Project Report:

State Line Biofuels

Safety Review and Engineering Study of an On-Farm, Small-Scale Biodiesel Production Facility

PREPARED FOR:

Vermont Sustainable Jobs Fund

Accelerating the Development of Vermont's Green Economy

PREPARED BY:

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January 15, 2009

Introduction

This report summarizes safety review and engineering support of a small-scale, on-farm biodiesel processing system at State Line Biofuels in Shaftsbury, VT. State Line recently constructed a biodiesel processor with an approximate batch capacity of 300 gallons. Previous biodiesel production at State Line was done in a converted 80 gallon water heater. Many lessons were learned in the smaller scale operation and have been leveraged in the larger scale processor. The work described in this report supplements and distills this experience with the support of a professional engineer with chemical process and safety systems experience. The authors would like to express their thanks to the funding agencies for support of this work and also to Scott Sawyer of the Vermont Sustainable Jobs Fund for his direct support in developing a handout about the State Line processor.

1. Project Goals and Objectives

The goal of this project was to increase the biofuels production capacity of the Vermont Biofuels Initiative designed to accelerate the growth of the biofuels market. Through accomplishment of the objectives below, the participants have conducted a safety review and engineering study of the existing biodiesel production system at State Line Farm. These studies help to ensure system design portability, and the design and construction of a safe and replicable model for small-farm biodiesel production.

Objectives:

1. Facilitate, guide and document a hazards review and failure modes and effects analysis (FMEA) of the State Line process and system.
2. Prepare design documentation (e.g. prints, descriptive documents, etc.) that captures the as-built biodiesel system.
3. Research and summarize applicable or relevant design code or standards associated with an on-farm, small-scale biodiesel production system.
4. Combine and supplement outputs from above tasks into a concise document intended to aid others with the design and fabrication of small scale biodiesel systems based on this design.
5. Project Management and Reporting

This work was led by Chris Callahan of Callahan Engineering, PLLC with support from John and Tanner Williamson at State Line Biofuels. Steve Plummer, formerly of State Line Biofuels, also contributed through his prior efforts relating to system design, safety review and documentation.

A summary of each task is provided in the following section.

Task 1) Safety Review: *Facilitate, guide and document a hazards review and failure modes and effects analysis (FMEA) of the State Line process and system.*

The intended product of this task was a professionally documented FMEA for a small-farm biodiesel production process and system. The outcome of this task was intended to be critical safety information for State Line Farm and other potential on-farm biodiesel producers.

Generally, the FMEA process involves:

1. Identifying all major components of a process and their associated hazards
2. Investigating what could go wrong with each part of the process (FAILURE MODE)
3. Estimating what the severity of the impact of that failure would be (SEVERITY)
4. Assessing what the likelihood of such a failure is (OCCURRENCE)
5. Estimating what the likelihood of detecting the failure would be (DETECTION)
6. Compiling these results and identifying mitigations and or design changes that reduce or eliminate the hazard.

A hazard is typically defined as "the inherent potential of a material or activity to harm people, property or the environment.[1]" Hazards inherent in an on-farm, small-scale biodiesel processor such as the one built at State Line Farm are summarized in Table 2 below and discussed in general in the following paragraphs.

	Hazard Type		
Process Component	People	Property	Environment
Vegetable Oil		●	●
Alcohol (Methanol or Ethanol)	●	●	●
Lye (Sodium Hydroxide or Potassium Hydroxide)	●	●	
Alcohol / Lye Mixture	●	●	●
Biodiesel (Methyl Ester)		●	●
Glycerol	●	●	●
Wash Water			●
Recovered Alcohol	●	●	●
Electrical Components	●	●	

Table 2 - Summary of Process Hazards Present in a Small-Scale Biodiesel Processor.

In considering the **hazards to people** present in each process component, toxicity is generally the main factor. Inhalation of alcohol vapors, alcohol absorption through skin, inhalation of caustic dust from oxide used as catalyst, and oxide burning due to skin or other membrane contact are all possible personnel exposures. Personal protective equipment (PPE) is critical in the production of biodiesel at any scale. But given the nature of most small scale operations, it is likely to be even more important. Many of these systems are installed in areas with multiple uses and which have foot traffic for other reasons. Furthermore ventilation of the production area needs to be considered. Specifically, exhaust ventilation of hazardous vapors and dust should be incorporated into the design. Electrical hazards may be present in the form of stray electrical voltage and/or current due

[1] R. H. Perry & D. W. Green. Perry's Chemical Engineer's Handbook. "Process Safety Analysis" Seventh Edition. McGraw-Hill. New York, NY. 1997. P.26-8

to improper bonding, grounding and insulation. Proper wiring, bonding, grounding and ground fault protection are necessary design features to avoid this risk.

Hazards to property are largely related to the combustibility and/or volatility of various chemicals used in the biodiesel production process. It should also be noted that any property hazard due to combustibility is also likely to be a personnel hazard. A useful reference for considering protection from combustible hazards is the "combustibility triangle" shown in Figure 1. Combustion requires a fuel, and oxidant and energy input (generally heat) to initiate and sustain the reaction. Since the majority of the combustibility hazards present are fuels and since ambient air is always present, the removal of ignition sources is a critical design feature. This often leads to a requirement for explosion proof ("XP") equipment that are constructed to either (a) not have any spark sources or (b) isolate any spark sources from the environment of use. However, it is also equally prudent to consider isolation of combustibles from the air and ignition sources. This can be accomplished using carefully designed and fabricated plumbing, providing dedicated outside storage areas for chemicals, and by incorporating SOP's into the operation of the process. One other consideration is that each combustible has a certain window of combustion that depends on the amount of oxidant present. The lower flammability limit (LFL) determines the minimum amount of oxidant required to result in combustion of a particular fuel. Careful venting of any combustible vapors resulting from the process to the outdoors is also prudent. Well placed combustibility sensors also provide a visual and/or audible alert that vapors are present. Proper wiring, bonding and grounding remain important in consideration of combustion since stray electrical voltage and/or current may present an ignition source in the form of a spark.

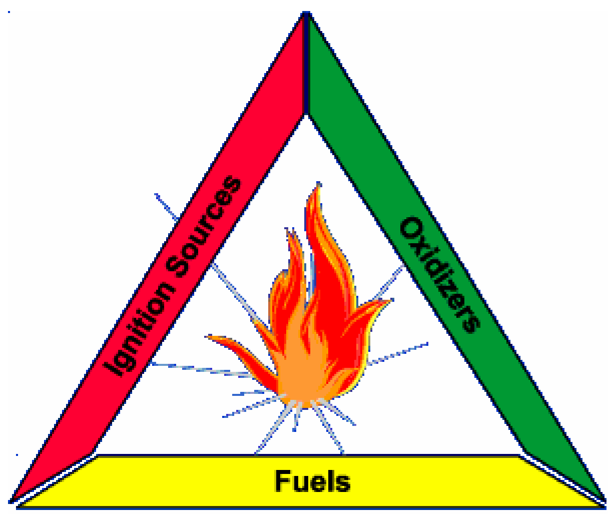


Figure 1 - The Combustion (or Fire) Triangle[2].
Combustion only occurs when three items are present: fuel, oxidant and an ignition source.
Safe use of combustibles requires separation of these three items.

Environmental hazards are largely regulated by state and federal agencies, and typically take the form of discharges to the ground, water or air. Leakage or spills of any of the chemical components in the biodiesel process may present a hazard to the environment. For this reason spill prevention, control and countermeasure (SPCC) planning is important. Spill prevention can take the form of operational considerations such as routinely checking for leaks, using proper dispensing equipment and following commonly accepted fabrication techniques. Spill control often takes the form of

[2] Image source: http://www.valleylabeducation.org/fire/images/triangle.gif.

containment curbs, pits, dikes, drip pans, collection pallets, absorbent "hogs", and basins. Spill countermeasures include chemical neutralization, collection and proper disposal.

The following section summarizes the team's assessment of how general hazards like those above become relevant when specifically considering the State Line Farm Biodiesel system. The system was assumed to be operated only when attended for purposes of this analysis. This is also the stated intention of John Williamson, who does not expect his system to ever be run without an operator present. Therefore a knowledgeable, attentive operator is assumed to be present whenever the process is operated.

The system design was documented as a schematic plumbing and instrumentation diagram (P&ID) (See Appendix 4.1). System components were assigned labels and numbers that signify their function (e.g. HV = hand valve, PMP = pump) and their primary use in the system (e.g. 100 = main biodiesel reaction, 200 = oxide mixing, 300 = settling, etc.) The labels used in the P&ID were also affixed to the physical hardware. This labeling aided the later drafting and use of standard operating procedures (SOP's).

Each component of the system was assessed relative to how it might fail, what the likelihood of that failure could be and what the effects could be. With that information severity, occurrence and detection (SOD) ratings were assigned to each failure to understand the relative risk of each one. The following guidelines, commonly used in the process industry, were used for this ranking.

SEVERITY

10	Hazardous without warning
9	Hazardous with warning
8	Process inoperable, loss of primary function
7	Process operable, reduced level of performance
6	Process operable, complete nuisance / discomfort
5	Process operable, partial nuisance / discomfort
4	Fit / finish, sloppy operation noticeable by lay person
3	Fit / finish, sloppy operation not noticeable by lay person
2	Fit / finish, sloppy operation noticed by experts
1	No effect

OCCURENCE

9-10	Very High Occurrence, failure almost inevitable
7-8	High Occurrence, repeated failures
4-6	Moderate Occurrence, occasional failures
2-3	Low Occurrence, relatively few failures
0-1	Remote Occurrence, Failure unlikely

DETECTION

10	Absolute uncertainty, no detection method exists
9	Very remote chance of detection
8	Remote chance
7	Very low chance
6	Low chance
5	Moderate chance
4	Moderately high chance
3	High chance of detection
2	Very high chance of detection
1	Almost certain detection

Using the schematic developed as part of Task 2 (below) and the guidelines summarized above, Chris Callahan conducted an initial FMEA. This draft was then reviewed in detail with John Williamson and Tanner Williamson two times with revision in between.

