MIE TALK - July 2015

HAZARDOUS AREA CLASSIFICATION

EXPLOSIVE GAS ATMOSPHERES

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Abstract

The classification of hazardous areas forms part of legislation and provides a process to ensure a safe working environment for the operations. Hazardous Area Classification (HAC) is therefore an important part of the design of a plant and needs to be completed before the selection of equipment is done. HAC can be done by direct example, source of release, risk studies or a combination of the three methods.

Introduction

HAC has historically been done by people who had experience and dispersion calculations were not used extensively. To facilitate this standards and codes of practice was developed to attempt to define a best practice and create a zone classification for certain areas where the probability existed of flammable atmospheres.

Legislation

Legislation forms part of the drive towards a more reliable plant and a safer working environment.

The constitution defines our “rights” in the bill of rights and this includes for example the right to life and to be safe.

The OHS ACT defines the “who” and the “why” of legislation. This specifically is defined in the accountabilities of the employer and the employee towards a safe working environment.

The regulations define “what” has to be done and in the case of Electrical Installation regulations (EIR) section 9(1) requires the identification of hazardous areas and the classification thereof.

The standards define the “how” of the requirements as per the regulations. In this case there are a number of standards that defines the process of area classification.

Further publications e.g. codes of practise and accepted publications may be referenced as well.

Scope of Work

To start with the area classification it is required that a specific scope of work (SOW) be defined. This would typically include the following:

- A physical scope i.e. GPS coordinates, walls of a building, road, fences of the plant etc.
- The operations battery limits i.e. input flanges and output flanges.
- All facilities that are included i.e. substations, control rooms, workshops, analyser shelters, etc.

The intent is to clearly define everything that is to be included in the area classification process for the specific job.

Team

The team must include all employees and contractors that have a connection in the specific SOW. The first person to choose will be the Subject Matter Expert (SME) regarding the HAC process. The SME will provide guidance for the rest of the team until the completion of the work. The rest of the members may form part of the team on an ad-hoc basis.

The team will consists of any number of the following. A description of a typical input has been added in brackets:

- Production (Usually the OHS Act 16(2) appointee) (Final accountability and approval of study and drawings)
- General Machinery Regulation appointee GMR 2(1) (Final accountability and approval of study and drawings)
- Subject Matter Expert (facilitation of the process, classification of the areas, and approval of the study and final drawings)
- Process (process description, operating envelope)
- Chemical (chemicals, product streams compositions)
- Mechanical (types of seals used)
- Electrical (existence of common lube systems)
- Analyser (analyser huts and chemicals measured)
- Instrumentation (types of instrument fittings)
- Process Safety (catastrophic events, areas of concern from risk management processes, historical events)
- Safety Health and Environment (SHE), (chemical stores, procedures, historical incidents or accidents)
- Document Management (current studies and drawings)
- CAD (draughting requirements)
- Draughting (plant walks and SOR identification)

It is important to note the specific inputs of each member to facilitate their time and effort during the classification. An example of the inputs or accountabilities for each member has been added to the above list.

Chemicals

Chemical list

A list of all the chemicals identified in the SOW must be compiled. Materials may include chemicals from the process, battery rooms, chemical stores, nearby plant’s dispersions that overlaps this SOW, chemicals transported in and out of the plant by truck, and any other chemical used during the operation and maintenance of the plant.

Chemical Flammability

The flammability of each chemical composition, component or element must be determined and added to the list. This may be done via the Material Safety Data Sheet (MSDS) or other sources. The team must agree on the validity and accuracy of the source of information. The values that are needed include:

- Flashpoint in ^{0}C
- Lowest Flammability Level (LFL) or Lower Explosive Level (LEL) in %.
- Upper Flammability Level (UFL) or Upper Explosive Limit (UEL) in %.
- Auto Ignition temperature (AIT) or Minimum Ignition Temperature (MIT) in ^{0}C

Physical Properties

Other properties also required include:

