Exhibit No.:	
Issue:	Gas Technology Institute
Witness:	Ronald Edelstein
Type of Exhibit:	Direct Testimony
Sponsoring Party:	Atmos Energy Corporation
Case No.:	GR-2006-____
Date Testimony Prepared:	April 4, 2006

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. GR-2006-____

DIRECT TESTIMONY

OF

RONALD EDELSTEIN

ON BEHALF OF

ATMOS ENERGY CORPORATION

April 2006

BEFORE THE
MISSOURI PUBLIC SERVICE COMMISSION

In the matter of Atmos Energy Corporation)
of Dallas, Texas, for authority to file tariffs)
reflecting an increase in rates for gas service)
provided to customers in the Missouri service)
area of the Company)

AFFIDAVIT

STATE OF ILLINOIS)
) ss
COUNTY OF COOKE)

RONALD B. EDELSTEIN, first being duly sworn, deposes and says that he is Ronald B. Edelstein referred to in the document entitled "Prepared Testimony of Ronald B. Edelstein on Behalf of Atmos Energy Corporation" before the Public Service Commission of the State of Missouri, and that the statements therein were prepared by him or under his direction and are true and correct to the best of his information, knowledge and belief.

Ronald B. Edelstein
Director, State Regulatory Programs
Gas Technology Institute

Subscribed and sworn to before me, this 4th day of April, 2006.

Notary Public

My commission expires 5-2-06

OFFICIAL SEAL
FREDERICK R. ROBKA
Notary Public - State Of Illinois
My Commission Expires 5/2/06

BEFORE THE

MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. __________

PREPARED DIRECT TESTIMONY

OF

RONALD EDELSTEIN

On Behalf of

ATMOS ENERGY CORPORATION

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 working on solar thermal systems for 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 1982 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 Georgia, Virginia, Kansas, Massachusetts, Tennessee, and Michigan.

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 Missouri natural gas consumers receive from GTI and its gas consumer benefits research and development ("R&D") program, and to request that the Missouri Public Service Commission ("Commission") give Atmos Energy Corporation ("Atmos Energy") the authority to fund natural 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 accrue almost entirely to gas consumers. These benefits include lower energy use (through increased-efficiency appliances), increased safety, increased system integrity, enhanced deliverability, and reduced energy costs (through lowering of gas local distribution company operating & maintenance – O&M -- 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 1,600 Bcf /year by 2003. 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 enabled 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 50% of our budget in the 1980's and 1990's, and is now about 25% of our budget. For the residential and small commercial sectors, the focus is on increased efficiency and safety, in particular dealing with developing affordable, high-efficiency equipment for low-income ratepayers. Applications include traditional gas uses such as residential and commercial space heating, water heating, and cooking. For the industrial sector, the focus is on increased efficiency, lower NOx and CO emissions, and increased productivity. Applications include the traditional gas uses such as boiler steam generation and process heating.

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 in the 1980's, 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 the most efficient furnaces on the market.

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

A. Yes, GTI is working on four projects that could directly benefit the low-income gas customer in Missouri. 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 furnace in smaller homes and apartments. This project has 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 "superboiler" that can meet the needs of apartment and multifamily dwelling units that rely on a gas boiler in the basement of the building. The superboiler offers efficiencies of up to 94% and NOx levels less than 5 ppm. It has been tested only for industrial applications, and requires funding for multifamily residential applications testing. Typical conventional boiler efficiencies run from 80-88%, even for new boilers, and under 60 percent for older boilers. The third low-income ratepayer project is a tankless water heater system that provides low-cost hot water for homes and apartments. Typical tank-based water heaters have efficiencies of 50-55 percent. The tankless water heater efficiency is 80 percent. Challenges here are to reduce first cost, remove supplemental electrical power from shower conditions and minimize the formation of sediments over time. The fourth low-income ratepayer project is the optimization of the energy delivery and temperature control systems, so as to minimize energy distribution system losses, provide maximum comfort in occupied rooms, and minimize energy use in unoccupied rooms. None of these projects will be funded without additional funding becoming available from public service commission approvals of an R&D surcharge.

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, for instance, 78 percent efficiency minimums for furnaces. 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. And manufacturers would rather develop high-end, higher-profit equipment than lower-cost equipment for low-income ratepayers.

Q. How does GTI contribute to safety?

A. Sometimes, 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 non-condensing furnaces sold before 1981. GRI designed improved heat exchangers and by 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. GTI also developed in 2003 upgrades to the National Fuel Gas Code for combustion air supply and corrugated gas vent connectors for gas appliances.

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 together 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.

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 and gas mains. 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. Recent Office of Pipeline Safety rulings have moved pipeline integrity requirements "downstream" to the gas LDCs, especially LDCs with higher-pressure distribution systems in high-consequence area. The development and validation of direct assessment techniques and protocols for internal corrosion, external corrosion, and stress corrosion cracking are absolutely critical to being able to use direct assessment methodologies for "unpiggable" sections of distribution lines. With about 1,300 miles of bare steel mains in Missouri, this is an important state issue.

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. With over 9,000 miles of plastic gas mains in Missouri, the issue is particularly pertinent here.

Preliminary indications on distribution system integrity indicate that different risk reduction remedies will be required than on pipeline integrity issues. The primary failure mode is due to third party damage in distribution systems, plastic pipe is not subject to corrosion like steel pipe, and cast iron pipe (almost 1,400 miles in Missouri) has special issues like joint leakage that need to be dealt with.

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 before boring though them is 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 ameliorate. 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. Forensics research is just now on the forefront of being able to provide "CSI" type answers to such issues as which plants or factories actually produced the tars and other wastes now being located.

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 93% efficient, a residential gas heat pump with a heating COP of 1.4, and an industrial super-boiler with efficiencies up to 94% currently being funded by DOE as a laboratory sub-scale pilot project, the derivative of which is being proposed for multifamily low-income applications).

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

A. There are at least fourteen R&D projects GTI is planning that support Atmos Energy's natural gas customers. Ten of these projects are in the operations area and four in the end-use area. The objectives of the operations projects are to increase safety and reduce operating and maintenance costs. The objectives of the end-use projects are to increase the efficiency and enhance the safety of gas use equipment.

Q. What are the Operations Projects Atmos Energy 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.

(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.

(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.

(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.

(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 new plastic pipe materials perform very well, some of the early materials could be problematic under certain applications.

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 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.

Q What are the end use projects being proposed?

A. These projects are: (11) Codes and Standards Program: The gas industry recognizes the importance of ensuring that gas technologies comply with appropriate codes and standards. Maintaining the option for cost-effective gas technologies is a critical, but often unseen, element of the broader product R&D process. Working closely with the gas industry and research partners, this program will develop and present in-depth technical information needed by codes and standards organizations and regulatory bodies. Further, this program will proactively investigate systemic issues, like mid-efficiency furnace venting, that arise unanticipated from the use of advanced gas technology to ensure that gas continues to remain the safe, reliable, and environmentally benign energy option.

