Non-Q Design Analysis Cover Sheet

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Complete only applicable items.

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7. Originator	Stephen Goodin	<i>Stephen Goodin</i>	5/14/99
8. Checker	Jerry Keifer	<i>Jerry Keifer</i>	5-14-99
9. Lead Design Engineer	Jerry Keifer	<i>Jerry Keifer</i>	5-14-99
10. Department Manager	William R. Kennedy	<i>William R. Kennedy</i> W.R.K.	5-14-99
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**Non-Q Design Analysis
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1. PURPOSE

This analysis evaluates the existing subsurface non-potable water system from the portal pump to the end of the water line in the South Ramp and determines if the pump size and spacing meets the system pressure and flow requirements for construction operations and incipient fire fighting capability as established in the Subsurface Fire Hazards Analysis (CRWMS M&O 1998b). This analysis does not address the non potable water system in the Cross Drift which is covered under a previous design analysis(CRWMS-M&O 1998g). The Subsurface Fire Hazards Analysis references sections of OSHA 29 CFR 1910 Subpart L for requirements applicable to the incipient fire fighting hose stations used underground. This analysis does not address mechanical system valves, fittings, risers and other components of the system piping. This system is not designed or intended to meet all National Fire Protection Association (NFPA) codes for a fire fighting system but is only considered a backup system to fire extinguishers that are installed throughout the Topopah Springs (TS) Loop and may be used to fight small incipient stage fires.

2. QUALITY ASSURANCE (QA)

The non-potable water system is a temporary system and therefore not classified in accordance with QAP-2-3. In accordance with NLP-2-0, there are no Determination of Importance (DIE) controls associated with this analysis since all controls associated with activities related to the water system (i.e. water use controls) are covered in subsurface specifications (CRWMS M&O 1999b). An activity evaluation (CRWMS M&O 1998e) has been completed for this analysis in accordance with QAP-2-0 and has determined also that the activities associated with this system are not Q. Therefore the classification of items in this analysis are not subject to QA controls in accordance with NLP-3-18.

3. METHOD

Total flow rate required in the subsurface water line is determined by evaluating current and future water use for the Exploratory Studies Facility (ESF) subsurface operations and construction including incipient fire fighting capability. The required minimum and maximum water line pressures are determined for incipient fire fighting conditions and then compared with existing line pressure in the system. The line pressure in the entire TS Loop system is calculated and plotted using Bernoulli's equation. The equation takes into account existing pressure in the system, pressure introduced into the system by pumps, pressure due to water column, friction loss of the system, and the required flow rate. The pressure versus station is then plotted for the entire length of the non-potable water line. This plot is then used to determine if the pressure for the entire system is above the required amount for incipient fire fighting at the given minimum flow rate.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

- 4.1.1 The measured static pressure at Pump #3 outlet (primary subsurface supply pump) located near the North Portal on the North Portal Pad was measured by Title III A/E as 65 psi (CRWMS M&O 1999c). The pump is has a capacity of 600 gpm @ 39 PSIG (CRWMS-M&O 1998g)
- 4.1.2 Pump # 3 is located near the portable tanks approximately 335 feet (scaled distance) from the North Portal Station 0+00 as measured from the portable tanks closest to the portal to the North portal (CRWMS M&O 1998c).
- 4.1.3 The required minimum pressure and flow rate at the fire hose station nozzle is 30 psi @ 100 gpm (CRWMS M&O 1998a, p. 24).
- 4.1.4 The pressure loss for smooth walled 6-inch diameter steel pipe with an assumed flow of 275 gpm (Assumption 4.3.5) = 0.00234 psi/ft of water pipe(CRWMS M&O 1994, Attachment II p. 7 of 13,)
- 4.1.5 Distance from Station 0+00 to grade break Station 28+04.323 $\cong$ 9200.5 ft (CRWMS-M&O 1996, p. 27)
Distance from Station 0+00 to Pump Station 40+00.00 $\cong$ 13123 ft (Assumption 4.3.3)
Distance from Station 0+00 to grade break Station 56+54.323 $\cong$ 18550 ft (CRWMS-M&O 1996, p. 27)
Distance from Station 0+00 to Pump Station 65+00.00 $\cong$ 21325 ft (Assumption 4.3.4)
Distance from Station 0+00 to Station 78+71.00 $\cong$ 25823 ft (CRWMS-M&O 1996, p. 27)
- 4.1.6 Main Drift slope from Station 28+04.323 to Station 56+54.323 = 1.35% (CRWMS M&O 1996, p.27)
- 4.1.7 South Ramp slope from Station 56+54.323 to Station 78+77.037 = 2.6189 $\cong$ 2.62% (CRWMS M&O 1996, p. 27)
- 4.1.8 Elevation of North Portal Station 0+00 $\cong$ 1122.560 m $\cong$ 3683 ft (CRWMS M&O 1996, p. 27)
- 4.1.9 Elevation of North Ramp Station 28+04.323 = 1065.000 m $\cong$ 3494 ft (CRWMS M&O 1996, p. 27)
- 4.1.10 The conversion factor for conversion from feet of water to psi = 0.4328 $\cong$.433 psi/ft (Ingersoll-Dresser Pumps 1996, p. 9-17)

