Dust Hazard Learning Review

Prepared for the U.S. Chemical Safety and Hazard Investigation Board

by Dynamic Inquiry LLC
Ivan Pupulidy PhD and Crista Vesel MSc

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Dust Hazard Learning Review Executive Summary

On October 24, 2018 the U.S. Chemical Safety Board, "as part of its investigation into the May 2017 Didion Mill explosion, issued "Call to Action: Combustible Dust" to gather comments on the management, control and understanding of combustible dust from companies, regulators, inspectors, safety training providers, researchers, unions, and the workers affected by dust-related hazards." The objective of this project was to make sense of comments submitted by stakeholders in response to the CSB Call to Action, regarding the hazards of combustible dust. The vehicle for analysis and sensemaking was the Learning Review process, which focuses on understanding the network of influences that surround people's decisions and actions.

The CSB Call to Action resulted in 57 total responses, which represented multiple industry perspectives focused on the issue of the hazards of dust and related topics. The responses submitted came from varied organizations and manufacturers. Many of the responses went beyond the original questions from the Call to Action and revealed many industry assumptions and challenges, as well as suggestions for improvement.

Several major topics emerged during the sensemaking phase: Barriers to Improvement, Controls, Reporting, Language & Communication, Learning, and Sharing information. Each of these topic areas is addressed in detail in the report.

Barriers to improvement explores how individuals and organizations approach risk. Respondents identified the inability to achieve a dust free environment. Sensemaking revealed that the longer operations proceed without injuries or accidents, the greater the belief that mitigation strategies are working and that the system, itself, is safe. The common term used by respondents to describe this was complacency, however, this can also be seen as a *normalization of risk*. Significant upsets resulted in challenges to the acceptance of status quo. This represented learning moments for the organizations that experienced the upset and, in some cases, nearby facilities who performed similar operations. This learning was expressed as an increase in both operational scrutiny and organizational desire to seek better techniques for risk management. It should be noted, the desire to implement simple solutions or singular causal statements contributed to the normalization of risk. When simple solutions are accepted, workers and leadership can point to specific failures and, either, rationalize that they did not share the same attributes or conclude that the problem has been solved.

Respondents recognized the pressures being placed on manufacturing facilities that produce dust. One respondent pointed directly to a perceived conflict, "Dust is looked at like spending money on garbage." Quotes like this were common and point to the goal conflict between safety and production. Goal conflicts are not easily resolved. Companies are not endowed with limitless resources and economic considerations are a very real concern. There is a "sense that the cost of full compliance is too high to sustain a competitive position." While the two most common goal conflicts named by respondents were between safety and cost, and safety and production, other goal conflicts are known to exist in most complex work environments.

Controls emerged as a major topic of emphasis. Many comments focused on the need for controls to 'keep us safe', including rules and regulations, routines around dust measurement and mitigation (e.g. "housekeeping"), audits and Dust Hazard Analyses (DHA's). An equal number of comments challenged the ability of facilities to comply with typical regulations and processes. Almost every response noted that it may be impossible to remove all dust from facilities. Respondents expressed concern over the lack of awareness of the risks related to dust and the lower importance that dust took to other primary safety concerns. Dust explosions are rare events and it is human nature to highlight the events that are most recent or prevalent.

For many safety events, Hierarchy of Controls has direct applicability at the most effective levels (remove or replace the hazard and/or isolation of people from the hazard). Respondents reported that dust did not fit into either of these control areas, mainly due to its constant presence in the system. The presence of dust is a major concern and is dealt with through dust removal. Yet, respondents reported that regulations and guidance do not address dust control systems or the companies that install them. The burden of dust removal falls on the manufacturing workforce who are responsible for detection, monitoring, control and mitigation.

Housekeeping represented the most utilized control of dust hazards, regardless of the industry or location. Yet, there was a repeated concern that workers are not fully aware of the dust risks. Respondents were concerned that a 'one size fits all' approach to housekeeping would not be applicable across industries, nor even in the same facility. It was suggested that other industries could learn from the food and medical manufacturers, where the handling of dust is a necessity for quality control and contamination, as well as hazard reduction.

Dust Hazard Learning Review Executive Summary

The honest **reporting** of issues at facilities is an expected part of operations, ranging from something a worker feels 'is just not quite right', to concrete safety issues and fires. Supervisors and safety managers often expect that workers who see something, will say something. This is actually a complex issue influenced by a number of interactive factors. Prescriptive methods of demanding reports from workers were reported to be largely ineffective.

The Call to Action revealed important problems with the **language** used to describe combustible dust and its mitigation, suggesting it be presented as a distinct hazard, not simply as an "issue of tidying up the place". Changing the common term 'housekeeping' to something that implies a serious hazard may have a generative effect on the safety of facilities. In addition, it was clear that all levels of **communication** need to improve within facilities that have combustible dust.

Learning is a function of the willingness to share information and the openness to change assumptions. Respondents identified a difference between training and learning as a significant issue. Most training programs were reported to be compliance-based and lacked practical application. Recommendations around training included the creation of scenario or dialogue forms of instruction.

Sharing information was the most reported topic in the Call to Action and naturally divided into three areas. Local Sharing (internal communication) is an important way for companies to learn from events, yet it was reported that workers fear that their honest reports will be used against them. A focus on a learning culture, where learning is emphasized in normal work events as well as accidents and incidents, may help the workforce feel a sense of connectedness and importance, thus increasing the likelihood of sharing information and learning from each other.

Sharing information between companies, industries and regulators was reported to be infrequent – yet this was also the most desired goal stated by Call to Action respondents. Having a platform to share information and experiences openly, without fear of reprisal or punishment, would offer the best path forward to learn from others regarding dust hazard mitigations and best practices. Some industries reported having made striking improvements, this platform could serve as the medium to share critical safety information.

U.S. based and international respondents called for a world-class specialized annual conference (*global summit*) with expert panels, training courses, and workshops, where multiple industries can share information and create networks of learning. Combustible dust is an international problem, which demands the "opportunity to learn from all sectors, nations, levels and approaches." A global combustible dust summit would give industries a chance to learn from professionals, regulators, inspectors, investigators and each other, resulting in a collaborative approach that could contribute to positive long-term change.

In summary, the responses from the Call to Action captured a number of industry wide insights into the issues, concerns and opportunities faced on a daily basis. Further research is needed to fully map conditions and understand goal conflicts and their influence on safety and production.

Introduction

On October 24, 2018 the U.S. Chemical Safety Board, "as part of its investigation into the May 2017 Didion Mill explosion, issued "Call to Action: Combustible Dust" to gather comments on the management and control of combustible dust from companies, regulators, inspectors, safety training providers, researchers, unions, and the workers affected by dust-related hazards."[1] The objective of this project was to assess comments submitted by stakeholders in response to the CSB Call to Action regarding the hazards of combustible dust. This study was designed to make sense of their comments and to coalesce their perceptions in a way that could be understood by the readers of this report. Therefore, the aim of this project is to achieve a better understanding of the varied challenges faced by each stakeholder group and potentially unearth yet-to-be-explored pathways of learning on the topic of combustible dust.

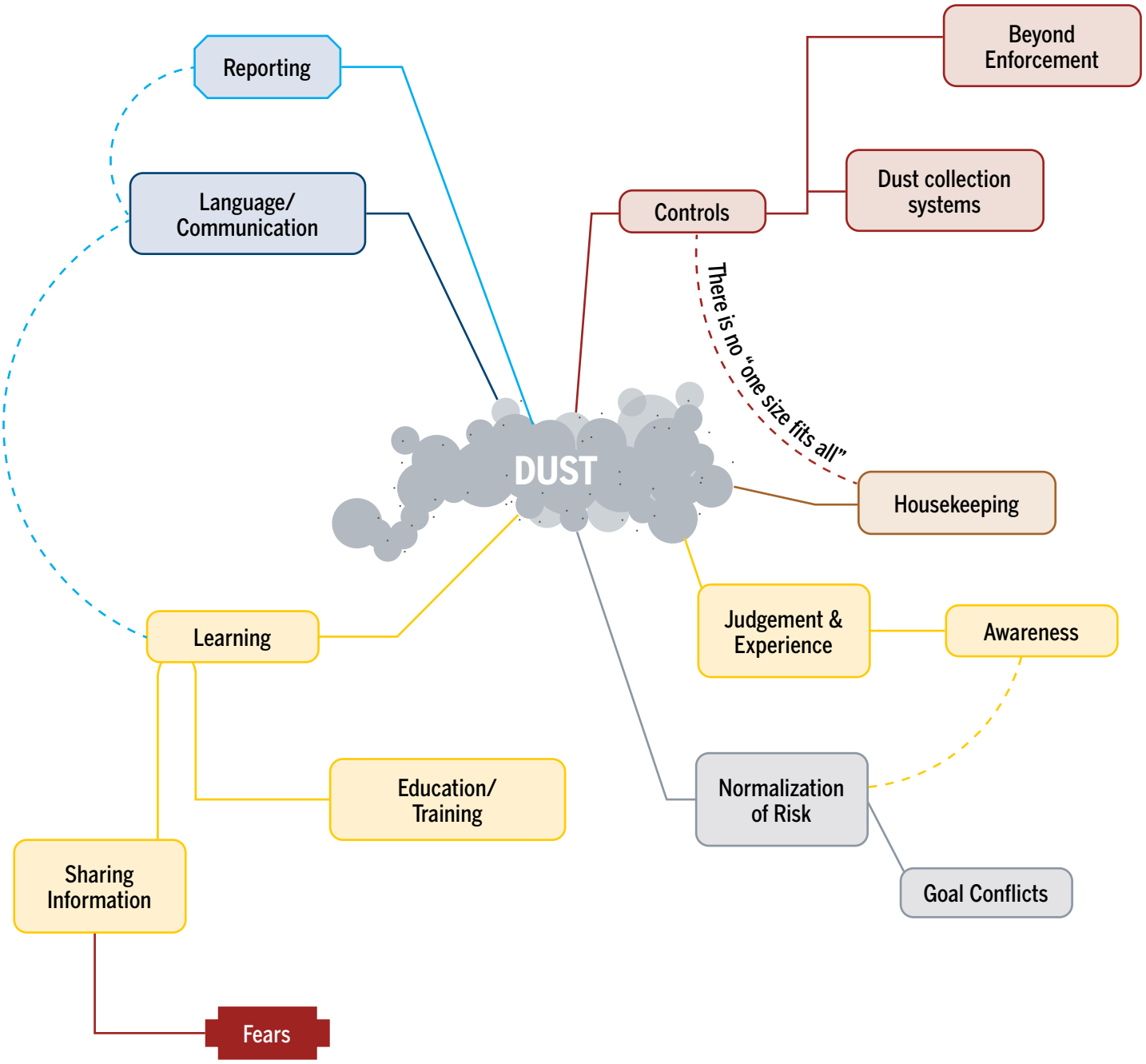
The CSB Call to Action resulted in 57 total responses, which represented multiple industry perspectives focused on the issue of hazardous dust and related topics. The responses extended beyond the United States, with comments from the UK, Canada, France, Denmark, New Zealand, Brazil, India, Australia, the Netherlands, Turkey, Nigeria, Italy and Jordan. Industries such as plastics, chemicals, grain, food, petroleum and metals were represented. Individual respondents included engineers, researchers, consultants, suppliers, safety advisors, managers, regulatory affairs officers, company owners and presidents, policy advisors, multiple unions, industry councils, a regulator and the National Fire Protection Association (NFPA).

Many of the responses went beyond the original questions from the Call to Action and revealed a myriad of industry assumptions and challenges, as well as suggestions for improvement. Each response was read multiple times by recognized experts in human and organizational factors analysis, who hold an in-depth understanding of the USDA Forest Service's Learning Review methodology. These specialists aggregated the responses into key topics on a Network of Influences Map. The map did not have predetermined categories, rather, themes were allowed to emerge as the responses were grouped by similar category. These major topics became the general outline for this report.[2] It became clear that the Didion Mill explosion was not an anomaly, rather it was just one example of how the myriad of issues, revealed by respondents to this study, could combine in an adverse outcome event.

1 Chemical Safety Board website, https://www.csb.gov/assets/1/6/call_to_action_-_final1.pdf

2 Note: The word diagram below contains the top 50 words associated with the quotes and notes taken from the Call to Action responses (see Appendix). This diagram was created on https://wordart.com/create

Since the publication of the CSB's dust hazard study in 2006, 111 additional combustible dust incidents have occurred, with the CSB conducting in-depth investigations of four of them, including most recently the Didion event. These four incidents alone have taken the lives of 27 workers and injured 61 others. In general, workers and management personnel from these various CSB investigations had similar perceptions of their work environments: Dust was present, normal, and maintained at a "safe" or "manageable" level. These commonalities between companies, which differ in their dust-producing operations and their industry (e.g., sugar, corn, automotive insulation, etc.), suggest similar real-world challenges exist across the industries regarding the identification and management of dust. There is value in unearthing these differences and perceptions, as well as noting the extent to which they hinder or support dust-producing facilities in their effort to prevent the "next" dust explosion.



Barriers to Improvement

Normalization of Risk

"Dust explosions are rare events that lull industrial organizations into a false sense of safety. While a greater level of recognition of these risks is present in the industries than ever before, still far too many dust related incidents occur as a result of ignorance or complacence. Because of the complex variables that must come together to enable a dust explosion, operations personnel are frequently unaware of the true likelihood of these events. While rare, they are frequently catastrophic when they occur. Often the original design of the equipment and safety processes of the operations are initially effective in at least reducing risk. However, over time I believe the process of practical drift occurs. Practical Drift was first proposed by Scott Snook in his book Friendly Fire. (2000, Princeton, NJ: Princeton University Press.). He defined it as: the slow uncoupling of practice from procedure. His theory is that as people operate in an environment controlled by procedures, they are constantly acting to reduce effort and improve efficiency based on real time results. With an infrequent event such as dust explosions, this iterative process can result in many iterations before the explosion occurs, allowing the system to change dramatically before the result of these changes are made known. I believe this theory is highly applicable to the prevention of combustible dust events." [53]

Organizations approach risk in rather prescriptive ways, most of which focus on the upstream management of risk. This is commonly related to risk benefit analyses and prescriptive hazard analyses. These processes define an acceptable risk value and many of them produce mitigation strategies or tactics. Mitigation refers to the action of reducing the severity, seriousness, or painfulness of something. There is a connotation associated with the use of this word, which implies that once a risk has been mitigated, it no longer poses a significant threat. The same implication exists when an acceptable risk level has been determined through a recognized process. The field application of risk management is therefore colored by the results of these processes, which contributes to a normalization of risk.

One respondent pointed out, "There is no such thing as 'safe' in an engineering sense... The actual concept is 'risk reduction' or 'risk minimalization'." [38] However, the lines are not clear, "The determination of 'safe' conditions incorporates risk-based decision making (with criteria not well defined). [37]

The longer a system remains safe (no injuries or accidents) the greater the belief that our mitigation strategies are working. The result is a belief by workers and managers that the system itself is safe. The values of probability and severity are socially constructed to be less than they may actually be. Accidents and close-calls (or near-misses) are formulated as stories which are made sense of in particular ways. Close-calls will frequently give rise to stories of superior ability or skill. Accidents are often viewed through the lens of hindsight bias, where blame is placed on a specific actor in the system of work. It becomes a matter of rationalization by those not involved, to re-establish a sense of safety before returning to work in the same environment. Both these approaches make light of inherent system vulnerabilities or unresolved risk.

We must understand risk in the way that is formulated by lived experience in the workplace, not merely as the probability and severity we calculate to exist in a system of work through our current risk management processes. The perception that our field personnel are in some way complacent in their recognition and valuation of risk is a very complex social issue. The use of the word 'complacency,' can move us away from learning from the event, as it focuses our attention on the individual action, rather than the systemic contribution.

The expected response of prolonged exposure to risk without injury or accident is that normative practices will develop. Many of these practices will be geared toward efficiency or production advantage. Only after an unplanned, adverse outcome event will enough scrutiny placed on the system to warrant a modification in the process or an awareness of the hazard. It may be suggested, after such events, that the workers placed themselves unduly at risk. This is an unfair and unproductive pathway that commonly interferes with learning from the events.

- "Many plants are still in the complacent mindset, where they have never experienced a major event and hence feel their risk is not high enough to worry about." [17]
- "Complacent mindset of being low risk purely based on no significant event history." [17]
- "The common thinking is, 'It never happened before, that costs too much money, we don't have a problem, etc,' are often the challenges in a growing climate of risk acceptance." [26]

- "Growing climate of risk acceptance, the challenge isn't getting new ideas in one's head, but rather getting old thoughts out of one's head." [26]

- "Dust fires in the workplace are quite common, but most of the time people say, 'Oh this has always happened,' and 'it's never resulted in an explosion before', so it does unfortunately result in a sense of complacency. [36]

- "People don't realize that all that's required is confinement for a dust explosion to occur under those conditions." [36]

- "If certain facilities are used to frequent fires, but have never had an explosion, the natural tendency is to believe that there would have been an explosion by now if one were going to happen." [51]

Managing causal attribution is a key way to minimize the normalization of risk.

Goal Conflicts

> *"If it is technically and economically feasible for an organization producing or handling combustible dusts to operate with no or negligible fugitive dust escape to the general working environment, then that is the safest condition to maintain. However, the reality is that some dust processing operations are going to operate, due to technical and/or economic constraints, with some level of fugitive dust present in the work environment." [53]*

Respondents recognized the pressures being placed on manufacturing facilities that produce dust. One respondent pointed to a perceived conflict, "Dust is looked at like spending money on garbage." [51] These quotes acknowledge the goal conflicts that frequently exist between safety and production.[3] "The next largest challenge is convincing unknowledgeable executive decision makers why the cost [of dust control] is a necessary part of the business model for the operation of combustible dust processes." [53]

Respondents indicated that dust control was seen as a significant cost to production:

- "Safety is a non-event, think of it as a control loop with a much-delayed feedback signal, then the control loop starts to drift. Production is tangible and can take priority over safety." [20]

- "One of the biggest issues is the attitude of, 'we've been operating for __ and we have never had an issue so why do we have to spend all this money on stuff that isn't going to happen here?'" [44]

- "Some customers fear that once they start understanding the issue that they will need to comply fully, and the cost will be too high to sustain a competitive position in the industry." [5]

- "Balance cost of doing everything they can to reduce risks and reducing risks as much as their budget will allow." [51]

- "[Safety choices] are based on fear of efficiency, not fear of danger and incidents." [40]

The majority of respondents indicated the importance of education and awareness of the hazard. No amount of regulation can overcome a lack of awareness of the issue or potential hazards associated with dust. One mitigation strategy is suggested in the way that the grain-handling industry met the risks associated with combustible dust. Their response indicated the need to include industry partners and regulators in a collaborative effort to develop meaningful easy to read/understand regulation, education and awareness programs. "One challenge I have observed is how NFPA standards are written. While thorough, they can be extremely confusing." [52]

Goal conflicts are not easily resolved. Companies are not endowed with limitless resources and economic considerations are a very real concern. "Sense that the cost of full compliance is too high to sustain a competitive position." [5] While the two most common goal conflicts named by respondents were between safety and cost, and safety and production, other goal conflicts are known to exist in most complex work environments. Further research is needed to fully map and understand these goal conflicts.