(12) Reduced-Cost Residential Desiccant Unit Development: GTI initiated a residential desiccant dehumidifier project with the intention of characterizing and field testing a reduced-cost unit. Preliminary design has been completed to accommodate the burner system as developed by the manufacturer and to better integrate and simplify the concept to create a cost-effective unit for the general residential home market, including Missouri. The proposed program would have two phases. The first phase 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/American Refrigeration Institute) characterization of the unit, and ANSI (American National Standards Institute) certification testing. The second phase of this program would be a field testing phase that would validate the various model configurations in field applications.

(13) Unitary Natural Gas Engine-Driven Combination Heat Pump and Standby Generator: The objective of this project is to develop a low-emission natural gas engine-driven generator set that provides high-efficiency heating and cooling for the residential customer and supplies electricity to meet standby electrical loads. The space conditioning system could thus continue to operate even during periods of electrical power outages or brownouts. Both laboratory development to verify proof-of-concept and field testing to validate (efficiency, emissions, durability) performance under actual field conditions are required.

(14) Superboiler Development: The objective of this project is to field test the Superboiler which has up to 94% energy efficiency, NOx and CO emissions less than 5 ppm, and reduced footprint and weight specifications. This technology has direct applications not only to the industrial

market but as the forerunner of low-income ratepayer residential multifamily dwelling boiler applications

Q How will the projects be chosen?

Atmos Energy will provide the authorization as to where their research-funding dollars are applied from the list of candidate projects. In future years, the selected projects will be funded to their conclusion.

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. Atmos Energy customers have supported GTI R&D through upstream suppliers prices which were in turn charged under Atmos Energy's retail cost of gas. The FERC has discontinued that charge in mid-2004 and has transferred the funding authority to the state jurisdiction. Thus, GTI no longer collects FERC-approved funds, but relies instead on state-based approval of R&D surcharges for gas-consumer-interest R&D

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 is recommending that revenues equivalent to 1.74 cents per MMBtu be collected from Atmos Energy's natural gas customers in its Missouri service area. The 1.74 cents 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. Atmos Energy would thus choose from amongst the list of projects just described. As these are multiyear projects and new projects will be proposed in following years, this amount of funding would be required each year.

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

A. There are 21 states currently authorizing research funding for gas-consumer-interest R&D for at one or more of the LDCs in their state. These are Alabama, Arizona, Delaware, Florida, Idaho, Illinois, Kentucky, Mississippi, Minnesota, New York, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Virginia, Washington, and Wyoming.

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

A. Not necessarily. Atmos Energy 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 gas-consumer-interest R&D purposes.

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 (see Schedule RE-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 Missouri 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 Missouri 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 Missouri and for the United States.

Q. Does this conclude your prefiled testimony?

A. Yes it does.

GRI-04/0061

Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1999 Through 2003

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Abstract

This report provides brief descriptions for sixteen new GRI RD&D products commercialized in 2003 and two enhancements of previously introduced products. The economic benefits are quantified for eighty-one items commercialized between 1999 and 2003 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 1999 through the end of 2003 was 8.0 to 1.

Acknowledgments

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Introduction

Between January 1, 2003 and December 31, 2003, sixteen GRI RD&D results were placed in commercial service. In addition, enhanced versions of two previously commercialized items were placed in use*. Those items are listed in Table 1, and brief descriptions of the eighteen items are included in Appendix A. With these new additions, some 133 GRI RD&D results have entered the commercial marketplace during the 5-year period between January 1999 and December 2003. The full list of the 133 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 81 out of the 133 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 2003 include:

- Upgrades to the National Fuel Gas Code relating to the requirements for combustion air supply and corrugated gas vent connectors.
- A software tool to estimate critical information such as annual or monthly loads and costs associated with air-conditioning, heating, and on-site power generation for commercial buildings.
- A low-NO_x, high-heat-transfer industrial burner that provides significantly higher heat transfer to furnace loads, higher furnace efficiency, and lower flame and combustion products temperature.
- Paralleling switchgear for distributed generation systems that reduces the barriers to installing gas-fired DG equipment.
- A report on the safety of vacuum excavation equipment used to remove soil from holes that are being dug by distribution companies.
- Evaluation of alternate methods for removing cyanide wastes from former manufactured gas plant sites.
- A chemical fingerprinting methodology for enhanced environmental forensic analysis to characterize complex manufactured gas plant wastes.
- A software package to evaluate potential adverse environmental effects of pipeline crossings of streams.
- Technology to improve the quality of the cement used to seal the annulus between the casing and surrounding rock in gas wells.
- Development of produced water atlases for 10 major gas-producing states and a handbook on actual produced water management practices and disposal economics for 26 basins.
- A comprehensive report on the gas potential of the Lewis shale formation of the San Juan Basin in Colorado and New Mexico.

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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 2003

RESIDENTIAL

1. Upgrades to the National Fuel Gas Code

COMMERCIAL

2. Building Energy Analyzer ™

INDUSTRIAL

3. Low-NO_x Combustion System for Glass Furnaces *
4. Low-NO_x, High-Heat-Transfer Burner
5. LNG Interchangeability in Burners

POWER GENERATION

6. Distributed Generation Switchgear
7. Guidebook to Gas-Fired Distributed Energy Technologies

DISTRIBUTION

8. Safety of Vacuum Excavation Operations
9. Gas Distribution Construction Guide
10. Removing Cyanide Wastes from MGP Sites
11. Chemical Fingerprinting for Enhanced Environmental Forensic Analysis

PIPELINE

12. Gas Leak Measurement Device (Hi-Flow® Sampler) *
13. Environmental Effects of Pipeline Crossings of Streams
14. Standard for Coriolis Meters

EXPLORATION AND PRODUCTION

15. Cement Pulsation Technology
16. Analysis for Radium in Marine Sediments
17. Produced Water Atlases and Handbook
18. Gas Resource and Production Potential of the Lewis Shales

* Enhancement to a previous product.

Benefits Results

Between January 1999 and December 2003, one hundred and thirty-three GRI RD&D results were placed in commercial service. The full list of the 133 items placed in commercial use is included in Appendix B. This report focuses on evaluating the benefits of 81 of the 133 GRI RD&D items that are known to have produced significant *quantifiable economic* benefits for their users. The 81 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 2008. 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 81 items are estimated to be between $3.4 and $5.9 billion. Table 3 shows the expected value of benefits, at about $4.9 billion, and the breakdown of the economic benefits by sector. We estimate that the 81 items account for most of the economic benefits that would be calculated for the entire set of 133 products. Omitted items often offer significant benefits to their users, but have not achieved widespread use as have the 81 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 gas resources and delivering the gas to consumers.

[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.

