

ANALYSIS OF THE STORAGE, DISPENSING, AND TRANSFER OF
FLAMMABLE AND COMBUSTIBLE LIQUID FLAVORINGS
AT THE CITY BREWING COMPANY, LLC

By

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ABSTRACT

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The significance of this study evolves from the potential hazards associated with the storage, dispensing, and transfer of flammable and combustible liquids. These materials are used to some extent in nearly all facilities for many different purposes. The hazards associated with flammable and combustible liquids include, at a minimum, fire and explosion. Over 21 percent of industrial fires, which result in an extensive amount of loss, injuries, and fatalities every year, start with ignition of a flammable or combustible liquid.

As part of their business operations, the City Brewing Company, LLC is required to store, dispense, transfer, and handle significant amounts and variations of flammable and combustible liquids. The purpose of this study was to analyze the practices currently

utilized by the City Brewing Company, LLC in relation to the storage, dispensing, and transfer of flammable and combustible liquid flavorings used in their operations. In order to analyze these practices, the objectives that served as the basis for this study involved identifying all flammable and combustible liquid flavorings, and their hazard classification, storage requirements, quantity stored, container size and construction, as well as the quantity of each used. Furthermore, the current practices for the storage, dispensing, and/or transfer of flammable and combustible liquid flavorings that pose significant risk to personnel or the facility were identified. The identification was accomplished by analyzing and comparing the current practices for the storage, dispensing, and transfer of these materials to the applicable federal codes and regulations for flammable and combustible liquids.

Upon completion of the analysis, recommendations were proposed regarding the practices utilized for the storage, dispensing, and transfer of flammable and combustible liquids. The objective of the proposed recommendations, based upon federal codes and regulations as well as recognized industry and risk control principles, was to reduce or eliminate the risks to personnel or the facility posed by the flammable and combustible liquid flavorings used in operations at the City Brewing Company, LLC.

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CHAPTER I

Statement of the Problem

Introduction

The City Brewing Company, LLC owns and operates the City Brewery in La Crosse, WI. In addition to the brewing, packaging, marketing and sales of its own proprietary line of beers, the City Brewery provides contract production and packaging services for other beverage manufacturers and marketers. This contracted production includes many different types of both alcoholic and non-alcoholic beverages that are produced either through brewing or batching operations. The batching operations include the use of various ingredients that are typically not involved with the brewing process. Many of these ingredients are alcohol-based flavorings that are classified as flammable or combustible liquids. These liquids must be received, stored, dispensed, measured, and transferred as part of the batching operations.

There are two primary hazards associated with flammable and combustible liquids; explosion and fire (OSHA, 1997a). These hazards are present wherever flammable or combustible liquids are handled, stored, or used. Statistics indicate that over 21 percent of industrial fires start with the ignition of a flammable or combustible liquid (Qualye, 2000). The hazardous nature of these substances is due to their ability to burn at relatively low temperatures, which makes them susceptible to catching fire or exploding when set off by even the smallest ignition source. Potential ignition sources may include sparks from tools and equipment, open flames, hot surfaces, and even sparks caused by static electricity from rotating belts, mixing equipment and improper transfer

of flammable or combustible liquids (Canadian Centre for Occupational Health and Safety [CCOHS], 2001).

The hazards of fire and explosion and the potential for a loss associated with them increases as more flammable and combustible liquids are handled, stored, transferred, and/or used. But, fire-related exposures can be significantly reduced and controlled if the correct measures are taken to ensure the proper handling, storage and use of flammable and combustible liquids. Unfortunately, although justification seems evident, convincing top management to expend additional resources to store hazardous materials safely can be difficult, especially when there are no accidents to magnify the need to exercise caution (Nighswonger, 2000).

As part of their latest business operations, the City Brewery is required to store, dispense, transfer, and handle ever-increasing amounts and variations of flammable and combustible liquids. Without adequate protective measures, safeguards, and procedures implemented to minimize the risks associated with these operations, the current practices for storing, dispensing, and transferring of various flammable and combustible liquid flavorings at the City Brewery places the organization at significant unnecessary risk of employee injury and/or facility damage.

Purpose of the Study

The purpose of this study will be to analyze the practices currently utilized by the City Brewery in relation to the storage, dispensing, and transfer of flammable and combustible liquids flavorings used in batching operations.

Research Objectives

Following are three objectives that will serve as the basis for this study.

1. Identify all flammable and combustible liquid flavorings used in batching operations through a review of applicable records (batch sheets and corresponding material safety data sheets).
2. Identify the class, storage requirements, quantity stored, container size and construction, and quantity used of each flammable and combustible liquid flavoring through a review of applicable records (material safety data sheets, purchase/inventory records, and/or batch sheets).
3. Identify current practices for the storage, dispensing, and/or transfer of flammable and combustible liquid flavorings, which pose significant risk to personnel or the facility.

Background and Significance

Fires result in an extensive amount of loss, injuries, and fatalities every year. In 2000, there were 1.7 million fires reported in the United States and direct property loss due to fires was estimated at \$11 billion (U.S. Fire Administration [USFA], 2001a). In addition to this extensive amount of property loss, the United States also has one of the highest fire death rates in the industrialized world at 14.5 deaths per million people (USFA, 2001a). Between 1991 and 1999, an average of 4,453 Americans lost their lives and another 26,445 were injured annually as a result of fire (USFA, 2001b).

Although a significant portion of these fatalities, injuries, and losses occurred outside of the workplace, fires take their toll on industry as well. In 2000, there were 126,000 industrial fires reported that resulted in 90 deaths, 2,200 injuries, and over \$2.9 billion in direct property loss (USFA, 2001c). As stated earlier, over 21 percent of these fires start with the ignition of a flammable or combustible liquid. This can take place

during any activities, storage, dispensing, use and/or transfer, involving flammable and/or combustible liquids. According to Qualye (2000), common factors that are attributed to these flammable or combustible liquid fires included:

- Improper container storage,
- Lack of bonding and grounding procedures,
- Lack of control of ignition sources, particularly during maintenance and contractor activities,
- No hot work permits and procedures, and
- Inadequate employee training in handling and dispensing of flammable and combustible liquids and in emergency response techniques (Qualye, 2000).

In 2001, a majority of the beverage production at the City Brewery consisted of contracted products that were produced through batching operations. This requires numerous flammable and combustible liquid flavorings to be stored on site, measured and dispensed in varying amounts from their original containers into secondary containers and vessels, and transferred throughout the facility. As the production of these products increases, the number of flammable and combustible liquids that are stored on-site and subsequently handled increases. This in turn results in increased exposure to the hazards associated with the liquids and the potential for loss.

Assumptions

The hazards and potential for loss associated with the storage and handling of flammable liquids are well documented. In order to totally eliminate these hazards and their potential for loss, the flammable and combustible liquids would have to be eliminated from the batching operations or suitable alternatives found and approved that do not present these hazards. For the purpose of this study, it will be assumed that there are no alternatives to the flammable and combustible liquids flavorings currently used in batching operations at the City Brewery. Therefore, it is believed that the only option for

minimizing and controlling the risks associated with these liquids is to ensure they are handled, stored, and used in the safest manner possible to reduce the hazards and the potential for loss.

A second assumption involves the vessels or containers in which flammable and combustible liquid flavorings are stored and received in at the City Brewery. Due to production and customer requirements, all flammable and combustible liquids are currently received and stored in containers that are less than 60 gallons. Therefore, it will be assumed for the purpose of this study that flammable and combustible liquid flavorings that are received and stored at the City Brewery will continue to be received and stored in containers that are less than 60 gallons.

Definition of Terms

The following terms used in this paper are defined as follows.

Boiling Point: The temperature at which the vapor pressure of a liquid exceeds atmospheric pressure (Rekus, 1997).

Closed Container: A container so sealed by a lid or other device that neither liquid nor vapor will escape from it at ordinary temperatures (OSHA, 1997a).

Combustible Liquid: Means any liquids having a flashpoint at or above 100° F. (37.8° C.). Combustible Liquids shall be divided in two classes as follows:

Class II Liquids: Shall include those with flashpoints at or above 100° F. (37.8° C.) and below 140° F. (60° C.), except any mixture having components with flash points of 200° F. (93.9° C.) or higher, the volume of which make up 99 percent or more of the total volume of the mixture.

Class III Liquids: Shall include those include those with flashpoints at or above 140° F. (60° C.). Class III liquids are subdivided into two subclasses; Class IIIA and Class IIIB. Class IIIA liquids includes those with flashpoints at or above 140° F. (60° C.) and below 200° F. (93.3° C.). Where the term “Class III liquids” is used in this study, it shall mean only Class IIIA liquids (OSHA, 1997a).

Combustion: A complex set of chemical reactions that result in the rapid oxidation of a fuel producing heat, light, and a variety of chemical by-products (NFPA, 1998).

Container: Applies to the storage of flammable or combustible liquids in drums or other containers not exceeding 60 gallons (OSHA, 1997a).

Flammable (explosive) limits: The percent of vapor in the air necessary for combustion to occur (Burke, 1995).

Flammable Liquid: Means any liquids having a flashpoint below 100° F. (37.8° C.), except any mixture having components with flashpoints of 100° F. (37.8° C.) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

Flammable liquids shall be known as Class I liquids. Class I liquids are divided in to three classes as follows:

Class IA Liquids: Shall include liquids having flashpoints below 73° F. (22.8° C.) and having a boiling point below 100° F. (37.8° C.).

Class IB Liquids: Shall include liquids having flashpoints below 73° F. (22.8° C.) and having a boiling point at or above 100° F. (37.8° C.).

Class IC Liquids: Shall include liquids having flashpoints at or above 73° F. (22.8° C.) and below 100° F. (37.8° C.) (OSHA, 1997a).

Flash Point: The minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid (OSHA, 1997a).

Ignition Temperature: Minimum temperature to which a material must be heated to cause auto-ignition without the presence of an ignition source (Burke, 1995)

Listed: Equipment included in a list published by an organization, such as Underwriters Laboratories or Factory Mutual, that is acceptable to the authority having jurisdiction and concerned with evaluation of products, that maintains periodic inspection of production of listed equipment, and whose listing states that the equipment meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Specific Gravity: Relative weight of a liquid compared to water (Burke, 1995).

Vapor Density: Relative weight of a vapor compared to air (Burke 1995).

Water Solubility: The ability of a liquid to mix with water (Burke, 1995).

CHAPTER II

Review of Literature

Introduction

There are very few operations that don't use flammable or combustible liquids in one form or another ("Flammable Liquid", n.d.). Flammable and combustible liquids are used for fuels, solvents, lubricants, and many other purposes in most facilities (Schroll, 2002). In further comments, Schroll also explains that some types of operations require more, but few operations are without at least some of these materials (Schroll, 2002). The hazards associated with these liquids include, at a minimum, fire and explosion (OSHA, 1997a). These hazards present the risk of employee exposure and facility damage wherever flammable or combustible liquids are stored, dispensed, handled or used. Statistics from the U.S. Fire Administration indicate that flammable and combustible liquids are one of the leading causes of industrial fires resulting in dozens of fatalities and billions of dollars of direct property damage on an annual basis (USFA, 2001a, 2001b, 2001c).

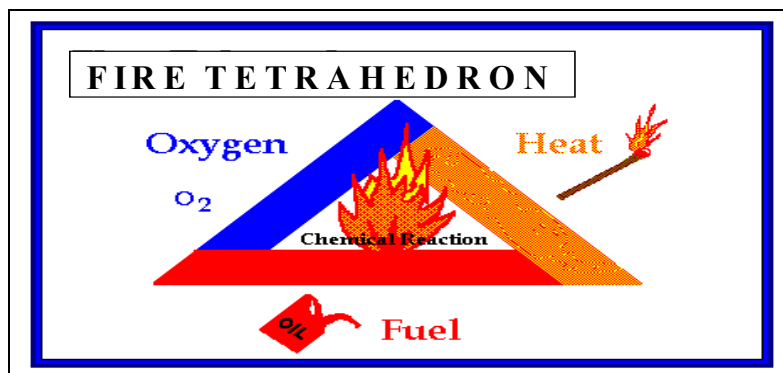
Fire Tetrahedron

The chemical reaction and elements necessary for fire to take place have long been represented and explained by the fire triangle. The fire triangle represents the three elements, oxygen, heat, and fuel, which are required to start fire and allow combustion to continue (Fire Safety Advice Centre [FSAC], 2002). This representation of fire demonstrates that there must be sufficient oxygen, a temperature maintained above a certain level, and sufficient fuel in order for fire to take place. And, if any of the three elements of the triangle are not in place, fire cannot occur (FSAC, 2002).