3 Hollnagel, E. (2009) The ETTO Principle, Efficiency-Thoroughness Trade-Off; Why things that go right sometimes go wrong. *Ashgate*, Burlington, VT.

Controls

The topic of 'controls' for combustible dust was one of the most populated areas on the Learning Review mindmap. Many comments focused on the need for controls to 'keep us safe', including rules and regulations, routines around dust measurement and mitigation (e.g. "housekeeping"), audits and Dust Hazard Analyses (DHA's). An equal number of comments challenged the ability of facilities to comply with typical regulations and processes. Almost every response noted that it may be impossible to remove all dust from facilities. "The goal would be to reduce the risk to a minimum, not eliminate it, as virtually no operation can eliminate all risks." [1] "It is not our mission to believe that dust will not be generated, rather that it must be managed and mitigated safely. Dust is an inevitable part of the manufacturing process in almost all cases." [5]

Awareness of Risk

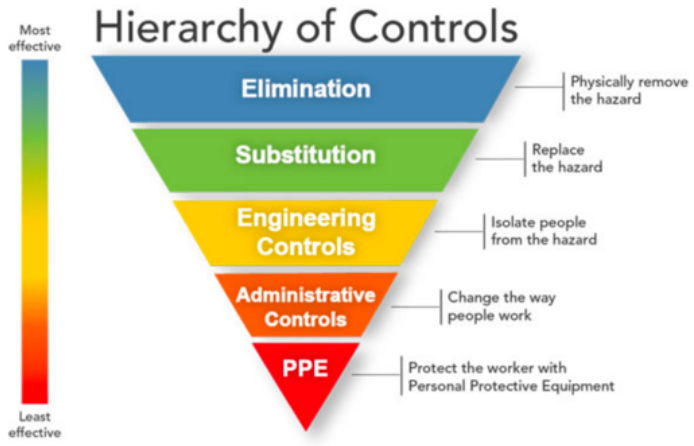
In order to mitigate a risk like combustible dust, there must first be an awareness that dust is a hazard. "Combustible dust should be a widely recognized hazard, just like any other workplace hazard." [51] Many other hazards are more clearly defined and regulated, such as fall arrest gear and personal protective equipment (e.g. gloves, protective clothing, hard hats etc.). It became clear that there is a network of assumptions about how the system can be made safe, with respect to dust and it differed from traditional or common safety protections. Some of these assumptions are rooted in language, some in folklore, and some in the historical response to accidents.

Respondents confided that dust seemed to have a lower priority than other safety issues – we must ask ourselves why that perception exists. Firstly, dust does not command the level of respect common to most other hazards. "Most companies visited don't understand the volatility of their dust problem." [27] "Most of our customers are not aware of their combustible dust and the required protections." [34B] Respondents proposed that fires are often not related to a dust hazard, which may block people from learning ahead of disaster by giving them a false sense of security. "If we have enough fear (respect) for dust explosions, we will take action using fires as leading indicators." [27] It was also suggested that the topic of dust hazard is ignored and that both leadership and regulators should, "continually bring up the topic in conversation." [26]

Hierarchy of Controls Approach

Dust explosion investigations have traditionally focused on lapses in processes or controls. Correspondingly, recommendations tend to recommend following the model of hierarchical control.

Lapses discovered during investigations may have existed immediately prior to the explosion; however, it is highly likely that they also existed for a long period of time prior to the accident without a catastrophic outcome. This contributes to confusion regarding what a safe level of dust is and what dust level requires immediate mediation. These assumptions and beliefs were voiced many times in the responses to the Call to Action and contributed to what was called a "false sense of security". The panorama of interrelated assumptions regarding the what is safe enough and the presence of dust, tend to undermine our ability to employ the Hierarchical Control model automatically.[4]



From the diagram above, the most effective control is considered to be ***elimination of the hazard***. Most respondents to the Call to Action felt that there was no way to completely eliminate the hazard of combustible dust. "You can't eliminate all dust – reduce it to keep the chances of an incident low." [51] Another respondent noted that it was "hard to remove fugitive dust – we default to 'remove ignition source'. "[27] There was also a strong belief that there is a difference between suspended dust and settled dust, "the workplace can fall anywhere in the continuum of dusty vs. safe". [13]

The utility of dust collection systems was considered inconsistent in the industry responses. "Many believe an industrial dust collection system works like a household vacuum, when in fact, it is far more complex. Understanding how the dust capture hoods, branching/

4 National Institute for Occupational Safety and Health, https://www.cdc.gov/niosh/topics/hierarchy/default.html

trunking for transport lines, collector/filter design, and cleaning system operate is usually not taught to engineers, and as a result, a trial-and-error approach is implemented, or the plant will rely on a vendor that supplies components, but not a system design." [35] Though dust collection systems can be a useful way to reduce risk in facilities, "defining critical dust levels is not an exact science." [15] The responses to these systems will be discussed more fully later in this section. Dust control systems can be located outside the facility to reduce the explosion risk from the processing plant. "Note that a large fraction of dust explosions that occur do so in dust collectors and those that are processing fines of the fines. If possible, these need to be located outdoors, away from people and property." [15]

The second most effective control in the diagram is ***substitution***. Respondents considered dust to be an inevitable byproduct of production. This was often coupled with comments regarding the variability of dust explosivity and amount of dust, which is often related to changes in process, material or production volume. Even in situations where the dust can be made into a viable byproduct (e.g. corn dust into ethanol, iron dust into pellets, etc.), there is still fugitive dust in the system. These beliefs challenge the substitution method.

Engineering controls, or isolating people from the hazard, are handled in a number of ways ranging from pressurized rooms to dust elimination systems. These are believed to be effective and are core in the current NFPA recommended practices. Due to normal system and human variability, these mitigation strategies literally 'work until they don't'. For example, in the Didion case the facility had been inspected and audited shortly before the accident. These inspections contributed or reinforced the sense that the existing dust levels were 'safe' or at least normal. This represents a normalization of risk, which can lead to the belief that engineering controls will keep the system safe and no action, beyond the usual, is required.

This leaves the least effective controls on the pyramid, **administrative and PPE**, which is where the majority of respondents suggested intervention:

> *Administrative controls and PPE are frequently used with existing processes where hazards are not particularly well controlled. Administrative controls and PPE programs may be relatively inexpensive to establish but, over the long term, can be very costly to sustain. These methods for protecting workers have also proven to be less effective than other measures, requiring significant effort by the affected workers.*[5]

5 Source: https://www.cdc.gov/niosh/topics/hierarchy/

Control Through Compliance

The Call to Action suggests that comprehensive regulatory standards for dust control have yet to be created. "To date, the CSB has issued four recommendations to OSHA calling for the issuance of a comprehensive general industry standard for combustible dust… yet the development of a general industry standard has not come to fruition."[6] The need to create a safer atmosphere in dust generating industries can lead to a belief that the only way to achieve this is through compliance and enforcement. [38] In fact, one response asked why the CSB would ask for voluntary comments, instead of issuing directives. "By its nature, the Call to Action clearly solicits a voluntary response; the concerns we have raised with the document raise questions about how effective this approach will be." [28] Another respondent said the "CSB needs to do more and extend their dragnets to other parts of the world." [34a] A Google search of the word dragnet suggests, "a systematic search for someone/thing, especially criminals or criminal activity".[7] This seems to imply that those who do not comply with standards should be treated like criminals, loading the combustible dust issue with the potential for increased fear and mistrust.

There are places where the issue of combustible dust has been helped by other necessary standards, such as in the food industry. Here, cleanliness is essential not only for safety, but also for the creation of the final saleable product. "Food facility sanitation compliments dust safety." [51] "Some of the same techniques for handling food safety will apply to dust safety." [35] "In the context of a lack of resources, priority is sometimes given to product quality. Food safety and explosion prevention can be ensured by using similar principles such as dust removal, visualization of dust accumulation on the floor." [12] The grain, feed, milling, processing and export industry contributed a long response to the Call to Action, where it suggested, "we firmly believe that the application of NFPA standard to the combustible dust rule would not be effective in significantly reducing risk of fires and explosions from what we experience under existing OSHA standards." [49A]

OSHA and The National Grain and Feed association (NFGA) co-created a grain handling standard in 1988, which resulted in fewer fire and explosion related fatalities since the rule was promulgated. "In addition, Bill Wright, interim chair of the U.S. Chemical Safety and Hazard Investigation Board (CSB), testified during the House Education and Labor committee's March 12, 2008 hearing on H.R.

6 Chemical Safety Board, "A Call to Action: Dust Hazard Perceptions Report".

7 https://www.google.com/search?q=Dictionary#dobs=dragnet

5522 – the 'Combustible Dust Explosion and Fire Prevention Act of 2008' – that the frequency of grain facility explosions declined by 60 percent following implementation of the grain-handling standard. This is a testament to the combination of industry research, education, training and government involvement." [49A]

From the outset, it seems as though the reduction in accidents resulted from the creation of this standard. However, the grain handling industry had also invested into education and information sharing. They had established a 50-member Fire and Explosion Research Council that gathered and disseminated information and technology. They focused on research proposals and projects that resulted in new practical information and results targeted at reducing explosion risks. They invested in education efforts, "to disseminate new knowledge gained through the research, and instruct grain handlers on their regulatory obligations under the standard." [49A] They held seminars, conferences, and workshops and teamed to sponsor a National Grain Handling Safety Day. In addition, many manuals, brochures and videos (some in Spanish, as well as English) were shared throughout the industry. These combined efforts could all be seen as assisting the industry to move to safer dust handling through research, education and sharing information. The grain handling standard may have helped create the impetus for this movement, yet the combined approach likely carried the mission to success.

Safety Defined as an Absence of Explosions

Currently, a major reported measure of the effectiveness of safety programs is the absence of explosions. This absence allows people to assume the system is safe and working well and may lead to a false sense of security. NFPA is clear that the absence of explosions should not be used as an indicator of safe operation.

> NFPA 652 5.2.3 states, "The absence of previous incidents shall not be used as the basis for deeming a particulate to not be combustible or explosible."
>
> The new NFPA 652 7.1.3 states, "The absence of previous incidents shall not be used as a basis for not performing a DHA."

This guidance suggests that the absence of previous incidents should not be used as an indication that the system is safe. Yet, respondents indicated that previous incidents, such as dust fires, could be a major indicator of plant safety. "Dust fires are common if you consider even small events (like golf ball size events) however, large events, like explosions, are very rare and thus they are not given much consideration in DHAs or PHAs." [38] "Regarding the other side of the question, my answer is "unfortunately yes" because the large proportion of the dust fires incident did not cause explosion, that indeed create a false sense of security." [41] "I do believe it can create a false sense of security. If certain facilities are used to frequent fires, but have never had an explosion, the natural tendency is to believe that there would have been an explosion by now if one were going to happen." [51]

Asking people to ignore their daily experience, as suggested in NFPA 652 5.2.3, is counter to human nature. Each day people are exposed to a hazard and nothing bad happens, a sense of safety is nurtured.[8] This realization dictates a need to understand the difference between work as imagined and work as performed and apply that understanding to both training and regulation.[9] In field application, "no explosion" has come to mean the system is safe enough - this is the way that field personnel view an operational.[10] No matter how many times we admonish workers to perform differently, system indicators that they face each day will have a profound effect on what they believe to be true.[11] Safe enough also fits into the workers need to balance goals that can vary as the system demands change, which is a form of 'satisficing' (term introduced by Herbert A. Simon in 1956). It is also consistent with human nature to have a predisposition that is biased toward efficiency.[12] Therefore, safe enough is a condition that workers strive for; often anything else is seen as an unreasonable cost to production. "Safety is a non-event, think of it as a control loop with a much-delayed feedback signal, then the control loop starts to drift... Production is tangible and can take priority over safety." [20]

Success in other industries has resulted from addressing this issue by emphasizing learning, rather than trying to regulate performance.

Challenges to the Compliance Approach

It seems as though compliance with a dust handling standard would be a clear and easy approach for companies to follow. Yet respondents to the Call to Action suggest, "Mandatory directives are not necessarily followed." [12] When asked about being in-line with NFPA standards, "Most companies don't even worry about it." [52]

8 Adams, J. (1995). Risk, Oxen, England: Routledge.

9 Hollnagel, E. (2004). Barriers and accident prevention. *Ashgate Publishing Company*, Aldershot, U.K.

10 Vaughan, D. (1996). The Challenger launch decision: Risky technology, culture, and deviance at NASA. *University of Chicago Press*, Chicago, Illinois.

11 Dekker, S. (2011). *Drift into failure: From hunting broken components to understanding complex systems*, Burlington, Vermont: Ashgate Publishing Company.

12 Hollnagel, E., Woods, D. D. & Leveson, N. C. (Eds.) (2006). Resilience engineering: Concepts and precepts. *Ashgate Publishing Company*, Aldershot, U.K.

Once again, a main factor in treating dust as a hazard is recognizing it as such. The presence of dust in a facility can sometimes be hazardous – but how can you know, for certain, that the dust has become combustible? It is difficult to know if the time, labor and money spent on the removal of dust is worth the cost. One respondent mentioned that "Dust is looked at like spending money on garbage." [51] Another said that handling dust is "very expensive, disruptive to the operations and time consuming." [56] Indeed, there is an efficiency (production) / thoroughness (cleanup) tradeoff when it comes to this work.

If facility owners, executives and workers believed that dust was a true hazard that could kill them all or flatten the facility (thereby stopping production), they would handle it differently. But the threat of dust is not the most obvious hazard faced in industry. Safety choices "are based on fear of efficiency, not fear of danger and incidents." [40] The need to make money on a product in the short-term tends to outweigh the investment in safety. Many responses described dust training inadequacies, including an oversimplification of combustible dust, computer based instead of interactive training, and infrequent training or dialogue. Overall, there seems to be a reluctance to discuss combustible dust, except as a 'clean up' issue. Handling dust can become simply a compliance issue – with facilities cleaning it up, not because they believe it is hazardous, but because they are afraid of punishment by regulators and insurance companies. As long as this tension exists, facilities will never be fully engaged in practices that help them become safer.

Measurement of Dust

In practice, it is very difficult to assess a safe dust threshold. "The trouble I see is that acceptable dust levels are often so small they are not practical to measure." [51] When compared to liquid chemical spills, dust losses are much harder to see and understand. Liquids can be measured more easily than dusts and releases are more visible, thus, regulations often allow for zero spills. Dust is harder to manage as it can be hard to accurately measure losses of containment. [15] The "Measurement can be assessed visually (subjective) or quantifiably (objectively). Both approaches are effectively employed in the industry and they can also be misinterpreted and allow unsafe conditions." [35]

Despite NFPA guidance, many respondents felt that a safe threshold of dust was not a commonly understood value. Even though the NFPA gives a standard for dust measurement, dust thickness can be difficult to measure, and layers are not consistent throughout a plant. [15] "A blanket depth criterion is not practical since the work environment can vary, and the dust will vary." [30] "Practical experience shows that dust layers do not settle evenly, so you cannot sensibly set a maximum thickness level of an acceptable layer." [42] "Dust profiles will vary dramatically," mentioned one respondent, who suggested that the distinction between primary verses secondary dusts may hold more meaning than a simple measurement value. [11]

There is also an issue with industries trusting the 'safe measurement levels' of fugitive dust that become regulatory standards. Questions arise, such as how the levels were set? Which 'dusts' were used in the research and does that really apply to my industry? Facilities may be more likely to trust the 'Sawdust Cannon' episode of Mythbusters, where they ignite a cloud of sawdust with a flare and get an unpredicted county-shaking explosion.[13] Respondents agreed, "Explosive testing should be conducted under real world conditions rather than assuming worst case scenarios." [6]

Interpreting the regulations is another challenge to the measurement of dust. "The large number of variables makes understanding the hazard difficult. Not everyone knows the science... There is confusion about which standards and regulations pertain to (a specific) combustible dust." [8] While workers handle dust on a daily basis, they may not recognize when conditions change and require different tactics. Safety managers may not be present on the floor, when work is being done. A safety specialist trained in hazardous dust measurement and control may infrequently visit the issue (such as when a DHA is performed).

Dust Hazard Analysis

> "The employer shall perform an initial process hazard analysis (hazard evaluation) on processes covered by this standard. The process hazard analysis shall be appropriate to the complexity of the process and shall identify, evaluate and control the hazards involved in the process. (US Occupational Safety and Health Administration 1992)"

Conceived in the 1960s, the Process Hazard Analysis (PHA)[14] has been used in many industries for decades. This approach has been refined and adapted for a variety of applications and it is now finding its way into combustible-dust hazard management. Several standards on combustible dust contain provisions for

13 See the Mythbusters episode here: https://www.dailymotion.com/video/x2mpe3d

14 "DHA differs from the more complex Process Hazard Analysis (PHA) used by industries such as refineries and chemical manufacturing. It is not the intent of the NFPA to force all manufacturers to undergo strict hazard analysis procedures that are necessary for industries such as these." https://www.ishn.com/articles/103759-nfpa-652-introducing-the-new-dust-hazard-analysis-method

conducting process hazard analyses, which are all predicated on process safety information.[15] The PHA uses brainstorming techniques to identify and evaluate hazards associated with processes, in order to develop safeguards.[16]

"NFPA 652: DHA is a fundamental step in creating a plan to safeguard facilities." [16] Several National Fire Protection Association (NFPA) standards on combustible dust contain provisions for conducting Process Hazard Analyses (PHAs). The newest, NFPA 652: Standard on the Fundamentals of Combustible Dust, became effective on Sept. 7, 2015. It requires that dust hazards analyses (DHAs) be completed on existing facilities and significant modifications. NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids, contains requirements for PHAs that include dust hazard assessments. Different hazard analysis requirements apply to facilities that fall under an industry- or commodity-specific NFPA standard (e.g., metals, agricultural and food, wood processing and woodworking, sulfur, dust).

