TECHNICAL ISSUES AND RESEARCH NEEDS IN GAS INTERCHANGEABILITY IN THE U. S.

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ABSTRACT

Changing U. S. domestic natural gas supplies and forecasts of increasing importation of LNG into the U. S. have raised concerns about the compatibility of these supplies with U. S. end uses developed around historical natural gas compositions and constituents. In response to these concerns, the U. S. Natural Gas Council commissioned a working group to evaluate and develop recommendations for gas interchangeability covering historical gas supply considerations, the changing nature of the U. S. natural gas market including increasing LNG importation, infrastructure and transportation issues associated with interchangeability, the breadth of end use interchangeability considerations, and knowledge gaps and research needs for addressing interchangeability of these new supplies.

The working group, the Gas Interchangeability Task Group, was chaired by the author and included representatives of all parts of the U. S. natural gas value chain, including non-U. S. importers. Working on the basis of technical information, data, and expert opinion, this broad set of interests developed consensus-based findings and recommendations on gas interchangeability and interim guidelines for interchangeability, which were presented to the U. S. Federal Energy Regulatory Commission (FERC) in June 2005.

Since that time, various efforts have been implemented to develop technical background on gas interchangeability requirements to build on the interim guidelines presented to FERC. These programs include appliance testing programs, power turbine testing projects, and studies of specialized end uses, including non-combustion uses of natural gas.

This paper presents the status and general findings to date of these studies, which include government and industry sponsored projects. In addition, the paper outlines additional areas where research is needed and where international collaboration may be explored for better understanding of basic interchangeability requirements and responses to increasingly stringent environmental regulation of end uses.
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1. BACKGROUND

Features of the U. S. natural gas market present unique and challenging differences from many other domestic markets with respect to gas interchangeability. These differences have only increased since the U. S. market was deregulated in the 1990s through actions including Federal Energy Regulatory Commission (FERC) Order 636. Salient features of the U. S. market include, but are not limited to, the following:

- Decreased vertical integration of producers, transmission pipeline operators, and local distribution companies (LDCs) in most regional and local markets. Within the LDC sector alone, the American Gas Association (AGA) represents over 185 natural gas utilities, which may act independently on issues such as gas interchangeability requirements.

- Increasing levels of horizontal diversity in terms of available domestic gas supplies and compositions, transportation infrastructure and associated costs, and end user mixes and associated gas quality requirements.

- Changes in compositions of domestic resources caused by drawdown of reservoirs and development of new resources, including development of “unconventional resources” such as coal seam methane.

- Changes in processing of domestically produced gas and resulting compositional variations due to changes in commodity prices and availability of processing infrastructure.

- Increasing prospects for expansion of importation of liquefied natural gas (LNG) well above U. S. historical levels from a variety of overseas sources and representing diverse compositions. In addition, the U. S market may be served by additional liquefaction capacity with uncertain gas quality specifications as an increasingly complex world market emerges.

- Changes in gas flows throughout the U. S. interstate pipeline system from more predictable linear flows from producing regions to consuming regions, with consequent reliable means for blending supplies of various compositions to meet end use requirements, to more unpredictable networked flows of natural gas. This trend is, in part, driven by seasonal changes in demand patterns and storage activity where blending requirements and capability is less predictable and where temporal variations in gases delivered, not seen before, are possible.

- The sheer size of the U. S. natural gas market, approximately 617.3 billion cubic meters consumption in year 2003, exacerbating the importance of domestic market changes and potentially influencing world markets if and when U. S. importation of natural gas and LNG represents a higher proportion of world market activity. While U. S. activity in the world gas market has been very limited, any growth to a level of significance in these markets may present unique challenges, especially for LNG suppliers and transporters.

Gas interchangeability has been a concern of the U. S. gas industry for over seven decades, beginning with early research sponsored by AGA in the 1930s (Reference 1). Gas interchangeability is defined in many of these historical publications and is most recently defined as follows:

"The ability to substitute one gaseous fuel for another in a combustion application without materially changing operational safety, efficiency, performance or materially increasing air pollutant emissions." (Reference 2)

Gas interchangeability always inferred gas composition requirements based on suitability for end use, specifically combustion. While gas interchangeability, in many cases, can be maintained by modifying end use equipment as well as modifying gas composition through gas processing, the general re-
quirement for evaluating interchangeability of a new gas supply based on end use performance remains the fundamental criterion.