These three elements, oxygen, heat, and fuel, have been recognized as the science of fire protection for over 100 years (USFA, n.d.). However, research and modern day thinking now accepts that there is fourth element required to sustain combustion (South Australian Metropolitan Fire Service [SAMFS], 2002). This fourth element is a chemical chain reaction and it must be present with all of the other elements at the same time in order to produce fire (FSAC, 2002). This element is necessary because specific chemical chain reactions between the fuel and oxygen molecules are essential to sustain a fire once it has begun (SAMFS, 2002). As a result, a fourth side has been added to the fire triangle concept resulting in the development of a new model called the fire tetrahedron, represented in Figure 1 (SAMFS, 2002). Therefore, the four elements required to produce and sustain fire are:

- Enough oxygen to sustain combustion,
- Enough heat to raise the material to its ignition temperature,
- Some sort of fuel or combustible material, and
- The chemical, exothermic reaction that is fire (FSAC, 2002).

Figure 1: Representation of Fire Tetrahedron (FSAC, 2002)



In order to fully understand the fire tetrahedron, a further explanation is required. First of all, it needs to be understood that solid or liquid materials or fuels do not burn. For combustion to take place, materials must be heated sufficiently to produce the vapors

or gases that will burn (USFA, n.d.). These vapors or gases are produced by a chemical reaction when heat or an ignition source is applied to the fuel (National Interagency Fire Center [NIFC], n.d.). This is the same chemical, chain reaction that makes up the fourth side to the fire tetrahedron. The vapors produced by the chemical reaction are found just above the surface of the fuel and need to rise to mix with oxygen in order for them to burn (NIFC, n.d.). In essence, this chemical reaction promotes combustion to become fire. And therefore, the fire produces more heat that promotes the chemical reaction and further fuels the fire.

As discussed earlier, the four elements required to produce and sustain fire are a fuel, oxygen, ignition, and a chemical reaction. If any one of these elements is absent, a fire cannot start or it will be extinguished. Therefore, in order to understand how to eliminate or control fire, one must have a thorough understanding of these elements. Since the role of the chemical reaction in a fire has already been explained, the other three elements, fuel, oxygen, and ignition sources need to be investigated further.

Fuel

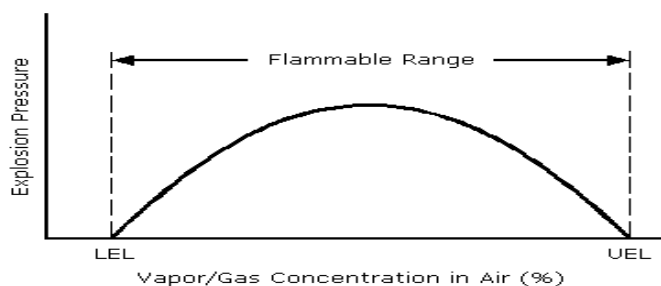
The National Fire Protection Association defines a fuel as any substance or matter that can undergo combustion (National Fire Protection Association [NFPA], 1998). These substances may exist in one of three phases; solid, liquid, or gas. The *NFPA 921* (NFPA, 1998) explains that the combustion of solid or liquid fuels takes place above the fuel surface in a region of vapors created by heating the fuel surface. The heat required to create the vapors can come from the ambient conditions, the presence of an ignition source, or exposure to an existing fire. The application of heat causes vapors or pyrolysis products to be released into the atmosphere where they can burn if in the proper mixture

with air and if a competent ignition source is present (NFPA, 1998). Therefore, it should be understood that it is not the matter itself that burns, but instead it is the vapors released from the matter that burn when the fire tetrahedron is complete.

Oxidizing Agent

As discussed earlier, the proper air mixture is required in order for fire to occur. According to the NFPA, the air or oxygen required is referred to as an oxidizing agent (NFPA, 1998). In most fire situations, the oxidizing agent is the oxygen in the earth's atmosphere, which contains about 21 percent oxygen (NFPA, 1998). For combustion to take place, the fuel vapor or gas and the oxidizer must be mixed in the correct ratio. Fuel burns only when the fuel/air mixture is within certain limits known as flammable limits. The NFPA explains these limits in the following manner. In cases where fuels can form flammable mixtures with air, there is a minimum concentration of vapor in air below which propagation of flame does not occur. This is called the lower flammable limit. There is also a maximum concentration above which flame will not propagate called the upper flammable limit. These boundary-line mixtures are limits of vapor with air also commonly referred to as the lower and upper explosive limits (LEL or UEL) respectively, and they are usually expressed in terms of percentage by volume of vapor in air (OSHA, 1997a). Therefore, it should be understood that for fire to occur, oxygen must not only be present with the other elements, but it must be mixed with the fuel in the correct ratio. Figure 2 provides a visual representation of the flammable range and limits.

Figure 2. Flammable Range (OSHA, 1997a)



Ignition Source

The final element discussed for fire to occur is heat or an ignition source. The heat component of the fire tetrahedron represents heat energy above the minimum level necessary to release fuel vapors and cause ignition (NFPA, 1998). Ignition sources in the workplace that may produce enough heat energy to cause a fire or explosion include, but are not limited to, electrical switches, open motors, static electricity, radiant heat, friction and mechanical sparks, heat guns, and cutting and welding activities (Quayle, 2000). Therefore, it should be understood that the heat element or ignition source does not necessarily have to be an open flame. It can be as minute as a single spark or even a heated surface. In fact, sparks are capable of achieving temperatures ranging from 2000°F to 6000°F (University of Nebraska – Lincoln [UNL], n.d.).

The roles and several contributing effects in which heat or an ignition source plays in a fire cannot be overstated. In a fire, heat produces fuel vapors, causes ignition, and promotes fire growth and flame spread by maintaining a continuous cycle of fuel production and ignition (NFPA, 1998). In review, as discussed throughout this section, in order for fire to take place the four elements represented in the fire tetrahedron must be present. Without these four elements available in the proper balance and for a sufficient period of time, ignition cannot occur and fire is not possible (Burke, 1995).

Flammable and Combustible Liquids

As discussed earlier, flammable and combustible liquids have many different purposes and uses throughout industry. Flammable and combustible liquids are commonly used in day-to-day operations at industrial and commercial sites throughout the world (UNL, n.d.). According to the University of Nebraska – Lincoln (n.d.), flammable materials are the most widely produced and utilized types of hazardous materials. The primary uses of these materials include fuels for transportation and heating, as well as in the production of a multitude of other products. They compose the largest pool of raw materials used in the production of almost all organic materials such as plastics, paints, solvents, and a multitude of other consumer and industrial products (UNL, n.d.). Based on this information, it is quite evident how heavily industry relies upon these materials and their prevalence throughout industry. But, as the amount and numbers of flammable and combustible liquids used in industry increases, so do the hazards and the potential for a loss associated with these liquids.

Hazards

As stated by OSHA (1997a), the two primary hazards associated with flammable and combustible liquids are explosion and fire. These hazards are so prevalent due to the relative ease of which flammable and combustible liquids can be ignited and become involved in a fire as well as the intensity at which they can burn. When combined with the prevalent use throughout industry, it's easily understood why incidents involving flammable liquids are the most commonly encountered types of incidents faced by emergency first responders (Burke, 1995).

Incidents involving flammable liquid fires are much more volatile than fires fueled by ordinary combustibles such as wood, paper, and cloth (Rekus, 1997). Rekus explains that flammable vapors can ignite with explosive force and the resulting fire gives off more than twice as much heat as ordinary combustibles – about 16,000 to 24,000 Btu/lb for flammable liquids versus 8,000 to 10,000 Btu/lb for ordinary combustibles. Also, a greater rate of temperature rise and billowing clouds of thick, black, acrid smoke are created by fires of flammable and combustible liquids (Rekus, 1997).

It should be noted that due to their form and chemistry, flammable and combustible liquids involved in a fire present a greater opportunity to fuel the fire and continue its spread. First of all, fires of flammable and combustible liquids can spread very rapidly when spilled material spreads (Rekus, 1997). Burning liquids can flow under doors, down stairs, and even into neighboring buildings, spreading fire widely (CCOHS, 1997). Secondly, once the ignition of flammable or combustible liquids takes place, the heat from the fire results in increased generation of vapors, further fueling the flame (Protectoseal Company, n.d.). Therefore, it should be understood that not only do flammable and combustible liquids present a fire and explosion hazard, but once involved in a fire, they also present an increased possibility for the fire to spread and an increased severity of the fire and the potential for loss.

Definitions and Classifications

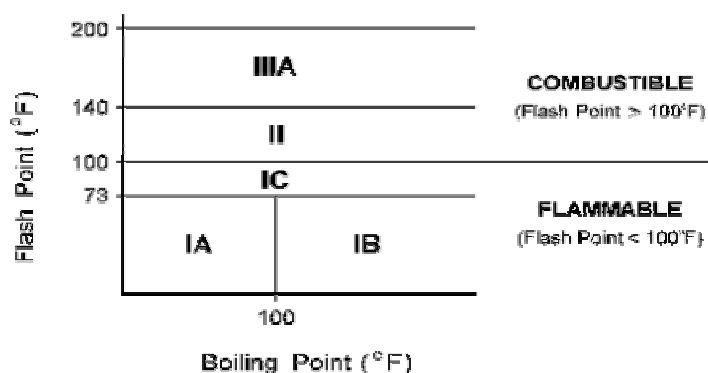
In order to truly understand the hazards associated with flammable and combustible liquids, a closer look must be taken at how these liquids are defined and classified. As defined earlier, a flammable liquid is basically any liquid with a flashpoint

below 100°F and a combustible liquid is any liquid with a flashpoint at or above 100°F (OSHA, 1997a). Flashpoint was selected as the basis for classification of flammable and combustible liquids because it is directly related to a liquid's ability to generate vapor (OSHA, 1997a). OSHA explains that since it is the vapor of the liquid, not the liquid itself, which burns, vapor generation becomes the primary factor in determining the fire hazard (OSHA, 1997a).

In order to further identify the hazards of flammable and combustible liquids, they have been classified according to their degree of hazard. The degree of hazard is based upon the flash point and boiling point of the liquid (Schroll, 2002). Schroll explains that the boiling point of liquids is also used in the classification because it is a measure of a liquid's ability to produce vapors that burn and fuel a fire. Along with identifying the degree of hazard for flammable and combustible liquids, the classification system is used to determine appropriate hazard control measures, and code requirements for storage, transportation, use, and protection (Schroll, 2002).

As defined earlier, flammable liquids are known as Class I liquids. These Class I liquids, having flashpoints below 100°F, are divided into three subclasses based upon their flashpoints and boiling points. Combustible liquids, with flashpoints at or above 100°F, are divided into two classes, Class II liquids and Class III liquids. The Class III liquids are then subdivided into two subclasses, Class IIIA liquids and Class IIIB liquids. These classifications for combustible liquids are based strictly upon the flashpoint of the liquid. Since the definitions provided for flammable and combustible liquids are quite complex, Figure 3 has been added to aid in their understanding (OSHA, 1997a).

Figure 3. Classes of Flammable and Combustible Liquids (OSHA, 1997a).



To sum up the differences between flammable and combustible liquids, the major distinction between flammable and combustible liquids is ease of ignition, not fire severity (Schroll, 2002). At normal, ambient conditions, flammable liquids produce enough vapors that even small sources of ignition may be enough to start a fire. But, combustible liquids require either a strong ignition source or preheating the liquid to be ignited (Schroll, 2002).

Other Fire Hazard Properties

Although flashpoint and boiling point are the main properties used to determine the degree of hazard and classification of flammable and combustible liquids, there are several other properties that should also be taken into account when evaluating the risk of flammable and combustible liquids. Some of the other properties include ignition temperature, flammability limits, specific gravity, vapor density, boiling point, and water solubility (Morris, n.d.). Since ignition temperature, vapor density, specific gravity, and water solubility have not been reviewed or discussed previously, they need to be explained in greater detail along with the roles they play.

Ignition temperature is the minimum temperature at which a material self-ignites without any obvious sources of ignition, such as sparks or flame (CCOHS, 1997). In other words, the material or vapors self-ignite by being heated to the ignition temperature. Most common flammable and combustible liquids have ignition temperatures in the range of 160°C (356°F) to 550°C (1022°F) (CCOHS, 1997). There have been circumstances where liquids with low ignition temperatures have had their vapors ignited by simple hot steam pipes or solvent evaporating ovens (CCOHS, 1997). Therefore, ignition temperature is another fire hazard factor, which must be reviewed and taken into account when storing, dispensing, and using flammable and combustible liquids.

Another factor that must be known and understood when handling flammable and combustible liquids is vapor density. Vapor density is the relative weight of a given vapor to air (Burke, 1995). Since air is given a hypothetical weight value of 1.0, the vapor of a material that has a density greater than 1.0 is considered to be heavier than air and these vapors will lay low to the ground or collect in confined spaces or basements. If the vapor is less than 1.0, the vapor is considered lighter than air and it will go up and travel away from the liquid or spill (Burke, 1995). Therefore, it is important to understand and take into account that these vapors have the ability to travel and potentially come in contact with an ignition source that may be a significant distance from the liquid itself.

