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INDUSTRIES LTD

Suite 2002 - 6250 Applied Science Lane
Vancouver, BC, Canada
www.nearcreek.ca

Memo

To: CIVL315 Students
From: Max Flowe, P.Eng
Subject: Pump Station Design
Project: 315-Lab-1

The completed contract has been received – thank you.

Attached are the testing procedures, the project specifications, the water use demands and delivery requirement for the town of Seeville, BC. The deliverables section from the contract is also included for reference.

The municipality is very concerned about its energy and is actively trying to reduce its GHG footprint so please pay special attention to any mechanisms to reduce energy use.

Note: NEARCreek is not a real company. It was created for the purpose of CIVL315/316 laboratories.

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Background Information

NEARCreek Industries Ltd. (NCI) has been contracted to construct a new pump station and supply pipeline for the community of Seeville, British Columbia. However, technical design for the pump station and supply pipeline has been sub-contracted out to you.

The sub-contracted engineering firm is expected to place a strong focus on limiting project energy consumption to reduce the projects environmental footprint and to limit capital costs to suit Seeville's small operating budget. As such NCI is proposing to purchase both pumps and motors from Volute Industries Ltd (Volute).

Volute is a new manufacturer of pumps and pump motors that are offered at significantly reduced costs. However, as they are new to pump manufacturing, confidence in their product is minimal and a scaled physical hydraulic model needs to be undertaken to validate the performance of one of Volute's pumps, and a numerical model needs to be used to validate the entire design.

NCI is aware of the costs of designing and constructing a scaled physical hydraulic model of Volute's product and running a numerical simulation, but it is expected that Seeville will save hundreds of thousands of dollars in capital and operating costs by doing so.

Deliverables

The *consultant* shall provide to *NCI* a report that contains the following content and analysis:

1. design of the pump configuration for the pump station;
2. specification of pumps, motors and drives for the Seeville, BC pump station;
3. specification of pipe sizing for the *Primary Supply Line;*
4. an energy use prediction for potable water pumping; and
5. an economic analysis supporting items 1 and 2 above.

The specifications shall be of a design that conforms to the requirements of the *Seeville* Potable Water Delivery Standards and the Project Specifications related to this contract.

The report produced for *NCI* by the *consultant* shall be:

1. consistent with the standards of Professional Engineering;
2. be submitted to *NCI* electronically using the Canvas system by end of day November 25th; and
3. contain comparison of theoretical, experimental, and simulated performance characteristics where applicable.

Engineering design and analysis of the proposed pump station shall assume the following:

- All work is to be based on experimentally validated analysis.
- The bulk electricity rate paid by town is $0.09290 /kWh.
- All NCI installations are standardized on a centrifugal pump that has scalable performance to an MP Pump Chemflo 4.

- The pump station is to be located at the Seeville Reservoir, which is 3.2km from the inlet to the municipal distribution system (Figure 1).
- The scope of work relates only to the pumping system. Water treatment need-not be considered.

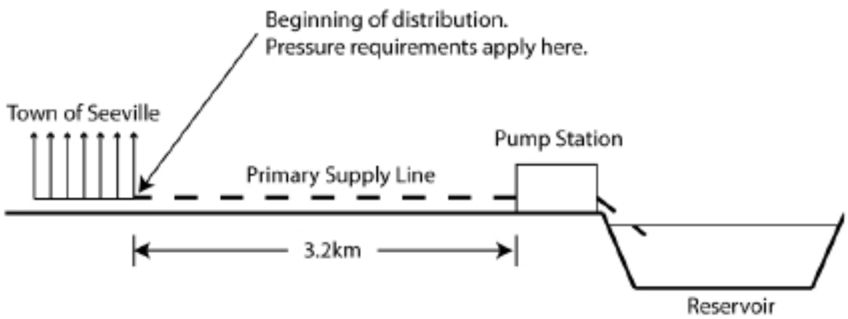

Figure 1: Arrangement of Water Supply

Physical Model Procedure

Note: This is the most challenging 315 lab and the procedures can take a long time if students are not prepared. It is strongly recommended that you familiarize yourselves with the procedures on the website before coming to your lab session. In particular, you should create a blank data table in Excel for the data you will be collecting. The data table should include a column for each measurement type (current, pressure, flow rate etc,…) and a row for each flow configuration (which distribution valves are open, pump configuration, PRV, etc…). This will help you to organize and streamline your measurements.

