



This document starts at page 73 of 241 of the publicly available document "SUBTASK 1.3 – INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION", Topical Report, U.S. Department of Energy, Co-operative Agreement DE-FE0024233, Energy & Environmental Research Center, University of North Dakota, May 2020 - which was available at <https://www.osti.gov/servlets/purl/1631156> on 30 Jan 2026

**RED TRAIL ENERGY CO₂ CAPTURE FACILITY PHASE III
COST ESTIMATE AND PROCESS DESIGN PACKAGE
ENERGY AND ENVIRONMENTAL RESEARCH CENTER**

This document has been revised as indicated below and described in the revision record on the following page. Please destroy all previous revisions.

Rev N°	Date	Originator's Name & Initials	Reviewed/Checked By Name & Initials	Description	Pages
0	09/30/19	BDP/AEV	RWM	Final Report	ALL
1	11/20/19	BDP		Revised for Content	ALL



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1 Summary and Conclusions

In this phase of the CO₂ capture and sequestration project at the Red Trail Energy (RTE) ethanol facility in Richardton, North Dakota, Trimeric developed a process design package (PDP) for a CO₂ liquefaction facility. The facility captures carbon dioxide produced in RTE's fermentation process, compresses the CO₂ up to approximately 350 psig, dehydrates the gas, and then liquefies it using a closed-loop ammonia refrigeration process. A conventional distillation column distills the liquid CO₂ to remove oxygen, in addition to other non-condensable gases. Liquid product CO₂ from the distillation column flows to storage tanks, where it can be sold to third parties via truck or injected into a local formation for geologic storage.

This PDP includes process flow diagrams in Appendix A, basic P&IDs in Appendix B, and a preliminary plot plan in Appendix C. The facility designed in this project is capable of processing 587 tonnes per day of CO₂, and recovers nearly all of the CO₂ emitted by RTE in their fermentation process. A small vent stream from the distillation column will be the only emission from the facility in this design. Trimeric also developed a request for quotation and solicited bids from three different equipment manufacturing firms that design and build liquid CO₂ facilities. During the bid process, RTE requested the facility be able to process 115% of the maximum design basis case, or 675 tonnes per day of CO₂. Details of the bid results are available in a separate document, but the average purchased equipment cost for the liquefaction facility equipment from the bidding process was \$10,700,000. Table 1 shows the expected total installed cost for the CO₂ liquefaction facility at RTE using the average purchased equipment cost from the bidding process.

Table 1. Estimated Capital Cost for Liquefaction Facility with Manufacturer Bids.

Purchased Equipment Cost (Excluding Storage Tanks)	\$10,700,000
Expected Installation Costs (Excluding Storage Tanks)	\$6,300,000
Storage Tank Total Installed Cost	\$2,600,000
Freight Costs (Excluding Storage Tanks)	\$170,000
Total Installed Cost Estimate	\$19,770,000

Utilities required for the liquefaction facility include electricity, cooling water, waste water disposal, water make up, and instrument air. Electricity is by far the largest utility need for the facility; the CO₂ liquefaction process involves compression of the feed gas and compression of the refrigerant system. Trimeric estimates the electrical requirement for liquefying and injecting the CO₂ at RTE to be 153.6 kWh/Tonne. Table 2 shows a summary of the estimated utilities required for this process.



Table 2. Major Utilities for Liquefaction Facility.

Utility	Expected Consumption
Electricity	3,763 kW
Cooling Water Circulation	3,610 gpm
Waste Water	9 gpm
Make Up Water	57 gpm
125 psig Steam	1,156 lb/hr
Instrument Air	1,760 SCFH

Some opportunities to optimize the capital and operating cost of the facility should be investigated further if the project moves forwards past this phase. This includes:

- Evaluate the need for liquid CO₂ storage tanks. The RTE liquefaction facility will initially inject most or all of the CO₂ captured from the fermentation area, and not sell any CO₂ to third parties. In this design, there is no need to have bulk storage of liquid CO₂ on-site, and the potential cost savings of \$2,600,000 by removing the storage tanks from the scope of the project is significant. Provisions can be made to include storage tanks in the future if the CO₂ can be sold to third parties or additional CO₂ received from third parties for injection is realized.
- Evaluate using liquid ammonia for the heating medium in the E-503 CO₂ Product Heater. This heater currently uses utility steam to heat the high pressure liquid CO₂, but liquid ammonia from the V-608 NH₃ Receiver could be used instead. This would subcool the liquid ammonia, which makes the refrigeration system more efficient while still heating the liquid CO₂ adequately. One potential drawback to this optimization is that injection would need to stop if the liquefaction facility was offline for some reason, and if CO₂ imports come to the facility for injection, they would need to stop as well. However, if storage tanks are eliminated from the project, there will be no CO₂ to inject if the liquefaction facility is offline.
- Evaluate the design of the E-607 NH₃ Condenser. The higher the condensation temperature of the ammonia, the more horsepower will be required for the C-601 NH₃ Compressor. As a result, the lowest operating cost for the facility will be achieved by condensing the ammonia refrigerant at a temperature as close to the wet bulb temperature as practical. One manufacturer proposed a wet surface air cooler for the E-607 NH₃ Condenser, which is a hybrid cooling tower design where a thin film of water is sprayed over the exchanger tubes while air is forced over the condenser tube banks. This design

minimizes the condensation temperature of the ammonia, but costs an additional \$400,000 of upfront capital investment.

2 Background

The Red Trail Energy (RTE) ethanol facility in Richardton, North Dakota produces ethanol by fermenting corn. During the fermentation process, carbon dioxide (CO₂) produced by the yeast bubbles out of the fermenting liquids, is scrubbed with water to remove alcohols and other volatile organic compounds, and then vents to atmosphere. RTE, the Energy and Environmental Research Center (EERC), and Trimeric Corporation (Trimeric) worked to design a CO₂ capture facility that will inject the captured CO₂ in a local formation so that RTE's ethanol can qualify for low carbon fuel standards and federal tax credits.

This phase of the project provided RTE with a process design for a facility that captures the CO₂ from the scrubber before it vents to atmosphere, and then compresses, liquefies, and purifies the CO₂. In previous phases of the project, Trimeric provided the EERC and RTE with preliminary process designs of different CO₂ capture facilities, and helped facilitate source gas CO₂ characterization. This report details the process design of the liquefaction facility, and provides RTE and the EERC with utility estimates for the liquefaction facility. Separate from this report, detailed +/- 10% accuracy proposals were provided by equipment manufacturers with CO₂ liquefaction expertise so that the project team could more accurately develop the investment case for the capture facility.

3 Design Basis and Feed Gas Composition

The CO₂ vented by RTE is very pure CO₂, typically more than 99% molar CO₂ on a dry basis. Trimeric identified three different facility designs in the initial phase of the project that would produce different levels of CO₂, including:

- Food and beverage quality CO₂ facility. This facility would produce a high purity liquid CO₂ product, suitable for use in the food and beverage grade industry. CO₂ would be loaded onto trucks for sale to third parties. This CO₂ has a high commercial value, but very tight specifications, and requires the most capital investment and the most cost per ton of CO₂ produced. RTE did not select this facility for this phase of design.
- Injection quality CO₂ facility. This facility produces a high pressure liquid CO₂ product for injection into a formation. The only impurity removed from the CO₂ is water, and the CO₂ has the lowest commercial value. Oxygen is not removed from the CO₂, which makes it unsuitable for use in enhanced oil recovery operations. This facility has the



lowest capital investment required, and the lowest cost per ton of CO₂ produced. RTE did not select this facility for this phase of design.

- EOR quality CO₂ facility. This facility produces a high pressure liquid CO₂ product for injection into the formation, or a medium pressure liquid CO₂ product for sale to companies that need CO₂ for industrial or enhanced oil recovery operations (but not food and beverage grade operations). This facility has a capital cost investment between the two other facility designs, and an almost identical cost per ton of CO₂ produced to the food and beverage grade facility. RTE selected this facility for this phase of the project.

More details on the food and beverage grade CO₂ facility and the injection quality CO₂ facility can be found in Trimeric’s earlier report, *Red Trail Energy CO₂ Capture and Sequestration Project CO₂ Surface Facility Design Report* issued on May 8, 2017.

RTE hired a third party to characterize the gas vented by the CO₂ Scrubber. Accurate analysis of the feed gas to the capture facility is critical, particularly when the facility will produce a liquid product. The presence of gases that do not condense at the CO₂ liquefaction temperature and pressure will determine how much of the CO₂ is recoverable as a liquid. Table 3 shows a summary of the feed gas composition measured by the third party; a detailed analysis of the feed gas can be found in a separate document provided by the analysis company.

Table 3. CO₂ Feed Gas Composition.

Gas Species	Fraction (Mole % or ppmv as indicated, dry basis)
Carbon Dioxide (CO ₂)	99.9+%
Oxygen (O ₂), Nitrogen (N ₂), Total Hydrocarbons, Total Sulfur	< 1,000 ppmv
Water (H ₂ O)	Saturated at feed gas conditions

RTE confirmed that this analysis met their expectations for the CO₂ source gas. Discussion with RTE operating personnel indicates that they make efforts to minimize the potential for air ingress into the fermentation system so the low amounts of oxygen and nitrogen are to be expected. The required product purity from the liquefaction facility is shown in Table 4.



Table 4. CO₂ Product Specification.

Species	Limit
Carbon Dioxide (CO ₂)	> 95 mol. %
Oxygen (O ₂)	< 10 ppmw
Water (H ₂ O)	< 30 lb/MMSCF (633 ppmv)
Hydrogen Sulfide (H ₂ S)	< 20 ppmw
Total Sulfur	< 35 ppmw
Nitrogen (N ₂)	< 4 mol. %
Hydrocarbons	< 5 mol. %

The feed gas already meets most of the required product specifications, with the exception of water and oxygen. The proposed liquefaction facility removes the water and oxygen from the CO₂ to meet the specifications shown in Table 4.

The liquefaction facility will be sized to process all of the source gas. Required CO₂ product conditions are provided in Table 5.

Table 5. CO₂ Delivery Requirements During Normal Operation.

Delivery Parameter	Project Design Requirement
Maximum Flow Rate	Maximum total flow at plant inlet 600 MTD (11 MMSCFD)
Minimum Flow Rate	Minimum total flow rate at plant inlet 300 MTD (6 MMSCFD)
Normal Pressure at Injection Wellhead	1,500 psig (maximum) at normal delivery temperature based upon the latest estimate from EERC.
Maximum Temperature at Inlet to Pipeline	120 °F
Minimum Temperature at Injection Wellhead	60 °F

The following sections detail the design basis for the potential CO₂ liquefaction facility for the Red Trail Energy site. Note that specific mass balances and utility values are considered business-sensitive.

4 Plant Layout and Process Description

Trimeric developed process flow diagrams (PFDs), heat and material balances (HMBs), basic piping and instrumentation diagrams (P&IDs), and a basic plot plan for the liquefaction facility as a part of this project. PFDs can be found in Appendix A, the P&IDs can be found in

Appendix B, and the basic plot plan can be found in Appendix C. The rest of this section is a description of the process flow and key operating conditions for the liquefaction facility. The PFDs may be used as a reference in this section.

4.1 Inlet Blower Area

The CO₂ feed stream exits the ethanol facility's CO₂ Scrubber near atmospheric pressure; the discharge of the CO₂ Scrubber is the battery limit for the inlet blower area. The gas stream enters the V-100 Blower Inlet Separator to remove any liquids that might have condensed or carried over from the ethanol facility CO₂ Scrubber. Liquids collect in the bottom of the separator and are pumped to the ethanol facility for disposal. The gas flows from the top of the separator to the B-102 CO₂ Inlet Blower, which compresses the gas from near atmospheric pressure up to 15 psig. Hot compressed gas from the blower flows to the E-103 CO₂ Blower Aftercooler to reduce the temperature of the gas stream and condense some water out of the gas stream. The cooled gas/liquid mixture flows to the V-104 CO₂ Blower Aftercooler Separator where liquids are removed from the gas stream and sent to the ethanol facility for disposal. The gas flows through a 16" line that will be about 400 feet long to carry the gas from the fermentation area to the liquefaction area. RTE did not want the open space around the fermentation area used up in case the ethanol facility expands in the future and requires more fermenters.

4.2 Liquefaction Area

In the liquefaction area, the gas first passes through the V-200 CO₂ Compressor Inlet Separator to remove any water that may have condensed in the line as the gas traveled through it. Liquid from the separator flows to the ethanol facility for disposal. The gas from the separator flows to an oil-flooded screw compressor, the C-201 CO₂ Compressor, which compresses the gas stream from approximately 14 psig up to 350 psig. The oil-flooded screw compressor technology injects oil into the process gas stream, and then compresses the oil and the gas up to the required discharge pressure. The gas and oil mixture flows out the compressor and into the V-206 CO₂ Compressor Oil Coalescer, which removes most of the oil from the gas stream. Oil collects in the bottom of the separator and flows through a cooling and filtering system (not depicted on the PFDs) so it can be reinjected into the compressor. Any compressor oil remaining in the gas stream can foul the downstream molecular sieve dehydration adsorbent, and essentially complete removal of the oil from the gas stream is required, so the V-207 CO₂ Carbon Bed downstream of the oil coalescer adsorbs any remaining oil from the gas stream.

Oil-free gas flows into a water-cooled aftercooler, the E-300 CO₂ Compressor Aftercooler, to reduce the gas temperature and condense water out of the gas stream. The cooled gas/water mixture flows into the V-301 Aftercooler Separator where liquid water is removed and sent to

the ethanol facility for disposal. Gas from the separator flows to a refrigerant cooled exchanger, the E-302 Refrigerant Aftercooler, which cools the gas stream down to approximately 50 °F to condense as much water out of the gas stream as possible before flowing to the molecular sieve dehydration unit. The coolant for this exchanger is liquid ammonia, which vaporizes at an intermediate pressure in this exchanger. More details on the ammonia refrigerant system can be found in Section 4.4. The cooled gas/liquid mixture flows into the V-303 Refrigerant Aftercooler Separator where liquid water is removed and sent to the ethanol facility for disposal. Gas from the separator flows through the E-304 CO₂ Superheater, which raises the temperature of the gas stream to 60 °F to eliminate the need for stainless steel construction.

Up to this point in the process, the gas stream is saturated with water and the equipment must be able to resist corrosion from acidic water that may be present. As a result, separators, heat exchanger tube bundles, and piping are constructed out of 304 stainless steel. Downstream of the superheater (E-304), the facility may be constructed of carbon steel or low temperature carbon steel if necessary. Gas flows from the superheater into a molecular sieve dryer system, which adsorbs essentially all of the water vapor remaining in the gas stream in a pair of batch-operated vessels, the V-305A/B CO₂ Dryer Vessels. One of the vessels is always adsorbing water from the gas stream, while the other is offline being regenerated with dry product gas. A slip-stream of dry product gas (the recycle gas required to regenerate the spent bed is around 5% of the total gas stream flowrate) passes through a control valve down to approximately the CO₂ compressor (C-201) suction pressure and flows through the E-306 Dryer Regenerator Heater, which heats the regeneration gas up to 500 °F. Hot gas flows through the offline dryer vessel and desorbs the water from the adsorbent. The hot gas flows out of the dryer vessel, and is cooled in the E-308 Regeneration Cooler. As water desorbs from the offline vessel, some water will condense out of the gas stream in the regeneration cooler, and it is separated from the gas stream in the V-309 Regeneration Separator. Liquid collects in the bottom of the separator and flows to the ethanol facility for disposal. The regeneration gas flows out of the regeneration separator back to the suction of the CO₂ Compressor to minimize CO₂ losses in the system.

Dry gas flows out of the bottom of the online dryer vessel and into the E-400 CO₂ Main Reboiler. The dry gas exchanges heat with liquid CO₂ in the main reboiler and cools down to near the liquefaction temperature. The cold, dry gas flows out of the reboiler to the E-402 CO₂ Main Condenser, where it is liquefied by exchanging heat with evaporating refrigerant (see Section 4.4 for more details on the refrigerant system). Liquid flows out of the main condenser into the column feed drum (not depicted on the PFDs), and then is pumped by the P-404 CO₂ Column Feed Pump into the T-405 CO₂ Distillation Column. In the distillation column, noncondensable gases such as oxygen, nitrogen, and methane are stripped out of the liquid stream and flow out of the top of the column. Essentially pure CO₂ collects in the bottom of the distillation column and flows to the CO₂ Main Reboiler and E-401 CO₂ Auxiliary Reboiler. The Auxiliary Reboiler, which is part of the refrigeration loop, provides additional heat to the bottom



of the column. A portion of the liquid CO₂ vaporizes and returns to the distillation column while the rest of the liquid CO₂ flows through the E-407 CO₂ Subcooler (E-407), where it exchanges heat with vaporizing refrigerant and subcools. Vapor from the top of the distillation column flows through the E-406 CO₂ Column Condenser, and exchanges heat with vaporizing refrigerant to condense some of the gas back to the liquid phase. The condensed liquids flow back to the column feed drum, and the remaining vapor vents to atmosphere. This maximizes the amount of CO₂ recovered by the process.

4.3 Storage and Injection Area

Pure CO₂ from the liquefaction area flows into the TK-500A/B/C CO₂ Product Storage Tanks, which operate at appx. 312 psig and -5 °F. From the storage tanks, the CO₂ may be pumped into trucks for sale to a third party, or it can be pumped to an injection well for geologic sequestration. The P-501 CO₂ Booster Pump pumps the liquid CO₂ up by 20 psi to provide adequate head for the P-502 CO₂ Injection Pump, which pumps the liquid CO₂ up to a pressure of 1,515 psig. The high pressure CO₂ flows through the E-503 CO₂ Injection Heater, and then through a local pipeline to the injection well for sequestration in a local formation. For this project, the injection well is 2,640 feet from the storage area.

4.4 Ammonia Refrigeration System

The ammonia refrigeration system is a closed-loop circulation system that provides refrigerant to the process. The refrigerant chosen for this project is anhydrous ammonia, which is a common refrigerant for liquid CO₂ facilities in other industries. Refrigerant is required in every exchanger that cools the process gas below the cooling water temperature. The heart of the refrigerant system is the C-601 NH₃ Compressor, which compresses ammonia vapor from atmospheric pressure up to a pressure at which the ammonia can be condensed in a water-cooled heat exchanger, the E-607 NH₃ Condenser. For the ambient conditions at RTE (and therefore the cooling water conditions), Trimeric estimated a condensing temperature of 92 °F which equates to a compressor discharge pressure of 189 psia. The condensed ammonia flows out of the NH₃ Condenser and into the E-608 NH₃ Receiver, which acts as a surge tank for the refrigerant system to absorb changes in demand as the flow rate of feed gas to the process changes, or the ambient conditions change substantially. Liquid ammonia flows out of the NH₃ Receiver and through two exchangers; the E-304 CO₂ Superheater and the E-401 Auxiliary Reboiler. Each of these exchangers subcools the liquid ammonia and makes the refrigeration loop more efficient.

Liquid ammonia then flows to other exchangers where it is vaporized to provide cooling to different parts of the process. The E-302 Refrigerant Aftercooler vaporizes medium pressure ammonia to cool the feed gas off to 50 °F while the E-402 CO₂ Main Condenser, the E-407 CO₂ Subcooler, and the E-406 CO₂ Column Condenser vaporize low pressure ammonia to cool or

liquefy the CO₂. The vaporized ammonia flows out of each exchanger back to the C-601 NH₃ Compressor.

