6 APPENDICIES

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6.2 STUDY ENDORSEMENT LETTERS

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA

April 1, 2019

RE: Request for Fixed-Roof Storage Tank Details at Selected Upstream Oil and Gas Locations

Dear Esteemed Colleague:

I am writing this letter on behalf of Clearstone Engineering Ltd, the Alberta Energy Regulator (AER), and Canadian Association of Petroleum Producers (CAPP) to inform you of an important research project on fixed-roof storage tank emissions, and to notify you that your organization has an important role in the research. This project is funded through the Alberta Upstream Petroleum Research Fund (AUPRF) which is funded by Explorers and Producers Association of Canada (EPAC) and CAPP. The PTAC Air Research Planning Committee (ARPC) has engaged Clearstone to investigate fugitive and venting emissions from fixed-roof storage tanks. The project objectives are: (1) determine the root-causes; (2) recommend basic survey checks that identify and mitigate tank venting and fugitives that exceed 42 m^3/day ; (3) develop cost-benefit curves for common mitigation actions; and (4) improve process condition assumptions used in emission inventories and regulatory impact assessments. A secondary objective is to support companies interested in accessing financial incentives from Energy Efficiency Alberta (EEA) for reducing methane emissions. (https://www.efficiencyalberta.ca/customsolutions/)

This project is motivated by regulations to control the release of methane in the oil and gas sector introduced by Environment and Climate Change Canada (ECCC) and the Alberta Energy Regulator (AER). Both regulators target a reduction in methane emissions by 45% by 2025 and require operators to limit storage tank losses and implement Leak Detection and Repair (LDAR) programs. AER Directive 060 limits site-wide venting to 100 m^3/day (new facilities) and 500 m^3/day (existing facilities) while ECCC limits site-wide venting to 42 m^3/day for all facilities. Regardless, the effectiveness of these requirements will depend on reliable and timely determination of root-causes, emission magnitude, and cost of mitigating actions.

You are receiving this request because the sites/tanks listed in the covering email are operated by your company and were recently surveyed by Greenpath Energy Ltd as part of an EEA Baseline Opportunity Assessment. To further petroleum industry research objectives, please confirm your voluntary participation in this study by providing the following details for subject storage tanks (plus any other tank you choose to volunteer).

Please submit the following details directly to yori.jamin@clearstone.ca by April 22, 2019.

- The tank list and emission details attached to this email.
- Site process flow diagram (PFD)
- Storage tank piping and instrumentation diagram (P&ID). If P&IDs are not available, provide the maximum **and** minimum allowable working pressure for the subject tank (a photo of the tank nameplate is ideal).
- If the site has an oil treater, the pump rate (m^3/hr) for recycling slop oil.
- Laboratory analysis of the oil/condensate and gas streams downstream of subject tanks.
- An explanation or copy of the spreadsheet currently used to estimate storage tank emissions.

This project is endorsed and supported by the PTAC ARPC which is comprised of industry and regulatory stakeholders. Please be assured that the proprietary interests of producers will be protected as delineated in the enclosed Clearstone confidentiality undertaking.

I wish to thank you for your cooperation and participation in this important initiative. Alberta upstream oil and gas operators have a unique opportunity to collaborate and benefit from this AUPRF funded project. Should you require further information, please contact yori.jamin@clearstone.ca (403-215-2733).

Kind Regards,

Soheil Asgarpour, Ph.D., FCAE, FCIM, P.Eng.
President, Petroleum Technology Alliance Canada

Enclosures: Clearstone Confidentiality Undertaking.pdf

cc:
Gerald Palanca, Manager, Air Technical Advisory Team, Alberta Energy Regulator (AER).
Wayne Hillier, Alberta Manager, Canadian Association of Petroleum Producers
Tristan Goodman, President, Explorers and Producers Association of Canada

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I am writing this letter on behalf of Clearstone Engineering Ltd, and Canadian Association of Petroleum Producers (CAPP) to inform you of an important research project on fixed-roof storage tank emissions, and to notify you that your organization has an important role in the research. This project is funded through the Alberta Upstream Petroleum Research Fund (AUPRF) which is funded by Explorers and Producers Association of Canada (EPAC) and CAPP. The PTAC Air Research Planning Committee (ARPC) has engaged Clearstone to investigate fugitive and venting emissions from fixed-roof storage tanks. The project objectives are: (1) determine the root-causes; (2) recommend basic checks that identify and mitigate tank venting and fugitives that exceed 42 m^3/day; (3) develop cost-benefit curves for common mitigation actions; and (4) improve process condition assumptions used in emission inventories and regulatory impact assessments.

This project is motivated by regulations to control the release of methane in the oil and gas sector introduced by Environment and Climate Change Canada (ECCC) and the BC Oil and Gas Commission. Both regulators target a reduction in methane emissions by 45% by 2025 and require operators to limit storage tank losses and implement Leak Detection and Repair (LDAR) programs. The BC regulation limits site-wide storage tank losses to 42 m^3/day (new facilities) and 300 m^3/day (existing facilities) while ECCC limits site-wide venting to 42 m^3/day for all facilities. The effectiveness of these requirements will depend on reliable and timely determination of root-causes, emission magnitude, and cost of mitigating actions.

You are receiving this request because the sites/tanks listed in the covering email are operated by your company and were surveyed during September 2018 by Greenpath Energy Ltd as part of the BC Field Emissions Study, conducted for the BC Climate Action Secretariat and the Oil and Gas Commission. To further petroleum industry research objectives, please confirm your voluntary participation in this study by providing the following details for subject storage tanks (plus any other tank you choose to volunteer).

Please submit the following details directly to yori.jamin@clearstone.ca by April 22, 2019.

- The tank list and emission details attached to this email.
- Site process flow diagram (PFD)
- Storage tank piping and instrumentation diagram (P&ID). If P&IDs are not available, provide the maximum **and** minimum allowable working pressure for the subject tank (a photo of the tank nameplate is ideal).
- Operating pressure and temperature of the vessel immediately upstream of the subject tank.
- Oil and gas disposition volume for each month in 2018.
- If the site has a treater, the pump rate (m^3/hr) for recycling slop oil.
- Laboratory analysis of the oil/condensate and gas streams downstream of subject tanks.
- An explanation or copy of the spreadsheet currently used to estimate storage tank emissions.

This project is endorsed and supported by the PTAC ARPC which is comprised of industry, government and regulatory stakeholders. Please be assured that the proprietary interests of producers will be protected as delineated in the enclosed Clearstone confidentiality undertaking. Also note that site specific details collected during the September 2018 surveys have not been disclosed to Clearstone.

I wish to thank you for your cooperation and participation in this important initiative. This is a unique opportunity for BC upstream oil and gas operators to collaborate and benefit from an AUPRF funded project. Should you require further information, please contact yori.jamin@clearstone.ca (403-215-2733).

Kind Regards,

Soheil Asgarpour, Ph.D., FCAE, FCIM, P.Eng.
President, Petroleum Technology Alliance Canada

Enclosures: Clearstone Confidentiality Undertaking.pdf

cc:
Don D'Souza, Unit Head, Industrial Mitigation, BC Climate Action Secretariat
Marie Johnson, Specialist, Air Emissions, BC Oil and Gas Commission
Wayne Hillier, Alberta Manager, Canadian Association of Petroleum Producers
Tristan Goodman, President, Explorers and Producers Association of Canada

6.3 METHODOLOGIES FOR QUANTIFYING FLASHING LOSSES

6.3.1 CLEARSTONE VAPOURSIM

The VapourSIM software application is designed to predict evaporative losses from the storage of stabilized or weathered and flashing products. VapourSIM features a number of simulation methods. The method selected for this study requires a pressurized oil sample collected at the desired separator operating conditions and analyzed by a laboratory to determine its composition[12]. A flash calculation is performed using an equation of state to determine the flash-gas factor and vapor speciation profile based on these results. The operating temperature and pressure of the separator are taken from the lab report. Two options are given for defining the flash calculation endpoint: (1) the flash endpoint is the temperature of the product in the storage tank and local barometric pressure, or (2) the flash endpoint is the Reid Vapor Pressure (RVP) of the stock tank sales oil and a temperature of 37.8°C (100°F). Results for both options are presented in Section 3.2 below. Option (1) provides peak instantaneous rates that occur upon delivery of liquids to the tank. Flashing peaks should occur at the same frequency as the separator delivery cycle. Knowing the peak magnitude and frequency is necessary for sizing VRUs. When tank operating conditions are used as the flash endpoint conditions, additional calculations should be performed to predict working and breathing losses in accordance with the applicable API evaporation loss correlations.

Option (2) provides the total amount of gas liberated from the product over a long period of time regardless of whether the weathering was due to flashing, working or breathing losses. Option (2) is equivalent to performing a mass balance between the flow and composition of pressurized liquid being dispensed to the stock tank and the flow and composition of the weathered sales product leaving the stock tank. The RVP of the sales oil will vary by month with the values in the winter being greater than those in the summer.

Regardless of the flash endpoint selected, pressurized sample analysis results should be checked to confirm sample integrity. This check demonstrates pressurized liquid hydrocarbon samples are collected correctly in the field and not compromised prior to testing. Colorado APCD specifies sampling pressure must be within Table 16 percent difference of the calculated bubble point pressure at field sample temperature (APCD, 2017). VapourSIM calculates bubble point pressure using the Peng-Robinson equation of state and analyte fractions.

[12] The pressurized liquid analysis should include at least C_1 through C_9 and C_{10+}, HAPs, He, H_2, N_2, and CO_2. H_2S concentrations and total sulphur content should be determined separately for each phase or sample. If O_2 is present in the analysis results, then this indicates some air ingress during the sampling and analysis activities, and the results should then be expressed on an air-free basis.

Table 16: Acceptable percent difference between bubble point and sampling pressure (at sample temperature) specified in Colorado AP Memo 17-01 (APCD, 2017).	
Maximum Percent Difference	**Field Sample Pressure Range (kPag)**
± 5%	>= 3,447
± 7%	1,724 to 3,446
± 10%	689 to 1,723
± 15%	345 to 688
± 20%	138 to 344
± 30%	< 138

6.3.1 AER 'RULE-OF-THUMB' CORRELATION

A "rule of thumb" estimate may be used as the flash gas factor for conventional light-medium oil production until a more accurate, specific flash gas factor is determined (AER, 2018b). It may be used on a continuous basis, without the need for determining a more accurate flash gas factor, if well oil production rates do not exceed 2 m^3/d or if all battery gas production is vented or flared. Directive 017 does not permit "rule of thumb" estimates for condensate or heavy oil. The rule of thumb is presented in Equation 1.

$$V_s = 0.0257 \times V_O \times \Delta P$$

Equation 1

Where,

V_S = volume of solution gas released (m^3)

V_O = oil production volume (m^3)

ΔP = pressure drop between upstream vessel and storage tank (kPa)

0.0257 = 'rule-of-thumb' factor (m^3 of gas/m^3 of oil/kPa of pressure drop at unspecified reference conditions)

6.3.1 VAZQUEZ AND BEGGS CORRELATION

This correlation is based on a regression of experimentally determined bubble point pressures for a variety of crude oil systems. The range of parameters for which the correlation is derived is presented in Table 18 (Vazquez and Beggs, 1980).

$$GOR = C_1 \gamma_{gs} P_{SP}^{C_2} \exp\left(\frac{C_3}{\gamma_o T_{SP}} - \frac{C_4}{T_{SP}}\right)$$

Equation 2

Where,

GOR = gas-to-oil ratio (m^3/m^3) at standard conditions 101.325 kPa and 15.6 ^oC

γ_{gs} = γ_g corrected to correlated separator pressure of 100 psig

$$= \gamma_g \left[1 + \left(\frac{8.365}{\gamma_o} - 7.774 \right) \frac{(1.8 \times T - 459.7)}{1000} \log_{10} \left(\frac{P}{790.83} \right) \right]$$

γ_g = Specific gravity of the solution gas with respect to air (dimensionless)

$$= \frac{Molecular\ Weight\ of\ Solution\ Gas}{Molecular\ Weight\ of\ Air}$$

P_{SP} = absolute pressure in the upstream vessel of interest (kPaa)

T_{SP} = temperature in the upstream vessel of interest (K)

γ_o = specific gravity of oil with respect to water (dimensionless)

$$= \frac{141.5}{131.5 + °API}$$

C_1, C_2, C_3, C_4 = correlation parameters presented in Table 17

Table 17: Values of the Vasquez Beggs correlation parameters.

Parameter	**$\gamma_o < 0.876$**	**$\gamma_o > 0.876$**
C_1	3.204×10^{-4}	7.803×10^{-4}
C_2	1.1870	1.0937
C_3	1881.24	2022.19
C_4	1748.29	1879.28

Table 18: Range of reservoir data used to develop Vasquez & Beggs flashing correlation.

Parameter	**Value**
Size of dataset	5008
Bubble pressure, kPa	345 to 36,190
Reservoir temperature, °C	21 to 146
Solution gas-to-oil ratio at bubble point pressure, sm^3/sm^3	3.5 to 369
Oil specific gravity, °API	16 to 58
Vapour specific gravity	0.56 to 1.8

6.3.1 VALKO AND MCCAIN CORRELATION

The Valko and McCain (2003) correlation is perhaps the most widely used correlation for predicting flash-gas factors for pressurized crude oil dispensed to a production storage tank (or stock tank). For example, it was approved for modelling and design of vapour control systems under EPA consent decree orders (SLR, 2018). The range of separator conditions for which the correlation is derived is presented in Table 20. It may also be used with data outside the range of values for which they were derived but with reduced accuracy.

The correlation requires information on the operating conditions (i.e., temperature and pressure) of the first upstream pressure vessel (referred to here as a separator) from which the oil is dispensed and the API gravity of the weathered sales product from the stock tanks. Valko and McCain recognized field sampling and laboratory analysis of stock tank vapours is seldom completed. Thus, a key benefit of their correlation is it relies on parameters typically measured in the field (e.g., stock tank liquid density and upstream pressure/temperature) and does not require a pressurized liquid sample analysis. However, this is at the loss of some accuracy and the ability to predict the composition of the flash gases. Default flash-gas compositions are typically applied in these circumstances (e.g., to estimate CH_4, VOC and selected air toxic emissions such as benzene, toluene, ethyl benzene and xylenes [BTEX]).

GOR for the product entering the stock tank is determined using the following relations:

$$GOR = exp(ln\ GOR)$$

Equation 3

Where,

$$\ln GOR = 3.955 + 0.83z - 0.024z^2 + 0.075z^3$$

Equation 4

Where,

$$z = \sum_{n=1}^{3} z_n$$

Equation 5

Where,

$$z_n = C_{0,n} + C_{1,n}VAR_n + C_{2,n}VAR_n^2$$

Equation 6

And,

GOR = gas-to-oil ratio (scf of flash gas/bbl of stock tank oil) at standard conditions 101.325 kPa and 15.6 ºC

z, z_n = calculation parameters (dimensionless)

C, VAR = correlation parameters (see Table 19).

Table 19: List of values for parameters C and VAR for Equation 47.

n	VAR	C0	C1	C2
1	$\ln P_{SP}$	-8.005	2.7	-0.161
2	$\ln T_{SP}$	1.224	-0.5	0
3	API	-1.587	0.0441	-2.29×10^{-5}

P_{SP} = separator pressure (psia).
T_{SP} = separator temperature (°F).
API = API gravity of the stock tank oil (°API).

Table 20: Range of separator/stock tank data used to develop Valko & McCain flashing correlation.

Parameter	**Value**
Size of dataset	881
Separator pressure, kPag	82.7 to 6550.0
Separator temperature, °C	1.7 to 90.0
Stock Tank Oil specific gravity, °API	6.0 to 56.8
Stock tank gas-to-oil ratio, sm^3/sm^3	0.36 to 93.9
Stock tank vapour specific gravity	0.581 to 1.598

6.4 SAMPLING PROTOCOL FOR MEASURING FLASHING LOSSES FROM STORAGE TANKS

6.4.1 OBJECTIVE:

The overall objective of the sampling work is to quantify flashing, working and breathing losses from storage tanks.

6.4.2 SAMPLING METHODOLOGY:

The basic methodology will include collecting (see Figure 35: Typical sampling points on separator and storage tank):

1. a high pressure (H.P.) separator bottoms (crude oil) sample (Sampling Point 1A or B if the separator is being manually discharged into the storage tank, or C),
2. a separator outlet gas sample (Sampling Point 2A or B),
3. a low pressure (L.P.) storage tank outlet crude oil sample (3A or B) and
4. a storage tank vapour sample from the vent or thief hatch (4A) or before the vapour recovery unit (VRU), if it exists (4B).

The vapour samples will be collected using evacuated 6L SilcoCan™ canisters and liquid samples will be collected using 500c.c. stainless steel sample cylinders. Analyses will be completed by an accredited laboratory. The vapour samples may be subjected to 4 different sets of analyses: GC/FID, GC/SCD, GC/TC and GC/MS. The laboratory will follow established procedures for each of these analyses and will use extensive calibration standards to minimize the potential for any unknown compounds.

If the storage tank is a fixed roof tank, there could potentially exist the injection of blanket gas in the ullage space (the vapour space above the liquid in a storage tank). This blanket gas rate will have to be measured and sampled (if possible), if the input rate and composition is not known by the site. When possible, always try to collect samples where the storage tank does not vent to a VRU. In addition, the vapour flow rate from the storage tank will be measured. This will occur at Sampling Point 4A or B.

6.4.3 MATERIALS REQUIRED:

- 6L SilcoCan sample canisters
- 500cc Stainless steel sample cylinders
- High pressure sampling system (rated up to 3000 psig)
- Low pressure sampling system
- Variety of pipe fittings and connections
- 1L Graduated container
- 1/4" Teflon tubing (50m)
- Gillian pumps and chargers
- Ultrasonic gas flow meter and various accessories
- Flexible ducting and duct tape
- Tape measurer
- Digital thermometer and thermocouples
- Digital pressure gauge
- Barometer
- Datasheets

For each facility sampled, barometric pressure and ambient temperature is to be recorded in the datasheets provided using a barometer and a digital thermometer and thermocouples.

The following sections describe the methodology used to collect liquid and vapour samples, and to measure flow. Field work is completed in compliance with applicable safe work procedures and field level risk assessments (FLRA).

6.4.4 LIQUID COLLECTION METHOD

Crude oil samples will be collected from both the storage tank and the separator located upstream of the tank using 500c.c. stainless steel cylinders and a high pressure sampling system. The three potential methods used for liquid sampling are as follows: **(1) Evacuated Cylinder**, (2) Gas Displacement and (3) Liquid Displacement. Detailed methodology is described below. These sampling procedures are based on the API Production Tank Emissions Model (E&P, 2000). To ensure single phase flow, separator crude oil samples need to be collected upstream of any metering device or flow restriction. This is so there will be minimal pressure reduction to minimize the release of entrained gases in the crude oil (flashing losses).

There is often a temperature reduction on the separator outlet flowlines caused by heat loss via conduction through the pipe wall, but this does not alter the sample integrity. In this case, the separator crude oil can be sampled from Sampling Point 1A, B or C. Conversely, if the crude oil temperature is greater than the operating temperature of the separator, it is advisable to sample directly from the level gauge on the separator (Sampling Point 1C in Figure 35). Care must be taken when sampling from the separator level gauge. The upper and lower values installed on level gauges have restricted flow orifices and check valves. There is a preferred flow of the gas phase through the top valve. One must control the flow of the sample collection to a slow enough rate to maintain the liquid level above the bottom level glass valve while collecting the separator liquid samples. If the liquid level is allowed to decrease to the point of sample collection, excess gas will be drawn into the cylinder with the separator liquid, voiding the validity of the separator crude oil sample. Flexible sampling lines used to connect the sample source to the sample cylinder should be as short as possible to minimize condensation effects due to heat loss via conduction through the sampling line.

Prior to sampling, make sure the pressure of the sample source does not exceed the maximum operating pressure of the sample cylinder (12,400 kPag) to ensure the cylinder will safely contain the liquid sample.

