Chapter 8

Segregation, Separation and Arrangement

The most inherent safety feature that can be provided at oil, gas and related facilities is the segregation, separation and arrangement of equipment. Some publications emphasize that separation is the prime safety feature that can be employed at any facility. This is true from the viewpoint of preventing exposure to personnel or facilities outside the area of concern. However, this becomes somewhat impractical for the large process plants and offshore production platforms that are designed and constructed today. Undoubtedly the manned locations at petroleum facilities should be located remotely as possible from high risk locations. Duplicate process trains, high numbers of vessels, multiple storage tanks and numerous incoming and outgoing pipelines limit the possibilities of remotely locating every single high hazard process risk from each other. Additionally operational efficiencies would be affected and construction costs would increase. The more practical approach is combine the features of segregation, separation and arrangement in a fashion that leads to more organized and operationally acceptable process facility. This represents the lowest practical risk but still avoids crowding.

Potential future expansion should be assessed and space provided for known and unknown needs. Logical and orderly expansion can only be made if provision at the time of original facility installation. The master plan should be frozen and only altered if a risk analysis of the changes is acceptable.

Surface runoff should be considered coincident with equipment layout. If surface runoff from one area goes directly to another area the feature of separation has been lost.

Segregation

Segregation is the grouping of similar hydrocarbon processes into the same major area. This allows an economical approach to achieve the maximum protection to all the high risk units while lessor protection is given to low risk equipment. The segregated high hazard areas can then also be further separated as far as necessary from other areas of the facility and the public. Some offshore facilities that do not have the luxury of large amounts of space, generally have to use segregation as the prime means of protection supplemented by fire and explosive resistant barriers for most areas.

The major facility segregation categories are process, storage, loading, flaring, utilities and administrative. Each of these categories can be further subdivided into smaller risk such as individual units for the process areas. The major segregation areas would be provided with maximum spacing distances while the subdivided areas are provided with lessor amounts depending on the protection afforded the area and individual risk of the units. Most petroleum and chemical processes are arranged in a systematic fashion from reception of raw materials, manufacturing and output to finished products. This arrangement is complementary to the needs of segregation for the purposes of loss prevention. Layout cost controls for
continuous flow operations also require that the distance personnel, information move is minimized. The exact technical process selected for a hydrocarbon process will also ultimately influence the general layout.

Some of the latest designs for platforms in the North Sea has segregated the process (i.e., separation, gas compression, etc.) facilities furthest from accommodations and utility support. Drilling modules are sited between the process and utility support modules based on the level of relatively lower risk drilling in a defined reservoir represents versus possible process incidents.

Safety systems should not be segregated together. Each safety system should be diversified as much as possible to avoid the possibility of a single point failure. A prime example is the firewater supply which should be pumped into a facility firemain at several separate and remote locations.

Tank farm areas are usually segregated based on the service and type of tank for economic reasons, besides segregating by levels of risk.

**Separation**

There has much analysis in the petroleum industry as what is the prudent spacing table to use in the layout of an onshore facility. Attempts have even been made to compare the spacing tables used by individuals companies. This would provide a consolidated table the entire industry could apply. Although such an idea is admirable, there are several obstacles in achieving such a goal.

First, the original insurance spacing tables (i.e., OIL, OIA, IRI, etc.), although commonly used in some sectors of the industry, have been formulated based on a few selective historical incidents and do not appear to be scientifically based on the current methods of determining the explosive or fire damage that can be released. They cannot account for all the possible design quantities of production processes. They may provide too much or too little spacing in some instances for the risk involved. Second, some facilities were constructed before the spacing tables were widely applied or were modified without too much consideration to a spacing table. Therefore any relocation of facilities under an "industry" spacing table will be very costly to retroactively apply or enforce. Some petroleum companies may also consider that the values listed in an "insurance industry" table are too conservative. On the basis of their own analysis, they may desire to apply lessor values. A survey of most industry spacing charts indicates they are not all similar. An obvious disparity exists between the operating company spacing charts and the recommended distances of the insurance industry, Ref. Table 7. Also the mandate for any facility project engineer is to save space and materials to achieve a less costly and easily built facility. He will therefore always desire to congest or compress the area for shorter piping runs, fewer pipe racks, etc., and be at odds for the requirements of loss prevention.