- Relative density in a ratio of vapour/gas to air
- Miscibility
- Chemical Abstract System (CAS) number
- The acentric factor (ω) of a compound is defined in terms of the reduced vapour pressure evaluated at a reduced temperature.
- Boiling point:
    - The **normal** boiling temperature is the temperature at which the vapour pressure equals exactly 101,325 Pa. Temperature values from older references where reported for the prevailing pressure (0.95–0.97 atmosphere) rather than at 1 atmosphere.
    - The boiling point is when the liquid will boil as soon as the liquid vapour pressure is equal to the specific pressure of the specific environment. This means the pressure must also be quoted in relation to the boiling point specified. In this case the boiling point at the specific elevation pressure must be used.
- The compressibility factor (Z), also known as the compression factor, is the ratio of the molar volume of a gas to the molar volume of an ideal gas at the same temperature and pressure. It is a useful thermodynamic property for modifying the ideal gas law to account for the real gas behaviour. In general, deviation from ideal behaviour becomes more significant the closer a gas is to a phase change, the lower the temperature or the larger the pressure.
- Critical point properties
    - Critical pressure P_c in Pascal
    - Critical temperature $T_{c\ in}$ ^{o}C
    - Critical volume in m^3
- Density g/m^3
- Molar mass in g/mol
- Percentage of each element in the composition
- Vapour pressure at the specific temperature in Pascal
- Polytrophic index of adiabatic expansion is the ratio of the heat capacity at constant pressure (C_p) to heat capacity at constant volume (C_v).

The above is an extraction of some of the details used in the dispersion calculation. In some cases the property is used to calculate another property in the absence of specific data.

Chemical Classification

The specific chemical or composition are classified as per SANS 60079-20-1 in terms of the Group and the temperature class. The Minimum Ignition Current (MIC) ratio and Maximum Experimental Safe Gap (MESG) are used to define the Group of the gas in terms of IIA, IIB, or IIC. Another method used is the Minimum Ignition Energy (MIE).

For most gases and vapours, it is sufficient to make only one determination of either Maximum Experimental Safe Gap (MESG) or Minimum Ignition Current (MIC) ratio to classify the gas or vapour.

One determination is adequate when:

- Group IIA: MESG > 0,9 mm, or MIC > 0,9.
- Group IIB: 0,55 mm ≤ MESG ≤ 0,9 mm, or 0,5 ≤ MIC ≤ 0,8.
- Group IIC: MESG < 0,55 mm, or MIC < 0,5.

Determination of both the MESG and MIC ratio is required when:

- for IIA: 0,8 ≤ MIC ≤ 0,9 need to confirm by MESG,
- for IIB: 0,45 ≤ MIC ≤ 0,5 need to confirm by MESG,
- for IIC: 0,5 ≤ MESG ≤ 0,55 need to confirm by MIC.

Le Chatelier's law may be used for mixtures within certain limits.

Chemicals tend to come in compositions and it is rare to encounter elements. The properties of all the different compositions are not defined in the standards or literature. A calculation may be used to get to the composition flashpoint, LEL etc. but due diligence must be applied to the applicability of equations used and understanding of mixtures.

Direct Example

At this point we have a SOW, a team, a list of chemicals, and each chemical is classified in terms of its Temperature Class and Gas Group. We can now go ahead and start to classify the area i.e. addressing the zones and the dispersion distance around the equipment. The easiest way to do this is by way of direct example. Examples of a number of sources of release are provided in the documents below:

- Area Classification Code for Installations Handling Flammable Fluids – Part 15 of the IP Model Code of Safe Practice in the Petroleum Industry (Energy Institute)
- API RECOMMENDED PRACTICE 505 - Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2 (American Petroleum Institute)
- SANS 10089-2 - The petroleum industry Part 2: Electrical and other installations in the distribution and marketing sector (South African National Standards)
- SANS 10108 - The classification of hazardous locations and the selection of equipment for use in such locations (South African National Standards)
- SANS 60079-10-1 - Explosive atmospheres Part 10-1: Classification of areas — Explosive gas atmospheres (South African National Standards)

The above list is not conclusive as there are numerous documents published over the years and each of these documents, standards or publications has attempted to make it easier for the user to classify the areas.

The above documents in general refer to petroleum facilities and therefore the chemicals, equipment and general discussions relates to such facilities. Challenges arise when scenarios are encountered which are not an exact match to the examples. In these cases the SOR method must be applied. Direct examples may also overextend the area of classification.

Concerns with direct example

Direct example has a number of limitations based on the following inputs:

- Chemical product – in general petroleum installations etc.

- Production equipment – bigger pump rates, higher volumes etc.
- Operational conditions – Nitrogen blankets, stable buffer capacity in tanks, safety release valves on vents, venting into a closed flare system etc.
- Meteorological conditions – different elevation, different ambient pressure and temperature, different wind conditions, etc.

In a number of cases there are mitigating circumstances that form part of the operational procedures that is not included in the direct example. A sample may be taken in a closed methodology resulting in a negligible amount of release. The same sample point could only be used during start-up and this may happen every three years.

Fortunately there is a better way to do HAC.

Source of Release

The Source of release (SOR) methodology defines the zone and dispersion extent for each SOR. Chemical composition and operating conditions are defined per SOR to enable the dispersion calculation per SOR in isolation. Further assessments of the SOR list is required based on other conditions e.g. congestion, constraints and meteorological conditions etc. The operational conditions must be defined per product stream. Secondly each individual SOR must be defined.