Major transformations in the U. S. gas market have led to peaks and valleys in U. S. gas interchangeability technical activities over this time. Peaks of activity coincide with factors such as the introduction of natural gas as a replacement to manufactured or “town” gas in the 1930s and 1940s, potentially large increases in LNG imports in the 1970s as a substitute to domestic natural gas, and most recently, reconsideration of increasing LNG importation due to expansion of U. S. natural gas demand, particularly to supply gas fired electricity generation. Generally speaking, the first two peaks in gas interchangeability activity tended to address issues of local supply (e.g., replacement of a local manufactured gas plant supply with natural gas and importing LNG to serve a local market area). As such, technical studies of LNG and, to a greater extent, gas interchangeability policy could be based on local supply and market conditions. However, with the changes to the U. S. market listed above, technical considerations and policies are forced to consider broader conditions of the U. S. market, except where more dedicated supplies and markets can be developed. This exception may be most apparent in the example of the Cove Point LNG facility in Maryland and, at least as the LNG terminal currently operates, its service of a fairly well defined and characterized market area within a limited geographical area. With the expansion of this and other facilities, the reliance upon local market requirements will become much less certain.

The current U. S. emphasis on interchangeability, again, is due to two major influences that can be summarized from the list of factors above. First is change in U. S. domestic supply. Second is the prospect of increased importation of LNG. Unlike the earlier focus of interchangeability studies and policies, these changes and transformations of the U. S. natural gas market require broader consideration of gas interchangeability specifications than has been considered before.

2. U. S. NATURAL GAS COUNCIL ACTIVITIES

In 1994, the U. S. Natural Gas Council (NGC), a coalition of natural gas trade associations composed of the Interstate Natural Gas Association of America (INGAA), the Natural Gas Supply Association (NGSA), the Process Gas Consumers Group (PGCG), and AGA, recognized the need for the U. S. natural gas industry and its customers to develop industry based recommendations for addressing changes in gas composition brought on by changes in domestic gas and anticipated LNG importation. A major influence on the NGC was the publication of a major study by the National Petroleum Council in 2003 (Reference 3) and subsequent concern expressed by the FERC. The NGC undertook the formation of two task groups: one working on gas interchangeability and a second working on condensable heavier hydrocarbons (butanes and heavier). The issue of condensable hydrocarbons was primarily a concern of gas transportation reliability and domestic natural gas that received little or no processing to remove these constituents. While these hydrocarbons have importance in gas interchangeability, the principal focus of the NGC task group was to address liquid dropout due to pressure drop and ambient temperatures and the potential operational problems of liquid dropout.

The Gas Interchangeability Task Group was formed in March 2004 and represented an ad hoc group of over 40 stakeholder organizations including gas producers, pipelines, LDCs, end use equipment manufacturers, trade associations, and regulators. All interested stakeholders were included in Task Group activities. Participation was voluntary and non-exclusive of any stakeholder group. The objective of the Task Group was to develop technically based findings and recommendations on gas interchangeability to the NGC for consideration for presentation to FERC. Beyond the presentation of results to the FERC, policy recommendations and advocacy were to be left to individual NGC members and other interest groups. The scope of the Task Group activities included all U. S. combustion end uses as well as non-combustion end uses such as for chemical feedstocks and domestic LNG liquefaction for storage.

Over a 15 month period, the Task Group convened 20 meetings and conference calls to discuss various aspects of gas interchangeability. The Task Group operated under informal procedures to achieve technical consensus on issues it considered. In February 2005, the Task Group presented to the NGC its “White Paper on Natural Gas Interchangeability and Non-Combustion End Use,” (Ref-
3. GAS INTERCHANGEABILITY TASK GROUP FINDINGS AND RECOMMENDATIONS

The Gas Interchangeability White Paper presents findings and recommendations on gas interchangeability representing the consensus of the Task Group and its stakeholders. The following are selected findings of the Task Group. The White Paper text presents the complete findings.

- Heating value specification alone, as used in some tariffs today, is not an adequate measure for gas interchangeability.

- Most pipeline tariffs do not contain adequate specifications to define or set interchangeability limits.

- There is a large body of work that has been conducted by the American Gas Association and other research bodies on interchangeability and interchangeability indices. In addition, a number of pipeline and distribution companies have amassed first-hand operating experience in managing interchangeability. Other parts of the world including Europe have also successfully instituted programs to manage interchangeability. However, it is not known to what extent this research and experience applies to low emissions combustion technology.

- The Wobbe Number provides the most efficient and robust single index and measure of gas interchangeability. There are limitations to the applicability of the Wobbe Number, and additional specifications are required to address combustion performance, emissions and non-combustion requirements.

