Leading the way in hazardous area static control

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Static Ignition Dangers of Ethanol in Distilleries

Kentucky is the birthplace of bourbon whiskey, and home to 532 distilleries making it an $8.6 billion signature industry and the greatest concentration of bourbon whiskey in the world. It is of prime importance to the state and country's economy responsible for over 20,000 jobs. Consequently, for every distilling job an additional three are created down the line. Bourbon production has increased more than 350% since the turn of the century, with premium small batch and single barrel brands driving the bourbon renaissance. With 4.3 million people, there are now almost two barrels for every person living in Kentucky and in 2020, the iconic distilleries filled 2.1 million barrels in their highest ever production year, having exported over $570 million the previous year.[1]

While being a proprietor of a distillery can be a rewarding and profitable undertaking, it is not without its challenges and risks. There are two major hazards in alcohol distilling; fire and explosion. The process of making hard alcohol, such as whiskey, bourbon and gin is fraught with danger, with the potential for fire occurring from the release of flammable compounds such as ethanol (alcohol). These vapors can come from leaks in tanks, casks and equipment such as transfer pumps, pipes and flexible hoses. A vapor explosion can occur if enough vapors are released in an enclosed space with an ignition source, such as static electricity. The processes that go into producing bourbon whiskey appear simple, but they can produce an infinitely complex and subtle drink.

Although the essence of whiskey distilling is steeped in heritage and tradition, when it comes to safety there is no room for nostalgia. The Gin Guild recently raised concerns over the growing popularity of micro-distilling and 'hobby-style gin schools' and warned new distillers about the explosive risks that come with using ethanol. Whether it be a bourbon whiskey distillery rich in history or a trendy gin start-up, distillery owners must take a proactive approach to identify and mitigate the unique hazardous elements that affect their operations.

> ***"Distillers need to be aware of the dangers of using ethanol, and of the need to ensure , regardless of the size of their operations, that they operate on the basis that this is an industrial issue and (albeit on a scalable and relatable basis), that they need to comply and observe with good practice"***
>
> ***- Nick Cook, Director General of the Gin Guild.[2]***

Many distilleries have undergone process automation upgrades to improve productivity and manpower efficiency but have failed to recognise their hazards and the need for risk reduction using the appropriate safeguarding measures. That noted, the risks also extend to distilleries that pride themselves on traditional production methods and are involved in each step of the bourbon whiskey making process. Whether automated or labour-intensive manual processes, both are susceptible to electrostatic discharges.

BS EN 1127-1:2019 Explosive atmospheres – Explosion prevention and protection. Section 5 details possible ignition sources and there are 13 sections in total (5.1 to 5.13).

Typically, in the brewing and distilling workplace 8 possible ignition sources are relevant but all sources should be assessed.

Section 5

5.1 Hot Surfaces

5.2 Flames and hot gases(including hot particles)

5.3 Mechanically generated impact, friction and abrasion

5.4 Electrical equipment and components

5.5 Stray electric currents, cathodic corrosion protection

5.6 Static electricity

5.7 Lightning

5.13 Exothermic reactions, including self-ignition of dusts

An 'effective' ignition source must have more energy than the minimum necessary to ignite the fuel, for example electrostatic discharges are a real hazard with vapor or gas, but less so for grain dust, however, it should not be dismissed. Mechanical ignition is one of the main hazards for dust. Elevators, conveyors, mills etc. can all be potent sources of mechanical friction and sparks if a malfunction occurs.

The generation of static electricity in a distillery can come via:

- Liquid moving through a pipe/hose
- Grain moving through a pipe
- Transferring liquid into conductive/non-conductive containers (plastic IBC/tote)
- Loading/unloading a tank truck

Ethanol Risks in Whisky Production

Whiskey production requires only a few raw materials; malted barley, yeast and water, which are malted, mashed, fermented, distilled and matured through a multi-stage production process, creating ethanol vapor, with whiskey almost exclusively consisting of ethanol and water. It is during the penultimate two stages, distillation and maturation, that the creation of a flammable spirit provides a significant hazard.

