HANDLING OF FLUIDS

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Keywords: Gas, liquid, storage, transportation, pumping, metering

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Summary

Fluids and their movement are essential for many of the processes which are fundamental to Chemical Engineering. Their handling can be considered through four aspects: they have to be stored, transported, pumped and their flow rates have to be metered. These aspects are considered for liquids and gases. The basic technology is presented together with practical considerations of the above four aspects.

1. Introduction

The handling of fluids underpins much of chemical engineering as gases and liquids, be they the reactants or the intermediate products, have to be brought to the plant equipment and products have to be taken to other units, other plants or sites or to customers. The necessary information for the design and specification of the required equipment can be gathered under the headings of storage, transport, pumping and metering.

Though much effort in chemical engineering is put into design of the various pieces of equipment such as the reactors, distillation columns, heat exchangers etc, fluid handling, in that it controls the movement of material between these pieces of equipment, is in reality as crucial.

2. Storage

In specifying the methods used for the storage of fluids, initial important questions are: how much is to be held, at what conditions, for how long and at what rate will it arrive/depart. For liquids held in large quantities the container will usually be a (vertical) cylindrical tank. Typical height/diameter ratios are in the range 0.5 – 2 with the former values being more relevant to very large tanks. Obviously, wall of a sufficient thickness (and hence strength) to withstand the head of liquid in the tank are required. However, attention must be given to a number of other facets. Elements such as bunding, breathing, blanketing, fill control and heating/cooling are all important. There are a number of useful standards which help in the design/operation of tanks, e.g. BS5502 (1993), BS7849 (1996), API 650 (2009). There is also safety legislation.

2.1 Bunding

Bunding is the provision of a catch system for the tank contents in case of rupture. For small tanks the base and walls of a bund system are usually made of concrete. In the case of larger tanks the walls have in the past been made up of earthworks. However, regulatory authorities are now insisting on concrete for these. The volume that is to be contained by a bund system should not just be the volume of the tank contents but should contain an allowance for the surge which would result from a catastrophic rupture of the tank. Rain water can accumulate within bunded areas and must be removed regularly. However, on no account must there be a rain water drain that is constantly open.

2.2 Breathing

Breathing refers to changes in the volume of liquid, and hence gas, within the tank. This can be caused by filling or emptying and has the consequence of expelling or drawing in gases. This gas movement could also be caused by fluctuations in temperature, e.g., the diurnal variation. More volatile liquid will have vapour in the gas space and an inert gas such as nitrogen might be used to blanket the liquid, i.e., to exclude air which could form explosive mixtures or bring in contamination. The inflow required can be best dealt though the blanketing gas. The gases expelled should be: passed through a scrubber, have the vapour condensed out of it or be sent to the flare stack.

In the case of smaller tanks, such as those which might by used on plant for intermediate storage, the bundage would be safer if spillages were made to drain away down a slope to one side to ensure that a pool fire did not occur under the tank.

2.3 Filling and emptying

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In the filling and emptying of tanks care needs to be taken to avoid over filling. Here, level alarms together with inventory control should be employed

Heating of tanks might be required to keep liquids, with a higher viscosity, mobile. A steam heated bundle is usually inserted at towards the bottom of the tank at a flanged port so that the bundle can be pulled out for cleaning and maintenance. Cooling might be required for more volatile materials. At summer peak periods external sprays can be employed to lower rates of vaporisation.

2.4 Boiling-liquid expanding-vapour explosion (BLEVE)

All tanks, particularly pressurised ones must be fitting with pressure relief devices whose outlet will connected to the site venting main or to the flare stack system. However, it has been observed, Banerjee (2004), that this “cannot ensure the integrity of a high-pressure vessel subject to an external fire”. Consider a spherical liquefied gas storage tank which is only partially full and which is subjected to the energy from a fire. There will be good cooling on those parts of the walls covered by liquid because of boiling and the consequent internal circulation. Those parts not covered by liquid will have poorer heat transfer and so will over-heat and the wall material will become weakened. This might result in rupture of the vessel and be a source of vapour which could produce a devastating explosion. This combination of events is termed a BLEVE. To prevent this, water sprays, which might be triggered automatically, are often provided for these storage vessels. An inner skin a few centimetres from the inside wall can also be inserted. The boiling in the liquid allows a vapour/liquid mixture to be pumped along the walls to the top of the vessel so providing good heat transfer throughout the vessel, Fauske (1986).