The final two fire hazard properties that need to be understood are similar in that they both relate to how flammable or combustible liquids will relate to water. These two properties are specific gravity and solubility. As defined, specific gravity is the

relationship of the weight of a liquid to water (Burke, 1995). Since water is given a hypothetical weight value of 1.0, a liquid with a specific gravity greater than 1.0 is heavier than water and will sink to the bottom in a water spill. Conversely, if a liquid has a specific gravity less than 1.0 it is lighter and will float on top of the water (Burke, 1995). Understanding specific gravity is important because it will determine what kinds of tactics are necessary to contain and control a spill or fire of flammable or combustible liquids.

The second property associated with the relationship between flammable or combustible liquids and water is solubility. Solubility is a liquid's ability to mix with water. If a flammable or combustible liquid is soluble in water, this means it will mix with the water (Burke, 1995). This property of a flammable or combustible liquid also plays a significant role in controlling or extinguishing a fire of a flammable or combustible liquid. If a flammable or combustible liquid is soluble in water, then a fire of these materials may be able to be controlled or contained with water. However, if a flammable or combustible liquid is not soluble, water may cause the flammable or combustible liquid and the fire to spread (Burke, 1995). Therefore, it is quite evident that this fire hazard property, as well as the others previously discussed, all play an important role and need to be understood to prevent, control, and extinguish fires of flammable or combustible liquids.

Standards/Regulations

There are a multitude of codes, standards, and regulations about fire. Much research has been conducted to improve our knowledge of how fires start, why they spread, and what we can do to contain and control them (Schroll, n.d.). Therefore, since

many of these codes, standards, and regulations are a legal requirement and a lot of research has went into their development, they are a starting point for ensuring safety and reducing the risk when handling, dispensing, and transferring flammable and combustible liquids. However, the reader should be cautioned that too often, the focus for ensuring safety with flammable and combustible materials is only on the regulations, such as the *OSHA 29 CFR 1910 Subpart H* and consensus standards like the *National Fire Protection Association Code 30*, for flammable and combustible liquids (Nighswonger, 2000). Conventional thinking that can lead to a false sense of security is that if the rules are followed, there will not be a problem (Nighswonger, 2000). Therefore, it needs to be understood that these standards and regulations are only minimum requirements and do not eliminate the hazards associated with flammable and combustible liquids; they only help to minimize them.

Two main agencies that have developed regulations and standards governing the storage and use of flammable and combustible liquids are the National Fire Protection Association (NFPA) and the Occupational Safety and Health Administration (OSHA). The NFPA addresses these matters in the *NFPA 30 Flammable and Combustible Liquids Code*. While for general industry, the OSHA standards for flammable and combustible liquids are primarily detailed in the *29 Code of Federal Regulations; 1910.106 Flammable and Combustible Liquids*. Therefore, this section of the study will include a review of the applicable sections of the *NFPA 30* and *29 CFR 1910.106*.

When addressing the fire and explosion hazards associated with flammable and combustible liquids, one of the first steps should be to understand and ensure compliance with the required standards and regulations. However, one should not be lulled into a

false sense of security, believing that everything will be satisfactory if compliance with the OSHA standard is achieved (Rekus, 1997). In further comments, Rekus explains that the OSHA flammable liquids standard, *29 CFR 1910.106*, is based on the 1969 edition of the National Fire Protection Association's *Flammable and Combustible Liquid Code NFPA 30*. And since the adoption by OSHA in 1972, the NFPA 30 has been revised eight times, with the most recent edition being published in 1996. Based on this information, the OSHA flammable liquid standard, which is 30 years out of date, is not a reliable source for some criteria and instead the most current edition of the NFPA Flammable and Combustible Liquids Code should be consulted (Rekus, 1997). Therefore, the primary focus of this study will be placed upon the applicable sections of the *NFPA 30 Flammable and Combustible Liquids Code* to complete the review of the standards and regulations for flammable and combustible liquids.

Containers

The first line of defense when trying to control flammable and combustible liquids and their vapors is to ensure they are properly contained. Both the NFPA and OSHA have defined a container, for the purposes of flammable and combustible liquids, as drums or other containers that do not exceed 60 gallons individual capacity. For storage purposes, it must be a closed container (OSHA, 1997a). Without a proper container, the risks and hazards associated with the liquid increase dramatically. If improperly contained, flammable and combustible liquids have an increased potential to leak or spill and cause a fire, injury or contamination (CCOHS, 2001). Therefore, the NFPA has provided specific guidance regarding the design, construction, and capacity of containers.

The NFPA states that only approved containers shall be used for flammable and combustible liquids (NFPA, 2000). Approved containers are those that have been approved by testing laboratories acceptable to government enforcement agencies (CCOHS, 2001). There are numerous agencies referenced in the NFPA that have conducted tests or received approval on various containers styles, construction materials, and sizes to ensure they will adequately and safely control the specified liquids. These agencies include the U.S. Department of Transportation, American Society for Testing and Materials, American National Standards Institute, Underwriters Laboratories, and the United Nations (NFPA, 2000). Therefore, users and handlers of flammable and combustible liquids need to have an understanding of the requirements of an approved container and how to determine which meet approval.

In addition to the construction requirements for containers, the NFPA has also established the maximum allowable sizes for containers of various construction and approval for the different liquid classes. Figure 4 indicates the allowable sizes of the different types of approved containers based on the liquid class.

Figure 4. Maximum Allowable Size – Containers (NFPA, 2000)

TYPE	FLAMMABLE LIQUIDS			COMBUSTIBLE LIQUIDS	
	Class IA	Class IB	Class IC	Class II	Class III
Glass	1 pt	1 qt	1 gal	1 gal	5 gal
Metal (other than DOT drums) or Approved plastic	1 gal	5 gal	5 gal	5 gal	5 gal
Safety cans	2 gal	5 gal	5 gal	5 gal	5 gal
Metal drum (DOT Specification)	60 gal	60 gal	60 gal	60 gal	60 gal
Polyethylene DOT Specification 34, UN 1H1, or as authorized by DOT exemption	1 gal	5 gal*	5 gal*	60 gal	60 gal
Fiber drum NMFC or UFC Type 2A; Types 3A, 3B-H, or 3B-L; or Type 4A	Not Permitted	Not Permitted	Not Permitted	60 gal	60 gal

* For Class IB and IC water-miscible liquids, the maximum allowable size of plastic containers is 60 gal, if adequately stored and protected in accordance with further requirements detailed in *NFPA 30* (NFPA, 2000).

From the information provided in Figure 4, it is quite evident that the greater the hazard, the more stringent the requirements are regarding container construction and allowable size.

Storage

Flammable liquids storage should be designed to prevent ignitable vapors from reaching an ignition source (Schroll, 2002). According to Schroll, loss prevention measures should address both of these issues; controlling the flammable or combustible liquid and its vapor and ignition sources. Two options for storing flammable and combustible liquids include storage cabinets and storage rooms. Storage cabinets are designed to protect their contents for up to ten minutes, which is the estimated time that a room is likely to be seriously burning (Rekus, 1997). But in order to provide this kind of protection, they have to meet strict design and construction requirements. According to Rekus, the major limiting factors regarding the use of storage cabinets are the restrictions regarding quantity stored inside a cabinet and the number of cabinets permitted in the same fire area or portion of a building separated from others by a one-hour fire rated wall. The *NFPA 30* (NFPA, 2000) allows not more than 60 gallons of a Class I or II liquid or 120 gallons of a Class IIIA liquid stored in a single cabinet and not more than three storage cabinets in any one fire area. Therefore, it is evident that if a facility requires a significant amount of flammable and combustible materials to be stored on-site, storage cabinets may not provide a feasible option.

A second option for storing flammable and combustible liquids, especially in larger quantities, is a liquid storage room (Rekus, 1997). When reviewing options for the location of a flammable and combustible liquids storage room, there are several possible

options. Listed below are the potential locations, in the order of preference, with an explanation for their preference:

1. Liquid warehouse (separate building or shed) – Provides the greatest safety factor because the separation of the building protects the vapor or spilled material in the storage area from coming in contact with ignition sources in the facility's main building.
2. Attached building with an exterior entrance – This building is physically attached but does not have an opening, access, or door leading into the main building.
3. Attached building – This building is physically attached and is connected or has access into the main building through an interior door.
4. Cutoff room – This is a separate room that is contained within the main building but can only be accessed through an exterior door.
5. Inside room – This is a separate room that is contained within the main building and can be accessed through an interior door (Schroll, 2002).

It should also be noted that the storage of flammable and combustible liquids in these locations is also dependent upon the class of liquid and the container it is stored in. For example, Class I and Class II liquids in plastic containers cannot be stored in general purpose liquid warehouses, but shall be stored in inside liquids storage areas, subject to design and construction requirements (NFPA, 2000).

Inside rooms for bulk storage of flammable and combustible liquids are subject to construction, arrangement, outfitting requirements, as well as capacity limitations (Justrite Manufacturing Company, 1985). Section 4.4 of *NFPA 30* (NFPA, 2000) details the design and construction requirements for inside liquid storage rooms. Included in these requirements are the specific fire resistance ratings for the walls, ceilings and roofs of such structures. Figure 5 details these basic requirements, minus the exceptions listed in *NFPA 30*.

Figure 5. Fire Resistance Ratings for Inside Liquid Storage Rooms (NFPA, 2000)

Type of Storage Area	Fire Resistance Rating (hr)		
	Interior Walls, Ceilings, Intermediate Floors	Roofs	Exterior Walls
Inside Rooms		--	--
Floor Area <150 ft ²	1		
Floor Area >150 ft ² And <500 ft ²	2	--	--
Cutoff rooms and Attached Buildings			
Floor Area <300 ft ²	1	1	--
Floor Area >300 ft ²	2	2	2
Liquid Warehouses	4	--	2 or 4

In addition to the basic construction requirements for inside liquid storage rooms listed in this section of the *NFPA 30* code, this section also details other various requirements that must be met in the construction of these areas. These requirements are detailed below:

- Every door should be a rated self-closing fire door;
- All doorway openings should be provided with curbing to prevent the escape of liquid (curbs, drains or other suitable means should be provided to prevent the flow of liquid under emergency conditions into adjacent building areas);
- Storage areas shall be equipped with suitable drainage;
- Floor level ventilation shall be provided to remove flammable vapors;
- Explosion-proof electrical equipment should be used; and
- Fire detection and suppression systems of the appropriate type for the specified hazard should be installed (Schroll, 2002 and NFPA, 2000).

Many of these requirements are defined in much greater detail in the code and will be discussed further later in this study.

One of the final requirements and restrictions regarding inside storage rooms relates to the allowable quantity that can be stored in these areas. Storage in these rooms is also restricted in quantity, based upon the total floor area of the room and whether or

not fire protection is provided. Figure 6 provides a simple explanation of these limitations.

Figure 6. Storage Limitations for Inside Rooms (NFPA, 2000).

Total Floor Area (ft ²)	*Automatic Fire Protection Provided?	Total Allowable Quantity (gal/ ft ² of floor area)
≤150	No	2
	Yes	5
>150 and ≤500	No	4
	Yes	10

*For the purpose of this table, fire protection system shall be automatic sprinklers, water spray, carbon dioxide, dry chemical, or other approved system (NFPA, 2000).

The final inside storage room design requirement to be discussed is fire protection. There are two types of fire protection for inside storage rooms that are discussed in the code. These two types are automatic fire protection systems and manual fire protection. The requirements regarding fire protection for inside storage are very specific. This is due to the fact that the severity of the hazards present in these rooms is usually very great because of the amounts and varying storage arrangement of flammable and combustible liquids in these rooms.

In order to clearly address the fire protection requirements for inside storage rooms, there have been many changes, updates, and clarifications to the *NFPA 30* over the years. Perhaps the most significant change is the new fixed fire protection design criteria for storage areas that were developed from full-scale fire tests (Rekus, 1997). According to Rekus, the tests examined the major variables that influence a fire's severity and growth rate, as well as the ability of fixed fire-suppression systems to control or extinguish a flammable liquid fire. The fire test data were used to develop a set of tables that govern the acceptable storage methods for flammable and combustible liquids in containers. These methods were based on the following factors:

- Specific type of sprinkler system;
- Liquid class;
- Container size, type, and arrangement;
- Maximum storage height; and
- Maximum ceiling height (Rekus, 1997 and NFPA, 2000).

With this information one can determine the design criteria, Section 4.8 of the *NFPA 30*, for protecting any inside storage room. However, it should be noted that where different classes of liquids and container types are stored in the same protected area, protection shall meet the requirements of this section for the most severe hazard class present (NFPA, 2000).

Manual fire protection includes both portable fire extinguishers and pre-connected hoselines. Although the *NFPA 30* is not real specific regarding the requirements for hoselines, it is specific for portable fire extinguishers. The code requires at least one 40:B extinguisher must be located outside of the storage room, but within 10 feet of the door leading into it (NFPA, 2000). The reason for requiring that portable fire extinguishers be located a distance away from the storage room is that fires involving Class I and Class II flammable liquids are likely to escalate rapidly, and if the extinguisher is too close to or inside the storage area, it may be impossible to access once such a fire has started (OSHA, 1997a).