5 Process Simulation and Compressor Modeling Results – Utility Estimates

VMGSim v10.0 (Build 128) with thermodynamic model APR for Natural Gas 2 was used to model the CO₂ liquefaction and distillation process from the blower feed to injection. The same version of VMGSim with thermodynamic model Advanced Peng-Robinson was used to model the ammonia refrigeration loop. Process simulation models do not accurately characterize the power requirements or discharge conditions of screw compressors. This is due to the fact that the compressors are compressing a two phase mixture, and the liquid oil can absorb a substantial amount of the heat generated by compressing the gas. This allows for lower than expected discharge temperatures from the compressor, but larger horsepower requirements than expected and it is critical to remember that the circulating compressor oil must also be cooled in an exchanger before flowing back to the compressor. The ammonia screw compressor was modeled using the MYCOM MYselect software. The CO₂ screw compressor was modeled by MYCOM technical support.

5.1 Refrigerant Options

Several different options were investigated to determine the best design for this application. When picking a refrigerant, the energy requirement and the boiling point of the refrigerant are important factors. The lowest temperature in the process is at the condenser, which operates at -20 °F. Assuming a temperature approach of at least 10 °F for the heat exchanger, the refrigerant must have a boiling point of less than -30 °F at the suction pressure of the compressor. Four refrigerants were investigated for this process, as they have been used in the past for liquid CO₂ production. The refrigerants chosen for further investigation were:

- Anhydrous ammonia. This is the most common refrigerant for this process, and is used in many facilities across the United States. Anhydrous ammonia is toxic, and presents a health hazard to personnel if there are leaks in the process. RTE expressed some reservations about using anhydrous ammonia for this reason.
- Propane. This refrigerant is common in gas treatment facilities, and can be used in CO₂ liquefaction as well. Propane is flammable, and propane refrigeration systems require the instrumentation and other electrical components near the process to be rated for flammable gases, which will represent an increased capital cost. Propane may be slightly less efficient than ammonia in this service, which will increase operating costs.



- R404A. This refrigerant is a mixture of other refrigerants including R125, R134a, and R143a. It is being phased out of the United States and was not pursued further for this project.
- R507A. This refrigerant is a mixture of other refrigerants, and is in common use in low temperature refrigeration applications. The R507a refrigerant has a substantially higher purchase cost than propane or ammonia, and is more prone to be leaked to atmosphere than those refrigerants, which makes operating costs higher than expected.

Ultimately, RTE chose to use anhydrous ammonia as the refrigerant for this process after considering the options above.

5.2 Recycle Dryer Regeneration Gas

A slip stream of dehydrated gas (5-10% of the feed flowrate) is used to regenerate the offline dryer vessel, as described above in Section 4.2. The regeneration gas is saturated with water and can be recycled back to the feed of the compressor or vented to atmosphere. Recycling the regeneration gas means a higher compressor horsepower and electricity cost as well as the additional capital cost of a cooler and separator. Venting the regeneration gas generally means the loss of 5-10% of the feed gas to atmosphere. Both options were considered in this project to determine which was the best for the RTE design.

RTE decided to move forward with recycling the regeneration gas due to an estimated reduction of about 3.0 kWh/tonne of CO₂ produced. Additional capital costs for the slightly increased size of the CO₂ compressor, the presence of a regeneration cooler and regeneration separator do materially affect the capital cost of the entire facility.

5.3 Electrical Requirements

Brake horsepower and operating kW estimates for most of the electrical equipment in the facility are shown below in Table 6.

Table 6. Equipment Generating Electrical Loads for the Potential Liquefaction Facility.

Equipment	P&ID	Description
B-102	PID-10002	CO ₂ Inlet Blower
C-201	PID-10005	CO ₂ Compressor
C-601	PID-10016	NH ₃ Compressor
P-101	PID-10002	Blower Inlet Separator Pump
P-203	PID-10005	CO ₂ Compressor Oil Pump
E-306	PID-10009	Dryer Regeneration Heater
P-404A	PID-10012	CO ₂ Column Feed Pump
P-404B	PID-10012	CO ₂ Column Feed Pump
P-501	PID-10014	CO ₂ Booster Pump
P-502	PID-10014	CO ₂ Injection Pump
P-503	PID-10014	CO ₂ Loading Pump
P-603	PID-10016	NH ₃ Compressor Oil Pump
F-700	PID-10019	Cooling Tower Fan
P-701A	PID-10019	Cooling Water Circulation Pump
P-701B	PID-10019	Cooling Water Circulation Pump

Total electrical demand for the liquefaction facility is estimated at 3,900 kW, for a total electricity demand of about 150 kWh/tonne of CO₂ produced.

5.4 Cooling Water Requirements

The RTE liquefaction facility will use cooling water in heat exchangers not using refrigerant. A new cooling tower will be required for the project, and the estimated cooling water circulation flow rates for the liquefaction facility are shown below in Table 7. RTE requested a maximum allowed temperature rise of 12 °F for the cooling water and set the maximum cooling water supply temperature to 82 °F.



Table 7. Equipment Requiring Cooling Water for the Potential Liquefaction Facility.

Equipment	P&ID	Description
E-103	PID-10003	CO ₂ Blower Aftercooler
E-204	PID-10005	CO ₂ Compressor Lube Oil Cooler
E-300	PID-10007	CO ₂ Compressor Aftercooler
E-604	PID-10016	NH ₃ Compressor Lube Oil Cooler
E-607	PID-10005	NH ₃ Condenser

Total estimated cooling water requirements for the liquefaction facility are 22.0 MMBTU/hr in heat exchanger duty, and about 3,600 gpm cooling water circulation rate.

5.5 Waste Water Requirements

The liquefaction facility will generate several liquid water streams as the CO₂ feed gas is compressed, cooled, and dehydrated. The water streams may be contaminated with small amounts of compressor lubrication oil, alcohols carried over from the RTE CO₂ Scrubber, or other minor contaminants from the gas stream. RTE will need to determine if this water can be recycled in their process or if it should be disposed of directly. An estimate of the waste water sources for the liquefaction facility is shown in Table 8.



Table 8. Equipment Generating Waste Water for the Potential Liquefaction Facility.

Equipment	P&ID	Description	Potential Contaminants
V-100	PID-10002	Blower Inlet Separator	Scrubber Carryover
V-104	PID-10003	Blower Aftercooler Separator	None
V-200	PID-10004	CO ₂ Compressor Inlet Separator	None
V-301	PID-10007	Aftercooler Separator	Compressor Oil
V-303	PID-10008	Refrigerant Aftercooler Separator	Compressor Oil
T-700	PID-10019	Cooling Tower Blow Down	High Conductivity

Total estimated waste water requirements for the liquefaction facility are about 9 gpm of water.

5.6 Process Water Requirements

The new cooling tower will need make up water continuously, but that will be the only constant demand for process water. The NH₃ Vent Header Tank will periodically need water as well, but this should be a minor requirement and only require water occasionally. Total process water needs for the liquefaction facility are shown in Table 9.

Table 9. Equipment Requiring Process Water for the Potential Liquefaction Facility.

Equipment	P&ID	Description	Operation
T-700	PID-10019	Cooling Tower Make Up	Continuous
TK-702	PID-10020	NH ₃ Vent Header Tank	Intermittent

Total estimated process water requirements for the liquefaction facility are about 57 gpm of water.

5.7 Miscellaneous Utility Requirements

In addition to the utilities noted above, the liquefaction facility will use saturated steam in the E-502 CO₂ Product Heater and instrument air throughout the facility. Estimates for this utility usage are shown in Table 10 and Table 11, respectively.



Table 10. Equipment Requiring Steam for the Potential Liquefaction Facility.

Equipment	P&ID	Description
E-502	PID-10014	CO ₂ Product Heater

Table 11. Equipment Requiring Instrument Air for the Potential Liquefaction Facility.

Equipment	Quantity	Notes
Pneumatic Valves	44	Estimate of 40 SCFH per Valve
Panel Purges	0	Estimate of 10 SCFH per Panel

6 Capital Cost Estimate

As part of this project, Trimeric developed a request for quotation (RFQ) and issued the RFQ to three separate reputable companies that design and manufacture equipment for liquid CO₂ production.

The average purchased equipment cost for the three bids received from the companies was \$10.7 million dollars, which excludes the expected costs of the storage tanks. Additional costs for installation, storage tanks, and freight are shown in Table 12. There is also no contingency included in this estimate, interest rates, or other costs that may be expected on a project of this size and complexity.

Table 12. Estimated Capital Cost for Liquefaction Facility with Manufacturer Bids.

Purchased Equipment Cost (Excluding Storage Tanks)	\$10,700,000
Expected Installation Costs (Excluding Storage Tanks)	\$6,300,000
Storage Tank Total Installed Cost	\$2,600,000
Freight Costs (Excluding Storage Tanks)	\$170,000
Total Installed Cost Estimate	\$19,770,000

Liquid CO₂ storage tanks are large vessels, heavily insulated, and operate at a high pressure for a vessel that is so large. Freight and installation costs for the liquid CO₂ storage costs are substantial, and feedback from one of the equipment manufacturers on this project was that a total installed cost for a single storage tank could be as high as \$1,300,000. Vendor equipment purchased cost estimates include the cost for the motor control centers. Installation costs for the other equipment in the facility are based upon the modular construction of the entire facility, and that the required fieldwork once the equipment is on-site and installed on foundations is minimal.

7 Cost Mitigation Opportunities

The CO₂ liquefaction unit designed in this project contains a number of assumptions that impact the overall capital cost of the facility and the overall operating cost of the facility. Some of these options are covered in this section, and should be investigated further during the detailed design phase of the project.

7.1 Liquid CO₂ Storage Tanks

The primary objective of capturing the CO₂ vented at the RTE facility is to sequester the CO₂ in a geologic formation to realize federal and state level tax credits and CO₂ credits. There may be opportunities in the future to sell or buy CO₂ to or from third parties as a truck or rail liquid product, but those opportunities are not being realized at this stage of the project. If bulk storage of liquid CO₂ is not required, and the liquid CO₂ product could be injected directly from the liquefaction facility, the liquid CO₂ storage tanks (TK-500A/B) would not be required for this project and could reduce the total project costs by \$2,600,000. Figure 1 shows a block diagram of this concept. Connections for liquid storage tanks could be provided initially and then the tanks could be installed if the anticipated third party sales or purchases were realized.

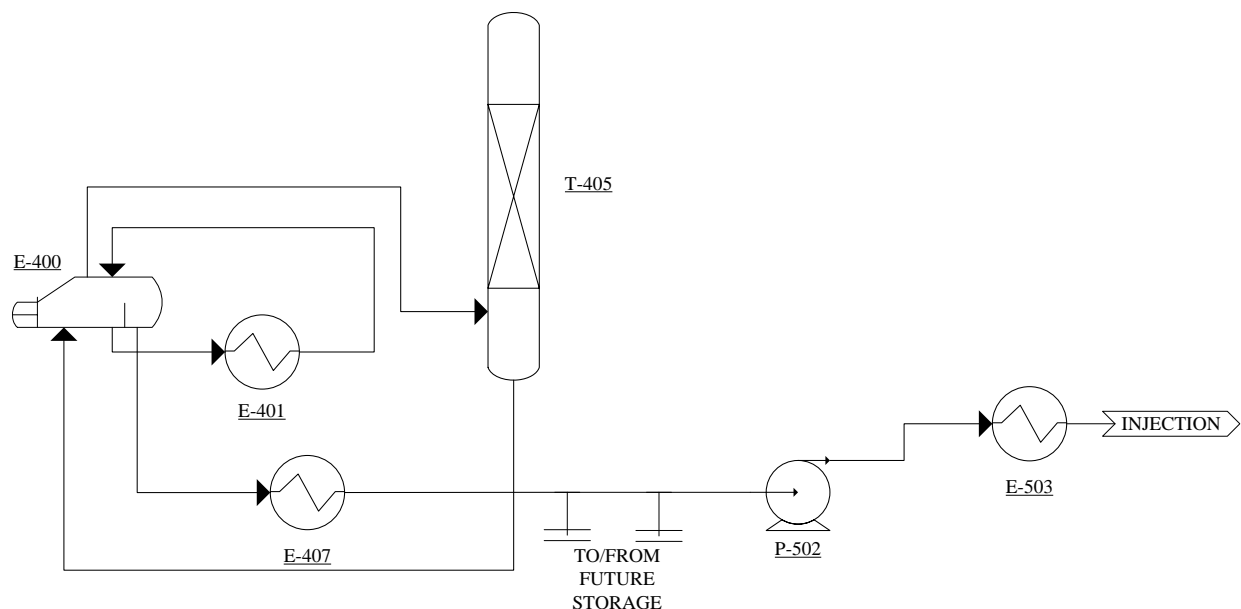


Figure 1. Product CO₂ Configuration Without Storage Tanks.

7.2 E-503 CO₂ Product Heater Heat Medium Change

Per the current design, the E-503 CO₂ Product Heater will heat the product CO₂ with saturated steam. One of the manufacturers contacted for this project suggested using liquid ammonia to heat the CO₂ stream; this would allow the refrigeration system to operate more efficiently since the liquid ammonia would be further subcooled, and ultimately reduce the amount of ammonia circulated in the refrigeration system. In this option, the liquefaction facility would need to be running in order to meet the temperature requirement on the discharge of the facility, so injection could not continue if the liquefaction facility shut down for maintenance or another reason. If RTE needs to continue injecting for some reason while the liquefaction facility is offline, the saturated steam heating medium may be the preferred option.

7.3 E-607 NH₃ Condenser Design and Approach Temperature

As discussed above, the condensation temperature of the ammonia in the refrigeration system is a key design point. The higher the condensation temperature of the ammonia, the more horsepower will be required for the C-601 NH₃ Compressor. As a result, the lowest operating cost for the facility will be achieved by condensing the ammonia refrigerant at a temperature as close to the wet bulb temperature as practical. One manufacturer proposed a wet surface air cooler for the E-607 NH₃ Condenser, which is a hybrid cooling tower design where a thin film of water is sprayed over the exchanger tubes while air is forced over the condenser tube banks. This design minimizes the condensation temperature of the ammonia, but costs an additional

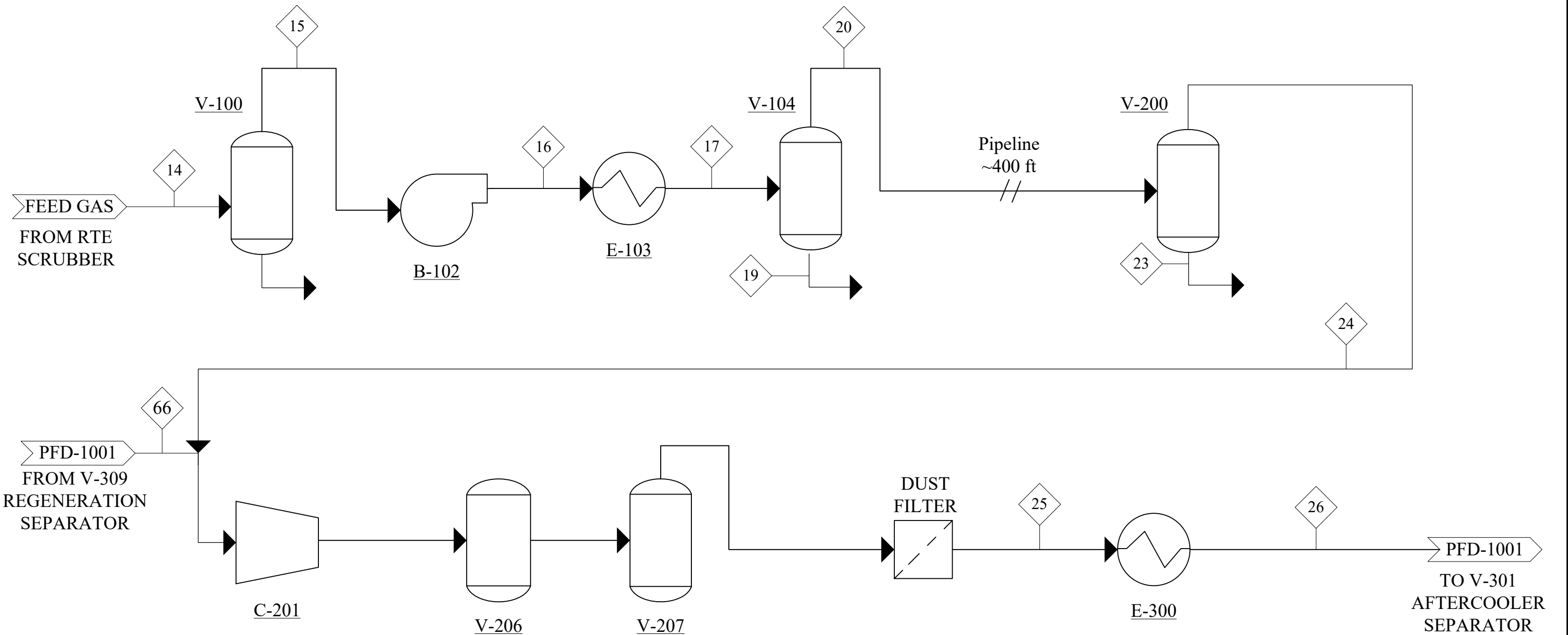


\$400,000 of upfront capital investment. Further work would be required to determine if this additional cost is justified for the reduction in operating costs.

Trimeric expects that the cooling water supply temperature of 82 °F will be easily achieved for most of the year at RTE's facility in North Dakota, and that the process will operate more efficiently than estimated for much of the year in any event.