The language used in guidance surrounding DHAs is often absolute and all encompassing. "DHA outlines each hazard and mitigation." [5] "Again, the DHA is critical to help identify the hazard and the action plan needed for cleaning to assure a safe operating environment." [35] The language coupled with the infrequent creation of DHAs, may lead users to believe that the risks have been mitigated entirely, rather than to an acceptable level (ALARP, which stands for "as low as reasonably practicable", or ALARA "as low as reasonably achievable")[17]. The residual risk in the system is often recognized by the DHA process and unrecognized by end users, which may adversely influence risk awareness and exposure[18]. "Organization can feel afraid to list their safety issues where outside parties can see them. Internal reviews may be incomplete." [5]

The variability in requirements and recommendations, related to the creation of a DHA, can make it difficult to know where to start and which risk/hazard analysis technique to use. "[XYZ Company] also supports the mandate to seek a qualified professional to conduct a DHA and address housekeeping as it relates to the end-to-end process." [10] Many organizations hire outside specialists to create DHAs, "To top it off, there is a very limited number of qualified people in the industry to perform the DHA's." [5] The need for specialists limits the flexibility of the DHA process to accommodate changes in the system or production.

The issue of flexibility relates to the intent of any Hazard Analysis, "The are numerous safety analyses methods ... However, they all have one aspect in common, the identification of hazards and recommendation of controls.[19]" Most responses indicated that a completed hazard analysis is the 'end goal' and that once it is achieved, nothing else happens. One respondent suggested a more flexible approach, "It could be a living document that is updated as necessary according to the changes in the materials, operations or facility." [1]. This could enhance the DHA process from a mandatory requirement, to a flexible risk and change management tool. The difficulty creating a DHA coupled with the rarity of events can put the original concept of brainstorming and risk learning out of reach of most companies.

Dust Collection Systems

Dust collection systems offer another control mechanism that was seen as helpful, by Call to Action respondents. Once installed, these systems can often provide a great reduction in hazard by reducing the amount of dust in the facility. However, these systems are not a 'simple fix' for the complex problem of combustible dust due to their cost, design, and problems with understanding the systems and their continual maintenance.

Why don't more industrial facilities have dust collectors? The first reason is the large upfront cost of investing in a new system. While housekeeping may represent a large cost over time, it does not have the initial impact on budget that even a single dust collector represents. Newer, more effective systems may also cost more, "There is a high investment cost required for adequacy." [24] This continued cost of maintaining the dust collectors is something that companies may not recognize is needed when they purchase the systems. [34B] Another respondent noted, "Many plants want to invest minimal time to perform routine maintenance and only want to repair/replace on condition." [35] Though respondents

15 Bahr, N. J. (1997), System Safety Engineering and Risk: A practical approach, Taylor and Francis, New York, NY

16 American Institute of Chemical Engineers (2017), Guidelines for Combustible Dust Hazard Analysis, John Wiley & Sons Inc., Hoboken, NJ

17 ALARA - As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (10 CFR 20.1003), ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. https://www.nrc.gov/reading-rm/basic-ref/glossary/alara.html

18 Adams, J. (1995). *Risk*, Oxen, England: Routledge.

19 Bahr, N., (2015) *System Safety Engineering and Risk Assessment: A Practical Approach, 2nd Ed*, CRC Press, Boca Raton, FL

agreed that it is necessary to continually evaluate dust collectors to ensure they are effective, these systems do not directly produce the end saleable product for a company, "Dust collection systems are often viewed as ancillary to the main process, and so they are not given the same level of attention for maintenance or inspection." [37]

Another challenge was noted by respondents regarding 'legacy' dust collector systems, as it can be difficult to apply current industry standards to old equipment. [37] Installations from over 30 years ago were built before dust was recognized to be explosive or combustible. These systems lacked initial design criteria and even with modifications over the years, they operate at a lower efficiency. "There is only so much you can do with older machines that didn't have dust control in mind when they were built." [56] However, facilities are under a financial pressure to continue their operations and cannot afford to stop production to install a new system. [40] "Legacy equipment creates large customized network hardware and practices, which are both difficult to change." [46]

The largest problem noted by multiple respondents was that few workers, supervisors, or even safety engineers actually understand their installed systems, or how or when to maintain them. "The full operation and performance understanding of dust collection systems is quite often limited or absent at a plant level leading to an 'I don't know, so I won't touch it' or 'someone else's problem' regard for these systems." [17] "Dust collection systems are something that most places want to set them up and forget about them." This respondent went on so suggest, "Facilities where someone is responsible ("owns") the system tend to have better success." [44]

It is understandable that no one would want to take 'ownership' of a system like this, "Dust collectors can be dirty, hazardous and awkward to work on; generally uninviting." [17]

In addition to companies not knowing about their dust mitigation systems, there also seems to be a problem with the dust collector sales representatives lack of knowledge about current combustible dust standards. "People who are selling dust collection systems to companies do not know the full scope of the 'rules', how to apply them, or the extent to which they should be applied. In turn, the customer is buying the equipment, thinking that the 'seller' knows what the best options is for handling the dust." (52) This respondent's following example highlights this area of concern.

> *"I recently spoke with an engineer at a company that manufactures dust collection systems. In speaking with him, I found many discrepancies regarding the information he was giving me about dust collection that pertained to 'what was allowed and what was not allowed' by the standards. When I questioned him on NFPA 484 and then told him what the clause says, he said he would have to look it up. In addition, he also stated that he has worked for this particular company for a number of years and 'been in the business even longer', and I am the first person to ever ask about being in line with NFPA standards. 'Most companies don't even worry about it', he stated." [52]*

Dust collectors may provide a safety benefit to dust mitigation but can also become inefficient or ineffective when they age, are not maintained, or are subject to other changes in the factory. These systems can also increase the likelihood of combustible dust explosions, as suggested by Occupational Health and Safety (OHS). "Combustible dust explosions are a risk in many areas of an industrial plant, and one of the likeliest locations for an explosion is in the plant's dust collection system."[20] In a closed vessel, like a dust collector, all elements necessary for an explosion may be brought together. "Dust collection systems have 4 out of 5 elements of dust explosion present when in service – there is dust, air, suspension, and containment. Therefore, it is only one element away from explosion – ignition source, such as spark." [46]

While dust collection systems can be sources for ignition, they can increase the margin of safety by removing the hazard, when they are properly installed and maintained. This is also an area where the hierarchy of controls can be a valuable approach. Removing the dust from the environment is part of this strategy and as some respondents pointed out, removing the dust collections systems from the facility can also serve the purpose of removing the hazard from the human component of the system.

The volatility of dust control systems and the potential for system inadequacies, along with the ease of their mishandling, may indicate the need for more regulation and oversight in this area. This may help "heighten the urgency for better safety methods and measures" [52] with companies, as well as equipment providers.

Housekeeping

The use of 'housekeeping' to control fugitive dust is perhaps the foremost method of risk reduction used in multiple industries. The Call to Action responses indicated a variation of awareness,

20 https://ohsonline.com/Articles/2014/03/01/Combustible-Dust-Compliance.aspx

understanding and management of this hazard. Some responses lauded the positive outcomes of a good, established housekeeping program. Others revealed problems with this approach and asked questions like, "who cleans?", "how do you know cleaning was effective?" and "how do you set a standard?". Even the language around 'housekeeping' was questioned and is covered in the Language/Communication section of this report.

The Call to Action question on housekeeping stated, "*How should the effectiveness of housekeeping be measured? What methods work best (e.g. cleaning methods, staffing, schedules)?*" One respondent indicated, "Standard procedures with documented monitoring and measurable results with known action will improve the effects of housekeeping." [35] Another said that housekeeping is the main avenue for reducing combustible dust. "Our customers that do have a solid housekeeping program remain at the lowest levels of dust in their facility, reducing the risk of explosion to virtually nothing." [5] Overall, responses indicated that housekeeping, in some form, should be part of a hazardous dust removal program.

If housekeeping is so important, then who cleans? "Ideally, any person working in the facility should be trained and capable of recognizing when dust accumulations have exceeded a threshold." [57] However, sometimes these workers are not capable of handling this risk reduction, "they are not professional cleaners... use poor techniques, inappropriate tools and equipment leading to unsafe, slow practices." [29] Another respondent said that staff should be, "Specific dedicated employees intended for industrial cleaning." [24] Arming all staff with the knowledge of how to clean 'hazardous dust' seems like a good plan, as there will be many eyes looking for this threat. Yet, comments showed that combustible dust as a risk is often not conveyed to employees. This is often because the threat is rarely revealed, other than small dust fires which workers believe can be handled with one or two fire extinguishers (in this case, the fire may not even need to be reported). Numerous comments suggested that even supervisors and safety managers were oblivious to the risk of dust.

There is also a problem with funding housekeeping, which is seen as a nonrecoverable expense [17]; "Dust is looked at like spending money on garbage." [51] Indeed, "Housekeeping is often sacrificed for 'more important' maintenance items directly impacting problems." [51] While a saleable product creates both satisfaction and revenue at the end of the process, "Manual labour resources for cleaning activities is often minimal and neglected longer than it should be as all these items provide no direct value to the process, a non-recoverable expense." [17] As long as housekeeping is seen in this way, it will never have the importance that is necessary for leadership to value, fund and reward employees for doing a thorough job. The field must also recognize that dust reduction is hazard reduction, which impacts both their own safety and job security. [17]

One place where housekeeping seems to be given a higher priority and funding seems to be in food and medical related industries, which fall under mandatory and often stricter cleanliness standards. Respondents indicated that clean food standards helped the dust problem, overall, which might also decrease the hazard of combustible dust. "Food safety regulations help dust problem." [12] "Food facility sanitation compliments dust safety." [51] "Some of the same techniques for handling food safety will apply to dust safety." [35] The regulation by another oversight agency, who has to approve the product before it can be sold, was the highest motivator for housekeeping. "FDA standard for cleanliness during food manufacture require aggressive cleaning of the facility." [56] However, it should be noted that food production facilities are not immune from dust explosions, even when they are in compliance with FDA requirements.

Even when housekeeping is funded and valued, there remains a challenge of understanding how much dust is necessary to create a risk of combustion or deflagration and what is an acceptable level of dust. OSHA had worked on creating a combustible dust standard since 2009 but removed this standard in 2017. The NFPA 652 Standard for the Fundamentals of Combustible Dust does include measurement criteria that are supposed to keep facilities 'safe' from combustible dust events. Even though this standard exists, the Call to Action responses pointed out many reasons why it would be difficult, if not impossible, to develop a dust measurement standard that could apply to multiple industries or situations. 'One size does not fit all' was a perspective shared across industries and responses from around the world. "Cleaning schedules, methods, and manpower cannot be universally defined," [35] said one bulk material engineering consultant.

In addition, the NFPA guidance is not written in plain language that is easily interpreted and followed. "One challenge I have observed is how NFPA standards are written. While thorough, they can be extremely confusing." [52] This difficulty interpreting the standard affects everyone involved with these facilities, including this respondent's interaction with a dust collection supplier, "I found many discrepancies regarding the information he was giving me about dust collection that pertained to 'what was allowed and what was not allowed; by the standards." [52]

Another response questioned the practical utility of regulations:

> "NFPA 654 is extremely complicated. To comply with the standard, a facility would need to utilize a specialist with a great deal of knowledge on ways to design and construct the explosion venting, isolation, mitigation and prevention systems required for all parts of the facility. It is clear the standard was written by those with little understanding of what it takes to practically design and build facilities and operate them with the equipment that is currently available. Thus, while the NFPA standard may contain certain valid concepts and principles, unfortunately, they are not practically applicable." (49A)

This need to resort to a 'specialist' who can interpret and apply the standard would have ramifications on housekeeping. If dust can only be measured to the standard by someone specifically trained in the method, the measurement will rarely be done – perhaps only when the facility spends the time and money on a full DHA. Those completing the actual housekeeping will still be 'in the dark' about what they are really looking for in a clean facility.

Respondents also noted the difficulty in measuring dust in facilities – whether it is done by a trained specialist, or a floor worker. The measurement of other substances, like liquids, is easier because you can see the spill. "Liquids allow for zero spills... It is hard to manage dust because it can be hard to see losses of containment." [15] The ability for dust to travel to many surfaces – including vertical ones, makes it particularly challenging to handle. "NFPA is standard but dust thickness can be difficult to measure. Dust layers are not consistent throughout plant." [15] The unique nature of different dusts and their measurability was suggested by several industries.

- "In common terms, dust or dusty, can be interpreted pretty broadly, going well beyond what NFPA or other regulators may define as deflagrable or explosive... The reality in many workplaces is that the dust profiles will vary dramatically, (both spatially and temporally), within the workplace so representative measurement and evaluation is a significant challenge. Real time measurement of dust accumulation levels or airborne concentration is also a significant challenge. In light of this challenge, we have accepted that course 'dust or debris' that is inevitably generated in wood manufacturing or similar process may be considered 'safe' where there is no likely ignition potential." [11]

- "We have had to conduct a significant amount of testing of specific powders to determine their ignitability (and occasionally their explosibility). These powders are sometimes unique to our process, so we have had to rely on in-house analysis instead of published guidelines." [8]

- "Combustible dust and its variability have also not been studied as much as flammable liquids and gases. Even the same sizes of aluminum dust can vary significantly depending upon shape, coating, morphology, etc. and that makes it difficult to generalize as to hazards." [13]

Respondents were concerned that a single standard would not be applicable across industries – nor even in the same facility if the dust profiles are not homogenous. "Materials are diverse – so dust is diverse. Dust can be unique to the process... We cannot use a 'one size fits all' approach." [8] It was suggested that we, "...must make a different evaluation for primary dust (course or heavier) vs. secondary dust (fine enough to migrate, settle on elevated surfaces away from the point of generation). These dusts have different qualities and deflagration points." [11] The wood industry also suggested that their particles are different, "particles are fibers, not round dust particles. That means they block the dust explosion test equipment." [42] The petroleum industry also acknowledged, "Not all dust particles create the same fire/explosion hazard." [50]

Except for the food and medical industries, where cleanliness is required for the end product, it can be difficult to motivate companies to invest the time, money and labor into housekeeping. Most facilities will never have a large catastrophic event that makes them realize the importance of dust mitigation. A single measurement standard ignores the diversity of industries and the dusts they may generate. Dusts can change in form or properties based on many factors and housekeeping should be individualized. "Housekeeping programs should pertain to each industry and their specific processing equipment." [23] Perhaps we, "can't eliminate all dust... but should reduce dust to keep the chances of an incident low." [51]

Some other suggestions indicated that housekeeping can be supported with other measures. For the general worker, "In the end, employees just want to be given a concrete threshold, they don't want to guess." [56] One respondent suggested that measurement reminders should be placed throughout the facility, "Monitoring should start with visual assessment of known dust accumulation areas with additional signage indicating allowable accumulation." [35] Another said that some guidelines are not helpful, such as dust "obscuring the color of the surface... There can be many areas in shades of grey that do not allow color dis-

tinction." [51] Another method of measurement could be to, "Map the accumulation of dust on 'collection plates' located around the facility. This will help determine the cleaning schedule." [44]

Overall, most respondents said that it is hard to eliminate fugitive dust, so the focus might need to shift to sources of ignition, "We default to 'remove ignition source'." [27] "5 of 8 incidents investigated showed mechanical equipment as the cause." [4] And the idea of using, "...a dust notification system to evaluate and interlock possible ignition sources." [35]

Dust hazard mitigation based on measurement of fugitive dust shows some promise, especially related to determining the frequency of housekeeping operations. The variability of processes and the materials being processed must be considered. "The reality in many workplaces is that the dust profiles will vary dramatically, (both spatially and temporally), within the workplace so representative measurement and evaluation is a significant challenge." [11] The process employed must be fluid and fast enough to reflect changes in the manufacturing process.

It was clear that there is no 'one size fits all' approach to housekeeping. "Not all combustible dust poses the same risk... We should focus on performance-based approaches, rather than prescriptive ones." [6]

Reporting

The honest reporting of issues at facilities is an expected part of operations, ranging from something that a worker feels 'is just not quite right', to concrete safety issues and fires. Supervisors and safety managers often expect that a worker who sees something, will say something. This emergent heading of the Call to Action responses suggested that reporting is not as frequent or honest as companies would like it to be. "Conditions have to get really bad before workers will speak up." [9] "Unfortunately, they are not empowered (to report)." [34B] Professor Sidney Dekker suggests that honest reporting is part of a *just* culture, "The point of reporting is to contribute to organizational learning. It is to help prevent recurrence by making systemic changes that aim to redress some of the basic circumstances in which work went awry."[21] Yet, deciding which event is worth reporting is not an easy task, because that decision is made with human judgment, which is colored with the experience of those empowered to make it, as well as the culture of the organization.

