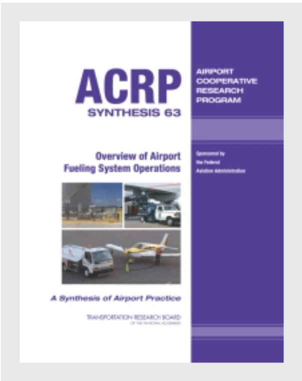

Overview of Airport Fueling Operations

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP SYNTHESIS 63

Overview of Airport Fueling System Operations

A Synthesis of Airport Practice

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

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Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

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This work was executed by cooperating organizations FAA and the National Academy of Sciences, acting through TRB, and was conducted through ACRP, which is administered by the Transportation Research Board of the National Academies. Appreciation is expressed to Kathleen O'Lenic for her research and editing assistance, and to the ACRP panel members for their guidance and assistance.

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

Airport operators are responsible for the good working conditions of all airport facilities. In many cases, staff knows little about the complexity of the aircraft fueling infrastructure and processes because they may be managed by others. Aviation fuel is flammable, jet fuel is a combustible liquid, and avgas is a volatile flammable liquid. Safeguarding the entire fuel system from contaminants, flash point sparking, and leaks is important, and built-in safety features such as fuel level and leak monitoring systems, automatic fire suppression systems, and vehicle collision protections are typical features included as integral parts of the airport fueling system.

In many aspects of fueling, the airport operator is identified as the primary responsible party. Airports receive and distribute fuel by various means. Many large airports are served by one or more dedicated pipelines, have underground hydrant fueling systems, and are a part of fuel consortiums with professional managers and trained staff operating their systems. Smaller airports may have less complex systems, but are still responsible.

Because aircraft fueling infrastructure is necessary for airport operations and requires specialized storage, handling, and dispensing, it is useful to airport operators to have a single document that describes common operations and serves as a reference for many fueling issues and practices.

Information used in this study was acquired primarily through the literature search and verified through select interviews with airport and fueling personnel.

Stephen M. Quilty, SMQ Airport Services, Lutz, Florida, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

ACRONYMS

AC	Advisory Circular
AIP	Airport Improvement Program
AST	Aboveground storage tanks
ATA	Air Transport Association
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
EI	Energy Institute
FEMA	Federal Emergency Management Administration
FBO	Fixed-base operator
FFS	Fitness for service
FSF	Flight Safety Foundation
FSII	Fuel system icing inhibitor
GA	General aviation
gpm	Gallons per minute
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
JIG	Joint Inspection Group
MSDS	Material Safety Data Sheet
NATA	National Air Transportation Association
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
psi	Pounds per square inch
SARA	Superfund Amendments and Reauthorization Act
SASO	Specialized Aviation Service Operations
SMS	Safety Management System
SPCC	Spill prevention, control, and countermeasure
SRA	Safety risk assessment
STI	Steel Tank Institute
UST	Underground storage tanks
UVCE	Unconfined vapor cloud explosion

OVERVIEW OF AIRPORT FUELING SYSTEM OPERATIONS

SUMMARY

Being knowledgeable about fueling operations and systems is an important factor in promoting safe fueling practices and mitigating negative outcomes. Preventing negative consequences from a fuel mishap is relevant to all sizes of airports. Of primary concern to an airport operator are the fuel processes, facilities, and equipment located within the property lines of the airport. Once fuel crosses onto airport property, its environmental safekeeping becomes the responsibility of the airport operator, no matter who is involved in the receipt, storage, or delivery of the fuel to aircraft. In many aspects of fueling, the airport operator is identified as the principal responsible party under environmental regulations because the operator owns the land upon which fueling occurs and controls the use of the land. The actual ownership of fuel facilities on airport property can vary. Airports contemplating taking over fueling operations or seeking to exercise greater safety oversight of existing operations can find the resources referenced in this report to be of value.

The purpose of this report is to promote understanding of airport fueling systems. Critical concepts for an airport manager in managing the risks associated with fueling systems include an understanding of the parties involved; the facilities, equipment, and main components; the regulatory and standard requirements; the available training resources; and the means to facilitate the safe operation of the airport fueling system. An additional purpose of this synthesis report is to inform readers of where to obtain information to become more knowledgeable about airport fueling systems. Fueling system operations and arrangements at all sizes of airports are addressed, with the focus on aviation turbine fuels (jet fuel) and aviation gasoline (avgas). Not discussed are fueling systems designed to serve airport vehicles, ground service equipment, or remote helicopter or off-site rural storage.

Described in the report are some of the safeguards for preventing contamination, flash point sparking, and leakage in the fuel system. Fuel storage tanks, distribution lines, hydrant systems, and refueler trucks are some of the specialized components that make up an airport's fuel delivery system. Each component is to be operated with utmost safety and environmental stewardship. It is the airport's responsibility to ensure the same, no matter who owns the fueling facilities or who is involved in the delivery and handling of the fuel. Of value to airport management is an understanding of how the fuel system works and what the risks are for each type of fuel activity.

Information for this synthesis was obtained primarily through a literature search and interviews with airport and fueling personnel. There is a large volume of literature related to airport fueling system design and operation. For safety and regulatory purposes, many aspects of a fuel system operation are standardized. New practices evolve slowly because of the vetting process that takes place through various national and international standards and committees. This synthesis provides a list of regulations, standards, suggested practices, guidelines, and training resources that can be referenced and used by airport organizations.

The overall fueling process includes a number of different organizational arrangements for obtaining, contracting for, and delivery of fuel, along with the means by which fuel is transported from the refinery to the airport and ultimately to the aircraft. Discussed are fuel consortiums, airport-operated fueling systems, fixed-base and special aviation service providers, and corporate and private installations. This report describes the different management arrangements for having fuel delivered to and on an airport, from the oil refinery to into-plane services. The information is intended to help airport managers better understand the processes involved.

Throughout the fuel delivery process, the goal of any fuel provider is to ensure that the correct grade, type, and quantity of fuel meet applicable requirements and specifications. A company's profitability and reduced liability exposure depend upon it, as does the safety of the pilot, crew, and passengers. This report provides an overview of the quality process and procedures but does not go into detail. Instead, reference is made to resources that provide more detailed information.

Industry standards provide a number of considerations involved in the design of a fuel system. Aboveground and underground tank designs are discussed, as are loading and unloading facilities, different means of fuel delivery to the aircraft (hydrant system, fuel truck, stationary pump), and several commonly installed components (filters, hoses, and nozzles). Also discussed are fire suppression and fire safety issues, environmental regulations, and fuel safety practices.

The primary risks associated with operating fuel facilities are fire, explosion, contamination, spillage, and environmental impact. The consequences of those risks affect many areas of the airport. Risk management is covered in chapter seven of this report.

The study found that airport fueling accidents and incidents are not well documented in a publicly available database. That makes it difficult to learn from the lessons of others. As reported by the Flight Safety Foundation (FSF), only refueling incidents that result in severe aircraft damage or personnel injury appear to be reported. Minor incidents often are not reported, despite anecdotal information that hundreds of incidents occur globally each day. An effort by the industry and the FAA to implement safety management systems (SMS) may help to correct the gap in practice. Information on several accidents is provided in the report, as are SMS tools for helping to mitigate accidents.

Individuals with responsibility for conducting airport inspections required by Part 139 may not have the in-depth knowledge of fueling operations that a specialized fueling agent, auditor, or industry expert may have. A finding of the study is that many of the standards, forms, and beneficial training courses are controlled by professional organizations or private entities that require fees or membership to receive the information.

As described by study participants, the element of trust is an important aspect of a fuel delivery process. The establishment of trust between the airport operator and those who manage the fuel on the airport is necessary because of the various levels of expertise and responsibility each has. Trust begins at the negotiating table, with the establishment of a lease or right to conduct fueling operations on the airport. The trust builds through documentation and the inspection of fueling activities, and culminates in safe outcomes and customer satisfaction. A responsibility of airport management is to ensure that fuel-handling agents on the airport are well trained and follow proper procedures for the protection of persons and property.

A number of most effective practices are cited in the report:

- Perform a condition assessment before acquiring property and facilities, such as fuel tanks, piping, and pumping equipment.
- Engage knowledgeable professional assistance in the negotiation, design, construction, and installation of fuel systems.
- Adopt a standard or recommended practice to follow.
- Have an operating manual that details the procedures and practices to be used on the airport by tenants and fueling agents.
- Have a diagram and list of components for any fueling system on the airport. Having the diagram promotes understanding of how the fuel flows through the system, the location of shutoff and routing valves, the types of pumps and filters, and the capacity of each tank and pipe system.
- Describe the settings of overflow protection devices and the operation of the alarm systems.
- Pass fuel through a filtration system each time it is moved.
- Use dedicated transport vehicles to reduce the possibility of contamination in the delivery of aviation fuel.
- Work with local representatives to ensure all environmental requirements are met.
- Develop airport contingency plans for the possibility of different system failures.

CHAPTER ONE

INTRODUCTION

Fueling operations at airports occur through the combined efforts of several entities working together to ensure the safe delivery of quality fuel. The basic framework for all on-airport fueling involves the airport as the landlord, with other entities as tenants that have obtained authorization from the airport owner to conduct fueling activities. As a landlord, the airport owner has legal oversight responsibilities for what takes place on the airport, good or bad. Legal responsibility stems from FAA regulations, environmental regulations, tort law, and other federal, state, or local requirements.

Being knowledgeable about fueling operations and systems is an important factor in promoting safe fueling practices and mitigating negative outcomes. Preventing negative consequences from a fuel mishap is relevant to all sizes of airports. Any number of fuel-related scenarios can affect an airport's operations and its liability exposure, including leakage of a fuel pipe, faulty tank or nozzle shutoffs, overfilling of tanks, a fixed-base operator (FBO) employee not following proper procedures, incorrect grade or contamination of fuel, vehicle breakdown, and inadequate fuel system inspection.

In many cases, airport staff may know little about the complexities of airport fueling infrastructure and processes, primarily because the processes are managed by others, such as with an FBO or a fuel consortium. In particular, general aviation (GA) airports can face economic decisions that could lead to the airport taking over fueling operations as a result of an FBO ceasing operations, or because of efforts by the local community to attract business, increase available services, or have the airport become more financially self-sufficient.

Outside of GA airports, operators of small- to large-hub airports have fuel consortiums operating on their airports. A consortium's purpose is to manage the costs and logistics of fuel delivery to the airline and cargo operators. Many airport managers are not versed in the dynamics of the consortia arrangements, but they have responsibility for what occurs on the airport as a result of being the landlord and having overall safety oversight of activities.

This synthesis will be of value to airport operators who provide oversight of fueling operations on airports, who may engage in any aspect of fueling operations, or who may be looking for a concise source of reference material related to airport fueling operations.

OBJECTIVES

The objectives of this synthesis are to provide an overview of airport fueling system operations at all sizes of airports; familiarize individuals with the standards and regulations; describe common operation and components; and serve as a reference for a number of fueling processes and procedures. On-airport fueling systems and components are the main focus of the information contained in the report. Not discussed are fueling systems designed to serve airport vehicles, ground service equipment, or fuel systems and totes used for remote helicopter operations. Practices in fuel quality testing are referenced but are not part of the study.

BACKGROUND

The FAA defines an airport fueling system as an arrangement of aviation fuel storage tanks, pumps, piping, and associated equipment, such as filters, water separators, hydrants and station, or aircraft fuel servicing vehicles, installed at an airport and designed to service aircraft at fixed positions

(AC 150/5320-4B). The design and use of an airport fuel system, whether new or existing, involves many considerations that can be grouped into three broad areas: (1) the fuel delivery processes, (2) equipment and facilities, and (3) operational consideration.

Fuel Delivery Processes

The overall fuel delivery process includes the organizational arrangements for obtaining, contracting and delivering fuel, along with the means by which fuel is transported from the refinery to the airport and ultimately to the aircraft.

Throughout the fuel delivery process, the goal of the provider is to ensure that the correct grade, type, and quantity of fuel meet applicable specifications. A company's profitability and liability exposure depend upon it, as does the safety of the pilot, crew, and passengers. Figure 1 illustrates the different stages and modes of fuel transport and delivery from the refinery to the aircraft.

As a fuel delivery crosses from an off-airport provider onto airport property, there are three general stages of fuel processing. The first is receiving. Whether delivered by pipeline, railcar, barge, or truck, the receiving stage involves the filtration, quality testing, and checking of volumes delivered (which are affected by temperature). The accounting of fuel quantity and the testing for fuel quality are an important part of the fuel delivery process.

The second stage is storage. The received fuel is transferred to the correct storage unit, and the unit is monitored to prevent overfill or other potentially hazardous situations. The delivery of fuel through each step exposes it to the potential for contamination, spillage, and error. During the second stage, fuel is allowed to sit for a time before dispensing to allow for settlement of any contaminants.

The third stage is the distribution of the fuel from the storage tanks to the aircraft, whether by underground hydrant, piping to a fuel island or stationary platform, or refueler truck. The rate that fuel is pumped depends on the size of pipe or hose through which it flows, the capability of the filtration system, the size and capability of the pumps, and the pump and line pressures.

Equipment and Facilities

Equipment and facilities involve the infrastructure needed to accomplish the fueling process. They include transport pipelines and vehicles, fuel storage tanks and trucks, filtration, pumps, and fuel dispensing equipment.

In the design and use of fuel systems, components are matched to the anticipated flow rates and pressures throughout the system, so as to not create pinch points or restricted capacity. Equipment and facility standards apply to components such as off-loading pumps, air eliminators, metering devices, prefilters, and filter separators. A component designed for an avgas system may not be suitable for use in a jet fuel system and vice versa.

Understanding how the fueling equipment and facilities operate requires knowledge of the proper valves to be positioned, filtration needed, testing required, tank storage capability, and safe operating procedures. A well-designed fueling system operation will allow for testing a fuel at the beginning, midpoint, and end of the receiving process, and at every filter, pump, and low point in the system. Low points are designed into a system to allow for drainage of fuel or for the sumping of water, sediment, and other contaminants that have settled in the system. There are two general low points designed into a system. One is for quality control sumping; the other is for drainage of an isolated section for maintenance purposes. When sumping, the most common types of contaminants are water, dirt, iron rust, scale, and sand. Other possible contaminants include metal particles, dust, lint from filter material and rags, gasket pieces, and sludge from microbacteria.

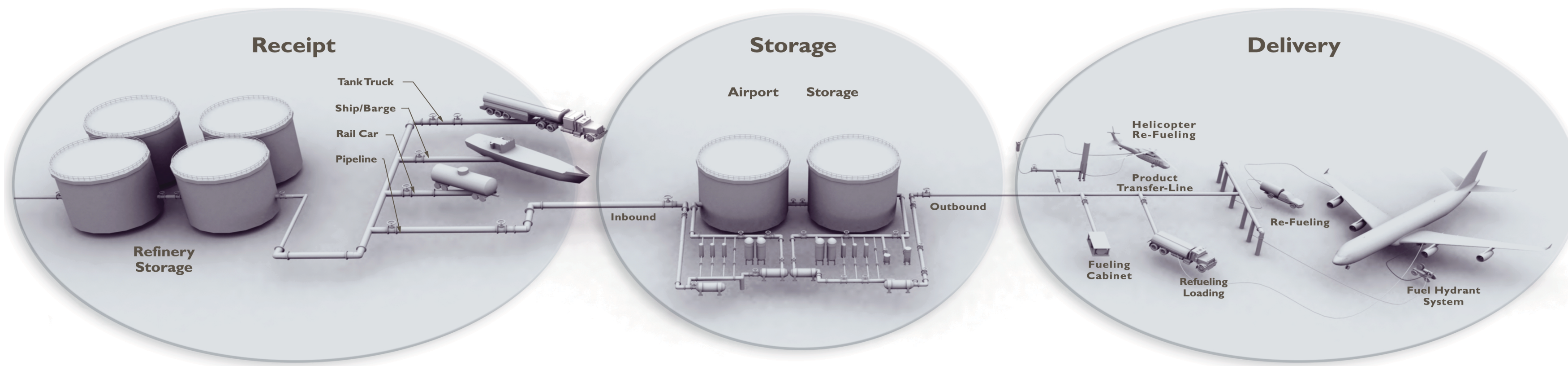

FIGURE 1 Fuel delivery system from refinery to aircraft. (*Source*: “Aviation Fueling: Technology Update.” *Courtesy*: Hatch Mott MacDonald.) Used with permission.

Operational Considerations

Operational considerations take into account the means and methods that fueling processes, equipment, and facilities use to ensure the fuel product makes it safely into the aircraft. Human interaction is one such consideration. Other factors include the location of fuel tanks in proximity to the airport, residential, or environmentally sensitive areas, and whether tanks are inside or outside airport-secured areas. How environmental regulations are addressed and how fire or other safety protections are accomplished are matters to be considered. Lastly, the delivery of fuel to the ramp and aircraft fueling areas requires the use of vehicles and trained personnel that can increase the amount of operational activity and risk exposure on a ramp.

Types of Fuel

The two types of fuel most commonly used at airports are aviation turbine fuel (jet fuel) and aviation gasoline (avgas). This synthesis focuses on these two types of fuel and distinguishes between them, as necessary.

Jet fuel is used in aircraft that have turbojet, turbofan, and turboprop turbine engines. Jet fuel is kerosene based, and there are a number of different grades, with the distinctions associated primarily with the additives contained in each. Two types of jet fuel are used for jet aircraft operation worldwide: Jet A and Jet A-1. The primary difference between them is the freezing temperature specification. The freezing temperature refers to the point at which water trapped in the fuel will freeze, not the freezing of the actual fuel. Jet A is the prevalent jet fuel used in the United States and has a freezing point higher than that of Jet A-1. Airlines are experimenting with biomass and other alternative fuels. The introduction of biomass fuels is discussed briefly in chapter seven.

Avgas is intended for use in reciprocating piston-engine aircraft. As with jet fuel, different grades are available. There are airports at which higher leaded content 100 octane (100/130) is available, but the most common avgas is 100 octane low lead (100 LL). The addition of lead has environmental consequences. Therefore, care must be taken against contaminating tanks or equipment not designed for leaded fuel. The FAA is conducting research to find a lead-free alternative for use in piston-engine aircraft.

A few GA airports allow nonethanol automotive gasoline (mogas) facilities to provide the fuel for aircraft approved to use such fuel. Mogas used in aircraft generally has to be free of ethanol. Local regulations in parts of the United States can make attaining mogas difficult. The current low level of demand and the need for separate tanks and equipment can hinder installation of such facilities at airports. However, demand may change as more aircraft are sold with engines able to use mogas or regular automotive fuel.

LITERATURE REVIEW

Preparation of this report involved a review of current literature in addition to interviews with fueling operators at airports and individuals with experience and expertise with airport fueling system operations. There exists a large volume of literature related to fueling system design and operation on airports. For safety and regulatory purposes, much of a fuel system operation is standardized. New practices evolve slowly because of the vetting process that takes place through various national and international standards and review committees.

A number of ACRP reports have researched and reviewed various aspects of fueling, fuel facility planning, and fueling safety on airports. ACRP studies have been conducted on fuel sampling (Hagerty 2014), the right to self-fuel (*ACRP Legal Research Digest 8* 2009), fuel facility planning on aprons and ramps (Quinn and Richter 2013), GA airports' facility planning (Sander et al. 2014), safety training of fuel operators (Landry and Ingolia 2011), and location of alternative fuel facilities and distribution (Miller et al. 2012). In addition, a number of published environmental reports have applicability to fuel system operation.

The feasibility and challenges of airport ownership of fuel facilities have been the topics of three AAAE management papers: "Getting Your Airport into the Fuel Business" (Held 1998); "A Case Study for Airport Ownership of Fuel Storage Facilities" (Potts n.d.); and "A Management Perspective of Design, Operation and Maintenance of a Fuel Farm" (Oosman n.d.).

An informative case study was published in 2008 that detailed several of the fueling issues facing airport owners and airlines across the country and how they could be addressed through joint problem solving (Lahey and Heilbron 2008). In the case study, the authors addressed a wide range of legal, financial, insurance, environmental, economic, capital improvement, and policy issues associated with aviation fueling at a medium hub airport. This ACRP report reflects many of those same issues.

The literature search also disclosed a number of articles published by *Airport Improvement Magazine* that document the replacement, installation, and refurbishment of fuel farm facilities. The problems encountered, the solutions developed, and the lessons learned are described; they are particular to each airport and reflect the many special circumstances that can arise at airports throughout the country. A list of the articles is presented in the bibliography.

In a follow-up to an earlier legal digest report, the ACRP is pursuing a study to produce a practical compendium that describes and explains the various models and legal issues that airport counsels will likely encounter during the consideration, negotiation, and administration of fuel-related issues (Pilsk forthcoming). The report is expected to be published in fall 2015.

Related to fuel consortium operation, *ACRP Synthesis Report 31* provides an overview of terminal building consortiums and their fundamental operations at airports (Demkovich 2011). Terminal consortiums operate on many of the same principles as a fuel consortium.

In reviewing the various standards, suggested practices, and guidance material associated with airport fueling systems, it was found that easy access to the standards requires purchase and/or licenses from the sponsoring organization. There is also a fair amount of proprietary information that is held by the industry, from forms to processes used by fuel, equipment, and service providers. One exception is Gammon Technical Products, which has a history of providing free technical, informative, and educational material and articles on jet fuel-handling operations (www.gammontech.com). Permission was obtained to reproduce a number of copyrighted diagrams and pictures that illustrate concepts expressed in this report. Appendix A contains a list of documents that are pertinent to fueling systems installation, operation, and maintenance.

Several professional organizations have established standards or guidelines for the safe design, manufacture, maintenance and operation of fuel systems and their components, equipment, and vehicles. The use of a particular standard is a determination made through generally accepted practices, contract or lease agreement, or regulatory adoption. The literature search identified several key documents that address fuel-handling operations at U.S. airports.

1. ATA Specification 103, *Standard for Jet Fuel Quality Control at Airports*, is produced by A4A and provides guidance for the safe storage and distribution of jet fuel at airports, as currently practiced in the commercial aviation industry. Domestic airlines in the United States use this standard.
2. The National Air Transportation Association's (NATA) *Refueling and Quality Control Procedures for Airport Service and Support Operations* (2000) provides information and detailed procedures on the safe handling and delivery of aviation fuels. It is used primarily by FBOs, GA, and air taxi operators.
3. The ASTM International Manual 5, *Aviation Fuel Quality Control Procedures* (2009), provides a complete explanation of several common procedures used by fuel handlers to assess and protect aviation fuel quality. Although not a specification, it is a useful reference document. It is intended to be an educational tool and provide sufficient information for fuel handlers to make an informed approach to aviation fuel quality.
4. The FAA's Advisory Circular (AC) 150/5230-4B (2012), *Aircraft Fuel Storage, Handling, Training and Dispensing on Airports*, contains specifications and guidance for the storage,

handling, and dispensing of aviation fuel on airports. In addition, this AC provides standards and guidance for the training of personnel who conduct fueling activities. A Part 139 certificated airport has requirements for inspection of fueling facilities and the training of personnel. This AC provides guidance for that purpose.

5. The National Fire Protection Association (NFPA) Code 407, *Standard for Aircraft Fuel Servicing*, outlines vital safety provisions for procedures, equipment, and installations during fuel servicing of aircraft. The standard covers design requirements of equipment and operational issues, such as for the prevention and control of spills, the need for emergency fuel shutoff, aircraft fuel service locations, defueling, and loading of aircraft fuel servicing vehicles. NFPA 407 is supported by the FAA for fire protection safety at airports. Other NFPA standards are applicable and have been adopted by local communities.
6. Petroleum Equipment Institute/Recommended Practice (PEI/RP) 1300-13, *Recommended Practices for the Design, Installation, Service, Repair and Maintenance of Aviation Fueling Systems*, was developed at the request of FBOs, equipment manufacturers, and service and repair contractors. The practices outlined in the publication constitute a synthesis of requirements and recommendations published by equipment manufacturers, petroleum marketers, and regulatory agencies.

Other standards, suggested practices, and guidance materials are available and shown in Appendix A.

COMMERCIAL VERSUS SELF-FUELING

The scope of this synthesis does not include aspects of self-fueling by tenants. However, a distinction is made between the terms "tenant self-fueling" and "commercial self-fueling."

In AC 150/5190-6 (2007), the FAA defines self-fueling as "the fueling or servicing of an aircraft . . . by the owner (or operator) of the aircraft with his or her own employees and using his or her own equipment." This contrasts to the definition of commercial self-fueling found in the same AC: "a fueling concept that enables a pilot to fuel an aircraft from a commercial fuel pump installed for that purpose by a fixed-base operator (FBO) or the airport sponsor. The fueling facility may or may not be attended." In either case, the fueling system components, equipment, and processes are often of the same design and function.

FAA specifically notes in Order 5190.6B, *Airport Compliance Manual*, that fueling from a pull-up commercial fuel pump is not considered self-fueling under federal grant assurances because it involves fueling from a self-service pump made available by the airport or a commercial aeronautical service provider (FAA Order 5190.6B 2009). In this regard, the fueling systems described in this synthesis include equipment and designs that incorporate aspects of self-fueling but that are commercial fueling in purpose.

An airline qualifies for tenant self-fueling. As a standard condition in their airport lease agreements, airlines and air cargo operators often reserve the right to obtain fuel from a supplier of their choice. They do this primarily to control their fuel and operational costs. However, most airlines choose to not use their own employees to fuel aircraft and instead use a management company or into-plane agent to serve their aircraft. The fueling of aircraft constitutes an aeronautical activity by FAA definition (AC 150/5190-7 2006). Thus, an airline is subject to an agreement with the airport for the right to dispense fuel and for inspections by the airport.

ACRP has published a legal digest report on the right to self-fuel (*The Right to Self-fuel* 2009). The digest serves to introduce readers to the topic of self-fueling, as well as to basic information vital to understanding the methodology used in determining compliance with federal grant assurances. It does not delve into the technical aspects of fueling services provided at airports. It does address topics such as security, environmental concerns, insurance requirements, exclusive rights violations, economic nondiscrimination, and the overall safe and efficient operation of the airport—all of which have applications to an airport operator's fueling responsibilities.

FUNDING OF FUEL INFRASTRUCTURE

Airports that receive federal Airport Improvement Program (AIP) grant funding assistance are obligated under the grant assurances to strive for financial self-sufficiency [*Grant Assurances (Obligations)—Airports* 2014]. Revenue generated at the airport is to be applied toward the capital and operating cost of the facility. The sale of fuel is often a primary means by which airports, especially smaller ones, can achieve self-sufficiency.

Before 2003, federal AIP funds were not available for funding fuel system installation or upgrades because such items were deemed a revenue-producing activity that did not fulfill the public purpose of the AIP requirement. Eligibility for funding was changed in 2003 with the Vision 100—Century of Aviation Reauthorization Act (Vision 100 2003). Project eligibility was expanded to include the funding of new fuel facilities at nonprimary airports only. Certain costs are ineligible, such as those associated with maintenance, including replacement or upgrades of existing fuel systems; replacement of existing pumps with card reader pumps; demolition of an existing fuel farm; or environmental mitigation and/or cleanup (*Revenue Producing Facility Policy* 2014). However, according to the policy, an airport's takeover of existing fueling activities from a fuel facility operator, such as an FBO going out of business, may be funded through AIP on a case-by-case basis.

DATA COLLECTION

Owing to the standardized nature of fuel system components and design, a formal survey was not part of this synthesis. A literature search, airport site visits, and interviews with knowledgeable individuals from oil companies, airport operators, fueling suppliers, fuel-handling service providers, fuel system auditors, and industry insurance providers were the primary means of data collection. This report synthesizes the literature, interviews, and communications.

Airports participating in interviews and site visits included: North Tampa Aero Park, Florida; Kenmore Air Harbor, Washington; Pekin Municipal Airport, Illinois; Auburn/Lewiston Municipal Airport, Maine; Greeneville–Greene County Municipal Airport, Tennessee; Renton Municipal Airport, Washington; Texas Gulf Port Regional Airport, Texas; Memphis–Shelby County International Airport, Tennessee; and Dallas–Fort Worth International Airport.

Organizations or individuals contributing to the synthesis include the Aircraft International Group; AAAE; A4A; National Air Transportation Association; Alaska Department of Transportation and Public Facilities; North Dakota Aeronautics Commission; AvFuel Corporation; LAX Fuel Corporation; Marathon Petroleum Company; Swissport International, Ltd.; Willis Insurance, Inc.; Wilson Air Center; and NATA Safety 1st Ground Handling Auditor consultants. In addition, a number of equipment and fuel providers at the National Business Aviation Association convention contributed to the report.

REPORT ORGANIZATION

This synthesis report is organized into eight chapters with additional sections for references, acronyms, glossary, and appendices.

Chapter one provides an introduction to the synthesis and describes its purpose, along with an overview of the literature review. Background information is provided on the fuel delivery processes, equipment and facilities, operational considerations for fueling aircraft, and the distinction between commercial fueling and self-service fueling.

Chapter two provides an overview of regulations affecting the fueling processes on an airport, including FAA and environmental regulations.

Chapter three describes the parties involved in ownership and management of fuel facilities and fuel handling.

Chapter four provides information on the design of fuel systems and describes the components and types of delivery systems from the oil producer to the into-plane agent.

Chapter five briefly provides background on organizations that develop standards, regulations, and training for fuel handlers.

Chapter six addresses fuel safety practices and issues associated with fire safety, human health, human factors, and failure modes. Highlighted are fuel characteristics and examples of accident and incidents. Various risks and issues in fuel-handling processes are described. Examples of safety risk assessment practices associated with a safety management system are given in the Appendices.

Chapter seven addresses risk management issues related to fueling processes by describing several areas of risk exposure. Case examples are provided to illustrate certain aspects of fueling practices at airports.

Chapter eight provides conclusions, suggestions for future research, and a list of suggestions from the literature and interviews.

Appendix A provides a list of resources that is can be of use to any operator having oversight or responsibilities for fueling operations.

CHAPTER TWO

REGULATORY AND ENVIRONMENTAL REQUIREMENTS

Aviation facilities fall under a number of different environmental regulations, just as do other industrial, commercial, or service-affected facilities. With the exception of Part 139, federal regulations related to fueling systems and operations on airports stem primarily from environmental regulations. Many federal EPA requirements are carried out and administered at state and local levels.

Part 139 regulations apply only to fueling activities at certificated air carrier airports. Not covered are the hundreds more GA or noncommercial airports. The standards and practices used at certificated airports represent the most effective practices for adoption at GA airports.

14 CFR PART 139 AIRPORT CERTIFICATION

Requirements exist for airports certificated under 14 CFR Part 139 for safety oversight and inspection of fueling facilities, equipment, and personnel training records. For airports not covered by Part 139, due diligence and public safety requirements suggest the same level of oversight is warranted.

Section 139.321 requires a certificated airport to establish and maintain standards for protecting against fire and explosions in the storing, dispensing, and handling of fuel on the airport. Section 139.321 is excerpted in Appendix B. The FAA uses the standards contained in the most recent edition of NFPA 407 when inspecting an airport. A local community or airport can choose other standards to cover facilities, procedures, and personnel training.

An inspection and recording of tenant fueling facilities is to be done at certificated airports every 3 consecutive months (quarterly inspection), along with regular (daily) inspection and reasonable surveillance of all fueling activities on the airport during special conditions. Quarterly airport inspections typically are performed by city or county fire marshals and/or personnel, airport fire department personnel, airport operations personnel, or others with knowledge and training in fueling system operation.