Referring Figures 2 and 3 the apparatus consists of:

- Gray control panel
- Two ultrasound flow meters
- Reservoir
- Three pressure ports with digital and mechanical displays
- Pipe and Distribution Valve assembly
- Variable Frequency Drives (VFD)

  A variable frequency drive (VFD) is a device that receives a constant frequency AC supply and outputs an AC current at a specified frequency. By supplying an AC motor from the output of a VFD, the motors speed may be precisely controlled.

- Pressure Reducing Valves (PRV)

  Pressure reducing valves control downstream pressure through a mechanical actuated constriction. As the flow passes through this constriction, there is a frictional dissipation of energy that results in a pressure drop.

- Pump with variable frequency drive: Henceforth referred to as “Pump 1” or “P1”
- Pump with fixed speed drive: Henceforth referred to as “Pump 2” or “P2”

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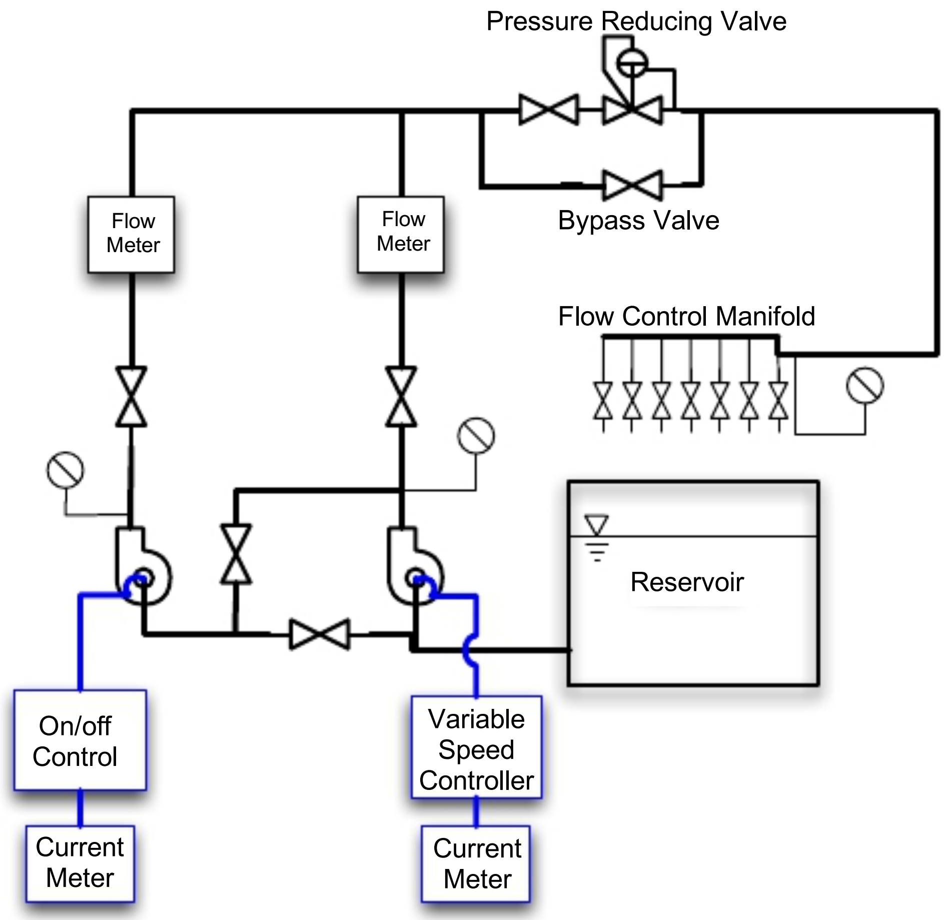

