ESTIMATING FIRE PROTECTION WATER DEMANDS FOR CHEMICAL PLANTS

INTRODUCTION

The water demand for fire protection systems in chemical plants is difficult to estimate due to the variety of hazards involved and the number of loss scenarios to consider. Factors such as plant layout, unit congestion, drainage, materials handled, exposures and flammable/combustible liquid hold-up will affect the overall water demand.

The purpose of this guide is to provide a consistent approach to determining the adequacy of a chemical plant water supply. The rating method is described in PRC.14.1.2.0. The water demands estimated by this method are not meant to define an “ideal” demand, but one that would be expected in credible fire emergencies.

This guide is to be used for the oil and chemical facilities covered by PRC.17.2.1, PRC.17.3.1, PRC.17.3.2, PRC.17.3.3 and PRC.14.1.1.0.

POSITION

Determine both instantaneous and continuous water demands for each facility.

The credible instantaneous fire water demand (IFWD) is the sum of the demands of all fixed systems (sprinklers, waterspray, weirs, etc.) that can be expected to activate automatically as well as flow from any wet barrel monitors, hydrants or fixed system risers which may be destroyed by the incident. The IFWD does not include demands from undamaged manually operated systems such as hose streams, or manually activated sprinkler systems. Due to emergency response control measures, the IFWD is not expected to necessarily become the basis for calculating the total amount of water required to meet the site fire water storage needs.

The continuous fire water demand (CFWD) is the sum of the demands of all fixed or manual systems (hose streams, monitor nozzles, etc.) expected to be flowing during the incident as well as any broken fixed or manual systems which cannot be shut off. The CFWD should then be used to determine the site fire water storage requirement.

- Evaluate multiple fire scenarios to determine which loss incident might generate the largest water demands.
- Calculate the probable water demands for the chosen loss incident, based on the system hydraulic designs and manual firefighting requirements.

Loss Incidents

Establish a water demand for each loss incident to be considered. Select the loss incident yielding the largest demand from among (but not restricted to) the following incidents:

- **Spill fire**: Determine the nature and size of the initial spill based upon the volume, temperature, pressure, reactivity, viscosity and type of material expected to be released. Determine the path followed by the spill based on the type, slope and grade of area drainage. From the path of the burning spill, determine which areas would be engulfed in flames or exposed by fire. Determine the fire protection requirements based on the fire size and spread, including the operation of systems in the fire area and systems needed to protect the exposures.
- **Tank farm fire**: Assess the size of a fire under reasonably adverse conditions, based upon factors such as the type of tank, contents and spacing.
- **Explosion in building or equipment**: Estimate the damage from vessel or building explosions due to overpressurization or sudden failure as described in PRC.8.0.1.1. The scenario should consider that ensuing fires could develop with parts of the fire protection installation rendered inoperative by the blast. Those systems designed to meet the requirements of PRC.12.2.1.2 should be assumed to remain operative.
- **Vapor cloud explosion**: Estimate the damage resulting from vapor cloud explosions using the guidelines in PRC.8.0.1.1. This scenario should consider that the initial explosion could also destroy, impair or actuate a large number of fire protection systems.

Probable Water Demands

The water demands depend on the fixed systems actuated (manually or automatically), the manual fire fighting equipment used, and the breaks in the systems under a selected loss incident.

Fixed Systems Demand

Determine the water demand for any single system from the hydraulic calculations or with the method outlined in PRC.14.1.1.0. When more than one system is expected to operate, balance the calculated systems demands for each system to the highest pressure. Add the balanced flows to obtain the total fixed demand.

- In a spill fire, assume that all fixed systems within the spill path or exposed by the fire will be actuated. Consider these part of both the instantaneous and continuous demands.
- In a tank farm fire, assume that the protection for the tank(s) on fire will be actuated. Assume that the fixed exposure protection (tank shell cooling) of adjacent tanks (depending on the spacing and layout) will also be actuated. Consider these part of both the instantaneous and continuous demands.
- In a vessel or building explosion, assume all fixed fire extinguishing systems located within the 5 psi (0.35 bar) overpressure circle to be destroyed. When isolation valves controlling the damaged fixed systems cannot be readily shut, accessed or are nonexistent, include the water wasted in the fixed systems as part of the instantaneous and continuous demands. If the damaged systems can be readily shut down, include their demands only in the instantaneous fire water demand. Also, include in the instantaneous demand the water demand of any extinguishing system that, even if undamaged by the blast, might be actuated by the overpressure wave or any ensuing fire.

