NBBJ

Samsung AHQ (DS)

Façade and Structural Risk Assessment of Natural Gas Pipeline Explosion Hazard: Report to City of San Jose

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1 Introduction

Arup has been commissioned by NBBJ to assess the risks of a natural gas pipeline located in an easement in close proximity to the proposed redevelopment of the Samsung AHQ (DS) campus buildings (the "Project") in San Jose, CA. The purpose of this report is to identify potential blast hazards associated with the natural gas pipeline owned and operated by Pacific Gas and Electric Company (PG&E) at its proposed new location and to estimate risks associated with the redevelopment site in proximity to the pipeline.

To quantify the risk, the following tasks were performed:

- Gather information on the existing natural gas supply arrangements in order to estimate the properties of new pipeline
- Develop deflagration scenarios (i.e. an explosion due to the delayed ignition and the combustion propagating through heat transfer of a vapour cloud formed by the mixing of natural gas with air following an accidental release from the pipeline) and associated likelihoods of occurrence; calculate explosive and flammable masses associated with each scenario
- Determine effects of deflagration events on the building design
- Assess the risk using provided and calculated data

In this study, the risk is defined as the potential exposure of the building structure to blast overpressures from a vapor cloud explosion that could occur as a result of a pipe failure or a leak originating along the pipeline. This study is related to impacts from a blast and the lethal and environmental exposures have not been evaluated.

The risk assessment methodology is described in the subsequent sections of this report.

2 Project Description

The Project consists of the Headquarter Tower, Podium structure, Parking structure, and Cafeteria pavilion in a campus setting located in the north-western corner of W. Tasman Drive and N. 1st Street. The proposed 50 feet standoff between the centreline of the relocated natural gas pipe easement and the south elevation of the proposed Samsung AHQ (DS) campus buildings is shown in Figure 1 and Figure 2.

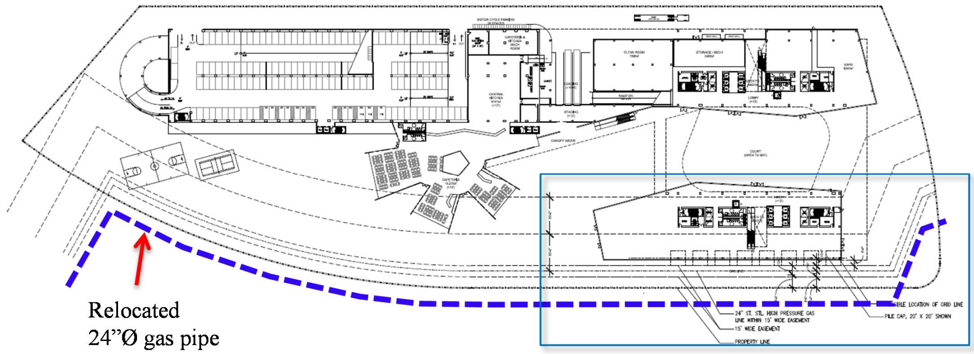

Figure 1 Site plan sketch and proposed location of natural gas pipeline

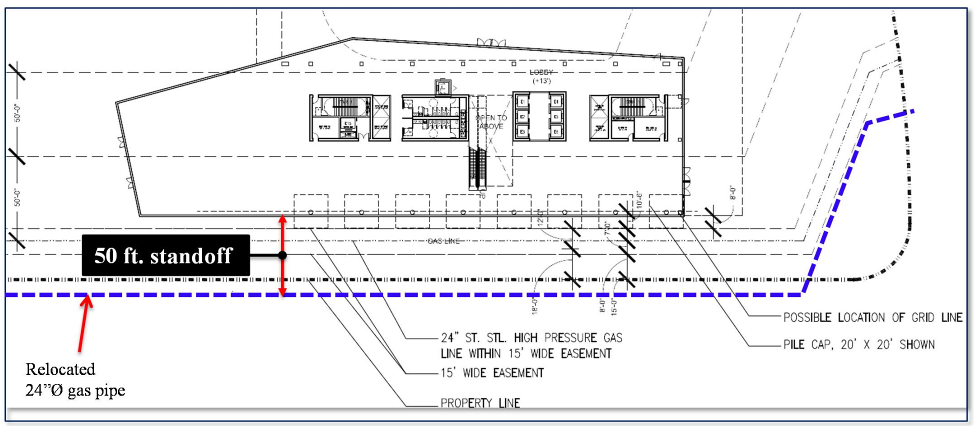

Figure 2 Proposed building foundation plan and proposed location of natural gas pipeline (Enlarged from Figure 1)

3 Data on Natural Gas Pipe

The preliminary risk assessment of the proposed redevelopment design is based on the following information obtained from PG&E at the time of this assessment (1/24/2013) including pipeline operating parameters, and material and section properties for the subject pipeline:

- Pipeline size: 24 inches.
- Pipeline operating pressure: 400 psig (27.6 bar).
- Pipeline length between upstream and downstream automatic valves to isolate the inventory approximately 5 miles.
- Natural gas flow rate: 25-30 MMSCFH (200-235 m^3/s).
- Automatic control valves that would close off the gas supply would “take several minutes to fully close” per PG&E. This study assumes close off time to be 5 minutes.

