

**11. Have you checked the sensitivity of the risk output (a) in relation to the proportion of time the tank is full, 90% full etc (p7 of QRA) (b) in relation to the use of the failure frequencies in the purple book**

- (a) The sensitivity of the risk output in relation to the proportion of time the tank is full has not been assessed in the QRA. However, we believe the approach taken is conservative overall as the analysis includes varying levels of storage in the assessment of risk.

General guidance on release quantities and durations given in HSE's PCAG Chapter 5A, pages 6 and 7, suggests the consideration of loss of 50% a tank's maximum contents for risk assessment <sup>(1)</sup>.

In the QRA, holes are assumed to be located at the bottom of the tank and a range of tank fill quantities has been modelled; between 25,000m<sup>3</sup> and 190,000m<sup>3</sup> (190,000m<sup>3</sup> being the assumed average maximum operating volume of LNG in a tank over time). The proportion of time each fill level occurs was determined following analysis of the expected filling and emptying cycle when the terminal is receiving LNG. In the assessment a tank is considered to be at least 50% full (i.e. between 50% and 100% full) for three quarters of each year.

Given that the assessment considers much larger tank fill cases in addition to the 50% full case, we believe the QRA is conservative overall.

- (b) The QRA has used the UK HSE approach principally because it gives outputs in terms of the risk of dangerous dose, and HSA's risk criteria are stated in terms of the risk of dangerous dose. The 'Purple Book' is another recognised approach but gives results in terms of risk of fatality, not risk of dangerous dose. Generally, it is not considered good practise to 'mix and match' frequency data from different methodologies.

In the case of the full containment storage tanks, the Purple Book (Table 3.5) gives a catastrophic failure frequency of 1E-8 per tank year, which is five times lower than the corresponding HSE frequency. In addition, the Purple Book does not require consideration of smaller failures of the tank (i.e. there are no tank hole scenarios), whereas the HSE method includes a 1m diameter and 0.3m diameter hole in addition to the catastrophic case (see Table 3.3 of the ERM QRA report). Therefore, if the Purple Book scenarios and frequencies were to be used in the ERM QRA in place of the HSE's, the calculated risks from the tanks would be lower.

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<sup>(1)</sup> MHAU generally uses the philosophy adopted for the chlorine siting policy (see PCAG Chapter 1B) to calculate release durations, i.e. Liquid releases are assumed to continue until the initial liquid inventory is reduced by half. The basis for this assumption is that holes below the liquid level may occur anywhere and it is reasonable to assume that on average half the inventory will be lost before the liquid level drops to the release point. Whilst this approach may be acceptable for a risk assessment, a worst case consequence assessment should assume that the hole is in the base of the vessel/tank and that the total inventory is available for release as a liquid.

## **Chapter 5A: Release Quantities from Vessels, Pipework and Bunds**

### **Introduction**

This chapter gives guidance on the choice and use of methods and models to determine release quantities and rates which can form the input to other MHAU hazard and risk assessment methods (e.g. pool spreading and evaporation, gas dispersion etc.). Some models are described elsewhere in the PCAG and these are referred to in the general guidance section and included in the contents list as appropriate. Detailed descriptions of the calculations performed by the various models can be found in PCAS Chapter 5A.

The methods and models described in this chapter can generally be used to determine release quantities and rates for a number of different substances. Additional parameters (e.g. temperature, aerosol fraction etc.) that are often required as inputs to other MHAU assessment methods and methods to determine them are described, as appropriate, in this chapter.

MHAU uses one of the options from the program STREAM to calculate release rates from vessel holes and pipework failures. This can model continuous 2-phase flow out of a pipe, continuous gas releases from pipes, liquid flow from a pipe, and transient flow from vessels when the hole is above the liquid.

In certain circumstances it may be necessary to consider the effects of the momentum of the released material as it escapes from containment. These can be significant, particularly in the case of pressurised liquefied gases where jet velocities may be high. The SRD computer program TRAUMA, which is described in PCAG Chapter 5G, may be used for this purpose.

When modelling instantaneous releases of pressurised liquefied gases, it is usually necessary to take account of flashing of the liquid and air entrainment. Part 2 of this chapter describes the MHAU computer program IRATE3 which can calculate a source term for a dense gas dispersion model, such as DENZ (see PCAG Chapter 5D).

In addition to a description of computerised methods, Part 3 of this chapter outlines several manual calculation methods which may be employed where the computerised methods cannot be used.

Background and information pertaining to assessment methods are not included in this chapter, however, they are listed in a bibliography which also lists papers containing detailed instructions for running individual computer programs.

### **General Guidance on Calculating Release Quantities and Rates**

Over a period of years MHAU has developed methods for assessing the hazards arising from vessel and pipework failures. This section gives general guidance on the failures to be considered and how to calculate release quantities and rates. In broad terms, the assessment method depends on whether the release is due to catastrophic vessel/tank failure, holes in a vessel/tank or a pipework failure.

#### **Failures to be Considered**

For land-use planning assessments, MHAU has developed a set of representative failures based on information in the 1987 chlorine siting policy (see PCAG Chapter 1B). These are:-

Catastrophic vessel failure - instantaneous loss of the entire contents.

Vessel holes - 50, 25, 13 and 6 mm diameter holes (above and below the liquid surface).

Liquid and vapour pipework failures - guillotine failure, severe split (equivalent to a 25 mm diameter hole), small split/loss of gasket (equivalent to a 4 mm diameter hole) and guillotine failure of a delivery hose.

These failures are considered typical of those associated with bulk storage of a pressurised liquefied gas, but MHAU planning casework also involves sites storing large inventories of toxic and/or flammable substances. In general, these are process plants which have large vessels, ducts etc. or storage tanks which hold hazardous liquids at atmospheric pressure. So whilst the above failures outlined form the main basis for planning case assessments, they often need to be tailored to suite the installation being assessed. Guidance on this process is provided in subsequent sections and more specific guidance for individual substances can be found in either PCAG Chapter 1 or Chapter 6.

MHAU usually assumes that any type of industrial storage vessel can suffer catastrophic failure. This includes cylindrical (bullet) or spherical pressure vessels, large process vessels such as columns, drums, separators, reactors, slug catchers etc and any large tank storing liquid at atmospheric pressure.

Consequence assessments usually focus on failures of the vessel, tank or road/rail delivery tanker which contains the greatest inventory. The chlorine siting policy (see PCAG Chapter 1B) assumed that risks associated with releases from a delivery tanker would not be significant because in general tankers are not on site for very long. However, a risk assessment for an installation where delivery tankers (road or rail) are on site for extended periods, should not exclude them.

Consequence assessments should invariably consider delivery tanker failure if the tanker has a greater inventory than the fixed vessel/tank. Tanker off-loading areas are rarely bunded and the spills of hazardous liquids can spread over a considerable area and vaporise very rapidly.

## **Release Quantities for Catastrophic Vessel/Tank Failures**

### **Pressure Vessels**

The method for assessing the consequences of catastrophic failure of pressurised storage vessels containing a liquefied gas is well developed and generally applicable to other types of pressure vessel encountered by MHAU.

It is usual to assume that, in the event of catastrophic failure, the entire contents of a vessel will be lost. Nominal maximum vessel capacities can generally be obtained from the HAZINST database, but it should be borne in mind that the actual tonnage a vessel may hold depends on the substance. For example when butane, which has a higher density than propane, is stored in a propane vessel, the inventory may be greater than the maximum propane capacity.

In general bunds around tanks provide some mitigation of accident consequences. A bund around a chlorine storage tank is usually assumed to retain 50% of the vessel contents in 50% of catastrophic failures. When bund retention does occur, the quantity of chlorine forming the initial cloud is reduced. Risk assessments should also take into consideration that vessels do not contain their maximum inventory continuously.

When a pressurised storage vessel containing a liquefied gas is located inside a building, MHAU usually assumes that in the event of catastrophic failure, the energy released is sufficient to severely damage or even destroy the building. Consequently no mitigation is allowed for the presence of a building.

In addition to destructive effects, the energy released when a liquefied gas suffers loss of containment has a significant effect on the gas cloud which is formed prior to dispersion commencing. Violent flashing which immediately follows loss of containment tends to shatter the remaining liquid (except any which is assumed to be retained in a bund) into an aerosol and entrain air. These effects are normally modelled using the MHAU computer program IRATE3 which is described elsewhere in this chapter. A simplified manual calculation method, which may be used in situations where use of IRATE3 is not possible, is also provided.

## **Atmospheric Pressure Storage Tanks**

When tanks storing liquids at atmospheric pressure (either at ambient, reduced or elevated temperatures) fail catastrophically, the whole contents are assumed to be lost. In general, the same considerations that apply to pressure vessels also apply to atmospheric storage, however, the provision or otherwise of bunding is of greater significance.

In the majority of cases, liquids released from storage at atmospheric pressure form pools and the magnitude of the hazard is usually related to the burning or evaporation rate. General methods for modelling pool fires are given in PCAG Chapter 2C, and for pool spreading and evaporation in PCAG Chapter 5B. Indoor location of atmospheric pressure storage tanks may provide mitigation against catastrophic tank failure. This mitigation in the context of risk assessment for sulphur trioxide installations is discussed in PCAG Chapter 6H.

