unit heaters have quicker response and cost less, but their efficiency is much lower when providing the same level of comfort to occupants, especially in buildings that have little roof insulation, where they are typically used. The radiant heaters were quieter, but they provided less comfort to occupants. Although unit heaters generate some local hot spots in the building, the radiant heaters generally overheat occupants' upper extremities and underheat their lower extremities.

Gas-Fired Commercial Steam Cooker. Commercial steam cookers are usually heated by electric elements mounted at the bottom of the cooker to boil water and at the top to prevent condensation that would drip onto the food. The need for multiple-point heating around the cooking cavity has been an obstacle to the use of gas, even though gas cookers would heat up faster and be less expensive to operate than electric steamers GRI RD&D developed a gas heating system for a steam cooker that enables multi-point heating and does not require an expensive boiler. The gas burners are directly fired into the cast-aluminum cooking cavity, which also holds the source of water for steaming, thus avoiding the need for a separate boiler GRI's innovative design provides secondary heating of the walls and top of the cooking cavity, slightly superheating the steam and generating a dry-steam cooking environment This design delivers more cooking energy in less time than existing designs, enables quick heat recovery, and costs less to clean and maintain Performance testing showed that the gas-fired steamer safely provides equivalent cooking characteristics to electric steam cookers. The steamer became commercially available in early 2002 as Stellar Steam's Sirius Steamer, manufactured by ColburnTreat LLC. Stellar offers the full-featured steamer in four sizes. The new steamer offers a better choice of energy services to commercial food preparers. It is faster and less expensive to operate than currently available steam cookers.

INDUSTRIAL

***Advanced U-Shaped Radiant Tubes.** Industrial furnaces for heat-treating metals use special atmospheres to nitride or carburize the metals. The burners in these furnaces are fired through radiant tubes to keep the combustion products from contaminating those special atmospheres. Normally, the inlet and the outlet of these tubes are on the same side of the furnace, so U-shaped tubes are used. Current practice is to use tubes made of high-alloy steels that have a service temperature of 2100°F. However, metal creep and other deterioration processes shorten the life of these tubes. Silicon carbide tubes would perform better than metal tubes, but their high cost limited their commercial use GRI RD&D developed processes for making tubes inexpensively from silicon and silicon carbide (Si-SiC). Si-SiC tubes allow service temperatures as high as 2450°F and have longer life than steel alloy, especially the U-bend portion of the tubes. Small diameter (2.75 and 3.25 inches) straight tubes were placed in service in 1989 and have performed well, but further RD&D was needed to scale up to larger diameters of 4.5 and 6 5 inches and to produce U-shaped tubes (only 17 percent of all radiant tubes currently in service are straight tubes, and 78 percent of all tubes have diameters of four to seven inches). The RD&D successfully developed processes for producing inexpensive U-shaped tubes with diameters of 4.5 and 5.125 inches. Schunk-Inex, Inc. made these large size U-shaped tubes commercially available in 2002. The higher service temperature of the Si-SiC tubes allows higher furnace efficiency and productivity. The larger U-shaped Si-SiC tubes will make these advantages available to a much larger fraction of U.S. heat-treating furnace operators, who now have 250,000 tubes of all kinds in service.

Low-NO_x Retrofit Burners for Fire-Tube Boilers. Gas-fired boilers and heaters typically emit 100 ppm of NO_x when no control methods are used, however, regulations usually require that these units emit no more than 10-30 ppm. Existing technology can achieve 25-30 ppm and can meet many regulatory limits, but these limits are becoming more stringent. In California, they are as low as 5 ppm, and anticipated future limits are 2 ppm. External control methods, such as the use of catalysts and flue gas recirculation can decrease NO_x emission, but these methods are costly. Burner redesign is usually preferable, and GRI pursued that path to develop the Forced Internal Recirculation (FIR) burner, which successfully achieved less than 10 ppm NO_x in field installations while keeping carbon monoxide levels below 50 ppm. The patented FIR burner combines staged combustion with internal recirculation of partial combustion products to reduce the formation of both thermal and prompt NO_x. The burner can operate at low levels of excess air, and this enables higher efficiencies than other low-NO_x burners. GRI licensed the technology to Johnston Boiler Company for use in fire-tube boilers. Johnston began selling the burners in 2002.

Low-Cost Multi-Gas Continuous Emissions Monitor. Single-gas continuous emissions monitors are costly to install, maintain, and calibrate for use in natural gas combustion facilities. GRI along with Emission Monitoring, Inc. developed a portable FTIR (Fourier-transform infrared) analyzer that can simultaneously measure all pollutants of interest with the required sensitivity. The analyzer can be used for stack emissions compliance testing and monitoring, emissions credit trading, ambient air monitoring, engine design optimization, selective catalytic reduction performance monitoring, and combined optimization of efficiency and emissions. Its robust design and easy-to-use data collection and analysis software enable practical operation in hostile industrial environments. The analyzer provides simultaneous analysis and display of more than 30 gases. Samples can be acquired and analyzed in less than a second, making transient analysis possible. The analyzer is relatively small and lightweight, and it has part-per-billion sensitivity for many gas species and a user-friendly software design that enables calibration and operation by minimally trained personnel. On-Line Products, Inc. made the analyzer commercially available as its model 2030 MultiGas™ Analyzer in 2002. A special feature is a unique calibration system, which uses permanent gas calibration spectra to avoid the time required for calibration and the cost of calibration gas cylinders The MultiGas software has multi-point calibration curves that cover a range from parts per billion to 100%. Calibrations for many gas species are provided with the instrument, and users can generate additional calibrations from gases of known concentration. The MultiGas Analyzer will enable large gas users to comply with expected environmental regulations for emissions monitoring. The analyzer performs the same measurements as a trailer-sized set of single-gas analyzers, while also providing real time data for aldehydes and other volatile organic compounds for which there are no suitable alternative analyzers. As a result, it enables emissions monitoring at much lower capital and operating costs

TRANSPORTATION

Advanced NGV Fueling Dispenser. A typical compressed natural gas dispenser for a NGV fueling station costs from $21,000 to $32,000 or more, depending on features. This high cost inhibits the use of natural gas vehicles by limiting the number of fueling stations available and increasing the cost of gas delivered To mitigate this problem, GRI sponsored RD&D at GTI and Tulsa Gas Technologies. The RD&D improved the electronic controls to enable complete filling of a vehicle tank and communication with a card reader, receipt printer, and keypad. It also developed new dispenser cabinet designs that provide lower-cost solutions to the issues of keeping the electronics safely away from any possible contact with combustible gases. The new equipment was tested and certified by the Canadian Standards Association under ANSI/CSA standard NGV 4 1-1999. The prototypes evolved into the Tulsa Gas Technologies 7000 Series dispenser, which became commercially available in 2002. The new dispenser costs $4,500 to $13,000 less than previous systems with similar capabilities.

