

LPG Forklift Fires Briefing Report

A report of the findings of an HSE investigation into a series of LPG forklift truck fires that occurred in GB in 2022-4

November 2024

Report on LPG Forklift Fires in GB 2022-24

This report has been prepared as a briefing covering the outcome of the recent HSE investigation into a number of fires involving liquified petroleum gas (LPG) powered forklift trucks. The detail provided in the report is limited by the requirements of Section 28(7) of the Health and Safety at Work etc Act 1974.

Background

1. HSE became aware, via an industry stakeholder, that on 17th October 2022 there had been a fire, involving two Liquefied Petroleum Gas (LPG) powered forklift trucks (FLT) at a paper factory. The incident was reported to HSE as a dangerous occurrence under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR).
2. Reports were then received from industry stakeholder groups of other LPG forklift truck fires and significant increases in the rate of breakdowns and demand for replacement parts caused by the build-up of a tar-like substance in the LPG vaporiser units and fuel systems of these vehicles.
3. In November 2022 the UK Material Handling Association (UKMHA) issued their own safety alert to warn forklift truck operators and repairers of the problem. This alert formed the basis of the HSE safety notice to allow wider circulation beyond UKMHA members.
4. On 17th January 2023 an industry stakeholder wrote to HSE to express their concern about the fires and the problems they knew about with a range of lift trucks used by member companies.
5. In February 2023 HSE began a wider investigation of the fires and the problems affecting the operation of LPG powered lift trucks. The remit of the wider investigation was to understand the extent and causation of the problem, to ensure that remedial measures were taken by the relevant duty holders to prevent further forklift truck damage and fires and to address any underlying causes of the contamination problem to prevent a re-occurrence in the future.

Industry Reporting

Reporting of Forklift Fires

6. During the investigation, four fires involving forklift trucks were reported directly to the HSE using the RIDDOR system to report dangerous occurrences, i.e. RIDDOR Dangerous Occurrence no. 25 - An unintentional fire in any plant (in this case a lift truck) ... which results in the stoppage of that plant for more than 24 hours.
7. It is known that a fifth forklift fire was correctly reported to the relevant local authority, as the enforcing authority for an incident that happened in a warehouse/distribution environment.
8. One further forklift fire was reported to the HSE, however initial investigations revealed that it was caused by the unsafe maintenance of the truck's LPG system by the engineer, rather than problems caused directly by the buildup of the tar-like substance.
9. During the course of the investigation, information was received from industry stakeholder groups about other LPG forklift truck fires, or "thermal incidents" as they were sometimes referred to; however, these incidents were not then reported to the HSE. The lack of timely information meant that evidence was lost before any of these additional incidents could be investigated.
10. Of the four forklift fires involving contaminated vaporisers, reported to the HSE, two still had evidence available that could be examined. These incidents were investigated by Field Operations Directorate (FOD) to check compliance by the duty holders in the maintenance and operation of their lift trucks. Only minor breaches were found regarding the site owners and FLT suppliers for these vehicles. Samples of LPG gas and damaged vehicle parts from these incidents were examined by HSE Science Division as part of the wider investigation.

Reporting of Problems with Forklift Vaporisers

11. Reports were received from industry stakeholder groups of significant increases in the rate of breakdowns and demand for replacement parts, caused by the build-up of a tar-like substance in the LPG vaporiser units and fuel systems of these vehicles.