Figure 2: Experimental Configuration

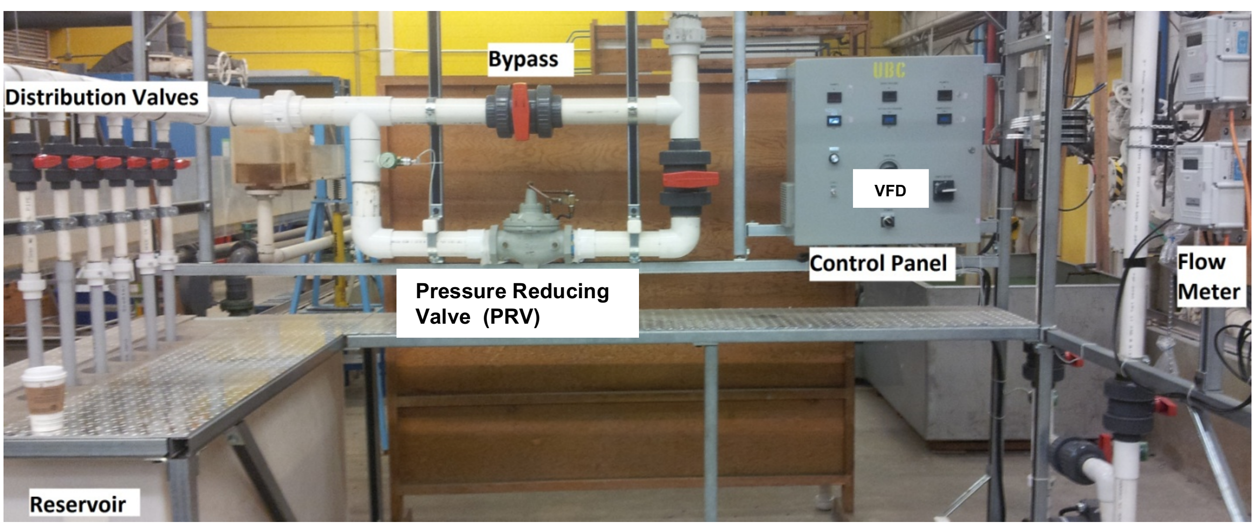

Figure 3: Distribution System Assembly

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Safety Considerations

- Closed-toed shoes are required in the Hydrotechnical Lab
- Safety glasses are required in the Hydrotechnical Lab
- Incorrect use of the apparatus may cause water hammer which has the potential to burst the pipes – this has recently occurred.

Pump 1 Current Measurement

Due to the switching power supply in the VFD, the built-in current meter gives erroneous results. The table below provides the conversion between displayed current and actual current draw.

Pump 1 Current Meter Reading (A)	Actual VFD Current Draw (A)
0.12	0
0.34	0.42
0.80	1.22
1.73	2.47
2.26	3.13
2.92	3.92
3.30	4.30
3.68	4.67
4.07	5.02
4.61	5.56
5.57	6.56
6.74	7.73
7.99	8.95
8.33	9.31

Water Demand for Seeville, British Columbia

Typical water use for the Town of Seeville is shown in Figure 6.

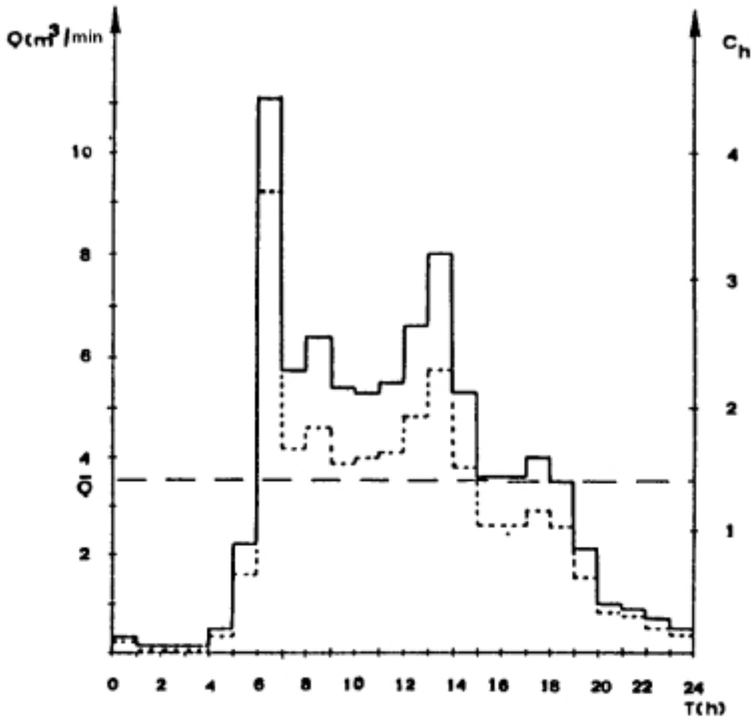

Figure 6: Daily water use demand. Source: Peak Coefficients of Household Potable Water Supply

