Collaborative Project

gti

Interchangeability of International LNG With Domestic U.S. Pipeline Natural Gas

Phase II – Industrial and Commercial Burners, Turbines and Microturbines

LNG imports into the United States are expected to grow significantly over the next decade as a means of filling the gap between growing demand for natural gas and available domestic supplies. Major LNG import projects are underway, including reopening existing Atlantic Coast LNG import terminals as well as planning new terminals along the West and Gulf Coasts. The growth of LNG's share of U.S. baseload supplies raises important issues about the compatibility, or interchangeability, of natural gas and LNG with existing combustion systems. Many world LNGs having a higher heating value per cubic foot than U.S. pipeline natural gas. The Gas Technology Institute (GTI) has completed the first phase of an LNG and Natural Gas Fuel Interchangeability Study focusing on new appliances. A proposed second phase will address fuel interchangeability concerns for industrial burners and turbines that are often more sensitive and more tightly regulated than home appliances. Controlled lab and field testing coupled with empirical modeling will facilitate the introduction of LNGs from around the world by determining the ranges for acceptable (or interchangeable) LNG and natural gas use in a wide range of industrial and commercial burners, turbines, and microturbines.

- **Proposed Total Funding:** $1,400,000
- **Required Investment**: $150,000 to $200,000 per company (7 to 10 sponsors)

BACKGROUND

LNG is a natural gas that has been treated to remove impurities, then condensed to liquid form. Most of the LNG used in the U.S. comes from peak shaving plants and thus is just a cleaner form of ordinary pipeline natural gas. There are some compositional differences between international LNG and domestic pipeline gas (including peak shaving LNG). These differences result from the cryogenic liquefaction process and from the unique economics of the LNG industry. These differences could lead to interchangeability issues when LNG is introduced into a domestic U.S. grid system. The term "LNG" in this document refers to international LNG that is expected to enter the U.S. market in greater quantities in the near future.

- LNG has very low HC and water dew points and CO_2 content compared to domestic gas. This is due to the need to prevent frost formation in the cryogenic liquefaction equipment. Even the richest LNGs (HHV $\geq$ 1,140 Btu/scf), have dew points below -100^{o}F. Pipeline gas is normally no lower than -20^{o}F. CO_2 in LNG is less than 50 ppm, compared to several thousand ppm in domestic gas.
- LNG has higher calorific value: 1,100 to 1,150 Btu/scf versus 1,020 to 1,060 for domestic gas. As the petrochemical and natural gas liquids industry developed in the U.S., increased stripping of heavier components dramatically reduced the typical HHVs of natural gas delivered to end-users. By contrast, major LNG exporters are usually remote from petrochemical markets. In addition, major LNG importers distribute richer gas to end consumers. The typical grid HHV in Japan (by far the world's largest LNG importer) is above 1,130 Btu/scf. Thus, while LPG is usually stripped from international LNG, economics do not favor the high level of extraction that is typical in the U.S.

In recognition of the potential for interchangeability problems with imported LNG, GTI and a diverse group of industry sponsors carried out a project to identify and quantify interchangeability of a wide range of LNGs, with a range of domestic pipeline natural gas. Project sponsors were BP, Southern Natural Gas, El Paso Merchant Gas, Enron, Shell International Gas, Washington Gas Co., and GRI.

The project studied the degree to which LNG changes the performance of a wide range of residential appliances compared to their performance with domestic gas. GTI measured and compared each appliance's performance (flame appearance and geometry, emissions, etc) as the fuel gas changed through dilution of LNG with natural gas, nitrogen and air. Appliances were chosen for inclusion based on widespread use in domestic markets and included two water heaters, two ovens, two range tops, a home furnace, an unvented space heater, a radiant space heater, an unvented fireplace log set, and a clothes dryer. The Final Report from the Study is for sale from GTI. The Study concluded that:

- Appliance burner performance (emissions, flame appearance) was related to values derived from fuel composition and physical properties.
- Appliances are fairly tolerant of fuel changes in the range tested. All operated within ANSI emission limits for all ranges of LNGs tested.
- Appliances with a closed combustion chamber (i.e. ovens) were far more sensitive to fuel changes than were other appliances. While oven emissions were within ANSI guidelines, the high rate of CO change with the richer of the Substitute Gases (Wobbe Index >1,400) was a cause for some concern.
- CO emission is a more sensitive measure of burner performance than flame appearance, which is subject to observer interpretation.
- Index values for yellow tipping (AGA, USBM and Wobbe) correlated better with CO emission than other indices.
- Dilution of LNG with air gave results similar to dilution with nitrogen.