12. Vaporisers on forklift trucks take liquid LPG from the tank, vaporise it, regulate the pressure and supply the LPG vapour to the engine where it is burnt as a fuel/air mixture. Any higher boiling point contaminants in the fuel supply can be deposited in the fuel system on vaporisation of the fuel.
13. Historically it normally takes 1000 to 3000 hours of lift truck use for enough of the normal contaminants in LPG to build up to a point at which they can cause a problem and require the vaporiser to be replaced. This equates to around half the service life of a typical lift truck. The evidence from industry was that, from the autumn of 2022, contamination was now building up much more quickly and that a new vaporiser fitted to a forklift truck in an affected area could require replacement after tens of hours of normal use.
14. Figures supplied to the HSE from forklift manufacturers/suppliers showed that at times there had been a seven-to-ten-fold increase in the demand for vaporiser replacements, compared with historic levels of use.
15. The contamination problem affecting the LPG has the following attributes:
 - a. It is geographically limited to sites predominantly in the Midlands and North of England,
 - b. Sites in other parts of GB were largely unaffected.
 - c. We could find no reports of a similar problem manifesting concurrently in Europe or the USA
 - d. It first appeared in September /October 2022.
 - e. The same truck models had worked safely, without design modification, since their introduction more than 10 years earlier.
 - f. It affects all types and ages of LPG forklift truck, some being worse affected than others, but there are potential safety risks from the contamination in all trucks.
 - g. There were also reports of it affecting the operation of other liquid LPG equipment, in other industries, including hot air balloons, large scale industrial users and bio-gas enrichment, although the HSE has not been made aware of any safety issues arising in these areas.

- h. The problem becomes worse in cold months, suggesting the repeated startup of the lift truck in cold conditions could lead to a quicker buildup of contamination in the vaporiser.
 - i. Some forklift users in the affected areas switched the source of their fuel to one from outside the affected area and the problem quickly resolved so that they ceased to have problems with blocking vaporisers.
 - j. HSE is not aware of any evidence that the LPG supplied in the affected areas was not to the relevant standards (BS 4250 and BS EN 589).
16. The contamination did not appear to adversely affect other types of LPG system in which the gas is produced within the storage tank or bottle and fed to the equipment in a gaseous form, for example an LPG supply to a boiler or cooker. This is understandable, any heavier components in the fuel will tend to stay in the LPG tank or bottle and therefore will not be drawn off and contact valves and nozzles etc. in these applications.

Immediate Causation of the Forklift Fires

17. Although all forklift truck makes and models were affected to a greater or lesser degree by the contaminant, the fires reported to HSE were happening to trucks from three major international brands. Their vehicles, fitted with a particular model of vaporiser, were found to be at increased risk of failing to danger if compromised by the contamination.
18. The mode of failure involved a primary valve sticking due to a buildup of the contaminant. At startup the liquid LPG would reach the vaporiser and the affected valves would allow excess LPG to pass through to the engine, which would not start because the fuel/air mixture was too rich. Continuing to turn the engine over in an attempt to get it to start would draw more unburned LPG through the engine, from where it would then be released into the air. The LPG released could then be ignited by a spark or contact with a hot surface causing a fire.
19. In May 2023 the HSE issued a Safety Notice (Bulletin Number EPD 02-2023) to warn the users of LPG forklift trucks of this issue and give them guidance on what to do if their truck failed to start normally (see Appendix 1). This Safety Notice expanded on the existing notice issued by the UK Material Handling Association (UKMHA) in December 2022.

20. The maker of the vaporiser that was particularly affected by the contaminant designed a modified unit which was intended to significantly reduce the risk of it failing to danger by shutting off flow in the event of over-pressure. They began supplying replacements to the truck manufacturers to retrofit to affected trucks on a risk basis. This work, involving over 8000 replacement units, is largely complete. We understand that a further modified vaporiser design was introduced in January 2024 with the intent of preventing excess flow of LPG, although the initial over-pressure modification is also still recommended in areas of high contamination.
21. The HSE Product Safety Market Surveillance Unit (PSMSU) has been monitoring the steps taken by the forklift manufacturers to address the vaporiser issue. The three forklift models fitted with the particular model of vaporiser most affected by the contamination have been referred to the Secretary of State (Department of Business and Trade) as high risk products in accordance with the General Product Safety Regulations 2005 (GPSR).
- <https://www.gov.uk/product-safety-alerts-reports-recalls/product-safety-report-lpg-powered-lift-trucks>
22. Whilst we have been verbally informed of contamination issues and a number of fires, only four contamination-related fires have been reported to HSE and one fire to a Local Authority. This has limited the ability of the HSE to understand risks and investigate causation in other makes and models.
23. Although the makes and models affected by the contamination had operated successfully within the UK for many years without a problem, there have been a number of reports of similar problems with blocked fuel systems occurring internationally over the last decade. It would be prudent for forklift manufacturers to examine whether there are changes they can make to their vehicles that would make them less susceptible to small quantities of contaminants of this sort in the LPG.
24. The primary cause of the fires has been identified, but the underlying cause, the presence of the contamination, required further investigation.