As part of the inspection requirements, verification of training is necessary for those who provide fueling services at Part 139 airports. Section 321 specifies individuals are to have received training in at least the following areas:

1. Bonding,
2. Public protection,
3. Control of access to storage areas,
4. Fire safety in fuel farm and storage areas,
5. Fire safety in mobile fuelers, fueling pits, and fueling cabinets,
6. Training of fueling personnel in fire safety, and
7. The fire code of the public body having jurisdiction over the airport.

Specific to item seven, airport operators holding a Part 139 certificate are to be aware that it is their duty to provide a briefing to tenant fueling agents on the fire codes in effect at the airport that differ from NFPA 407 (AC 150/5230-4B 2012).

Although Section 321 addresses the handling and storage of hazardous substances and material, fueling personnel at certificated airports also must heed Section 329, which covers pedestrian and ground vehicle operation at the airport. Employees of fueling agents with access to the movement and safety areas of the airport are to be trained and authorized to operate on the airport; this preparation is known as an airport driver training program. The training is to occur before the initial performance of their duties and at least once every 12 consecutive calendar months thereafter.

Part 139.325 further requires the airport to develop an airport emergency plan that provides a coordinated response to a number of emergencies, including fuel fires. Responding fire personnel are to be versed in the airport emergency plan and participate in required annual drills or exercises.

49 CFR PART 1542 AIRPORT SECURITY

Related to the need for fueling personnel to have access to the airport, the TSA requires those airports affected by 49 CFR Part 1542 to comply with an airport's security plan (49 CFR Part 1542). This involves employment history and background checks, badging and access control requirements, and training. Tenant fueling agents may have their own security program as well. Recent security concerns have been raised related to attempts to disrupt fuel supplies and to third-party access to air carrier aircraft, such as with refueling personnel (Faiola and Mufson 2007; Garrett 2015).

ENVIRONMENTAL REGULATIONS

Both jet fuel and avgas have properties that can affect the environment if spillage or vapor release occurs. For this reason, fuel facilities and fueling operations can be covered by a number of environmental regulations, depending on the amount and nature of fuel involved. Appendix A provides a primary list of federal regulations that affect fueling operations. Other requirements can exist, including state and local laws, regulations, and ordinances. A best practice is for an airport to work with the local environmental representatives to ensure all requirements are met.

ACRP Report 43 (McGormley et al. 2011) identifies resources and tools that small airports can use to be proactive in their responsibilities for environmental stewardship. Included in the report are summaries and practices of applicable federal environmental compliance requirements that apply to fueling systems installed at airports.

CHAPTER THREE

ORGANIZATIONAL ROLES

Fuel facilities and equipment can be owned by the airport, an oil company, fuel consortium, FBO, Specialized Aviation Service Operations (SASO), corporate or business organization, private group or individual, or any mix of the parties involved. This chapter reviews common relationships found at airports.

A fueling agent is a person or company that sells fuel products on the airport (14 CFR Part 139). The description is intended to exclude the self-fueling activities of an airline or corporation that conducts self-fueling. Part 139 makes a distinction between an airport fueling agent and a tenant fueling agent. An airport fueling agent is an airport operator/certificate holder that sells fuel products on the airport. A tenant fueling agent is a person or company, other than the certificate holder (airport), that sells fuel products on the airport. Although the description of a fueling agent excludes an airline that self-fuels, the airline is to use its own employees. If not, the airline is a tenant fueling agent upon engaging a third party to dispense the fuel (AC 150/5230-4B 2012).

MANAGEMENT OF FACILITIES AND EQUIPMENT

There are different ownership arrangements of property, fuel tanks, equipment, facilities, and vehicles, and different ways to manage them and deliver fueling services. The following are examples of the different options. In any case, airport management has a right to establish minimum standards, rules, and/or regulations that govern fueling operations on its airport as part of its landlord responsibilities.

Airport Management

There are various ways to manage and maintain fueling facilities and equipment if the airport organization chooses to do so. The arrangements are:

1. The airport owns the facilities, vehicles, and equipment, and dispenses the fuel to aircraft through its own employees. The airport would have a direct agreement with a fuel supplier. Depending on the volume of fuel, there can be a direct relationship and provision of fuel from the refinery supplier, an independent refinery, a merchant refinery, or a fuel trader.
2. The airport leases any or all storage, facilities, equipment, and vehicles from an oil refinery or intermediary provider and operates as the fuel service provider (dispenser) of fuel using its own personnel.
3. The airport is a fuel distributor and owns any or all of the bulk storage facilities, equipment, and vehicles, and leases them to a contractor to manage the fueling operation. The airport purchases fuel from an oil refinery or trader and resells it.

For each of these arrangements, the airport meets the Part 139 designation of an airport fueling agent.

Fixed-Base Operator Management

A second possibility for fuel facility management is that of an FBO or SASO. The FBO or SASO normally leases property from an airport. This can include the rental of buildings, fueling facilities, and vehicles, or the FBO may seek to construct or own its buildings, facilities, and/or vehicles. The FBO can also lease vehicles and equipment from a fuel supplier. The latter is common for several reasons, the first of which is quality control and branding. The second reason is cost control. For purposes of Part 139, the FBO is known as a tenant fueling agent because it sells fuel and is a tenant of the airport.

The FBO or SASO obtains fuel from any fuel provider it chooses. Many FBOs align themselves with a branded fuel supplier as a means to distinguish themselves from others and obtain pilot loyalty. Pilots flying across the country are inclined to frequent one particular brand as a result of known quality processes, loyalty programs, or discounted fuel agreements. The integrity and consistency of the fueling process is vital to the branding effort. Different arrangements can exist with branded fuel suppliers for the provision of vehicles and equipment, from leasing to outright ownership. A fuel supplier might own the vehicles and equipment and lease them to the FBO or SASO to help ensure proper maintenance and safety oversight of the fuel delivery process. Through a lease agreement with the fuel supplier, FBOs are able to benefit from a fixed lease rate and regular vehicle and equipment maintenance.

Airline or Investment Organization Management

Financial, economic development, or investment considerations may result in an airline, aviation, or nonaviation entity owning and leasing the fuel facilities. To serve as an attraction for aviation business, a private investor, an economic development agency, or an airline may undertake the construction and ownership of a fuel tank system with the intent to use, lease, or resell the facilities. Any such arrangement would involve a lease or operating agreement with the airport. The owners would become a fueling agent for Part 139 purposes.

An airline can own bulk storage and distribution equipment on leased airport property or own or lease property or facilities off airport. An airline will not normally staff the facilities, preferring to contract a third-party operator to deliver the fuel to the airline's aircraft. The third party can be a dedicated fuel service provider or an airport FBO. Each company would need access rights onto the airport granted by the airport organization.

Fuel Consortium Management

A fuel consortium is an arrangement in which several airlines at an airport join to form a separate organization for the purpose of managing and operating fuel facilities at a particular airport. The consortium operates the fueling system under an agreement that spells out the various rights, duties, and obligations of each airline.

A typical fuel consortium is organized as a limited liability corporation (LLC) or as a nonprofit organization owned by member airlines at a particular airport. A governing board made up of individuals from each participating airline guides the consortium. Usually, the airline member with the greatest fuel volume chairs the consortium.

In a 2009 presentation, the Air Transport Association, now called A4A (Airlines for America), identified 27 of 30 large hub airports, 18 of 37 medium hub airports, and six of 70 small hub airports in the United States as having fuel consortium or advisory committees on the airport (Heimlich 2009). At that time, none of the 248 nonhub airports in the United States had any such arrangements.

A fuel consortium is not involved in the actual buying, selling, or owning of jet fuel. A consortium is formed to obtain economy of scale in the financing and use of infrastructure, reduce overall costs, gain operational efficiencies, and share risk among member airlines. With a consortium arrangement, fuel is purchased and owned by an individual airline, an oil company, or a fuel trader, and is delivered to a fuel storage facility owned or leased by the fuel consortium. The costs of operating a consortium's fuel storage facility are shared by the member airlines using a predetermined member rate. The storage facility can be located on or near an airport. The consortium governing board contracts with a third-party firm to provide the professional expertise and capability to manage the consortium's fuel farm operation, maintenance, fuel delivery, and records management. The third-party company can manage one or all aspects of the process. It is not uncommon to have one company manage the storage facility and another company provide into-plane services. Often, the fueling equipment and vehicles are owned by the airlines and leased to the consortium or fuel management company.

An airline in need of fuel that is not a member of the consortium or is itinerant would need to acquire fuel independently or make arrangements through the consortium to pay nonmember rates.

For its member airlines, a consortium has responsibilities similar to those identified for the Vancouver Airport Fuel Facility Corporation (Fact Sheet) in their agreement:

- Operate and maintain the fuel facility system;
- Comply with regulations;
- Direct new investment, maintain insurance, and structure debt;
- Plan, construct, and operate a safe, reliable, and cost-effective fuel infrastructure to meet near- and long-term demand projections; and
- Obtain regulatory permits, approvals, and authorizations as they relate to fuel system operation and expansion.

At medium, small, and nonhub airports, there may be reasons to not form a fuel consortium and share risks among member airlines, although the airlines do seek to cooperate with each other and form fuel or advisory committees. The committees work with airport management, fuel providers, and into-plane agents to address the same issues as would be addressed by a consortium.

Corporate Aviation Management

For the same reasons as the airlines, a corporate entity that owns aircraft located on an airport may seek to install its own tanks and service equipment. The airport may allow the installation through a lease or operating agreement. Fueling can be provided only by the company's own personnel and to its own aircraft. Fueling facilities, equipment, and vehicles located or used on airport property are subject to the requirements of local codes, ordinances, or agreements. If the airport is certificated under Part 139, the fueling facilities, equipment, and vehicles are subject to airport inspection under Part 139.321.

Individual, Flying Club, Flight School Management

Some airports, primarily GA, have allowed for the installation of a fuel tank and pumping equipment for a private individual, flying club, or flight school. An airport can allow the individual or group management option under the self-fueling allowance, provided fueling is restricted to those individuals. A common clause specified in a lease includes a fuel flowage fee and for the facilities to revert to the airport at a future date.

Department of Defense Management

On shared-use airports, where the airport owns the property and leases land to the Department of Defense (DoD), the military installation most likely will operate its own fuel storage and supply. Similar to other arrangements noted previously, because the facilities will be on airport property, a lease agreement will identify ownership or management relationships. Military standards for installation, operation, and maintenance can vary from civilian standards.

RELATIONSHIP OF PARTIES

There are a number of legal, financial, and operational relationships involved in the delivery of fuel onto airport property. Of major concern to an airport are the possibilities for environmental damage and the responsibility for mitigation and cleanup. With several parties involved in the fuel-handling process, it was explained in interviews how important it is for an airport to identify and delineate the various relationships through written agreements and approvals.

Parties that may be involved in the delivery of fuel to the airport can be any of the following:

- Major oil refinery—An oil-producing company that is global or national in scope that produces and delivers fuel.
- Independent oil refinery—A specialized oil company with national or regional operation that produces and delivers fuel.
- Merchant oil refinery—A company that purchases and processes crude oil produced by others and then produces and delivers fuel.
- Wholesale or trade seller—A company that purchases processed fuel and resells to others.
- Transport deliverer—A company engaged in moving fuel from the refinery to the intermediate storage facility and/or to the airport.
- Airport organization—The owner of the property where fuel facilities are located and into-plane deliveries are made.
- Fuel consortium—An airline organization designed to manage and facilitate fuel purchased for its member airlines.
- Airline, cargo, charter, or air taxi operator—Companies that purchase fuel for their own use.
- Fuel farm depot operator—A company responsible for oversight of fuel storage facilities.
- Into-airplane service provider—A company responsible for delivering fuel from storage depot to the aircraft.
- Maintenance provider—A fuel facility, equipment, and vehicle maintenance provider.
- FBO or SASO—A company that purchases fuel from others, stores fuel in a separate tank, and provides into-plane services.
- Corporate operator—A company that purchases fuel from others, stores fuel in a separate tank, and services its own aircraft.
- Private individual/flight school/flying club—Individuals or nonprofits that purchase fuel from others, store fuel in a separate tank, and service their own aircraft.

PARTIES INVOLVED IN FUEL HANDLING

A number of parties are involved in the acquisition of fuel from refineries (Figure 2). The primary parties responsible for getting fuel from the refineries to the airport are oil refinery traders and schedulers, fuel or energy traders, schedulers and/or dispatchers, and airline fuel department personnel.

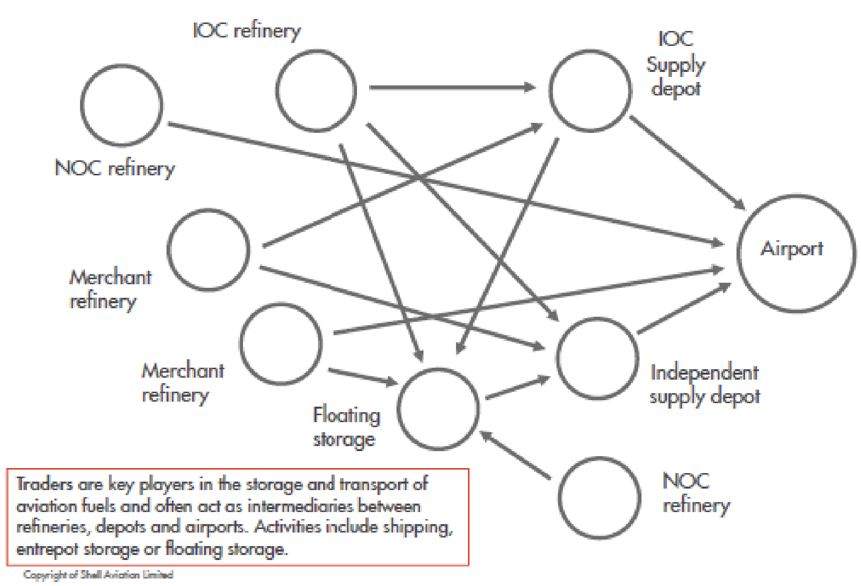

FIGURE 2 Schematic of various relationships for fuel delivery to an airport. NOC = national oil company; IOC = independent oil company. (*Courtesy*: Shell Oil Company.) Used with permission.

Depending on where the processed fuel is coming from, U.S. Customs, custom brokers, marine agents, and certified gaugers may be involved before the fuel goes into the pipeline, figuratively and literally. For truck and barge deliveries, the same brokers, agents, and gaugers can be involved, as well as depot/terminal schedulers and trucking/rail/barge company dispatchers.

The legal, risk management, and financial aspects of fuel delivery to an airport normally are worked out among various legal counselors, risk and environmental managers, and financial and accounting officers of each respective party. Two of the larger airports interviewed engaged outside firms with expertise to assist in their negotiations with a consortium.

FUEL ORDERING

As fuel comes onto the airport, fuel inventory control is important, especially for a fuel consortium arrangement in which fuel from different sources is commingled and distributed. Fuel facility operators, maintenance mechanics, fuel accounting staff, and departmental managers are involved. Depending upon the arrangement at any one airport, the into-plane disbursements can include fueling personnel and managers, calibration technicians (calibration of into-wing meters and load racks), and maintenance personnel.

Individuals within each airline, FBO, and airport organization have responsibility for ordering the processed fuel. If a third party is to manage the fuel, that party is informed of the fuel order purchase so it can reconcile and keep track of the fuel allocation. ATA Specification 123 provides procedures for the accounting of jet fuel inventory (*Procedures for the Accounting of Jet Fuel Inventory* 2014).

FUEL AUDITING

The following organizations or individuals can provide auditing oversight of one or more steps in the fuel-handling process: city/county fire department, airport authority, airline compliance auditors, fuel handler company internal auditors, independent financial auditing firms, professional trade organizations, federal and state environmental agencies, Internal Revenue Service, and state tax auditors. Challenges can exist in the process to obtain permits for the installation of fuel facilities, as evidenced by the case example for one airport (see chapter seven).

CHAPTER FOUR

DELIVERY AND DISTRIBUTION PROCESSES

The concept of the fuel supply chain from refinery to an aircraft is fairly simple and straightforward. From the refinery and bulk oil company storage facility, the fuel is transmitted to the airport by one of several transport modes: pipeline, ship or barge, railcar, or transport truck. The fuel is then transferred to an airport-related storage facility through similar transport modes and is eventually placed into the aircraft.

Although the concept may appear simple and straightforward, the actual delivery of clean fuel within the standards and required specifications involves numerous steps, components, and processes, along with the related opportunities for mistakes and error. The possibility of fuel contamination exists every time fuel is transferred. For that reason, fuel is filtered and checked every step of the way, as illustrated in Figure 3.

TRANSPORT

The transport of fuel to an airport generally has two stages: primary and secondary. Primary transport will be the shipment and transport of fuel from the refinery to a "pre-airfield" supply terminal, as described by the International Civil Aviation Organization (ICAO; *Manual on Civil Aviation Jet Fuel Supply* 2012). In some circumstances, primary transport can bypass a pre-airfield storage facility and go directly to an airfield's storage facility from the oil refinery. The majority of airports receive fuel through a secondary stage involving intermediary storage of fuel at a pre-airfield terminal facility. An airport operator is interested in any disruption in the supply chain that can affect airport operation and any changes in the quality and specification of fuel; these are concerns for both primary and secondary stage transport.

The quality of fuel and its transfer through different modes is a concern because once a fuel delivery is accepted from another party, the receiving party takes responsibility for the fuel's condition and use. For this reason, fuel quality tests are performed at each stage of the fuel delivery process before introduction into an established clean fuel system.

ATA 103 states it is important that a facility operator sample inbound deliveries upstream of the receiving filtration point for any potential contamination or excessive levels of water and/or dirt (*Standard for Jet Fuel Quality Control at Airports* 2009). According to interviews and the literature, this is done for two reasons: (1) to prevent cross-contamination of fuel, and (2) to isolate responsibility, accountability, and liability for any fuel that may be contaminated. Both reasons have operational implications and economic costs associated with them.

The design of a fuel system will include filters and water separators to help ensure the proper quality of fuel. The introduction of large amounts of contaminants into a system can affect the service life or functionality of system filters and can increase the maintenance and cost of operation. The issue of where or how a fuel becomes contaminated points to the need for proper testing and documentation in the event of a dispute over a "bad" batch of fuel. Significant economic and operational costs can be incurred through the need to refilter all the fuel, defuel, clean tanks, and dispose of the bad fuel as a hazardous waste; other costs include those related to delayed flights and the additional worker-hours needed to rectify the situation.

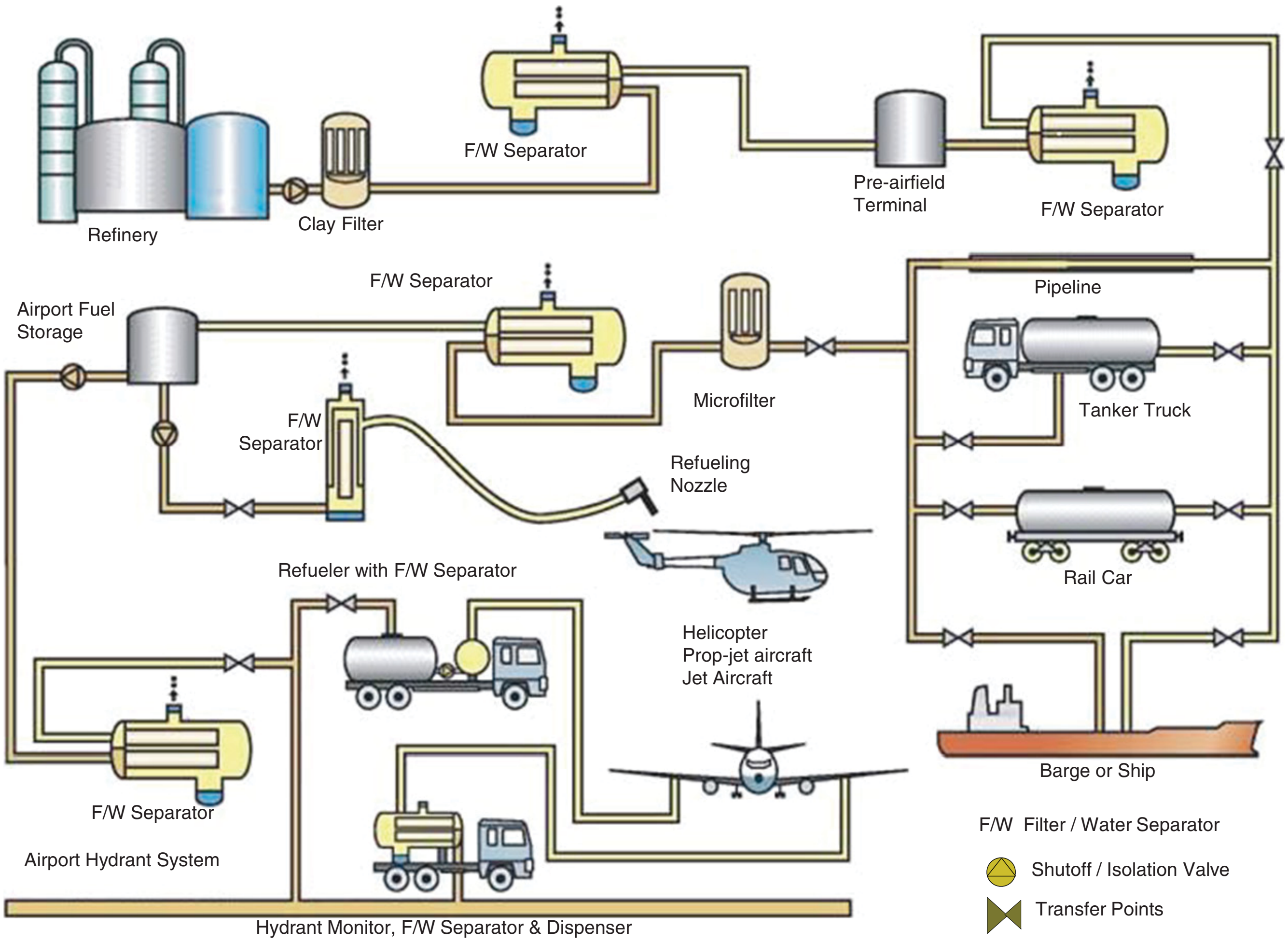

FIGURE 3 Fuel delivery diagram from refinery to aircraft showing filtration points and transportation modes. (*Courtesy*: FAUDI Aviation.) Used with permission.

DEDICATED FUEL TRANSPORT

The use of segregated and dedicated transport systems is considered important in minimizing the potential for cross-contamination of any fuel. Per ATA 103, "unacceptable operational and economic issues based on upstream jet fuel purity levels are to be resolved between applicable shipper, facility operator and/or customer." To help reduce the possibility of contamination in the delivery of aviation fuel, fuel suppliers consider it a most effective practice to use dedicated transport vehicles. A dedicated transport is one that transports only one type of product, whether it is jet fuel or avgas (Figure 4).

If a nondedicated transport is used or a different grade of fuel was previously transported in the container, a higher risk for cross-contamination exists unless the tanker has been cleaned according to acceptable standards, such as Joint Inspection Group (JIG) 3, American Petroleum Institute Recommended Practice (API RP) 1595, and Energy Institute (EI) Standard 1530 (*Manual on Civil Aviation Jet Fuel Supply* 2012). Because of the higher possibilities for fuel contamination from residual fuels, it is the policy of one FBO in the study to reject any fuel shipped in a nondedicated transport that has not been properly cleaned according to acceptable standards, and for all quality checks to prove the fuel is on-specification, clear and bright (R. Hartwein, personal communication, Aug. 27, 2014). Fuel that does not meet acceptable quality standards is called off-specification (off-spec) fuel and is to be disposed of properly. The off-spec fuel can be sold to a recycler or otherwise disposed of per environmental hazardous waste regulations.

FIGURE 4 Example of a dedicated Jet A tanker delivering fuel to an airport tank farm. (*Courtesy*: S. Quilty, SMQ Airport Services.)

FUEL FACILITY DESIGN

The design purpose of a fuel system is to receive, store, monitor, filter, and transfer fuel in accordance with quality standards (Lahey and Heilbron 2008). The primary difference between a fuel system at a large hub airport or a small GA airport is the scale of infrastructure and the number of components. Little difference exists in the actual components that are used because standardization of components exists throughout the industry.

Fuel storage can be located on or off airport property, depending on factors related to the land available, such as environmental and site preparation costs, and the efficiency of methods for final delivery to the aircraft. From an airport storage facility, the fuel is piped to a central dispensing pump or a decentralized underground hydrant fuel system with a pit at each aircraft gate, or is loaded into refueler trucks or dispensers for final delivery to the aircraft.

The focus of this study is on the fuel processes, facilities, and equipment that are located or situated within the property lines of the airport. Once fuel crosses onto airport property, its environmental safekeeping ultimately becomes the responsibility of the airport operator, no matter who is involved in the receipt, storage, or delivery of the fuel to aircraft. To that extent, an airport can specify the type of fuel facility and its location, even over the objection of a tenant (Docket No. 16-07-06 2008).

A fuel farm is the consolidated location of bulk fuel storage and equipment on or off an airport. The design of a fuel farm normally includes an area large enough to meet tank separation standards and contain all associated piping, filter assemblies, and pump equipment; a containment dike or bund; a fire protection system, including separate water storage for foam; a control room or similar building; security fencing; and a truck loading/unloading platform (also known as a rack system) to include adequate maneuvering area and room for the parking of service vehicles. Backup emergency generators can also be included.

A modern control room or building will house test equipment; an area for quality control testing, manuals, and documentation; a computerized management system that controls and monitors aspects of the fueling system, such as tank levels, motor operated valves, pump operations, emergency shutdown of fueling operations, alarms, pump runtime, system pressure and flow instrumentation; and other items as required by the individual system.

With the exception of a dedicated control building, similar facility and equipment requirements are needed for smaller airports, although within a much smaller land footprint. Some fuel tanks installed

FIGURE 5 Example of a modular fuel tank. (*Courtesy*: S. Quilty, SMQ Airport Services.)

at GA airports are modular, with the pump, filters, and meter equipment self-contained with the tank or are on skids for easy or temporary transport (Figure 5). *ACRP Report 113* provides an overview for the planning of fuel facilities at general aviation airports (Sander et al. 2014).

Fuel Piping

The size of pipes and hoses used in a hydrant fueling system is based on peak demand requirements. Aircraft operators and engineers make volume calculations as to how many and what types of aircraft are expected to be fueled over a given time period. Fuel flow delivery rates to an aircraft determine how long it will take to service an aircraft, which affects turnaround times and variable operating costs for the airlines.

To prevent corrosion and contamination, pipes for jet fuel systems can be made of coated or epoxy-lined carbon steel or nonferrous epoxy-lined or stainless steel. Metals in pipes, valves, equipment, and accessories that interact negatively with jet fuel are zinc and copper, including alloys with either of those metals. To mitigate leakage, underground piping and hydrant fuel system designs often incorporate a line leak detection system. Standards exist for the marking of pipes (EI 1542 and API 1637) and for the testing of hydrant pipe systems (EI 1594, API RP 1540, and UFGS-33 58 00).

Fire Suppression

Of major consideration in the design of a fuel facility is the provision for a fire protection system and emergency response (*NFPA 11* 2010). At a minimum, portable fire extinguishers are required under NFPA, FAA, and state or local codes. The provision of a particular fire suppression system is based on the overall fuel storage capacity or flow rate of the system and outlined in adopted codes or standards. For aboveground storage tank (AST) systems, fire protection systems normally consist of a water supply with fixed or semifixed foam fire suppression capability (Figure 6). For hydrant fuel systems, consideration is given to aircraft rescue and firefighting response to a ramp incident. Considerations include the impact of access to hydrants and equipment, fuel and isolation cutoff locations, and surface and storm water drainage.

Electrostatic Protection

Provisions are made in the design of a fuel system to minimize the potential for static electricity generation. The Coordinating Research Council (CRC) has a number of publications addressing the

FIGURE 6 Foam suppression inlet point for aboveground tanks. (*Courtesy*: S. Quilty, SMQ Airport Services.)

electrostatic properties of fueling systems (see Appendix A). NFPA 77, ATA 103, and AC 150/5230-4B provide guidance for reducing static electricity potential; routine testing of ground rods and bonding cables; and conductivity testing of filters, hoses, equipment, and piping. Standards and requirements exist for both bonding and grounding. Bonding is the creation of an electrical path between two components to establish a neutral electrical potential, such as between a refueler truck and an aircraft. Grounding (also known as earthing) is the creation of a neutral electrical path between a vehicle, equipment, or component and the earth, such as an aircraft to ground or a refueler truck to ground.

Fitness Testing and Fitness for Service

Fitness testing is a quality control measure used to determine if a fuel system component meets acceptable standards before it is placed or returned to service. Fitness testing for hydrant fuel systems is periodically necessary, according to API/EI 1594 standards. The piping system is to be pressure tested for leaks every 5 or 10 years. For newly installed tanks, a soak test determines if a new tank is suitable for the storage of jet fuel or if a tank can be brought into service after repairs have been completed (EI 1540 and Jig Bulletin 35).

Should damage occur to a fuel system component, an assessment for “fitness for service” (FFS) can be made as to whether replacement is needed or if the component can remain in service (API 579-1). For repairs that are performed on a fueling system, an FFS test is performed on it before the system is returned to service. FFS is a means for performing a quantitative engineering evaluation that demonstrates the structural integrity of an in-service component containing a flaw or damage (*Fitness for Service* 2007). The API guide provides examples of what fueling mechanisms and component types can incur damage. Equipment manufacturers can also provide guidance in an evaluation. FFS tests normally are performed by third-party, state-qualified or authorized firms.

Local requirements can exist for placing a new or refurbished fuel truck into service. A certificate of FFS from a company that refurbishes or otherwise provides refueler trucks would certify that no contaminant exists in the fueling system and that the fuel tank system, components, and piping have been properly flushed and tested.

Security

Protection from intentional damage or attack is critical to the prevention of malfunctioning of or serious damage to the airport fueling system, which can cause major disruption to communities, transportation networks, and economic markets. The TSA has published guidelines for the security of fuel delivery and storage facilities on airports (*Security Guidelines for General Aviation Airports* 2004). Threat and vulnerability assessment methodologies, guidelines, and standards have been developed by U.S. government agencies, including DoD, DHS's Federal Emergency Management Administration (FEMA) and TSA, and U.S.DOT's FAA.

Beyond the installation of security fencing, gates, and locks, security measures that can be used include access control devices and requirements, intrusion detection, video surveillance, patrols, blast protective screens, lighting, barricades and terrain obstacles, and security patrols.

STORAGE TANKS

The storage of a particular fuel necessitates keeping it segregated from other types of fuels, keeping it free of contamination, and having adequate amounts of fuel to meet the needs of the airport users. NFPA 30A provides guidance on the design of fuel storage facilities (*NFPA 30A* 2015). International Air Transport Association (IATA) provides guidance for assessing the amount of fuel storage capacity needed by an airport (*IATA Guidance on Airport Fuel Storage Capacity* 2008). For delivery by fuel truck to an airport, IATA suggests adequate storage would provide reserves of 3 to 10 days. For pipeline delivery to the airport, the amount of reserve time can be less.