6.4.4.1 EVACUATED CYLINDER METHOD:

1. The cylinders should be evacuated by the laboratory prior to shipment to the field.

2. Select a sample point (i.e. sample valve, level gauge) from which an appropriate representative sample can be collected; separator samples are to be collected upstream of any metering device or flow restriction to ensure single phase flow, and storage tank samples are to be collected downstream of the tank.

3. The cylinder temperature should not be more than 6°C lower than the source temperature. If it is, this technique should not be used. Low cylinder temperatures often cause the cylinder to completely fill with liquid, thus resulting in a potentially hazardous situation when the cylinder is allowed to warm. To avoid the hazardous situation, use either the Gas Displacement or Liquid Displacement technique, which creates a gas cap (a finite volume of gas that allows for volume expansion within the cylinder). These displacement methods are defined below.

4. Remove the hex plug from one end of the cylinder. A hex plug acts as a secondary seal on the valve.

5. Connect the high pressure sampling line to the crude oil source and the sample cylinder, leaving the fitting on the cylinder end of the connector line finger tight. Make sure the valve on the sampling line is open.

6. Open the source valve and slowly purge the sample line to displace air and to vent sufficient liquid to clean the sample point and sampling system. Purge oil into a waste container provided by the site operator.

7. Using a wrench, properly tighten the connecting line fitting to the cylinder fitting.

8. With the sample line purged and full of liquid and the liquid source valve still open, close the valve on the sampling system. Hold the cylinder in a vertical position with the inlet valve at the **bottom** and slowly (but fully) open the **lower** cylinder valve to admit crude oil into the cylinder.

9. When the liquid stops flowing into the cylinder, close the inlet valve before moving the cylinder out of the vertical position. The sample collected in this manner will be in two phases, gas and liquid. The sample cylinder will have some portion of its volume as gas cap, which can safely accommodate any liquid expansion if the cylinder temperature increases during shipment to the laboratory.

10. Close the valve from the sample source and de-pressurize the sampling system by opening the valve on the sampling system and allowing the crude oil to drain into the waste container.

11. Measure the sample cylinder pressure with a digital pressure gauge and record on the sample tag along with the separator pressure. These pressures should be the same.

12. Dismantle the sample cylinder from the sampling line and install the hex plug in the lower sample cylinder valve (used for sample entry).

13. Fill in information on the sample tag provided with the sample cylinder as completely and accurately as possible and attach the tag to the cylinder. Additionally, fill out the liquid and gas sample datasheet with all necessary details (including sample tag information, facility name, unit number, etc.).

Note: Following the methodology above, it is safe to transport a sample cylinder containing a two phase system unless any of the following is allowed to occur:

- Sample container is agitated while filling,
- Containers being filled are much colder than the source, and/or
- Containers are left on the pressure source for an extended length of time. It is not important to have the container completely full of sample. The representative liquid has been admitted to the cylinder and is not altered in composition; it merely has been flashed to a two phase condition for transport to the laboratory. When this sample is received by the laboratory, it is pressured up to considerably above the source pressure by mercury injection prior to removal of any portion of the contents. During the re-pressurization, the saturation pressure is measured to check the validity of the sample contained. If the saturation pressure obtained does not approximate the separator conditions, the analyses are still performed, but a note will be included with the sample analysis stating that the results could potentially be inaccurate due to discrepancies between the saturation pressure and the separator conditions.

Medium gravity, 20 to 27 API (~900 - 930 kg/m^3), crude oils are particularly susceptible to foaming and, if sampled directly into an evacuated cylinder, could result in obtaining a cylinder virtually full of gas with a small amount of foamy oil. To overcome this potential foaming problem, a liquid is sampled using either the Liquid or Gas Displacement Method, as described below.

6.4.4.2 GAS DISPLACEMENT METHOD:

1. Select a sample point (i.e. sample valve, level gauge) from which an appropriate representative sample can be collected; separator samples are to be collected upstream of any metering device or flow restriction to ensure single phase flow, and storage tank samples are to be collected downstream of the tank.

2. Fill the evacuated cylinder that will be used for collecting a separator bottoms sample with separator gas (off the top of the separator) as per the procedure outlined in Vapour Collection Method - Evacuated Cylinder Method.

3. Remove the hex plug from both ends of the cylinder.

4. Connect the high pressure sampling line to the liquid source and the gas-filled sample cylinder, leaving the fitting on the cylinder end of the connector line finger tight. Make sure the valve on the sampling line is open.

5. Open the source valve and slowly purge the sample line to displace air and to vent sufficient liquid to clean the sample point and sampling system. Purge oil into a waste container provided by the site operator.

6. Using a wrench, properly tighten the connecting line fitting to the cylinder fitting.

7. With the sample line purged and full of crude oil and the sample source valve still open, close the valve on the sampling system. Hold the cylinder in a vertical position with the inlet valve at the **bottom** and fully open the **lower** cylinder valve.

8. Still holding the cylinder vertical, slowly open the top valve of the cylinder to bleed off gas at a very low rate. The low bleeding rate is necessary so no appreciable pressure drop occurs in the sampling system, thus maintaining the liquid in one phase while it enters the sample cylinder.

9. When crude oil flows from the top valve, close first the top valve and second the bottom valve of the cylinder. Close the valve from the source and depressurize the sampling system by opening the valve on the sampling system and allowing the crude oil to drain into the waste container.

10. Disconnect the sample cylinder from the sampling line.

11. Still holding the cylinder vertical, quickly release a small amount of liquid from the bottom valve in a single motion into the waste container. This will relieve the dangerous situation of having a cylinder completely filled with liquid for transport to the laboratory, without altering the sample. Creating a gas cap in this manner can easily alter the sample composition. To prevent the alteration of the sample composition, the liquid must be taken in one quick motion.

12. Install hex plugs securely in both ends of the sample cylinder.

13. Fill in information on the sample tag provided with the sample cylinder as completely and accurately as possible and attach the tag to the sample cylinder. Additionally, fill out the liquid and gas sample datasheet with all necessary details (including sample tag information, facility name, unit number, etc.).

6.4.4.3 LIQUID DISPLACEMENT METHOD:

1. Use a brine-filled cylinder already filled by the laboratory. If you do not have a brine-filled cylinder on hand, you can fill an evacuated cylinder with a suitable liquid that is more dense than, and immiscible with the source liquid. Such suitable liquids include mercury, glycol/water mixtures and water; however, the latter two should not be used in sour systems.

2. Select a sample point (i.e. sample valve, level gauge) from which an appropriate representative sample can be collected; separator samples are to be collected upstream of any metering device or flow restriction to ensure single phase flow, and storage tank samples are to be collected downstream of the tank.

3. Remove the hex plug from both ends of the cylinder.

4. Connect the high pressure sampling line to the crude oil source and the brine-filled sample cylinder, leaving the fitting on the cylinder end of the connector line finger tight. Make sure the valve on the sampling line is open.

5. Open the source valve and slowly purge the sample line to displace air and to vent sufficient liquid to clean the sample point and sampling system. Purge oil into a waste container provided by the site operator.

6. Using a wrench, properly tighten the connecting line fitting to the cylinder fitting.

7. With the sample line purged and full of liquid and the liquid source valve still open, close the valve on the sampling system. Hold the cylinder in a vertical position with the inlet valve at the **top** and fully open the **upper** cylinder valve.

8. Still holding the cylinder vertical, slowly open the bottom valve of the cylinder to allow a slow stream of displacement liquid to drain into the 1L graduated container.

9. Maintain the slow rate of displacement liquid removal so that no appreciable pressure drop occurs in the sampling system. Do not rush this procedure.

10. When 90 percent of the sample cylinder volume has been collected (approximately 450mL), close first the bottom valve and then the top valve of the sample cylinder.

11. Keeping the top valve of the cylinder closed, slowly drain the remaining 10 percent of the displacement liquid from the bottom of the cylinder. Close the bottom valve of the sample cylinder as soon as the source liquid appears. Creating a gas cap in this manner is easily accomplished, perfectly safe and of very little risk to the integrity of the sample.

12. Close the valve from the sample source and de-pressurize the sampling system by opening the valve on the sampling system and allowing the crude oil to drain into the waste container.

13. Dismantle the sample cylinder from the sampling line. Install hex plugs securely in both ends of the sample cylinder.

14. Fill in information on the sample tag provided with the sample cylinder as completely and accurately as possible and attach the tag to the cylinder. Additionally, fill out the liquid and gas sample datasheet with all necessary details (including sample tag information, facility name, unit number, etc.).

6.4.5 VAPOUR COLLECTION METHOD

Vapour samples will be collected from both the storage tank and the separator located upstream of the tank using the Evacuated Canister Method (using evacuated 6L SilcoCan™ canisters). Separator gas samples are to be collected off the separator gas outlet line or level gauge (Sampling Point 2A or B from Figure 35).

6.4.5.1 EVACUATED CANISTER METHOD:

1. The SilcoCan™ canisters should be evacuated by the laboratory prior to shipment to the field (confirmed by the canister pressure gauge).

2. Select a sample point (i.e. sample valve, tank thief hatch, etc) from which an appropriate representative sample can be collected.

Note: If sampling off a separator (high pressure source), follow steps 3 to 5:

3. Connect a pressure regulator to the high pressure vapour source and regulate to less than the maximum allowable SilcoCan^{TM} canister pressure (i.e., less than 40 kPag).

4. Connect the sampling line (with 'T-valve') to the regulator and the sample canister. The sample line should have two exists: a short line connected to the sample canister (closed) and the other to atmosphere for purging (open).

5. Open the vapour source and slowly purge the sample line for a minute or two to displace air and to vent sufficient process gas to clean the sample point and sampling system. The short line between the canister and T-valve should also be purged by opening/closing the T-valve.

Note: If sampling off a storage tank (low pressure source), follow steps 6 and 7:

6. Connect the low pressure sampling line to the vapour source and the sample canister, leaving the fitting on the canister end of the connector line finger tight. Make sure the valve on the sampling line is open.

7. Open the vapour source and slowly purge the sample line for a minute or two to displace air and to vent sufficient process gas to clean the sample point and sampling system. When sampling vapour off a storage tank, there may not be enough pressure to purge the sampling line (as in the case of sampling through a thief hatch). In such cases, connect a Gillian (or hand) pump to the open end of the sampling line next to the open valve. Turn the Gillian pump on (during flashing/filling events to minimize air contamination). This will draw process gas to purge the sampling system of all contaminants.

8. Using a wrench, properly tighten the connecting line fitting to the canister fitting.

9. With the sample line purged and full of process gas and the vapour source valve still fully open, turn the T-valve so that source vapours are direct to the sample canister. Slowly (but fully) open the canister valve to admit process gas into the container.

10. When the process gas stops flowing into the canister, close the inlet valve on the canister.

11. Close the valve from the sample source and de-pressurize the sampling system by opening the T-valve on the sampling system. Dismantle the sample canister from the sampling line and replace the canister plug fitting.

12. Fill in information on the sample tag provided with the sample canister as completely and accurately as possible and attach the tag to the canister. Additionally, fill out the liquid and gas sample datasheet with all necessary details (including sample tag information, facility name, unit number, etc.).

6.4.6 FLOW MEASUREMENT METHOD:

The flow rate of the vapours coming off the storage tank is measured according to one of the following methods.

6.4.6.1 GE PANAMETRICS ULTRASONIC GAS FLOW METER:

1. Set up and calibrate the ultrasonic flow meter in a non-hazardous location before attaching it to the emission source (includes installing the transducers to the flow cell and programming all necessary parameters into the ultrasonic flow meter)..

2. Confirm zero-flow and speed of sound readings before installing the flow meter on the emission source.

3. Isolate the flow coming off the storage tank so it is only exiting the tank via one location (i.e. close and ensure the thief hatch is properly sealed, plug all other leak points).

4. If oil is produced into more than one tank at a battery, request the operator to flow oil production into a single tank for the duration of the testing period (to ensure complete capture of venting emissions).

5. Position the handheld data logger and flow cell upwind of the vent and direct flow cell exhaust to the downwind side of the tank (away from the transmitter/receiver).

6. Connect the flow cell with flexible ducting and duct tape to the source vent so that it captures all the vapours exiting the isolated vent (it is sometimes helpful to have a selection of different sized hoses and reducers given that the tank vent diameter can range from 2 to 12 inches).

7. Begin recording the flow rate measured by the ultrasonic flow meter.

8. Survey the tank for other leaks with a Flir IR camera (or Bascom-turner). If a leak is identified, take remedial action to stop the leakage (e.g., re-seat the thief hatch, close valves, etc). If the leak cannot be stopped, measure it with the HiFlow Sampler and add to the measured vent flow.

6.4.6.2 HONTZSCH FLOW METER:

1. Isolate the flow coming off the storage tank so it is only exiting the tank via one location (i.e. close and ensure the thief hatch is properly sealed, plug all other leak points).

2. If oil is produced into more than one tank at a battery, request the operator to flow oil production into a single tank for the duration of the testing period (to ensure complete capture of venting emissions).

3. Position the flow meter across the isolated vent.

4. Record the velocity measured by the Hontzsch flow meter.

5. Measure the diameter of the vent opening to calculate the vent area.

6. Multiply the measured velocity by the vent area to get the flow rate of the vapours exiting the tank.

7. Survey the tank for other leaks with a Flir IR camera (or Bascom-turner). If a leak is identified, take remedial action to stop the leakage (e.g., re-seat the thief hatch, close valves, etc). If the leak cannot be stopped, measure it with the HiFlow Sampler and add to the measured vent flow.

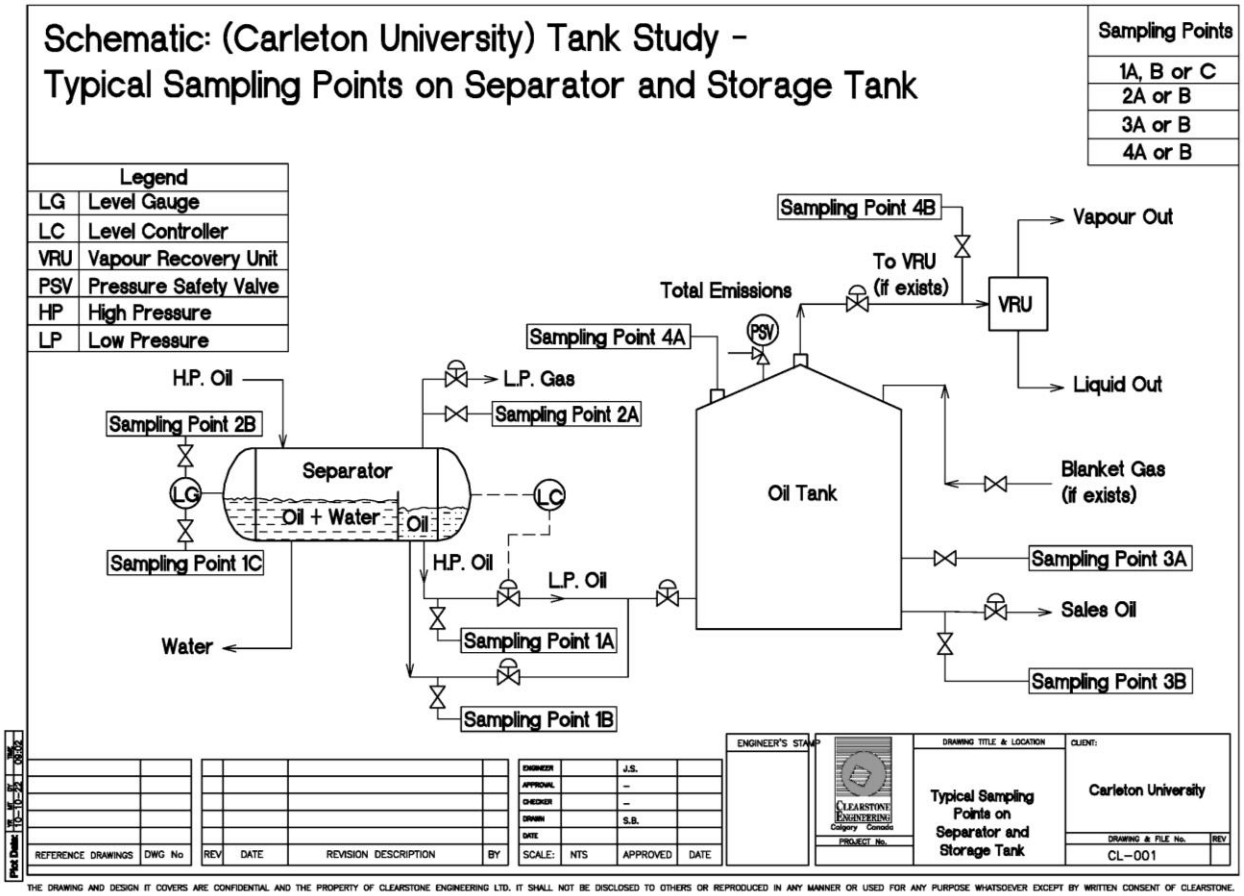


Figure 35: Typical sampling points on separator and storage tank.

6.4.7 GOR CALCULATION

The simulator is first used to perform bubble and dew point calculations on the sample compositions by comparing the calculated saturation pressures and temperatures to those measured on site. In this manner, problems with the pressurized liquid samples, collected from the separator, can be identified and only valid samples used in the GOR determination.

The GOR ratio (sm^3 gas/sm^3 oil) is determined using the relationship,

$$GOR = \frac{V_g}{V_o} \qquad \textbf{Equation 1}$$

where V_g is the total volume of tank vapours (air-free) flashed during the measurement period (m^3 gas) and is calculated using the equation,

$$V_g = \int Q(t) \times \frac{100 - Air\%}{100} \qquad \textbf{Equation 2}$$

where Q(t) is the volumetric flow rate of tank vapours (m^3gas/hr) as a function of time during the measurement period, discounted to account for the physical displacement of liquid entering the tank and adjusted to standard

conditions (101.325 kPa, 15ºC). A numerical integration technique is used in Equation A2. V_o is the total volume of weathered oil produced during the measurement period (m^3 oil) and is calculated using Equation A3,

$$V_O = LR \times V_{SL}$$ **Equation 3**

where LR is the liquid volume reduction (fraction) from separator to tank (shrinkage) due to flashing and V_{SL} is the total volume of un-weathered separator oil produced during the measurement period (m^3 oil). V_{SL} is determined using the Equation A4,

$$V_{SL} = \sum \int L_i(t)$$ **Equation 4**

where $L_i(t)$ is the volumetric flow rate of oil from the separator for each dump cycle (m^3 oil/hr) as a function of time. LR is calculated in Equation A5,

$$LR = \frac{V_W}{V_{UW}}$$ **Equation 5**

where weathered (V_w) and un-weathered (V_{uw}) oil volumes leaving the separator are predicted using a proprietary in-house process simulator.

6.5 ECONOMIC CONSIDERATIONS

The key economic metrics and assumptions used to determine NPV and abatement costs for emission mitigation options are described in the following sections.

6.5.1 NET PRESENT VALUE

The NPV of a project is the algebraic sum of the present value of projected incremental benefits, less the present value of projected incremental costs over the project's useful life. More specifically, it refers to the sum of the present value of an investment's future net cash flow (NCF). NCF is the difference between cash inflow (i.e., benefits) and outflow (i.e., capital and operating costs) of a project. The NPV is calculated by multiplying the projected incremental benefits (i.e., where relevant: revenue from sales, avoided fuel purchases and the salvage value of project infrastructure) and incremental costs (i.e., investment expenditures and recurring operating costs) incurred each year, by the appropriate discount factor, and summing all the resulting discounted values over the useful life of the project.[13] Project NPVs are calculated on a *before-tax* basis and exclude contingency and overhead costs. The NPVs are an indicator of the profitability of given emission mitigation scenario. The formula to calculate NPV is given by:

$$NPV = \sum_{n=1}^{n} \left(\frac{\text{NCF}}{(1+i)^n} \right)$$

Equation 7

Where:

n = operating life of a project or technology
NCF = Net cash flow (net benefits minus net costs) per year, for future years
i = nominal (discount) rate of return on investment

Benefits in the NCF expression are cost savings due to reduced fuel usage and potential savings in carbon levies. Costs are both operating and capital expenses. All numbers are expressed in terms of future years and then discounted back to today's dollars using the $(1+i)^n$ term. If the calculated NPV is greater than zero, this means that an investor can expect to recover the invested capital and earn a nominal rate of return on their investment equal to the discount rate. Hence, a positive NPV reflects that the investment will make money. A negative NPV represents something that is projected to lose money from the initial investment. The *before-tax* addition to net worth is equal to the positive amount of the NPV.

