An explosive atmosphere cannot exist if the flashpoint is significantly above the relevant maximum temperature of the flammable liquid. The lower the flashpoint, the greater the extent and/or rate of build-up of a flammable atmosphere will be.

Some liquids (for example certain halogenated hydrocarbons) do not possess a flashpoint although they are capable of producing an explosive gas atmosphere. In these cases, the equilibrium liquid temperature which corresponds to the saturated concentration at the lower flammable limit should be compared with the relevant maximum liquid temperature.

Liquids have to be taken into account when their temperature is above (TF-*x*) K, where TF is the flashpoint and *x* is a safety margin. This safety margin is about 5 K for pure chemicals, but should be increased to 15 K for mixtures.

NOTE Under certain conditions, the mist of a flammable liquid can be released at a temperature below its flashpoint and still produce an explosive atmosphere.

e) liquid temperature.

The vapour pressure increases with temperature, thus increasing the release rate due to evaporation.

The temperature of a liquid after it has been released may be increased, for example by a hot surface or by a high ambient temperature.

7.1.3 Flammable limits

The lower the LFL as a volume fraction of flammable gases or vapour in air, the greater will be the extent and/or rate of build-up of a flammable atmosphere. Given identical release rates, gases with lower LFL values will reach their ignition concentration more quickly than gases with high LFL values.

LFL and UFL both vary with temperature and pressure, but normal variations in these parameters do not appreciably affect the limits. A useful reference is IEC 60079-20-1.

NOTE Because LFL and UFL values are experimental, different countries specify different values for LFL and UFL, which have a legal standing. As two examples:

– NFPA 30 is a publication used within the USA,

– GESTIS is a publicly available database used within Germany.

7.1.4 Ventilation

An increased efficiency of ventilation usually reduces the extent and/or rate of build-up of a flammable atmosphere. Obstacles which impede the ventilation may increase the extent and/or rate of build-up of a flammable atmosphere. On the other hand, some obstacles, for example a bund, or walls or ceilings, may limit the extent and/or rate of build-up of a flammable atmosphere.

7.1.5 Relative density of the released gas or vapour

The behaviour of gas which is released with negligible initial velocity (for instance, vapour produced by a liquid spillage) will be governed by buoyancy and will depend on the relative density of the gas with respect to air.

If the gas is significantly lighter than air, it will tend to move upwards. If the gas or vapour is significantly heavier, it will tend to accumulate at ground level. The horizontal extent and/or rate of build-up of a flammable atmosphere at ground level increases with increasing relative density and the vertical extent and/or rate of build-up of a flammable atmosphere above the source increases with decreasing relative density.

NOTE 1 For practical applications, a gas mixture which has a relative density below 0,8 is regarded as being lighter than air (e.g. methane, hydrogen or ammonia). If the relative density of a gas or vapour mixture is above 1,2, it is regarded as being heavier than air.

NOTE 2 Mixtures of high and low density gases with air will show less variation of density and, once mixed, they will not separate again; they can only become more diluted.

7.1.6 Temperature and/or pressure

If the gas or vapour prior to release is at a temperature and/or pressure significantly different from the ambient pressure and temperature, the absolute density of the release will be affected, and hence its behaviour, at least in the vicinity of the source.

A gas at high pressure escaping into the atmosphere may be strongly cooled as it expands adiabatically. Similarly an escape of compressed liquefied gas (e.g. LPG or ammonia) will be cooled to its boiling point, well below 0 °C.

Any thermally induced flow (e.g. convection currents from hot or cold surfaces or plant or equipment), particularly if adjacent to a source of release, may affect the propagation, and hence distribution, of a gas/air mixture.

7.1.7 Other parameters to be considered

Other parameters such as climatic conditions and topography may also have to be taken into consideration.

If there is significant ambient air movement or the release is into enclosed spaces, then the above behaviour will be modified as described in 7.2 and 7.3.

7.1.8 Outdoor sites and open structures

In the case of outdoor sites and open structures, the dispersion of gas following a release may be affected both by the wind speed and by the wind direction. In open areas, the lateral spread of gas upwind of the release will be reduced, whilst downwind of the release it will be increased. This effect will be greater at high wind speeds. More complex air flow patterns will occur around buildings or other structures. In these cases, the wind direction may have a significant influence, and the possibility of gas accumulating in partially enclosed spaces, or in spaces with restricted air movement, should be considered. Where it is intended to install gas detectors in a major plant, the use of mathematical models of gas dispersion, or of scaled wind tunnel tests, may be appropriate at the design stage.