- 4.1.11 Equivalent length for 90° flow through 6-inch tee is 30 feet (CRWMS M&O 1994, Attach II, p. 4 of 13)
- 4.1.12 Equivalent length for flow through 6-inch isolation valves (butterfly) is 10 feet (CRWMS M&O 1994, Attach II, p. 4 of 13)
- 4.1.13 Equivalent length for flow through 1 ½ inch butterfly valve is 0.0 feet (CRWMS M&O 1994, Attach II, p. 4 of 13)
- 4.1.14 Equivalent length for straight flow through 6-inch tee $10.1 \cong 10$ ft. (Ingersoll-Dresser Pumps 1996 p. 3-120)
- 4.1.15 Pressure loss for 150 feet of 1 ½-inch diameter (CRWMS M&O 1998b, p. 71) rubber lined linen fire hose @ 100 gpm $FL = 24 q^2 L = 24(1)^2 (1.5) = 36$ psi, where FL is total friction loss, $q = \text{gpm}/100$, $L = \text{hose length in hundreds of ft.}$ (NFPA 1997, p. 10-243)
- 4.1.16 The existing in-line booster pumps (Pump #4 and Pump #5) used in this calculation are manufacturer Model SMP 3000-1 ½ x 1 x 7, 10 hp with operating characteristic of 145 ft (63 psi) @ 120 gpm. (CRWMS M&O 1999a, CRWMS M&O 1998a)
- 4.1.17 Flow through 3/16 inch diameter nozzle (Assumption 4.3.1) = 8.45 gpm (Ingersoll-Dresser Pumps 1996, p.2-9)
- 4.1.18 The number of valves used for each equivalent length calculation were summed using the correspondence provided by Title III A/E (CRWMS M&O 1998f) are given below. The effects of short segments of rubber hose as provide in the correspondence were considered negligible in affecting the head loss through the system and were ignored.

Point P₁ (Sta 0+00)

Point P₂ (Sta 28+04.323)

Isolation valves = 18

Utility valve tees = 34

Point P₃ (Sta 40+00)

Isolation valves = 27

Utility valve tees = 52

Point P₄ (Sta 56+54.323)

Isolation valves = 38

Utility valve tees = 75

Point P₅ (Sta 65+00)

Isolation valves = 45

Utility valve tees = 87

Point P₆ (Sta 78+71)

Isolation valves = 55

Utility valve tees = 107

4.1.19 Water used for Alpine mining activities is approximately 8gpm. (CRWMS M&O 1998d, p.7)

4.1.20 Alcove #1 located at Station 0+42.672 m $\cong$ 0+43 m (CRWMS M&O, 1999d)

4.1.21 Maximum nozzle pressure at hose stations is 100 psi (CRWMS M&O 1998b, p. 71)

4.2 CRITERIA

4.2.1 Utility systems will support the testing utility requirements listed in Section B.2.3.3.B of Appendix B of the Exploratory Studies Facility Design Requirements (ESFDR) document, and construction utility requirements (YMP 1997) (Section 7.4)

4.3 ASSUMPTIONS

4.3.1 Dust control spray nozzle for spraying down inverts has a diameter 3/16-inch diameter. This is based on the use of a fine spray mist being used for wetting the inverts. (Section 7.1)