What is LPG?

25. LPG is produced in a number of refineries in the UK, as well as being imported. LPG is a gas at room temperature and pressure, but is supplied in liquid form by road tanker or as bottled gas. The LPG market is concentrated with only a limited number of suppliers in the UK, most of which are represented by the Liquid Gas UK trade association (LGUK).
26. Liquefied Petroleum Gas (LPG) is essentially commercial propane, supplied in the UK nominally to BS 4250:2014. The actual specification of commercial propane supplied in the UK is slightly tighter than BS 4250, by commercial agreement within the supply chain.
- The standard BS 4250 defines commercial propane as a hydrocarbon mixture containing predominantly propane and/or propene (C3 hydrocarbons).
 - The standard limits the amount of C4 and higher hydrocarbons to 10%.
 - It limits C5 and higher hydrocarbons to 2%.
 - It also limits the quantities of dienes, ethene and alkynes, ammonia, hydrogen sulphide and sulphur containing molecules.
 - There is a limit placed on heavier residues, set by the results of the R and O number tests.
27. The R (Residue) and O (Oil Stain) number tests involve collecting a set volume of liquid LPG and allowing the gas to boil off, leaving any liquid or solid residue in the measuring flask. The R - number sets a maximum total amount of this residue and the O – number, the maximum oily fraction. These tests do not seek to identify or quantify the individual substances within the residue.
28. There is another standard, BS EN 589 for Automotive Fuels – LPG. BS 589 and BS 4250 are very similar, the main difference being in the allowable quantity of sulphur species (BS4250 200 mg/kg and EN589 30 mg/kg). BS EN 589 also places requirements on the performance of the fuel in the engine, setting a minimum Motor Octane Number (MON).

Of the two standards, only BS EN 589 directly refers to a known issue with plasticisers, in Section 7, which says: *Remarks concerning vehicle application issues like residues in vaporisers or injectors: The presence of plasticiser additives (e.g. phthalates) in elastomer hoses or other materials which can come into contact with LPG can lead to increased contamination of LPG by high molecular substances. Therefore, great care should be taken*

by the automotive industry and LPG retailers to avoid such contacts, e.g. by internal coating or introducing materials which do not release those plasticisers.

29. Most of the LPG supplied for use in forklift trucks in the UK is supplied to BS 4250
30. Commercial propane (LPG) to either standard is not a pure substance. All commercial LPG samples will contain predominately propane and/or propene, plus a wide range of other substances, mostly in very small quantities, that are dependent upon the feed stocks and source of the LPG.

Enforcement responsibility for LPG Fuel Quality

31. Having undertaken extensive research it was identified that there is no specific regulator for LPG fuel quality, the industry is largely self-regulating. However, legal advice has been provided that HSE is the relevant product safety authority for LPG where the product may affect the safety of users in a work environment (Health and Safety at Work etc Act 1974 Section 6(4)).

