Review Paper

FIREWATER SYSTEM DESIGN AND SELECTION OF OPTIMIZED LOCATION FOR FIREWATER TANKS AND PUMPS IN GAS OIL SEPARATION FACILITY

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ABSTRACT

Fire protection refers to prevention & reduction of fire hazards to protect people, properties and environment with the application of scientific & engineering principles. The purpose of this project was to assess the existing fire water system and define the fire water requirement for the combined new and existing facility modifications for the Gas Oil Separation facility.

The objective of this project was to select the most suitable location for fire water tanks and pumps and also to determine the fire water requirements, the capacity of fire water tank, the capacity of fire water pumps, and the firefighting requirements for the facilities.

Based on the options study for locating the firewater pumps and firewater tanks, it was concluded that new firewater tanks and new firewater pumps are to be located in the greenfield location.

Two main firewater pumps of 2000 USGPM each was considered for the simulation and the requirements such as minimum residual pressure at the hydraulically most remote piece of firefighting equipment were met. Firewater tank capacity, Firewater pump discharge pressure and existing line size of firewater network were assessed to be adequate to cater for the maximum firewater demand scenario.

Keywords: Fire Protection, Firewater Demand, Firewater Pumps, Firewater Tanks, Gas Oil Separation Facility.

INTRODUCTION

Fire protection refers to prevention & reduction of fire hazards to protect people, properties and environment with the application of scientific & engineering principles. This occupation is considered as one of the noblest profession due to its role in saving life & property and demands a strong commitment to serve the humanity. Fire protection involves not only extinguishing fires, but fire compartmentalization, fire suppression, fire mitigation, fire investigation, study of human behavior in fire conditions, research & development etc. The role of fire engineers span engineering to operations and management.

The gamut of fire protection spreads from residential buildings to hospitals, wild land areas, factories, refineries, oil & gas production fields, off shore platforms, ships, exploration bases in Antarctica, aircrafts, space shuttles etc. Thus, the field of fire protection is ubiquitous around the world.

The major goals of fire protection are:

- Life safety
- Property protection

- Continuity of operations
- Environment protection

The goal of life safety is the minimum goal of the fire protection. Property protection is the requirement of the Operator & insurance. Sometimes protection of building components / industrial equipment to enable life safety is a regulatory requirement. Interruption of operations is very costly.

The objective of this research paper is

1. To determine the fire water requirements for the GOSP
2. To determine the capacity of fire water tanks
3. To arrive at the fire water pumps capacity and pump curve
4. To define the firefighting requirements for the facilities.

This research paper includes the assessment fire water system of the new and existing facilities.

The fire water demand estimation is based on the assumption that only one major fire occurs at the facility at any given time. Thus the maximum fire water demand corresponds to the worst credible fire in any one fire area.

OVERVIEW OF EXISTING FIRE WATER SYSTEM

The existing fire water system at the facility comprises of one (1) fire water tank F07-T-2, two (2) electric motor driven main fire water pumps F07-G-6 A/B plus one (1) diesel engine driven standby fire water pump F07-G-7 each pump providing 1500 USGPM (340 m^3/hr) discharge flow. These main pumps are designed to operate on a cascade method on falling pressure in the fire main with two (2) pumps operating together to provide the maximum expected fire water demand of 3000 USGPM (681 m^3/hr), with the diesel engine pump used as a spare.

In addition to the main fire water pumps, two (2) jockey pumps F07-G-25 & 51 are provided. These jockey pumps provide a discharge flow of 300 USGPM (68 m^3/hr) and maintains the fire main pressure.

OPERATOR'S REQUIREMENTS FOR FIREWATER SYSTEM

- All process facilities shall be segregated into process risk areas for the purposes of fire water system design.
- The following applies to process areas with vessels and equipment which contain flammable or combustible liquids or combustible gases:
  - Each shall be a logically defined area that may be described in terms of areas containing process, handling, or storage equipment, piping, buildings or other structures.
  - The minimum distance between equipment and vessels in one risk area and equipment, vessels, or drainage swales in other risk areas shall be 15 m (50 ft).
  - There shall be clear fire vehicle access to at least two opposite sides of a risk area. Road width shall meet Operator standard requirements.
  - For the purposes of fire water capacity design calculations, when there is a common pipeway located between two risk areas, and the space between equipment and the pipeway is less than 7.5 m from both risk areas, the pipeway shall be a part of both risk areas. If a

pipeway is less than 7.5 m from only one risk area, the pipeway shall be included in only that risk area. Fin-fan coolers shall be considered as pipeways.

