Educational Needs for Agri-Industrial Facility Designers and Managers

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Abstract. This paper summarizes educational needs for agri-industrial facility designers and managers. Relevant skills required for the design, planning, and operation of agri-industrial facilities are discussed. Continuing and University educational needs for facility designers and managers are also presented.

Introduction

Agri-industry encompasses post-harvest handling, storage, processing and distribution operations for agricultural, food, and fiber products. Representative industries include: animal slaughter and processing, seafood product preparation and processing, grain and oilseed milling, sugar and confectionary product manufacturing, dairy product manufacturing, fruits and vegetable preservation and specialty manufacturing, bakery and tortilla manufacturing, animal food manufacturing, beverage manufacturing, and other food manufacturing. Additionally, other non-food biological and industrial sectors, such as forest products, pulp and paper, and fiber processing industries are members of the agri-industrial community. Finally, the distribution system, which consists of farm product wholesaler-distributors and warehouses such as food and beverage wholesalers, and wholesalers-distributors of other agricultural based commodities, are also part of this community. Currently, agri-industrial production and associated support accounts for about 13 percent of the United States’ Gross Domestic Product (GDP) (Williams et al, 2004).

Companies such as ADM, Cargill, Coca Cola, Del Monte, General Mills, Georgia Pacific, Hormel, Tyson and thousands of other companies comprise agri-industry. The agri-industrial market segment has a large number of specialized regulatory programs, as well as design and operational requirements and challenges that do not exist in any other industry segment. For example, in addition to the OSHA safety and operational requirements that general manufacturing must meet, agri-industrial firms must also meet sanitary, handling, security, and processing regulations as prescribed by the USDA, FDA, and other trade and governmental bodies and representatives.

People who work in agri-industry must possess a wide-ranging and unique set of skills. Agri-industrial facilities typically have specific planning, processing, safety, and structural requirements that are not easily transposed with other industries. The common denominator for a majority of agri-industrial firms is sanitary and health requirements, which are required to preserve the quality and safety of the US food production system.

Engineers who work in the agri-industrial market segment can be classified into two major categories of employment: (1) those that design facilities, and (2) those that manage and operate facilities. Facility designers typically work for in-house engineering departments, design-build contractors that provide design and construction services for agri-industrial firms, and engineering consulting firms. Facility operators and managers work at individual plants and are responsible for production, maintenance, operation, quality control and process upgrades and improvements at these facilities. Engineering job descriptions for different agri-industrial design, operation and management positions have been compiled by Bohnhoff et al (2004) and are not discussed in this paper.

The purpose of this paper is to summarize the unique combination of educational requirements for agri-industrial engineers. To this end, this paper will examine specific design codes and practices that are essential to agri-industrial facility designers and managers, and will discuss related opportunities for continuing education and university teaching programs.

Engineering Skill Sets

A focus group comprised of 16 engineers and managers from various agri-industrial firms met on December 17, 2003, in Madison, Wisconsin. This brainstorming session discerned a variety of skills desired by practicing engineers in the design, operation, and management of agri-industrial facilities. These skills sets are summarized in the following sections. Note that the
authors have expanded upon the focus group discussions by including some of the more common standards and sub skills required for successful practice in each area. Although not specifically mentioned, most of these skill sets require a science or engineering education that includes such courses as fluid mechanics, dynamics, statics, strength of materials, heat transfer, thermodynamics, physics, and calculus.