Local thermal effects may be significant in controlling air flow patterns and may, therefore, influence the dispersion of gas. For example large thermal gradients may be generated close to hot surfaces. In addition, the relative density of the gas will be affected by both the temperature of the gas itself and of the surrounding air.

7.2 Buildings and enclosures

7.2.1 General

Within buildings and enclosures the tendency for gases to form a hazardous accumulation following a release is generally greater than in outdoor locations. When a gas is released into an enclosed space, it mixes with the air in the enclosure to form a gas/air mixture. The manner in which this mixture forms will depend upon the gas release velocity, the location of the release, the gas density, ventilation, and any superimposed thermal flows. These factors should be taken into consideration in determining appropriate positions for sensors.

7.2.2 Unventilated buildings and enclosures

Theoretically, in the absence of any ventilation air flow and/or thermal effects, the release of a lighter than air gas will tend to form a layer of gas/air mixture extending from the level of the source of release to the ceiling. The release of a heavier than air gas will tend to produce a layer of gas/air mixture extending from the level of the source of release to the floor.

If the release takes the form of a momentum jet, this behaviour may be modified. For example if a jet of lighter than air gas is directed downwards from the source of release, then the layer of gas/air mixture may extend from the ceiling to a position below the level of the source of release. Similarly, if a jet of heavier than air gas is directed upwards from the source of release, then the layer may extend from the floor to a position above the level of the source of release.

If a potential source of a gas release is present in buildings or enclosures, then adequate ventilation should be provided.

7.2.3 Ventilated buildings and enclosures

7.2.3.1 General

The ventilation of buildings and enclosures is achieved by "natural means," "mechanical means", or a combination of the two.

NOTE When a release concentration has decreased to considerably less than the LFL (lower flammable limit), it will tend to move with the normal air flow due to the small difference in density between the gas mixture and the uncontaminated air.

7.2.3.2 Natural ventilation

Natural ventilation is the flow of air into and out of a building or enclosure through any purposely built or adventitious openings in its structure. Ventilation air flows are caused by two effects; firstly, any pressure difference across the enclosure created by wind and, secondly, buoyancy due to any difference in temperature (and hence density) of the atmosphere contained within the enclosure and the outside air. For natural ventilation due to the latter effect where the temperature in the building or enclosure is higher than that of the outside air an upward flow will tend to be produced. Conversely, if the inside temperature is below that of the outside air, a downward flow will tend to be produced.

The release of a gas or vapour into a naturally ventilated building or enclosure will tend to result in the formation of a gas/air mixture in a manner similar to that described in 7.2. However, in this case, the gas concentration in the mixture will be lower for a given release rate due to dilution by the ventilation air flow.

If a heavier than air gas or vapour is released into an enclosure in which natural ventilation produces an upward flow, then the gas/air mixture may extend above, as well as below, the level of the source of release. Conversely, if a lighter than air gas or vapour is released into an enclosure in which ventilation produces a downward flow, then the gas/air mixture may extend below, as well as above, the level of the source of release.

NOTE Further information on natural ventilation is given in IEC 60079-10-1.

7.2.3.3 Mechanical ventilation

Mechanical ventilation is the term used to describe air flow through an enclosure induced by mechanical means, i.e. fans. Ventilation air flows set up by mechanical means can be high (for example greater than 12 volume changes per hour).

NOTE 1 Mechanical ventilation is the technique used to control methane levels and provide breathable air in coal mines.

The gas concentration within an enclosure ventilated by mechanical means will, in general, be much less than that resulting from a similar release into a naturally ventilated enclosure.

NOTE 2 In case of very high gas concentrations (above LFL), or in the area above a flammable liquid with low flashpoint, an increased ventilation may lead to an increased volume of the explosive atmosphere.

In a well-designed ventilation system the whole volume within an enclosure is swept by the ventilation air flow. Where the geometry of the enclosure gives rise to regions of poor air movement or "dead spaces," a gas/air mixture may accumulate. Therefore, detectors should be sited in these spaces.

