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Consequences of a 12-mm diameter high pressure gas release on a buried pipeline. Experimental setup and results

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ABSTRACT

When considering the transportation of gas through high pressure pipeline and associated permitting, the 12-mm diameter breach is one of those commonly considered as accidental scenarios and the associated consequences must to be calculated for determining the required safety measures. Up to now this "12-mm" scenario was modeled at the convenience of each risk analyst with no certitude on the real behaviour of the gas in the soil for these types of releases.

To obtain concrete information on the "12-mm" scenario considered as the sizing event for safety distances associated to a little breach due to corrosion for instance, AIR LIQUIDE, ENGIE, NATIONAL GRID, PETROBRAS and TIGF decided to launch in 2013 a JIP (Joint Industrial Program) named "CRATER". The aim of this project was to improve knowledge on the consequences of leakages occurring on buried high pressure pipes, and to determine what were their behaviour and their impact on the soil – i.e. crater formation, or not, according to release parameters – in order to use the appropriate methodology for risk and consequences assessment. Thus by changing several parameters – like nature of gas, initial gas pressure, type of soil … – the threshold between crater formation and gas dispersion in the soil following such leakages was investigated (specifically for methane and hydrogen, flammable and light gases). INERIS was chosen as subcontractor to perform nearly-full scale tests on its experimental site in order to collect reference data, understand phenomena and correctly assess the gas behaviour for accurate risk evaluation.

1. Introduction

Western Europe is crossed by a network of onshore gas transmission pipelines 145 000 km long. Most of these pipelines are buried with the exception of some above ground components that are necessary for their effective functioning (compressor/pumping stations, block valve stations …). Approximately 20 incidents leading to unintentional gas release are reported each year on this network. From 2004 to 2013, 35% of these incidents were caused by third party (external aggressions) and 24% by corrosion, 16% by material weakness, 13% by ground movement. The origin of the other incidents is unknown (EGIG, 2015).

Associated to these major causes, release sizes were defined according to operation feedback through several years. Thus, by compiling recognized databases (e.g. EGIG, UKOPA, DOT …), it results that the most foreseeable cause of damage on a buried pipeline is the corrosion and a representative size of these releases is given from 12-mm diameter hole for the lower end and 50-mm diameter hole for the upper end. Higher release sizes are attributed for instance to "pirate" works, ground movement … Regarding these values the consortium decided to focus the study on the lowest size, i.e. the 12-mm diameter hole release (GESIP, 2012).

When considering the safety of pipelines, it is necessary in case of an accidental gas release on a buried pipeline to realistically determine the phenomenon to calculate the consequences of such an event. Fig. 1 presents assumptions made on the behaviour of releasing gas and ground during the release.

A number of previous experimental programmes have been carried

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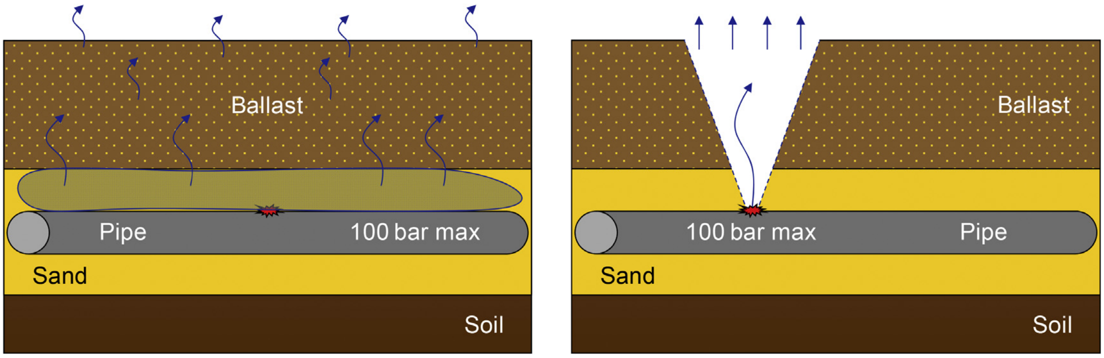

Fig. 1. Impact on the ground of an accidental release on a buried pipeline and assumption on gas evacuation from release point to ground surface: gas diffusion in the soil at left, crater formation giving free gaseous release at right.

out on pipelines mainly to investigate the fire characteristics of a gas release from ruptured pipelines (Acton et al., 2010). Also several references were published in the scientific literature presenting the results of trials campaigns and for lots of them a pre-formed crater was present before the release. This was because the objectives were mainly to study the consequences and the effects of the released gas, ignited or not (for instance, see review of scenarios for CO_2 releases by Gant for COOLTRANS research programme, 2012).