Operations

As discussed earlier, there are obvious hazards and exposures associated with the storage of flammable and combustible liquids. However, there are also some of the same hazards and possibly some additional hazards and exposures associated with operations involving flammable and combustible liquids. The NFPA has defined operations involving flammable or combustible liquids as those that involve the use or handling of

these materials either as a principal or incidental activity (NFPA, 2000). Therefore, the NFPA has developed provisions to control the hazards of fire involving liquids in operations. These provisions are detailed in Chapter 5 of the *NFPA 30* (NFPA, 2000).

In general, the *NFPA 30* (NFPA, 2000) states that liquid-processing operations must be located and operated in a manner that does not constitute a significant fire or explosion hazard to life, to property of others, or to important buildings or facilities within the same plant. Furthermore, the specific requirements for an operation involving flammable or combustible liquids shall be dependent upon the inherent risk of the operation itself, including the liquids being processed, operating temperatures and pressures, and the capability to control any vapor or liquid releases or fire incidents that could occur (NFPA, 2000). Basically, this means that many factors, and their interrelationships, must be taken into account and decisions based on good engineering and management practices in order to ensure a safe operating environment and procedures.

Because there are so many variables to take into account for each specific situation, this section will present an overview of the main applicable requirements for incidental operations. Incidental operations are defined as areas where the use, handling, and storage of liquids is only a limited activity to the established occupancy (NFPA, 2000). These requirements for incidental operations are detailed in Chapter 5, Section 5 of the *NFPA 30* and are not quite as detailed as those for operations where the use, handling, and storage of flammable and combustible is a principal activity of the facility. However, there are still many issues and concerns regarding these incidental operations that must be addressed. Some of the requirements for storage rooms that have not yet

been discussed in detail will also be reviewed in this section, since many of these are similar to requirements for operations.

One of the first requirements discussed in the *NFPA 30* for incidental operations involves the dispensing or transfer of flammable and combustible liquids. The *NFPA 30* explains that Class I liquids or Class II or Class III liquids that are heated up to or above their flashpoints shall be drawn from or transferred into vessels, containers, or portable tanks as follows:

1. From original shipping containers with a capacity of 5 gal (19 L) or less;
2. From safety cans;
3. Through a closed piping system;
4. From portable tanks or containers by means of a device that has anti-siphoning protection and that draws through an opening in the top of the tank or container;
5. By gravity through a listed self-closing valve or self-closing faucet (NFPA, 2000).

Although there are several factors why these requirements are so strict in regards to how flammable and combustible liquids are dispensed and transferred, the main reasons are to eliminate spills and ensure containers are closed when not in use and to ensure the operator is in control of the dispensing or transfer at all times. According to Schroll (2002), operator attention during dispensing is critical. Numerous spills and fires have resulted from transfer operations that were left unattended. Therefore, it appears that the requirements are written to ensure that somebody must be present during most dispensing and transferring operations.

Other requirements directly related to the transfer and dispensing include:

- If a hose is used in the transfer operation, it shall be equipped with a self-closing valve without a hold-open latch in addition to the outlet valve. Only listed or approved hose shall be used.
- Where pumps are used for liquid transfer, means shall be provided to deactivate liquid transfer in the event of a liquid spill or fire.

- Means shall be provided to minimize generation of static electricity (NFPA, 2000).

Although these requirements are fairly self-explanatory, minimizing the generation of static electricity needs to be further explained. Static electricity is the electric charge generated when there is friction between two things made of different materials or substances (CCOHS, 1999). Static electrical charges can build up on an object or liquid when certain liquids move in contact with other materials and can occur when liquids are poured, pumped, filtered, agitated, stirred, or flow through pipes or hose (CCOHS, 1999). Static electricity can be a significant ignition source when transferring and dispensing flammable and combustible liquids (Schroll, 2002). During dispensing or any other product transfer operation, both containers must be bonded and grounded to prevent the development of a difference in electrical potential that might result in an electric arc during dissipation of static charges (Schroll, 2002).

To prevent the build up of static electricity and prevent sparks from causing a fire, it is important to bond metal dispensing and receiving containers together before pouring or transferring (CCOHS, 1999). Bonding is performed by making an electrical connection from one metal container to another. This is accomplished by:

- Attaching a metal bonding strap or wire to both containers;
- Using self-bonding hoses between containers, or;
- Metal-to-metal contact between containers or between a container and nozzle (CCOHS, 1999).

Grounding is accomplished by establishing an electrically conductive path between a container and an electrical ground (Schroll, 2002) and is accomplished by connecting the container to an already grounded object that will conduct electricity (CCOHS, 1999). According to the CCOHS, this could include a buried metal plate, a

metallic underground gas piping system, metal water pipes, or a grounded, metal building framework. Since all bonding and grounding connections must be bare metal to bare metal (CCOHS, 2002), containers other than metal, such as polyethylene or glass, also need to be discussed since they are nonconductive. According to OSHA, they will permit the transfer of flammable and combustible liquids between plastic or other non-conductive containers under the following conditions:

- A non-conductive container must be equipped with an approved metallic suction pump and draw tube for taking liquid through the top of a plastic container. The pump must be electrically grounded, or
- The non-conductive container must be equipped with a metallic, self-closing faucet that can be grounded electrically (OSHA, 1999).

The requirements for the storage of flammable and combustible liquids for incidental operations is the same as discussed earlier in this study, although there are exceptions regarding how much is allowed outside of designated storage areas.

According to both the *NFPA 30* (NFPA, 2000) and OSHA (1997a), the quantity of flammable or combustible liquids in containers that may be located outside of an inside storage room or storage cabinet or in any one fire area of a building shall not exceed:

- 25 gal of Class IA liquids in containers
- 120 gal of Class IB, Class IC, Class II or Class III liquids in containers.

There is also an exception to these allowances. According to the *NFPA 30* (NFPA, 2000), where quantities of liquid in excess of the above limits are needed to supply an incidental operation for one continuous 24-hour period, the greater quantity shall be allowed.

The remaining requirements specified by the *NFPA 30* (NFPA, 2000) for incidental operations also apply and relate to the inside storage rooms discussed earlier. Therefore, the applicability of these requirements for inside storage rooms and incidental

operations will both be reviewed. According to the *NFPA 30* (NFPA, 2000) areas in which liquids are transferred from one tank or container to another shall be provided with the following:

- Separation from other operations that can represent an ignition source by distance or by fire-resistant construction.
- Drainage or other means to control spills.
- Natural or mechanical ventilation.

Although ignition sources were discussed briefly throughout other discussions in this study, they truly have not been adequately covered in entirety. The *NFPA 30* (NFPA, 2000) states that precautions shall be taken to prevent the ignition of flammable vapors by sources such as open flames, lightning, hot surfaces, radiant heat, smoking, cutting and welding, spontaneous ignition, frictional heat or sparks, static electricity, electrical sparks, stray currents, ovens, furnaces, and heating equipment. Therefore, it is evident that all areas where flammable or combustible liquids are stored, used, dispensed, or transferred must be scrutinized very closely for all potential ignition sources.

Electrical equipment shall not constitute a source of ignition for flammable vapor that might be present under normal operation or during a spill (NFPA, 2000). The *NFPA 30* (NFPA, 2000) states that all electrical equipment and wiring shall be of a type specified by and installed in accordance with *NFPA 70, National Electrical Code*. The electrical requirements for a given area are based upon a hazardous location classification system that defines areas by class and division. This classification system, as it applies to flammable and combustible liquids, specifies that a Class I Hazardous Location is one which flammable gases or vapors may be present in the air in significant quantities to ignite or explode (Adalet Enclosure Systems, n.d.). The Class I locations are then broken

down into two divisions; Division 1, hazardous vapors present, and Division 2, hazardous vapors contained but may be present.

As discussed above, electrical equipment and wiring is a potential ignition source and must be addressed for both storage rooms and incidental operations. In inside storage rooms, electrical wiring and equipment for Class I Liquid storage shall be Class I, Division 2 and for Class II and III liquids electrical wiring and equipment for general purpose must be suitable, unless stored at temperatures above their flashpoints (NFPA, 2000). However, the requirements regarding electrical wiring around incidental operations differ based upon the operations taking place. According to Rekus (1997), where Class I liquids are dispensed, or where Class II or Class III are dispensed at temperatures above their flashpoints, all wiring within 3 feet of dispensing nozzles must conform to Class 1, Division 1 electrical requirements.

Controlling and limiting spills is another requirement that applies to both storage areas and incidental operations. In addition, Rekus (1997) explains that these requirements vary based upon numerous factors, including quantities, solubility, and specific gravity. Controlling and limiting spills can range from approved drip cans below drum faucets, to HAZMAT teams, to drainage systems (CCOHS, 2001). Therefore, each process and the factors involved must be analyzed to determine which means for controlling and limiting spills is adequate for the particular operation.

As discussed earlier, drains and drainage systems are an option for containing and controlling spills of flammable and combustible liquids. However, if a drainage system is used, it must have sufficient capacity to carry the expected discharge from spills and water from fire protection systems and hose streams to a safe location (NFPA, 2000).

These drains, however, should not be connected to regular sewer lines, but instead suitable drainage should trap liquids in a containment sump or underground tank (Schroll, 2002). If they are connected to public sewers or discharged into public waterways, they shall be equipped with traps or separators (NFPA, 2000). It is important to note that the spill containment provisions are not based on environmental concerns, but rather on preventing spills from migrating to other areas where they could be ignited (Rekus, 1997).

One of the last requirements for storage areas and incidental operations involves ventilation. A natural or mechanical ventilation system is required in both inside storage rooms and for incidental operations. Well-designed and maintained ventilation systems remove flammable vapors from the area and reduce the risk of fire (CCOHS, 2001). In liquid storage areas, where dispensing is conducted, there shall be either a gravity or continuous mechanical exhaust ventilation system (NFPA, 2000). In addition, the NFPA requires that it must be a mechanical system if Class I liquids are dispensed. Other requirements of such systems include:

- Exhaust air shall be taken from a point near a wall one side of the room and within 12 inches of the floor;
- Make-up air inlets shall be located on the opposite side of the room within 12 inches of the floor;
- Exhaust from the room shall be directly to the exterior of the building without recirculation;
- Mechanical ventilation systems shall provide at least one cubic foot per minute of exhaust per square foot of floor area, but not less than 150 cubic feet per minute;
- Mechanical ventilation systems for dispensing areas shall be equipped with an airflow switch or other method that is interlocked to sound an audible alarm upon failure of the system (NFPA, 2000).

Ventilation for incidental operations can also be accomplished through mechanical or natural exhaust ventilation. However, these systems differ in that they are to be designed

to ventilate at a rate sufficient to maintain the concentration of vapors within the area at or below 25 percent of the lower flammable limit (NFPA, 2000).

The final requirements that need to be met in order to reduce and minimize the hazards associated with flammable and combustible liquids include developing safe work practices, training and emergency planning. Personnel should thoroughly understand the hazards and the behavior of the materials they are expected to use and how to respond in an emergency (Schroll, 2002). In addition, Schroll comments that people cannot be expected to perform effectively and safely without adequate training.

In addition to this planning and training, the *NFPA 30* (NFPA, 2000) also requires that inspections and maintenance be performed in flammable and combustible liquid storage and operating areas to ensure the requirements are being met. Inspection and maintenance areas of concern include all fire protection equipment, leakage or spills, disposal of waste, housekeeping and emergency access and exits (NFPA, 2000). To assist with these compliance activities, self-inspection checklists and forms are available from a variety of different sources, including state and federal agencies and manufacturers of related equipment. Two examples (OHSA, 1997b and Justrite Manufacturing Company, n.d.) are provided in the appendix of this study.

Summary of Available Regulations and Resources

As stated earlier, the applicable NFPA and OSHA codes and standards are only a minimum requirement for beginning to address the hazards associated with flammable and combustible liquids. Furthermore, it needs to be understood that these the standards and regulations do not eliminate the hazards associated with flammable and combustible liquids, but rather they only help to minimize them. Therefore, in order to truly minimize

or eliminate the hazards associated with flammable and combustible liquids, other alternatives for these liquids and other sources of information and recommended practices must be sought. Other sources may include insurance companies, professional organizations, and manufacturers of related equipment. Therefore, some examples of additional resources that provide more information regarding these matters were reviewed but were not discussed in this study. These resources include the Factory Mutual Insurance Company (2000a, 2000b, 2000c, and 2001) *FM Global Data Sheets* and are listed as a reference in this study. But as a starting point for the basis of this study, the focus will be placed upon analyzing the practices currently used in the storage, dispensing and transfer operations of flammable and combustible liquids at the City Brewery in relation to the minimum standards and requirements described in this chapter.