- Gas interchangeability guidelines must consider historical regional gas compositional variability as well as future gas supply trends. Interchangeability is an issue for both domestic gas supply and LNG imports.

- Presently, there are limited data characterizing the changes that have occurred over time in natural gas composition on a regional basis.

- The time rate of change of fuel composition changes is problematic for some end use applications, including combustion turbines. As a practical matter, in general, the [Task Group] found that gas composition variability rate of change should not be a significant issue and should meet existing turbine manufacturers’ requirements.

- Presently, there are limited publicly and readily available data for the full range of end use equipment and gas supplies.

- Historical interchangeability indices have been widely used for conventional combustion appliances and are recognized default specifications when actual operating data are unavailable.

- The European experience in gas interchangeability highlights important issues for establishing U. S. interchangeability guidelines and demonstrates significant differences from the U. S.
Overly broad limits in the interchangeability specifications may result in reduced reliability, increased emissions, and decreased safety on end use equipment, and consequently higher costs to consumers. On the other hand, unduly conservative restrictions on the interchangeability specifications due to lack of data may result in both limited supply options and higher costs to the consumers.

Gas supply compositions within the U.S. vary by region depending on demand, available supply, the degree of processing and pipeline blending.

It has become apparent through the work of the [Gas Interchangeability Task Group] that significant data gaps exist that inhibit non-traditional supplies from entering the North American market. There is general recognition that a collaborative effort will be necessary to conduct research and obtain essential information necessary to maximize supplies into the marketplace including the DOE [the U.S. Department of Energy], equipment manufacturers, suppliers, pipelines, LDC's and other industry trade groups.

In addition, the following represent a partial list of conclusions arrived at by the Gas Interchangeability Task Group. Again, the White Paper presents the full list of conclusions:

- The [Task Group] recommends that appliance manufacturers and equipment certifying organizations for gas burning equipment consider adopting limit gases testing that is representative of current and future supplies. Such testing as part of the design certification process will help ensure that new appliances and equipment can deliver safe and reliable performance under varying and changing gas supply conditions.

- Additional research must be conducted to define the compositional limits of natural gas to support development of longer-term interchangeability guidelines for low emission and high efficiency combustion designs.

- The [Task Group] recognized the value in adopting a national range for key parameters such as the Wobbe Number to provide certainty for producers and suppliers. This specification is equally important for domestic supply and for imported LNG. However, the [Task Group] also recognized the need for flexibility since certain areas may be able to utilize a wider range of gas compositions than other areas.

- While adopting a wide national range for key specifications such as the Wobbe Number is important for supply flexibility, acceptable interchangeability ranges for specific regions or market areas may be more restrictive as a consequence of historical compositions and corresponding end use settings.

- The [Task Group] has identified several “information gaps” that must be addressed to better understand the overall impacts of gas interchangeability in North America. These gaps must be addressed to provide the maximum level of supply flexibility considering current global LNG import composition profiles as well as evolving domestic supply compositions.

- The [Task Group] recommends that a transition plan be adopted given the lack of readily available historical data to characterize both the change in natural gas supply and in end use equipment. The purpose of the transition period is to maximize supply while gaining additional experience and knowledge.

- The [Task Group] recognizes that compositional limits for specific gas constituents may be needed (in addition to the proposed Interim Guidelines to address non-combustion feedstock issues including but not limited to domestic LNG peak shaving liquefaction plants.

- The [Task Group] recommends that interim interchangeability guidelines be applied during a transition period of no more than three years so that the data gaps can be closed and inter-
changeability guidelines/standards can be formally developed. Alternative language was suggested as well, and long-term guidelines will be developed within a timeframe to be defined.

Finally, the Task Group proposed Interim Guidelines for gas interchangeability for the U. S. These are shown in Table 1. It is important to note that all requirements shown in the Interim Guidelines are to be met simultaneously, not individually. For example, the Wobbe and higher heating value limits shown are to be used in conjunction with the requirements for local historical Wobbe ranges. As such, a local Wobbe range cannot exceed the Wobbe and higher heating value limits. Likewise, these limits would not represent the interchangeability specifications where local historical Wobbe upper bounds were less than the limits. The Interim Guidelines also provide an exception mechanism for local market areas already characterized by interchangeability requirements and operating experience that might be inconsistent with the Interim Guidelines to continue to use their interchangeability requirements.