The involvement of John and Tanner in this process was critical. On the one hand, they informed the process tremendously based on their intimate knowledge of the as-built system and their intended use of it. Secondly, the FMEA process identified risks that had not occurred to either of them in the design and development of the system. This enabled some design changes to take place prior to the initial batch of fuel being made. By "walking through" the system operation on paper and predicting possible failures and their impact the design was improved before any fuel was even made.

Finally, by independently scoring the severity, occurrence and detection rankings of each failure a somewhat objective cumulative ranking could be developed. This overall ranking is known as the risk priority number (RPN) and is the product of the three rankings for severity, occurrence and detection (S x O x D) for the failure. A higher RPN indicates a more significant risk associated with that failure mode.

After the first revision of the FMEA with input from John and Tanner, the rankings were updated and RPN's were calculated. This analysis identified two items with unacceptable RPN's (>199). It also noted several items that were borderline (>100 and ≤199). The team reviewed the results and identified appropriate mitigations to address these hazards. The complete FMEA is provided in Appendix 4.2

The main design and operational changes resulting from the FMEA included:

1. Add a pressure relief valve to avoid over pressure in the reaction tank
2. Add a combustibility sensor above the process to detect leakage of combustible vapors.
3. Draft standard operating procedures to make operation consistent and to include daily checklists (e.g. sumps clear, no leaks, etc.)
4. Review pump and drive controls; assess dead-head pressure rise
5. Review capacity of spill containment (pallet and floor trough)
6. Add temperature control (aquastat) in the primary hot water loop [once installed].

Item #1 (Pressure Relief Valve, PRV) was addressed using an existing pressure relief valve (PRV) the farm had from another application. It happened to be appropriately sized for this process and was bench-top tested using compressed air and a pressure gauge.

Item #2 (Combustibility Sensors) was addressed by purchasing two (2) Industrial Test Equipment HC-822 Combustible Gas Sensors at a cost of approximately $200 each. John opted to purchase two sensors so that one could be mounted high above the entire system to detect long-term distributed leaks and the other could be mounted close to the methoxide mix tank to detect significant localized leaks more quickly.

Item #3 (Standard Operating Procedures, SOP's) and Item #4 (Pump Dead Head Pressure) were addressed by drafting SOP's (see Appendix 4.3) and by conducting a "wet trial run" using water as the working fluid. This enabled the team to step through the process in real time with the pump running, valves being opened and closed and fluid flowing through the plumbing. The use of water allowed for benign failures to be observed during the trial run (e.g. leaking fittings, loose clamps, valves incorrectly opened, etc.). This trial was done following an initial review of the FMEA and with a draft copy of the standard operating procedures in hand. Many details were noted during this trial that were corrected in the documentation.

Item #5 (Spill Containment Capacity) resulted in the calculation of how much direct spill containment capacity the system offers. This building design included a trough in the concrete floor which measures 1 ft wide by 45 ft long and has an inclined base resulting in height measurement of 15 inches on one end and 24 inches on the other. This results in a capacity of approximately 238 gallons. The skid which the processor was built on includes a 1 gallon sump and a 1" lip around the 58 inch x 179 inch foot print (another 45 gallons). Therefore total spill containment is about 284 gallons. The floor of the building is pitched toward the sump which provides additional margin above this level.

Item #6 (Temperature Control) has not yet been addressed since there is not currently a hot water system for heating the reaction vessel.

Task 2) Design Documentation: *Prepare design documentation (e.g. prints, descriptive documents, etc.) that captures the as-built biodiesel system.*

The intended product of this task was professional engineering documentation of an on-farm biodiesel production system. The expected outcome of this task was to help farmers and other potential small-scale biodiesel producers design and construct a successful production system and efficient processes.

As noted in the previous section, the system design was documented as a schematic plumbing and instrumentation diagram (P&ID) (See Appendix 4.1). System components were assigned labels and numbers that signify their function with physical labels also being affixed to the system.

The SOP's are another important component of the system documentation. They illustrate how the system is operated and help to ensure safety of personnel and property as well as the quality of the fuel produced.

It is important to note that both the P&ID and the SOP's are intended to be "living documents" that will change as State Line Biofuels changes their system and how it operates. Lessons learned in the process of making fuel will force changes in the SOP's. Process enhancements such as alcohol recovery will require changes in the system design and, therefore, the P&ID and SOP's.

Task 3) Technical Regulatory Review: *Research and summarize applicable or relevant design code or standards associated with an on-farm, small-scale biodiesel production system.*

The intended product of this task was a report outlining design codes and/or standards relevant to small-scale, on-farm biodiesel production. The outcome of this task was to assist Vermont farmers, other potential small-scale biodiesel producers, and industry supporters determine the feasibility of – and costs and timelines associated with – developing a biodiesel production system.

Pennsylvania State University has also developed a very user-friendly best practices manual for small scale biodiesel production[3] and the Vermont Sustainable Jobs Fund provides a succinct summary of regulatory issues in their Feed, Food and Fuel report[4]. Farmer's are encouraged to work with local municipal, zoning and fire officials when considering adding biodiesel production capability to their operation. If plans include storage of 1300 or more gallons of fuel or vegetable oil an SPCC plan will be required.

[3] Pennsylvania State University – College of Agricultural Sciences. Biodiesel Safety and Best Management Practices for Small-Scale Noncommercial Use and Production. 2008. University Park, PA. Downloaded from http://pubs.cas.psu.edu/FreePubs/pdfs/agrs103.pdf on December 20, 2008.
[4] Stebbins, E. J. – Homegrown Feed, Food and Fuel: The Market Potential of Farm-Scale Oilseed Crop Products in Vermont. Final Draft. September 2007. Prepared for the Vermont Sustainable Jobs Fund and Vermont Biofuels Association.

From a technical design and operation perspective, the main design code relevant to small-scale, on-farm biodiesel production is the National Electric Code (also known as NFPA #70)[5]. Equally important is the recommended practice present in National Fire Protection Association #497[6]. Both of these publications deal with the presence and management of potentially hazardous environments. These documents are very clear that each installation needs unique review. In the case of State Line the following design features were indicated based on review of the NFPA documents.

1. All vessels are vented directly outdoors and all have lids with functional seals to prevent escape of flammable vapors into the interior of the building
2. Flammable liquids and vapor-producing liquids are stored outside the building.
3. Flammable liquids are moved from one container to another using solid, sealed plumbing and without synchronous the use of pumps (i.e. vacuum is drawn on the receiving container, the vacuum pump is shut off and the source container is referenced to the receiving container to initiate flow.)
4. Combustibility sensors are installed both low and high in order to alert the operator to any abnormal conditions which have resulted in leakage of flammable liquids or vapors from the processor.
5. All equipment used when flammables are being handled has been specified as Class One, Division Two suitable.
6. An emergency stop switch circuit has been installed to remove power from the processor based on operator discretion.

Task 4) Aid Replication and Portability of Design: *Combine and supplement outputs from above tasks into a concise document intended to aid others with the design and fabrication of small-scale biodiesel systems based on this design.*

The intended product of this task was a report outlining design portability and system replication considerations for small-scale biodiesel production operations. The expected outcome of this task was to assist Vermont farmers, other potential small-scale biodiesel producers, and other industry players in the design and construction of safe and replicable biodiesel production facilities.

This report, and the design documents provided in the appendix provide a summary description of one small-scale, on-farm biodiesel system that has been demonstrated and works well. The system has been reviewed by a team comprised of a professional engineer and two farmers with significant mechanical skill and experience producing biodiesel in less refined processors. The lessons learned by the Williamsons in their earlier biodiesel production efforts have been incorporated into the present system design and have been assessed with the assistance of an engineer with regard to their safety. The authors feel that this design is quite portable and may work well for other Vermont farms interested in producing biodiesel from oilseed crops.

An introductory system overview handout has been prepared which provides a brief introduction to the State Line processor. The authors wish to express thanks to Scott Sawyer at the Vermont Sustainable Jobs Fund for his expert formatting and design of this handout. FMEA, SOP and P&ID documents have also been made available to any interested party.

[5] National Fire Protection Association (NFPA). National Electric Code (NFPA #70). 2008 Edition. Quincy, MA.
[6] National Fire Protection Association (NFPA). NFPA #497 - Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas. 2004 Edition. Quincy, MA.

