ioMosaic LNG Experience Summary

ioMosaic Corporation

The founding partners of ioMosaic Corporation have worked on many assignments involving LNG terminals, send-out facilities and associated pipelines and power plants. Since forming the company, ioMosaic formed a strategic alliances with two world-class experts in LNG risk assessment, namely, Dr. Elizabeth Drake and Dr. Ashok Kalelkar. A summary of ioMosaic and alliance partner assignments is presented below.

LNG Code of Practice for Nova Scotia

For the Nova Scotia Department of Energy, ioMosaic Corporation developed an LNG Code of Practice which is the companion document that is incorporated by reference into the Nova Scotia Gas Plant Facility Regulations. As part of that contract we also provided formal comments and suggested changes/additions to the proposed amendments to the Gas Plant Facility Regulations. In the course of drafting the Code, ioMosaic staff reviewed numerous international LNG regulations and standards and incorporated some of the best features of these documents into the Code. We also identified some areas in the existing Canadian LNG Standard, CSA Z276-01, where existing requirements could be supplemented.

LNG Design, Operations, and Consequence Analysis and Modeling Advice to the Canadian National Energy Board

ioMosaic Corporation has been awarded two contracts to assist the Canadian National Energy Board in their review and assessment of the application by Rabaska to construct and operate an LNG import terminal in Quebec. The first contract is to provide advice relative to the design, operation and hazard identification and control issues and concerns. The second project is to provide advice relative to consequence analysis and modeling issues and concerns. The first task will be to provide training in LNG codes and standards, and hazards and risk assessment to NEB staff.

Hazard and Operability Study of LNG Import Terminal Expansion

For Chicago Bridge and Iron, ioMosaic Corporation led a hazard and operability (HAZOP) study of the expansion of the Cove Point LNG import terminal operated by Dominion. The expansion includes new single containment LNG storage tanks and pumps, boil off gas system, shell and tube vaporizers, and baseload gas turbine power generators.

HAZOP and SIL Analysis of a new LNG Import Terminal

For Aker Kvaerner/IHI, ioMosaic Corporation led a hazard and operability study of the new LNG import terminal in Cameron LA to be operated by Sempra. The terminal will include dual marine terminal, full-containment LNG storage tanks and pumps, boil off gas system, and submerged

combustion vaporizers. In addition, a review will be conducted on all safety instrumented interlocks and shut-downs to determine the required safety integrity levels (SILs).

Other Relevant Qualifications Are Summarized Below:

We assisted a Middle East company on methods to debottleneck an existing LNG facility as well as studies on adding another liquefaction train to the facility. This work has involved a study of the plant operating data for the existing trains to identify where bottlenecks are and how to eliminate the bottlenecks. An analysis of competing technology for LNG base load liquefaction plants, the type and configuration of compressor drivers and the method of heat removal have been considered in the study for the additional liquefaction train.

For a planned LNG receiving terminal and re-vaporization facility in Japan, we conducted a hazard and operability study for a major engineering and construction contractor. The contractor was interested in comparing his design and siting practices with those in other parts of the world. Our study pinpointed a number of differences, some with the potential for the release of LNG.

We carried out an assessment of the Total Hazard Control Plan (THCP) which was prepared by Woodside Offshore Petroleum Pty. Ltd. for their Northwest Shelf Development Project in Karratha, Western Australia. This project involved a two-week analysis of the THCP for Woodside gas plant and LNG plant that required plant inspection, discussions with operating personnel and review of documents.

For the Peneulas project in Puerto Rico we evaluated the level of risk associated with the transportation, storage and handling of LNG. The proposed LNG project included a LNG marine unloading terminal, LNG storage tanks, a vaporization system, a power plant capable of producing up to 507 MW in a base mode configuration (with supplemental firing), an auxiliary diesel-cycle generator, and a sea water desalination plant. LNG for operation of the power plant would be supplied from one or more suppliers outside of Puerto Rico. The risk assessment contained several components including hazard identification (HAZOP), failure rate analysis, consequence analysis, and a quantitative risk analysis. Potential hazards to, and posed by, an adjacent refinery were also evaluated.

For the Dabhol India power facilities we performed the HAZOP study of the LNG facilities at the offices of the engineering contractor in London. The scope of this study included the ship unloading operations, storage facilities, vapor recovery and gas vaporization. In addition to the LNG facilities fire protections systems were also reviewed. The team for this study consisted of Enron personnel and essential design team members. A qualitative risk assessment approach employing a risk matrix was conducted. Based on the risk ranking of HAZOP scenarios, recommendations to minimize possible loss of containment, maloperation, failure of personnel safety systems, and fire protection were generated by the team. The recommendations for the high-risk scenarios will be implemented before the facility is placed in operation.

