**FUEL-GRADE ETHANOL**

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## 1.0 SCOPE

This document provides recommendations for the prevention of losses at fuel-grade ethanol facilities. It does not cover ethanol production for human consumption, or ethanol derived from petrochemical processes.

This data sheet does not include dust explosion prevention and protection schemes associated with grain handling, storage, or processing. Loss prevention recommendations for these occupancies are covered in Data Sheet 7-76, *Combustible Dusts*.

### 1.1 Hazards

Ethanol manufacturing facilities have inherent fire and explosion hazards due to handling of combustible dusts, flammable vapors, ignitable liquids, and fuel-fired equipment. Explosions involving fuel-fired equipment are currently the leading cause of loss, followed by fire. There have also been significant losses from mechanical breakdown, wind, and hail.

### 1.2 Changes

**January 2023.** Interim revision. Minor editorial changes were made.

## 2.0 LOSS PREVENTION RECOMMENDATIONS

### 2.1 Construction and Location

#### 2.1.1 General

2.1.1.1 Follow the construction and location guidance in the following data sheets:

- 7-14, *Fire Protection for Chemical Plants*
- 7-76, *Combustible Dusts*
- 7-88, *External Ignitable Liquid Storage Tanks*
- 7-32, *Ignitable Liquid Operations (guidance for ethanol loadout)*

#### 2.1.2 Damage-Limiting Construction

2.1.2.1 Provide damage-limiting construction (DLC) designed in accordance with Data Sheet 1-44, *Damage Limiting Construction*, for buildings with dust explosion or ethanol explosion hazards.

#### 2.1.3 Ethanol Process Areas (Distillation/Dehydration)

Ethanol process areas are areas where process equipment handling ethanol vapor or ethanol liquid (concentration greater than 20% ethanol) are located. This includes evaporators where 200-proof (100%) ethanol vapor from molecular sieves is used as the heat source.

2.1.3.1 Locate ethanol processes in the open whenever possible, with a minimum of enclosing structure, and a minimum 75 ft (23 m) away from important buildings, outdoor storage, and other equipment.

2.1.3.2 Provide perimeter curbing with adequately sized scuppers to direct overflow from deluge systems to a safe location.

2.1.3.3 For indoor evaporators, provide at least one of the following:

A. Drainage and containment per Section 2.1.3.2

B. Interlocks to shut down the flow of ethanol (and possibly steam) to the indoor evaporators or mole sieves upon activation of heat detection in the immediate area around the evaporators

2.1.3.4 Provide hazardous location-rated electrical equipment in accordance with Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*.

2.1.3.5 Provide low-level ventilation for indoor ethanol process areas in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*. Low-level mechanical ventilation is not necessary where classified electrical equipment is provided and the process is normally closed (i.e., no dispensing). Natural draft ventilation in these areas is acceptable.

### 2.2 Process Hazards

#### 2.2.1 Process Safety

2.2.1.1 Establish a process safety program in accordance with Data Sheet 7-43, *Process Safety*. Process hazards analysis (PHA) should be conducted for the following areas (if present):

A. Ethanol distillation and processing areas, including tank storage and truck/rail loading

B. Dryers, thermal oxidizers, regenerative thermal oxidizers, and other energy recovery and emissions control equipment

C. Grain/dust-handling areas (dust evaluations)

D. Biodeisel or other derivative products units

2.2.1.2 Establish an operator training program for normal operation and emergency shutdown of distillation and grain-drying processes. Emphasise the following key areas:

A. Response to out-of-specification fermentation batches.

B. Response to low temperature in the beer column bottoms with recycle back to beer well.

C. Elevated ethanol concentration in the liquor from centrifuge operations.

D. Response to loss of cooling to ethanol vapor condensers that can result in vapor carryover through vents to the emission control equipment (TOs and/or RTOs). Steam flow to distillation columns driving vaporization may need cutback or to be stopped.

E. High-temperature excursions in RTOs and dryers.

F. Shutdown procedures of dryers to prevent or respond to dryer fires.

G. Response to a power outage that shuts down water for fire protection systems (including process water pumps feeding dryer protection).