Settling Tank

Settling time is a factor in the delivery and use of fuel. Settling time is the length of time the industry has established for allowing sediment and moisture to settle to the bottom of a fuel. Depending on the vertical height of a tank, settling time can be anywhere from as little as 1 hour for avgas to several days for jet fuel (*Refueling and Quality Control Procedures for Airport Service and Support Operations* 2000). For jet fuel, the normal allowable settling time is 1 hour for each foot of tank depth. For avgas, allowable settling time is 15 minutes for each foot of tank depth (AC 00-34A 1974). The tank volume and daily fuel consumption rate dictate the number and volume of tanks needed. Settling time also applies to transport vehicles. Once a vehicle has arrived at the airport, standard practice is to provide a wait time before fuel is transferred to allow for settling of the fuel, which is jostled during transport.

Airports that produce a high turnover of jet fuel on a daily basis normally have three or more storage tanks (*IATA Guidance on Airport Fuel Storage Capacity* 2008). One tank is designated as the receiving tank and is used for accepting a load of fuel. A second tank is a holding and settling tank and is used to allow time for contaminants to settle. The third tank is called the operating tank and is the one from which fuel is drawn for daily use. The designated use of the tanks is routinely rotated, or fuel is pumped from one tank to another. Should a tank require maintenance or cleaning, the airport can continue to function with just two tanks.

For GA airports having just one jet or avgas fuel tank, industry practice is to plan delivery and use carefully to ensure adequate time for settling of the fuel before fuel is drawn from the tank. For avgas, one tank usually is sufficient because of the shorter settling time required. In either case, good risk management practices assess the likelihood of any one tank being unavailable for extended periods of time and determine a plan for actions to take in the event of a tank becoming contaminated or not usable.

Aboveground and Underground Tanks

The categories of permanent large capacity bulk storage facilities are known as aboveground storage tanks (AST) and underground storage tanks (UST). As taken from API, NFPA, and DoD standards, the determination of the tank construction material to be used is affected by a number of factors. The primary factors are local or state building codes or regulations, installation and maintenance costs, environmental requirements, available land, expected design life, risk and liability exposure, insurance, security, and aesthetics.

Tank material is also contingent upon the type of material to be stored. Tanks are coated or otherwise have protection from the environment, fire, and explosion. Epoxy-coated steel is the standard for jet fuel, and epoxy-coated steel or fiberglass is used for avgas and mogas. A stainless steel tank eliminates the need for epoxy coatings, although such tanks can be more difficult to repair or maintain.

Jet fuel storage tanks have a floating suction tube that draws fuel from several inches below the upper surface of the fuel. Avgas tanks draw from several inches above the bottom of a tank. The withdrawal point is the result of the water and contaminant settling properties of each fuel. If jet fuel is not to be used for a period of time, large jet fuel storage systems have design requirements for recirculating the fuel on a regular basis. This is because of the potential for microbial growth in the fuel and to maintain thermal stability. Water precipitates into the fuel from humidity and condensation on the tanks, allowing microbial growth to occur. Avgas is not susceptible to microbial growth.

Local or state regulations are to be referenced as to whether a tank is to be installed above or below ground. A literature review of several state regulations identified the requirements for the installation and inspection of ASTs and USTs, which were to be performed by tank installers with the experience, integrity, and requisite state certification approvals to do so. Both ASTs and USTs are required to meet specifications for corrosion protection, spill and overfill prevention devices, leak detection devices, and secondary containment (40 CFR 280). One consideration for AST construction is that the tanks remain below heights that penetrate obstruction clearance surfaces at airports (14 CFR Part 77).

The NFPA is a primary source of information for what flammability standards are to be met for fire-rated fuel tanks, whereas the Steel Tank Institute (STI) and the Fiberglass Tank & Pipe Institute set standards for tank construction in general (see Appendix A).

A number of benefits exist for ASTs. One is their ability to hold large capacities (5,000 to millions of gallons). Given their capacity to hold thousands of barrels of fuel (1 barrel equates to approximately 42 gallons), ASTs generally are more economical to construct for larger fuel volumes than are USTs. ASTs allow for easy inspection and detection of leaks. In the event of a leak, containment is provided through construction of a bund or earthen embankment. The drawbacks to ASTs are the physical exposure to weather, security, potential for external physical contact damage, aesthetics, and the effects of temperature change on the fuel.

USTs usually are installed horizontally below ground and are prefabricated steel or fiberglass with linings and secondary containment (double-walled). Advantages of USTs include economical installation of small capacity tanks (5,000 to 80,000 gallons), compartmentalization of the tank into two or more holding capacities, less exposure to physical damage, and more stable and consistent internal fuel temperatures. The drawbacks for USTs are related primarily to the requirement for leak detection and fuel-monitoring wells, cathodic (corrosion) protection, and the cost of a double- or triple-wall construction.

According to federal and state regulations, owners of USTs are to provide financial assurance information that demonstrates they have the financial ability to cover potential corrective actions or compensate third parties for accidental releases (The Hazardous and Solid Waste Amendments of 1984). In addition, owners and operators of new UST systems are to certify compliance with tank and piping installation, cathodic protection, financial responsibility, and release detection. All cathodic protection systems are to be tested within 6 months of installation and at least every 3 years thereafter (40 CFR 280).

Determining Fuel Tank Levels

The determination of fuel level is an important safety practice for preventing overfills. Different gauging methods exist, including resistive tape, floats, tapes, hydrostatic, radar, and servo-mechanisms, as well as the tried-and-true dipstick measurement. Figure 7 is an example of a float-type clock

FIGURE 7 Fuel tank float type clock measurement gauge. (*Courtesy*: S. Quilty, SMQ Airport Services.)

gauge. The recalibration of electrical or mechanical gauge equipment is accomplished according to the manufacturer's recommendations or local codes. There are third-party companies that specialize in calibration.

FUEL DISPENSING METHODS

Several methods exist for dispensing fuel to an aircraft. At large and medium hub airports, hydrant fuel systems are prevalent (Figure 8). In a 2003 survey of 128 member airports in North America, Airports Council International–North America (ACI–NA) found that 91 airports had fuel farms, and of those, 47 had underground fuel hydrant systems (General Information Survey 2003). A second method of fuel dispensing is a refueling truck. A third method is through a stationary fuel dispenser located adjacent to a fuel tank or away from the tank at a remote or island location.

Hydrant Fuel System

A hydrant system delivers fuel to an aircraft through an underground piping system. The piping system terminates near an aircraft parking station on the ramp. From there it can be designed as a fuel pit location or a hydrant pit. A fuel pit system is equipped with its own hose, reel, filter, and air eliminator at each pit location, thereby eliminating the need for the mobile dispenser unit. A hydrant pit is smaller and contains a connection for a hydrant service cart or similar mobile pump that connects the underground pipe to the aircraft (Figure 9). The service carts are small in comparison to a refueler truck or dispenser vehicle. Although towable, hydrant service carts usually are stationed at one particular aircraft parking spot (Figure 10). To service aircraft with high wing fueling points, a mobile fueling cart with a platform lifter is often used (Figure 11).

Fuel is pumped through a hydrant fuel system using any number of centrifugal, positive displacement, or turbine pumps operating in parallel to each other (Figure 12). A design goal for a hydrant fuel system and controller interface is to minimize pressure fluctuations within the system that could damage piping or equipment, result in loss of fuel, or adversely affect the safety of operating personnel. A nonfueling pump may operate to maintain pressure in the line, or the line may maintain static pressure through the use of ball or check valves. If a static pressure line is maintained, there is

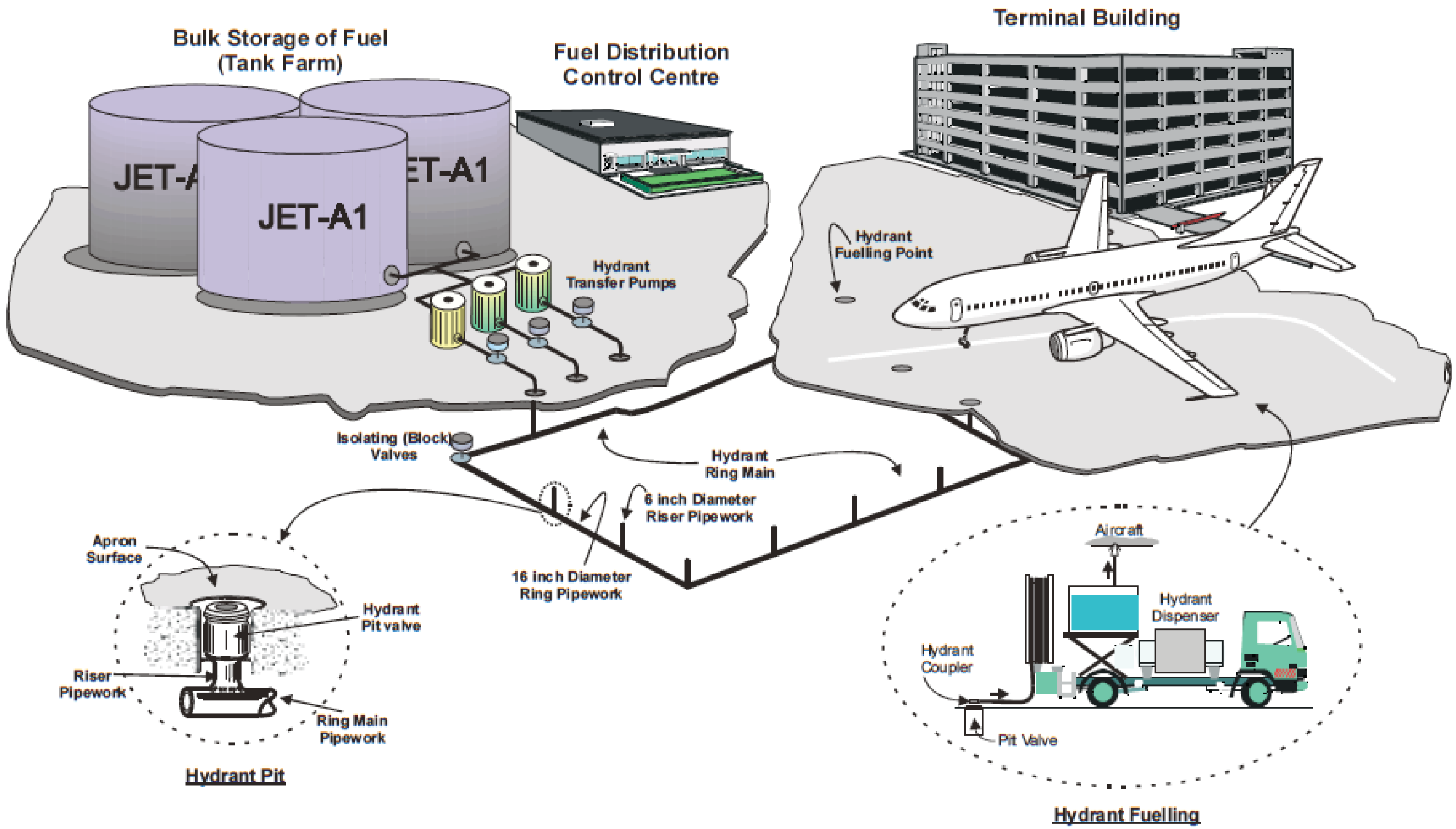

FIGURE 8 Typical fuel hydrant delivery system. (*Courtesy*: Jones et al. 2000, p. 15.)

FIGURE 9 Example of a hydrant pit connection on a terminal ramp. (*Courtesy*: S. Quilty, SMQ Airport Services.)

FIGURE 10 Example of a towable hydrant transfer cart. (*Courtesy*: S. Quilty, SMQ Airport Services.)

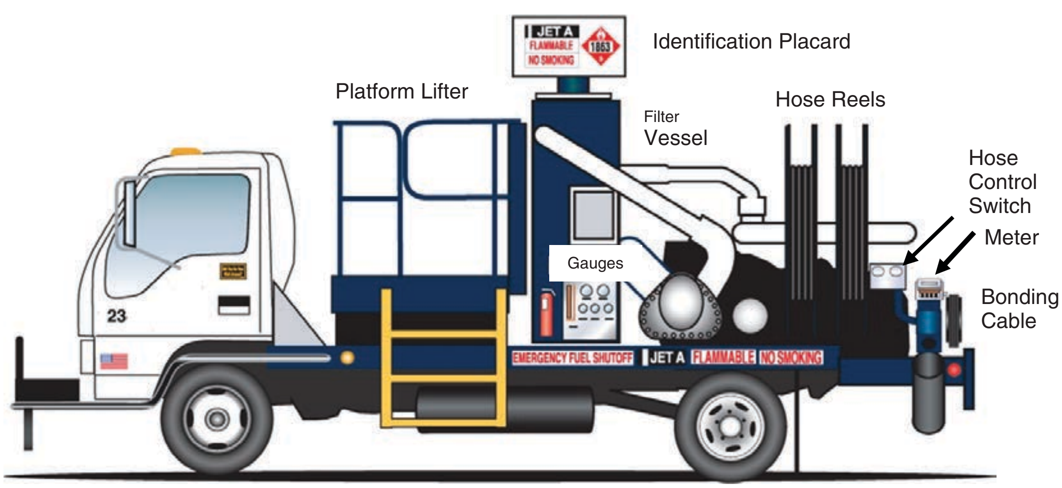

FIGURE 11 Example of a mobile platform lifter hydrant transfer vehicle. (*Courtesy*: A. Villaverde, LaxFuel Corporation.)

FIGURE 12 Example of parallel pumps for hydrant fuel system. (*Courtesy*: S. Quilty, SMQ Airport Services.)

a potential problem of spikes in pressure as a pump comes on line once a hydrant valve is opened. In-line accumulators or surge suppressors help to dampen pressure spikes.

With a constant pressure system and several aircraft being fueled concurrently, an additional pump will start to operate as needed to maintain the volume and pressure throughout the hydrant system with minimal pressure spike. An electronic control system monitors and regulates the pressures and pumps. The electronic controller can be programmed to change the lead pump each day as a means for managing wear and tear on the pumps.

The installed locations of hydrant systems built underground can limit the ability of an airline to use a type of aircraft at that position that is different from what the position initially was designed to serve. This limitation is because of the different location of aircraft fill positions and the range of service cart hoses (Anderson and Hirsh 2010).

A most effective practice in hydrant fuel system design is to have a continuous loop, rather than a terminus point. A loop system helps to eliminate stagnant fuel and the potential for microbial or other contaminant accumulation. A properly designed hydrant system takes into account the need for maintenance, testing, shutoff, and drainage without affecting other fueling areas of the airport. The placement of isolation valves allows for easy maintenance, inspection, and emergency shutoff.

One way to help mitigate the impact of a hydrant system going off-line is to install two smaller diameter pipes in parallel, as personnel at the Memphis–Shelby County International airport explained in an interview. Although such a system costs more, the design allows for shutting one line down for maintenance while retaining the capability to fuel aircraft by means of the parallel line, albeit not at the same capacity as two lines. Because it is more economical to extend an existing hydrant loop than to construct a new line from the depot area, the airport designed its system with adequate capacity, pressure, and volume to be able to expand the hydrant system for added gates or service areas.

In designing the throughput rate of fuel delivery systems, a minimum rate of 200 gallons per minute (gpm) is sought for fuel truck, barge, or railcar delivery. Higher fuel flow rates are preferred and are contingent upon system design. Considering that transport trucks often are designed to transport 8,000 to 10,000 gallons, it would take anywhere from 40 to 50 minutes to offload a single truck at a rate of 200 gpm. Pipeline deliveries can be at higher rates. Often the pipe sizes range in diameters of 8 to 22 inches. The fuel delivery system at Los Angeles International Airport pumps between 4.5 and 5 million gallons of fuel each day.

With fuel capacities of aircraft such as the B-777 and A-380 ranging from 45,000 gallons to 84,000 gallons, hydrant fueling is preferred over truck filling. Today's jet aircraft are designed to accept flow rates of 600 to 800 gpm through multiple nozzles. It is because of the length of time required to fuel an aircraft and refuel the truck at the rack-loading platform that hydrant systems are installed at airports. There is also a large impact on reduced turnaround times for aircraft occupying gates and reduced vehicle activity on the ramp.

Spill Protection

A properly designed hydrant system will take into account the potential for spillage and leakage. Newer hydrant designs accommodate a side entry of pipes into a hydrant pit, rather than the older style of entry from the bottom. Side entry allows for less chance of fuel migration into the soil if there is leakage or spillage than a bottom entry pipe seal. Side entry also allows for a catchment of any fuel spill and easy removal.

Truck Refueler Delivery System

Another method of getting fuel to the aircraft is through a self-contained refueler truck or dispenser. The fuel is stored in a chassis-mounted tank with an integral pump, filter, and meter system. The vehicle receives a load of fuel from a rack or similar loading area and is driven to each aircraft requiring fuel. The design allows for flexibility, but the size of the vehicle limits the amount of fuel available and the amount of maneuvering space in proximity to an aircraft.

Fuel trucks have typical capacities of 1,000, 3,000, 5,000, 8,000, 10,000, 12,000, and 15,000 gallons. Capacity of avgas trucks tends to be in the range of 500 to 5,000 gallons, whereas capacity for jet fuel trucks ranges from 1,000 to 15,000 gallons (Figure 13). With gross vehicle weights of 70,000 pounds or more for the largest trucks, terminal ramps and access roadways need to be designed to accommodate truck movements. The design of a truck loading/unloading area requires secondary containment per EPA regulations (40 CFR Part 112).

Stationary Fuel Dispensing System

Many small airports have a remote or stationary fuel dispenser stand that allows aircraft to taxi up to receive fuel (Figure 14). The hose, pumps, meters, and filters are commonly housed in a lockable

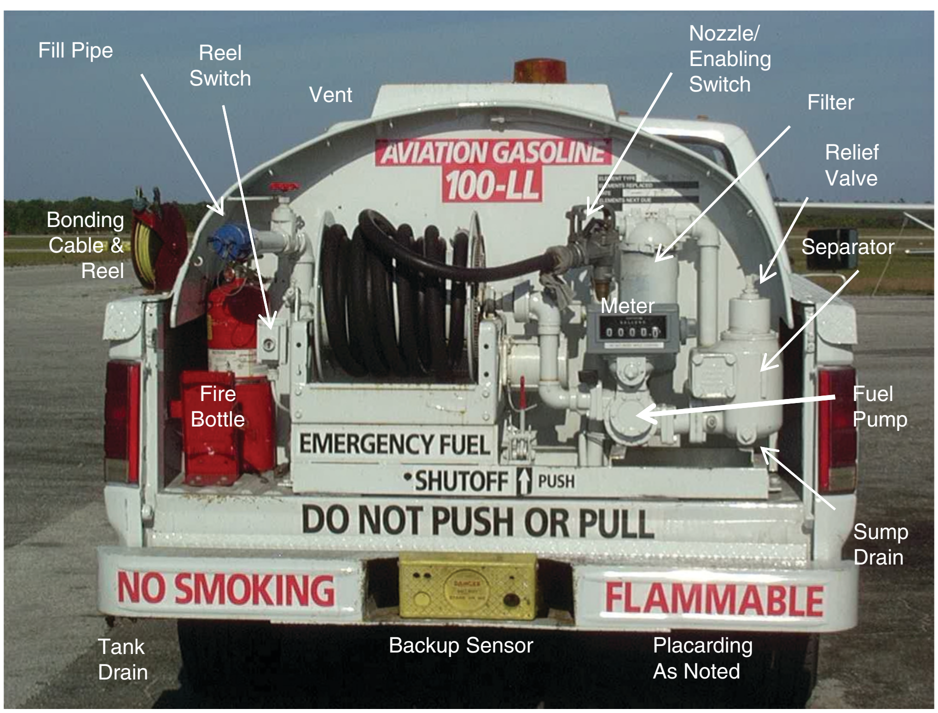

FIGURE 13 Typical 500-gallon avgas mobile refueler. (*Courtesy*: S. Quilty, SMQ Airport Services.)

FIGURE 14 Typical fuel island arrangement with low-profile cabinets. (*Courtesy*: R. Lanman, Auburn–Lewiston Airport, Maine.)

fueling cabinet. For a fuel island arrangement, the cabinet location is of low profile and is fed by underground pipes from a nearby storage tank. The island location allows for clearance of aircraft wings or helicopter rotors. Self-service fuel stations are typical of stationary fuel dispensing systems.

OTHER FUEL SYSTEM COMPONENTS

In addition to fuel storage tanks, the distribution of fuel to aircraft occurs using a number of different components, such as supply pumps, filters, meters, pressure and flow control valves, refueler trucks, hydrant piping, hydrant pits, hydrant carts, fuel hoses and nozzles, bonding equipment, and cutoff switches and valves.

Safety officials tend to agree it is important to know all of the components of a fuel system and the correct nomenclature (Smith 2005). A most effective practice is to have a diagram and list of components for any fueling system on the airport. Having the diagram promotes understanding of how the fuel flows through the system, the location of shutoff and routing valves, the types of pumps and filters, and the capacity of each tank and pipe system.

It is not uncommon for operators or managers of a fuel facility to lack facility drawings and diagrams of a system. Generally, an airport that has a spill prevention, control and countermeasure (SPCC) plan, which is required by the Oil Pollution Control Act (OPA) of 1990, has a description of the fueling facilities within the plan. The SPCC would also spell out fuel transfer procedures and the type of overflow or spill protection a fuel system has in place. The degree of detail a facility plan provides and the degree to which the equipment is adequately described can vary greatly among airports. Figure 15 illustrates a typical AST layout with bund wall containment and identification of facility components.

Fuel system diagrams are also of value in training local and mutual aid emergency response crews and for those who have inspection or operational roles, such as maintenance or operations personnel. A useful diagram includes a description of the fire suppression system or location and type of fire extinguishment. Finally, the fuel farm diagram describes the location of drains and shutoffs for containment in the event of a spill and the switches needed to cut off energy to circuits.

For safety purposes, fuel tanks can be equipped with overfill level alarms, low level alarms, automatic product level gauging, manual gauge ports, sampling ports, floating suction units, access manways, and vents, as necessary to comply with standards and codes. The most effective practice is to describe the settings of overflow protection devices and the operation of the alarm system, and provide directional flow and other markings on the piping (Figure 16). The building or fire codes of the local or state government will dictate what is required. Additional requirements may exist for meeting a certain fire resistance level and minimum distances between separate tanks and between tanks and buildings, property lines, public areas, and dispensing equipment.

Fuel Hoses and Nozzles

API/EI 1529 and NFPA 407 standards set out the requirements for fuel hose material. Inspection of a fuel hose entails checking for abrasion and cracking. If the braid is showing as a result of scuffing

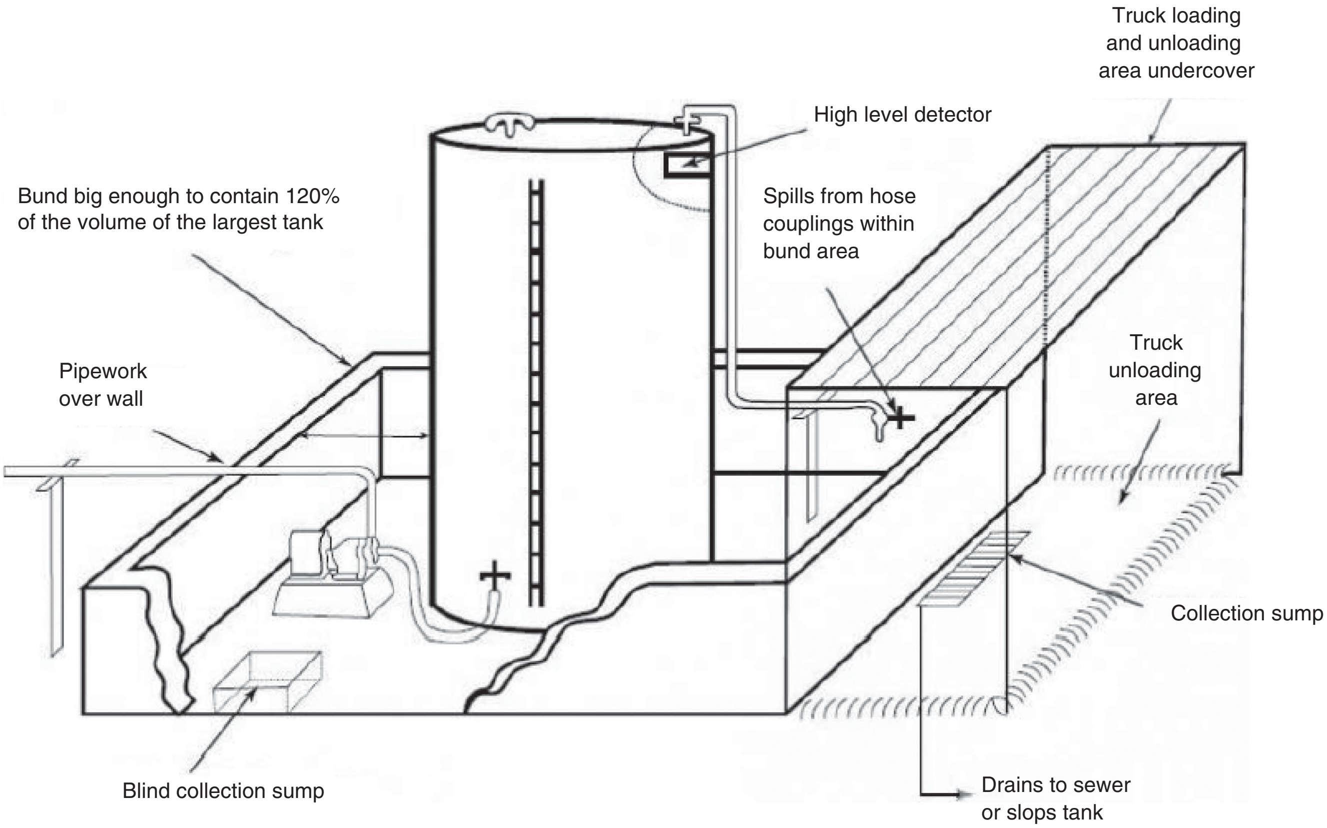

FIGURE 15 Typical aboveground tank with containment and spill protection. (*Courtesy*: Flexibund, Australia.) Used with permission.

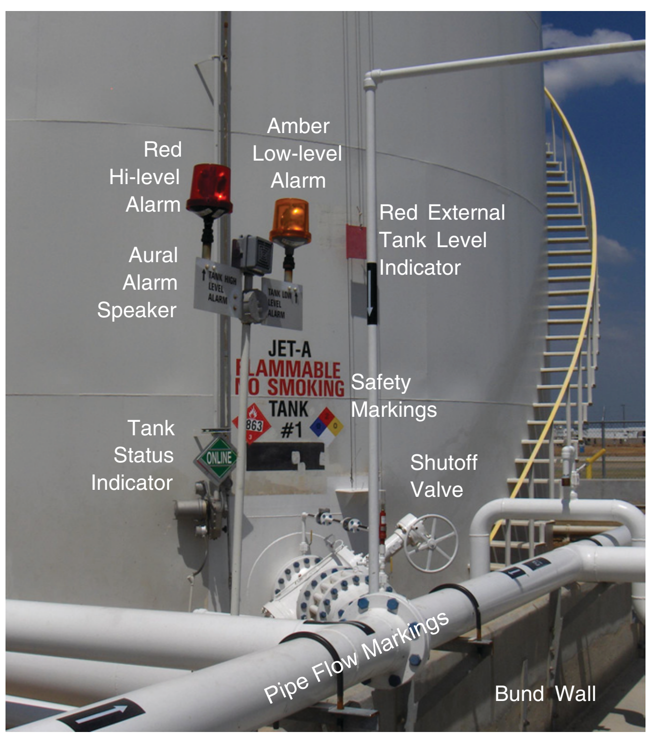

FIGURE 16 Example of a fuel tank's high-level and low-level alarms and markings. (*Courtesy*: S. Quilty, SMQ Airport Services.)

or dragging, industry practice is to replace the hose. ATA 103 establishes a maximum service life for an aircraft fuel hose of 10 years for those using that particular standard. ASTM D380 and local codes require periodic hydrostatic testing of fuel hoses.

Aircraft are designed with fuel receptacles for one or both of two fueling methods: single-point pressure feed or over-the-wing gravity feed. Single-point nozzles are used for jet fueling. The nozzle is attached to a receptacle under a wing or in the fuselage of an aircraft. It is used for high volume jet fuel transfer and helps to eliminate open exposure to static and vapor buildup.

Over-the-wing fueling is used for dispensing avgas into piston-engine aircraft or jet fuel into commercial or business jet aircraft without single-point refueling. To help safeguard against misfueling in over-the-wing situations, the industry uses safety measures including nozzle design, color coding, and placarding.

The design of jet fuel nozzles can be a single-point, flared (duckbill or J-spout), or straight (rogue spout) design (Figure 17). Avgas nozzles are round. Since 1985, aircraft manufacturers have produced aircraft with gravity feed fuel filler openings designed to prevent misfueling of jet or piston aircraft (AC 20-122A 1991). The fuel filler opening, ports, and nozzles are designed to meet Society of Automotive Engineers (SAE) 1852D standard. Fuel tank filler openings in aircraft using avgas have a maximum diameter of 2.3 inches. Jet or turbine engine fuel nozzle assemblies are equipped with nozzle spouts with a minimum diameter of 2.6 inches, thereby reducing the probability of introducing jet or turbine engine fuel nozzles into the filler openings of aircraft that require gasoline. In addition, a flared jet fuel nozzle design was introduced at that time to further distinguish the fuel type in use.

Misfueling accidents can (and do) occur because older aircraft may not have been modified to the smaller avgas opening; operators continue to use small round diameter nozzles; operators get tired of switching out the flared nozzle for a straight nozzle when filling different types of aircraft, especially helicopters; or operators prefer the reduced flow rates of a smaller nozzle (Mooney 2006). One commercial operator who needs a reduced flow rate uses a 1.5-inch straight nozzle with a 2.6-inch collar attached to help prevent the introduction of jet fuel into an avgas port (Figure 18).

AC 20-122A recommends that airport owners amend their airport operations manual to encourage FBOs and other suppliers to meet the SAE size specifications for jet fuel nozzle spouts.

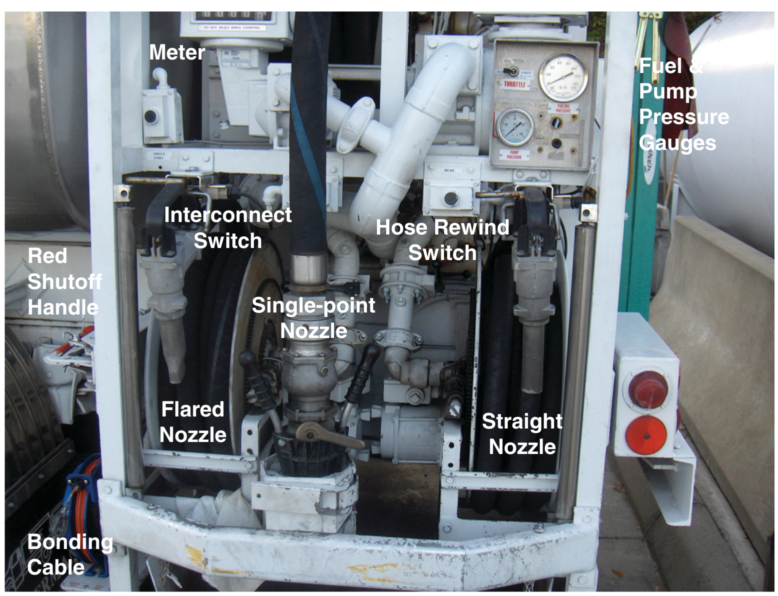

FIGURE 17 Different nozzles used on jet fuel truck dispenser. (*Courtesy*: S. Quilty, SMQ Airport Services.)