Manual Fire Fighting

Review the site pre-emergency plans to determine the anticipated manual response for each scenario. Base the demand for monitor nozzles on the rating of the nozzle at 100 psi (6.9 bar) and straight stream flow. Assume the demand for each yard hydrant to be 500 gpm (1890 L/min).

- Assume all hydrants and monitor nozzles within 100 ft (30 m) of the limits of the fire will be used to control burning materials and cool fire exposed equipment. Include them in the continuous demand but not in the instantaneous demand. Modify this assumption as required by site layout, availability of access, fire brigade manpower levels, and applicable pre-emergency plans.
- In a tank farm fire, use semi-fixed and manual foam application rates per NFPA 11 to calculate water demand. Include portable or fixed monitors used to provide tank shell cooling and exposure protection. Include them in the continuous demand but not in the instantaneous demand.
- In an explosion resulting from a building, vessel or vapor cloud, assume all hydrants and monitors located within the 5 psi (0.35 bar) overpressure circle to be destroyed. When isolation valves controlling damaged wet barrel monitors and hydrants cannot be readily shut or accessed or are nonexistent, include the water wasted in the instantaneous and continuous water demand. If the damaged units can be shut down, include their demand only in the instantaneous demand.

Total Water Demand

For each scenario selected, compute an instantaneous water demand and a continuous water demand. Each such demand is the sum of the fixed system and manual fire fighting demand for either instantaneous or continuous demands.

Duration of Water Demands

Estimate the total quantity of water required to meet the fire fighting demands. The guiding principles for oil and chemical plants, outlined in PRC.17.2.1, PRC.17.3.1 and PRC.17.3.4, require that the water supplies and water distribution system be adequate to supply the demand for fixed water based extinguishing systems and manual fire fighting for a minimum period of 4 hours. Assume that for the first 30 minutes water is flowing at the instantaneous demand rate. Assume further that for the next 210 min water is flowing at the continuous demand rate.

DISCUSSION

Because most of the fire protection water is discharged at the continuous demand rate, the CFWD usually drives the size of the water storage. On the other hand, since the IFWD is usually larger than the CFWD, it tends to drive the size of the underground piping and size and number of the pumps.

Fixed systems include foam, sprinklers and water spray installations. Water spray can be actuated by gas detectors, temperature sensors, pilot heads, ultraviolet or infrared detectors, and remote manual control actuators. Gas, ultraviolet, infrared and pneumatic detectors are more sensitive than pilot heads and, therefore, might actuate more water spray systems. Plant procedures might require that all systems within a given area be tripped manually in a fire situation.

A vapor cloud explosion may destroy or impair fixed fire extinguishing systems. Total destruction of aboveground installations is expected in areas within the 5 psi (0.35 bar) overpressure circle. Aboveground water spray piping for installations within the 3 psi (0.21 bar) overpressure circle could be damaged unless properly shielded as described in PRC.12.2.1.2. An explosion will also actuate numerous extinguishing systems that may be unnecessary in fire fighting operations. HAD, infrared and ultraviolet detectors located within the 1 psi (0.07 bar) overpressure circle could actuate fixed systems. Gas detectors located within the gas cloud prior to ignition will also trip systems. Pilot heads are less sensitive and therefore are assumed to trip systems located within the 3 psi (0.35 bar) overpressure circle.

When isolation valves controlling the damaged or unnecessary fixed system cannot be readily shut, accessed or are nonexistent, the water wasted will have to be included in the fixed system water demand.

Manual fire fighting requires the use of hoses, hydrants and monitors and is generally an essential line of defense. Where fixed water spray protection is missing or impaired, use of hoses and monitors will be important and will create larger water demands. Fixed monitor nozzles should be located around the perimeter of process blocks. If the process block is too large to reach the center with monitor nozzle streams from the perimeter, monitor nozzles should be placed in the interior of the unit. Nozzles should be located with consideration given to accessibility and desired coverage. All areas of the process blocks should be reached by at least two monitor nozzle streams.

In an explosion resulting from a building, vessel or vapor cloud, manual fire fighting is essential especially in areas where the fixed protection systems have been damaged. Hydrants and monitors located in the vicinity of the explosion center may be sheared off. Large amounts of fire water may be wasted if wet barrel hydrants (or dry barrel hydrants left in the open position) are sheared off.

The total water demand may be as low as 1000 gpm (3780 L/min) for very small process areas or as high as 12,000 gpm (45,360 L/min) or more for large oil or chemical facilities. The estimation of the water demand for an oil and chemical facility is a complex issue, and not one that can be determined by a simple formula. The hazards, exposures, process features, facility layout and many other factors must be taken into consideration, and good judgment must be used when evaluating water demands.