CHAPTER III

Methodology

Introduction

Flammable and combustible liquids are used and present in many different forms and applications. To some extent, flammable and combustible liquids exist in nearly all operations and industries. The potential fire and explosion hazards associated with flammable and combustible liquids are prevalent wherever these liquids are stored, dispensed, transferred, or used. The City Brewery is required to store, dispense, and transfer flammable and combustible liquid flavorings as part of their batching operations. The author is analyzing the current practices utilized by the City Brewery and the associated risks in relation to their storage, dispensing, and transfer of flammable and combustible liquid flavorings. In order to analyze these practices, the objectives of the study included the following:

1. Identify all flammable and combustible liquid flavorings used in batching operations through a review of applicable records (batch sheets and corresponding material safety data sheets).
2. Identify the class, storage requirements, quantity stored, container size and construction, and quantity used of each flammable and combustible liquid flavoring through a review of applicable records (material safety data sheets, purchase/inventory records, and/or batch sheets).
3. Identify current practices for the storage, dispensing, and/or transfer of flammable and combustible liquid flavorings, which pose significant risk to personnel or the facility.

This chapter will describe how the flammable and combustible liquid flavorings used in batching operations were identified, the current storage, dispensing, and transferring practices for these liquids, and the resources and references used in the collection of this data. A description will follow of the methodology and resources used to analyze these practices and conclude with the research methodological limitations of this study.

Identification of Flammable and Combustible Liquid Flavorings

In order to assess the hazards and analyze the practices associated with the flammable and combustible liquid flavorings used in the batching operations, the first step was to identify each of the liquids used in these processes. This included identifying each liquid flavoring and determining its liquid class, storage requirements, quantity stored, container size and construction, and the quantity used in a typical batch for each of the flammable and combustible liquid flavorings identified. As explained below, the identification and determinations were accomplished through a review of the batch sheets used in the batching operations, material safety data sheets, purchase and inventory records, as well as through personal observation of the storage areas and batching operations at the City Brewery.

For every product that is batched or mixed at the City Brewery, a batch sheet has been developed by the Brewing Department. A batch sheet is basically a recipe listing the ingredients required for proper mixing of the product. Each batch sheet lists the ingredients, amounts of each to be used in a batch, and the order they are to be added or mixed in order to produce the product. For the purpose of this study, copies of batch sheets were requested from the Brewing Department for all products that are batched.

Each of these batch sheets was then reviewed to identify the liquid ingredients. The liquid flavoring ingredients were identified from the other ingredients on the batch sheet based upon their names, specified volumes, and the author's knowledge of the batching operations and required ingredients.

Once all of the liquids used in each of the batching operations were identified, the material safety data sheet for each of these liquids was reviewed. First of all, the material safety data sheet for each of the liquids was reviewed to determine the flashpoint for each of the identified liquids. The flashpoint of each of the liquids was reviewed in order to determine which of the liquid flavorings used in batching operations were flammable or combustible liquids. Those liquids that had flashpoints below 200° F were recorded, since they are considered as being flammable or combustible liquids.

With the flammable and combustible liquids used in batching operations identified, the next step was to determine the liquid class for each of these materials. As discussed earlier, liquid class is based upon the flash point and boiling point of the material. Therefore, the flashpoint and boiling point for each of the identified flammable and combustible liquid flavorings was identified on the corresponding material safety data sheet and recorded. With the use of the liquid classification definitions provided in Chapter II, the liquid class of each of the flavorings was determined based on the recorded flashpoints and boiling points. For most of these liquids there was no boiling point identified on the material safety data sheet. On these material safety data sheets the boiling point was never referenced or it was listed as "not applicable" or "not determined". Those liquids that had no boiling point identified on the material safety data sheet were assigned the highest, most hazardous, classification for their flash point.

Also at this time, any information regarding the solubility of each of the liquids was also reviewed and recorded.

Once all of the flammable and combustible liquid flavorings had been identified and classified, the next step involved determining storage requirements, containers received in, and storage and usage amounts for each of the materials. In order to determine if any of these liquids had any special storage requirements, above and beyond those discussed in the Chapter II, the material safety data sheet for each of the flavorings was reviewed. Any listed special storage requirements, such as temperature, for each of the flammable or combustible liquid flavorings was recorded.

The next step in identifying the flammable and combustible liquid flavorings used in the batching operations involved identifying the sizes and construction of the containers in which these materials were received. This was accomplished through personal observation and inspection of the stored materials, their labels, and shipping papers. These observations regarding the container sizes and constructions were documented.

The final steps involved in identifying the flammable and combustible liquid flavorings used in batching operations required the batch sheets for each of the products containing these materials and the purchase/inventory records for each of the identified materials. The batch sheets were reviewed to determine the quantity of each flammable or combustible liquid that must be used in a typical batch. The purchase/inventory records for the past two years were reviewed to determine the maximum quantity of each flammable or combustible liquid flavoring that is stored on site. The usage and storage quantities of each flammable and combustible liquid flavoring were both recorded. This

information, along with all of the other items identified and recorded previously, will be used later in this study in the analysis section of this chapter.

Current Storage, Dispensing, and Transferring Practices

In addition to the identification of the flammable and combustible liquid flavorings used in the batching operations, the current storage, dispensing, and transferring practices for these materials also needed to be identified and understood in order to analyze these operations. In order to identify and understand these practices, several methods of investigation were utilized. These methods of investigation and identification included personal observation and documentation of current practices, techniques, and equipment, a review of documented batching instructions and related material, as well as information and knowledge gained from involvement with the operations and discussions with Brewing Department personnel prior to the start of this study.

Resources and Instrumentation

To analyze the current practices utilized by the City Brewery in relation to their storage, dispensing, and transfer of flammable and combustible liquid flavorings, significant emphasis was placed upon ensuring these operations were compliant with the applicable regulatory codes and standards. Specifically, the *NFPA 30 Flammable and Combustible Liquids Code, 2000 Edition*, was used as a resource and reference for the applicable codes and standards. In addition to the *NFPA 30*, the *29 Code of Federal Regulations; 1910.106 Flammable and Combustible Liquids* standard and the two inspections checklists referenced in Chapter II, *Flammable and Combustible Materials Self-Inspection Checklist* (OSHA, 1997b) and *Checklist for Flammable and Combustible*

Liquid Safety (Justrite Manufacturing Company, n.d.), were also used as secondary references for analyzing the applicable items of these operations.

Analysis

Having completed the identification of the flammable and combustible liquid flavorings used in the batching operations and the current practices for the storage, dispensing, and transfer of these materials, the next objective in the study was to identify which, if any, of these practices pose significant risk to personnel or the facility.

As discussed, the primary method for identifying the practices that pose significant risk to personnel or the facility was to compare these operations for the storage, dispensing, and transfer to the requirements of the *NFPA 30* detailed in Chapter II. The analysis and comparisons included the following applicable items or issues for both storage areas and incidental operations:

- Container sizes and construction;
- Storage practices and inside liquid storage room construction, including fire rating, capacity, fire protection, drainage, containment, and ventilation;
- Dispensing methods;
- Bonding and grounding;
- Elimination of ignition sources;
- Electrical equipment;
- Fire Protection;
- Controlling and limiting spills, including curbing and drainage;
- Ventilation
- Safe work practices, training, and emergency planning; and
- Inspection and maintenance.

Secondary sources or references used to assist with this analysis included the two inspection checklists and the applicable OSHA standards detailed earlier. The inspection checklists were used as a reference to assist with ensuring that all applicable items and

issues involved with the storage, dispensing, and transfer of these flammable and combustible liquid flavorings were analyzed and addressed.

The results of the analysis of these items and issues were documented. This documentation included an explanation of each item or issue resulting in or creating a significant unnecessary risk to personnel or the facility as well as why it was considered to be a significant risk.

Limitations

Since this study relied solely upon the author's ability to identify each of the flammable or combustible liquid flavorings used in batching operations and the current practices for the storage, dispensing, and transfer of flammable and combustible liquid flavorings, one of the major limitations is the fact that there are no measures of validity or reliability to ensure every one of the liquids was identified or that all of the current practices were understood or documented correctly. An additional limitation to the study is that if any of the liquids or practices were misidentified, their comparison to the applicable code may have resulted in a misrepresentation and may not have been applicable. And, due to confidentiality agreements between the City Brewery and its contract customers, neither product or ingredient names nor material safety data sheets could be provided in this study to be used for verification of data. In regards to these first limitations, the author did feel that after conducting the literature review a much better understanding of flammable and combustible liquids and the applicable requirements was gained and made the author more proficient in these areas. A final limitation to this study involved the assumption that the only means for identifying and defining significant risks was to distinguish and document current practices that were not in compliance with the

applicable code or standard. As stated earlier, these codes and standards are only minimum requirements and do not necessarily eliminate all risks. Therefore, even if all the requirements of these codes and standards are met, it is likely that some level of risk is still present and therefore an acceptable level may not have been achieved.

CHAPTER IV

Results

Introduction

The purpose of this study was to analyze the practices currently utilized by the City Brewery in relation to the storage, dispensing, and transfer of flammable and combustible liquids flavorings used in batching operations.

Following are three objectives that served as the basis for this study.

1. Identify all flammable and combustible liquid flavorings used in batching operations through a review of applicable records (batch sheets and corresponding material safety data sheets).
2. Identify the class, storage requirements, quantity stored, container size and construction, and quantity used of each flammable and combustible liquid flavoring through a review of applicable records (material safety data sheets, purchase/inventory records, and/or batch sheets).
3. Identify current practices for the storage, dispensing, and/or transfer of flammable and combustible liquid flavorings, which pose significant risk to personnel or the facility.

This chapter includes all the results on the analysis of the practices utilized by the City Brewery in relation to the storage, dispensing, and transfer of flammable and combustible liquid flavorings used in batching operations. The results presented are based upon the identification and investigation of the practices involving flammable or combustible liquid flavorings. Included in this presentation of results is information and data pertaining to the flammable and combustible liquid flavorings used in batching

operations as well as the current practices used to store, dispense, and transfer these materials. The chapter concludes with the analysis and discussion of these practices in relation to the applicable federal codes and standards for flammable and combustible liquids.

Flammable and Combustible Liquid Flavorings In Use

A total of 26 different batch sheets were received and reviewed to identify the liquid flavorings used in batching operations. From these 26 batch sheets, 27 different liquid flavorings were identified. A review of the material safety data sheets for 25 of these materials identified a total of seven liquids that possessed flashpoints below 200° F. For two of the 27 liquid flavorings, there were no material safety data sheets available. Therefore, the flashpoints for these two materials were reviewed from the container labels. Both of these liquids also had flashpoints below 200° F. The nine liquid flavorings that had flashpoints below 200° F were documented, since according to the definitions were flammable or combustible liquids.

During this process it was also discovered that preparations were being made to test-batch a new product for a contract customer. Therefore, the batch sheet for this potential product was also requested and reviewed. A review of this batch sheet identified 3 liquid flavorings required for the production of this product, one of which had already been identified from a previous product as a flammable or combustible liquid. Although the other two liquids were currently not on site or in use, it was determined that material safety data sheets were available for these two flavorings. Copies of these material safety data sheets were received and the flashpoints reviewed.

Both of these flavorings had flashpoints below 200° F and by definition were flammable or combustible liquids.

Through the analysis of process batch sheets a total of 11 different potential flammable or combustible liquid flavorings were identified in the batching operations. As stated earlier, due to confidentiality agreements, the names of these ingredients could not be identified in this study. In order to differentiate between each of these liquids later in this study, each of these flavorings was assigned a number, one through eleven. The two liquids currently not in use were identified as numbers 10 and 11. Each of these liquids and their corresponding flashpoints were recorded in the first two columns of Figure 7 in this study.

With eleven different flammable or combustible liquid flavorings identified, the next step was to identify the boiling point, liquid class, and potential water solubility of each of these materials. The available material safety data sheets were again reviewed to determine the boiling point and water solubility for each of these liquids. This information from the corresponding material safety data sheets was then recorded for each of the applicable liquids in Figure 7. As documented in Figure 7, the majority of the material safety data sheets did not list or provide the boiling point for the respective materials, which will be discussed and taken into account later in this chapter.

With the flashpoints and some boiling points documented for each of the applicable liquids, the liquid classification for each of these materials was determined based upon the information provided in Chapter II. For those flammable liquids that had flashpoints <73° F, but did not have a boiling point recorded, their liquid class could not be accurately determined. Therefore, they were assigned the highest, most hazardous,

classification, Class IA. The liquid classification for each of these materials is also presented in Figure 7.