APPENDIX A
PROCESS FLOW DIAGRAMS

<u>V-100</u>	<u>B-102</u>	<u>E-103</u>	<u>V-104</u>	<u>V-200</u>	<u>C-201</u>	<u>V-206</u>	<u>V-207</u>	<u>E-300</u>
BLOWER INLET SEPARATOR	CO ₂ INLET BLOWER	CO ₂ BLOWER AFTERCOOLER	CO ₂ BLOWER AFTERCOOLER SEPARATOR	CO ₂ COMPRESSOR INLET SEPARATOR	CO ₂ COMPRESSOR	CO ₂ COMPRESSOR OIL COALESCER	CO ₂ CARBON BED	CO ₂ COMPRESSOR AFTERCOOLER



PRELIMINARY – NOT FOR CONSTRUCTION

FILENAME EERC P3 PFD 091819.VSD	DATE	DRAWN BY Austyn Vance
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REVISIONS

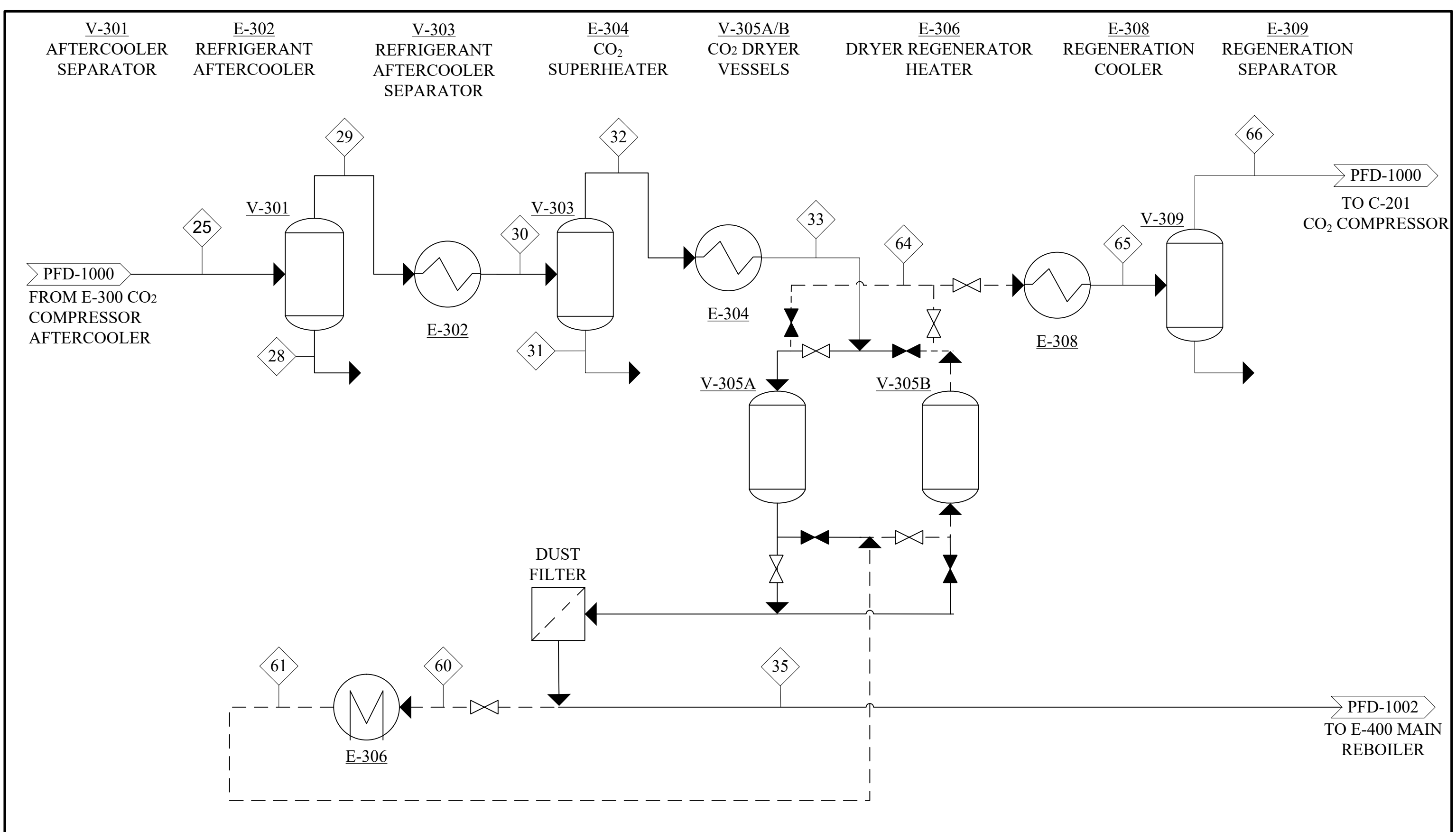
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1	4/26/19	Revised equipment tags and names	AEV	BDP		
2	05/29/19	Revise for RFQ	BDP			



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**EERC Ph. III
FEED COMPRESSION**

CLIENT/SITE EERC	JOB NUMBER 50168.04
DRAWING NUMBER PFD-1000	SCALE NONE



PRELIMINARY – NOT FOR CONSTRUCTION

FILENAME: EERC P3 PFD 091819.VSD DATE: DRAWN BY: Austyn Vance

REVISIONS						
REV	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
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1	4/26/19	Revised equipment tags and names	AEV	BDP		
2	05/29/19	Revise for RFQ	BDP			

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**EERC Ph. III
COOLING AND
DEHYDRATION**

CLIENT/SITE: EERC JOB NUMBER: 50168.04
DRAWING NUMBER: PFD-1001 SCALE: NONE

E-400
CO₂ MAIN
REBOILER

E-401
CO₂ AUXILIARY
REBOILER

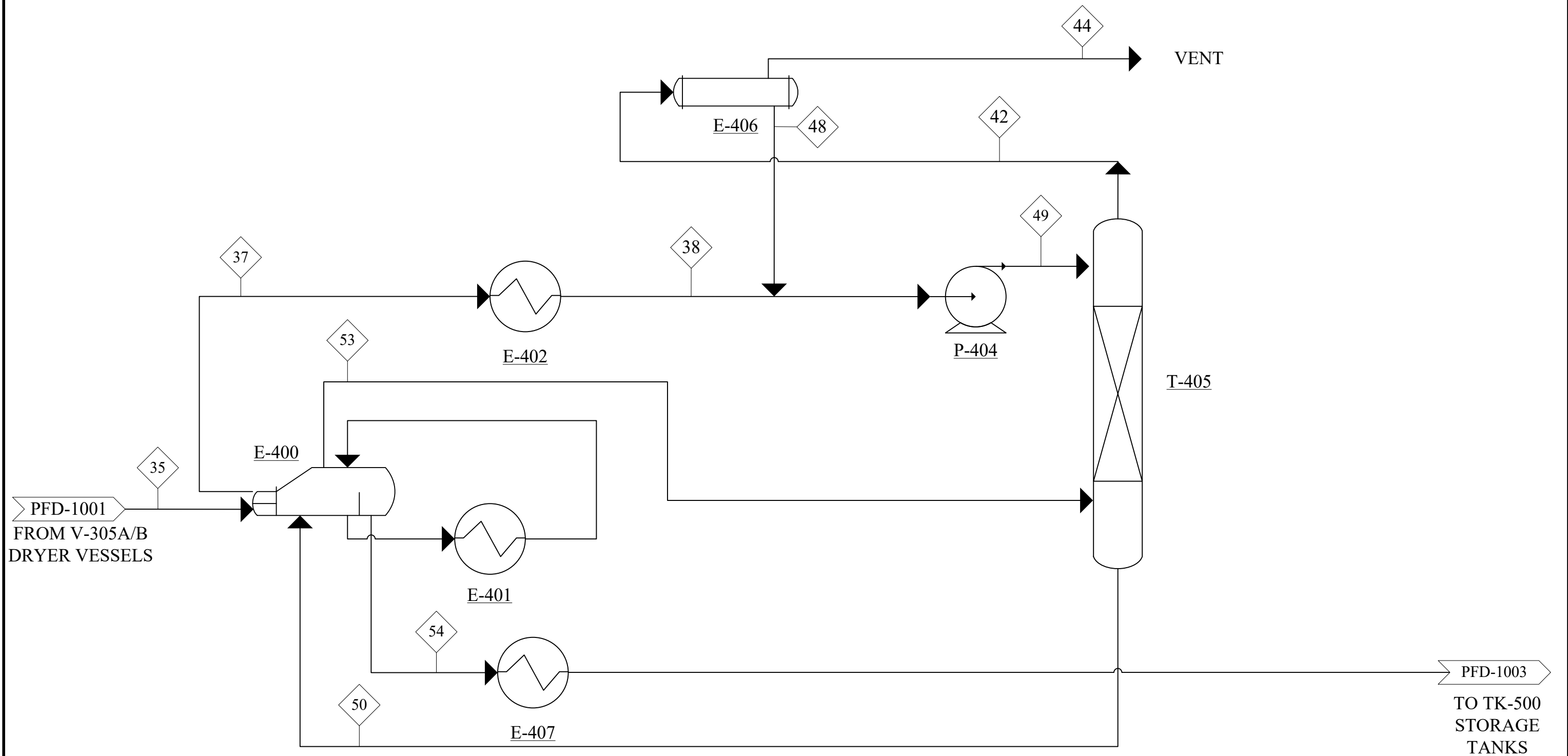
E-402
CO₂ MAIN
CONDENSER

P-404
CO₂ COLUMN
FEED PUMP

T-405
CO₂ DISTILLATION
COLUMN

E-407
CO₂ SUBCOOLER

E-406
CO₂ COLUMN
CONDENSER

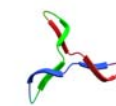


PRELIMINARY – NOT FOR CONSTRUCTION

FILENAME: EERC P3 PFD 091819.VSD DATE: DRAWN BY: Austyn Vance

REVISIONS

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0	3/21/19	Draft for EERC Review	AEV	BDP		
1	4/26/19	Revised equipment names and tags	AEV	BDP		
2	05/29/19	Revise for RFQ	BDP			



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**EERC Ph. III
LIQUEFACTION AND
DISTILLATION**

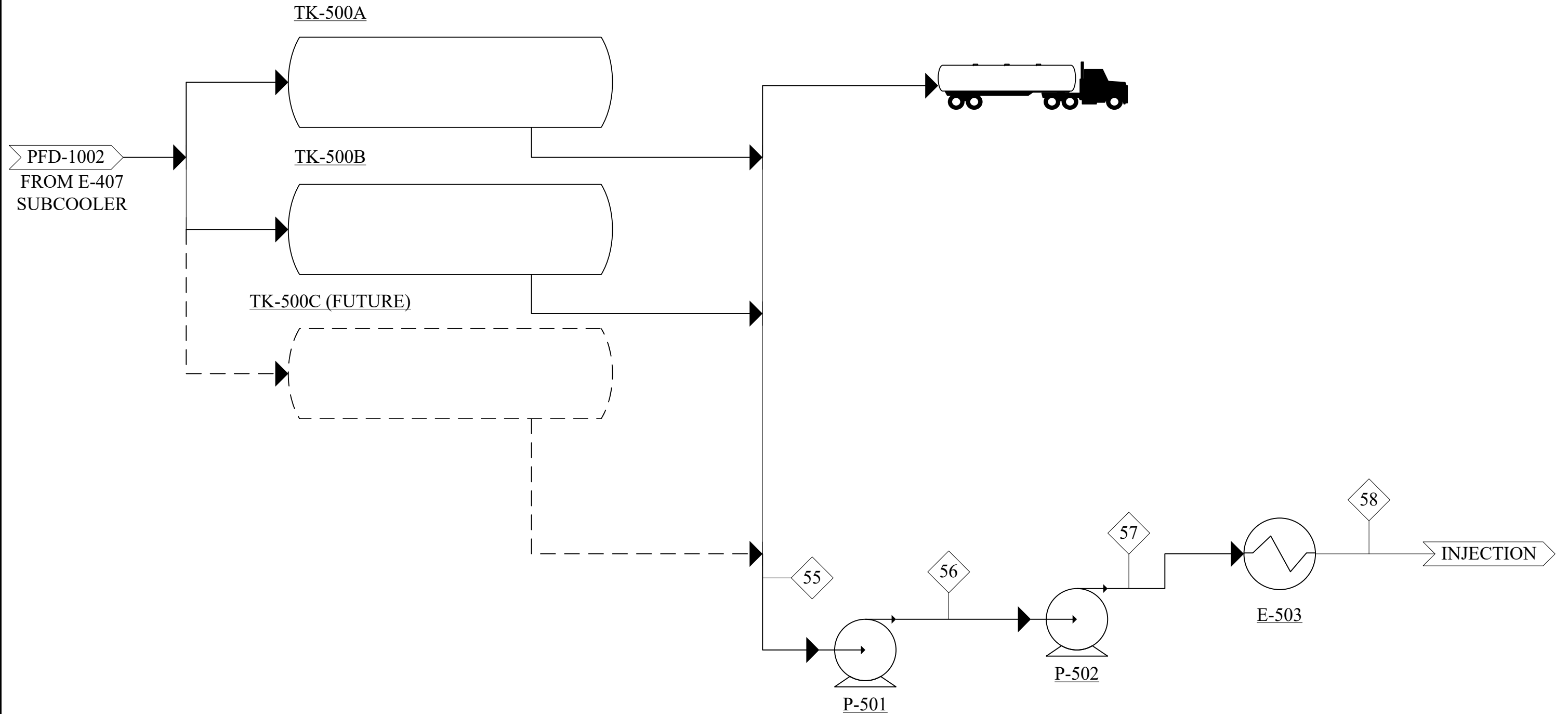
CLIENT/SITE	EERC	JOB NUMBER	50168.04
DRAWING NUMBER	PFD-1002	SCALE	NONE

TK-500A/B/C
CO₂ PRODUCT
STORAGE TANKS

P-501
CO₂ BOOSTER
PUMP

P-502
CO₂ INJECTION
PUMP

E-503
CO₂ INJECTION
HEATER

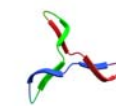


PRELIMINARY – NOT FOR CONSTRUCTION

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DATE: _____
DRAWN BY: Austyn Vance

REVISIONS

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1	4/26/19	Revised equipment tags and names	AEV	BDP		
2	05/29/19	Revise for RFQ	BDP			

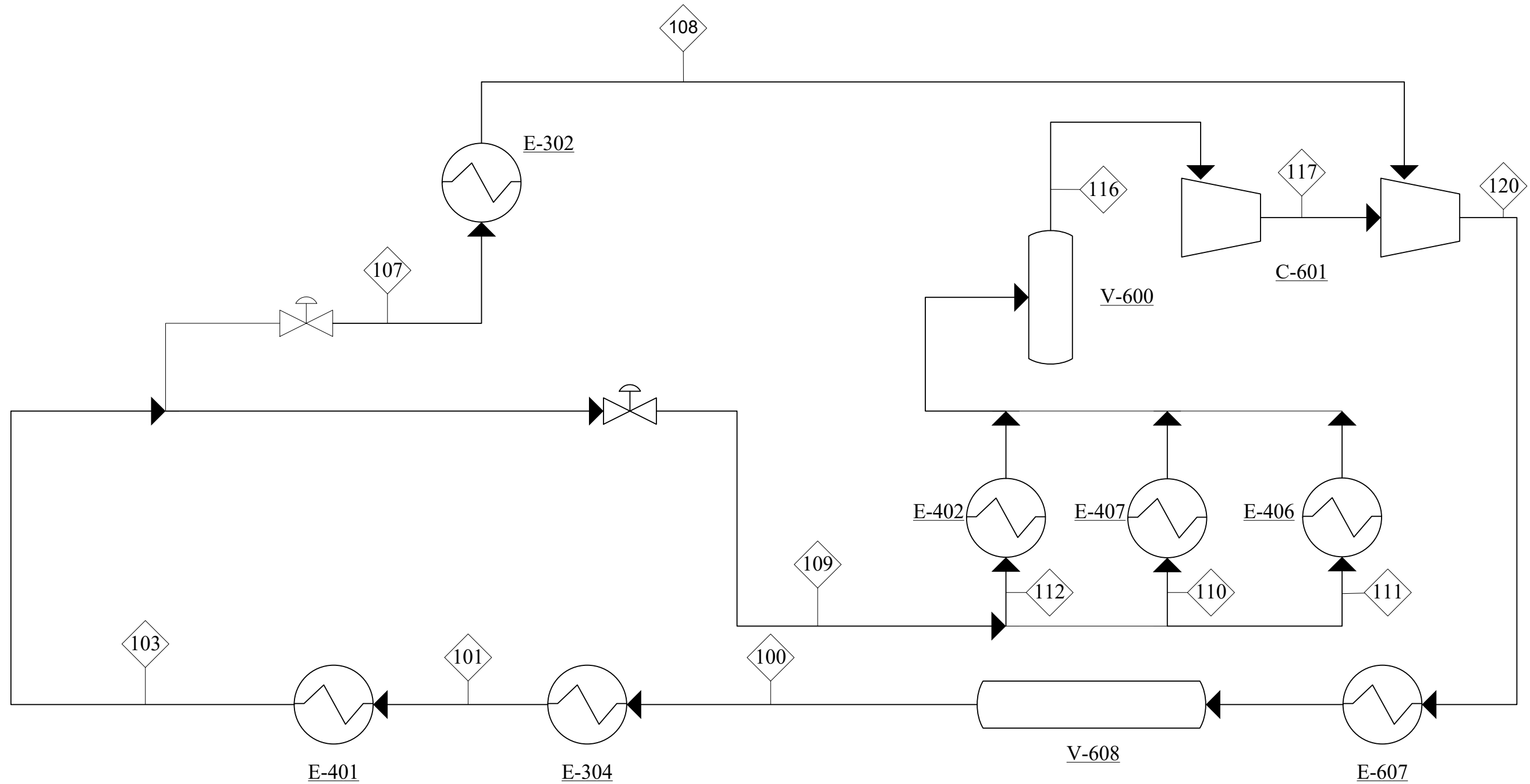


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**EERC Ph. III
STORAGE AND INJECTION**

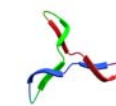
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DRAWING NUMBER	PFD-1003	SCALE	NONE

<u>E-402</u> CO ₂ MAIN CONDENSER	<u>E-407</u> CO ₂ SUBCOOLER	<u>E-406</u> CO ₂ COLUMN CONDENSER	<u>E-401</u> CO ₂ AUXILIARY REBOILER	<u>E-304</u> CO ₂ SUPERHEATER	<u>C-601</u> NH ₃ COMPRESSOR	<u>V-600</u> AMMONIA SEPARATOR	<u>E-302</u> REFRIGERANT AFTERCOOLER	<u>VE-1</u> AMMONIA ECONOMIZER	<u>V-608</u> NH ₃ RECEIVER	<u>E-607</u> NH ₃ CONDENSER
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REVISIONS						
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1	4/26/19	Revised equipment tags and names	AEV	BDP		
2	05/29/19	Revise for RFQ	BDP			



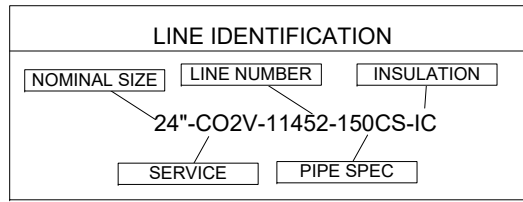
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**EERC Ph. III
AMMONIA REFRIGERATION**

FILENAME EERC P3 PFD 091819.VSD	DATE	DRAWN BY Austyn Vance	
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CLIENT/SITE EERC	JOB NUMBER 50168.04
DRAWING NUMBER PFD-1004	SCALE NONE

APPENDIX B
PRELIMINARY P&IDs



SERVICE CODES

CO2V	VAPOR CARBON DIOXIDE
CO2L	LIQUID CARBON DIOXIDE
NH3V	VAPOR AMMONIA
NH3L	LIQUID AMMONIA
CWS	COOLING WATER SUPPLY
CWR	COOLING WATER RETURN
PW	PROCESS WATER
WW	WASTE WATER
LPS	LOW PRESSURE STEAM
CND	STEAM CONDENSATE

PIPE SPECIFICATION

150CS	CARBON STEEL 150#
300CS	CARBON STEEL 300#
600CS	CARBON STEEL 600#
900CS	CARBON STEEL 900#
150SS	STAINLESS STEEL 150#
300SS	STAINLESS STEEL 300#
600SS	STAINLESS STEEL 600#
900SS	STAINLESS STEEL 900#

INSULATION CODES

0	NONE
IC	COLD CONSERVATION
IH	HEAT CONSERVATION
PP	PERSONNEL PROTECTION
FP	FREEZE PROTECTION

VALVES

	CONTROL VALVE
	ON/OFF VALVE
	BALL VALVE
	GATE VALVE
	BUTTERFLY VALVE
	GLOBE VALVE
	3-WAY VALVE

DEVICES AND MISCELLANEOUS

	SCOPE BREAK
	SPECTACLE BLIND, OPEN
	WYE STRAINER
	PRESSURE RELIEF VALVE
	RUPTURE DISK
	CHECK VALVE
	RESTRICTION ORIFICE
	ORIFICE METER
	ROTAMETER
	DRAIN TO SUMP
	STEAM TRAP
	HOSE

VALVE FAILURE POSITION

FC	FAIL CLOSED
FO	FAIL OPEN
FL	FAIL LAST

INSTRUMENT AND CONTROL LETTERS

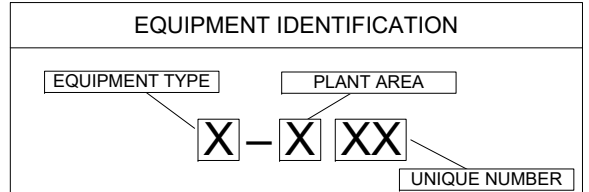
	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED	MODIFIER	READOUT	OUTPUT	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER				
C				CONTROL	
D		DIFFERENTIAL			
E	VOLTAGE		ELEMENT		
F	FLOW	RATIO			
G	ACCEL		GAUGE		
H	HAND				HIGH
I	CURRENT		INDICATE		
J	POWER	SCAN			
K	TIME	TIME ROC			
L	LEVEL		LIGHT		LOW
M		MOMENTARY			
N					
O			ORIFICE		
P	PRESSURE				
Q	QUANTITY	TOTALIZE			
R	RADIATION				
S	SPEED	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMITTER	
U	UNDEFINED		UNDEFINED	UNDEFINED	UNDEFINED
V	VIBRATION				
W	WEIGHT				
X	UNDEFINED		UNDEFINED	UNDEFINED	UNDEFINED
Y	EVENT			RELAY	
Z	POSITION			FINAL CONTROL	