- ☞ The boundaries of a risk area shall be determined by the outermost equipment, vessels, and any included pipeways, containing process flammable/ combustible liquids or combustible gases.

High-Risk Process Area

✯ A "high-risk process area" is an area where one or more of the following conditions exist:

- ☞ Equipment containing fractionated, liquefied light hydrocarbons (butane or lighter).
- ☞ Equipment processing any of the following substances at auto-ignition temperature: flammable liquid, combustible liquid, or combustible gas.
- ☞ Equipment processing flammable/combustible liquid or combustible gas at a pressure of 6,900 kPag (1,000 psig) or greater.
- ☞ Equipment that is unusually congested or a concentration of equipment of high value.
- ☞ The surface area of a high-risk process area shall not exceed 1,860 m² (20,000 ft²).

Medium-Risk Process Area

• An area shall be designated a "medium-risk process area" when the following are processed or handled:

- Crude oil or other hydrocarbon products processed or handled above its flash point
- Where flammable fuel products are processed or where gas treatment facilities are operated.
- Examples of such medium-risk areas are stabilizers, gas treating units, asphalt oxidizers, sulfur plants, and onshore GOSPs.

Low-Risk Process Area

✯ A "low-risk process area" is an area where one or more of the following conditions exist:

- ☞ An area in which combustible liquids are processed or handled at ambient temperatures shall be designated as a "low-risk process area". An example of a low-risk facility would be a diesel-handling pump station. Boiler and air/water utility areas have also been classified as low-risk facilities, despite the presence of fuel gas piping, as long as gas piping is only for fuel to local boilers.

METHODOLOGY OF FIRE WATER DEMAND CALCULATION FOR PROCESS RISK AREAS

The fire water demand for a high risk area shall be computed by:

Either calculating flow rate using the water density [minimum 0.21 L/m²s (0.30 gpm/ft²)] for the entire area within the risk area boundaries or summing the design flow rates of each monitor and spray system, whichever is greater.

The flow rate range provided to a high-risk process area shall not be less than 126 L/s (2,000 gpm) but is not required to exceed 378 L/s (6,000 gpm), including

fixed spray requirements.

Deluge system demand is not included in the 6,000 gpm ceiling.

For medium-risk process areas, the demand requirement shall be calculated in the same manner to that of high-risk process areas, with the following exceptions:

The flow rate provided to a medium-risk process area shall not be less than 63 L/s (1,000 gpm) but is not required to exceed 252 L/s (4,000 gpm), including fixed spray requirements.

The density used to initially estimate flow shall be at least 0.14 L/m²s (0.2 gpm/ft²).

For low-risk process areas, the demand shall be calculated in the same manner to that of high-risk process areas;

The flow rate provided to a low-risk process area shall not be less than 63 L/s (1,000 gpm) but is not required to exceed 126 L/s (2,000 gpm) including fixed spray requirements.

The minimum water application density for exposed surface area in low-risk process areas shall be at least 0.10 L/m²s (0.15 gpm/ft²).

FIRE WATER SYSTEM CAPACITY DESIGN BASIS

A fire water system shall be designed to provide the maximum flow rate requirement of any single risk area served by the system. The capacity design basis of the system is set by the risk area having the highest flow rate requirement.

Hydraulic conditions shall be analyzed using computer software specialized for cross loop flow analysis of fire water systems to assure that the system will meet flow-rate and residual pressure requirements at each piece of fire protection equipment.

Pressure-drop calculations shall be based upon Hazen-Williams formulae. The following flow factors (C-factors) shall be used:

90/10 Cu/Ni C = 140

RTRP C = 135

Cement-Lined Steel C = 130

Minimum Residual Pressure

Fire water systems shall be designed to provide the minimum residual pressure at the hydraulically most remote piece of firefighting equipment in each risk area assuming:

Minimum Residual Pressure at Design Flow	kPag	psig
Firewater Monitors	700	100
Hose Reels	700	100
Firewater Hydrants	700	100
Deluge Nozzles	175	25
Spray Nozzles	175	25
Sprinkler	140	20

Table 1: Minimum Residual Pressure requirement

Firewater Storage Capacity

- Every fire water system shall be supplied from dedicated fire water storage. The storage shall contain a volume of water sufficient to provide the design flow rate, for the duration stated below, to the most demanding risk area (capacity design basis.