FIGURE 18 Collar attachment to nozzle to prevent fueling of jet fuel into avgas aircraft. (*Courtesy*: S. Quilty, SMQ Airport Services.)

To further help prevent misfueling, black lettering and color coding are applied to jet fuel facilities (Figure 19). Red coding is applied to avgas facilities and components. NFPA 407, ATA 103, and AC 00-34A identify standards for placarding fuel trucks, piping, and storage facilities (see Figures 13 and 16).

The third method for preventing misfueling is through placarding. Accepted standards for the marking of fuel systems are found in EI 1542, API 1637, NFPA 385, and AC 00-34A.

Fuel Type and Grade	Color of Fuel	Equipment Control Color	Pipe Banding and Marking	Refueler Decal
AVGAS 82UL	Purple	82UL AVGAS	AVGAS 82UL	82UL AVGAS
AVGAS 100	Green	100 AVGAS	AVGAS 100	100 AVGAS
AVGAS 100LL	Blue	100LL AVGAS	AVGAS 100LL	100LL AVGAS
JET A	Colorless or straw	JET A	JET A	JET A
JET A-1	Colorless or straw	JET A-1	JET A-1	JET A-1
JET B	Colorless or straw	JET B	JET B	JET B

FIGURE 19 Standard color coding and marking of pipes and equipment. (*Courtesy*: FAA Aviation Maintenance Technician Handbook—Airframe 2012.)

Fuel Filtering

A general rule and common practice in the design of jet fuel and avgas systems is that each time fuel or gas is moved, it passes through a filtration system (see Figure 3). Fuel is filtered from the supplier tanker vessel to the storage tank, from one storage tank to another, from the storage tank to the hydrant or refueler truck, and from the hydrant or refueler truck to the airplane.

The filtering system is intended to remove all particles, including dirt, rust, and live microbial organisms. Fungi and bacteria are prone to grow in jet fuel that has remained stagnant for a period of time. A typical large two-stage vertical fuel coalescer filtering system is shown in Figure 20. Filter

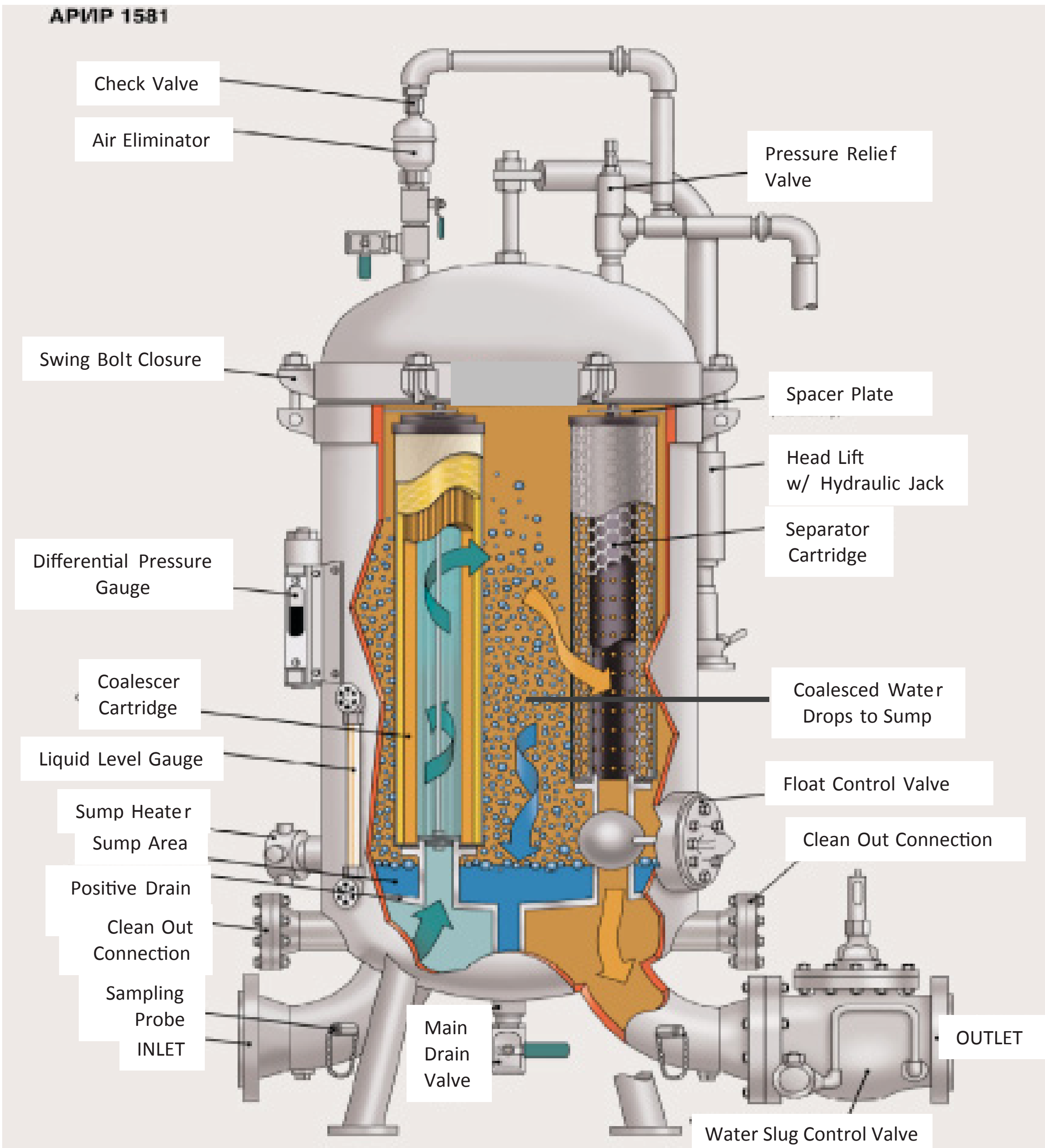

FIGURE 20 Typical fuel coalescer filter system for bulk storage. (Adapted from Precision Filtration Products.) Used with permission.

vessels can also be designed for horizontal installation. Fuel trucks and smaller tanks have smaller individual filter water/separator vessels.

The condition of a filter media within a vessel is generally measured using a differential pressure gauge. Differential gauges can be visual, mechanical, or electrical. Standard industry practice is for a maximum differential of 15 psi when operating at design flow rates (PEI Aviation Fueling Committee 2013). If flow rates are reduced from what the system was designed for, lower filter media differential pressures are to be applied per the standards or manufacturer recommendations.

Other Design Components

As part of a quality control management program and for environmental and operational reasons, familiarity with the function, purpose, and location of all the design components of a fuel system is important. Gaining familiarity with the system can lead to better decisions about maintenance, operation, and emergency response in the event of a malfunction. The glossary provides a list of common components and terms used in the design of storage facilities, pump transfer and piping systems, and truck, stationary, and hydrant delivery systems (see Glossary and Fuel System Terminology). Figure 21 shows several system components associated with a horizontal AST.

Accessible on the web and within many of the standards, suggested practices, and guidance material listed in Appendix A are detailed descriptions and functional explanations of common components used in fueling systems.

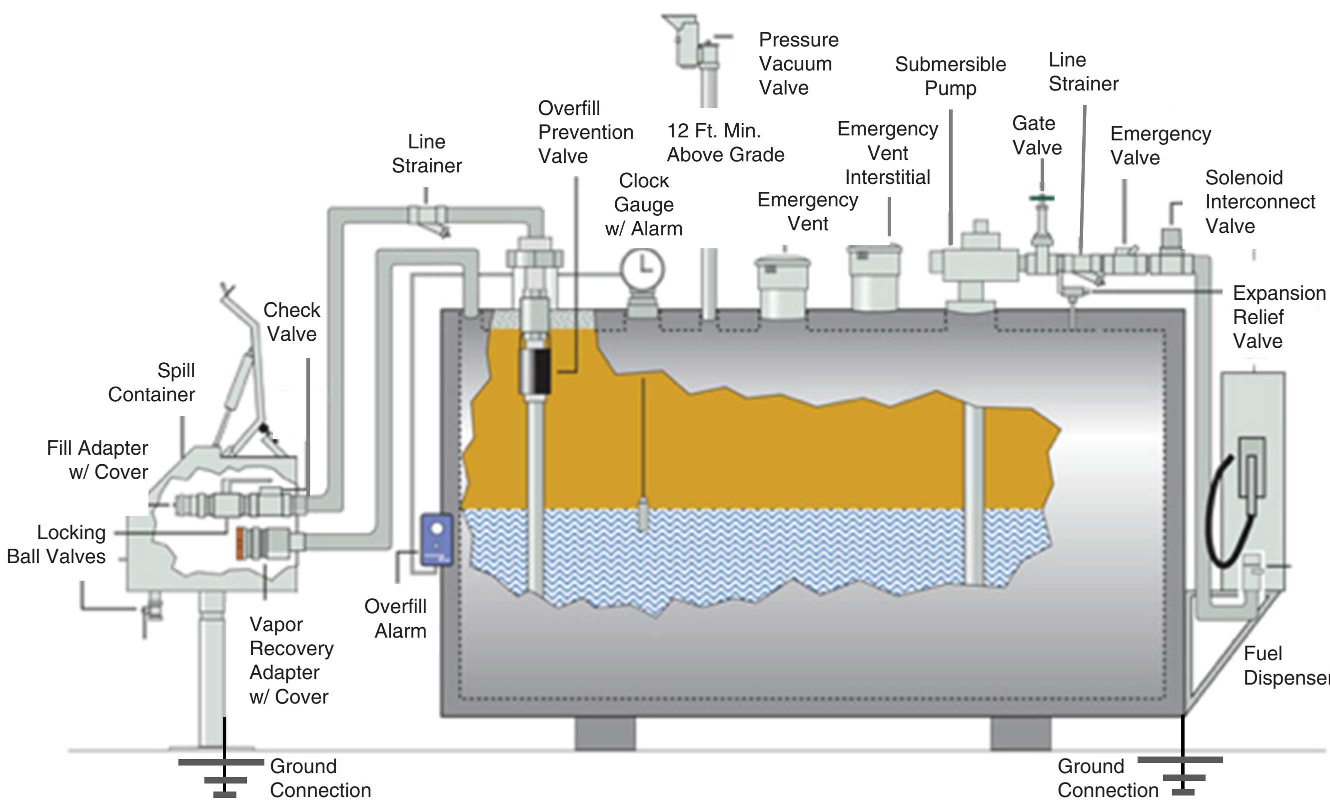

FIGURE 21 Components for a horizontal AST. (Adapted from Morrison Bros.) Used with permission.

CHAPTER FIVE

RESOURCES AND TRAINING TOOLS

The nature and importance of fuel processing, distribution, and delivery require that standards be established for safety and quality purposes. A number of different professional and governing bodies have formed committees or boards to oversee the development of standards throughout the world.

There is no regulatory requirement for the acceptance of any one particular standard because conditions, requirements, and operations vary throughout the world. What has emerged has been the development of standards that have gained prominence and acceptance over the years and whose strength as a standard stems from incorporation into operating agreements and contracts. A local governmental unit, an airline, or an airport organization can adopt a certain set of standards to be followed, thereby making the adopted standards the accepted way of doing business.

Most standards have evolved from professional organizations having expertise in a particular matter or the members of such groups seeking to standardize equipment, processes, and quality for their benefit. For instance, in the United States, airlines sought to achieve standardization of fueling delivery and distribution through their organization, the Air Transport Association (ATA), which is now called A4A. The work that came out of committee was ATA Specification 103, *Standard for Jet Fuel Quality Control at Airports*. Because ATA 103 was adopted by member airlines, it has become the de facto standard for how fuel is handled by or for the airlines in the United States. Elsewhere in the world, JIG and EI are the prevalent standards. A comparison of what areas of fuel processing the ATA, JIG, and EI standards cover is shown in Figure 22.

ORGANIZATIONS

The following list includes descriptions of several major organizations involved in establishing standards and certification and providing training regarding fuel delivery and handling practices at airports.

American Petroleum Institute

API is an organization that represents oil and natural gas producers, refiners, suppliers, pipeline operators, and marine transporters, as well as service and supply companies that support all segments of the industry. API has developed and published numerous voluntary standards for equipment, materials, operations, and processes for the petroleum and natural gas industry. The standards are used by private industry and governmental agencies. Since 2010, many of the publications generated by API have transitioned to the EI.

Energy Institute

EI is a professional organization for the energy industry. Its purpose is to deliver good practices and promote professionalism across the depth and breadth of the industry. It achieves its goals by developing and disseminating knowledge and skills about good practices for energy system operation worldwide. In that regard, EI has taken over the distribution of many industry standards and suggested practices, in particular those of global aviation fuel handling equipment standards.

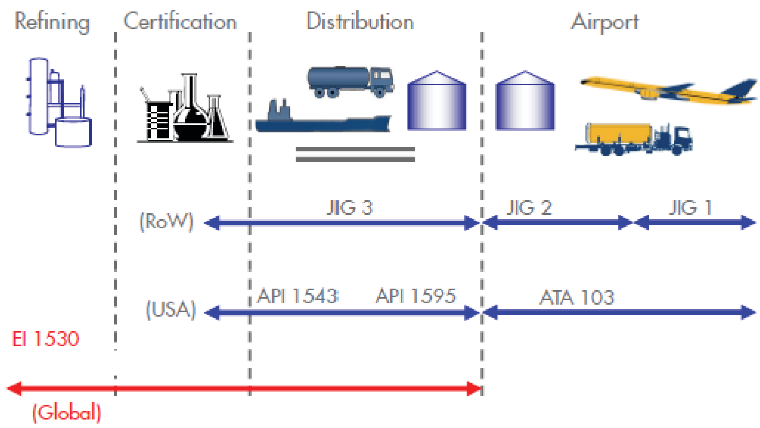

FIGURE 22 Comparison of API, ATA, JIG, and EI standards and point of industry application. RoW = rest of world. (*Courtesy*: Shell Aviation Limited.) Used with permission.

Joint Inspection Group

Similar to the purpose of ATA Specification 103, JIG was formed to develop a set of standards that govern the operation of shared fuel storage and handling facilities at the world's major airports outside the United States where JIG members operate.

Petroleum Equipment Institute

PEI is a professional organization made up of companies engaged in the manufacturing and distribution of equipment used in the petroleum and energy handling industry. It offers a variety of items covering technical and regulatory information of special concern to manufacturers, sellers, installers, and users of petroleum marketing equipment. It further provides education, testing, and audit services.

International Civil Aviation Organization

ICAO has responsibility for fostering the orderly development, growth, and safety of international aviation. The 9977 *Manual* specifies the role and responsibility of a business entity involved in the aviation fuel supply chain. The *Manual* lists a number of organizations that have developed policies, procedures, and standards for safeguarding aviation fuel quality and ensuring the safe management of fuel operations from the point of manufacture to delivery into aircraft fuel tanks.

ASTM

Now called ASTM International, this professional organization develops and delivers a large number of voluntary consensus standards for test methods, specifications, guides, and practices that support industries and governments worldwide. Related to aviation, ASTM standards are used to ensure the consistent quality and delivery of fuel.

Coordinating Research Council

Through committee action, the CRC is a nonprofit organization that directs engineering and environmental studies on the interaction between automotive and other mobility equipment (including aviation) and the use of petroleum products. The formal objective of CRC is to encourage and promote the arts and sciences by directing scientific cooperative research to develop the most effective possible combinations of fuels, lubricants, and the equipment in which they are used, and to afford a means of cooperation with the government on matters of national or international interest within the field.

SAE

SAE International is a global association of engineers and related technical experts in the aerospace, automotive, and commercial vehicle industries. It also helps develop voluntary consensus standards in the aerospace industry on safety issues.

International Business Aviation Council

IBAC is an international, nongovernmental association that represents, promotes, and protects the interests of business aviation in international policy and regulatory forums. It sponsors the International Standard for Business Aircraft Handling (IS-BAH), which is a set of most effective practices for the industry and standardization for ground handlers and operators around the world to meet the coming SMS requirements from the ICAO.

STANDARDS AND RESOURCES

Appendix A provides a sample resource list of the standards, documents, training, and certifications that various organizations have developed regarding airport fuel handling. Many are technical in nature but are useful for better understanding the operation and design of components and enhancing the knowledge and education of individuals. Found within the documents, in particular those of ICAO, ASTM, API, EI, PEI, and FAA, are additional lists of referenced and useful documents.

TRAINING

A number of factors make it prudent for an organization with responsibility for fueling to have well-trained individuals. Factors include reduced liability and risk exposure, reduced insurance premiums, compliance with state or local fire codes, compliance with industry best practices, compliance with fuel supplier or customer requirements, and enhancement of public and business relations. Fuel system operation and training can be obtained through any of five general categories of providers:

1. Airport.
2. Fuel providers and agents.
3. Professional trade organizations.
4. Consulting companies.
5. Educational institutions.

For airports certificated under 14 CFR Part 139, FAA requires the development of standards for protection against fire and explosions in the storing, dispensing, and handling of fuel on the airport. The standards, policies, and procedures are more focused on the safety aspects of fueling than on the functional operation of systems and components. Airports that are not certificated under Part 139 do not have the same requirements, although state or local codes may apply to them.

FAA AC 150/5230-4B (2012) provides guidance for the training of individuals involved in airport fuel handling. Examples of airports that provide fuel-handling training can be found at the Phoenix Sky Harbor International Airport (*Study Guide for Fuel Handlers* 2006) and the Juneau International Airport (*Juneau International Airport Study Guide for Fuel Handlers* n.d.).

A standard web search will provide information on available courses, consultants, professional organizations, and fuel providers. Cited most frequently as an industry standard in interviews with fuel service agents and providers is the Safety 1st program sponsored by NATA ("Education & Training Programs" 2014). Other programs are noted in Appendix A and in an addendum to AC 150/5230-4B (2014). The addendum provides a list of fuel safety training course providers that have been approved by the FAA (AC 150/5230-4B—Addendum 2014). Most of the major aviation fuel providers, because of the importance of delivering safe, clean, dry fuel, will provide specialized training to member organizations. Training programs offered by the oil industry generally are offered and provided as part of their agreements with fuel distributors and fueling agents.

A training program for fueling personnel can contain topics similar to those identified in ICAO Document 9977 (*Manual on Civil Aviation Jet Fuel Supply* 2012), including

- receipts;
- transfers;
- storage;
- dispensing;
- product inspection and routine check program;
- quality control and maintenance record-keeping requirements and record retention times;
- emergency response;
- reporting of observed deficiencies or hazards that could generate risks to the safety of personnel, facilities, or equipment, including aircraft;
- managing and handling contaminated fuel;
- procedures for handling defueled fuel products; and
- customer notification.

JOB DESCRIPTION

The responsibilities for the delivery of safe, clear, and bright fuel to aircraft lies with the skill and knowledge of the individuals engaged in the fueling process at all stages of fuel delivery, from the refinery to the into-plane agent. Job duties can vary from position to position in the fuel supply chain. Typical duties and essential knowledge requirements for an individual engaged in fueling operations might include any of the following:

- Maintain a safe and efficient operation.
- Ensure customer standards are met and contract services are performed.
- Ensure company safety and health policies are enforced.
- Ensure compliance with FAA, TSA, IATA, ATA, U.S. Customs, airport authority, and company rules and regulations.
- Ensure compliance with ATA 103 Fuel Quality Control Specification, NFPA 407, and Federal Aviation Regulations (FAR) Part 139.321.
- Ensure accurate accounting of fuel transactions.
- Perform daily quality control checks on equipment.
- Maintain equipment in clean and functional condition.
- Ensure the correct loading and balancing of fuel.
- Check equipment for unsafe conditions and take appropriate action to remove any such conditions.
- Operate valves and manifolds for product receipt from suppliers by means of pipeline, tanker or barge, tank truck, and railcar deliveries.
- Receive/dispatch jet fuel, gasoline, diesel fuel, avgas, and glycol by means of pipelines and trucks.
- Sample and test products for quality control and perform inspections and basic maintenance on facilities, fuel systems, and fueling vehicles.
- Complete daily fuel reports and log entries of fuel transactions, quality control, and maintenance.
- Audit and correct fuel-related paper work, as required.
- Transfer product and monitor storage tanks, pipelines, and related equipment to ensure that they are in good working order to prevent spills, releases, overfills, and product contamination.

CHAPTER SIX

FUELING SAFETY PRACTICES

In 1964, the CRC reviewed technical information on the safe handling and usage of aviation gasoline and jet fuel available at that time. The report concluded: "safety of fuel handling is more a function of equipment design, proper handling techniques, and rigorous precautions than of the particular fuel type employed" (*Aviation Fuel Safety* 1964). Safeguarding the entire fuel system from contaminants, flash point sparking, and leakage is an important aspect of the fueling industry. Built-in safety features, such as fuel level and leak monitoring systems, automatic fire suppression systems, and vehicle collision protections, are integral features of an airport fueling system.

FUEL CHARACTERISTICS

Jet fuel is a combustible liquid, whereas avgas is a volatile flammable liquid. Contaminated fuel results in underperforming or failed engines. Spilled fuel can contaminate the ground, water, and air. Fuel vapor can affect human health. Over-the-wing fueling exposes a worker to the vapors, and in the case of avgas, such vapors are easily ignited by static electricity. It is for these reasons that the industry takes utmost care and concern in the safe handling of fuel.

Basic Properties of Aviation Fuels and Gasolines

A review of training material developed for the industry generally includes information on the properties and characteristics of fuel. A basic understanding helps to minimize or prevent injury, damage, or loss as a consequence of fuel use or misuse. Table 1 presents basic data about different fuel properties and characteristics; the data are taken from various material safety data sheets (MSDS). Specific oil company products can vary from the table listings. To be used in aviation, fuels must meet the standards established by API, ASTM, IATA, JIG, or EI. For a more comprehensive description of the properties and their fuel handling procedures, refer to ASTM's *Fuel Quality Control Procedures* (2009).

Clear and Bright

When examined visually, industry standards call for jet fuel to appear clean and dry, clean and bright, or clear and bright. The standards identify clean fuel as one that lacks particles, silt or sediment, flakes, dye, rust, or solids. A bright fuel is one that visually sparkles and is not cloudy or hazy. Although no definition for the term "dry fuel" was found in the literature, "wet fuel" is described as any form of free water appearing as droplets or bulk water on the bottom of a white bucket or clinging to the sides (*Standard for Jet Fuel Quality Control at Airports* 2009). A dry fuel appears bright because of the absence of water. The bright distinction is made because a sample of fuel that is wholly water would appear clear but dull and not have a sparkle to it. Figure 23 shows different stages of jet fuel contamination from clear and bright (*left*) to opaque with excess water (*right*).

The term "clear and bright" is used more commonly by the industry than the other terms. According to ASTM D6986, the terms "clean and bright" and "clear and bright" have identical meaning. FAA AC 20-125 provides this distinction:

> Smaller amounts of entrained water can be detected by testing with a clean and dry clear glass bottle. If fuel is acceptably dry it will appear bright with a fluorescent appearance and will not be cloudy or hazy. The clear and dry bottle test is known as the 'clean and bright' test. The fuel is clean when it is clear and is bright when it is dry. (AC 20-125 1998)

TABLE 1
PROPERTIES AND CHARACTERISTICS OF VARIOUS AVIATION FUELS

Type of Fuel	Jet-A	Jet-A1	Jet-B	JP-5	JP-8	Avgas100	Avgas 100LL
Fuel basis	Kerosene base	Kerosene base	Kerosene/ naphtha blend	Kerosene base	Kerosene base	Gasoline	Gasoline
Use	Commercial, narrow cut	Commercial, cold climate	Commercial/ military, wide cut, easy start	US Navy/ US Coast Guard	US Air Force	High HP/ compression piston	Low compression piston engines
Additive	SDA	FSII, SDA	SDA	CI/FSII/SD A	CI/FSII/SDA/ lubricants		Antiknock/ antioxidant/ SDA
Flash point	37.8°C/ 100°F	>38°C/ 100°F	≤29°C/ −20°F	60°C/140°F	38°C/100°F	−46°C/ −51°F	≤40°C/−40°F
Autoignition temperature	210°C/ 410°F	>220°C/ 428°F	246°C/ 475°F	246°C/ 475°F	210°C/ 410°F	440°C/ 824°F	>250°C/ 482°F
Lower/Upper flammability or explosion limits	0.6–4.7% (V)	1–6% (V)		0.7–7% (V)	0.7–5.0% (V)	1.0–6.6% (V)	1.4–7.6% (V)
Vapor pressure	0.0077 psia	<0.014 psia at 20°C/68°F	2.5 psia at 38°C/100°F	<1 psia at 38°C/100°F		5.5–7.1 psi at 38°C/100°F	>5.5 psia at 38°C/100°F
Flame spread rate	100 fpm	100 fpm	100 fpm	100 fpm	100 fpm	700–800 fpm	700–800 fpm
Boiling point/ boiling range	149°–300°C/ 300°–572°F	150°–300°C/ 302°–572°F	72°C/162°F	179°C/ 354°F	160°C/ 320°F	60°–170°C/ 140°–338°F	25°–170°C/ 77°–338°F
Freezing point	≤40°C/ −40°F	≤47°C/ −53°F	−65°C/ −85°F	−46°C/ −51°F		−58°C/ −72°F	−58°C/−72°F
Color	Clear, light yellow	Pale straw	Clear	Colorless	Clear, white	Green	Clear, blue

Adapted from Material Safety Data Sheets (MSDS) of various manufacturers. Use for illustrative purposes.
fpm = feet per minute; HP = horsepower; psia = pounds per square inch absolute.

The goal of jet fuel transport and delivery is for jet fuel to conform to the latest revision of ASTM D1655, *Standard Specification for Aviation Turbine Fuels, Jet A or Jet A-1 Kerosene Type*. Two common means to quickly and easily check for the clear and bright characteristics are with a "white bucket" test, or with use of a clear glass jar. A white porcelain bucket is necessary for the proper detection of fuel color (*Standard for Jet Fuel Quality Control at Airports* 2009). Jet fuel has an appearance of no color (clear) to straw color. Kerosene-based fuels used for nonaviation purposes

FIGURE 23 Different contamination levels of jet fuel. (*Courtesy*: Precision Filtration Products; used with permission.)

have colored dyes that make cross-contamination more easily apparent. Avgas has a blue or green dye tint, depending on the grade.

Additional quality control checks used in the industry include the use of water detection kits (because the human eye is not capable of detecting free water below approximately 30 parts per million) and API gravity testing (*Refueling and Quality Control Procedures for Airport Service and Support Operations* 2000). ASTM Manual 5, ASTM D3240, ASTM D1298, and ANSI/ASTM D287 provide further guidance on water detection, gravity, and other quality checks.

The literature indicates the most common types of contaminants found in fuel are water, dirt, iron rust, scale, and sand. Other contaminants found include metal particles, dust, lint from filter material and rags, gasket pieces, and sludge from microbacteria.

FIRE SAFETY ISSUES

Of major concern to all involved in the operation of a fuel system is the potential for fire and explosion. A fire is the result of a heat source igniting a correct mixture of fuel and oxygen. The fire tetrahedron is a model for understanding the components needed for a fire; FAA efforts to prevent a fire are focused on eliminating one or more of the three components. It is difficult to eliminate oxygen or the use of fuel in aviation, so safety efforts are focused on reducing sources of heat or ignition (AC 150/2530-4B 2014).

Sources of ignition can include lightning, open flame, electrical spark, static discharge, chemical reaction, or any heat source that can raise or ignite the fuel-air vapor mixture. It is for this reason that fuel trucks have sealed lights, wiring, and switches; no cigarette lighters; enclosed battery boxes; and other measures designed to eliminate a potential spark, ignition, or heat source.

The distinction between jet fuel as a combustible liquid and avgas as a volatile flammable liquid lies in their flash points, or the point that a readily ignitable mixture of air and vapor exists. If a material has a flash point at or above 100°F, it is considered combustible. Flammable materials are those with flash points below 100°F and/or a vapor pressure not exceeding 40 pounds per square inch (psi). Jet fuel can have a flash point between 95°F and 140°F, making it either a flammable or combustible product, depending upon its product formulation. Avgas easily produces adequate vapors to mix with air and can be ignited at temperatures warmer than −40°F. For this reason, caution with avgas is to be taken under any temperature condition because it is very volatile (will ignite easily).

A primary safety concern for avgas and jet fuel storage, piping, transfer equipment, and vehicles is the possibility of static discharge or lightning igniting a fuel. Industry standards call for provisions to be made for the grounding and/or bonding of facilities and equipment, as per regulations, standards, fire code, or other design and operating requirements.

Fuel moving through a fuel pipe or hose generates electrostatic potential. API 2003 provides information on acceptable flow rates given pipe size and other factors (Protection Against Ignitions Arising Out of Static Lightning and Stray Currents 2008). The slower the flow rate, the less the electrostatic potential. Bottom or single-point loading helps to reduce vapor generation. Over-the-wing fueling (splash filling) has bonding and flow rate requirements different from those of bottom or single-point loading. For low flow over-the-wing nozzles, having or maintaining a bond with the aircraft filler at the nozzle is a most effective practice. In either case, standards call for the fuel pump, cart, or truck to be bonded to the aircraft.

When a fuel/air mixture is ignited, the speed with which the flame will spread across the pool of vapors is an indication of the fuel's volatility. This is called flame spread rate. Jet fuel has a slow flame rate, such that if a pool of jet fuel is ignited at one end, a person can briskly walk away from the advancing flame. For avgas, if a pool is ignited at one end, it will propagate faster than a person can escape.

A number of tutorials exist on the web to familiarize employees with fire and explosion hazards and with combustible and flammable products. Available from FEMA is a report on the experiences of the Pittsburgh International Airport (PIT) with fuel-related emergencies and how to minimize or mitigate such emergencies (Eicher n.d.).

HEALTH SAFETY ISSUES

A number of health issues are involved with the handling of fuels. Information is best found on the MSDS for the product being used or through the *Emergency Response Guidebook* (2012). An MSDS identifies the specific safe handling procedures and health effects of exposure. A proper fuel handling training program normally addresses these safety issues.

According to Occupational Safety and Health Administration (OSHA) and a review of MSDS, health can be affected by acute or chronic exposure to gasoline, diesel, and jet fuels. Avgas can cause skin and eye irritation. Inhaling its vapors can cause unconsciousness; ingestion into the lungs is harmful and can be fatal. Jet fuel is harmful or fatal if swallowed. Lung damage can occur from inhalation of the mist, and its fumes will irritate the skin, eyes, and respiratory tract. Consistent skin contact can result in cancer. OSHA guidance provides that eyewash facilities and deluge showers are to be available for use in the event of splashing or spraying of fuel on a person (Figure 24). A review of MSDS is commonly provided in any industry training material.

Studies have shown neurotoxic effects of hydrocarbon exposures may lead to neurobehavioral consequences (*Medical Management Guidelines for Gasoline* 2014). A search of literature from the U.S. National Institute for Occupational Safety and Health (NIOSH) showed a number of studies have been completed on exposure to jet fuel and avgas during fueling operations. Although none of the NIOSH investigative reports found exposure to the effects of jet fuel beyond acceptable limits, they did find a hazard exposure to carbon monoxide (CO) as a result of a fuel handler's exposure to refueler truck operation. During inclement weather, operators often sit inside idling fuel trucks to stay warm. CO exposure occurs as a result of the cabin's closeness to the exhaust outlets (Millar 1984).