**Geotechnical Engineering**

Knowledge in this area should include soil mechanics, foundation engineering, slope stability, seepage, dewatering, and environmental site surveys. Of the dozens of soil testing standards that geotechnical engineer’s use, some of the most frequently referenced include:

- D2487-00 *Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)* (ASTM, 2000a)
- ASTM D2166-00 *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil* (ASTM, 2000b)

Additionally, there are a limited number of standards of practice related to geotechnical foundation engineering. Among these are ASCE 20-1997 *Standard Guidelines for the Design and Installation of Pile Foundations* (ASCE, 1997). Other design guidelines are available from other sources, including the Army Corps of Engineers:

- Army Corps of Engineers - Engineer Manual 1110-1-1804 Engineering and Design – *Geotechnical Investigations* (USACE, 2001)

**Site Engineering**

This skill set entails the overall planning of storm water, hydrology, water supply, building layout, and road construction related to the development of agri-industrial process facilities. Engineers with this skill set should have a background in surveying, highways, pavements, erosion control, and hydrology. They should also have an extensive background in regulations, laws, and engineering standards related to site development, including but not limited to:

- ASCE 60 *Gravity Sanitary Sewer Design and Construction* (ASCE, 1982)
- ASCE 13-93 *Installation of Urban Subsurface Drainage* (ASCE, 1993)

**Structural Design Engineering**

This skill set requires an extensive background in concrete, steel, masonry, timber, bulk storage, and foundation system design. Agri-industrial facilities have a number of unique foundation and structural requirements that are much more complex than traditional commercial and industrial structures. Often bulk storage of commodities requires heavy foundations supported on piles or piers. Engineers practicing in this area must have a working knowledge of the design requirements for the major materials of construction, including:
Because bulk storage is often a critical aspect of agri-industrial facilities, a working knowledge of bulk storage design codes should include the basics, which consist of:

- API 650 Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure, Storage Tanks (API, 1998)
- API 620 Welded Steel Tanks for Oil Storage (API, 2002)
- AWWA100-96 Standard for Steel Tanks, Standpipes, Reservoirs and Elevated Tanks, for Water Storage (AWWA, 1996)

**Structural Loads Calculation**

Structural loads required for the design and analysis of agri-industrial facilities are beyond those required for ordinary building design. Key to this is utilization of non-building load provisions. The *International Building Code* (ICC 2003a) and *ASCE 7 Minimum Design Loads for Buildings and Other Structures* (ASCE 2002) have separate provisions for wind and seismic loads for non-building structures. Note that a variety of agricultural commodities are stored in special structures, and each different commodity has unique loading characteristics. Additionally, animals, as well as material handling and processing equipment induce dynamic loads on support structures and buildings that require specialized skills to analyze. The loadings caused by bulk materials are highly unique, and are not well understood by the general structural engineering community, yet these skills are critical for the design and analysis of agri-industrial facilities. Other loads that are important for agri-industrial facility designers and managers include loads due to bulk storage of granular, powder, and liquid materials, as covered in documents such as:

- API 650 Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure, Storage Tanks (API, 1998)
- API 620 Welded Steel Tanks for Oil Storage (API, 2002)
- ANSI/ASAE EP545 Loads Exerted by Free-Flowing Grain on Shallow Storage Structures (ASAE, 2000)
- ANSI/ASAE EP433 Loads Exerted by Free-Flowing Grain on Bins (ASAE, 2001)

**Materials of Construction**

Knowledge of appropriate materials of construction is necessary for both the design and construction of agri-industrial facilities. This includes both structural and non-structural materials, such as asphalt, concrete, steel, masonry, specialty metals, coatings, and finishes. An engineer using these concepts should be familiar with the performance, stress-strain
behavior, and physical properties, of the materials of construction. Several specific standards organizations that develop standards related to construction materials include:

- **International Code Council (ICC).** Evaluation of construction materials and components. Online at www.intlcode.org
- **United States Department of Agriculture (USDA).** Requirements for food grade construction. Online at www.usda.gov
- **Construction Specification Institute (CSI).** Standards and procedures for the specification of construction products and materials. Online at www.csinet.org
- **National Association for Corrosion Engineers (NACE).** Material standards aimed at reducing effects of corrosion from a variety of sources. Online at www.nace.org
- **American Concrete Institute (ACI).** Standards for design and construction of concrete and masonry structures. Online at www.aci-int.org
- **Food and Drug Administration (FDA).** Standards related to food and drug grade facility construction. Online at www.fda.gov
- **SSPC – the society for protective coatings (formerly known as the Steel Structures Painting Council).** Standards covering protection of industrial steel structures. Online at www.sspc.org
- **American Institute of Steel Construction (AISC).** Fabrication, erection, painting and construction standards for steel construction. Online at www.aisc.org

**Building Life Safety and Fire Codes**

Agri-industrial facility design is highly dependent on the specific processing operation(s) that will be conducted in that facility. Because of this, traditional commercial and light industrial designers, such as architects, may not execute designs that support the processing operation(s). This is particularly true in areas relating to life safety and fire control.