Reference Guide of Best Practices for Medium-and Heavy-Duty NGV Fuel System Design. Problems with NGV operation and performance can often be traced back to insufficient experience with gaseous fuel delivery systems. Most vehicle developers and operators are familiar with conventional liquid fuel delivery systems, but few are familiar with the high-pressure piping systems used for compressed natural gas (CNG) or the cryogenic systems for liquefied natural gas (LNG) To ameliorate this problem, GRI developed the Reference Guide for Integration of Natural Gas Vehicle Fuel Systems. It is a reference for those who develop, build, or maintain medium- and heavy-duty vehicles fueled by natural gas. It provides tools and resources for achieving greater safety and reliability in NGV fuel systems and NGV service. The Guide presents current industry practices and the recommendations of the project team for developing and maintaining on-board fuel systems for medium-duty, heavy-duty, transit, school bus, and paratransit NGVs. It is the most comprehensive source available of the design, manufacturing, operation, and maintenance segments of the vehicle life cycle. It will help designers, manufacturers, and users of NGVs avoid potential problems with fuel systems and locate appropriate references to learn more about specific topics. The Guide was compiled from interviews and workshops with vehicle builders, component suppliers, and vehicle users and from detailed reviews of the technical literature, codes and standards, and analyses of failure modes and effects. It covers both CNG and LNG systems and their components, and it contains information on design, maintenance, material compatibility, component selection, relevant codes and standards, safety, and reliability GRI published the Guide in 2002. It is available on CD and in notebook form. The practices recommended in these reference guides will improve the quality of vehicle design, thus enhancing vehicle safety.

Clean Cities Initiative to Evaluate NGV Technology. When this joint GRI-DOE RD&D began in 1997, the use of natural gas vehicles was encouraged by public policies but was retarded by a lack of information about NGV technology and uncertainties about vehicle fueling capacities and locations.

Proposals were solicited for projects to improve understanding; support broader use; and demonstrate the security, efficiency, safety, reliability, and environmental characteristics of NGV technology. A team of GRI, DOE, and industry experts selected six proposals for implementation. The six projects achieved the following and the results have been disseminated to the industry: 1) Atlanta FuelNet Project added 7 CNG stations, serving 26 different fleets. The software and experience from this project can be applied in other cities; 2) Natural Gas Passenger Ferry Project – fully planned natural-gas-fueled ferry systems for Boston and New York. Local businesses, environmentalists, and regulators in other cities are now considering natural-gas-fueled ferries; 3) Chicago Airport Infrastructure Project – installed a fueling station at the airport in 2000 and expanded it in 2001. The station delivers about 130,000 gge per year and enables increased use of NGVs at this airport. The project also enabled the introduction of the Fuelman fleet credit card into the Chicago area. The project also helped the City of Chicago Department of Environment obtain a Congestion Mitigation and Air Quality grant that led to the installation of nine new NGV fueling systems, 4) Salt Lake City Olympic Infrastructure Project – installed three stations at educational institutions for use by school buses and transit buses. The station also supported the use of NGV buses at the 2002 Winter Olympic Games; 5) Central Valley (California) Medium-Duty Vehicle and Infrastructure Project – supported the design, production, and performance monitoring of two medium-duty road repair trucks and a comparison of their performance to a similar diesel powered truck. The project also installed a LNG (liquefied natural gas) to CNG station at the City of Tulare, supplying 3 heavy-duty LNG trucks and 37 light- and medium-duty CNG vehicles. The station also strengthens the California-Arizona-Nevada Clean Transportation Corridor, 6) West Virginia I-79 Corridor Project – installed two CNG fueling stations. The stations strengthened the NGV corridor through West Virginia. In addition to the six projects, analysis of the proposed Clean Diesel Rule indicated that the NGV industry should continue to improve exhaust emissions and fuel efficiency so it can provide attractive alternatives to heavy-duty diesel engines.

Resource Guide for Heavy-Duty LNG Vehicles. The use of liquefied natural gas for heavy-duty vehicles has been hindered by a lack of information for fleet managers and other decision makers to use in evaluating vehicle fuel alternatives. To help remedy this situation, GRI developed the Resource Guide for Heavy-Duty LNG Vehicles, Infrastructure, and Support Operations. The guide answers questions about LNG fuel in fleet vehicles, such as how to begin implementation, likely costs and benefits, safety, availability, and potential problems. The guide also provides contact information for representatives of companies that are now using LNG, manufacturers and suppliers of the LNG and supporting equipment, and technical and governmental reference materials. The information in the guide is useful to both new and existing end-users of heavy-duty LNG vehicles, to help them conduct their implementation cost-effectively with minimal disruptions. This Resource Guide includes planning and handling issues that can occur before and during purchase decisions, after the point of sale of equipment or acceptance of funding, and after the vehicles are on the road. GTI published the Guide in 2002. The guide will help potential NGV users appropriately consider the use of LNG, anticipate important issues, successfully install the necessary infrastructure, and deploy LNG-fueled vehicles.

Regional Natural Gas Vehicle Fueling Infrastructure Standards. If natural gas vehicles are to become a significant factor in U.S. transportation, adequate fueling facilities must be available. However, investment in fueling facilities will not occur until there are many natural gas vehicles in service Therefore, a key tenet of the NGV Industry Strategy is the need for fueling infrastructure development, mainly focused on fleet customers during the initial phase and publicly accessible for use by various customers. GRI teamed with regional stakeholders in the Chicago metropolitan area to develop strategies and resources to expand the NGV fueling infrastructure and to demonstrate pathways for infrastructure development. A successful program, the NGV Regional Cooperative, was formed. Specific project tasks included fueling station optimization, manufacturing, testing, and installation; start-up and training; and coordination of service, maintenance, and emergency backup supplies. The Cooperative's members worked together to develop the two standardized state-of-the-art skid-mounted NGV fueling systems and install nine NGV fueling stations, using these systems, throughout the greater Chicago metropolitan area The use of standardized fueling systems enabled rapid installation and deployment of fueling infrastructure with minimal costs for site preparation and engineering and improved maintenance support. One of the two standardized systems can deliver the equivalent of 500 gallons per day and the other can deliver 70 gallons per day. Each system provides fast filling, achieving fill times of three to seven minutes. The systems have one fast-fill dispenser with a single hose and should provide sufficient fueling capability for several years of growth in the size of the NGV fleet Because the systems are modular, additional delivery capacity can be added to meet future growth. The systems are transportable and can be relocated easily, if necessary. GTI was the prime contractor for the City of Chicago and worked with Peoples Energy and NICOR to facilitate NGV station installation, start-up, and training. The nine NGV fueling stations went into service in 2002. Three of them are located in the City of Chicago, and six are strategically located in near or distant suburbs. The results are available in a GTI report, GTI-02/0178, "Development of a Regional Natural Gas Vehicle Infrastructure".