INSTRUMENT AND CONTROL SYMBOLS

SYMBOL	DESCRIPTION	LOCATION
	FIELD MOUNTED	FIELD
	PANEL MOUNTED, ACCESSIBLE	CONTROL PANEL
	COMPUTER SCREEN, ACCESSIBLE	HMI (HMI/DCS)
	COMMS SIGNAL	CONTROL PANEL

LINE DEFINITIONS

---	PROCESS
- * * * -	CAPILLARY
- - - - -	PNEUMATIC
- - - - -	ELECTRIC
- o - o - o -	DATA



EQUIPMENT TYPE

B	CENTRIFUGAL BLOWER
C	COMPRESSOR
E	EXCHANGER
P	PUMP
T	TOWER
TK	TANK
V	VESSEL

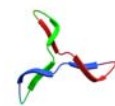
PLANT AREA

1	INLET BLOWER
2	COMPRESSION
3	COOLING AND DEHYDRATION
4	LIQUEFACTION AND DISTILLATION
5	PRODUCT STORAGE AND INJECTION
6	REFRIGERATION
7	UTILITIES

PRELIMINARY – NOT FOR CONSTRUCTION

REVISIONS

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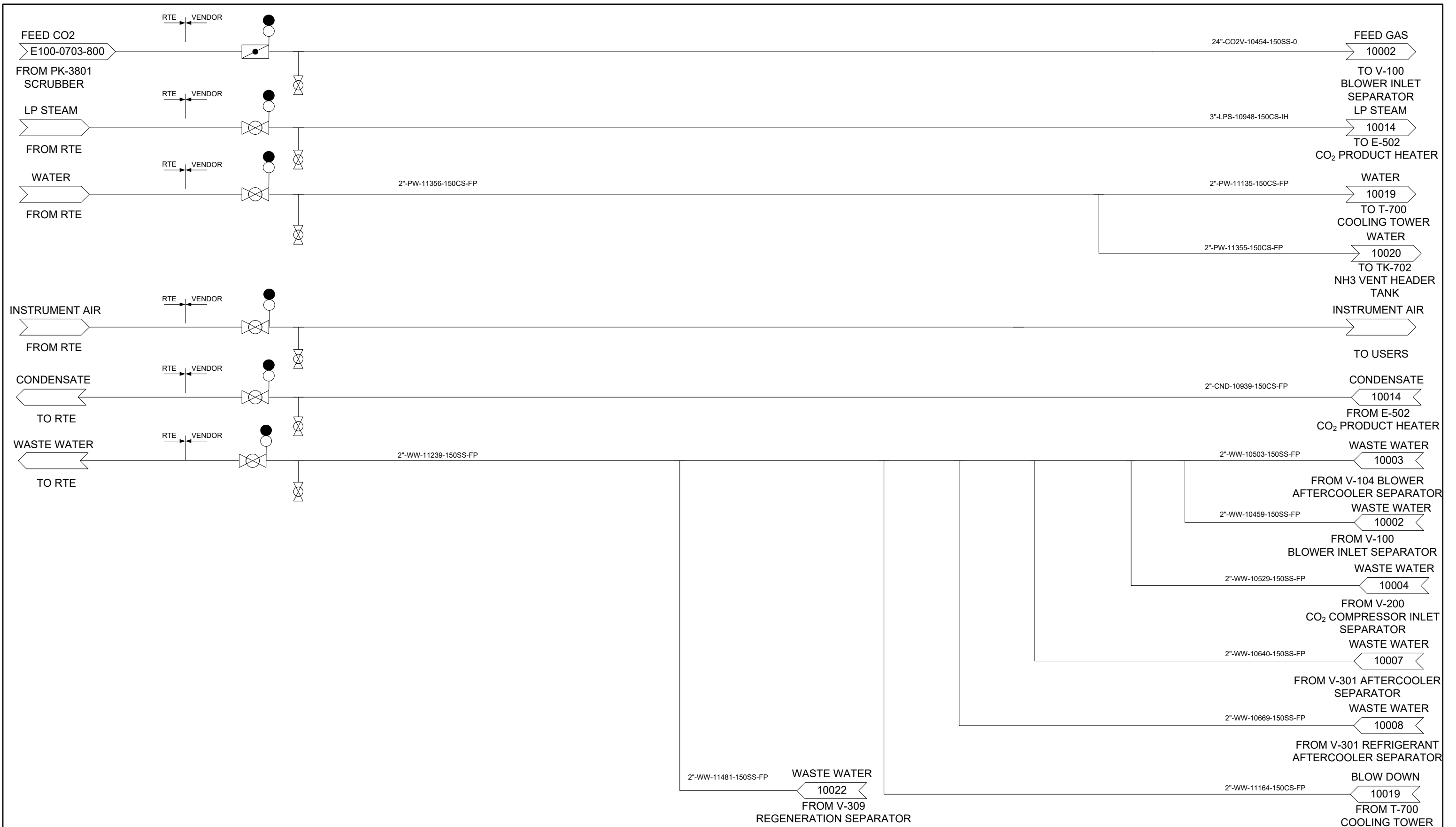


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**EERC – RTE CO₂ INJECTION FACILITY
LEGEND**

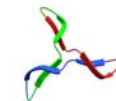
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CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-00000	NONE



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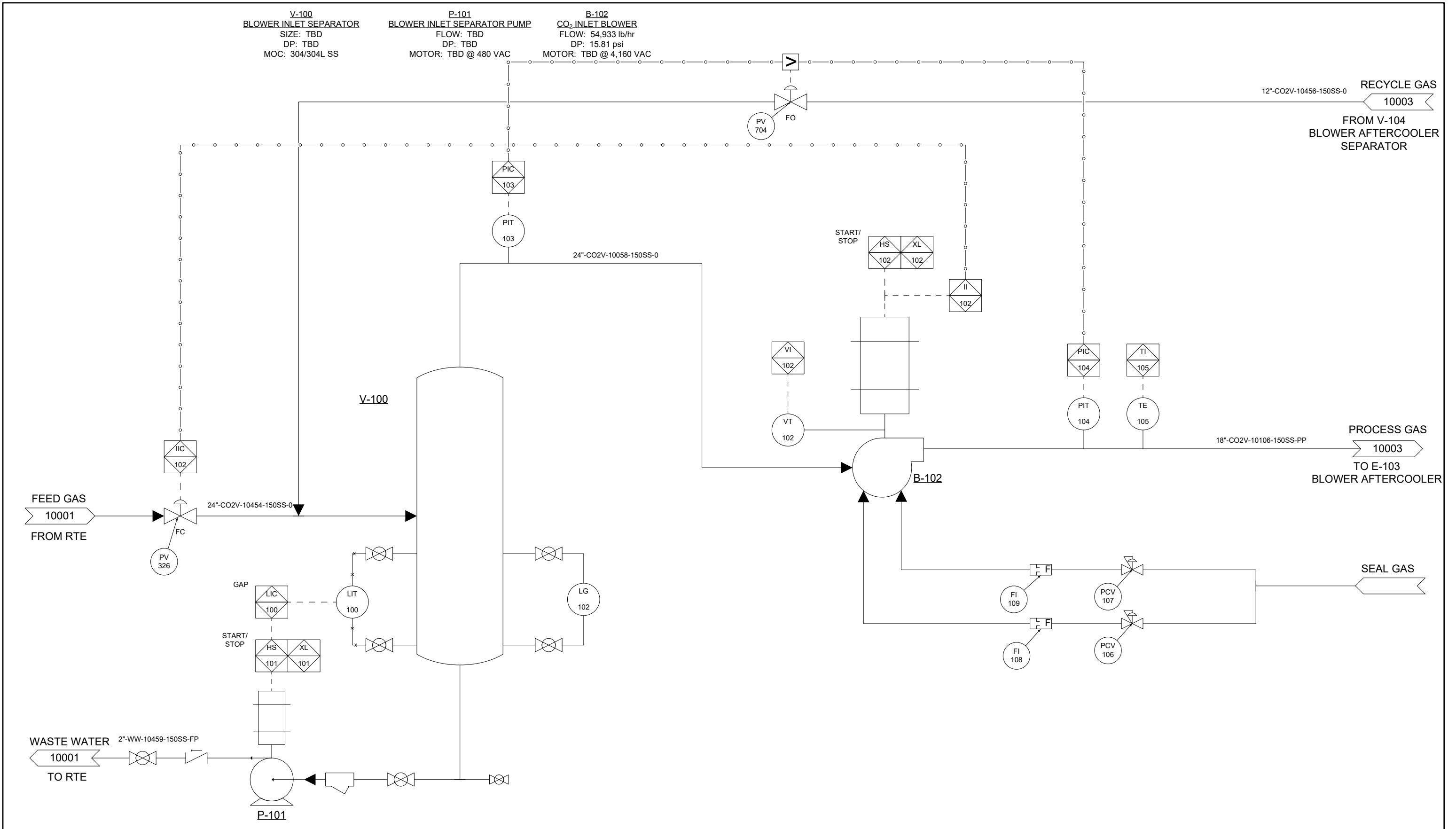


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**EERC – RTE CO₂ INJECTION FACILITY
BATTERY LIMITS**

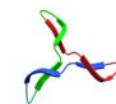
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EERC_P&IDS_REV0.VSD	04/17/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10001	NONE



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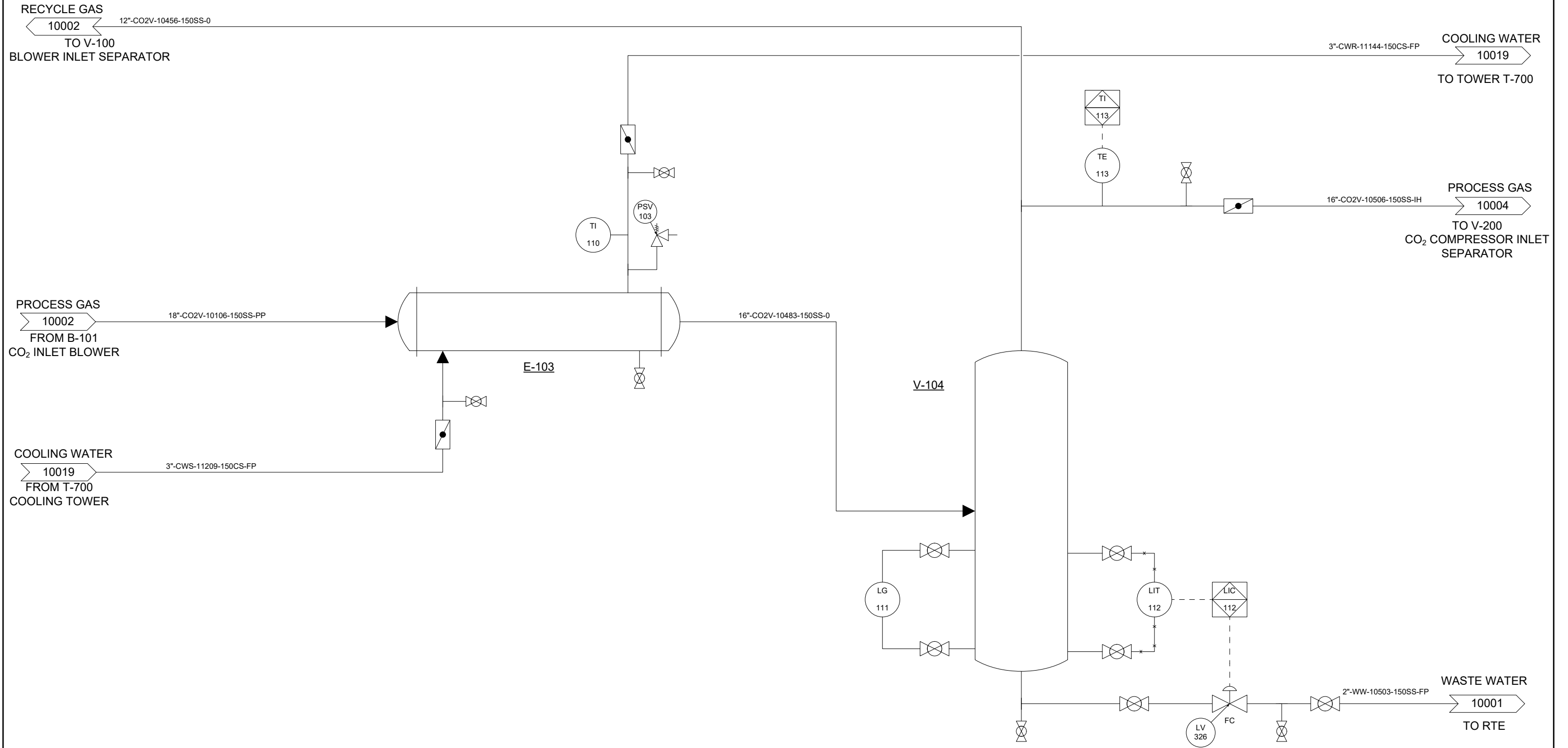
**EERC – RTE CO₂ INJECTION FACILITY
 CO₂ INLET BLOWER**

FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/12/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10002	NONE

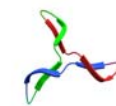
E-103
 CO₂ BLOWER AFTERCOOLER
 DUTY: 1.665 MMBTU/hr
 SHELL/TUBE: CS/304SS
 MDMT: -20 °F

V-104
 CO₂ BLOWER AFTERCOOLER SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: 304/304L SS



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REVISIONS						
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0	04/12/2019	ISSUED FOR REVIEW	BDP			



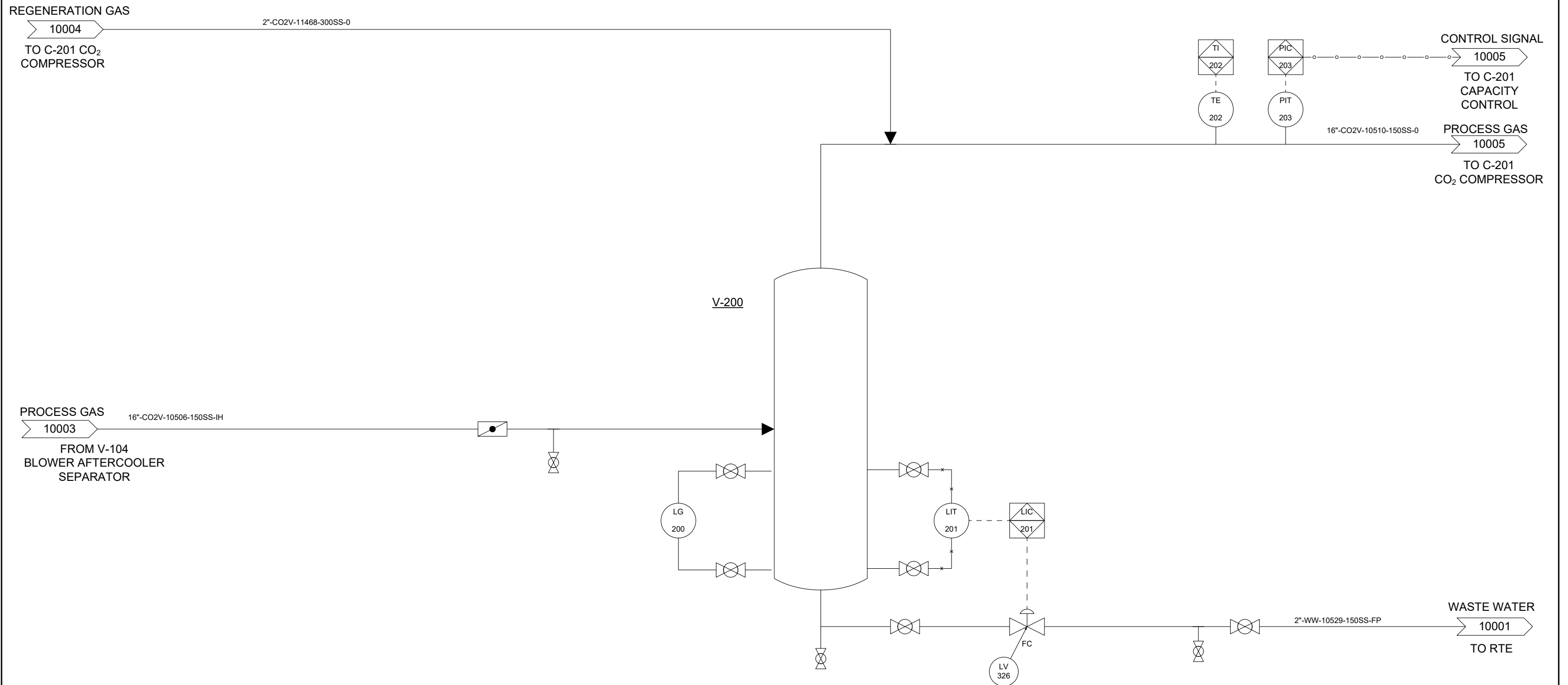
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 P.O. Box 826
 Buda, Texas 78610

EERC – RTE CO₂ INJECTION FACILITY
BLOWER AFTERCOOLER AND SEPARATION

FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/12/2019
 DRAWN BY: BRAD PIGGOTT

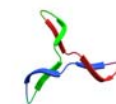
CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: PID-10003
 JOB NUMBER: 50168.04
 SCALE: NONE

V-200
 CO₂ COMPRESSOR INLET SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: 304/304L SS