If fires and other safety issues are not consistently reported, how can popular 'statistical trending' reports be of any value? On the issue of dust fires, "A significant portion of these, dare I say most of them, are NOT reported. I believe it does create a false sense of security." [5]

On a company level, the reception of reports was varied. "Some are praised for identifying risk reduction opportunities and some are regarded as rocking the boat." [17] It was suggested that there is not a serious mechanism for reporting – thus, there is no way to track, trend, or learn globally. [20]

Workers are often blamed for not reporting safety issues, yet there are multiple, systemic pressures that may block this action. "A system where employees can address hazards will only be successful if there is a safe culture to report unsafe issues." [40] Several respondents said that reporting should be a cultural norm. [13] A computer Google search for 'safety culture' returned 1,340,000,000 results – indicating that this is currently a very relevant topic. Based on the Call to Action responses, workers do not feel empowered to give honest reports – this empowerment relies on the worker's trust for the person receiving the reports (supervisor, safety manager, safety engineer...). "Empowerment to report is at the mercy of the person receiving the report, who is likely influenced by goal pressure." [46] Another respondent said, "...many of these incidents could have been avoided if the workers were empowered to report issues... some of them answered that they were afraid of ridicule and scorn by safety engineers." [41]

Even if workers do report issues, the organizational culture may prevent systemic improvements from being enacted. "If the production leader and plant personnel create the right culture, where anybody is invested in ensuring plant cleanliness, reporting is not an issue." [15] "Workers are empowered to report unsafe conditions, but whether anything gets done about it is pretty hit or miss." [36] This idea of 'nonaction by superiors' was a clear theme within the responses and leads to several questions. *Are supervisors empowered to act on information given by workers? Is the system set up fairly – are workers rewarded for speaking up (or are they punished?)*

Some responses that stated their reporting was not a problem. "Every end of shift the workers report issues in all aspects of the operation." [24] Another respondent went further, "All employees must turn in a certain number of safety improvement suggestions monthly." [56] This idea of 'forced' or 'compulsory' reporting may not provide the honest, reliable, or valuable feedback that facilities believe they are getting. Simply making reporting a

21 Dekker, S. (2007). *Just culture: Balancing safety and accountability*. Burlington, VT: Ashgate Publishing Company, 39-40.

requirement will not remove the potential fear that workers have of their superiors, their image created with peers, or their concern for the stability of their position. A large study on the New York State Department of Health mandatory adverse event reporting system found, "that creating a mandatory reporting system is very complex and there is no evidence to show that it results in meaningful improvement in practice...reporting that is tied to punitive action or public disclosure will encourage making the reporting system a "numbers game" and drive reporting underground by perpetuating a culture of blame."[22]

Information can be viewed as the currency of safety. This means that it is important to cultivate sources of information regarding all aspects of the operation. There are a number of conditions or factors that influence a worker's willingness to report; these are artifacts, or the visible parts, of organizational culture and include:

How is bad news received?
What happens to safety reports?
Does the culture support reporting?
What happens to the person who delivers the report?

It can be quite difficult for leaders in organizations to accept that the system is flawed or prone to failure. It can also be difficult for individuals to report what they observe, especially when they recognize the potential for the company to lose production capacity. This places the employee in a position where they may feel they have to be 100% correct about their prediction.

A significant amount of research has been done on what is required for a person to give a report. There is a need to create an environment that supports the worker, which is commonly referred to as *psychological safety*.[23] The aviation community chose the Aviation Safety Reporting System (ASRS) as their way to create an open reporting system that guarantees anonymity for participants. To ensure this, it is housed in a non-regulatory agency, the National Aeronautics and Space Administration (NASA).

Designed and operated by NASA, the NASA ASRS security system ensures the confidentiality and anonymity of the reporter, and other parties as appropriate, involved in a reported occurrence or incident. The FAA will not seek, and NASA will not release or make available to the FAA, any report filed with NASA under the ASRS or any other information that might reveal the identity of any party involved in an occurrence or incident reported under the ASRS. There has been no breach of confidentiality in more than 34 years of the ASRS under NASA management. [24]

Both individual workers and companies could benefit from an anonymous or non-punitive reporting structure. "Currently data on the number of explosions, fires, and near misses due to combustible dust is unreliable and surely underreported due to the perceived liability by end-users in sharing this information with outside groups." [2] The respondent also suggested, "The creation of a reliable reporting system (even if it means that reports are anonymous), would be a huge step in helping the industry to fully define the problem and work together on a solution." [2] Research indicates, companies should value the quality of reports, instead of the quantity. "The importance of near miss reporting in the development of a safety culture and in proactive safety work has been generally recognized in literature about near miss reporting". [25]

It is imperative that leadership create an atmosphere of openness and support for workers, which includes a system of rewarding those who report – even if the report turns out to be misinformation or not useful. Workers also need to know that their reports will be acted on and valued by all levels of the organization and absent of punitive or retaliatory action.

Upward voice is a specific kind of feedback that allows workers to speak truth to power. It is when someone with less power willingly provides feedback to someone in a position of authority.[26] The capacity to speak truth to power is a function of psychological safety.[27] Most employees carefully examine the social contexts before speaking up to leaders. Critical information is gained or lost based on the employee's sense of psychological safety. It is critical to the safety culture of any organization to cultivate relationships and to build psychological safety in ways that facilitate upward voice. The importance of having a safe place to share information was strongly recommended by 37 different respondents.

22 Flink, Chevalier, Ruperto, Dameron, Heigel, Leslie, . . . Agency FOR Healthcare Research Quality Rockville MD. (2005). Lessons Learned from the Evolution of Mandatory Adverse Event Reporting Systems.

23 Edmonson, Amy. (1999). Psychological safety and learning behavior in work teams. Administrative Science Quarterly, 44(2), 350-383.

24 https://asrs.arc.nasa.gov/overview/immunity.html; Accessed March 29, 2019.

25 Brazier, A.J. "A Summary of Incident Reporting in the Process Industry." Journal of Loss Prevention in the Process Industries 7.3 (1994): 243-48. Web.

26 Pupulidy, I. (2015). The transformation of accident investigation: From finding cause to sensemaking. S.l.: [s.n.]. https://pure.uvt.nl/portal/files/7737432/Pupulidy_The_transformation_01_09_2015.pdf

27 Edmonson, Amy. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly*, 44(2), 350-383.

Language and Communication

The Call to Action illuminated an important problem with the language used to describe the hazards associated with combustible dust.

> "For dust hazard to be properly reduced and/or controlled, it must be presented as its own distinct hazard issue, not as an issue of tidying up the place. Although some may consider that controlling dust will do both, the mixing of the two concepts will only downplay the gravity of combustible dusts. In order to effectively change the work culture, control of combustible dust must be presented as a purely hazard reduction/safety issue that has nothing, per se, to do with cleanliness... A "Control of Combustible Dust" procedure should be developed that is distinct and separate from a "Housekeeping Procedure". The reason for this separation is that the average worker sees housekeeping as a broad term addressing all sorts of clean up issues. I believe the reference to a "Housekeeping Procedure" for, or including dust control, will diminish the interest in it and the perceived value of it, as a whole, since most people would see housekeeping as a nicety rather than a necessity." [1]

The word **hazard** comes from the 14th century French word for playing a game of chance with dice. This evolved into a "chance of loss or harm, risk" with the first English use of the word in the 1540's. A quick search for synonyms on Thesaurus.com for 'hazard' results in: peril, risk, threat and jeopardy. The word **housekeeping** can mean "the management of household affairs". Synonyms include: housework, housewifery, domestic science and home economy.

From these and other extended definitions, it can be seen that the words 'housekeeping' and 'hazard' share very little in common. Indeed, housekeeping does not inspire the thought of risk or threat. When questioned on whether the term 'housekeeping' was sufficient to imply a hazard, one subject matter expert stated, "Why do we use the same term to clean the bathroom as we do for major risk mitigation?"

It was suggested that, "The average worker sees housekeeping as a broad term addressing all sorts of cleanup issues." [1] Another respondent said that workers view dust as a fuel, not as a risk. [46] Also, "Most organizations communicate the hazards of combustible dust poorly, if at all." [2] "Dusty is an ambiguous term, open to interpretation." [15] The use of the term 'housekeeping' to describe the cleanup of a major component of risk in operations, reduces the power of the term to keep the staff on alert for dust.

If dust is only seen as a form of dirt that increases the time and effort a worker spends on the job, it will never be given the respect needed to be seen and treated as a hazard. Let's face it, few people like to do housekeeping in their own home. Indeed, much of the workforce of factories and mills is made up of men – who may not commonly engage in this activity in other parts of their lives, or comfortably see themselves in the role of 'housekeeper'.

In order to give combustible dust the respect and attention it deserves as an explosive hazard, housekeeping needs a new common term. This term should indicate to the worker the importance of their job – that the removal of dust can have a serious impact on the safety of everyone at the facility. A few alternate terms for 'housekeeper' have been suggested by people associated with the Call to Action project:

Guardian
Keeper
Dust Patrol
Dust Control

Another question that emerged in the sensemaking phase asked if the term for 'housekeeping' or 'housekeeper', in combustible dust industries, is the same in other languages? Do other languages utilize a term that implies a sense of hazard in association with the cleanup of dust? The Call to Action resulted in responses from multiple countries, which were all written in English. The respondents used the word 'housekeeping' to refer to the task of dust cleanup. However, it is possible that this was due to word priming that came from question #6, which asked, "How should the effectiveness of housekeeping be measured?..." By using the common American English term for hazardous dust cleanup, 'housekeeping', the respondents may have defaulted to this, instead of their own local term. For example, German factories have used, "SOS – Sicherheit – Ordnung – Sauberkeit" (Safety – Order – Cleanliness)." The researchers suggest that the exploration and suggestion of new terms be a topic for focus groups made up of industry specialists.

The Language of the 'Call to Action'

The Call to Action resulted in 57 responses, from two different outreaches. The first outreach was made on the CSB website and resulted in 20 responses, "The CSB asks for comment from companies, regulators, inspectors, safety training providers, researchers, unions and the workers of dust-producing operations themselves on some very fundamental questions. Please add to our understanding by answering any or all of the following questions..." The CSB responses were mostly formalized, with the

respondents sticking to the questions and format of the request. These came mostly from industry organizations, unions and major corporations and sometimes seemed defensive in tone, or content. There were, however, a couple of respondents who chose to write a letter to the CSB Investigations Team Lead, instead of answering the specific questions. These responses were more open and creative and usually explored one or two concepts in greater detail. An example of this is response #1, which is quoted above.

The second request for comment was made by in a podcast recording, website posting and personal outreach of Chris Cloney of DustEx Research Ltd. (DustSafetyScience.com), which resulted in 37 responses. Dr. Cloney reformatted the original Call to Action, with the addition of an introductory page and a 'cheat sheet' format. He personalized the outreach with the suggestion, "Responding to the call to action is not meant to be a time-intensive process. Any information you can provide whether it is a 5-minute quick response (see description below) or 30 minutes allowing each focus question to be covered, will provide invaluable insight to the project." He also added a 'Quick Answer Section' encouraging any kind or size of response; Dr. Cloney also numbered original CBS questions.

The DustSafetyScience.com outreach resulted in a higher number of responses, overall. In addition, many of them were from the field, mostly from health and safety specialists and engineers. These responses were candid and seemed less defensive or protective than some of the responses to the original outreach. The respondents who chose to write the CSB a letter, mirrored the open format of the Quick Answer Section, which often resulted in more thought-provoking information about the issue of combustible dust.

Communication Within Facilities

Many responses highlighted areas where communication needs improvement within facilities that handle combustible dust. "The root of the dust explosion problem is ineffective communication of the hazards of combustible dust to plant managers, engineers and operators." [45] "Most organizations communicate the hazards of combustible dust poorly, if at all. Even management is under informed." [2] It was suggested that this hazard is not talked amongst workers on the floor, between newer workers and more experienced ones, between workers and their direct supervisors, or between supervisors up to their highest level of authority. If there is no dialogue regarding this hazard, the recognition of the hazard does not improve safety.

Noted organizational culture specialist, Professor Edgar Schein, suggested that safety culture, language and communication are all interrelated.[28] Thus, the lack of communication about this hazard may be exacerbated by the language surrounding the issue, as well as the cultural environment of the organization. As with the word "housekeeping", broad terms may be used to describe much larger concepts, such as the hazard associated with combustible dust. 'Combustible dust' has become the normal way to refer to dust. Yet the true fear is centered on the risk of large explosions or deflagration, not general fires, which can be considered controllable. By referring simplistically to 'dust' on a daily basis we may be conditioning the workforce to underestimate the importance of this hazard. This may also explain why fires frequently go unreported in facilities. "Often, these fires go unreported as combustible dust events, because even the facilities staff isn't aware that the dust is the ignition source." [10] "It is common to have a fire without an explosion. Employees don't first think about combustible dust explosion potential when these fires occur." [8] Though dust may not always explode, the use of a more assertive term for 'dust', such as 'explosive dust', may help workers stay alert to this hazard and communicate about it more clearly.

This Learning Review explored the link between communication and culture. Throughout the responses it was noted that there is a lack of reporting culture in multiple industries. But is reporting the same as communicating? Is it possible that the formal term 'reporting' given to the communication of information from workers up the chain of command may be blocking workers form doing this very thing? Several respondents referred to this communication as 'whistleblowing', which can be seen as a negative term among workers. What worker wants to be a 'whistleblower' when this can result in mistrust from peers/leaders, disbelief from the organization, reduced production, or even punishment from superiors?

How else can we look at information exchange within facilities (particularly from the bottom up), instead of 'reporting'? A better method might be "an open environment where individuals can share their thoughts and see improvements." [26] Another respondent suggested, "Make that information freely available. Ensure that there is no such thing as a stupid question and there is no question that would be used to prosecute or penalize..." [22] By replacing the formal 'report' with dialogue and informal sharing of thoughts, workers may feel safer and more willing to talk about combustible/explosive dust issues. (See the 'Learning' section of this report)

28 Schein, E. H. (2004). *Organizational culture and leadership* (3rd ed.), San Francisco, California: John Wiley & Sons.

Language Barriers

Though this study did not address language barriers, such as multiple languages spoken by facility workers or a lack of literacy, these are most certainly topics that should be explored. Lindhout and Ale [29] found that language issues frequently affect the safety culture of organizations and may create more risk in hazardous environments. Language issues can lead to miscommunication, or reduced communication between all levels of the workforce.

> *"The main causes are poor education and training and poor information exchange, in writing, verbally and even by signs or gestures. Individual factors, the multi-lingual shop floor setting and a variety of circumstances affecting communication are the conditions under which a language issue can become a safety problem."*

The authors refer to a meta-study in the Netherlands, which looked at language barriers in 800 installations. "The main result is that on the one hand 76% of the companies acknowledge language issues as a danger but on the other that 65% of the companies have no risk controls in place whatsoever." The findings also showed:

65% do not mention language issues anywhere in their management systems

36% do not appoint a contact person/translator for a group of foreign workers

32% ignore illiteracy among foreign workers in their own language while providing translated documents

17% issue safety instructions to foreign workers in writing only

14% do not verify whether safety instructions are understood before work commences

11% acknowledge illiteracy among own personnel but do not act on this.

The U.S. has many multilingual facilities, with Spanish being the most common second language. Accident reports have found that communication between English and Spanish speakers often noticeably break down before a tragic event. Non-native speakers will be less likely to speak up to a supervisor about an issue they see, simply because they may not feel comfortable using the second language. That worker may speak up to a Spanish speaking coworker and the message may be relayed to a supervisor, but this may decrease the fidelity of the original message and increase the time it takes to be communicated. This is only one issue that faces combustible dust organizations – further inquiry and research is needed on the topic of language barriers.

Learning

> *"The currency of safety is information."* (Pupulidy, 2018)

Research in High Reliability Organizing and Resilience Engineering point to the capacity of workers to notice when systems are drifting close to margins of safety and production. Production related skills are generally more practiced and therefore margins are better recognized and communicated. Recognition and communication of safety issues can be more nebulous and therefore less commonly voiced. This research emphasizes the importance of fostering an environment where people are prone to speak up when they say see something. This is somewhat alien to our culture and requires a great deal of organizational support to build psychological safety. People have to feel that their comments and concerns will be accepted, that they will be listened to and that some action will result. The tone of the comments regarding employee empowerment are summarized by one respondent who wrote, "People are happy to share information as long as there is not risk of retribution."

- "A system where employees can address hazards will only be successful if there is a safe culture to report unsafe issues." [40]

- "Entities involved with a tragedy have a wealth of knowledge – most are willing to share transparently." [14]

Creating a safety culture is predicated on communication, sharing information and learning from the information that exists in the system of work. Communication is both strategic, in terms of how we assess risks and tactical, which refers to how we recognize and communicate hazards and changes in the system. There is a strong need to be able to ask questions, even the 'stupid' ones. This realization refines the concept of safety culture and focuses attention on how we learn and make learning part of our system of work. Creation of an atmosphere of inquiry has been proven successful in aviation operations and most aviation organizations devote energy to learning and communicating through Crew Resource Management (CRM). One primary concept of CRM is fostering humility. "The better method is an open environment where individuals can share their thoughts and see improvements." [26]

29 Lindhout, & Ale. (2009). Language issues, an underestimated danger in major hazard control? *Journal of Hazardous Materials,172*(1), 247-255.

There are three direct learning opportunities, which can lead to improving system performance. One happens before you engage in the scheduled activity – the pre-work briefing. The second occurs during work and involves recognition of anomaly, sensemaking and innovation. The third is post-work learning, which commonly takes place after there is an unexpected work outcome. For many organizations, this only takes place when the outcome is both unexpected and undesired (adverse). These should not be viewed as separate items to be performed; they function best in an interrelated fashion where each informs the next in a cyclic fashion.

Pre-work Learning

The pre-work briefing is an opportunity to set the stage for the work by sharing expectations. This can range from simulator preparation to a pre-work briefing. The importance taking advantage of this opportunity cannot be understated. In order for team members to be able to identify anomalies, or the capacity to know when the system is delivering the unexpected, they have to be in a position to understand what is the expected normal for that operation. Respondents were clear in their desire to better develop pre-work strategic as well as tactical learning:

Traditional Training:

Employee training is often limited to a yearly cycle, sometimes only on a computer. Several respondents pointed out the need for experiential learning/training. There is a recognized need to examine better ways to learn about dust hazards.