A properly designed, constructed and maintained bund will restrict the spread of liquid in the event of most tank failures and hence reduce the pool surface area available for burning or for evaporation. Since the mitigating effect of bunding around atmospheric pressure storage tanks is so significant, failure of a delivery tanker outside the banded area may give rise to a greater hazard range. However, the guidance in HSG176 "The Storage of Flammable Liquids in Tanks" that "a bund capacity of 110% of the capacity of the largest storage vessel will normally be sufficient" and that "the bund wall should have sufficient strength to contain any spillage or fire-fighting water" is usually interpreted in terms of a static liquid volume and a static pressure head. A bund designed thus is unlikely to provide complete containment of the released liquid if the failure of the tank is catastrophic. Fluid flows may be so great that the bund is either overtopped or breached. With regard to overtopping, a Planned Special Visit exercise in 1994 obtained field data on bunding provisions at many sites around the country which stored HFLs in bulk; the incumbent Topic Specialist then undertook a theoretical study, using the best available (though small scale and limited in scope) experimental data, which concluded that overtopping fractions would range from almost zero to almost 100% for these sites. With regard to breaching, test data for high collar bunds has shown transient pressures at least three times, and possibly six times, the static head; a bund may also be damaged by erosion, by impact with tank debris, or by contact with a cryogenic liquid. Further research is planned to generate overtopping data over the full range of practical interest and at a more realistic scale, to measure dynamic pressures on bund walls, and to study the spreading of cryogenic liquids, for which level swell would be expected to increase the overtopped fraction.

The fate of the overtopped liquid requires further consideration. The current practice when considering catastrophic release of a flammable liquid (for which bunding is recommended, HSG176) is to assume, unless there is site-specific information to the contrary, formation of a circular pool of burning liquid with a diameter capped at 100 metres and located directly outside the bund in the direction that is worst in relation to the development proposal being considered. The same practice applies when considering release of a toxic liquid from a tank which is provided with a bund. However, for storage of general toxics HSE has published no recommendation that bunding be provided, and often it is not. In such cases current practice is to assume, again in the absence of site-specific information to the contrary, formation of a circular pool with a diameter capped at 100 metres and centred on the tank. Current practice when considering release of a cryogenic liquid such as liquid oxygen where bunding is usually not provided is to make a site visit and reach a

judgement on both the size and location of the pool. These practices should continue until further guidance is issued. Details of the pool size calculation are given in PCAG Chapters 2C (Pool Fires) and 5B (Pool Spreading and Evaporation).

If it is found that use of a 100-metre diameter pool leads to onerous conclusions in a particular case then the responsible officer may provide the values of tank radius, maximum fill height, minimum tank-to-bund gap and bund height to the Overtopping Topic Specialist, who will then advise on the quantity of liquid that can be assumed retained within the bund on the basis of calculations with OVERTOP and/or LSMS. However, the responsible officer should be aware that if the volume of liquid released is greater than about 500 cubic metres then enough will overtop to generate a 100-metre pool, unless the bunding is exceptional.

## **Release Rates and Durations for Vessel/Tank Holes**

MHAU assumes that holes can occur in any cylindrical (bullet) or spherical pressure storage vessels, any large process vessel (columns, drums, separators, reactors, slug catchers etc.) and any tank storing liquid at atmospheric pressure.

For a consequence assessment, MHAU is usually interested in the hole which gives rise to the largest release rate. This may be a hole in a delivery tanker (road or rail). The chlorine siting policy (see PCAG Chapter 1B) assumed that risks associated with releases from delivery tankers visiting bulk storage installations is not significant because the tanker is on-site for only a small proportion of the time. This assumption is not applicable to some installations, and in such cases it would be wrong to exclude tanker failures from a risk assessment.

A risk assessment may justifiably discount holes in the delivery tankers, but it is almost always necessary to consider such failures in consequence assessment, particularly if the tanker is padded to a higher pressure than the fixed storage vessel/tank during offloading. Since bunds are not normally provided at the off-loading point, the consequences of a hole in a delivery tanker may be greater than the consequences of holes in the fixed vessel/tank on account of the absence of a bund.

The chlorine siting policy (see PCAG Chapter 1B) considered bulk storage vessels could suffer failures involving a range of hole sizes with equivalent diameters of 6, 13, 25 and 50 mm in both the liquid and the vapour space. MHAU normally considers these to be representative of the failure modes that should be considered in land-use planning assessments for major hazard installations.

The maximum hazard range arising from localised failure of a vessel or tank is almost always associated with a 50 mm hole below the liquid level. However, this conclusion needs to be viewed with some caution, because there may be circumstances where it does not apply.

## **Releases Rates for Pressure Vessel Holes**

Release rates for holes in either the gas or liquid space of pressure vessels are usually calculated using the MHAU computer program STREAM which is described Part 2 of this chapter.

Leaks from tanks below the liquid level are modelled as single-phase releases on the basis that the residence time in the vicinity of the hole is insufficient to allow flashing to impede the outward flow. However, once a liquid is out of containment, a two-phase jet consisting of aerosol and vapour may be formed. It is often necessary to calculate the initial flash fraction in order to proceed with the assessment and this is normally done using the MHAU computer program FLASH which is described in Part 2 of this chapter.

Once the initial flashing has occurred, the resulting two-phase jet travels away from the release point and air entrainment causes more of the aerosol to evaporate. Where releases take place inside a building, it is generally assumed that the jet impinges on a wall or the ground causing loss of momentum. This interrupts the process of air entrainment and evaporation and the remaining aerosol is assumed to form a pool. Impingement therefore provides mitigation because the overall release rate of vapour is reduced as compared with an uninterrupted jet for which MHAU normally assumes that all of the released liquid is vaporised and available for dispersion. Methods of determining the extent of consequence mitigation for releases of flashing liquids inside buildings are described in PCAG Chapter 5G.

A bund around an outside vessel can interrupt a two-phase jet formed by liquid escaping from a hole in the vessel wall, but for a hazard assessment, where the worst case consequence is normally of interest, MHAU assumes that a jet release from a pressurised vessel, would pass over the bund. Bund mitigation is therefore discounted.

In practice, a significant proportion of jet releases from a pressurised vessel will impinge on the ground or on the bund wall, if one is provided, and a risk assessment should make allowance for this effect. Where the bund wall is relatively low and distant from the vessel, the degree of risk mitigation is likely to be negligible, but in other cases the methods used to assess mitigation for releases inside buildings, (described in PCAG Chapter 5G), can be used.

Releases from the vapour space tend to reduce with time due to evaporation cooling of the liquid phase which leads to a reduction of pressure in the vapour space. STREAM takes account of this effect and provides data on the initial and average release rates. One of the options in STREAM calculates the rate of release from the vapour space of vessels storing liquefied gas when liquid entrainment occurs.

For vessels containing only gas, a rough estimate of the pressure reduction can be obtained using the following relationships:

$$M(t) = M_0 - R t$$

Where  $M(t)$  is the mass (kg) of gas in the vessel at  $t$  seconds from the start of the release,  $M_0$  is the mass (kg) of gas in the vessel at the start of the release and  $R$  is the release rate (kg/s).

Assuming ideal gas behaviour and no temperature change, the pressure  $P(t)$  (bar g) at time  $t$  is given by:

$$P(t) = \frac{1.013 M(t) 22.4}{V Mwt}$$

Where  $V$  is the vessel volume ( $m^3$ ) and  $Mwt$  is the molecular weight of the gas (kg/kg mole). It should be noted that this rough calculation is only valid for small values of  $t$  as the release rate  $R$  varies with pressure. An iterative approach is required to assess how  $P(t)$  varies over a longer timescale.

The results of vessel hole release rate calculations often provide inputs to gas dispersion models, but because current gas dispersion models cannot accept time varying release rates, the average release rate, or the initial release rate, if a conservative assessment is required, should be used.

In addition to the release rate, some gas dispersion models, (e.g. CRUNCH see PCAG Chapter 5D), require the initial dilution of the plume to be specified. This has a significant effect on the predicted hazard range and it may be necessary to calculate an appropriate figure using the SRD computer program TRAUMA, which is described in PCAG Chapter 5G. A manual method for modelling jet momentum effects is also described in Part 3 of this chapter.

## Release Rates for Atmospheric Pressure Storage Tank Holes

Releases of liquids from atmospheric pressure storage tanks usually form pools and give rise to either a thermal radiation hazard (poolfire), a flashfire or a toxic hazard due to release of vapour from the pool surface. Liquid release rates from holes in atmospheric pressure storage tanks are calculated using the liquid flow option in the MHAU program STREAM, which is described in this chapter. Thermal radiation hazards from poolfires are modelled using methods described in PCAG Chapter 2C. General methods for modelling pool spreading and evaporation are given in PCAG Chapter 5B, but pools formed by releases of sulphur trioxide or oleum are modelled using methods described in PCAG Chapter 6H.

Where a bund is provided around an atmospheric pressure storage tank, MHAU usually assumes that releases from holes will form a pool that is restricted by the bund wall. Calculations have shown that under certain circumstances, so-called spigot flow (horizontal 'jet' of liquid from the tank side) can result in the liquid passing over the bund wall.

The ability of spigot flow to overtop the bund is a function of the geometry of the tank and the bund. If  $D$  is the distance between the tank wall and the bund wall,  $H$  is the height of the tank (or the maximum liquid level) and  $h$  is the height of the bund wall, assuming the hole in the tank is an ideal orifice, spigot flow will not overtop the bund if:

$$D > H - h$$

The above relationship assumes an ideal orifice with a discharge coefficient of 1 whereas, in reality, holes which form accidentally tend to be far from ideal. MHAU usually assumes a discharge coefficient of 0.6 when calculating release rates from vessel holes, therefore spigot flow can be assumed not to overtop the bund if:

$$D > 0.6 \times (H - h)$$

Should spigot flow be capable of overtopping the bund, the above equation can be used to calculate how much liquid will overtop the bund before  $H$  (the liquid height) reduces below its critical value. The liquid overtopping the bund will form a pool which may increase the hazard range compared to the situation where a pool forms within the bund.