***Heavy-Duty Engine Efficiency Improvements (Deere 8.1L and Mack Truck E7G).** Engine efficiency is extremely important in natural gas vehicles because their range is limited by the difficulty of storing large amounts on natural gas on a vehicle The ranges of NGVs are typically much shorter than those of liquid-fuel-powered vehicles, and range is directly proportional to engine efficiency. GRI undertook RD&D to improve the efficiency of the John Deere PowerTech 8.1L engine and Mack Truck E7G engine, which are used in many medium-duty NGVs The main goal of the John Deere RD&D was to increase the efficiency of the natural gas engines, both at full and part load, to make it more competitive with diesel engines. In addition, the low emissions nature of the engine was to be maintained. John Deere improved the performance of its 250-horsepower 8.1 L engine. Knock reduction was achieved over the entire speed and load range of the engine using high-volume automotive components. Also, GRI undertook RD&D to improve the efficiency of the Mack Truck E7G engine while keeping NO_x emissions below 2 5 g/bhp-hr. Mack improved the efficiency and NO_x emissions of its 425-horsepower engine by air-assisting the turbocharger. Planned future changes for the Mack engine include delaying intake valve closing and the use of exhaust gas recirculation. The improved engines became commercially available in 2002. Improving the efficiency of NGV engines will reduce vehicle operating costs and increase range.

DISTRIBUTION

***Pipe Splitting Tool.** When a copper or polyethylene gas service line must be replaced, it is better to restore it by pulling new plastic pipe though it. This saves the cost of excavating, backfilling, and site restoration However, in some cases, the inside diameter of the plastic pipe insert would be too small to deliver enough gas. Therefore, GRI developed a tool for splitting old service lines to allow larger plastic pipe to be inserted. The tool can be used to replace copper or plastic service lines from 1/2 to 1-1/4 inches in diameter. Depending on the condition of the plastic or copper pipe, the tool head may split the old pipe as it travels through the line, pushing and expanding the existing pipe into the surrounding soil while simultaneously pulling in the new pipe. In other situations, even when the splitting head does not split a fitting such as a repair coupling, the tool will extrude the old line out in one piece while pulling in the new pipe. The new tool offers LDCs a way to replace gas service lines that are too small to be restored by inserting smaller plastic pipe through them Savings in distribution costs will accrue because fewer excavations and reduced worker time will now be needed to replace customer service lines. The new tool has passed its qualification testing, and TT Technologies, Inc. began marketing it in 2002 under the name Grundocrack Jr. and GrundoWing splitter system.

Gas Distribution Cost Database. U.S. gas distribution companies spend $5.5 billion per year to install new or replacement mains and services and another $2.8 billion to maintain and operate the distribution system. To help reduce this cost, GRI developed a detailed database of the components of these overall costs. The data are reported by company category, based on customer density (number of customers per mile of main) and the fraction of gas main under paving. These aspects are major factors in gas distribution costs. The first version of the database was so useful that GRI published Version 2, based on data from 28 LDCs, in 1998. The popularity of Version 2 led GRI to extend the database, using data from 40 LDCs, representing more than 60 percent of U.S. gas consumers. The data from the 40 companies was extrapolated to the entire gas distribution industry. The extended database was published in 2002, as Version 3. The database is used to guide GRI's RD&D by providing information on potential markets for new technology and calculating the benefits of that technology. The database can be used by LDCs to benchmark their construction, repair, replacement, renewal, leak identification and pinpointing, automation and communication protocols, and other operations and maintenance practices against those of other companies and national averages. This helps the LDCs decide where to focus their attention to improve corporate performance and reduce costs. The database also helps users understand what elements comprise a cost and how those elements affect overall cost of service The database describes the nature of the activities that characterize the cost element and the key cost variables for those activities. In addition, it provides information on charges for employee benefits, overhead, transportation and tools, and other applicable administrative factors The database contains statistical information, such as length of mains and numbers of services by pipe size and material, causes of leaks, number of excavations, and number of pressure regulators.

Effect of Bomb Blasts on Gas Distribution Equipment. The terrorist attacks in New York and Washington in 2001 and the 1997 bombing of the Murrah Building in Oklahoma City have increased the gas industry's interest in protecting its critical infrastructure. GRI considered approaches to preventing or mitigating the escape of natural gas in such instances. Burning gas could hinder rescue teams who respond to such emergencies and could cause additional damage. The approaches included infrastructure changes, hardware innovations, and revised standard operating procedures. Two tests were conducted in a full-scale building to evaluate bomb blast effects on the exterior and interior piping systems. This led to the development of potential remedies to mitigate the effects of terrorist bombings to exposed gas infrastructure. The tests revealed the vulnerabilities of natural gas piping systems outside and inside the building. The results of the GRI RD&D were published in 2002 and included specific recommendations. The RD&D developed general guidelines and many specific examples of incidents that gas companies should consider when upgrading their disaster prevention, training, communications, and response plans. A comprehensive evaluation approach was suggested, including three stages of response awareness, evaluation, and implementation. It was recommended that pre-incident planning should give special attention to the number of shut-off valves, quickly identifying the location of valves that will isolate damaged parts of a gas distribution network, and the need for shut-off valves well away from gas meter sets, which are especially vulnerable to damage from vehicle impact, external explosion, or other physical abuse. The RD&D also identified a number of examples of potential technology solutions, including: valves that would automatically shut down a feeder line when an excess flow condition occurs; distributed controls to allow local rerouting of the network to bypass problem areas without shutting off downstream customers; hardened or armor-protected exposed piping and meter sets; piping that would self-seal around a leak; sensors that would annunciate a leak; techniques for rapidly locating and tracing pipe; and remotely operated valves for emergency shut-off inside buildings.

Assessment of PVC Pipe. Most of the plastic piping used for gas distribution is polyethylene (PE). Polyvinyl chloride (PVC) piping, used by some companies, is less expensive and somewhat stronger, but uncertainty about predicting its service life has impeded its adoption. GRI has conducted extensive RD&D on PE pipe to characterize the tendency for cracks to grow slowly from small flaws, such as surface scratches, ultimately causing the pipe to fail in long-term service. That RD&D resulted in a short-term quality control test (ASTM Test Method F1473) that reflects the ability of polyethylene pipe and fittings to resist long-term crack growth and computer software (PE LIFESPAN FORECASTING™) that predicts the service life of PE piping systems However, similar RD&D had not been done for PVC piping. GRI undertook research to extend the methods that were developed for PE pipe to PVC pipe. In 2002, GRI developed software that prompts users for readily available system information such as pipe size, PVC resin type, hypothesized or actual flaw sizes, service temperature, and operating pressure The software uses the data to calculate pipe life expectancy and parametric studies can be conducted with one execution of the program. The software can also be used to specify the maximum values of different service parameters in order for new gas piping systems to achieve their intended design lives. The extensive on-line help facility and user's manual provide detailed information on how to specify input data and interpret the results, which are presented in graphical and tabular form. The enhanced ability to predict PVC pipe service life will give LDCs more confidence in using a less expensive alternative to PE piping, thus reducing gas distribution costs.