It is important to note that the Interim Guidelines do not represent standards, either formally or as de facto standards, for gas interchangeability. These are proposed as interim requirements (covering approximately three years) while other technical data is developed and more complete interchangeability specifications covering more end uses are promulgated.

4. ONGOING GAS INTERCHANGEABILITY TECHNICAL ACTIVITIES

As explicitly identified in the findings and recommendations of the Gas Interchangeability Task Group, additional data is needed to develop more robust and technically strong gas interchangeability specifications. Current gas interchangeability technical reviews and research studies will be very helpful in the long term. The following are some of the activities in planning or underway as of this writing.

The Gas Appliance Manufacturers Association (GAMA) is sponsoring development of a voluntary, manufacturer-based testing program for new residential and light commercial appliances produced in the U. S. Testing, expected to begin the second quarter of 2006, includes invitations for manufacturers from other organizations including the Association of Home Appliance Manufacturers (AHAM), the Health, Patio, and Barbeque Association (HPBA), and the National Association of Food Equipment Manufacturers (NAFEM), as well as AGA, and would potentially cover the breadth of U. S. residential and light commercial gas fired equipment.

Research performed and ongoing sponsored by SempraUtilities/Southern California Gas will continue to provide important contributions to understanding of end use equipment, especially with respect to newer end use technology and stringent air emissions limitations in effect in southern California. The website provides very useful information on its past and ongoing work in gas interchangeability: [http://www.socalgas.com/business/gasquality/](http://www.socalgas.com/business/gasquality/).

GTI (also referred to as the Gas Technology Institute and the successor organization to the Gas Research Institute) has initiating a survey project under sponsorship from an 11 member sponsor group to evaluate gas interchangeability issues associated with industrial and commercial gas burners. GTI is also planning to initiate a testing project on industrial burners in 2006 under sponsorship from the California Energy Commission.

The National Energy Technology Laboratory (NETL) of DOE has initiated projects on gas infrastructure affecting interchangeability, development of a database on gas interchangeability, status reviews on appliance and reciprocating engines and changes in gas compositions, and limited combustion testing of gas turbines. It is expected that NETL project work will be completed by mid to late 2006. It is unclear whether DOE will sponsor additional gas interchangeability technical activities beyond this NETL program.

In addition to these publicly accessible projects on gas interchangeability, a number of proprietary studies are ongoing. These mainly support positions in legal proceedings in the U. S. and, unfortunately, may not provide input to U. S. policy on gas interchangeability until some time later. One initially proprietary project sponsored at GTI in 2003 was released to the public in 2004 and providing
invaluable information to the Gas Interchangeability Task Group (Reference 5). It is hoped that other proprietary studies will be released in order to provide timely information.

The U. S. also needs to maintain awareness of European activities in gas interchangeability. For example, the U. S. needs to consider the activities of United Kingdom’s Department of Trade and Industry since many of the issues defined in this program mirror issues at the forefront of the situation in the U. S.

5. **REGULATORY ISSUES AFFECTING U. S. STAKEHOLDERS**

Major issues facing the U. S. gas industry are how gas interchangeability criteria are implemented in contractual arrangements between gas suppliers, pipelines, and end users (including LDCs) and how U. S. regulations, chiefly through the FERC, promulgate interchangeability criteria. Differences in linkages of regional supplies and infrastructure place different demands upon stakeholders in arriving at technically sound approaches for developing specifications. For example, suppliers spatially removed from consuming regions might expect blending of natural gas to alleviate the need for these suppliers to directly meet end user criteria such as the Interim Guidelines. However, suppliers closely linked to markets as a principal supply source, such as LNG importers and closing located LDCs, may not expect such blending and may have to meet local end user criteria directly.

With respect to federal actions, several alternative approaches may be considered. At the time of this writing, it is unclear which approach might be pursued by AGA and other principal stakeholder organizations. Approaches under consideration currently under consideration range from (1) development of policy positions between the interstate pipelines and LDCs to pave the way for future technical specification for gas interchangeability in pipeline tariffs to (2) advocacy of a formal FERC rulemaking to open up existing tariffs with the objective of introducing technical specifications for gas interchangeability. Between these extreme cases, a number of intermediate approaches may be exercised. Nevertheless, introduction of specifications for gas interchangeability will require greater exchange of information and data on gas compositions among producers, pipelines, and LDCs and other end users. In addition, LDCs and end users will need to develop and make available gas compositional data characterizing historical conditions under which local end use equipment was installed and adjusted and other information capturing operating requirements in the market area.