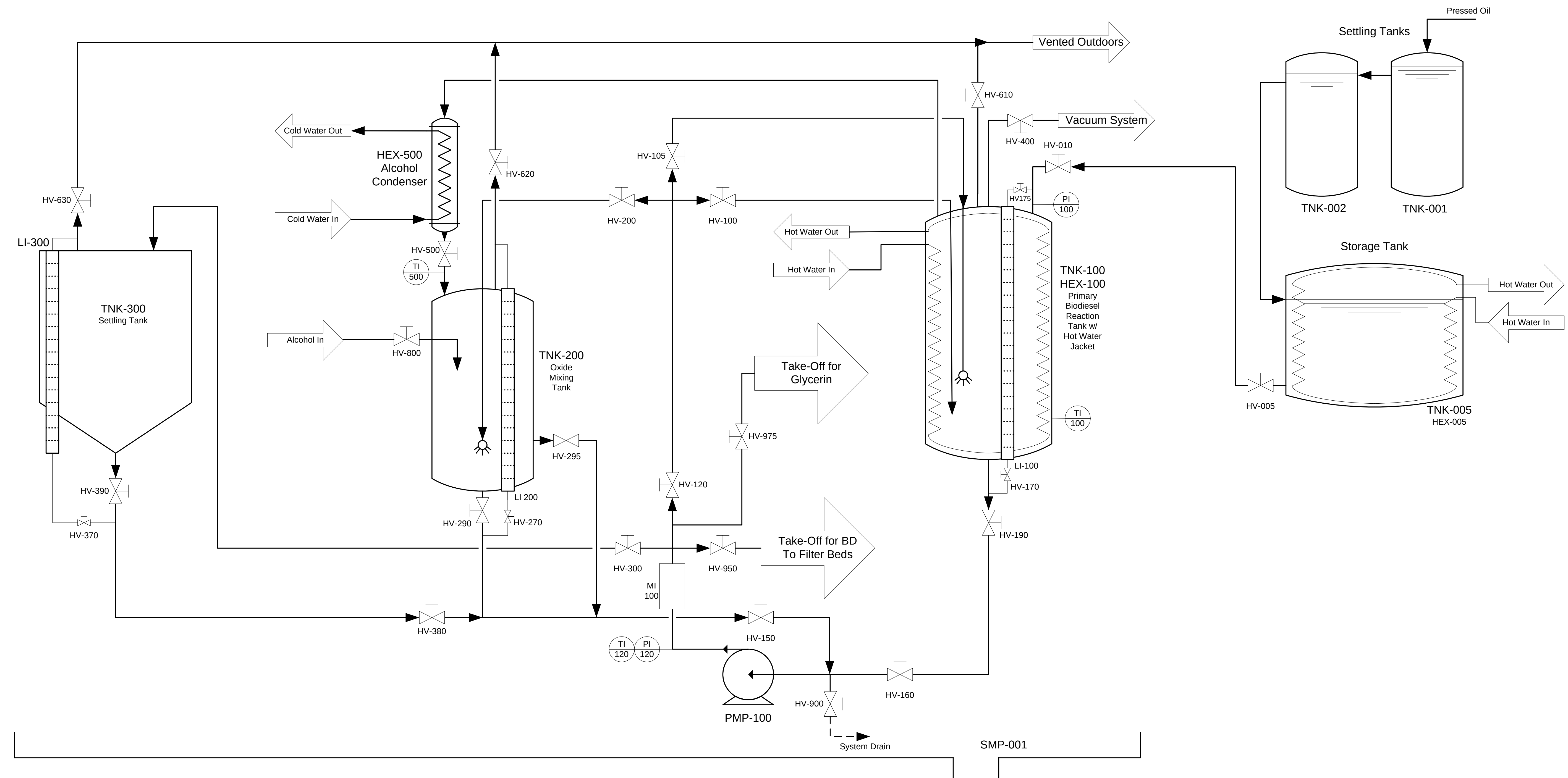
Task 5) Project Management and Reporting – *Reports and other deliverables will be provided in accordance with the Federal Assistance Reporting Checklist following the instructions included therein. Project progress reports will be provided to VSJF as described in the project proposal.*

Quarterly reports were made by the project participants through the Vermont Sustainable Jobs Fund (VSJF) which highlighted the progress made on the project. The current report concludes the reporting task.

5. Appendices

5.1 Schematic Drawing – P&I Diagram
5.2 FMEA Forms
5.3 SOP's
5.4 System Overview Handout

5.1 Schematic Drawing



REV.	DESCRIPTION	DATE	BY
-	First electronic version from hand sketch.	11/11/07	CC
1	As built corrections, review with JW 11/14	12/4/07	CC
	Rev 1 Details: TNK-200 is not jacketed, therefore removed HEX-200. Corrected plumbing to HEX-500 to reflect as built. Removed HV-275. Moved HV-290 to match as built. Added HV-380 isolation valve between TNK-300 and TNK-200 outlets. Added TI-120. Changed HV-155 location and made as system drain. Moved HV150 per as built. Added drain valve near PMP-100. Moved location of MI-100. Added vacuum reference on TNK-100. Corrected location of Hot Water inlet on TNK-100 (to bottom). Removed HV-195 and associated line per as built. Added vegetable oil storage tank and associated components for reference.		
2	As built corrections, review with JW 12/6	12/11/07	CC
	Rev 2 Details: Remove HV-375. Add separate Glycerin take-off (HV-975) near BD take-off (near MI-100). Add HV-500. Rename HV-900 (BD take-off) to HV-950 to avoid duplicate name. Add HV-400 (anticipated) vacuum control valve.		

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CLIENT: VERMONT SUSTAINABLE JOBS FUND for STATE LINE FARM BIOFUELS

TITLE: **PLUMBING AND INSTRUMENTATION DIAGRAM (P&ID)**
BIODIESEL REACTION PROCESS

DRAWN BY:	SIZE	FSCM NO	DWG NO	REV
C. W. Callahan	B	N/A	SLD-1000	2

DATE: December 11, 2007 | SCALE No To Scale | SHEET 1 OF 1

5.2 FMEA Forms

FMEA

☑ System ☐ Design ☐ Process

Document name	Date	Issue	Issued by	Approved by	Document status
FMEA - State Line Farm Biodiesel System	1/2/2008	INTERNAL USE ONLY			Revision 1

RPN 200 -
RPN 100 -199
RPN 1-99

TYPE	#	FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL CAUSES	POTENTIAL EFFECTS	DETECTION METHOD	SEV	OCC	DET	RPN	RECOMMENDED ACTION(S)	SEV	OCC	DET	RPN
TNK	001	**Vegetable Oil Settling Tank #1**	Leakage	Loose Fitting	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
				Vessel Failure	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
TNK	002	**Vegetable Oil Settling Tank #2**	Leakage	Loose Fitting	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
				Vessel Failure	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
TNK	005	**Vegetable Oil Collection Tank**	Leakage	Loose Fitting	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
				Vessel Failure	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
HEX	005	**Water Jacket for Vegetable Oil Collection Tank**	Over temp	Hot Water Temp Control Failure	Veg Oil Too Hot, up to limit of hot water (assumed to be controlled with high limit.)	None	10	1	10	100	1. Consider temperature gauge at inlet when installing hot water system. 2. Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	9	1	1	9
					Veg Oil Too Cold	None	5	1	10	50	1. Consider temperature gauge at inlet when installing hot water system. 2. Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	5	1	1	5
			Leakage	Jacket Failure	Water in Oil	Visual Inspection	3	1	3	9		3	1	3	9
					Water on floor	Visual Inspection	4	1	1	4		4	1	1	4
HV	005	**Shutoff Valve at Main Vegetable Oil Collection Tank**	Leakage	Valve Failure / Stem Failure	Veg Oil Spill onto floor	Visual Inspection	9	1	3	27	Consider basin / sump below oil storage tank.	4	1	1	4
HV	010	**Shutoff Valve - Veg Oil to BD Reaction Tank**	Leakage	Valve Failure / Stem Failure	Veg Oil Spill onto basin / sump	Visual Inspection	4	1	3	12	Consider basin / sump below oil storage tank.	4	1	1	4
PMP	100	**Process Pump - Fill, Mix, Empty - All Fluids**	Leakage	Seal Failure	Spill onto basin / sump	Visual Inspection	4	3	3	36	Review pump design, seals?	4	1	1	4
			Over pressure	Blockage, valves not open down or upstream	Pump runs at max pressure, zero flow	Visual inspection (PI-120), audible change in pump operation.	9	5	3	135	1. Review motor drive controls and also pump dead-head pressure rise. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	1	35
TNK	100	**Biodiesel Reaction Tank**	Leakage	Loose Fitting	Veg Oil Spill onto basin / sump	Visual Inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual Inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual Inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
				Vessel Failure	Veg Oil Spill onto basin / sump	Visual Inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual Inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual Inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
			Over temp	Hot Water Temp Control Failure	Contents too hot, up to limit of hot water (assumed to be controlled with high limit.)	Visual inspection of temperature gauge on vessel (TI-100).	9	3	3	81	1. Consider temperature gauge at inlet when installing hot water system. 2. Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	9	3	1	27