Concerning the real behaviour of the gas on the soil in case of release, even if experiments were carried out on this subject, it is more difficult to find published references. One study performed by DNV GL for National Grid was presented at the 23rd Hazards international symposium arranged by the Institution of Chemical Engineers (I.Chem.E.) in 2012. This was on a CO_2 buried pipeline and considered a horizontal release giving an uplift of the soil for a 50.8-mm diameter release hole at 35 bar; i.e. no formation of open crater at the ground surface was observed (Allason et al., 2012). Other studies were found, but for diameter of release higher than 12 mm.

Because of the lack of available data on this subject which is fundamental for a realistic assessment of the consequences associated with gas releases on buried pipelines, AIR LIQUIDE, ENGIE, NATIONAL GRID, PETROBRAS and TIGF launched in 2013 a JIP (Joint Industrial Program) named “CRATER” aiming at studying the behaviour of a light and flammable gas in the soil by simulating accidental releases on a high pressure buried pipeline.

Thus the objective of this collaborative work was to increase knowledge and understanding to correctly assess the consequences of this kind of accidental scenario.

In order to reach this goal, the CRATER JIP consisted mainly in a nearly-full scale test campaign performed by INERIS on its own experimental site located in Verneuil-en-Halatte (France). The test facility specifically developed, set up and operated by INERIS allowed the tests to be carried out in nearly-real conditions of transmission pipeline operation. The scenario specified initially for this campaign was the 12-mm breach – representing the potential consequence of the corrosion phenomenon on the basis of operation feedback through several years – commonly evaluated to demonstrate the safe operation of pipelines located close to public areas.

This paper describes the experimental set-up and conditions, and gives an overview of the findings on the 12-mm diameter release accidental scenario.

2. Presentation of the test facility and experimental means

2.1. Leak simulation experimental test facility

First of all, it is very important to highlight that the experiments targeted in the CRATER project were complex, technically difficult, and had the capability to be highly dangerous if the potential hazard was not seriously considered at the design stage for the test facility, during the set-up, the trials and afterwards. Thanks to a thorough analysis of the risks and the production of comprehensive procedures and robust safety features, the tests were carried out safely.

Regarding the objectives of the work, a dedicated test facility was proposed by INERIS and set up on its experimental site of Verneuil-en-Halatte (France). A diagram which shows the main elements of this test facility is presented in Fig. 2 to help understand how the tests were carried out.

For the simulation of an accidental release on a buried pipeline and in order to carry out nearly-full scale trials, the idea was to bury at a 1-m depth a specific pipe of 40-cm external diameter and 3-m length as shown in Fig. 3 (so-called “representative pipe”, described later in more details) (see Fig. 4).

Note that there is no “golden rule” for pipeline burial, but some Regulations can require that transmission pipelines be buried at least 75 cm below the surface in rural areas and deeper in more populated areas. Moreover, practices of the operations have been investigated as well. Thus 1-m depth for this study appeared as a realistic and generic location.

As shown in Fig. 2, a nitrogen reserve is available for inerting the experimental facility in case of dangerous event during the tests performed with the flammable gases, i.e. methane and hydrogen.

Because it is technically and economically difficult to pressurize a 40-cm diameter pipeline, it was decided to feed the releasing point with a smaller pipe of a 1-inch inner diameter. This smaller pipe was connected to several bundles of 200-bar gas cylinders; the number of bundles depending on the targeted pressure and the duration of the trial.

By following this experimental design, consumption of gas was minimized and it was possible to keep a quasi-constant pressure during the trial. The preliminary tests performed with nitrogen allowed release time duration to be defined, regarding the pressure variation and the behaviour of the soil. Thus a duration of release of 30 s appeared to be sufficient enough in most of the cases to establish the phenomenon. Additionally, the presence of camrecorders – giving a real time view of the releasing zone – permitted to adapt release time when needed.

The 40-cm diameter “representative” pipe hosts the 1-inch feeding pipe, and simulates the real congestion in the soil which can be an obstacle for releasing gas and modifying its behaviour.

Before a trial, the release point was blocked by a rupture disk calibrated to burst at a specified pressure. Thus several rupture disks were used according to the targeted release pressures.

The 40-cm diameter “representative” pipe was installed inside a trench and buried in the soil as shown in Fig. 5 at a 1-m depth from the ground surface.

After each release test, the soil was removed from the trench, a new rupture disk placed at the release point, and the 3-m “representative” pipe possibly physically turned to change the release orientation (i.e.