FIGURE 24 Example of eye wash and water deluge system at a fuel loading area. (*Courtesy*: SMQ Airport Services.)

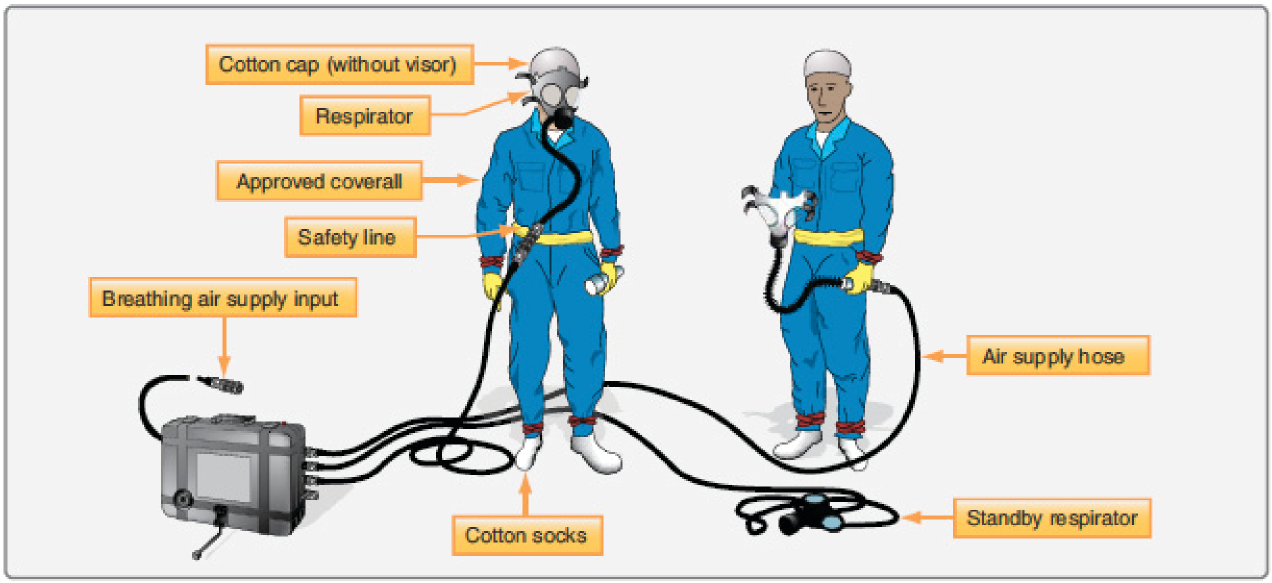

FIGURE 25 Equipment required for certified confined space fuel tank entry. (*Courtesy*: FAA *Aviation Maintenance Technician Handbook—Airframe* 2012.)

Fuel system icing inhibitors (FSII) can be toxic if absorbed into the skin because of their affinity to join with water. FSII is not contained in Jet A, which is the prevalent fuel in the United States. However, there are certain jet aircraft engines that require FSII. For civilian aircraft needing an FSII, the agent normally is injected into the fuel tank along with the jet fuel to achieve proper atomization. Any spillage is to be immediately addressed according to the product's MSDS.

OSHA guidance is for fuel handlers and testers to use fuel-resistant gloves and approved protective eyewear when fueling aircraft or testing fuel (*Personal Protective Equipment* 2003). If entering a confined space, such as a UST or AST, OSHA's confined space entry regulations apply. In particular, nonstatic protective suits and respirators are to be worn, fuel vapors are to be purged from the tank, forced air provided, respiratory equipment used, and a spotter is to be positioned just outside of the tank to assist if needed (Figure 25).

HUMAN FACTOR ISSUES

Human factors are described by the FAA as a multidisciplinary effort to generate and compile information about human capabilities and limitations, and apply that information to equipment, systems, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, and effective human performance (FAA Order 9550.8A 2005). The factors that affect humans and their work performance can be varied, as compiled from various human factor definitions. They can include the following:

- workload,
- fatigue,
- shift work,
- human error,
- visibility,
- user interface,
- vigilance,
- attention,
- individual differences,
- cognition,
- learnability,
- accessibility,
- sensation,
- data visualization,
- aging,
- stress,
- situational awareness,
- perception,
- human performance,
- usability,

- control and display design,
- motor control,
- muscular strength, and
- work in extreme weather conditions.

From interviews with fueling operators and from the literature review, it was found that training on human factors is increasingly incorporated into the material for fueling operators. This is in conjunction with overall efforts by the airlines and trade organizations to reduce accidents and by the FAA to advance SMS processes into the airport and ground handling functions.

A lack of vigilance and complacency are two factors of concern in the fueling industry. For instance, a required safety practice in place for the pumping of fuel is to have an enabling switch (a dead man's switch) (*NFPA 407* 2012). In addition to a pump switch that activates the flow of fuel, the enabling switch is triggered to allow for continued operation. It requires the presence of a human operator to monitor the fueling activities. Should the employee become incapacitated or face an emergency, a release of the switch or a lack of a human response will shut off the fuel (Figure 26). For over-the-wing fueling operation, the switch can be integrated into the pump handle. For fuel transfer operations from a truck or hydrant system, the enabling switch can be a separate electrical or pneumatic switch.

The problem of complacency can arise during transfer of fuel, especially for large volumes. As noted, the loading or unloading of fuel can be a lengthy process. During that time, the human operator is to be doing nothing but monitor the transfer and clutch or press the enabling switch. For an A-380 aircraft with a capacity of 84,000 gallons, fueling through a hydrant system and double nozzles can take upward of 2 hours of monitoring time. It is easy for a lack of vigilance or complacency to affect the human operator, especially if no incidents have occurred in recent memory. Operators have been known to attempt to defeat the need to hold the enabling switch by blocking or tying it off (Figure 27). To combat complacency or defeated safeguards, some switches require activation at certain intervals during the fueling process to ensure the operator remains attentive.

Human factor problems with fueling are seen in accident reports in which an operator misfueled an aircraft with quantities other than what was expected, such as delivering the fuel in pounds, rather than in liters or gallons. One FBO operator in the study has painted "WE PUMP IN POUNDS" in large letters on its jet fuel truck. Employees are trained to verify pilot fuel order quantities and calculate proper conversion if necessary.

Human factor issues can further be seen in a fuel-handler confusing a turbojet-powered aircraft that uses jet fuel with one that has a turbocharged piston engine that uses avgas. Misfueling will

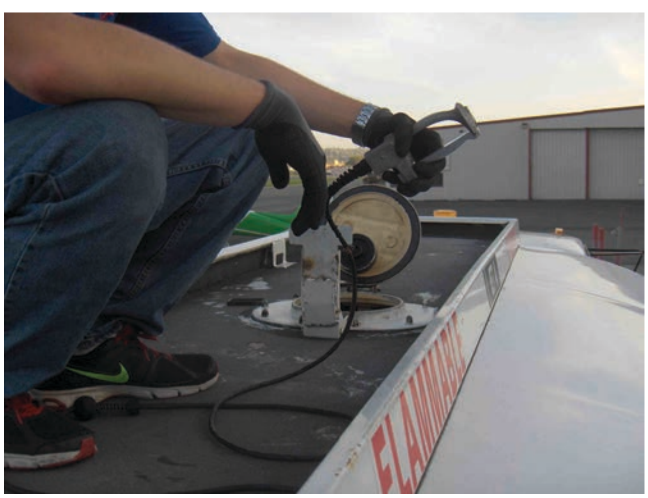

FIGURE 26 Example of employee monitoring mobile tank fill and operating an enabling switch. (*Courtesy*: S. Quilty, SMQ Airport Services.)

FIGURE 27 Sign designed to deter an unsafe fuel loading practice. (*Courtesy*: S. Quilty, SMQ Airport Services.)

result in a damaged engine and poses a severe safety threat. EI 1597 (2006) provides a comprehensive set of procedures for addressing the many possible causes of misfueling. To enhance safety and reinforce training, two airports in the study posted their fuel loading and off-loading procedures at their respective transfer stations (Figure 28).

ACCIDENT INFORMATION

The review for this synthesis did not discover a public lesson-to-be-learned database of accident or incident reports. Although data are collected through insurance, oil companies, and professional organizations, the data generally are retained within those organizations and not made freely

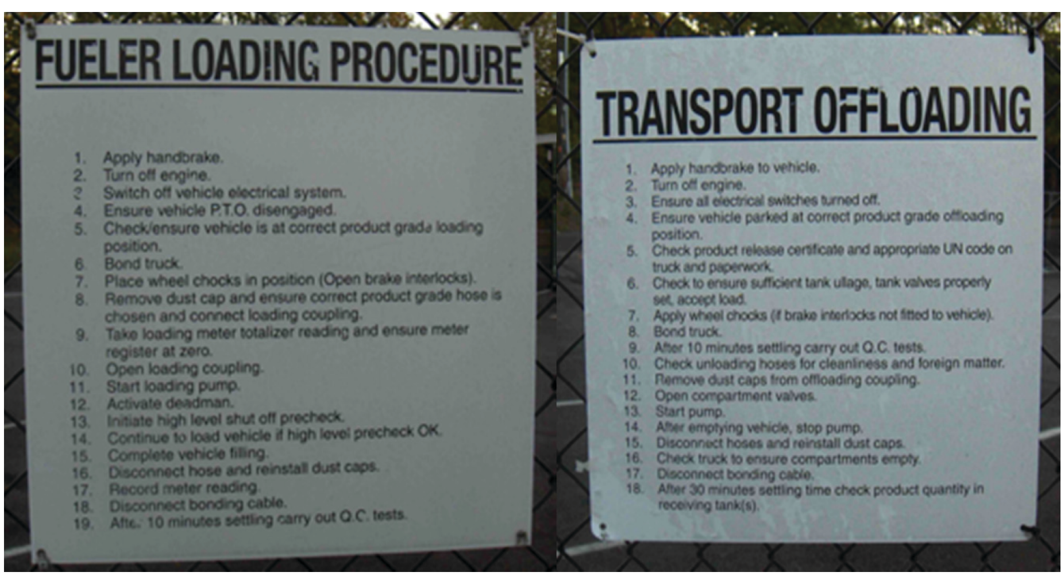

FIGURE 28 Example of procedures to load and offload fuel posted at transfer station. (*Courtesy*: S. Quilty, SMQ Airport Services.)

available to the public. A report from the United Kingdom (Jones et al. 2000) also indicates that such information is scarce. Workplace accidents involving fueling accidents are reported to OSHA in the United States. Information on individual instances of worker injuries during fueling operations can be searched on OSHA's website (www.osha.gov). Fuel tanker truck mishaps are reported to the U.S.DOT.

As reported by the Flight Safety Foundation (FSF), only refueling incidents that result in severe aircraft damage or personnel injury appear to be reported (FSF Editorial Staff 2001). Minor incidents are often not reported because injuries related to refueling tend to be rare or there is no requirement to report the data. In the same report, FSF reviewed fueling-related fire occurrences from 1966 to 1998 worldwide and found only 15 reported cases. Yet, as FSF noted, each year thousands of fuel spillage events occur worldwide.

As part of the 2013 FAA Design Challenge for Airports, one entry proposal reviewed a number of environmental spills at airports (Table 2).

A loss prevention company in the United States compiles a list of the 100 largest losses in the hydrocarbon industry (The 100 Largest Losses 1972–2011 2012). Although many of the losses are not aviation related, brief summaries contained in the report have applicability to airport installations and provide insight into what can go wrong and lessons to be learned. PEI has an incident reporting function for its members that is published in the organization's member safety letter.

FAILURE MODES

Two recent disruptive fuel fires that affected two large airports in the United States were fuel pump failures: Miami International Airport in 2011 and Boston Logan International Airport in 2013. A question is raised as to the prevalence of fuel pump failures that result in fires. A literature search did not find the frequency of fuel pump failures.

TABLE 2
SAMPLE ENVIRONMENTAL FUEL SPILL ACCIDENTS AT AIRPORTS

Date	Location	Operation in Progress	Gallons Spilled	Incident Description
1/13/13	Tokyo, Japan	Defueling	26	During the defueling operations of Boeing 787, a valve was found open on aircraft wing. Unknown clean-up measures.
1/8/13	Boston, Massachusetts	Taxiing to runway	40	While the Boeing 787 was taxiing to the runway, a leak was discovered. Unknown cause and clean-up measures.
1/3/13	Marion, Ohio	Truck refueling	2,500	While a fuel truck was refueling, the fuel overflowed and migrated into a creek. Unknown cause of overflow. Booms and vacuums used for cleanup.
1/12	Milwaukee, Wisconsin	Pipeline fuel transport	Unknown	Fuel leaked from pipeline for 2 weeks and was discovered because of a strange odor. Booms installed in water for cleanup.
7/12	Fresno, California	Fuel truck transporting fuel to aircraft	200	While a fuel truck was driving on tarmac, it overturned. Unknown cause for overturn and clean-up measures.
1/27/12	Chicago, Illinois	Pipeline fuel transport	42,000	Pipeline burst and spilled fuel into a ditch. The Coast Guard and EPA were involved in the cleanup.
1999	Kirtland AFB, New Mexico	Pipeline fuel transport	24 million	Fuel coming up from underground at aircraft storage center. Monitoring for wells is being installed to determine contamination levels.

Source: Bielefeldt et al. (2013).

A 2000 United Kingdom Health and Safety Executive report on risk assessment in fueling operations provides a list of global fueling accidents and is a good source for lessons to be learned and recommended actions to be taken (Jones et al. 2000). The accidents reported were a result of many varied actions or failures. Faulty shutoff valves at the tank or at the nozzle/hydrant were the most common causes of fuel spills. However, human error resulted in the largest amount of spillage. In the report, common failures during fueling operations included:

- underwing couplings becoming detached from the aircraft;
- nozzle quick disconnects separating;
- vehicle impact damage to hydrant couplers;
- failure of hydrant couplers as a result of incorrect reassembly after the couplers were modified;
- hose ruptures;
- failure of valve or poppet to close; and
- accidental disconnection of a coupling after the failure of an interlock.

Hydrant fueling operations pose a particular environmental risk because the frequency, volume, and pressures can result in large quantities of spillage or escaping high-pressure leaks are atomized quickly and are more susceptible to ignition. Although rare, the rupture of an underwing fuel hose can result in a spillage rate upward of 550 gpm, whereas the rate for a hydrant pipe or connection failure could be upward of 1,600 gpm (*Ramp Operational Safety Procedures* 2014).

A major fuel tank fire at the Buncefield Oil Terminal in England was determined to be the result of failure of an AST's high-level switch, coupled with a failure of the alarm system during the nighttime hours, when only one person was on duty. The chain of events resulted in an overflow that was not detected. Weather conditions allowed for an unconfined vapor cloud explosion (UVCE). The accident significantly reduced jet fuel delivery to major airports in the United Kingdom (Buncefield Major Incident Investigation 2006).

SAFETY MANAGEMENT SYSTEM AND HAZARD IDENTIFICATION

An SMS is the formal, top-down, businesslike approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety, including safety risk management, safety policy, safety assurance, and safety promotion (Advisory Circular 150/5200-37 2007).

Research and interviews for this study found the use of SMS principles at airports to exist primarily at the larger organizations of into-plane fuel providers or FBO chains. Organizations that sought certification from third parties, such as those offered by IATA Safety Audit for Ground Operations (ISAGO), NATA Safety 1st, or International Standards Organization (ISO) quality management for fuel handling practices, were most likely to have an SMS or similar process in place. The FAA has issued a Notice of Proposed Rule Making (NPRM) to require Part 139-certificated airports adopt SMS principles as part of their airport certification manual (75 FR 76928 2010). Noncommercial or GA airports initially will be unaffected.

A number of engineering tools can be applied to the identification of hazards in any industry and to the determination of failure causes. Known as hazard assessments (HA), failure mode and effects analysis (FMEA), fault tree analysis, and other terms, these analyses can be applied to the airport fuel system. Fault tree analysis is used to better assess and calculate the risk or cost benefit of a particular operation. When auditors were asked in interviews about whether an FBO, airline, or airport organization conducted such analyses, none indicated that they were involved in such assessments at their level. Examples of HA, FMEA, and fault tree analyses are shown in Appendices C through I.

The 2000 United Kingdom report previously mentioned provides examples of various risk assessments and failure modes performed to illustrate the benefit of safety risk assessment (SRA) using the fault tree analysis and FMEA tools (Jones et al. 2000). The use of the tools focused on identifying what measures would reduce the frequency of a spill; what could reduce the size of the

FIGURE 29 Marking and flag identification of fuel hydrant pit. (*Courtesy*: FAA.)

spill; and what could reduce the possibility of ignition after a spill. An evaluation of the risk assessment tools in the report identified a significant proportion of the fuel spills at UK airports were caused by vehicles striking a hydrant during fueling. In determining the cause and risk, potential technical and SMS solutions were identified. For instance, under the category of hardware, solutions examined were to:

- Increase the visibility of the hydrant through pavement marking cones or flags (Figure 29),
- Provide a physical protective barrier,
- Reduce the need for vehicle operations or backup in the area, and
- Increase the reliability of the primary isolation system.

Solutions examined as part of the overall SMS were to:

- Raise awareness through training,
- Improve supervision of fueling operations,
- Increase the number of audits of fueling operations to ensure practices are followed,
- Make provisions for use of second person for vehicle backups, and
- Improve the location and identification of emergency shutoff switches to reduce reaction time to a spill response.

INSPECTION

Airports certificated under 14 CFR Part 139 have a regulatory requirement to perform inspections of fueling facilities at their airports, in particular to conduct regular daily inspections, continuous surveillance as necessary, and more detailed inspections every 3 months. AC 150/5200-18C provides guidance on the three types of inspection processes to occur. Part 139 also requires certification from fueling agents on the airport as to the training records of individuals engaged in fueling operations.

In AC 150/5200-18C, FAA cites NFPA guidelines as acceptable means of compliance for Part 139. A state, municipality, airport operator, or local fire jurisdiction may choose to have different standards. During an annual certification inspection, differences between the standards used at an airport may need to be discussed with the FAA inspector. In addition to NFPA, other standards exist, such as those of individual air carriers, local fire and building codes, and those of petroleum and fuel producers.

Specific inspections of fuel facilities, vehicles, and equipment are to follow those outlined in any standards or operating manual adopted by the airport. Appendix J excerpts the fuel system inspection criteria from the FAA. In general, some industry practices for inspection of fuel systems include the following:

- Daily
  - general cleanliness and conditions of grounds
  - filter and tank sumps
  - differential pressure at full flow
  - enabling switch operation
  - grounding rods, reels, cables, and clamps
  - fire extinguishers.
- Monthly
  - Millipore testing
  - grounding cable continuity (continuity test)
  - bottom loader fuel strainer
  - signs and placards
  - floating suction cables
  - fire extinguishers.
- Quarterly
  - emergency shutdown system
  - water defense and foam system
  - tank high-level controls and alarms.
- Yearly
  - storage tank interior
  - differential pressure gauge
  - filter elements
  - filter separator heaters
  - tank vents
  - cathodic protection
  - pump line filters
  - water defense and foam systems.
- Periodic
  - maintenance of all equipment
  - manufacturer recommendations.

The focus of Part 139 inspections is on safety in fueling operations and not on quality control. There is no federal regulatory mandate for private companies to perform fuel quality assessments. However, the consequences of not providing proper fuel quality are understood in the industry because the outcome can have catastrophic consequences. Safety of operations, corporate responsibility, legal liability, customer expectations, and good business practice dictate the requirement to diligently monitor, inspect, and test fueling operations. It is for this reason that the airlines first formed a committee to identify fuel standards, resulting in ATA 103.

According to a well-known industry fueling expert, the key to safe fueling is knowing what to look for, in both quality control and operations, and understanding what you see ("TOP 5 Fuel Quality Issues You Need to be Aware of" 2005). The author states, "You have to look for things out of the ordinary and understand their importance." The top five problem areas identified were: (1) inadequate or poorly organized fuel quality control records and documentation, (2) irregular or inadequate inspection or audit, (3) improper storage of fuel quality devices, (4) inadequate or poor signage and marking, and (5) haphazard white bucket testing and daily sumping. This has implications for training and also for the quality of those who inspect.

Research seeking to identify a centralized database of fuel facility inspection results was not successful. Information culled from articles published in trade journals and interviews highlights a wide range of problems or issues (Crotty 2007). Interviews conducted with several NATA Safety 1st ground handling auditors support the list of problems cited previously at FBOs across the country.

RECORD KEEPING

Documenting fuel deliveries, inspections, and tests is a standard of any quality control program. Record keeping allows for the determination of a change in a process, demonstrates compliance with regulations, acts as a check against claims by others, and serves as historical record of the business. ATA 103, NATA Safety 1st, and the branded fuel suppliers provide forms for recording all aspects of fueling operations. Several of the forms are reproduced in Appendices L through S.

In the words of one airport operator, the role of the airport inspector is to "trust but verify." Verifying fueling agent records is one industry practice the FAA supports to ensure safe fueling operations. The airport inspector is verifying that the fueling agent is doing what the agent is supposed to do according to the operating manual, industry specifications, and airport or local government requirements. Based on the literature and interviews with auditors, the absence of written records for many fuel-related procedures included the following (Crotty 2007):

- filter changes,
- hose replacement,
- tank and equipment inspection,
- fuel receipts and settling time,
- ground and bonding cable resistance checks,
- gauge calibration, and
- personnel training.

CHAPTER SEVEN

SPECIAL ISSUES

RISK MANAGEMENT

From a risk management standpoint, the more fuel stored and dispensed on an airport, the greater the perceived risk and consequences a disruption in fuel supply can have. A fuel contingency plan is an important consideration for an airport operator, fuel provider, and fueling agent (Corzine 2013). The primary risks associated with operating fuel facilities are fire, explosion, contamination, spillage, and environmental impact. Consequences of those risks affect many other areas of the airport, as delineated in Corzine's 2013 *ACRP Report 93*.

Fire and explosion risks are addressed through safety policies, procedures, and measures put into place during the design, installation, operation, and maintenance of the facilities. Building, electrical, and fire codes are established for safe operations. Adequate insurance coverage helps mitigate unforeseen accidents or liability. Risk of fuel contamination is mitigated by a number of standards and procedures identified in Appendix B. Standards also exist for the testing of fuel quality. Additional protective measures are the training of personnel in standards and procedures.

The level of risk exposure will change with a change in technologies, procedures, or organizational assignment. For that reason, common practice in the petroleum industry is to have a robust system for managing safety, most commonly known as a safety management system (SMS). As part of an SMS, ICAO specifically addresses the need for process change management in its guidance documents, to include evaluation of risk and notice to other stakeholders in the fueling chain (*Manual on Civil Aviation Jet Fuel Supply* 2012). Examples of changes that can affect risk in fuel system processes can include major system modification, introduction of new equipment, revised maintenance practices, new hiring and training practices, change in employee assignments or shifts, new supervisory or management assignments, substitution or introduction of different aircraft types on various established routes, changes in fuel suppliers, change in performance or safety standards, etc. Each example introduces a change in risk exposure that, under a properly instituted fuel handler's SMS, is to be evaluated as part of its quality assurance requirements.

Fuel Consortium Risk

In conversation with personnel at the Memphis–Shelby County Airport Authority, it was noted that three parties are generally involved in a fuel consortium: the fuel farm operator, the airport authority or municipality, and the airlines. Some airports have a fourth party involved, the into-plane agent, which is different from the fuel farm operator. For each party involved in the consortium, risks generally are evaluated separately. An article by Lahey and Heilbron (2008) provides insight into the structure of an airline interline agreement and identifies several areas of risk and uncertainty an airport and fuel consortium face when negotiating agreements. An LLC helps protect a company from financial and legal liability in the event of an accident or environmental breach. An airport's assessment of risk normally includes an evaluation of the airport's exposure given the limits of a LLC.

Fuel Storage Risk and Liability

During a telephone conversation, a noted aviation insurance expert said that there are three general concerns associated with the risk and liability exposure of owning or operating fueling facilities

(John Shorten, Willis Insurance, personal communication, Aug. 22, 2014). The first is environmentally related spills or releases; the second is UVCE exposure; and the third is infrastructure liability.

Environmental Risk

If an airport is acquiring property and facilities, such as fuel tanks, piping, and pumping equipment, the importance of conducting a condition assessment beforehand is a most effective practice. Whether or not federal AIP or state grant funding is used to make the acquisition, EPA documents available on the agency's website suggest that a preliminary environmental inquiry or assessment be made. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA) establish environmental accountability for those who own or acquire property, including any equipment or facilities located on them (42 U.S.C. §9601 et seq. 1980). Conducting due diligence of an acquisition site before purchase can limit an airport's liability exposure.

A Transaction Screen Process (TSP) assessment is one method for conducting a limited due diligence review (*Standard Practice for Limited Environmental Due Diligence: Transaction Screen Process* 2014). A TSP is limited to assessment of low-risk, small-value property acquisitions and does not meet CERCLA's or SARA's requirements for financial responsibility. State laws and regulations for conducting an assessment can also exist and apply.

A Phase I Environmental Site Assessment is a more involved due diligence approach than is a TSP. It is designed to identity potential environmental concerns associated with property acquisition (*Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process* 2013). A Phase I assessment determines a property's or facility's baseline environmental condition, identifies environmental liabilities that may come with acquiring the property or equipment, and identifies potential issues that need further inquiry or resolution (40 CFR 312 2014). A Phase I assessment satisfies an airport's liability investigation required under CERCLA and SARA. The procedures for conducting a Phase I assessment are found in ASTM E1527-05 (78 FR 79319 2013). If an airport does not conduct a Phase I assessment, it opens the airport to greater liability exposure if a question of environmental condition is raised at a later date.

Should a Phase I assessment determine additional inspection or analysis is required, a Phase II assessment is in order. Performed by an environmental specialist, a Phase II inspection includes soil and groundwater sampling, underground or aboveground tank testing, and pipeline testing. More information on environmental assessment can be found on the FAA's website (http://www.faa.gov/airports/environmental).

Unconfined Vapor Cloud Explosion Risk

A second risk area is related to the exposure of others from an airport having a UVCE, primarily from a fuel farm tank mishap. UVCE refers to the release of flammable gas into the air such that the collection of vapor can be easily ignited and, if ignited, produce significant blast pressures. The consequences of the resultant blast can extend outside the airport fence and affect the community downwind of the blast. For this reason, airport contingency planning for such risks is a most effective practice.

Infrastructure Risk

A third area of risk exposure is related to the fueling infrastructure and its proximity to physical assets, such as terminal buildings, aircraft, hangars, aprons, and the public.

To minimize both UVCE and infrastructure risks, airport planners take into consideration the location of installed tanks, pipes, fuel transfers, fuel truck parking, and the degree of exposure to others in, on, and around the airport. Although many airports in the United States have claimed tort immunity under governmental laws, operating a fueling concession is considered a proprietary function that may not be covered by such immunity laws; gross negligence, if proven, also is not usually covered.

INSURANCE

A 2011 study identified most airports carry property, general liability risk, and business interruption insurance (Rakich et al. 2011). Insurance policies are normally available and acquired to mitigate environmental risks. Other coverage to consider is contingent, service, and/or supply chain interruption insurance.

An example of the impact of a supply chain interruption is the Buncefield refinery explosion in 2005 at the Hertfordshire Oil Storage Terminal in the United Kingdom. It was a UVCE event that required the evacuation of the local community downwind of the tanks and disrupted 30% of the jet fuel capacity at Heathrow International Airport. Jet fuel rationing affected the air carriers at Heathrow for months after the explosion, forcing airlines to adjust their operations.

Coverage for war and terrorism insurance is a concern at several of the larger airports (Rakich et al. 2011). An alleged attempt to disrupt the fuel supply line at New York's John F. Kennedy International Airport points toward this concern (Faiola and Mufson 2007). In his report, Rakich found that smaller airports tend to not purchase terrorism or pollution liability insurance. A recommendation of the study was for further research to determine whether the decision to not purchase insurance was related to cost or whether there was a valid reason to assume limited exposure.

Airport leases often require a tenant fueling agent to indemnify and hold harmless the airport operator and require the fuel handler's insurance policy to have the airport as named-insured on the policy. Although those clauses are good practices, airports may not be adequately covered for the environmental, UVCE, or infrastructure risk exposures mentioned. The limitations of named-insured clauses are found in the limits-of-liability covered or from certain aspects of coverage not being included in the fueling agent's policy. A benefit to an airport and fueling agent on an airport from a branded fuel supplier can be the availability of a supplemental or umbrella liability policy.

Of potential concern for an airport is the stability of any company or organization managing fuel on an airport to adequately address environmental mitigation or clean-up issues in the unlikely event of a spill. Having airport legal counsel review all documents and requiring adequate insurance or reserves is an important consideration for such a situation (Brian Kuhn, Memphis–Shelby County Airport Authority, personal communication, Aug. 28, 2014). Airport owners can manage the environmental risks of fueling operations through one or more approaches:

- purchase insurance,
- establish a rate ordinance or something similar to recover the costs of environmental or capital costs,
- establish covenants in leases or other agreements to protect the airport, and
- require tenants to have appropriate and adequate insurance coverage.

ALTERNATIVE FUELS

Dependency on fossil-derived fuels and their associated environmental, political, and economic costs has led to efforts to consider alternative fuels. Background information on alternative fuel possibilities at airports can be found in ACRP Reports 48 and 60 (Spitz and Berardino 2011; Miller et al. 2012) and on the FAA's Office of Environment and Energy website.

Although efforts to develop and produce a cost-effective alternative to fossil fuel are ongoing, the literature indicates it may be some time before the use of such fuels becomes mainstream (Blease 2013). The difficulty is in the need to meet the precise fuel properties required by jet fuel specifications, such as ASTM D1655. Industry expectations and efforts are for any alternative fuel to be 100%

compatible with existing tanks, piping, and equipment because the industry is hesitant to replace or add to existing infrastructure because of capitalization costs.

Biomass fuel is one of several alternative fuels being considered to substitute for fossil-based jet fuel. Biomass fuel takes organic compounds such as trees, shrubs, grasses, seeds, fungi, seaweed, algae, and animal fats and turns them into a usable jet fuel. It has been tested and used in several commercial aircraft on scheduled routes because it is similar to fossil-based jet fuel in chemical and physical characteristics. A changeover to biomass fuel is anticipated to require little infrastructure modification of the currently used jet fuel delivery systems. The drawback to greater use of biomass fuel has been the cost of production. The cost of biomass fuel is more than three times that of jet fuel because the buildup of manufacturing capacity is rolled into the cost of production, whereas fossil fuel systems previously have been amortized over many years (Davies 2014).

Should an airport organization seek to accommodate alternative fuels, a report has been published to assess the opportunities (Miller et al. 2013). Background information on the research can be found in the *Contractor's Final Report* (Miller et al. 2012). From the 2013 report, a guidebook was produced that includes a description of the steps necessary to evaluate opportunities and constraints for program delivery and a toolkit that enables airport decision makers to evaluate all of the elements needed to implement an alternative fuels marketing and distribution program (Miller et al. 2014).

For avgas, the challenge is to find a suitable replacement for lead-infused specifications that are required for the majority of piston engine aircraft still in existence and use. Lead-contaminated infrastructure will need to be cleaned or replaced. The FAA recently started testing several replacement fuels, but it may be several years before alternatives are approved and accepted by the industry ("FAA Selects Four Unleaded Fuels for Testing" 2014). The challenges for avgas are the number of high-horsepower aircraft engines that will continue to need the benefits of higher octane avgas and the need to clean infrastructure of lead before introduction of a nonlead alternative. The FAA's Fuels Program Office, AIR-20, has responsibility for efforts to transition GA to an unleaded avgas.