RPN 200 -
RPN 100 -199
RPN 1-99

TYPE	#	FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL CAUSES	POTENTIAL EFFECTS	DETECTION METHOD	SEV	OCC	DET	RPN	RECOMMENDED ACTION(S)	SEV	OCC	DET	RPN
			Over pressure	Blockage downstream (closed valve, etc.)	Mechanical failure of attached parts or vessel, overflow of contents in unintended locations	Visual inspection of pressure gauge on vessel (PI-100), audible spilling.	9	1	3	27	Consider pressure relief valve on BD reaction tank. Set point TBD.	9	1	3	27
			Over fill	Providing too much fluid to tank, or filling at too great a speed.	Veg Oil Spill onto basin / sump	Visual Inspection	4	3	3	36	Consider level sensor in sump to detect severe leakage.	4	3	1	12
					Reaction Mix Spill onto basin / sump	Visual Inspection	10	3	3	90	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	3	1	27
					BD Spill onto basin / sump	Visual Inspection	4	3	3	36	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	3	1	12
HEX	100	**Water Jacket for BD Reaction Tank**	Over temp	Hot Water Temp Control Failure	Reaction mix too hot	Visual inspection of temperature gauge on vessel (TI-100).	9	3	3	81	1. Consider temperature gauge at inlet when installing hot water system. 2. Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	9	1	1	9
			Under temp	Hot Water Temp Control Failure	Reaction mix too cold, slow reaction	Visual inspection of temperature gauge on vessel (TI-100).	2	3	3	18	1. Consider temperature gauge at inlet when installing hot water system. 2. Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	2	1	1	2
			Leakage	Jacket Failure	Water in reaction	Visual Inspection	2	1	4	8		2	1	4	8
					Water on floor	Visual Inspection	3	1	3	9		3	1	3	9
LI	100	**Level Indicator / Sight Tube for BD Reaction Tank**	Unreadable	Fowling	Unknown level or settling status	Visual Inspection	5	5	1	25	Confirm cleaning plan.	5	1	1	5
			Leakage	Cracks, loose fittings	Spill onto basin / sump	Visual Inspection	9	1	3	27		9	1	3	27
TNK	200	**Oxide Mixing Tank**	Over fill	Too much fluid pumped to vessel	Spill out vent line, or to other vessels	Visual Inspection, sight tube (LI-200)	7	3	3	63	Consider overflow pipe	5	3	3	45
LI	200	**Level Indicator / Sight Tube for Oxide Mixing Tank**	Unreadable	Fowling	Unknown level or settling status	Visual Inspection	5	5	1	25		5	5	1	25
			Leakage	Cracks, loose fittings	Spill onto basin / sump	Visual Inspection	9	1	3	27		9	1	3	27
TNK	300	**Settling Tank**	Leakage	Jacket Failure	BD on floor	Visual Inspection	3	1	3	9		3	1	3	9
			Over fill	Too much fluid pumped to vessel	Spill out vent line, or to other vessels	Visual Inspection, sight tube (LI-300)	7	1	3	21	Consider overflow pipe. TNK300 is larger than TNK100, unlikely event	5	1	3	15
LI	300	**Level Indicator / Sight Tube for Settling Tank**	Unreadable	Fowling	Unknown level or settling status	Visual Inspection	5	5	1	25		5	5	1	25
			Leakage	Cracks, loose fittings	Spill onto basin / sump	Visual Inspection	4	1	3	12		4	1	3	12
MI	100	**Mix Indicator - Pump Outlet to Oxide and BD Tanks**	Unreadable	Fowling	Unknown process flow or mixing status.	Visual Inspection	5	5	1	25		5	5	1	25
			Leakage	Cracks, loose fittings	Spill onto basin / sump	Visual Inspection	9	1	3	27		9	1	3	27
PI	100	**Pressure Indicator / Gauge - BD Reactor Tank**	Bad / no reading	Gauge failure	Unknown pressure condition in BD tank.	Visual Inspection, possible backup in PI-120.	9	1	5	45		9	1	5	45
			Leakage	Cracks, loose fittings	Vapor leakage overboard	None	9	1	10	90	Consider combustibility sensor above process	9	1	1	9
PI	120	**Pressure Indicator / Gauge - Pump Outlet**	Bad / no reading	Gauge failure	No indication of pump operation other than noise.	Visual Inspection	10	1	3	30		10	1	3	30
			Leakage	Cracks, loose fittings	Leakage of any fluid onto basin / sump	Visual Inspection	9	1	3	27	Consider level sensor with alarm to alert operator that something has reached the sump.	9	1	1	9
TI	120	**Temperature Indicator / Gauge - Pump Outlet**	Bad / no reading	Gauge failure	No indication of pump outlet temperature, or inaccurate indication.	None	5	1	3	15	TI120 is not a process critical instrument. It serves as a backup for TI100.	9	1	1	9
			Leakage	Cracks, loose fittings	Leakage of pumped contents to basin / sump	Visual Inspection	9	1	3	27	Consider level sensor with alarm to alert operator that something has reached the sump.	9	1	1	9
TI	100	**Temperature Indicator / Gauge - BD Reactor Tank Bottom**	Bad / no reading	Gauge failure	No indication of reaction mixture temperature, or inaccurate indication.	Could use TI-120 as substitute	10	1	3	30	Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	9	1	1	9

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			Leakage	Cracks, loose fittings	Leakage of BD tank contents to basin / sump	Visual Inspection	9	1	3	27	Consider level sensor with alarm to alert operator that something has reached the sump.	9	1	1	9
TI	500	**Temperature Indicator / Gauge - Condenser Inlet**	Bad / no reading	Gauge failure	No indication of condenser inlet temperature, or innacurate indication.	None	10	1	10	100	Consider including an aquastat or other electronic temperature control on hot water loop so visual becomes backup.	9	1	1	9
			Leakage	Cracks, loose fittings	Leakage of alcohol vapor or liquid	Visual inspection	10	1	3	30	Consider combustibility sensor above process	9	1	1	9
SMP	001	**Process Sump / Basin - Integrated with Base**	Overflow	Too much fluid	Spill onto floor	Visual Inspection	10	3	3	90	Consider level sensor with alarm to alert operator that something has reached the sump.	9	3	1	27
				Blockage of areas, material displacement	Spill onto floor	Visual Inspection	10	3	3	90	1. Review secondary containment (trough in floor) 2. Consider high level sensor in basin with audible alarm.	9	3	1	27
HEX	500	**Alcohol Condenser**	Over temp	Water Temp Control Failure	Incomplete alcohol recovery	None	2	3	10	60	Need to review alcohol recovery process in detail. What is intended operation, what are intended controls.	2	3	10	60
			Leakage	Loose Fitting	Leakage of alcohol vapor or liquid	Visual Inspection	10	1	5	50	Consider combustibility sensor above process	9	1	1	9
				Vessel Failure	Leakage of alcohol vapor or liquid	Visual Inspection	10	1	5	50	Consider combustibility sensor above process	9	1	1	9
HV	500	**Isolation Valve - Alcohol Condenser**	Closed when should be Open	Operator error	Will not permit condensate alcohol to leave HEX-500 and drop back into TNK-200. Possible rise in pressure in TNK-100, with subsequent pressure relief.	Visual inspection, lack of accumulation of alcohol, no rise in LI-200.	6	5	3	90	Confirm pressure relief at TNK-100. Appropriate settings and line sizing?	2	5	3	30
			Open when should be Closed	Operator error	Will prevent intended operation and use of TNK-100 (vacuum fill will be prohibited). Potential routing of any process fluid to TNK-200 when not intended. Possible routing of alcohol vapors to other vessels.	Visual inspection of sight tube or other tanks (LI-100 / LI-300) to note unintended change in levels. Inability to draw a vacuum on other vessels.	7	5	3	105	Consider combustibility sensor above process.	7	5	1	35
			Leakage	Stem seal failure	Leakage of alcohol onto basin / sump.	Visual inspection.	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
				Seat seal failure	Routing of any process fluid to the oxide mix tank when not intended. Possible routing of alcohol vapors to other portions of the system.	Visual inspection of sight tube on oxide mix tank (LI-200).	10	1	5	50	Consider combustibility sensor above process.	9	1	1	9
HV	610	**Vent Valve - Biodiesel Reaction Tank**	Closed when should be Open	Operator error	Lack of venting for reaction vessel, pressure increase during fill.	Visual inspection, pressure gauge on reaction tank (PI-100) or pressure gauge at pump outlet (PI-120)	9	5	5	225	Consider pressure relief valve on BD reaction tank. Set point TBD.	7	5	5	175
					Lack of replacement air when emptying tank.	Low outlet flow, pump work increase.	7	5	5	175	Consider pump suction pressure gauge (vac / pos) for better detection.	7	5	3	105
			Open when should be Closed	Operator error	No effect	None	1	5	10	50		1	5	10	50
			Leakage	Stem seal failure	Vapor leakage overboard	None	10	1	10	100	Consider combustibility sensor above process	9	1	1	9
				Seat seal failure	Vapor leakage through valve	None	10	1	10	100	Consider combustibility sensor above process	9	1	1	9
HV	620	**Vent Valve - Oxide MixTank**	Closed when should be Open	Operator error	Lack of venting for oxide mix tank, pressure increase during fil	Visual inspection (PI-120).	7	5	5	175	1. Consider pressure relief valve on Oxide mix tank. Set point TBD. 2. Consider pressure gauge on tank for detection.	5	5	1	25
					Lack of replacement air when emptying tank.	Low outlet flow, pump work increase.	7	5	5	175	Consider pump suction pressure gauge (vac / pos) for better detection.	7	5	3	105
			Open when should be Closed	Operator error	No effect	None	1	5	10	50		1	5	10	50
			Leakage	Stem seal failure	Vapor leakage overboard	None	10	1	10	100	Consider combustibility sensor above process	9	1	1	9
				Seat seal failure	Vapor leakage through valve	None	10	1	10	100	Consider combustibility sensor above process	9	1	1	9

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HV	630	**Vent Valve - Settling Tank**	Closed when should be Open	Operator error	Lack of venting for settling tank, pressure increase during fill.	Visual inspection (PI-120).	7	5	5	**175**	1. Consider pressure relief valve on Settling tank. Set point TBD. 2. Consider pressure gauge on tank for detection.	5	5	1	**25**
					Lack of replacement air when emptying tank.	Low outlet flow, pump work increase.	7	5	5	**175**	Consider pump suction pressure gauge (vac / pos) for better detection.	7	5	3	**105**
			Open when should be Closed	Operator error	No effect	None	1	5	10	**50**		1	5	10	**50**
			Leakage	Stem seal failure	Vapor leakage overboard, possibly some residual alcohol vapor.	None	**10**	1	10	**100**	Consider combustibility sensor over process.	9	1	1	**9**
				Seat seal failure	Vapor leakage through valve	None	**10**	1	10	**100**	Consider combustibility sensor over process.	9	1	1	**9**
HV	390	**Outlet Valve - Settling Tank**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	**120**	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	**105**
			Open when should be Closed	Operator error	Mix of air (empty tank) or final product (BD/glycerin) with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	3	**105**	Operator checklist and operation sheets need to be developed and followed. Consider LOTO prior to operating pump (PMP-100).	7	5	3	**105**
			Leakage	Stem seal failure	Leakage of final product (BD or glycerin) onto basin / sump.	Visual inspection	7	1	3	**21**	Consider level sensor in sump to detect severe leakage.	7	1	1	**7**
				Seat seal failure	Mix of air (empty tank) or final product (BD/glycerin) with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	3	**21**		7	1	3	**21**
HV	380	**Isolation Valve - Outlet of Settling Tank to Pump**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	**120**	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	**105**
			Open when should be Closed	Operator error	Mix of air (empty tank) or final product (BD/glycerin) with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	3	**105**	Operator checklist and operation sheets need to be developed and followed. Consider LOTO prior to operating pump (PMP-100).	7	5	3	**105**
			Leakage	Stem seal failure	Leakage of final product (BD or glycerin) onto basin / sump.	Visual inspection	7	1	3	**21**	Consider level sensor in sump to detect severe leakage.	7	1	1	**7**
				Seat seal failure	Mix of air (empty tank) or final product (BD/glycerin) with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	3	**21**		7	1	3	**21**
HV	290	**Outlet Valve - Oxide Mixing Tank**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	**120**	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	**105**
			Open when should be Closed	Operator error	Mix of air (empty tank) or oxide mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	3	**105**		7	5	3	**105**
			Leakage	Stem seal failure	Leakage of oxide mix or alcohol onto basin / sump.	Visual inspection.	**10**	1	3	**30**	Consider combustibility sensor above process.	9	1	1	**9**
				Seat seal failure	Mix of air (empty tank) or oxide mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	3	**21**		7	1	3	**21**