Figure 7. Identification of Flammable and Combustible Liquid Flavorings

LIQUID #	FLASHPOINT	BOILING POINT	WATER SOLUBLE	LIQUID CLASS
1	79° F	Not Found	Yes	IC
2	75° F	173° F	Yes	IC
3	>68° F	Not Applicable	Yes	IA
4 *	98° F	Unknown	Unknown	IC
5 *	194° F	Unknown	Unknown	IIIA
6	127° F	Not Determined	Yes	II
7	196° F	Not Listed	Not Listed	IIIA
8	176° F	Not Determined	Yes	IIIA
9	74° F	Not Listed	Yes	IC
10	88° F	Not Listed	Not Listed	IC
11	70° F	Not Applicable	Yes	IA

* For liquids numbered 4 and 5 there were no material safety data sheets on file. Therefore, the flashpoints for these liquids were recorded from the container labels but the other information is unknown.

With each of the flammable or combustible liquid flavorings and their applicable physical properties as well as liquid class identified, the next step was to identify, through a review of the available material safety data sheets, any special storage requirements for each of these materials. This information is presented in Figure 8.

Figure 8. Liquid Flavoring Special Storage Requirements/Temperatures

LIQUID #	SPECIAL STORAGE REQUIREMENTS/TEMPERATURES
1	Ambient (55 - 75° F)
2	Tightly sealed containers protected from excessive heat and open flames.
3	Tightly sealed containers protected from excessive heat and open flames.
4*	Unknown
5*	Unknown
6	Usual precautions for combustible liquids.
7	Keep containers tightly closed, store in a cool dry area away from heat and direct sunlight.
8	Usual precautions for combustible liquids.
9	Store in tightly sealed containers away from heat and flame.
10	Keep containers tightly closed, store in a cool dry area away from heat and direct sunlight.
11	Store in tightly closed and upright containers in a cool, dry, ventilated area. Store away from light, heat and sources of ignition.

* For liquids numbered 4 and 5 there were no material safety data sheets on file. Therefore, the special storage requirements for these liquids are unknown.

Although the information presented in Figure 8 does not demonstrate it, the facility was operating under the assumption that, based on instructions provided by the ingredient suppliers or contract customers, many of these materials were required to be refrigerated. Therefore, this requirement will have to be taken into consideration later in this study. Also, for those liquids that did not have material safety data sheets available, some of the information could not be determined and therefore is listed as “Unknown” on Figures 7 and 8.

Finally, the last step in identifying the flammable and combustible liquid flavorings used in the batching operations involved documenting the type and size of the containers the liquids were received and stored in, the maximum quantities stored on site, and the typical quantity of each used at a time or in a single batch. Through a review of batch sheets and procedures it was determined that for the ingredients numbered one to five the typical finished batch size was 750 barrels, and for 6 to 11 it was about 1,400 barrels. For information purposes, it should be explained that a barrel is equivalent to about 31.5 gallons. This information regarding the storage and usage of these liquids, obtained through the processes described in Chapter III, is provided in Figure 9. It should also be noted if each of the liquids were present at the same time at their documented maximum quantity listed in Figure 9, it would total over 21,000 gallons of flammable or combustible liquids. Figure 9 does not include any additional storage amounts for liquids #10 and #11 that were not on site but were planned to be used in the future. The actual maximum amount that was stored on site at any time during this study was determined to be just less than 14,000 gallons.

Figure 9. Storage and Use of Flammable and Combustible Liquid Flavorings

LIQUID #	CONTAINER		QUANTITY	
	CONSTRUCTION	SIZE (gal.)	STORED (gal.)	USED (gal.)
1	Plastic	55	441	33.5
2	Plastic	55	210	30
3	Plastic	5	10	15
4	Plastic	55	1,539	262.5
5	Plastic	55	1,023	465
6	Plastic	55 and 5	2,695	21.9
7	Plastic	55	1,434	7.9
8	Plastic	55	11,579	94.6
9	Plastic	55	2,423	22.3 and 8.8
10*	Plastic	55	Not applicable	0.84
11*	Plastic	55	Not applicable	4.2

* For liquids numbered 10 and 11 there is no stored quantity listed since the liquid have not yet been received or stored on-site.

Storage, Dispensing, and Transferring Practices

With the flammable and combustible liquid flavorings used in batching operations identified, the next step in the study was to document the storage, dispensing, and transferring practices for these materials. These practices, documented in this section, were identified utilizing the methods described in Chapter III.

Materials received at the loading dock were transferred on pallets via forklift to an area of the facility referred to as the keg cooler. The keg cooler is an insulated and refrigerated room inside the facility that was originally designed to store full kegs/barrels of beer. Located inside the keg cooler is a separate smaller cut-off room designated as the flammable liquid storage and dispensing room. This room had recently been designed and constructed specifically for the storage and dispensing of the flammable and combustible liquid flavorings. Through involvement with the operation and a review of related documentation, it was determined that the property insurance company for the brewery recommended many of the design requirements and specifications for this room.

A review of these recommendations, the design and construction of this room, as well as the storage practices included the following observations:

- Interior room dimensions measure 14.5 feet by 16 feet.
- Constructed of materials having at least a two-hour fire resistance rating; 8-inch concrete block walls and a stud framed ceiling with 5/8-inch Type X Gypsum board attached to both sides.
- Class 1, Division 2 light fixtures and wiring inside the room, with the switch located outside the room.
- Sprinkler system installed according to recommendations made and approved by insurance company, sprinkler contractor and local fire department; including a density of 0.60 gallon per minute/square foot, schedule 10 piping with galvanized interior, and 4 sprinkler heads FM-listed extra-large-orifice (ELO) type with a 165° F rating and a maximum coverage of 100 square feet.
- Hinged, 3-hour fire-rated double doors.
- A 6-inch drain in middle of room. This drain line connects to the City Brewery's wastewater treatment plant operations.
- Lack of room ventilation system
- Lack of liquid-tight containment and curbing at room entry point.
- Lack of portable fire extinguisher, none observed in or in the immediate vicinity outside the room.
- Containers stacked on top of one another.
- Containers stored in room were not closed or sealed.
- The amount of liquid or drums stored in the room varied greatly. Significant amount of liquid was always stored outside the room.
- Although area in front of door was clear, there was no aisle designated or observed in this room.
- Minimal signage observed regarding the hazards in the room and the necessary precautions that should be followed.
- Spilled or leaking liquids observed on the floor.

It was determined through the methods described in Chapter III that the dispensing and transfer of the flammable and combustible liquid flavorings was conducted by several different methods. One of the methods, recommended by a contract customer, for dispensing and transferring one of the flammable or combustible liquid flavorings involved the following recorded procedures and observations.

1. Locate the proper liquid flavoring in the flammable and combustible liquid storage room. This particular was always stored in this room.
2. Using a plastic piston-style hand pump and hose, the material was pumped from its original plastic container into a metal container. A pre-determined measured mark was located on the metal container to identify how much liquid should be pumped into it for a batch. No procedures for grounding or bonding of these containers were documented or practiced during these dispensing procedures. This metal container, approximately 30 gallons, was fabricated in-house out of 2 former stainless-steel beer kegs, mounted on a hand cart, and equipped with a threaded hose fitting and hand valve on the bottom of the container. There was no labeling or identification on this container regarding its contents or the associated hazards.
3. Once filled with the appropriate material, this container was transferred through the plant to another building and onto an elevator where it was transferred up several floors to the area where it was dispensed.
4. The dispensing of this material was conducted by connecting a plastic/rubber hose to the hose fitting on the bottom of the container. The other end of the hose was attached to a stainless-steel pipe that had another liquid ingredient flowing through it.
5. Once the valve on the bottom of the container was opened by the operator, the liquid was dispensed from the container via gravity and suction. The theory involved was that the flammable or combustible liquid flavoring

would be immediately diluted when it mixed with the other material in the pipe.

6. There were no measures practiced or in place for these operations in relation to safe drainage and/or and containment of spilled liquids, ventilation, fire protection, or elimination of ignition sources as they relate to flammable or combustible liquids.

The remaining flammable or combustible liquid flavorings were basically all dispensed and transferred in the same manner. This method involved the following recorded procedures and observations.

1. Flammable or combustible liquid flavorings in their original plastic containers were removed from the designated storage area or keg cooler and transferred on a pallet via forklift to a room where the batching operations were conducted.
2. Liquids were then dispensed from their original containers via a plastic air-operated diaphragm pump, with plastic hose, into a large (approximately 300-gallon) hinged lid, stainless steel batching tank or into other smaller, open, plastic containers. This pump could be turned on and left to run without the employee being present to oversee the operation.
3. The dispensing of these liquids into other containers was conducted in order to measure the weight of the material on a scale or to a pre-designated level in the container. The liquid from this container would then be transferred into the batching tank by dumping it by hand or through the use of the pump. To explain this process better, the following

example is provided: If a batch required 60 gallons of a particular liquid ingredient, a full 55-gallon drum would be dispensed via the pump directly into the batching tank. Then, another 5 gallons of the liquid would be dispensed via the pump into another container to the pre-determined mark or weight. The liquid in this container would then transferred to the batching tank via dumping or the pump to make the required total of 60 gallons.

4. There were no measures practiced or in place for these operations in relation to safe drainage and/or and containment of spilled liquids, ventilation, fire protection, or elimination of ignition sources as they relate to flammable or combustible liquids.

Finally, a review of the batch sheets and batching procedures as well as personal experience with the operation revealed that very little, if any, consideration was given to ensuring that the applicable employees were trained in the hazards of the materials, the development and documentation of safe work practices, or emergency planning.

Current Practices which Pose Significant Risk to Personnel or the Facility

With the flammable and combustible liquid flavorings and the current practices for storage, dispensing and transfer in batching operations identified, the next step in the study was to identify and document the current storage, dispensing, and transferring practices that pose significant risk to personnel or the facility. Identifying the practices that pose significant risk was completed by reviewing and analyzing each of the current storage, dispensing, and transfer practices identified in this chapter and comparing each of them to the applicable flammable and combustible liquids code or standard. For the

purpose of this analysis, a significant risk is identified as any practice that does not comply with the applicable code or standard and thus poses the danger for personnel injury or facility damage.

Container Size and Construction

With the exception of one, all flammable and combustible liquid flavorings were received only in 55-gallon plastic or polyethylene containers. The one other flavoring was received in both 5 and 55-gallon plastic containers. According to the information presented earlier in the study, the liquids identified as 3, 4, 10, and 11 should not be stored in plastic containers of this size. Liquids 3 and 11 have been identified as Class IA liquids. The largest allowable size of a plastic container for Class IA liquids is one gallon. Liquids 4 and 10 have been identified as Class IC, but the water solubility of these two liquids was unknown. The largest allowable size of a plastic container for these liquids is 5-gallons. Therefore, the four liquids are stored in containers that are larger than the allowable size for the particular construction type and therefore this practice, according to the definition provided earlier, poses significant risk.

The second practice involving containers that poses a risk involves the 30-gallon metal container that was fabricated in-house and used in operations involving flammable and combustible liquids. As discussed previously, only approved containers shall be used for flammable or combustible liquids. Since this container was constructed in-house it has not been tested to ensure it will adequately and safely contain the liquids. It was also noted this container had no labeling regarding its contents or the associated hazards.

Storage and Inside Liquid Storage Room Construction

The floor area inside the liquid storage room is 232 square feet. Based on the information presented regarding the fire resistance rating of the construction and the fire protection system installed, the maximum total allowable quantity that can be stored in this room is 2,320 gallons. The identified maximum amount that has been stored on-site was nearly 14,000 gallons. Therefore, it is obvious that the current size and storage capacity of the inside liquid storage room is insufficient and the practice of storing some flammable or combustible liquid flavorings outside of this room exceeds the allowable amounts discussed and poses a significant risk.

Other issues or concerns identified regarding the inside liquid storage room that pose significant risk include the following:

- Although the current drain in the room was sized to handle the expected potential volume, it is connected to the City Brewery's own wastewater treatment plant via its main sewer and drain lines with no trap or separator in place.
- No ventilation system in place.
- No curbing, drainage system, or other measures in place to prevent the flow of liquids under emergency condition into adjacent building areas.
- No portable fire extinguishers available.
- Containers stored in the room were stacked upon one another.
- Containers in the room were not closed or sealed.
- No aisle in the room.
- Spilled or leaking liquids observed on the floor.
- Lack of signage in place regarding the hazards in the room and the necessary precautions or procedures that must be followed.

Dispensing Methods, Bonding, and Grounding

As discussed, the only two allowable methods for transferring flammable or combustible liquids between plastic containers include the following:

- A non-conductive container must be equipped with an approved metallic suction pump and draw tube for taking liquid through the top of a plastic container. The pump must be electrically grounded, or

- The non-conductive container must be equipped with a metallic, self-closing faucet that can be grounded electrically (OSHA, 1999).

The current procedures for dispensing flammable or combustible liquids from plastic containers include the use of a plastic piston-style hand pump or a plastic air-operated diaphragm pump. Neither of these procedures are compliant with the allowable methods discussed. This method of transferring the liquids from plastic containers poses a significant risk because neither the pumps nor the containers are bonded or grounded. Another concern regarding the diaphragm pump is the fact that it can be left running unattended with no means for the pump to automatically shut down in the event of a spill or fire.