It's not just the storage of spirits that's the hazard, the distillation process itself requires heat and produces ethanol vapor – elements that, when combined, can produce fires or explosions. The distillation process area is typically where the liquid contains high concentrations of ethanol and becomes flammable. This part of the facility, therefore, has significant flammability hazards due to the presence of highly concentrated ethanol vapors and heat. For a liquid fire, sufficient air and high enough temperature has to be present to ignite the liquid. The temperature may be from the ignition source such as a static spark or from the liquid itself being above its auto-ignition temperature.[3]

In the distilling industry the threat is double edged; both the raw ingredients and finished product can form hazardous explosive atmospheres. Two of the biggest challenges engineers must consider when looking at site architecture and zoning layouts of distillery buildings is heat and ethanol. Ethanol vapor has relatively low ignition energy and control of ignition sources is paramount – as is suitable protection against electrostatic discharges.[4] Static control measures need to be taken wherever ignitable mixtures might be present. Ignition is always a serious concern due to the flash point of ethanol created during the distillation process. As a result of the distillation process, the area is also classified as a hazardous area and falls under NFPA classification and ATEX directive to protect against potentially explosive atmospheres – anyone who has been on a distillery tour will notice the vast majority of distilleries do not allow cameras into the still house as a result of the potential spark.

In California, USA, an employee was distilling a bath of single malt and brewing beer while working in the distillery and brewery areas of the store. The employee was operating a 1,000 liter still with the still hatch door closed and heated steam supplied from a boiler in the boiler room. Fluids were leaking from the edge of the hatch and the employee was trying to tighten a replacement clamp on the still's door. The employee was subsequently hospitalised.[5]

Read the full report here.

Although this article focuses on distillery environments, the use of ethanol extends beyond the production of alcoholic beverages. Ethanol is found in numerous consumer products; paints, varnishes, inks, and biofuels to name but a few. It'll come as no surprised that between 2000 and 2010, the number of ethanol manufacturing facilities in the U.S. nearly quadrupled, with the coronavirus outbreak even seeing over 800 distilleries in the US alone producing hand sanitiser to aid the fight of COVID-19.[6]

The diversity of ethanol, is of course, a positive. However, as well as being colourless, volatile and highly flammable liquid, it ignites very quickly and is among a host of chemical and petroleum products categorised as static accumulators. Hydrocarbon liquids including ethanol can act as static accumulators and may form ignitable vapor-air mixtures in storage tanks or other containers. During the transfer of ethanol molecules will become electrostatically charged. If the vessel (tank car, storage container, drum etc.) is not grounded, contact with the charged ethanol will cause it to become electrified, presenting a potentially serious source of ignition in the presence of ethanol atmospheres.

Distillery Explosion

In November 2012, Oldbury gin distillery in Langley, UK, caught fire and exploded destroying the facility and severely damaged surrounding residential and private property. 100 Firefighters took over 18 hours to extinguish the blaze, which inevitably destroyed the three storey, 19 century distilling facility, neighbouring houses and cars.

> ***"The fire was most likely caused by a discharge of static electricity while highly flammable ethyl acetate was being transferred from a storage tank into a container"***
>
> ***- The Health and Safety Executive (HSE)***

The HSE criticised the maintenance of pipework and valves and said there was a "failure" to inspect equipment or check how it was being used. One employee sustained 20% burns to his hands, head and neck in the incident. The company was fined £270,000 as a result.[7/8]