Sampling and testing by the HSE

32. With the assistance of the industry, samples were collected by HSE from many different sources to try to identify the contaminant and discover its source within the supply chain. The work carried out by HSE Science Division included:
 - a. testing residues found in contaminated vaporisers, including those involved in the fires.
 - b. testing components of uncontaminated vaporisers to identify changes.
 - c. testing residues in LPG from pre and post 2022
 - d. testing residues found in LPG cylinders, bulk storage tanks and the supply chain.
 - e. scrutinising quality control (QC) testing records from the supply chain

33. The various samples were analysed by Science Division using Gas Chromatograph-Mass Spectrometry (GC-MS).
34. Five suitably anonymised samples were also provided for comparative analysis at a lab in the USA that was able to do more advanced GC-MS/MS testing. The results of this tandem MS testing were consistent with HSE findings.
35. GC-MS proved the most useful technique for doing this analysis. Infrared (IR) and Nuclear Magnetic Resonance (NMR) techniques could provide information on which functional groups were present in the different molecules within the LPG, but were less useful for identifying specific compounds as they do not involve separation of the multitude of different substances present within the gas.

Results of HSE Analysis

36. As expected, the samples analysed contained a complex mixture of many different chemical compounds. Amongst these, it was noted that the samples of contaminant tested contained quantities of materials commonly used as plasticisers, including Dioctyl terephthalate, Didecyl phthalate and Adipate ester. Plasticisers of this sort are commonly used in industry to improve the flexibility and performance of plastic and rubber components.
37. These chemicals did not provide a strong match with the plasticisers detected in the polymers used in gaskets and seals within the forklift fuel systems investigated and they were found at similar levels throughout the LPG supply chain.
38. The specification of hoses and gaskets on forklift trucks did not suddenly change during 2022. The same gaskets and hoses had functioned safely for the previous decade or more and there were no known regional variations in the use of different types of hoses or gaskets in particular makes or model of truck.
39. Therefore the investigation has concluded that the plasticiser contamination found in the vaporisers does not result from components within the FLT's themselves or a reaction between these components and the normal constituents of LPG.

40. The concentration of propene (aka propylene) in the LPG was initially suspected as a possible cause of the problem, stripping plasticisers and other substances from the hoses used in the LPG supply chain. While there were elevated levels of propene from one source in October 2022, propene levels quickly returned to historic norms and elevated levels of propene do not account for the extended duration of the vaporiser problem, which has lasted for the last two years.
41. The HSE has not seen any evidence to support the claim that the concentration of stenching agent (ethyl mercaptan), used to give LPG its smell, has changed or that the ethyl mercaptan has been substituted with other products in the affected areas.
42. The GC-MS analysis allows an estimation to be made of the total concentrations for the residue components detected within the samples, these typically range from < 1 µg/ml to around 25 µg/ml, or around 0 - 25 ppm. This compares with a maximum permitted concentration, using the R-value test in BS 4250, of 0.05%, or 500 ppm. This confirms the results of the gas testing and industry quality control records which showed that the gas samples complied with BS 4250 throughout this period.
43. All the estimates of total contaminant concentrations were far below those maximum permitted levels and, of course, the concentrations of the individual compounds within the contaminant are much lower still.
44. A total residue content of 10 ppm would equate to around 3 ml of residue in a 15 kg cylinder of LPG, which is typically what is consumed in approximately 8-hours of forklift use. The amounts of the individual residue components within that 3 ml would be tens or even hundreds of times less than that. However, even at these low levels, it is possible to envisage the build-up of some low volatility components inside the vaporisers over time if enough cylinders are consumed.
45. The concentrations of the various residue components tested by HSE were broadly similar over the 3-month sampling window with just the occasional outlier. Concentrations of components such as the phthalate and adipate esters showed a similar range of concentrations across samples from the three source refineries that were scrutinised.

46. Amongst the many different chemicals found within the contamination, concentrations of thiophene and thienothiophene (TTP) compounds were found in the affected vaporisers. The levels of TTP compounds were also significantly higher, on average, in LPG from one source refinery. These compounds appeared to be a marker of where geographically the problem with contamination in the vaporisers would be found.
47. It has not been possible for HSE to determine whether these chemicals cause the valves to stick, react with other chemicals to cause sticking, or merely confirm the most likely source of the fuel. Such work would involve considerable additional scientific work, resource and expenditure and is unlikely to produce definitive results.

