VOC vapour recovery processes and control technologies

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Abstract

This article explores the potential for a complex technical implementation of petrol vapour recirculation in the European Union, with a focus on the recovery of volatile organic compounds (VOCs) generated during the transport and storage of petrol. The legal framework, including directives such as the Stage I and Stage II petrol directives, plays a crucial role in reducing VOC emissions. The impact of these measures on air quality and resource protection, and the positive effects of the technologies used in terms of significant VOC emission reductions over the years, are highlighted. This article provides an insight into the state of the science and opportunities for further improving VOC recovery and emission reduction efforts. Our work was supported by the Research and Development Grant 2018-1.1.1.-MKI-00153.

Keywords:
Petrol stations, gas recirculation, inspection

I. Introduction

The handling and filling of petrol releases petrol vapours, including the carcinogen benzene. Consumers, staff and residents living near petrol stations are particularly vulnerable. To limit petrol vapour emissions, the Air Pollution Control Regulation requires petrol stations to be installed and operated in such a way that they can emit no more than 5 per cent of the organic substances in the displaced air when petrol-fuelled vehicles are refuelled.

At the request of the enforcement authorities, the "Manual for Refuelling Stations" was compiled and published in 2004, for the first time in Germany. This listed, among other things, the vapour recovery systems and measuring devices tested by EMPA. In the meantime, European standards regulate the type approval of vapour recovery systems (SN EN 16321-1) and the inspection of vapour recovery systems (SN EN 16321-2) throughout Europe. These two European standards have been mandatory in the EU since May 2016 under Directive 2014/99/EU. This implementation guide for petrol stations is from this point on based on these standards and replaces the list of systems and devices with the corresponding standard references. For example, a vapour recovery system is considered to be properly installed if it complies with the relevant standard. Similarly, individual measuring instruments are no longer listed, but only the requirements of the standard.

II. Regulation

Petrol vapour recovery ("petrol vapour cycle") is an international success story in emissions reduction. It is practically free of negative side effects and involves not only large industry (refineries) but also small and medium-sized enterprises (petrol stations) and end-users (motorists).

The process involves the principle of a high reverse flow of petrol as a vapour and the return of petrol vapours displaced during tank filling and car refuelling processes back to refineries or petrol storage facilities.

Liquid petrol is transported from the producer, through refineries and filling stations, to the end user via a large number of distribution stations. Due to its relatively high vapour pressure, petrol readily enters the gas phase and reaches a relatively high saturation concentration of about 1 kg/m3 (the steady state rule of thumb2). These petrol vapours are returned from the vehicle tanks to the tank farms or refinery in the opposite direction to the petrol transport. There they are liquefied again. As a result, around 1 ‰ of the petrol transported can be recovered and is once again available as a valuable feedstock. This completes the "petrol vapour cycle". In principle, this is a simple relationship, but the technical implementation is complex. [1][2]

III. RESystem structure

In general, the conditions of SN EN 16321-1 apply, according to which the following concepts are distinguished:

"Phase 1" steam recovery

"Phase 1" describes technical routines to prevent possible emissions of petrol vapour during transport to the service station. These measures concern the transport vehicle, the hose and connection lines and the storage tanks of the

service station, including the pressure equalisation lines.

These measures are designed to capture the petrol vapours that escape when the storage tanks are filled and return them to the transport vehicle's tank. [9]

"Phase 2" steam recovery

"Phase 2" describes the technical measures to reduce petrol vapour emissions during refuelling of vehicles. These apply to pistols, hoses, dispensers, connecting lines and filling station storage tanks, including pressure equalisation lines.

These measures are designed to capture the petrol vapour that escapes when vehicles are refuelled and return it to the storage tank.

"Active systems"

Active systems are systems that use a special transport device (a gas transfer pump) to recover the steam.[6]

"Passive systems"

Passive systems are systems that use the delivery pressure of the fuel pump to recover the vapour.

"Automatic function assurance, monitoring"

The automatic functional safety device automatically detects faults in the operation of the vapour recovery system and in its own operation (self-monitoring functional safety device). Self-monitoring functional safety devices for vapour recovery systems may, if necessary, control the vapour recovery rate up to 100 %.