Operational Conditions

The operational envelope is used as a written record of the operation of the plant. This information is transferred to a Process Flow Diagram (PFD), in essence a two dimensional view of the operations that includes the different process streams, pressures and temperatures of main equipment. The end result of this is the clear definition of each process stream that can then be used to model the operating conditions for each individual SOR.

If the operation conditions are not available plant personal may be used to compile an as-built record of how they operate the plant.

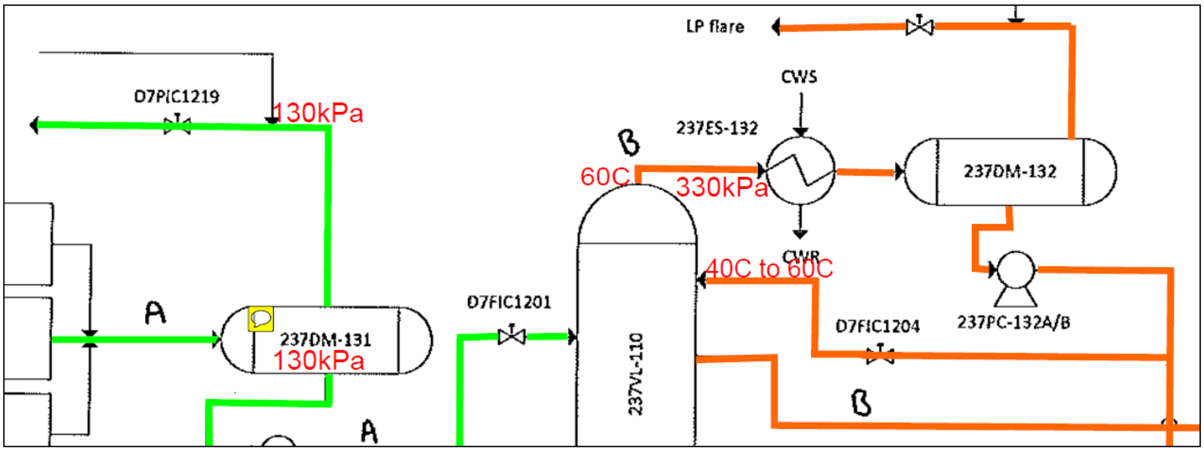

Figure 1: PFD Depicting Process Streams on major equipment

Individual Sources of Release

Each and every source of release is identified. This may be done by site visit, or using the Mechanical Flow Diagrams (MFD). As each of the SORs must be addressed they are numbered and transferred to a table as required by SANS 60079-10-1. The table is then also further populated with all the details as already accumulated e.g. chemical product stream and properties etc.

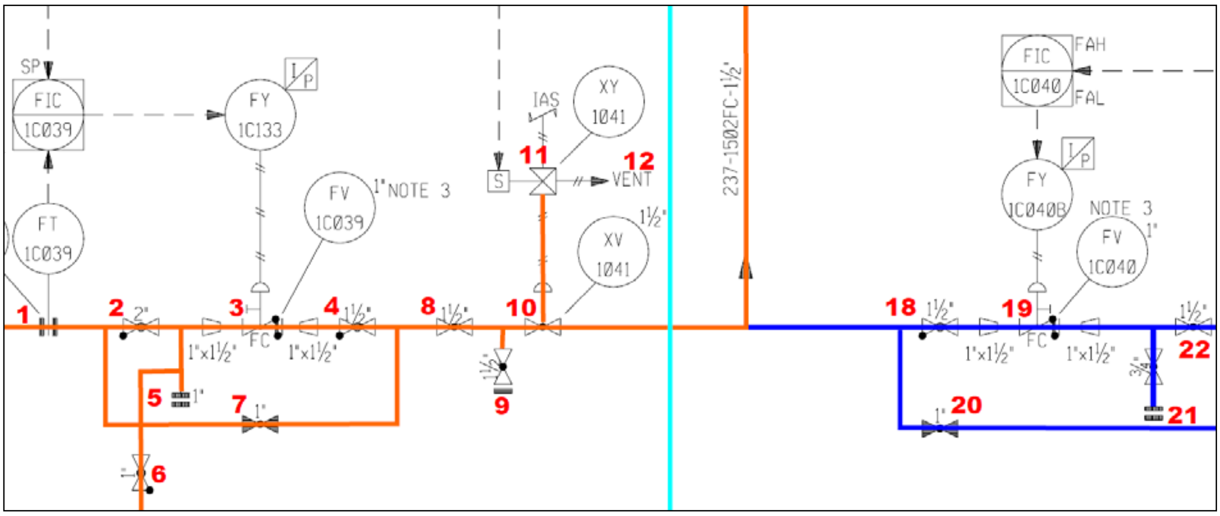

Figure 2: MFD Depicting Individual SORs

Zones

The zones are selected as per the grade of release. Typical examples are depicted in the table below.