CASE EXAMPLES

The following cases provide an example of the processes, challenges, and opportunities regarding the topics discussed in this synthesis.

Example: Fuel Island Installation

Pekin Municipal Airport in Illinois is a small GA airport with approximately 54 based aircraft. It was faced with the problem of having to upgrade its fuel system. The airport owned the fuel system, including two 10,000-gallon tanks—one for avgas and one for jet fuel. What drove the decision to upgrade the system was the high maintenance costs and difficulty of obtaining parts for the old pumps and dispensers.

The tanks are thought to be 50 years old. It was assumed they were installed in 1964, when the airport was built; no records were found indicating exactly when they had been installed or if they had been replaced. Leaking Underground Storage Tank (LUST) program regulations in 1988 required airports to address underground storage tanks. As a result, the airport plumbing was upgraded in the early 2000s. A decision was also made to line the tanks rather than replace them. The piping was replaced to new EPA standards. A 10-year-in-service fitness test had resulted in a 5-year extension for the tanks because they were still good.

A lease agreement extension with the FBO was not agreed to in 2008, and the FBO left the airport. The state of Illinois code requires fuel sales to be available at public-use airports. After the branded fuel provider to the previous FBO approached the city and suggested the city operate the FBO, the city took over fueling operations. The city recognized the need for fuel services because the airport serves numerous business and corporate aircraft and is a base for several agricultural operators and other aeronautical activities. The city agreed to manage the fueling operation because the fuel provider offered a turnkey operation, set the airport up with training and quality control measures, and provided a third-party insurance umbrella.

Because of liability concerns and the desire to keep personnel costs low, the city decided to opt for commercial self-service with "assisted service." The lone airport employee, the airport manager, was available to provide guidance to fueling operation but would not actually pump the fuel. This was not deemed an issue because pilots frequented the airport to obtain fuel at costs lower than those at surrounding airports. Pilots, even the jet operators who frequented the airport, had no issues with fueling their aircraft. The airport manager indicated that self-fueling by corporate operators could pose a problem in the future if the airport runway is extended, allowing use by larger jet aircraft.

The fuel delivery process is simple as a result of the fuel management, tank monitoring, and automated billing system provided by the branded fuel provider. The airport manager conducts the daily inspections and tests, monitors the tank levels, and is alerted to fuel purchases by the fuel management system and fuel provider. The fuel provider handles all requirements for transport of fuel to the airport upon a fuel order from the manager. At the time of the interview, a load of avgas had been delivered by a dedicated tanker truck from Houston, while jet fuel was dispatched on a dedicated tanker truck from the Chicago area.

The fuel provider handles all electronic transactions through a point-of-sale terminal associated with the fuel management system, accepting various credit and travel cards. Sales can also be completed through a web-based application on an Internet-capable device, such as a computer or smartphone. The airport receives a check in the mail from the fuel provider. The airport has agreements with the several on-airport commercial operators for discounted fuel. The point-of-sale terminal/fuel management system is set up with two readers, one for transient pilots at regular price and one for discount cards issued by the airport.

The airport is listed in the National Plan of Integrated Airport Systems (NPIAS) because Illinois is a state block grant state. Pekin Municipal Airport is eligible to receive $148,000 AIP entitlement funds annually from the state program. The grant amount did not cover the cost for full system replacement, so it was decided to stage improvements over several years. The airport recently upgraded the fuel island, which is a low-profile dispensing unit placed in the middle of its ramp for 360-degree access. The dispenser is a skid-mounted cabinet because the intent is to be able to move the unit, if necessary, when the tanks are replaced within the next 5 years. Currently, the tanks are located close to the runway and require the fuel delivery transport vehicle to drive across the ramp to the tanks.

A challenge faced by the airport during the upgrade was the different interpretations made by fire marshals throughout the state because Illinois law was not clear on what was required for an airport. The laws were written primarily to address automotive convenience store installations and required such things as video surveillance.

In contemplating tank removal, the city is not sure which type of tank to install—AST or UST. A new AST could not be placed in the same location as the current tanks because doing so would violate FAA standards for objects close to the runway. Installing a UST would require a tank decommissioning, and the current operating issues would still exist. Environmental issues will play a part in the decision because monitoring wells are required for USTs.

The bidding process for the fuel island installation was problematic because of the limited number of state-qualified vendors able to perform the work. Accurate engineering estimates for the cost of the project were difficult to obtain. That made it difficult to meet AIP guidelines once bids were received. A company outside the state was awarded the contract. Problems were incurred with the installation, and the travel distance may have been a factor. The local fuel company now services the maintenance needs of a system installed by others.

When asked what lessons could be learned, the airport manager stated if he had it to do over again, he would want to bite the bullet and do a complete installation of tanks, pipes, and dispenser, rather than do it piecemeal. He also would like to see more consistent interpretation or clarification of state regulations and guidance from the Office of the State Fire Marshal and the Department of Agricultural Bureau of Weights and Measures.

Example: Tank Farm Approval Process

To illustrate the environmental process and permitting required for fuel tank installations, a case example was found in the literature about the installation of a fuel farm at Centennial Airport, Colorado ("XJet Fuel Farm" 2007–2008).

To have a successful installation process, airport management and the consultant had to acquire permits and approvals from the following governmental and environmental agencies:

- Arapahoe County Public Airport Authority,
- Arapahoe County Engineering,
- Arapahoe County Water and Wastewater Authority,
- South East Metro Storm Water Authority,
- South Metro Fire & Rescue,
- Cherry Creek Basin Water Quality Authority, and
- InterPort Development Design Review Committee.

Specific engineering services included site layout, grading, drainage, erosion control, fire access and hydrant locations, utilities, landscaping, primary and secondary fuel spillage containment, SPCC planning, state storm water management pollution prevention plan (SWMPPP), and FAA 7460 obstruction permitting.

The lesson to be learned is that the installation of a fuel tank can require approval at many different levels and can be a lengthy process. Planning and stakeholder involvement is imperative to a successful installation. With so many factors to consider, a qualified airport design and engineering firm along with input from users is invaluable to help an airport obtain the most effective results. This point was echoed by A4A and several other participants in this study.

Example: Fixed-base Operator Inspection

This report highlights the need for the airport to provide safety oversight of fueling activities on the airport. There are other stakeholders in the process as well. The following examples illustrate the various stakeholders and responsibilities for ensuring the safe delivery of fuel.

In an interview with the manager of an FBO at a medium hub airport, the manager indicated the following organizations have inspected his fuel facilities:

- direct oil company fuel supplier (annually),
- air carrier operator (annually),
- air cargo operator (annually),
- airport authority operations (regular and continuous),
- airport authority fire department (quarterly),
- airport authority environmental officer (continuous),
- FAA airport Part 139 inspector (annually),
- state fire marshal (annually),
- state EPA (as necessary),
- state Department of Agriculture (certified meters—annually),
- insurance company (annually),
- internal FBO company risk manager (as necessary),
- DoD (has military service contract—annually), and
- OSHA (as necessary).

With all the inspections, the FBO manager was comfortable with the processes and procedures he uses to ensure proper fuel quality. His company places an emphasis on safety culture and adherence to procedures. His biggest fear was that of a spill getting into the airport's drainage system (R. Hartwein, personal communication, Aug. 24, 2014).

The lesson to be learned is the importance of management setting the tone for a positive safety culture, including having policies and procedures in place, following them, and keeping records that help build trust among stakeholders.

CHAPTER EIGHT

CONCLUSIONS AND FURTHER RESEARCH

The objective of this synthesis is to provide an overview of fueling system operations at all size airports by describing stakeholders, typical elements, common issues, and current practices and standards.

This study was broad in its approach because a substantial amount of detailed information on airport fueling systems and safe handling exists. This is owing to the important responsibility an airport organization and its tenants have for operating a fuel facility in a safe and efficient manner. Unsafe operation of such facilities can have catastrophic results in terms of the effect on people's lives, capital equipment and facilities, airport and aircraft operations, financial performance, legal exposure, and environmental guardianship, to name a few affected areas. The airport owner is ultimately responsible for what occurs on the airport.

There is a strong desire and effort to standardize much of what occurs in the fueling business, from the design of facilities, equipment, and components, to the processes used to deliver fuel to an aircraft. This is evident by the number of standards and recommended practices that have been developed to provide guidance to fueling providers and agents, equipment and vehicle manufacturers, and airport operators. Those involved in the fueling process choose the standards they will adhere to and incorporate them into their facility operation. Airport organizations can further use lease or minimum standards to support the standards. For certificated air carrier airports, Part 139 provides a minimum standard for safety in fueling operations. GA airports can benefit from the same.

In reviewing the various standards and literature on fueling components and systems, it was found that easy access to the standards require purchase and/or licenses from the sponsoring organization. This study did not locate a centralized public database of accidents or incident reports that could ultimately be of value to the airports. Although data are collected through insurance and oil companies, the data generally are retained within those organizations and not widely disseminated.

A review of accident data indicates that any component can fail at any time but that many fuel incidents are the result of human error. The collection of data into a central database available to the public is not apparent. The risks a fueling operator faces are not well disclosed, and better assessment would help the industry.

Fuel systems can be complicated, and technical expertise is important, from the negotiation of leases, to the design of the facilities, the use of equipment, the testing of material, the delivery of fuel, and the maintenance of facilities. Airport owners need counsel and education. There are many resources, including manuals, references, publications, and name-brand fuel providers, that can provide expertise and training. Especially at airports with fuel consortiums, study participants suggested engaging individuals or firms with experience in consortium arrangements to assist in lease, project development, and construction.

There are both aviation and environmental regulations that affect fueling operations. For airports with FAA operating certificates, Part 139 requires the airport organization to address safety issues in fueling operations. At GA airports, knowledge and resources generally are not available to the same extent as is required at Part 139 airports, yet GA airports have the same responsibility to the public and the environment for safety oversight. Interviews for the study found that larger airports have dedicated individuals on staff to address legal and environmental requirements. Smaller airports, especially GA airports, lacked similar organizational capabilities.

To that extent, airport operators tend to trust fueling operators on the airport. The study found that although trust was the norm, it was important to verify that trust through inspection, audit, leases, and the establishment of rules and regulations. Audits at small GA airports appear to be few and inconsistent: few because of the perceived cost, and inconsistent because local inspectors may not have familiarity with aviation fuel operations or state or local regulations are not specific.

This synthesis did not discover a centralized public database of accidents or incident reports that could ultimately be of value to airports. Collection and reporting of data on accidents, incidents, component failures, and equipment repair could assist airport operators and others to better understand risks and improve safety.

Research is suggested into fuel system component failures and human factor issues because they have an impact on a safe system. The publication of hazard identification and failure mode and effects analysis can better educate individuals and raise greater awareness of safety-related fueling practices.

Research that compiles state requirements on environmental and fuel-related issues can be useful, especially as an assist to local communities seeking better inspections and enforcement of standards.

The broad spectrum of ownership and fuel delivery possibilities suggests a more focused study on a particular market is warranted. In particular, communities with GA airports would benefit from a synthesis on the advantages and disadvantages of municipal ownership, along with decision-support tools. A number of factors enter into the debate, such as the level of activity, volume of fuel sold, infrastructure available, management capabilities, and goals of the community. A quick-start guide of what to do and what not to do in the transfer of ownership at GA airports would be valuable.

GLOSSARY AND FUEL SYSTEM TERMINOLOGY

The following descriptions are provided for several common terms and components associated with or used in an airport fueling system.

14 CFR Part 139—The federal regulation that requires certain airports serving air carrier aircraft to obtain an airport operating certificate and comply with certain standards, in particular the inspection of fueling facilities.

Aeronautical service provider—A company engaged in any activity that involves, makes possible, or is required for the operation of aircraft or that contributes to or is required for the safety of such operations.

Air elimination/air block valves—A device that allows for control of fuel gas in a vent line to eliminate the buildup of air.

Anti-syphon valve—A device that prevents fuel in a pipe from discharging in the event of a leak downstream.

Automatic leak detection system—Monitoring system to detect leakage in tanks and piping.

Automatic shutoff nozzle—A fuel nozzle device designed to shut off the fuel dispensing process when activated.

Avgas—Gasoline used for reciprocating piston engines.

Barrels of fuel—The common description of fuel quantity at a refinery. One barrel equates to approximately 42 gallons of jet fuel when distilled.

Bleed valves—Valves designed to check for leakage when plug valves are closed or allow for siphoning of fuel.

Block valve—*See* double block valve and gate valve.

Bonding—The creation of an electrical path between two components to establish a neutral electrical potential, such as between a refueler truck and an aircraft.

Bottom filling (Bottomwing)—The introduction of fuel into a tank receptacle through pressure fueling from the bottom of the tank that minimizes vapor generation.

Cathodic protection—Various means used to prevent corrosion in metal tanks, pipes, and equipment.

Check valves—Used to allow fuel to flow in one direction only or to maintain fuel in a line, such as fuel prime for a pump.

Clay treater filter—Filter that removes surfactants, color, and additives in fuels.

Clock gauge—A mechanical device that provides a visual indication of the amount of fuel in a tank.

Coalescer filter—Filter that removes ultra-fine solids and enhances the separation of water from jet fuel by attracting minute water molecules and consolidating them for removal.

Control valves—Mechanism to maintain fuel pressure and provide emergency shutoff.

Dead man's switch—*See* enabling switch.

Double block valve—A single valve with two seating surfaces installed in a pipe that, in the closed position, provides a seal against pressure from both ends of the valve with a means of venting/ bleeding the cavity between the seating surfaces.

Double-walled—A tank construction method that allows for containing fuel in the event of a leak. A tank within a tank having interstitial space.

Duckbill nozzle (flared or J-spout)—A jet fuel nozzle designed to prevent misfueling.

Earthing—*See* grounding.

Emergency vent—A red vent that allows for full venting of a tank in the event of fire or blockage (NFPA 30).

Enabling switch—A device that requires a fuel operator to activate it to allow for fueling operation to continue. If the device is released, fueling stops.

FBO—Fixed-base operator. A commercial business granted the right by an airport owner to operate on an airport and provide aeronautical services, such as fueling, hangaring, tie-down and parking, aircraft rental, aircraft maintenance, and flight instruction.

Filler neck spill containment—A receptacle or catchment area designed to retain fuel spillage.

Filter housings—Container used to hold various filter cartridges.

Filter separators—A device to repel water and collect contaminants.

Flame arrestor—A device that dissipates the heat of ignited fuel and prevents a flame front from extending further into a pipe.

Flared nozzle (duckbill or J-spout)—A jet fuel nozzle designed to prevent misfueling.

Floating suctions—Systems used in fuel tanks to draw fuel from a predetermined point below the surface of the fuel.

Flow indicators—Devices that provide an indication of flow through a fuel system.

Flow meter—Device for measuring the fuel flow rate in mass or volume.

FSII—Fuel system icing inhibitor: a jet fuel additive that helps prevent freezing of water molecules in the fuel.

Fuel farm—A consolidated location for bulk fuel storage and equipment, on or off an airport.

Fueling agent—A person or company that sells fuel products on the airport.

Fusible link valves (tank/loading hose)—An emergency device that is sensitive to heat and shuts off fuel in the event of a fire or excess heat.

Gate valves and ball check valves—Valves that turn on, shut off, or direct the flow of fuel through the system. Such valves are used to block a line for maintenance.

Gauge or level indicator—A mechanical, electronic, or electromechanical device that provides an indication of the amount of fuel in a tank.

Grounding (earthing)—The creation of a neutral electrical path between a vehicle, equipment, or component and the earth, such as an aircraft to ground or a refueler truck to ground.

Interlock valve or switch—A device used to shut off fuel or prevent an operation when activated. Primarily used in conjunction with fuel nozzles or fuel truck pumps and brakes.

Interstitial space—The space in a double-walled tank between the holding tank and the containment tank and used for testing and monitoring of leakage.

Isolation valve—Device designed to isolate a fuel product, hold the fuel, or control flow of fuel.

J-spout nozzle (duckbill or flared)—A jet fuel nozzle designed to prevent misfueling.

Jet fuel—Fuel designed to burn in aviation turbine engines.

Merchant refinery—An oil refiner who procures crude, processes it, and sells refined products to marketers while continuing to process oil for a fee.

Micronic filters—Devices used to remove small particle contamination.

Mogas—Automotive gasoline that can be used in aviation reciprocating piston engines.

Monitor filter and system—A filtering system that absorbs water, removes solids, and shuts down the system if a slug of water is encountered.

Off-specification fuel (off-spec)—Fuel that does not meet relevant quality specifications set forth in standards or agreements.

Oil refinery—An industrial plant that refines crude oil into petroleum products, such as diesel, gasoline, and heating oils.

Oil/water separators—Filter system designed to separate water from fuel.

Overfill alarm—A device intended to provide a visual, audible, or other indication of a tank overfill situation. Used in conjunction with a mechanical and automatic overfill shutoff device.

Overfill shutoff—Mechanical or automatic devices designed to shut off a fuel system pump upon reaching a preset fuel tank point.

Over-wing fueling (splash fueling)—Term used to describe the fueling of an aircraft or tank through an open hose or pipe above the tank.

Parallel pumps—Installation of pumps to sequentially maintain pressure and increase flow of fuel through a hydrant or piping system.

Rack system—A truck loading/unloading platform.

Rogue spout nozzle—A straight round jet fuel nozzle.

SASO—Specialized Aviation Service Operations: operators on airports who provide a single service or perform services that are less than that provided by a full-service FBO.

Secondary containment—A device that will hold or contain a fuel spill.

Self-fueling—The fueling or servicing of an aircraft by the owner of the aircraft with his or her own employees and using his or her own equipment.

Separator filter—Filter media designed to provide high efficiency water repellency and separation.

Settling time—The amount of time necessary for sediment and moisture to settle to the bottom of a fuel.

Single-point fueling—A feature on an aircraft that allows for the filling of all fuel tanks from one central fueling point and hose.

Splash filling—The introduction of fuel into a receptacle by means of a gravity feed that results in a splash effect and increased potential for vapor generation.

Sumping—Term used to describe the process of collecting fuel from the low point of a pipe, vessel, or fuel pit.

Sump saver—A small settling tank or container that allows for the settling of sumped fuel samples and allows for the reintroduction of fuel into the system, rather than becoming waste.

Sump separators—Filter system designed to draw fuel from the bottom of a tank.

Surge suppressors—A diaphragm or bladder valve and tank designed to reduce shock and oscillating pressures in a pipeline when a fuel flow valve is opened or closed.

Tank vent—A safety device that allows for vapors to escape. It extends at least 12 feet above ground for a UST. Can be open vent or pressure type to reduce vapor loss.

Thermal expansion relief and bleed valves—A device that allows for the heat expansion of a fuel product in a pipe and vents back to the tank.

Top loading—The loading of fuel into a tanker truck or tank using a stand pipe or hose that delivers the fuel to the bottom of the tank to prevent splash and vapor buildup.

Totalizers—Mechanical, electronic, or electromechanical device used to calculate the amount of fuel in a system.

Transfer valves—Mechanisms for allowing fuel to flow from one tank to another.

Water scavenging hand pumps—A mechanical pump used to sump or draw fuel from the bottom of a tank.

Water slug valve—A device that senses the rapid buildup of water in the system and shuts down fuel flow until water is drained.

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APPENDIX A

List of Regulations, Organizational Standards, Recommended Practices, and Guidance Material

Compiled from the literature review.

REGULATIONS

Code Of Federal Regulations (CFR)

14 CFR Part 139	Certification Of Airports
29 CFR Part 1910	Occupational Safety and Health Standards
33 CFR Part 154	Facilities Transferring Oil or Hazardous Material in Bulk
40 CFR Part 60	Standards of Performance for New Stationary Sources
40 CFR Part 112	Oil Pollution Prevention
40 CFR Part 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System (NPDES)
40 CFR Part 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)
40 CFR Part 281	Approval of State Underground Storage Tank Programs
49 CFR Part 100-185	Transportation of Hazardous Materials Regulations
49 CFR Parts 300-399	Federal Motor Carrier Administration (FMCA) Regulations
49 CFR Part 195	Transportation of Hazardous Liquids by Pipeline

United States Code (U.S.C.)

33 U.S.C. §1251	Clean Water Act (CWA)
33 U.S.C. §1251	Federal Water Pollution Control Act
33 U.S.C. §2701	Oil Pollution Control Act (OPA)
42 U.S.C. §4321	National Environmental Policy Act (NEPA)
42 U.S. Code § 6901	Solid Waste Disposal Act
42 U.S.C. §9601	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
42 U.S. Code Chapter 85	Clean Air Act (CAA)
42 U.S.C. §11001	Emergency Planning and Community Right-to-Know Act (EPCRA)
49 U.S.C. §5101	Hazardous Materials Transportation Act (HMTA)
52 U.S.C. § 6901	Resource Conservation and Recovery Act (RCRA)

ORGANIZATIONS

Airlines for America (A4A) (formerly Air Transport Association—ATA)

ATA	Airport Fuel Facility Ops and Maintenance Guidance Manual
ATA Spec 103	Standard for Jet Fuel Quality Control at Airports
ATA Spec 123	Procedures for the Accounting of Jet Fuel Inventory
ATA Spec 124	Standard Budget Format for Airline Fuel Consortia

American National Standards Institute (ANSI)

Standard B31.3	Petroleum Refinery Piping
Standard B31.4	Liquid Petroleum Transportation Piping System

American Petroleum Institute (API)

API RP 540	Electrical Installations in Petroleum Processing Plants
API RP 570	Piping Inspection Code: In-Service Inspection, Rating, Repair and Alteration of Piping Systems
API RP 571	Damage Mechanisms Affecting Equipment in the Refining Industry
API 579-1	ASME FFS-1, Fitness-For-Service
API RP 580	Risk-Based Inspection Technology
API RP 610	Centrifugal Pumps For Petroleum, Petrochemical, and Natural Gas Industries
API RP 650	Welded Steel Tanks for Oil Storage
API RP 651	Cathodic Protection of Aboveground Petroleum Storage Tanks
API RP 652	Lining of Aboveground Petroleum Storage Tank Bottoms
API RP 1004	Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles
API RP 1540	Testing of Tightness Integrity of Aviation Fuel Hydrant Systems
API RP 1543	Documentation, monitoring and laboratory testing of aviation fuel during shipment from refinery to airport
API RP 1595	Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals
API RP 1604	Closure of Underground Petroleum Storage Tanks
API RP 1615	Installation of Underground Petroleum Storage Systems
AP RP 1632	Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems
API RP 1637	Using the API Color-Symbol System to Mark Equipment and Vehicles for Product Identification at Gasoline Dispensing Facilities and Distribution Terminals
API RP 1615	Installation of Underground Petroleum Storage Systems
API RP 2003	Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
API RP 2013	Cleaning Mobile Tanks in Flammable or Combustible Service
API RP 2350	Overfill Protection for Storage Tanks in Petroleum Facilities
Bulletin D16	Suggested Procedure for Development of Spill Prevention Control and Countermeasure Plans
Pub 2202	Dismantling and Disposing of Steel from Tanks which have Contained Leaded Gasoline
MPMS Chapter 2	Tank Calibration
MPMS Chapter 3	Tank Gauging
MPMS Chapter 5	Metering
API STD 2000	Venting Atmospheric and Low-Pressure Storage Tanks
API STD 2015	Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks
API STD 2510	Design and Construction of Liquefied Petroleum Gas (LPG) Installations
API STD 2610	Design, Construction, Operation, Maintenance, and Inspection of Terminal & Tank Facilities
API STD 607	Testing of Valves—Fire Type-Testing Requirements
API STD 608	Metal Ball Valves—Flanged, Threaded and Butt-Welding Ends
API STD 610	Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries
API STD 650	Welded Tanks for Oil Storage
API STD 653	Tank Inspection, Repair, Alteration, and Reconstruction

American Society of Testing Material International (ASTM)

MNL 5–4th	Aviation Fuel Quality Control Procedures: 4th Edition
ASTM D910	Standard Specification for Aviation Gasoline (Avgas)
ASTM D7826 - 13	Standard Guide for Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives
ASTM D7547 - 14b	Standard Specification for Hydrocarbon Unleaded Aviation Gasoline
ASTM D7223 - 11	Standard Specification for Aviation Certification Turbine Fuel
ASTM D6986 - 03(2010)	Standard Test Method for Free Water, Particulate and Other Contamination in Aviation Fuels (Visual Inspection Procedures)
ASTM D5452 - 12	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
ASTM D5006 - 11	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
ASTM D5001 - 10(2014)	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D4865 - 09(2014)	Standard Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
ASTM D4860 - 13	Standard Test Method for Free Water and Particulate Contamination in Middle Distillate Fuels (Clear and Bright Numerical Rating)
ASTM D4308 - 13	Standard Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter
ASTM D4306 - 13	Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
ASTM D4176 - 04(2014	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D4171 - 11	Standard Specification for Fuel System Icing Inhibitors
ASTM D4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products
STM D4054 - 09	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D3242 - 11	Standard Test Method for Acidity in Aviation Turbine Fuel
ASTM D3240 - 11	Standard Test Method for Undissolved Water In Aviation Turbine Fuels
ASTM D2624 - 09	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
ASTM D2392 - 96(2011)	Standard Test Method for Color Of Dyed Aviation Gasolines
ASTM D2386 - 06(2012)	Standard Test Method for Freezing Point of Aviation Fuels
ASTM D2276 - 06(2014)	Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
ASTM D1655 - 14a	Standard Specification for Aviation Turbine Fuels
ASTM D1094 - 07(2013)	Standard Test Method for Water Reaction of Aviation Fuels
ASTM E1527-13	Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process
ASTM E2107	Standard Practice for Environmental Regulatory Compliance Audits

Association for Composite Tanks (Defunct organization-ACT-100 still referenced)

ACT-100	Specification for the Fabrication of FRP Clad Underground Storage Tanks

Coordinating Research Council (CRC)

CRC-663	Aviation Fuel Properties Handbook—2014 Fourth Edition
CRC-614	Development of a Test Method for the Determination of the Hydroperoxide Potential and Antioxidant Effectiveness in Jet Fuels During Long Term Storage
CRC-601	The Effect of Stadis 450 on MSEP Rating and Coalescence-Technical Basis of Re-doping Turbine Fuels with Stadis 450
CRC-590	Investigation of Electrostatic Effects of Commingled Aviation Fuels
CRC-583	Aircraft and Refueler Bonding and Grounding Study
CRC-573	Survey of Current Aircraft Engine Conditions

CRC-559	Determination of the Hydroperoxide Potential of Jet Fuels
CRC-552	Clay Filters
CRC-534	Electrostatic Charging Test for Aviation Fuel Filters
CRC-521	Fuel Effects on Gas Turbine Combustors and Engines—An Annotated Bibliography
CRC-509	CRC Literature Survey on the Thermal Oxidation Stability of Jet Fuels
CRC-504	Survey on the Use and Experience of Aircraft Fuel Biocides
CRC-496	Research Technique for Thermal Stability by Modified Jet Fuel Thermal Oxidation Test (JFTOT)
CRC-482	Aviation Fuel Safety—1975
CRC-478	A Survey of Electrical Conductivity and Charging Tendency Characteristics of Aircraft Turbine Fuels
CRC-475	Investigation of Techniques for Evaluating Oxidative Stability Deposits of Aviation Turbine Fuels
CRC-474	Research Technique for Evaluating New and Used Coalescer and Separator Elements of Aviation Jet Fuel Filter/Separators
CRC-473	Electrostatic Charging Survey of Airport Fueling Systems
CRC-470	Evaluation of Fuel Test Methods for Predicting the Performance of Filter/Separators and Clay Filters
CRC-469	Microbiological Aircraft Fuel Tank Contamination: A Bibliography
CRC-466	Generation and Dissipation of Electrostatic Charge During Aircraft Fueling—A Selected Literature Survey
CRC-460	Water/Fuel Separation Characteristics: A Bibliography
CRC-458	Electrostatic Charging Characteristics of Jet Fuel Filtration Equipment
CRC-450	Oxidative Stability of Aircraft Gas Turbine Fuels
CRC-435	Evaluation of 5-ml Bomb Procedure for Measuring High-Temperature Oxidation Stability of Gas Turbine Fuels
CRC-428	Evaluation and Precision of the Gas Drive Modified Fuel Coker
CRC-392	Evaluation of Modified Fuel Coker for Measuring High-Temperature Stability of Fuels for High-Performance Aircraft
CRC-388	Investigation of High Temperature Thermal Stability of Aviation Turbine Fuels
CRC-380	Aviation Fuel Safety
CRC-376	Development of Research Technique for Assessing the Water Separation Characteristics of Fuels Containing Surfactants
CRC-365	Distribution of Electrical Conductivity of Aviation Turbine Fuels
CRC-358	Development of Research Technique for Assessing the Water Separation Characteristics of Fuels and Fuel Additives Combinations
CRC-355	Electrostatic Discharges in Aircraft Fuel Systems—Phase I
CRC-346	Electrostatic Discharges in Aircraft Fuel Systems—Phase I
CRC-333	Fuel Thermal Stability Exchange Program
CRC-327	Jet Fuel Storage Stability
CRC-312	Report on Aviation Gasoline Desert Storage Program
CRC-310	Investigation of Thermal Stability of Aviation Turbine Fuels with CFR Fuel Coker
CRC-294	Temperature Coefficient of Viscosity of Aviation Fuels
CRC-290	Vapor Pressure Relations of Gasolines
CRC-286	Volatility Characteristics of Aircraft Fuels at Elevated Temperatures
CRC-270	Temperature of Stored Gasoline 1943–1945 Desert Storage Tests on Motor and Aviation Gasoline

Energy Institute (EI)

IP 475	Petroleum liquids—Manual sampling (ISO 3170: 2004)
EI 1529	Aviation fuelling hose and hose assemblies, 6th edition
EI 1530	Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports
EI 1540	Design, Construction, Operation and Maintenance of Aviation Fueling Facilities
EI 1541	Performance requirements for protective coating systems used in aviation fuel storage tanks and piping, 1st edition
EI 1542	Identification Markings for Dedicated Aviation Fuel Manufacturing and Distribution Facilities, Airport Storage and Mobile Fuelling Equipment
EI 1550	Handbook on Equipment Used for the Maintenance and Delivery of Clean Aviation Fuel
EI 1560	Recommended practice for the operation, inspection, maintenance and commissioning of aviation fuel hydrant systems and hydrant system extensions, 1st edition
EI 1570	Handbook on electronic sensors for the detection of particulate matter and/or free water during aircraft refueling
EI 1581	Specification and Qualification Procedures for Aviation Jet Fuel Filter/Separators
EI 1582	Specification for Similarity for API/EI 1581 Aviation Jet Fuel Filter/ Separators
EI 1583	Laboratory tests and minimum performance levels for aviation fuel filter monitors, 6th edition
EI 1584	Four-Inch Aviation Hydrant System Components and Arrangements
EI 1585	Guidance in the Cleaning of Aviation Fuel Hydrant Systems at Airports
EI 1590	Specifications and Qualification Procedures for Aviation Fuel Microfilters
EI 1594	Initial Pressure Strength Testing of Airport Fuel Hydrant Systems with Water
EI 1595	Design, construction, operation, maintenance and inspection of aviation pre-airfield storage terminals
EI 1596	Design and Construction of Aviation Fuel Filter Vessels
EI 1597	Procedures for Overwing Fuelling to Ensure Delivery of the Correct Fuel Grade to an Aircraft
EI 1598	Considerations for Electronic Sensors to Monitor Free Water and/or Particulate Matter in Aviation Fuel
EI 1599	Laboratory tests and minimum performance levels for aviation fuel dirt defence filters
EI HM 20	Meter proving: Aviation fuelling positive displacement meters, 2nd edition
EI HM 50	Guidelines for the cleaning of tanks and lines for marine tank vessels and refined products carrying petroleum
EI Research Report	Review of methods of bonding a hydrant dispenser (servicer) to an aircraft for refueling
EI Research Report	A qualitative review of electrostatic risks in jet fuel handling and equipment (excluding filtration) distribution
EI Research Report	Electrostatic discharges in 2-inch fuel filter monitors
EI Research Report	Electrostatic discharges in 2-inch aviation fuel filter monitors Phase 2: Properties needed to control discharges
EI Research Report	Investigation into the effects of lubricity additives on the performance of filter/water separators