NOTE 3 A device which generates smoke or mist to be used for checking the air flow visually can assist in identifying the air movement within an enclosure and the presence of any dead spaces where gas/air mixture may accumulate.

If a sensor is installed in the intake or exhaust duct of a mechanical ventilation system (depending on where the release might occur), then the alarm set point should be set as low as reasonably practical.

Some sensors use sintered materials as flame arrestors and the ability of an air/gas mixture to diffuse through the sinter to the sensing element can be adversely affected by very high air velocities that may occur in ducting arrangements. If this happens, additional shrouding of the sensor can help.

7.3 Environmental considerations

Environmental operational parameters should be included in the instruction manual of the intended equipment.

Where environmental conditions are beyond specified values, the manufacturer should be contacted to ensure that the equipment is suitable.

8 Design and installation of fixed gas detection systems

8.1 General

A fixed gas detection system should be capable of giving an early warning of both the presence and the general location of an accumulation of flammable gas, in order to initiate one or more of the following actions, either automatically or under manual control:

a) safe evacuation of premises;
b) appropriate fire-fighting and other emergency procedures;
c) removal of hazard;
d) shutdown of process or plant;
e) increasing ventilation.

The consequences to the safety of personnel, and the economic effects of potential damage following an undetected release should be of major concern. This should lead at the outset to consideration of integrity of the system, redundancy, integrity of power supplies, fail-safe operation, etc.

Therefore, it is of great importance that gas detection equipment is installed and used in such a way that only authorized personnel will have access to the functional controls of the equipment.

A major consideration is the selection of the quantity, and the locations, of sensors, sample points, or open path equipment. Practically this must be done by consideration of a wide range of factors including industry standards and regulatory authority requirements, the local environment and safety, and therefore usually requires a wide range of expertise.

8.2 Basic considerations for the installation of fixed systems

8.2.1 General

If the equipment or any auxiliary components are installed in a hazardous location (i.e. ‘classified’ or ‘zoned’ area), they should be suitable for the area in which they are installed and so marked.

Four main types of fixed systems are commonly used:

a) Systems consisting of individual point detection equipment (single point sensors), self-contained apart from their power supply, with either analogue outputs or voltage-free contacts, or both, for connection to alarm and control equipment by electrical cables.

b) Systems consisting of remote sensors connected to dedicated alarm and control equipment typically by electrical cables.

c) Sampling Systems, usually with multiple sampling points, feeding sample gas via tubes to a centralised sensor package with alarm and control equipment.

d) Open path equipment, sensing the gas in its optical path.

Systems of this type should, in general, be installed so as to be capable of continuously monitoring every part of the plant or other premises where flammable gases may accidentally accumulate. They should be capable of giving the earliest possible warning of an accidental release or accumulation of gas within practical limits of the system, for example as related to the number and location of sensors or line of sight open path.

8.2.2 Point detection equipment and remote sensors

Remote sensors and point sensors should be connected to their associated control and alarm equipment according to the national requirements for installation of electrical equipment. The sensors and any other parts of the system which are located in a hazardous area should incorporate an explosion protection technique covered by the IEC 60079 series of standards for the intended Zone of use. It should be noted that this might be somewhat easier to achieve for remote sensors. In this case the safe area control equipment is specifically designed to a part of IEC 60079 to be compatible with the remote sensors as regards power supply and outputs.

NOTE At excessively high and low temperatures the sensor can be operating outside the temperature range specified by the manufacturer and therefore might no longer comply with its explosion protection and/or performance certificate (IEC 60079 series).

8.2.3 Systems consisting of sampling equipment

These systems are used when comparatively static process conditions apply, and rapid response is less important; for instance monitoring for the early stages of progressive leakage. There are several technical advantages of this type of system:

- They can permit all of the electrical parts of the equipment to be located outside the hazardous area, with only tubes filters, etc., inside it and a suitable of flame arrester at the interface.
- They can be used where the desired measuring points are relatively inaccessible, or are under extreme environmental conditions.
- The central sensor package can use highly sensitive or bulky detection principles, and those requiring external gases; e.g. FID or FTA (see 5.7 and 5.8).
- The central sensor package can be readily equipped with automatic calibration and possibly some automatic maintenance.
- One sensor package can be used for sequential sampling from a large number of measuring points, and can contain sensors for more than one gas.