Residential appliances represent less than 40% of U.S. natural gas consumption. Industrial and power generation (turbine) segments consume more natural gas than the residential segment, and information gathered by GTI indicates that a number of industrial and commercial users are far more sensitive to gas quality changes than are residential users. AGA and USBM (Weaver) Indices for fuel interchangeability are not generally applicable to industrial burners and gas turbines. As larger quantities of LNG enter the U.S. pipeline system, there is a need to understand, and predict, if possible, the behavior of commercial and industrial combustion equipment and gas turbines as their fuel is changed from natural gas to LNG, or enriched by imported LNG.

This appears to be an enormous undertaking due to the large number and variety of equipment and burner types used in the U.S. Industrial and commercial equipment, however, can be divided into types and then grouped based on the level of sensitivity and concern in specific applications. For example, gas turbines can be adjusted to handle a wide range of fuels; however, once adjusted, they cannot handle significant fluctuations in quality. Low NO_x burners may be sensitive to changes in fuel composition that affect flame geometry. Equipment operating with low excess air may be sensitive to changes in fuel calorific value.

Important interchangeability concerns that must be addressed today include fuel and oxidant (air or oxygen) supply, mixing, and ratio control equipment performance; operation of flame safety and monitoring equipment, and burner emissions (CO, unburned hydrocarbons, and NO_x) for a wide range of traditional and low-NO_x burners.

VALUE TO INVESTORS

Findings from this project will benefit LNG suppliers and terminal operators, pipeline operators, LDCs, and turbine and industrial process operators. Specific benefits to these groups will include:

LNG suppliers and terminal operators. Data provided will enable LNG suppliers and terminals to determine acceptable LNG property limits and select means of blending LNG and deciding where (and to what extent) in the LNG path to remove the higher hydrocarbons.

Pipeline operators and LDCs. Establishing limits of acceptable performance and regulatory characteristic changes with fuel changes will make it possible to establish and maintain acceptable limits in gas pipeline and delivery systems. Determining the impacts of rapid fuel supply changes will make it possible to mitigate the effects of fuel changes on combustion systems.

Turbine and industrial process operators. Information about specific burner and turbine types will facilitate selection of stable and reliable combustion systems and provide benchmarks for acceptable ranges of fuel compositions for acceptable process operation.

PROJECT DESCRIPTION

The project will involve experimental determination and modeling of changes in industrial burner, turbine, and microturbine performance with natural gas, LNGs, and other fuel gases. This will establish the interchangeability of U.S. domestic natural gas with world LNGs, high ethane fuel gas, and lower quality gas. The project will consist of the following three Tasks.

Task 1. Industrial and Commercial Burners. Industrial and commercial burners can be classified into broad groups such as high momentum, nozzle-mixed, flat-flame, etc. A list of all major burner types will be compared with a list of industrial combustion processes sensitive to fuel changes. These include:

- Processes sensitive to flame temperature changes (bakeries, process heaters, etc.)
- High-temperature processes with emissions limits (steel, glass, etc.)
- Processes operated close to flame stability limits (sub-stoichiometric combustion, etc.)

The two lists will be compared, 6 to 8 types of representative burners will be selected for fuel interchangeability testing. Each burner will be separately tested in a new, highly flexible, fully instrumented GTI industrial combustion test chamber Two groups of measurements will be made over a typical range of firing rates and air-to-fuel ratios:

- Performance characteristics: Flame properties of length, shape, temperature, heat flux, stability, appearance, etc.
- Regulatory characteristics: Emissions (CO, NO_x, hydrocarbons, etc.).