Effect of Utility Cuts on Pavement Quality. A 1998 theoretical study, based on finite element analysis (FEA) modeling of the effect of utility cuts in asphalt concrete pavement indicated that the walls of the cut moved inward about 0.003 inches, thus creating a stress on the paving material The study recommended that repair of the paving should involve removing pavement for several feet around the cut, then tamping both the backfill and the exposed crushed stone base before restoring the pavement. Because this recommended procedure would significantly increase the cost of restoring utility cuts, GRI and others commissioned research to characterize the issues more fully The GRI research was more complete than the original study. It not only included FEA modeling, but it also verified the accuracy of the model with controlled laboratory experiments. This validation demonstrated that FEA is able to make reasonably accurate predictions of the stiffness of both the original and repaired pavement The GRI research went beyond the original study by analyzing not only the open excavation, but also the restored backfill and pavement The research also thoroughly considered the effect of traffic loads on the restored pavement. Like the earlier study, the GRI research found that the excavation produces small horizontal displacement and plastic strains The GRI research further found that the restored pavement system stiffness, as measured by response to simulated traffic loading, is unaffected by the residual strains. It also found that the stiffness of the backfill material has only a small effect on the pavement stiffness. The research concluded that the restoration procedure recommended in the earlier study is not supported by the experimentally validated FEA modeling. When pavement is restored, without cutting it back, with materials whose properties are close to those of the original paving materials, the cut and restoration have a negligible impact on the structural performance of the pavement system. GRI published the reports of the research in 2002 and made them widely available.

Plastic Pipe Informational Web Site. The use of plastic piping by gas distribution companies has increased significantly, and there are frequent introductions of new plastic pipe materials and technologies. It has become difficult for the engineering and operations staff of LDCs to keep up with the changes. GRI developed a Web site to provide a central source of pertinent, up-to-date information on the safe and effective use of plastic piping systems. The Web site lists relevant publications of GRI and the Plastic Pipe Institute, as well as specifications and test methods of the American Society of Testing and Materials. It also lists U.S. Department of Transportation Pipeline Safety Regulations (Code of Federal Regulations Title 49, Part 192), "Federal Minimum Safety Standards· Transportation of Natural and Other Gases by Pipeline", which, by inclusion, references all applicable code requirements. Technical information available on the site includes. material properties and engineering and procurement considerations for plastic pipe; pipe installation techniques, joining, squeeze-off, and purging; mechanical and electrofusion fittings and valves; and new technologies, such as magnetic pipe, Polyamide 11 pipe, the self-loading trailer, and the scratch/ovality tester. The Web site consolidates information pertinent to engineering considerations, procurement, quality control, construction and maintenance practices, and new technologies.

Evaluation of the Performance of Carbon Monoxide Alarms. Residential carbon monoxide (CO) alarms began gaining popular acceptance in 1992. Between 1992 and 1998, about 20 million alarms were shipped and an estimated 8-15% of homes had at least one. Unfortunately, their growing popularity was accompanied by increased numbers of false or nuisance alarms. Most alarm manufacturers complied with Underwriters Laboratories' standard UL-2034, but research by GRI, the Consumer Products Safety Commission, and others showed that such compliance did not guarantee adequate performance of the alarms. A significant fraction of the alarms tested, falsely indicated dangerous CO concentrations when dangerous conditions did not actually exist UL-2034 was updated in October 1998 to improve upon this situation, although the standard did not call for the time-of-manufacture quality control testing and in-service testing that was recommended by GRI and the Consumer Products Safety Commission. Since then, GRI has performed further research to assess whether CO alarms certified according to the 1998 version of UL-2034 perform better than earlier alarms; whether alarms are especially prone to failure to alarm at low relative humidity; and the accuracy of the digital displays on alarms. GRI concluded that UL-2034 should specify more complete sensitivity testing, both at the time of manufacture and later, over a presumed three-year service life. GRI also recommends that, whenever possible, gas companies, appliance manufacturers, and other resellers of alarms require that alarms in their jurisdiction be certified according to the Canadian National Standard CSA 6.19-01 or International Approval Services Standard 6-9, which require such testing In 2002, GRI released a report detailing its findings and recommendations The report includes an algorithm that integrates the two factors that characterize CO hazards: concentration and exposure time. The report also includes guidelines for quality assurance sampling and testing of CO alarms to insure their reliability.

Worker Exposure to Hazardous Substances Database. Both the gas industry and regulatory agencies are increasingly interested in protecting workers from exposure to hazardous chemicals. However, there has been no ready source of information for gas companies to assess the possibilities for worker exposure, and there was no common format for companies to share information. GRI developed a Microsoft® Access database, based on information from 29 gas companies and from literature sources to provide well-organized, valuable information on employee health and safety operational exposure. The database contains information that will support good industrial hygiene practices in gas transmission and distribution companies. The database provides sorted information on exposure issues, work practices, and control technologies There are more than 600 exposure data points for asbestos and for lead, chromium, and cadmium-based paints. Most of the data indicate a high level of compliance with OSHA Permissible Exposure Limits. The database was designed for each gas company that contributed confidential data to have a private code for accessing its own company-confidential data. The database program allows users to create custom reports based on company category (transmission or distribution) or confidential company-specific codes, hazardous substance of interest, and the geographic region or state of interest. The database also provides telephone numbers and Web site links for all state and federal agencies that have jurisdiction over employee safety and health.

PIPELINE

Predicting the Integrity of Storage Caverns in Thin Salt Beds. The rising need for natural gas storage to accommodate winter peak demands has met with a scarcity of places to store large volumes of natural gas underground, near the point of use. Gas has been stored in depleted oil and gas formations and in porous aquifers by displacing the water with pressurized gas. However, there are not enough suitable formations in the northeastern U.S. to meet the heavy winter demand for gas in that region. Caverns in salt domes are used to store gas in these regions, and GRI RD&D helped determine the engineering characteristics of those formations. Stresses in the salt caused by the swings in pressure and temperature that occur when injecting and removing gas could damage the integrity of the cavern walls. Creating caverns in thin salt beds that are interleaved with other rock layers are an extremely interesting alternative. The engineering conditions to maintain their integrity are more complex than salt domes. GRI research developed techniques to predict and model stress behavior and rock slippage in a wide variety of basins that have thin salt beds. The research evaluated how such factors as the ratio of cavern height to diameter, the number and thickness of non-salt layers, and the thickness of salt and non-salt roof beam thickness affect cavern deformation and bedding-plane slippage. The report includes a detailed step-by-step process to assess design and operating conditions for caverns in bedded salt.

