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Standard Practice for Design of Fuel-Alcohol Manufacturing Facilities[1]

This standard is issued under the fixed designation E 1117; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice shall apply to all fuel alcohol manufacturing facilities (FAMF) as defined in Terminology E 1705. This specification is primarily intended for, but not exclusively limited to fermentation ethanol processes.

1.2 This practice applies to both batch and continuous FAMF systems. Since a wide variety of equipment configurations can exist, this engineering practice will describe the necessary general requirements common to all FAMF facilities.

1.3 This practice is to be used in conjunction with applicable local, state, and Federal codes for designing, constructing, and operating FAMF facilities.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For hazard statement, see Section 11.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 1705 Terminology Relating to Biotechnology

2.2 *ANSI Standard:*

Z21.22 Relief Valves and Automatic Shut-Off Devices for Hot Water Supply Systems[3]

2.3 *ASME Standard:*

Boiler Construction Codes, Sections I, IV, VII, and VIII[4]

2.4 *Code of Federal Regulations Standard:*

Bureau of Alcohol, Tax, and Firearms (BATF), Part 19, Title 27, Chapter 1[5]

2.5 *NFPA Standard:*

85A Prevention of Furnace Explosions in Fuel Oil and Natural Gas-Fired Single Burner Boiler-Furnaces[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accessible*, *n*—permitting close approach or contact that could include requiring removal or opening of an access panel or door.

3.1.2 *durability*, *n*—the quality of a component to perform as designed for its design life.

3.1.3 *extreme weather conditions*, *n*—environmental conditions that have occurred only once during the past 30 years.

3.1.4 *good engineering practices*, *n*—include design practices and criteria accepted in professional societies (ASTM, AIChE, ASME, ACS, etc.), proved by experience, verified by actual data, etc., that will meet the process, safety, and environmental requirements of the system.

3.1.5 *normal operating conditions*, *n*—the usual range of physical operating conditions (flow, pressure, temperature, etc.) for component or system.

3.1.6 *normal weather conditions*, *n*—the range of environmental conditions in a local climatic region that occurred during the past 30 years. This excludes extreme conditions that have occurred only once during that period.

4. Summary of Practice

4.1 The following procedures described provide minimum practices to be used in designing, constructing, operating, and modifying fuel alcohol manufacturing facilities. These practices are to provide guidelines that incorporate good engineering practices for personnel and organizations engaged in these FAMF activities.

4.2 These minimum practices are summarized in the following general categories of equipment as applicable:

4.2.1 *Vessels and Towers*—Cookers, fermenters, distillation stills, tanks, etc. (see Section 6).

[1] This practice is under the jurisdiction of ASTM Committee E48 on Biotechnology and is the direct responsibility of Subcommittee E48.05 on Biomass Conversion Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[5] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[6] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

4.2.2 *Heat-Exchange Equipment*—Exchangers, condensers, etc. (see Section 7).

4.2.3 *Rotating Equipment*—Pumps, blowers, compressors, fans, centrifuges, etc. (see Section 8).

4.2.4 *Electrical*—Motors, motor controls, etc. (see Section 9).

4.2.5 *Instruments, Controls*—Sensing and controlling devices, computers, processors, etc. (see Section 10).

4.2.6 *Safety*—Pressure relief devices, equipment allowances for corrosion, pressure and temperature, personnel safety, etc. (see Section 11).

4.2.7 *Environmental*—Solids, water, and air emissions (see Section 12).

4.2.8 *Utilities*—Boilers, power distribution, fresh water, air, etc. (see Section 13).

4.2.9 *Piping*—Pipe, valves, insulation, etc. (see Section 14).

4.2.10 *Quality Control*—FAMF equipment performance, production quality assurance, etc. (see Section 16).

4.2.11 *Other Guidelines*—Special equipment, stillage dryers, molecular-sieve dryers, etc. (see Section 15).

NOTE 1—Practices and guidelines for the design of FAMF systems are described in Sections 6-16. Some categories, such as safety and environmental, contain practices that are common to specific equipment categories and are not repeated in the safety or environmental categories.

5. Significance and Use

5.1 These practices and guidelines are intended to be used by engineers, designers, constructors, and operators who may have responsibilities for design, fabrication, modification, and equipment improvement for mass-produced FAMF systems.

5.2 This practice provides minimum guidelines to be used in protecting public safety and enhancing equipment reliability for the intended life of the facility.

5.3 The objective of these practices and guidelines are to identify the overall design, manufacturing, and modification considerations for the FAMF systems. This practice is not intended to list all the practices to be used with every type of process since there are many different types of designs and equipment. The application of the following guidelines are the responsibility of the appropriate designer, manufacturer, etc.

6. Vessels and Towers Design

6.1 The design pressure and temperature for all vessels and towers shall be established for the maximum conditions that can be expected in the system under such abnormal operating conditions, as improperly closed valves, control valve failures, fire, and cooling water failure. Safety valves shall be provided to relieve overpressure (see Section 11). After construction, the vessels shall be tested where possible to withstand the design conditions prior to routine operation.