4.3.2 Total water flow rate requirement in Cross Drift is three times that of the TS Loop. This assumption is based on the possibility of construction operations occurring simultaneously in three separate alcoves or niches in the Cross Drift. Whereas, water use in the TS Loop will occur infrequently and in single occurrences at any given time since this portion of the tunnel is in non-construction status. (Section 7.1)

4.3.3 The first in-line pump is located at Station 40+00 in the TS Loop

4.3.4 The second in-line pump is located at Station 65+00 in the TS Loop

4.3.5 Maximum flow rate in non-potable 6 inch water line is 275 gpm

4.3.6 Assumed water pressure available for dust control operations is 65 psi

4.3.7 Water use for specific mining activities in the TS Loop such as mining and drilling operations will require the same quantities of water as that used in the Cross Drift

4.4 CODES AND STANDARDS

Not Used

5. REFERENCES

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CRWMS M&O 1999f. Interoffice Correspondence, S.W. Goodin to File, LV.TFD.SWG.04/99-038, April 13, 1999, *ESF Main Drift Supply Water*. MOL.19990409.0156

Ingersoll-Dresser Pumps 1996. *Cameron Hydraulic Data*. Liberty Corner, NJ: Ingersoll-Dresser Co. 242444

NFPA (National Fire Protection Association) 1997. *Fire Protection Handbook*, 18th Edition. Quincy, MA: National Fire Protection Association. 233110.

YMP (Yucca Mountain Site Characterization Project) 1997. *Exploratory Studies Facilities Design Requirements Document*. YMP/CM-0019 REV 02, ICN1, Las Vegas, Nevada: YMP MOL.19980107.0544 & MOL.19960926.0065

6. USE OF COMPUTER SOFTWARE

Not Used

7. DESIGN ANALYSIS

7.1 DISCUSSION

The required flow rate in the tunnel is determined based on the required use of equipment and other water use operations in the tunnel. Water use in the tunnel is to be minimized as per the Determination of Importance Evaluation for the ESF (CRWMS M&O 1999b, p. 105). Currently, operations in the TS Loop require very minimal water use since there are no planned excavations required in the future for site characterization activities. However, limited excavation and/or construction activities that would require water may possibly be done in the TS Loop in the future. Water may be used for wetting down inverters for dust control and is the most frequent and largest use of water foreseen in the TS Loop at the current time. The amount used for an assumed nozzle diameter size of 3/16 inch (Assumption 4.3.1) at 65 psi (Assumption 4.3.6) is approximately 8.45 gpm (Input 4.1.17). Mining and bolting operations could be done concurrently and would require a very small flow of approximately 8 gpm, (Input 4.1.19, Assumption 4.3.7). Thus the total minimum flow required for TS Loop operations and construction would be 8.45 gpm (dust control) + 8 gpm (required during mining activities) = 16.45 gpm $\cong$ 20 gpm. Adding fire fighting flow requirement of 100 gpm to this gives 100 + 20 = 120 gpm.

The same type of water use activities and equipment will be used in the Cross Drift and associated alcoves, with the exception of additional test drilling equipment which will not be done concurrent with construction operations. However, the construction water use activities may be occurring concurrently in these locations due to construction being done in more than one alcove at a time. Thus, the total amount of water to be used will be assumed to be three times the amount needed in the TS Loop or 60 gpm. This pump needs to supply at least 60 gpm (dust control and mining activities) to the Cross Drift. Thus, the total fire fighting requirement for the subsurface would be 120 (TS Loop) + 60 (Cross Drift) = 180 gpm. This total flow requirement is less than the assumed flow of 275 gpm (Assumption 4.3.5) and thus the friction factor used for this calculation is valid and conservative.

The minimum pressure required in the TS Loop at each fire hose station nozzle for incipient fire fighting capability is 30 psi. The requirement is based on 29 CFR 1910 regulations as discussed in the Subsurface Fire Hazards Analysis and not NFPA code (Input 4.1.3). The following calculation determines the pressure available at the hose nozzle at any point along the TS Loop based on a 6 inch supply line (CRWMS M&O 1998g, p. 5). The hose used for the calculation was a 150 ft long and 1 1/2 inch diameter rubber lined linen hose which is the required length and diameter for each fire hose station. (Input 4.1.15) The calculation determines the nozzle pressure in psi at the North Portal (Station 0+00), at the grade break in the TS Loop (Station 28+04.323 m), the location of the first in-line Pump #4 (inlet) at Station 40+00, the grade break at Station 56+54.323 m, the location of the second in-line Pump #5 (inlet) at Station 65+00 and the last valve station at Station 78+71. The pressure at these points are then used to plot the pressure for the entire TS Loop.

7.2 CALCULATION

The Bernoulli equation is defined as follows:

$$P_1 + V_1^2/2g + Z_1 = P_2 + V_2^2/2g + Z_2 + \text{Friction Loss (CRWMS M\&O 1994, Attach II, p. 3)}$$

Where V is the velocity of flow and $V_1 = V_2$ from continuity for constant flow and flow area, P = static pressure, Z = distance from common datum, g = acceleration of gravity and solving for P_2

$$P_2 = P_1 + (Z_1 - Z_2) - \text{Friction Loss}$$

Pressure P_1

$Z_1 - Z_2 = 0$, since elevation change on North Portal Pad is considered insignificant between the tanks and the tunnel portal,

Portal pump head = 65 psi

Length of pipe (scaled distance) to the portal is 335 ft

Head lose in fire hose is 36 psi

Length of pipe is 335 ft

Friction Loss Factor (FL) = .00234

$$P_1 = 65 - [36 + (335)(0.00234)] = 28.22 \text{ psi}$$

Pressure P_2

Elevation of North Portal Station 0+00 = 1122.5m (3683 ft) (Input 4.1.8)

Elevation of Station 28+04.323 = 3494 ft (Input 4.1.9)

Equivalent lengths = number of fittings x equivalent length for fitting

Number of existing valves provided below where provided by Title III A/E and are listed as input parameters in Section 4. Equivalent length for isolation valves = 18 valves x 10 ft/valve = 180 ft

Equivalent length for straight flow through outlet tees = 34 tees x 10 ft/tee = 340 ft

Equivalent length for 90 ° flow through tee at hose station = 1 tee x 30 ft/tee = 30 ft

Equivalent length for 1 ½ -inch valve = 0 ft

Total equivalent length = 180 + 340 + 30 + 0 = 550 ft

Length of pipe $\cong$ 2804m (9200 ft) (Input 4.1.5) = 9200 + 400 (length from pump #3 to portal) = 9600 ft

Portal pump head = 65 psi

Head loss in fire hose = 36 psi

FL = .00234

$$P_2 = 65 + (3683-3494)(0.433) - 36 - (9600 + 550)(0.00234) = 87.1 \text{ psi}$$

Pressure P_3 at Pump inlet

Slope of Main Drift = 1.35 % between Station 28+04.323 and Station 40+00 (Input 4.1.6).

$$Z_1 - Z_2 = 3683 - [3494 + (13123 - 9200)(0.0135)] = 136 \text{ ft}$$

Equivalent length for isolation valves = 27 valves x 10 ft/valve = 270 ft

Equivalent length for straight flow through outlet tees = 52 tees x 10 ft/tee = 520 ft

Equivalent length for 90 ° flow through tee at hose station = 1 tee x 30 ft/tee = 30 ft

Equivalent length for 1 ½ -inch valve = 0 ft

Total equivalent length = 270 + 520 + 30 + 0 = 820 ft

Length of pipe = 4000m (Input 4.1.5) = 13123 ft + 400 ft (length from pump # 3 to portal) = 13523 ft, and

Head loss in fire hose = 36 psi

Portal pump head = 65 psi

FL = .00234

$$P_3 \text{ (pump inlet)} = 65 + (136) (0.433) - 36 - (13523 + 820) (0.00234) = 54.33 \text{ psi}$$

Pressure P_4 at grade break

$$Z_1 - Z_2 = 3683 - 3494 + (18550 - 9200) (0.0135) = 63 \text{ ft}$$

Equivalent length for isolation valves = 38 valves x 10 ft/valve = 380 ft

Equivalent length for straight flow through outlet tees = 75 tees x 10 ft/tees = 750 ft

Equivalent length for 90 ° flow through tee at hose station = 1 tee x 30 ft/tee = 30 ft