Table 2. Summary of Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1999 Through 2003

	Sales or Applications Projected Through 2008 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2003$)		
RESIDENTIAL							
Upgrades to the National Gas Fuel Code		***		2003	$62.5	to	$109.3
COMMERCIAL							
kitchenCOST™ Software	545	to	1,000	1998/99	$37.3	to	$68.5
Modulating Indirect-Fired Make-Up Air Unit with Clean Modulation	1,800	to	3,300	1999	$6.4	to	$11.8
GATC: AERCO Benchmark Boiler	1,350	to	2,700	1999	$26.5	to	$53.0
PITCO Gas Fryers	75,000	to	138,000	1999	$45.7	to	$86.6
AUTOFRY ™ Deep Fat Fryer	2,130	to	4,260	1999	$8.1	to	$16.2
York 600 RT 134a Chiller	60	to	95	2000	$32.7	to	$51.3
Tecogen 150 RT 134a Chiller	65	to	105	2000	$2.2	to	$3.6
INDUSTRIAL							
Process Application of Composite Radiant Tubes	39,600	to	68,600	1994/99	$66.6	to	$115.4
High Performance Infrared Burners	125	to	190	1995/00	$612.27	to	$918.40
Natural Gas Cofiring in Biomass-Fueled Stoker Boilers	13	to	20	1999	$103.9	to	$163.3
Ultra-Low-NOx Boiler Burner	120	to	180	1999	$62.1	to	$93.1
METHANE de-NOX® Reburn Technology	6	to	11	1999	$136.2	to	$233.5
Forced Convection Heater (FCH) Systems – Automotive	11	to	19	2000	$14.2	to	$23.6
Oscillating Combustion Burner	125	to	225	2001	$17.0	to	$30.4
Low-NO_x Combustion System for Glass Furnaces	11	to	21	1995/03	$69.7	to	$127.9
Low-NOx, High-Heat-Transfer Burner	170	to	300	2003	$31.6	to	$56.5
POWER GENERATION							
IR PowerWorks Microturbine Cogeneration Systems	2,600	to	4,000	2000	$50.2	to	$78.9
Advanced High-Output Gas Engine-Generator (Caterpillar 3500® Series)	40	to	60	2001	$12.6	to	$21.6
Distributed Generation Switchgear		***		2003	$3.0	to	$4.7
TRANSPORTATION							
NGV Cylinders Types 1 and 2	28,500	to	69,700	1999	$5.5	to	$13.4
Advanced NGV Fueling Dispenser	80	to	170	2002	$1.2	to	$2.6
DISTRIBUTION							
Plastic Pipe Across (and on) Bridges	4,125	to	8,660	1995/99	$63.2	to	$132.8
DrillPath™ Software for Directional Drilling Operations	110	to	160	1996/99	$2.4	to	$3.6

	Sales or Applications Projected Through 2008 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2003$)		
Starline® 2000 Renewal Technology	135,300	to	248,000	1999	$1.9	to	$3.5
Guided Mole	20	to	40	1999	$4.6	to	$8.0
Gas Holder Manual of Practice	7	to	12	1999	$6.3	to	$11.5
One-Step Paving	230	to	430	2000	$3.4	to	$6.7
Soil Compaction Supervisor	470	to	820	2000	$19.4	to	$33.9
Self-Loading, High-Efficiency Trailer for Coiled PE Pipe	22	to	43	2001	$70.8	to	$141.7
Cold-Mix Restoration of Pavement Cuts	130	to	330	2001	$9.4	to	$24.4
Imaging Underground Utility Structures	900	to	1,650	2001	$6.4	to	$11.7
Comparative Evaluation of PE Pipe Materials	55	to	110	2001	$50.1	to	$100.3
Directional Drilling for Plastic Pipe under Railroad Crossings	46	to	100	2001	$12.6	to	$27.2
PE LIFESPAN FORECASTING ™	135	to	250	1994/01	$83.7	to	$154.9
Pipe Splitting Tool	15	to	30	1998/02	$9.5	to	$19.0
Gas Distribution Cost Database	450	to	800	2002	$11.8	to	$21.0
Assessment of PVC Pipe	4,300	to	9,500	2002	$20.0	to	$44.1
Plastic Pipe Informational Web Site		***		2002	$4.3	to	$7.9
Worker Exposure to Hazardous Substances		***		2002	$5.4	to	$16.2
Safety of Vacuum Excavation Operations	50	to	160	2003	$2.6	to	$8.3
Gas Distribution Construction Guide	22,500	to	54,000	2003	$2.9	to	$6.9
Removing Cyanide Wastes from MGP Sites	6	to	14	2003	$4.6	to	$11.9
Chemical Fingerprinting for Enhanced Environmental Forensic Analysis	185	to	290	2003	$49.5	to	$77.8
PIPELINE							
Breeze Haz ™ Environment and Safety Offsite Consequence Modeling Software	3,000	to	5,300	1999	$14.0	to	$24.4
Emeritus Report B31.8 Code, Federal Pipeline Safety Regulations		***		2000	$19.2	to	$57.7
Elastic Wave Vehicle Tool		***		2000	$67.6	to	$146.5
API 14.1 Gas Sampling Standard.	5	to	11	2001	$5.0	to	$10.9
Ultrasonic Meter Installation Effects	2,500	to	5,000	2001	$65.4	to	$130.7
Orifice Meter Operational Effects	20	to	40	2001	$38.0	to	$70.7
DamageExpert™ Software	35	to	75	2001	$61.4	to	$133.0
Satellite Radar Interferometry Measurement of Slope Movement	20	to	45	2001	$48.8	to	$105.8
AIRCalc™ Software	145	to	265	2001	$79.4	to	$145.5
Predicting the Integrity of Storage Caverns in Thin Salt Beds	3	to	9	2002	$0.4	to	$1.2
ASME Standard for Pipeline Integrity Management		***		2002	$5.0	to	$10.8
NACE Standard for Direct Assessment of Pipeline Corrosion		***		2002	$0.7	to	$1.7
Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effect in Wetlands	75	to	250	2002	$2.0	to	$6.5
Best Environmental Practices for Pipeline Construction	600	to	1,200	2002	$2.6	to	$5.2

	Sales or Applications Projected Through 2008 (in units)			Year of First Sale	Net Present Value of Benefits** (Million 2003$)		
Gas Leak Measurement Device (Hi-Flow® Sampler)	30	to	120	2000/03	$4.6	to	$18.4
Environmental Effects of Pipeline Crossings of Streams	745	to	1,150	2003	$45.4	to	$71.3
Standard for Coriolis Meters	115	to	230	2003	$6.2	to	$12.4
EXPLORATION AND PRODUCTION							
Unconventional Natural Gas Database	110	to	190	1999/01	$10.4	to	$18.3
Downhole Gas/Water Separation CD-ROM	75	to	130	1999	$8.8	to	$15.2
Advanced Crosswell Seismic Source	200	to	400	1999	$33.7	to	$66.8
High Power VSP Mechanical Seismic Source	520	to	750	1999	$25.4	to	$37.0
Advanced Stimulation Technologies CD-ROM	45	to	80	1999	$5.5	to	$10.0
Coiled Tubing Standards	3	to	5	1999	$15.7	to	$30.3
GRI–MSTR ™ Software and Report to Predict Toxicity of Produced Water Discharged to the Marine Environment	280	to	440	1999	$12.5	to	$19.7
Glycol Dehydrator Emissions Calculation Program - GLYCalc ™ 4.0	720	to	1,330	1992/00	$76.0	to	$140.7
ProTreat ™ Software for Amine Gas Treating Applications	45	to	75	2000	$136.1	to	$226.9
Cased Hole Resistivity Tool	800	to	1,300	2000	$12.3	to	$20.0
Cased Hole Pressure Tool	725	to	1,245	2000	$106.5	to	$182.6
Well Siting in Carbonates – EGI Report	90	to	140	2000	$72.2	to	$108.3
Portfolio of Emerging Natural Gas Resources – Rocky Mountain Basins	480	to	720	2000	$110.6	to	$165.9
Mercury Contamination Training Workshop	300	to	500	2000	$3.0	to	$5.1
New Gas Exploration Concepts	65	to	100	2001	$280.8	to	$441.2
StreamAnalyzer ™ Software	370	to	820	2001	$80.3	to	$176.6
Enhanced Seismic Spectral Processor	200	to	330	2002	$35.0	to	$56.8
Cement Pulsation Technology	670	to	1,340	2003	$23.9	to	$47.9
Analysis for Radium in Marine Sediments	12	to	24	2003	$3.3	to	$6.6
Gas Resource and Production Potential of the Lewis Shales	45	to	70	2003	$32.1	to	$48.2
TOTAL (million of 2003 dollars, 5% discount rate)					$3,402		$5,934

* 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 2003 dollars.