4 Preliminary Risk Assessment

4.1 Design Conditions

In the preliminary risk assessment, we determined in consultation with Samsung that the risk of the existing pipe of relatively unknown quality in close proximity to the proposed building is too large for Samsung to accept. Thus we are proposing that a new pipe of known quantity is placed at a minimum standoff of 50 feet from the proposed building.

The detailed design of the pipeline has not yet been developed. Specifically, the design life, wall thickness, location of flanges, leak detection, location of additional isolation valves, and the design of protective over-slabs are unknown at the time of this preliminary assessment. Consequently, the preliminary risk assessment is not based on specific leak scenarios but based on conclusions about the probable maximum credible leak size derived from the available data on the design approach for the new pipeline. This is combined with the output of engineering calculations and with engineering judgement and assumptions to evaluate the potential risk exposure of the Samsung AHQ (DS) campus.

Limited design information has currently been developed on the design, material properties, construction tolerances, quality controls and inspection and the location of isolation valves for the proposed relocation of the pipeline. However, given the new nature of the construction, the design is planned to be developed such that the likelihood of a rupture occurring in the pipeline is minimized, and further that the likelihood of a fractional leak escalating to a full-bore rupture is sufficiently small.

Consequently the pipeline can be designed to be largely safe by design such that the likelihood of a full-bore pipe rupture occurring is sufficiently remote and the maximum credible event is a fractional gas leak. The design requirements for the proposed building are assessed upon the basis of the residual risk associated with this hazard scenario, not upon the basis of a full-bore pipe rupture.

In the preliminary risk assessment we have made the following assumptions about the design of the pipeline. It is envisaged that these criteria will be included in the design of the new pipeline by PG&E:

- The wall thickness for the design of the new pipeline will be sized, taking into account maximum corrosion rates that may be considered, such that the risk of through-wall corrosion during the design life of the Samsung AHQ (DS) campus development is negligible.
- Flanged connections will be minimized such that the leak sources are eliminated in the vicinity of the building so far as it is practicable to do so.
- Weld inspection procedures will be utilized which minimize the risk of undetected wall defects.
- A protective slab will be designed over the pipeline to minimize the risk of accidental rupture e.g. by a backhoe excavator during road repairs.
- Pipeline inspection and maintenance procedures will be implemented to ensure that undetected damage is identified and rectified.

- Quality assurance and record keeping procedures will be implemented such that a good level of knowledge about the presence and design of the pipeline can be assured amongst all relevant parties during the operating life of the pipeline.

The risk exposure of the Samsung AHQ (DS) campus is estimated based on:

(1) The hazard scenarios leading to deflagration;

(2) Evaluation of blast effects on the new development under the given hazard scenario

(3) Assessment of risk by combining the estimated likelihood and consequences of the hazard scenario.

4.2 Hazard Scenario

As discussed in Section 4.1 the design requirements for the proposed building are assessed upon the basis of a fractional gas leak, not upon the basis of a full-bore pipe rupture.

Deflagration requires a delayed ignition of the flammable gas vapour cloud, or immediate ignition leading to a jet fire. The potential consequences of a gas leak leading to deflagration vary according to the characteristics of the surrounding area. An ignition source within the flammable volume of the gas vapour cloud will result in the combustion of the gas, and the associated generation of overpressures through the form of a blast wave which will propagate through, and then away from, the gas cloud, and will load the building and other structures and objects in the vicinity. Per Natural Transportation Safety Board[1] (NTSB), the typical ignition sources are sparks generated from the sudden rupture of the pipe steel or from mechanically generated sparks (i.e. sparks related to the pipe breaking). Secondary ignition sources (i.e. sources leading to either immediate or delayed ignition) include street lighting, telecoms switchgear cabinets, electrical switching gear, naked flames, cigarettes, static electricity, spark, hot work, welding and grinding operations, hot vehicle exhausts and arcing/discharge from overhead high voltage cables.