The ideal solution is to perform a risk analysis for each item in a facility to determine the probable maximum fire and explosive range the location may produce. The calculations and expense to accomplish such a task today does not appear to justify a unilateral application to every piece of equipment at a facility. Consequently the use of a spacing table for a facility design provides for an economical and expedient solution. This is especially important when several options on the layout of the facility are available. However in some instances the use of risk analysis may demonstrate less spacing is necessary that what a spacing chart requires.

The first task in applying a spacing table to a facility is to ensure it corresponds to the philosophy of protection adopted by the company. Where limited space is available to provide the required spacing, an examination of the equivalent fire and explosive barriers or active fire suppression system should be confirmed. This analysis should be accepted by the company as part of the design risk analysis.

In establishing process spacing philosophy or if used, the ratings of fire and explosion barriers (as may be the case offshore), fire suppression effectiveness, a number of principle factors should be considered. These
include:

1. Fire, explosion, and toxic health hazards of the processes and of the materials being handled.

2. The volume of material contained in the process, how it is isolated or removed during an emergency.

3. The strength of process vessel to maintain integrity during exposure to a hydrocarbon fire.

4. The manning and location of employees in the facility.

5. The concentration and valve of equipment in a particular area.

6. The criticality of the equipment to continued business operations.

7. Possible fire exposures to the facility from adjacent hazards.

8. The effectiveness of fire protection measures, both passive and active.

9. The possibility of the flare to release liquids or unignited combustible vapors.

To achieve these principals the following features are usually adopted:

1. Individual process units should be spaced so that an incident in one will have minimal impact on the other.

2. Utilities such as steam, electricity, fire water should be separated protected by the effects of an incident so that they may be continuously maintained. Where large facilities or critical installations are present the supply of these services from two or more remote locations should be evaluated.

3. The most critical important single equipment for continued plant operation or highest valued unit should be afforded the maximum protection by way of location and spacing.

4. Unusually hazardous locations should be located as far away as practical from other areas of the facility.

5. Consideration should be given to use the general prevailing environmental conditions such as wind and terrain elevation to best advantage for spill and vapor removal. Facility equipment should not be located where they would be highly vulnerable to a major spill or vapor release.

6. Consideration should be given to the adjacent exposures or other utilities which may transverse the site, i.e. pipelines, railroads, highways, power lines, aircraft, shipping routes (if offshore), etc.

7. Adequate arrangements for emergency service access to all portions of the facility for fire fighting, rescue, evacuation means.

8. Placement of the flare at the most remote downwind location of the facility.

Manned Facilities and Locations

The primary design consideration at any oil, gas or related facility should be the protection of employees and the general public from the effects of an explosion or fire. In all cases highly populated occupancies should be located as far as practical upwind of the process or storage areas. Where this cannot be practically
achieve the manned location should be provided with fire and blast resistant features commensurate with the exposure it faces.

The siting of manned locations should be considered the highest safety priority in the layout of a hydrocarbon facility. The primary locations where high levels of personnel may be accumulated relatively close to the hazards of hydrocarbon operations are control rooms and offshore accommodations.

Control rooms and offshore accommodations are also the most vulnerable fixed locations where a high fatality possibility can occur at hydrocarbon facility. In both of these installations a high number of employees may be present during most periods. Consequentially, an adequate risk analysis for both locations should be accomplished as part of any facility design scope. There is really no overwhelming reason why both need to be near operating processes other than cost impacts and convenience to operating personnel. Historical evidence has dramatically shown that control rooms, and in the case of offshore platforms - accommodations, can be highly vulnerable to the effects of explosions, fires, and smoke if not adequately protected.

The ideal situation for offshore facility is to locate the accommodation on a separate installation jacket that is spaced as far as practical from the production processes and the process platform oil or gas pipeline risers. Inclusion of the facility control room can also be conveniently provided in the accommodation increasing personnel safety and providing a cost benefit.

The latest designs for onshore installations cater for a centralized control room, well distanced from the operating facility with sub control areas as part of a distributed control system (DCS). The sub-control areas are closer to the processes but contain fewer personnel and process control systems for the overall plant, so the overall risk level for the facility from a major incident is lowered. The outlying control buildings (sometimes referred to as PIBs or SIHs) still need to be sited against impacts from explosions and fires.