ASME Standard for Pipeline Integrity Management. U.S. gas pipeline operators have been working with regulators for the past nine years to develop a more systematic, standardized approach to managing pipeline safety and integrity. GRI and the gas pipeline industry undertook a number of performance- and reliability-based initiatives to address the technical concerns that must be resolved in order to create a standard on integrity management Intensive work by many technical experts led to twenty GRI reports that provided the foundation of technical information needed to complete the standard These reports are referenced in the standard. On January 31, 2002, ASME International (formerly, the American Society of Mechanical Engineers) issued a supplement to its B31 8 2001 standard, "ASME B31.8S 2001 Supplement to B31 8 on Managing System Integrity of Gas Pipelines," covering the management of gas pipeline system integrity. The Supplement provides a systematic, comprehensive, integrated approach to managing pipeline system safety and integrity. It applies to on-shore ferrous-metal gas pipelines, and it is specifically designed to give pipeline operators the information they need to develop and implement effective integrity management programs using proven industry practices and processes. The Supplement covers all parts of pipeline systems, including pipe, valves, appurtenances attached to pipe, compressor units, metering stations, regulator stations, delivery stations, holders, and fabricated assemblies. The Supplement is unusual for a B31.8 standard in that it is a process standard, describing the process an operator may use to develop an integrity management program. It provides two approaches for developing an integrity management program, a prescriptive approach and a performance-based approach. Many pipeline operators have begun to use performance-management principles to improve the safety of their systems. The use of comprehensive, systematic, integrated integrity management programs will improve the safety of pipeline systems

NACE Standard for Direct Assessment of Pipeline Corrosion. Natural gas pipeline operators and pipeline regulators are adopting performance-based management practices to improve pipeline safety and manage the cost of providing safe operation. Direct assessment, one approach to performance-based management, is a reliability-based method requiring that a wide variety of knowledge and experience be taken into account in interpreting direct inspection and sampling techniques. Direct assessment is a relatively new method that is especially important for assessing the condition of piping that cannot be reached by in-line inspection devices or taken out of service for hydrostatic testing. The essential element of direct assessment is the continuous improvement of the cathodic protection systems and evaluation of potential corrosion damage. NACE International (formerly the National Association of Corrosion Engineers) has taken responsibility for standardizing the direct assessment of external corrosion. NACE International Task Group 041 wrote Standard RP0502-2002, entitled "Pipeline External Corrosion Direct Assessment Methodology," and officially released it as a standard in 2002. ECDA, as described in this standard recommended practice, specifically addresses onshore buried ferrous-metal pipelines The standard guides pipeline operators in applying ECDA to typical pipeline systems. It is flexible enough for operators to tailor the process to their specific pipeline situations GRI provided technical leadership, technical data and analysis that accelerated this ANSI process and enabled the NACE International committee to develop a comprehensive standard in less than a year. The NACE standard will help pipeline companies apply direct assessment of external corrosion in the best possible ways, enhance public safety and reduce future costs and service interruptions resulting from unplanned incidents.

Revegetation of Rights-of-Way in Wetlands. Natural gas pipeline construction often crosses environmentally sensitive wetlands. Cut-and-trench construction clears vegetation in a 50- to 100-foot-wide corridor and excavates a trench up to 10 feet wide. In order to protect the wetlands, recent regulatory requirements have trended to be more prescriptive, and they may be inflexible and costly and still may not adequately protect some wetlands. GRI developed consistent ways to identify appropriate goals and techniques for restoring wetlands crossed by natural gas pipeline construction. The RD&D focused on identifying functional effects on wetlands that may result from cut-and-trench crossings and de-emphasized effects that do not occur at those crossings. The RD&D demonstrated that major wetland functions can be maintained after pipeline crossings and that the cut-and-trench method can be environmentally acceptable and cost-effective. The results show that many wetlands are resilient and recover quickly from the effects of cut-and-trench crossings These results may help applicants and regulators understand when cut-and-trench crossings are appropriate and help avoid mandatory requirements for more costly crossing alternatives. The evaluation process will help gas companies flexibly and cost-effectively meet wetland revegetation goals GRI's recommended approach incorporates aspects of the U.S. Army Corps of Engineers' hydrogeomorphic method and the U.S Bureau of Land Management's method for determining proper functional conditions. GRI verify the efficacy of the evaluation process and developed a database tool that can be used by gas companies when applying the decision process. The database tool is based on Microsoft® Access and can be used on personal computers, laptops, or pocket computers. The efficacy of the database tool was tested through field surveys at eleven cut-and-trench crossing sites. GRI published the results of this RD&D in two reports, GRI-00/0112, "An Approach for Determining and Meeting Wetland Revegetation Goals in Pipeline Construction Rights-of-Way" and GRI-02/0116, "Evaluation of Wetland Revegetation in Pipeline Rights-of-Way in Michigan and Field Verification of the GRI Wetland Evaluation Database."

Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effect in Wetlands. The three most prevalent pipeline construction techniques used for wetland crossings are trench-and-lay construction, trench-and-push construction, and horizontal directional drilling (HDD). Trench-and-lay construction has inherently high environmental impacts. Trench-and-push construction often has short-term, localized impacts to water quality, aquatic species habitat, and vegetation. It costs about twice as much as trench-and-lay construction. HDD costs more than trench-and-push construction for pipe diameters larger than 12 inches; and it costs, on average, two to three times as much as trench-and-lay construction for 12- to 36-inch pipes. HDD has emerged as the technology often preferred by regulatory agencies for pipeline construction that crosses wetlands because, theoretically, it is the least intrusive technique. HDD can install the pipeline below the surface without having heavy machinery enter the wetland However, in some cases, the bentonite mud that is used to lubricate drilling, transport spoils, and stabilize the hole can inadvertently travel up through fractures in the soil and into or above the saturated root zone of wetlands. If sizable volumes of inadvertent drilling mud returns are deposited in a wetland, they may impair water quality, aquatic species habitats, and the vegetative community, at least for the short-term. GRI research examined the effects of inadvertent mud returns at five wetland sites, and reaffirmed that, when drill mud returns are properly removed from the surface, the pre-existing vegetation rebounds fully within one to two growing seasons. Invasive pioneer species had not displaced pre-existing vegetation at any of the sites as a result of the HDD returns. The areas that had been disturbed by cleanup machinery showed no discernable, long-term impacts, although the speed at which one site rebounded was slowed by overly aggressive cleanup operations. The results were published in GRI-99/0236, "Evaluating the Effects of Muds on Wetlands from Horizontal Drilling: Field Investigations Topical Report," GRI-01/0233, "Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling: The Relationship of Subsurface and Geophysical Conditions to Inadvertent Returns," and GRI-02/0145, "Evaluating the Effects of Muds on Wetlands From Horizontal Directional Drilling: Phase II Field Investigations". In addition, GRI developed an HDD best management practices manual for use as a comprehensive decision-making tool that covers many facets of HDD planning, engineering, construction, and environmental protection and mitigation, including management of drilling mud and contingency planning. The manual covers construction, engineering, and environmental best practices The manual provides technical guidance on predicting and managing mud releases during HDD operations. The manual will help pipeline companies use the most effective techniques for construction that crosses wetlands.

