Missouri Natural Gas Customer R&D Needs

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Missouri Public Service Commission
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GTI Overview

ESTABLISHED 1941 (Gas Research Institute est. 1977)

> Independent, *not-for-profit* company established by natural gas industry

> Providing natural gas research, development and technology deployment services to industry, consumers, and government clients

> Performing contract research, program management, consulting, and training

> Wellhead to the burner tip including energy conversion technologies
Addressing Key Issues Across the Energy Value Chain

- **Supply**: Expanding the supply of affordable energy
- **Delivery**: Ensuring a safe and reliable energy delivery infrastructure
- **End Use**: Developing technology for the efficient use of energy resources

- Reducing carbon emissions to the environment
- Supporting sustainable economic growth
GTI/DOE Research Investments Sowed the Seeds of Unconventional (e.g., Shale Gas) Natural Gas Production

Sources: GTI, EIA, DOE Department of Fossil Energy

Shale expected to exceed 50% of U.S. gas production by 2035
Huge Benefits to Missouri Consumers of E&P R&D

> Based on 2006 prices and 2015 prices,

   - Savings to *Missouri* (R, C, I) consumers of $765 million per year
   - *Residential customer savings of about $200 per year per customer*

> National savings for R, C, I customers of $58 billion per year, compared to 30-year R&D costs of $744 million total
Technology Solutions for Natural Gas End Use

> Affordability of Energy Use

- Lower energy bills
- Increase appliance efficiency
- Reduce equipment first cost
- Reduce environmental impact
- New high-efficiency, low-emission options for Missouri commercial and industrial customers to aid economic development
Missouri Residential Gas Use

Missouri home gas use dropped an amazing 42% over four decades

Ref: A.G.A. Gas Facts, uncorrected for degree days
Why has Missouri Residential Gas Use Dropped?

> High efficiency furnace (90%+) first developed by GRI/GTI, introduced in the 1980s

> Gas company energy efficiency programs

> Tighter homes, better insulation and windows

> Warmer weather: Not necessarily!

> **Savings per residential customer at 2014 prices: $670/customer/year**

**Conclusion:** R&D and Technology Deployment has made a major difference in Missouri residential gas use and gas bills
Energy Efficiency R&D

- Ultramizer® Super Boiler*
- Water/Space Heater Combo
- Gas Heat Pump
- Tankless Water Heater*
- FlexCHP
- Equinox Solar-Assisted Heating System*

*Commercialized
Next Step-Function Opportunities in Energy Efficiency

> Gas heat pump water heater (EF = 1.38)

> Gas heat pump
  COP(h) = 1.6
  COP(c) = 1.2

EF = Energy Factor
COP = Coefficient of Performance
Lower-Cost High-Efficiency Equipment for Low-Income Customers

Water/Space Heater Combo System (90% + efficiency)

Low-cost condensing water heater (90%+ efficiency)

Low-Capacity "Right Sized" Condensing Furnace (15k-30k Btu/hr, 90% + efficiency)
Commercial/ Industrial Opportunities

- Ultramizer condensing boiler (90% + efficiency*)
- FlexCHP
- Low-NOx industrial furnace

* Commercially available
Environmental and Energy Savings Benefits
Water Heating Efficiency Improvements With Natural Gas Heat Pumps

Source Energy Water Heating Efficiency

- Gas Storage Energy Star, 62%
- Gas Tankless Condensing, 88%
- Electric Storage, 29%
- Electric Heat Pump, 70%
- Gas Heat Pump, 138%

Source: GTI (source to site, natural gas source to site: 91.9%, electric: 31.8%)

Natural gas heat pump water heater provides highest-rated source energy efficiency – over 50% advantage over electric heat pump water heaters.
Operations R&D Challenges

> Aging infrastructure
> Pipeline and distribution safety and integrity
  – Identification of high-risk sections of pipe
  – Prevention of third party damage
> Cybersecurity/physical security/resiliency
# Missouri’s Natural Gas Mains

<table>
<thead>
<tr>
<th>Material</th>
<th>Miles</th>
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<tbody>
<tr>
<td>Bare, Unprotected Steel</td>
<td>0</td>
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<tr>
<td>Coated, Protected Steel</td>
<td>11,631</td>
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<tr>
<td>Steel, Other</td>
<td>1,169</td>
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<tr>
<td>Plastic</td>
<td>13,486</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>1,028</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>27,315</strong></td>
</tr>
</tbody>
</table>

Ref: A.G.A. Gas Facts, with 2014 Data
Note: 1 mile of copper in total
New Operations Technologies

- Crossbore prevention best practices
- Handheld Acoustic PE Pipe Locator*
- Radio Frequency ID tags for Gas Distribution
- Obstacle Detection for Horizontal Boring Tools
- Metallic Joint Locator*
- Portable Methane Detector*

*Commercialized
GTI Cross Bore Program

> **Cross Bore Best Practices Guide** - single source of information for natural gas operators to investigate and remediate existing cross bores as well as prevent future cross bores.

> **Outreach and Education Program** - information to effect positive changes in attitude, practices and operations.

> **Cross Bore Database** - A national database of damages and incidents to assist in identifying trends.

> **New Developments** – Acoustic Pipe Locator, Cross Bore Detection, Obstacle Detection
New Operations Technologies

GPS, GEOSPATIAL

> GPS-enabled leak surveying
> GPS cameras for joint Inspection
> GPS for new installations
> Geospatial mapping for emergency response
> GPS for third party damage prevention
> Asset Lifecycle Tracking
Alternative Pigging Techniques

Smaller diameter electromagnetic acoustic transducer (EMAT) sensor development to find cracks and planar defects

> Background
  - Need to find cracks in pipe body and welds with tools that don’t require a liquid couplant
  - Must work with inspection tools for unpiggable (difficult-to-inspect) pipe with variable diameter, dead legs, reduced diameter fittings, and low flow conditions
  - More inspection tools for small diameter pipe; as small as 6-inch
  - Able to fit onto existing unpiggable pipe inspection platforms

> Objective
  - To transfer EMAT sensors for integrity management inspections to the LDC industry with a specific focus on unpiggable pipe
  - Working with Quest Integrated

> End Result
  - Small diameter EMAT sensor integrated with an unpiggable platform that is bidirectional and collapsible (commercially available by Quest)
Breakaway Fittings for MSA’s (OTD)

Objective:

> To develop a working breakaway disconnect / shutoff fitting for meter set assemblies (MSA) and other aboveground gas systems.

Focus

> Reduce the risk from vehicle collision or ice/snow falling from a building roof.
Delta R&D Program Map
– Approved States 30

- Company and Regulatory Approval (# of companies)
- Pending filings (DC also)
Why Collaborative R&D Programs?

> Highly cost-effective, highly leveraged dollars

> Only funders drive research agenda, select projects, and influence product/process

> **Major benefits to company customers:** reduced energy usage and energy bills, reduced emissions; lower company O&M costs, increased safety, increased integrity, increased deliverability

> Leverages collective intelligence and experience of funders to develop the **best possible solutions**

> Provides opportunity for field tests within company service territory, enabling acceptance by utility personnel, customers and regulators

> While hardware is available to all, technical reports are available only to the funders
Conclusions

> End-use efficiency R&D and deployment will increase end-use equipment efficiency, lower first costs, enhance consumer safety

> Operations R&D will contain O&M costs, and increase system safety, integrity, and deliverability

> R&D costs: $1.00 per customer per year for end-use and Operations R&D, less than 9 cents per customer per month

> Funding R&D in Missouri will help to ensure that R&D projects get chosen that will benefit Missouri consumers, field tests will be conducted in Missouri, and that the results of the R&D will be used in and benefit Missouri gas consumers and industry
Questions

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Appendix

> End Use R&D
> GTI Emerging Technology Program
> Energy Delivery R&D
End-Use R&D Areas of Technology Focus

> Residential/Commercial Water Heating
> Venting Safety
> Residential/Commercial Space Conditioning
> Commercial Food Service
> Industrial Processes
> Distributed Power/CHP and Steam Generation
> Transportation
> Renewable Energy (biogas, solar thermal)
> Carbon Management
Energy Efficiency R&D

NovelAire Dehumidification*
BRC FuelMaker’s Phill*
Stellar Countertop Steamer*

Energy Source Analysis Tool*
Packaged Air Conditioner Furnace Condensate Freeze-up Prevention
Cummins High-Horsepower NGV Engine*

*Commercialized
Residential ‘Low-Load’ Heating: One Size Does Not Fit All

- **Combined Space and Water Systems**
  - Improves utility/customer value proposition for water heating by piggy-backing on larger space heating load.
  - Equipment, system specification, operation, and load profiles all have significant impact on energy savings potential.
  - Market development and training critical, new construction likely first significant market entry point

- **Through wall packaged heating, cooling systems**
  - Systems represent growing portion of multi-family market
  - Manufacturers are beginning to roll out condensing options
  - Barriers exist related to codes and standards, as well as practical matters such as condensate management and compliance with voluntary programs (e.g. ENERGY STAR)

- **Low capacity ‘right-sized’ furnace**
  - Low capacity high AFUE furnaces with full modulation, very small footprint, quiet operation, variable speed blowers, and high efficiency cooling
  - 15,000-30,000 Btu/hr modulating down to 6,000 Btu/hr
  - Ideal for multi-family with 2.5 inch supply ducts
Role for Natural Gas in Emergency Power Systems

> Working to position natural gas as a viable option for standby and emergency power generation use

  — Natural gas as answer for critical infrastructure and resiliency

> Address existing restrictive code language for onsite fuel storage in life safety applications (NEC 70/NEC and NFPA 110)

> Potential for complementary role in electric demand response programs
Energy Efficiency Program Collaboration

Emerging Technology Program

> Gas Technology Institute led, utility supported, **North American** collaborative targeting **residential, commercial, and industrial** solutions

> ETP’s principle goal is to **accelerate** the **market acceptance** of emerging energy efficient technologies

2016 ETP Members Listed Above
Potential Deployment Projects for Residential/Commercial Customers

> High-efficiency PAC Rooftop Units (RTU)
> Combination space/water heating systems
> GHPs
Potential Deployment Projects for Industrial Customers

> Ultramizer® super boiler and heat recovery system

> Air curtains

> SRU flue gas condenser for waste heat recovery

> Automated steam trap monitoring

> CHP systems for industrial customers
GTI Energy Delivery Programs

- Inspection and Verification
- Intelligent Utilities
- Risk and Decision Analysis
- Construction Techniques
- Methane Emissions and Detection
- Grid Resilience
# Internal Inspection – Optimization Program

<table>
<thead>
<tr>
<th>Threats</th>
<th>Parameters of Interest</th>
<th>Sensor Technology</th>
<th>Platforms</th>
<th>Overarching Influencers / Other Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• External Corrosion</td>
<td>• Wall Thickness and Loss</td>
<td>• Ultrasonic/microwave</td>
<td>• Tethered (e.g., mechanical cable or coiled tube pulled)</td>
<td>• Existing and Impending Regulations (i.e., Post San Bruno)</td>
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<tr>
<td>• Internal Corrosion</td>
<td>• Cracking</td>
<td>• Eddy Current/RFEC</td>
<td>• Push Rod (e.g., coiled tube pushed)</td>
<td>• Market Size (diameters, distances, obstructions)</td>
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<tr>
<td>• Stress Corrosion Cracking (surface and subsurface)</td>
<td>• Residual Stress Levels</td>
<td>• Guided Wave UT</td>
<td>• Robotic Tethered (e.g., self-driven brush drive but with trailing power cord)</td>
<td>• Cost (development and per inspection unit)</td>
</tr>
<tr>
<td>• 3rd Party Damage</td>
<td>• Hardness and Ultimate Strength</td>
<td>• X-Rays</td>
<td>• Robotic Autonomous (no tether for power, etc.)</td>
<td>• Time to market</td>
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<tr>
<td>• Fabrication / Weld Quality</td>
<td>• Yield Strength</td>
<td>• Magnetic Flux Leakage</td>
<td>• Flowable Sensors (e.g., Fluidized Sensors, Smart Balls, etc.)</td>
<td>• Sponsors</td>
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<tr>
<td>• Wrinkle Bends / Miter Bend</td>
<td>• Toughness</td>
<td>• Magnetic Field Strength</td>
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<td>• Repeatability of Inspections</td>
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<tr>
<td>• Residual Stresses</td>
<td>• Physical Dimensions (ID)</td>
<td>• Electromagnetic</td>
<td></td>
<td>• Commercializers</td>
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<tr>
<td>• Soil and Other Superimposed Stresses</td>
<td>• Internal Defects (Porosity, Laminations, etc.)</td>
<td>• Optical/IR/UV</td>
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<td></td>
<td>• Physical Contact to Other Structures</td>
<td>• Video/Stills</td>
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<td>• Hardness</td>
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<td>• Modulus</td>
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<td>• Stress-Strain Probe</td>
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<td>• EMAT</td>
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High Accuracy GPS