#### 2.2.2 Grain Handling

2.2.2.1 For grain/dust-handling equipment, provide dust explosion protection per Data Sheet 7-76, *Combustible Dusts*.

#### 2.2.3 Fermentation

2.2.3.1 Ensure fermentation process vessels and tanks are provided with emergency pressure and vacuum-relief devices sized for the worst-case credible upsets.

### 2.3 Protection

If ignitable liquids other than ethanol are used (e.g., cyclohexane or monoethylene glycol) in the manufacturing process, see protection guidance for those specific materials in Data Sheet 7-32, *Ignitable Liquid Operations*, or 7-14, *Fire Protection for Chemical Plants*.

#### 2.3.1 Ethanol Processes

2.3.1.1 Provide automatic wet sprinkler, deluge, or pre-action systems to protect all areas where ethanol liquid in concentrations greater than 20% is handled, per Data Sheet 7-14, *Fire Protection for Chemical Plants*.

#### 2.3.2 Corn Oil

2.3.2.1 Treat corn oil that is manufactured at corn-to-ethanol plants as having a confirmed closed cup flash point of 450°F (232°C). Protect the liquid and the tank holding the liquid in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

### 2.3.3 Tank Farm

2.3.3.1 Protect aboveground outdoor cone roof or covered (internal) floating roof storage tanks containing ethanol (190 and 200 proof), denaturant, and ethanol fuel in accordance with Data Sheet 7-88, *External Ignitable Liquid Storage Tanks*.

### 2.3.4 DDGS Dryer Fire Protection

2.3.4.1 Provide automatic water spray inside dryers because accumulations of combustible deposits are common. Key locations are the following (see Figure 1):

- Inlet screw conveyor
- Outlet area of the dryer (drop box)
- Return dampers

Steam snuffing can also be used as protection. For guidance on steam snuffing, refer to Data Sheet 7-4, *Paper Machines and Dryers*, with particular reference to airborne pulp dryers, and Data Sheet 7-99, *Heat Transfer Fluid Systems*.