6.2 All appropriate components of a distillation column, such as glass viewing windows and sight glasses, shall be designed to withstand the distillation column design pressure and temperature.

6.3 Fermentation, cooking, yeast, and other storage vessels used in the biologically active system shall be designed for efficient sterilization and cleaning to reduce process contamination problems.

6.4 All pressure vessels shall be designed and fabricated in accordance with ASME Sections I, IV, VII, or VIII of the ASME Boiler Construction Code[4] as appropriate.

6.5 The vessel design shall include adequate vapor disengaging surface to accommodate foaming, liquid level variations, changes in feedstock, and other operating considerations as specified in the FAMF design basis.

7. Heat Exchangers

7.1 Good engineering practices shall be used to design all heat exchangers with adequate heat transfer surface based on the anticipated temperatures and heat transfer coefficients based on realistic fouling factors.

7.2 All heat exchangers for slurry streams (such as mash) shall be designed to reduce plugging problems caused by solids settling out of the slurry. Avoid low slurry velocities where solids will separate from the slurry, constrictions that can trap solids, process conditions that can“ centrifuge” solids from the slurry and cause plugging, and other potential slurry handling problems.

7.3 Mechanical design of the heat exchangers should comply with applicable ASME and local, state, or Federal codes.

8. Rotating Equipment

8.1 All pumps, blowers, compressors, fans, centrifuges, etc. shall have appropriate shaft sealing devices to avoid or minimize leakage of process fluids.

8.2 Special design considerations to avoid pump plugging problems and process upsets shall be included in pumping slurries or process streams that could contain solids under upset conditions causing water pollution.

8.3 Personnel protection shall be provided around exposed drive shafts, pulleys, drive belts, gears, etc., by properly designed belt guards and other protective devices.

8.4 Positive displacement pumps shall have suitable pressure relief vents installed in the pipeline immediately after the pump.

9. Electrical

9.1 The selection of motors and motor controls, conduits, enclosures, etc. shall conform to hazard classifications as specified by insurance companies, local, state, or National Electrical Codes as appropriate. Explosion-proof electrical Class J, Group C or D shall be considered in the design of FAMF equipment where the explosive hazard of alcohol vapors exists or where required by local code. See Section 11 for additional details.

10. Instruments and Controls

10.1 Sensing and detection instruments (temperature, pressure, flows, etc.) shall be located at the effective position for accurate measurements. Follow the manufacturer’s recommendations for proper installations.

10.2 Controls, sensors, valves, dampers, and other instruments shall be identified clearly. Use labels, tags, signs, or other devices to identify these and emergency shutdown devices.

10.3 Alarms and automatic shutdown facilities shall be provided on critical process controls such as boilers (high-pressure, low-water, fuel ignition failure), distiller dried grains with solubles dryer (high temperatures), etc. A thorough instrument study and design documentation shall be made for the FAMF system to identify the proper controls, failure action of each control loop, application of alarms, and automatic shut-down devices.

10.4 Where automatic control devices are used, a backup manual control system shall be provided, such as a manual bypass around the control valve. In small FAMF systems the entire section can often be shut down if an automatic control device fails. However, the safety devices on the system must avoid equipment over-pressure and other unsafe conditions.

10.5 Controls shall be placed at locations convenient to the operator and centralized if possible.

11. Hazards

11.1 Each item of equipment in the FAMF system shall have a specified design pressure and temperature based on the maximum abnormal process conditions expected. Safety devices, such as pressure-relief valves, shutdown controls, etc., can be used to limit the magnitude of the abnormal process condition. Relief valves shall comply to the requirements of ANSI Z21.22.

11.2 Appropriate materials of construction shall be used based on the process conditions of pressure, temperature, corrosivity of the fluids, and other engineering considerations. Avoid joining dissimilar metals in contact with process chemicals since accelerated corrosion may result.

11.3 Anticipated equipment modifications should be thoroughly reviewed to meet the above criteria. If possible the original plant designer shall be consulted prior to making the change. For example, a pump modification may require subsequent adjustments or modifications to existing controls or pressure-relief valves.

11.4 All equipment shall be installed in accordance with the manufacturer's instructions. Actual equipment to be purchased should be reviewed for appropriate operation in the system since oversize equipment may require revisions to control valve sizes, relief valve settings, etc.

11.5 Bulk storage of flammable materials is to conform to local standards. Where possible, underground storage should be avoided if the environmental design of the FAMF system is improved.

11.6 The FAMF system shall include written operating, maintenance, and emergency procedures to the owner/operators before plant operation begins. Training shall be available to the owner/operators to include background theory, operating techniques, startup/shutdown, quality control, and emergency procedures for all phases of the operation. This training should include process operations and utilities systems (boilers, power, water, gas, etc.). Startup assistance shall be a service available to the owner/operator. The preceding items can be provided by the system vendor, designer, constructor, or other resources as appropriate.

11.7 The design of FAMF facilities shall conform to current OSHA, NIOSH, and other local, state, and Federal regulations, including personnel protection.

11.8 All electrical equipment, controls, and devices shall be designed to meet local codes. NEMA standards should be used where applicable.

11.9 Personnel safety facilities, such as eye-wash or full deluge showers shall be provided near hazardous chemical (acids, caustics, etc.) work areas.

11.10 Suitable warning labels shall be permanently mounted where hazardous or corrosive materials are used in the system. Instructions for emergency treatment shall be displayed prominently.

12. Environmental

12.1 All discharges from the FAMF facilities shall conform to local, state, and Federal regulations and codes. Careful consideration should be given to discharge streams from distillation columns which can be significant pollution sources.

12.2 Applicable permits for construction and operation shall be obtained by the appropriate party with technical data being supplied by the designer/engineer for the FAMF design. Plant design and facilities may have to be modified to meet applicable standards.

12.3 Ventilation within FAMF buildings shall conform to local, state, and Federal codes as well as applicable fire protection and insurance company requirements. Design shall include emergency air and routine evacuation provisions for carbon dioxide or ethanol fumes buildup.

12.4 The FAMF systems shall be designed for proper operation in normal ranges of weather conditions for the site specific location. This means that a FAMF design may have to be modified to operate in cold or hot, humid or dry, rain or snow, inside or outside of buildings, and other variations of operating conditions. Designer and owner should have specific understandings of the design conditions under which the plant will operate so that appropriate plant facilities can be provided.

13. Utilities

13.1 Steam generators and boilers shall be designed or specified in accordance with local, state, Federal, and NFPA 85a codes. Applicable alarms and emergency facilities shall be included in the design for partially attended boiler operations.

13.2 Appropriate boiler feed water treatment capability shall be available to assure design performance of the boiler over its expected life.

13.3 Fuel (gas, fuel oil, coal, biomass, etc.) shall meet applicable boiler manufacturer specifications and resulting emissions will meet local, state, and Federal requirements.

13.4 All electrical, fuel gas, steam, water, and other utilities supply lines shall have easily identified shut-off devices that are accessible during an emergency.

13.5 Fresh, potable water supply sources shall be isolated from process water systems with approved back flow preventers. Local state codes normally specify these requirements.

13.6 Cross connections between different utilities such as fuel gas, water, inert gas, etc. shall be avoided. If interconnections at a manifold are necessary, then isolation systems (double block valves and bleeder, back flow preventors, etc.) shall be installed to prevent undesired mixing.

14. Piping and Insulation

14.1 Vent lines shall discharge to the atmosphere and flammable vapor vents shall have flame arrestors or other devices to prevent explosions. Flammable vapor vents shall be grounded and discharged at least 50 ft (15.3 m) away from ignition sources or as prescribed by local, state, fire insurance, or other requirements.

14.2 Design pressure and temperatures shall be established for all piping and valves based on the maximum conditions that can be expected in the system under abnormal operating conditions resulting from improperly closed valves, equipment failures, fire, etc. After construction, the piping and equipment associated with the system shall be tested where possible to meet these design conditions.

14.3 Fire safe piping, valve, and gasket materials shall be used for all flammable fluid. Insulation materials for piping and other equipment shall be fire-resistant as specified by local, state, Federal, or other applicable standards.

14.4 Equipment shall be insulated for personnel protection if the equipment design temperature can exceed 54.4°C (130°F) and can be contacted by an employee during normal working situations.

14.5 Marking and color coding of pipes is suggested.

15. Other Considerations

15.1 Maintenance guidelines and procedures shall be provided to the owner/operator for the FAMF system equipment.

15.2 If novel or special equipment is used in the process, the vendor shall provide guidance to the owner/operator for obtaining special repair or replacement parts.

15.3 After the owner/operator has formally accepted the full responsibility for the plant, it is recommended that future revisions of the process be reviewed for applicability with the original designer. It is also recommended that these revisions, modifications, and changes be evaluated with the same care and consideration as identified in this ASTM standard engineering practice.

15.4 It is recognized that many other specific guidelines and engineering practices can be included in any specific FAMF design. Accordingly, good engineering practices are encouraged at all times to achieve high standards of public safety and plant performance.

16. Quality Control

16.1 All laboratory test and analytical procedures shall be specified for the specific FAMF design to monitor, control, and adjust the process to achieve expected process performance.

16.2 Appropriate sample points, product run down tanks, and other quality control provisions shall be included in the system design.

16.3 Storage and sampling facilities shall be designed to provide ethanol security required by BATF, Part 19 or other appropriate agencies.

17. Keywords

17.1 alcohol; ethanol; FAMF; fuel-alcohol; plant design