- "Xxx's global training content was developed by technical experts in the field and may be delivered as instructor-led training, preferable when training a large group such as a plant work group, or web-based training, which is useful for just-in-time delivery. The global training is a minimum for the roles at risk. Completion of the training is tracked and audited. Individual plants often supplement the global training with the specifics on their local dust hazards. Employees at risk are required to complete combustible dust training before engaging in activities in which combustible dusts may be involved. For those working with dusts on a routine basis, the training recurs every 3 years. The content is reviewed annually to ensure it is effective and relevant." [15]

- "Videos, Power Point, accident reviews, testing, procedures most effective ways to educate workers." [56]

- "We have annual training in wood dust safety which covers dust hazards recognition and how to deal with them." [32]

- "Just showing a simple 1-1/2 minute movie very easy creates a much higher awareness." [33]

- "How (means) and when (frequency) very much depends on the (line) management, role/job, and safety culture inside the organizations." [33]

- "Doing practical experiments that simulate dust hazards; take lessons from previous incidents." [41]

Pre-work or toolbox briefings:

- "Training that includes hazard recognition and hazard mitigation components for all personnel involved with combustible dusts, including external contractors, is conducted across the industry but at varying frequency. Contents of this training varies by company but can include formal classroom presentations, toolbox training at job sites, videos of dust deflagration testing, and reviewing lessons learned from past incidents." [13]

- "Practice lessons where your powders are ignited and explode – so employees can see, can feel and experience the dangers of working with these materials." [40]

- "Having a systematic approach that factors basic awareness training, video demonstrations, pre-job safety meeting and open discussion will likely improve overall awareness and reduce safety issues." [35]

During Work Learning

During work, there are levels of expertise that are common to all fields. These levels range from novice to expert. Experts operate from a mature, holistic, well-tried understanding and often

without conscious deliberation. Experts blend intuitive responses with analytical performance. When experts recognize the system is delivering the unexpected, they move from intuitive decision-making to rational decision-making (analytics). This change in approach is based on recognition of the uncertainty of the situation. When this happens, the expert begins by making sense of the information, then learns in the moment and finally, they innovate a path forward. This sensemaking, learning and improvisation skill is primarily learned through experience, although, there are cues and skills that can increase the capacity of the workforce to deal with the unexpected[30].

30 McDaniel, R. R. (2007). "Management strategies for complex adaptive systems: Sensemaking, learning, and improvisation," Performance Improvement Quarterly, 20, 21-41.

Novice performance is limited to prescriptive, rules-based performance. This does not mean that novices are not included in the observation, recognition and reporting of production or safety issues. Their voice can be extremely valuable to understanding when the system is not delivering what was expected. Often, a novice will notice things that a more senior worker will have normalized through their work experience[31].

- "Learning – visualize the hazard. Subjectivity in risk assessment directly related to normal systems variability." [12]
- "Learning from an on-field specialist is the best way to check problems, including in front of a field audience." [39]

Post-work Learning

Post-work is a key opportunity that is often overlooked or under maximized. It refers to learning from normal work, or work where there is no near miss or adverse outcome. A common issue is that the objective is reached, and we quickly move to the next work assignment, this even happens when the expectations of the work outputs are exceeded; A key learning opportunity is often lost. Post action is actually the best time to begin the preparation cycle. Taking a moment to review what just happened can result in system improvements that will make the next work process easier, faster, or safer. Post event learning is where most organizations can make significant short-term improvement.[32]

- "These entities involved with a tragedy such as what befell in 2012 in the . . . wood product manufacturing industry tend to collector to develop a wealth of knowledge around the catastrophe. Most are willing to share transparently. Entities which are not on the front lines of facing the tragedy often get a sense of complacency ('it can't/probably won't happen to us'), especially if the actions required to address the risk of said catastrophe take extensive effort/cost (which combustible dust indeed does)." [14]
- Understanding this dynamic (from both the entities who have the information and those who don't) can lead to better, deliberate discussions and more likely uptake on the information that is readily available." [14]
- "Near misses are to be properly investigated as these provide valuable insight in small details, often lost after catastrophic events." [33]
- "The organization's accident/incident investigation process for combustible dust is particularly important in ensuring knowledge of process hazards, are transferred to employees." [53]
- "Great value in databases like Dust Safety Science and OSHA citations. Need a platform to share progress, improvements and successes, without judgement." [17]
- "The organization's accident/incident investigation process for combustible dust is particularly important in ensuring knowledge of process hazards, are transferred to employees." [53]

Strategic or Upstream Learning

There is a systemic or upstream pre-work learning component. This relates to how the organization prepares employees through training and education and how the organization positions itself to learn. A majority of upstream learning is related to risk management and requires leadership engagement. Systemic learning involves the community of practice, including the regulator, professional organizations, company safety professionals and leaders.

- "Regulators should better leverage industry, health and safety associations, labor unions, employer groups, as well as public and social media to cast as wide a net as possible." [11]
- "Regulatory agencies, insurance companies, safety consultants, salesmen, equipment manufacturers, employees, industries – could more easily share information back and forth!" [23]
- "NGFA has pursued many education efforts: meetings, seminars, conferences, guidance manuals, videos, reports, workshops on OSHA safety, National Grain Handling Safety Day." [49A]
- "Need to create bridges between the technical/cultural gap of big and small factories. "Spread the word and culture amongst safety technicians." [39]

Respondents pointed to the relatability of learning as an issue of concern, "From my experience performing NFPA 652 audits at facilities workers are more aware of dust explosibility from watching 'Mythbusters' and not internal company training efforts." [38] The key concept relates to humility and the realization that no one is immune to dust explosions. "I think that the organization should come up with the idea that the worker, who works in a dusty place, is like an explosives expert who is trying to disrupt a time-bomb." [41] This quote points to a concept introduced by Jarrod

31 Flyvbjerg, B. (2001). Making social science matter: why social inquiry fails and how it can succeed again, Oxford, United Kingdom: Cambridge University Press.

32 Kahneman, D. (2011) Thinking, fast and slow. *Farrar, Straus and Giroux*, New York.

Diamond, called, "Constructive Paranoia."[33] "If we have enough fear (respect) for dust explosions, we will take action using fires as leading indicators. [27] This concept ties to relatability, in that it creates an awareness at all levels of the organization regarding the system vulnerability to dust explosions.

Who Has to Learn?

While this was not addressed directly in the Call-to-Action, it emerged as a question during the sensemaking phase of the study. Recognition that all levels of the organization were not only responsible to foster learning, they were also responsible to be members of the learning community. A second question emerged regarding specific improvements to learning strategy that could lead to increased safety. "Team learning, to encourage voicing opinion. Collective learning. Need a system for collecting information. Promote training of all actors. Provide free information and training." [12]

Learning from Near Miss Events

Near miss opportunities are underutilized in most industries. A near miss incident on job sites is traditionally defined as one that leaves no injuries, no property or equipment damages, and little or no evidence that it even occurred. As a result, a near-miss incident can easily go unreported or be ignored. When reported and acted upon, near misses can be viewed as an opportunity to learn, and as such, are great opportunities to improve organizational safety performance.[34]

Many respondents to the Call-to-Action indicated that fires were not uncommon events, whereas, explosions were common. Workers may only imagine the worst-case scenario based on what they have experienced - most respondents reported they had never experienced a dust explosion. Two opportunities emerge with this realization. First, small events like localized and controllable fires should be considered near misses and should be treated as opportunities to understand why an explosion did not occur. Current approaches to near misses are typically to apply standard accident investigative protocols, which may be less effective than asking very different questions. For example, rather than focusing simply on what happened and why, the opportunistic approach would be to focus on why things did not happen that could have happened. Part of this is identifying the natural or man-made barriers and factors contributed to a dynamic non-event (USFS Learning Review Guide).

Asking questions with the specific goal of learning about the system, rather than on determining what actions should have been taken, has been shown to help workers to learn about their system of work. This approach provides information geared to improving the system and to help workers become more aware of their surroundings. Near misses reporting and learning can directly contribute to improved safety performance.[35]

This approach has been shown to be consistent with adult learning methodology, where training is specifically designed not to be routine. Respondents referred to the CSB videos as an important and valuable resource. Other innovative approaches to dust explosion education centered on very non-traditional methods. One such example was the use of a "Mythbusters" episode where they examined the potential of dust explosions. "Workers are more aware of dust cloud explosibility from watching Mythbusters and not internal company training efforts." [38]

Learning Summary

Learning should be considered as important as dust control; it serves as the trigger for most safety operations, including 'housekeeping'. Respondents were clear that most training programs are based on compliance, rather than developing learning programs consistent with adult education models, which have been shown to be a superior way to facilitate awareness. This is an area that deserves attention.

There is a strong body of research that highlights the disadvantages of the top-down approach for transfer of information to workers, which is supported by respondent comments. The dissemination of knowledge proves to be more effective through the process of discovery or experiential learning.[36] This approach is participatory and consistent with adult learning concepts in which leaders, workers and stakeholders are involved collaboratively.[37] Respondents indicated that social, economic and cultural factors are also often ignored, as traditional methods are less likely to allow for extended interaction or discussion of techniques in gathering and making sense of information.

33 Diamond, Jared. (2013). 'Constructive paranoia' saves lives; Witnessing the deaths of careless people can keep you living longer. *International Herald Tribune*, p. International Herald Tribune, Jan 30, 2013.

34 Williamsen, Mike. "Near-Miss Reporting: A Missing Link in Safety Culture." *Professional Safety* 58.5 (2013): 46-50.

35 "Near-miss Reporting Linked to Improved Organizational Safety Performance, Study Shows." *J. J. Keller's Supervisor Safety Alert* 10.7 (2013): 4

36 Kaagan, S. (1999). Leadership games: experiential learning for organizational development. *Sage Publications*, Thousand Oaks, CA.

37 Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Teams. *Administrative Science Quarterly*, 44(2), 350–383. https://doi.org/10.2307/2666999

Sharing Information

The topic of 'sharing information' received the strongest response in the Call to Action, with 35 direct recommendations suggesting the sharing of information within companies, as well as across industry, regulatory and international boundaries. "This is a global problem, not a North American one." [31] Another respondent said that all companies faced with the problem of combustible dust need to take the opportunity to learn from all sectors, nations, levels and approaches. [33] The grain and aluminum sectors showed how their own safety improvements had come from sharing information and making a commitment to learn within their industries. Some responses from companies indicated that they (or at least the person writing the response) believe they are sharing information internally. However, the following perception seemed much stronger in the overall Call to Action. "Sharing information is not common. Fear of sharing 'your' mistakes and fear of sharing your process 'secrets'. This often blocks the higher goal of 'safety awareness'." [40]

Though there are challenges to sharing information, there were many ideas and suggestions contained within the responses to the Call to Action. These tended to fall into three main categories: local sharing within a company, industry-wide or cross-industry sharing of information, and a need for a 'global summit' where all industries could come together to learn from each other.

Local Sharing

Many respondents indicated that sharing information was not done consistently within their company. Sharing information is related to reporting and the quality and quantity of reports given by workers to their superiors is related to the amount of trust present in the workforce. If workers do not trust that their observations will be believed or acted upon in a non-punitive manner, they may not share any information about hazardous situations that they notice.[38] Developing a psychologically safe workplace is the responsibility of supervisors, safety managers, and anyone else entrusted with shared information. Only then can workers be expected to honestly share information in a timely manner.[39]

Sharing information is also related to learning from events. "Sharing incidents (both internal and external) is important for maintaining awareness and a sense of vulnerability." [37] Responses showed that there is often a sense of 'complacency' (what we call 'normalization of risk') throughout the ranks of companies. This can be directly related to the sense of vulnerability of the workers or supervisors – if they do not feel that dust is hazardous, they will not treat it with respect. This will filter through their sharing of information around dust and the lack of learning from dust related events.

Once workers are aware and alert to hazards like combustible dust, there emerges another vulnerability related to sharing what they see – the worker's fear of retribution by superiors and potential shunning by peers. Respondents agreed that it is critical to have, "an open environment where individuals can share their thoughts and see improvements." [26] The strongest recommendation contained within multiple responses was to create an anonymous reporting system. "Once workers are aware of combustible dust hazards, ensure anonymous reporting is easy within organization." [36] Though anonymity may be valued by workers, it may also prevent leadership from responding directly to the informant or engaging in dialogue to learn more about the situation. For example, a manager may wish to give an employee feedback about the concern, or even offer an award for sharing information. Thus, a guarantee of 'safe reporting' may be more important than a system that uses 'anonymous reporting'.

The internal sharing of information is often blocked within a company.[40] Even if workers communicate about a hazard openly, they may never know if the information was acted upon or useful. Thus, learning from the event is blocked. Respondents strongly suggested, "Frequent and effective communication of the outcomes must be shared with all affected employees to sustain a healthy culture of combustible dust processing safety." [53] Another said that the perceived quality of the information should not be the guiding factor, "I believe that the administration of the company/facility has the responsibility of making best communication with all workers whatever their positions, and this could be achieved through intensive meetings and opinions sharing, no matter how simple or not useful." [41] In addition, all workers should feel they are part of the 'internal community of practice' where there can be, "training discussions of new and emerging technology, updates on guidance and standards." [37] In this way, the entire workforce can feel a sense of connectedness and importance, thus increasing the likelihood of sharing information and learning from each other.

38 Connelly, C.E., Kelloway, E.K., 2003. Predictors of employees' perceptions of knowledge sharing cultures. *Leadership and Organization Development Journal* 24, 294–301.

39 Cox, S., Jones, B., Collinson, D., 2006. Trust relations in high-reliability organizations. *Risk Analysis* 26, 1123–1138.

40 Foss, N.J., Minbeava, D.B., Pedersen, T., Reinhold, M., 2009. Encouraging knowledge sharing among employees: how job design matters. *Human Resource Management* 48, 871–893.

Sharing Within and Between Industries

"The next step in process safety management is proactive sharing of prevention measures within and between industries." [40] This was a common belief of respondents, who suggested that this currently happens infrequently. Combustible dust fires are rarely tracked within a facility, yet these may lead to learning from events because they happen with greater frequency. "...small fires could be leading indicators for significant fire and explosion risks. This starts by asking the question 'why was there no explosion?'" [37] Dust explosions are more obvious, trackable events but tend to inspire reactive measures that focus more on punishment than learning. Respondents said that they read combustible dust accident reports on sites like www.csb.gov with the intention of learning – yet these high-level events represent a very small portion of the day to day situations that arise.

Extensive Call to Action responses were received by two industries who showed a link between open sharing of information and trackable safety improvements. For example, the Aluminum Association developed its own guidelines, videos, workshops, and training around combustible dust. "Training that includes hazard recognition and hazard mitigation components for all personnel involved with combustible dusts, including external contractors, is conducted across the industry... can include formal classroom presentations, toolbox training at job sites, videos of dust deflagrations testing, and reviewing lessons learned from past incidents." [13] The grain industry also self-initiated and self-funded system-wide improvements and research, which is reflected in their reported improved safety record. [49B] The National Feed and Grain Association created a 50-member Fire and Explosion Research Council in 1978 to gather and share information, in order to learn about causes and prevention. Grain dust explosions were said to have decreased by 60% due to a combination of, "industry research, education, training and government involvement." [49A] Though these industries still have dust related events, their commitment to sharing and learning could be emulated by others.

Responses suggested a need to share incidents and near misses broadly, openly and anonymously. [37] "Transparency and reporting between end-users, standard organizations and operators would be the most effective way to prevent future incidents." [2] Like the fear of sharing information within a single company, there exist compounded fears when sharing is done across an industry or between industries. "Unfortunately, many industries regard sharing safety related incidents as a detriment to their reputation and/or giving competition too much information." [17] In addition, respondents said that companies feared sharing information with regulators and insurance companies due to the likelihood of retributive response. These fears may be preventing companies from sharing their experiences – and experience was seen as an extremely valuable way to learn about safe practices. "I believe that the experience is the strongest factor in safety judgement". [41] "Experience is often the best way to know what is normal and safe." [13]

Since the publication of the CSB's dust hazard study in 2006, 111 additional combustible dust incidents have occurred in North America. The loss of life and property is extreme. Identification and awareness of the hazard has been recognized in almost every response, as a key aspect of dust safety, all of which lends credence to the need for better ways to share and learn from each other. Open availability of information has been recognized as a key method of fostering a learning environment. Organizations including the US Coast Guard, US Army, the Department of Energy and US Forest Service have developed 'lessons learned centers' to facilitate learning from events. Several of these are simply on-line libraries of information, while others create learning products, which are shared in a variety of ways with field personnel and/or leadership.

The Call to Action responses praised online learning methods, "CSB videos are awesome, and we use these a lot as a form of information sharing... Dust Ex Research information has proven to be the best way to find out about other incidents." [56] Yet they also felt that a larger, more extensive format was necessary, such as the idea of creating an online site where multiple industries could share, discuss, and learn about combustible dust was mentioned by numerous people.

- "Improve process safety performance by learning from each other." [47]
- "Team learning, to encourage voicing opinion. Collective learning (teaming). Need a system for collecting information. Promote training of all actors. Provide free information and training." [12]
- "Make that information freely available. Ensure that there is no such thing as a stupid question and there is no question that would be used to prosecute or penalize the company or organization asking. Never say no to providing guidance to those that need assistance." [22]
- "From an external perspective, it would be helpful to have effective ways to share incidents and near-miss event broadly. One option for this is through the use of anonymous reporting boards, allowing incidents to be shared without direct attribution to an individual organization. While it is

difficult to share incident-related information for legal and regulatory reasons, incidents offer some of the best training opportunities and any systems that facilitate the sharing of incident summaries would be beneficial." [37]

- "First, there should be a sharing of information on a global scale by establishing an electronic platform for dust science in which all international facilities that generate and manage dust will be involved in order to exchange information, experiences, highlight all that is new, and benefit from previous incidents. The best experience I have seen is the website www.dustsafetyscience.com. It is a very useful website with a great experience in this field." [41]

- There needs to be a bigger, open format where customers, suppliers and regulators alike can come together to tackle the issues. [5]

- "Share the information on social networks, make videos to educate people about the risks, and talking about solutions that exist." [54]

One respondent suggested that the CSB Call to Action would not generate any responses – because it was voluntary. "By its nature, the Call to Action clearly solicits a voluntary response; the concerns we have raised with the document raise questions about how effective this approach will be." [28] The relatively large number of responses from multiple industries and countries relieves that concern. Indeed, respondents frequently thanked the CSB for allowing them the opportunity to voice their opinions. "The CSB has done a great job with this 'Call to Action' and bringing this to the forefront." [32] Sharing information about combustible dust can be uncomfortable, for many reasons, yet these fears may be overcome by creating a sharing site with the goal of learning, not retribution. This site might include some of the following elements:

- A forum that allows users to share their own experiences or ask questions on numerous topics. Users could choose to be anonymous or choose a private user name.

- Videos and other training material that all users can benefit from. These might be placed into industry specific categories that make learning more practical for users.

- An event calendar that lists upcoming seminars, conferences, and other training opportunities provided by suppliers, regulators, and educators.

