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Fire and Their Mitigation Efforts in Gas Processing Facilities

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Abstract:

Many hazard identification and risk management techniques are used in chemical process industries (like HAZOP, QRA, PHA) at the design stage and in operational plants to ensure smooth and safe run of all plant operations and activities. The implementation of these techniques is robust, yet accidents happen in chemical process industry. The investigation of such accidents has shown that the active measures for prevention are inadequate and are often poorly designed. The purpose of this manuscript is to study a gas processing facility and identify the needs for such active measures which will act as first line of intervention to fire incidents, that will help in avoiding the escalation of small incident towards a catastrophic event.

Keywords: Fire Zoning, Pool Fire, Spray Density, Top Event

1. Introduction

Process safety in industry has used several tools such as PHA, HZAOP, QRA to cater risks and failures. Each tool or technique can prevent the transformation of hazardous events to accidents by design improvements [1]. But the history of chemical industry has shown that with all these techniques implemented, the state of the art plants can undergo accidents which will result in inevitable loss as described by the following examples.

In September 2011, a fatal explosion at natural-gas plant in Mexico killed 30 workers and injured another 46. The cause of the incident was a leak from a ruptured pipe at the downstream of gas processing facility in the export line, causing an explosion [2]. In September 1998, two people were killed in an explosion and fire at the Esso Longford facility in Australia, which led to severe disruption of gas supplies to the State of Victoria's industry and retail customers for two weeks [3]. In July 1988, 167 men were killed at an offshore platform named as Piper Alpha, resulting from oil and gas leakage and probable ignition. The fire protection systems installed at the facility were inadequate and were poorly designed to cater with the small leakage event which later on escalated and engulfed the whole facility. This raised many questions on the safety practices in the offshore as well as onshore oil and gas industry [4, 5].

All these and other incidents in chemical process industry show that the active measures for the prevention of such events were inadequate or were poorly designed. The purpose of this manuscript is to identify the need of these active measures and provide the basis of design for these measures so that they can be used effectively. The basics of active measure starts from the fire zoning in which the process plant is divided into fire zones, for the purpose of allocating resources to the zone once a fire is initiated. This is done to limit the damages caused by fire in one equipment which transfers heat to nearby equipment and this heat will eventually become a source of fire for the other equipment as well. Once the fire zones are identified then, the water demand for particular equipment is calculated to extinguish the fire or control the temperature increase of the equipment so as to avoid the mechanical failure.

The fire zoning is an important part to calculate the fire water demand of equipment's. The criteria for calculating the fire water demand that will be required for control of burning or cooling purposes, which will be consumed by individual equipment is calculated so that in case of any emergency the fire water to respective equipment is provided and the spreading of fire is minimized. This fire water demand calculated then helps in identifying the number of fire water equipment (hydrants, monitors, hydrant/monitor combinations etc.) and determination of their strategic location. The location is determined by keeping in mind the safety of the personnel operating these fire water equipment and damages that will be caused by the process equipment.

Subsequently, the isolation philosophy for this fire water equipment is decided to cater the requirements when this equipment is required. This manuscript will identify the fire zoning criteria which provides the basis for water demand calculation which will be required in case of fire for the protection of process equipment.

In Pakistan, gas processing facilities are under the stage of development. Robust design and management protocols are followed at the initial stages of the project which has the result that no recordable catastrophic [6] incident has occurred in these gas processing facilities in Pakistan. But these procedures and protocols do not rule out the probability of catastrophic events, as they are a struggle to minimize such events.