Potable Water Supply Standards for Seeville, British Columbia

Quality

Potable water shall be delivered within the requirements of the British Columbia Drinking Water Protection Act and Regulation except with relation to the following:

Pressure

Water entering the distribution system shall be no higher than 65 pounds per square inch (psi) and not lower than 40psi. At no point in the potable water system shall the pressure be below that of atmospheric.

Availability

Consumers must be able to expect 99.99% availability of potable water in the distribution system.

Background Material

Volutes Theoretical Pump Curve

A centrifugal pump produces head that is a function of the flow rate and rotational speed. This relationship is provided by the Volute and is known as a *pump curve.* See Figure 7.

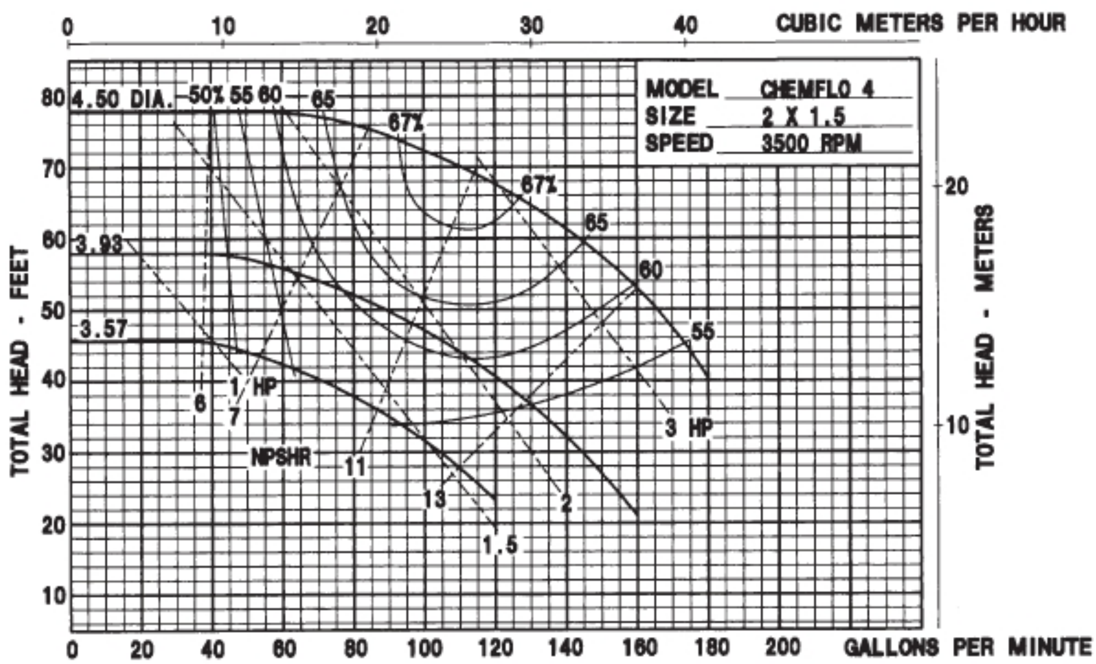

Figure 7: Pump curve for Chemflow 4 Pump

Power

The rate of work (P_{fluid}) that a pump imparts on a fluid is given by

$$P_{fluid} = \rho g H_p Q$$

where ρ is fluid density, g is gravitational acceleration, H_p is pump head and Q is the volumetric flow rate through the pump. The pump is driven by an input of mechanical power from a rotating shaft (P_{shaft}), the power of which is given by

$$P_{shaft} = \omega T$$

where ω is the angular velocity of the shaft and T is the torque applied to the shaft. This power is produced in many cases by an electric motor. The power input to the electrical motor ($P_{electric}$) is given by

$$P_{electric} = VI$$

where V is the input voltage and I is the input current. The efficiency (η) of the pump system is a relationship between the input of electrical power and the output of fluid power, as given by

$$\eta = \frac{P_{fluid}}{P_{electric}}$$

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Scaling

Pumps of similar geometry and performance can be scaled using the following coefficients:

$$K_Q = \frac{Q}{nD^3} \qquad K_h = \frac{H_p}{n^2 D^2} \qquad K_p = \frac{P}{n^3 D^5}$$

where P is pump fluid power, H_p is pump head, n is pump rotational speed, D is pump impeller diameter and Q is volumetric flow rate.