When the principal hazard is due to a poolfire and there is liquid both inside and outside the bund, the hazard range depends on the relative size of the pools. With a large bunded area, containing a number of tanks, the hazard range from a poolfire inside the bund is generally much larger than that from a poolfire outside the bund. In other situations the poolfire outside the bund may dominate the hazard. Thermal radiation fluxes from poolfires are calculated using methods described in PCAG Chapter 2C.

When a toxic liquid forms a pool outside the bund, the hazard range tends to increase on account of the more rapid vaporisation rate from a greater surface area. If there is a pool outside the bund and one inside it, vapour released from both pools contributes to the toxic plume. Methods for modelling pool spreading and evaporation are given in PCAG Chapter 5B, but pools formed by releases of sulphur trioxide or oleum are modelled using methods described in PCAG Chapter 6H.

## Release Durations for Vessel/Tank Holes

MHAU generally uses the philosophy adopted for the chlorine siting policy (see PCAG Chapter 1B) to calculate release durations, i.e. liquid releases are assumed to continue until the initial liquid inventory is reduced by half. The basis for this assumption is that holes below the liquid level may occur anywhere and it is reasonable to assume that on average half the inventory will be lost before

the liquid level drops to the release point. Whilst this approach may be acceptable for a risk assessment, a worst case consequence assessment should assume that the hole is in the base of the vessel/tank and that the total inventory is available for release as a liquid.

Although on-site action to stop leaks from vessels/tanks is not usually possible, MHAU assessments usually assume that the maximum release duration is 30 minutes. This is based on the assumption that action by the emergency services will afford protection to the affected off-site population within 30 minutes.

In the majority of release from the vapour space of a pressure vessel, evaporation maintains the pressure in the vapour space. This process cools the liquid to such an extent that the release rate may decrease to an insignificant level before 30 minutes have elapsed. STREAM takes account of this effect and will display the time at which pressure in the vapour space reduces to atmospheric pressure. A rough idea of the timescale for pressure reduction for vessels containing only gas can be obtained using the method outlined above.

## **Release Rates and Durations for Pipework Failures**

MHAU usually assumes that failures can occur in any pipe or duct containing a hazardous gas or liquid under pressure. Pipes include above ground pipework between storage areas and process plants, pipework within process plants, pipework between delivery tankers and storage areas, and underground pipelines. Releases may be either single-phase (liquid or gas), or two-phase.

For consequence assessment, MHAU is interested in the pipework failure which gives the largest release rate. This may be from a rigid or flexible pipe used to off-load a road or rail delivery tanker. The chlorine siting policy (see PCAG Chapter 1B) recommended a range of pipework failures for 25/50 mm nominal bore liquid and gas pipework. This included guillotine failure, severe split (equivalent to a 25 mm diameter hole), small split and partial loss of a gasket from a flanged joint (both equivalent to a 4 mm diameter hole). MHAU methodology has been expanded to take account of pipework with diameter greater than 50mm and up to 1000mm and Chapter 1B amended accordingly.

MHAU considers the above pipework failures to be representative of those occurring at major hazard installations and recommends their use in land use planning assessments, while noting that all-welded pipework cannot suffer gasket failure. Representative failures similar to those mentioned above have been identified for releases from underground pipelines, and these are described in PCAG Chapter 1C for British Gas natural gas pipelines and in PCAG Chapter 6C for other pipelines.

Pipework failures are assumed to include failures of the body of valves in the pipe run. Failure of a pump body is assumed to be equivalent to a guillotine failure of the associated pipework. Where pipework is larger than around 150 mm nominal bore, it is appropriate to consider that a severe split will produce a hole which is equivalent to one third of the pipework diameter. In large bore pipework, a small split is assumed to be equivalent to a 25 mm diameter hole. A pinhole remains at 4mm diameter.

With larger diameter pipework and/or thicker gaskets, it may be necessary to increase the equivalent hole size for gasket failure/flange leaks. When assessing such failures, MHAU assumes that a section of gasket between bolts is lost and the equivalent hole size may be calculated as follows:

For a 50mm NB pipe, internal circumference of flange =  $\pi 50 = 157\text{mm}$

Assuming an 8 bolt flange, gasket circumference lost =  $157 / 8 = 19.6\text{mm}$

Assuming a 0.8mm (1/32") thick gasket, hole area is  $19.6 \times 0.8 = 15.7\text{mm}^2$

Equivalent hole diameter is calculated using  $\pi D^2/4 = 15.7$  hence  $D = 4.4\text{mm}$

For simplicity, the 4.4mm diameter is usually rounded down to 4mm so as to be equivalent to a small split (see above).

A similar calculation for a 50mm 4 bolt flange with a 3.2mm (1/8") thick gasket gives an equivalent hole diameter of 13 mm.

The maximum hazard range is associated with the highest release rate, which is usually produced by a guillotine failure. However, this conclusion needs to be viewed with some caution because there may be circumstances where other failures can give rise to equally great or an even greater hazard range.

## **Liquid Releases from Pipework**

Single-phase liquid releases occur with non-flashing liquids or with flashing liquids when the residence time in the pipework is too small to allow two-phase flow to become established (short pipes). In general, two-phase flow leads to lower release rates than single-phase liquid flow.

With flashing liquids, it is difficult to predict the exact point along a failed pipe at which two-phase flow becomes established, but it is generally accepted that it is of the order of a few pipe diameters from the vessel. On this basis, releases of flashing liquids from pipework are usually assumed to be two-phase. The considerations described in paragraphs 32 to 35, in connection with vessel hole releases apply to single-phase release of a flashing liquid from a short pipe.

Single-phase liquid release rates are usually calculated using the liquid flow option of the MHAU computer program STREAM, which is described in Part 2 of this chapter. Manual methods for calculating release rates are described in Part 3. STREAM can be used for modelling most types of release from pipework, but two specialist programs, PUMPIT and PADIT, are available to perform branched flow calculations. PUMPIT models a pipeline which is fed from a pump and PADIT models a pipeline which is fed from a constant pressure source such as a padded storage tank. These programs should only be used in consultation with the appropriate MHAU topic specialist.

A single-phase release of liquid from pipework usually forms a pool which can give rise to a thermal radiation hazard (poolfire), a flashfire or a toxic hazard if the pool surface releases a toxic vapour. Thermal radiation hazards from poolfires are modelled using methods described in PCAG Chapter 2C. General methods for modelling pool spreading and evaporation are given in PCAG Chapter 5B, but pools formed by releases of sulphur trioxide or oleum are modelled using methods described in PCAG Chapter 6H.

## **Two-Phase Releases from Pipework**

Two-phase releases occur with flashing liquids when there is sufficient residence time in the pipework to allow flashing to occur (i.e. the pipe between the vessel containing the flashing liquid and the release point is more than a few pipe diameters long).

Two-phase liquid release rates are normally calculated using the MHAU computer program STREAM which is described in Part 2 of this chapter. Manual methods for calculating two-phase release rates being described in Part 3. Information given in paragraphs 32 to 35, in connection with vessel hole releases, generally applies to two-phase liquid releases from pipework.

Two-phase liquid releases may form pools and give rise to a thermal radiation hazard (poolfire), a flashfire or a toxic hazard due to the release of vapour from the pool surface. Thermal radiation hazards from poolfires are modelled using methods described in PCAG Chapter 2C. General methods for modelling pool spreading and evaporation are given in PCAG Chapter 5B, but pools

formed by releases of sulphur trioxide or oleum are modelled using methods described in PCAG Chapter 6H.

## **Effect of Vessel or Pump Pressure on Liquid Two-phase Releases from Pipework**

Liquid flowing along pipe may be under pressure on account of its vapour pressure in the source vessel, the presence of a padding gas in the source vessel or the action of a pump. In the former case, the vapour pressure can only be maintained by evaporation which cools the liquid, therefore the driving pressure for a release gradually decreases. This effect is modelled by STREAM. Following consultation with the appropriate MHAU topic specialist, the specialist program, PADIT can be used to calculate single-phase liquid releases from branched pipelines where the source pressure is maintained by a padding gas.

Gross failures of pipework containing a pumped liquid are likely to depressurise the pump and increase the pumping rate of a centrifugal pump. This in turn increases the pressure drop between the pump and the release point. There is a balance point where the pump maintains a steady pumping rate that is more than the duty flow rate, but less than that which would occur if normal operating pressure was maintained.

The balance point may be found by calculating the inlet pressure versus flowrate characteristics of the failed section of pipe (from pump discharge to release point) using STREAM or a manual method (see below) and comparing the results with the pump performance curve for various pump discharge pressures up to the normal operating pressure. If the resulting release rate/pressure plot is superimposed on the pump curve, the balance release rate is where the two curves intersect. For single-phase liquid releases from a pipeline, the specialist program, PUMPIT, may be used. This program performs branched flow calculations to determine the release rate from a pipe, taking into account the pump curve and the continuing 'normal' flow along the pipeline beyond the release point. However, PUMPIT should only be used in consultation with the appropriate MHAU topic specialist.

If a centrifugal pump has been sized in accordance with normal chemical engineering practice, the release rate following pipework failure will not generally greatly exceed the duty flowrate. In the absence of a pump performance curve, MHAU assumes that the release rate, in the event of guillotine failure of pipework, is 50% greater than the duty flowrate. Whilst this assumption usually leads to a conservative assessment, it is always preferable to obtain the pump curve, particularly if a specific consequence assessment is required. For a risk assessment, the short-cut method will usually suffice when the risks are not dominated by releases from pipework.