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HV	295	**Skim Valve - Oxide Mixing Tank**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Mix of air (empty tank) or oxide mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	3	105		7	5	3	105
			Leakage	Stem seal failure	Leakage of oxide mix or alcohol onto basin / sump.	Visual inspection.	10	1	3	30	Consider combustibility sensor above process.	9	1	1	9
				Seat seal failure	Mix of air (empty tank) or oxide mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	3	21		7	1	3	21
HV	190	**Outlet Valve - BD Reaction Tank**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Mix of air (empty tank) or reactor mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	3	105		7	5	3	105
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	9	36
				Seat seal failure	Mix of air (empty tank) or reactor mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	3	21		7	1	3	21
HV	400	**Vacuum Reference Valve - Top of BD Reaction Tank**	Closed when should be Open	Operator error	Inability to draw vacuum on vessels for vacuum fill process	Noted lack of fill, lack of vacuum on specific vessel.	2	5	3	30		2	5	3	30
			Open when should be Closed	Operator error	Possible leakage of vented vapors from BD tank or others. Possible vacuum on any vessel when unintended (would require double failure including vacuum pump on)	Vacuum on TNK-100 when not intended.	2	5	3	30		2	5	3	30
			Leakage	Stem seal failure	Poor vacuum draw performance on system	Vacuum measurement on TNK-100	2	2	3	12		2	2	3	12
				Seat seal failure	Possible leakage of vented vapors from BD tank or others. Possible vacuum on any vessel when unintended (would require double failure including vacuum pump on)	Vacuum on TNK-100 when not intended.	2	5	3	30		2	5	3	30
HV	800	**Inlet Valve - Alcohol to Oxide Tank**	Closed when should be Open	Operator error	Will not permit filling of oxide tank with alcohol and catalyst, potential spill onto sump / basin	Visual inspection	10	5	3	150	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	5	1	45
			Open when should be Closed	Operator error	Venting of vapor to area other than intended vent termination.	Visual inspection	10	5	5	250	Consider combustibility sensor above process.	9	5	1	45
					Overflow of contents onto basin / sump.	Visual inspection	10	5	3	150	Consider level sensor in sump to detect severe leakage.	9	5	1	45
			Leakage	Stem seal failure	Venting of vapor to area other than intended vent termination.	Visual inspection	10	1	5	50	Consider combustibility sensor above process.	9	1	1	9
					Overflow of contents onto basin / sump.	Visual inspection	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9

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				Seat seal failure	Venting of vapor to area other than intended vent termination.	Visual inspection	10	1	5	50	Consider combustibility sensor above process.	9	1	1	9
					Overflow of contents onto basin / sump.	Visual inspection	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
HV	300	**Inlet Valve - Settling Tank**	Closed when should be Open	Operator error	Will not permit filling of settling tank / transfer of product. Pump blockage, increased pump work (PMP-100) and system pressure.	Visual inspection of sight tube or settling tank (LI-300). Pump work increase, audible change. Possible pump dead-end.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of other fluids to settling tank when not intended.	Visual inspection of sight tube or settling tank (LI-300).	7	5	3	105		7	5	3	105
			Leakage	Stem seal failure	Leakage of final product (BD or glycerin) onto basin / sump.	Visual inspection	7	1	3	21	Consider level sensor in sump to detect severe leakage.	7	1	1	7
				Seat seal failure	Routing of other fluids to settling tank when not intended.	Visual inspection of sight tube or settling tank (LI-300).	7	1	5	35		7	1	5	35
HV	900	**System Drain Valve**	Closed when should be Open	Operator error	Will not permit drainage of system, possible future blockages or spills.	Visual inspection of outflow, lack of flow. Audible change in pump if run during drain cycle.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	5	3	150	Consider level sensor in sump to detect severe leakage.	9	5	1	45
			Leakage	Stem seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
HV	950	**Outlet Valve - Take Off for BD**	Closed when should be Open	Operator error	Will not permit take-off of final products. Pump blockage, increased pump work (PMP-100) and system pressure.	Visual inspection of outflow, lack of flow. Audible change in pump.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	5	3	150	Consider level sensor in sump to detect severe leakage.	9	5	1	45
			Leakage	Stem seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
HV	975	**Outlet Valve - Take Off for Glycerin**	Closed when should be Open	Operator error	Will not permit take-off of final products. Pump blockage, increased pump work (PMP-100) and system pressure.	Visual inspection of outflow, lack of flow. Audible change in pump.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	5	3	150	Consider level sensor in sump to detect severe leakage.	9	5	1	45

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Date: 1/2/2008

Issue: INTERNAL USE ONLY

Issued by

Approved by

Document status: Revision 1

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			Leakage	Stem seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Routing of any process fluid overboard or to take-off termination. Likely spill onto basin / sump.	Visual inspection, audible spilling.	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
HV	200	**Inlet Valve - Oxide Mixing Tank**	Closed when should be Open	Operator error	Will not permit pump-driven mixing and circulation of alcohol oxide mix. Increased pump work (PMP-100) and system pressure.	Visual inspection, pressure increase on pressure gauge (PI-120) lack of intended flow. Audible change in pump operation.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid to the oxide mix tank when not intended. Possible routing of alcohol vapors to other portions of the system.	Visual inspection of sight tube on oxide mix tank (LI-200).	7	5	3	105	Consider combustibility sensor above process.	7	5	1	35
			Leakage	Stem seal failure	Leakage of oxide mix or alcohol onto basin / sump.	Visual inspection.	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
				Seat seal failure	Routing of any process fluid to the oxide mix tank when not intended. Possible routing of alcohol vapors to other portions of the system.	Visual inspection of sight tube on oxide mix tank (LI-200).	10	1	5	50	Consider combustibility sensor above process.	9	1	1	9
HV	100	**Fill Valve - BD Reaction Tank**	Closed when should be Open	Operator error	Will prevent filling of BD reaction tank. Pump work increase (PMP-100), system pressure rise.	Visual inspection of process sight tube (MI-100), audible change in pump operation.	7	5	3	105	Consider pressure relief at pump outlet with vent line referenced to containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid to the BD tank when not intended.	Visual inspection of BD tank sight tube (LI-100).	7	5	5	175		7	5	5	175
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
				Seat seal failure	Routing of any process fluid to the BD tank when not intended.	Visual inspection of BD tank sight tube (LI-100).	7	1	5	35		7	1	5	35
HV	105	**Mix Inlet Valve - BD Reaction Tank**	Closed when should be Open	Operator error	Will prevent mixing and recirc of BD reaction tank contents. Pump work increase (PMP-100), system pressure rise.	Visual inspection of process sight tube (MI-100), audible change in pump operation.	8	5	3	120	Consider pressure relief at pump outlet with vent line referenced to containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid to the BD tank when not intended.	Visual inspection of BD tank sight tube (LI-100).	7	5	3	105		7	5	3	105
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
				Seat seal failure	Routing of any process fluid to the BD tank when not intended.	Visual inspection of BD tank sight tube (LI-100).	7	1	5	35		7	1	5	35

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TYPE	#	FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL CAUSES	POTENTIAL EFFECTS	DETECTION METHOD	SEV	OCC	DET	RPN	RECOMMENDED ACTION(S)	SEV	OCC	DET	RPN
HV	120	**Main Mix Line Valve - Pump Pressure Side**	Closed when should be Open	Operator error	Will prevent flow of process fluids from pump (PMP-100)	Visual inspection at process sight tube (MI-100), audible change in pump operation.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Routing of any process fluid to either BD tank or Oxide mixing tank when not intended.	Visual inspection at process sight tube (MI-100), BD tank sight tube (LI-100) or oxide mix tank sight tube (LI-200)	7	5	5	175		7	5	5	175
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
				Seat seal failure	Routing of any process fluid to either BD tank or Oxide mixing tank when not intended.	Visual inspection at process sight tube (MI-100), BD tank sight tube (LI-100) or oxide mix tank sight tube (LI-200)	7	1	5	35		7	1	5	35
HV	150	**Isolation Valve - Pump Inlet**	Closed when should be Open	Operator error	No flow, pump work increase, pump outlet pressure increase and suction pressure decrease.	Visual inspection, pressure increase on pressure gauge (PI-120) lack of intended flow. Audible change in pump operation.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Leakage of system contents during maintence operation. Likely spill on containment basin into sump.	Visual inspection, leakage at point of intended line break (rapid detection).	3	5	1	15		3	5	1	15
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	3	12
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	1	4
				Seat seal failure	Slow leakage of system contents during maintence operation. Likely spill on containment basin into sump.	Visual inspection, leakage at point of intended line break (rapid detection).	3	1	1	3	Consider having a plug / cap available for these fittings. Or do not work on system unless it is completely drained. Install a dedicated drain for this purpose?	3	1	1	3
HV	160	**Isolation Valve - BD Reaction Tank Bottom**	Closed when should be Open	Operator error	Will not draw tank down, pump over work, suction pressure on pump inlet (PMP-100).	Low outlet flow, pump work increase.	8	5	3	120	1. Review motor drive controls and also pump dead-head pressure ride. 2. Consider recirc loop for pump. 3. Consider pressure relief valve at pump outlet with vent line referenced to secure containment.	7	5	3	105
			Open when should be Closed	Operator error	Mix of air (empty tank) or reactor mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	5	5	175		7	5	5	175
			Leakage	Stem seal failure	Veg Oil Spill onto basin / sump	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4

FMEA ☑ System ☐ Design ☐ Process

Document name: FMEA - State Line Farm Biodiesel System
Date: 1/2/2008
Issue: INTERNAL USE ONLY
Issued by
Approved by
Document status: Revision 1