Table 1: Grades of Release

Equipment	Example of Leak	Grade of Release
Pumps	Seal	S
Compressors	Seal	S
Vents	Full Bore	P
Valves	Gland/Seal	S
Pressure relief valves	Full Bore	P
Small bore connections	Fitting Leak	S
Piping systems	Gasket	S
Flanges, blinds	Gasket	S
Pig receivers and launchers	Full bore or Partial Release	P
Liquid pools	Vaporisation	C
Sumps	Vaporisation	C
Drains (Open)	Vaporisation	C
Drain Points	Full bore or Partial Release	P
Sample points	Full bore or Partial Release	P
C - Continuous	**P – Primary**	**S - Secondary**

The relationship between grade of release and zone is as follows:

- Continuous grade of release = Zone 0
- Primary grade of release = Zone 1
- Secondary grade of release = Zone 2

A combination of zones may be allocated to a source of release that has multiple grades of release.

Part of the assessment of the grade of release is to attempt to improve the grade of release which will result in a reduction of the zone. An example would be to block in an unused sample point. A sample point will then move from a primary SOR (Zone 1) to a flange which is a secondary SOR (Zone 2). Another method to reduce the grade of release is by operating conditions. Sample taking may be done without flushing the sampling equipment into atmosphere e.g. reducing the quantity and probability of a release.

Ventilation

Once the zones have been defined for each SOR the ventilation must be assessed. Ventilation is assessed based on the degree of ventilation and the availability. Ventilation may reduce or increase the zone classification.

Table 2: Ventilation as per SANS 60079-10-1

	Ventilation						
Grade of release	**Degree**						
	High			**Medium**			**Low**
	Availability						
	Good	**Fair**	**Poor**	**Good**	**Fair**	**Poor**	**Good, fair or poor**
Continuous	(Zone 0 NE) Non-hazardous [a]	(Zone 0 NE) Zone 2[a]	(Zone 0 NE) Zone 1[a]	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	(Zone 1 NE) Non-hazardous [a]	(Zone 1 NE) Zone 2 [a]	(Zone 1 NE) Zone 2[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[c]
Secondary [b]	(Zone 2 NE) Non-hazardous [a]	(Zone 2 NE) Non-hazardous [a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even zone 0[c]

NOTE 1 '+' signifies 'surrounded by'.
NOTE 2 Particular care should be taken to avoid situations where enclosed areas containing sources that give only secondary grades of release might be classified as zone 0. This applies also to small non- purged and non-pressurized enclosed areas, e.g. instrument panels or instrument weather protection enclosures, thermally insulated heated enclosures or enclosed spaces between pipe installations and envelope of thermal insulation.
Such enclosures should preferably be provided with at least some kind of appropriately located apertures that will enable unimpeded movement of air through the interior. Where that is not possible, practicable or desirable, effort should be made to keep major potential sources of release out of enclosures, e.g. pipe connections should normally be kept out of insulation enclosures as well as any other equipment that may be considered a potential source of release.
NOTE 3 Continuous and primary sources of release should preferably not be located in areas with a low degree of ventilation. Sources of release should be relocated, ventilation should be improved or the grade of release should be reduced.
NOTE 4 The summation of sources of release with regular (i.e. well predictable) activity should be based on detailed analysis of operating procedures. For example, *N* sources of release with common mode of release should be normally considered as a single source of release with *N* different discharge points.

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.
[b] The zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.
[c] Will be zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

Improving the degree or the availability of ventilation may result in a lower zone classification. An analyser hut for example has forced ventilation. This is achieved by forcing clean air into the enclosure. The degree of ventilation therefore may be good depending on the quantity of air changes per hour achieved. Loss of the fan will result in loss of ventilation. The electrical energy must then be removed from all the non-certified equipment installed in the hut to remove the possibility of ignition. To improve the ventilation availability the fan may be complemented by a secondary fan fed from a different power supply improving the availability of the ventilation from poor or fair to good.

As can be seen on this table it is also possible to improve the risk (zone) by reducing the SOR from a primary to a secondary SOR.

Dispersion

Dispersion of the liquid, vapour or gas requires an in-depth knowledge of the equations used by the industry. Research has shown that equations utilised vary and the results are not the same.