Alternating Current (AC) Motors

An electrical motor converts electrical power into mechanical shaft power using magnetic inductance. While both alternating current (AC) and direct current (DC) motors exist, virtually all industrial applications utilize AC motors including those used in this laboratory. The rotational speed of an AC motor is a function only of the frequency of the electrical supply and the number of windings; thus it is independent of the load placed upon the motor shaft. Increasing the load has the effect of increasing the amount of current the motor draws.

Variable Frequency Drives

A variable frequency drive (VFD) is a device that receives a constant frequency AC supply and outputs an AC current with a variable and controlled frequency. By supplying an AC motor from the output of a VFD, the motors speed may be precisely controlled. Like any power electronics component, a VFD is not 100% efficient and will consume more power than it supplies.

Pressure Reducing Valves

Pressure reducing valves (PRV) control downstream pressure through a mechanically actuated constriction. As the flow passes through this constriction, there is a frictional dissipation of energy that results in a pressure drop.

Numerical Modeling Procedure

Using the United States Environmental Protection Agency's numerical model EPANET, confirm that (1) your final design limits the pressure entering the distribution network to 40-65psi, and (2) what is the computed energy demand for your final design.

EPANET is free and can be downloaded from the web:

http://www.epa.gov/nrmrl/wswrd/dw/epanet.html

Instructions on how to use EPANET can be found on the same website.

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Component Pricing

AC Motors

Part	Description	Price
MTC-003-3BD36	AC MOTOR 3HP 3600RPM 208-230/460VAC 3PH 182T	$195.00
MTC-003-3BD18	AC MOTOR 3HP 1800RPM 208-230/460VAC 3PH 182T	$191.00
MTC-003-3BD12	AC MOTOR 3HP 1200RPM 208-230/460VAC 3PH 213T	$300.00
MTC-005-3BD36	AC MOTOR 5HP 3600RPM 208-230/460VAC 3PH 184T	$250.00
MTC-005-3BD18	AC MOTOR 5HP 1800RPM 208-230/460VAC 3PH 184T	$216.00
MTC-005-3BD12	AC MOTOR 5HP 1200RPM 208-230/460VAC 3PH 215T	$380.00
MTC-7P5-3BD36	AC MOTOR 7.5HP 3600RPM 208-230/460VAC 3PH 213T	$335.00
MTC-7P5-3BD18	AC MOTOR 7.5HP 1800RPM 208-230/460VAC 3PH 213T	$312.00
MTC-7P5-3BD12	AC MOTOR 7.5HP 1200RPM 208-230/460VAC 3PH 254T	$470.00
MTC-010-3BD36	AC MOTOR 10HP 3600RPM 208-230/460VAC 3PH 215T	$385.00
MTC-010-3BD18	AC MOTOR 10HP 1800RPM 208-230/460VAC 3PH 215T	$337.00
MTC-010-3BD12	AC MOTOR 10HP 1200RPM 208-230/460VAC 3PH 256T	$635.00
MTC-015-3BD18	AC MOTOR 15HP 1800RPM 208-230/460VAC 3PH 254T	$476.00
MTC-020-3BD18	AC MOTOR 20HP 1800RPM 208-230/460VAC 3PH 256T	$514.00
MTC-025-3BD18	AC MOTOR 25HP 1800RPM 208-230/460VAC 3PH 284T	$722.00
MTC-030-3BD18	AC MOTOR 30HP 1800RPM 208-230/460VAC 3PH 286T	$765.00
MTC-040-3BD18	AC MOTOR 40HP 1800RPM 208-230/460VAC 3PH 324T	$981.00
MTC-050-3BD18	AC MOTOR 50HP 1800RPM 208-230/460VAC 3PH 326T	$1,199.00
MTC-060-3BD18	AC MOTOR 60HP 1800RPM 208-230/460VAC 3PH 364T	$1,498.00
MTC-075-3BD18	AC MOTOR 75HP 1800RPM 208-230/460VAC 3PH 365T	$1,730.00
MTC-100-3BD18	AC MOTOR 100HP 1800RPM 208-230/460VAC 3PH 405T	$1,975.00
MTC-125-3BD18	AC MOTOR 125HP 1800RPM 208-230/460VAC 3PH 444T	$2,880.00
MTC-150-3BD18	AC MOTOR 150HP 1800RPM 208-230/460VAC 3PH 445T	$3,125.00
MTC-200-3BD18	AC MOTOR 200HP 1800RPM 208-230/460VAC 3PH 445/7T	$4,150.00
MTC-250-3D18	AC MOTOR 250HP 1800RPM 460VAC 3PH 449T	$5,140.00
MTC-300-3D18	AC MOTOR 300HP 1800RPM 460VAC 3PH 449T	$6,750.00