The *International Building Code* (ICC, 2003a) contain a large number of applicable building/facility safety requirements, among these provisions include:

- **Use/occupancy classification.** Occupancy classification is a function of how the facility will be used. This will trigger specific requirements for the type of construction and building geometry.
- **Type of construction.** Type of construction is dictated by the fire resistive ratings of materials used to frame the building, as well as the materials used to finish interior and exterior surfaces.
- **Fire protection systems.** For certain occupancies fire protection systems may be required due to a hazardous process.
- **Building heights and areas.** The maximum height and maximum allowable area per floor are a function of the occupancy classification, type of construction, fire protection system, and degree of access to the building for fire fighting purposes.
- **Special detailed requirements based on use and occupancy.** Processing facilities have specific explosion and processing requirements that must be considered in design.
• Means of egress. Exiting has a major influence on the facility layout and design
• Accessibility. Applicable handicap access standards must be incorporated into the facility design where required.

Additionally, there are a number of codes specifically related to the detailed occupancy design requirements of agri-industrial facilities, which are referenced in the *International Building Code*. Examples of these include:

• NFPA 68 *Guide for Venting of Deflagrations* (NFPA, 1998a)
• NFPA 69 *Standard on Explosion Prevention Systems* (NFPA, 1998b)
• NFPA 61 *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities* (NFPA, 1999a)
• NFPA 30 *Flammable and Combustible Liquids Code* (NFPA, 2003)
• NFPA 13 *Standard for the Installation of Sprinkler Systems* (NFPA, 2002a)

Building codes also reference numerous standards relating to mechanical, electrical, and processing systems. Some of these are listed in following sections.

**Building Systems and Construction Methods**

In the design, construction and operation of agri-industrial facilities, there is a need to develop an understanding of non-life safety and building codes construction and design issues, which can help in the execution of high-quality construction, as well as improve overall facility performance. These include:

• Building Space and Use Planning. Good planning provides a functional design that meets the facility requirements and is more than just meeting the building code.
• Building Systems. The non-structural aspects of the frame including stairs, partitions and similar nonstructural items.
• Insulation. This includes thermal, sound and moisture barriers.
• Cladding and Enclosures.
• Doors and Windows.
• Coatings and Finishes. This includes paints, sealants, and other moisture resistant finishes that are key to decay/corrosion resistance and sanitation.

These areas of knowledge are dealt with, in part, by the *International Building Code* (ICC, 2003a).

**Sanitary Facility Design**

One of the most important aspects of the design, construction and operation of an agri-industrial processing facility is sanitation. This area of practice is strongly influenced by Titles 9 and 21 of the Code of Federal Regulations (NARA, 2004). Specific areas of focus for sanitation include:

• Plant Layout. This relates to the flow of the work and the grounds of the facility as it influences sanitation.
• Building Design Elements (roofs, floors, etc.). This area relates to the proper construction and detailing of building elements for sanitation.
• Equipment. Proper design and support of equipment has a significant effect on the overall sanitation and operation of an agri-industrial facility

• Paints, Coatings, and Finishes. The types and use of coatings and finishes influence how easy to plant is to clean and maintain

• Electrical and Mechanical Systems. Mechanical and electrical construction techniques can have a major effect on plant sanitation and safety

• Maintenance/Cleaning. Proper maintenance and cleaning programs have a significant effect on plant sanitation

• Pest Control. Elimination and control of insects and animals is critical for the sanitary operation of an agri-industrial facility.