**Storage Facilities - Tanks**

Tank farm areas require additional consideration for spacing not only between other process hazards but from other storage tanks. Minimum shell to shell spacings for storage tanks are provided in NFPA 30. It also includes requirements for minimum spacings from other exposures such as property lines and buildings.

The provisions for spacings are based on the commodity stored, pressure, temperature, and fire protection measures afforded to each tank. Each parameter adjusts the minimum requirements. For large tanks and those containing crude oil, heated oil, slop oil or emulsion breading materials additional spacing requirements should be considered. These include the following:

- Where tanks exceed 45.7 meters (150 ft.) in diameter, the spacing between tanks should be a minimum of 1/2 the diameter of the largest tank.

- Tanks 45.7 meters (150 ft.) or more in diameter containing crude oil should be arranged such that the tanks are a minimum of one diameter apart.

- Hot oil tanks heated above 65.6 °C (150 °F), excluding flash asphalt, slop oil and emulsion breaking tanks should be spaced apart by the diameter of the largest tank in the group.

A major factor in location of storage tanks within a tank farm is the topography of the tank farm area. The slope of the natural topography can be used to assist in the drainage requirements for a diked area and minimized the accumulation of spilled liquids near a storage tank. Diversion dikes or curbing can be used to divert spillage so it runs off remotely to a safe location.

The prevailing wind conditions should also be used to the best extent. Where rows of tanks are designed,
they should be arranged so they are perpendicular to the prevailing wind instead of parallel. This allows smoke and heat from a fire to dissipate with respect to impacts to other storage facilities.

The location of storage tanks to adjoining property or exposures on adjacent exposures should be treated the same as would be case with exposure to or from a refinery process, however the added consideration of public exposure should not be overlooked.

**Process Units**

Units operating at high pressures, at high or low (refrigerated) temperatures, having a large inventory of flammable fluid above its atmospheric boiling point, or handling of toxic materials are more hazardous than other process units. Historical evidence of the petroleum industry indicates that pumps, compressors, heaters are a common high volume source of leakage and should be as far as practical from ignition sources and other critical equipment.

**Flares**

The general principles for the location of flares should be governed by the following

- They should be located as close as practical to the process units being served. This allows the shortest and most direct route for the disposal gas header and will also avoid passage through other risk areas.

- Flare should be located as remote from the facility and property line due to their inherent hazardous features. They should be well away from high hazard areas or public occupied areas. A location perpendicular to the prevailing wind direction remote from the major sources of vapor releases and process or storage facilities is preferred. The chosen location should not allow liquids which may be ejected from the flare system to expose the facility. This principal should apply even if a liquid knock out feature is incorporated.

- Where more than one flare is provided, the location of each should be mainly influenced by operational requirements, but the need for maintenance and independent operation should also be considered.

**Critical Utilities and Support Systems**

During a fire or explosion incident the primarily utilities may be effected in not adequately protected. These utilities may provide critical services to emergency systems that should be preserved. The most common services are mentioned below:

**Firewater Pumps**

Several catastrophic fire incidents in the petroleum industry have been the result of the facility firewater pumps being directly affected by the initial effects of the incident. The cause of these impacts has been mainly due to the siting of the fire pumps in vulnerable locations without adequate protection measures from the probable incident and the unavailability or provision of other backup water sources. A single point failure analysis of firewater distribution systems is an effective analysis that can be performed to identify where design deficiencies may exist. For all high risk locations, fire water supplies should be available from several remotely located sources that are totally independent of each and utility systems which are required for support.
Power Supplies

Power is necessary to operate all emergency control devices. Where facility power sources or distribution networks are unreliable or vulnerable self contained sources should be provided to emergency systems and equipment. Unless protected power, control and instrumentation cabling will be the first items destroyed in a fire. The most obvious is local engine drives at fire pumps, batteries for emergency lighting, etc. However where ESD components located close to possible fire or explosion exposures, simple and direct backup power supplies are usually provided for higher reliability factors during an incident. These include spring return fail safe valves, local air reservoirs, etc. The capacity of the selected backup sources should be based on the WCCE.

Communication Facilities

Communications plays a vital role in alerting and notifying both in facility personnel and outside emergency agencies that a major incident has occurred. Communication systems should not be arranged so a single point failure exists. Of primary concern is the provision of a backup source of power and a remote backup activation and signaling post.