6. **RESEARCH NEEDS AND RECOMMENDATIONS**

Beyond ongoing technical work and research, the Gas Interchangeability Task Group identified a list of gas interchangeability research priorities. These priorities were directed to DOE and presented in December 2005 meeting for consideration. These priorities continue to be the basis for advocacy for government research funding. The following is an abbreviated summary of the research priorities:

- The DOE Office of Fossil Energy should lead federally sponsored research on interchangeability.
- DOE should establish a research steering committee made up of industry and public stakeholders to oversee planning and execution of DOE sponsored research.
- As a top priority, DOE should implement projects on gas turbines used in power generation and industrial applications.
- DOE should also implement projects that focus on industrial and heavy commercial burners and control systems and their response to changes in gas composition.
- Stationary and mobile engines and associated refueling systems also require attention to address the real versus perceived impacts of varying gas composition.
Finally, DOE should conduct analyses to forecast future gas compositions available to the U. S. market and to identify the gas specifications utilized by other countries and/or required by other international jurisdictions.

7. CONCLUDING COMMENTS

In brief, the following are some observations of the author who served the Chairman of the Gas Interchangeability Task Group. These comments are based on the activities and findings discussed above throughout this recent activity in gas interchangeability:

- Natural gas as a fungible commodity? Domestically, changes in the U. S. gas market suggest a need for broad, robust gas interchangeability specifications to serve the broadest definition of the market. Nevertheless, such specifications cannot ignore local historical conditions or, in some cases, regional markets that may remain significantly different from broader, national average conditions. Internationally, it appears clear that the U. S. market requirements are distinct from many European and Asian requirements and are unlikely to converge with overseas technical specifications in the near future. As a result, U. S. participation in the development world market may require segmentation according to gas interchangeability requirements.

- Balance of end user requirements with U. S. supply needs? Clearly, the U. S. needs access to additional gas resources if current trends in sector gas use are to continue. Maximizing supply to the U. S. market is an important strategic interest of the U. S. However, protection of consumer interests, especially end users who do not have the ability to rapidly adjust or change out end use equipment in response to supply changes, is critical to LDCs and regulatory authorities responsible for protecting public safety. Balance in meeting supply needs and end user requirements need to stand the tests of what is most economically efficient and what is equitable in allocating costs.

- Gas interchangeability requirements and the potential of excluding supply? Throughout the recent discussion of interchangeability requirements, concerns about stringent requirements excluding supply, particularly imported LNG, were voiced. Clearly, stringent requirement would place burdens at some points in the value chain for modifying gas compositions to meet the requirements. However, there is no public consensus on where such burden would or should fall and what the associated costs would be. Nevertheless, it appears less likely that such burden would, in fact, exclude supply technically. Also, while today’s costs of processing supply may raise product costs above current market clearing prices, changes in processing costs associated with production, the value of extracted products, and changes in the U. S. domestic and world markets make analysis of this situation a very fluid one with uncertain outcomes.
TABLE 1. INTERIM GUIDELINES FOR GAS INTERCHANGEABILITY, GAS INTERCHANGEABILITY TASK GROUP, 2005.

Interim Guidelines

A. A range of plus and minus 4% Wobbe Number Variation from Local Historical Average Gas or, alternatively, Established Adjustment or Target Gas for the service territory.¹

Subject to:

- Maximum Wobbe Number Limit: 52.16 mJ/m³ [1,400]²
- Maximum Heating Value Limit: 41.36 mJ/m³ [1,110 Btu/scf]²

B. Additional Composition maximum limits:¹

- Maximum Butanes+: 1.5 mole percent
- Maximum Total Inerts: 4 mole percent

C. EXCEPTION: Service territories with demonstrated experience³ with supplies exceeding these Wobbe, Heating Value and/or Composition Limits may continue to use supplies conforming to this experience as long as it does not unduly contribute to safety and utilization problems of end use equipment.

Notes:

¹ Experience has shown that using this plus/minus four percent formula in combination with the compositional limits will result in a local Wobbe range that is above 1,200.

² Based on gross or higher heating value (HHV) at standard conditions of 14.73 psia, 60°F, dry, real basis. Numbers from Interim Guidelines (shown in brackets) used to convert to IS units based on conversion constant of 37.259.

³ Demonstrated experience refers to actual end use experience established by end-use testing and monitoring programs.
REFERENCES


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Table 1. Interim Guidelines for Gas Interchangeability, Gas Interchangeability Task Group, 2005.