In this last case, the interval in time between two successive samples being taken at any one sample point should be sufficiently short that a potentially hazardous accumulation of flammable gas cannot occur during the interval. The length of any sample tube and the sampling flow rate should also be such that a potentially hazardous accumulation of flammable cannot occur during the time taken for a sample to pass from the sampling point to the sensor. For this reason, sample tubes should be as short as is reasonably practicable.

For systems with lines more than a few tens of metres long, the sample transit time from sampling point to sensor package is likely to be significant. In such cases the use of a second pump drawing on all lines not currently being sampled, or at least the next one or two lines due to be sampled, is recommended. The former requires simpler equipment but a larger pump.

8.2.4 Open path (line of sight) equipment

Such systems usually employ an infrared technique, where the transmitter and receiver are installed at opposite ends of a 'line of sight' path traversing an area. A retroreflector may be used on one side of the area so that the transmitter and receiver may be adjacent on the other side combined as a transceiver, and other configurations are possible.

Installation requires a clear line of sight which will not be interrupted, and an absence of vibration at each end. This usually requires substantial footings and mountings. Response is quick and to an extent independent of direction of air currents. For instance three or more such units located around the perimeter of an installation should pick up a release anywhere inside their perimeter, provided there is some air movement. Multiple units should be located in such a way as not to interfere with each other by reflection, particularly in fog or rain.

8.3 Location of detection points

8.3.1 General

The principal objective is that sensors, open path equipment and sampling points should be placed such that gas accumulations are detected before they create a significant hazard. Inappropriate location can completely nullify the effect and integrity of a gas detection system.

Furthermore, sensors, open path equipment and sampling points should be located in positions determined in consultation with those who have a knowledge of gas dispersion, those who have a knowledge of the process plant system and equipment involved, and safety and engineering personnel.

This determination should consider:

a) the combination of sources of release with propagation effects (see Clause 7);
b) whether the sources of release can be inside or outside confining structures, buildings etc.;
c) what can happen at access points such as doorways, windows, tunnels, trenches etc.;
d) local environmental conditions;
e) occupational health and safety;
f) access for maintenance including calibration and verification, and protection of the system against operational hazards of the plant.

The decisions reached on the locations of sensors and sampling points should be recorded in a safety dossier for the plant (refer also to 8.12).

NOTE Gas dispersion analysis can assist in determination of the appropriate location and numbers of sensors to be installed.

8.3.2 General site considerations

Where it is necessary only to detect the escape of gas from within a given area, then sensors or sample points may be placed at intervals around the perimeter of the site. Alternatively, a series of open path units may be used. However, such an arrangement may not provide an early warning of a release. This arrangement should not be used alone if a release could cause a significant hazard to personnel or property within the perimeter itself.

Sensors or sample points should be located close to any potential sources of major release of gas, although to avoid nuisance alarms, measuring points should generally not be located immediately adjacent to equipment which may produce inconsequential minor leakage in normal operation. In general, on open sites minor leaks may be dispersed without causing a hazardous accumulation.

Sensors or sample points should also be located in all areas where hazardous accumulations of gas may occur. Such areas might not necessarily be close to potential sources of release but might, for instance, be areas with restricted air movement. Heavier than air gases are particularly likely to flow like a liquid and to accumulate in cellars, pits and trenches if these are present. Similarly, lighter than air gases might accumulate in overhead cavities.

If there is significant ambient air movement, or if the gas is released into enclosed spaces, then the behaviour of gas is modified. The behaviour of gases following a release is complex and depends on many parameters. However, knowledge of the influence of these parameters is not sufficient, in practice, to predict the extent and/or build-up speed of a flammable atmosphere. The prediction can be improved by:

1) the application of generally accepted empirical rules developed by experts, based on their past experience;
2) on site experimentation to simulate and describe precisely the behaviour of the gases. This includes the use of smoke tube tests, anemometer readings or more detailed techniques such as tracer gas analysis;
3) numerical simulation of gas dispersion.

In general, gas detection equipment should be sited above the level of exhaust ventilation openings and close to the ceiling for the detection of gases lighter than air, and below the exhaust ventilation openings and close to the floor or ground for the detection of gases heavier than air.

Where it is required to detect the possible ingress of gas or vapour into a building or enclosure from an external source, sensors or sample points should be sited adjacent to the ventilation openings. These sensors or sample points should be in addition to any required for the detection of releases within the building or enclosure.