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 Buda, Texas 78610

**EERC – RTE CO₂ INJECTION FACILITY
 COMPRESSOR INLET SEPARATION**

CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10004	SCALE NONE

FILENAME EERC_P&IDS_REV0.VSD	DATE 04/12/2019	DRAWN BY BRAD PIGGOTT
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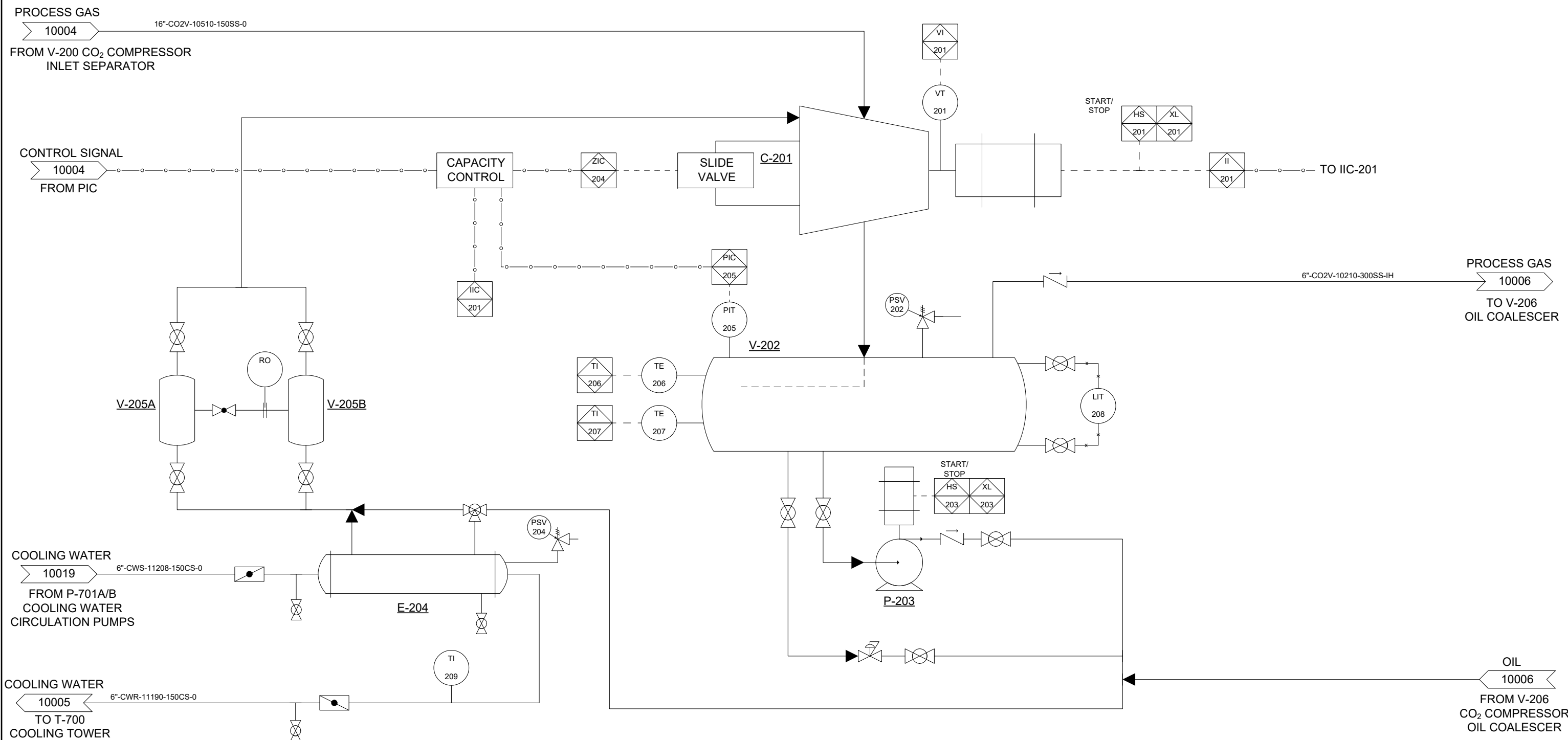
C-201
CO₂ COMPRESSOR
FLOW: 54,620 lb/hr
DP: 336.2 psi
MOTOR: TBD @ 4,160 VAC

V-202
CO₂ COMPRESSOR OIL SEPARATOR
SIZE: TBD
DP: TBD
MOC: 304/304L SS

P-203
CO₂ COMPRESSOR OIL PUMP
FLOW: TBD
DP: TBD
MOTOR: TBD @ 480 VAC

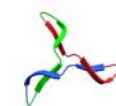
E-204
CO₂ COMPRESSOR LUBE OIL COOLER
DUTY: 5.76 MMBTU/hr
SHELL/TUBE: CS/CS
MDMT: -20 °F

V-205A/B
CO₂ COMPRESSOR LUBE OIL FILTERS
SIZE: TBD
DP: TBD
MOC: CS



PRELIMINARY – NOT FOR CONSTRUCTION

REVISIONS						
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0	04/15/2019	ISSUED FOR REVIEW	BDP			



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**EERC – RTE CO₂ INJECTION FACILITY
CO₂ COMPRESSOR**

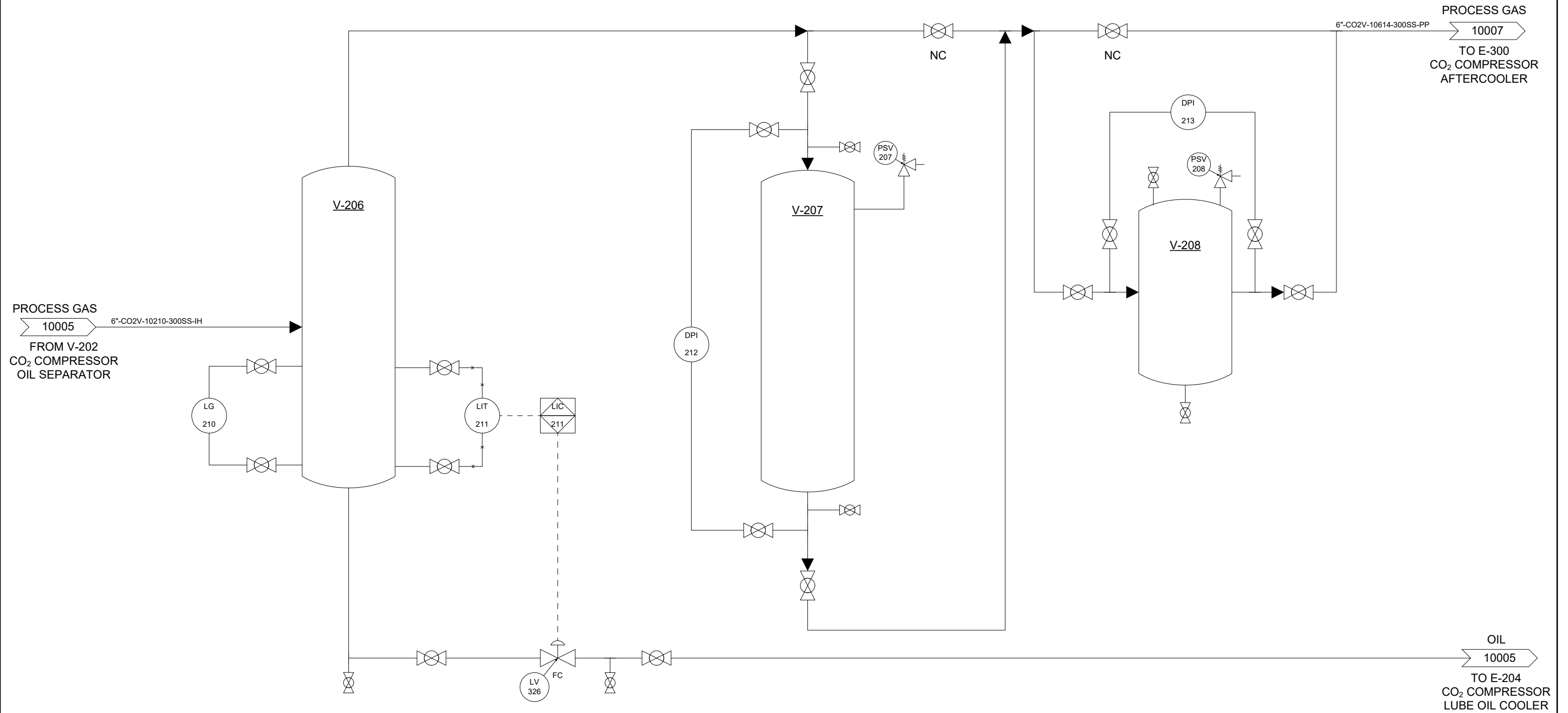
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DATE: 04/15/2019
DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
JOB NUMBER: 50168.04
DRAWING NUMBER: PID-10005
SCALE: NONE

V-206
CO₂ COMPRESSOR OIL COALESCER
SIZE: TBD
DP: TBD
MOC: 304/304L SS

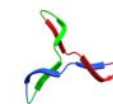
V-207
CO₂ CARBON BED
SIZE: TBD
DP: TBD
MOC: 304/304L SS

V-208
CARBON BED DUST FILTER
SIZE: TBD
DP: TBD
MOC: 304/304L SS



PRELIMINARY – NOT FOR CONSTRUCTION

REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/15/2019	ISSUED FOR REVIEW	BDP			



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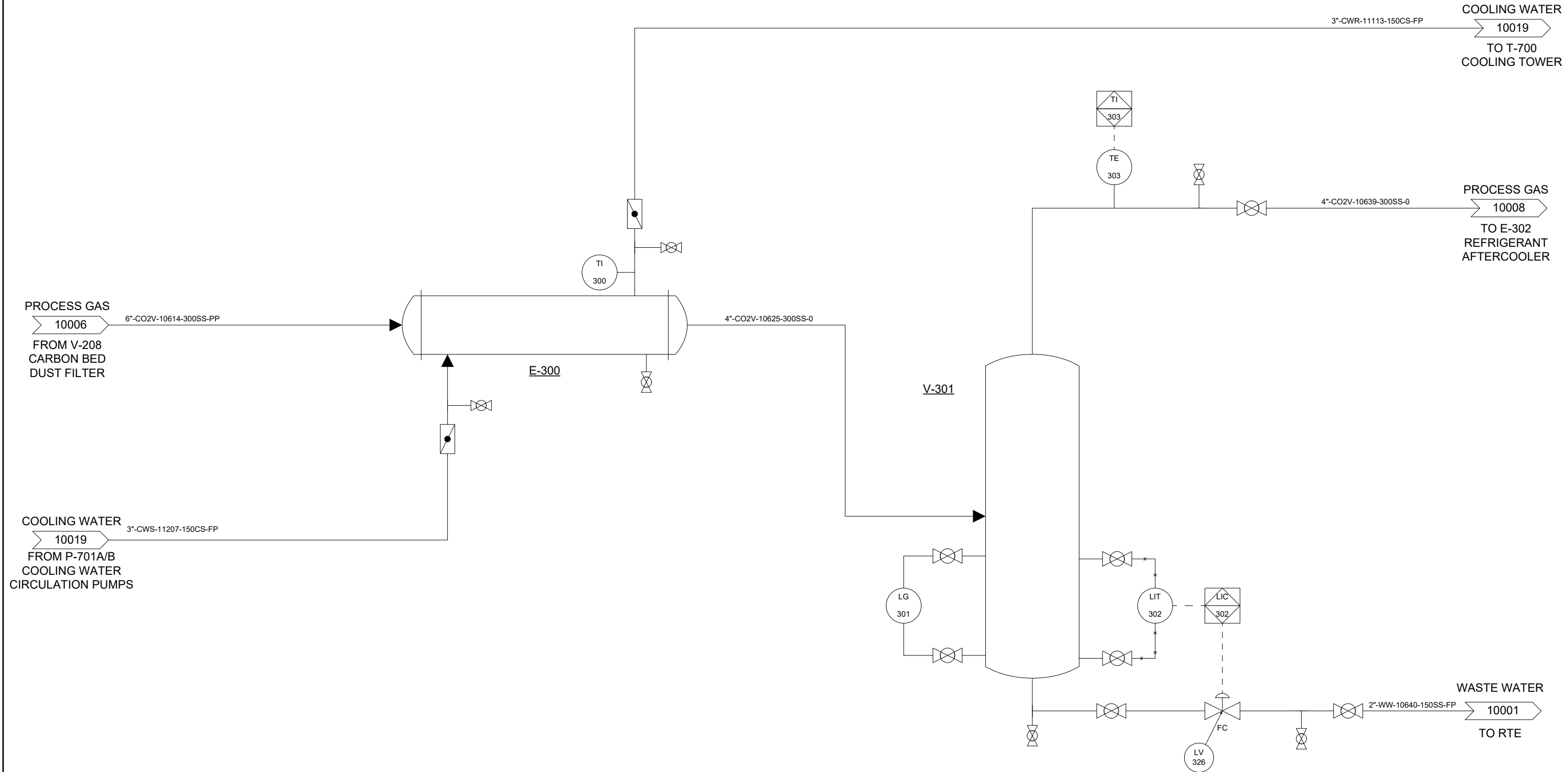
**EERC – RTE CO₂ INJECTION FACILITY
CO₂ COMPRESSOR OIL POLISHING**

CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10006	SCALE NONE

FILENAME EERC_P&IDS_REV0.VSD	DATE 04/15/2019	DRAWN BY BRAD PIGGOTT
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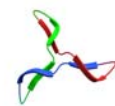
E-300
 CO₂ COMPRESSOR AFTERCOOLER
 DUTY: 1.686 MMBTU/hr
 SHELL/TUBE: CS/SS
 MDMT: -20 °F

V-301
 AFTERCOOLER SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: 304/304L SS



PRELIMINARY – NOT FOR CONSTRUCTION

REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/15/2019	ISSUED FOR REVIEW	BDP			



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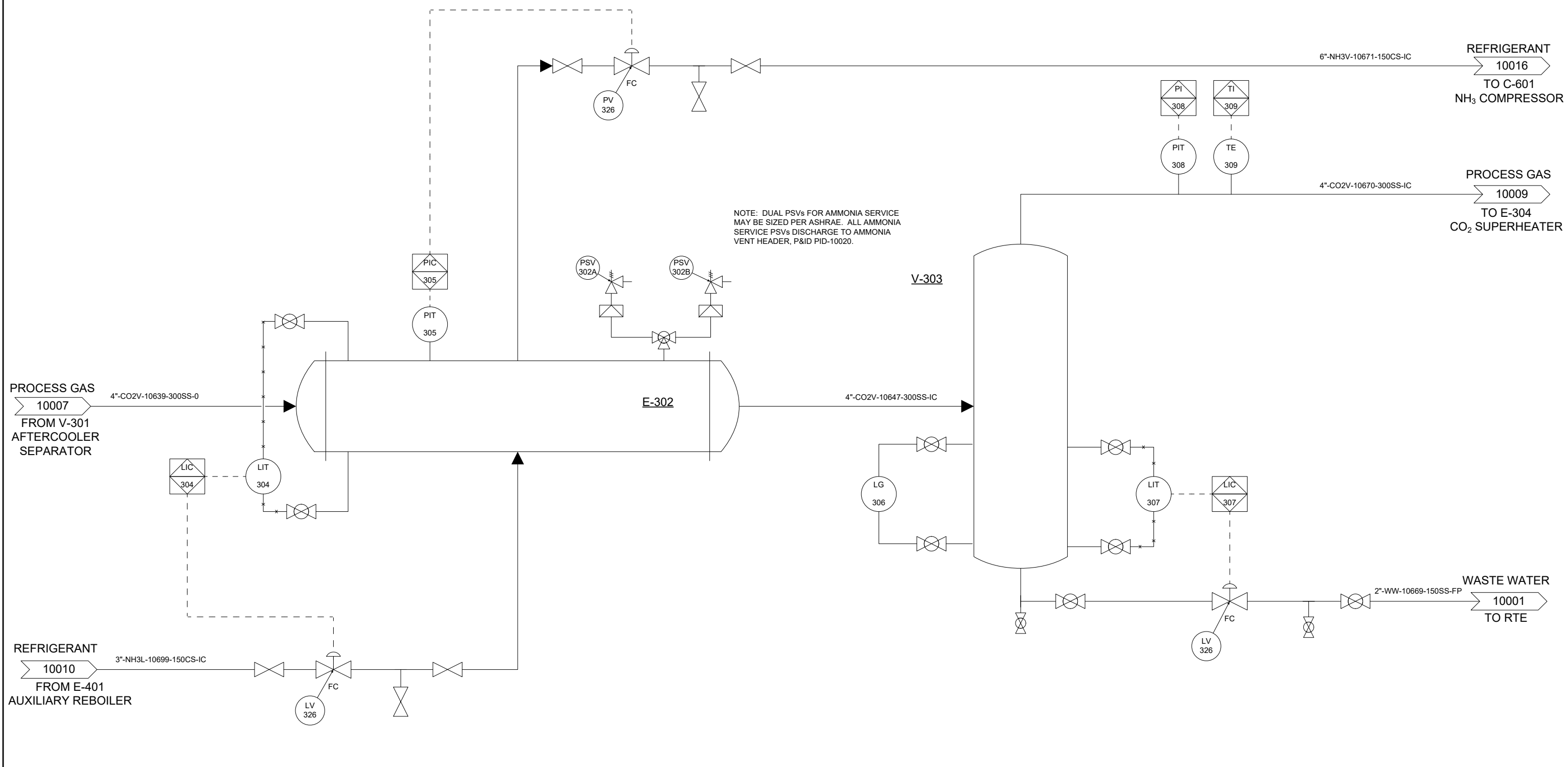
**EERC – RTE CO₂ INJECTION FACILITY
 CO₂ COOLING**

FILENAME	DATE	DRAWN BY
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CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10007	NONE

E-302
REFRIGERANT AFTERCOOLER
 DUTY: 0.534 MMBTU/hr
 SHELL/TUBE: CS/SS
 MDMT: -20 °F

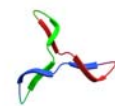
V-303
REFRIGERANT AFTERCOOLER SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: 304/304L SS



NOTE: DUAL PSVs FOR AMMONIA SERVICE MAY BE SIZED PER ASHRAE. ALL AMMONIA SERVICE PSVs DISCHARGE TO AMMONIA VENT HEADER, P&ID PID-10020.

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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/15/2019	ISSUED FOR REVIEW	BDP			

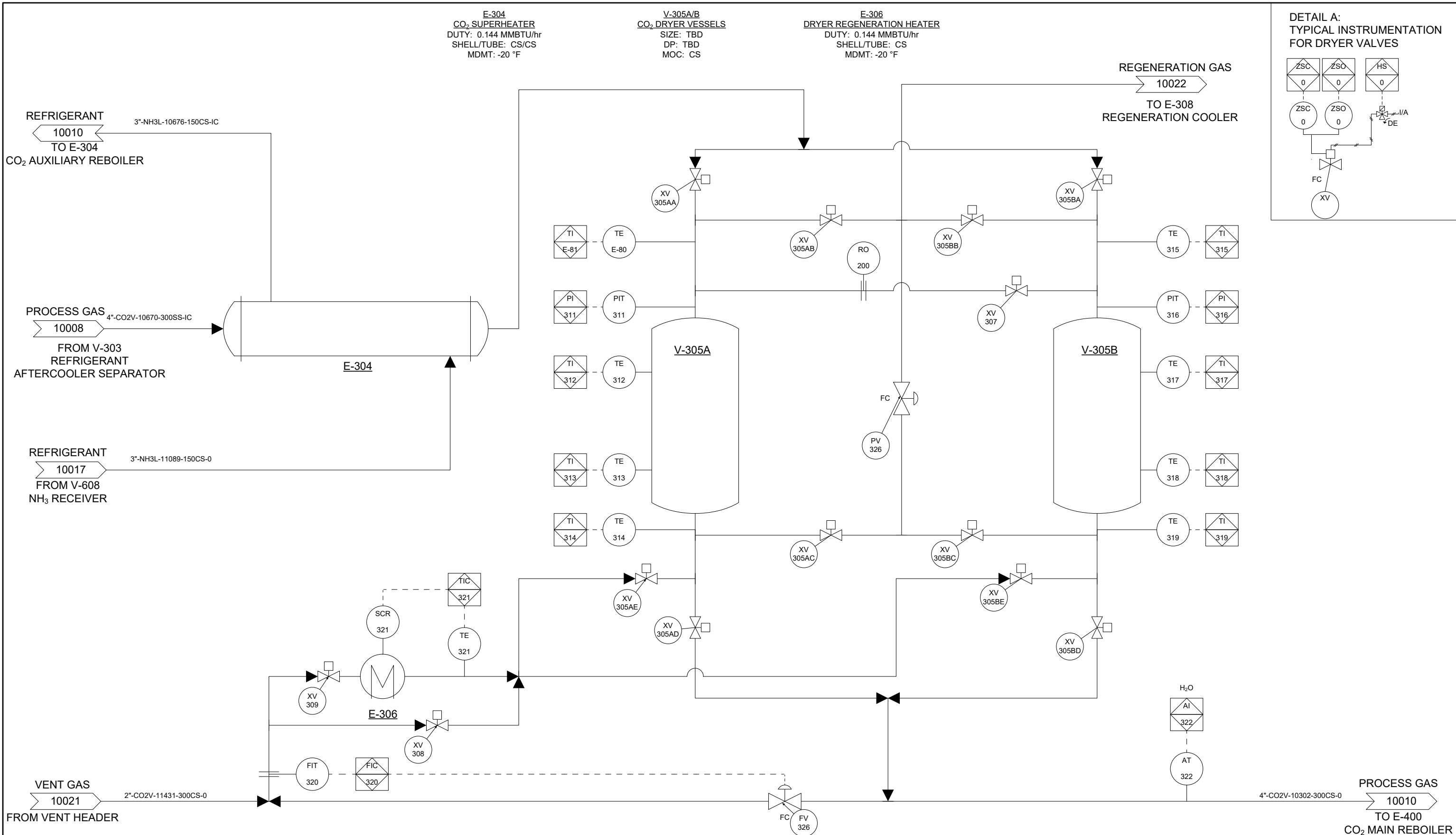


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 Buda, Texas 78610

EERC – RTE CO₂ INJECTION FACILITY
CO₂ COOLING

FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/15/2019
 DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: PID-10008
 JOB NUMBER: 50168.04
 SCALE: NONE