## **Gas Releases from Pipework**

Gas releases from pipework, in the absence of any means to maintain pressure, reduce with time as the pipework and any vessel feeding it empties. This effect is modelled for releases from gas pipelines using methods described in PCAG Chapter 2E for British Gas natural gas pipelines and PCAG Chapter 6C for other pipelines. For gas releases from pipework associated with process plants, storage areas etc., each situation will require individual scrutiny to determine whether or not depressurisation of the pipework will be a significant factor in the assessment.

The release rate of gas from pipework connected to the vapour space of storage vessels containing liquefied gases, will reduce with time as the liquid evaporates to maintain the pressure and cools in the process. STREAM takes account of this effect and reports the initial, final and average release rates. For releases from pipework connected to vessels containing only gas, a rough idea of the pressure reduction effects can be obtained using the method outlined above.

The results of pipework release rate calculations often provide inputs to gas dispersion models, but current gas dispersion models cannot accept time varying release rates. In such cases the average release rate can be used, or the initial release rate when a conservative assessment is required.

## Durations for Releases from Pipework

MHAU usually uses the philosophy adopted for the chlorine siting policy (see PCAG Chapter 1B) to calculate release times. These takes into consideration the available inventory and whether or not there is provision to isolate failed pipework.

In the absence of any provision to isolate failed pipework, the release duration is controlled by the available inventory. In most cases, liquid lines are fed from the base of vessels and the whole liquid inventory is available for release. In the case of a gas release from pipework, the release will normally continue until the pressure reduces to atmospheric although at some point before this, the effects of the release may become insignificant.

The duration of releases from pipework connected to the vapour space of storage vessels containing liquefied gases, may be determined by the time taken for the pressure to fall to atmospheric pressure. This is calculated by STREAM. In the other cases it may be necessary to make a judgement as to when the release rate is sufficiently low that its effects can be neglected. An indication of the variation of the pressure inside vessels containing only gas when a connected pipe line fails, can be obtained using the method outlined above.

MHAU assessments usually assume a maximum release duration of 30 minutes on the basis that the emergency services can afford protection to the affected off-site population within this time.

General principles of risk reduction require that, where possible, pipework conveying hazardous substances should have provision for isolation in the event of failure. MHAU makes use of the philosophy adopted for the chlorine siting policy (see PCAG Chapter 1B) to reduce release durations where there is provision to isolate pipework. A number of different isolation devices have been identified and MHAU has allotted typical closure times to them which determine the release duration as follows:

Device (MHAU abbreviation)	Release Duration in minutes
Excess flow valve (XSFV)	1
Non return valve (NRV)	1
Automatic shut-off valve (ASOV)	1
Remotely operable shut-off valve (ROSOV)	5
Pump (if remotely operable)	5
Manual valve	20

### Notes

- (i) ASOV normally held open, and closed by detection equipment, e.g. pressure drop or gas detection.
- (ii) ROSOV normally held open, and closed by button operation at one or more locations remote from the release point.
- (iii) Manual valve closed by an operator taking suitable precautions, e.g. donning a breathing apparatus and approaching the valve to close it manually.
- (iv) For worst case consequence assessment, it is assumed that an XSFV, a NRV, an ASOV a ROSOV or a remotely operated pump may fail to terminate the release and therefore the

release duration will be 20 minutes where manual isolation is possible or 30 minutes where it is not.

## **Descriptions of Methods and Models**

### **Calculation of Instantaneous Release Source Term Conditions Using IRATE3.**

IRATE3 is an MHAU computer program which calculates the initial release conditions for instantaneous releases of pressurised liquefied gases. Immediately following loss of containment, liquefied gas will rapidly boil and flash producing an expanding vapour cloud. Flashing will continue to occur until the remaining liquid has cooled to its boiling point.

The process of flashing and expansion is violent and some of the remaining liquid will be in the form of droplets which are entrained into the vapour cloud together with a certain amount of air. This air which is initially at ambient temperature will cool to the liquid boiling point or lower and in so doing will provide heat to evaporate some of the entrained liquid droplets.

IRATE3 calculates the initial flash fraction and the quantity of air that is entrained into the vapour cloud. The final equilibrium temperature and liquid fraction in the vapour cloud are calculated using a full enthalpy balance on the basis that more liquid droplets will be evaporated until the vapour partial pressure is equal to the liquid vapour pressure.

#### **Inputs for IRATE3**

IRATE3 requires the following inputs:

##### **Substance number**

IRATE3 displays a list of substances and selecting a substance number allows IRATE3 to read various physical properties from a datafile. IRATE3 uses substance property datafiles with the extension PTX and the contents of these datafiles are described in PCAG Chapter 5B. For pressurised liquefied gases which are not listed by IRATE3, a manual calculation method may be used and this is described elsewhere in this chapter. It should be noted that not all substances listed by IRATE3 may be stored as pressurised liquefied gases.

##### **Stagnation temperature**

This is the storage temperature of the pressurised liquefied gas which, in the case of ambient temperature storage, is normally taken to be the standard day-time ambient temperature of 288°K. The cooling effect of lower night-time temperatures will have little effect on the storage temperature.

##### **Temperature of air**

MHAU normally uses 288°K for the ambient temperature which is assumed to be representative of typical day-time conditions and for night-time conditions, an ambient temperature of 278°K is often used.

##### **Mass of substance**

This is the total quantity of pressurised liquefied gas released from storage and MHAU normally assumes that the entire vessel contents are lost following vessel rupture. General guidance for determining release quantities is given above.

## **Output from IRATE3**

After the inputs substance number and stagnation temperature have been entered, IRATE3 produces output on the screen which consists of various parameters evaluated at the specified stagnation (storage) temperature. These outputs (which are not given in the printed output) are the vapour pressure (Pa), the vapour density ( $\text{kg/m}^3$ ), the liquid density ( $\text{kg/m}^3$ ), the liquid heat of vaporisation ( $\text{J/kg}$ ), the liquid specific heat ( $\text{J/kg}^\circ\text{K}$ ) and the vapour specific heat ( $\text{J/kg}^\circ\text{K}$ ).

IRATE3 produces printed output which reproduces the inputs, gives physical properties which have been calculated using the data in the physical properties datafile for the chosen substance and gives various parameters which describe the vapour cloud. The physical properties are evaluated at a temperature which is the average of the boiling point for the specified substance (obtained from the PTX datafile) and the specified stagnation temperature, see above.

The vapour cloud parameters are the initial flash fraction, the mass (kg) of air entrained, the final equilibrium temperature ( $^\circ\text{K}$ ) and the final vapour fraction. These parameters are normally used to provide inputs to a dense gas dispersion model such as DENZ which is described in PCAG Chapter 5D.

If DENZ is used for gas dispersion modelling, the initial flash fraction, the mass of air entrained and the final equilibrium temperature are normally used as inputs. One minus the initial flash fraction becomes the aerosol fraction, the mass of air entrained divided by the mass of substance (see above) becomes the initial dilution and the final equilibrium temperature becomes the release temperature. The final vapour fraction is not required for DENZ because the program sets this to 1 anyway.

Where IRATE3 predicts that the cloud temperature is below the liquid boiling point, because DENZ assumes that the cloud temperature cannot drop below the boiling point, the initial cloud temperature is adjusted upwards. The net effect of this is that when calculating how much dilution air is needed to evaporate all of the aerosol present in the initial cloud, DENZ predicts slightly more air is required than IRATE3 would.

Thus the amount of entrained air predicted by IRATE3 may be increased by DENZ either because IRATE3 does not predict full evaporation of the liquid (final vapour fraction less than 1) and/or because the cloud temperature predicted by IRATE3 is below the liquid boiling point.

## **Calculation of Flash Fractions Using FLASH**

FLASH is an MHAU computer program which calculates the initial flash fraction for releases of pressurised liquefied gases. This initial flashing is assumed to reduce the temperature of the remaining liquid to the boiling point. FLASH uses a standard relationship, which is also used in a number of other MHAU programs, e.g. IRATE3, to calculate the flash fraction.

The physical properties which the FLASH relationship uses are temperature dependent and the program reduces the temperature in  $0.1^\circ\text{K}$  steps in order to calculate an overall flash fraction. In this way, the flash fraction calculated by FLASH is usually more accurate than those calculated by other MHAU programs such as IRATE3 which usually use a single average temperature to evaluate physical properties.

## **Inputs for FLASH**

FLASH requires the following inputs

## **Substance**

FLASH requires certain physical properties to its calculations and these are obtained from a datafile (no file extension). The exact file name must be specified and a list of substances and their corresponding file names is given in Table 5A.1.

## **Initial temperature**

This is normally the temperature of the substance in storage which for ambient temperature storage is normally taken to be the standard day-time ambient temperature of 288°K. The cooling effect of lower night-time temperatures will have little effect on the storage temperature. In some cases, substances may be above or below ambient temperature but providing they are above their boiling point (at atmospheric pressure) flashing will occur. FLASH always assumes that substances are at the saturated vapour pressure which corresponds to the specified initial temperature.

## **Output from FLASH**

FLASH produces printed output which reproduces the inputs and gives the saturation vapour pressure (Pa) and the flash fraction.

## **Description of the Program STREAM**

The program STREAM is a collection of about twenty models that calculate the properties of fluids and determine the rate of flow out of a pipe or hole. Detailed descriptions of the various models, including the calculations performed, are given in PCAS Chapter 5A. Users have a choice from five main types of calculation which are:-

- Continuous two phase flow from pipes and orifices
- Continuous flow of vapour from a pipe or orifice
- Classic liquid flow out of a pipe or orifice
- Flow of vapour out of a hole above the liquid level in a vessel
- Flow of vapour from an orifice or pipe connected to a vessel containing liquid

The first three models produce time independent flow rates, while the fourth and fifth take account of temperature changes and liquid depletion in a vessel. The first model is the most complex and uses the largest number of subroutines.