Buoyancy and Propulsion Capability

Floating vessels for offshore operations offer reduced installation costs but also present additional vulnerability factors. All floating structures must ensure buoyancy integrity is maintained otherwise the vessel may sink with catastrophic results. Similarly propulsion are provided at some installations to provided position stability. All major vessels are required by insurance requirements and most marine regulations to maintain buoyancy systems and loss of position stability will impact ongoing operations. Both of these systems can therefore be considered critical support systems and must be evaluated for risk and loss control measures either thorough duplication and protection measures or a combination of both.

Air Intakes

Air intakes to heating and ventilation systems, air compressors for process, instrument and breathing air, and to prime movers for gas compressors, power generation and pumps should be located as far as practical from contamination by dust, toxic and flammable materials release sources. They should not be located in electrically classified areas. If close to possible vapor releases (as confirmed by dispersion analyses) they should be fitted with toxic or combustible gas detection devices to warn of possible air intakes and shut down and isolate the incoming air ductwork and fans.

Fire Zones

Petroleum facilities located both onshore and offshore can be identified into "fire zones". These are areas where a fire can be expected to occur and be contained provided all safety and process emergency systems are operable in addition the arrangement of the facility should be kept to the original design intent for segregation and spacing factors that would prevent to spread of an incident. They are essentially based on the area a liquid spillage might encompass or highly probable high pressure gas release fires. In this fashion they are similar to electrical area classification drawing which outline areas vapors may be present but are generally smaller.

The fire zone drawings serve as an aid in determining which areas need special protection measures such as adequate fireproofing, firewater protection systems, drainage facilities, etc.
Arrangement

Arrangement means the orientation and assemblage of the equipment in a facility. By far the highest concern is the arrangement vessels, columns, tanks and process trains containing combustible materials of large capacity, especially at high pressures or temperatures. To meet the needs of loss control but still maintain efficient operations high risk plots are arranged so they are never completely enclosed by other processes or risks. A fire break, usually a road and sometimes pipe racks or open drainage system are provided for both economical process pipe routings, access convenience and as a convenient method for separation arrangement of related processes or storage areas. The possible loss of common pipe racks (piping and structural steel) are minimal compared to long lead time vessel and process equipment with high technology process control and instrumentation.

Tanks should be grouped so that no more than two rows of tanks are provided within diked areas separated by roads to ensure fire fighting access is available. Large tanks within a common diked area should be provided with intermediate spill dikes or drainage channels between the tanks, as an intermediate level of protection against spill spread. When a small number of small tanks are located together the level of major impacts is less and therefore the financial risk is lower. In these cases it is acceptable not to provide full or intermediate dikes.

A high pressure process or storage vessel should never be "pointed" at manned or critical facilities or other high inventory systems for concerns of a BLEVE of the container with the ends of the vessel rocketing towards the vulnerable location. As a further inherent safety enhancement, spheroid separation vessels may be used in some instances instead of horizontal pressure vessels (bullets). This reduces the possibility of a BLEVE incident directed towards other exposures.

Pipe racks normally divide a facility into major areas. For economy and process efficiencies the piping arrangement is typically a central corridor in any facility. On either side of this pipe corridor or rack the process units are provided buy its nature divides the facility into units or process areas.

Facility Access and Egress

The main access and egress to a facility preferably should be from the upwind side, with secondary points at cross wind locations. These locations should also be at a relatively higher elevations that the process areas so that possible spillages will not hinder supplemental emergency aid measures from outside the facility. As a minimum two access point should be provided to each facility.
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<th>Difference from Insurance Recommendations</th>
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Table 9

Comparison of Industry and Insurance Spacing Tables

*Average of Six Integrated Petroleum Operating Companies
Bibliography


3. Factory Mutual (FM), FM 7-44, Spacing of Facilities in Outdoor Chemical Plants, FM, Norwood, MA.

4. Factory Mutual (FM), FM 7-45S, Process Control Houses and Other Structures Subject to External Explosion Damage, FM, Norwood, MA.

5. Industrial Risk Insures (IRI), IM.2. Section 2.5.2, Plant Layout and Spacing for Oil and Chemical Plants, Tables 1 and 2, IRI, Hartford, CT, 1992.