*** Benefits are based on user feedback about technical and market influence of the RD&D items.

Table 3. Total Expected Benefits by Sector

	Quantified GRI RD&D Results	Net Present Value of Benefits (Million 2003$)
• Residential	1	$104
• Commercial	7	$256
• Industrial	9	$1,360
• Power Generation	3	$94
• Transportation	2	$15
• Distribution	22	$760
• Pipeline	17	$772
• Exploration and Production	20	$1,582
TOTAL	81	$4,943

GRI RD&D Costs

Between January 1999 and December 2003, GRI outlays totaled $530 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 2003. As with the benefits calculation, a 5% real discount rate was used in the net present value calculation. The calculated equivalent cost was $619 million. These costs include all outlays made by GRI during the past 5-year period, not just the costs incurred to produce the 133 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 5.5 : 1 to 9.6 : 1 (benefits of $3.4 to $5.9 billion divided by outlays of $619 million) with an expected value of 8.0 : 1 ($4.94 billion divided by $619 million). In a similar analysis carried out in 2003 for RD&D items placed in commercial use between 1998 and 2002, the calculated ratio of the benefits to gas customers to total GRI costs incurred during the same period was 8 to 1[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 81 of the 133 GRI RD&D items placed in commercial service between January 1999 and December 2003 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

[2] A.D. Bournakis, " Benefits of GRI RD&D Results That Have Been Placed in Commercial Use in 1998 Through 2002," Gas Research Institute, May 2003, GRI-03/0106.

RD&D items are included in the benefits calculation, all of the costs of GRI's operations during the 1999 to 2003 period have been included in the calculation of the benefit-to-cost ratio.

Appendix A
GRI RD&D Results That Have Been Placed in Commercial Use in 2003

RESIDENTIAL
Upgrades to the National Fuel Gas Code: GRI research led to recommendations for the 2002 National Fuel Gas Code (NFGC), published by the National Fire Protection Association in 2003, relating to the requirements for combustion air supply and corrugated gas vent connectors. These recommendations were intended to improve installation practices and energy efficiency. GRI's recommendations for appliance air requirements were to: 1) remove the designation of "unusually tight construction," because all new homes have what was previously considered unusually tight construction; 2) increase the required volume of rooms containing natural-draft gas appliances from at least 50 cubic feet per thousand Btu per hour of gas input to at least 52.5; and 3) specify a required volume of at least 37.5 cubic feet per thousand Btu per hour of gas input for rooms containing fan-vented appliances. GRI's recommendations for corrugated vent connectors were: 1) corrugated connectors to be equivalent to normal vent connectors and should both be oversized and have long-radius bends; 2) oversized corrugated connectors should be designed to avoid sudden expansions or contractions at the connections; and 3) flexible chimney reliners should have a design capacity 15% less than comparable Type B gas vents. The adoption of GRI's recommendations will allow greater flexibility in placing appliances in homes and will help reduce construction costs. Many installations that formerly required outdoor air to be ducted to the appliance will no longer require that expensive ducting.

COMMERCIAL
Building Energy Analyzer ™: The Building Energy Analyzer ™, developed by GRI, is a software tool that aids heating, ventilation, and air-conditioning (HVAC) professionals in tailoring economic analyses for several types of facilities. The program allows users to estimate critical information such as annual or monthly loads and costs associated with air-conditioning, heating, and on-site power generation for commercial buildings. The Building Energy Analyzer compares the performance of a wide variety of HVAC technologies, such as standard- and high-efficiency electric chillers, variable-speed electric chillers, absorption chillers, engine-driven chillers, on-site power generators, thermal storage, heat recovery, and desiccant systems. It estimates annual or monthly loads and costs associated with air-conditioning, heating, power generation, thermal storage and cogeneration systems for a given building and location. It performs quick-to-use economic analysis for the customer's utility rates, location, and building type. Additional features include: templates for each of the 15 most typical commercial building types; capability to handle complex utility rates; weather data for 233 cities; ability to perform life-cycle cost analysis on building cooling, heating, and power generation (BCHP) equipment. The software program is compatible with Windows® 95, 98, 2000, and XP and ME systems. Version 2.0 of BEA was released in 2003. The program with a complete manual in PDF format is distributed by GTI, with user support, maintenance, and upgrades provided through GTI's InterEnergy Software Project.

INDUSTRIAL
*** Low-NO_x Combustion System for Glass Furnaces:** Regenerative glass furnaces use extremely high air-preheat temperatures, which result in very high uncontrolled emissions of NOx. These furnaces are being placed under stringent regional and state regulations. GRI developed a furnace system that cost-effectively reduce NOx emissions from regenerative glass melters to less than 2.5 pounds per ton of glass. The new combustion technology, called oxygen-enriched air staging (OEAS), uses a unique method of introducing combustion air to control NOx formation. In a first combustion stage, the amount of combustion air through the firing ports is limited to decrease the oxygen available in the flame's high-temperature zone. This reduces NOx formation but leads to high concentrations of carbon monoxide and unburned hydrocarbons. Oxygen-enriched air is injected into the furnace in a second stage near the exit ports to complete the combustion. OEAS has been successfully retrofitted to endport container-glass

furnaces with flint and amber glass production capacities of 135 to 320 tons per day. NOx levels were reduced by 50-70%. The OEAS technology has now been adapted to operate similarly on sideport furnaces, which are used for nearly 65% of U.S. glass production. Endport and sideport furnaces are similar in concept, but significantly different in physical design and flame characteristics. OEAS has been successfully retrofitted to seven endport container-glass furnaces and three sideport container-glass furnaces. NOx was reduced by 50 to 70% on endport furnaces, with no adverse impacts on other emissions, furnace performance, or glass quality. OEAS technology applied to three sideport furnaces reduced NOx by 40% to as much as 70%. GRI licensed OEAS technology to Combustion Tec, the glass division of Eclipse Combustion. In 2003, Combustion Tec began marketing OEAS for endport and sideport glass furnaces.

Low-NO_x, High-Heat-Transfer Burner: Two serious problems with high-temperature combustion processes, such as glass melting, are their intrinsically low efficiency and high emissions of NO_x. Efficiency is low because of the high energy content of the combustion products leaving the process. NO_x emissions are high because NO_x yield increases as combustion temperature increases. The use of recuperative heat exchangers to increase efficiency and the use of post-process NO_x emissions control equipment are costly solutions to the problems. Both problems could be mitigated by using oxygen instead of air to support the combustion. However, although oxy-gas firing has been implemented commercially to some extent, oxy-gas flames emit less thermal radiation than is desired for high process productivity. GRI developed a new oxy-gas burner that increases flame radiation by forming soot in the flame and then consuming the soot before it leaves the furnace. The High-Luminosity burner provides a preheating zone at the burner inlet to form soot, a fuel-rich flame zone to radiate heat to the furnace load, and a fuel-lean zone to burn out the soot. The soot radiation increases the effectiveness of heat transfer within the furnace and cools the flame, thereby reducing NO_x formation. The new burner provides significantly higher heat transfer to furnace loads, higher furnace efficiency, lower flame temperature, lower combustion products exit temperature, and significantly lower NO_x emissions. The high-luminosity burner can be used in conjunction with other NO_x reduction techniques, including combustion modifications and oxygen-enriched air staging. The burner is an easily installed, low-cost process modification that can, in oxy-fuel applications, increase process and energy efficiency by up to 10 percent while emitting 50 percent less NO_x than conventional oxy-gas burners. Test results showed a 4.5 percent increase in total heat transfer, which corresponds to a 10 percent decrease in fuel use. Combustion Tec Division of Eclipse™, Inc. licensed the technology and began marketing the burner to the glass industry in 2003 under the brand name Primefire® 400.

LNG Interchangeability in Burners: GRI evaluated the sensitivity of selected burners to compositions typical of LNG that is rich in heavier hydrocarbons. With LNG poised to play an increasingly important role in U.S. natural gas supplies, one of the issues of interest to the gas industry is the degree to which natural gas from LNG is interchangeable with pipeline quality gas in terms of its performance in combustion equipment, especially if heavier hydrocarbon components become more concentrated during handling. The heavier hydrocarbons would increase the density, heating value, and flame speed of the gas. If these increases are large enough, they may adversely affect the performance of some gas burners. The selected burners represent a variety of U.S. residential appliances. This study replicated previous methods that were used to study interchangeability to demonstrate their applicability to LNG, identified a set of indices that can be used to predict combustion behavior, investigated several ways to reduce the heating value of LNG, and related the performance of a specially designed test burner to the performance of a variety of residential appliances. The R&D determined interchangeability indices for natural gases used in the U.S. and for a range of anticipated world LNG imports to the U.S. It determined that, for the residential burners studied, expected LNG compositions are adequately interchangeable with U.S. pipeline gases if their heating value and density are suitably adjusted by dilution with air or nitrogen.

POWER GENERATION

Distributed Generation Switchgear: GRI developed paralleling switchgear for distributed generation (DG) systems that offer lower capital costs; plug-and-play simplicity; integration with leading natural gas engine-generator set manufacturers; conformity with basic electric utility interconnection requirements; conformity with existing or projected industry standards; and remote monitoring, communications, and control functions. Consolidating system functions reduced the number of components, and this reduction in components led to a smaller footprint, lower material costs, and less engineering. In addition to cost reduction, the new switchgear has more features, and this makes gas-fueled DG systems more attractive. The switchgear offers the widest array of communication capabilities found in DG systems today. The cost of switchgear was reduced from $75-$100 per kilowatt to $40-$60 per kilowatt. This was accomplished by reducing the number of components in the generator control section by 40-60%, reducing the space required for mounting the generator controls by 50%, reducing the engineering time by 30%, and reducing sheet metal and bus bar by 40-70%. The results of this R&D have significantly reduced the barriers to installing gas-fired DG equipment. The switchgear became commercially available from GE Zenith Controls in 2003 under the name Entellysis®.

Guidebook to Gas-Fired Distributed Energy Technologies: There has been an increase in interest in on-site generation of electric power systems, also known as distributed energy (DE) systems. DE systems that recover and use exhaust heat from the engines to provide other thermal needs at the site are called cogeneration systems or combined heat and power (CHP) systems. CHP systems offer users high energy efficiency (up to 80%) because they make heat available that would be wasted if the electric power were generated at a central power station. Although DE and CHP systems offer very high energy efficiencies, they have not had high market penetration. Potential DE and CHP users are not familiar with DE and CHP equipment performance and cost. To help overcome the lack of familiarity, GRI cooperated with the National Renewable Energy Laboratory (NREL) to publish a definitive guidebook on the performance and cost of the various prime mover technologies that can be used to generate power in DE and CHP applications. These technologies are reciprocating engines, small gas turbines, microturbines, steam turbines, fuel cells, and Stirling engines. The guide was published in 2003 and is available from NREL. It describes each of the six technologies, their power generation performance, cost, and emissions characteristics. Because some of the technologies have not yet been fully commercialized, the guide also predicts the performance and cost that the prime mover technologies will achieve in the future (2010, 2020, and 2030).

DISTRIBUTION

Safety of Vacuum Excavation Operations: Vacuum excavation involves the use of equipment to remove soil from holes that are being dug by distribution companies. Interest in using it has expanded greatly with the introduction of keyhole repair technologies, which depend on vacuum excavation. Keyhole repairs often encounter leaking gas in small spaces, and this has raised the question of whether vacuum excavation will pose unexpected hazards from ignition of gas-air mixtures in the vacuum hoses or the soil collection tank. Vacuum hoses are often made of plastic materials that are inexpensive and lightweight. Flow of air and solids through plastic pipes can create static electricity, which could be an ignition source. Flying rocks hitting the steel wall of the soil collection tank could also create sparks. GRI performed experiments designed with the deliberate goal of causing ignition. The experiments demonstrated that both high static electricity voltages and flammable gas-air mixtures can co-exist in the hoses and soil collection tanks without ignition occurring. A report, GRI-03/0128, “Vacuum Excavation of Potentially Flammable Gases,” was released in September 2003. It gives gas companies confidence that vacuum excavation can be accomplished at least as safely as more traditional mechanical excavation. It is impossible to prove that ignition cannot occur under any condition that may occur during vacuum excavation. If gas company supervisors believe that there is an unacceptably high likelihood of gas ignition during a specific vacuum excavation operation, they can use aluminum-coated or other highly conductive vacuum hoses and ground both the soil collection tank and the hose. Small amounts of water can also be used to prevent static charge accumulation. The report also contains recommendations for maintaining safety during the use of suction techniques to remove water from flooded gas mains.

Gas Distribution Construction Guide: To help LDCs appropriately adopt new construction and repair technologies, GRI developed a Web site that describes many commercially available technologies that have been developed. It is called the Utility Construction Methods Selection Guide. The site covers many trenching and boring technologies for replacing deteriorating gas pipes, pipe lining technologies for pipe rehabilitation without replacement, and pipe bursting and splitting technologies for situations where lining is not feasible. In general, for each technology, the Guide contains the following sections: introduction, general description, advantages, limitations, technical application data, special considerations, application trends, U.S. utility experience, and contact information. The Guide describes six case studies in which trenchless or "no-dig" methods have been used for rehabilitating or replacing old and deteriorating gas mains and service lines. The six case studies cover the following six technologies: Amex® 2000, horizontal directional drilling, RENU™, starline®, Swagelining™, and U-Liner. Information on each case study is organized into the following sections: introduction, method applied, participating utility, application location, technical data, cost and savings data, economic analysis, and contact information. The Web site also contains an on-line economic calculator that compares various utility construction methods. Based on user inputs, the calculator selects appropriate rehabilitation or replacement methods for comparison. The analysis of the selected methods includes total installed cost, annual cost over the life of the project, net present value, and life-cycle cost. The Web site was put into operation in 2003 at www.gtiservices.org.