The two phase option is for use with liquids that are stored under pressure at a temperature that is above their normal boiling temperature. It is not applicable to all substances in the list box and if the user selects a substance that does not satisfy this condition, the program will fail to run and display an error message.

The continuous gas flow option is applicable to gas pipelines and systems where the driving pressure (reservoir pressure) remains constant for the duration of the discharge. The program will fail to run if the user selects a liquid or a liquefied gas.

The classic liquid flow option in STREAM can be used to calculate the rate of release of a liquid from a pipe when the driving pressure remains constant and the rate of release of liquids and flashing liquids from holes below the liquid line in the wall of a storage vessel. In the latter case the flashing liquid is assumed to vaporise only after it has been released from the vessel, because there is insufficient time for the flashing to take place as the liquid passes through the hole in the vessel wall. However, the program does not account for changes in driving pressure and calculates a constant flow rate out of the vessel.

The fourth option in STREAM is used to calculate the flow rate of vapour with entrained liquid from a hole above the liquid line in a pressurised storage vessel. It can only be used for flashing liquids (i.e. those stored at a temperature that is above their boiling temperature at atmospheric pressure). If the user selects a substance and a storage temperature that is below its normal boiling point, the program will fail to run and produce an error message. Strictly speaking the model is not a two-phase model because it does not deal with flashing flow. The user can specify a liquid entrainment factor, but this remains constant and only has the effect of increasing the density of the released fluid and therefore the mass release rate. The model accounts for evaporation cooling of the liquid and heat transfer into the vessel from the atmosphere, as appropriate, therefore the release rate is not constant. The output is the initial and final flow rate and an average value over the period of the discharge.

The last flow rate option in STREAM is the calculation of the flow rate of vapour from a failed pipe connected, above the liquid line, to a vessel containing a flashing liquid. The fluid released is assumed to be 100% vapour and the basis of the model is identical to that of option 2 (continuous gas flow from a pipe), except that the driving pressure is allowed to decrease as the contents of the vessel cool on account of evaporation. The program does not predict the same orifice flow rate as the previous option with the liquid entrainment factor set to zero because it uses a different method which is more suited to pipework releases.

The various models are briefly outlined below together with a description of the program. More detailed information on the equations and their method of solution can be found later in this chapter.

The 2-phase flow option in STREAM calculates the flow of vapour and liquid from a pipe by solving the conservation of momentum equation for the fluid assuming homogeneous equilibrium.

$$vdP + G^2\left(vdv + \frac{4f \cdot v^2 \cdot dL}{2D}\right) = 0$$

This is written in the form:-

$$\Delta L = -\frac{D}{2f}\left(\frac{\Delta P}{G^2 v_m} + \frac{\Delta v}{v_m}\right)$$

Friction is accounted for by an iterative process that involves dividing the pipe length into 50 elements and calculating the length of each using the above equation. The difference between total length of the elements and the actual length is used to update the flow rate and friction. A reasonable accurate first guess for the flow rate is needed and this is provided by a solution of the flow equations proposed by Leung and Ciolek. It is known that their approaches produces an reasonably accurate, but slightly low value for the flow rate out of a pipe.

The program makes use of a number of subroutines and these are called after the first form has been completed and the "next" button is clicked is as follows:-

SetResForm	sets the captions on the results form
Get_Sub_Data	retrieves a SPI file and reads in property data
CkCopterS	checks the temperature is not above the critical temperature and calculates the vapour pressure of the fluid at the specified temperature. Also calculated is the density of the liquid.
DoNonCopterS	calculates an approximate flow rate using the equations of Leung and Ciolek
DoCopterS	main flow rate calculation which uses the fluid momentum equation to calculate the length of each element of pipe. These are summed and the result compared to the actual equivalent of the pipe. The program iterates by changing the friction factor and recalculating the elemental length of pipe.

In addition to the above programs, DoCopterS makes use of a number of functions and subroutines to calculate the physical and thermodynamic properties of the fluid and to solve simultaneous equations. These include:-

ROHG	calculates the density of the gas
ROHL	calculates the density of the liquid phase
Compressibility	calculates the compressibility factor using Redlich-Kwong equation of state
DHV	calculate the heat of vaporisation of the liquid
PRES	calculates the saturation vapour pressure given the temperature using the Reidel equation.
TEMP	calculates the temperature corresponding to a saturated vapour pressure
LHS	calculates the specific heat of the liquid
LVISC	calculates the viscosity of the fluid
Fanning	calculates the Fanning friction factor for the pipe
Equation1000	sets up three pairs of equations to be solved simultaneously
GaussElim	solution of the simultaneous equations
+PartialPivoting	
HandleHole	uses a correlation to calculate the flow out of holes and splits

### **Inputs to Two-Phase Flow Program**

The two-phase flow option in STREAM requires different input data according to the type of calculation being performed and whether the user wishes to calculate the head losses for the pipe given a set of fittings. Data is entered via two input forms and the results are displayed on a third form. If a head loss calculation is required, the user enters details of the pipe fittings via a separate input screen.

#### **Substance**

The input form has a drop down list box containing the names of all substances that the user may select. However, the program is only suitable for liquids that have a vapour pressure at the specified input temperature that is greater than ambient pressure - i.e. the temperature of the substance is above its boiling point, and it will flash on loss of containment. If the user selects a substance that does not satisfy this condition, a message "CopterS model not applicable" is displayed.

#### **Substance Temperature**

The temperature of the substance is entered in °K in the appropriate box. Unless the liquid is refrigerated its storage temperature is usually the same as ambient temperature, however, the contents of some process vessel are maintained at temperatures well above ambient. MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during nighttime.

Having selected the substance and entered its temperature the user has to click one of three buttons. The first labelled "load" offers the user the opportunity to load an input data file, thereby by allowing previous runs to be repeated. The centre button is labelled "next" and takes the user to the next input screen. The third button is labelled "exit" and allows the user to exit the program.

#### **Pipe or Orifice Flow**

The orifice or pipe flow options are selected via linked "radio buttons" at the top of the form. If the orifice button is clicked the user is prompted for the coefficient of discharge of the orifice, and other input data boxes become "greyed out". If the pipe flow radio button is clicked, the coefficient of discharge box disappears and the user has to enter details of the pipe.

## **Pipe Details**

The user enters the length of the pipe in metres, the diameter also in metres (this box is on the right hand side of the form) and the pipe roughness in microns.

## **Pipe Fittings - Velocity Head Loss Data**

Most pipes encountered in hazard/risk assessments have several fittings which affect the rate of flow of fluid out of a hole. The fittings are typically bends and valves, but can also include an entry nozzle or dip pipe. Each has a certain head loss associated with it which can be read-in from a data base and totalled by clicking on the K factor "calculate" button. This opens up a new input form with a drop down list box of pipe fittings. The user simply selects the fittings on the pipe under study and the total number of velocity head losses are automatically transferred to the previous input form. There is a "load" option which allows the user to recall a previously saved set of fittings.

## **Driving Pressure**

The pressure driving fluid out of a hole in a pipe connected to a liquefied gas storage vessel is usually the vapour pressure at the storage temperature. However, many storage tanks for flammable and toxic liquids are either permanently or occasionally pressurised with a padding gas. The user therefore has two main options - to set the driving pressure equal to the vapour pressure, or to set it equal to the padding pressure plus an appropriate head of liquid. This second option is selected by removing the X from the box indicating that the saturated vapour pressure is the total driving pressure. The padding pressure is entered in the "Stagnation pressure" box and the liquid head is entered in the box labelled "height of liquid above the discharge".

The saturation vapour pressure at the specified temperature is always displayed whichever of the above two options is selected. In either case the driving pressure must be above ambient pressure otherwise a warning message will be displayed.

## **Outputs for the Two Phase Flow Option in STREAM**

Clicking the "calculate flow" button runs the program and displays the output screen which presents data for six discharge parameters. On the right hand side is a box which contained buttons to allow the user to calculate the flow out of a split or hole in the pipe as distinct from the flow for a guillotine fracture. To make use of this option the user clicks on the small box labelled "hole/split", enters the equivalent diameter in metres and clicks the "calculate" button. The approximate release rate out of this split/hole is then displayed underneath the other parameters.

The output parameters all refer to the two phase fluid released from the pipe. Flow rate is the mass of liquid and vapour escaping per second. The outlet temperature and pressure refer to the fluid conditions as it leaves the pipe. Vapour mass fraction is the fraction of the total mass release rate that is composed of vapour, and the discharge velocity is the velocity of the two phase mixture as it leaves the pipe. The output density is the average density of the fluid leaving the pipe accounting for vapour fraction and temperature.

## **Description of the Model in the Two Phase Flow Option in STREAM**

The model is described in detail in PCAS Chapter 5A.

## Description of the Continuous Gas Flow Option in STREAM

This STREAM option models the flow of gas from an orifice or pipe using the method developed by Gyori which is outlined in PCAS Chapter 5A. It is based on a solution of standard equations for compressible flow taking account of pipe friction. A compressibility factor for the fluid is determined using the Redlich Kwong equation of state.

The program calls the following subroutines and functions:-

Get_Sub_Data	Reads in property data from the SPI file
SetResForm	Sets captions on the results form
CkCopterS	Carries out no calculations but calls CkGFlow
CkGFlow	Checks critical temperature is not exceeded and calculates the vapour pressure at the specified temperature.
CalcGFlow	Sets some of the variables used by the Gyori model
Compressibility	Calculates a compressibility factor for the fluid
N1tol	Calculates variables used by Gyori model
MainProg	Performs the solution of the Gyori equations
FuncA	Performs the iteration as part of the Gyori solution
FuncC	Calculates parameters used by Gyori

### Input Data for the Gas Flow Option in STREAM

The gas flow option in STREAM requires different input data according to the type of calculation being performed and whether the user wishes to calculate the head losses for the pipe given a set of fittings. Data is entered via two input forms and the results are displayed on a third form. If a head loss calculation is required, the user enters details of the pipe fittings via a separate input screen.