Best Environmental Practices for Pipeline Construction. The U.S. Environmental Protection Agency has noted that water runoff associated with construction activities can have serious water quality impacts, such as pollution of waterways and drinking supplies. Erosion and sediment transport can disturb fish and wildlife habitats, clog streams and storm drains, and cause silting of reservoirs and other bodies of water If gas pipeline construction does not follow acceptable practices, companies are subject to fines, litigation, and poor public relations. GRI developed a manual of best management practices to serve as a reference document and field guide. The manual will help users establish site-specific best management practices (BMPs) for erosion and sediment control during natural gas pipeline construction projects. It supplements the erosion control baseline BMPs outlined in Federal Energy Regulatory Commission guidance documents. The alternative BMPs presented in the Manual represent current, up-to-date technologies that, if implemented correctly and appropriately, should provide equal or better protection than the baseline BMPs presented in FERC's Upland Erosion Control, Revegetation, and Maintenance Plan and Wetland and Waterbody Construction and Mitigations Procedures. The alternative BMPs provide the pipeline industry a wider range of protection measure alternatives that can be considered for implementation, but these BMPs do not replace the baseline BMPs presented in FERC's Plan and Procedures documents. The Manual also presents controls that represent new technologies or are appropriate for specific sites or projects. The Manual will help pipeline companies identify BMPs appropriate for use on a specific site or project to control erosion and meet regulatory requirements at minimum cost

Integrated Vegetation Management. Vegetation management on natural gas pipeline rights-of-way (ROWs) is required by both regulations and operational necessity. ROW plants are most commonly maintained as grass communities or as regularly mowed woody plant communities. Vegetation is usually managed by mechanical means, such as mowing, use of chainsaws, and other physical means of cutting. The technique of integrated vegetation management (IVM) could be more effective and less costly. IVM integrates the use of physical, chemical, horticultural, and biological treatments to ecologically control vegetation in ways that are compatible with the environment, economically feasible, and socially acceptable. GRI investigated the opportunities and benefits of IVM for gas pipelines. The technical literature showed that IVM could be applied to pipeline ROWS. A survey of gas companies indicated that 80% of their ROW management uses mechanical methods, and the companies, for the most part, have given little consideration to using IVM. The research, summarized in a report published by GRI, found that IVM is not addressed under current ROW agreements. Easement contract language and ways to use ROWs to enhance wildlife habitats require additional attention. IVM controls vegetation by identifying the plant communities that require attention and using a combination of control options, including mechanical cutting, tillage practices, and biological and chemical herbicide controls. IVM techniques offer pipeline companies the opportunity to reduce the cost of caring for their ROWs at a fundamental and continuing level. In addition to cost savings, IVM techniques can diversify ecological conditions for plant and animal communities in the ROWs and, thereby, help meet the needs of landowners and local interest groups and facilitate good relationships with fish and wildlife and environmental agencies.

EXPLORATION AND PRODUCTION

Enhanced Seismic Spectral Processor. Seismic signals are usually processed using traditional Fourier analysis. However, when signal frequency changes with time, Fourier transforms can give misleading results because they only provide time-averaged information. More accurate seismic analysis of potential gas reservoirs means that fewer unproductive wells will be drilled, and the average cost of finding and producing natural gas will decrease. GRI research developed a signal analysis method, called enhanced spectral processing (ESP), which uses wavelet transforms to extract time-dependent information, thereby allowing very high-resolution analysis. The research demonstrated the high resolution of the technique through synthetic modeling and case studies based on actual seismic data. The results for several gas reservoirs showed the ability of this method to identify hydrocarbon-bearing formations. In 2002, Fusion Geophysical began using the technique commercially, under the name INSPECT, to provide services to E&P companies

Evaluating Ecological Impacts at E&P Sites. The use of screening criteria for ecological risk-management decisions for hazardous waste sites is gaining momentum and is helping to focus attention on sites that may truly benefit from the ecological risk assessment (ERA) process. U.S. EPA risk managers recognize that, although the ERA process is a valuable tool, it is not necessarily needed for every ecological risk decision Resources spent on ERAs that do not provide meaningful information for risk management decisions are wasted. GRI developed screening criteria applicable to natural gas E&P sites, based on precedents for the use of screening criteria in regulatory programs throughout the United States and Canada. The American Society of Testing and Materials (ASTM) Risk-Based Corrective Action (RBCA) Standard Guide for the Protection of Ecological Resources (known as Eco-RBCA) (in process) has highlighted the issue that every site does not need an ERA, and has led EPA to acknowledge that industry and government must consider how to differentiate between sites that need ERAs and those that do not. The GRI RD&D supported the GRI/American Petroleum Institute Upstream RBCA and the Petroleum Environmental Research Forum 99-01 projects. The RD&D identified a variety of categories and specific screening criteria that may be useful for ecological risk-management decisions. The RD&D considered the release of natural gas, natural gas liquids, drilling fluids, and produced water. Useful screening criteria for E&P sites should be based on environmental performance, proximity of release to relevant ecological receptors, and the significance of the ecological exposures The GRI report, "Evaluating Potential Ecological Impacts at Exploration & Production Sites. A Compilation of Screening Criteria", is the first published, coordinated effort to compile screening criteria that could be used to evaluate potential ecological impacts to E&P sites.

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* Enhancement to a previous product

Appendix B
GRI RD&D Results That Have Been Placed in Commercial Use in 1998 Through 2002

RESIDENTIAL

1. Combo Systems Sizing and Installation Guidelines – 1992/2000
2. Flammable Vapors – 1998
3. NAECA Water Heater Assessment - 2000
4. Indoor Emissions from Cooking – 2001
5. Summary Report of GRI's Venting Research - 2002
6. Gas Venting Safety Assessment - 2002
7. Accurate Assessment of Heat Pump Efficiency - 2002