If ceilings or floors are compartmentalized by equipment or other obstructions, sensors or sample points should be installed in each compartment.

8.3.3 Environmental conditions

8.3.3.1 General

Fixed equipment, or more particularly their sensors, may be exposed to a very wide range of environmental conditions for very long periods of time. Great care should be exercised in the selection and location of this equipment in relation to the likely environmental conditions applying in normal and abnormal use.

8.3.3.2 Adverse weather conditions

Sensors and open path equipment located on outdoor sites and open structures can be subjected to severe environmental conditions, and account should be taken of these conditions at all times. For example high winds may cause drift of the zero reading. High winds can even cause apparent transient loss of sensitivity during calibration due to dilution of the calibration gas being detected, if using the manufacturer's normal calibration equipment. For high wind applications, the manufacturer should be consulted about these points.

Great care should be taken in the location of sensors and open path equipment in exposed sites, and adequate weather protection measures should be provided for the sensor. Steam, driving rain, snow, ice and dust, etc. can also adversely affect sensors. Certain materials, although otherwise suitable for sample lines or weather guards, can deteriorate from sunlight or other environmental conditions.

In open path equipment, there will be possible effects as above on the equipment itself, such as de-focussing due to water droplets on windows. However, the effects of dust, mist and mild rain or snow in the air of the open path itself will be minimal in equipment that complies with the requirements of IEC 60079-29-4.

Gas detection equipment located in buildings or enclosures is generally not exposed to adverse weather conditions.

In underground mines, consideration should be given to the effect of changing barometric pressure on gas releases.

8.3.3.3 Excessive ambient temperatures

All gas detection equipment should be mounted in areas which ensure compliance with the manufacturer's operating temperature specifications.

Where there are excessively high or low ambient temperatures, the detector might be operating outside the temperature range specified by the manufacturer, and detection errors and reduced sensor life may occur. In addition, at both excessively high and low temperatures, the equipment might no longer comply with its hazardous area certificate.

For example the electrolyte in many electrochemical sensors operating at temperatures much below –10 °C might be limited by freezing. Portable applications might get around this limitation by keeping the detector in a warm area when not in use.

In general, the positioning of gas detectors directly above sources of heat such as ovens and boilers should be avoided and a suitable position at an adequate height away from the source of heat should be chosen.

In tropical and subtropical applications, external sensors and equipment should be shielded from direct sunlight, as this can raise equipment temperatures above 65 °C even with ambient temperatures around 40 °C. The normal maximum for hazardous area certificates is 40 °C and the maximum for performance with IEC 60079-29-1 or with IEC 60079-29-4 is 55 °C, unless otherwise specified on the certificate.

Where temperatures at the measuring points are to be expected outside the specifications of sensors, sampling systems should be considered.

8.3.3.4 Vibration

Where vibration is expected, particularly for equipment mounted on machinery, care should be taken to ensure that it has been designed to withstand vibration, or that suitable vibration isolation mountings are provided. Open path equipment will require special anti-vibration mounting.

Where excessive vibration or buffeting at the measuring points is expected, sampling systems should be considered.

8.3.3.5 Use of sensors in corrosive atmospheres

Precautions should be taken to protect sensors from damage resulting from exposure to corrosive atmospheres (for example ammonia, acid mist, H_2S etc.). Particular care should be taken to protect wiring (and other components made of copper or brass) if ammonia can be present, as it can cause severe corrosion and electrical failures.

Sampling systems with filtering at the sample points against the corrosive atmosphere are a possible option.

8.3.3.6 Galvanic corrosion

Precautions should be taken to protect sensors from damage resulting from exposure to galvanic corrosion resulting from contact with other materials.

8.3.3.7 Mechanical protection

Sensors mounted in positions where they may be exposed to mechanical damage (e.g. from normal plant operations, or the use of mobile equipment such as fork lifts) should be adequately protected without impeding the free flow of air around them. If necessary, recommendations should be obtained from the manufacturer.

8.3.3.8 Electromagnetic immunity

Appropriate precautions, for example the use of screened cables, should be incorporated when installing the complete cabling system (including that to ventilation controls etc.) to ensure that the total system is adequately protected from the effects of electromagnetic interference.

NOTE It might be necessary to make reference to applicable national regulations regarding electromagnetic compatibility.