#### **Substance**

The input form has a drop down list box containing the names of all substances that the user may select. If the user selects a fluid with a vapour pressure that is less than one atmosphere at the specified temperature, the program will display a warning message "pressure minimal". However, because the program does not involve comparisons with ambient pressure, it will run with a wide variety of input data and calculate a flow rate when the pressure in the pipe is less than one atmosphere. Users are recommended to treat with great caution any results obtained after seeing the message "minimal pressure".

#### **Substance Temperature**

The temperature of the substance is entered in °K in the appropriate box. Unless the liquid is refrigerated its storage temperature is usually the same as ambient temperature, however, the contents of some process vessel are maintained at temperatures well above ambient. MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during nighttime.

Having selected the substance and entered its temperature the user has to click one of three buttons. The first labelled "load" offers the user the opportunity to load an input data file thereby by allowing previous runs to be repeated. The centre button is labelled "next" and takes the user to the next input screen. The third button is labelled "exit" and allows the user to exit the program.

## Pipe or Orifice Flow

The orifice or pipe flow options are selected via linked "radio buttons" at the top of the form. If the orifice button is clicked the user is prompted for the coefficient of discharge of the orifice, and other input data boxes become "greyed out". If the pipe flow radio button is clicked, the coefficient of discharge box disappears and the user has to enter details of the pipe.

### Pipe Details

The user enters the length of the pipe in metres, the diameter also in metres (this box is on the right hand side of the form) and the pipe roughness in microns.

### Pipe Fittings - Velocity Head Loss Data

Most pipes encountered in hazard/risk assessments have several fittings which affect the rate of flow of fluid out of a hole. The fittings are typically bends and valves but can also include an entry nozzle or dip pipe. Each has a certain head loss associated with it which can be read-in from a data base and totalled by clicking on the K factor "calculate" button. This opens up a new input form with a drop down list box of pipe fittings. The user simply selects the fittings on the pipe under study and the total number of velocity head losses are automatically transferred to the previous input form. There is a "load" option which allows the user to recall a previously saved set of fittings.

### Initial Pressure

The default driving pressure for the flow calculation is the saturation vapour pressure of the fluid at the specified temperature. However, the user can input a higher pressure via the initial pressure box, but they should be aware of the fact that in practice it is not possible to increase the pressure of a fluid above its saturated vapour pressure unless it is above its critical temperature.. The gas flow rate option in STREAM does not make this check and allows the user to specify any initial pressure irrespective of the critical temperature. Vapours are treated as almost ideal gases which do not quite obey the simple gas law equation, therefore considerable caution is recommended when carrying out vapour flow rate calculations. If the source of the pressure is a vessel at high temperature, the user is advised to use one of the depleting gas source models in STREAM.

### Outputs for the Gas Flow Option in STREAM

Clicking the "calculate flow" button runs the program and displays the output screen which presents data for five discharge parameters. These all refer to the properties of the "gas" leaving the pipe (or orifice) which is assumed to behave like a perfect gas except that:-

$$\frac{PV}{T} = zR$$

The compressibility factor "z" is generally close to 1 but varies with temperature. If the user observes that the compressibility is less than 0.1 then all of the results should be treated with great caution, because it suggests that the fluid may be a condensing vapour.

### Flow Rate

The flow rate is the rate at which gas leaves the pipe in kg/s assuming the initial upstream pressure is maintained.

## **Outlet Pressure**

This is the pressure of the gas as it exits the pipe, assuming that the initial upstream pressure is maintained. It is a function of the length of the pipe and the internal roughness as well as the upstream pressure. Clearly it must be greater than atmospheric pressure, and any results which show a pressure of less than one atmosphere should be rejected.

## **Outlet Temperature**

This is the temperature of the gas as it exists in the pipe. It is generally lower than the initial upstream pressure due to expansion cooling.

## **Gas Compressibility**

This is the value of "z" in the equation relating temperature, pressure and specific volume to the gas constant "R". In general it is a number close to unity. If the program predicts a compressibility of less than 0.1 the user should reject all of the output because it suggests that the model is unsuitable for the fluid.

## **Outlet Density**

This is the density of the gas as it leaves the pipe.

## **Description of the Model forming the basis of the Gas Flow Option in STREAM**

The model is described in detail in PCAS Chapter 5A.

## **Description of the Classical Liquid Flow model in STREAM**

The classic liquid flow option in STREAM is used to calculate the flow rate of non flashing liquids in pipes and the flow rate of all types of liquid from holes in the wall of a storage vessel. However, it assumes a constant driving force hence it cannot account for a decreasing source pressure when applied to flow from a vessel.

The program is made up of the following subroutines:-

Get_Sub_Data	Reads in property data from the SPI file
SetResForm	Sets captions on the results form
CkCopterS	Carries out no calculations but calls CkGFlow
CkGFlow	Checks critical temperature is not exceeded and calculates the vapour pressure at the specified temperature.
LFlowCalc	Main calculation/iteration
ROHL(T)	Calculation of the density of the liquid at temperature T
LVISC(T)	Calculation of the viscosity of the liquid at temperature T

## **Input data**

The classical liquid flow option in STREAM requires different input data according to the type of calculation being performed and whether the user wishes to calculate the head losses for the pipe given a set of fittings. Data is entered via two input forms and the results are displayed on a third form. If a head loss calculation is required, the user enters details of the pipe fittings via a separate input screen.

## **Substance**

The input form has a drop down list box containing the names of the substances that the user may select. The program is not suitable for calculating the flow of flashing liquids down pipes (the 2-phase option in STREAM should be used), but can be used to calculate the flow of a liquefied gas out of a hole in the wall of a storage vessel, below the liquid level, because there is not sufficient time for flashing to occur during passage through an orifice. If the user selects a substance with a boiling temperature at a pressure of one atmosphere that is above the specified temperature, the program displays a warning message "should you be using a 2-phase model". If the "yes" button is clicked the calculations are terminated. If the "no" button is clicked, the calculations can proceed, but the user must treat the results with caution. Flow through an orifice is correctly calculated for flashing liquids but flow down a pipe is not.

## **Substance Temperature**

The temperature of the substance is entered in °K in the appropriate box. Unless the liquid is refrigerated its storage temperature is usually the same as ambient temperature, however, the contents of some process vessel are maintained at temperatures well above ambient. MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during nighttime.

Having selected the substance and entered its temperature the user has to click one of three buttons. The first labelled "load" offers the user the opportunity to load an input data file thereby by allowing previous runs to be repeated. The centre button is labelled "next" and takes the user to the next input screen. The third button is labelled "exit" and allows the user to exit the program.

## **Pipe or Orifice Flow**

The orifice or pipe flow options are selected via linked "radio buttons" at the top of the form. If the orifice button is clicked the user is prompted for the coefficient of discharge of the orifice, and other input data boxes become "greyed out". If the pipe flow radio button is clicked, the coefficient of discharge box disappears and the user has to enter details of the pipe.

## **Pipe Details**

The user enters the length of the pipe in metres, the diameter also in metres (this box is on the right hand side of the form) and the pipe roughness in microns.

## **Pipe Fittings - Velocity Head Loss Data**

Most pipes encountered in hazard/risk assessments have several fittings which affect the rate of flow of fluid out of a hole. The fittings are typically bends and valves but can also include an entry nozzle or dip pipe. Each has a certain head loss associated with it which can be read-in from a data base and totalled by clicking on the K factor "calculate" button. This opens up a new input form with a drop down list box of pipe fittings. The user simply selects the fittings on the pipe under study and the total number of velocity head losses are automatically transferred to the previous input form. There is a "load" option which allows the user to recall a previously saved set of fittings.

## **Stagnation Pressure**

The pressure driving fluid out of a hole in a pipe connected to a storage vessel is usually the vapour pressure of the fluid at the storage temperature plus any liquid head. However, many storage tanks for flammable and toxic liquids are either permanently or occasionally pressurised with a padding gas. The user therefore has two options - to set the driving pressure equal to the vapour pressure,

or to set it equal to the padding pressure plus an appropriate head of liquid. The first option is not really an option for non flashing liquids because it would mean that the driving pressure is less than ambient pressure in which case a message is displayed "atmospheric pressure assumed at surface" and then a second message "LFLOW model not applicable" is displayed. The user has to ensure that the driving pressure is significantly above ambient pressure by a combination of liquid head and padding (stagnation) pressure. To do this the X from the box indicating that the saturated vapour pressure is the total driving pressure is removed by clicking on it. The padding pressure is entered in the "Stagnation pressure" box and the liquid head is entered in the box labelled "height of liquid above the discharge".

The saturation vapour pressure at the specified temperature is always displayed which ever of the above two options is selected. In either case the driving pressure must be above ambient pressure otherwise a warning message will be displayed.

## **Outputs of the Classical Liquid Flow Option in STREAM**

Clicking the "calculate flow" button runs the program and displays the output screen which shows only the flow rate out of the pipe. Buttons allow the user to return to the input screen, save the results or exit the program. This flow rate is a constant because the program cannot take account of changes in driving pressure due, for example, to a decrease in liquid head and evaporation cooling.

## **Description of the Classic Liquid Flow Option in STREAM**

The model is described in detail in PCAS Chapter 5A.

## **Description of the Depleting Source Vessel Vapour & Liquid Discharge Calculation in STREAM**

This option in STREAM calculates the rate of flow of a fluid out of a hole in a vessel when the puncture is above the liquid level. The liquid should have a vapour pressure at ambient temperature that is above 1 atmosphere. The calculations are based on standard equations for choked and non choked flow. Liquid entrainment is allowed for by use of a simple multiplying factor.