Plant Area	Primary 100% Flow
High- and Medium-risk Areas	12 hours
Hydrocarbon Storage Facilities	12 hours
For onshore GOSPs that are stand-alone and not part of other plant facilities, bulk plants and associated storage facilities	4 hours
Low-Risk Areas	4 hours

Table 2: Water Requirement for Different Facilities

- Fire water system storage shall be provided by at least two storage tanks.

Firewater Pumps

- For all process risk areas, the capacity design basis for fire

water shall be furnished by two or more centrifugal fire pumps.

- Additional backup capacity equal to at least 100% of the capacity design basis shall be provided by one or more diesel-driven pumps. Jockey pumps shall not be counted toward meeting the fire system demand design basis.
- Fire pumps areas shall be located only in electrically unclassified areas.
- The maximum allowable size for any one fire pump is 189 L/s (3,000 gpm) capacity (for backup diesel fire pumps, 370 L/s or 6,000 gpm).
- All fire water pumps feeding the same fire water system shall have the same head characteristics.
- Fire pump discharge pressure at zero flow shall be not less than 860 kPag (125 psig).
- All fire pumps shall deliver at least 150% of rated flow at 65% rated head. The total shutoff head shall not exceed 140% of total rated head for any type of pump.
- Fire pump drivers shall be a) electric motors or b) diesel engines listed for fire protection service.
- Fire protection systems of greater than 32 L/s (500 gpm) capacity shall have the piping downstream of the fire pumps continuously maintained at a minimum of 875 kPag (125 psig), by means of a motor-driven jockey pump system designed to meet NFPA 20.
- For installations requiring 32 L/s (500 gpm) or less, no jockey pump is required.
- Fire systems of over 32 L/s (500 gpm) shall be provided with two jockey pumps, one jockey pump rated at 19 L/s (300 gpm) at 875 kPag (125 psig), plus one 100% installed spare jockey pump.

FIRE WATER DEMAND FOR THE NEW GOSP FACILITIES

In accordance with Operator's requirements "Examples of Medium-risk process area are onshore GOSPs, Stabilizers, gas treating units" and the maximum fire water demand to be considered for any single fire risk in such medium risk process area shall not exceed 4000 USGPM. Thus, for this project, maximum fire water demand is based on 4000 USGPM.

Fire Water System Assessment Scenarios

Three options are assessed to arrive at the best possible fire water system arrangement to cater for the facilities.

OPTION 1

- Addition of 1 no. new fire water tank + addition of 2 nos. of fire water pumps (1 Electric driven + 1 Diesel driven) to the existing fire water system adjacent to the existing firewater tank location (F07-T-02)
  - Add 1 no. of new fire water tank adjacent to the existing fire water tank (capacity of new fire water tank to be similar to the existing fire water tank). Retain existing fire water tank (F07-T-02) as standby. Two number of fire water tanks are considered in compliance with the Operator standard's requirements.

    Add 2 nos. of fire water pumps (1 Electric Main + 1 Diesel Standby) each having 2000USGPM capacity adjacent to the existing fire water pumps.