8.3.3.9 Hosing down

The practice of "hosing down" (use of high pressure hose) in a plant may cause severe degradation of gas sensors and contaminate sampling lines. It should, therefore, be avoided if possible. If it cannot be avoided, the sensors should be protected against this, without impeding the free flow of air around them. This can be a complex problem.

8.3.3.10 Airborne and other contaminants

Sensors should not be exposed to airborne contaminants which can adversely affect their operation.

For example, materials containing silicones or other known poisons should not be used where catalytic or semi-conductor sensors are installed.

Dusts, or wet, oily adhesive sprays and mists, or condensed droplets can block key items, such as the diffusion screens of sensors, or sample lines and their filters, causing loss of sensitivity or function. This is of even greater consequence if both wet and solid materials are present to form pastes. This contamination might require regular cleaning or similar maintenance. Sample extraction and special filtration may be required in extreme cases.

There are many examples where paint overspray, or deliberate painting has been responsible for failure of sensors. This requires some education of maintenance personnel.

Care should be taken to avoid water condensation on diffusion screens and in sample line(s). Where high humidity samples are involved, this can require heating of critical parts or deliberately removing condensed water in traps, coalescing filters etc.

There are particular problems where a vapour of interest can condense on (or the liquid can otherwise come into contact with) diffusion screens, filters, or sample lines or the windows of open path transmitters and receivers. This type of contamination will lead to incorrect and misleading signals until the last trace of contamination is removed. This can be extremely dangerous. If this type of contamination is possible, the only solution might be to heat the components that come into contact with the sample.

8.4 Access for calibration and maintenance

Measuring point equipment should be readily accessible to permit regular calibration, maintenance and electrical safety inspections. It shall be possible to access and fit all accessories or test equipment needed for these operations at the measuring point.

Where the sensor location makes this difficult (e.g. where it is high and over machinery) a system of lowering the sensing point on a pulley system or swinging arm to gain access may be practicable. Obviously, the cabling or sample tubing must be flexible or pivoted to permit this arrangement. The arrangement should preferably permit the original sensor orientation to be preserved for calibration.

If it is impossible to achieve regular direct access to the sensor then, as a minimum requirement, some form of remote gas calibration facility should be provided.

8.5 Additional considerations for sample lines

Sampling lines are usually permanently installed in fixed installations. Even if they are made of a flexible plastic material they will usually be less flexible and harder to install than cabling. Consideration should be made at the time of installation that they may need to be replaced in the future, for instance if they become badly contaminated or damaged. Joints need to be accessible.

Sample lines should be as short as possible since the response time is determined by the overall length.

Filters may be used to protect the equipment from dust and interfering or poisoning substances. Generally a particulate filter is needed at each sampling point so that its sampling line is kept clean internally. Additional devices are required for this purpose where mists may be sampled. Frequently additional filtration is provided at the sensor equipment.

Filters will increase the response time.

The lifetime of filters is dose dependent (dust or interfering substance). This can shorten the maintenance intervals of the equipment. For details refer to the instruction manual.

The flow rate through the sampling line should be monitored.

The material of the sample line(s) should be selected so as to avoid adsorption, absorption and chemical reactions with the gas being detected. In addition, care should be taken to avoid dilution of the sample by leakage or diffusion of dilutant air, or gas, into the sampling line or flammable gas out of the sampling line.

Where water condensation can occur it can block the sampling line. This is particularly likely to happen if the line runs through areas that can be cooler than the sampling point (e.g. air conditioned areas in hot humid climates). If going through cool areas the sample line should if possible run slightly downhill from the sample point towards the sensor. Water traps might be needed at any low spots along the sample line length. Care shall be taken with these, since long or high-speed sampling lines may operate at a high partial vacuum. This means that automatic emptying can only be done using manometric ‘legs’ of adequate length, or some sort of blow-back system with non-return valves. Alternatively, the line may be heated, as explained in the next paragraph.

Consideration should also be given to the effects of condensation of the vapours of high flash point liquids in sampling systems. This will reduce the concentration in the sample and hence the reading. Subsequent samples with lower concentrations of the vapour will permit it to re evaporate, giving incorrectly high readings. To minimize this effect, heating of the sampling line might be necessary. In hazardous areas if this heating system is electrical it shall comply