[13] The discount factor constitutes the weight applied to dollars received in future years. It is used to convert future dollar flows into present day equivalents. The discount factor = $(1 + r)^{-t}$, where *r* is the nominal annual discount rate and *t* is the year in which a cost or benefit is incurred.

The NCF for future years, divided by the discount factor, has time value attached to it and is referred to as the time value of money. This means that today's dollars are worth more than future dollars. Undiscounted cash flows correspond to actual dollar amounts which have no bearing on time. The effect of time is captured in discounted cash flow analysis, taking into account adjusted dollar amounts with passage of time. In other words, the discounted cash flows could be viewed as the current value of future cash streams which allows comparison of different investments to investigate profitability of emission mitigation options. NPV is generally reported using discounted cash flows, as shown in Equation 7, but can also be reported undiscounted in order to compare against other reported data sources, which may have been run using different discount rates.

6.5.2 TANK VENTING FORECAST

The assessment considers flashing losses from storage tanks to be reasonably constant over the project life. This may not be representative of all sites because production flows are controlled by drilling and completion program success, technology advancements and investment choices that are beyond the scope of this project to predict. Economic results are representative of production strategies where new wells are drilled or recompleted to compensate for well decline so that battery production is reasonably stable over its entire life span.

NPV calculations are completed with corresponding capital costs for each of the following flow rates that align with provincial and federal methane regulatory limits.

- 42 m^3 per day tank vent limit specified by ECCC for 2020 and BC OGC for 2022.
- 100 m^3 per day Defined Vent Gas (DVG) limit specified by AER for 2022.
- 300 m^3 per day tank vent limit specified by BC OGC for 2020
- 500 m^3 per day Overall Vent Gas (OVG) limit specified by AER for 2020.
- 300 kg methane per day Overall Vent Gas (OVG) limit specified by AER for 2020 (equivalent to **1,000 m^3 per day** for tank vapour containing 44 percent methane by volume).
- 300 kg methane per day Overall Vent Gas (OVG) limit specified by AER for 2020 (equivalent to **3,000 m^3 per day** for tank vapour containing 15 percent methane by volume).

6.5.3 OIL PRODUCTION FORECAST

The reliable and reasonable methods for forecasting oil production is important in terms of evaluating economics. The decline curve analysis is a useful tool for establishing future outlooks for oil production. A study examines average well performance by defining a range of decline rates varying from 8 to 65 percent (NEB, 2017). The different decline rates that are applied to describe the production change over time. The decline is usually very rapid during the initial period (first decline rate of 65 percent) and then followed by slower but continuous decreases

(third decline rate of 25 percent). During these periods, it is expected that the oil will be recovered through the energy that is occurring naturally in the reservoir (i.e., buoyancy, pressure, etc.). The oil pressure decreases over time, and artificial lift is required on wells when it approaches a period with insufficient pressure in the reservoir to lift the oil to the surface. Ghassemzadeh and Pourafshary (2015) studied an approach to optimize the initiation time of gas lift operation and found that delaying the start of the gas lift operation does not reduce much of its benefits. Considering the variable nature of well decline rates and the need for establishing time of gas lift as stated above, a fourth decline rate of 16 percent is considered for the base case. For sensitivity analysis, upper and lower bound rates of 8% and 65% are used.

6.5.4 PRICE FORECASTS

Natural gas prices are based on the commodity price forecast from GLJ Petroleum Consultants (GLJ, 2019) as presented in Table 21. Assessments use 'forward curve' values provided by GLJ over the period 2018-2020 and then increments these based on an annual price inflation rate. Forward curve values are reasonably reliable for the first few years because they are based on actual market decisions and commodity valuation, whereas prices for future years are much less certain.

The electricity purchase price in 2018 is based on rates currently paid by producers in Alberta (AESO, 2019) and is escalated at the long-term annual rate of general price inflation presented in Section 6.5.5. The purchase price also includes distribution ($45 per megawatt hour (MWh)) and retail ($1/MWh) costs charged by the utility company for power line infrastructure and administration (Producers, 2019). The projected electricity purchase prices are also provided in Table 21. The sale vale of electricity in 2018 is obtained from AESO (AESO, 2019) and is used for calculating NPV benefit value (for project cases where electricity is sold by the oil company to the electric utility company), as shown in Table 21.

Table 21: Projected (Current Dollars) Natural Gas and Electricity Prices used in the NPV Calculations.

Year	Natural Gas		Electricity Purchase		Electricity Sales	
	Base-case	Sensitivity	Base-case	Sensitivity	Base-case	Sensitivity
	($/GJ)	($/GJ)	($/MWh)	($/MWh)	($/MWh)	($/MWh)
2018	1.28	1.15 – 1.41	96.38	86.74 – 106.02	50.38	45.34 – 55.42
2019	1.06	0.96 – 1.17	98.47	88.10 – 108.32	51.47	46.05 – 56.62
2020	1.64	1.48 – 1.80	100.61	89.49 – 110.67	52.59	46.78 – 57.85
2021	1.68	1.50 – 1.84	102.79	90.89 – 113.07	53.73	47.51 – 59.10
2022	1.71	1.52 – 1.88	105.02	92.32 – 115.52	54.90	48.26 – 60.39
2023	1.75	1.55 – 1.92	107.30	93.77 – 118.03	56.09	49.02 – 61.70

Table 21: Projected (Current Dollars) Natural Gas and Electricity Prices used in the NPV Calculations.						
Year	Natural Gas		Electricity Purchase		Electricity Sales	
	Base-case	Sensitivity	Base-case	Sensitivity	Base-case	Sensitivity
	($/GJ)	($/GJ)	($/MWh)	($/MWh)	($/MWh)	($/MWh)
2024	1.79	1.57 – 1.97	109.63	95.24 – 120.59	57.31	49.78 – 63.04
2025	1.83	1.60 – 2.01	112.01	96.74 – 123.21	58.55	50.57 – 64.40
2026	1.87	1.62 – 2.05	114.44	98.25 – 125.88	59.82	51.36 – 65.80
2027	1.91	1.65 – 2.10	116.92	99.80 – 128.61	61.12	52.17 – 67.23
2028	1.95	1.67 – 2.14	119.46	101.36 – 131.41	62.44	52.99 – 68.69
2029	1.99	1.70 – 2.19	122.05	102.96 – 134.26	63.80	53.82 – 70.18
2030	2.03	1.72 – 2.24	124.70	104.57 – 137.17	65.18	54.66 – 71.70
2031	2.08	1.75 – 2.28	127.41	106.21 – 140.15	66.60	55.52 – 73.26
2032	2.12	1.78 – 2.33	130.17	107.88 – 143.19	68.04	56.39 – 74.85
2033	2.17	1.81 – 2.38	133.00	109.58 – 146.30	69.52	57.28 – 76.47
2034	2.21	1.84 – 2.44	135.88	111.30 – 149.47	71.03	58.18 – 78.13
2035	2.26	1.86 – 2.49	138.83	113.04 – 152.71	72.57	59.09 – 79.83
2036	2.31	1.89 – 2.54	141.84	114.82 – 156.03	74.14	60.02 – 81.56
2037	2.36	1.92 – 2.60	144.92	116.62 – 159.41	75.75	60.96 – 83.33
2038	2.41	1.95 – 2.65	148.07	118.45 – 162.87	77.40	61.92 – 85.14
2039	2.47	1.98 – 2.71	151.28	120.31 – 166.41	79.08	62.89 – 86.98

For the purpose of the NPV calculations, and to facilitate one-way sensitivity analysis, all prices (natural gas, electricity, and carbon savings) are represented as levelized prices. A levelized price is the "annualized' dollar amount which, over a period of *N* years (i.e. the lifetime of a project), and discounted at the nominal annual discount rate, will be equivalent to the present value of a stream of annual prices over the same period. The levelized natural gas price, AB electricity prices and sales prices corresponding to the annual price series in Table 21 under the base-case are, respectively, $1.79 per GJ, $109.72 per megawatt hour (MWh), and $57.35 per MWh. The levelized prices for natural gas and electricity can be thought of as an average price, which can be applied to future fuel or electricity demands in the NPV calculation, rather than applying a variable cost per future year.

6.5.5 INFLATION RATE

The long-term annual rate of general price inflation under the base-case is 2.17% in Alberta. These rates are the average year-to-year change in (all-item) Consumer Price Index (CPI) observed over the period 2000 to 2018 (CPI inflation rate) in the province. The CPI is generated by and available from Statistics Canada (2019). The long-term annual rate of general price

inflation rate is used to escalate net annual costs, commodity prices and estimated salvage values (where relevant). This is necessary to ensure consistent treatment of all cost and benefit streams in the NPV calculations, which is performed in current (or nominal) dollars. For sensitivity analysis, the lowest estimate of CPI for Alberta in 2018-2019 is 1.57% and the highest estimate is 2.17% (2000-2018).

6.5.6 DISCOUNT RATE

The nominal discount rate under the base-case is 6.95% per year. It is based on current prime lending rate of ATB Financial on loans payable in Canadian dollars (3.95% per year) plus 3% per year (as per Directive 060) (ATB Financial, 2019). As noted earlier, the discount factor determines the weight assigned to future benefits in the NPV calculations. It is the rate of return in a series of discounted cash flow analysis to estimate the present value of future cash streams. NPV declines exponentially with the discount rate: the higher the annual discount rate, the lower the weight assigned to future benefits in the determination of a project's NPV. All future cost and benefits flows are discounted at the nominal annual discount rate in the NPV calculations - i.e., converted to present day equivalents. For sensitivity analysis, lower (upper) bound nominal annual discount rates reflect the highest (lowest) prime lending rate observed since 2010. The lower bound discount rate is: 4.00% + 3.00% = 7.00% per year; the upper bound discount rate is: 2.23% + 3.00% = 5.23% per year (Trading Economics, 2019).

6.5.7 ROYALTIES

Projects that increase oil production are subject to royalty payments while natural gas conservation projects are eligible for royalty waivers (AER, 2018a). Therefore, NPV calculations include royalty costs for incremental oil production and otherwise calculated on a royalties-out basis. The royalty rate adopted for base-case NPV is 5 percent of incremental oil sales value with upper and lower bounds of0 percent and 40 percent (KPMG, 2018).

6.5.8 CAPITAL AND INSTALLATION COSTS

The equipment, material, installation, and engineering costs are determined from vendor quotes, the detailed breakdown of which is presented in Section 6.8 (Suppliers, 2019). Installation and engineering costs are conservative and based on professional expertise and judgement for installation of a single unit. The experience and actual costs incurred by producers is considered most representative and data collection efforts focused on companies actively engaged in Canadian oil and gas production.

6.5.9 SALVAGE VALUE

The net salvage value of equipment at the end of a conservation project's useful life would be estimated by a qualified professional and included as project revenue in the last year of operating life. Salvage values have generally not been included as part of this study, and are left equal to zero in all cases studied.

6.5.10 OPERATING COSTS

Operating costs depend on the frequency and duration of site visits by field operators and maintenance staff, plus the cost of replacement parts and materials. The cost of electricity that may be required to operate mitigation equipment is also considered. A base-case and lower and upper bound estimate are provided for each technology option.

6.5.11 GLOBAL WARMING POTENTIAL

The total radiative forcing contributed by the sum of target GHG emissions is expressed in terms of CO_2 equivalent (CO_2E). This is done by applying global warming potentials (GWP) specified by the Intergovernmental Panel on Climate Change (IPCC, 2007 and IPCC, 2013) and presented in Table 22. Base case abatement scenarios adopt IPCC Fourth Assessment Report (AR4) GWPs over a 100 year time horizon to be consistent with current federal and provincial GHG reporting regulations. However, more recent science indicates that a more appropriate value for methane GWP is 34 when evaluated on a 100-year time horizon (Gasser et al., 2017). To test the relative importance of GWP selection, abatement costs determined using methane GWP of 34 are also presented.

Table 22: GWPs over 100 year time horizons from IPCC AR4, AR5 and Gasser et al.

Substance	AR4 GWP	AR5 GWP	Gasser et al
Carbon dioxide	1	1	1
Methane	25	34	34
Nitrous Oxide	298	297	267

6.5.12 CARBON PRICING

Avoided GHG emissions can potentially be monetized according to carbon price (or levy) implemented by provinces. Average abatement cost curves can also be compared to the social cost of carbon as a method for considering the broader economic costs of climate change.

6.5.12.1 CARBON LEVY

In 2019, the Alberta government passed legislation to repeal its provincial carbon levy (GOA, 2019) and triggered the federal carbon pricing backstop for provinces that do not have their own program. As shown in Table 23, the federal price starts at $10 per tonne CO_2E in 2018 and rises by $10 per year to $50 per tonne in 2022 (Department of Finance Canada, 2019). A series of reviews with provincial and territorial governments are planned to provide price certainty after

2022. In the meantime, base-case assessments consider that carbon prices will remain fixed at $50 per tonne after 2022. Upper bound pricing assumes pricing increases by $10 per year after 2022 up to a maximum of $100 per tonne. The lower bound assumes carbon pricing is removed from the Canadian economy. The levelized carbon price used to calculate base-case abatement costs is $46.10 per tonne CO_2E.

Table 23: Carbon Pricing (modeled after economy-wide federal carbon pricing).

Year	Base-case ($/t CO_2E)	Upper Bound ($/t CO_2E)	Lower Bound ($/t CO_2E)
2018	10	10	--
2019	20	20	--
2020	30	30	--
2021	40	40	--
2022	50	50	--
2023	50	60	--
2024	50	70	--
2025	50	80	--
2026	50	90	--
2027	50	100	--
2028	50	100	--
2029	50	100	--
2030	50	100	--
2031	50	100	--
2032	50	100	--
2033	50	100	--
2034	50	100	--
2035	50	100	--
2036	50	100	--
2037	50	100	--
2038	50	100	--
2039	50	100	--

6.5.12.2SOCIAL COST OF CARBON

The social cost of carbon -or SCC as it is known - is used in the US to evaluate the climate change benefits of proposed new rules or changes to existing rules.

The US EPA defines the SCC as “an estimate of the economic damages associated with a small increase in CO_2 emissions, conventionally one tonne, in a given year.” It measures the full global damage costs of an incremental unit of carbon (or equivalent amount of other GHGs) emitted at a

point in time; summing the full global cost of the damage that unit imposes over its lifetime in the atmosphere. Damage costs include a wide range of anticipated climate-related impacts, including *inter alia* net changes in agricultural productivity, adverse human health outcomes, property and infrastructure damage from flooding, and changes in energy system costs associated with changes in cooling and heating demand. It is thus a measure of overall social costs from these GHG emissions.

Calculating the SCC requires quantification of the whole process linking anthropogenic emissions of GHGs with impacts on social welfare at a global scale; this task is performed by integrated assessment models (IAMs). Three IAMs from the peer-reviewed literature were used to generate values of the SCC for rulemaking in the US (EPA, 2015); these are shown in current Canadian dollars in Table 24. Many climate-related impacts associated with an incremental unit of carbon emitted today are expected to occur for many decades and even centuries. The present value of those damages is thus highly sensitive to the chosen discount rate. This is evident from the values in Table 24, which are provided for three different discount rates typical of climate policy analysis. Moreover, since the amount of damage done by each incremental unit of carbon in the atmosphere depends on the concentration of atmospheric carbon today and in the future to which the increment is added, the SCC associated with emissions in 2020, 2025 and 2030 rises as global emissions and concentrations of GHGs in the atmosphere increase. The SCC also increases over time as natural and socio-economic systems become increasingly stressed in response to greater levels of climatic change (reducing their coping capacity).

The SCC is important because it signals what society should, in theory, be willing to pay now to avoid the future damage caused by incremental carbon emissions. Policymakers should be willing, in the interests of society, to make rules that result in emissions savings which cost up to and no more than the damage they expect the emissions to cause, because to do so would make society better off. This is how the SCC values are applied in the US, i.e., to value the benefits (and justify the implementation) of GHG emission reductions in rules like the proposed New Source Performance Standards (NSPS, 2019) for the oil and natural gas industry.

In conjunction with estimates of the average abatement costs for each project, the tank venting rates are determined at which the project would be economic if GHG emission reduction benefits are valued at the base-case SCC for 2025.

Table 24: Estimates of the Social Cost of Carbon (Average across all three IAMs, in current Canadian dollars).

Year	Base-case (3% discount rate)	Upper Bound (2.5% discount rate)	Lower Bound (5% discount rate)
	($/t CO_2E)	($/t CO_2E)	($/t CO_2E)
2018	59	89	17

Table 24: Estimates of the Social Cost of Carbon (Average across all three IAMs, in current Canadian dollars).			
Year	**Base-case (3% discount rate)**	**Upper Bound (2.5% discount rate)**	**Lower Bound (5% discount rate)**
	($/t CO_2E)	**($/t CO_2E)**	**($/t CO_2E)**
2019	62	92	17
2020	65	96	17
2021	66	99	17
2022	69	103	19
2023	72	107	19
2024	76	111	20
2025	79	117	22
2026	83	121	22
2027	86	126	24
2028	90	130	24
2029	92	135	25
2030	96	140	27
2031	100	145	27
2032	104	150	29
2033	108	155	30
2034	113	161	32
2035	117	166	33
2036	122	172	35
2037	127	180	35
2038	132	186	38
2039	137	193	38

6.5.13 ABATEMENT COSTS

For each project, the average (net) abatement cost (in current $ per tonne CO_2E avoided) is calculated. This metric defines the total cost, *net*, of revenue from sales or avoided fuel purchases, incurred by the operator to avoid the release of one tonne of CO_2E to the atmosphere. It is given by:

$$Average\ Abatement\ Cost = \frac{PVC - PVB}{GHG}$$

Equation 8

Where:

PVC = Present Value Costs

=

		$\sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$
PVB	=	Present Value Benefits
	=	$\sum_{t=0}^{N} \frac{B_t}{(1+r)^t}$
GHG	=	Avoided GHG Emissions
	=	$\sum_{t=0}^{N} E_t$
t	=	year (with year t = 0 being the year in which the investment is made)
N	=	useful life of project (in years)
r	=	nominal annual discount rate
C_t	=	project's costs in year t
B_t	=	project's benefits in year t (excluding the monetization of CO_2E savings)
E_t	=	project's CO_2E savings in year t determined with AR4 GWPs of 25 for CH_4 and 298 for N_2O for a 100 year time horizon.

Although it is acknowledged that reducing one tonne of CH_4 emissions now is of greater environmental benefit than reducing one tonne of CH_4 emissions in the future, CO_2E emissions used in the average abatement cost calculation are not discounted because of limitations in the GWP term as a measure of climate forcing effects. The GWP is an overly simplified means of comparing instantaneous emissions and evaluating their effects over a common time horizon (e.g., often 100 years) while assuming the ambient environment remains relatively constant (IPCC, 2013). Because GWPs are simple and practical to apply, they are almost universally adopted. More rigorous alternatives to model the actual climate forcing effect of specific GHG reduction projects are beyond the capability of most project proponents. Developing engineering estimates for a CO_2E discount rate was considered but preliminary analysis suggested the discount would be close to zero. Moreover, the most recent IPCC Fifth Assessment Report (AR5) specifies methane has a GWP of 36 (i.e., 44% greater than the previous AR4 GWP of 25) plus it can be argued a 20 year horizon GWP of 72 is more appropriate for project lifetimes considered in this assessment (i.e. 288% greater than the AR4 GWP of 25). While this study does not discount future CO_2E, it does adopt AR4 GWPs (100 year time horizon) because they produce conservative (i.e., lower) estimates of future CO_2E. Also, AR4 GWP aligns with current western Canadian GHG regulations.