In addition to an online repository of information, respondents requested specialized conferences about combustible dust. "Initiating a world-class specialized annual conference with expert panels, training courses, workshops, and vendors specializing in explosion prevention/protection equipment would be highly effective at information exchange." [35] Learning conferences have become recognized as opportunities to share information as a means to enhance organizational learning. These conferences often include multiple perspectives such as practitioners, leaders, academics and regulators. They serve as opportunities to openly discuss new information and emerging trends[41]. Conferences could also be held regionally, which might lower costs and, therefore, facilitate attendance.

It was noted that regulators infrequently attend current trade shows and conferences – the attendance of the CSB, NFPA, OSHA and other agencies is essential for both the sharing of information by these regulators and the feedback loop that members of the industry can provide from their perspectives. "Customers want to comply, but don't know how." [5] "There is generally a lack of trust between industry and regulators." [9] If these agencies can attend learning events with the intent of learning and sharing, it may go a long way to helping reduce this lack of trust. Compliance with NFPA has been discussed earlier in this paper and comments pointed to difficulties on the part of practitioners in both understanding and applying guidance. Resolving this issue requires dialogue to explore the contributing factors that inhibit compliance, which is frequently discovered during audits, inspections or investigations and is responded to with admonishment or punitive action. Cooperative learning has been pointed to as a better approach than forced compliance[42].

Global 'Summit'

The Call to Action resulted in responses from the United States and 13 additional countries, each having a unique view of combustible dust safety. Many of the international responses said that their country looked to the U.S. for guidance on dust standards, indicating that their country is less advanced in training, tracking events, regulation and even understanding the hazard of combustible dust. "Combustible dust safety is a far-fetched concept in India and other neighboring countries." [27] "Combustible dust safety is not well known in Turkey. Our legislation just started to make the industrial facilities be responsible for the protection from

41 E.g. International Conference on Intellectual Capital and Knowledge Management and Organisational Learning.

42 Batthish, M., Baker, G. R., Kuper, Ayelet, & Laxer, Ronald. (2015). *Organizational Learning in the Morbidity and Mortality Rounds,* ProQuest Dissertations and Theses.

dust explosion." [34b] "The existence of a body like CSB helps in bringing sanity to affected industry operations in North America to an extent but the same cannot be said about other parts of the world, especially in Africa, where knowledge of Combustible Dust seems short in supply." [34a] There were also countries who indicated that North American may not have the best practices and should stay open to learning, "There are significant differences between North American and European practice... This is a global problem, not a North American one." [31]

The generous response to the CSB inquiry about combustible dust from such a variety of cultures indicates that the global sharing of lessons learned could benefit the entire community of industries dealing with dust explosibility issues. "An industry activity is a world citizen and same measures to prevent an accident should be given a top priority at the world stage." (34A) Respondents asked for this, specifically. "There should be a sharing of information on a global scale. Exchange information, experience, new information..." [41] "Global accessible logging of such data and programs must be promoted to increase insight and help with overall safety." [33]

This interest in global sharing went beyond the desire for this report and called for, "Initiating a world-class specialized annual conference with expert panels, training courses, workshops, and vendors specializing in explosion prevention/protection equipment would be highly effective at information exchange." [35] Similar to the section above, where people want regional or nationwide conferences on combustible dust, there is a need for a global event where multiple industries can share information and create networks of learning. This is an international problem, where we should have the "opportunity to learn from all sectors, nations, levels and approaches." [33] A global combustible dust summit would give industries a chance to learn both from professionals and each other, resulting in a collaborative approach that could contribute to positive long-term change. This in-person summit could also reach people who value face to face interaction over online learning.

Conclusion and Recommendations

The Call to Action on combustible dust released by the U.S. Chemical Safety Board received a strong response from multiple industries around the world. Replies from this voluntary outreach revealed many industry assumptions and challenges and also offered suggestions for improvement. Important and innovative topics emerged through the sensemaking phase of the Learning Review. Barriers to improvement explored how individuals and organizations approach risk. Controls examined the efficacy of traditional approaches to risk and hazard management. Reporting identified the importance of creating psychological safety in the workforce to facilitate the open sharing of information. Language and Communication revealed that even the words used to describe combustible dust can introduce vulnerabilities to the system and that effective communication within and between facilities is essential for safe practices. Learning was shown to be a function of the willingness to share information and change assumptions and was not guaranteed through traditional training methods. Sharing information was found to be the most desired and valued topic from respondents.

- The feedback received on all topics indicated key areas of systemic improvement that could reduce the likelihood of future dust explosions.
- Create a 'living risk' document that is updated as the system changes, to supplement the DHA.
- Explore what can be learned from industries that report success with dust hazard education and mitigation.
- Develop standards to certify dust collection system manufacturers, installation and training.
- Develop combustible dust procedures that are distinct from 'housekeeping' and unique to each facility's manufacturing variability. Present dust as a unique hazard, not just as 'tidying up the place'.
- Explore how common terms and language may adversely influence the awareness of hazards.
- Identify and mitigate language barriers that exist within facilities.
- Create psychological safety in organizations to facilitate the willingness of personnel to provide information and ask questions.
- Recognize that training does not always lead to learning. Develop experiential and collaborative learning methods to help all personnel understand combustible dust risks and mitigation strategies.
- Share learning and experience within a company, industry and across industries.
- Develop a "Global Summit" where all industries can come together to learn from each other.
- Develop an online forum and/or Lessons Learned Center, where the community can explore combustible dust issues and learn from each other.
- Hold focus groups to identify and share best practices with regard to dust control, language, training techniques, awareness, and critical lessons learned.

APPENDIX

A. Methods Used for this Report

B. Quotes & Ideas from Call to Action Responses

A. Methods Used for this Report

Context of Study

On October 24, 2018 the U.S. Chemical Safety Board, "as part of its investigation into the May 2017 Didion Mill explosion, issued "Call to Action: Combustible Dust" to gather comments regarding "the management and control of combustible dust from companies, regulators, inspectors, safety training providers, researchers, unions, and the workers affected by dust-related hazards." Initial data was derived from this Call to Action, which was posted on the CSB website and generated 20 responses (some responses were not used because they did not answer the call to action, such as advertisements for business). A private company, Dynamic Inquiry LLC, was hired to make sense of the responses.

During the initial assessment of this data, Dynamic Inquiry LLC contacted Christopher Cloney of www.dustsafetyscience.com, who had responded to the outreach. Dr. Cloney has been an advocate of dust safety for several years and has created this website designed to further discussions regarding how to prevent and mitigate dust explosions in a number of industries. Dr. Cloney offered to help by coordinating a podcast recording that further explained the Call to Action to his listeners and placed the Call to Action questions on his website in a form that encouraged responses of any length or formality. This resulted in an additional 37 responses from around the world, which were forwarded through www.dustsafetyscience.com to the CSB.

Design of Study

As with any survey, the method of assessment of data can bias the product. Dynamic Inquiry LLC chose to use a modification of the 'Learning Review' process to categorize and interpret the data received through the 57 responses. The Learning Review[43] was first developed for the U.S. Forest Service as an alternative way to make sense of accidents and incidents and to reduce bias to a minimum in the organizational response to accidents and incidents. The Learning Review offers a combination of practical and scientific principles to facilitates learning from events.

The purpose of any Learning Review is to learn and improve. They are designed to help understand why it made sense for people to 'do what they did', whether the event resulted in positive or negative consequences. The recommendations emerging from a Learning Review are focused on improving the 'whole system,' which is accomplished by involving all levels of the organization in designing improvements.

The Learning Review consists of three main phases: collection of information, analysis and sensemaking, reporting and sharing.

Analysis of Data

All Call to Action responses were forwarded to Dynamic Inquiry LLC, where two human factors specialists reviewed the answers to the questions and additional comments. The Team Lead holds a Ph.D. and was the developer of the Learning Review process; the second specialist has worked extensively with the process since its inception and holds a graduate degree in Human Factors & System Safety.

Analysis and sensemaking was initiated for this study by reading each narrative response and noting specific recommendations made by respondents, notations of hazards, mitigation strategies/techniques, novel approaches, topics needing further inquiry/study, and any issues with language or regulatory framework (both positive and negative). Each notation was read and discussed between the specialists. This formed an academic review of the data points, which facilitated further coding of the information. Wherever possible, the responses were captured as quotes.

43 To read more about the Learning Review process please see: http://www.safetydifferently.com/wp-content/uploads/2018/08/171024TheLearningReview.pdf

A. Methods Used for this Report

Each data point was recorded on a sticky note, which were sorted into categories on a 12-foot by 24-foot wall (see inset picture). The use of these notes, over such a large surface, allowed freedom of movement and broad perspective of the emerging topic areas during the sorting phase. The categories were not pre-determined, instead the contents of the notes were compared and grouped, which resulted in the emergence of major themes and questions. This approach is used to help limit bias and allow for new ideas to develop. The notes were also marked with the randomly assigned response number, which remained attached to the quote throughout the study. Sticky note content and quotes were then collected into a master document, "Quotes & Ideas from Call to Action Responses", which were used in the final report.

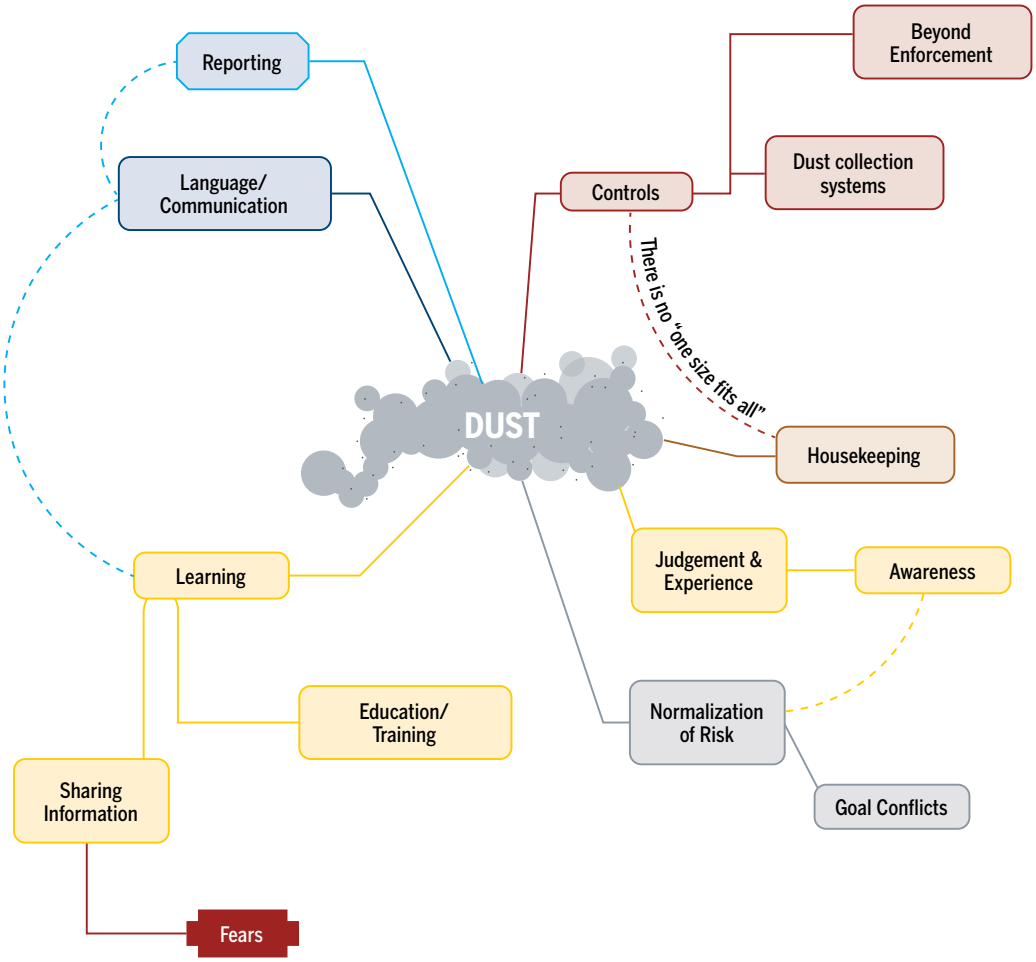
Sensemaking

Categories of responses shaped the content of the report. Each category was examined in terms of the information supplied by respondents and academic research derived from peer reviewed papers. Academic and regulatory experts were consulted to verify general information and data, without compromising confidentiality of information specific to the report or study.

During the end of the sensemaking phase, members of the Chemical Safety Board were given a webinar explaining findings from the study and a general outline of the proposed paper. This helped to verify concepts and generate new ideas on where the project might lead.

Reporting

For the final written report, the main categories were assembled into a mindmap (Network of Influences Map), which served to organize key points for the written report. The map graphically represented key topics, which became the header sections of the report. Quotes and ideas from respondents were used as supporting evidence of these ideas. Thus, this review became a reflection of the perceptions of respondents, augmented by occasional academic research that supported the observations and conclusions.



Network of Influences Map, representing key topics generated by the Combustible Dust Call to Action

B. Quotes & Ideas from Call to Action Responses

**Responses received through the Call to Action resulted in ideas and specific quotes, which were listed under emergent topics on the Network of Influences Map. These were assigned numbers by Learning Review team members, to assist the anonymity of respondents in the report.

AWARENESS

Combustible dust should be a widely recognized hazard, just like any other workplace hazard. [51]

Close the knowledge gap. Safety managers have knowledge, production facility personnel do not. [51]

"But the people working on the floor, in a lot of cases, are told the dust is combustible and that's about it." [44]

Varying levels of awareness of dust hazards – within the facility and between facilities. [51]

Lack of awareness. New technology (3D printers), new dust problems. [23]

"For a dust hazard to be properly reduced and/or controlled, it must be presented as its own distinct hazard issue, not as an issue of tidying up the place." [1]

"Dusty is an ambiguous term, open to interpretation." [15]

Communication of dust hazards is poor. Even management is under informed. [2]

It's never happened here before – does not mean it can't or won't. More wide-spread outreach directly to facility owners and operators. Constructive paranoia. [51]

Personnel are frequently unaware of the true likelihood of these events. [53]

"The more you know about your process and the related factors that can impact dust generation, dispersion, and ignition potential – the better is your ability to identify and assess whether dust levels are safe or not." [11]

LANGUAGE/COMMUNICATION

"For dust hazard to be properly reduced and/or controlled, it must be presented as its own distinct hazard issue, not as an issue of tidying up the place. Although some may consider that controlling dust will do both, the mixing of the two concepts will only downplay the gravity of combustible dusts. In order to effectively change the work culture, control of combustible dust must be presented as a purely hazard reduction/safety issue that has nothing, per se, to do with cleanliness." [1]

"A 'Control of Combustible Dust' procedure should be developed that is distinct and separate from a 'Housekeeping Procedure'. The reason for this separation is that the average worker sees housekeeping as a broad term addressing all sorts of clean up issues. I believe the reference to a 'Housekeeping Procedure' including dust control will diminish the interest in it and the perceived value of it, as a whole, since most people would see housekeeping as a nicety rather than as a necessity." [1]

The average worker sees housekeeping as a broad term addressing all sorts of cleanup issues. [1]

"Dusty is an ambiguous term, open to interpretation." [15]

"The root of the dust explosion problem is ineffective communication of the hazards of combustible dust to plant managers, engineers and operators." [45]

If management doesn't address safety concerns of employees, employees can become apathetic toward reporting. [2]

View dust as a fuel, not as a risk. [46 – is it a fuel management problem?]

"Most organizations communicate the hazards of combustible dust poorly, if at all." [2]

"Whistleblower" [5 – should we look for a standard way to refer to people who inform?]

B. Quotes & Ideas from Call to Action Responses

JUDGMENT & EXPERIENCE

Personal judgment (in my experience) is very often incorrect. Regulation is needed. [5]

Experience plays a large role in consideration of hazard. [12]

"The challenge we face is the number of new faces coming into all industries – have fewer and fewer experienced stakeholders to show them the ropes." [57]

Very few people have experience with dust explosions, yet our system relies on knowledge to know when to do housekeeping (what levels are safe enough). [36]

"I believe that the experience is the strongest factor in safety judgement". [41]

"Experience is often the best way to know what is normal and safe." [13]

Judgement and experience should not play a role. Solid dust safety program should cover those decisions. [32]

Training programs are good but on the job training is best. Pass down knowledge from experienced operators to newer ones. [37]

Is it difficult to find workers with experience in acceptable levels of combustible dust explosions. [36]

"Judgement without a system for defining acceptable vs. unacceptable conditions will yield inconsistent results." [37]

The more you know, the better you can assess. [11]

LEARNING

Entities involved with a tragedy have a wealth of knowledge – most are willing to share transparently [14]

Highest level of organization has to believe this can happen at their site. More effective use of CSB videos. [12]

"Make that information freely available. Ensure that there is no such thing as a stupid question and there is no question that would be used to prosecute or penalize the company." [22]

"Regulators should better leverage industry, health and safety associations, labor unions, employer groups, as well as public and social media to cast as wide a net as possible." [11]

Just-in-time instructor led, web-based compliance driven training, rather than learning. [15 - emphasis on training, not learning]

Great value in databases like Dust Safety Science and OSHA citations. Need a platform to share progress, improvements and successes, without judgement. [17]

Near misses are to be properly investigated, as these provide valuable insight that is often lost after catastrophic events. [33]

The organization's accident/incident investigation process for combustible dust is particularly important in ensuring knowledge of process hazards, are transferred to employees. [53 – learning teams]

Learning – visualize the hazard. Subjectivity in risk assessment directly related to normal systems variability. [12]

Root cause analysis results in fixes. Action plans coupled with awareness at plant. Extend beyond plant? [13]

Videos, Power Point, accident reviews, testing, procedures most effective ways to educate workers. [56]

Convincing senior management that investing in dust safety doesn't require a payback, like investing in a new piece of equipment. [32 – learning that dust safety is like insurance]

"Statistics sadly prove that implementing lessons learned from catastrophic incidents is not a human forte." [33]

Regulatory agencies, insurance companies, safety consultants, salesmen, equipment manufacturers, employees, industries – could more easily share information back and forth! [23]

Doing practical experiments that simulate dust hazards; take lessons from previous incidents. [41]

NGFA has pursued many education efforts: meetings, seminars, conferences, guidance manuals, videos, reports, workshops on OSHA safety, National Grain Handling Safety Day. [49A]

Multiple hazards of dust, aside from explosions: slips, health, invisible threat of accumulation. [15]

Learning from an on-field specialist is the best way to check problems, including in front of a field audience. [39]

B. Quotes & Ideas from Call to Action Responses

"Practice lessons where your powders are ignited and explode – so employees can see, can feel and experience the dangers of working with these materials." [40]

Need to create bridges between the technical/cultural gap of big and small factories. "Spread the word and culture amongst safety technicians." [39]

"...small fires could be leading indicators for significant fire and explosion risks. This starts by asking the question 'why was there no explosion?'" [37]

SHARING INFORMATION

"Transparency and reporting between end-users, standard organizations and operators would be the most effective way to prevent future incidents." [2]

People are happy to share information as long as there is not risk of retribution. [?]