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/15/2019	ISSUED FOR REVIEW	BDP			

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**EERC – RTE CO₂ INJECTION FACILITY
 CO₂ DEHYDRATION**

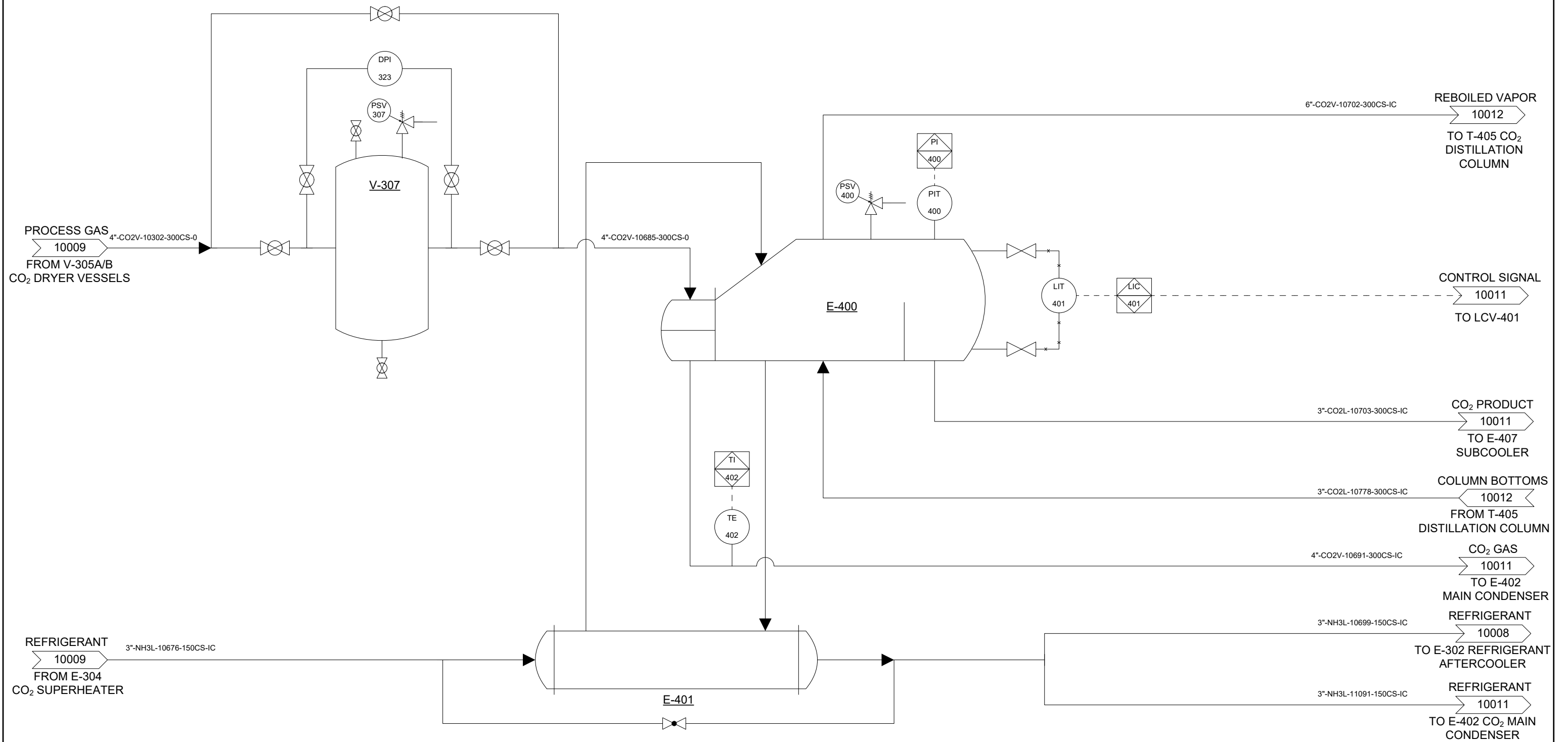
FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/15/2019
 DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: PID-10009
 JOB NUMBER: 50168.04
 SCALE: NONE

V-307
 DRYER BED DUST FILTER
 SIZE: TBD
 DP: TBD
 MOC: CS

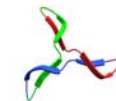
E-400
 CO₂ MAIN REBOILER
 DUTY: 0.621 MMBTU/hr
 SHELL/TUBE: LTCS/LTCS
 MDMT: -50 °F

E-401
 CO₂ AUXILIARY REBOILER
 DUTY: 0.75 MMBTU/hr
 SHELL/TUBE: LTCS/LTCS
 MDMT: -50 °F



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0	04/12/2019	ISSUED FOR REVIEW	BDP				



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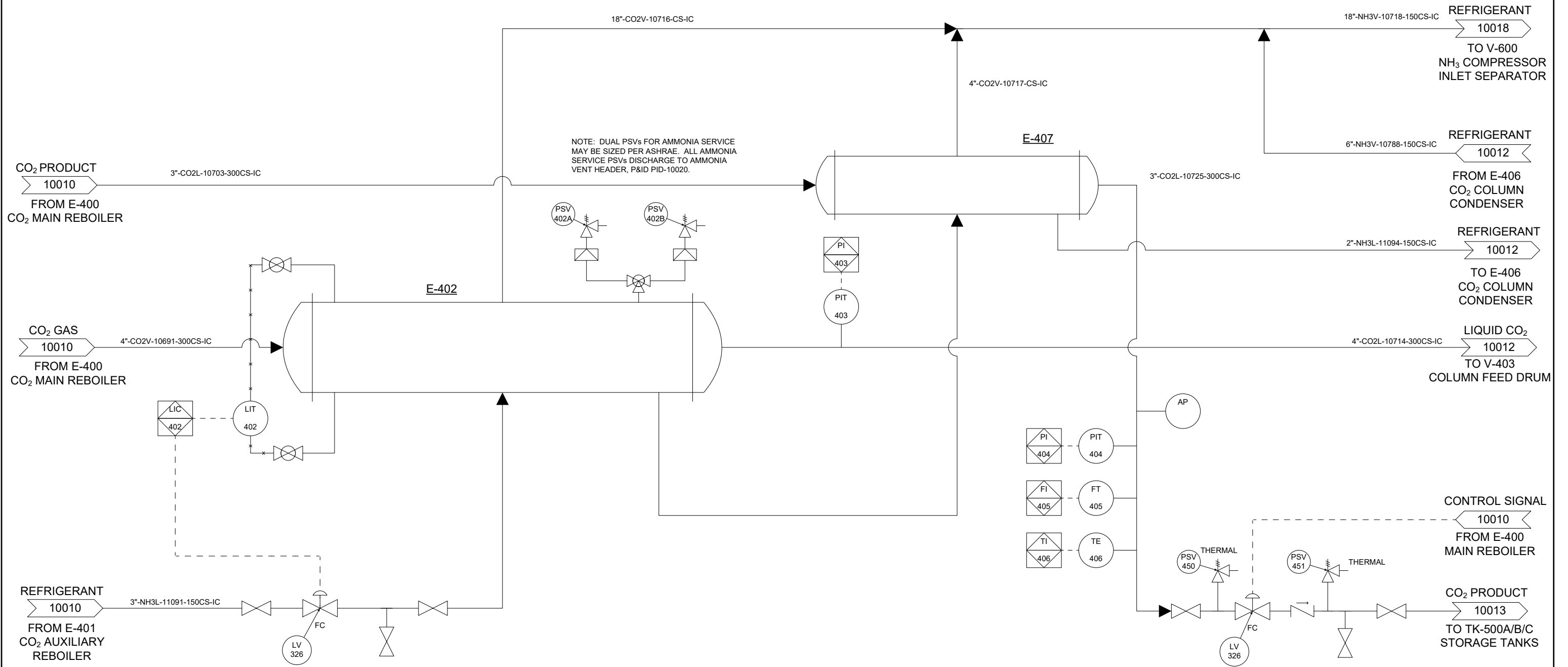
**EERC – RTE CO₂ INJECTION FACILITY
 DISTILLATION REBOILERS**

CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10010	SCALE NONE

FILENAME EERC_P&IDS_REV0.VSD	DATE 04/12/2019	DRAWN BY BRAD PIGGOTT
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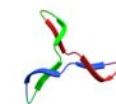
E-402
 CO₂ MAIN CONDENSER
 DUTY: 7.115 MMBTU/hr
 SHELL/TUBE: LTCS/LTCS
 MDMT: -50 °F

E-407
 CO₂ SUBCOOLER
 DUTY: 0.285 MMBTU/hr
 SHELL/TUBE: LTCS/LTCS
 MDMT: -50 °F



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/12/2019	ISSUED FOR REVIEW	BDP			

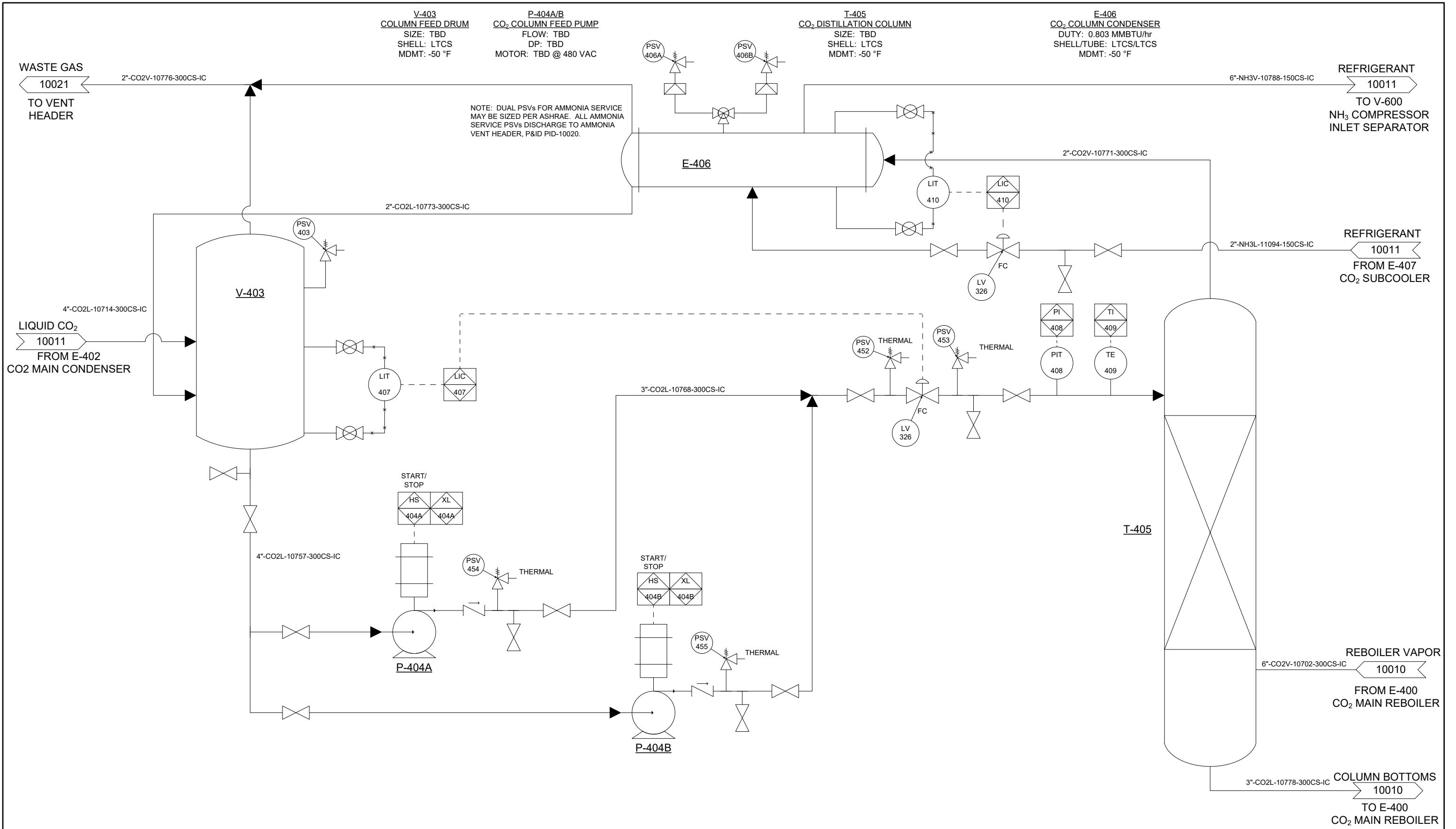


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EERC – RTE CO₂ INJECTION FACILITY
CO₂ CONDENSER AND SUBCOOLER

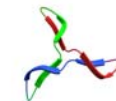
FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/12/2019
 DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: PID-10011
 JOB NUMBER: 50168.04
 SCALE: NONE



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0	04/12/2019	ISSUED FOR REVIEW	BDP			



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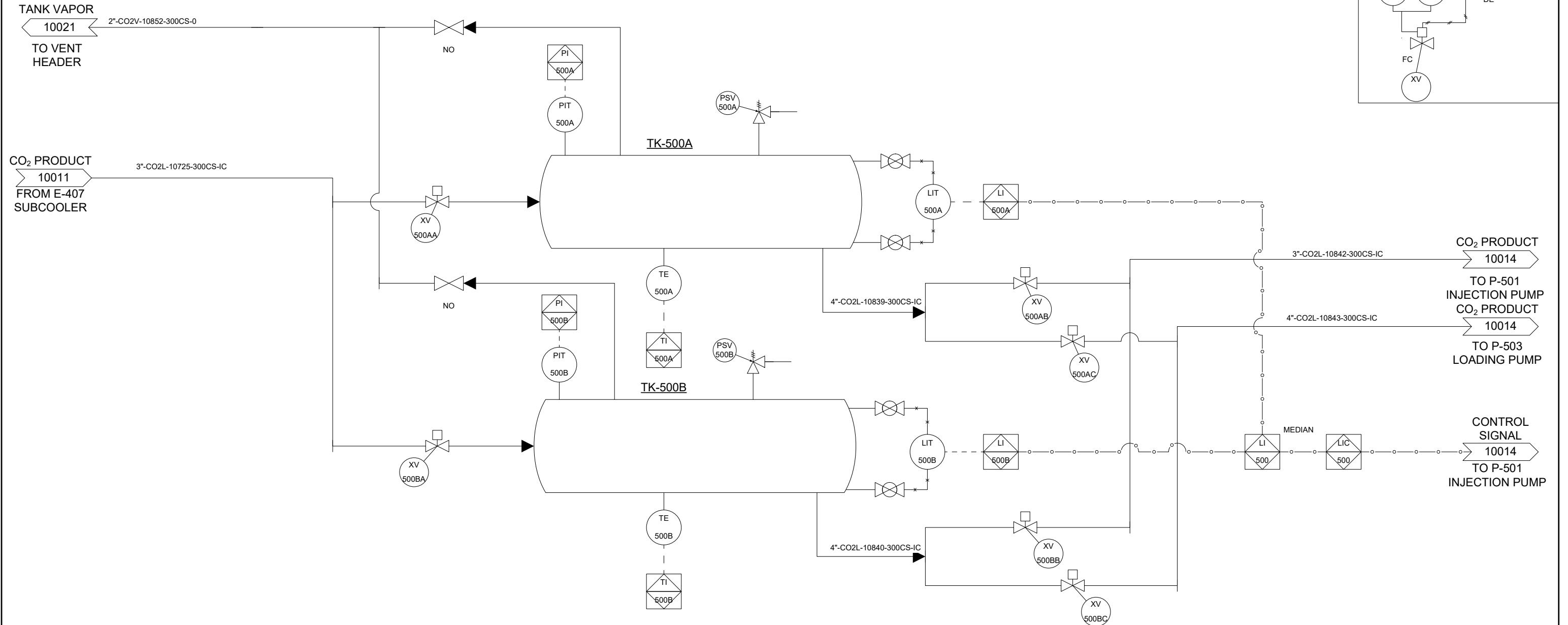
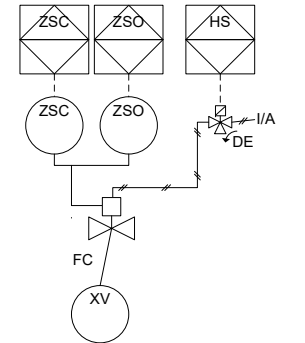
**EERC – RTE CO₂ INJECTION FACILITY
CO₂ DISTILLATION**

FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/12/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10012	NONE

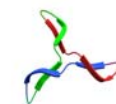
TK-500A/B/C
 CO₂ PRODUCT STORAGE TANKS
 SIZE: 12.5' D x 115' L
 MDMT: -50 °F

DETAIL A:
 TYPICAL INSTRUMENTATION
 FOR STORAGE TANK VALVES



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REVISIONS							
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED	
0	04/12/2019	ISSUED FOR REVIEW	BDP				



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**EERC – RTE CO₂ INJECTION FACILITY
 PRODUCT STORAGE**

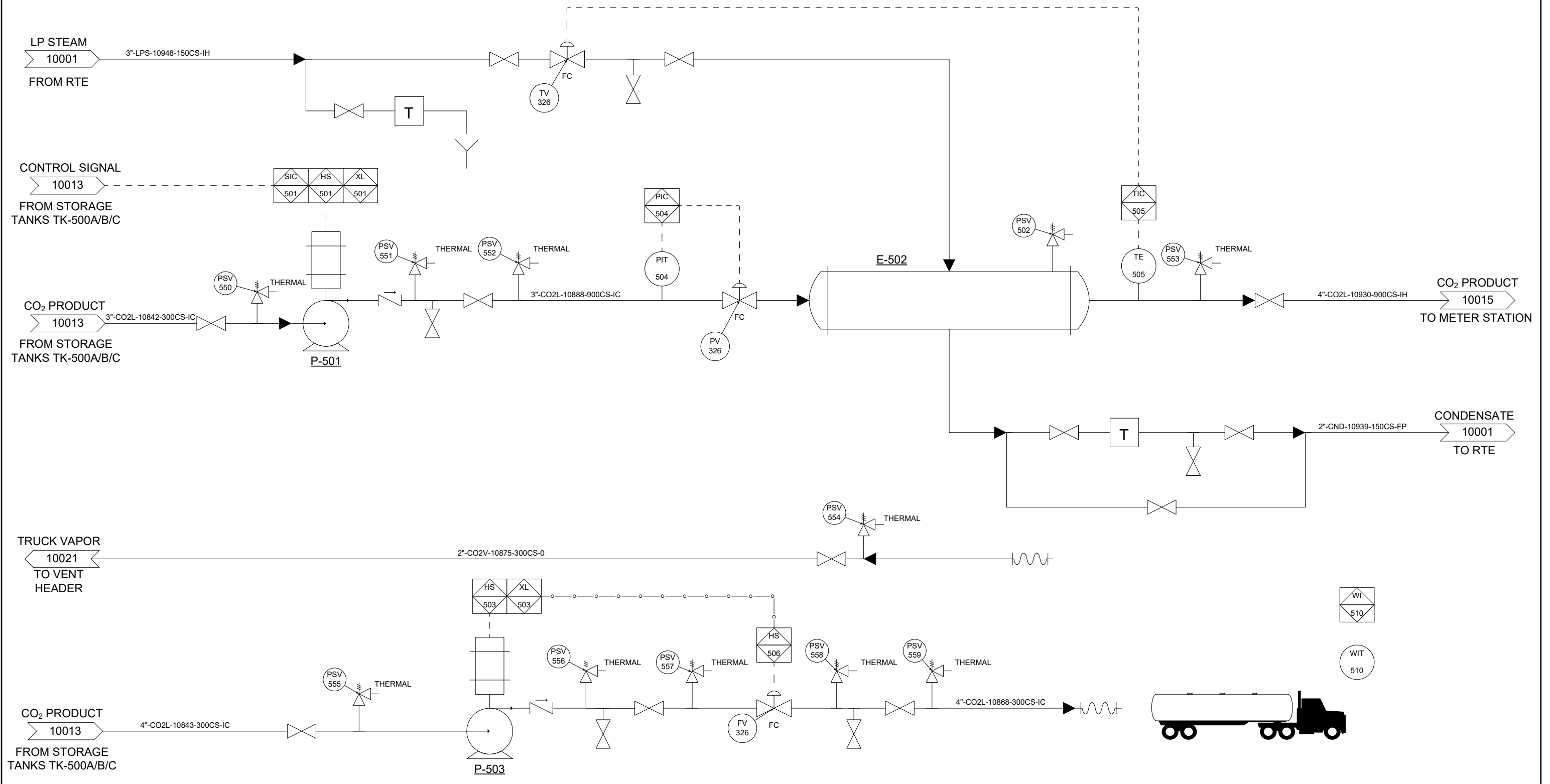
FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/12/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10013	NONE