If PVC >PVB, then the average abatement cost is positive. This implies the operator incurs a net cost for each tonne of CO_2E saved. In contrast, if PVC < PVB, the average abatement cost is negative, and the operator accrues a resource saving for each tonne of CO_2E saved. The average abatement cost has several useful interpretations. In the current context, it provides a yardstick for determining whether or not a project (at different tank venting rates) is economic relative to different valuations of the CO_2E savings. In general:

- If the average abatement cost of a project is negative, then that project is economic even without the monetization of non-combustion CO_2E savings;

- If the average abatement cost of a project is positive (i.e. currently costs money), but is significantly less than the prevailing carbon price, then that project would be economic if non-combustion CO_2E savings are monetized and included in the benefits stream; and
- If the average abatement cost of a project is positive, but is greater than the prevailing carbon price, then that project would remain uneconomic even if non-combustion CO_2E savings are monetized and included in the benefits stream.

6.6 INPUT PARAMETERS FOR NPV EVALUATIONS

6.6.1 CASE 1: TANK TOP TO EXISTING HIGH PRESSURE FLARE STACK

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	2.14	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$195,000	$146,250	$292,500
Annual operating costs of conservation project	% of total capital	7.6%	4.0%	10.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sale	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$3,850	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 36: Case #1 base-case, upper bound and lower bound input values.

6.6.2 CASE 2: TANK TOP TO LOW PRESSURE FLARE STACK

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW		-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$155,000	$116,250	$232,500
Annual operating costs of conservation project	% of total capital	7.6%	4.0%	10.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sale	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$3,120	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 37: Case #2 base-case, upper bound and lower bound input values.

6.6.3 CASE 3: TANK TOP TO BOOSTER COMPRESSOR FOR GAS LIFT

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
Gas Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	5.13	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$780,000	$585,000	$1,170,000
Levelized oil price (life of project)	$/bbl	67.47	81.11	57.33
	$/m3	424	510	361
Annual operating costs of conservation project (fixed)	% of total capital	4.5%	4.0%	8.0%
Ratio of gas injected to incremental oil produced	m3/m3	223.4	361.1	35.7
Incremental oil production	m^3/year	817	3032	429
Oil production decline rate	%	-16.0%	-8.0%	-65.0%
Royalty rate	% of oil sales	5.0%	0.0%	40.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$22,700	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 38: Case #3 base-case, upper bound and lower bound input values.

6.6.4 CASE 4: TANK TOP TO VAPOUR COMBUSTOR

Metrics (Static)	Units	Assumed Metric Values		
		Base Case	Upper Bound	Lower Bound
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	0.33	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$235,000	$176,250	$352,500
Annual operating costs of conservation project	% of total capital	7.0%	4.0%	10.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sale	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$5,095	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 39: Case #4 base-case, upper bound and lower bound input values.

6.6.5 CASE 5: FLASH VESSEL TO ELECTRIC GENERATOR

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	-	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$245,000	$183,750	$367,500
Annual operating costs of conservation project	% of total capital	4.5%	4.0%	8.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sale	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$4,525	$0	$0
Thermal efficiency	%	30%	30%	30%
Generator efficiency (power factor)	%	80%	80%	80%
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 40: Case #5 base-case, upper bound and lower bound input values.

6.6.6 CASE 6: TANK TOP TO ELECTRIC GENERATOR

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	0.26	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$300,000	$225,000	$450,000
Annual operating costs of conservation project	% of total capital	4.5%	4.0%	8.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sale	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$7,100	$0	$0
Thermal efficiency	%	30%	30%	30%
Generator efficiency (power factor)	%	80%	80%	80%
Thermal electric generator efficiency	%	3.6%	3.6%	3.6%
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 41: Case #6 base-case, upper bound and lower bound input values.

6.6.7 CASE 7: FLASH VESSEL TO EXISTING HIGH PRESSURE FLARE STACK

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	-	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$125,000	$93,750	$187,500
Annual operating costs of conservation project	% of total capital	0.0%	0.0%	0.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sales	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$2,675	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 42: Case #7 base-case, upper bound and lower bound input values.

6.6.8 CASE 8: FLASH VESSEL TO COMBUSTOR

Metrics (Static)	Units	Assumed Metric Values		
		Base Case	Upper Bound	Lower Bound
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	-	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$200,000	$150,000	$300,000
Annual operating costs of conservation project	% of total capital	7.0%	4.0%	10.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sales	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$4,125	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 43: Case #8 base-case, upper bound and lower bound input values.

6.6.9 CASE 9: TANK TOP TO VRU PACKAGE INSTALLATION

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	2.80	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$430,000	$322,500	$645,000
Annual operating costs of conservation project	% of total capital	4.5%	4.0%	8.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sales	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$6,970	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 44: Case #9 base-case, upper bound and lower bound input values.

6.6.10 CASE 10: FLASH VESSEL TO VRU PACKAGE INSTALLATION

		Assumed Metric Values		
Metrics (Static)	**Units**	**Base Case**	**Upper Bound**	**Lower Bound**
Physical Metrics:				
Tank vent rate	m^3/day	500	3,000	42
	10^3m^3/year	182.5	1,095.0	15.3
Decline rate		0.0%	0.0%	0.0%
Tank Vapour Methane Fraction	mol fraction	0.56	0.87	0.10
HHV	MJ/m3	59.0	40.8	85.1
Methane GWP	dimensionless	25	34	25
Fuel Combustion CO2E emission factor	t $CO_2E/10^3m^3$	3.4	2.2	5.2
Venting CO2E emission factor	t $CO_2E/10^3m^3$	9.6	14.8	1.7
Flaring CO2E emission factor	t $CO_2E/10^3m^3$	3.5	2.4	5.1
Rated power for blower motor	KW	1.87	-	-
Economic Metrics:				
Levelized carbon valuation - Federal Pricing (life of project	$/t CO2E	46.10	80.27	-
Levelized electricity purchase price (life of project)	$/MWh	109.72	131.91	92.15
Levelized natural gas price (life of project)	$/GJ	1.79	2.15	1.52
Levelized electricity sales price (life of project)	$/MWh	57.35	68.95	48.17
Capital + installation cost of conservation project	$	$525,000	$393,750	$787,500
Annual operating costs of conservation project	% of total capital	4.5%	4.0%	8.0%
Natural gas royalty rate	% of gas sales	0.0%	0.0%	0.0%
Crude oil royalty rate	% of incremental sales	5.0%	40.0%	0.0%
Operating life of conservation project	Years	10	20	5
Salvage value at end of conservation project	$	$9,470	$0	$0
Long-term inflation rate	%	2.17%	2.17%	1.57%
Discount rate (nominal)	%	6.95%	5.23%	7.00%

Figure 45: Case #10 base-case, upper bound and lower bound input values.

6.7 DRAWING PACKAGE FOR STORAGE TANK EMISSION MITIGATION CASES

VANGUARD
ENGINEERING INC

CLEARSTONE ENGINEERING

Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks

Drawing Package

CEL-18001

Issued For Information

Sept. 26 2019

VANGUARD ENGINEERING INC

Drawing Index

Client	Clearstone Engineering Ltd.
Project	Emissions Reduction Study
Project No.	CEL-18001
Sheet	1 of 1

DRAWING CATEGORY	DRAWING No.	DRAWING NAME	ISSUED FOR	Rev	Date
PFD	13910-0201	Single Well Battery Schematic - Case #1 Tank Top - Existing HP Flare Stack	Information	D	Sept 26/19
PFD	13910-0202	Single Well Battery Schematic - Case #2 Tank Top - New LP Flare Stack	Information	D	Sept 26/19
PFD	13910-0203	Single Well Battery Schematic - Case #3 Tank Top - Booster Compressor for Gas Lift	Information	D	Sept 26/19
PFD	13910-0204	Single Well Battery Schematic - Case # 4 Tank Top - New Combustor	Information	D	Sept 26/19
PFD	13910-0205	Single Well Battery Schematic - Case # 5 Separator - New Electrical Generator	Information	D	Sept 26/19
PFD	13910-0206	Single Well Battery Schematic - Case # 6 Tank Top - New Electrical Generators	Information	D	Sept 26/19
PFD	13910-0207	Single Well Battery Schematic - Case # 7 Separator - New Flash Vessel	Information	D	Sept 26/19
PFD	13910-0208	Single Well Battery Schematic - Case # 8 Separator - New Flash Vessel & Combustor	Information	D	Sept 26/19
PFD	13910-0209	Single Well Battery Schematic - Case # 9 Tank Top - VRU to Sales Compressor	Information	D	Sept 26/19
PFD	13910-0210	Single Well Battery Schematic - Case # 10 Flash Vessel - Booster Compressor for Sales	Information	D	Sept 26/19

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

T–900/901
OIL STORAGE TANK

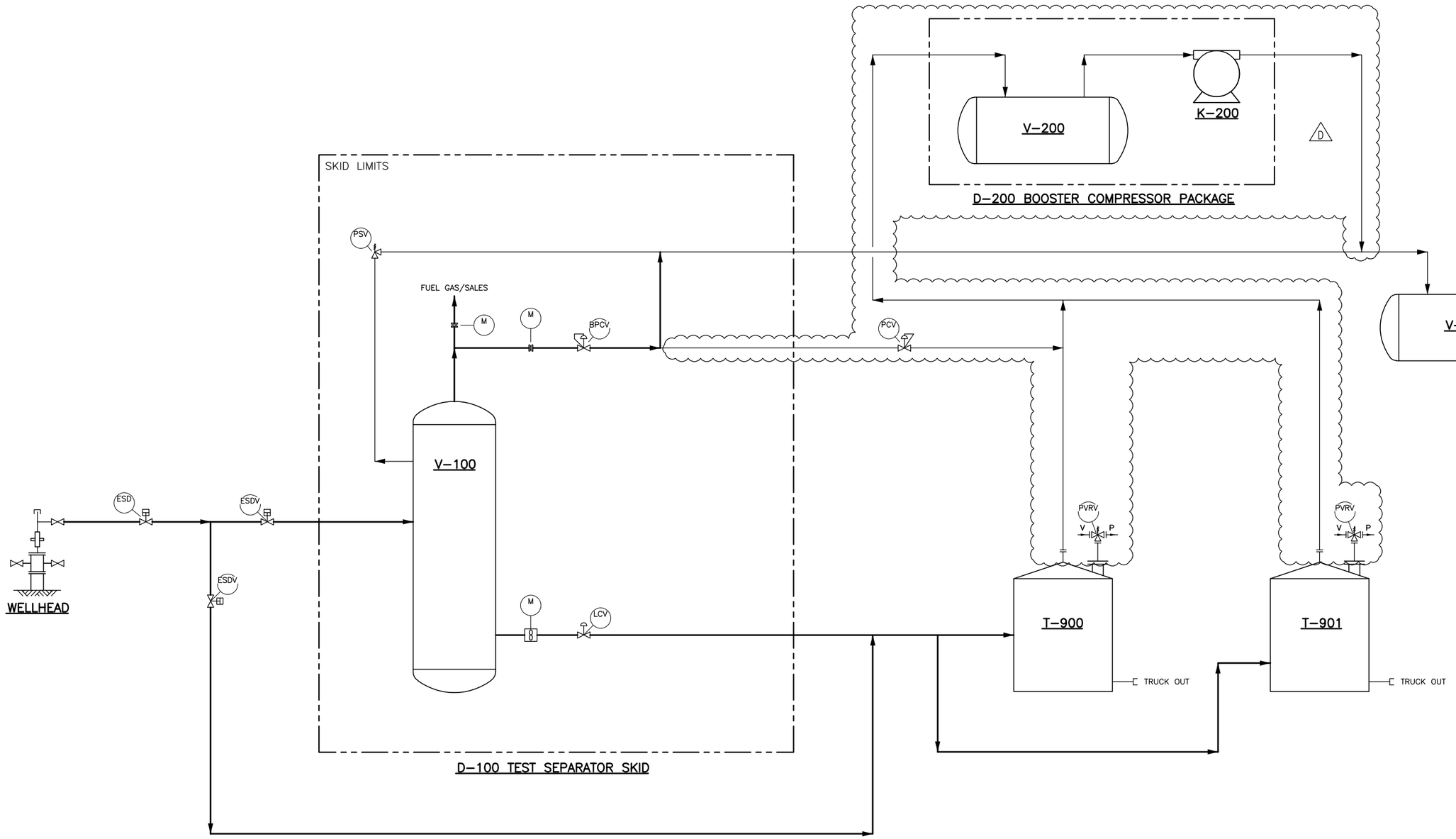
V–800
HP FLARE KNOCK–OUT DRUM

V–200
SUCTION SCRUBBER

K–200
BOOSTER COMPRESSOR

D
D–200
BOOSTER COMPRESSOR PACKAGE

FL–800
HP FLARE STACK



NOTES:

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B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN		
BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT
CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #1
TANK TOP – EXISTING
HP FLARE STACK

SINGLE WELL BATTERY
SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0201
REV	D

REFERENCE DRAWING TITLE/No.

–

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

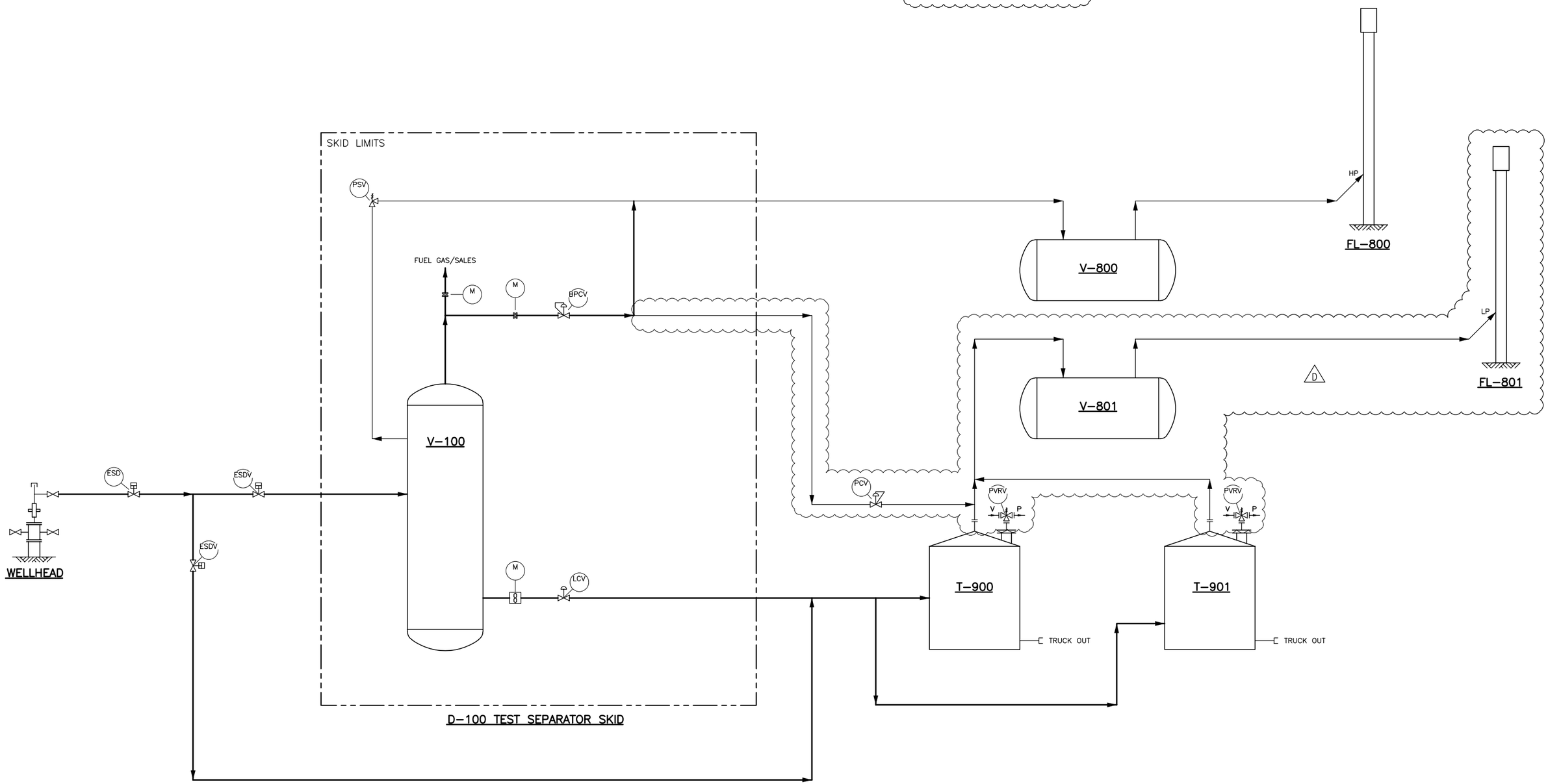
T–900/901
OIL STORAGE TANK

V–800
HP FLARE KNOCK–OUT DRUM

V–801
LP FLARE KNOCK–OUT DRUM
△D

FL–800
HP FLARE STACK

FL–801
LP FLARE STACK △D



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CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #2
TANK TOP – NEW
LP FLARE STACK

SINGLE WELL BATTERY
SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0202
REV	D

–
REFERENCE DRAWING TITLE/No.

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

T–900/901
OIL STORAGE TANK

V–800
HP FLARE KNOCK–OUT DRUM

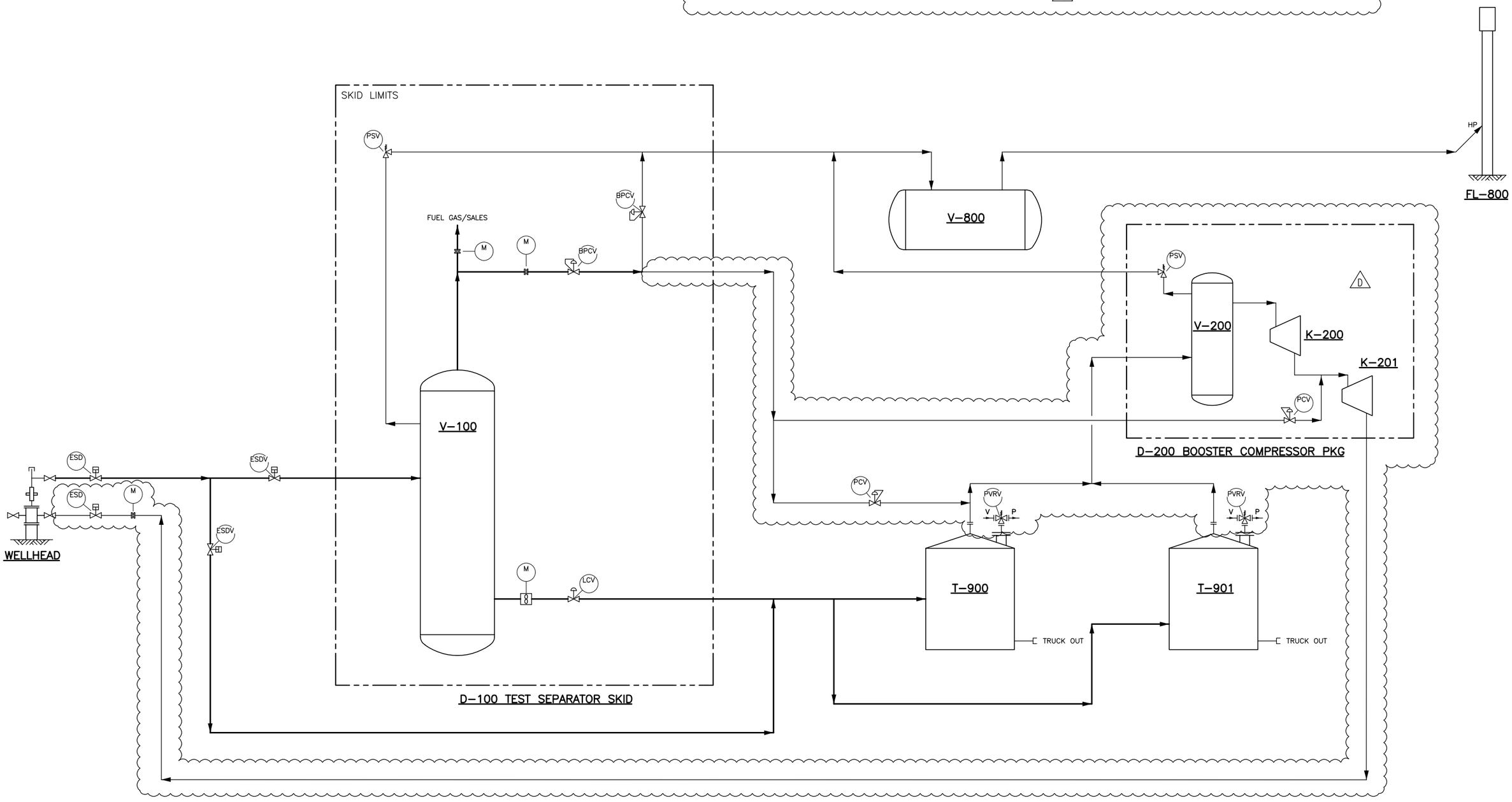
D–200
BOOSTER COMPRESSOR PACKAGE

V–200
SUCTION SCRUBBER

K–200
VRU COMPRESSOR
ROTARY VANE

K–201
INJECTION COMPRESSOR
ROTARY SCREW

FL–800
HP FLARE STACK



NOTES:

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ENGINEER'S STAMP

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PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #3
TANK TOP – BOOSTER COMPRESSOR FOR GAS LIFT

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0203
REV	D

–
REFERENCE DRAWING TITLE/No.