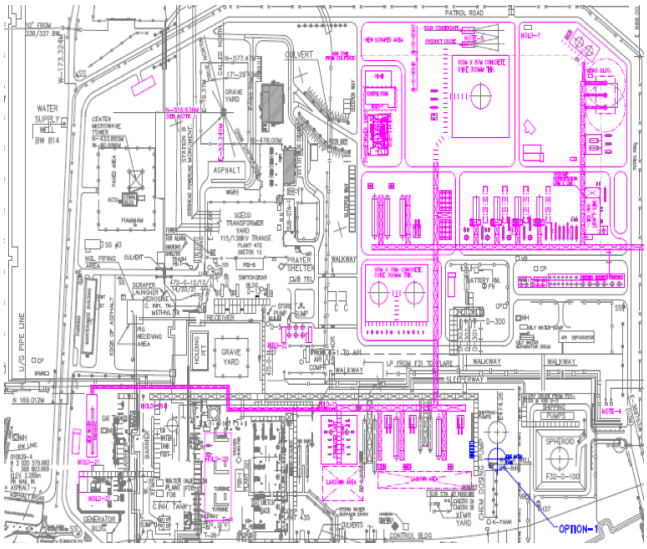

FIGURE: OPTION 1 - FIRE WATER SYSTEM ARRANGEMENT

OPTION 2

- Addition of 1 no. of new fire water tank at GOSP-6 and retain the existing fire water tank F07-T-2 (as Standby) + Install new fire water pumps (2 Electric Main + 2 Electric Jockey + 1 Diesel Standby) at GOSP-6. Tie-in the fire water piping between existing and new fire water tanks.
  - Add 1 no. new fire water tank at upwind of GOSP-6 and retain 1no. existing fire water tank (F07-T-02) as standby storage. Two number of fire water tanks are considered in compliance with the Operator standard's requirements.
  - Add 5 nos. of new fire water pumps (2 nos. Elec. driven main pumps each having 2000USGPM capacity + 1 no. Diesel standby pump having 4000USGPM capacity + 2 Elec. jockey pumps each having 300USGPM capacity) at GOSP-6. Existing pumps (F07-G-6 A/B, F07-G-7, F07-G-25/51) are not considered in this option, as the capacity of the existing pumps will not cater for the fire water demand specified in Operator standard's requirements.

New GOSP-6 fire water tank will be connected with existing fire water tank (F07-T-2) via UG piping.

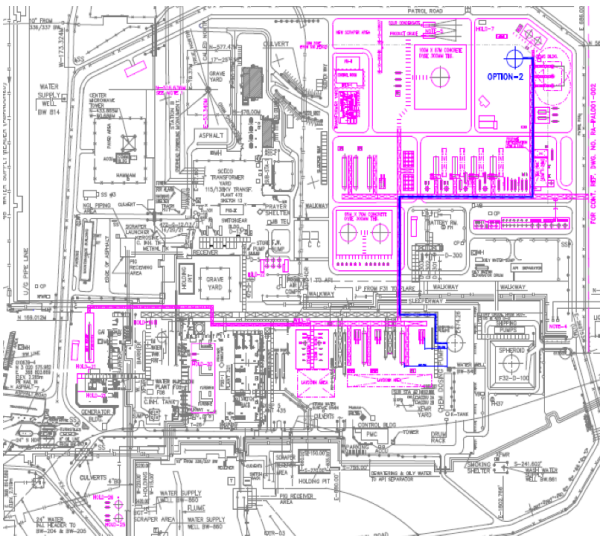

FIGURE 2: OPTION 2: FIRE WATER SYSTEM ARRANGEMENT

OPTION 3

- ✶ Completely new firewater system for GOSP-6. New firewater system piping distribution connects with GOSP-5 existing firewater distribution network.
- ✶ Add 2 nos. of new fire water tanks at GOSP-6. Firewater storage capacity shall be sufficient to provide 100% fire water flow for 12 hours for the medium-risk process area. Firewater storage shall be provided by Two (2) new fire water tanks (1No. Main + 1No. Stand-by) each having a capacity of ~70000 bbl (11000 m3)
- ✶ Add 5 nos. of new fire water pumps (2 nos. Elec. driven main pumps each having 2000USGPM capacity + 1 no. Diesel standby pump having 4000USGPM capacity + 2 Elec. jockey pumps each having 300USGPM capacity) at GOSP-6. Existing pumps are not considered in this option, as the capacity of the existing pumps (F07-G-6 A/B, F07-G-7, F07-G-25/51) will not cater for the fire water demand specified in Operator standard's requirements. New GOSP-6 fire water distribution piping network will be connected with the existing fire water piping network of GOSP-5.