• Foreign Matter Control. Eliminating points of product contamination is critical for the operation of most agri-industrial facilities

In general, sanitation begins by preventing/eliminating infestation, contamination, and unsanitary operational conditions. This area of knowledge is strongly influenced by the next engineering skill set area -- Plant Operation Regulations.

**Plant Operation Regulations**

Agri-industries operate under unique regulations. Three organizations are responsible for most of these regulations; they are the United States Department of Agriculture (USDA), the Food and Drug Administration (FDA), and the Occupational, Safety and Health Administration (OSHA). The following codes and laws influence day-to-day operations of agri-industrial facilities.


• The Umbrella Good Manufacturing Practice. This is a broad guidelines published by the FDA relating to the operation of food manufacturing facility.

• Occupational Safety and Health Administration (OSHA) Regulations. These standards relate to the safe operation of industrial facilities and appear under title 29 of the Code of Federal Regulations (NARA, 2004).

• Hazard Analysis and Critical Control Points (HACCP) Program. This is a program used to establish a sanitation program. It involves a detailed analysis of the process flow and identifies critical points for sampling and monitoring for sanitation.

• Sanitation Standard Operating Procedures (SSOPs). SSOPs are plans that are specific for the processing plant, species processed, processing methods, and sanitation procedures used.

• FSIS USDA Food Safety and Inspection Service. The Food Safety and Inspection Service (FSIS) is the public health agency in the U.S. Department of Agriculture responsible for ensuring that the nation's commercial supply of meat, poultry, and egg products is safe, wholesome, and correctly labeled and packaged.
• State and Local Laws. Each State or jurisdiction can amend or alter the model federal code as long as they do not make the federal code less restrictive. For this reason, it is always prudent to check local laws.

**Building Mechanical Systems**

This skill set involves the design of building mechanical and environmental systems, including piping and plumbing, as well as heating, ventilating, and air conditionings systems. Agri-industrial facilities also have many specialty systems, such as dust control, pumps, fans, water systems, boilers, hydraulic and pneumatic systems, and small-scale waste and water treatment plants. The mechanical engineering subset may also involve the development of energy efficient systems. Engineers working on mechanical systems must have broad knowledge of these areas. Representative standards include:

- **International Mechanical Code** (ICC, 2003b). This code establishes minimum regulations for mechanical systems using prescriptive and performance-related provisions, including boilers, refrigeration, and combustion systems.
- **International Plumbing Code** (ICC 2003c). This code provides comprehensive minimum regulations for plumbing facilities both in terms of performance as well as prescriptive objectives providing for the acceptance of new and innovative products, materials, and systems.
- **International Energy Efficiency Code** (ICC 2003d). This code encourages energy conservation through efficiency in envelope design, mechanical systems, lighting systems, and the use of new materials and techniques.

Other codes and standards essential to mechanical engineers include:

- ASME B31.3 *Process Piping* (ASME, 2002)
- ASME B31.5 *Refrigeration Piping and Heat Transfer Components* (ASME, 2001a)
- ASME B31.9 *Building Services Piping* (ASME, 1996)
- ASME B73.1 *Specification for Horizontal and Suction Centrifugal Pumps for Chemical Process* (ASME, 2001b)

**Building Electrical Systems**

This skill set involves the design and analysis of facility electrical systems. This encompasses a basic knowledge of NFPA 70 *The National Electrical Code* (NFPA, 2002b), and the ability to design power systems and controls, lighting systems, special equipment and motors. Power systems include items such as substations, feeder bus systems, panel boards, motor control circuits, and electrical conductors. Additionally, programmable logic control design is an area of vital importance for agri-industrial facility designers, because of their widespread use.