The current method for transferring from the metal container, that was fabricated in-house, is by gravity. Although this is allowable, there are also some concerns with this method. First of all, when dispensing via gravity, it is to be through a listed self-closing valve or faucet. The hose used must also be listed and equipped with a self-closing valve. The current valve and hose used do not meet these requirements. Neither the valve or the hose are listed, the hose does not have its own valve, and the valve on the container is not self-closing. Also, there are no measures in place to ground or bond the containers. These issues, involving potential uncontrolled spills and a failure to prevent static electricity, pose significant risks.

Ignition Sources and Electrical Equipment

Although measures were taken in the liquid storage room to eliminate potential ignition sources and safeguard electrical installations with Class 1, Division 2 wiring and equipment, there are still some procedural issues in this area that need to be discussed as well as related concerns in the other operational areas. Besides ensuring containers are

properly grounded and bonded, the other concerns in the liquid storage room may include ensuring that smoking is not allowed, hot work is prohibited, and other ignition sources are not brought into the room. Other obvious potential ignition sources could include power tools, unapproved pumps not designed for the application, and forklifts. Any time a potential ignition source is allowed in the liquid storage room, it poses a significant risk.

Many of the same potential ignition sources, including improper bonding and grounding, are possible or may be present in the other areas where flammable or combustible liquids are dispensed and therefore pose a risk. But, another potential ignition source also exists in these areas that must be discussed. According to the NFPA, in these areas all wiring and electrical equipment within 3 feet of dispensing nozzles must conform to Class 1, Division 1 electrical requirements. The dispensing in these areas is conducted through hoses that are attached to pipes via threaded or cam-lock fittings. Although the liquids should be enclosed in the hoses and pipes, the potential for a leak or spill exists at these fittings. Also, the large 300-gallon tank into which some of these liquids are dispensed is not sealed and has a hinged lid on top. With this lid open, the tank is open to the room when liquids are being dispensed into it and the vapors are allowed to travel outside of the tank. In all of these areas there is significant electrical equipment present. Since none of this equipment conforms to the Class 1, Division 1 requirements, these issues and the operations also pose significant risk.

Fire Protection

Since the fire protection requirements for inside liquid storage rooms have already been discussed, this section will focus specifically on these issues as they relate to the

other operational areas where flammable or combustible liquids are dispensed or transferred. The NFPA does not provide specific design requirements for fixed systems or placement for portable equipment in these areas, but they do state that these determinations are to be based upon many factors, including the hazards and exposures. In the operational areas where the flammable and combustible liquids are dispensed and handled, there are no fixed fire protection systems in place and no portable fire extinguishing equipment was readily available. Based upon the hazards and exposures associated with the liquids and the operations taking place in these areas, the lack of this equipment poses a significant risk.

Controlling and Limiting Spills

Although the methods for controlling and limiting spills in relation to the liquid storage room were already discussed, issues as they apply to the operational areas also need to be reviewed. In the two other areas where the flammable and combustible liquids are handled and dispensed, as well as areas where these materials are transferred through, there are concerns associated with these issues. Although most of these areas are fairly well drained, they, like the storage room, drain via the plant's main sewer and drain lines to the wastewater treatment plant. Also, for these areas as well as for all other operations, there are no procedures documented or in place for controlling, cleaning up, or disposing of spills. Obviously with no means to control, limit, dispose of or clean up spills, this poses a very significant risk. In fact, with many of the areas draining to the plant sewer and drain lines there is potential that a spill could possibly be transported to and affect other areas of the facility great distances away from the original spill. Another observed practice related to this issue involved the disposal of flammable and combustible liquid

flavorings. Some of these liquids were disposed of by dumping them down the drain while diluting with water from a hose.

Ventilation

As discussed previously, there are very specific ventilation requirements for both inside storage rooms and other areas where flammable or combustible liquids are dispensed or transferred. These requirements have not been met in any of the areas at the facility where flammable or combustible liquids are stored or dispensed. Without the proper ventilation in these areas, there is an increased possibility for the accumulation or travel of flammable and combustible liquid vapors that in turn pose a significant fire risk.

Work Practices, Training, Emergency Planning, Inspection, and Maintenance

Although the employees involved with these operations had been trained on the basics of the OSHA Hazard Communication Standard, they had not been instructed on the specific hazards associated with the flammable and combustible liquids nor have they received instruction on the proper handling of these materials. A review of the documented procedures demonstrates a focus on the production and quality-related issues, but the associated safety-related concerns had not been addressed in these procedures. In conjunction with this, there has been no formal planning, documentation, or training in regards to emergencies, disposal, spills, or inspection procedures specific to flammable or combustible liquids. The only formal, completed inspections identified are conducted by the local fire department on a semi-annual basis and an annual inspection by a fire protection equipment contractor on the applicable fire control equipment. In regards to the maintenance of the equipment and areas, deficiencies were also noted during this study. Some of these deficiencies included a lack of lighting in the liquid

storage room, pumps that leaked or did not work properly, as well as failing to establish and maintain clear aisles in storage and operational areas. Without the proper documentation, training, implementation, along with the enforcement of policies that address the issues of safe work procedures, emergency planning and notification, fire detection, inspection, and maintenance, there is significant risk associated with these activities.

CHAPTER V

Discussion, Conclusions and Recommendations

Introduction

The purpose of this study was to analyze the practices currently utilized by the City Brewery in relation to the storage, dispensing, and transfer of flammable and combustible liquids flavorings used in batching operations. Chapter V will include discussion regarding the findings of this study on the analysis of these practices. This discussion will briefly review practices, based on a comparison to the literature review in Chapter II, which are not in compliance with the applicable federal codes and standards related to flammable and combustible liquids and therefore pose a significant risk to personnel or the facility. The chapter will conclude with the author's recommendations for minimizing or eliminating the risks related to the practices at the City Brewery associated with the storage, dispensing, and transfer of flammable and combustible liquids in batching operations.

Discussion and Conclusions

The literature review in Chapter II provided documentation of the chemistry of fire and how to control it as well as the identification, classification and hazards of flammable and combustible liquids. In addition, Chapter II also reviewed and documented the applicable federal codes and standards related to these materials. The documentation included in this review provided the author with an understanding of flammable and combustible liquids, the hazards associated with these materials, as well as the knowledge and tools necessary to analyze the current practices utilized by the City Brewery in relation to the storage, dispensing, and transfer of these liquids.

In order to complete the analysis of the current operations and practices for the storage, dispensing, and transfer of flammable and combustible liquids, the analysis of practices was broken down into and focused on the following applicable items or issues.

- Container sizes and construction;
- Storage practices and inside liquid storage room construction, including fire rating, capacity, fire protection, drainage, containment, and ventilation;
- Dispensing methods;
- Bonding and grounding;
- Elimination of ignition sources;
- Electrical equipment;
- Fire Protection;
- Controlling and limiting spills, including curbing and drainage;
- Ventilation;
- Safe work practices, training, and emergency planning; and
- Inspection and maintenance.

As discussed in Chapter III, the analysis of the current practices was conducted through a comparison to the applicable related codes and standards for flammable and combustible liquids; including both the NFPA and OSHA. Although some attempts had been made to address the hazards and exposure concerns associated with the flammable and combustible liquid operations, the author can conclude from results of the analysis that a significant number of practices or issues identified pose significant risk to personnel or the facility. These practices or issues included a variety of different concerns ranging from engineering and facility-related recommendations to administrative-related recommendations regarding proper documentation, planning, and training. Of the applicable items or issues listed above that were included in the analysis, there was at least one practice or concern identified as a risk to personnel or the facility in each one of these categories. Therefore, until these concerns are addressed, they will continue to pose a significant risk to personnel or the facility. Furthermore, as these operations involving

flammable and combustible liquids continue to grow and increase, so will the exposures and risks associated with them.

Recommendations

The author's recommendations for minimizing or eliminating the risks related to the practices at the City Brewery associated with the storage, dispensing, and transfer of flammable and combustible liquids in batching operations will be presented in two sections. First of all, the author will present individual recommendations to each of the current separate practices or issues identified in Chapter IV that pose a risk. Finally, the author will present some additional recommendations or alternatives, which although may not be requirements would positively affect the risks of the operations as a whole.

In response to the current practices identified that pose a significant risk to personnel or the facility, the author's recommendations for minimizing or eliminating the risks include the following and are based upon the requirements of the *NFPA 30*. Therefore, these codes can be reviewed for further clarification of the recommendations. The recommendations are broken down into the applicable items or issues discussed previously.

Container Size and Construction

As presented in Chapter IV there were four liquids, which according to their classifications, were not received or stored in a properly sized and constructed 55-gallon container. However, because there was information lacking that may have changed the classification of these liquids, this may be inaccurate. If information is received that changes the classification of these liquids, these requirements can be re-evaluated. However, until the class of each of these liquids can be determined correctly, the facility

should request from the supplier that these liquids be shipped in approved, metal containers.

A second recommendation regarding containers is to eliminate the use of the 30-gallon metal container that was fabricated in-house. This is not an approved container and therefore should not be used for flammable or combustible liquids.

Storage and Inside Liquid Storage Room Construction

The first concern to address regarding the storage of flammable and combustible liquids is the required approved storage capacity that will be needed. While it is known that the facility has stored as much as nearly 14,000 gallons at one time on-site, the current inside liquid storage room has capacity for only 2,320 gallons. Therefore, the facility has several options regarding proper storage. First of all, if possible, the quantity of flammable and combustible liquids stored on-site should be limited to the capacity of the inside liquid storage room. If that option is not possible, another liquid storage area that meets the requirements of the code should be designed and constructed to store the required maximum inventory of these liquids. This area would preferably be a structure that is separate from the main facility.

If the facility chooses to continue using the inside liquid storage room for storing and dispensing flammable liquids, the author also has numerous recommendations for this area that include the following:

- Installation of a mechanical ventilation system that meets or exceeds the applicable code. This system will need to be designed based upon the size of the room.
- Ensure current drainage system is adequate and does not pose or spread the risk to other areas of the facility. If inadequate, means must be implemented to ensure flammable and combustible liquids are trapped or separated and do not enter the main sewer or drain lines.

- Locate and mount the appropriate portable fire extinguishers according to code. At a minimum, at least one 40:B extinguisher must be located outside of the storage room, but within 10 feet of the door leading into it.
- Ensure all containers are closed and sealed when not in use and containers over 30-gallons are not stacked upon one another.
- Designate and maintain an appropriate aisle in the room.
- Establish procedures to ensure the immediate and proper clean-up of spilled liquids.
- Install signage in the room warning of the hazards and precautions that need to be taken.

Dispensing Methods, Bonding, and Grounding

Both methods currently utilized by the facility for the dispensing of flammable or combustible liquids, between non-conductive containers and for dispensing from the metal container, were identified as a risk. Therefore, the author recommends that either an approved, grounded, metallic suction pump and draw tube or an approved, grounded, metallic, self-closing faucet should be used for dispensing these liquids. The pump could be either manual or automatic, but it must be compatible with the liquids. If an automatic pump is used, means must be provided to shut it down in the event of a liquid spill or fire. Any hoses that are used in these processes must also be listed and equipped with a self-closing valve. Recommendations for dispensing from the 30-gallon metal container will not be provided since it was previously recommended that this container not be used.

All containers need to be grounded and bonded during dispensing operations. As discussed in Chapter II, this can be accomplished either separately, if possible, or through the metal pumps. Measures must also be taken to ensure the recommended metal pump or original container is bonded to the container, vessel, or piping into which the liquid is being pumped. A simple method to accomplish this would be through the use of self-bonding hose between the pump or faucet and the container.

Ignition Sources and Electrical Equipment

Precautions must be taken to eliminate potential ignition sources wherever flammable or combustible liquids are stored, dispensed, present in open containers or as the result of a leak or spill. In regards to recommended procedures, various areas and practices need to be closely scrutinized to identify potential ignition sources that may be present or brought into these locations. These sources may include but are not limited to smoking material, hot work, and spark-generating tools or equipment. Then, the proper tools and equipment required for these areas need to be supplied or installed. Finally, policies and procedures regarding these issues need to be implemented and all applicable employees trained on this material as well as the hazards and risks associated with the presence of ignition sources in these areas.

In regards to electrical installations, the facility needs to ensure that all electrical equipment and wiring within 3 feet of dispensing operations conform to Class 1, Division 1 requirements. Any additional electrical installations in the liquid storage room must meet Class 1, Division 2 requirements.