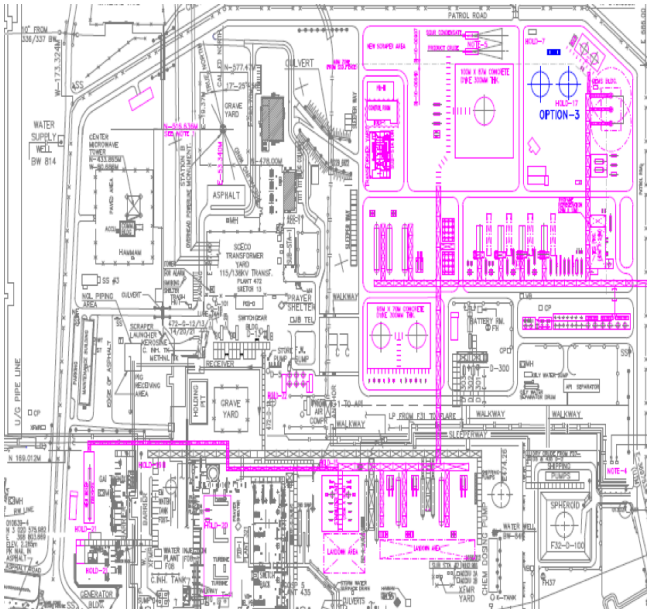

FIGURE 3: OPTION 3: FIRE WATER SYSTEM ARRANGEMENT

BENEFITS, LIMITATIONS AND GAPS ASSESSMENT OF OPTIONS

- The benefits, design limitations, technical gaps, operability issues and concerns among the different scenarios are discussed below.

OPTION 1

Advantages:

- Less capital cost due to the utilization of existing fire water system.

Technical Deficiencies/Gaps:

- This option does not meet the minimum spacing criteria between the main fire water pumps and the plant hydrocarbon handling equipment of 45m as per Operator requirement.
- The available distance (as per Plot plan) from Main Fire Pumps to Wet Crude Heater is 17m & distance between Main Fire Pumps to 2nd Stage Desalter is 32m.
- Operator requirement specifies the maximum fire water demand of 4000 USGPM for GOSP facility. Existing fire water main pumps F07-G-6 A/B can cater only 3000USGPM. In order to cater for the maximum fire water demand of 4000 USGPM, 2 nos. of new fire water pumps (1 Elec. + 1 Diesel) are to be added. Also, 1 no. of new fire water tank is considered adjacent to the existing fire water tank. The addition of pumps & tank to existing fire water header requires the shutdown of the entire fire water system, when the plant is in operation. Non-availability of fire water system during plant operation is not advisable. However, early tie-ins can be proposed during the planned shutdown to reduce the downtime / unavailability.
- As per Operator requirement, minimum of 60m spacing is required from plant equipment to water supply well. With reference to the Plot Plan, the existing fire water system installation location has space constraint to accommodate the new fire water tank. The addition of new fire water tank will clash with existing water supply well (BW-849).
- The available distance from existing Water Well (BW-849) to existing firewater tank (F07-T-02) is 28m, distance between Water Well (BW-849) to 2nd Stage Desalter is 53m & distance between Water Well (BW-849) to Wet Crude Heater is 52m.
- The existing fire water tank (F07-T-2) and fire water pumps (F07-G-6 A/B, F07-G- 7, F07-G-25/51) are located downwind of the process facility. As a good engineering practice and considering the survivability of safety critical system (fire water tanks & pumps) in case of emergency scenario, locating the firewater tanks and pumps downwind of process facility is not advisable.
- Existing fire water tank (F07-T-2) and fire water pumps (F07-G-6 A/B, F07-G-7, F07-G-25/51) are in close proximity to the process area and are vulnerable to fire or explosion hazard. Also, new process vessels are expected to be added in the process area close to the existing fire water tanks & pumps. Addition of new fire water tank and pumps to this location is also anticipated to have the same level of impact as of the existing fire water tank and pumps.
- Operation concerns on existing fire water system (as per operator input) are listed below:
- The annular plate (bottom plate) of existing fire water tank (F07-T-2) requires frequent maintenance. Over a period of time, the existing fire water tank (F07-T-2) replacement with a new fire water tank may be inevitable.
- Considering the service life of existing fire water system (i.e. more than 25yrs), the reliability and availability of existing fire water tank (F07-T-2) (considered as stand by storage in this option) is a major concern for operations.
- Existing fire water jockey pump

seal failure and flange leakage causes frequent maintenance. To maintain the fire water main header pressure, frequent intervention from Operations is made.

- The existing fire water tank (F07-T-2) is currently "open to atmosphere" without roof in place. As per NFPA 22, clause 4.14 "Roofs" mention that "All tanks shall have roofs". The existing fire water tank (F07-T-2) is not meeting NFPA 22 requirements.
- Design short falls & technical deficiencies/gaps are present in this option. The following Violation of Operator standard's requirements are evident in this option:
- Minimum spacing distance between main fire pump to hydrocarbon Equipment
- Minimum spacing distance between water well to plant equipment.
- Reliability concerns on the existing fire water system and operational issues on the existing fire water tanks & pumps are also observed. Hence, this option is considered not to be suitable to satisfy the requirements.