Preferences differ from Subject Matter Expert (SME) to SME. Different consultants will provide different dispersion distances. It is clear that a variety of results is possible from the same quantity of SMEs. It is therefore imperative that the SME is knowledgeable and the results are supported by the team.

The figure below shows an example of the dispersion phases of a liquid leak from a pressurised enclosure. The example includes liquid flashing of to two phase flow e.g. droplets and vapour leading to a liquid pool. Evaporation occurs from the droplets and from the pool.

The dispersion calculation has to include all the areas of vapour where a flammable environment (between LEL and UEL) may occur. This will include the evaporation from the aerosol (droplets) phase to the pool evaporation. The distance of the pool from the SOR will depend on a number of things like pressure, velocity, density, direction, height from the ground, SOR orifice size etc.

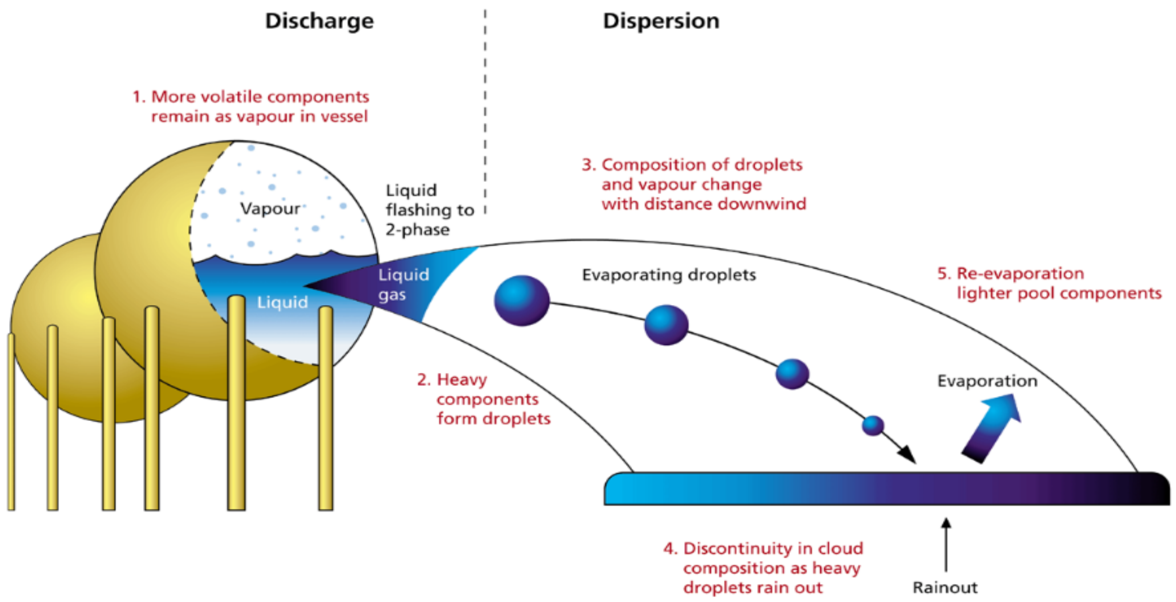

Figure 3: Dispersion: PHAST Pamphlet from Det Norske Veritas (DNV)

Another example is the phases that gas dispersion will go through for a jet release as indicated in the figure below. In the first section the gas velocity is high and the calculation as per SANS 60079-10-1 is used.

In the transition and passive phase the meteorological conditions takes on a larger effect and the calculation requires different equations.

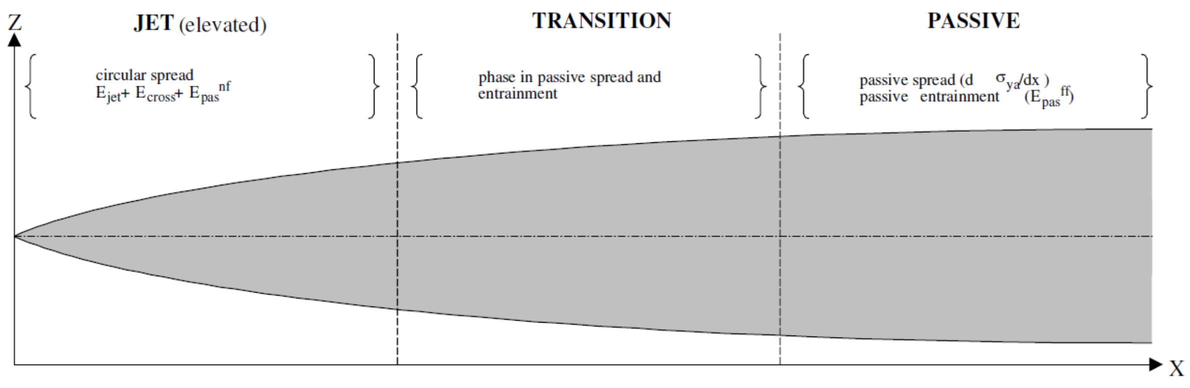

Figure 4: Witlox, H W M and Holt, A 1999, A unified model for jet, heavy and passive dispersion including droplet rainout and re-evaporation, Det Norska Veritas, London UK

A Gaussian model is generally used for the passive cloud dispersion which includes dispersion coefficients (Pasquill or other) for the x and y axis.