Fire Protection

Since fire protection recommendations have already been made for the inside liquid storage room, this section will focus on the fire protection requirements for the other areas where flammable or combustible liquids are dispensed or handled. In these other areas, the need and requirement for fixed fire prevention and control equipment should be evaluated. This evaluation will determine the extent to which these areas need to be protected. This process will be completed by evaluating the operations and applying fire protection and process engineering principles. The evaluation and analysis,

which would be best completed by a fire protection equipment contractor, property insurer, as well as the local fire department, should include a review of the fire and explosion hazards, the construction and facility design, methods of liquid handling and use, local conditions and exposures, as well as the response capabilities of local emergency services. Based upon this evaluation and resulting recommendations, the appropriate fixed fire protection system should be installed in these areas to reduce the risk of fire.

The same recommendation regarding evaluation of the areas, operations, and hazards applies to portable fire protection equipment. In these other areas where flammable or combustible liquids are dispensed or handled, portable fire protection equipment should be provided in appropriate sizes, types, and quantities as needed for the hazards of these other operations.

Controlling and Limiting Spills.

As discussed in the recommendations for the storage room, the facility must ensure that in other areas where flammable or combustible liquids are dispensed or transferred, the current drainage system is adequate and does not pose or spread the risk to other areas of the facility. If inadequate, means must be implemented to ensure flammable and combustible liquids are trapped or separated and do not enter the main sewer or drain lines. In addition to drainage, another recommendation for controlling spills is to ensure that all containers involved in these operations are placed on spill-containment pallets. This includes all containers that are being dispensed from or into as well as those being transferred.

Ventilation

Recommendations regarding the installation of an appropriate ventilation system in the liquid storage room have already been discussed. Therefore, these recommendations will focus specifically upon the other areas where flammable or combustible liquids are dispensed or handled. Ventilation should be provided in these areas by either mechanical or natural methods at a rate sufficient to maintain the concentration of vapors within the areas at or below 25 percent of the lower flammable limits. These requirements can be confirmed by calculations based on the anticipated fugitive emissions or sampling of the actual vapor concentration under normal operating conditions.

Work Practices, Training, Emergency Planning, Inspection, and Maintenance

In addition to the engineering and facility-related recommendations discussed, there are also numerous administrative-related recommendations regarding proper documentation, planning, and training. First of all, employees involved with these operations or working in these areas need to be trained on the specific hazards, properties, and characteristics of flammable and combustible liquids. In addition, all aspects of the operations, including storage, transfer, dispensing, leaks or spills, and equipment operation, involving flammable or combustible liquids need to be clearly documented, adopted, and enforced as policy. Once this documentation is complete, all employees involved with or working around these operations should be trained on this material. In order to ensure these policies are being followed and the equipment compliant with these policies is in good operating condition, specific inspection and maintenance programs related to these issues need to be developed. The checklists in the Appendix can be used

as a reference to assist in developing inspection procedures. It should be policy that any noted deficiencies related to the flammable and combustible liquid operations be corrected or addressed before operations continue in these areas.

In addition to the documentation and training related to the operational procedures, the same recommendations apply to emergency planning, disposal of materials, as well as spill and leak response. Policies and procedures regarding these issues also need to be developed and documented as well as all applicable employees provided with training regarding these matters.

Additional Recommendations or Alternatives

The primary focus of this study was to analyze and identify the practices involving the flammable and combustible liquids that were not in compliance with the applicable codes and standards, and which in turn resulted in operations that posed significant risk to personnel or the facility. However, although they are not requirements of the code, there are a few other issues that should be discussed that relate to the risks posed by these materials.

The first two additional concerns involve the liquid flavorings and the containers in which they are received. The inability to eliminate these liquid flavorings and replace them with others that do not pose the fire and explosion hazards was discussed in Chapter I. The facility does not have the option to use different materials. They are required by the contract customers to use the current liquids. However, it may be possible to use the same liquid flavorings in diluted versions that may eliminate the hazards and associated risks of the materials. Therefore, this option should be discussed with the contract customers and flavoring suppliers to determine if this is a viable option.

In regard to the containers in which the liquids are received, recommendations have already been made for requiring that some of these materials be shipped in approved metal containers. However, if all flammable and combustible liquids were received and stored in approved metal containers, the risks associated with all these materials would be decreased. This option should also be reviewed with the suppliers of these materials.

The next additional concern relates to drainage and spill containment as well as the current and recommended fixed fire protection systems. As discussed in Chapter II, the drainage and spill containment requirements are not only for ensuring the proper drainage and containment of spill or leaks of the liquid flavorings, but also the extinguishing agent from fire protection systems. The fire protection systems that use water as an extinguishing agent require significant drainage and containment. However, those that use an alternative agent, such as foam, have minimal drainage and containment requirements. Therefore, when evaluating fixed fire protection systems, the facility needs to ensure they evaluate all options and the related effects each will have on the other aspects of these operations. The choice of fire protection system may influence some of the risks associated with the operations.

As discussed in this chapter, the facility is in need of additional approved storage space for the flammable and combustible liquid flavorings. Currently, the facility is operating under the assumption that all of these liquids need to be kept refrigerated while in reality, according to the material safety data sheets, none of these liquids are required to be stored at refrigerated temperatures. Therefore, this requirement of refrigeration needs to be investigated because if the facility constructs an additional approved storage

building or room, a refrigeration unit that meets the requirements for installation in this area will significantly increase the cost for this structure.

Another issue related to the storage of the flammable and combustible liquids involves the transfer of these materials. Currently, these liquids are received at the main loading dock, transferred through the plant to the current storage room, and then back through the plant when they are needed to where the batching operations are conducted. Every time these materials are transferred through the facility all of these areas are also exposed to the hazards and risks associated with these materials. Therefore, if the facility proceeds to construct an additional storage room or building, consideration should be given to its location in regards to minimizing the transfer of these materials throughout the facility.

The final recommendation involves the equipment and materials that come in contact with the liquids as they are stored, dispensed, and transferred. Since this is a food processing facility, all of the equipment and materials must be approved and of food-grade construction if it comes in contact with the liquids. The author has learned during this study that equipment meeting all of these requirements can be difficult to obtain. Although this recommendation does not directly relate to the hazards associated with these materials, improper handling of these liquids does present additional risks.

Although not totally related to the requirements of the code, these few additional recommendations deserved to be discussed since they were identified during this study and do have an effect on the risks associated with these materials. Further investigation of these practices and operations would probably identify additional recommendations

that, although not required, would decrease the risks associated with these flammable and combustible liquids.

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APPENDIX
Inspection Checklists

Flammable and Combustible Material Checklist
Occupational Safety and Health Administration

	Are combustible scrap, debris, and waste materials (oily rags, etc.) stored in covered metal receptacles and removed from the worksite promptly?
	Is proper storage practiced to minimize the risk of fire including spontaneous combustion?
	Are approved containers and tanks used for the storage and handling of flammable and combustible liquids?
	Are all connections on drums and combustible liquid piping, vapor and liquid tight?
	Are all flammable liquids kept in closed containers when not in use (for example, parts cleaning tanks, pans, etc.)?
	Are bulk drums of flammable liquids grounded and bonded to containers during dispensing?
	Do storage rooms for flammable and combustible liquids have explosion-proof lights?
	Do storage rooms for flammable and combustible liquids have mechanical or gravity ventilation?
	Is liquefied petroleum gas stored, handled, and used in accordance with safe practices and standards?
	Are "NO SMOKING" signs posted on liquefied petroleum gas tanks?
	Are liquefied petroleum storage tanks guarded to prevent damage from vehicles?
	Are all solvent wastes and flammable liquids kept in fire-resistant, covered containers until they are removed from the worksite?
	Is vacuuming used whenever possible rather than blowing or sweeping combustible dust? Are firm separators placed between containers of combustibles or flammables, when stacked one upon another, to assure their support and stability?
	Are fuel gas cylinders and oxygen cylinders separated by distance, and fire-resistant barriers, while in storage?
	Are fire extinguishers selected and provided for the types of materials in areas where they are to be used?
	Class A Ordinary combustible material fires.

		Class B Flammable liquid, gas or grease fires.
		Class C Energized-electrical equipment fires.
		Are appropriate fire extinguishers mounted within 75 feet of outside areas containing flammable liquids, and within 10 feet of any inside storage area for such materials?
		Are extinguishers free from obstructions or blockage?
		Are all extinguishers serviced, maintained and tagged at intervals not to exceed 1 year?
		Are all extinguishers fully charged and in their designated places?
		Where sprinkler systems are permanently installed, are the nozzle heads so directed or arranged that water will not be sprayed into operating electrical switch boards and equipment?
		Are "NO SMOKING" signs posted where appropriate in areas where flammable or combustible materials are used or stored?
		Are safety cans used for dispensing flammable or combustible liquids at a point of use?
		Are all spills of flammable or combustible liquids cleaned up promptly?
		Are storage tanks adequately vented to prevent the development of excessive vacuum or pressure as a result of filling, emptying, or atmosphere temperature changes?
		Are storage tanks equipped with emergency venting that will relieve excessive internal pressure caused by fire exposure?
		Are "NO SMOKING" rules enforced in areas involving storage and use of hazardous materials?

Flammable and Combustible Liquid Safety
Justrite Manufacturing Company

Checklist for Storage Room Safety (Refer to NFPA Code 30 for details)

- Drum count (maximum capacity).
- Aisles clear (main aisle at least 36" wide).
- Ventilation OK (if forced air, check blowers, motors, switches).
- Explosion-proof switches intact, guards on all fixtures.
- Fusible links intact on self-closing doors.
- Self-closing doors operational, sills intact.
- Grounding integrity OK to earth ground.
- Each drum grounded.
- Provision for bonding to containers being filled.
- Safety vent in each drum.
- Approved faucet or pump on each drum being drained.
- Approved drip can under each drum faucet (check liquid level in can, empty as necessary).
- Approved filler/vent on each drum being filled.
- Sprinkler system checkout.
- Floor clean of drips, spills, trash.
- Required cautionary signs in place and legible.

Checklist for In-plant Storage and Transfer

For safe use and temporary storage of flammables in hand containers:

- Type I Safety Cans for receiving liquids from drums and use throughout the plant.
- Hose or Funnel Attachments for accurate pouring from Type I Safety Cans.
- Type II Safety Cans for filling fuel tanks, small-mouth tanks and other containers.
- Oval Safety Cans for space-saving shelf storage.
- Nonmetallic Safety Cans for abusive or corrosive conditions.
- Stainless steel cans for reagent grade solvents or high purity liquids.

For Safe transfer of flammables from dispensing containers:

- Laboratory Cans with approved safety faucets, shelf-mounted.
- Tilt Cans with approved safety faucets, mounted on tilt frames.

For in-plant mobile storage and dispensing:

- Justrite Liquid Caddy portable solvent tank can be taken right to the spot for filling or draining safety containers.

For safe storage of safety cans near work stations:

- Cabinets with self-closing doors, holding up to 45 gallons of liquids in 1 pint to 5 gallon containers.
- Double-door cabinets holding up to 60 gallons of liquid in 5 gallon containers.
- Cabinets for wall-mounting, bench-mounting or undercounter installation, capacities from 12 gallons in 1 pint to 5 gallon containers.

For in-plant dispensing drum storage:

- Cabinets for storage of faucet-drained drums.
- Cabinets for storage of pump-drained drums.

Checklist for Production Line and Point of Use Safety**For safe application of flammable liquids in small quantities:**

- Plunger Cans that dispense liquid by pump action to moisten swabs and cloths.
- Dispenser Cans for one-hand operation to apply liquid directly on work or cloths.
- Polyethylene dispensing bottles for dispensing flammable liquids directly on small pieces.
- Bench Cans with flame arrester screens and covers for washing small parts and wetting large wash cloths.

For safe cleaning of parts and tools:

- Rinse Tanks with self-closing covers for cleaning large items, and reduction of flammable, toxic vapors of solvents.
- Cleaning Tanks with fusible-link cover-closing device for parts cleaning.
- Drain Baskets for easy placement and removal of parts, without wetting hands.
- Tank stands for placement at convenient working levels and safe locations.

Checklists for Safe Waste Disposal

- Oily Waste Cans for oily and solvent-soaked rags, with self-closing cover and all-ground air circulation to prevent spontaneous ignition.
- Liquid waste cans for flammable and combustible liquid wastes. Large spout opening, with self-closing safety cap.
- Drain Cans for collecting used solvents. Wide mouth funnel with flame arrester.
- Cease-Fire combustible waste receptacles automatically snuff out fires in contents. Open top for easy access. Available complete or Cease-Fire heads to fit standard drums.
- Cease-Fire ash and cigarette receptacles.
- Fill Vent and Funnel to provide venting of waste disposal drums and safe, convenient emptying of small containers into the drums.

Checklist for Hazardous Materials Storage

- Spill containment pallets beneath all drums stored indoors
- Hazmat accumulation centers or storage platforms used to segregate and organize drums
- FM approved hazardous materials storage lockers used to house drums at satellite locations.
- Aerosol systems used to manage aerosol cans.

Checklist for reducing volume of hazardous waste transported to disposal site

- In-drum compaction systems used to reduce volume and cut transportation costs.
- Drum crusher used to destroy damaged or contaminated 55 gallon drums.