GTI partnered with NavCom to provide high accuracy GPS for smart phones and tablets

> Sub-foot quality data in real-time
> No need for post processing or a base station
> Field data directly inserted into the GIS (with controls)
Characterization and Fitness for Service of Corroded Cast Iron Pipe (U.S. DOT)

> Objective

— Provide a Fitness-For-Service (FFS) model and method for operators to characterize and grade graphitic corrosion defects on cast iron natural gas pipes. This will help operators make monitoring, repair, and replacement decisions, as well as prioritize accelerated replacement decisions related to cast iron mains and services.

— Summarize and categorize the required input parameters to the FFS model related to cast iron material, graphitic corrosion geometry and characteristics, and operational environment.

— Validate the FFS model by comparing its output to a statistically analyzed set of historical cast iron failure data.

— Provide a physical testing program to fully validate the FFS model.

> Focus

— FFS model and method for Cast Iron Pipe
Slow Crack Growth Evaluation of Vintage Polyethylene Pipes (U.S. DOT)

> **Objective**

  — Develop a novel endoscopic structured light scanning tool for internal inspection of small diameter plastic pipe – especially for slow crack growth issues.
  
  — Provide a probabilistic estimate of the remaining effective lifetime of individual segments of vintage plastic pipe and a yes/no determination of whether a short-term pressure test is capable of validating the maximum defect size in the system.

> **Focus**

  — GTI – Development of fitness for service calculations, Bayesian network and decision support tool, and guidelines for short-term pressure testing of vintage plastic pipelines.
  
  
  — Arizona State University – Development of feature recognition and data reduction algorithms.
Approaches for Preventing Catastrophic Events (U.S. DOT)

> Objective

– Review of approaches for preventing catastrophic “Black Swan” events, both within and outside the natural gas industry.
– Empower the selection of the most appropriate approach(es) and model(s), develop them further, and ultimately issue guidelines for effective implementation in risk models and integrity management programs.

> Focus

– A structured review of the existing methodologies.
– Identify gaps.
– Prepare the ground for the adoption and/or development of a suitable approach for the gas sector.
Asset Lifecycle Tracking

A GTI technology solution to implement ASTM F2897-11a

> Barcode scanner
> High accuracy GPS receiver
> Tablet device with GIS-based data collection software
> Application to convert barcode into asset attributes to auto populate the GIS
Pipe Defense with Combined Vibration, Ground Movement, and Current Sensing (U.S. DOT / CEC / OTD)

Objective

- Demonstrate the feasibility of a wireless pipeline right-of-way (ROW) defense system based on stationary sensors mounted on, or adjacent to, the pipeline.
- Analytics will correlate the data to alert operators to events of interest occurring in the ROW with minimal latency.

Focus

- State-of-the-art review and gap analysis of pipeline ROW monitoring techniques.
- Design and build a ROW monitor hardware based on testing results.
- Develop a database structure and analytics to capturing pipeline data and discriminate significant events and display with a user interface to allow visualization of data.
- Deploy and field test ROW monitor system.
GPS Excavation Encroachment Notification System (GPS EENS)

> Objective

- Develop and deploy the GPS EENS technology to increase situational awareness of operating excavators and significantly reduce the risk of third party damage on utility infrastructure.

> Focus

- Provide high-accuracy GPS location, which overlays the utility’s GIS map services, 811 ticket boundaries, and custom geo-fences (defined by Utility)

- Provide real-time indications of the “state” of the geospatially located excavator device.

- Provide instant alerts (graphical, text, etc.) to relevant parties, including alerts to utility operators/inspectors when an excavator enters an 811 boundary or ROW, or to the excavator operator if unauthorized digging is occurring over utility infrastructure.