Fuel gases studied may include up to two representative domestic natural gases, three representative world LNGs covering a wide composition and heating value range, ethane-rich gas, and lower-quality gas. Tests will include pure and blended fuel gases and LNGs mixed with up to 6% nitrogen.

Task 2. Turbines and Microturbines. Up to two turbines and one microturbine will be selected for fuel interchangeability testing. The project team will work with turbine manufacturers and the ASME Turbine Fuels Codes and Standards Committee to conduct similar performance characteristics and regulatory characteristics as described in Task 1. Because of equipment size, these tests will be conducted off-site with working turbines and microturbines.

Turbines and microturbines are particularly sensitive to changes in fuel supply. The impacts of different fuels and switching between natural gas and LNG fuels on turbine performance will be determined and quantified.

Task 3. Combustion System Modeling. As data are collected from industrial burner tests, the project team will incorporate results and trends into a database. A set of correlations and empirical relationships will be developed describing fuel interchangeability over different types of industrial burners. With a sufficient number of industrial burners tested, an empirical model will be developed identifying and describing the burners most sensitive to fuel interchangeability concerns and the degree of performance and regulatory characteristics changes that can be expected with changes in fuel gas. This model will serve as a tool for gas industry and industrial experts to use in considering changes in fuel supply composition and in selection of burners for industrial and commercial processes.

DELIVERABLES

The following deliverables will be provided to participating sponsors.

- Regular project meetings, either in person or by teleconference, at least every 2 months to review project status, to present and discuss findings, and to plan upcoming activities.
- Topical reports summarizing tests and findings for each industrial combustion system, turbine, and microturbine studied.
- A Final Report incorporating the topical reports, a project introduction, the modeling results for all combustion systems studied, and a summary of all project findings.

PROJECT MANAGEMENT

For this project, GTI will:

- Plan the project and individual Tasks
- Manage all Tasks
- Manage day-to-day project administration
- Provide periodic progress reports after testing of each burner system
- Prepare the Final Report

Each participating sponsor will appoint one individual to act as its representative. The representative will be the primary contact for all technical and administrative communications during the performance of the project.

PROJECT RIGHTS AND PRIVELEGES

Participating sponsors will have the following rights and privileges:

- Initial approval of project tasks, including the number of burner systems and turbines tested
- Prior approval of major deviations or new tasks
- Sponsor group advisory and decision-making roles

PROJECT CONFIDENTIALITY

No participating sponsor confidential information will be required, collected, or shared in this project. The proprietary information collected in this project will remain confidential to sponsors for 6 months after receipt and acceptance of the Final Report. After that time, the Final Report will be available for sale, with proceeds divided between GTI and participating sponsors.

TIMEFRAME

It is anticipated that this LNG interchangeability collaborative project will be two years in length. The project Final Report is anticipated in late 2005. GTI is aware of the time pressures associated with the studies in this project. Data and analysis for each burner system, turbine, and microturbine will be reported in a separate, stand-alone chapter that will be part of the Final Report. This publication approach will provide information to participating sponsors in the most timely manner possible while enabling the project to cover a large enough group of industrial burners, turbines, and microturbines to provide a broad and comprehensive perspective. The project will be closed to new participating sponsors after full project funding and initiating of project work.

PROJECT INVESTMENT

Total project cost is estimated to be $1,200,000. GTI is seeking 6 to 8 participating sponsors. Depending on the number of sponsors, the cost for each collaborating company will be between $150,000 and $200,000 over one to one and a half years. Investment would be in two payments made at the start of each year of the project.

Task budgets and approximate timing is shown below. When possible, work will be conducted on several Tasks simultaneously.

- Task 1 – Burners - $850,000
- Task 2 – Turbines - $400,000
- Task 3 - Modeling - $150,000

Total project length is estimated between 12 and 18 months. Task 1 tests will include tests with 6 to 8 industrial burner systems. Task 2 will involve tests on up to 2 turbines and one microturbine.

CONTACT

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