RPN 200 -
RPN 100 -199
RPN 1-99

TYPE	#	FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL CAUSES	POTENTIAL EFFECTS	DETECTION METHOD	SEV	OCC	DET	RPN	RECOMMENDED ACTION(S)	SEV	OCC	DET	RPN
					Reaction Mix Spill onto basin / sump	Visual inspection	10	1	3	30	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	9	1	1	9
					BD Spill onto basin / sump	Visual inspection	4	1	3	12	1. Consider level sensor in sump to detect severe leakage. 2. Consider combustibility sensor above process.	4	1	3	12
				Seat seal failure	Mix of air (empty tank) or reactor mix with other parts of process when not intended.	Visual inspection by sight tubes and mixing indicator (MI-100)	7	1	5	35		7	1	5	35
HV	170	**Level Indicator Valve - BD Reaction Tank Bottom**	Closed when should be Open	Operator error	Unknown or inaccurate level or settling status	Visual Inspection	6	5	3	90		6	5	3	90
			Open when should be Closed	Operator error	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell, audible spilling.	10	5	1	50	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	5	1	45
			Leakage	Stem seal failure	Spill of alcohol or oxide mix onto basin / sump	Visual Inspection	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell.	10	1	1	10	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	1	1	9
HV	175	**Level Indicator Valve - BD Reaction Tank Top**	Closed when should be Open	Operator error	Unknown or inaccurate level or settling status	Visual Inspection	6	5	3	90		6	5	3	90
			Open when should be Closed	Operator error	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell, audible spilling.	10	5	1	50	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	5	1	45
			Leakage	Stem seal failure	Spill of alcohol or oxide mix onto basin / sump	Visual Inspection	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell.	10	1	1	10	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	1	1	9
HV	270	**Level Indicator Valve - Oxide Mix Tank Bottom**	Closed when should be Open	Operator error	Unknown or inaccurate level or settling status	Visual Inspection	6	5	3	90		6	5	3	90
			Open when should be Closed	Operator error	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell, audible spilling.	10	5	1	50	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	5	1	45
			Leakage	Stem seal failure	Spill of alcohol or oxide mix onto basin / sump	Visual Inspection	10	1	3	30	Consider level sensor in sump to detect severe leakage.	9	1	1	9
				Seat seal failure	Leakage of oxide mix or alcohol onto basin / sump during maintenance operation (rapid detection).	Visual inspection, smell.	10	1	1	10	Consider using on-body combustibility sensors (Crickets) during maintenance operations.	9	1	1	9
HV	370	**Level Indicator Valve - Settling Tank Bottom**	Closed when should be Open	Operator error	Unknown or inaccurate level or settling status	Visual Inspection	6	5	3	90		6	5	3	90
			Open when should be Closed	Operator error	Leakage of settling tank contents to basin / sump during maintenance procedure (rapid detection).	Visual inspection, audible spilling.	3	5	1	15	Consider level sensor in sump to detect severe leakage.	3	5	1	15
			Leakage	Stem seal failure	Leakage of settling tank contents to basin / sump.	Visual inspection	4	1	3	12	Consider level sensor in sump to detect severe leakage.	4	1	1	4
				Seat seal failure	Leakage of settling tank contents to basin / sump during maintenance procedure (rapid detection).	Visual inspection, audible spilling.	3	1	1	3	Consider level sensor in sump to detect severe leakage.	3	1	1	3

MAX 250
AVG 60.2
MIN 3

MAX 175
AVG 35.5
MIN 2

5.3 SOP's

Batch Information

Date: _____________ Time: _____________

Operator: _________________________

Oil Source / Description: ____

Other Comments / Observations:

S.O.P. #1 - PREPARATION

STEP 1.1 - Confirm Starting Conditions

ACTION 1.1.1 - Confirm tanks are empty, clean and dry. ....☐ ____

ACTION 1.1.2 - Ensure working area is free of ignition sources. ....☐ ____

ACTION 1.1.3 - Ensure spill containment systems are empty and in working order. ....☐ ____

ACTION 1.1.4 - Confirm system vent termination outdoors is clear. ....☐ ____

ACTION 1.1.5 - Confirm System Safe Condition:

1. **Combustibility Sensors** are **ON** **.................................**☐ ____
2. **PMP-100** (Main Pump) is **OFF**....................................☐ ____
3. **HV-005** (Oil Tank Valve Bottom) is **OPEN**.....................☐ ____
4. **HV-010** (BD Tank Oil Inlet) is **CLOSED** ....☐ ____
5. **HV-400** (Vacuum Reference Valve) is **CLOSED**..............☐ ____
6. **HV-900** (System Drain) is **CLOSED** **.............................**☐ ____
7. **HV-975** (BD Take-off) is **CLOSED** ....☐ ____
8. **HV-950** (Glycerin Take-off) is **CLOSED** ....☐ ____
9. **HV-120** (____________) is **CLOSED**...........................☐ ____
10. **HV-300** (Settling Tank Inlet) is **CLOSED** ....☐ ____
11. **HV-200** (Oxide Tank Fill Inlet Valve) is **CLOSED**............☐ ____
12. **HV-105** (BD Tank Mix Inlet Valve) is **CLOSED**...............☐ ____
13. **HV-100** (BD Tank Fill Inlet Valve) is **CLOSED**................☐ ____
14. **HV-150** (Ox/Settling Pump Inlet) is **CLOSED** ....☐ ____
15. **HV-500** (Condenser Drain) is **CLOSED**.........................☐ ____
16. **HV-290** (Oxide Tank Bottom) is **CLOSED** ....☐ ____
17. **HV-295** (Oxide Tank Skim) is **CLOSED** ....☐ ____
18. **HV-380** (Settling Pump Inlet) is **CLOSED** ....☐ ____
19. **HV-390** (Settling Tank Bottom) is **CLOSED**...................☐ ____
20. **HV-800** (Alcohol Inlet) is **CLOSED**...............................☐ ____
21. **HV-610** (BD Tank Vent Valve) is **OPEN** ....☐ ____
22. **HV-620** (Oxide Mix Tank Vent Valve) is **OPEN**................☐ ____
23. **HV-630** (Settling Tank Vent Valve) is **OPEN** ....☐ ____

-- S.O.P. #1 - Continued on Next Page --

S.O.P. #1 - PREPARATION (Continued)

ACTION 1.1.5 - - Confirm System Safe Condition (continued):

24. **HV-170** (BD Tank LI Valve Bottom) is **OPEN**.................. ☐ ____
25. **HV-175** (BD Tank LI Valve Top) is **OPEN**....................... ☐ ____
26. **HV-270** (Oxide Tank LI Valve Bottom) is **OPEN**.............. ☐ ____
27. **HV-370** (Settling Tank LI Valve Bottom) is **OPEN**........... ☐ ____

-- END OF S.O.P. #1 --

S.O.P. #2 - FILL TNK-100 (BIODIESEL REACTION TANK)

STEP 2.1 - Set Valves for TNK-100 Fill

1. **CLOSE HV-160** (BD Pump Inlet) ....☐ ____
2. **OPEN HV-170** (BD Tank LI Valve Bottom) ....☐ ____
3. **OPEN HV-175** (BD Tank LI Valve Top) ....☐ ____
4. **CLOSE HV-610** (BD Tank Vent Valve) ....☐ ____
5. **CLOSE HV-500** (Condenser Drain) ....☐ ____
6. **CLOSE HV-100** (BD Tank Fill Inlet Valve) ....☐ ____
7. **CLOSE HV-105** (BD Tank Mix Inlet Valve) ....☐ ____
8. Confirm **Top Hatch** on TNK-100 is **CLOSED** ....☐ ____

STEP 2.2 - Fill TNK-100 with Oil using Vacuum

1. Turn **Vacuum Pump ON** ....☐ ____
2. **OPEN HV-400** (Vacuum Reference Valve) ....☐ ____
3. **Confirm Vacuum** using PI-100 ....☐ ____
4. **OPEN HV-010** (BD Tank Oil Inlet) ....☐ ____
5. **OPEN HV-005** (Oil Tank Valve Bottom) ....☐ ____
6. **Monitor LI-100** to observe the increasing level.............☐ ____
7. **Fill TNK-100** with oil to desired level ....☐ ____
8. **CLOSE HV-010** when oil is at desired level ....☐ ____
9. **Record oil level** indicated b LI-100:_____________________ ❶

Only do the following two steps if you plan to raise the oil temp using the PMP-100 for circulation.

10. **CLOSE HV-400** (Vacuum Reference Valve) ....☐ ____
11. **OPEN HV-610** (BD Tank Vent Valve) ....☐ ____

-- END OF S.O.P. #2 --

S.O.P. #3 - RAISE OIL TEMP (IN TNK-100)

STEP 3.1 - Ensure oil level in tank (LI-100) .... ☐ ____

STEP 3.2 - Start circulation of water in HEX-100 .... ☐ ____

STEP 3.3 - Start circulation of oil using PMP-100

ACTION 3.3.1 - Set Valves to Direct Flow Correctly

1. Confirm **HV-900** is **CLOSED** .... ☐ ____
2. Confirm **HV-950** is **CLOSED** .... ☐ ____
3. Confirm **HV-975** is **CLOSED** .... ☐ ____
4. Confirm **HV-150** is **CLOSED** .... ☐ ____
5. Confirm **HV-300** is **CLOSED** .... ☐ ____
6. Confirm **HV-200** is **CLOSED** .... ☐ ____
7. Confirm **HV-100** is **CLOSED** .... ☐ ____
8. **OPEN HV-105** .... ☐ ____
9. **OPEN HV-120** .... ☐ ____
10. **OPEN HV-190** .... ☐ ____
11. **OPEN HV-160** .... ☐ ____
12. Check for leaks from TNK-100 to PMP-100 .... ☐ ____

ACTION 3.3.2 - Start Circulation of oil

1. Turn **PMP-100 ON** .... ☐ ____
2. Set **PMP-100 SPEED** to _________ .... ☐ ____
3. Confirm **PMP-100 pressure** on **PI-120** .... ☐ ____
4. Confirm circulation with **MI-100** .... ☐ ____
5. Check for leaks in system .... ☐ ____
6. Check that LI-200 and LI-300 are stable to ensure the fluid is only being directed to TNK-100 .... ☐ ____