For the California Public Utilities Commission (CPUC), we prepared an environmental impact report for proposed LNG import terminal facilities at Point Conception, California, a remote site about 40 miles west of Santa Barbara. Siting of such a major industrial facility in an area presently used for ranching, recreational purposes and low-density residential development necessarily involves significant environmental impacts. The study evaluated a broad range of impacts involving air and water quality, geoseismic factors, marine and terrestrial biology, land use, visual aspects, socioeconomics, induced growth, cultural resource, transportation impacts, and energy use. Special studies were conducted on important issues of safety and reliability of the project as well.

We were retained by an Algerian company to conduct a detailed review and analysis of bids submitted for their 600 MMSCFD liquefied natural gas plant to be constructed in Algeria and to assist in contractor selection. Complete review of the suggested processes and/or equipment for gas pre-treatment, liquefaction, storage facilities, materials of construction, loading terminal, LNG tankers, off-site facilities, power generation, and other ancillaries were conducted, as well as evaluation of production capabilities. Plant operating costs and capital charges were reviewed in depth. Recommendations for modifications in the proposed plant were prepared. We assisted the client's engineers in their discussions with the bidders concerning modifications, changes, errors and other unacceptable portions of their proposals for a resubmittal. Final selection of the contractor was made on our recommendations.

We conducted an independent operations and maintenance safety audit of the LNG liquefaction facility in Alaska. This work included a review of applicable regulatory requirements and a thorough, on-site review of plant operations, records, plans and procedures in order to assess compliance.

Although a number of independent safety-related analyses had already been performed during planning, approval, design and construction of the project, the operators of an LNG terminal wished to have a final comprehensive audit conducted before the terminal was put into service. The audit included not only the physical facilities themselves, but also the planned operating and maintenance procedures as well as personnel selection and training programs for the terminal. This final safety audit provided a means by which problems involving both human and mechanical failures could be identified, with sufficient time before startup to implement minor modifications in design and procedures to improve safety.

For the operator of several LNG facilities, we conducted a program that consisted of the development of a generalized methodology for quantifying the risks associated with LNG facilities and the evaluation of these risks for a specific site. The scope of work consisted of an evaluation of the existing design and layout of the plant, an examination of the operational, maintenance and emergency procedures, the identification and estimation of the frequency of abnormal events that may lead to the release and ignition of LNG and the quantification of the risks to which the public may be exposed as a result of these events.

For an East Coast gas transmission company we provided consulting services during the design and construction of their LNG terminal. The terminal consists of a 600,000 barrel LNG storage tank, barge unloading capability, and 100 MMSCFD vaporization capacity. In this project we assisted the client in establishing the design criteria for this facility. During the detailed design of the facility we made complete design reviews of the contractor's specifications and drawings on behalf of the client. The facility was designed to be expanded by the addition of two more 600,000-barrel LNG tanks and 375 MMSCFD of additional vaporization capacity.

Associated with this terminal we assisted the client in the preparation of a complete draft environmental impact statement for the terminal and for the shipping of LNG required for their terminal. A complete analysis of the fire and safety hazards associated with the transportation and storage of LNG was prepared. On behalf of the client we prepared and gave testimony to the Federal Power Commission during the hearings for the approval of this facility.

For another major LNG import terminal we reviewed the design of the LNG storage tanks and foundations. This facility involves the construction of three 400,000-barrel LNG storage tanks in an area of poor soil bearing characteristics. As a result, a complete analysis of the foundation design of the tanks was made.

The operators of a major LNG terminal retained us to perform a final comprehensive safety audit just prior to

commissioning their facility. This supplemented a number of independent safety-related analyses that had already been performed during planning, approval, design, and construction of the project. The audit included not only the physical facilities themselves, but also the planned operating and maintenance procedures as well as personnel selection and training programs for the terminal. This final safety audit provided a means by which problems involving both human and mechanical failures could be identified and quantified via fault tree analysis where required, with sufficient time before startup to implement minor modifications in design and procedures to improve safety. Several significant improvements in procedures were adopted and some minor hardware problems were identified and corrected.