The program calls the following functions/subroutines

GetSubstanceList	Retrieves a SPI file and reads in property data
SetResForm	Sets the captions on the results form
CKCopterS	Checks the temperature is not above the critical temperature and calculates the vapour pressure at the specified temperature. It also calculates the density of the liquid
SetResForm	To set up the results form
Pres(T)	To calculate the saturated vapour pressure at temperature T
ROHL(T)	To calculate the density of the liquid at temperature T
DHV(T)	To calculate the heat of vaporisation

## **Input Data for VHFLOW Option in STREAM**

### **Substance**

The input form has a drop down list box containing the names of the substances that the user may select. However, the program is only suitable for liquids that have a vapour pressure at the specified input temperature that is greater than ambient pressure - i.e. the temperature of the substance is

above its boiling point and it will flash on loss of containment. If the user selects a substance that does not satisfy this condition, a message "CopterS model not applicable" is displayed.

### **Substance Temperature**

The temperature of the substance is entered in °K in the appropriate box. Unless the liquid is refrigerated, its storage temperature is usually the same as ambient temperature, however, the contents of some process vessel are maintained at temperatures well above ambient. MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during nighttime.

Ambient temperature is entered in the next box. As noted above MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during night time.

Having selected the substance and entered the two temperatures the user has to click one of three buttons. The first labelled "load" offers the user the opportunity to load an input data file thereby by allowing previous runs to be repeated. The centre button is labelled "next" and takes the user to the next input screen. The third button is labelled "exit" and allows the user to exit the program.

### **The second Input Data Form**

On clicking the "next" button the user is taken to the second input screen where the diameter of the hole in the vessel, the mass of fluid in the vessel and the time period for the release are specified. On this form the user can specify the amount of liquid entrainment and whether heat flow into the vessel to compensate for evaporation cooling should be allowed.

### **Entrained Liquid Mass Ratio**

The program allows the user to specify how much liquid is entrained in the vapour as it escapes from the vessel. It is entered as a simple mass ratio. For example 1 would mean the mass of vapour and liquid leaving the vessel are equal. This is the value MHAU would normally adopt for releases of liquefied gases from pressure vessels.

### **Duration of the Discharge**

In practice little can be done to mitigate the consequences of accidents involving the release of a fluid from a punctured storage vessel and the release generally continues until either the vessel is empty or the pressure inside it decreases to atmospheric pressure. MHAU usually assumes such releases that do not shut-off automatically have a duration of 30 minutes.

### **Heat Flow into the Vessel**

When a pressure vessel containing a vaporising liquid is punctured above the liquid level, vapour escapes through the hole and the liquid evaporates to maintain the saturated vapour pressure inside the vessel. The vaporisation process removes heat from the liquid which, in the absence of any heat transfer into the vessel, cools. The user has the option to allow heat to be conducted into the vessel from the atmosphere using a standard heat transfer equation. This prevents the liquid temperature falling as fast as it otherwise would, and hence tends to maintain the pressure inside the vessel, which in turn maximises the flow of vapour out. MHAU usually assumes heat can be transferred through the vessel walls unless they are insulated.

## **Initial Mass in Vessel**

In consequence assessments, when the worst accidents are considered, MHAU assumes that a vessel is filled to capacity. For risk assessment calculations the limited time a vessel remains full to capacity should be taken into account. One simple way of doing this is to assume that the vessel is half full.

## **Hole Size**

The chlorine siting policy (see PCAG Chapter 1B) assume that bulk storage vessels can suffer failures involving a range of hole sizes with equivalent diameters of 6, 13, 25 and 50 mm in both the liquid and the vapour space. MHAU normally considers these to be representative of the failure modes that should be considered in land-use planning assessments for major hazard installations.

## **Outputs for the VHFLOW option in STREAM**

Clicking the "calculate flow" button runs the program and displays the output screen which presents data for seven discharge parameters. If the user has selected a short discharge period, the vessel is likely contain liquid and be above ambient pressure at the end of the discharge, in which case, no data will be displayed in the "time to reach atmospheric pressure" box. The first five output parameters refer to the discharged fluid while the "final temperature" and "final pressure" refer to conditions inside the vessel.

## **Initial Flow**

The initial flow rate is the rate at which fluid (vapour and liquid) escape from the vessel the instant the hole appears in the wall. It is the maximum rate of loss of vessel contents because as time goes on the liquid cools due to evaporation, the pressure falls and the rate of discharge decreases.

## **Time to Atmospheric Pressure**

This is the time taken for the pressure inside the vessel to fall to atmospheric pressure. It is equal to the time taken for the temperature of the fluid to fall to the value at which the saturated vapour pressure is one atmosphere, or it is equal to the time taken for the vessel to loose all its contents. If a value is not displayed, the vessel continues to hold liquid at the end of the discharge period and the internal pressure is above atmospheric pressure.

## **Final Flow**

The final flow is the rate of discharge of fluid (vapour + liquid) at the end of the discharge period. If the pressure inside the vessel falls to atmospheric pressure before the end of the discharge period, the final flow rate is zero.

## **Average Flow**

The average flow rate in kg/s is equal to the total mass of fluid lost from the vessel during the discharge period, divided by that period. It therefore represents a true average flow rate.

## **Total Mass Discharged**

The program calculates the flow over a large number of time steps and accumulates the loss over each in order to provide data on the total mass of fluid discharged at the end of the release period, (or when the pressure falls to atmospheric pressure).

## Final Temperature and Pressure

A vaporising liquid in a vessel with a hole in the vapour space has to evaporate to maintain the saturation vapour pressure. The process removes heat from the liquid which is rarely made up by heat transfer from outside, hence the contents of the vessel cool. STREAM calculates the liquid temperature and the saturation vapour pressure throughout the period of the discharge and is able to display this information at the end of the calculation.

### Description of the depleting vessel flow in STREAM

The model is described in detail in PCAS Chapter 5A.

### Description of the Gas Flow from a Vessel option in STREAM

This program is used to calculate the flow of out of pipe connected above the liquid level to a vessel containing a liquefied gas. The methodology is essentially the same as that employed in the continuous gas flow option except that here the reservoir pressure is decreasing as the liquid in the vessel cools due to evaporation. The flow rate is consequently time dependent but program actually only displays on the output form the initial flow rate, the final flow at the end of the period and the average flow rate over the discharge period. An error occurs if there is no liquid phase in the vessel at the start of the calculations, in which case a message "VGHFlow Model is unsuitable" is displayed and the program terminates.

The program calls the following functions/subroutines

Get_Sub_Data	Reads in property data from the SPI file
SetResForm	Sets captions on the results form
CkCopterS	Carries out no calculations but calls CkGFlow
CkGFlow	Checks critical temperature is not exceeded and calculates the vapour pressure at the specified temperature
CalcGFlow	Sets some of the variables used by the Gyori model
Compressibility	Calculates a compressibility factor for the fluid
N1tol	Calculates variables used by Gyori model
MainProg	Performs the solution of the Gyori equations
FuncA	Performs the iteration as part of the Gyori solution
FuncC	Calculates parameters used by Gyori

### Input Data for Depleting Gas Flow Calculations in STREAM

The depleting source gas flow rate option in STREAM can calculate the flow rate from a pipe connected to the vapour space of a vessel or from a hole in the vessel wall above the liquid level. In the first case the user has the option to calculate the head losses for the pipe given a set of fittings. Data is entered via two input forms and the results are displayed on a third form. If a head loss calculation is required, the user enters details of the pipe fittings via a separate input screen.

### Substance

The input form has a drop down list box containing the names of all substances that the user may select. However, the program is only suitable for liquids that have a vapour pressure at the specified input temperature that is greater than ambient pressure - i.e. the temperature of the substance is above its boiling point, and it will flash on loss of containment. If the user selects a substance that does not satisfy this condition, a message "VGHFLOW model not applicable" is displayed.

## **Substance Temperature**

The temperature of the substance is entered in °K in the appropriate box. Unless the liquid is refrigerated, its storage temperature is usually the same as ambient temperature, however, the contents of some process vessel are maintained at temperatures well above ambient. MHAU normally assumes that ambient temperature is 288°K during the day and 278°K during night time.

Having selected the substance and entered its temperature the user has to click one of three buttons. The first labelled "load" offers the user the opportunity to load an input data file thereby by allowing previous runs to be repeated. The centre button is labelled "next" and takes the user to the next input screen. The third button is labelled "exit" and allows the user to exit the program.

## **Pipe or Orifice Flow**

The orifice or pipe flow options are selected via linked "radio buttons" at the top of the form. If the orifice button is clicked the user is prompted for the coefficient of discharge of the orifice, and other input data boxes become "greyed out". If the pipe flow radio button is clicked, the coefficient of discharge box disappears and the user has to enter details of the pipe.

## **Pipe Details**

The user enters the length of the pipe in metres, the diameter also in metres (this box is on the right hand side of the form) and the pipe roughness in microns.

## **Pipe Fittings - Velocity Head Loss Data**

Most pipes encountered in hazard/risk assessments have several fittings which affect the rate of flow of fluid out of a hole. These are typically bends and valves but can also include an entry nozzle or dip pipe. Each has a certain head loss associated with it which can be read-in from a data base and totalled by clicking on the K factor "calculate" button. This opens up a new input form with a drop down list box of pipe fittings. The user simply selects the fittings on the pipe under study and the total number of velocity head losses are automatically transferred to the previous input form. There is a "load" option which allows the user to recall a previously saved set of fittings.