In addition to NFPA 70, another essential design code is the *ICC Electrical Code* (ICC, 2003e). This document contains administrative text necessary to administer and enforce the NFPA 70, and complies with electrical provisions contained in the other International Codes. Representative standards for building electrical systems include:

- NFPA 70 B *Recommended Practice for Electrical Equipment Maintenance* (NFPA, 2002c)
• NFPA 70 E Standard for Electrical Safety Requirements for Employee Workplace (NFPA, 2002d)
• NFPA 72 National Fire Alarm Code (NFPA, 1999b)
• NFPA 73 Electrical Inspection Code For Existing Dwellings (NFPA, 2000)
• NFPA 75 Standard for the Protection of Information Technology Equipment (NFPA, 1999c)
• NFPA 79 Electrical Standard for Industrial Machinery (NFPA, 1997)

**Process Engineering Systems**

One of the most critical aspects of agri-industrial facilities are the processing operations themselves because they are the heart of plant operations, and thus company profitability. Because of this, it is necessary for all agri-industrial facility designers, operators, and managers to have at least some basic knowledge of:

- Handling/conveying equipment
- Size reducing, sorting, mixing, extruding and other mechanical processing equipment
- Ovens, frying and other cooking equipment
- Drying/dehydration equipment
- Refrigeration and freezing equipment
- Cleaning systems
- Food packaging equipment

Proper process design incorporates many of the standards, references, and codes previously discussed (i.e., the mechanical, electrical, sanitation, and building life safety code sections, etc.). There are, however, very few codes that deal specifically with processing equipment.

**Construction and Project Management**

This skill set involves the broad areas of project conception, planning, initiation, execution, and closing. Major project themes can be further decomposed into productivity management, procurement, scheduling, cost estimation, and contract specifications and project cost control. Construction and project managers need these skills in order to effectively plan and/or operate facilities. Although not dictated by statute, people in this area of practice may find the following standards from the Project Management Institute to be beneficial for the practice of project management.

- The Project Management Institute Practice Standard for Work Breakdown Structures (PMI, 2001)
- The Project Manager Competency Development Framework (PMCDF) Standard (PMI, 2002)

**Business Operations and Planning**

Business skills are an essential component to the operation and management of agri-industrial facilities. Engineering has an enormous influence the overall profitability of these facilities, and those engineers involved in planning and operating need skills in accounting, planning, contract
law, logistics, risk management, and finance to assist in the design and operation of these complex facilities.

**Environmental**

The environmental skill set requires complete knowledge of environmental testing procedures and permitting processes, and awareness of environmental regulations governing items such as building services (e.g., facility water, gas, etc.), boilers, water supplies, effluents, air discharges, and other related items. These regulations include Environmental Protection Agency (EPA) rules, ASME codes (see Building Mechanical Systems section), as well as other federal, state and local laws and codes related to the environment. Engineers should be familiar with the *Code of Federal Regulations: Title 40 Protection of the Environment* (NARA, 2004) which establishes minimum standard for emissions, as well as any local emission codes which may be more stringent than the federal codes.

**Health and Safety**

This engineering skill set requires that the engineer be aware of relevant workplace legislation and regulations related to safety. Key components of this are knowledge of labor standards, such as the Occupational Safety and Health Administration (OSHA) regulations. These regulations are contained in Title 29 of the *Code of Federal Regulations* in volumes 5 to 9 (NARA, 2004). These regulations are a federal minimum, and States may enforce stricter regulations. Engineers have to be knowledgeable of the required administration and duties set forth by these regulations and statutes including the delineation of corporate policies and standards.

**Planning and Plant Layout**

This is a key area for plant designers, operators, and managers, and it entails specific knowledge of proper approaches for the layout and planning of an agri-industrial facility for optimal efficiency, productivity, and cost effectiveness. Plants are essentially assemblies of individual pieces of equipment, or subassemblies of processing operations, and they must be optimized to increase the efficiency of the facility’s operations. Key to this skill set is developing an understanding of the various processes, as well as the overall facility itself. The ability to optimize human and capital resources via computer, statistical, and practical methods and models is essential to this skill set. Bringing a plant to a level of optimal production is a primary goal with this skill set.