COMMERCIAL

8. GATC Quick Response Activities – 1995/1999
   (Life-Cycle Cost Model for Food Service Technologies)*
9. BinMaker™ Pro The Weather Summary Tool – 1997/2000
10. TecoFROST™ Gas Engine Driven Refrigeration - 1997/98
11. Alturdyne Hybrid Electric/Gas Engine Chiller - 1998
12. kitchenCOST™ Software- 1998/99
13. DesiCalc™ Software - 1998
14. Low-NO_x Power Burner - 1998
15. ASHRAE Standard 155P for Boilers - 1998
16. Modulating Indirect-Fired Make-Up Air Unit - 1999
17. GATC AERCO Benchmark Boiler - 1999
18. Engine Rooftop Heat Pump (Goettl 15-20 ton) - 1999
19. PITCO Gas Fryers - 1999
20. AUTOFRY™ Deep Fat Fryer - 1999
21. Analysis of Commercial Sizing and Installation Guidelines - 2000
22. Gas Cooling Guide – Pro Version - 2000
23. York 600 RT 134a Chiller - 2000
24. Tecogen 150 RT 134a Chiller - 2000
25. Trane Single Effect Horizon Chiller - 2000
26. Chiller Application Briefs - 2000
27. Restaurant Kiosk Ventilation and High-Performance Gas Countertop – 2000
28. Comparison of Radiant and Convective Unit Heaters - 2002
29. Gas-Fired Commercial Steam Cooker - 2002

INDUSTRIAL

30. Process Application of Composite Radiant Tubes (and Case Studies) and Advanced U-Shaped Radiant Tubes - 1994/99/2002
31. Industrial Boiler Gas Cofiring (including Biomass) - 1995/99
32. High Performance Infrared Burners (and Application Tools) – 1995/99
33. RAPIDFIRE™ Products - 1998
34. METHANE de-NOX® Controls for Stoker Boilers - 1999

35. Ultra-Low-NO_x Burner for Boiler Retrofit - 1999
36. Forced Convection Heater (FCH) Systems – Automotive – 2000
37. Oscillating Combustion Burner - 2001
38. Radiant Heater Characterization Facility - 2001
39. Low-NO_x Retrofit Burners for Fire-Tube Boilers - 2002
40 Low-Cost Multi-Gas Continuous Emissions Monitor - 2002

POWER GENERATION

41. DGen Pro™ Software – 1998/99/2000
42. SOAPP™ Modules – 1998/99
43 Fuel-Lean Gas Reburn (including Amine-Enhanced FLGR) - 1998
44 Microturbines (Capstone and Honeywell) - 1999
45. Distributed Generation Guidebook for Municipal Utilities - 1999
46. IR PowerWorks Microturbine Cogeneration Systems – 2000
47. Advanced High-Output Gas Engine-Generator (Caterpillar 3500® Series) - 2001

TRANSPORTATION

48. Ford Crown Victoria Natural Gas Vehicle - 1995/98
49. Cummins C8.3G Engine – 1996/2001
50. John Deere 8.1L Engine – 1996/99/2002
51. Caterpillar Dual-Fuel Truck Engine - 1996/98
52. MACK E7G Refuse Hauler – 1996/2002
53. John Deere 6.8L – 1998/99
54. CNG Cylinder Maintenance Handbook - 1998
55. Risk Management Program for Liquid Natural Gas Vehicle Refueling Stations - 1998
56. NGV Cylinders (Types 1 and 2) - 1999
57. Glass-Fiber-Wrapped Fuel Tanks for NGVs - 2000
58. Advanced NGV Fueling Dispenser
59. Best Practices for Medium-and Heavy-Duty NGV Fuel System Design - 2002
60. Clean Cities Initiative to Evaluate NGV Technology - 2002
61. Resource Guide for Heavy-Duty LNG Vehicles - 2002
62. Regional Natural Gas Vehicle Fueling Infrastructure Standards - 2002

DISTRIBUTION

63. Design Methods to Prevent Rapid Crack Propagation in Polyethylene Pipe - 1984/98
64. Field Failure Catalog for Polyethylene (PE) Pipe - 1987/98
65. PE LIFESPAN FORECASTING™ – 1994/2001
66. Plastic Pipe Across Bridges – 1995/99
67. DrillPath™ Guided Boring Software – 1996/99
68 Utility Communications Architecture (UCA™) Protocol for Gas Distribution Systems - 1998
69. Optical Methane Detector (OMD) - 1998
70. Distribution Internal Inspection System - Magnetic Flux Leakage (MFL) - 1998
71. Pipe Hawk™ (Buried Pipe Locator) - 1998
72. Predictive Control District Regulators - 1998

73. Pipe Splitting Tool - 1998/02
74. Main/Services Tester - 1998
75. TUBIS™ Software for Repair/Replace Decisions - 1999
76 Pipe Ovality and Scratch Depth Measurement Device and Guidelines - 1999
77. Plastic Pipe Repair Techniques - 1999
78. Starline® 2000 Renewal Technology - 1999
79. Guided Mole - 1999
80. Gas Holder Manual of Practice - 1999
81. Precision Pipe Locator - 2000
82 One-Step Paving - 2000
83. Bare Steel Maintenance Optimization System (BASMOS) Software - 2000
84. Soil Compaction Supervisor - 2000
85. Self-Loading, High-Efficiency Trailer for Coiled PE Pipe - 2001
86. Cold-Mix Restoration of Pavement Cuts - 2001
87. Imaging Underground Utility Structures - 2001
88. Comparative Evaluation of PE Pipe Materials - 2001
89. Directional Drilling for Plastic Pipe under Railroad Crossings - 2001
90. Gas Distribution Cost Database - 2002
91. Effect of Bomb Blasts on Gas Distribution Equipment- 2002
92. Assessment of PVC Pipe - 2002
93 Effect of Utility Cuts on Pavement Quality - 2002
94. Plastic Pipe Informational Web Site - 2002
95. Evaluation of the Performance of Carbon Monoxide Alarms - 2002
96. Worker Exposure to Hazardous Substances - 2002

PIPELINE

97. Meter Research Facility - 1991/98
98. Clock Spring® Composite Pipeline Repair Material – 1995/99
99. Risk Assessment/Risk Management Guidelines – 1996/99
100.Orifice Meter Information - 1990/92/97/98
101 NO_x Portable Analyzer Operator Guidelines - 1998
102 Oxidation Catalyst Costs for Aldehyde Control - 1998
103.Magnetostrictive Sensor - 1998
104.TurboCharger Testing Facility - 1998
105.Breeze Haz™ Environment and Safety Offsite Consequence Modeling Software - 1999
106.Emeritus Report B31.8 Code, Federal Pipeline Safety Regulations - 2000
107.Elastic Wave Vehicle Tool - 2000
108.Advanced Leak Detection and Repair at Gas Processing Plants – Hi-Flow™ Sampler - 2000
109.API 14.1 Gas Sampling Standard - 2001
110.Ultrasonic Meter Installation Effects -2001
111.Orifice Meter Operational Effects - 2001
112.Orifice Plate Installation Effects - 2001
113.Gas Storage Well Rehabilitation and Damage Prevention - DamageExpert™ Software -2001
114.Satellite Radar Interferometry Measurement of Slope Movement - 2001
115.AIRCalc™ Software – 2001
116.Predicting the Integrity of Storage Caverns in Thin Salt Beds - 2002
117.ASME Standard for Pipeline Integrity Management - 2002
118.NACE Standard for Direct Assessment of Pipeline Corrosion - 2002

