ATMOSPHERIC DISPERSION OF EMISSIONS DUE TO LEAKAGES IN PRESSURIZED NATURAL GAS DUCTS

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Abstract — A simplified approach is presented to the transient atmospheric dispersion of accidental releases of natural gas, originated by leakages in pressurized ducts on sea level. In this scenario, shut-off valves are used for instantaneous shutdown of tube operation, isolating the harmful inventory, whose transient release is simulated providing estimations of gas instantaneous atmospheric concentration. The analysis further covers the transient behavior inside the ducts through a leakage model and the occurrence of multiple ruptures, synchronized or not, with known spatial distribution. The time-space dispersion model employed accounts for: (i) atmospheric conditions, (ii) wind speed, (iii) transient conditions of gas release into the atmosphere, and (iv) plume rise. The process of continuous release is approximated by a finite sequence of pulses, known as “puffs”. Discrete puffs have volume dependent on release intensity, which depends on the actual time instant, as inventory decreases due to emission.

Keywords — Atmospheric Dispersion, Multi-Source Plumes, Plume Rise and Leakage.

I. INTRODUCTION

Considering the flammability risk of materials in offshore processes, the pressures and flow rates involved, the atmospheric releases of natural gas from leakages (or failures) in a platform and/or in its neighbor pipeline system configure events of high risk, which, in case of pipeline rupture, can cause significant fatalities and damages to the environment. The prediction of the ensuing release rate and its variation with time are the two critical pieces of information required in assessing and quantifying the consequences associated with such failures and may dictate the survival time of the mechanical integrity of the production platform (Mahgerefteh et al., 2003). An example of an offshore incident related to gas release is the propagation of fire from the Tartan riser failure, in 1988 on North Sea. This leakage set the destiny of the Piper Alpha platform, generating 167 deaths, total loss of the platform and hundreds of millions of dollars in losses (Cullen, 1990).

On the occurrence of an emergency, the main strategy of protection against a leakage of light hydrocarbons consists on isolation of the damaged duct and its dangerous inventory through shut-off valves, while the gas is liberated to the atmosphere. This solution is difficult to put into practice due to interconnecting ducts and risers, being the failure of those, in general, the main factor defining the risk level. The crew proximity to possibly dangerous situations and its confinement on vessels bring extra need to risk assessments, such as: (i) transient behavior on leakage flow rates; (ii) response time of detection and shutdown systems; (iii) time-space distribution of the leakage plume around the rupture point; (iv) effects of gas transport in the atmosphere.

The present work focuses on the occurrence of leakages on pressurized gas pipelines (risers and ducts to mainland) on production platform adjacencies. Specifically, the occurrence of ruptures on natural gas pipelines is investigated. Therefore, physical effects of a particular event are approached, such as discharge flow rate, alterations on ducts network flow and atmospheric dispersion of the leakage plume around the rupture point. The dispersion model employed is based on numerical resolution of the Tri-dimensional Diffusion Equation, under turbulence and on semi-infinite domains (Medeiros, 1993). The model accounts for: (i) ample variety of atmospheric conditions, changing the dispersion coefficients in function of the Pasquill stability classes recommended by Briggs (1973) and E.P.A. (1995); (ii) wind velocity, admitted constant, parallel to the sea level and corrected to the discharge height (E.P.A., 1995); (iii) transient conditions of gas release into the atmosphere, such as velocity, flow rate, pressure, temperature and density (Medeiros, 1993); (iv) plume rise as a function of buoyancy force, momentum, discharge height, wind velocity and atmospheric conditions (E.P.A., 1989). The analysis contemplates the impact of shut-off valves location, and spacing among them, as well as the gas release to the atmosphere.

II. ATMOSPHERIC CONDITIONS

Atmospheric dispersion of hydrocarbon clouds depends strongly on how the atmospheric emission interacts with the wind, according to stability conditions. Dispersion conditions may vary drastically on the same instant, on the same location, as function merely of a small height difference with respect to the observed emissions – Fig. 1 (Turner, 2002).

Therefore, the dominant factor in a time-space dispersion model of the leakage plume is the determination of stability conditions related to the simulated atmospheric emission. The main atmospheric conditions are divided into six different classes of...