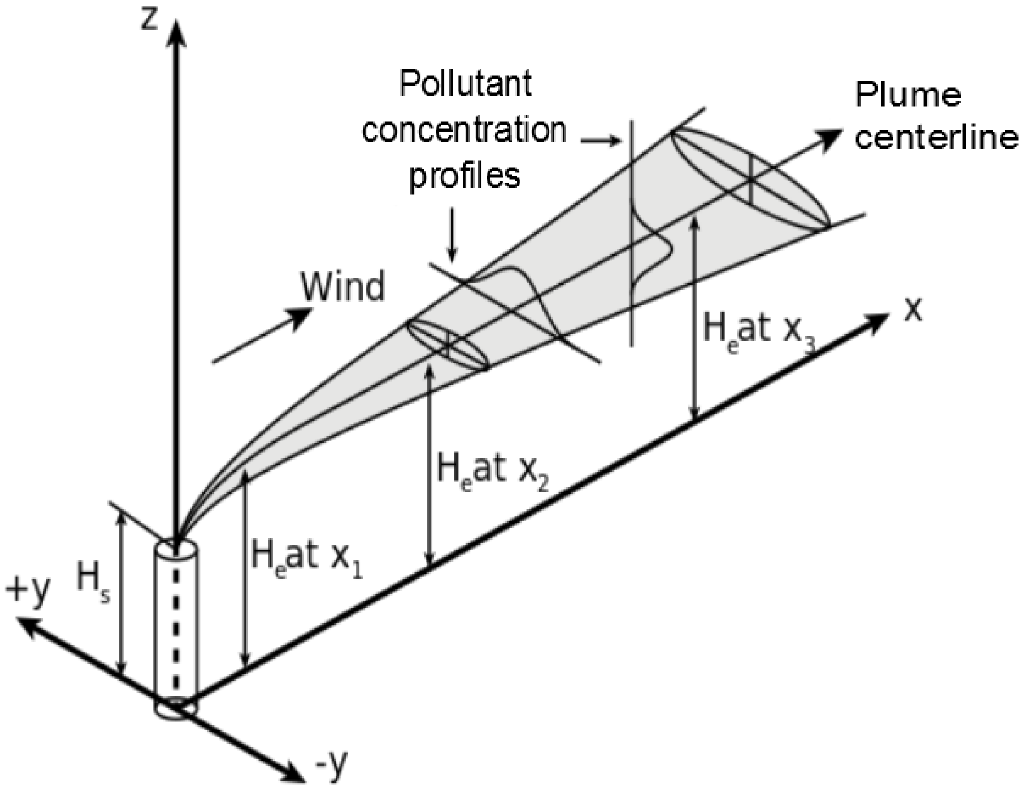

Figure 5: Gaussian Dispersion Model

The Gaussian model is used for dispersions that may extend to hundreds of kilometres.

Dispersion calculations require a couple of steps as per national standards:

- Gas release velocity (Sonic or subsonic release) – to define which gas release rate equation to use.
- Gas release rate – to enable the calculation of the volumetric rate of gas
- Volumetric flow rate of gas – to enable the calculation of the dispersion extend
- Liquid release rate – to enable the calculation of the pool volume and surface area
- Pool surface area – to calculate the calculation of the pool evaporation rate
- Pool evaporation rate – to calculate the volumetric pool evaporation rate
- Volumetric pool evaporation rate – to enable the calculation of the dispersion extend from the pool
- Degree of ventilation or dilution – to enable the calculation of the effect of ventilation on the final dispersion extend
- Extent of the zone – calculation of the final extend
- Safety factor – a safety factor is used to ensure that inaccuracies in the input data or equations are compensated for

The evaporation rate of all the different dispersions must be added to the final dispersion distance. A high pressure liquid that disperses over a large distance and then also gathers in a pool will have a number of dispersions to add together i.e. aerosol vaporisation plus the pool vaporisation.

Computational Fluid Dynamics

Dispersion using standard calculations is not that accurate and the 60079-10-1 standard defines a safety factor. The safety factor should be applied if the accuracy of the input data or the calculations is not that defendable.