Regular safety communications, like "safety beacon". [37]

"Initiating a world-class specialized annual conference with expert panels, training courses, workshops, and vendors specializing in explosion prevention/protection equipment would be highly effective at information exchange." [35]

CSB not present at trade shows, conferences (says they should be present). Customers want to comply, but don't know how. [5]

Make information freely available. Ensure there is no such thing as a stupid question that would be used to prosecute or penalize. Put people together. [22]

Reporting, information sharing. A better method is "an open environment where individuals can share their thoughts and see improvements." [26]

Share information through different EHS associations: CSSE, ASSP, CSB, Dust Safety Science, health and safety conference, industrial conference. [32]

Database system with information on accidents or linking them to technology that would get people together to talk about what works and what doesn't work. [22]

"This is a global problem, not a North American one." [31]

Industry standardization, regulation, safety experts, hold regional seminars that include operators. Present case studies, re-training procedures and audit results. [48]

"The next step within the industry is to share information between different companies. The next step in safety evolution." [40]

Internal community of practice – training discussion of new and emerging technology, updates on guidance and standards. [37]

"From an external perspective, it would be helpful to have effective ways to share incidents and near-miss event broadly. One option for this is through the use of anonymous reporting boards, allowing incidents to be shared without direct attribution to an individual organization. While it is difficult to share incident-related information for legal and regulatory reasons, incidents offer some of the best training opportunities and any systems that facilitate the sharing of incident summaries would be beneficial." [37]

"An industry activity is a world citizen and same measures to prevent an accident should be given a top priority at the world stage." [34A]

"Instituting a world class specialized conference with expert panels, training courses, workshops, and vendors specializing in explosion prevention/protection equipment would be highly effective at information exchange." [35]

Global accessible logging of such data and programs must be promoted to increase insight and help with overall safety. [33]

Global problem – opportunity to learn from all sectors, nations, levels and approaches. [33]

Western culture is based on punishment, not reward. Companies should be recognized for their good record of safety. "Companies should be praised and rewarded for washing their dirty linen in public and not vilified." Need a cultural shift. [31]

There needs to be a bigger, open format where customers, suppliers and regulators alike can come together to tackle the issues. [5]

The successes listed by AFPM points to the need for a global system of sharing information and investment in safety culture. [47]

B. Quotes & Ideas from Call to Action Responses

"Sharing incidents (both internal and external) is important for maintaining awareness and a sense of vulnerability." [37]

The next step in process safety management is proactive sharing of prevention measures within and between industries. [40]

"First, there should be a sharing of information on a global scale by establishing an electronic platform for dust science in which all international facilities that generate and manage dust will be involved in order to exchange information, experiences, highlight all that is new, and benefit from previous incidents. The best experience I have seen is the website www.dustsafetyscience.com. It is a very useful website with a great experience in this field." [41]

"Perhaps a periodic report summarizing incidents, causes, and recommendations for similar facilities could be generated and distributed?" [51]

"Frequent and effective communication of the outcomes must be shared with all affected employees to sustain a healthy culture of combustible dust processing safety." [53]

More collaboration between CSB and ASSP, institute of hazmat managers, national safety council... would bring dramatic improvements to the industry. [53]

"Our members continuously look for opportunities to enhance safety and recognize that an effective means to improve process safety performance is to learn from each other." [47]

"Share the information on social networks, make videos to educate people about the risks, and talking about solutions that exist." [54]

"CSB videos are awesome, and we use these a lot as a form of information sharing." "Dust Ex Research information has proven to be the best way to find out about other incidents." [56]

Learning about dust through written handouts, photos of work areas, training videos, Worksafe BC educational resources. "communication – a multifaceted approach works best." [11]

"Breaking down industries might help specific industry mitigate combustible dust challenges as a group." [23]

Team learning, to encourage voicing opinion. Collective learning (teaming). Need a system for collecting information. Promote training of all actors. Provide free information and training. [12]

"I believe that the administration of the company/facility has the responsibility of making best communication with all workers whatever their positions, and this could be achieved through intensive meetings and opinions sharing, no matter how simple or not useful." [41]

EDUCATION/TRAINING

There has been a move away from instructor led training toward web-based training; e.g. PRG coal users group. [26]

Companies not willing to spend time and money on lessons learned. It has to be regulatory. [20]

"We do need to train the workforce to recognize changes that matter." [42]

Examples of safe and unsafe levels should be captured photographically – photos should be provided to people conducting inspections. [37]

Site leader – dust awareness has improved over last 10 years. Employers are taking risks more seriously and employees are getting better training and education. [32]

Some organizations use Stop-Think-Plan-Prevent- and Protect to help improve safety. [35 – awareness tools]

In France, training is compulsory but rarely effective in practice. Real demonstrations help. Must convince workers that dust is bad. [12]

"Just showing a simple 1 ½ minute movie very easy creates a much higher awareness." [33]

NGFA creates 50-member Fire and Explosion Research Council in 1978 to: gather information and share it, research effort to learn about causes and prevention. [49A]

"Create awareness and share statistics, starting at subject matter colleges, technical schools, etc." [33]

"The skilled workers of today do not understand what to look for and the older generation does not have enough time to give the proper knowledge to the next generation. As a result, we are in a gap of knowledge and education becomes our key." [5]

B. Quotes & Ideas from Call to Action Responses

"In my opinion the #1 reason for reluctance to addressing combustible/explosible dust hazards is a lack of awareness/education at the fundamental level." Move education upstream – academics, engineer students. [35]

"Training that includes hazard recognition and hazard mitigation components for all personnel involved with combustible dusts, including external contractors, is conducted across the industry... can include formal classroom presentations, toolbox training at job sites, videos of dust deflagrations testing, and reviewing lessons learned from past incidents." [13]

Need training resources for combustible dust that are accurate and trustworthy. [5]

"We like to show videos of CD incidents (such as the Taiwan night club incident) to set off alarm bells and make people realize that CD handling has very real and serious consequences." [36]

It takes training to see the risk in dust. [24]

Combustible dust training, including CSB videos. [7]

"Training on combustible dust hazards is highly variable." "Having a systematic approach that factors basic awareness training, video demonstrations, pre-job safety meeting and open discussion will likely improve overall awareness and reduce safety issues." [35]

"Workers are more aware of dust cloud explosibility from watching Mythbusters and not internal company training efforts." [38]

Dust safety is under emphasized in most industries. [29]

REPORTING

"A system where employees can address hazards will only be successful if there is a safe culture to report unsafe issues." [40]

"Unfortunately, they are not empowered (to report)." [34B]

"Conditions have to get really bad before workers will speak up." [9]

Reporting issues varies company to company. "Some are praised for identifying risk reduction opportunities and some are regarded as rocking the boat." [17]

"Empowerment to report is at the mercy of the person receiving the report, who is likely influenced by goal pressure." [46]

"...many of these incidents could have been avoided if the workers were empowered to report issues... some of them answered that they were afraid of ridicule and scorn by safety engineers." [41]

Reporting issues should be a cultural norm. Meetings, audits, open door policy. [13]

"All employees must turn in a certain number of safety improvement suggestions monthly." [56 – 'forced reporting'; not only empowered but encouraged or forced to report]

Reporting - need an understanding of what a dust explosion is and how it happens. [27]

"Transparency and reporting between end users, standard organizations and operators would be the most effective way to prevent future incidents." [2]

"Currently data on the number of explosions, fires, and near misses due to combustible dust is unreliable and surely underreported due to the perceived liability by end-users in sharing this information with outside groups." [2]

"The creation of a reliable reporting system (even if it means that reports are anonymous), would be a huge step in helping the industry to fully define the problem and work together on a solution." [2]

Once workers are aware of combustible dust hazards, ensure anonymous reporting is easy within organization. [36]

"Non-punitive reporting of safety issues is a key element of a refinery's SMS." "Site leaders strive to ensure open communication." [50]

Facilities tend to not see any value in reporting an incident. The first step is making facilities understand the importance. [44]

Data on the number of explosions, fires and near misses is unreliable and under reported dur to perceived liability. [2]

"Workers are empowered to report unsafe conditions, but whether anything gets done about it is pretty hit or miss." [36 – culture]

(fires not reported) "A significant portion of these, dare I say most of them, are NOT reported. I believe it does create a false sense of security." [5]

B. Quotes & Ideas from Call to Action Responses

Incidents can go unreported – those reported can be masked as other incidents, due to lack of awareness. [27]

Creating a reliable reporting system (even anonymous) would help industry define the problem and work together on a solution. [2]

Workers at all (chemical manufacturing company) facilities are encouraged to report health and safety concerns; methods vary facility to facility. Supervisors are expected to take prompt action on any reported concerns. [37 – does the culture truly embrace reporting?]

"If the production leader and plant personnel create the right culture, where anybody is invested in ensuring plant cleanliness, reporting is not an issue." [15]

"Every end of shift the workers report issues in all aspects of the operation." [24]

FIRE REPORTING

"often, these fires go unreported as combustible dust events, because even the facilities staff isn't aware that the dust is the ignition source. [10]

It seems that fires are quite common. [2]

"Common to have a fire without an explosion. Employees don't fist think about combustible dust explosion potential when these fires occur." [8]

(Fires without explosion) "When communicating statistics in our 'training program' we find most attendees are very surprised about these numbers. [33]

Fires often occur and are unreported. "I believe this can create a false sense of security." [5]

The industry cannot be expected to report, investigate and share information. [20]

Reporting dust fires – there is no serious mechanism for reporting (thus no way to track, trend, or learn globally). [20]

"Experience has shown that industry cannot be expected to report, investigate and share information. It's gotta be a task for a regulatory agency." [20]

"One of the difficulties with this topic is in the definition of and 'explosion'. NFPA connect the word 'explosion' to an event which causes damage to the containment vessel. Many of these events take the form of a 'deflagration' and although the event is still dangerous it doesn't affect the structure of the vessel. As such some do not count it as an explosion and even more problematic is that some deflagration events are not recognized." [?]

"Dust fires are common if you consider even small events (golf ball size events) however, large events, like explosions, are very rare and thus they are not given much consideration in DHA's or PHA's. [38]

"Regarding the other side of the question, my answer is "unfortunately yes" because the large proportion of the dust fires incident did not cause explosion, that indeed create a false sense of security." [41]

CONTROLS

"The goal would be to reduce the risk to a minimum, not eliminate it, as virtually no operation can eliminate all risks." [1]

Some of the challenges implementing guidance or standards = "cost of implementation". [34A]

"Again, the DHA is critical to help identify the hazard and the action plan needed for cleaning to assure a safe operating environment." [35]

"Measurement can be assessed visually (subjective) or quantifiably (objectively). Both approaches are effectively employed in the industry and they can also be misinterpreted and allow unsafe conditions." [35]

On a comprehensive regulatory approach: "In trying to cover all cases, they will either be too simple to be helpful or too complex to be helpful." [49B]

Controls can cause other problems: dust control system changes; need flexibility to address unforeseen changes. [11]

"There are often even procedures in place on how to respond to fires without an understanding that this is a warning sign that something is wrong with the process and the facility is at risk of explosion." [2]

Confusion about which standards and regulations pertain to (a specific) combustible dust. [8]

B. Quotes & Ideas from Call to Action Responses

Belief that the only way to achieve success is through compliance and enforcement. [38]

Food safety regulations help dust problem. "In the context of a lack of resources, priority is sometimes given to product quality. Food safety and explosion prevention can be ensured by using similar principles such as dust removal, visualization of dust accumulation on the floor." [12]

Employees continue to underestimate the risk despite training. [15 – full awareness and comprehension is required to be able to maintain compliance]

Guidance and standards can be seen as too complex. [31]

These powders are sometimes unique to our process, so we have had to rely on in-house analysis instead of published guidelines. [8]

Conduct a baseline dust and ignition source survey. [1]

Room by room survey of dust hazard: analyze to best mitigate; ignition source identification. [1]

"It could be a living document that is updated as necessary according to the changes in the materials, operations or facility." [1]

CSB should highlight the need for dust testing and the relevance of tests to make the workplace safer. [27]

Risk assessment should be used to set the baseline of what is acceptable and what is unacceptable. [30]

Dust hazard must be presented as its own distinct hazard issue. [1]

Establish a distinct "control of combustible dust" program. [1]

Mandatory directives are not necessarily followed. [12]

Culture trumps regulations. Question regarding the need for compliance – unfamiliar with laws/regulations. Years of working in dust "the old-fashioned way". [40 – culture, drift]

Some of the same techniques for handling food safety will apply to dust safety. [35]

Food facility sanitation compliments dust safety. [51]

When asked about being in line with NFPA standards, "most companies don't even worry about it." [52]

"Explosive testing should be conducted under real world conditions rather than assuming worst case scenarios." [6]

"CSB needs to do more and extend their dragnets to other parts of the world." [34A – dragnet: a systematic search for someone/thing, especially criminals or criminal activity]

Laws – rules – regulations are hard to understand, hard to read, in conflict with each other, don't seem to apply. [40]

"One challenge I have observed is how NFPA standards are written. While thorough, they can be extremely confusing." [52]

Verify and observe system operation, don't just try to predict system problems. [2]

Automation can result in "less eyes", less available labor to maintain and clean production lines. [5]

NFPS standards and housekeeping regulations help mitigate dust risks. [50]

Audits and inspections are scheduled, but workers are trained to identify upset conditions and how to address them. [14]

Preventative maintenance on dust mitigation equipment must be on a schedule, not on condition. [2]

Engineering and administrative controls required to keep operation safe; e.g. NFPA standards. [2]

Policies must be both enforceable and practical. Dust is inevitable. "It is not our mission to believe that dust will not be generated, rather that it must be managed and mitigated safely. Dust is an inevitable part of the manufacturing process in almost all cases." [5]

Consider NFPA and minimum explosible concentration (MEC) to determine dust threshold. [2]

B. Quotes & Ideas from Call to Action Responses

Current rules cannot all be followed, may be too stringent. "I believe there are physics that were not considered during the initial writing of the rules. (How can static build up high enough in an end of arm tool if everything attached to it is bonded and grounded?) I think our standards are necessary but may have gone a little too stringent in some areas." [5]

"Combustible dust management should primarily rely on performance-based approaches rather than prescriptive specifications." [6]

"NFPA 654 is extremely complicated. To comply with the standard, a facility would need to utilize a specialist with a great deal of knowledge on ways to design and construct the explosion venting, isolation, mitigation and prevention systems required for all parts of the facility. It is clear the standard was written by those with little understanding of what it takes to practically design and build facilities and operate them with the equipment that is currently available. Thus, while the NFPA standard may contain certain valid concepts and principles, unfortunately, they are not practically applicable." [49A]

FEARS

Even the higher-ups view safety requirements as a means of avoiding fires by OSHA and protection against insurance claims and legal action. [46]

"Workers typically do not want to risk their job to whistle blow on their employers. The fear is that either they are wrong about their fears, or that it will come back on them." [5]

"Some customers fear that once they start understanding the issue that they will need to comply fully, and the cost will be too high to sustain a competitive position in the industry." [5]

"If the customer makes an audit and sees a 'dusty plant' it becomes a critical item (trust). The risk of losing the customer is high." [15]

DHA outlines each hazard and mitigation. Organization can feel afraid to list their safety issues where outside parties can see them. Internal reviews may be incomplete. [5]

"Sharing information is not common. Fear of sharing 'your' mistakes and fear of sharing your process 'secrets'. This often blocks the higher goal of 'safety awareness'." Believe we are on the right track with dustsafetyscience.com [40]

There is generally a lack of trust between industry and regulators. [9]

Sense that the cost of full compliance is too high to sustain a competitive position. [5]

Many of these incidents could have been avoided if workers were empowered to report issues. [41]

Unfortunately, many industries regard sharing safety related incidents as a detriment to their reputation and/or giving competition too much information. [17]

BEYOND ENFORCEMENT

Most companies visited don't understand the volatility of their dust problem. [27]

Awareness sessions are valuable. Dialogue, dust explosion demonstration, apparatus, periodic incident videos (CSB). [?]