Federal Aviation Administration (FAA)

Advisory Circular 150/5230-4B	Aircraft Fuel Storage, Handling, Training, and Dispensing on Airports
Advisory Circular 150/5390-2C	Heliport Design
Advisory Circular 20-125	Water in Aviation Fuel
Advisory Circular 20-122A	Anti-Misfueling Devices: Their Availability And Use
Advisory Circular 20-116	Marking Aircraft Fuel Filler Openings With Color Coded Decals
Advisory Circular 00-34A	Aircraft Ground Handling and Servicing

Fiberglass Tank & Pipe Institute

FTPI RP 2007-2	Field Test Protocol for Testing the Annular Space Of Installed Underground Fiberglass Double and Triple-Wall Tanks With Dry Annular Space
FTPI RP 1997-5	Fiberglass Reinforced Thermoset Plastic Tank & Piping Standards

Gammon Technical Products

GamGrams	Educational articles and technical bulletins

Helicopter Safety Advisory Conference (HSAC)

HSAC RP 2004-02	Jet Fuel Quality Control Procedures
	Jet Fuel Quality Control Inspection Checklist

International Air Transportation Association (IATA)

Guidance Material for Aviation Turbine Fuels Specifications, Part I—Guidance Material on Product Specifications	
Guidance Material for Aviation Turbine Fuels Specifications, Part II—General Guidance on Additive	
Guidance Material for Aviation Turbine Fuels Specifications, Part III—Cleanliness and Handling	
Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks	
Guidance Material on Standard Into-Plane Fueling Procedures	
Guidance on Airport Fuel Storage Capacity	
Guidance on Microbiological Contamination in Aircraft Fuel Tanks	
IATA 8402-01	Introduction to Safety Management Systems (SMS)
IATA/EASA	Fuel Tank Safety—Levels I and II
IATA/IFQP	Control of Fuel Quality & Fuelling Safety Standards
IATA/IFQP	IFQP Training Manual

International Business Aviation Council (IBAC)

International Standard for Business Aircraft Handling (IS-BAH)	Set of global industry best practices for business aviation ground handlers

International Civil Aviation Organization (ICAO)

Doc 9137	Airport Service Manual
Doc 9859	Safety Management Manual (SMM)
Doc 9977 AN/489	Manual on Civil Aviation Jet Fuel Supply 2012

International Safety Equipment Association (ISEA)

ISEA Z358.1	Emergency Eyewash and Shower Equipment

Joint Inspection Group (JIG)

JIG 1	Aviation Fuel Quality Control and Operating Standards for Into-Plane Fuelling Services
JIG 2	Aviation Fuel Quality Control and Operating Standards for Airport Depots.
JIG 3	Aviation Fuel Quality Control and Operating Standards for Supply & Distribution Facilities.
JIG 4	Aviation Fuel Quality Control and Operating Standards for Smaller Airports.
JIG Bulletin No. 35	Soak Testing
JIG Bulletin No. 39	Fuel Hydrant Commissioning

National Air Transportation Association (NATA)

NATA	Refueling and Quality Control Procedures for Airport Service and Support Operation

National Association of Corrosion Engineers (NACE)

SP 0169	Control of External Corrosion on Underground or Submerged Metallic Piping Systems
SP 0285-2011	External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
SP 0169-2007	Control of External Corrosion on Underground or Submerged Metallic Piping Systems
RP-02-85	Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems

National Fire Protection Association (NFPA)

NFPA 11	Standard for Low-, Medium-, and High-Expansion Foam
NFPA 16	Standard For The Installation Of Foam-Water Sprinkler And Foam-Water Spray Systems
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection
NFPA 30	Flammable and Combustible Liquids Code
NFPA 70	National Electrical Code
NFPA 77	Recommended Practice on Static Electricity
NFPA 326	Standard for Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair
NFPA 327	Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers Without Entry
NFPA 329	Underground Leakage of Flammable and Combustible Liquids
NFPA 385	Standard for Tank Vehicles for Flammable and Combustible Liquids, 2000 edition
NFPA 407	Standard for Aircraft Fuel Servicing
NFPA 415	Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways
NFPA 704	Standard System for the Identification of the Hazards of Materials for Emergency Response
NFPA Report	Aircraft Fuel Hydrant System Design Issues

National Leak Prevention Association (NLPA)

NLPA 631 A	Entry, Cleaning, Interior Inspection, Repair, and Lining of Underground Storage Tanks
NLPA/KWA 1-2009	Recommended Practice for Inspecting Buried Lined Steel Tanks Using a Video Camera

National Safety Council International (NSC)

NSC	Aviation Ground Operation Safety Handbook, 6th Edition

Petroleum Equipment Institute (PEI)

PEI/RP100-11	Installation of Underground Liquid Storage Systems
PEI/RP-600-12	Recommended Practices for Overfill Prevention for Shop-Fabricated Aboveground Tanks
PEI/RP800-13	Recommended Practices for Installation of Bulk Storage Plants
PEI/RP900-08	Recommended Practices for the Inspection and Maintenance of UST Systems
PEI/RP1200-12	Recommended Practices for the Testing and Verification of Spill, Overfill, Leak Detection and Secondary Containment Equipment at UST Facilities
PEI/RP1300-13	Recommended Practices for the Design, Installation, Service, Repair and Maintenance of Aviation Fueling Systems

Sandpiper Publications

Sandpiper Publications	Aircraft Handlers Guide
Sandpiper Publications	Aircraft Service Guide
Sandpiper Publications	Aircraft Towing Guide

Society of Automotive Engineers (SAE)

SAE AS 6401	Storage, Handling and Distribution of Jet Fuels at Airports
SAE AS 5877A	Detailed Specification for Aircraft Pressure Refueling Nozzle
SAE ARP 5918	Standard Test Criteria for Aircraft Refuelers
SAE ARP 5818	Design and Operation of Aircraft Refueling Tanker Vehicles
SAE ARP 5789	Aviation Fuel Facilities
2011-01-2794	Behaviour of Water in Jet Fuel in a Simulated Fuel Tank
2007-01-3866	The Commercial Aviation Alternative Fuels Initiative
1999-01-5603	Aviation and Exposure to Toxic Chemicals
831205	Fuel Stability and Storage Life of Middle Distillate Fuels
800771	A New Technique to Evaluate Performance of Jet Fuel Filtration Equipment
760542	Airport Jet Fuel Handling and Quality Control
720866	The Electrostatic Charging Tendencies of Jet Fuel Filtration Equipment
720324	Crash Fire Hazard Evaluation of Jet Fuels
670869	Microbes and Their Jet Fuel Environment
650269	Aviation Fuel Safety
640110	Storage Behavior of High Temperature Jet Fuels
630467	Jet Fuel Contamination: Water, Surfactants, Dirt and Microbes
AS5877B	Detailed Specification for Aircraft Pressure Refueling Nozzle
AS1852D	Nozzles and Ports - Gravity Refueling Interface Standard for Civil Aircraft

Steel Tank Institute (STI)

STI P3	Specification and Manual for External Corrosion Protection of Underground Steel Storage Tanks
STI SP001	Aboveground Tank System Inspector Training

U.S. Department of Defense (DoD)

AW 78-24-27	Aboveground Vertical Steel Fuel Tanks with Fixed Roofs
MIL-HDBK-1022A	Petroleum Fuel Facilities
NAVFAC MO-230	Maintenance and Operation of Petroleum Fuel Facilities
PWTB 200-1-66	Detection of Fuel Spills in Wastewater Collection Systems
UFC 3-260-01	Airfield and Heliport Planning and Design
UFC 3-460-01	Design: Petroleum Fuel Facilities
UFC 3-460-03	Operation and Maintenance: Maintenance of Petroleum Systems
UFC 3-575-01	Lightning And Static Electricity Protection Systems
UFGS-33 01 50.01	Cleaning Fuel Storage Tanks
UFGS-33 52 10	Service Piping, Fuel Systems
UFGS-33 52 43	Aviation Fuel Distribution (Non-Hydrant)
UFGS-33 52 43.23	Aviation Fuel Pumps
UFGS-33 52 43.28	Filter Separator, Aviation Fueling System
UFGS-33 56 10	Factory-Fabricated Fuel Storage Tanks
UFGS-33 56 13.13	Steel Tanks with Fixed Roofs

UFGS-33 56 63	Fuel Impermeable Liner System
UFGS-33 57 00	Bulk Fuel Receiving/Dispensing Equipment
UFGS-33 58 00	Leak Detection for Fueling Systems

Underwriters Laboratories, Inc. (UL)

UL 58	Standard for Steel Underground Tanks for Flammable and Combustible Liquids
UL 142	Steel Above Ground Tanks for Flammable and Combustible Liquids
UL 330	Standard for Hose and Hose Assemblies for Dispensing Flammable Liquids
UL 567	Standard for Emergency Breakaway Fittings, Swivel Connectors and Pipe-Connection Fittings for Petroleum Products and LP-Gas
UL 971	Standard for Nonmetallic Underground Piping For Flammable Liquids
UL 969	Standard for Marking and Labeling Systems
UL 971A	Outline of Investigation for Metallic Underground Fuel Pipe
UL 1316	Standard for Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products
UL 1746	External Corrosion Protection Systems for Steel Underground Storage Tanks
UL 2080	Fire Resistant Tanks for Flammable and Combustible Liquids
UL 2085	Protected Aboveground Tanks for Flammable and Combustible Liquids

APPENDIX B

Regulations Governing Fueling Operations at Certificated Part 139 Airports

Excerpted from 14 CFR Part 139 Certification of Airports (retrieved November 5, 2014, http://faa.gov/).

§ 139.321 Handling and storing of hazardous substances and materials.

(a) Each certificate holder who acts as a cargo handling agent must establish and maintain procedures for the protection of persons and property on the airport during the handling and storing of any material regulated by the Hazardous Materials Regulations (49 CFR 171 through 180) that is, or is intended to be, transported by air. These procedures must provide for at least the following:

(1) Designated personnel to receive and handle hazardous substances and materials.

(2) Assurance from the shipper that the cargo can be handled safely, including any special handling procedures required for safety.

(3) Special areas for storage of hazardous materials while on the airport.

(b) Each certificate holder must establish and maintain standards authorized by the Administrator for protecting against fire and explosions in storing, dispensing, and otherwise handling fuel (other than articles and materials that are, or are intended to be, aircraft cargo) on the airport. These standards must cover facilities, procedures, and personnel training and must address at least the following:

(1) Bonding.

(2) Public protection.

(3) Control of access to storage areas.

(4) Fire safety in fuel farm and storage areas.

(5) Fire safety in mobile fuelers, fueling pits, and fueling cabinets.

(6) Training of fueling personnel in fire safety in accordance with paragraph (e) of this section. Such training at Class III airports must be completed within 12 consecutive calendar months after June 9, 2004.

(7) The fire code of the public body having jurisdiction over the airport.

(c) Each certificate holder must, as a fueling agent, comply with, and require all other fueling agents operating on the airport to comply with, the standards established under paragraph (b) of this section and must perform reasonable surveillance of all fueling activities on the airport with respect to those standards.

(d) Each certificate holder must inspect the physical facilities of each airport tenant fueling agent at least once every 3 consecutive months for compliance with paragraph (b) of this section and maintain a record of that inspection for at least 12 consecutive calendar months.

(e) The training required in paragraph (b)(6) of this section must include at least the following:

(1) At least one supervisor with each fueling agent must have completed an aviation fuel training course in fire safety that is authorized by the Administrator. Such an individual must be trained prior to initial performance of duties, or enrolled in an authorized aviation fuel training course that will be completed within 90 days of initiating duties, and receive recurrent instruction at least every 24 consecutive calendar months.

(2) All other employees who fuel aircraft, accept fuel shipments, or otherwise handle fuel must receive at least initial on-the-job training and recurrent instruction every 24 consecutive calendar months in fire safety from the supervisor trained in accordance with paragraph (e)(1) of this section.

(f) Each certificate holder must obtain a written confirmation once every 12 consecutive calendar months from each airport tenant fueling agent that the training required by paragraph (e) of this section has been accomplished. This written confirmation must be maintained for 12 consecutive calendar months.

(g) Unless otherwise authorized by the Administrator, each certificate holder must require each tenant fueling agent to take immediate corrective action whenever the certificate holder becomes aware of noncompliance with a standard required by paragraph (b) of this section. The certificate holder must notify the appropriate FAA Regional Airports Division Manager immediately when noncompliance is discovered and corrective action cannot be accomplished within a reasonable period of time.

(h) FAA Advisory Circulars contain methods and procedures for the handling and storage of hazardous substances and materials that are acceptable to the Administrator.

APPENDIX C

Mobile Fueler Preliminary Hazard List

System Element Type: Aircraft mobile avgas refueler		Preliminary Hazard List (PHL)	Analyst: S. Quilty, SMQ Airport Services ©	
			Date: January 1, 2015	
No.	**System Item**	**Hazard**	**Hazard Effects**	**Comments**
1	Avgas fuel storage	Release of combustible vapors	Potential for fire and/or explosion	
2	Electric pump motor	Over pressurization of the system	Destruction of filter or pipes	
3	Electric pump motor	Heat or ignition source for combustible fuel	Potential for fire and/or explosion	
4	Pump impeller	Mechanical breakdown/disintegration	Destruction of filter and separator	
5	Pump impeller	Worn seal allowing leakage	Potential for fire and/or explosion	
6	Pressure vessels and pipes	Bad welds/fasteners or incorrect assembly	Potential for fire and/or explosion	
7	Recirculation and venting	Plugged vents	Over pressurization of the system causing malfunction	
8	Hose and nozzle	Tripping hazard	Personal injury or equipment damage	
9	Hose and nozzle	Broken or frayed grounding wire	Potential for cuts/personal injury	
10	Hose and nozzle	Nozzle has debris	Contamination of the fuel	
11	Electrical switches	Creates ignition source	Potential for fire and/or explosion	
12	Electrical bonding	Broken bonding wire creates ignition source	Electrical potential to create spark for fire and/or explosion	
13	Electrical bonding	Frayed bonding wire	Potential for cuts/personal injury	
14	Filter and separator	Clogged filter or separator	Contamination of the fuel	
15	Filter and separator	Torn filter or separator	Contamination of the fuel	

From S. Quilty, SMQ Airport Services ©

APPENDIX D

Mobile Fueler Operating and Support Hazard Analysis

System:	Mobile Fueling System	Operating and Support Hazard Analysis (O&SHA)					Analyst:	S. Quilty SMQ Airport Services ©	
Operation:	Fueling aircraft procedure						Date:	January 1, 2015	
Task	**Hazard No.**	**Hazard**	**Causes**	**Effects**	**IMRI**	**Recommended Action**	**FMRI**	**Comments**	**Status**
Operator parks vehicle	OSA-1	Kinetic energy hazard of mobile fueler striking object	Operator does not properly engage gear shift; Operator in a hurry or distracted	Damage to vehicle, equipment and/or aircraft	2C	Provide light indicator on dashboard; Provide procedures and operator training - situational awareness	2D		
Operator parks vehicle	OSA-2	Kinetic energy hazard of mobile fueler striking object	Operator does not properly engage brake system; Mechanical problem with brake handle	Damage to vehicle, equipment and/or aircraft	2C	Conduct routine maintenance of mobile fueler	2D		
Operator exits vehicle	OSA-3	Fall hazard from height of seat and floor to ground	Operator in a hurry or distracted	Slip and fall injury to Operator	2C	Provide person assist handle; Provide procedures and operator training - situational awareness	2D		
Operator exits vehicle	OSA-4	Slip hazard on pavement	Wet or icy surface	Slip and fall injury to Operator	2C	Require slip resistant shoes; Provide procedures and operator training - situational awareness	2D		
Operator leaves engine running	OSA-5	Fire and explosion hazard from ignitable material	Heat from engine can create ignition source	Explosion and fire damaging aircraft, mobile fueler and injuring operator	1C	Seal electrical wiring and devices; route exhaust away from fuel dispenser	1D		
Operator chocks wheels	OSA-6	Nip points and sharp edges on vehicle	Bodily movement strikes vehicle	Injury to operator	2D	Provide procedures and operator training: identify and label danger points on vehicle	2D		
Operator connects bonding cable to aircraft	OSA-7	Static electricity hazard from ignition source	Spark jump from fueler connecting cable	Explosion and fire damaging aircraft, mobile fueler and injuring operator	2d	Provide procedures and operator training; make connection away from fuel vapor area.	2D		
Operator connects bonding cable to aircraft	OSA-8	Physical wound hazard from steel cable	Frayed steel cable exposure	Injury to operator	2B	Use plastic sheathing over cable; Require use of gloves	2D		
Operator reels out hose to aircraft	OSA-9	Muscle strain hazard from operational activity	Excessive drag on reel movement and length of hose pull	Injury to operator	2B	Provide procedures and operator training: parking proximity to aircraft, proper pull techniques	2C		
Operator sets meter dial	OSA-10	Muscle strain hazard from operational activity	Improper hand twist motion	Injury to operator	2B	Provide procedures and operator training; redesign handle	2D		
Operator turns on pump	OSA-11	Electrical activation can create ignition source	Short or spark in motor or wiring	Explosion and fire damaging aircraft, mobile fueler and injuring operator	1D	Seal electrical wiring and devices; route exhaust away from fuel dispenser; routine maintenance checks	1E		
Operator turns on pump	OSA-12	Fuel contamination hazard from mechanical failure	Seizure of the pump shaft or other bearings	Fuel contamination and equipment damage	1D	Conduct routine maintenance of mobile fueler	1E		
Operator activates fuel nozzle	OSA-13	Personal injury or exposure from splashing of fuel; fire hazard	Improper placement of fuel nozzle	Explosion and fire damaging aircraft, mobile fueler and injuring operator	1C	Provide procedures and operator training; wear safety goggles and protective clothing	1D		
Operator deactivates fuel nozzle	OSA-14	Fuel spill hazard from malfunctioning nozzle	Fuel nozzle handle does not seal properly	Explosion and fire damaging aircraft, mobile fueler and injuring operator	1C	Conduct routine maintenance of mobile fueler	1D		

From S. Quilty, SMQ Airport Services ©

APPENDIX E

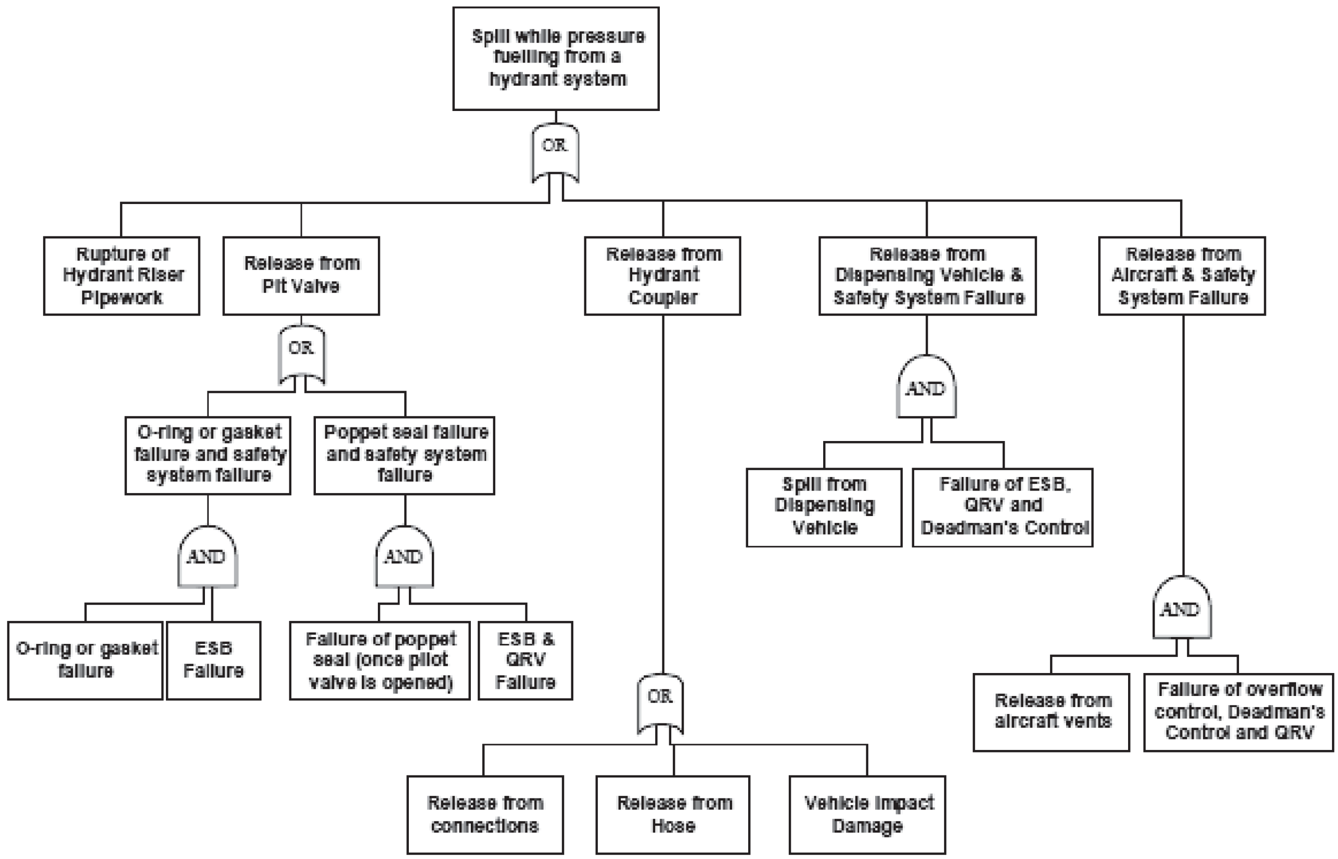
Mobile Fueler Failure Mode and Effect Analysis

Failure Mode and Effects Analysis (FMEA)										
System:	**Mobile Fueler**		**Subsystem:**	**Fuel delivery & Filtration**			**Mode/Phase:**	**Operational**		
Item	**Failure Mode**	**Failure Rate**	**Causal Factors**	**Immediate Effect**	**System Effect**	**Method of Detection**	**Current Controls**	**Hazard**	**Risk**	**Recommended Action**
Fuel Pump	Fails to pump fuel	From Manufact urer	Bearing failure	Pump stoppage	Fuel flow stoppage	Pressure gauge; pump sound	Pressure gauge	Engine failure from contamination of fuel from bearing / pump debris	3D	Continue routine maintenance per manufacturer
	Fails to pump fuel	From Manufact urer	Bearing failure	High Temperatur es	Reduced fuel flow rate	Touch; heat sensor	None	Fire / explosion hazard from vapor release	2D	Continue routine maintenance per manufacturer; Add temperature sensor monitor
	Performs Incorrectly	Internal records	Seal deterioration	Fuel leakage	Reduced fuel flow rate	Visual	Daily Inspection	Environmental hazard; Fire / explosion hazard from vapor release	2D	Continue daily checks; Follow manufacturer's replacement schedule
	Fails to pump fuel	From Manufact urer	Electric motor failure	Pump stoppage	Fuel flow stoppage	Pressure gauge; motor sound	Pressure gauge; circuit breaker	Fire / explosion hazard from electrical spark	2d	Continue monitoring per manufacturer
Fuel Filter	Fails to filter fuel	Internal records	Debris in fuel;	Tear in filter	Increased nozzle fuel pressure; contaminat ed fuel	Pressure gauge;	Pressure gauge; Regular filter maintenance	Engine failure from contamination of fuel from filter debris	2D	Add metal chip detector; Add warning switch on pressure gauge
	Fails to allow fuel flow	Internal records	Debris in fuel;	Clogs filter	Reduce fuel flow pressure	Pressure gauge	Pressure gauge; Regular filter maintenance	Pump failure	3D	Add metal chip detector; Add warning switch on pressure gauge
	Performs incorrectly	Internal records	Filter or seal deterioration	Leakage	Reduce fuel pressure	Pressure gauge	Pressure gauge; Regular filter maintenance	Environmental hazard from leakage; Engine failure from contamination of filter debris	2D	Continue daily checks; Follow manufacturer's replacement schedule
Analyst:	**S. Quilty, SMQ Airport Services ©**			Date:	**January 1, 2015**			Page:	**1**	

From S. Quilty, SMQ Airport Services ©

APPENDIX F

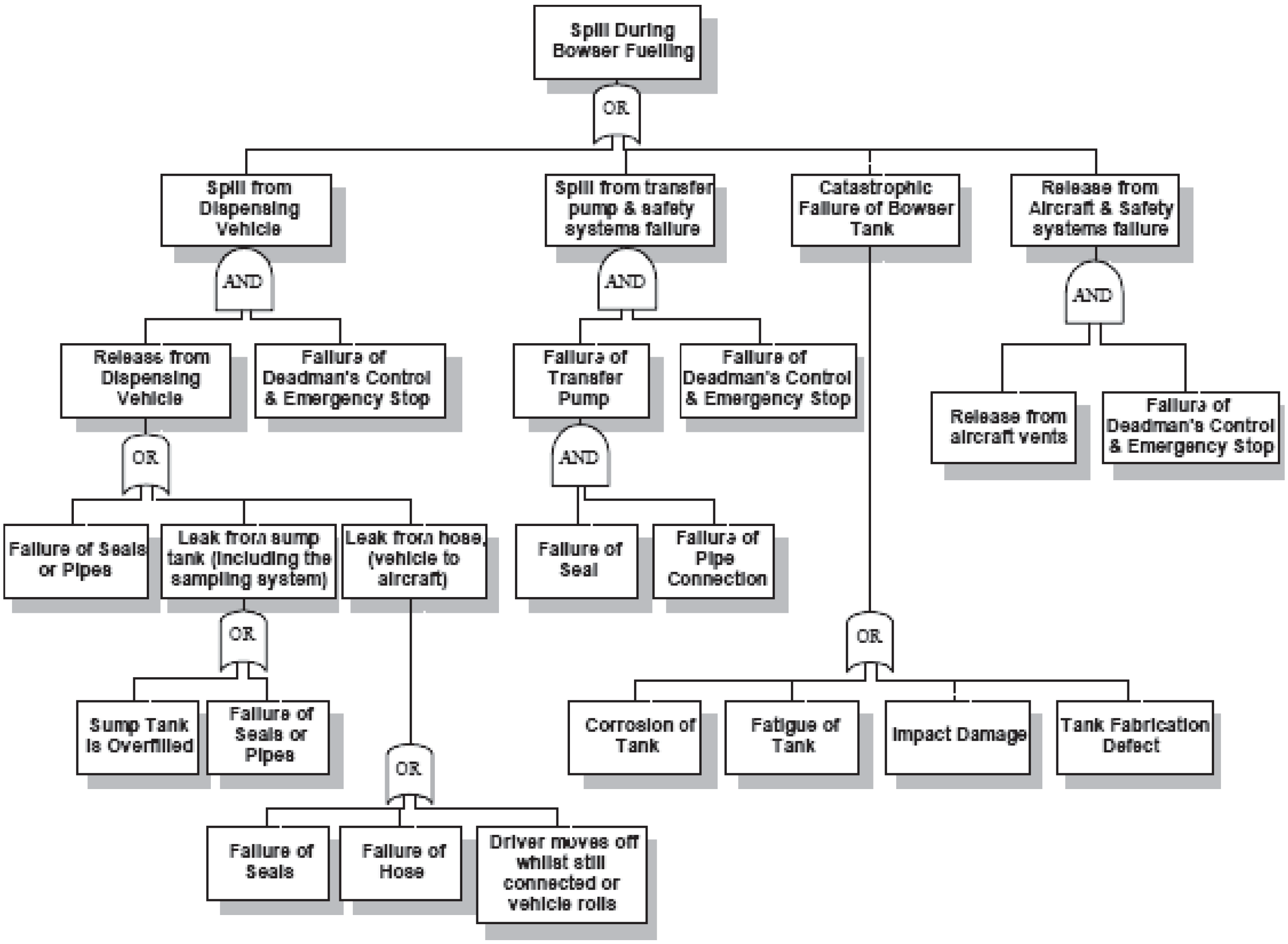
Fuel Hydrant System Fault Tree Analysis



Reprinted with permission Jones et al. (2000, p. 61).

APPENDIX G

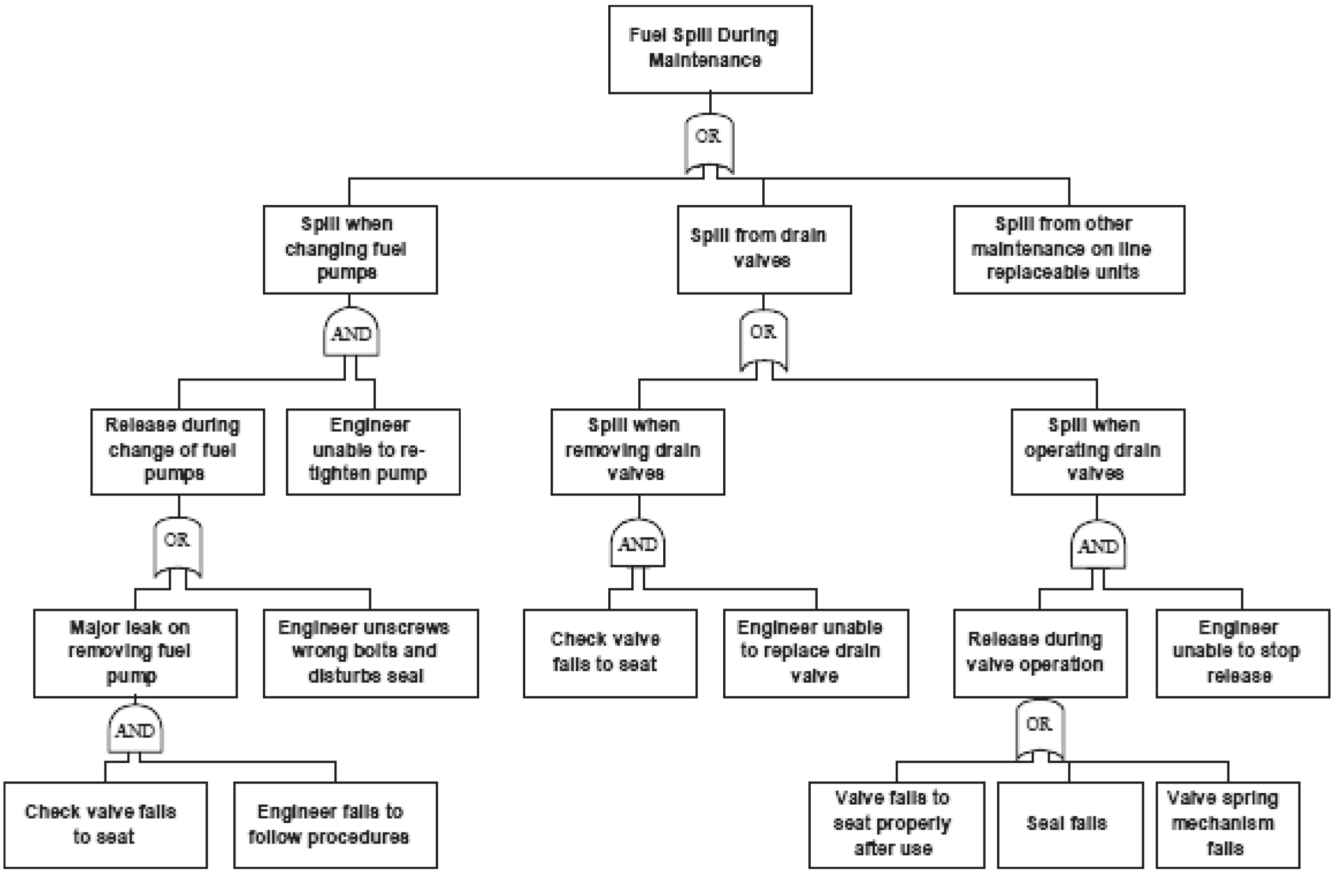
Fuel Tank Truck Fault Tree Analysis



Reprinted with permission Jones et al. (2000, p. 63).