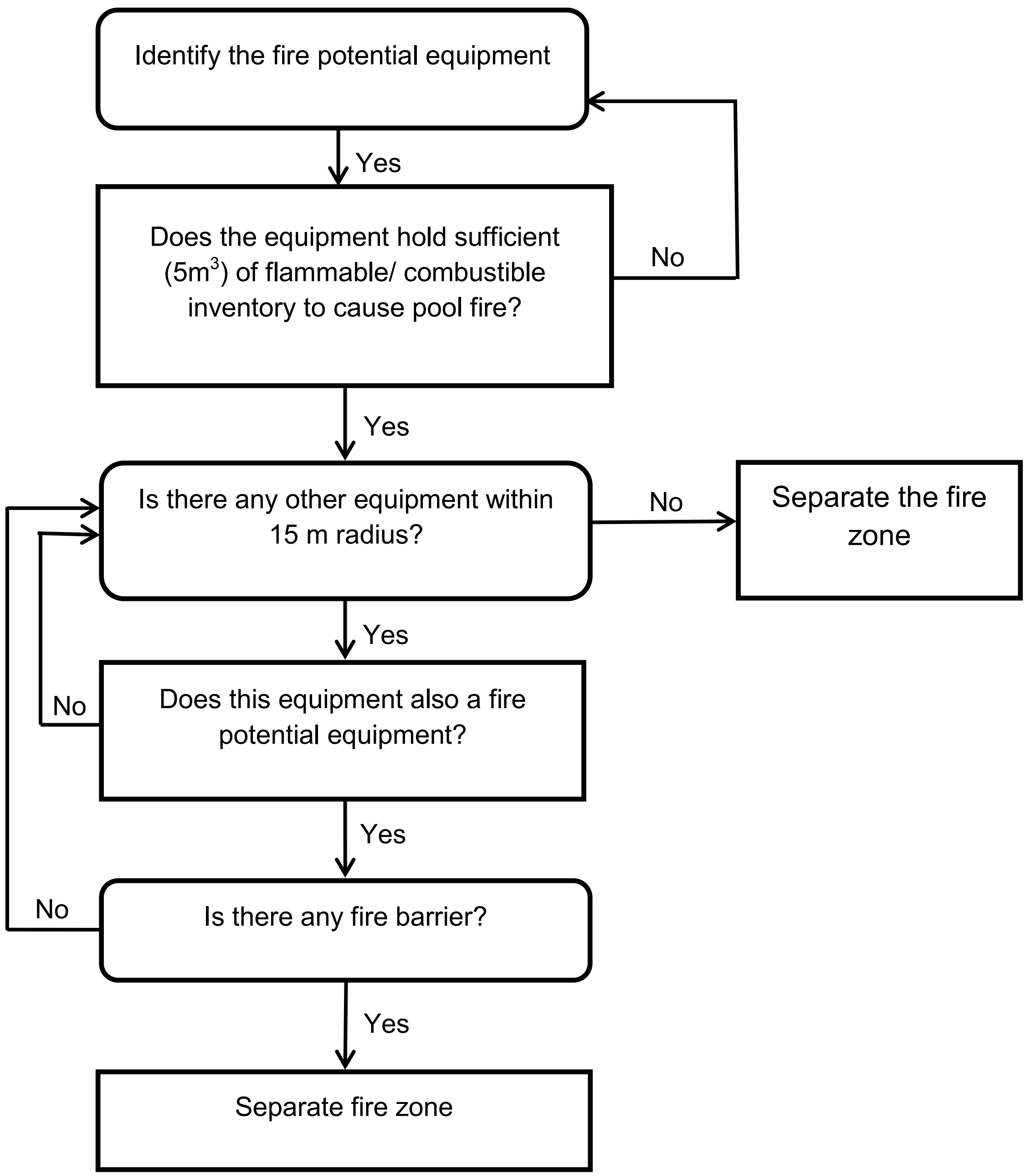

Fig. 1 Fire Zoning Criteria

2. Fire Zoning

Chemical plant is divided into sections, including process area, utilities, and storage, buildings, workshops, and product transportation units/areas. Amongst these sections, the process and storage areas consist of the many hidden hazards. Amongst these hazards, lies the containment of chemicals which are the source of fire.
inventory of the process units. The basis for dividing the process area into fire zones are:

- Equipment that are 15m apart from each other are considered to be in a separate fire zone
- Equipment separated by pipe racks, fire walls from other process equipments

Fire in one fire zone will not spread into another fire zone. The step by step fire zoning procedure is described in figure 1.These areas are further subdivided into individual fire zones based upon the hazardous

The fire zones are defined on the basis of the above mentioned criteria and fire water demand of individual fire zone is calculated. The fire water demand is calculated for individual equipment and then all the fire water demand for individual equipment is summed together to calculate the fire water demand of one fire zone.

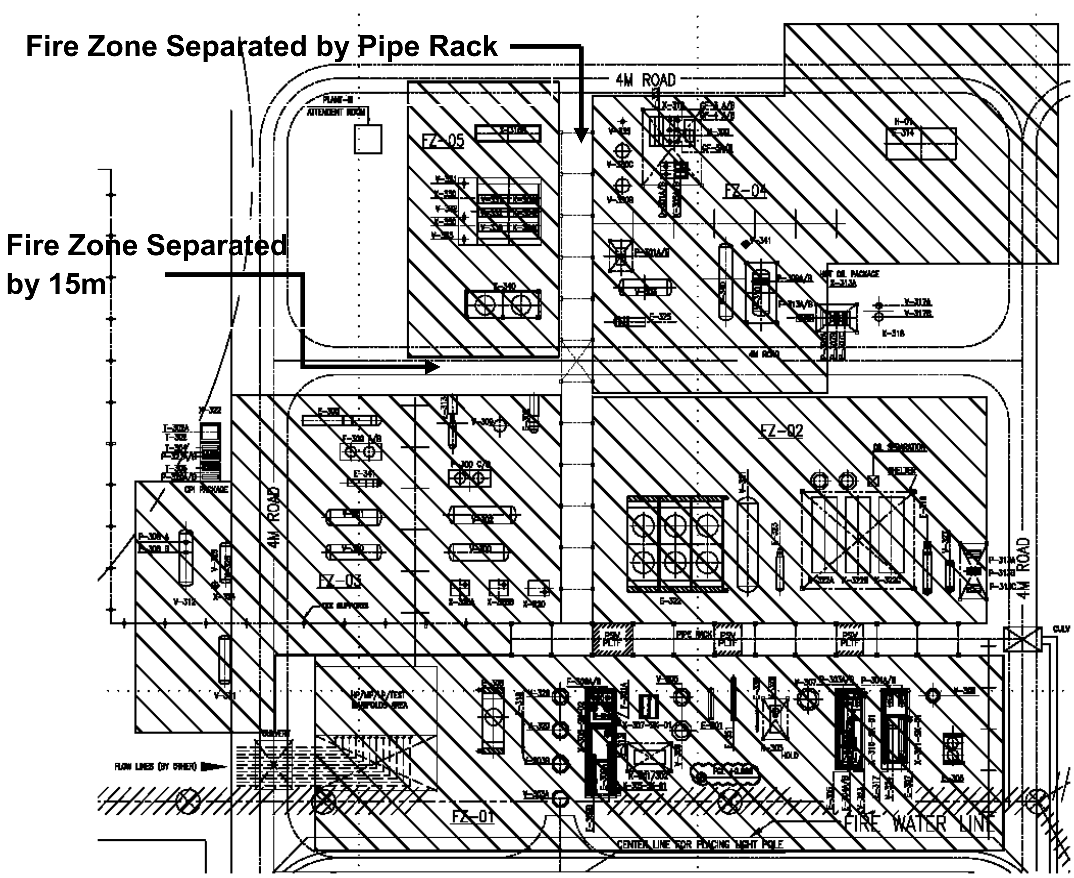

Fig. 2 Fire Zoning of a Gas Processing Facility

Figure 2 shows the fire zoning being carried out as an example, according to the criteria mentioned for hydrocarbon liquid fire in a gas processing facility. The fire zones developed under these conditions provide a conservative approach in determining the active fire protection system needs. The fire zoning helps in the calculation of fire water demand and positioning of hydrant, monitors etc. which will be used to cope with the fire scenarios and helps in optimizing the resources.

Fire Water Demand

The fire water demand for individual equipment is calculated on the basis that the hold-up volume of the process equipment is $5m^3$ or greater. The next step to calculate the fire water demand is to know the actual dimensions of that equipment. The surface area for every equipment is calculated with some margin to remain on the conservative side like for pumps and compressors an additional 0.6m [10, 11] is added to the length and width of the equipment for calculating the area. Figure 3 identifies the basic steps to calculate the fire water demand of equipment.

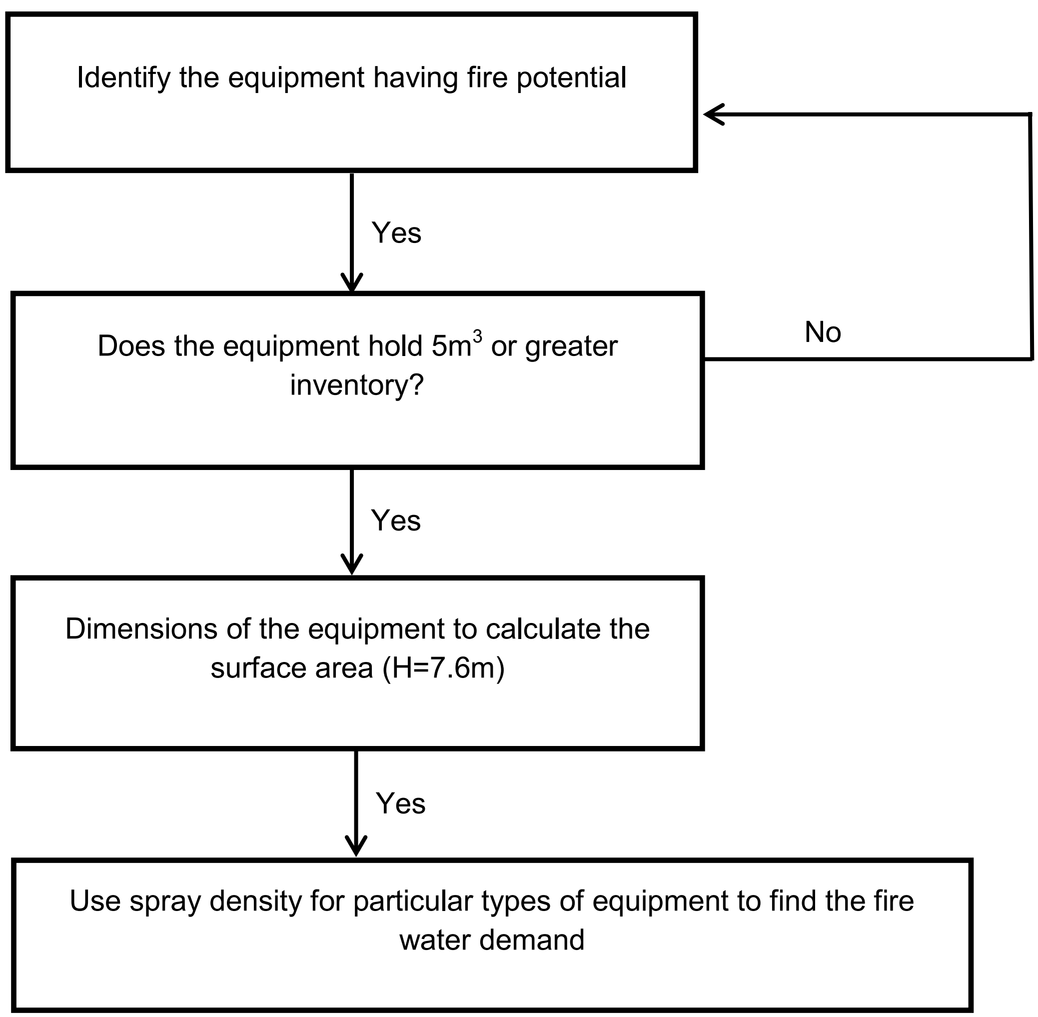

Fig. 3 Fire Water Demand Calculation

The individual equipment demands add up to give the fire water demand of a fire zone. Once the area of the process equipment is calculated this area is then multiplied by the water spray density. The spray density is taken from different international standards. The resulting fire water demand of individual equipments is added together to calculate the amount of fire water needed for the complete one zone in case of pool fire. The individual equipment fire water demand is calculated because in case of fire on any equipment, the remaining euipments in that fire zone will require water for the cooling purpose especially for those equipments in which the hazardous inventory is processed near the auto-ignition temperature. As an example the fire water demand for a fire zone is calculated in Table 1.

Table. 1 Fire Water Demand Calculation

Sr.#	EQIPMENT NAME	Area (ft^2)	Water Spray Density ($USGPM/ft^2$)[11]	Water Demand (GPM)	Zone Water Demand (GPM)
1	DEHYDRATION INLET SEPARATOR	341.19	0.25	85.29	1829.86
2	INLET FILTER SEPARATORS	506.98	0.25	126.74	
3	DUST FILTERS	386.67	0.25	96.66	
4	GAS MOLECULAR SIEVE BEDS	322.30	0.25	80.57	
5	CRYO BYPASS KO DRUM	375.00	0.25	93.75	
6	PLATE-FIN BRAZED ALUMINIUM HEAT EXCHANGER	114.192 Yes	0.25	28.54	
7	TURBO EXPANDER	196.33	0.25	98.16	
8	TURBO COMPRESSOR	196.33	0.25	98.16	
9	EXPANDER SUCTION DRUM	364.26	0.25	91.06	
10	LOW TEMPERATURE SEPARATOR	455.44	0.25	113.86	
11	DE-ETHANIZER COLUMN	780.37	0.25	195.09	
12	DE-ETHANIZER CONDENSER	758.47	0.25	189.61	
13	DE-ETHANIZER REBOILER	758.47	0.25	189.61	
14	DE-BUTANIZER CONDENSER	193.79	0.25	48.44	
15	BEBUTANIZER REBOILER	730.50	0.25	182.62	
16	NGL RUNDOWN COOLER	445.19	0.25	111.29	
17	DEBUTANZER	506.55	0.25	126.63	
18	DEBUTANZER OVER HEAD DRUM	338.20	0.25	84.55	
19	DE-ETHANIZER OVER HEAD COMPRESSOR	153.81	0.25	76.90	

3. Strategic Location of Fixed Fire Water Equipments

Fixed water protection systems are subdivided into fire water ring main and associated hydrants/monitors/foam system and spray/sprinkler systems. After calculating the water demand for individual equipment these systems are placed in the processing facility on the basis to provide quick intervention in case of emergency and to minimize the impacts of small event at the earliest possible stage so as to stop the escalation towards the top event. The major sources of these leaks/fires is near the valves, pump flanges, compressor flanges and major pipe flanges. The leakage is considered to be full bore leakage from the leak sources.

The fire water ring is routed around the process area. The piping of the main ring is placed at 15m distance from the equipment so as in case of pool fire the network is at a safe distance from the equipment to be protected. If this distance of the main ring piping is not maintained than the piping is undergrounded. Hydrant/monitor combination is proposed for the quick response to incidents and also minimizing the probability for the operator to move in the processing area. These devices are kept at a distance of 15m from the equipment to be protected so as to provide a safe distance to the operator of these devices. The travel distance between adjacent hydrant/monitors is reduced to 30m to improve the system performance in case of the adjacent equipment is under maintenance at the time of need. These distances are allocated on the basis that the hydrants/monitors are operating in jet mode.

4. Isolation Philosophy

The isolation philosophy determines the operation of this firefighting equipment in case of the blockage in the ring main or if a system in taken under maintenance and fire incident happens. For this purpose a robust isolation philosophy has been proposed which includes that the travel distance between two isolating valves be reduced to 100 m and that in no case more than three hydrant/monitor combination is isolated. On this basis the firefighting devices are optimized so as in case one portion of the ring main is isolated the fire water demand of the fire zone is fulfilled by other active hydrants/monitors combination.

5. Conclusions

The catastrophic incidents are preventable only under the circumstances that the protection systems are robust and fulfill the needs of the process design. This research work was conducted to improve the design stage efforts for the gas processing facilities in Pakistan and cater the needs of small incidents of fire which will escalate to the top event if not addressed properly and in time frame manner. Due to these efforts the asset life can be enhanced and subsequent loss of finance can be minimized.

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