Using a Computational Fluid Dynamics (CFD) software application and accurate chemical properties may result in a smaller dispersion extent.

Meteorological Conditions

A number of meteorological conditions will affect the dispersion. A simple example is where a liquid is leaking into a pool and rain distributes the flammable liquid. Another example may be the ground temperature that changes the pool temperature and may take it from above its flash point to below its flash point or vice versa. Meteorological conditions include the following:

- Topography – may allow heavier than air gasses or vapours to gather in a low lying area.
- Barometric pressure – will affect the dispersion calculation as the dispersion pressure will change according to the elevation
- Ambient air temperature – may affect the dispersion volume or may even keep the gas below its flashpoint
- Land surface temperature – this relates mostly to liquid spills and may heat up or cool down the liquid
- Precipitation – may affect the spreading or dilution of liquid pools
- Wind speed and direction – may affect the direction and extend of the dispersion
- Evaporation – has a direct relationship to humidity, air quality and composition
- Solar radiation – direct effect on the heating effect of the gas cloud or liquid pools (about 1 250 W/m^2 for the Highveld)

Other effects may include the type of surface e.g. cement or gravel.

Constraints

Dispersion constraints will affect the dispersion and even the risk measurement of the area. Dispersion constraints may include:

- Congestion of SORs
- Obstacles to dispersion
- Enclosed spaces

Each of the above may change the dispersion or zone of the area. A high congestion of zone 2 SORs may result in a zone 1 area. Obstacles to dispersion will change the dispersion shape and the level and position of the explosive mixtures inside the dispersed cloud. Enclosed spaces will entrap the dispersion or flammable environment and without ventilation will end in a zone 1 or 0.

Risk

Risk may be calculated to add to the argument on which the classification is based.

Risk based area classification are used for zone 2 areas only.

Using risk assessment in area classification requires a basic set of inputs:

- Probability of occurrence i.e. grade of release

- Probability of ignition i.e. grade of ignition
- Magnitude of deflagration or detonation and the consequences on man (damage to the human body) or machine (damage to the equipment, buildings, structures etc.). The consequences are measured against overpressure, heat radiation, time of the fire etc.
- Lastly define a risk rating based on the items above as an indication of risk level.

The figure below shows a proposed flow diagram to manage the risk assessment. The figure includes all zones and could be used to add value to the argument on which the classification is based.