APPENDIX H

Fuel System Maintenance Fault Tree Analysis



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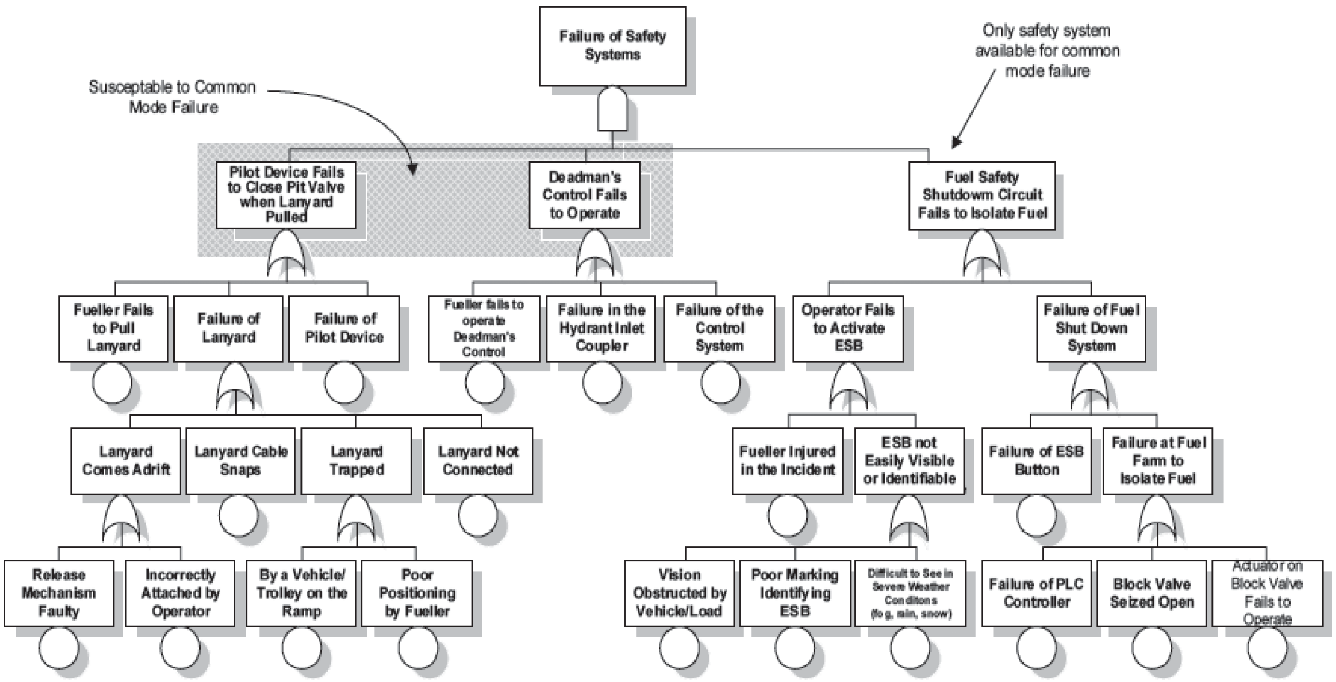
APPENDIX I

Fuel System Safety Failure Fault Tree Analysis



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APPENDIX J

FAA Advisory Circular Fueling Inspection Procedures

Excerpted from AC 150/5200-18C *Airport Safety Self Inspection* (retrieved Nov. 5, 2014, http://faa.gov/)

10. REGULARLY SCHEDULED INSPECTION.

e. Lighting.

(2)(iii) Lighting in fuel storage areas.

h. Fueling Operations. The daily inspection on aircraft fueling operations should concentrate on a quick inspection for the most common problems concerning compliance with local fire safety codes at fuel storage areas and with mobile fuelers. The inspection should also include security, fire protection, general housekeeping, and fuel dispensing facilities and procedures. A more detailed fueling operation inspection should be scheduled quarterly (see Quarterly Fueling Operations under Periodic Condition Inspection). During the daily inspection of aircraft fueling operations, the inspector should:

(1) Determine if the fueling operator is permitting any unsafe fueling practices or is in violation of local fire code, such as failure to bond aircraft with the mobile fuelers during fueling operations or fueling personnel smoking while fueling aircraft.

(2) Check to ensure that the appropriate signs for the fuel farm are installed and that all gates are locked except when the facility is occupied by an authorized user.

(3) Report and monitor any unsafe fueling practices and violation of local fire codes. At Part 139 airports, report any noncompliance with fuel fire safety procedures specified in the FAA-approved Airport Certification Manual.

11. CONTINUOUS SURVEILLANCE INSPECTION.

b. Fueling Operations. The inspector should:

(1) Emphasize fire and explosion hazards inherent in aircraft refueling.

(2) Ensure proper bonding is being used, deadman controls are not blocked, and no smoking prohibitions are being observed, and aircraft are not being fueled inside hangars.

(3) Check for proper parking of mobile fuelers to ensure these vehicles are at least 10’ apart and 50’ from buildings.

(4) Check for fuel leaks or spills in the fuel storage area and around mobile fuelers.

(5) Determine if the fuel farm is free of flammable materials, including litter and vegetation.

(6) Report and monitor any of unsafe fueling conditions discussed above and other obvious violations of local fire code and airport fuel fire safety procedures.

12. PERIODIC CONDITION INSPECTION.

d. Quarterly Fueling Inspections. Airports certificated under Part 139 are required to establish fire safety standards for safe fueling operations and conduct quarterly inspections of the fueling facilities. The inspection procedures in this section are based on the NFPA 407 fire code for airport fueling operations, which is one of the more common fire codes in effect at certificated airports. The fire safety standards for fueling operations should be listed in the Airport Certification Manual (ACM) and the quarterly inspections should be conducted for compliance to the fueling fire safety standards listed in the ACM. Sample quarterly inspection checklists for fuel storage areas and mobile fuelers are included in Appendix 5. Typical fire safety standards to inspect quarterly are listed here. Airports certificated under Part 139 are required to maintain a record of this inspection for at least 12 months.

(1) Fuel storage areas and loading/unloading stations. The inspector should:

(i) Check fuel storage areas for adequate fencing and security to prevent unauthorized access or tampering.

(ii) Check for “No Smoking” signs that are clearly visible.

(iii) Check fuel storage areas for materials such as trash or vegetation that could contribute to the spread of fire. Also check for equipment, functions or activities that could be ignition sources.

(iv) Note if fueling equipment appears to be in good operating condition and free of fuel leaks.

(v) Check piping for reasonable protection from damage by vehicles if piping is above ground.

(vi) Check fuel storage areas for at least two accessible and serviceable fire extinguishers. Where the open hose discharge capacity of the equipment if more than 200 gallons per minute, at least one wheeled extinguisher with at least 125 lbs of agent is also required.

(vii) Check for explosion proof equipment, switches and wiring that is reasonably protected from heat, abrasion or impact, which could cause an ignition source.

(viii) Check for piping, filters, tanks and pumps being electrically bonded together and interconnected to an adequate grounding rod.

(ix) Check for a serviceable bond/ground wire with clip at each loading/unloading facility for grounding tankers and mobile fuelers.

(x) Check loading stations for deadman control features.

(xi) Look for a boldly marked emergency cutoff capable of stopping all fuel flow with one physical movement. The emergency cutoff should be located outside the probable fuel spill area near the route that normally is used to leave the spill area or to reach the fire extinguishers.

(2) Mobile fuelers. At least once every 3 months, inspect all fuel trucks to ensure they meet fire safety standards. The inspector should:

(i) Note if mobile fuelers appear to be in good operating condition and free of fuel leaks.

(ii) Check mobile fuelers for parking at least 50 feet from a building and at least 10 feet from each other. Note: Some airports have a mobile fueler maintenance building that is approved by the local fire marshal.

(iii) Check for flammability decals on all sides. Lettering should be at least 3 inches high. Also check for hazardous materials placards on all sides. The Hazmat number for Jet A trucks should be **#1863** and **#1203** for 100LL trucks.

(iv) Check the cab for a "No Smoking" sign and the presence of smoking equipment. Ashtrays and cigarette lighters are not to be provided.

(v) Check for two fire extinguishers, accessible from each side of the mobile fueler. Fire extinguishers should be charged, sealed and tagged from the last fire extinguisher inspection. Check dry chemical extinguishers to ensure they are only B-C rated. ABC rated multi-purpose dry chemical extinguishers are not to be used on mobile fuelers as they are highly corrosive to aircraft and can cause significant damage to aircraft engines.

(vi) Check emergency fuel cutoffs to ensure they are boldly marked and operable. There should be an emergency fuel cutoff accessible from each side.

(vii) Check electrical equipment, switches, wiring and tail light lens covers for explosion proof construction and reasonable protection form heat, abrasion or impact which could be an ignition source.

(viii) Check for serviceable bonding wires and clamps.

(ix) Check nozzles for deadman control feature.

(x) Check the vehicle exhaust system for exhaust leaks and for adequate shielding if it extends under the fuel tank portion of the vehicle.

APPENDIX K

FAA Flight Standards Fueling Inspection Procedures

Excerpted from FAA Order 8900.1 Flight Standards Information Management System (FSIMS)
(retrieved Nov. 5, 2014, http://fsims.faa.gov/)

B. REVIEW PROCEDURES

A. Review the Operator's Manual. Ensure that the manual indicates whether services will be performed by the operator or contracted out.
   (1) Review the operator's manual to ensure that it defines the following:
   - Lines of authority and responsibilities
   - The operator's training program
   - The vendor's training program, if applicable

   (2) Ensure that the manual contains procedures for the following:
   - Inspection of incoming fuels
   - Elimination of fuel contamination
   - Use of dispensing equipment
   - Refueling and defueling, by specific make and model of aircraft

   (3) Ensure that the manual includes procedures for record retention and ongoing inspections of the following:
   - Fuel (millipore checks, etc.)
   - Storage facilities and dispensing equipment
   - Filters
   - Safety equipment
   - Training programs for servicing personnel
   - Individual training records
   - Vendors (in accordance with operator's program)

   (4) If the manual is acceptable at this point, continue on to the facilities inspection. If the manual is unacceptable, return it to the operator for corrections and/or revisions.

B. Inspect the Facility
   (1) Ensure that:
   - Personnel training requirements are documented and current
   - Training is conducted according to the manual curriculum
   - Piping is marked and color coded to identify fuel type and grade
   - Control/cutoff valves are clearly marked with instructions for emergency use, e.g., on/off

   (2) Ensure that the fuel farm/storage area provides for the following:
   - Proper security (fenced and posted)
   - Proper display of "Flammable" and "No Smoking" signs
   - Markings to identify type/grade of fuel

   (3) Ensure that the equipment includes the following:
   - A positive low point sump
   - Adequate fire extinguishers

   (4) Ensure that fuel filters/filter separators contain, at a minimum, the following:
   - An inlet strainer
   - Inflow and outflow filter/separators sized to match maximum pump flow capacity
   - Differential pressure check system
   - Positive water defense system
   - Sump drain with outlet located to facilitate capture of outflow
   - Fuel sampling (millipore or equivalent) fittings downstream of all filters and filter/separators

   (5) Ensure that hoses, nozzles and outflow connectors are:
   - Specifically designed and tested for delivery of aviation fuels
   - Controlled by spring loaded, nonbypassable automatic (deadman) fuel flow cutoff valves
   - Equipped with dust cap or other feature that will minimize contaminant introduction into fuel/system
   - Equipped with nonbypassable 100 mesh nozzle/connector screens
   - Color coded to identify fuel type

   (6) Ensure that electrical equipment, switches, and wiring are of a type or design approved for use in hazardous locations (explosion proof; e.g., free of exposed conductors, contacts, switches, connectors, motors, etc.).

   (7) Verify that grounding and bonding equipment ensures that piping, filters, tanks, and electrical components are electrically bonded together and interconnected to an adequate electrical ground. The system should have ground wires, bonding wires, and clamps adequate to facilitate prompt, definite electrical ground connection between fueler/pit/cabinet, grounding system, and aircraft being fueled.

   (8) Ensure that fuel tenders and fueling pits have the following:
   (a) Appropriate markings displayed; e.g., "DANGER," "FLAMMABLE," "NO SMOKING," fuel grade, standard hazardous material placard, filter due dates, and emergency fuel shutoff
   (b) Appropriately placed fire extinguishers
   (c) Air filter/spark arrestor and a leak-free exhaust system terminating in a standard baffled original equipment type muffler, if equipped with internal combustion engine

APPENDIX L

Sample Filtration Test Record Form

FILTRATION TEST RECORD

AIRPORT:	FACILITY:
TRUCK # / EQUIP. #:	DATE:

SAMPLING POINT	MEMBRANE FILTRATION TEST ASTM D 3830	ENTRAINED / FREE WATER TEST TYPE	WATER TEST RESULTS
BEFORE FILTRATION ( ) MONITOR ( ) FILTER / SEPARATOR ( ) OTHER ______________ DP* PSI _____ ACTUAL FLOW RATE _____ CORRECTED DP _____	ATTACH MEMBRANE IN APPROVED PROTECTIVE TRANSPARENT BAG DRY RATING ____ FLUSH SIZE _____ SAMPLING SIZE _____ GALLONS		
AFTER FILTRATION ( ) MONITOR ( ) FILTER / SEPARATOR ( ) OTHER ______________ DP* PSI _____ ACTUAL FLOW RATE _____ CORRECTED DP _____	ATTACH MEMBRANE IN APPROVED PROTECTIVE TRANSPARENT BAG DRY RATING ____ FLUSH SIZE _____ SAMPLING SIZE _____ GALLONS	( ) Velcon ( ) Shell ( ) Aqua-Glo	[ ] PPM

* DP = OBSERVED DIFFERENTIAL PRESSURE (PSI) ACROSS FILTER SHOULD BE AT MAXIMUM FLOW

NOTES:

____

____

____

____

____

____

____

____

____

TEST PERFORMED BY:	SIGNATURE:	DATE:
SUPERVISOR NAME:	SIGNATURE:	DATE:

(RETAIN ON FILE FOR 36 MONTHS)

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX M

Sample Filter Vessel Record Form

FILTER VESSEL RECORD

COMPANY:	AIRPORT:	FACILITY:
GRADE OF FUEL: AVGAS JET JET W/FSII	REFUELER OR STORAGE FILTER #:	

VESSEL MANUFACTURER:	VESSEL MODEL #:	SERIAL #:

TYPE OF FILTER	
FILTER / SEPERATOR VESSEL (TWO STAGE VESSEL)	
1st STAGE ELEMENTS:	NUMBER OF ELEMENTS:
2nd STAGE ELEMENTS:	NUMBER OF ELEMENTS:
LID GASKET:	MAX. FLOW RATE:
WATER DEFENSE SYSTEM	
TYPE: (EXAMPLE: SLUG VALVE WITH FLOAT)	MANUFACTURER:
MONITOR VESSEL	
ELEMENTS:	NUMBER OF ELEMENTS:
LID GASKET:	MAX. FLOW RATE:

FILTER CHANGE RECORD	
DATE OF LAST CHANGE:	DUE DATE:
BEGINNING SERVICE DATE:	INITIAL DP OBSEVERD AT FULL FLOW RATE:
GALLONS PER MIN. AT FULL FLOW:	CORRECTED DP :
MAX. OBSERVED DP ALLOWED FOR VESSEL*:	

* THIS IS THE CALCULATED MAXIMUM DP OBSERVED BEFORE VESSEL REQUIRES CHANGEOUT OF FILTERS.

Note #1: Recommend copy of similarity data report to be kept with records.
Note #2: Filter vessel shall have correct data tag for elements installed.

COMMENTS: ______________________________

Form # AVQA3 REV. 0113

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX N

Sample Product Receipt Record Form

PRODUCT RECEIPT RECORD

FACILITY NAME:		AVFUEL CUSTOMER#:	TANK#:
TANK SIZE:	MONTH:		TYPE OF PRODUCT:

RECEIPTS / BOL	#	#	#	#	#	#
BEFORE UNLOADING						
Date						
Fire Equipment Operable and Ready						
Storage Tank Gauge, Inches						
Storage Tank Contents, Gallons						
Storage Tank Available Capacity, Gallons						
Vol. Ordered vs. Available Space, O.K.?						
Drain Storage Tank Sump						
Drain Filter / Separator Sump						
Condition of Offload Hose						
Align All Valves for Receipt						
INSPECTING THE TRANSPORT						
Bond /Ground Transport						
Transport Name & Truck #						
Avfuel Product Release Certificate						
Product Verified: Color, Odor, Seals, Etc.						
Truck Capacity - Gallons						
BOL Gallons - Gross						
BOL Gallons - Net						
No Visible Debris or Water In Truck						
Product Sample Clear & Bright						
API Gravity Corrected to 60 Deg. F *						
API Observed Fuel Temperature *						
FSII Field Test (.10 - .15% Concentration)						
UNLOADING						
Time Unloading Started						
Unload - (Someone Stay With Operator)						
Differential Pressure Filter / Separator						
AFTER UNLOADING						
Check All Truck Compartments For Empty						
Close Unloading Valves - Realign To Use						
Uncouple Transport						
Drain Filter / Separator Sump						
Drain Storage Tank Sump						
Storage Tank Gauge, Inches						
Storage Tank Contents, Gallons						
Time Unloading Completed						
Time Tank Ready To Dispense Fuel						
Secure Tank Outlets And Storage Area						
Ready						
Person Receiving And Cleaning, Initials						
Remarks:						

* Additional tests may be required at your facility. Check with your operations supervisor for any additional tests needed.

1.4.13 PRODRCPT REV.1 (RETAIN ON FILE FOR 36 MONTHS)

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX O

Sample Refueler Daily Inspection Form

Note: All unsatisfactory ratings must include a remark / comment for that day

DAILY INSPECTION RECORD REFUELERS	MONTH:	EQUIP. #:

DATE	INSPECTED BY (Signature)	REMARKS / COMMENTS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

Vehicle Checks - Weekly	Date -	Date -	Date -	Date -	Date -
1. Ensure Oil Level					
2. Belts, Hoses, and Tires					
3. Fluids (Coolant, Brake, Power)					
4. Lights, Lenses, Beacon					

ENTER DATE	CHASSIS LUBRICATION			OIL CHANGE			WASH		

Notes : 1) OIL SHALL BE CHANGED AND THE CHASSIS SHALL BE LUBED EVERY SIX (6) MONTHS OR 350 OPERATING HOURS.
2) PUMPING SYSTEM SHALL BE LUBED A MINIMUM OF EVERY THREE (3) MONTHS (ALWAYS FOLLOW CHASSIS AND COMPONENT MANUFACTURER GUIDELINES)

COMMENTS:

SUPERVISOR NAME: SIGNATURE: DATE:

(RETAIN ON FILE FOR 36 MONTHS)

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX P

Sample Fixed Equipment Fuel Storage Daily Inspection Form

Note: All unsatisfactory ratings must include a remark / comment for that day.

DAILY INSPECTION RECORD
FIXED EQUIPMENT FUEL STORAGE SYSTEM

DATE	INSPECTED BY (Signature)	REMARKS / COMMENTS	Tank ___ Gallons	Tank ___ Tank Gauge*	Tank ___ Gallons	Tank ___ Tank Gauge*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						

COMMENTS:

* Tank Gauge = Physical stick reading in inches.

Storage Tank Inspection and Cleaning		
Tank #	Date Cleaned	Remarks

SUPERVISOR NAME: SIGNATURE: DATE:

(RETAIN ON FILE FOR 36 MONTHS)

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX Q

Sample Refueler Vehicle Inspection Form

REFUELER VEHICLE INSPECTIONS	Airport:	Facility:	Equip. #:	Date:

DAILY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1. General Conditions																															
2. Filter Sump / Record Rating																															
3. Tanker Sump(s) / Record Rating(s)																															
4. Filter Differential Pressure / Record PSI																															
5. Deadman Controls																															
6. Brake (Safety) Interlocks																															
7. Nozzle(s) Fueling Pressure (PSI)																															
8. Hoses, Swivels, and Nozzles																															
9. Ground Reels, Cables, and Clamps																															
10. Fire Extinguishers																															
11. Tanker Troughs & Drains																															
12. Air Tanks (Drain)																															
13. Tanker Bottom Loading - Pre-Check																															
14. Spill Kit																															
15. FSII Desiccant Dryer																															
16. Lift Platforms																															
17. Surge Tank Sump																															
18. Fuel Leaks																															
19.																															
20.																															
Signature of person performing tasks or person accepting responsibility that tasks were performed.																															

MONTHLY	MK	Date	Signature
21. Filter Membrane Test & Water Test			
22. Bond Cable Continuity Test			
23. Nozzle Screens			
24. Fuel Hoses			
25. Signs and Placards			
26. Meter Seals			
27. Fire Extinguishers			
28. Emergency Fuel Shutdown System			
29. FSII Calibration % of Inj. _____			
30. Tanker Interior (Visual)			
31. Tanker Vent(s) & Dome Cover			
32. Tanker Troughs & Drains			
33. Internal Valve - Integrity Check			
34.			

QUARTERLY	MK	Date	Signature
35. Vehicle Inspection			
36. Primary Pressure Control ___ psi			
37. Secondary Pressure Control ___ psi			
38. Water Defense (External Check)			
39. Brake Interlock Override			
ANNUAL	**MK**	**Date**	**Signature**
40. Filter Elements (Change)			
41. Pressure & DP Gauges (Calibrate)			
42. Fuel Meters (Proving)			
43. Water Defense System (Tested by Injecting Water)			
44. Fire Extinguisher Certifications			
45.			
46.			

MARKINGS (MK)
S = Satisfactory
X = Unsatisfactory
N/S = Not in Service
N/A = Not Applicable
Rating of Sump Samples
Record First Observed - Sump to 1A
Solids = (1) Clear (2) Slight (3) Particulate (4) Dirty
Water = (A) Bright (B) Hazy (C) Cloudy (D) Wet (E) Surfactant

Note #1: These are recommended minimum quality assurance checks for aviation fueling equipment.

Note #2: All unsatisfactory ratings must include a remark / comment for that day on back of sheet.

Form # AVQA1 REV. 0113

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX R

Sample Fuel Storage Daily Inspection Form

FUEL STORAGE INSPECTIONS	Airport:	Facility:	Tank(s) #:	Date:

DAILY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1. Security, Fire & Safety Deficiencies																															
2. General Condition of Tank Yard																															
3. Fire Extinguisher(s)																															
4. Ground Reels, Cables, and Clamps																															
5. Hoses, Swivels, and Nozzles																															
6. Deadman Controls																															
7. Nozzle Fueling Pressure (PSI)																															
8. Fuel Leaks																															
9. Storage Tank ___ Sump / Record Rating																															
10. Storage Tank ___ Sump / Record Rating																															
11. Filter ____ Sump / Record Rating																															
12. Filter ____ Differential Pressure																															
13. Filter ____ Sump / Record Rating																															
14. Filter ____ Differential Pressure																															
15. Waste Fuel Tanks / Sump Saver																															
16. Spill Kit																															
17. Surge / Relaxation Tank Sump																															
18.																															
Signature of person performing tasks or person accepting responsibility that tasks were performed.																															

MONTHLY	MK	Date	Signature	ANNUAL	MK	Date	Signature	MARKINGS (MK)
19. Filter Membrane Test & Water Test				34. Storage Tank Interior(s) (Visual)				S = Satisfactory
20. Fuel Hoses				35. Meter Calibration (Resale)				X = Unsatisfactory
21. Water Sensitive Paste Test				36. Pressure & DP Gauge(s) (Calibrate)				N/S = Not in Service
22. Floating Suction(s)				37. Filter Elements (Change)				N/A = Not Applicable
23. Nozzle Screens				38. Water Defense System(s)				
24. Bond / Ground Cable Continuity				(Tested by Injecting Water)				**Rating of Sump Samples**
25. Signs & Placards				39. Filter / Separator Heater(s)				Record First Observed - Sump to 1A
26. Fire Extinguisher(s)				40. Tank Vent(s)				
27. FSII Level % in Tank if Pre-Blended				41. Cathodic Protection				Solids = (1) Clear (2) Slight
28. Interstitial Checks				42. Line Strainer(s)				(3) Particulate (4) Dirty
29.				43. Fire Extinguisher Certification(s)				
QUARTERLY	**MK**	**Date**	**Signature**	44.				
30. Water Defense (External Check)				45.				Water = (A) Bright (B) Hazy
31. Emergency Fuel Shutdown System				46.				(C) Cloudy (D) Wet
32. Tank High Level Alarm / Controls				47.				(E) Surfactant
33.				48.				

Note #1: These are recommended minimum quality assurance checks for aviation fuel facilities. Additional checks may be necessary for into-plane cabinets/locations.

Note #2: All unsatisfactory ratings must include a remark / comment for that day on back of sheet.

Note #3: Signature of person performing actual checks must be on supporting documents.

Note #4: Multiple tanks, filters and other equipment must have supporting documentation showing results of required checks.

Form # AVQA2 REV. 0113

Form courtesy of AvFuel Corporation. Used with permission.

APPENDIX S

Sample Product Receipt Record Explanation of Terms Form

Form courtesy of AvFuel Corporation. Used with permission.

Product Receipt Record Explanation of Terms

Facility Name: FBO or Flight Department Name

Avfuel Customer #: Your Avfuel Customer Code

Tank#: Number of the tank this record is for in case of multiple tanks for 1 product.

Tank Size: Total Capacity of Tank.

Month: Month this record is being filled out. If you receive more than 6 loads in 1 month denote that if this sheet is the first or second of 2 (ex: 1 of 2, 2 of 2).

Type of Product: Which product is being received on this form? (Avgas, Jet A, Jet A with FSII, JP8, JP5).

Receipts / BOL #: Bill of Lading (BoL) or Manifest number for the load being received.

BEFORE UNLOADING

Date: Date each load is received.

Fire Equipment Operable and Ready: Check that fire extinguishers are present and in operable condition.

Storage Tank Gauge, Inches: Physically stick the tank with driver present and record the result in inches for before delivery inventory.

Storage Tank Contents, Gallons: Use a sticking or strapping chart to convert inches from the above entry into starting gallons in the tank

Storage Tank Available Capacity, Gallons: Tank size minus storage tank contents, gallons.

Vol. Ordered vs. Available Space OK?: Is the amount of fuel ordered less than the space available calculated above? (Remember that tanks should not be filled to more than 95% liquid capacity to allow for expansion) DO NOT receive the fuel load if you do not have the capacity to hold the entire load.

Drain Storage Tank Sump: Sump the product tank that you are receiving the fuel into in order to verify it is free of contaminants.

Drain Filter/Separator sump: Sump the filter separator that the fuel will be received through under pressure in order to verify it is free of contaminants.

Condition of Offload Hose: Inspect the hose being used to transfer the product from the transport to your tank. It should be clean and in good condition with no visible residue, cracks, or worn spots.

Align All Valves for Receipt: Position valves to receive product then connect vapor recovery hose as needed.

INSPECTING THE TRANSPORT

Bond /Ground Transport: Bond transport truck to Fuel farm. Ground if required locally.

Transport Name & Truck #: Name of the Trucking company that has brought this load of fuel and the Truck number that carried it (should be on BoL).

Product Verified: Physical confirmation that the transport is carrying the product indicated on the BoL. 100LL Avgas is Blue, Jet Fuel is colorless to straw or amber.

Truck Capacity-Gallons: Transports available capacity.

BOL Gallons- Gross: Gross gallons indicated on the BoL or Manifest.

BOL Gallons-Net: Net gallons indicated on the BoL or Manifest.

No Visible Debris or Water in Truck: Visually check the transport tank from the top of the transport truck through the manway.

Product Sample Clear & Bright: Using a White Bucket, have the driver take a sample from each of the compartments of the transport truck after letting the truck settle with Internal Valves open for 10 minutes. Verify the sample is clear (absence of particulates) and bright (absence of water).

API Gravity Corrected to 60° F: Test the fuel sample for API Gravity. Calculate the API Gravity to 60° F. Enter the result here.

API Observed Fuel Temperature: Record the observed temperature of the fuel sample from the API gravity test in °F.

FSII Concentration: Perform a Refractometer (B/2 kit) field test for proper concentration of Fuel System Ice Inhibitor additive. Results should be between 0.1-0.15% volume.

UNLOADING

Time Unloading Started: Record the time that the fuel transfer was started.

Unload: Connect transport delivery hose to start unloading the transport. Someone from the FBO AND the transport driver should remain for the entire fuel transfer.

Differential Pressure Filter/Separator: Record the maximum differential pressure that occurs during the fuel delivery.

AFTER UNLOADING

Check All Truck Compartments for Empty: Visually verify that each compartment that fuel was received from is empty from the top of the transport truck through the manway.

Close Unloading Valves-Realign to Use: Reposition valves on the fuel farm to allow for delivery of fuel.

Uncouple Transport: Detach the product hose, vapor recovery hose, and bonding/grounding wire from the transport (bonding wire last).

Drain Filter/Separator Sump: Sump the filter /separator to make sure there are no contaminants from the transfer process.

Drain the Storage Tank Sump: Sump the storage tank sump to verify there were no contaminants transferred to the storage tank.

Storage Tank Gauge, Inches: Physically stick the tank with driver present and record the result in inches for after delivery inventory.

Storage Tank Contents, Gallons: Use a sticking or strapping chart to convert inches to gallons of product in the tank.

Time Unloading Completed: Record the time that the fuel transfer and inventorying was completed. Sign the BoL or Manifest accepting load for quantity and quality.

Time Tank Ready to Dispense Fuel: Record the time the tank will be ready to dispense fuel (1 hour per foot of product received).

Secure Tank Outlets and Storage Area: Resecure the fuel farm and all fuel farm outlets (i.e. close the gate, cap and lock sumps).

Person Receiving and Cleaning, Initials: The person receiving the fuel initials this block.

Remarks: Record remarks of anything out of the ordinary that happened during fuel delivery.

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation