A major consideration in the implementation of appropriate process safety management must be the prevention of fires and explosions. When processing and handling combustible or flammable materials, the possibility that a flammable atmosphere will be ignited must be considered. A flammable atmosphere can be created from the vapors of a liquid heated above its flash point, a flammable gas, combustible mist, or combustible dust. These fuels, if mixed with air or other oxidant in the correct proportions, can be ignited with devastating consequences.

When charging powders into a vessel containing a liquid at a temperature above its atmospheric flash point (the temperature at which the vapor concentration is sufficient to support combustion), a flammable atmosphere will exist at the charging point, if oxygen is not excluded. Even if the powder is not combustible, discharges resulting from electrostatic charging caused by powder handling/processing could ignite the vapors. Many commonly processed powders, when in motion against other surfaces/materials create electrostatic charge. When the magnitude of the charge is sufficiently high, electrostatic discharges can result, depending on their nature, could ignite flammable vapor atmospheres and/or powder dust clouds. The resulting deflagration in an operating area can have extreme effects including operator injury or fatality, or the initiation of secondary fires or even the explosive rupture of the vessel. A Basis of Safety (BOS) must be established and maintained wherever a flammable material is processed, to ensure safe operation.
A BOS is that combination of safeguards that either prevent or mitigate the ignition of a flammable atmosphere and the consequences to personnel and facilities. The most effective BOS is the prevention of the formation of a flammable atmosphere through the control of the fuel or the oxidant. A more challenging, but often used BOS, is the management of ignition sources such that - although a flammable atmosphere may occur - all ignition sources that could have sufficient energy to ignite the flammable atmosphere are prevented. This BOS is predominantly administrative in nature and is subject to human error, inappropriate material property data and safety culture failings. It is generally not appropriate to use only the management of ignition sources as a BOS (primary) without additional mitigative safeguards (protections such as inerting or relief venting or suppression) when easily ignited flammable atmospheres could occur.

When transferring (pouring) powder to a vessel containing a flammable liquid (whenever conditions allow a liquid to be at a temperature above its flash point) two undesired events are of most concern including: ignition of released vapors outside of the vessel, a flash fire; and flash back of the fire into the vessel with vessel overpressure, i.e. an “explosion”. Operator exposure can result in serious and even fatal injuries. Because both events are of a catastrophic nature, the BOS must be both rigorous and reliable. For discussion purposes, the base case for powder pouring activities is shown below in Figure 1.

This base case is very commonly used throughout the chemical process industries (CPI). In the base case, the primary BOS for the vessel freeboard (the volume above the liquid) to prevent explosive rupture is the prevention of effective ignition sources (because the freeboard is routinely flammable). A secondary BOS could be containment if the vessel is of significant strength. In this case, the primary BOS for the operator’s workspace is also the prevention of effective ignition sources. A secondary BOS for the operator could be the use of appropriate personal protective equipment such as flame-resistant clothing and face/head protection.

It is generally recognized within the CPI that when easily ignited flammable atmospheres such as vapors and gases are processed and the consequences of ignition are dire, control of ignition sources is not an appropriate primary BOS. Because prevention of effective ignition sources is difficult to ensure (in the Base Case), another BOS should be considered. Closed charging can remove the operator from exposure, for example, and provide an effective BOS outside of the vessel.

One approach to the Base Case above is shown in Figure 2 below. Inert gas blanketing/purging of the vessel is an effective method of preventing the formation of a flammable atmosphere. In this concept, an inert gas (commonly nitrogen, although carbon dioxide, argon and other gases can be used) is introduced to the vessel to displace the air and reduce the oxygen content. If the oxygen concentration is reduced to a level below the Limiting Oxidant Concentration (by an appropriate safety margin) combustion can be prevented. The Limiting Oxidant Concentration, LOC, is the lowest concentration of oxidant within the flammable atmosphere that supports combustion (generally 10 to 12 vol %). The effectiveness of this method can only be assured, if the vessel can be completely closed by considering one of several “closed system” design alternatives. As Figure 2 below shows the inerting of the vessel does not ensure that the operator will be protected from a flash fire. Opening the vessel can both release the inerting gas and allow charging of the powder to drag air into the manhole. Even with local exhaust ventilation a small area at the manhole and within the drum can remain flammable subject to electrostatic ignition sources.
Elimination of an operator’s exposure to inert gas and flash fire hazards using inert gas purging (as depicted in Figure 2) requires use of closed charging methods. If a device or system can be installed between the operator and the dust cloud or vapor/gas atmosphere, then the BOS can be control of the flammable atmosphere. The simplest method commonly employed is installation of a rotary valve or flooded screw conveyor above the vessel inlet. These methods prevent ignition of the vapor/gas within the vessel by maintaining an inert atmosphere but continue to expose operators to a limited flash fire hazard (ignition of a dust cloud) while dumping combustible powders into the screw or valve. These devices also introduce electrical and mechanical friction ignition hazards.

Several closed system methods have been developed that use pneumatic transfer to convey the powder into a closed and inerted vessel. These methods are both negative-pressure and positive-pressure types. Although dilute-phase transfer is the most common, dense-phase systems are also available. Each method has both advantages and disadvantages, and they present different safety challenges. In dilute-phase transfer, for example, a large volume of carrier air is required and at some point this air must be separated from the powder. Such a separation device creates new explosion hazards if the powder contains explosible dust. Dense-phase transfer uses a low gas volume but relies on good flow characteristics of the powder. The low gas consumption of dense-phase can also allow use of inert gas for the transfer. Figure 3 shows a simple dense-phase feed system, and Figure 4 depicts a typical negative-draft dilute-phase technique. The requirement of both methods is that the receiving vessel be rated for vacuum service. To overcome this problem, a positive-pressure dilute-phase system can be used, as shown in Figure 5 below.
Whenever a manufacturing site handles and/or processes combustible or flammable materials, a key to appropriate safety management is the establishment and effective maintenance of a Basis of Safety to prevent concurrent existence of the three elements of the fire triangle. Flash fires and explosions can have particularly dire consequences, and thus the BOS must include an assessment of ignition sources and material properties to ensure that incendive ignition sources are adequately managed. The charging of powders into an open vessel containing a flammable vapor atmosphere presents an opportunity for electrostatic ignition that could result in injury to exposed personnel and/or damage to facilities. For the transfer of powders to flammable liquids, information on the flammability (including Limiting Oxygen Concentration), ignition sensitivity, and electrostatic properties is critical to the understanding of risk and determination of adequate risk control. Operating conditions, material properties and contaminants, equipment characteristics, and processing sequences can all impact the validity of data for a specific use. Charging methods must consider appropriate material properties, and operator exposure. The electrostatic properties of powders charged must be determined in order to assess the electrostatic charging hazard. Volume resistivity and charging rate are two key powder properties. Use of vapor-space inerting and closed-system powder charging methods often provide the greatest degree of safety.
David E. Kaelin Biography

David E. Kaelin, Sr., B.S.Ch.E., Mr. Kaelin has over 25 years experience in the specialty chemical manufacturing industry and 15 years specializing as a Process Safety Engineer. He has participated in the design and construction of numerous chemical processing facilities and provided support and training in all areas of PSM. As a Process Safety Engineer he has led process hazard analysis, risk assessments and facility siting reviews. At the corporate level he has created and taught courses in PSM and hazard recognition methods. Mr. Kaelin is an expert in the application of hazard recognition techniques including: HAZOP, FMEA, What-If, Fault Tree Analysis, Risk Screening and Checklist. He is an active member of AIChE, and NFPA.

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- Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

Specialist Consulting (technical/engineering)
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