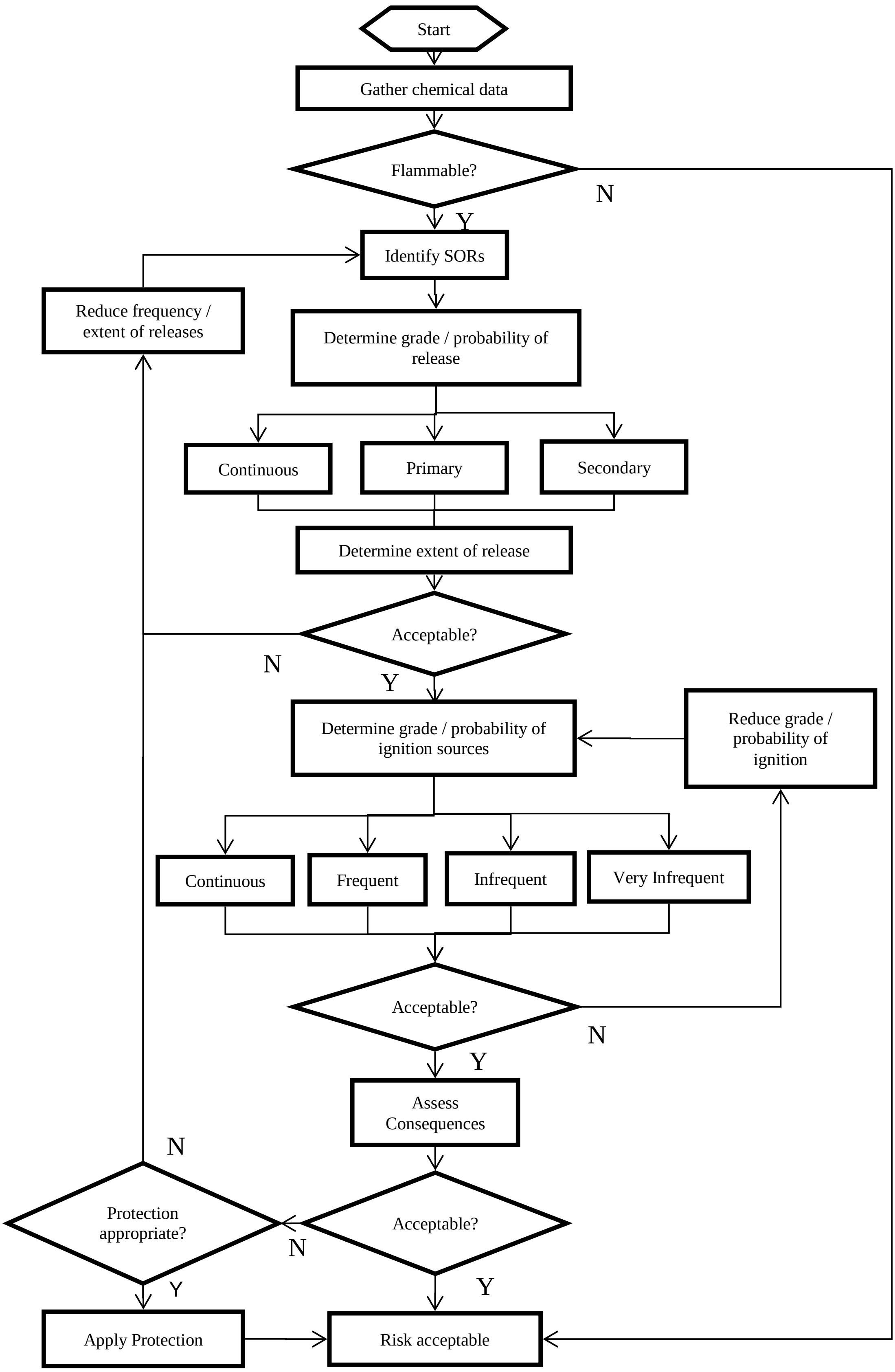

Figure 6: Risk based flow diagram

The Hazardous Area Classification (HAC) study is basically a record of the following:

- List of team members and their involvement
- Signatures of the study approval by accountable parties
- A list of the chemicals identified and included or excluded. This will include a clear and accurate table of the physical and chemical properties used.
- A reference to the sources of information used e.g.:
    - Material Safety Data Sheets (MSDS) for the chemicals
    - A national standard for the physical and chemical properties
    - An accepted database for the physical properties
    - An accepted equation to estimate any of the physical properties
    - Other publications e.g. accepted methodologies and equations
    - Plant walks
    - Mechanical Flow Diagrams (MFD)
    - Process flow diagrams (PFD)
    - Operating envelope
    - Internal procedures e.g. sample taking, start-up, venting etc.
- A description of the process followed e.g. direct example or calculation or risk based or a combination.
- Calculations used for each typical SOR (some SORs are generic in data and will only require one calculation)
- A list of all the SORs identified and the classification details for each.
- Any minutes of meetings held and decisions taken

In essence the study is a clear record of the arguments used to define the classification of each and every area that formed part of the scope of work. The study must be defendable and scientific so that it may be reproduced if done by another team. If the area is changed in any way then the study may be used to accommodate the changes.

Drawings

Area classification drawings are a spatial representation of the study. Care must be taken to have an exact replica of the intention of the HAC study. This may include on-site measurements and location of specific SOR points especially on the perimeter of the plant. In general the centre of the plant may be a congestion of SORs and therefore may be a zone 2 in total for example.

The drawings must include the following:

- Top view
- Side views of all large structures and any structure that requires additional detail
- Detail in terms of the usability of the drawing. An example of this is that the HAC drawing may not be applicable during shutdown periods when stable operation condition does not exist. In a plant shutdown case the areas must be made safe under a permit to work condition for all activities.
- Zone areas will be indicated by a symbol. The standard symbols as proposed by the standard may be used for the top page. As details are required the top page may be split into smaller pages where details may be enhanced. Symbols may be split into more symbols i.e. per group and temperature.
- A table with all the symbols used and the zone specifications of the symbols.

- A chemical products table with the applicable material properties of each chemical. Properties will include relative density, group, temperature class, flash point, ventilation availability and grade, and composition amongst others.
- A SOR table depicting the Zone 0 and 1 points for the page. This is to indicate specific high risk areas.
- Approval portion will indicate the signatory name, function and date of approval. If the drawing has not been approved then it is not valid and may have been produced by anyone. Document management is imperative.

Conclusion

Hazardous Area Classification is a verb and is required by legislation. It provides a method of defining high risk areas and allows the selection of Explosion Protected Equipment (EPE) to be installed in the area reducing the risk of explosive conditions.

The classification must be done before the selection of the equipment and after process design has been completed.

The classification must be kept up to date through change management or regular reviews.

Hazardous area classification must be done properly to reduce costs, increase safety and manage risk.

Hazardous Area Classification will not be completed accurately if an SME does not form part of the team.