119.Revegetation of Rights-of-Way in Wetlands - 2002
120.Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effects in Wetlands - 2002
121 Best Environmental Practices for Pipeline Construction - 2002
122.Integrated Vegetation Management - 2002

EXPLORATION AND PRODUCTION

123.Advanced Process Control for Gas Processing/Industrial Applications (Multi-Variable Control (MVC®)) - 1991/98
124.Glycol Dehydrator Emissions Calculation Program – GLYCalc - 1992/2000
125 Gas Composition Database – 1996/2001
126 Calcite Scale Handbook - 1998
127.ASTM Standards - 1998
128.Drill String Safety Valves (DSSVs) - 1998
129.Mesa-GRIP Seismic Survey Design Software - 1998
130 Crosswell Seismic Imaging - 1998
Fracturing Information and Diagnostics - 1998
131.M-Site Advanced Diagnostics Insights - 1998
132.Hydraulic Fracture Mapping System - 1998
133.Downhole Tiltmeters - 1998
134 Fracturing Fluid Characterization Facility (FFCF) Insights - 1998
135.GRI Sulfur Recovery Workshop Proceedings – 1998
136.Unconventional Natural Gas Database – 1999/2001
137.Nitrogen Removal Requirements Report - 1999
138.Downhole Gas/Water Separation CD-ROM - 1999
139.Advanced Crosswell Seismic Source - 1999
140.High Power VSP Mechanical Seismic Source - 1999
141.Advanced Stimulation Technologies CD-ROM - 1999
142.Coiled Tubing Standards - 1999
143.GRI–MSTR™ Software and Report to Predict Toxicity of Produced Water Discharged to the Marine Environment – 1999
144.ProTreat™ Software for Amine Gas Treating Applications - 2000
145.Cased Hole Resistivity Tool - 2000
146.Cased Hole Pressure Tool - 2000
147.Well Siting in Carbonates – EGI Report - 2000
148 Portfolio of Emerging Natural Gas Resources – Rocky Mountain Basins - 2000
149.Mercury Contamination Training Workshop – 2000
150.New Gas Exploration Concepts - 2001
151.StreamAnalyzer™ Software - 2001
152.Enhanced Seismic Spectral Processor - 2002
153.Evaluating Ecological Impacts at E&P Sites - 2002

** This product is no longer available for sale or it has been superseded by a new model incorporating the GRI technology

EXHIBIT 2

TO QUALIFICATIONS AND

DIRECT TESTIMONY

OF RONALD B. EDELSTEIN

Summary of Chattanooga Gas Projects

Project Number	Program Area	Project	Project Benefits	2005 Funding ($000)
1.0	Operations Technology Development (OTD)			
1 1		Miniature Methane/Ethane Detector for Leak Surveys	More accurate leak surveys, reduced gas leakage, increased safety, reduced O&M costs	$20
1 2		Hand-Held Acoustic System for Plastic Pipe Location	More accurate PE pipe location (for existing PE), reduced O&M costs	$20
1 3		Remote Laser Leak Surveys	More accurate, faster leak surveys, increased safety, reduced O&M costs	$20
1 4		Integration of Electromagnetic and Acoustic Obstacle Detection Systems for Utility Construction operations	Reduced damage from horizontal directional drilling tools, increased safety, reduced O&M costs	$5
1 5		Product Development of an Obstacle Detection System Using Ground Penetrating Radar	Alternative technical pathway to Project # 1 5, Reduced damage from horizontal directional drilling tools, increased safety, reduced O&M costs	$25
1 6		Inspection Platforms for Unpiggable Lines	Enhanced detection of metallic gas main deterioration, increased system integrity, increased safety, lower O&M costs	$20
1 7		Safe, Reliable Operation of Aldyl A Plastic Gas Pipe Systems	Reduced probability of plastic pipe failure, increased safety, reduced O&M costs	$10
1 8		Alternative Methods for Pavement Cutting	Reduced O&M costs, reduced environmental impact	$10
1 9		Micro-Excavation System Applications	Reduced O&M costs	$15
2 0		Service-Applied Main Stopper	Stops flow of blowing gas, increased safety	$20
1 0	**OTD Subtotal**			**$165**
2 0	Utilization Technology Development (UTD)			
2 1		Combination Space/Water Heater Field Test	Lower first costs, increased efficiency, reduced energy use	$125
2 2		Residential/Commercial Codes & Standards Project	Development of the technical basis for increased venting and indoor air quality and efficiency standards, increased safety, enhanced indoor air quality, increased cost-effective efficiency standards	$25
2 3		Advanced Gas Water Heater Assessment	Increased efficiency, reduced risk of flammable vapors, reduced emissions, resulting in enhanced safety, reduced gas use, and enhanced environmental quality	$25
2 4		Combination Gas Engine Heat Pump/Generator for Combined Heat and Power (CHP)	Increased efficiency, reduced gas and electricity loads	$25
2 5		Superboiler for Commercial/Industrial Applications	Increased efficiency, reduced Nox emissions, reduced gas load	$25
2 0 UTD Subtotals				**$225**
Totals				**$390**

	Customers	Funding Unit ($/Mcf)	Load (Bcf/yr)
	60,000	$0 0174	20

Avg gas use (Mcf)	62 0		
Total Dollars Available		$348,000	Based on gas use

CERTIFICATE OF SERVICE

I hereby certify that a true and exact copy of the foregoing has been served on the following person(s), via the method(s) indicated, on this the 16 day of April, 2004:

[✓] Hand [ ] Mail [ ] Facsimile	D. Billye Sanders, Esq. Waller Lansden Dortch & Davis PLLC 511 Union Street, Suite 2100 P.O. Box 198966 Nashville, Tennessee 37219-1760
[ ] Hand [✓] Mail [ ] Facsimile	David C. Higney, Esq. Grant, Konvalinka & Harrison PC Republic Centre, 633 Chestnut Street, Suite 900 Chattanooga, TN 37450-0001
[✓] Hand [ ] Mail [ ] Facsimile	Paul G. Summers, Esq. Vance L. Broemel, Esq. Consumer Advocate and Protection Office of the Tennessee Attorney General P.O. Box 20207 Nashville, TN 37202

R. Summers

VERIFICATION

STATE OF ILLINOIS)
)
COUNTY OF COOK)

Ronald B. Edelstein, being duly sworn and upon his oath deposes and states that he is Director, State Regulatory Programs for Gas Technology Institute; that he has read and is familiar with the foregoing Direct Testimony filed herewith; and that the statements made therein are true to the best of his knowledge, information and belief.

OFFICIAL SEAL
DOLORES CLARK
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:08/01/04

Ronald B. Edelstein

Ronald B. Edelstein

Subscribed and sworn to before me
this 12TH day of APRIL, 2004.

Dolores Clark
Notary Public

My Commission Expires:

8-01-04