The Devilish Hazard in the Angel's Share

Through fire safety engineering, owners and designers of production and storage facilities seek to eliminate the risk of fire and explosion. If these risks cannot be eliminated, then the impact must be reduced as far as reasonably possible. Several potential hazards in a whiskey production facility must be addressed, some of which are much more easily controlled and preventable than others. For example, creation of an explosive atmosphere from grain dust in the milling plant and from flammable vapor arising from the evaporation of ethanol from the casks. The latter colloquially known as the 'angel's share' in Scotland and the whiskey industry. Due to the porous nature of an oak cask, some of the whiskey evaporates causing the barrel to lose both bulk volume and alcoholic strength. Approximately 2% of ethanol is lost annually to the atmosphere as a result of the slightly porous nature of the casks and barrels in which Scotch whiskey is matured.[9]

It is not uncommon for a cask that is 15 years old to be half empty by the time it's bottled. Bourbon Whiskey must be matured for a minimum of two years (three years for Scotch whiskey) with many distilleries believing that the wood makes the whiskey, and that this 'loss' is a necessary sacrifice in creating the perfect blend.

There's so much alcohol vapor in the air at some distilleries that they've implemented methods to collect and reuse it. The Distilled Spirits Council of the United States (DISCUS) manual requires either mechanical or natural ventilation to keep the concentration of vapors in the air at or below 25% of the lower flammable limit, or the minimum concentration at which the vapors can ignite in air, which varies based on temperature and alcohol concentration.[10]

With flammable liquids stored in wood barrels in a potentially explosive atmosphere, it is not surprising that many of the larger fires at distilleries have occurred in their barrel storage facilities. With around 20 million oak casks lying maturing in Scottish distilleries, the loss of ethanol/water vapor can be problematic; not in terms of cost but in terms of safety. Ethanol, even at the concentration used in whiskey maturation, is classed as being flammable. Both OSHA and the NFPA have classified ethanol as a flammable category 2 liquid. This is because ethanol ignites at normal room temperature, has a flash point of 55°F/13°C, and has a boiling point of 173°F/78°C.[11]

Fig 1. – The Jack Daniel's distillery fire brigade was created after a blaze tore through the distillery during prohibition in 1930. Named after Jack Daniel's famous No. 7 brand, Firehouse No. 7 is staffed by 34 distillery workers who double as volunteer firefighters, focusing on distillery-specific hazards. The company has invested more than $4 million into their sophisticated fire prevention strategy to protect the 153 year old distillery in Tennessee which houses more than 2 million barrels of whisky on its 3,000 acre site.[12/13]

Methods of Static Control

Before control can be explored, it is important the elements that combine to produce a fire or explosion are understood. At facilities where ethanol is manufactured, fire and explosion hazards are present from the time ethanol is first formed through product purification, storage and transport. Three elements must be present for fire to occur: fuel, oxygen and heat. All these components must be present for a fire. Fire will burn until one or more of the components are removed. For ethanol fires, the ethanol vapor represents the "fuel", oxygen is the "oxidizing agent" and the "heat" element comes from ignition sources (static electricity) that cause the vapor to burn.

The generation of static charges within liquids occurs with movement in such operations as liquids flowing through pipes; the mixing of liquids; the pumping, filtering and agitating of liquids; or by pouring a liquid from one container to another. All liquids in motion can generate static electricity even though they flow or are contained in bonded and earthed pipes or vessels. It is fundamentally critical to take necessary precautions to prevent discharges that are powerful enough to cause ignition in a flammable or combustible atmosphere. Naturally, the most desirable method of control is the prevention of charge accumulation, this however, is rarely attainable.

The solution lies in preventing charge from accumulating to unsafe levels where a discharge is likely to occur. The object of static control measures is to provide a means by which charge can safely dissipate to earth. The most secure means of preventing charge accumulation is to provide a reliable path to a verified earth via grounding and bonding methods. To avoid spark discharges from conductors and powdered materials which could become charged, all metal and static dissipative plant, low resistive and persons should be earthed.