Equivalent length for 1 ½ -inch valve = 0 ft

Total equivalent length = 380 + 750 + 30 + 0 = 1160 ft

Length of pipe = 5654m (Input 4.1.5) = 18550 ft + 400 ft (length from pump # 3 to portal) = 18950 ft

Pump input head to system at Station 40+00 = 63 psi, and

Portal pump head = 65 psi

Head lose in fire hose = 36 psi

FL = .00234

$$P_4 = 63 + 65 + (63)(0.433) - 36 - (18950 + 1160)(0.00234) = 72.2 \text{ psi}$$

Pressure P_5 at Pump inlet

Slope of South Ramp = 2.62 % (Input 4.1.7)

$$Z_1 - Z_2 = 3683 - [3494 + (9350)(0.0135) + (21325 - 18550)(0.0262)] = -10 \text{ ft}$$

Equivalent length for isolation valves = 45 valves x 10 ft/valve = 450 ft

Equivalent length for straight flow through outlet tees = 87 tees x 10 ft/tee = 870 ft

Equivalent length for 90 ° flow through tee at hose station = 1 tee x 30 ft/tee = 30 ft

Equivalent length for 1 ½ -inch valve = 0 ft

Total equivalent length = 450 + 870 + 30 + 0 = 1350 ft

Length of pipe = 6500m (Input 4.1.5) = 21325 ft + 400 ft (length from pump # 3 to portal) = 21725 ft

Pump input head to system at Station 40+00 = 63 psi,

Portal pump head = 65 psi

Head lose in fire hose = 36 psi, and

FL = .00234

$$P_5 \text{ (pump inlet)} = 65 + 63 + (-10)(0.433) - 36 - (21725 + 1350)(0.00234) = 33.67 \text{ psi}$$

Pressure P_6 at last valve Station

$$Z_1 - Z_2 = 3683 - [3494 + (9350)(0.0135) + (25823 - 18550)(0.0262)] = -127.8 \text{ ft}$$

Equivalent length for isolation valves = 55 valves x 10 ft/valve = 550 ft

Equivalent length for straight flow through outlet tees = 107 tees x 10 ft/tee = 1070 ft

Equivalent length for 90 ° flow through tee at hose station = 1 tee x 30 ft/tee = 30 ft

Equivalent length for 1 ½ -inch valve = 0 ft

Total equivalent length = 550 + 1070 + 30 + 0 = 1650 ft

Length of pipe to Station 78+71 = 400 + 25823 = 26223 ft

Pump input head to system at Station 40+00 and Station 65+00 = 63 + 63 = 126 psi,

Portal pump head = 65 psi

Head lose in fire hose = 36 psi

FL = .00234

$$P_6 = 126 + 65 + (-127.8)(0.433) - 36 - (26223 + 1650)(0.00234) = 34.44 \text{ psi}$$

7.3 CALCULATION RESULTS AND DISCUSSION

The pressures as calculated are plotted vs. distance in the ESF Loop (Figure 1) showing the total pressure available at the hose station nozzle at any location along the entire length of the non-potable water line. The plot indicates that the pressure in the system is insufficient to meet the 30 psi requirement at the hose station nozzle at Alcove #1, which is located at TS Station 1+40 (Input 4.1.20). The requirement in the Subsurface Fire Hazards Analysis (CRWMS M&O 1998b, p. 71) is for a minimum of 150 feet of hose at each hose station. This was partially based on the fact that 150 ft of hose exist on many of the stations underground at the present time. As stated in the analysis, OSHA 29CFR 1910 does not stipulate a minimum required length. It is recommended that the hose length at Alcove #1 be reduced to 100 ft in length to provide a pressure at the hose nozzle of at least 30 psi with 100 gpm. Alcove #1 is a short alcove and reducing the hose length will not adversely effect the hose station capability. The head loss through 100 feet of rubber lined hose is recalculated using the formula $FL = 24q^2L$, and the friction loss $FL = (24)1^2(1) = 24$ psi which reduces the head loss through the hose by $36 - 24 = 12$ psi. Thus, adding 12 psi to P_1 gives a total pressure at the nozzle of $28.1 + 12 = 40.1$ psi. This nozzle pressure meets the 30 psi requirement.