IV. Technological description

Phase 1 vapour recovery

a. The pressure-vacuum valves on the tank breather line operate so that the system remains closed under normal conditions. This is guaranteed up to 25 mbar pressure. The negative pressure in the vacuum range shall not exceed -10 mbar.

b. Valves that leak and are therefore not fit for purpose are replaced immediately.

c. Pressure vacuum valves and deflagration flame arresters are maintained and functionally tested in accordance with the manufacturer's instructions, for example during water protection inspections.

The following equipment is also recommended:

- A latching condition to ensure that the fuel flow can only start when the vapour recovery system is connected and is interrupted if the vapour recovery system is not functioning properly.
- A tank level measuring device that does not require a tank opening for measurement (e.g. electronic device) [10].

Phase 2 steam recovery

- Steam recovery gas hose lines are laid with a minimum 1% continuous slope towards the tank... If low points and subsequent back slope cannot be avoided for technical reasons, labeled condensate drains shall be installed.
- The pipe diameters of the entire vapour recovery system (individual lines, manifolds, interconnecting lines between storage tanks, pressure equalisation lines, etc., including all fittings) are sufficiently large to take into account the transport capacity of the system and the length of the filling station. The installation instructions and the manufacturer's maximum permissible back pressure are decisive. When replacing one system with another in an existing piping system, compatibility must be guaranteed and, if necessary, correct operation must be checked by measurement. Verification of operation can be done by metrological verification of vapour recovery rates.
- The fuses of the electrically driven components of the vapour recovery system (pump, control unit, etc.) are connected to the fuses of the electrically driven components of the fuel delivery system.
- Deflagration flame arresters are sized so that the increased back pressure does not damage the vapour recovery system.

Automatic function lock is also recommended:

In the event of a failure or malfunction of the vapour recovery system, the automatic function assurance system will give an audible or visual alarm and automatically cut off the fuel supply if the system is not repaired within 72 hours of the alarm sounding in each country. A fault code may appear on the display or on the web back-up service interface to quickly rectify the fault. [6][7]

V. Practical experience of the system

Examples of faults that trigger an appropriate signal from the monitoring system:

- Faulty gas pump
- Failure of the pump drive (power supply, drive, etc.)
- Control unit failure
- Vapour recovery rate exceeding the permissible limit (The deviation of the vapour recovery rate from the petrol volume must not exceed ± 15 %. 3.)

Gas hose lines

- Vapour recovery units containing different products are fitted with connections to ensure that the petrol vapours are directed to the correct petrol tanks.
- In the case of siphoned tanks, the gas side of the tanks is also siphoned.
- In the case of new construction or alterations, the steam recovery and pressure equalisation piping shall be designed as shown in the following schematic drawings. If a different version of the piping is chosen, it must be demonstrated that it will not result in higher emissions.
- To prevent product mixing in case of overfilling, the tanks can be equipped with ball valves at the inlet of the vapour recovery and siphon lines. [3]

VI. Conclusion

The monitoring systems used in petrol stations play an important role in improving the efficiency and safety of the plant. These systems typically perform a number of functions, some of which include:

Supervision and intervention

Remote monitoring: it is possible to monitor the system remotely and intervene to respond immediately to threats.

Monitoring and user notification: operators will be notified or alerted of problems that arise, allowing for immediate action.

Regulatory compliance

Environmental regulations: such systems can help plants comply with environmental regulations.

Safety compliance: helping plants to comply with safety regulations and avoid hazards[4]

Performance analysis and maintenance

Data analysis can be used to monitor the performance of machines, equipment and infrastructure. This enables the planning and optimisation of maintenance work, minimising downtime and improving equipment efficiency.[8]

Energy efficiency and environmental protection

By using data analytics, operators can monitor energy consumption and improve energy efficiency. This can reduce environmental impacts and minimise operating costs.

Data analysis can therefore help service stations to operate more efficiently and improve their business performance in a number of areas. Collecting and analysing data can help operators make smarter decisions, respond to customer needs and improve business outcomes.

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