Small isolated components such as containers seem innocuous in comparison to larger plant equipment, but still have the capability to accumulate and discharge static electricity. Sometimes it is the most routine of processes that go unnoticed, e.g. material transfer (small drums, containers etc.) Each explosion threat presents its own unique challenge. The variables involved, from the combustible material, ignition source, process vessel, operational procedures and environmental conditions all impact on the severity of the risk. In the transportation of flammable and combustible materials produced in distilleries, bottling plants are often separated from distilleries and receive spirits by road tanker, which is then stored before dilution to final bottle strength. The loading/unloading of such material is not without its risks and poses industries with one of the most complex problems, in terms of applying a suitable solution that can control the electrostatic hazard in a safe and reliable way.

In Iowa, USA, an employee transferred ethanol from storage tanks to a semi-trailer tanker where the ethanol ignited.[14]

Read the full report here.

The Bond-Rite® range from Newson Gale provides enhanced safety and security by continuously testing the connection of the clamp to the container or other conductive item of plant equipment in a complete loop made via the designated grounding point. Designed for process areas where interlocking (automatic shutdown) is not possible/or required, operation is manual and monitored by an operator's presence or where the process times are not permanent. These systems are designed around processing hazards where the responsibility is placed on the operator to provide the earthing process. Such restrictions do not mean that specifiers have to take a downward leap to passive grounding clamps (non-monitored). An intermediate layer of static grounding protection is possible from the Bond-Rite solutions that can continuously monitor and verify that the resistance between the equipment to be grounded and a true earth ground source is 10 Ohms or less.

IEC TS 60079-32-1, 13.3.1.4 "Movable metal items" states:

Portable conductive items (e.g. trolleys equipped with conductive rollers, metal buckets etc.) are earthed through their contact with dissipative or conductive floors.

However, in the presence of contaminants like dirt, or paint on the contact surface of either the floor or the object the leakage resistance to earth may increase to an unacceptable value resulting in possible hazardous electrostatic charge on the object. Where such situations are expected, the object should be earthed by an alternative means (e.g. earthing cable). A connection resistance of 10 Ω between the cable and the item to be earthed is recommended.

NFPA 77, 7.4.1.3.1, "Bonding and Grounding" states:

Where the bonding/grounding system is all metal, resistance in continuous ground paths typically is less than 10 ohms. Such systems include those having multiple components. Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion.

If interlocking with the process is required, the Earth-Rite® range of systems provide an optimum level of control for mitigating against the risk of static charge accumulation. All Earth-Rite products feature electronics that continuously monitor the ground path resistance between the grounded object and a verified grounding point, operator displays with LED indicators and internal relays that can be interlocked with the material transfer equipment.

A HAZOP risk assessment will identify hazards, evaluate the associated risks and provide guidance on the subsequent control of the hazards. To help control these risks, Newson Gale offers a wide range of static grounding and bonding equipment which is made to provide optimum safety in explosive atmospheres for a variety of process applications. The Newson Gale product range mitigates static charge accumulation by using practical and innovative design, and ensures effective grounding and bonding clamps, visual verification and interlockable control systems. The mind set should be to source a grounding solution that provides the best level of protection and is capable of being incorporated alongside current operations. The more layers of control implemented to protect against an ignition source, the more likely static will be controlled in a safe, repeatable and reliable way, day in and day out.

As is with processing industries, the distillery sector has had to evolve with the times, especially with regards to safety and protection of personnel. As The Dalmore's Andrew Scott says, "We've come a long way from the times where the distillery manager would smoke a pipe while taking the spirit charge and open flames were commonplace in the still house!"[15]

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United Kingdom
Newson Gale Ltd
Omega House
Private Road 8
Colwick, Nottingham
NG4 2JX, UK
+44 (0)115 940 7500
groundit@newson-gale.co.uk

United States
IEP Technologies LLC
417-1 South Street
Marlborough, MA 01752
USA

+1 732 961 7610
groundit@newson-gale.com

Deutschland
IEP Technologies GmbH
Kaiserswerther Str. 85C
40878 Ratingen
Germany

+49 (0)2102 58890
erdung@newson-gale.de