P-501
CO₂ INJECTION PUMP
 FLOW: 54,055 lb/hr
 DP: 1,209 psi
 MOTOR: 150 hp @ 480 VAC

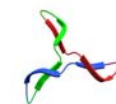
E-502
CO₂ PRODUCT HEATER
 DUTY: 1.695 MMBTU/HR
 SHELL/TUBE: CS/LTCS
 MDMT: -50 °F

P-503
CO₂ LOADING PUMP
 FLOW: TBD
 DP: TBD
 MOTOR: TBD @ 480 VAC



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0	04/12/2019	ISSUED FOR REVIEW	BDP			

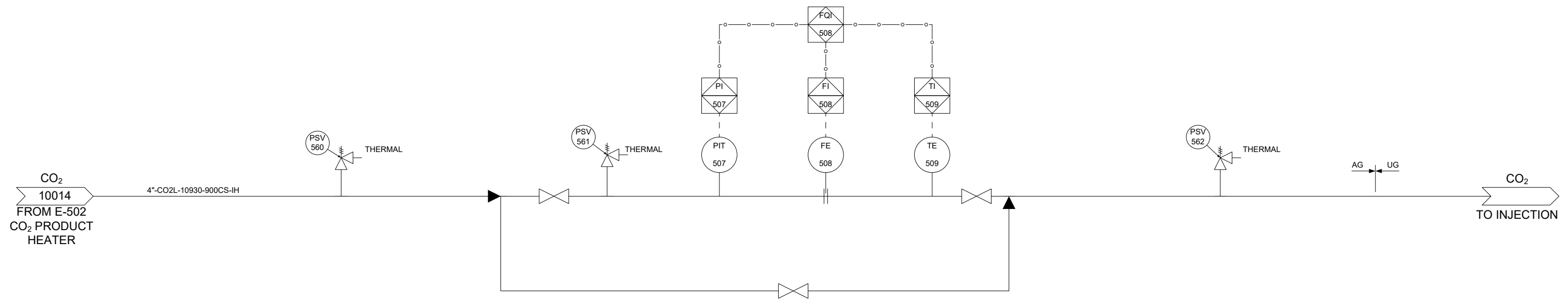


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EERC – RTE CO₂ INJECTION FACILITY
PRODUCT PUMPING

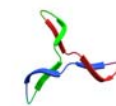
FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/12/2019
 DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: PID-10014
 JOB NUMBER: 50168.04
 SCALE: NONE



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/12/2019	ISSUED FOR REVIEW	BDP			

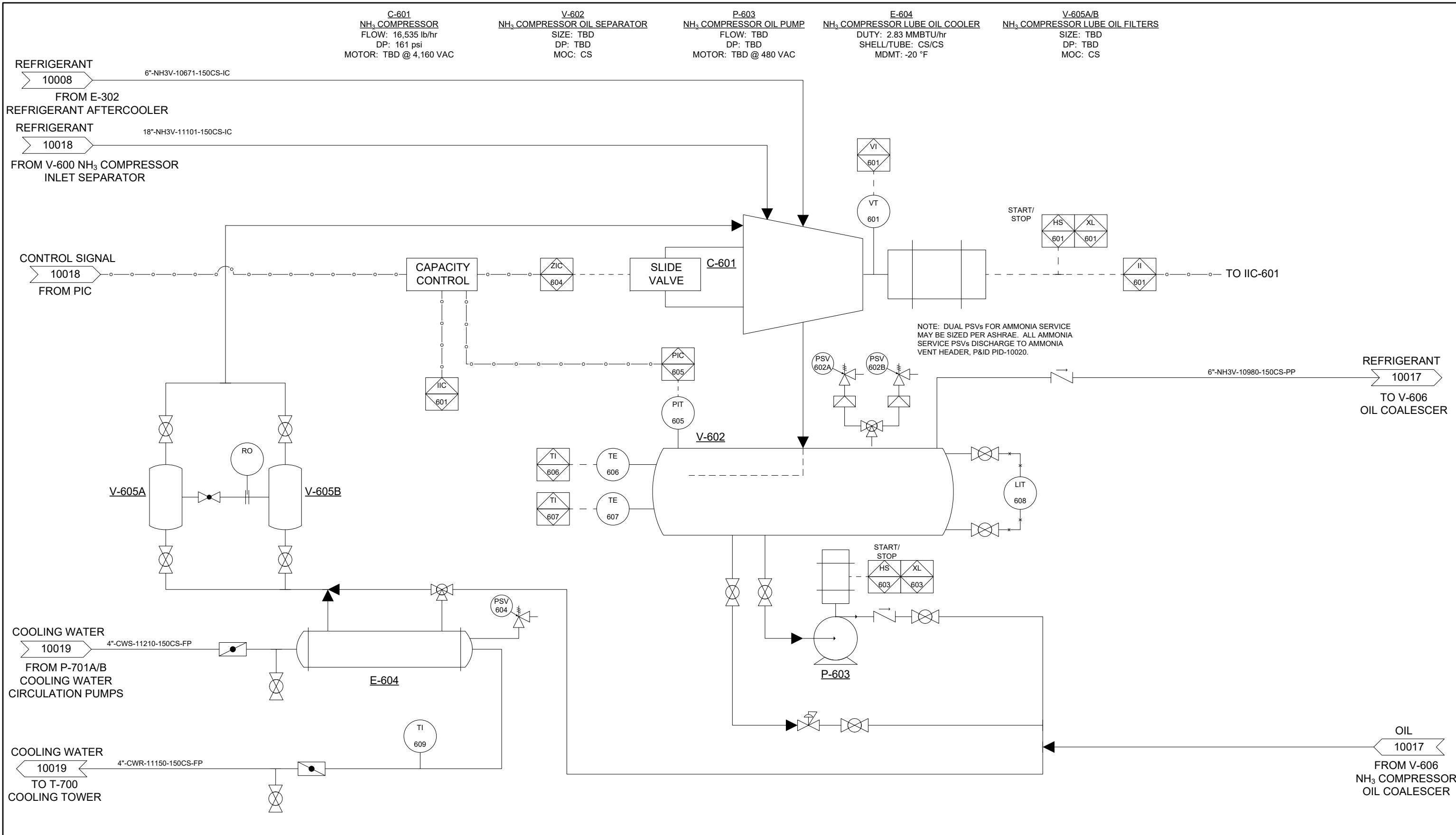


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**EERC – RTE CO₂ INJECTION FACILITY
INJECTION METER STATION**

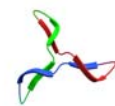
FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/12/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10015	NONE



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**EERC – RTE CO₂ INJECTION FACILITY
REFRIGERATION COMPRESSOR**

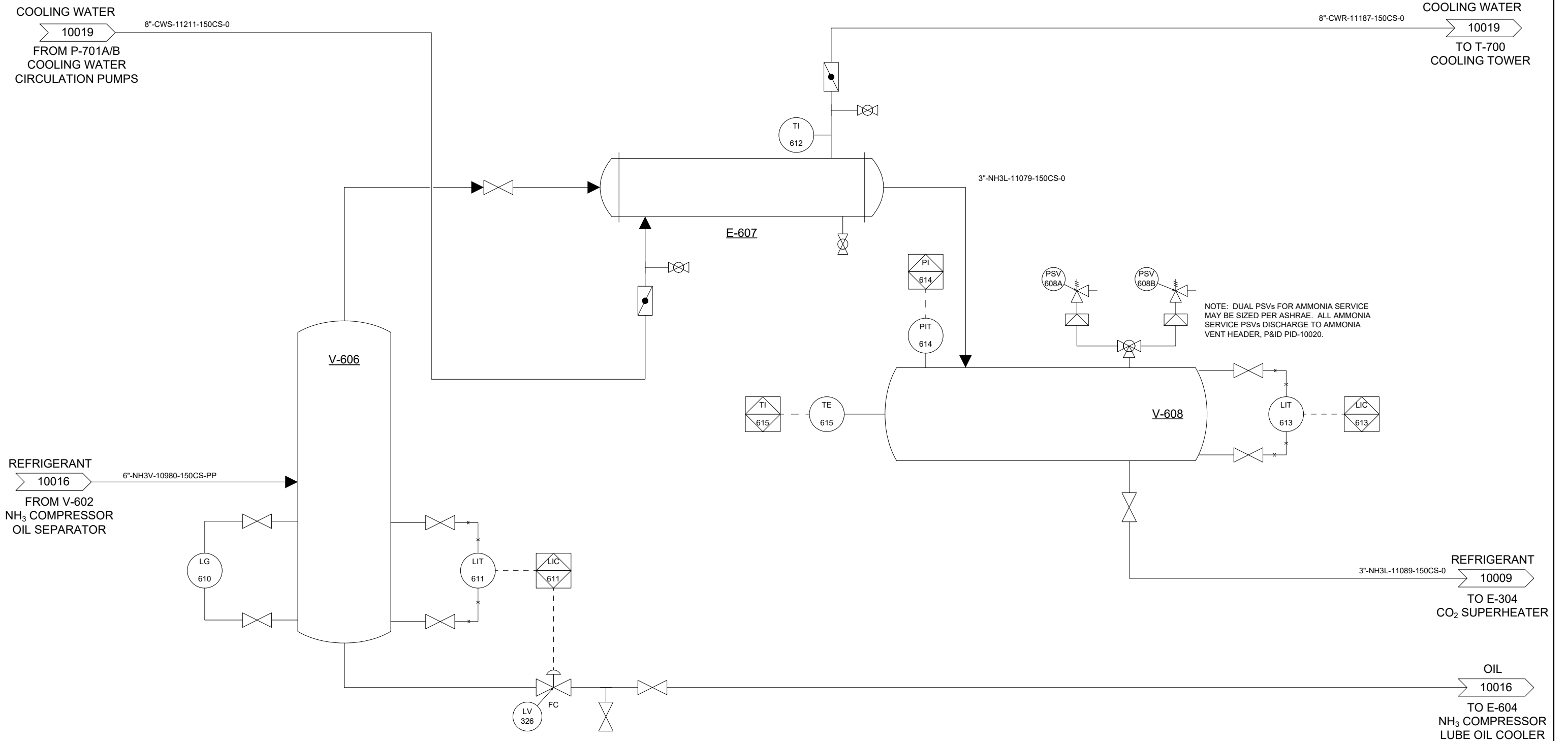
FILENAME: EERC_P&IDS_REV0.VSD
DATE: 04/17/2019
DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
JOB NUMBER: 50168.04
DRAWING NUMBER: PID-10016
SCALE: NONE

V-606
NH₃ COMPRESSOR OIL COALESCER
SIZE: TBD
DP: TBD
MOC: CS

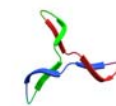
E-607
NH₃ CONDENSER
DUTY: 9.26 MMBTU/HR
SHELL/TUBE: CS/LTCS
MDMT: TBD

V-608
NH₃ RECEIVER
SIZE: TBD
DP: TBD
MOC: CS



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/17/2019	ISSUED FOR REVIEW	BDP			



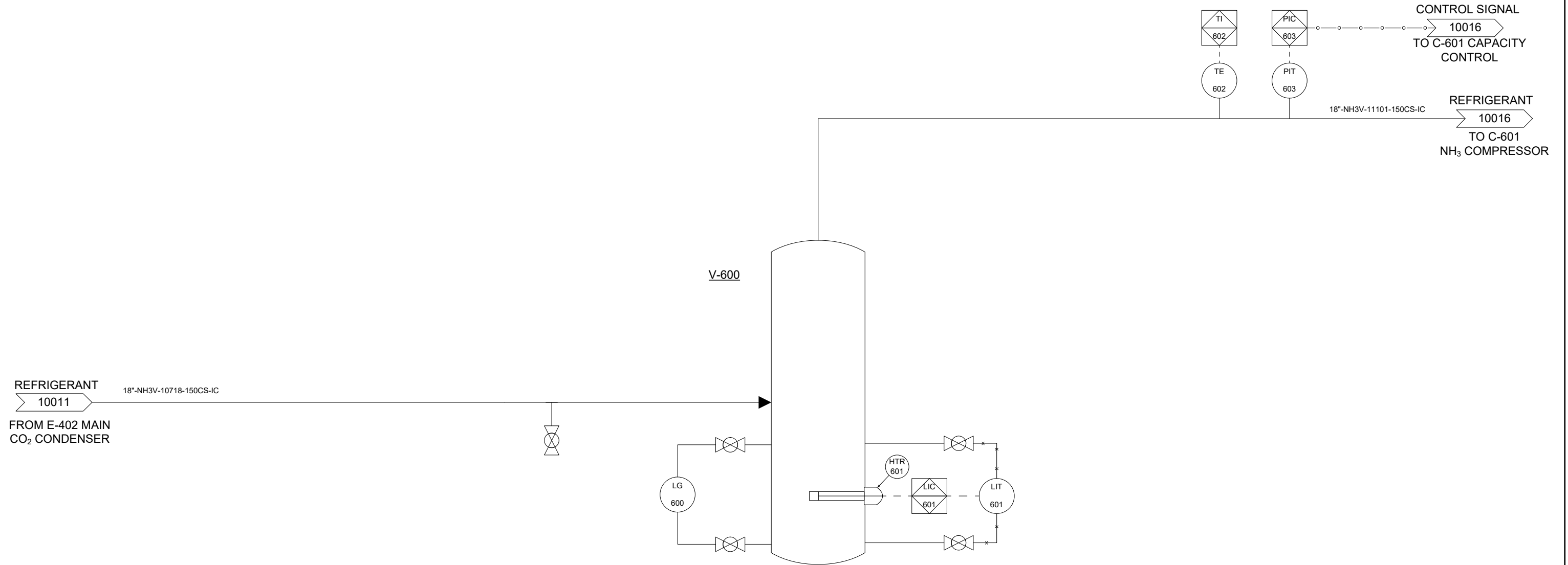
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**EERC – RTE CO₂ INJECTION FACILITY
NH₃ CONDENSER AND RECEIVER**

CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10017	SCALE NONE

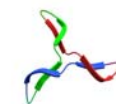
FILENAME EERC_P&IDS_REV0.VSD	DATE 04/17/2019	DRAWN BY BRAD PIGGOTT
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V-600
 NH₃ COMPRESSOR INLET SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: CS



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**EERC – RTE CO₂ INJECTION FACILITY
 NH₃ COMPRESSOR INLET SEPARATION**

FILENAME: EERC_P&IDS_REV0.VSD
 DATE: 04/12/2019
 DRAWN BY: BRAD PIGGOTT

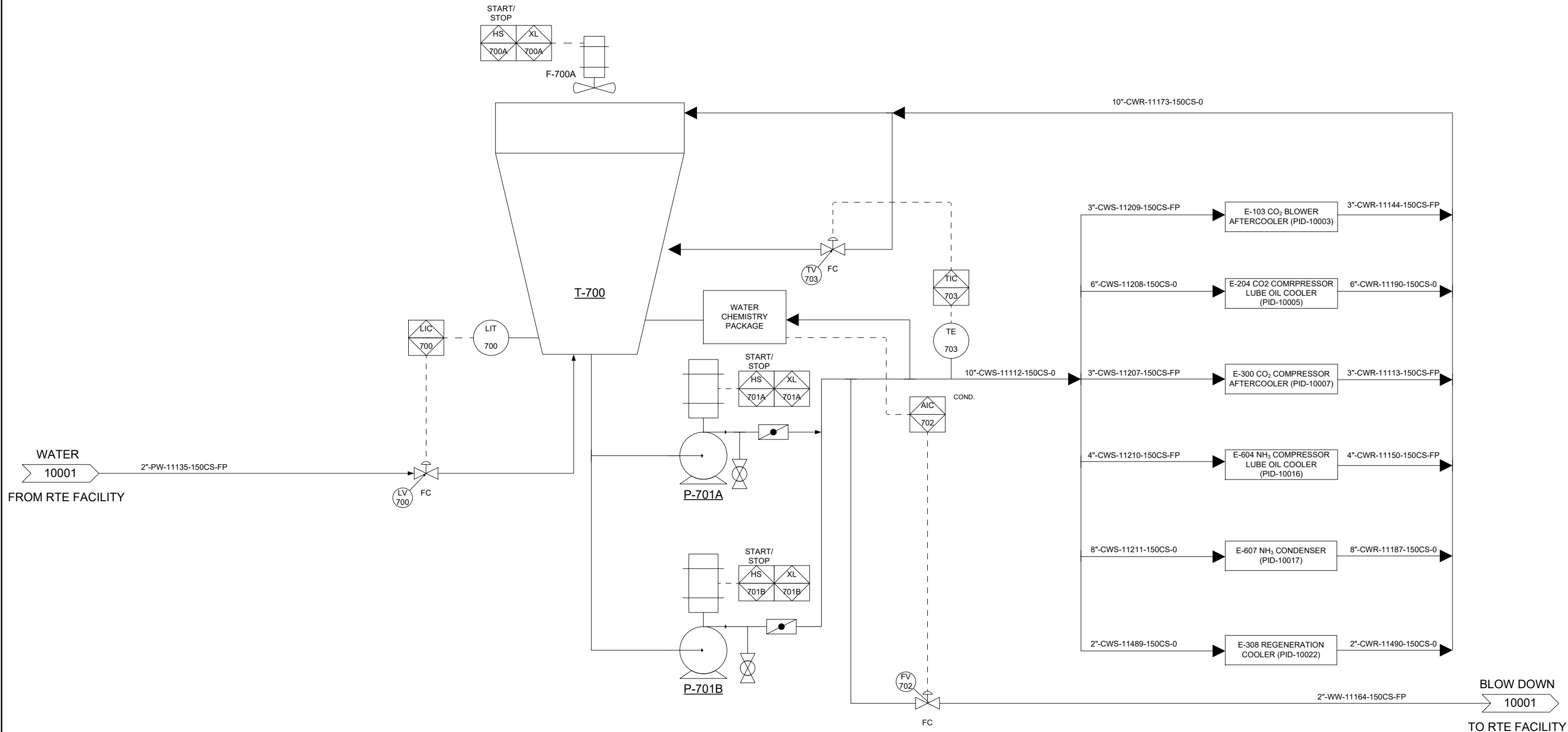
CLIENT/SITE: EERC / RTE ETHANOL RICHARDTON, ND
 DRAWING NUMBER: 10018
 JOB NUMBER: 50168.04
 SCALE: NONE

T-700
COOLING TOWER
 SIZE: 21.1 MMBTU/HR
 CELLS: 2

F-700A
COOLING TOWER FAN
 FLOW: TBD
 DP: TBD
 MOTOR: TBD @ 480 VAC

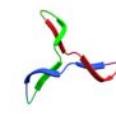
P-701A/B
COOLING WATER CIRCULATION PUMPS
 FLOW: 1,695 gpm
 DP: 50 psi
 MOTOR: 66 hp @ 480 VAC

NOTES
 1. ORDER OF EXCHANGERS TO BE DETERMINED DURING DETAILED DESIGN.
 2. SEE INDIVIDUAL P&IDs FOR BALANCING VALVES AND TEMPERATURE GAUGES.