STEP 3.4 - Establish temperature set point of oil (TI-100) .... ☐ ____

ACTION 3.4.1 - **Record** oil **temperature** set point: __________________ ❷

STEP 3.5 - Stop circulation of oil using PMP-100

ACTION 3.5.1 - Turn **PMP-100 OFF** .... ☐ ____

ACTION 3.5.2 - **CLOSE HV-160** .... ☐ ____

ACTION 3.5.3 - **CLOSE HV-120** .... ☐ ____

ACTION 3.5.4 - **CLOSE HV-105** .... ☐ ____

-- END OF S.O.P. #3 --

S.O.P. #4 - FILL TNK-200 (OXIDE MIX TANK)

STEP 4.1 - Set TNK-100 for Vacuum

ACTION 4.1.1 - Confirm **Combustibility Sensors** are **ON** .... ☐ ____

ACTION 4.1.2 - Prepare Alcohol

1. Relocate Alcohol tank from storage to front of system .... ☐ ____
2. Connect grounding strap between Alcohol tank and main system ground connection.................. ☐ ____
3. Connect Alcohol feed line to HV-800 connection using quick coupling....................................... ☐ ____

ACTION 4.1.3 - Set valves for development of vacuum on TNK-100

1. Confirm **HV-010** is **CLOSED** .... ☐ ____
2. Confirm **HV-160** is **CLOSED** .... ☐ ____
3. Confirm **HV-100** is **CLOSED** .... ☐ ____
4. Confirm **HV-105** is **CLOSED** .... ☐ ____
5. Confirm **HV-500** is **CLOSED** .... ☐ ____
6. **CLOSE HV-610** .... ☐ ____
7. Turn **Vacuum Pump ON**................................ ☐ ____
8. **OPEN HV-400**... ☐ ____
9. **Confirm Vacuum** using PI-100........................ ☐ ____

STEP 4.2 - Setup TNK-200 for Fill

ACTION 4.2.1 - Ensure **top hatch is closed** on TNK-200.................. ☐ ____

ACTION 4.2.2 - Set valves for vacuum fill of TNK-200

1. Confirm **HV-380** is **CLOSED** .... ☐ ____
2. Confirm **HV-150** is **CLOSED** .... ☐ ____
3. Confirm **HV-200** is **CLOSED** .... ☐ ____
4. **OPEN HV-295**[a] .... ☐ ____
5. **OPEN HV-290**... ☐ ____
6. **OPEN HV-270**... ☐ ____
7. **CLOSE HV-620** .... ☐ ____

-- S.O.P. #4 - Continued on Next Page –

[a] NOTE: The level lines on LI-200 were calibrated with HV-295 open and account for the volume of plumbing associated with it. This is the reason this valve needs to be open during this step; for accurate metering of alcohol fill.

S.O.P. #4 - FILL TNK-200 (OXIDE MIX TANK) (Continued)

STEP 4.3 - Fill TNK-200 with Alcohol

ACTION 4.3.1 - Start filling TNK-200 with Alcohol

1. **OPEN HV-500** .... ☐ ____
2. **OPEN HV-800** .... ☐ ____
3. **Monitor LI-200** to observe the increasing level............. ☐ ____
4. **Fill TNK-200** with alcohol to desired level...................... ☐ ____
5. **CLOSE HV-800** when alcohol is at desired level............. ☐ ____
6. **Record oil level** indicated by LI-200:____________________ ❸
7. Check for leaks in system... ☐ ____

ACTION 4.3.2 - Stop Vacuum Fill of TNK-200

1. Turn **Vacuum Pump OFF**... ☐ ____
2. **OPEN HV-620** .... ☐ ____
3. **OPEN HV-610** .... ☐ ____
4. **CLOSE HV-500**.. ☐ ____
5. **CLOSE HV-400**.. ☐ ____
6. **CLOSE HV-270**.. ☐ ____
7. Check for leaks in system... ☐ ____

STEP 4.4 - Load Catalyst in TNK-200

ACTION 4.4.1 - Obtain measured quantity of catalyst from storage .... ☐ ____

ACTION 4.4.2 - Record catalyst quantity: ___________________________ ❹

ACTION 4.4.3 - Load Catalyst

1. **OPEN Top Hatch** on **TNK-200** .... ☐ ____
2. **Pour Catalyst** into **TNK-200**....................................... ☐ ____
3. **CLOSE Top Hatch** on **TNK-200**.................................. ☐ ____

-- END OF S.O.P. #4 --

S.O.P. #5 - MIX OXIDE in TNK-200 (OXIDE MIX TANK)

STEP 5.1 - Set Valves for Oxide Mixing

1. Confirm **HV-290** is **CLOSED** .... ☐ ____
2. Confirm **HV-380** is **CLOSED** .... ☐ ____
3. Confirm **HV-300** is **CLOSED** .... ☐ ____
4. Confirm **HV-975** is **CLOSED** .... ☐ ____
5. Confirm **HV-950** is **CLOSED** .... ☐ ____
6. **OPEN HV-295** .... ☐ ____
7. **OPEN HV-150** .... ☐ ____
8. **OPEN HV-120** .... ☐ ____
9. **OPEN HV-200** .... ☐ ____
10. Check for leaks in system.. ☐ ____

STEP 5.2 - Mix Oxide – Phase One (from Skim Port of TNK-200)

1. Turn **PMP-100 ON** .... ☐ ____
2. Set **PMP-100 SPEED** to **50 Hz (water)**........................ ☐ ____
3. Confirm **PMP-100 pressure** on **PI-120** (60 psig water) .. ☐ ____
4. Confirm circulation and mixing with **MI-100** .... ☐ ____
5. Check for leaks in system.. ☐ ____
6. Circulate to mix Oxide for ________ minutes................. ☐ ____

STEP 5.3 - Mix Oxide – Phase Two (from Bottom of TNK-200)

1. **OPEN HV-290** .... ☐ ____
2. **CLOSE HV-295**... ☐ ____
3. Confirm **PMP-100 pressure** on **PI-120** (60 psig water) .. ☐ ____
4. Confirm circulation and mixing with **MI-100** .... ☐ ____
5. Check for leaks in system.. ☐ ____
6. Circulate to mix Oxide for ________ minutes................. ☐ ____

STEP 5.4 - Stop Oxide Mixing

1. Turn **PMP-100 OFF** .... ☐ ____

-- END OF S.O.P. #5 --

S.O.P. #6 - TRANSFER OXIDE FROM TNK-200 to TNK-100

STEP 6.1 - Set Valves for Oxide Transfer to TNK-100

1. Confirm **HV-610** is **OPEN** .... ☐ ____
2. Confirm **HV-620** is **OPEN** .... ☐ ____
3. Confirm **HV-380** is **CLOSED** .... ☐ ____
4. Confirm **HV-120** is **OPEN** .... ☐ ____
5. Confirm **HV-100** is **CLOSED** .... ☐ ____
6. Confirm **HV-150** is **OPEN** .... ☐ ____
7. Confirm **HV-290** is **OPEN** .... ☐ ____
8. Confirm **HV-295** is **CLOSED** .... ☐ ____
9. Confirm **HV-190** is **OPEN** .... ☐ ____
10. **OPEN HV-105** .... ☐ ____
11. **CLOSE HV-200** .... ☐ ____
12. **OPEN HV-170** .... ☐ ____
13. **OPEN HV-175** .... ☐ ____
14. Turn **PMP-100 ON** .... ☐ ____
15. Set **PMP-100 SPEED** to _________ .... ☐ ____
16. Confirm **PMP-100 pressure** on **PI-120** .... ☐ ____
17. Check system for leaks .... ☐ ____
18. **Monitor** transfer of Oxide to TNK-100 using **LI-100 (increasing level)** and **LI-200 (decreasing level)**. Transfer typically takes _______ minutes....................... ☐ ____
19. **CLOSE HV-150** .... ☐ ____
20. **OPEN HV-160** .... ☐ ____

NOTE: When Oxide transfer step is complete, be prepared to do the following two steps (in S.O.P. #7 - MIX BD…) quickly as possible

-- END OF S.O.P. #6 --

S.O.P. #7 - MIX BD and START REACTION

NOTE: When Oxide transfer step is complete, be prepared to do the following two steps as quickly as possible

1. Confirm **HV-150** is **CLOSE**... ☐ ____
2. Confirm **HV-160** is **OPEN** .... ☐ ____
3. Set **PMP-100 SPEED** to **47 Hz** (water) .... ☐ ____
4. Confirm **PMP-100 pressure** on **PI-120** .... ☐ ____
5. Check system for leaks .... ☐ ____
6. **Monitor** mixing of biodiesel reactants using **MI-100** .... ☐ ____
7. **Continue mixing** for _____ minutes (typically) .... ☐ ____
8. Turn **PMP-100 OFF** .... ☐ ____
9. **CLOSE HV-105**... ☐ ____
10. **CLOSE HV-120**.. ☐ ____

-- END OF S.O.P. #7 --

S.O.P. #8 - TRANSFER FUEL TO TNK-300 (SETTLING TANK)

STEP 8.1 - Set valves for transfer

1. Confirm **HV-390** is **CLOSED** .... ☐ ____
2. Confirm **HV-610** is **OPEN** .... ☐ ____
3. Confirm **HV-630** is **OPEN** .... ☐ ____
4. **OPEN HV-300** .... ☐ ____
5. Note level in **TNK300** using **LI-300** .... ☐ ____

STEP 8.2 - Start transfer of fuel from TNK-100 to TNK-300

1. Turn **PMP-100 ON** .... ☐ ____
2. Set **PMP-100 SPEED** to **30 Hz** (water) .... ☐ ____
3. Confirm **PMP-100 pressure** on **PI-120** .... ☐ ____
4. Check system for leaks .... ☐ ____
5. **Monitor** transfer of Fuel to TNK-300 using **LI-100 (decreasing level)** and **LI-300 (increasing level)** . Transfer typically takes _______ minutes.. ☐ ____