For the U.S. General Accounting Office, we conducted a survey of safety regulations relating to storage, transportation, and handling of LNG, LPG, and naphtha. In this project, federal, state and selected local regulations relating to the three fuels were analyzed to evaluate jurisdictional patterns, potential overlaps or gaps, and inconsistencies. Where regulations were found, we examined a number of current issues relating to environmental conditions, material selection, design for extreme environmental conditions, material selection, truck and ship design and operations, and insurance and liability. This material was used as one input to a GAO study on the safety of LNG and other energy liquids.

For the American Gas Association, we performed an evaluation of methods for reducing LNG vapor dispersion hazards. The evaluation included methods related to site development (high dikes, sloping dikes, sumps in dikes, etc.) and various active methods (e.g., water sprays, heating systems). Information is presented to assist a facility designer to use hazard alleviation methods individually or in combination as required.

We conducted a safety analysis of a nine-year-old LNG peak shaving facility in light of improvements in safety equipment, advances in LNG hazard estimation techniques and potential risks, if any, to a contiguous gas turbine used for peak electrical power generation. While the facility is exempt from compliance with many of the new regulatory requirements, the gas utility asked us to evaluate reasonable modifications in facility design or procedures to improve the level of facility safety.

For several utilities which may have potential for "LNG rollover" problems, we performed analyses of the potential for various operations which might lead to stratification of LNG, and eventually, to rollover. Using such analyses, facility owners are able to establish operating procedures or make design modifications to minimize the occurrence of a potentially dangerous "rollover" event.

For the American Gas Association, we conducted an analytical investigation of LNG safety. This included a quantitative risk analysis of the hazards of LNG storage in large tanks. As another part of this program, we evaluated and improved upon analytical models that we had previously developed for predicting the behavior of LNG when accidentally spilled on land and also considered its behavior when spilled onto water. We also reviewed, analyzed, and compared other methods for quantitatively predicting evaporation rates, vapor dispersion, and thermal radiation from burning LNG. The research program suggested experiments for verifying and enlarging the models for LNG spills on land and water.

For the Department of Transportation, Office of Pipeline Safety, we completed a project to provide current state-of-the-art safety information relative to the handling of LNG. The study included four tasks: (1) To provide a detailed review and comparison of all current major LNG code, standards, practices and regulations,

(2) To provide an evaluation of present trends in LNG safety requirements, (3) To provide a status report on LNG safety research, (4) To formulate an approach to the quantitative assessment of risks that LNG facilities present to the public in general, to abutters and to employees. This compendium of information was intended to provide a resource to be utilized by OPS in their development of improved federal LNG regulations.

We were active in the formulation and interpretation of regulations applicable to the shipment and storage of LNG. Members of our staff are familiar with the U.S. Coast Guard, Lloyd's of London, American Bureau of Shipping, and Bureau Veritas requirements for LNG tankers; we also have staff members familiar with the details of the regulations of the National Fire Protection Association, and a number of these staff members have been active in committee work with the American Gas Association and the Compressed Gas Association.

We were was retained by the Canadian National Energy Board to assist them in reviewing the primary safety issues associated with the proposed construction of an LNG important terminal at Lorneville, New Brunswick.

A conceptual design for a proposed base load LNG facility in the Arctic was prepared for a Canadian consortium. The related capital and operating costs were estimated. The economics were determined for a number of different capacity ranges between 750 mm standard cubic feet per day and 4.5 billion standard cubic feet per day. The conceptual design was based on a module concept of liquefaction plants with each module (comprising three individual liquefaction lines) having a capacity of 500 MMSCFD. The proposed means of transporting the LNG from the Arctic was by railroad so that a tank car loading facility was incorporated in the base design.

For a Middle East country a study was made to utilize offshore flare gas as a feed to an LNG facility. This study included the conceptual design and economics relating to natural gas liquid extraction facilities, natural gas liquefaction, storage and tanker loading. During the course of this work the available gas reserves, gas composition and preferred plant sites were determined. The overall economic viability of the project was estimated for two different locations of the liquefaction facilities.

For a Far East country, the feasibility of importing LNG from an existing liquefaction plant was determined. The siting of the import terminal was chosen and the economics of the terminal, harbor facilities and pipeline system determined.

We also assisted the CPUC in technical areas relating to preparation of new regulations concerning safety of LNG facilities during construction and operation. Project staff prepared over 30 supporting technical reports on various aspects of the study, and team members appeared as expert witnesses during public hearings by the Commission.

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