Removing Cyanide Wastes from MGP Sites: Cyanide compounds are found in the groundwater at many former manufactured gas plant (MGP) sites in the U.S. The cyanide compounds are residues of the manufactured gas purification process, which used iron-impregnated solid materials, such as wood chips, in purifier boxes to remove hydrogen sulfide from the manufactured gas. The iron compounds in the purifier box also removed some cyanide from the product gas. Spent iron compounds were often regenerated by spreading them on the ground. Some of the iron compounds remained in the soil and, upon contact with water, released cyanide compounds, which later entered the groundwater. Previous studies indicate that the dominant forms of cyanide compounds in purifier box wastes are iron cyanide complexes, which are highly stable in groundwater and resist natural decontamination by microorganisms. Current stringent limitations on allowable concentrations of cyanide in groundwater pose a compliance challenge. GRI evaluated alternate methods for removing iron cyanide complexes from the treatment plant effluent. The evaluation found that certain anion-exchange resins would adsorb the cyanide complexes, with a sorption capacity of up of up to 10% iron cyanide by weight. The resin functioned in the presence of high concentrations of sulfate ions, which interfere with the operation of most ion-exchange resins. GRI then developed a process based on the anion-exchange resins. The process was successfully demonstrated, at full scale, in an MGP waste treatment plant. It is recommended for treatment of water that contains up to 10,000 ppb of cyanide compounds. US Filter, in cooperation with GTI, is offering the process commercially.

Chemical Fingerprinting for Enhanced Environmental Forensic Analysis: Environmental forensic techniques are increasingly used to identify specific wastes, particularly at former MGP sites. However, currently, available analytical methods of environmental forensic techniques do not have enough conclusive discriminating power to insure scientific accuracy, reproducibility, and overall confidence in the use of chemical fingerprinting to characterize complex MGP wastes. These wastes, primarily dense non-aqueous phase liquid tars consisting of polynuclear aromatic hydrocarbon (PAH) compounds, are often aged, exceptionally dense, commingled with other wastes, and subjected to weathering over extended periods of time. With GRI support, the Gas Technology Institute has used chemical fingerprinting to successfully discern tar wastes from wholly different sources, and even to distinguish manufactured gas plant wastes from different plant operations. As a service to utility companies and others, GTI is providing fingerprinting, forensic engineering, and technical support for the identification of pollutants at particular sites, as well as for the study of process mechanisms. GTI takes a two-tiered approach in its environmental forensic services: The first is to characterize the discrete organic pollutants (e.g., BTEX, PAHs, PCBs, and endocrine-disrupting compounds) in water, soil, or sediment samples. These organic compounds all possess distinct "chemical fingerprints" which often can provide sufficient information to determine the origin(s) or source(s) of the contamination. The second tier is to characterize or "chemically fingerprint" the complex macromolecular organic matter in the sample matrix itself for signatures of various sources (e.g., natural, agricultural, industrial, and anthropogenic). Specifically, natural organic matter (NOM) is characterized for water samples, soil organic matter (SOM) is characterized for soil samples, and sediment organic matter (SdOM) is characterized for sediment samples. This technique has proven to be a sufficient monitoring tool that quantitatively compares changes in the organic quality of NOM/SOM/SdOM due to seasonal influence, changes in inputs or discharges, as well as treatment. Furthermore, the chemical fragments that are the reflection of these influences can be identified, quantified, and compared with other chemical and biological data to establish relationships.

PIPELINE

*** Gas Leak Measurement Device (Hi-Flow® Sampler):** GRI has developed an improved version of the Hi-Flow® Sampler, an inexpensive instrument for field measurement of leak rates. The Hi-Flow Sampler can be used to measure the rate of gas leakage around various pipe fittings, valve packings, and compressor seals in natural gas transmission, storage, and compressor facilities. It also measures background methane concentration in the air and automatically corrects the leak rate measurement for this background methane. The instrument is based on straightforward principles of dynamic dilution and concentration measurement. A very large, measured flow of air sweeps the area of the leak, completely capturing any gas leaking from the component being tested. The rate of the gas leak is calculated from the concentration of methane in the sweep air. The instrument is intrinsically safe for use in Class I hazardous locations. It has been approved by the Canadian Standards Association (C22.2 No. 157, June 1992), American National Standards Institute (June 27, 2002), and Underwriters Laboratories (UL913-2002). It provides data logging and instantaneous leak-rate display, and only minimal operator training is needed. In 2003, Bacharach®, Inc. began marketing the Hi-Flow Sampler.

Environmental Effects of Pipeline Crossings of Streams: Regulatory agencies have expressed concern about the environmental impact of pipeline water crossing construction on stream and river ecosystems. The main issue is the entrainment of sediment during pipeline construction and the effects of the sediment on downstream aquatic organisms. Because there were limited data and no field-proven predictive tools to quantify the effects of sediment released during water-crossing construction, assessment of impacts has been based on professional judgment and consideration of worst-case scenarios. This has led to the use of construction methods that were unnecessarily costly and often did not actually improve the degree of environmental protection. Because of the large number of pipeline water crossings and the large differences in cost among crossing methods, there was a need for scientifically defensible planning tools that allow industry to construct cost-effective, environmentally acceptable watercourse crossings. To meet this need, GRI developed CROSSING™ software and released it in 1998. It estimates how much the release of sediment during in-stream construction affects downstream fish communities. In 2003, CROSSING™ version 2.0, a more robust software package, was released. CROSSING™ 2.0 helps gas companies and regulators evaluate potential adverse effects of water crossing construction. This enables the selection of least-cost construction methods that satisfy environmental goals. Gas consumers will benefit from lower cost of pipeline service and from the prompt availability of pipeline service without delays in construction caused by unnecessarily extended permitting procedures.

Standard for Coriolis Meters: As part of its continuing search for better gas meters, the gas industry has become interested in using Coriolis meters in certain applications. Coriolis meters are of interest because they measure mass flow rate, which can be converted to a "standard" gas flow rate with only knowledge of the density of the gas at reference conditions. This is important because it avoids the need to predict the density of high-pressure gases with an equation of state and would avoid the errors associated with that prediction. Because of the mechanics involved in these meters, they are typically limited in size to pipe diameters less than 6 inches. Therefore, they would not be used for mainline meters, but would be used to measure gas flow to large customers or small municipalities. Manufacturers developed Coriolis meters for gas applications and reported the results of their development efforts, but no comprehensive, independent tests results were published. GRI evaluated the suitability of these meters for gas flow measurement, based on a test plan developed under the auspices of the American Gas Association. The tests verified that some of the meters that have been developed are accurate enough for gas custody transfer measurement. The results were incorporated into an American Gas Association report, issued in 2003. This report will serve as a standard for the gas industry. It provides a performance-based specification and test methods for Coriolis meters intended for natural gas flow measurement. It contains several appendices addressing theory, operation, accuracy, research, and test data.