STEP 8.3 - Stop transfer of fuel

1. When transfer is complete, turn **PMP-100 OFF**.. ☐ ____

STEP 8.4 - Drain pump

1. Drain **PMP-100** using **HV-900** .... ☐ ____
2. Check system for leaks .... ☐ ____

-- END OF S.O.P. #8 --

S.O.P. #9 - SAFE THE SYSTEM (SHUTDOWN)

ACTION 9.1.1 - Confirm System Safe Condition:

1. **Combustibility Sensors** are **ON** .... ☐ ____
2. **PMP-100** (Main Pump) is **OFF**..................................... ☐ ____
3. **HV-005** (Oil Tank Valve Bottom) is **CLOSED** .... ☐ ____
4. **HV-010** (BD Tank Oil Inlet) is **CLOSED** .... ☐ ____
5. **HV-400** (Vacuum Reference Valve) is **CLOSED**.............. ☐ ____
6. **HV-190** (BD Tank Bottom) is **CLOSED** .... ☐ ____
7. **HV-160** (BD Pump Inlet) is **CLOSED**............................ ☐ ____
8. **HV-900** (System Drain) is **CLOSED** .... ☐ ____
9. **HV-975** (BD Take-off) is **CLOSED** .... ☐ ____
10. **HV-950** (Glycerin Take-off) is **CLOSED** .... ☐ ____
11. **HV-120** (____________) is **CLOSED** .... ☐ ____
12. **HV-300** (Settling Tank Inlet) is **CLOSED** .... ☐ ____
13. **HV-200** (Oxide Tank Fill Inlet Valve) is **CLOSED**............ ☐ ____
14. **HV-105** (BD Tank Mix Inlet Valve) is **CLOSED**................ ☐ ____
15. **HV-100** (BD Tank Fill Inlet Valve) is **CLOSED**................ ☐ ____
16. **HV-150** (Ox/Settling Pump Inlet) is **CLOSED** .... ☐ ____
17. **HV-500** (Condenser Drain) is **CLOSED**......................... ☐ ____
18. **HV-290** (Oxide Tank Bottom) is **CLOSED** .... ☐ ____
19. **HV-295** (Oxide Tank Skim) is **CLOSED** .... ☐ ____
20. **HV-380** (Settling Pump Inlet) is **CLOSED** .... ☐ ____
21. **HV-390** (Settling Tank Bottom) is **CLOSED**.................... ☐ ____
22. **HV-800** (Alcohol Inlet) is **CLOSED**............................... ☐ ____
23. **HV-610** (BD Tank Vent Valve) is **OPEN** .... ☐ ____
24. **HV-620** (Oxide Mix Tank Vent Valve) is **OPEN** ☐ ____
25. **HV-630** (Settling Tank Vent Valve) is **OPEN** ☐ ____
26. **HV-170** (BD Tank LI Valve Bottom) is **OPEN** ☐ ____
27. **HV-175** (BD Tank LI Valve Top) is **OPEN** ☐ ____
28. **HV-270** (Oxide Tank LI Valve Bottom) is **OPEN** ☐ ____
29. **HV-370** (Settling Tank LI Valve Bottom) is **OPEN** ☐ ____

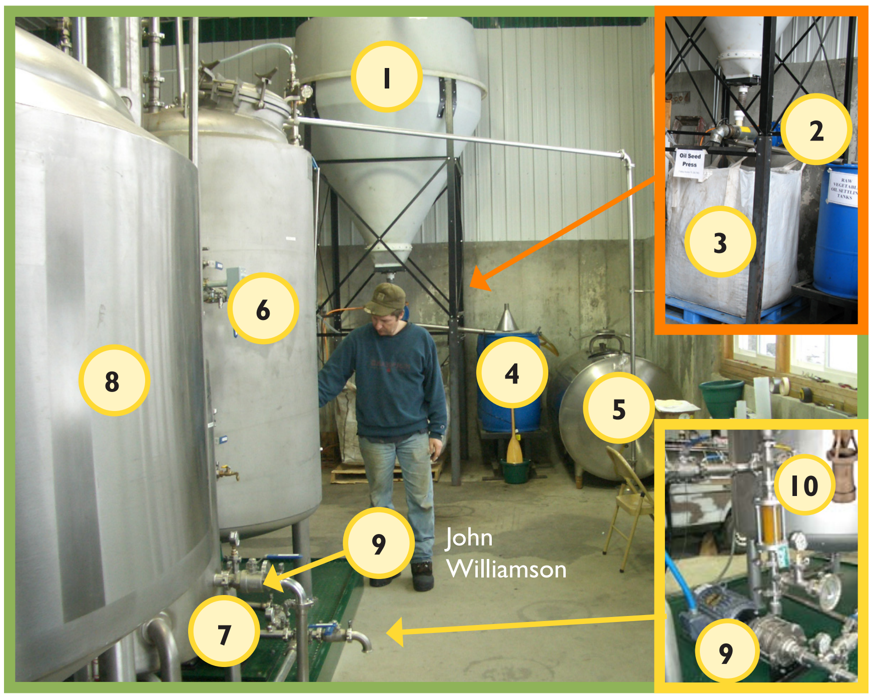
-- END OF S.O.P. #9 --

5.4 System Overview Handout

State Line Biofuels

System Overview

The biodiesel process at State Line Biofuels begins with a harvested crop of oilseed which is first dried and then stored in the 100 bushel grain hopper (1). From the hopper it is fed by gravity to the oil mill (2) directly below which presses up approximately 3 gallons of oil from the seed each hour. The mill also separates the remainder of the seed as meal. The meal is dropped into a bag (3) and the oil is diverted to a set of two 55 gallon primary settling drums (4). This settling process occurs by gravity and separates some of the sediment and remaining particles from the vegetable oil. The settled oil moves by gravity into a 300 gallon milk tank converted for use as a raw oil storage tank (5). This portion of the system provides the raw oil used in the production of biodiesel. Filtered waste vegetable oil can also be added into the storage tank.



Conversion of vegetable oil to biodiesel occurs in the 400 gallon reaction tank (6). This tank is "jacketed" meaning it has a double wall with a heat transfer surface between the walls. Hot water can be circulated through this jacket to heat the oil in the tank to a reaction temperature of 120-130°F. A similar process can be used to reclaim alcohol after the reaction has been completed. The oil is moved to this tank by drawing a small vacuum on the tank using a vacuum pump (not shown). Oil is then drawn into the reaction tank (6) from the storage tank (5) by opening a hand valve.

Alcohol and hydroxide are combined in a separate 115 gallon mix tank (7) which has also been drawn to a vacuum. This allows the transfer of alcohol into the tank without using a transfer pump. Hydroxide is presently added manually through a hatch on the top of the mix tank. The operator needs to be very careful when doing this as these ingredients are hazardous. Proper personal protective equipment (PPE) and careful handling are critical for safety reasons. The solid hydroxide is dissolved into the alcohol by mixing vigorously in a closed loop. This is done using a specially designed pump (9) and an eductor nozzle (10) which is attached to the return line of the loop inside the mix tank. A sight tube located directly above the pump allows for the operator to visually check the progress of the mixing.

Once sufficiently mixed, the alcohol / hydroxide mixture is transferred to the reaction tank and mixed with the vegetable oil. This is the start of the biodiesel reaction (*transesterfication*). The pump is used to circulate the vegetable oil, alcohol and hydroxide until the reaction is complete. The progress of the reaction can be visually monitored using the sight tube above the pump. When the reaction is complete, the same pump is used to transfer the biodiesel and glycerin to a 500 gallon, conical bottom settling tank (8) which allows the two to separate with gravity. The glycerin is removed off the bottom of the tank. The remaining fuel can then be tested for quality, passed through a final filter and used to power the farm's machinery.

System Components

Number	Component	Model / Size	Approximate Cost*
1	Grain Hopper	100 bushel, Polypropylene	$900
2	Täby Oil Mill	Model 70	$8,000
3	Meal Bags	N/A	N/A
4	Primary Settling drums	(2) 55 gallon PVC drums	N/A
5	Oil Storage Tank	Milk Tank 300 gallon, jacketed	$400
6	Reaction Tank	400 gallon jacketed	$6,000
7	Mix Tank	115 gallon, flush bottom valve with Parylene coating on valve seal	$4,250
8	Settling Tank	500 gallon, conical bottom	$2,000
9	Pump	Eastern Centrichem, ECH3 w/ explosion proof motor and variable speed drive.	$3,500
10	Mixing Nozzle	BETE Fog Nozzle Turbomix Eductor mixing nozzle, TM150.	$200
N/A	Hand Valves	Various, 30 valves @ $100 each	$3,000
N/A	Plumbing	Milk Line and Fittings, 300 feet & 30 fittings	$500
N/A	Gas Sensors	(2) Industrial Test Equipment HC-822 Combustible Gas Sensors @ $200 each	$400
N/A	Pallet	Spill containment skid pallet, custom made	$2,000
		Total	$31,150*

System Features

- **Efficiency**
  - -Single pump design with variable speed control
  - -Passive nozzle enhances catalyst mixing, shorter batch times
  - -Design features allow for planned alcohol recovery
- **Safety**
  - -Standard operating procedures
  - -Spill prevention and containment (skid and trough)
  - -Vacuum fill system (no machines operate when moving alcohol)
  - -Combustibility sensors
  - -Separation of wiring from hazardous locations
  - -Emergency shut down button
  - -Personal protective equipment
  - -Manual operation, always attended
- **Flexibility**
  - -Most tanks have more than one use
  - -Manual operation of valves allows for highly flexible use

Disclaimer - This information sheet is intended to provide general background about this specific system for those interested in considering on-farm biodiesel production. The processor at State Line Biofuels is a work in progress and this description is not complete. The reader is encouraged to carefully consider all technical aspects of their own processor as unique and take care when applying specific features from one design to another.

* Costs indicated are for this particular system. Many of the components were purchased used and labor has not been included.

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