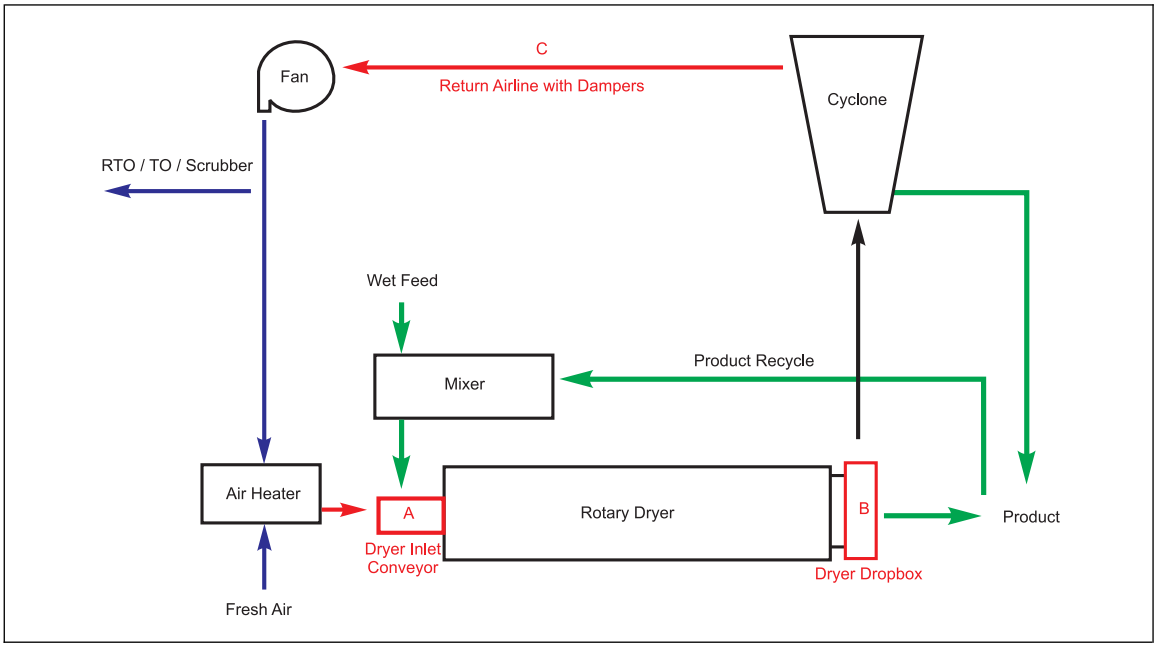


*Fig. 1. Typical indirect-fired rotary dryer and associated systems*

2.3.4.2 Actuate the water spray protection via high temperature at the dryer outlet. The water supply for such protection can be from an available service line.

2.3.4.3 Identify the valves associated with the automatic and bypass lines to the water spray nozzles inside the dryers. Include them as part of the fire protection inspection program. In addition, flow the nozzles at least annually to ensure no obstructions are present.

2.3.4.4 For the protection of ring dryers, provide manual water spray protection at the following locations (see Figure 2) in each of the dryer trains:

- The bottoms of both cyclones
- Top of the primary cyclone
- Upstream of the wet/dry manifold
- At the bottom of the pre-separator

Design the system for manual activation from a safe/remote location (e.g., a control room).

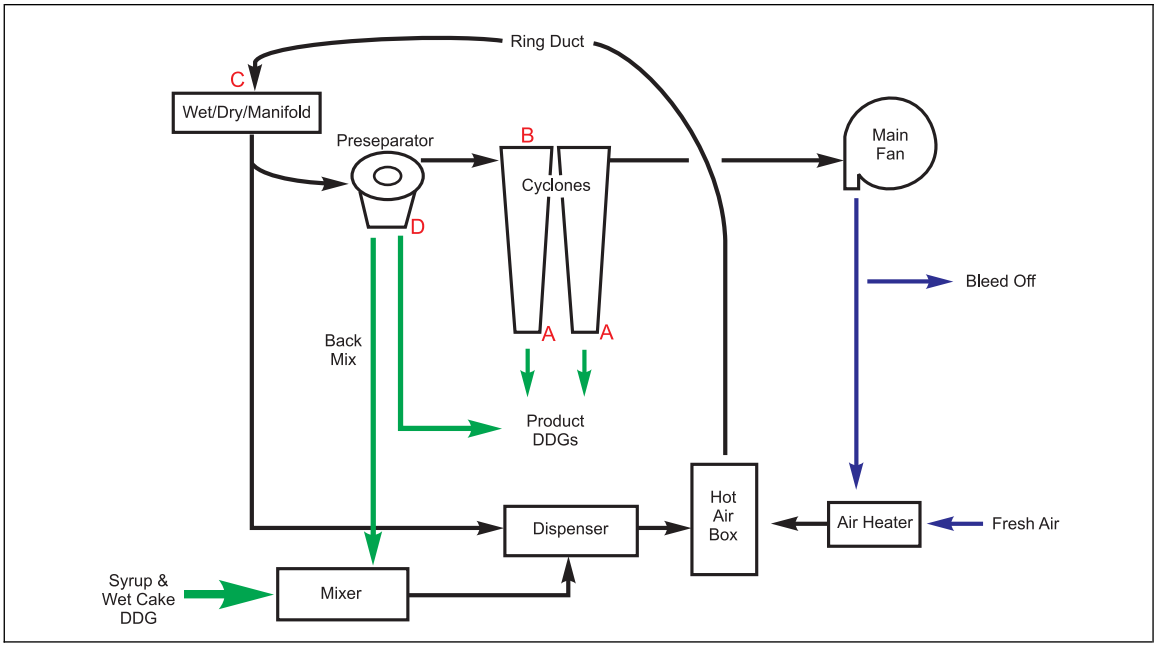


*Fig. 2. Typical ring dryer and associated systems*

2.3.4.5 Install risers fitted with manual bypass valves for the water spray systems, at a safe distance from the dryer area.

2.3.4.6 Provide a separate manual control valve and water spray system to protect the paddle mixer.

2.3.4.7 When starting up drying trains, ensure wet stillage loads into dryers are adequately managed to avoid overheating and the potential for fire or explosion.

### 2.4 Equipment and Processes

#### 2.4.1 Centrifuges

2.4.1.1 Provide monitoring, alarms, and independent interlocks arranged to safely shut down the unit in the event of overspeed, high vibration, high bearing temperatures, low lubrication oil pressure, loss of cooling, and/or other critical deviations.

#### 2.4.2 DDGS Dryers (Rotary and Ring)

2.4.2.1 Provide and maintain safeguards to prevent fuel explosions in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers*, and Data Sheet 6-17, *Rotary Kilns and Dryers*.

2.4.2.2 Provide an adequate inspection, testing, and maintenance (ITM) program for the rotary dryers. Dryers typically have large-diameter segmented gears and failure can cause equipment downtime.

2.4.2.3 Regularly inspect and clean condensate low point drains in fan housings and drying systems. Route condensate drains containing low-ph liquid away from equipment and ensure they drain to a safe location.

#### 2.4.3 Thermal Oxidizers

Refer to Data Sheet 6-11, *Thermal and Regenerative Catalytic Oxidizers*, for protection guidelines for thermal oxidizers.

2.4.3.1 Maintain a clear understanding of all the potential sources of fuel to these systems, such as methanator, carryover of ethanol from the centrate tank, and cook water and vents from fermenters.

2.4.3.2 Provide controls and independent safety interlocks for the thermal oxidizer and coupled equipment to ensure safe shutdown in the event of process upsets during startup and normal operation.

2.4.3.3 Provide automatic shutoff valves for all streams that may contain ethanol vapors during normal or upset conditions. Valves should shut on high temperature in the thermal oxidizer. A vent to atmosphere will be required for some streams if the flow of material cannot be completely stopped (i.e., from the dryers to the TO/TRO).

2.4.3.4 Ensure process conditions, alarms, and interlocks can be monitored in the control room.

### 2.4.4 Steam Turbines and Associated Systems

2.4.4.1 Provide protection on steam turbines and associated systems per Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*.

### 2.4.5 All Equipment Types

2.4.5.1 Complete all service bulletins issued by the original equipment manufacturer (OEM). Maintain and document completed service bulletins.

### 2.5 Operation and Maintenance

2.5.1 Establish a maintenance and asset integrity program per Data Sheet 9-0, *Asset Integrity*.

2.5.2 Ensure no restart attempts are made until the cause of the alarm or trip is fully understood and a detailed inspection has been conducted to verify the affected equipment is suitable for continued service.

## 3.0 SUPPORT FOR RECOMMENDATIONS

### 3.1 Loss History

From 2004 to 2018, FM client losses at corn-to-ethanol plants were most frequently attributable to equipment breakdown, natural hazards, and fire, as shown in Figure 3.

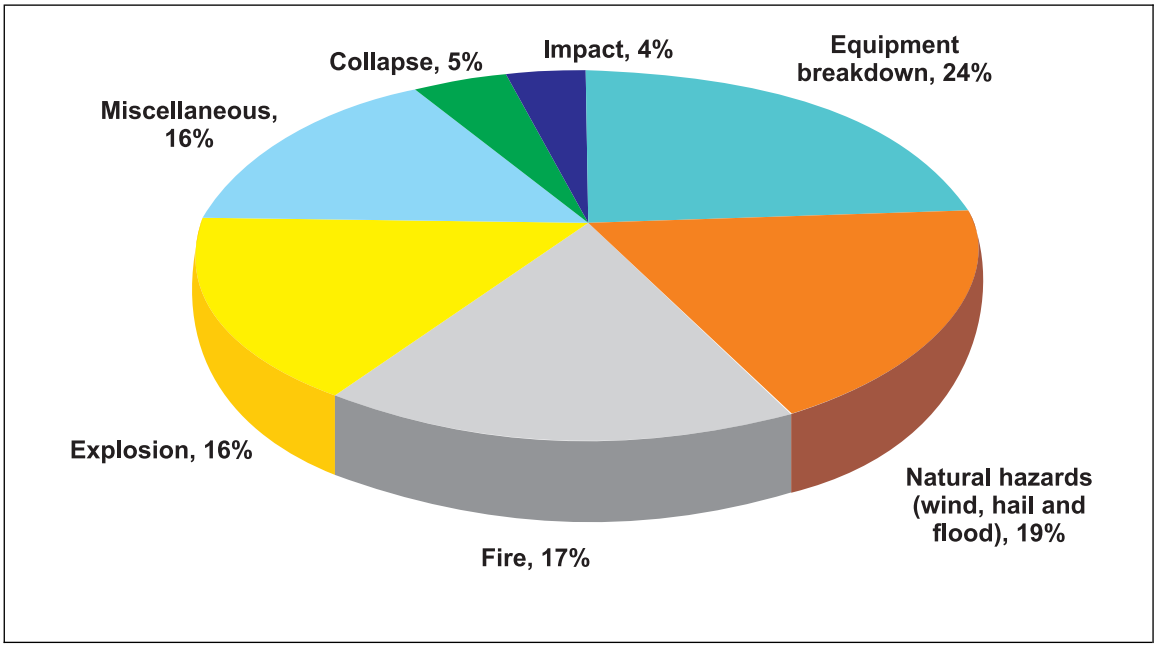


*Fig. 3. Ethanol plan losses by frequency, 2004-2018*

### 3.2 Occupancy Overview

Fuel-grade ethanol is typically made by the fermentation of sugar/starch-containing materials such as corn and sugar cane. The source material varies by region of the world.

From grain, either a dry-mill or wet-mill process is used. The dry mill process grinds the whole grain kernel for fermentation. There are very few co-products produced. Wet-mill processes separate the grain kernel into its constituent parts and frequently make a much wider variety of products, such as starch and dextrin. Wet-mill processes are more complicated are not covered in detail here. Figure 4 is a schematic of a dry-mill process.