EXPLORATION AND PRODUCTION

Cement Pulsation Technology: Cement is used to seal the annulus between gas well casings and surrounding rock, to insure that gas flows are taken from the intended formation, that the gas does not leak into shallower (lower pressure) formations, and that the gas is not contaminated with flows from other formations. It has been estimated that the cement in 20% of cemented wells on land fail within the first five years and as many as 65% of offshore wells fail within 15 years. Without remediation, the well may not reach its full gas production potential, and the annular leakage may present safety issues. GRI found that the quality of the cement structure can be improved significantly by vibrating the cement with pressure pulses transmitted from the surface immediately after cementing. Applying the pulses from the surface is less costly than the chemical additives that are now used to help reduce the occurrence of cement integrity problems. This low-cost technology will improve the ability of well cementing operations to seal gas zones. It will improve cement quality and decrease well repair costs. The pulsing technique was tested in 150 wells in gas fields that have been prone to gas leakage through the cement. An estimated $2 million in cement remediation costs was avoided. GRI's research included modeling to understand gas migration in cement and to study pulse propagation, technique effectiveness, and cement quality. In 2003 the technique was made commercially available in the U.S. by Reservoir Isolation Technical Services (RITS).

Analysis for Radium in Marine Sediments: Environmental concerns arose in regulatory agencies over the possible presence of naturally occurring radioactive materials in natural gas. Nuclear reactions of naturally occurring uranium and thorium in the rock of producing formations can form radium isotopes such as radium-226 and radium-228, which have long half-lives. In addition to long half-lives, these isotopes have long biological residence times because they incorporate into living skeletal material. They present health risks to gas industry workers because they may be deposited in gas processing equipment. To enable accurate assessment of possible risks, GRI investigated methods for determining the concentrations of these radium isotopes in produced water, fish, and sediments. The goal was to identify a reliable analysis method for measuring concentrations as low as 0.01 picoCuries per gram of material. Based on this information a method for inter-laboratory tests was developed. It was found that commercial radiochemical laboratories could obtain reliably accurate results with this method. In addition, a new, analytical method for seawater was evaluated and found to be accurate and sensitive to less than 0.01 picoCuries per gram. A report, GRI/01-0244, "Development, Evaluation, and Validation of Radioanalytical Methods for the Measurement of Radium 226 and 228 in Environmental Media Relevant to the Offshore Oil and Gas Industry," was made available in 2003 to gas production companies and service laboratories. The research results will help gas companies focus their remediation and control efforts on sites that pose true risks. This will enhance worker safety and reduce the overall cost of gas production.

Produced Water Atlases and Handbook: Changing environmental regulations and subsequent changes in permitting processes for produced water disposal are obliging oil and gas producers to modify their water treatment and disposal practices, often incurring higher costs. Surface discharge, which is the most economical strategy for produced water disposal, is no longer a viable option in many states where regulations have increasingly restricted the quality and quantity of water that can be disposed in that manner. When surface disposal is not a choice, beneficial use of recycled water becomes a favorable option. GRI compiled data to characterize the amount of water produced, production trends, and pertinent environmental regulations and analyzed localized produced water management strategies and costs. Annual oil, gas, and water production volumes were documented for key fields in each of the oil and gas basins in ten states. Producers reporting high volumes of water coupled with high hydrocarbon production were identified and interviewed to obtain specific information about their strategies for managing or disposing of produced water and the costs associated with those strategies. The data are contained in ten atlases, one for each of the following major gas-producing states: Wyoming, Colorado, Utah, New Mexico, Montana, Kansas, Oklahoma, Illinois, Michigan, and Louisiana. The research also produced a handbook that is a resource for gas producers and provides them with actual produced water management practices and disposal economics for 26 basins in ten states. The handbook also describes technologies that are used to treat or handle produced water. GRI published the atlases on a single compact disc in 2003. The Handbook is a separate GRI publication, also published in 2003.

Gas Resource and Production Potential of the Lewis Shale: The Lewis shale formation of the San Juan Basin in Colorado and New Mexico has an enormous gas-in-place volume. The properties of the reservoir and the mechanisms that control gas production from this formation are not well understood. GRI conducted formation evaluation research to quantify the gas-in-place volume stored by sorption, compression, and solution mechanisms; the depths of the most permeable rock; and the production mechanisms. The research collected and interpreted new data that were needed to improve the analysis of the wireline log data that are used to quantify the amount of gas in place and to determine the zones of greatest gas deliverability within the Lewis Shale. The research determined in situ gas permeabilities and estimated the amount of gas in place and how much of it should be recoverable. Shale gas reservoirs extend throughout the Western Cretaceous Basins from New Mexico to Canada. The amount of gas in place documented for the San Juan Basin are likely to be present in at least eight western basins. The formation evaluation approach implemented and documented during this research is applicable to all of these basins. The results of the research were published in a comprehensive report in 2003, GRI-03/0037, Final Report: "Lewis Shale Gas Resource and Production Potential". The information will help E&P companies understand this unconventional resource and will serve as a starting point for applying improved reservoir characterization technology to the development of the Lewis and other shale gas reservoirs. The enhanced understanding will lead to lower exploration costs and increased production of natural gas from shale formations.

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* Enhancement to a previous product.

Appendix B
GRI RD&D Results That Have Been Placed in Commercial Use in 1999 Through 2003

RESIDENTIAL

1. Combo Systems Sizing and Installation Guidelines – 1992/2000
2. NAECA Water Heater Assessment - 2000
3. Indoor Emissions from Cooking – 2001
4. Summary Report of GRI's Venting Research - 2002
5. Gas Venting Safety Assessment - 2002
6. Accurate Assessment of Heat Pump Efficiency – 2002
7. Upgrades to the National Fuel Gas Code - 2003

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. kitchenCOST ™ Software- 1998/99
11. Modulating Indirect-Fired Make-Up Air Unit - 1999
12. GATC: AERCO Benchmark Boiler - 1999
13. Engine Rooftop Heat Pump (Goettl 15-20 ton) - 1999
14. PITCO Gas Fryers - 1999
15. AUTOFRY ™ Deep Fat Fryer - 1999
16. Analysis of Commercial Sizing and Installation Guidelines - 2000
17. Gas Cooling Guide – Pro Version - 2000
18. York 600 RT 134a Chiller - 2000
19. Tecogen 150 RT 134a Chiller - 2000
20. Trane Single Effect Horizon Chiller - 2000
21. Chiller Application Briefs - 2000
22. Restaurant Kiosk Ventilation and High-Performance Gas Countertop – 2000
23. Comparison of Radiant and Convective Unit Heaters - 2002
24. Gas-Fired Commercial Steam Cooker – 2002
25. Building Energy Analyzer ™ - 2003