Phillips 66 (P66)

48. Phillips 66 produces around 15-20% of all LPG consumed in the UK and are one of the main suppliers in the affected region – the Midlands and North of England.
49. HSE analysis has identified the presence of the TTP marker chemicals and other similar sulphur compounds, which were present both in contaminated vaporisers and in the LPG refined by P66, but which were either absent or at low levels in LPG from other refineries/sources (to the extent LPG from such sources has been available for testing).
50. Phillips 66 have confirmed the presence of these markers through analysis of their own and HSE provided samples. Their analysis also showed the presence of the plasticisers referred to earlier in this report. These plasticiser compounds, which probably derive from rubber and plastic components in the distribution chain, had previously not been captured on the P66 product safety data sheet (SDS). In February 2024 (with further clarifications in August 2024) P66 updated its SDS to inform purchasers of the LPG of these previously unknown plasticiser and sulphur compounds.
51. The investigation has identified that the presence of the residue chemicals is likely to be due to certain feedstocks used at the P66 refinery at Immingham. As already noted in the analysis section of this report, the residue is at very low levels, which could not have been identified by testing to BS 4250, the standard for this fuel.

52. The HSE is working with P66 to achieve the following:

- characterising the problem and identifying the source within the production process
- monitoring the effectiveness of the steps already taken
- ensuring that further steps are taken where necessary to resolve the issue in the short and the medium term by alterations and improvements to the refinery process.

53. The most likely cause of the residue appears to have been related to an increase in the processing of used cooking oil as a co-processed feedstock through the refinery, with specific compounds being found in the propane product, but not impacting on the other products produced at the refinery. Processing of used cooking oil is part of a strategy to meet renewable fuels obligations, reducing the reliance on fossil fuels as part of achieving Net Zero.

54. There is evidence that the steps taken so far may have reduced the rate at which replacement vaporisers are required in the affected areas; however, as of July 2024, the replacement rate had not returned to pre-September 2022 levels.

UK Propane Standards Consultation (BS 4250)

55. Work has started within the BSI committee responsible for BS 4250 to review the standard and produce a new specification for residues in LPG with a view to preventing the problem with vaporiser blocking re-occurring.

56. Producing a workable update to BS4250 is not straightforward because the contaminants are at very low levels and the tests necessary to find them are complicated.

Further HSE Actions

57. The HSE investigation of the contamination problem has reached a stage where it is not proportionate for the HSE to investigate further.

58. The HSE will continue to monitor the issue and ensure that relevant parties, including LPG suppliers and forklift manufacturers, continue to take appropriate actions to deal with and

resolve the outstanding matters.

59. The forklift truck manufacturers and the LPG supply industry are better placed to characterise the problems and deliver solutions.

60. HSE will review lessons learned with appropriate Government departments.

Conclusions

1. The contamination problem began in September 2022 and affected forklift trucks mainly in the Midlands and North of England.
2. Although the problem was thought to be more prevalent by the industry, HSE was notified of four fires involving contamination of forklift truck vaporisers that could be investigated.
3. Although all forklift truck makes and models were affected to a greater or lesser degree by the contaminant, the fires notified to the HSE only happened on trucks fitted with a particular model of vaporiser, which had the potential to fail to danger if compromised by the contamination.
4. The maker of the vaporiser that was particularly affected by the contaminant designed a modified unit which was intended to significantly reduce the risk of it failing to danger by shutting off flow in the event of over-pressure. They began supplying replacements to the truck manufacturers to retrofit to affected trucks on a risk basis. This work, involving over 8000 replacement units, is largely complete. We understand that a further modified vaporiser design was introduced in January 2024 with the intent of preventing excess flow of LPG, although the initial over-pressure modification is also still recommended in areas of high contamination.
5. HSE testing of LPG fuel and equipment concluded that:
 - a) The LPG supplied in the affected areas met the relevant standard (BS 4250)
 - b) Propene levels and the ethyl-mercaptan stenching agent in LPG were ruled out as causal agents of the contamination.
 - c) The problem was not caused by stripping plasticisers and other components from the hoses or other components within the fuel system of the forklift trucks themselves.
 - d) The contaminant was found in all parts of the LPG supply chain in the affected areas.
 - e) Amongst the many different chemicals found within the contamination, concentrations of thiophene and thienothiophene (TTP) compounds were significantly higher, on

average, in LPG from one source refinery. These compounds appeared to be a marker of where geographically the problem with contamination in the vaporisers would be found.