HDPE Piping

Pipe Diameter (in)	Pipe Cost ($/ft)
4	$1.32
6	$2.74
8	$4.60
12	$8.54
15	$16.32
18	$19.62
24	$33.58
30	$53.50
36	$62.32
42	$91.02
48	$115.80

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Variable Frequency Drives

Part	Description	Price
GS3-2015	GS3 15HP AC DRIVE 230VAC 3 PHASE	$864.75
GS3-2020	GS3 20HP AC DRIVE 230VAC 3 PHASE	$1,073.75
GS3-2025	GS3 25HP AC DRIVE 230VAC 3 PHASE	$1,262.75
GS3-2030	GS3 30HP AC DRIVE 230VAC 3 PHASE	$1,445.25
GS3-2040	GS3 40HP AC DRIVE 230VAC 3 PHASE	$2,117.25
GS3-2050	GS3 50HP AC DRIVE 230VAC 3 PHASE	$2,565.00
GS3-41P0	GS3 1HP AC DRIVE 460VAC 3 PHASE	$319.75
GS3-42P0	GS3 2HP AC DRIVE 460VAC 3 PHASE	$350.25
GS3-43P0	GS3 3HP AC DRIVE 460VAC 3 PHASE	$374.50
GS3-45P0	GS3 5HP AC DRIVE 460VAC 3 PHASE	$415.25
GS3-47P5	GS3 7.5HP AC DRIVE 460VAC 3 PHASE	$595.75
GS3-4010	GS3 10HP AC DRIVE 460VAC 3 PHASE	$713.50
GS3-4015	GS3 15HP AC DRIVE 460VAC 3 PHASE	$930.75
GS3-4020	GS3 20HP AC DRIVE 460VAC 3 PHASE	$1,133.75
GS3-4025	GS3 25HP AC DRIVE 460VAC 3 PHASE	$1,345.00
GS3-4030	GS3 30HP AC DRIVE 460VAC 3 PHASE	$1,527.50
GS3-4040	GS3 40HP AC DRIVE 460VAC 3 PHASE	$1,945.75
GS3-4050	GS3 50HP AC DRIVE 460VAC 3 PHASE	$2,370.00
GS3-4060	GS3 60HP AC DRIVE 460VAC 3 PHASE	$2,712.00
GS3-4075	GS3 75HP AC DRIVE 460VAC 3 PHASE	$3,044.00
GS3-4100	GS3 100HP AC DRIVE 460VAC 3 PHASE	$3,402.25

Pumps

Part	Description	Price	Diameter (in)
15684-9	ChemFlo 4-4	$970.00	4.5
15684-10	ChemFlo 4-5	$1,090.00	5
15684-11	ChemFlo 4-5-2	$1,185.00	5.5
15684-17	ChemFlo 4-8	$1,850.00	8.5
15684-18	ChemFlo 4-9	$2,000.00	9.25
15684-20	ChemFlo 4-10	$2,150.00	10
15684-20	ChemFlo 4-10	$2,200.00	10.25
15684-22	ChemFlo 4-11	$2,400.00	11
15684-24	ChemFlo 4-12	$2,600.00	12
15684-26	ChemFlo 4-13	$3,000.00	13.25
15684-28	ChemFlo 4-14	$3,250.00	14
15684-31	ChemFlo 4-15	$3,600.00	15.5
15684-33	ChemFlo 4-16	$3,950.00	16.75