Figure 1- Existing system nozzle pressure vs. station

It can be seen additionally from the plot that the nozzle pressure exceeds 100 psi and goes as high as 117 psi at the first in-line booster pump. The maximum pressure allowed at each hose nozzle is 100 psi (Input 4.1.21) and a pressure regulator will be required on all stations that would exceed this limit. The regulator can be set based on the pressure loss attributed to the fire hose having the required flow of 100 gpm. The pressure loss in 150 ft of 1 ½ inch linen rubber lined hose is given by $FL = 24 q^2 L$ (NFPA 1997) and $FL = 24 (1)^2 (1.5) = 36$ psi and for the Alcove #1 100 ft long hose $FL = 24 (1)^2 (1.0) = 24$ psi. The regulators will be set so that the pressure at the nozzle is not less than 30 psi and not greater than 100 psi. Additional, regulators may be required for operation of mining or other construction equipment underground where the line pressure exceeds the maximum operating pressure in equipment.

Fire hose nozzles will be required that provide 100 gpm of flow at the available pressure and are that electrically safe (CRWMS-M&O 1998b, p.24 and 71). A fire hose nozzle that meets these requirements will be an Akron Brass Co., 1 ½ inch Assault Tip with twist shutoff and spinning teeth, Model 4817, with the 175 gpm @ 75 psi size orifice, or equal.(Ref. CRWMS-M&O 1999e).

The static pressure head when the portal Pump#3, is operating but pumps #4 and #5 are off was measured at 15 psi in the non-potable line near the South Portal (Ref. CRWMS-M&O 1999f). When flow in the line exceeds 10-20 gpm in-line Pumps #4, and #5 should be started. The pumps can be shut off when the flow goes below 8 gpm. This will require flow switches to be installed near each of the pumps to provide proper operation. The portal Pump #3 can be operated on a timer that shuts the pump off during non-operation hours thereby minimizing the operating time of the pump and lengthening pump bearing life. In the case that a low flow higher pressure application (30psi or higher) is required the in-line pumps should be allowed to operate with a manual override in the case the the flow is not adequate to start the pumps. The in line pumps may require to have a small flow recirculation line from the inlet side of the pump to keep from damaging the pump seals in this case. A small flow of approximately 5 gpm will circulate water through the pump seal and prevent heat build up. Procedural controls can be established by the constructor to minimize the continued operation of the pump during no flow conditions in the case a manual override is used.

The Title III Evaluation Report (CRMS M&O 1998a) for the non-potable water system recommends an automatic shut off valve be installed at the North Portal. This valve should be a slow closing valve with an electric actuator that will prevent water hammer from occurring during shut-off. The valve should close if flow in the line exceeds 250 gpm for ten minutes since the maximum use underground is estimated at 180 gpm and a flow of 250 gpm or more should indicate a broken line and major leakage underground.

7.4 REQUIREMENTS

The constructor's subsurface non-potable water supply system meets the requirements of providing water to the subsurface testing activities since the pump currently selected and used provides water to all parts of the subsurface. (Section 4.2.1)

8. CONCLUSIONS

The existing portal Pump #3 can continue to be used in the subsurface non-potable water system based on the flow and pressure requirements for the system described in this analysis. The two in-line pumps that are presently installed in the system can continue to be used and will have to be installed with flow switches to start the pumps when flow occurs in the line. Flow switches will be required at in-line Pump # 4, and Pump #5 to start the pump at approximately 10-20 gpm flow and stop at approximately 8 gpm flow. For low flow and higher pressure conditions a manual override to the pumps may be required to provide adequate water pressure below 8 gpm flow. The pump should be plumbed with a small recirculation line from the outlet side of the pump to provide flow to improve seal cooling. A small flow of approximately 5 gpm will circulate water through the pump seal and remove heat from the seal.

The minimum 30 psi nozzle pressure can be achieved at each of the fire hose stations in the TS Loop. The Alcove #1 station will require a reduced hose length of 100 ft to achieve this pressure at the nozzle while the other hose stations will have hose lengths of 150 ft. Pressure regulators will be required to reduce pressure at hose stations where nozzle pressure exceeds 100 psi.

An automatic shut off valve will be installed at the portal that will be electrically actuated by a flow switch that closes the valve at any flow in excess of 250 gpm.

A timer should be installed on Pump #3 to start the pump during operational hours and shut the pump off when operation is not required.

9. ATTACHMENTS

Not Used