T–900/901
OIL STORAGE TANK

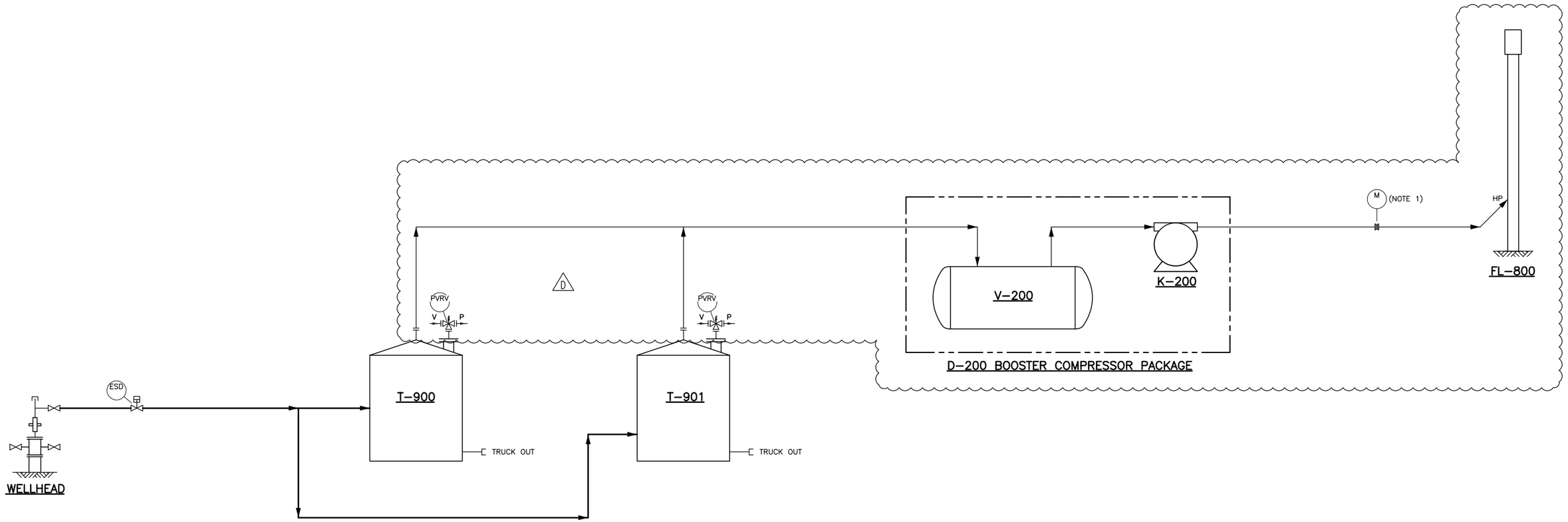
V–200
SUCTION SCRUBBER

K–200
BOOSTER COMPRESSOR

D–200
BOOSTER COMPRESSOR PACKAGE

△D

FL–800
COMBUSTOR



NOTES:

1. GAS METER REQUIRED FOR GAS VOLUMES GREATER THAN 500m³/D.

REV	DATE	REVISION DESCRIPTION	BY
D	SEP 26/19	ISSUED FOR INFORMATION	SM
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A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN

BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

REFERENCE DRAWING TITLE/No.

–

CLIENT

CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #4
TANK TOP –
NEW COMBUSTOR

SINGLE WELL BATTERY
SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0204
REV	D

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

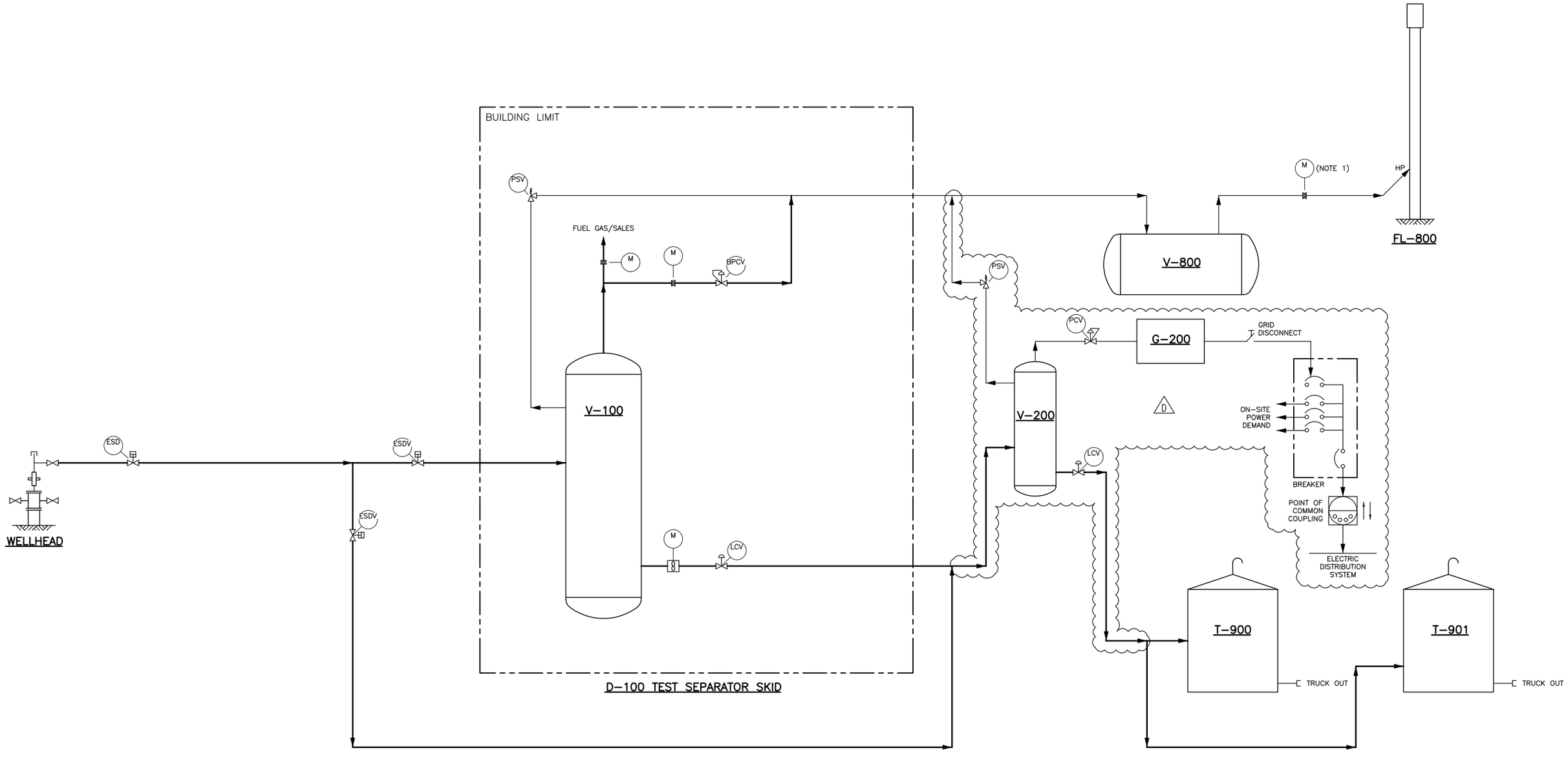
T–900/901
OIL STORAGE TANK

G–200
ELECTRICAL GENERATOR
D

V–800
HP FLARE KNOCK–OUT DRUM

V–200
FLASH VESSEL
D

FL–800
HP FLARE STACK



NOTES:

1. GAS METER REQUIRED FOR GAS VOLUMES GREATER THAN 500m³/D.

REV	DATE	REVISION DESCRIPTION	BY
D	SEP 26/19	ISSUED FOR INFORMATION	
C	SEP 20/19	RE–ISSUED FOR APPROVAL	SM
B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

REFERENCE DRAWING TITLE/No.: –

ENGINEER'S STAMP

DRAWING ORIGIN

BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #5
SEPARATOR – NEW ELECTRICAL GENERATOR

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0205
REV	D

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

T–900/901
OIL STORAGE TANK

V–800
HP FLARE KNOCK–OUT DRUM

V–200
SUCTION SCRUBBER

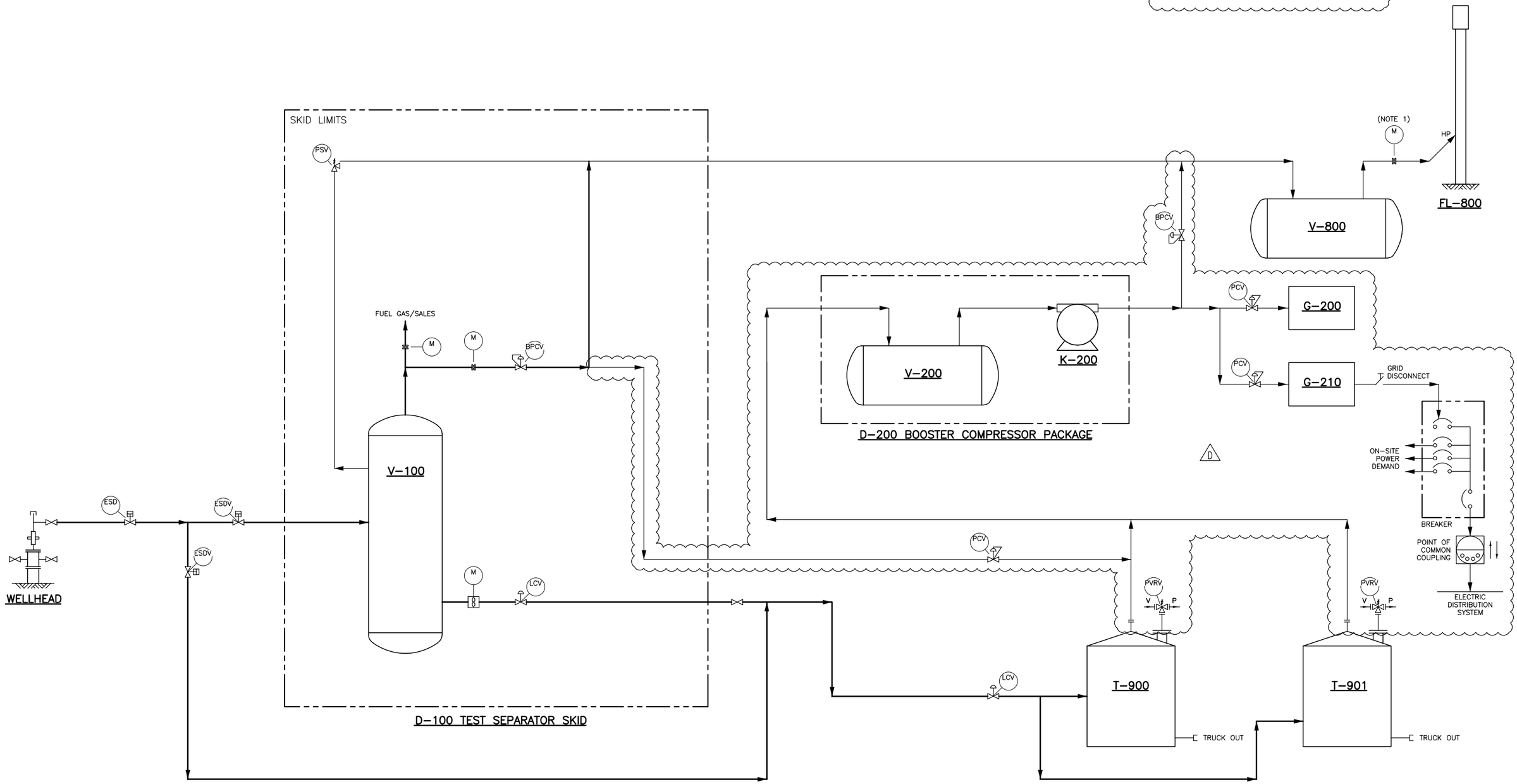
K–200
BOOSTER COMPRESSOR

D–200
BOOSTER COMPRESSOR PACKAGE

G–200
THERMO–ELECTRIC GENERATOR

G–210
ELECTRICAL GENERATOR

FL–800
HP FLARE STACK



NOTES:

1. GAS METER REQUIRED FOR GAS VOLUMES GREATER THAN 500m³/D.

REV	DATE	REVISION DESCRIPTION	BY
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B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN		
BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #6
TANK TOP – NEW ELECTRICAL GENERATORS

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0206
REV	D

–
REFERENCE DRAWING TITLE/No.

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

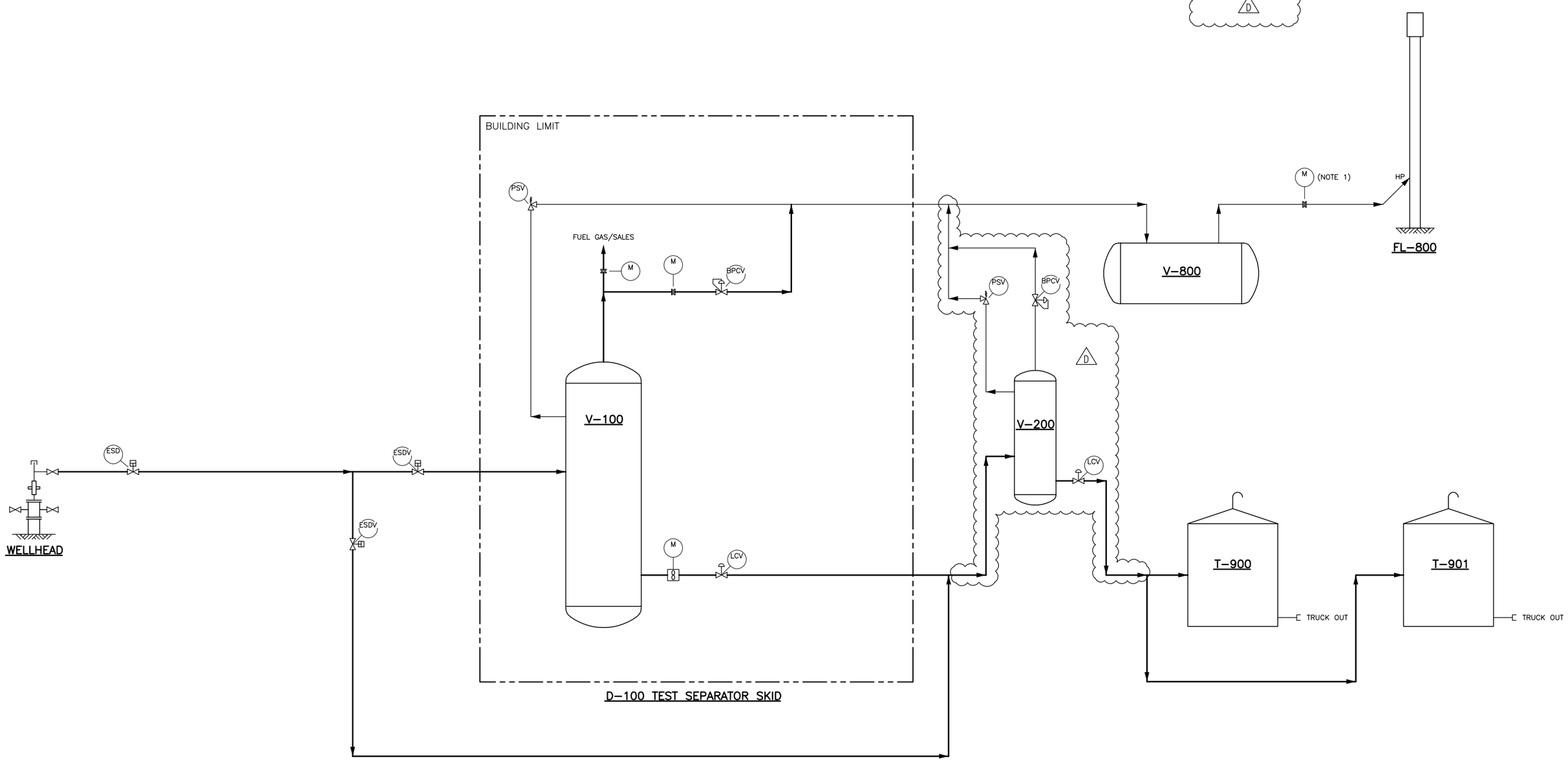
T–900/901
OIL STORAGE TANK

G–200
ELECTRICAL GENERATOR

V–800
HP FLARE KNOCK–OUT DRUM

V–200
FLASH VESSEL

FL–800
HP FLARE STACK



NOTES:

1. GAS METER REQUIRED FOR GAS VOLUMES GREATER THAN 500m^3/D.

REV	DATE	REVISION DESCRIPTION	BY
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A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN		
BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #7
SEPARATOR – NEW FLASH VESSEL

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0207
REV	D

REFERENCE DRAWING TITLE/No.

–

D–100
TEST SEPARATOR SKID

V–100
HP TEST SEPARATOR

T–900/901
OIL STORAGE TANK

FL–800
COMBUSTOR

V–200
FLASH VESSEL

D

BUILDING LIMIT

PSV

FUEL GAS/SALES

M

M

BPCV

V–100

ESD

ESDV

ESDV

WELLHEAD

M

LCV

D–100 TEST SEPARATOR SKID

PSV

BPCV

V–200

LCV

D

M (NOTE 1)

HP

FL–800

T–900

T–901

TRUCK OUT

TRUCK OUT

NOTES:

1. GAS METER REQUIRED FOR GAS VOLUMES GREATER THAN 500m^3/D.

REV	DATE	REVISION DESCRIPTION	BY
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B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

REFERENCE DRAWING TITLE/No.