- f) It has not been possible for HSE to determine whether these chemicals cause the valves to stick, react with other chemicals to cause sticking, or merely confirm the source of the fuel.
6. The refinery that appears to be the source of the LPG has taken steps to understand the problem and what is causing it within their production process. They are working to modify their production processes to prevent the formation of the contaminant and/or remove it before supply.
 7. Co-operation is required within the LPG supply industry to define an updated BS 4250 standard for LPG supply to test for and control the presence of harmful contaminants. The industry needs to be clear on the source of the contamination within the refining process in order to prevent this or other similar contamination occurring within the UK or other countries worldwide.
 8. The HSE investigation of the contamination problem has reached a stage where it is not proportionate for the HSE to investigate further.
 9. The HSE will continue to monitor the issue and ensure that relevant parties continue to take appropriate actions to deal with and resolve the outstanding matters.

Appendix 1

LPG forklift truck fire risk

Health and Safety Executive - Safety notice

Department name: Engagement and Policy Division (EPD)

Bulletin number: EPD02-2023

Issue date: 05/23

Target audience: Anyone responsible operating, supplying, inspecting or maintaining LPG powered forklift trucks.

Issue

HSE is aware of a number of fires on, and around, liquefied petroleum gas (LPG) powered forklift trucks and other similar vehicles that have occurred during starting.

Outline of the problem

Build-up of deposits in fuel systems, in particular, the vaporiser units of LPG powered vehicles has led to a number of fires.

Trucks not starting due to sticking valves

Deposits in vaporiser units, flow regulators and shut off valves cause the truck to fail to start, particularly from cold. Build-up of deposits can lead to sticking valves and the mixture supplied to the engine being too rich to be ignited.

Repeated starting attempts can release unburned LPG

Repeated starting attempts can result in the release of unburned LPG, which in extreme cases can be ignited, setting fire to the vehicle and surrounding materials.

Action required

Operators

- review your safe system of work in relation to the use of all LPG powered lift trucks and similar vehicles
- provide information, instruction and training for all operators about the hazards raised in this alert
- park LPG vehicles in well ventilated areas free from flammable material, particularly when parking overnight or for longer periods

If a truck does not start within the normal few seconds

- do NOT continue to turn (crank) the engine over using the starter
- do NOT repeat the normal engine starting procedure
- do NOT spray volatile agents into the air intake in an attempt to aid starting
- get off the truck and close the shut off valve to isolate the gas bottle
- secure the truck to prevent further starting attempts
- ensure the area is well ventilated
- do NOT attempt to solve or repair the problem yourself, arrange for a competent maintenance engineer to do a check of the LPG system

Service and maintenance engineers

If you are presented with an LPG powered truck with a starting problem:

- do NOT follow the normal starting procedure
- isolate the LPG supply by closing the shut off valve
- ensure that the area is well ventilated
- disconnect the battery
- release LPG pressure trapped in the fuel supply system
- follow the manufacturer's guidance for inspection of the LPG system

LPG is cold, take appropriate precautions when working with it. Once released LP gas is heavier than air and can pool in low lying areas, where it can be ignited by any source of ignition, including static electricity, electrical sparks and hot surfaces.

Guidance

- Approved Code of Practice and guidance [Rider-operated lift trucks: Operator training and safe use](#)

Further information

For information about health and safety, visit the HSE [website](#). You can order HSE priced publications at the HSE books website.

The LPG Forklift Truck Fire Risk – Safety Bulletin is available at [LPG forklift truck fire risk - Safety bulletin - HSE](#)

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