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0	04/12/2019	ISSUED FOR REVIEW	BDP				



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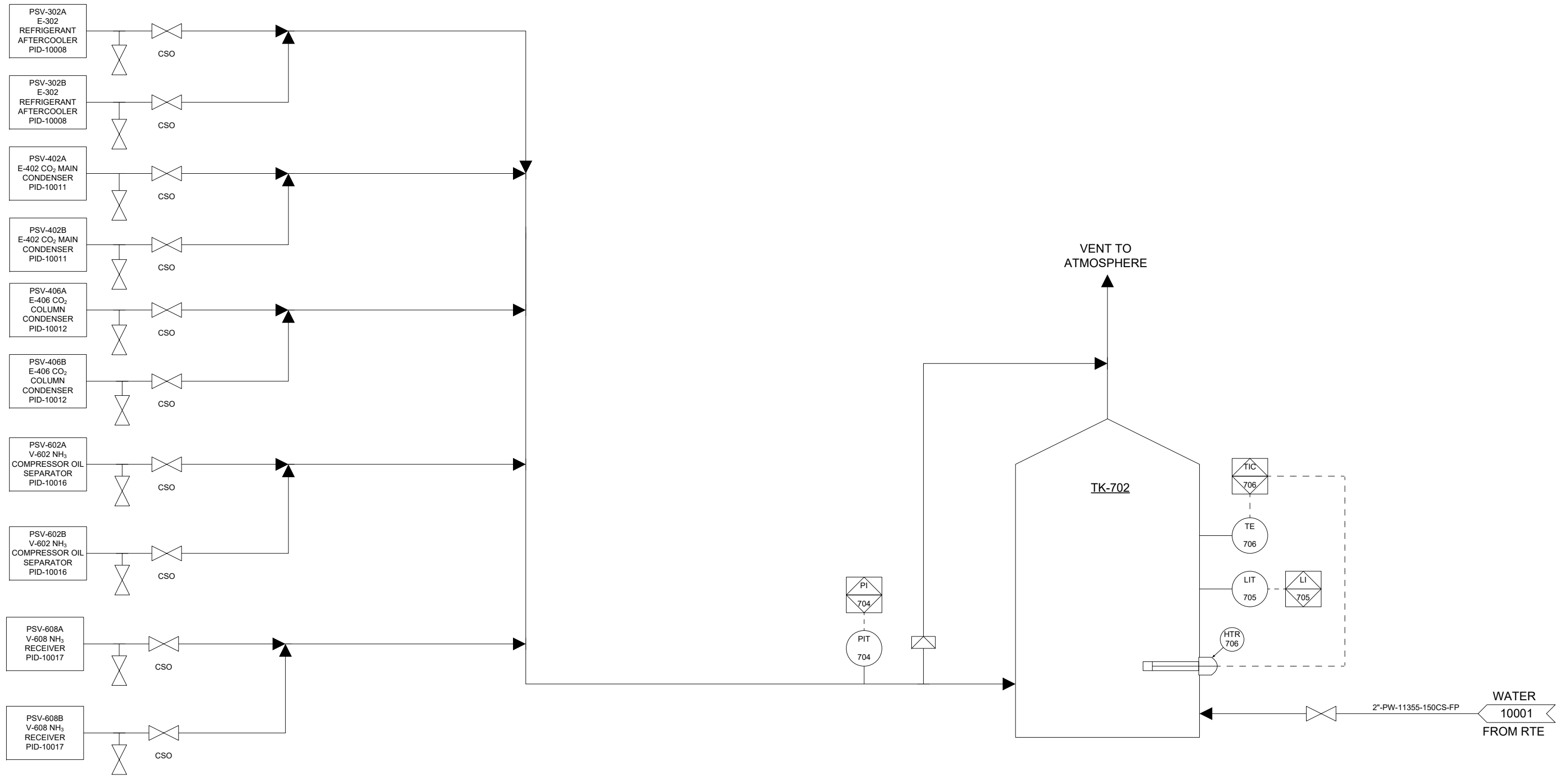
EERC – RTE CO₂ INJECTION FACILITY
COOLING TOWER

FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/12/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10019	NONE

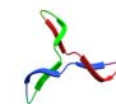
TK-702
 NH₃ VENT HEADER TANK
 SIZE: TBD
 DP: TBD
 MOC: CS

PIPING NOTES
 1. PIPING TO SLOPE CONTINUOUSLY DOWNSTREAM 1" EVERY 10'.
 2. TRIMERIC RECOMMENDS NO POCKETS IN VENT HEADER PIPING.
 3. TRIMERIC RECOMMENDS THAT CONNECTIONS TO MAIN HEADER ALLOWED FROM THE TOP ONLY AT 45°.



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/18/2019	FOR REVIEW	BDP			

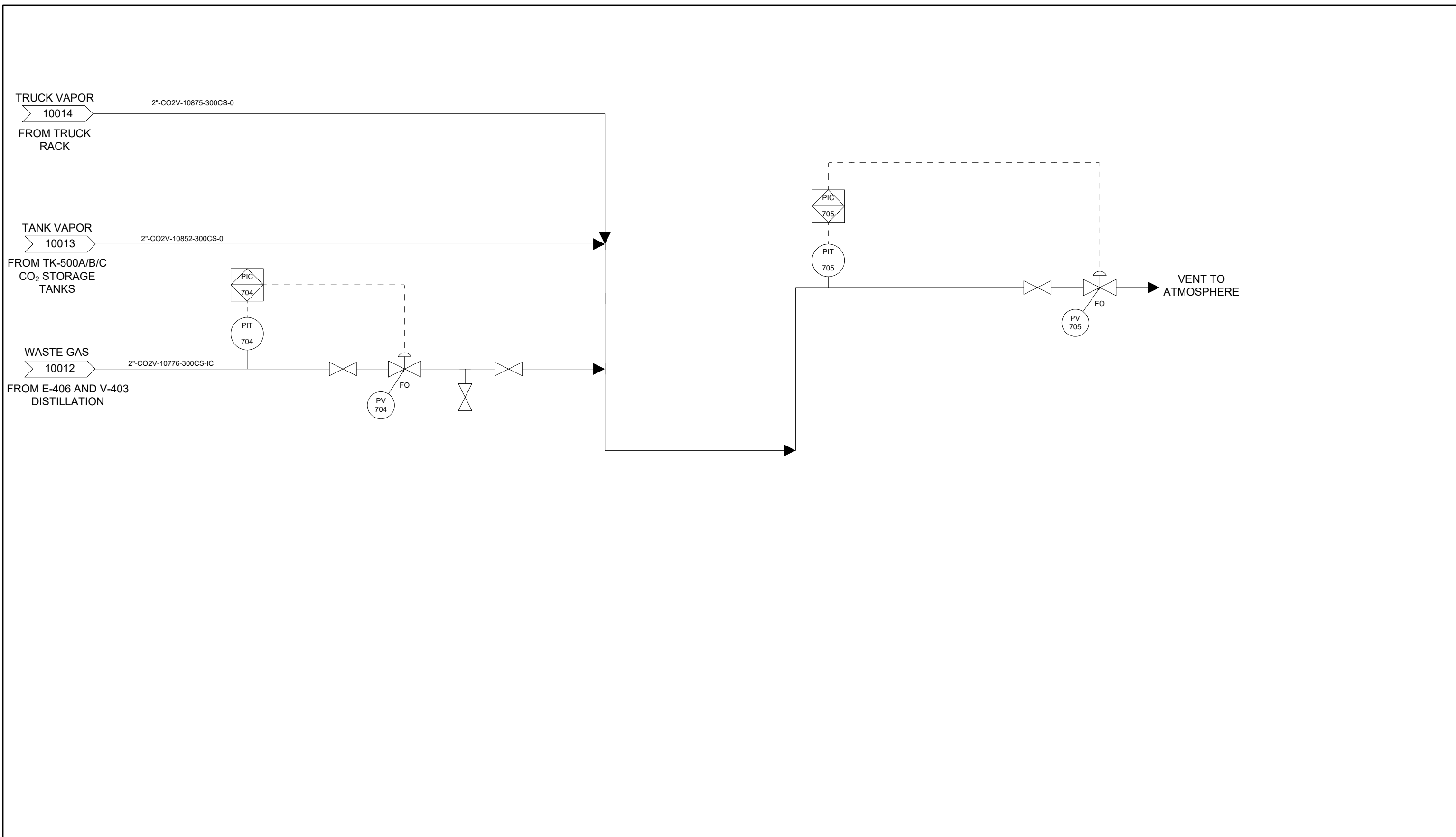


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**EERC – RTE CO₂ INJECTION FACILITY
 AMMONIA RELIEF HEADER**

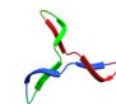
CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10020	SCALE NONE

FILENAME EERC_P&IDS_REV0.VSD	DATE 04/18/2019	DRAWN BY BRAD PIGGOTT
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0	04/18/2019	FOR REVIEW	BDP			



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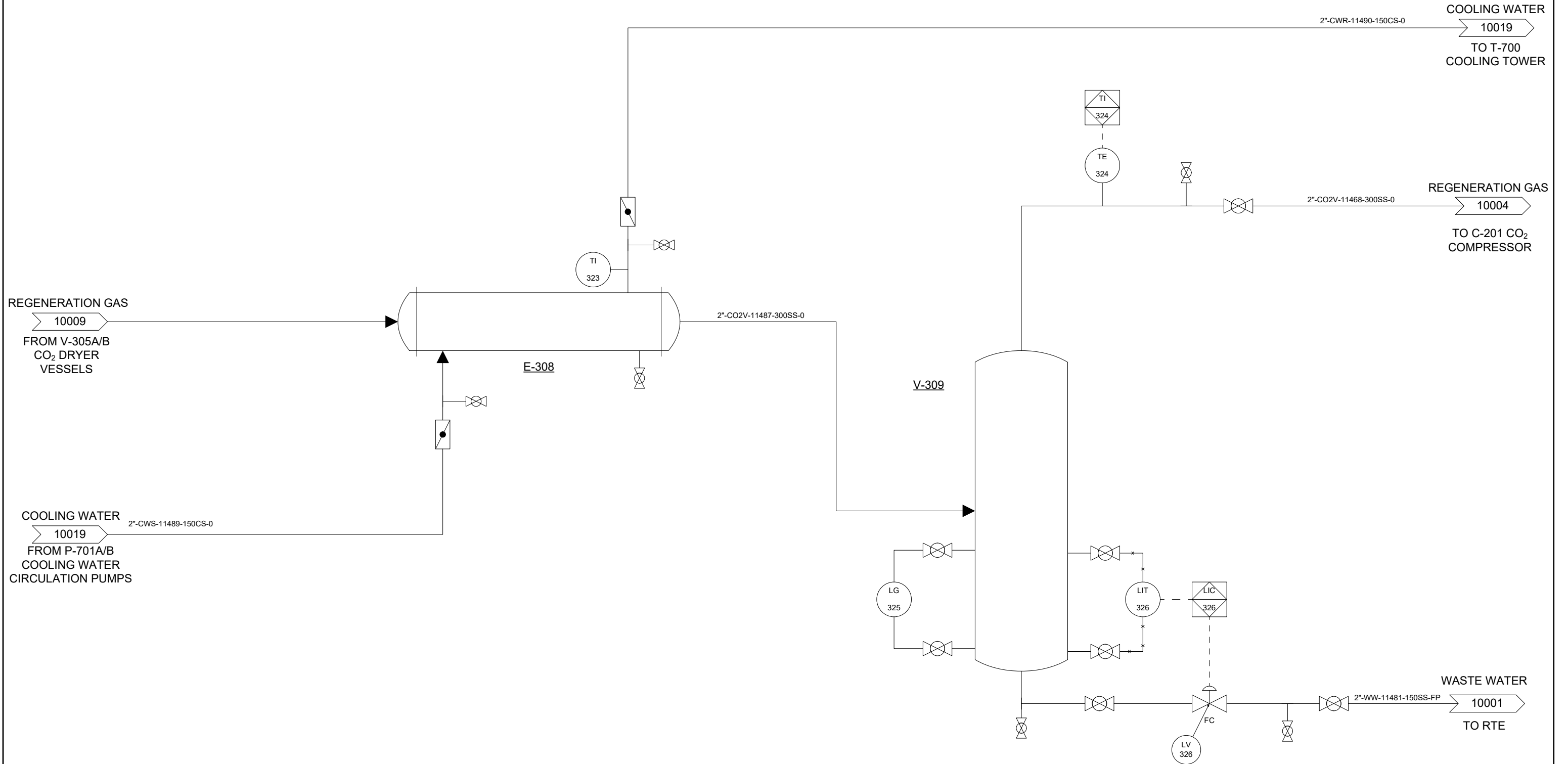
**EERC – RTE CO₂ INJECTION FACILITY
WASTE GAS VENT HEADER**

FILENAME: EERC_P&IDS_REV0.VSD DATE: 04/18/2019 DRAWN BY: BRAD PIGGOTT

CLIENT/SITE EERC / RTE ETHANOL RICHARDTON, ND	JOB NUMBER 50168.04
DRAWING NUMBER PID-10021	SCALE NONE

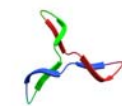
E-308
 REGENERATION COOLER
 DUTY: TBD
 SHELL/TUBE: CS/SS
 MDMT: TBD

V-309
 REGENERATION SEPARATOR
 SIZE: TBD
 DP: TBD
 MOC: 304/304L SS



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	04/15/2019	ISSUED FOR REVIEW	BDP			



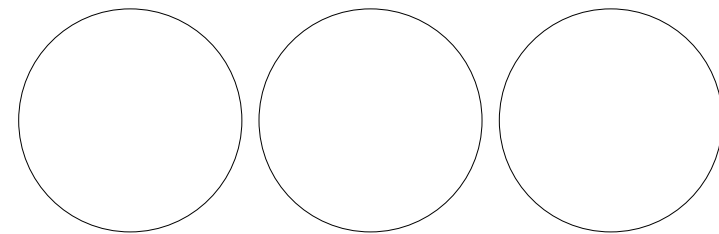
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 Buda, Texas 78610

**EERC – RTE CO₂ INJECTION FACILITY
 REGENERATION GAS COOLING**

FILENAME	DATE	DRAWN BY
EERC_P&IDS_REV0.VSD	04/15/2019	BRAD PIGGOTT

CLIENT/SITE	JOB NUMBER
EERC / RTE ETHANOL RICHARDTON, ND	50168.04
DRAWING NUMBER	SCALE
PID-10022	NONE

APPENDIX C
PRELIMINARY PLOT PLAN



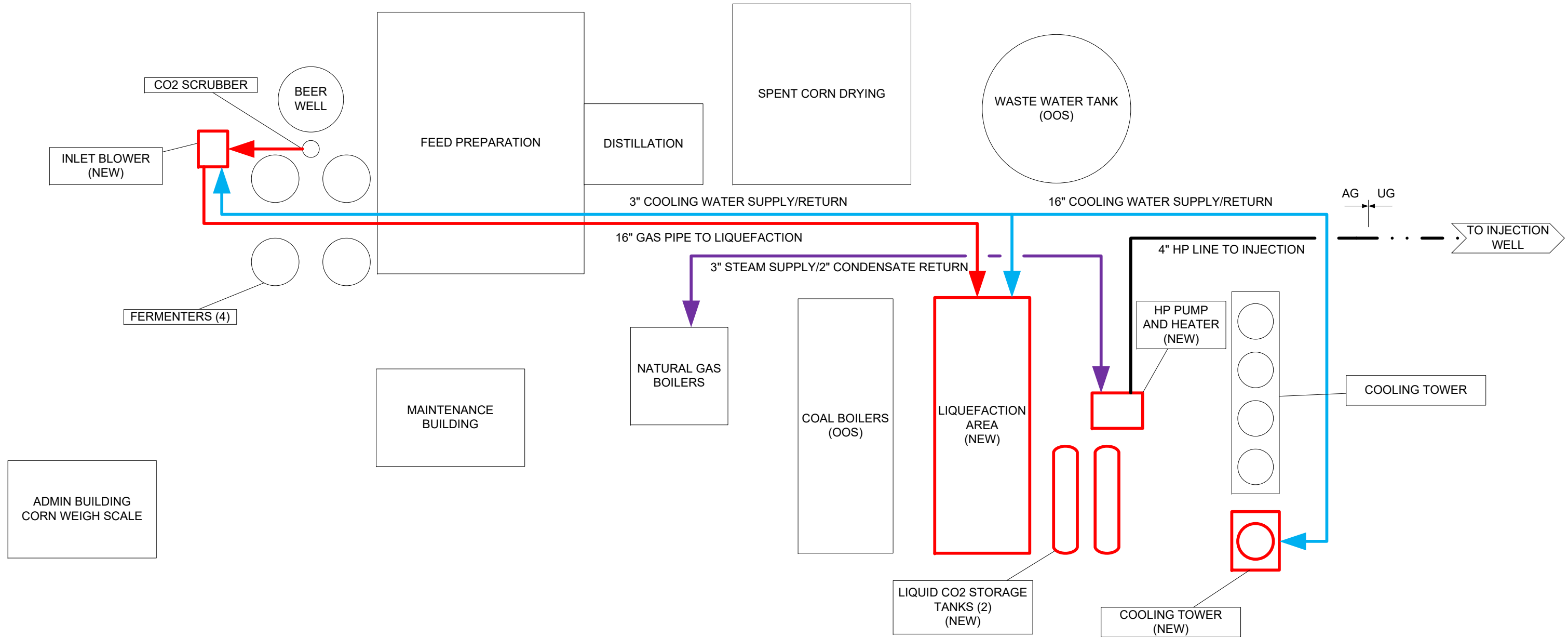
CORN FEED STORAGE



DRY SPENT CORN STORAGE

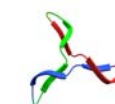
NOTES:

1. DRAWING NOT TO SCALE.
2. ALL LINES USE EXISTING PIPE RACKS WHERE POSSIBLE.
3. HP INJECTION LINE UTILIZES EXISTING BRIDGE OVER ROAD, THEN UNDERGROUND TO INJECTION WELL.
4. WASTE WATER AND INSTRUMENT AIR LINES NOT SHOWN.



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REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	05/08/2019	FOR REVIEW MEETING	BDP	AEV		



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EERC – RTE CO2 INJECTION FACILITY
PRELIMINARY PLOT PLAN

FILENAME: EERC RTE CAPTURE FACILITY PLOT PLAN_0.VSD
DATE: 05/08/2019
DRAWN BY: BRAD PIGGOTT

CLIENT/SITE: EERC/RTE ETHANOL RICHARDTON, ND
JOB NUMBER: 50168.04
DRAWING NUMBER: PLT-10000
SCALE: NONE