Leak modelling has been undertaken which shows that due to the high volumetric gas flow in the pipe, the initial release rate will be maintained until isolation valves are closed. Using deflagration plume models, it has been determined that a fractional leak will rapidly lead to a steady-state plume, which will be maintained while the release rate remains constant. The release rate and plume size begin to decay once the isolation valves begin to close. The total flammable volume between the upper and lower flammable limits (UFL and LFL respectively) has been calculated for a range of leak rates (hole sizes) based on a steady-state plume size. Atmospheric conditions are assumed negligible as leak modelling has shown that the UFL and LFL are within the momentum-driven plume.

The TNO Multi-Energy Model (van den Berg, 1985[2]; van den Berg et al., 1991[3]) is used for a rapid assessment of explosion overpressures and positive phase

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[1] Records on pipeline incidents are maintained by NTSB and are available at http://www.ntsb.gov/investigations/reports_pipeline.html

[2] van den Berg, A.C., J. Hazardous Materials 12, 1-10(1985).

durations. This commonly used model is developed based on the extensive research in to blast models by The Netherlands Organization for Applied Scientific Research (TNO). The TNO Multi-Energy method assumes that the vapour cloud explosion is composed of a number of sub-explosions occurring inside specific areas of the vapour cloud, corresponding to the various sources of blast that exist in the cloud. Based on the overall dimensions of the vapour cloud volume, the volume of the blast source (i.e. fuel-air mixture) is calculated. The corresponding combustion energy and blast strength are then estimated, and the resulting overpressures calculated.

4.3 Blast Effects on the Samsung AHQ (DS)

The consequences of a potential explosion on the Samsung AHQ (DS) campus buildings is investigated by determining the damage level of the structural components and façade elements subjected to the blast pressures and impulses calculated using the TNO multi-energy method as described in Section 4.2. For this purpose, appropriate structural and façade analysis[4] are used to estimate the performance of the structural system. Acceptable performance criteria for the structural and façade design are per technical standards including ASCE Design of Blast Resistant Buildings in Petrochemical Facilities (1997).

Based on the results of the blast this preliminary analysis, it is found that the current building design is generally adequate. Minimal design enhancements may be required as the building design is developed further. Potential enhancements to façade systems include use of double-laminated annealed insulated glazed units to the south façade, structurally silicone glazed with blast design and detailing of framing members. Minor structural enhancements may also be required.

4.4 Risk Assessment

Based on the consequence analysis summarized in Section 4.3, the façade and structural risk associated with natural gas pipeline explosion hazard at the standoff distance of 50 feet has been found to be tolerable. Depending on the final engineering of the pipeline design and of the building design, some minor amendments to the façade and structural design may be necessary.

5 Summary and Recommendations

The intent of this preliminary risk assessment is to provide an indicative level of risk associated with a deflagration of a new natural gas pipeline at its proposed new location (i.e. 50 feet away from the Samsung AHQ (DS) campus buildings), so that Samsung AHQ (DS) can make informed decisions at this stage of design.

The study has undertaken a preliminary estimation of the impact associated with a gas leak leading to deflagration for the proposed natural gas pipeline which is

[3] van den Berg, A.C., van Wingerden X.J.M., The, H.G., Transactions of IChemE. Part B, Vol. 69, 139-148(1991).

[4] Blast calculations are performed using in-house software; Ergo, which is proprietary software based on the information in the military technical manual UFC 3-340-02 and other good-practice blast engineering manuals. Analytical methodologies employed by Ergo are derived from the first principles of structural dynamics using nonlinear generalized stiffness methods to predict response of structural components.

located at a stand-off distance of 50 feet from the proposed development. It is shown that the risk associated with deflagration is generally tolerable with only minimal enhancements to the building structure and façade potentially being required. These findings are based on a number of design assumptions about the design of the new gas pipeline, which are summarized in section 4.1 above. These assumptions will be verified as the design becomes further developed.

The preliminary nature of this study necessitates that more refined risk and engineering analysis be performed as the design develops, to determine the detailed requirements for the design and construction of the pipeline and the building options discussed herein. To better quantify the risks to the development from the gas line and the necessary design measures, the following steps are recommended:

- Review PG&Es construction standards and quality control procedures for the design, construction and installation of the proposed gas pipeline against our assumptions and provide recommendations.
- Develop a more refined risk analysis and engineering design appraisal as further design information becomes available to determine the specific leak scenario corresponding to the design life of the building, based on detailed information about the design of the gas pipeline.
- Develop in further detail the consequence assessment of the design of the façade and structural design, and incorporate any necessary design enhancements as outlined in Section 4.3.