**Continuing Education Opportunities**

A scan of major university and professional society websites revealed a lack of continuing education programming dedicated to the agri-industrial design community. Needs in this area could, in fact, be filled by agricultural engineering programs, or by ASAE. The following areas would be worth considering for development into continuing education courses for practicing professionals:

- **Bulk Storage and Material Handling Design.** Currently in the United States there are no continuing education courses taught on bulk storage loads and the associated design requirements for vessels, tanks, bins, or silos that hold liquid, powder, or granular solids. The special design and load requirements for these storage structures are seldom covered in undergraduate engineering teaching curricula.
• *Facility Planning, Design, and Engineering for Food Safety.* This type of professional development course would focus on the design, construction, and operation of facilities to meet USDA and FDA food processing plant requirements. Subject matter covered could include sanitary equipment and plant construction methods, HCCAP programs, GMPs, SSOPs, and other related codes, standards and regulations.

• *Loads for Non-Building Structures.* Agri-industrial plants feature numerous non-building type structures. Determination of design loads for these structures is a subject that has not been well covered by the structural engineering community. A course in this area could highlight dynamic loading requirements (seismic and wind) as prescribed for non-building structures in ASCE 7 (ASCE, 2002) and other documents.

• *Building Codes and Life Safety for Agri-industrial Processing Facilities.* Much of the current focus of the professional development community has been on presenting these codes and regulations to engineers and architects involved in commercial facility design. This proposed training would focus on the unique aspects of agri-industrial process facilities.

• *Unit Operations and Processing Methods for Plant Managers and Engineers.* An overview of the major types of agri-industrial processing methods and their assembly into working systems would be of great benefit to the agri-industrial community. Furthermore, highly detailed sessions discussing the design and application of specific unit operations, such as material handling equipment, pumping and piping design, heat exchanger design, etc., would be of enormous benefit specifically to process development engineers.

• *Sanitation and Cleaning of Food Process Plants.* Currently very little is offered relating to sanitary design and operation of agri-industrial facilities. Bringing this type of continuing education to the agri-industrial community would be of great benefit to many practitioners.

• *Food Laws and Regulations.* A course that covers the requirements of Title 9 and Title 21 of the Code of Federal Regulations (NARA, 2004) would be beneficial to those that design and operate agri-industrial processing facilities.

• *Facility Planning and Layout.* Optimization from an operational standpoint would be the focus of this type of continuing educational offering. This course would be focused on plant operators and managers, but would also benefit plant designers.

ASAE is one of the few engineering societies with the diverse membership required to service the unique continuing educational needs of the agri-industrial community. The multi-disciplinary background of agricultural engineers amalgamates the expertise of food processing, machinery systems, structures and their environments, and the surrounding environment and ecosystem of a processing facility, which thus lends itself well to supporting agri-industrial needs and demands.

**Recommendations for University Programs**

Companies that manufacture and produce agricultural-based consumer products require engineers who are knowledgeable and experienced in all aspects of facility design and management. To help meet this need, universities need to adjust their curricula. Possible additions include such courses as:

• *Agri-Industrial Processes.* Most universities have courses in unit operations, but few have courses covering the development and operation of entire processing systems. This course would provide a comprehensive sampling of the most common agri-industrial processing systems. With a large design component, this course could serve as a capstone type course.
• **Structural Design and Facility Planning for Agri-industrial Facilities.** Few, if any agricultural engineering programs have a course on planning and structural design of agri-industrial process facilities. This course would focus on the life safety, fire, sanitary and structural codes issues controlling agri-industrial facility planning and design.

• **Mechanical and Electrical Systems.** This course would introduce students to the mechanical systems common to agri-industrial process facilities, including boilers, piping, electrical, and the other areas of plant design and operation.

• **Regulations for Agri-industrial Facility Design, Construction and Operation.** A course focusing on sanitary and regulatory issues related to agri-industrial facility design and construction.

**Summary**

A series of specific skill sets were outlined that are necessary for the proper planning, implementation, and operation of agri-industrial facilities. Recommendations for continuing education programs and university engineering curricula were also presented.

**References**