Need a central database and investigation team to analyze patterns and identify the root cause. [27]

Regulators must continually bring the topic up in conversation. When leaders do nothing, it is the norm. [26]

If we have enough fear (respect) for dust explosions, we will take action using fires as leading indicators. [27 – learning ahead of disaster]

"Do not compromise on investments related to safety. The ones at risk are usually not the ones making such decisions." [33]

"A key element of a successful dust management problem is a focus on systems rather than individual components." (p. 3) "Often the investigation focuses too narrowly on the physical causes of the event without probing the systematic issues that may have broader implications." (p.4) [37]

"Most of our customers are not aware of their combustible dust and the required protections." [34B]

Organizations should share and review information on events and potential hazards found. [30]

B. Quotes & Ideas from Call to Action Responses

"The 'survey' represented in the Call To Action questions does not appear to be an effective mechanism for understanding the conditions that influence combustible dust management; an in depth study of past incidents and a meaningful statistical analysis might be better." [28]

"By its nature, the Call to Action clearly solicits a voluntary response; the concerns we have raised with the document raise questions about how effective this approach will be." [28]

We must have an open learning forum. Go beyond prescription and punitive action. World class forum. [35]

"The trouble I see is that acceptable dust levels are often so small they are not practical to measure." [51]

Guidance should be safety first – reality is business first. [39 – no company produces 'safety']

*Challenges with implementing #4 safety: low budget, poor safety culture, sometimes low technical level of workers. [39]

CSB still keeps calling for a national standard for combustible dust. This would be a bad idea – we don't need more laws. There are good tools set in NFPA that quickly become antiquated with industry and scientific knowledge changes. [38]

THERE IS NO 'ONE SIZE FITS ALL'

Liquids are measured better than dusts. Liquids allow for zero spills. Hard to manage dust because it can be hard to see losses of containment. [15]

"Each process creates dusts with unique combustion/explosion properties." [53]

"One size does not fit all." Grain industry doesn't want CSB to combine their industry with others. [49B]

Difficult to go from non-compliance to full compliance because it is costly. [5]

There is a lot of conflicting information and sources trying to provide safe solutions. [5]

Not all combustible dust poses the same risk. Focus on performance-based approaches, rather than prescriptive ones. [6]

Wood industries are different, "particles are fibers, not round dust particles. That means they block the dust explosion test equipment." [42]

NFPA is standard but dust thickness can be difficult to measure. Dust layers are not consistent throughout plant. [15]

Risk tolerance if dust cannot be eliminated. A blanket depth criterion is not practical since the work environment can vary and the dust will vary. [30]

The large number of "variables makes understanding the hazard difficult." Not everyone knows the science. [8]

A 'one size fits all' approach is not effective. [15]

"Cleaning schedules, methods, and manpower cannot be universally defined." [35]

Dust collection systems: defining critical dust levels is not an exact science. Spending money for higher frequency cleaning can be challenging. [15]

Process safety management. [13 – not a panacea, audits can't guarantee safety - like Didion]

"Not all dust particles create the same fire/explosion hazard." [50]

"Practical experience shows that dust layers do not settle evenly, so you cannot sensibly set a maximum thickness level of an acceptable layer. [42]

Materials are diverse – so dust is diverse. Dust can be unique to the process. Cannot use a 'one size fits all' approach. [8]

Moving from one product to a new one may increase risk. [27]

"Dust profiles will vary dramatically." Measurement is a challenge. Primary vs. secondary dusts. [11]

"It is not our mission to believe that dust will not be generated rather that it must be managed and mitigated safely." [5]

Must make a different evaluation for primary dust (course or heavier) vs. secondary dust ("fine enough to migrate, settle on elevated surfaces away from the point of generation" These dusts have different qualities and deflagration points. [11]

B. Quotes & Ideas from Call to Action Responses

"Sometimes, controls are implemented that cause other problems. For example, in an attempt to control fugitive dust a company may build containment vessels around equipment. In doing so they have removed the fugitive aspect however they have inadvertently created a 'containment' around the dust, thus raising the risk of an explosion." [11]

Employers may be faced with multiple sets of regulations in the operation of their business." [11]

"Combustible dust and its variability have also not been studied as much as flammable liquids and gases. Even the same sizes of aluminum dust can vary significantly depending upon shape, coating, morphology, etc. and that makes it difficult to generalize as to hazards." [13]

"We have had to conduct a significant amount of testing of specific powders to determine their ignitability (and occasionally their explosibility). These powders are sometimes unique to our process so we have had to rely on in-house analysis instead of published guidelines." [8]

NORMALIZATION OF RISK

"Many plants are still in the complacent mindset, where they have never experienced a major event and hence feel their risk is not high enough to worry about." [17]

Too many people acknowledge the risk and choose to ignore the problem. [19]

"Complacent mindset of being low risk purely based on no significant event history." "Some people need to see it to believe it." [17]

Probability vs. severity. Decrease one and you are better off. [17 – how do we know the probability?]

Growing climate of risk acceptance. "The challenge isn't getting new ideas in one's head but rather getting old thoughts and experiences out of one's head." [26]

A workplace that is dusty cannot be safe. [27]

"With the sheer number of variables involved, I'm not sure if (dust explosions) can be avoided at all." [33]

"Two of the most popular excuses are: "we have been operating for 'x' number of years and have not had a problem!"; "we have fire insurance on our dust collector – so if it burns up the insurance company will pay for it." [19]

"Safety is a non-event, think of it as a control loop with a much delayed feedback signal, then the control loop starts to drift." Production is tangible and can take priority over safety. [20]

Controls – normalization of risk as with any other safety measure/ precaution. Gradual degradation is being tolerated. [20]

"The common thinking is, 'It never happened before, that costs too much money, we don't have a problem, etc,' are often the challenges in a growing climate of risk acceptance." [26]

You can't make quality products if your people are dead form an explosion. [32]

"Dust fires in the workplace are quite common, but most of the time people say, 'Oh this has always happened,' and 'it's never resulted in an explosion before', so it does unfortunately result in a sense of complacency. [36]

"People don't realize that all that's required is confinement for a dust explosion to occur under those conditions." [36]

"Even when our clients are aware of combustible dust handling safety, many underestimate the dangers with CD handling and so they assume 'we clean a lot, so we're safe'". [36]

Many of our clients do not take combustible dust handling seriously until something serious happens. [36]

The determination of 'safe' conditions incorporates risk-based decision making (with criteria not well defined). [37]

Dust explosion event data focuses upon half of explosions occurring in a dust collector, which provides false sense of security, as most emphasis is on dust collector. [35]

Employees who must work with dust do not have a clear picture of how work should be done. Blurred over time, boundaries are fading, frame of reference gone. [40]

"There is no such thing as 'safe' in an engineering sense... The actual concept is 'risk reduction' or 'risk minimalization'. [38]

"Fires and explosions are rare, which creates false hope." [40]

B. Quotes & Ideas from Call to Action Responses

"I don't think there's a strong perceived link between dust fire and dust explosion." [39]

Fear reduces recklessness and mistakes. [41]

"One of the biggest issues is the attitude of, 'we've been operating for ___ and we have never had an issue so why do we have to spend all this money on stuff that isn't going to happen here?'" [44]

"I do believe it can create a false sense of security. If certain facilities are used to frequent fires, but have never had an explosion, the natural tendency is to believe that there would have been an explosion by now if one were going to happen." [51]

Challenges: lack of awareness of explosion risks; procedures focused on productivity, not safety. [48]

"Dust explosions are rare events that lull industrial organizations into a false sense of safety." [53]

Dust explosions are rare – they system can change dramatically before the result of the changes is known. [53]

"We might have an incident once every 5 years and no, it doesn't create a false sense of security – we take every incident very seriously and perform a thorough investigation to make sure it doesn't happen again." [56 – what about smaller 'incidents'?]

Large fires are investigated. Small fires are more common – far more likely to go unreported. If small fires are tolerated, a sense of security could result. [15]

"The natural apathy created by the 'we haven't had an issue here for 35 years' mentality." [10]

"About 70% of all dusts may form a combustible concentration, but maybe only 30% of our clients are aware of the risks – clear disconnect!" [36]

Companies who have not had a tragedy can develop a sense of complacency, "It can't/probably won't happen to us." [14]

"The most significant risk from ongoing operations is the normalization of deviation, or practical drift, that complex systems naturally move toward. Frequent and aggressive internal auditing and inspective... is the best defense." [53]

Perception that dust is not a serious risk at the facility. [2]

Many plants have never experience a major event and hence feel their risk is not high enough to worry about. [17]

Fires without explosions – "procedures to deal with fire numb operators into believing the system is safe rather than recognizing the potential." [?]

ETTO (Efficiency – Thoroughness tradeoff)

"Dust is looked at like spending money on garbage." [51]

Managers can be financially driven – safety strategies cannot be seen as cost effective. [40]

In our case, specifically, the fight is against security and production. [24]

Balance cost of doing everything they can to reduce risks and reducing risk as much as their current budget will allow. [51]

Some dust processing operations are going to (go on) operating due to technical or economic constraints, with some level of fugitive dust. [53]

Requests for proposals must have mandated safety features – but they ask for a low-cost option, which can introduce risk. (p.2) "The competitive bidding always leads to low-cost offers that can be ambiguous on whether a standard is met or not." (p. 5) [46]

An OSHA standard would help motivate the industry to invest more resources for communicating information. [53]

Focus on money instead of hazard controls. [26]

It's very expensive, disruptive to the operations and time consuming – getting management to spend money would be easier with an OSHA standard. [56]

(Safety choices) are based on fear of efficiency, not fear of danger and incidents. [40]

Cost and effort inhibit dust control management. Dust control competes with production. [2]

B. Quotes & Ideas from Call to Action Responses

"The others have either a carrot or stick motivator to control their dust and reduce the hazards. The carrot motivator could be a revenue stream for collected dust or insurance premium discounts. Alternatively, the stick motivators are more often authority-imposed fines/risk or being shut down and insurance provider stipulations." [17]

HOUSEKEEPING

Housekeeping = nonrecoverable expense. Carrot vs. stick analogy. [17]

Standard procedures with documented monitoring and measurable results with known action will improve the effects of housekeeping. [35]

Time spend cleaning could be better spend preventing the dust release (like fluid releases). [42]

On the grain handling standard set by OSHA, "A singular focus on more stringent housekeeping criteria, e.g. dust accumulation levels, at this stage would be a mistake in our judgment." "...the safety improvement record indicates that over 80% of the safety hazard has now been eliminated." [49A]

"Housekeeping is often sacrificed for 'more important' maintenance items directly impacting problems." [51]

Suspended dust vs. settled dust. Workplace can fall anywhere in the continuum of dusty vs. safe. [13]

Housekeeping is the main avenue for reducing combustible dust. "Our customers that do have a solid housekeeping program remain at the lowest levels of dust in their facility, reducing the risk of explosion to virtually nothing." [5]

"Frustration due to increased, more difficult, time consuming housekeeping tasks." [8]

Ideally, any person working in the facility should be trained and capable of recognizing when dust accumulations have exceeded a threshold. [57]

Specific dedicated employees intended for industrial cleaning. [24]

Not professional cleaners. Poor techniques, inappropriate tools and equipment leading to unsafe, slow practices. Overhead dust. Budget. Staff, including EHS. [29]

Cleaning schedule, cleaning plan, cleaning budget. All staff must be aware of the hazard more than training – active learning. [44]

When reading the standards you can gather that it only takes a small amount to cause an explosion. It makes it seem impossible. [52]

Hidden surfaces can be dusty, even if excellent housekeeping. Psychological benefit to a dust free environment. 'Dust fires' should be a goal, but it is not necessarily achievable. [15]

"FDA standard for cleanliness during food manufacture require aggressive cleaning of the facility." [56]

Housekeeping – nested in a program. "In common terms, dust or dusty, can be interpreted pretty broadly, going well beyond what NFPA or other regulators may define as deflagrable or explosive." "The reality in many workplaces is that the dust profiles will vary dramatically, (both spatially and temporally), within the workplace so representative measurement and evaluation is a significant challenge. Real time measurement of dust accumulation levels or airborne concentration is also a significant challenge. In light of this challenge, we have accepted that course 'dust or debris' that is inevitably generated in wood manufacturing or similar process may be considered 'safe' where there is no likely ignition potential." [11]

Inspections and audits are carried out on frequencies that are based on historical accumulation rates, with the caveat of having an upset condition. Not just a schedule. [14 – flexibility]

"All too often, housekeeping needs are postponed until there is an event that draws attention to the need (i.e. spills, fires, explosions, OSHA fines, fire department inspections, etc.) Preventative maintenance is often perceived as 'a lower priority', 'too time-consuming', or 'too costly'." [29]

"Even when there is a health and safety officer at the facility who is cognizant of the dangers posed by combustible dust, funding is often hard to acquire for such cleaning projects." [29]

Monitoring should start with visual assessment of known dust accumulation areas with additional signage indicating allowable accumulation. [35]

Can't eliminate all dust. Reduce dust to keep changes of an incident low. [51]

B. Quotes & Ideas from Call to Action Responses

"In the end, employees just want to be given a concrete threshold, they don't want to guess." [56 – requisite variety?]

Effectiveness of housekeeping – leader who can make changes, log book, identify applicable cleaning methods. [15, dust teams?]

5 of 8 incidents investigated showed mechanical equipment as the cause (in the UK). "The root cause of each event focused with a high degree of certainty (mechanical cause). [4]

Cost and downtime required to comply with industry standards. Major challenges of compliance. [23]

Housekeeping (programs) that pertain to each industry and their specific processing equipment. [23]

Map the accumulation of dust on 'collection plates' located around the facility. This will help determine the cleaning schedule. [44]

Some guidelines around dust are not helpful, such as "obscuring the color of the surface." There can be many areas in shades of grey that do not allow color distinction. [51]

Safety improvement to housekeeping – add a dust notification system to evaluate and interlock possible ignition sources (p. 2). Particle monitors (p. 4). [35]

"An independent 'quality' check done by someone other than those directly involved in the process so that fresh eyes see and determine system effectiveness." [26]

Housekeeping frequency depends on site operations. [27]

Housekeeping schedule should be required. [33]

Housekeeping is a nonrecoverable expense. Leadership needs to value housekeeping, fund and reward it. Field must recognize importance. [17]

Hard to eliminate fugitive dust. We default to 'remove ignition source'. [27]

"Manual labour resources for cleaning activities is often minimal and neglected longer than is should be as all these items provide no direct value to the process, a non-recoverable expense." [17]

DUST COLLECTION SYSTEMS

Compressed air clean-up is highly limited and generally not recommended but is routinely employed in a variety of industries. Belief problem is at the dust collector. [35]

Dust can only be safe if it is not confined. [24]

"High investment cost required for adequacy." [24]

Proper design. Workers who understand the system – what they need to know, what they don't know. [26]

Many plants want to invest minimal time to perform routine maintenance and only want to repair/replace on condition. [35]

Dust explosion event data focuses upon half of explosions occurring in a dust collector, which provides false sense of security, as most emphasis is on dust collector. [35]

Dust control systems: lack of understanding of changes to systems helping prevent explosions; often not designed properly; changes can affect system negatively; dust collectors processing fines of fines should be located outdoors because they are very hazard prone. [15]

"Many believe an industrial dust collection system works like a household vacuum, when in fact, it is far more complex. Understanding how the dust capture hoods, branching/trunking for transport lines, collector/filter design, and cleaning system operate is usually not taught to engineers, and as a result, a trial-and-error approach is implemented, or the plant will rely on a vendor that supplies components, but not a system design." [35]

Dust collection systems: people who sell them are not familiar with the rules and standards. Customers expect seller to know these things and give good advice. [52]

Challenges to dust control system are two-fold: characteristics of specific dust; challenges that depend on the nature of the organizations' work. [41]

Challenge to maintaining effective systems – the biggest challenge is budget. [34B]

Maintenance of equipment is always variable depending upon the industry, management, initiative and sensitivity to safety hazards. [35, safety culture]

B. Quotes & Ideas from Call to Action Responses

It can be challenging to apply current industry standards to old equipment. [37 – if it is old equipment, what is the sense of safety or vulnerability?]

"Dust collection systems are often viewed as ancillary to the main process, and so they are not given the same level of attention for maintenance or inspection." [37]

Airflow balancing is poorly understood and seemingly minor changes can significantly affect system performance. [37]

"Humidity can also affect filtration efficiency." [37]

Old installations (30+ years) were built before dust was assumed to be explosive/combustible. These systems are modified, lack design criteria, lower efficiency. Cost – pressure to continue. [40]

"Dust collection systems have 4 out of 5 elements of dust explosion present when in service – there is dust, air, suspension, and containment. Therefore, it is only one element away from explosion – ignition source, such as spark." [46]

"I recently spoke with an engineer at a company that manufactures dust collection systems. In speaking with him, I found many discrepancies regarding the information he was giving me about dust collection that pertained to ' what was allowed and what was not allowed' by the standards. When I questioned him on NFPA 484 and then told him what the clause says, he said he would have to look it up. In addition, he also stated that he has worked for this particular company for a number of years and 'been in the business even longer', and I am the first person to ever ask about being inline with NFPA standards. 'Most companies don't even worry about it', he stated." [52]

"People who are selling dust collection systems to companies do not know the full scope of the 'rules', how to apply them, or the extent to which they should be applied. In turn, the customer is buying the equipment, thinking that the 'seller' knows what the best options is for handling the dust." [52]

"Dust collection systems are something that most places want to set them up and forget about them." "Facilities where someone is responsible ("owns") the system tend to have better success." [44]

"Legacy equipment creates large customized network hardware and practices, which are both difficult to change." [46]

Continue to evaluate dust collector systems to ensure they are effective. [32]

Formal integrity program – but there is only so much you can do with older machines that didn't have dust control in mind when they were built. [56]

Dust fires tend to start outside the process. Explosions start inside the process. [42]

Dust collection systems often neglected and undermaintained (p. 6). Lack of experience with them can be intimidating. Regarded as 'big vacuum cleaners'. [17]

"The full operation and performance understanding of dust collection systems is quite often limited or absent at a plant level leading to an 'I don't know, so I won't touch it' or 'someone else's problem' regard for these systems." [17]

"Dust collectors can be dirty, hazardous and awkward to work on; generally uninviting." [17]

Heighten the urgency for better safety methods/measures. [52 – see Jarod Diamond]

"To maintain the equipment are carried out preventative maintenance, however, some failures occur, and these failures cause us to have much problem with excess dust in the environment." [24]

B. Quotes & Ideas from Call to Action Responses

TOPICS REQUIRING FURTHER RESEARCH

"The NFPA has no record of a facility that fully conformed to the combustible dust standards having a dust explosion." [38]

Current level of 1/32 or .8mm is not a conservative rule of thumb. Most dusts with MEC below 125 g/m3 could form deflagrations at layers half that amount. However, catastrophes occurred where layers were measured in inches. [38]

Combustible dust and its variability have not been studied as much as flammable liquids and gasses. [13]

No current way to compare dust explosion frequency in parts of the world that are regulated. Need world-wide comparison. [40]

History has shown that these events run in cycles, where intensive efforts are applied, followed by a great reduction. Once everyone relaxes their guard, the problem reappears. [34A]

Does Europe have laws in place that regulate dust differently? Is their rate of explosion lower? [35]

The European standard is different than U.S. – EU is .3mm less than U.S. [39]

The grain industry has self-initiated and self-funded their improvements and research, which is reflected in their improved safety record. [49B]

"Since 2010, both the refining and petrochemical industries have reduced the process safety event incident rate by approximately 40%." [47 – gives link to metrics]

NFPA 652: DHA is a fundamental step in creating a plan to safeguard facilities. [16 – sense of security & safety? Is this working?]

Grain dust explosions decreased by 60% due to a standard, which was a combination of "industry research, education, training and government involvement." [49A]

Dust Hazard Learning Review

Prepared for the U.S. Chemical Safety and Hazard Investigation Board

by Dynamic Inquiry LLC
Ivan Pupulidy PhD and Crista Vesel MSc