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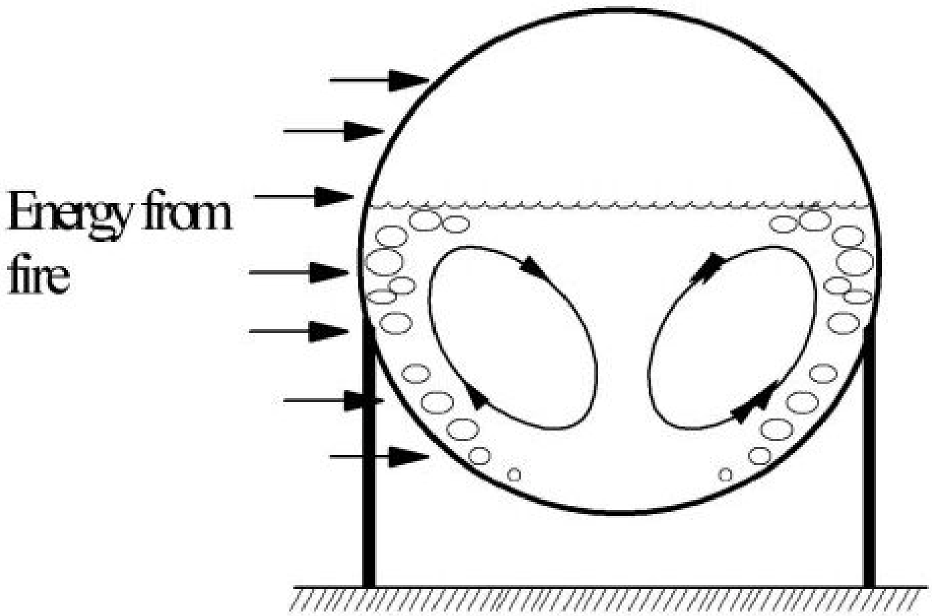

Figure 1: Processes occurring with a spherical liquefied gas storage tank as precursors of a BLEVE

3. Transportation

The method used in the transportation of fluids depends on its state, the distance involved and the rate of flow required. The static approach, the transmission of gases or liquid by pipeline, is suitable for locations link by land. However, the oil industry has used pipelines laid along the sea bed to bring both gas and liquid (mainly separately but sometimes combined) products to shore. In many countries there are pipe networks disturbing natural gas to industrial and domestic properties. In addition there are pipelines taking ethylene, petrol (gasoline) and aviation fuel from production site to users or distribution depots. Though pipelines provide a great saving in road traffic, there is a socio-political consideration in that in some situations security is essential. There have been destructive attack on pipelines as well as unauthorised removal of the transported material which has led to incidents.

Tank ships or barges can be used for transportation of kilo-tonne quantities of liquids. Though many of these tankers carry but a single material as cargo, others, sometimes known as parcel tankers, can convey different chemicals each in separate tanks. In this case, important factors to be considered are tank wall material, environmental protection and tank cleanliness. The lining to the tanks must obviously be compatible with the material carried. Some ships have coatings compatible with the cargo whilst others have internal tanks of a high grade corrosion resistance metal. A significant worry is the possibility of a breach of the tank allowing escape of chemical into the sea or waterway. This can be minimised by good maritime practice. Lately, there has been the additional good practice of using ships with a double hull construction, i.e., with two steel plates between the cargo and the external water. Tank cleaning is essential if different cargoes are to be carried in the same tank. Ensuring a safe atmosphere in the tanks is important for liquids with higher vapour pressures.

Natural gas (mainly methane) and petroleum gas (propane/butane) are transported by sea in liquid form. The former has been carried since the 1960s mainly at atmospheric pressure but under refrigerated conditions (temperature -162ºC). Liquefied Petroleum Gas (LPG) has been carried in pressurised tanks in the hulls of ships since the 1930's. For example the Royal Dutch/Shell tanker **Agnita** had vertical cylindrical tanks built into her conventional liquid cargo tanks with their domed tops visible above the deck. Typically, she carried sulphuric acid from Europe to Curacao. There the space around the pressure tanks would be filled with diesel. Then she would move to Port Arthur, Texas to take on her cargo of LPG for transportation to Europe.

For smaller quantities of liquids, rail or road tankers can be utilised. The tank can be built into a steel frame the size of a standard container for carriage by sea, rail or road. Again, environmental protection, filling control, breathing and cleansing are important. For smaller quantities, e.g., ~50-500 kg, steel drums or plastic containers can be used. The latter are, in some cases protected by a metal framework to provide mechanical strength.

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Biographical Sketch

Barry Azzopardi was born in Gibraltar; he obtained his B.Tech. in Chemical Engineering (1972) at the University of Bradford (UK). In 1977, he obtained his Ph.D. in Chemical Engineering from the University of Exeter, UK. After post doctoral experience at the Department of Engineering Science,

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University of Oxford, Dr. Azzopardi was a Principal Scientific Officer at the Harwell Laboratory of the United Kingdom Atomic Energy Authority. In 1990 he moved to take up the Lady Trent Chair of Chemical Engineering at the University of Nottingham which he still holds. He was Head of the Department of Chemical Engineering until 1997. At Nottingham, he has taught at undergraduate and graduate levels in the Department of Chemical Engineering and later in the School of Chemical and Environmental Engineering. Professor Azzopardi' research focus is mainly on multiphase flow, drop size measurement and gas cleaning. He has been coordinator of diverse research projects within the mentioned areas. He was Chairman of the Working Party on Multiphase Flow of the European Federation of Chemical Engineers. Professor Azzopardi is also author of more than 90 scientific publications in refereed journals and more than 150 presentations in international congresses. He is author of the book, Gas Liquid Flows. He is an editor of Chemical Engineering Research and Design and member of Editorial Boards for different journal. He evaluates research projects in Norway, the Netherlands, Canada, Israel ad the United Kingdom. He has been visiting professor in Canada and Chile.

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