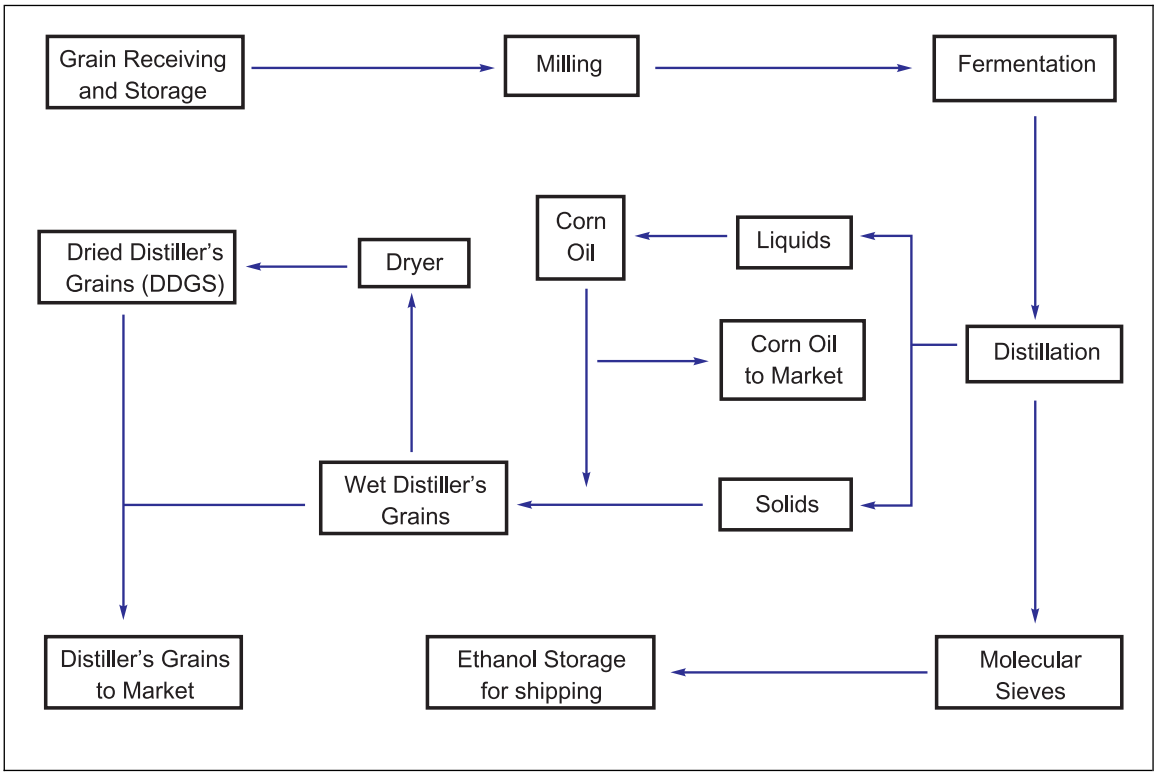


*Fig. 4. Typical dry-mill ethanol process*

Ethanol is also produced from sugar cane or as a co-product from sugar mills. From fermentation on, the process is similar to that shown in Figure 4. Sugar cane-derived ethanol includes additional hazards such as bagasse boilers. Bagasse boilers are covered in Data Sheet 6-13, *Waste Fuel-Fired Boilers*.

#### 3.2.1 Chemical/Material Hazards

##### 3.2.1.1 Liquid in Ethanol Production

Ethanol flow rates can be anywhere from 200 gpm to 800 gpm (760 to 3000 L/min) in a typical 100 million gallon (380 million L) per year ethanol plant. Liquid hold-up in process areas is usually 1000 to 2000 gal (3800 to 7600 L) in varying concentrations from 20% to 100% ethanol. Pressures within ethanol-handling equipment are typically anywhere from a general vacuum to 60 psi (4.1 bar).

Ethanol concentration in fermentation starts at 10%-13% and gets higher as it moves through the process. Only ethanol concentrations greater than 20% support combustion. Fire protection is typically provided from the point at which the concentration exceeds 20%.

##### 3.2.1.2 Dust

Grain dust and dried distillers grains with solubles (DDGS) dust are combustible dusts. DDGS can form combustible deposits inside ductwork.

#### 3.2.1.3 Dryers and RTOs

Frequent fires and explosions have occurred in DDGS dryers and thermal oxidizers [including regenerative thermal oxidizers (RTOs)]. There are multiple process streams directed to the dryers and RTOs, and process upsets can change the ethanol concentration in these streams.

The most common cause of explosions has been the introduction of ethanol vapor into TO/RTO equipment during upset conditions of which the ethanol stream was not isolated and diverted to a safe location.

Explosions can also result from overdrying of DDGS, inadequate purging of fuel gas that results in a fuel-air explosion upon startup, and particulates that have been carried past the dryer and settled out in the ductwork.

Dryers operating at rated capacities may need an increased frequency of cleaning to remove internal deposits than can lead to fires. Causes of deposit buildup include incomplete fermentation (which increases the corn sugar and starch load to the dryers) and numerous startup/shutdown cycles. The use of dry ice pellets has been effective in removing deposits.

## 4.0 REFERENCES

### 4.1 FM

Data Sheet 1-44, *Damage Limiting Construction*
Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 6-11, *Thermal and Regenerative Catalytic Oxidizers*
Data Sheet 6-17, *Rotary Kilns and Dryers*
Data Sheet 7-4, *Paper Machines and Dryers*
Data Sheet 7-14, *Fire Protection for Chemical Plants*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-88, *External Ignitable Liquid Storage Tanks*
Data Sheet 7-99, *Heat Transfer Fluid Systems*
Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*
Data Sheet 9-0, *Asset Integrity*

### 4.2 Other

Ebert, Jessica. “Costly Chemicals.” *Ethanol Producers Magazine* (2008).

## APPENDIX A GLOSSARY OF TERMS

See also Data Sheet 7-111.

**Ethanol fuel:** Finished product, 200-proof ethanol denatured by an additive present in small concentration, primarily intended for use as a fuel for transportation.

## APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

**January 2023.** Interim revision. Minor editorial changes were made.

**January 2022.** Interim revision. Minor editorial changes were made.

**October 2020.** Interim revision. Minor editorial changes were made.

**July 2019.** This is the first publication of this document. This document replaces Data Sheet 7-38, *Loss Prevention in Ethanol Fuel Facilities*.