INDUSTRIAL

26. Process Application of Composite Radiant Tubes (and Case Studies) and Advanced U-Shaped Radiant Tubes - 1994/99/2002
27. Low-NO_x Air Staging for Glass Melting/Low-NO_x Combustion System for Glass Furnaces 1995/2003
28. Industrial Boiler Gas Cofiring (including Biomass) - 1995/99
29. High Performance Infrared Burners (and Application Tools) – 1995/99
30. METHANE de-NOX® Controls for Stoker Boilers - 1999
31. Ultra-Low-NO_x Burner for Boiler Retrofit - 1999
32. Forced Convection Heater (FCH) Systems   Automotive – 2000
33. Oscillating Combustion Burner - 2001

34. Radiant Heater Characterization Facility - 2001
35. Low-NO_x Retrofit Burners for Fire-Tube Boilers – 2002
36. Low-Cost Multi-Gas Continuous Emissions Monitor – 2002
37. Low-NO_x, High-Heat-Transfer Burner 2003
38. LNG Interchangeability in Burners - 2003

POWER GENERATION

39. DGen Pro™ Software – 1998/99/2000
40. SOAPP™ Modules – 1998/99
41. Microturbines (Capstone and Honeywell) - 1999
42. Distributed Generation Guidebook for Municipal Utilities - 1999
43. IR PowerWorks Microturbine Cogeneration Systems – 2000
44. Advanced High-Output Gas Engine-Generator (Caterpillar 3500® Series) – 2001
45. Distributed Generation Switchgear – 2003
46. Guidebook to Gas-Fired Distributed Energy Technologies - 2003

TRANSPORTATION

47. Cummins C8.3G Engine – 1996/2001
48. John Deere 8.1L Engine – 1996/99/2002
49. MACK E7G Refuse Hauler – 1996/2002
50. John Deere 6.8L – 1998/99
51. NGV Cylinders (Types 1 and 2) - 1999
52. Glass-Fiber-Wrapped Fuel Tanks for NGVs - 2000
53. Advanced NGV Fueling Dispenser
54. Best Practices for Medium-and Heavy-Duty NGV Fuel System Design - 2002
55. Clean Cities Initiative to Evaluate NGV Technology - 2002
56. Resource Guide for Heavy-Duty LNG Vehicles - 2002
57. Regional Natural Gas Vehicle Fueling Infrastructure Standards - 2002

DISTRIBUTION

58. PE LIFESPAN FORECASTING ™ – 1994/2001
59. Plastic Pipe Across Bridges – 1995/99
60. DrillPath ™ Guided Boring Software – 1996/99
61. Pipe Splitting Tool - 1998/02
62. TUBIS ™ Software for Repair/Replace Decisions - 1999
63. Pipe Ovality and Scratch Depth Measurement Device and Guidelines - 1999
64. Plastic Pipe Repair Techniques - 1999
65. Starline® 2000 Renewal Technology - 1999
66. Guided Mole - 1999
67. Gas Holder Manual of Practice - 1999
68. Precision Pipe Locator - 2000
69. One-Step Paving - 2000
70. Bare Steel Maintenance Optimization System (BASMOS) Software - 2000
71. Soil Compaction Supervisor - 2000

72. Self-Loading, High-Efficiency Trailer for Coiled PE Pipe - 2001
73. Cold-Mix Restoration of Pavement Cuts - 2001
74. Imaging Underground Utility Structures - 2001
75. Comparative Evaluation of PE Pipe Materials - 2001
76. Directional Drilling for Plastic Pipe under Railroad Crossings - 2001
77. Gas Distribution Cost Database - 2002
78. Effect of Bomb Blasts on Gas Distribution Equipment- 2002
79. Assessment of PVC Pipe - 2002
80. Effect of Utility Cuts on Pavement Quality - 2002
81. Plastic Pipe Informational Web Site - 2002
82. Evaluation of the Performance of Carbon Monoxide Alarms - 2002
83. Worker Exposure to Hazardous Substances – 2002
84. Safety of Vacuum Excavation Operations - 2003
85. Gas Distribution Construction Guide - 2003
86. Removing Cyanide Wastes from MGP Sites – 2003
87. Chemical Fingerprinting for Enhanced Environmental Forensic Analysis - 2003

PIPELINE

88. Clock Spring® Composite Pipeline Repair Material – 1995/99
89. Risk Assessment/Risk Management Guidelines – 1996/99
90. Breeze Haz ™ Environment and Safety Offsite Consequence Modeling Software - 1999
91. Emeritus Report B31.8 Code, Federal Pipeline Safety Regulations - 2000
92. Elastic Wave Vehicle Tool - 2000
93. Gas Leak Measurement Device (Hi-Flow® Sampler) – 2000/03
94. API 14.1 Gas Sampling Standard - 2001
95. Ultrasonic Meter Installation Effects -2001
96. Orifice Meter Operational Effects - 2001
97. Orifice Plate Installation Effects - 2001
98. Gas Storage Well Rehabilitation and Damage Prevention - DamageExpert ™ Software -2001
99. Satellite Radar Interferometry Measurement of Slope Movement - 2001
100. AIRCalc™ Software – 2001
101. Predicting the Integrity of Storage Caverns in Thin Salt Beds - 2002
102. ASME Standard for Pipeline Integrity Management - 2002
103. NACE Standard for Direct Assessment of Pipeline Corrosion - 2002
104. Revegetation of Rights-of-Way in Wetlands - 2002
105. Reference Manuals of Best Practices for Horizontal Directional Drilling and its Effects in Wetlands - 2002
106. Best Environmental Practices for Pipeline Construction - 2002
107. Integrated Vegetation Management – 2002
108. Environmental Effects of Pipeline Crossings of Streams - 2003
109. Standard for Coriolis Meters - 2003

EXPLORATION AND PRODUCTION

110. Glycol Dehydrator Emissions Calculation Program – GLYCalc ™ - 1992/2000
111. Gas Composition Database – 1996/2001
112. Unconventional Natural Gas Database – 1999/2001

113.Nitrogen Removal Requirements Report - 1999
114.Downhole Gas/Water Separation CD-ROM - 1999
115.Advanced Crosswell Seismic Source - 1999
116.High Power VSP Mechanical Seismic Source - 1999
117.Advanced Stimulation Technologies CD-ROM - 1999
118.Coiled Tubing Standards - 1999
119.GRI–MSTR ™ Software and Report to Predict Toxicity of Produced Water Discharged to the Marine Environment – 1999
120.ProTreat™ Software for Amine Gas Treating Applications - 2000
121.Cased Hole Resistivity Tool - 2000
122.Cased Hole Pressure Tool - 2000
123.Well Siting in Carbonates – EGI Report - 2000
124.Portfolio of Emerging Natural Gas Resources – Rocky Mountain Basins - 2000
125.Mercury Contamination Training Workshop – 2000
126.New Gas Exploration Concepts - 2001
127.StreamAnalyzer ™ Software - 2001
128.Enhanced Seismic Spectral Processor - 2002
129.Evaluating Ecological Impacts at E&P Sites – 2002
130.Cement Pulsation Technology - 2003
131.Analysis for Radium in Marine Sediments - 2003
132.Produced Water Atlases and Handbook - 2003
133.Gas Resource and Production Potential of the Lewis Shales - 2003