## **Heat Flow into the Vessel**

When a pressure vessel containing a vaporising liquid is punctured above the liquid level, vapour escapes through the hole and the liquid evaporates to maintain the saturated vapour pressure inside the vessel. The vaporisation process removes heat from the liquid which, in the absence of any heat transfer into the vessel, would cool. The user has the option to allow heat to be conducted into the vessel from the atmosphere using a standard heat transfer equation. This prevents the liquid temperature falling as fast as it otherwise would and hence tends to maintain the pressure inside the vessel. This in turn maximises the flow of vapour out. MHAU usually assumes heat can be transferred through the vessel walls unless they are insulated.

## **Initial Mass in Vessel**

In consequence assessments, when the worst accidents are considered, MHAU usually assumes that a vessel is filled to capacity, but for risk assessment account should be taken of the small time vessel remain full. One simple way of doing this is to assume that the vessel is half full at the time of the accident.

## **Duration of the Discharge**

In practice little can be done to mitigate the consequences of accidents involving the release of a fluid from a punctured storage vessel and the release generally continues until either the vessel was empty or the pressure inside it decreases to atmospheric pressure. MHAU usually assumes such releases that do not shut-off automatically have a duration of 30 minutes.

The saturation vapour pressure at the specified temperature is always displayed whichever of the above two options is selected. In either case the driving pressure must be above ambient pressure otherwise a warning message will be displayed.

## **Outputs for the depleting source gas flow rate option in STREAM**

Clicking the "calculate flow" button runs the program and displays the output screen which presents data for six discharge parameters. Unlike the other vessel outflow calculation, the time the pressure falls to atmospheric pressure is not displayed. If the user specifies a very long release duration, the program displays a message "pressure minimal" which indicates that the vessel pressure has fallen below atmospheric pressure. However, the program does not fail to run under these conditions and will calculate both a flow rate and a vessel pressure.

## **Mass Remaining**

The mass remaining is the mass of fluid remaining in the vessel at the end of the discharge period. This is rarely zero because the evaporation to support the discharge cools the liquid and reduces the flow to a very low level before all the contents are lost.

## **Temperature**

The temperature is the temperature of the fluid in the vessel at the end of the discharge period. It is usually less than 273°K due to evaporation cooling. If the user specifies a very large diameter pipe the amount of liquid lost during one time step (10 sec) can be very large and cause a correspondingly large decrease in temperature. Unrealistic input conditions can cause the program to stop calculating and display a "model unsuitable" message.

## **Pressure**

The pressure data refers to the pressure inside the vessel which is the saturation vapour pressure at the temperature of the liquid. If the temperature of the liquid has fallen dramatically due to rapid evaporation, the pressure can be below atmospheric pressure, under these circumstances the program displays a warning message "pressure minimal" and any results should be viewed with caution.

## **Initial Flow rate**

The initial flow rate is the rate at which vapour escape from the broken pipe. It is the maximum rate of loss of contents because as time goes on the liquid cools due to evaporation, the pressure falls and the rate of discharge decreases.

## **Final Flow**

The final flow rate in kg/s is the rate of release of vapour at the end of the discharge period. If the pressure inside the vessel falls to atmospheric pressure before the end of the discharge period, the final flow rate is not zero because it is calculated using the equation:

$$Flow\ Rate = Area\sqrt{2\rho}$$

where  $\rho$  is the density of the gas which is determined from its equation of state without reference to atmospheric pressure.

### **Average Flow**

The average flow rate in kg/s is equal to the total mass of fluid loss from the vessel during the discharge period, divided by that period. It therefore represents a true average flow rate.

### **Description of the model forming the basis of the depleting gas flow rate calculation in STREAM**

The model is described in detail in PCAS Chapter 5A.

### **Calculation of Bund Overtopping Fraction using OVERTOP and/or LSMS**

Both OVERTOP and LSMS estimate the fraction of the liquid released that overtops a surrounding bund following catastrophic failure of an atmospheric storage vessel which is surrounded by a concentric circular bund.

OVERTOP uses data generated in small-scale experiments. The OVERTOP model is described in detail in PCAS Chapter 5A.

LSMS (Liquid Spill Modelling System) is a computer code developed by Cambridge Environmental Research Consultants Ltd to calculate the spreading and vaporisation of a liquid pool, with sponsorship by BG, Gaz de France, the US Gas Research Institute and HSE. It solves the hydrodynamic shallow-layer equations in one (x or r) dimension and includes interaction with a vertical retaining bund wall, including overtopping and further spreading of liquid beyond the bund. It allows a solid, porous or liquid substrate. Its thermodynamic equations incorporate a unified treatment of cryogenic and volatile liquids, and there is a software interface with GASTAR to allow straightforward study of dispersion of the vapours that emanate from the pool.

Use of OVERTOP and LSMS is currently limited to the Overtopping Topic Specialist.

### **Inputs for OVERTOP and LSMS**

OVERTOP and LSMS requires as inputs the tank radius, the maximum tank fill height, the minimum tank-to-bund-wall gap, and the bund height.

### **Outputs from OVERTOP and LSMS**

OVERTOP estimates the fraction of released liquid that will overtop three styles of bund; a vertical wall, a 60 degree embankment and a 30 degree embankment. Each value should be between zero and one, and the three values should be in increasing order. However, due to imperfections in the underpinning experimental data and in the fitting algorithm, exceptions may occur. The Topic Specialist will advise accordingly. LSMS is currently limited to vertical bund walls.

### **Manual Calculation Methods**

This part of Chapter 5A has not yet been written. In the mean time, descriptions of various manual methods for calculating release rates may be found in the documents Source Terms (D A Carter)

and Discharge Rate Calculations for Use in Plant Safety Assessments (P K Ramskill) which are listed in the bibliography.

## **Bibliography**

The following is a list of documents which contain the background information which has been used in the preparation of this chapter.

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Discharge Rate Calculation Methods for Use in Plant Safety Assessments. P K Ramskill. SRD R 352. February 1986.

## **Table 5A.1 - List of Substance Properties Datafiles Available for use with FLASH**

<b>Substance Name</b>	<b>Datafile Name</b>	<b>Substance Name</b>	<b>Datafile Name</b>
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Acrylonitrile	ACN	Ammonia	AMMONIA
Arsine	ARSINE	Benzene	BENZENE
Bromine	BROMINE	Butane	BUTANE
Chlorine	CHLORINE	Carbon monoxide	CO
Crude oil	CRUDEOIL	Carbon disulphide	CS2
Cyclohexane	CYHEXANE	Dimethyl ether	DME
Dimethyl sulphate	DMS	Ethane	ETHANE
Ethanol	ETHANOL	Ethylene	ETHYLENE
Ethylene oxide	ETOX	Freon 113	FREON113
Hydrogen sulphide	H2S	Sulphuric acid	H2SO4
Hydrochloric acid	HCL	Hydrogen cyanide	HCN
Heptane	HEPTANE	Hexane	HEXANE
Hydrogen flouride	HF2	Hydrogen	HYDROGEN
Methane	METHANE	Methanol	METHANOL
Methyl bromide	METHBR	Methyl chloride	METHCL
Nitrogen dioxide	N2O	Oleum 65%	OLEUM65
Oxygen (liquid)	OXYGEN	Pentane	PENTANE
Phenol	PHENOL	Phosgene	PHOSGENE
Phosphine	PHOSPHIN	Phosphorus oxi-chloride	POCL3
Propane	PROPANE	Propylene oxide	PROPOX
Propylene	PROPYLEN	Sulphur dioxide	SO2
Sulphur trioxide	SO3	Thermex	THERMEX
Vinyl chloride monomer	VCM	Water	WATER

Note that FLASH is normally used for modelling pressurised liquefied gases and not all of the substances listed above are stored or handled in that form.

## Document History

1st Draft 13/07/93	Part 1 issued for comment to MHAU topic specialists (D A Carter and J Bugler).
1st Issue 20/08/93	Part 1 incorporates comments of and approved for issue by MHAU topic specialists.
2nd Draft 06/12/93	IRATE3 write-up in Part 2 issued for comment to MHAU topic specialist (D A Carter).
3rd Draft 07/12/93	FLASH write-up in Part 2 issued for comment to MHAU topic specialist (D A Carter). Structure now separates manual methods into Part 3.
1st Revision 10/01/94	Bibliography Modified.
2nd Issue 17/01/94	IRATE3 and FLASH write-ups approved for issue by MHAU Topic Specialist. References added for write-ups not yet done. Reference to specialist programs PUMPIT and PADIT now included.
1st Revision 08/11/96	Bookmarks inserted prior to Corporate Recall implementation
2nd Revision 09/01/97	Outlined & linked for CR
3rd Revision 01/03/97	(Draft) Description of STREAM by P Kinsman
3rd Issue 17/04/97	Approved for issue by topic specialist. IRATE3 and FLASH write-ups reintroduced. Re-bookmarked and linked for Corporate Recall.
1st Revision 30/04/97	(Draft Only) Descriptions of models and theory removed to PCAS Chapter 5A.
2nd Revision	(Draft Only) Pagination and cross-refs checked. Re-bookmarked.

29/05/97	
2nd Issue 25/07/97	Approval for issue under new document system agreed at UMM, July 1997.
3rd Issue 23/10/97	Document altered at paras 54 -56 to take account of new Unit policy on frequencies for failures of large bore pipes. Paper presented by John Gould and agreed by MHAU Panel on 15th September 1997.
Version 15 03/08/1998	Converted to Word Pro format ready for HSE Intranet
Version 16 14/08/2001	Amended to align with new policies on bund overtopping and calculation of pool size.

## **Document Control Information**

Open Government Status: Full Disclosure

Review Date: 01 July 2002

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Checked by:	P Appleton		
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