OPTION 2

Advantages:

- Less capital cost due to utilization of existing fire water tank (F07-T-2).

Design and Operations Issues:

- As per Operator standard's requirements, fire water mains are to be routed underground. Routing and hooking up of underground piping between the new and existing fire water tanks will require crossing the existing pipe racks and UG facilities resulting in complex UG design leading to operation disruption.
- The distance of ~700m between inter-connection piping of new and existing fire water tank will be resulting in to high pressure drop, existing fire water tank (F07-T-2) will never provide enough NPSH to be connected to new pump station and new fire water pumps require to be designed with much higher pressure.
- Inter-connection/tie-in of new fire water tank & fire water pumps to the existing fire water header requires shutdown of the existing fire water system, when the plant is in operation. Non-availability of fire water system during plant operation is not advisable. Early Tie-ins can be proposed during the planned shutdown. This will reduce the downtime / non availability of fire water system during operations.
- For emergency fire scenario during fire water tank inspection/ maintenance, switching of firewater supply (tank discharge valve operation) from existing fire water tank to new fire water tank and vice versa is required. This switching being a manual operation, considering the distance between new and existing fire water tank (700m), time required for switching will not be immediate.
- The existing fire water tank (F07-T-2) and fire water pumps (F07-G-6 A/B, F07-G- 7, F07-G-25/51) are located downwind of the process facility. As a good engineering practice and considering the survivability of safety critical system (fire water tank & pumps) in case of emergency scenario, locating the fire water tank downwind of process facility is not preferable.
- Existing fire water tank (F07-T-2) is in close proximity to the process area and are vulnerable to fire or explosion hazard. Also, new process vessels are expected to be added in the process area close to the existing fire water tanks & pumps. Refer to the distance marked on plot plan layout, the available distance from existing fire water tank (F07-T-2) to Wet Crude Heater is 35m & distance between existing fire water tank (F07-T-2) to 2nd

Stage Desalter is 60m.

- Operation concerns on existing fire water system (as per operator input) are listed below:
- The annular plate (bottom plate) of existing fire water tank (F07-T-2) requires frequent maintenance. Over a period of time, the existing fire water tank (F07-T-2) replacement with a new fire water tank may be inevitable.
- Considering the service life of existing fire water system (i.e. more than 25yrs), the reliability and availability of existing fire water tank (F07-T-2) (considered as stand-by storage in this option) is a major concern for operations.
- The existing fire water tank is currently "open to atmosphere" without roof in place. As per NFPA 22, clause 4.14 "Roofs" mention that "All tanks shall have roofs". The existing fire water tank (F07-T-2) is not meeting NFPA 22 requirements.
- Considering the difficulty in routing the underground piping, NPSH issues and reliability concerns of the existing firewater tank (F07-T-2), this option is not suitable to be adopted.

OPTION 3

Advantages:

- New GOSP-6 fire water system design meets the Operator standard's requirement (compliance with sparing philosophy of fire water tanks & pumps, capacity of fire water tanks & pumps, UL/FM compliance of fire water equipment etc).
- Minimum spacing criteria of the fire water system with other facilities is achieved to comply with Operator standard's requirements.
- Reliable fire water system (considering fire water demand requirement from Operator standard and providing adequate sparing of fire water pumps) is ensured for the new GOSP facilities as well as existing GOSP facilities.
- Entire GOSP facility is covered with one dedicated, reliable, independent fire water supply system without disturbing existing fire water system (except for tie-ins with existing distribution network). Existing fire water supply system (tanks and pumps) are proposed to be decommissioned after the new firewater system is put into operation.
- New GOSP fire water system is located upwind of GOSP process facilities (safe by location).
- Optimization of capital cost by considering utilization of existing GOSP fire water network to the maximum extent possible. Reduction in repair and maintenance cost of the existing fire water tanks and pumps.

Challenges:

- Achieving minimum residual pressure (7barg) at the remotest node (hydrant) in the existing facilities can be challenging, given that the existing facility UG distribution header pipe size is fixed (10"). The pressure requirement needs further evaluation with hydraulic analysis.

Considering the following factors:

- New fire water system complying with Operator Standard's requirements
- Resolving existing system deficiencies/gaps, reusing the existing UG network
- Maintain technical integrity/ survivability of safety critical systems by virtue of the location of the fire water tanks and pumps
- Reducing repair and maintenance cost of existing fire water

tanks and pumps.