–

ENGINEER'S STAMP

DRAWING ORIGIN

BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT

CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #8
SEPARATOR –
NEW FLASH VESSEL &
COMBUSTOR

SINGLE WELL BATTERY
SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0208
REV	D

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

T–900/901
OIL STORAGE TANK

V–800
HP FLARE KNOCK–OUT DRUM

D–300
SALES COMPRESSOR PACKAGE

K–300
SALES COMPRESSOR

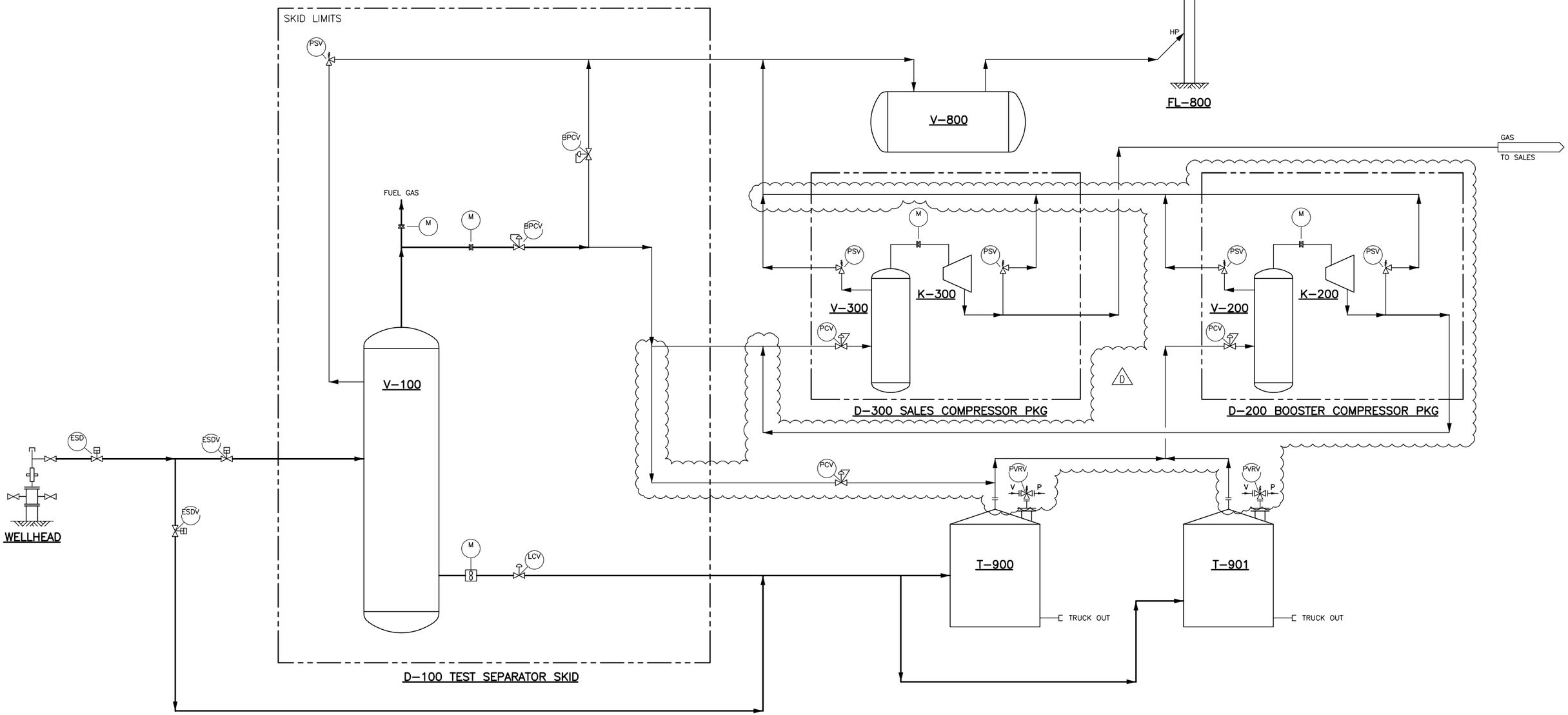
K–300
SUCTION SCRUBBER

D–200
VRU COMPRESSOR PACKAGE

V–200
SUCTION SCRUBBER

K–200
VRU COMPRESSOR
ROTARY VANE

FL–800
HP FLARE STACK



NOTES:

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B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN		
BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #9
TANK TOP – VRU TO SALES COMPRESSOR

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0209
REV	D

–
REFERENCE DRAWING TITLE/No.

V–100
HP TEST SEPARATOR

D–100
TEST SEPARATOR SKID

T–900/901
OIL STORAGE TANK

V–800
HP FLARE KNOCK–OUT DRUM

D–300
SALES COMPRESSOR PKG.

K–300
SALES COMPRESSOR

K–300
SUCTION SCRUBBER

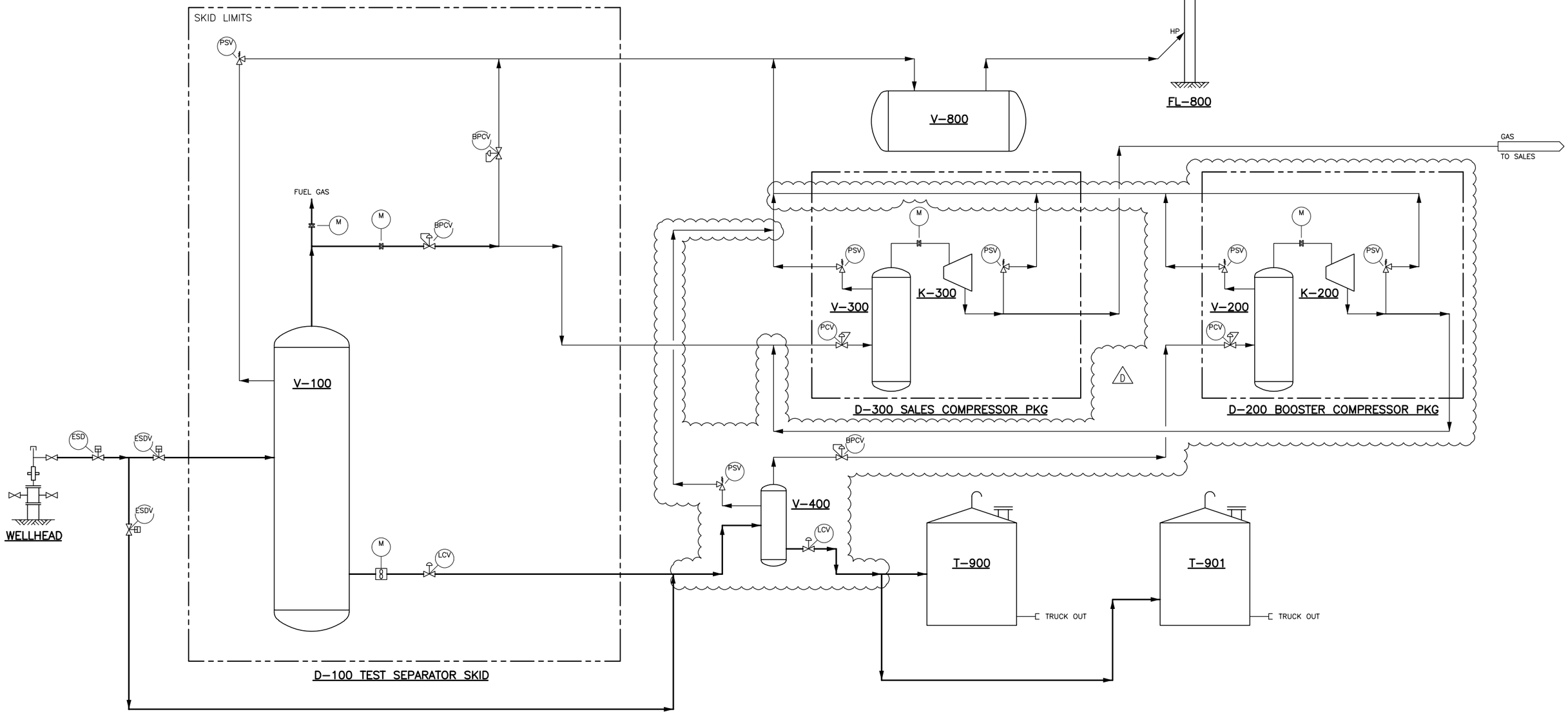
D–200
BOOSTER COMPRESSOR PKG.

V–200
SUCTION SCRUBBER

K–200
BOOSTER COMPRESSOR
ROTARY VANE

V–400
FLASH VESSEL

FL–800
HP FLARE STACK



NOTES:

REV	DATE	REVISION DESCRIPTION	BY
D	SEP 26/19	ISSUED FOR INFORMATION	SM
C	SEP 20/19	RE–ISSUED FOR APPROVAL	SM
B	SEP 12/19	ISSUED FOR APPROVAL	SM
A	AUG 21/19	ISSUED FOR REVIEW	SM

ENGINEER'S STAMP

DRAWING ORIGIN

BY	SM	JUL 31/19
CHECK	–	–
PROCESS	–	–
MECH	DB	JUL 31/19
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE

CASE #10
FLASH VESSEL – BOOSTER COMPRESSOR FOR SALES

SINGLE WELL BATTERY SCHEMATIC

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–18001
SCALE	NTS
DRAWING No.	13910–0210
REV	D

–
REFERENCE DRAWING TITLE/No.

6.8 CAPITAL AND INSTALLATION COST DETAILS FOR NPV EVALUATIONS

Case	Existing Equipment	Name	New Equipment	Gas Volume (m3/Day)	TIC Cost (CDN $)	Comments
1	Test Separator Storage Tanks HP FKOD HP Flare Stack Gas Sales Pipeline	Tank Top – Existing HP Flare Stack	LP to HP Blower Tank PVRVs	42 100 300 500 1000 3000	195,000	3 hp blower capacity greater than 3000 m3/d (0 PSIG to 5 PSIG)
2		Tank Top – New LP Flare Stack	LP FKOD LP Flare Stack Tank PVRVs	42 100 300 500 1000 3000	155,000	Separator and HP flare system may or may not be existing. Low Pressure flare stack capacity greater than 10,000 m3/d
3		Tank Top – Gas Lift Compression	Compressor (LP to gas lift injection pressure) Tank PVRVs	42 100 300 500 1000 3000	780,000	30 hp VRU required for 3000 m3/d. 30 hp is smaller than standard minimum compressor size
4		Tank Top – New Combustor	Combustor LP to HP Blower Tank PVRVs	42 100 300 500 1000 3000	235,000 245,000 340,000	No Separator and HP flare system. Integrated FKOD for cases up to 1000 m3/d
5		Separator – New Electrical Generator	Generator Flash Vessel	50 100 1400 2100 2800	245,000 295,000 348,000 395,000	Natural Gas Generators sized for 700 m3/d each. Tied into grid for sale of surplus energy.
6		Tank Top – New Electrical Generator	TEG Electrical Generators Tank PVRVs LP to HP Blower	50 700 1400 2100 2800	185,000 300,000 360,000 410,000 455,000	Largest available TEG capable of consuming 50 m3/d of gas. Minimum required supply pressure is 15 psig. Natural gas generators used for rates above 50m3/day.
7		New Flash Vessel to Existing HP Flare Stack	Flash Vessel	42 100 300 500 1000 3000	125,000	
8		Separator – New Combustor	Combustor Flash Vessel	42 100 300 500 1000 3000	200,000 210,000 285,000	Integrated FKOD for cases up to 1000 m3/d
9		Tank Top – VRU to Sales Compressor	Compressor (tank vent pressure to sales compressor suction pressure) Tank PVRVs	42 100 300 500 1000 2800 5700	430,000 465,000 480,000	15 hp Compressor up to 1000 e3m3/d. 25 hp Compressor up to 2800 e3m3/d. 50 hp Compressor up to 5700 e3m3/d
10		New Flash Vessel – Booster Compressor to Sales Compressor	Compressor (flash vessel pressure to sales compressor suction pressure) Flash Vessel	42 100 300 500 1000 3000	525,000	15 hp Compressor up to 3000 e3m3/d

Notes:

All equipment, including piping and vessels is sweet service only (<0.3 kPa partial pressure H2S)
Assume two existing 750 bbl storage tanks, with design pressure as low as atmospheric
Summer construction. For winter or severe weather, construction costs could increase by 10-15%.
Minimal travel time included (less than 1 hour per day). For remote locations, camps and/or addition construction time required
Mean Time Between Failures (MTBF) for electrical motors assumed to be 100,000 hours. Life expectancy of motors may be impacted if incorrect size of motor selected or supply power susceptible to surges or voltage and frequency variations.
No lease expansion required. Costs not included to acquire additional land
Existing leases assumed to be cleared and level with good access
Existing facilities have required electrical power, fuel gas, and/or propane. Upgrade of electrical service not included
Low Pressure vent header operating pressure - 0.5 psig
High Pressure vent header operating pressure - 5 psig
Separator operating pressure - 50 psig - 300 psig
Separator liquid and emulsion level controllers included to reduce instantaneous gas flashing inside storage tanks
Flash Vessel operating pressure - 25 psig
Rotary Vane compressor selected for VRU
Gas lift injection pressure - 1200 psig
Rotary screw compressors selected for gas lift and sales compressors
Sales gas compressor discharge pressure - 3000 psig
New gas meters not required for gas rates below 500 e3m3/d
New flare stack, incinerators, and combustors equipped with continuous spark ignitor and pilot
Costs are in Canadian currency.

Cost Estimate - Case 1 - Tank Top - Existing HP Flare Stack			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 27, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 1: General estimate of boosting tank vapour for HP flare tie in. New equipment includes low pressure blower, tank vapour header, tank PVRVs and low pressure header piping tied into the high pressure flare header.		

Notes: See Page 2 of Cases Summary

1) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%

Flow Rate [m3 per day]	Required Power [hp]	Required Power [kW]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 3000	2.3	2.14	$60,000	$194,865	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 17,000
	Piles for supports - c/w material	12	each	$ 1,000.00	$ 12,000	
	Gravel - site preparation	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 25,000
	Above Ground piping	2	lot	$ 10,000.00	$ 20,000	
	place building, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 8,000
	E & I Work	2	Day	$ 4,000.00	$ 8,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 17,715
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 17,715.00	$ 17,715	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,750
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,750.00	$ 1,750	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 17,000
	LP Vapour suction header and discharge PVF	1	lot	$ 15,000.00	$ 15,000	
	NPS 4 Header Piping	100	m	$ 20.00	$ 2,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 10,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 10,000.00	$ 10,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 3,000
	hydrovac	1	day	$ 3,000.00	$ 3,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 7,500
	blower and building	1	lot	$ 5,000.00	$ 5,000	
	PVF	1	lot	$ 2,500.00	$ 2,500	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 11,000
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	0	each	$ 2,500.00	$ -	
	ESD	0	each	$ 7,000.00	$ -	
	Gas Meter	0	each	$ 10,000.00	$ -	
					$ -	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 194,865	$ 194,865
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 194,865	$ 194,865

Cost Estimate - Case 2 - Tank Top - New LP Flare Stack			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project #:	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Fan Yang**	Rev:	**0**
Description:	Case 2: General estimate of installing a new low pressure flare stack for tank vapour. New equipment includes low pressure flare header, knockout drum, and flare stack.		

Notes: See Page 2 of Cases Summary

1) Pricing assumes 200 meters of 4" flare header

Flow Rate [m3 per day]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 13000	$53,000	$154,495	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 18,000
	Piles for supports - c/w material	12	each	$ 1,000.00	$ 12,000	
	Structural steel supports	1	lot	$ 3,500.00	$ 3,500	
	Gravel - site preparation	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 15,000
	Above ground piping	1	lot	$ 10,000.00	$ 10,000	
	erect stack, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 4,000
	E & I Work	1	Day	$ 4,000.00	$ 4,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 14,045
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 14,045.00	$ 14,045	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,050
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,050.00	$ 1,050	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ -
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 9,400
	NPS 4 Flare header Piping	200	m	$ 22.00	$ 4,400	
	PVF	1	lot	$ 5,000.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 5,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 5,000.00	$ 5,000	
					$ -	
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 3,000
	hydrovac	1	day	$ 3,000.00	$ 3,000	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 9,000**
	PVF	1	lot	$ 2,500.00	$ 2,500	
	Stack and FKOD	1	lot	$ 6,500.00	$ 6,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ -**
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 10,000**
	ESD	0	each	$ 7,000.00	$ -	
	PCV/LP flare divert	1	each	$ 4,000.00	$ 4,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	0	each	$ 2,500.00	$ -	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ -**
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ 18,000**
	Low pressure flare stack	1	each	$ 18,000.00	$ 18,000	
					$ -	
					$ -	
991	**MISCELLANEOUS**					**$ 35,000**
	Flare Knockout Drum	1	each	$ 35,000.00	$ 35,000	
					$ -	
sub	**SUBTOTAL DIRECT COSTS**				$ 154,495	$ 154,495
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 154,495	$ 154,495

Cost Estimate - Case 3 - Tank Top - Gas Lift Compression			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Fan Yang**	Rev:	**0**
Description:	Case 3: General estimate of boosting tank vapour and separator vapour for gas lift. New equipment includes VRU, vapour header with blanket gas, compressor and discharge piping tied back into the wellhead.		

Notes: See Page 2 of Cases Summary

1) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%

Flow Rate [m3 per day]	Required Power [hp]	Required Power [kW]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 50	0.5	0.47	$410,000	$779,075	Custom
50 to 100	1	0.93	$410,000	$779,075	Custom
100 to 300	3	2.80	$410,000	$779,075	Custom
300 to 500	5.5	5.13	$410,000	$779,075	Custom
500 to 1000	11	10.25	$410,000	$779,075	Custom
1000 to 3000	30	27.96	$410,000	$779,075	Custom

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 42,000
	Piles for supports - c/w material	35	each	$ 1,000.00	$ 35,000	
	structural steel	1	lot	$ 2,000.00	$ 2,000	
	gravel and site grading	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 75,000
	A/G piping	6	day	$ 10,000.00	$ 60,000	
	Place compressor, misc	1	day	$ 15,000.00	$ 15,000	
504	CONSTRUCTION LABOUR - E & I					$ 20,000
	E & I Work	5	Day	$ 4,000.00	$ 20,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 70,825
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 70,825.00	$ 70,825	
508	FIELD SUPERVISION					$ 14,000
	Construction Supervision	10	day	$ 1,400.00	$ 14,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	START-UP & COMMISSIONING	2	lot	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 5,250
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 5,250.00	$ 5,250	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 10,000
	Line locate	2	day	$ 1,500.00	$ 3,000	
	survey and locate piles	2	day	$ 3,500.00	$ 7,000	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 44,000
	VRU suction header and discharge PVF	1	lot	$ 40,000.00	$ 40,000	
	NPS 4 Header Piping	100	m	$ 22.00	$ 2,200	
	NPS 2 Header Piping	100	m	$ 18.00	$ 1,800	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 27,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 15,000.00	$ 15,000	
	VFD	1	each	$ 12,000.00	$ 12,000	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 6,000
	hydrovac	2	day	$ 3,000.00	$ 6,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 29,000
	VRU	1	lot	$ 6,500.00	$ 6,500	
	PVF	1	lot	$ 2,500.00	$ 2,500	
	Compressor	1	lot	$ 20,000.00	$ 20,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 410,000
	K201 - New Injection Compressor - Rotary Screw	1	each	$ 300,000.00	$ 300,000	
	K200 - 30 HP VRU - rotary vane	1	each	$ 110,000.00	$ 110,000	
536	INSTRUMENTATION MATERIAL					$ 20,000
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	1	each	$ 3,000.00	$ 3,000	
	Blanket gas PRV(s)	2	each	$ 2,500.00	$ 5,000	
	ESD	1	each	$ 7,000.00	$ 7,000	
	Gas Lift Meter Run	0	each	$ 10,000.00	$ -	
					$ -	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 779,075	$ 779,075
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 779,075	$ 779,075

Cost Estimate - Case 4 - Tank Top - New Combustor			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Fan Yang**	Rev:	**0**
Description:	Case 4: General estimate of installing a new high pressure combustor for tank and separator vapour. New equipment includes high pressure gas header, low pressure gas header with booster compressor, and combustor.		