This option (OPTION 3) is evaluated to be the preferred option to proceed with.

FIRE WATER HYDRAULIC ASSESSMENT

Hydraulic analysis was performed to model the Firewater Ring Main network considering OPTION 3. A scenario of two main firewater pumps of 2000 USGPM each is considered in the simulation to deliver firewater for the maximum firewater demand. NFPA 20 compliant fire water pump curves were used for the hydraulic assessment.

FIRE WATER HYDRAULIC ASSESSMENT OUTCOME

- Minimum residual pressure at the hydraulically most remote piece of firefighting equipment during maximum fire water demand scenario for the facility is 7.88 barg. This is in compliance with the Operator standard's residual pressure requirements of 7barg.

- A maximum of 7 nos. monitors were opened in the crude storage tank area and 1 no. of remote hydrant was opened in the remotest STP area. Firewater pump discharge pressure for PUMP A was found to be 1987 USGPM @ 9.06 barg pressure and for PUMP B was found to be 1981 USGPM @9.06 barg. Hence, the proposed 2 Nos. of 2000 USGPM each firewater pumps are assessed to be adequate to provide fire protection in case of fire at the facility.
- The existing pipe size of 10" diameter combined with proposed new pipe size of 10" is adequate to provide the required flow in case of maximum firewater demand scenario.
- Maximum velocity in the Underground Firewater Ring Main network did not exceeding 5m/s during maximum fire water demand scenario in any part of the network.

Figure: Fire Water Hydraulic Network Arrangement Fire Water System Flow Diagram

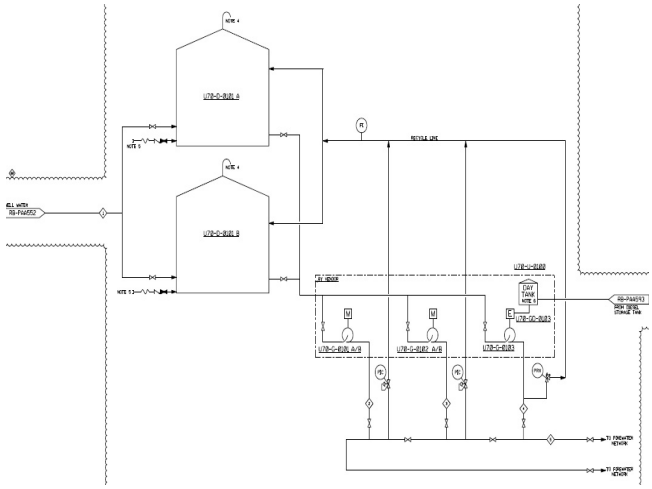

Figure: Fire Water System Flow Diagram

CONCLUSION & DISCUSSIONS

Based on the options study for locating the firewater pumps and firewater tanks, it is concluded that new firewater tanks and new firewater pumps are to be located in the greenfield location. This option provides the following advantages

1. New fire water system complies with Operator Standard's requirements
2. Reliable fire water system (considering Operator

standard's fire water demand requirement and providing adequate sparing of fire water pumps) is ensured for the new facilities as well as existing facilities

3. Resolving existing system deficiencies/gaps, reusing the existing UG network
4. Maintain technical integrity/ survivability of safety critical systems by virtue of the location of the fire water tanks and pumps
5. Reducing repair and maintenance cost of existing fire water tanks and pumps.

New firewater tanks and firewater pumps are located in the upwind direction, and also in electrically unclassified area.

Firewater storage is provided by Two (2) new fire water tanks (1No. Main + 1No. Stand-by) each having a capacity of ~70000 bbl (11000 m3). This will ensure availability of one firewater tank (availability of 100%), when the other tank is taken up for maintenance or inspection.

Minimum residual pressure at the hydraulically most remote piece of firefighting equipment during maximum fire water demand scenario for the facility is arrived to be 7.88 barg. This is in compliance with the Operator standard's residual pressure requirements of 7barg.

Through hydraulics analysis, Firewater pump discharge pressure for PUMP A is found to be 1987 USGPM @ 9.06 barg pressure and for PUMP B is found to be 1981 USGPM @9.06 barg. Hence, the proposed 2 Nos. of 2000 USGPM each firewater pumps are assessed to be adequate to provide fire protection in case of fire at the facility.

Maximum velocity in the Underground Firewater Ring Main network did not exceeding 5m/s during maximum fire water demand scenario.

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