Notes: See Page 2 of Cases Summary

1) Pricing assumes 200 meters of 4" gas header
2) Up to 1000m3 per day assume integrated knock out drum
3) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%

Flow Rate [m3 per day]	Required Power [hp]	Required Power [kW]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 500	0.35	0.33	$90,000	$235,180	Stock
501-1000	0.7	0.65	$100,000	$243,980	Stock
1001-6000	2	1.86	$140,000	$337,728	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 25,000
	Piles for supports - c/w material	15	each	$ 1,000.00	$ 15,000	
	Structural steel	1	lot	$ 5,000.00	$ 5,000	
	Gravel - site preparation	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 25,000
	A/G piping	2	lot	$ 10,000.00	$ 20,000	
	erect combustor, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 8,000
	E & I Work	2	Day	$ 4,000.00	$ 8,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 21,380
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 21,380.00	$ 21,380	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,750
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,750.00	$ 1,750	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 750
	Programming	1	day	$ 750.00	$ 750	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 11,900
	NPS 4 gas header Piping	200	m	$ 22.00	$ 4,400	
	LP Vapour suction header and discharge PVFF	1	lot	$ 7,500.00	$ 7,500	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 6,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 6,500.00	$ 6,500	
					$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 6,000
	hydrovac	2	day	$ 3,000.00	$ 6,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 12,000
	PVF	1	lot	$ 2,000.00	$ 2,000	
	Combustor	1	lot	$ 5,000.00	$ 5,000	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 12,500
	ESD	0	each	$ 7,000.00	$ -	
	PCV	1	each	$ 4,000.00	$ 4,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	gas PRV(s)	0	each	$ 2,500.00	$ -	
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ 30,000
	Combustor	1	each	$ 30,000.00	$ 30,000	
					$ -	
					$ -	
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 235,180	$ 235,180
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 235,180	$ 235,180

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 25,000
	Piles for supports - c/w material	15	each	$ 1,000.00	$ 15,000	
	Structural steel	1	lot	$ 5,000.00	$ 5,000	
	Gravel - site preparation	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 25,000
	A/G piping	2	lot	$ 10,000.00	$ 20,000	
	erect combustor, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 8,000
	E & I Work	2	Day	$ 4,000.00	$ 8,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 22,180
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 22,180.00	$ 22,180	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,750
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,750.00	$ 1,750	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 750
	Programming	1	day	$ 750.00	$ 750	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 11,900
	NPS 4 gas header Piping	200	m	$ 22.00	$ 4,400	
	LP Vapour suction header and discharge PVFF	1	lot	$ 7,500.00	$ 7,500	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 6,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 6,500.00	$ 6,500	
					$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 3,000
	hydrovac	1	day	$ 3,000.00	$ 3,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 12,000
	PVF	1	lot	$ 2,000.00	$ 2,000	
	Combustor	1	lot	$ 5,000.00	$ 5,000	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 12,500
	ESD	0	each	$ 7,000.00	$ -	
	PCV	1	each	$ 4,000.00	$ 4,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	gas PRV(s)	0	each	$ 2,500.00	$ -	
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ 40,000
	Combustor	1	each	$ 40,000.00	$ 40,000	
					$ -	
					$ -	
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 243,980	$ 243,980
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 243,980	$ 243,980

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 30,000
	Piles for supports - c/w material	20	each	$ 1,000.00	$ 20,000	
	Structural steel	1	lot	$ 5,000.00	$ 5,000	
	Gravel - site preparation	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 27,500
	A/G piping	2	lot	$ 10,000.00	$ 20,000	
	erect combustor, misc	1	lot	$ 7,500.00	$ 7,500	
504	CONSTRUCTION LABOUR - E & I					$ 8,000
	E & I Work	2	Day	$ 4,000.00	$ 8,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 30,703
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 30,702.50	$ 30,703	
508	FIELD SUPERVISION					$ 11,200
	Construction Supervision	8	day	$ 1,400.00	$ 11,200	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,925
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,925.00	$ 1,925	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,000
	Programming	1	day	$ 1,000.00	$ 1,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 13,400
	NPS 4 gas header Piping	200	m	$ 22.00	$ 4,400	
	LP Vapour suction header and discharge PVFF	1	lot	$ 9,000.00	$ 9,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 8,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 8,000.00	$ 8,000	
					$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 3,000
	hydrovac	1	day	$ 3,000.00	$ 3,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 17,000
	PVF	1	lot	$ 2,000.00	$ 2,000	
	Combustor	1	lot	$ 5,000.00	$ 5,000	
	FKOD	1	lot	$ 5,000.00	$ 5,000	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ 35,000
	Flare Knockout Drum	1	each	$ 35,000.00	$ 35,000	
					$ -	
					$ -	
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 29,000
	ESD	0	each	$ 7,000.00	$ -	
	PCV	2	each	$ 4,000.00	$ 8,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Gas meter	1	each	$ 10,000.00	$ 10,000	
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ 55,000
	Combustor	1	each	$ 55,000.00	$ 55,000	
					$ -	
					$ -	
991	MISCELLANEOUS					$ -
					$ -	
					$ -	
sub	SUBTOTAL DIRECT COSTS				$ 337,728	$ 337,728
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 337,728	$ 337,728

Cost Estimate - Case 5 - Separator - New Electrical Generator			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 5: General estimate of consuming gas in electrical generator. New equipment includes piping, flash vessel and electrical generator.		

Notes: See Page 2 of Cases Summary

1) Costs included for new generator(s) to be tied into existing electrical grid for sales of excess power.

Flow Rate [m3 per day]	Required Power [hp]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 700	N/A	$77,000	$245,663	Stock
700 to 1400	N/A	$114,000	$295,790	Stock
1400 to 2100	N/A	$151,000	$347,842	Stock
2100 to 2800	N/A	$188,000	$395,692	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 12,500
	Piles for supports - c/w material	10	each	$ 1,000.00	$ 10,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 19,000
	A/G piping	2	lot	$ 7,500.00	$ 15,000	
	structural steel and install	1	lot	$ 4,000.00	$ 4,000	
504	CONSTRUCTION LABOUR - E & I					$ 62,000
	E & I Work	3	Day	$ 4,000.00	$ 12,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 22,333
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 22,333.00	$ 22,333	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,330
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,330.00	$ 1,330	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 13,500
	LP Vapour suction header and discharge PVF	1	lot	$ 8,500.00	$ 8,500	
	NPS 2 Header Piping	25	m	$ 200.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 5,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 5,000.00	$ 5,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 1,500**
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 6,500**
	Vessel and generator	1	lot	$ 5,000.00	$ 5,000	
	PVF	1	lot	$ 1,500.00	$ 1,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 10,000**
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 37,000**
	Generator	1	each	$ 37,000.00	$ 37,000	
					$ -	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 245,663	$ 245,663
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 245,663	$ 245,663

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 16,500
	Piles for supports - c/w material	14	each	$ 1,000.00	$ 14,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 20,000
	A/G piping	2	lot	$ 8,000.00	$ 16,000	
	structural steel and install	1	lot	$ 4,000.00	$ 4,000	
504	CONSTRUCTION LABOUR - E & I					$ 62,000
	E & I Work	3	Day	$ 4,000.00	$ 12,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 26,890
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 26,890.00	$ 26,890	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	2	day	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,400
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,400.00	$ 1,400	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 15,000
	LP Vapour suction header and discharge PVF	1	lot	$ 9,000.00	$ 9,000	
	NPS 2 Header Piping	30	m	$ 200.00	$ 6,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 5,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 5,000.00	$ 5,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 1,500**
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 6,500**
	Vessel and generator	1	lot	$ 5,000.00	$ 5,000	
	PVF	1	lot	$ 1,500.00	$ 1,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 11,000**
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 3,500.00	$ 3,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 74,000**
	Generator	2	each	$ 37,000.00	$ 74,000	
					$ -	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 295,790	$ 295,790
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 295,790	$ 295,790

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 20,500
	Piles for supports - c/w material	18	each	$ 1,000.00	$ 18,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 21,000
	A/G piping	2	lot	$ 8,500.00	$ 17,000	
	structural steel and install	1	lot	$ 4,000.00	$ 4,000	
504	CONSTRUCTION LABOUR - E & I					$ 62,750
	E & I Work	3	Day	$ 4,250.00	$ 12,750	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 31,622
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 31,622.00	$ 31,622	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	2	day	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,470
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,470.00	$ 1,470	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 16,500
	LP Vapour suction header and discharge PVF	1	lot	$ 9,500.00	$ 9,500	
	NPS 2 Header Piping	35	m	$ 200.00	$ 7,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 5,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 5,000.00	$ 5,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 1,500**
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 9,000**
	Vessel and generator	1	lot	$ 7,500.00	$ 7,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 11,500**
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 4,000.00	$ 4,000	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 111,000**
	Generator	3	each	$ 37,000.00	$ 111,000	
					$ -	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 347,842	$ 347,842
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 347,842	$ 347,842

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 24,500
	Piles for supports - c/w material	22	each	$ 1,000.00	$ 22,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 21,000
	A/G piping	2	lot	$ 8,500.00	$ 17,000	
	structural steel and install	1	lot	$ 4,000.00	$ 4,000	
504	CONSTRUCTION LABOUR - E & I					$ 62,750
	E & I Work	3	Day	$ 4,250.00	$ 12,750	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 35,972
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 35,972.00	$ 35,972	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	2	day	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,470
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,470.00	$ 1,470	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 16,500
	LP Vapour suction header and discharge PVF	1	lot	$ 9,500.00	$ 9,500	
	NPS 2 Header Piping	35	m	$ 200.00	$ 7,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 5,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 5,000.00	$ 5,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 1,500**
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 11,500**
	Vessel and generator	1	lot	$ 10,000.00	$ 10,000	
	PVF	1	lot	$ 1,500.00	$ 1,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 11,500**
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 4,000.00	$ 4,000	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 148,000**
	Generator	4	each	$ 37,000.00	$ 148,000	
					$ -	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 395,692	$ 395,692
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 395,692	$ 395,692

Cost Estimate - Case 6 - Tank Top - New Electrical Generator(s)			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 6: General estimate of consuming gas in thermoelectric generator. New equipment includes piping, LP to HP blower and generator(s).		

Notes: See Page 2 of Cases Summary

1) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%
2) For gas rates up to 50 m3 per day, a thermoelectric generator will be installed
3) For gas rates above 50 m3 per day, electrical generator(s) will be installed with costs included to be tied into existing electrical grid for sales of excess power

Flow Rate [m3 per day]	Required Power [hp]	Required Power [kW]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 50	0.2	0.19	$91,000	$183,480	Stock
50 to 700	0.4	0.37	$128,000	$300,751	Stock
700 to 1400	0.8	0.75	$165,000	$357,918	Stock
1400 to 2100	1.1	1.03	$202,000	$407,457	Stock
2100 to 2800	1.5	1.40	$239,000	$454,795	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 5,500
	Piles for supports - c/w material	4	each	$ 1,000.00	$ 4,000	
	Gravel, site prep	1	lot	$ 1,500.00	$ 1,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 10,000
	A/G piping	1	lot	$ 5,000.00	$ 5,000	
	place building, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 8,000
	E & I Work	2	Day	$ 4,000.00	$ 8,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 16,680
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 16,680.00	$ 16,680	
508	FIELD SUPERVISION					$ 5,600
	Construction Supervision	4	day	$ 1,400.00	$ 5,600	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 700
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 700.00	$ 700	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 11,000
	LP Vapour suction header and discharge PVFF	1	lot	$ 5,000.00	$ 5,000	
	NPS 2 Header Piping	30	m	$ 200.00	$ 6,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 6,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 6,000.00	$ 6,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 1,500
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 10,000
	TEG	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 11,000
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	0	each	$ 2,500.00	$ -	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
					$ -	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ 31,000
	Thermoelectric generator	1	each	$ 31,000.00	$ 31,000	
					$ -	
					$ -	
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 183,480	$ 183,480
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 183,480	$ 183,480

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 8,500
	Piles for supports - c/w material	6	each	$ 1,000.00	$ 6,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 13,000
	A/G piping	1	lot	$ 6,000.00	$ 6,000	
	place building, misc	1	lot	$ 6,500.00	$ 6,500	
	structural steel and install	1	lot	$ 500.00	$ 500	
504	CONSTRUCTION LABOUR - E & I					$ 59,000
	E & I Work	2	Day	$ 4,500.00	$ 9,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 27,341
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 27,341.00	$ 27,341	
508	FIELD SUPERVISION					$ 7,000
	Construction Supervision	5	day	$ 1,400.00	$ 7,000	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 2,000
	Commissioning	2	day	$ 1,000.00	$ 2,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 910
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 910.00	$ 910	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 14,000
	LP Vapour suction header and discharge PVFF	1	lot	$ 6,000.00	$ 6,000	
	NPS 2 Header Piping	40	m	$ 200.00	$ 8,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 7,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 7,500.00	$ 7,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 1,500
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 12,500
	TEG	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	Generator	1	lot	$ 2,500.00	$ 2,500	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 13,500
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ 68,000
	Thermoelectric generator	1	each	$ 31,000.00	$ 31,000	
	Generator	1	each	$ 37,000.00	$ 37,000	
					$ -	
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 300,751	$ 300,751
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 300,751	$ 300,751

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 10,500
	Piles for supports - c/w material	8	each	$ 1,000.00	$ 8,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 14,000
	A/G piping	1	lot	$ 7,000.00	$ 7,000	
	place building, misc	1	lot	$ 6,500.00	$ 6,500	
	structural steel and install	1	lot	$ 500.00	$ 500	
504	CONSTRUCTION LABOUR - E & I					$ 60,000
	E & I Work	2	Day	$ 5,000.00	$ 10,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 32,538
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 32,538.00	$ 32,538	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	3	day	$ 1,000.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 980
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 980.00	$ 980	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 15,500
	LP Vapour suction header and discharge PVFF	1	lot	$ 6,500.00	$ 6,500	
	NPS 2 Header Piping	45	m	$ 200.00	$ 9,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 7,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 7,500.00	$ 7,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 3,000**
	hydrovac	2	day	$ 1,500.00	$ 3,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 12,500**
	TEG	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	generators	1	lot	$ 2,500.00	$ 2,500	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ -**
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ 60,000**
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	**INSTRUMENTATION MATERIAL**					**$ 19,000**
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	3	each	$ 3,000.00	$ 9,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	2	lot	$ 2,500.00	$ 5,000	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 105,000**
	Thermoelectric generator	1	each	$ 31,000.00	$ 31,000	
	Generator	2	each	$ 37,000.00	$ 74,000	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 357,918	$ 357,918
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 357,918	$ 357,918

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 12,500
	Piles for supports - c/w material	10	each	$ 1,000.00	$ 10,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 14,500
	A/G piping	1	lot	$ 7,500.00	$ 7,500	
	place building, misc	1	lot	$ 6,500.00	$ 6,500	
	structural steel and install	1	lot	$ 500.00	$ 500	
504	CONSTRUCTION LABOUR - E & I					$ 61,000
	E & I Work	2	Day	$ 5,500.00	$ 11,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 37,042
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 37,041.50	$ 37,042	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	3	day	$ 1,000.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,015
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,015.00	$ 1,015	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 17,000
	LP Vapour suction header and discharge PVFF	1	lot	$ 7,000.00	$ 7,000	
	NPS 2 Header Piping	50	m	$ 200.00	$ 10,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 8,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 8,000.00	$ 8,000	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 3,000
	hydrovac	2	day	$ 1,500.00	$ 3,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 15,000
	TEG	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	generators	2	lot	$ 2,500.00	$ 5,000	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 60,000
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	INSTRUMENTATION MATERIAL					$ 19,000
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	3	each	$ 3,000.00	$ 9,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	2	lot	$ 2,500.00	$ 5,000	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ 142,000
	Thermoelectric generator	1	each	$ 31,000.00	$ 31,000	
	Generator	3	each	$ 37,000.00	$ 111,000	
					$ -	
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 407,457	$ 407,457
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 407,457	$ 407,457

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 15,000
	Piles for supports - c/w material	12	each	$ 1,000.00	$ 12,000	
	Gravel, site prep	1	lot	$ 3,000.00	$ 3,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 15,000
	A/G piping	1	lot	$ 8,000.00	$ 8,000	
	place building, misc	1	lot	$ 6,500.00	$ 6,500	
	structural steel and install	1	lot	$ 500.00	$ 500	
504	CONSTRUCTION LABOUR - E & I					$ 62,000
	E & I Work	2	Day	$ 6,000.00	$ 12,000	
	Tie Power in to grid for buyback	1	lot	$ 50,000.00	$ 50,000	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 41,345
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 41,345.00	$ 41,345	
508	FIELD SUPERVISION					$ 8,400
	Construction Supervision	6	day	$ 1,400.00	$ 8,400	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	Commissioning	3	day	$ 1,000.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,050
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,050.00	$ 1,050	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 3,000
	Programming	2	day	$ 1,500.00	$ 3,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 18,500
	LP Vapour suction header and discharge PVFF	1	lot	$ 7,500.00	$ 7,500	
	NPS 2 Header Piping	55	m	$ 200.00	$ 11,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 8,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 8,500.00	$ 8,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 3,000**
	hydrovac	2	day	$ 1,500.00	$ 3,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 15,000**
	TEG	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	generators	2	lot	$ 2,500.00	$ 5,000	
	blower and building	1	lot	$ 5,000.00	$ 5,000	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ -**
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ 60,000**
	3hp Blower	1	each	$ 30,000.00	$ 30,000	
	Building and skid	1	each	$ 30,000.00	$ 30,000	
536	**INSTRUMENTATION MATERIAL**					**$ 19,000**
	Pressure & temperature transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	3	each	$ 3,000.00	$ 9,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	2	lot	$ 2,500.00	$ 5,000	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ 179,000**
	Thermoelectric generator	1	each	$ 31,000.00	$ 31,000	
	Generator	4	each	$ 37,000.00	$ 148,000	
					$ -	
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 454,795	$ 454,795
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 454,795	$ 454,795

Cost Estimate - Case 7 - Separator - New Flash Vessel			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 7: General estimate of adding flash vessel to reduce tank emissions. New equipment includes piping and flash vessel.		

Notes: See Page 2 of Cases Summary

1) Site has existing HP flare system including flare stack and flare knock out drum

Flow Rate [m3 per day]	Required Power [hp]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 3000	N/A	$40,000	$124,696	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 10,500
	Piles for supports - c/w material	8	each	$ 1,000.00	$ 8,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 18,000
	A/G piping	2	lot	$ 7,000.00	$ 14,000	
	structural steel and install	1	lot	$ 4,000.00	$ 4,000	
504	CONSTRUCTION LABOUR - E & I					$ 2,500
	E & I Work	1	Day	$ 2,500.00	$ 2,500	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 11,336
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 11,336.00	$ 11,336	
508	FIELD SUPERVISION					$ 5,600
	Construction Supervision	4	day	$ 1,400.00	$ 5,600	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,260
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,260.00	$ 1,260	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 3,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 1,500.00	$ 1,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 13,500
	LP Vapour suction header and discharge PVF	1	lot	$ 8,500.00	$ 8,500	
	NPS 2 Header Piping	25	m	$ 200.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 2,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 2,500.00	$ 2,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 1,500**
	hydrovac	1	day	$ 1,500.00	$ 1,500	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 5,000**
	Vessel	1	lot	$ 3,500.00	$ 3,500	
	PVF	1	lot	$ 1,500.00	$ 1,500	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 7,500**
	Level transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ -**
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ -**
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 124,696	$ 124,696
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 124,696	$ 124,696

Cost Estimate - Case 8 - Separator - New Combustor			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 8: General estimate of installing a new high pressure combustor for separator vapour. New equipment includes piping, flash vessel and combustor.		

Notes: See Page 2 of Cases Summary

1) Pricing assumes 200 meters of 4" gas header

2) Up to 1000m3 per day assume integrated knock out drum

Flow Rate [m3 per day]	Required Power [hp]	Major Equipment Cost ($)	Total Installed Cost ($)	Availability
Up to 500	N/A	$70,000	$197,043	Stock
Up to 1000	N/A	$80,000	$208,043	Stock
1000 to 3000	N/A	$130,000	$283,476	Stock

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 28,500
	Piles for supports - c/w material	20	each	$ 1,000.00	$ 20,000	
	Structural steel	1	lot	$ 6,000.00	$ 6,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 19,000
	A/G piping	2	lot	$ 7,000.00	$ 14,000	
	erect combustor, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 5,000
	E & I Work	2	Day	$ 2,500.00	$ 5,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 17,913
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 17,913.00	$ 17,913	
508	FIELD SUPERVISION					$ 9,800
	Construction Supervision	7	day	$ 1,400.00	$ 9,800	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,330
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,330.00	$ 1,330	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 12,500
	LP Vapour suction header and discharge PVF	1	lot	$ 7,500.00	$ 7,500	
	NPS 2 Header Piping	25	m	$ 200.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 3,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 3,500.00	$ 3,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 2,000**
	hydrovac	1	day	$ 2,000.00	$ 2,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 10,000**
	Vessel	1	lot	$ 3,500.00	$ 3,500	
	FKOD	0	lot	$ 5,000.00	$ -	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	combustor	1	lot	$ 5,000.00	$ 5,000	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
	Flare Knockout Drum	0	each	$ 35,000.00	$ -	
					$ -	
					$ -	
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 10,000**
	Level transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	2	each	$ 2,500.00	$ 5,000	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ -**
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ 30,000**
	Combustor	1	each	$ 30,000.00	$ 30,000	
					$ -	
					$ -	
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 197,043	$ 197,043
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 197,043	$ 197,043

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 28,500
	Piles for supports - c/w material	20	each	$ 1,000.00	$ 20,000	
	Structural steel	1	lot	$ 6,000.00	$ 6,000	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 19,000
	A/G piping	2	lot	$ 7,000.00	$ 14,000	
	erect combustor, misc	1	lot	$ 5,000.00	$ 5,000	
504	CONSTRUCTION LABOUR - E & I					$ 5,000
	E & I Work	2	Day	$ 2,500.00	$ 5,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 18,913
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 18,913.00	$ 18,913	
508	FIELD SUPERVISION					$ 9,800
	Construction Supervision	7	day	$ 1,400.00	$ 9,800	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,330
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,330.00	$ 1,330	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 12,500
	LP Vapour suction header and discharge PVF	1	lot	$ 7,500.00	$ 7,500	
	NPS 2 Header Piping	25	m	$ 200.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 3,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 3,500.00	$ 3,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 2,000**
	hydrovac	1	day	$ 2,000.00	$ 2,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 10,000**
	Vessel	1	lot	$ 3,500.00	$ 3,500	
	FKOD	0	lot	$ 5,000.00	$ -	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	combustor	1	lot	$ 5,000.00	$ 5,000	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ -**
	Flare Knockout Drum	0	each	$ 35,000.00	$ -	
					$ -	
					$ -	
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 10,000**
	Level transmitters	1	lot	$ 2,500.00	$ 2,500	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	2	each	$ 2,500.00	$ 5,000	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ -**
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ 40,000**
	Combustor	1	each	$ 40,000.00	$ 40,000	
					$ -	
					$ -	
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 208,043	$ 208,043
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 208,043	$ 208,043

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 34,000
	Piles for supports - c/w material	25	each	$ 1,000.00	$ 25,000	
	Structural steel	1	lot	$ 6,500.00	$ 6,500	
	Gravel, site prep	1	lot	$ 2,500.00	$ 2,500	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 21,500
	A/G piping	2	lot	$ 7,000.00	$ 14,000	
	erect combustor, misc	1	lot	$ 7,500.00	$ 7,500	
504	CONSTRUCTION LABOUR - E & I					$ 5,000
	E & I Work	2	Day	$ 2,500.00	$ 5,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 25,771
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 25,770.50	$ 25,771	
508	FIELD SUPERVISION					$ 11,200
	Construction Supervision	8	day	$ 1,400.00	$ 11,200	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 1,000
	Commissioning	1	day	$ 1,000.00	$ 1,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 1,505
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 1,505.00	$ 1,505	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 5,000
	Line locate	1	day	$ 1,500.00	$ 1,500	
	survey and locate piles	1	day	$ 3,500.00	$ 3,500	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 1,500
	Programming	1	day	$ 1,500.00	$ 1,500	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 14,000
	LP Vapour suction header and discharge PVF	1	lot	$ 9,000.00	$ 9,000	
	NPS 2 Header Piping	25	m	$ 200.00	$ 5,000	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 3,500
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 3,500.00	$ 3,500	
	VFD	0	each	$ 12,000.00	$ -	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	**DESCRIPTION**	**QUANTITY**	**UNITS**	**UNIT COST**	**Sub Total**	**Code Total**
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					**$ 2,000**
	hydrovac	1	day	$ 2,000.00	$ 2,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					**$ 15,000**
	Vessel	1	lot	$ 3,500.00	$ 3,500	
	FKOD	1	lot	$ 5,000.00	$ 5,000	
	PVF	1	lot	$ 1,500.00	$ 1,500	
	combustor	1	lot	$ 5,000.00	$ 5,000	
531	**EQUIPMENT RENTALS**					**$ -**
532	**STORAGE TANKS**					**$ 35,000**
	Flare Knockout Drum	1	each	$ 35,000.00	$ 35,000	
					$ -	
					$ -	
533	**PRESSURE VESSELS**					**$ 40,000**
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	**HEAT EXCHANGERS**					**$ -**
535	**COMPRESSORS**					**$ -**
536	**INSTRUMENTATION MATERIAL**					**$ 12,500**
	Level transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	0	each	$ 3,000.00	$ -	
	Gas PRV(s)	2	each	$ 2,500.00	$ 5,000	
	ESD	0	each	$ 7,000.00	$ -	
	Blower Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 2,500.00	$ 2,500	
537	**SAFETY & PROTECTIVE EQUIPMENT**					**$ -**
538	**ELECTRICAL EQUIPMENT**					**$ -**
539	**SPECIAL EQUIPMENT**					**$ -**
540	**PUMPS/PUMPJACKS**					**$ -**
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					**$ -**
543	**COMPOSITE / PLASTIC PIPE**					**$ -**
544	**FIRED HEATERS & BOILERS**					**$ -**
550	**PRIME MOVER (ENGINES/MOTORS)**					**$ -**
551	**FLARE STACK**					**$ 55,000**
	Combustor	1	each	$ 55,000.00	$ 55,000	
					$ -	
					$ -	
565	**WAREHOUSE HANDLING**					**$ -**
991	**MISCELLANEOUS**					**$ -**
sub	**SUBTOTAL DIRECT COSTS**				$ 283,476	$ 283,476
990	**ESTIMATED CONTINGENCY**					**$ -**
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 283,476	$ 283,476

Cost Estimate - Case 9 - Tank Top - New VRU Package Installation			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Fan Yang**	Rev:	**0**
Description:	Case 9: General estimate to boost tank vapour for sales. New equipment includes vapour header, VRU compressor, and discharge piping tied into existing sales compressor.		

Notes: See Page 2 of Cases Summary

1) VRU pricing assumes an inlet pressure of 0 psig and discharge pressure of 150 psig, for gas with Specific Gravity of approximately 0.9 or lower

2) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%

VRU Package Options:

Sour Service $20,000 to $40,000 (or 25% to 30% of base price)

Other VRU Sizes and Reference Costs

Flow Rate [m3 per day]	Power Rating (hp)	Required Power [hp]	Required Power [kW]	VRU Cost ($)	Total Installed Cost ($)
up to 1000	15	6	5.59	$85,000	$428,945
2800	25	18	16.78	$110,000	$461,945
5700	50	33	30.76	$120,000	$477,345

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 35,000
	Piles for supports - c/w material	30	each	$ 1,000.00	$ 30,000	
	gravel and site grading	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 75,000
	A/G piping	6	day	$ 10,000.00	$ 60,000	
	Place compressor, misc	1	day	$ 15,000.00	$ 15,000	
504	CONSTRUCTION LABOUR - E & I					$ 24,000
	E&I work	6	day	$ 4,000.00	$ 24,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 38,995
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 38,995.00	$ 38,995	
508	FIELD SUPERVISION					$ 16,800
	Construction Supervision	12	day	$ 1,400.00	$ 16,800	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	START-UP & COMMISSIONING	2	lot	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 5,250
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 5,250.00	$ 5,250	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 10,000
	Line locate	2	day	$ 1,500.00	$ 3,000	
	survey and locate piles	2	day	$ 3,500.00	$ 7,000	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 6,000
	Programming	4	day	$ 1,500.00	$ 6,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 54,400
	NPS 4 suction header and NPS 2 discharge PVFF	1	lot	$ 50,000.00	$ 50,000	
	NPS 4 Flare header Piping	200	m	$ 22.00	$ 4,400	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 32,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 25,000.00	$ 25,000	
	VFD	1	each	$ 7,000.00	$ 7,000	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 12,000
	hydrovac	4	day	$ 3,000.00	$ 12,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 11,000
	VRU	1	lot	$ 7,500.00	$ 7,500	
	PVF	1	lot	$ 3,500.00	$ 3,500	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 85,000
	15 HP VRU	1	each	$ 85,000.00	$ 85,000	
536	INSTRUMENTATION MATERIAL					$ 20,500
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	1	each	$ 7,000.00	$ 7,000	
	Sales Gas Meter Run	0	each	$ 10,000.00	$ -	
					$ -	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 428,945	$ 428,945
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 428,945	$ 428,945

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 35,000
	Piles for supports - c/w material	30	each	$ 1,000.00	$ 30,000	
	gravel and site grading	1	lot	$ 5,000.00	$ 5,000	
					$ -	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 75,000
	A/G piping	6	day	$ 10,000.00	$ 60,000	
	Place compressor, misc	1	day	$ 15,000.00	$ 15,000	
					$ -	
					$ -	
					$ -	
504	CONSTRUCTION LABOUR - E & I					$ 24,000
	E&I work	6	day	$ 4,000.00	$ 24,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 41,995
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 41,995.00	$ 41,995	
508	FIELD SUPERVISION					$ 16,800
	Construction Supervision	12	day	$ 1,400.00	$ 16,800	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	START-UP & COMMISSIONING	2	lot	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 5,250
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 5,250.00	$ 5,250	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 10,000
	Line locate	2	day	$ 1,500.00	$ 3,000	
	survey and locate piles	2	day	$ 3,500.00	$ 7,000	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 6,000
	Programming	4	day	$ 1,500.00	$ 6,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 54,400
	NPS 4 suction header and NPS 2 discharge PVFF	1	lot	$ 50,000.00	$ 50,000	
	NPS 4 Flare header Piping	200	m	$ 22.00	$ 4,400	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 37,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 25,000.00	$ 25,000	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
	VFD	1	each	$ 12,000.00	$ 12,000	
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 12,000
	hydrovac	4	day	$ 3,000.00	$ 12,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 11,000
	VRU	1	lot	$ 7,500.00	$ 7,500	
	PVF	1	lot	$ 3,500.00	$ 3,500	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ -
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 110,000
	25 HP VRU	1	each	$ 110,000.00	$ 110,000	
536	INSTRUMENTATION MATERIAL					$ 20,500
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	1	each	$ 7,000.00	$ 7,000	
	Sales Gas Meter Run	0	each	$ 10,000.00	$ -	
					$ -	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
sub	SUBTOTAL DIRECT COSTS				$ 461,945	$ 461,945
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 461,945	$ 461,945

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 35,000
	Piles for supports - c/w material	30	each	$ 1,000.00	$ 30,000	
	gravel and site grading	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 75,000
	A/G piping	6	day	$ 10,000.00	$ 60,000	
	Place compressor, misc	1	day	$ 15,000.00	$ 15,000	
					$ -	
					$ -	
					$ -	
504	CONSTRUCTION LABOUR - E & I					$ 24,000
	E&I work	6	day	$ 4,000.00	$ 24,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 43,395
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 43,395.00	$ 43,395	
508	FIELD SUPERVISION					$ 16,800
	Construction Supervision	12	day	$ 1,400.00	$ 16,800	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	START-UP & COMMISSIONING	2	lot	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 5,250
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 5,250.00	$ 5,250	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 10,000
	Line locate	2	day	$ 1,500.00	$ 3,000	
	survey and locate piles	2	day	$ 3,500.00	$ 7,000	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 6,000
	Programming	4	day	$ 1,500.00	$ 6,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 54,400
	NPS 4 suction header and NPS 2 discharge PVFF	1	lot	$ 50,000.00	$ 50,000	
	NPS 4 Flare header Piping	200	m	$ 22.00	$ 4,400	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 41,000

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 25,000.00	$ 25,000	
	VFD	1	each	$ 16,000.00	$ 16,000	
529	**HEATING / PRESSURE / VAC TRUCKS / HYDROVAC**					$ 12,000
	hydrovac	4	day	$ 3,000.00	$ 12,000	
					$ -	
530	**EQUIPMENT & MATERIAL HAULING**					$ 11,000
	VRU	1	lot	$ 7,500.00	$ 7,500	
	PVF	1	lot	$ 3,500.00	$ 3,500	
531	**EQUIPMENT RENTALS**					$ -
532	**STORAGE TANKS**					$ -
533	**PRESSURE VESSELS**					$ -
534	**HEAT EXCHANGERS**					$ -
535	**COMPRESSORS**					$ 120,000
	50 HP VRU	1	each	$ 120,000.00	$ 120,000	
536	**INSTRUMENTATION MATERIAL**					$ 20,500
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	2	each	$ 3,000.00	$ 6,000	
	Blanket gas PRV(s)	1	each	$ 2,500.00	$ 2,500	
	ESD	1	each	$ 7,000.00	$ 7,000	
	Sales Gas Meter Run	0	each	$ 10,000.00	$ -	
					$ -	
537	**SAFETY & PROTECTIVE EQUIPMENT**					$ -
538	**ELECTRICAL EQUIPMENT**					$ -
539	**SPECIAL EQUIPMENT**					$ -
540	**PUMPS/PUMPJACKS**					$ -
541	**PACKAGE UNITS - PROCESS EQUIPMENT**					$ -
543	**COMPOSITE / PLASTIC PIPE**					$ -
544	**FIRED HEATERS & BOILERS**					$ -
550	**PRIME MOVER (ENGINES/MOTORS)**					$ -
551	**FLARE STACK**					$ -
565	**WAREHOUSE HANDLING**					$ -
991	**MISCELLANEOUS**					$ -
sub	**SUBTOTAL DIRECT COSTS**				$ 477,345	$ 477,345
990	**ESTIMATED CONTINGENCY**					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 477,345	$ 477,345

Cost Estimate - Case 10 - Separator - New Flash Vessel and Booster Compressor Package Installation			
Project:	**Investigation of Fugitive and Venting Emissions from Fixed-Roof Storage Tanks**	Vanguard Project	**CEL-18001**
		Date:	**September 26, 2019**
Prepared By:	**Duane Biblow**	Rev:	**0**
Description:	Case 10: General estimate to boost separator vapour for sales. New equipment includes flash vessel, booster compressor compressor, and discharge piping tied into existing sales compressor.		

Notes: See Page 2 of Cases Summary

1) Booster Compressor pricing assumes an inlet pressure of 20 psig and discharge pressure of 150 psig, for gas with Specific Gravity of approximately 0.9 or lower

2) For power consumption assume TEFC motor running at 1200 rpm with an efficiency of 80%

Other VRU Sizes and Reference Costs

Flow Rate [m3 per day]	Power Rating (hp)	Required Power [hp]	Required Power [kW]	VRU Cost ($)	Total Installed Cost ($)
3000	15	12	11.19	$125,000	$522,126

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
500	TRAVEL - PERSONAL / RENTAL VEHICLE					$ -
501	MEALS & ENTERTAINMENT					$ -
502	CONSTRUCTION LABOUR / MATERIALS - CIVIL					$ 43,000
	Piles for supports - c/w material	38	each	$ 1,000.00	$ 38,000	
	gravel and site grading	1	lot	$ 5,000.00	$ 5,000	
503	CONSTRUCTION LABOUR - MECHANICAL					$ 88,000
	A/G piping	6	day	$ 10,000.00	$ 60,000	
	structural steel and install	2	lot	$ 4,000.00	$ 8,000	
	Place compressor, vessel, misc	2	day	$ 10,000.00	$ 20,000	
504	CONSTRUCTION LABOUR - E & I					$ 24,000
	E&I work	6	day	$ 4,000.00	$ 24,000	
					$ -	
505	TECHNICAL SUPPORT SERVICES					$ -
506	ENGINEERING DESIGN					$ 47,466
	Mechanical, civil and E/I (10% of direct costs)	1	lot	$ 47,466.00	$ 47,466	
508	FIELD SUPERVISION					$ 19,600
	Construction Supervision	14	day	$ 1,400.00	$ 19,600	
					$ -	
					$ -	
509	START-UP & COMMISSIONING					$ 3,000
	START-UP & COMMISSIONING	2	lot	$ 1,500.00	$ 3,000	
					$ -	
510	PIPELINE SERVICES					$ -
511	X-RAY / EQUIPMENT & MATERIAL INSPECTION					$ 6,160
	Estimated @ 7% of construction labour - mechanical	1	lot	$ 6,160.00	$ 6,160	
					$ -	
512	ENVIRONMENTAL					$ -
513	ACCESS ROADS					$ -
514	SURVEY & LINE LOCATING					$ 11,000
	Line locate	2	day	$ 1,500.00	$ 3,000	
	survey and locate piles	2	day	$ 4,000.00	$ 8,000	
515	SITE CLEAN-UP & TIMBER SALVAGE					$ -
516	CAMP & CATERING COSTS					$ -
517	MATERIAL DISPOSAL					$ -
518	COMMUNICATIONS					$ 6,000
	Programming	4	day	$ 1,500.00	$ 6,000	
519	BUILDINGS					$ -
520	SURFACE LAND COSTS - EASEMENTS					$ -
521	NEW ACQUISITIONS FIRST NATIONS CONSULT					$ -
522	SURFACE LAND COSTS / DAMAGES					$ -
523	BONDS, PERMITS & INSURANCE					$ -
524	TEMPORARY STORAGE & HAULING					$ -
526	PIPE, VALVES AND FITTINGS					$ 64,400
	NPS 4 suction header and NPS 2 discharge PVFF	1	lot	$ 60,000.00	$ 60,000	
	NPS 4 Flare header Piping	200	m	$ 22.00	$ 4,400	
527	CHEMICALS & CATALYSTS					$ -
528	ELECTRICAL MATERIALS					$ 32,000
	Cable, cable tray, fittings, heat trace, etc.	1	lot	$ 25,000.00	$ 25,000	
	VFD	1	each	$ 7,000.00	$ 7,000	

Project:	Tank Venting Emissions Reduction			Cost Estimate Work Sheet		
Minor	DESCRIPTION	QUANTITY	UNITS	UNIT COST	Sub Total	Code Total
529	HEATING / PRESSURE / VAC TRUCKS / HYDROVAC					$ 12,000
	hydrovac	4	day	$ 3,000.00	$ 12,000	
					$ -	
530	EQUIPMENT & MATERIAL HAULING					$ 14,500
	VRU	1	lot	$ 7,500.00	$ 7,500	
	PVF	1	lot	$ 3,500.00	$ 3,500	
	vessel	1	lot	$ 3,500.00	$ 3,500	
531	EQUIPMENT RENTALS					$ -
532	STORAGE TANKS					$ -
533	PRESSURE VESSELS					$ 40,000
	Flash Vessel (36"od x 30 ft)	1	each	$ 40,000.00	$ 40,000	
					$ -	
534	HEAT EXCHANGERS					$ -
535	COMPRESSORS					$ 85,000
	15 HP VRU	1	each	$ 85,000.00	$ 85,000	
536	INSTRUMENTATION MATERIAL					$ 26,000
	Pressure & temperature transmitters	2	lot	$ 2,500.00	$ 5,000	
	PVRV(s)	3	each	$ 3,000.00	$ 9,000	
	Blanket gas PRV(s)	0	each	$ 2,500.00	$ -	
	ESD	1	each	$ 7,000.00	$ 7,000	
	Sales Gas Meter Run	0	each	$ 10,000.00	$ -	
	misc	1	lot	$ 5,000.00	$ 5,000	
537	SAFETY & PROTECTIVE EQUIPMENT					$ -
538	ELECTRICAL EQUIPMENT					$ -
539	SPECIAL EQUIPMENT					$ -
540	PUMPS/PUMPJACKS					$ -
541	PACKAGE UNITS - PROCESS EQUIPMENT					$ -
543	COMPOSITE / PLASTIC PIPE					$ -
544	FIRED HEATERS & BOILERS					$ -
550	PRIME MOVER (ENGINES/MOTORS)					$ -
551	FLARE STACK					$ -
565	WAREHOUSE HANDLING					$ -
991	MISCELLANEOUS					$ -
					$ -	
					$ -	
sub	SUBTOTAL DIRECT COSTS				$ 522,126	$ 522,126
990	ESTIMATED CONTINGENCY					$ -
	Contingency @ 0%				$ -	
	TOTAL DIRECT COSTS				$ 522,126	$ 522,126