Appendix C: Didion Dust Collector Calculations Analysis

In **Section 4.1.3**, the CSB concluded that Didion made several critical errors in calculating the dust concentrations inside their dust collectors, leading to the mistaken conclusion that the dust collectors did not contain explosive concentrations of combustible dust. This Appendix provides the details and technical basis behind these errors.

Dust Concentrations Inside Dust Collectors

As stated in **Section 4.1.3**, Didion calculated the concentration of dust particles in the transport air supply to its dust collectors, rather than inside the dust collectors themselves. A dust collector is designed to collect the finest particles in the highest concentrations. This discrepancy caused Didion to underestimate the dust concentration inside their dust collectors.

As an example, the Dry Grit Filter calculations used a concentration measured or calculated in a steady-state, providing a total solids flow of 17,500 lb/hr. Dividing this total solids flow by the measured clean air flow of 63,549 actual cubic feet per minute (acfm) (**Figure C-1**) gives a total solids concentration in a steady-state pipe, but does not account for pulse events when the dust collector goes through its normal self-cleaning cycle. During these normal pulsing events, dust concentration is much more dependent on the dust particle size adhered to the filter cloth. This particle size is not known from measuring particle size distribution in process streams input to or output from the dust collector itself, but from measuring particle size of material adhered to the filter media.

From nclabor.com page 11 table 1	http://www.nclabor.com/osha/etta/indguide/ig43.pdf				
Lower explosive limit for corn dust.					
55	grams/M3				
Granulation	1	2	3	Average	NFPA 61
40 Wire	95.2%	96.0%	93.2%	94.8%	
Pan	4.8%	4.0%	6.8%	5.2%	
Material flow					
17500	Lb/hr gross mass flow rate thru 6 filters				
910	Lb/hrflow rate of less than 40 wire				
910*453.59237=					
412,769.06	Grams/hr				
Air flow					
63549	acfm				
63549*0.028316846592*60=					
107970	cubic meters/hr				
412769.06	/107970.437=				
3.82	grams/M3				
7.0%	Percentage of lower explosive limit.				

3.3 General Definitions.

3.3.1* Agricultural Dust. Any finely divided solid agricultural material 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

3.3.2* Air-Material Separator (AMS). A device designed to sepa-

Figure C-1: Example dust explosibility calculation for Dry Grit Filter (Credit: Didion)

The true concentration inside the dust collector during normal self-cleaning events is a difficult concentration to estimate accurately. Didion did not necessarily need to calculate the potential concentration during a pulsing event in any scenario. In fact, NFPA 652 *Standard on the Fundamentals of Combustible Dust* (2019 Edition) provides an example DHA which includes a dust collector. This example essentially recommends presuming an explosive atmosphere inside most dust collectors, rather than attempting to calculate that the concentration is not explosive:

> Usually such dust collection systems operate at dust loadings in the ducts in the range of 1 to 3 g/m^3; well below the 25 percent MEC range for most dusts. But this parameter must be verified and documented. So the ducts are probably not a deflagration hazard, but the dust collector's job is to concentrate that dust. So an ignitable concentration of dust within the dust collector is probably certain [46, p.64].

Therefore, in its dust collector calculations, Didion underestimated the dust concentration by using a concentration that was not representative of the true dust concentration inside the dust collectors and did not account for normal self-cleaning pulse events. Instead, Didion could have presumed an explosive dust concentration inside the dust collector during pulse events and mitigated the hazard accordingly.

Particle Size Data

In the example Didion calculation above for the Dry Grit Filter, Didion also used the assumption that any particles that measured greater than 425 microns in size could be safely ignored. Accordingly, Didion only counted 5.2% of the total solids in the concentration calculated inside the dust collector, used to compare to MEC, on the basis that 94.8% of the material was larger than 425 microns (**Section 4.1.3**).

However, Didion's reported particle size was likely much larger than the material inside the Dry Grit Filter. The CSB independent testing indicated that material in other, similar dust collectors at the mill facility exhibited much smaller particle sizes. Didion's own calculations for other dust collectors also used much smaller average particle sizes. **Table C-1** shows this discrepancy in various sample particle sizes.

Table C-1: Particle Size Comparisons of Didion Materials (Credit: CSB, Didion, OSHA)

Sample Location	Source	% of sample under 425 (microns)
Torit Filter	CSB Independent Testing (as received)	97.7
Torit Filter	Didion Calculations reported to OSHA	24.1
4D Filter	CSB Independent Testing (as received)	100
4D Filter	Didion Calculations reported to OSHA	100
6A Filters (collectively)	Didion Calculations reported to OSHA	97.7
Dry Grit Filter	Didion Calculations reported to OSHA	5.2

Whatever the true particle size inside the Dry Grit Filter, or any filter, the assumption that the particle size is stable and cannot be reduced by attrition as it is transported to or inside the dust collector is not valid. At the time much of the Didion mill facility was designed and built, NFPA 650 *Standard for Pneumatic*

Conveying Systems for Handling Combustible Particulate Solids (1998 edition) guidance pointed this out:[a]

> [I]t is crucial to address the fact that there is attrition of the material as it is conveyed. Pieces and particles rub against each other and collide with the walls of the duct as they travel through the system. This breaks the material down and produces a mixture of pieces and much finer particles, called "dusts". Consequently, we should expect every conveying system to produce dusts as an inherent byproduct of the conveying process, regardless of the starting size of the material.

Even with all the other dust collector calculation issues identified still in place, had Didion instead assumed that all the dust in the Dry Grit Filter system could become smaller than 425 microns at some point through attrition, process changes, or upsets, their calculations would have shown that the Dry Grit Filter reached 134% of MEC.[b] Reaching the conclusion that the Dry Grit Filter did contain a combustible atmosphere would only have required this one change in Didion's calculations.[c]

In its dust collector calculations, Didion underestimated the dust concentration by discounting any material they deemed larger than 425-micron particle size. Didion did not account for the potential of attrition or process changes decreasing particle size, affecting calculations and making it more likely to be a combustible atmosphere than anticipated. Instead, Didion could have calculated that an explosive dust concentration existed inside the dust collector(s) by considering all the dust rather than only the dust they considered under 425 microns, or simply presumed that an explosive dust concentration existed, and mitigated the hazard accordingly.

Flammability of Larger Particles

Discounting any dust particles larger than 425 microns is dangerous not only for the reasons stated above regarding calculations and particle attrition but also because fines in a stream of larger solids could make the larger particles more likely to burn. In essence, once the fine dust is burning, it creates an immediate ignition source for all other materials, regardless of particle size. Assuming otherwise creates an arbitrary barrier at 425 microns, above which the material is no longer combustible at all and can be treated as if it does not exist. In reality, particles larger than 425 microns are combustible, particularly so if smaller particles are present. Smaller or smoldering particles act as an ignition source for larger particles, which then also participate in the combustion reaction. At the time Didion's dust collector calculations were performed, NFPA Standards generally no longer defined combustible dust by particle size, but simply defined combustible dust as a "finely divided combustible particulate solid that presents a flash fire hazard or explosion hazard when suspended in air […] over a range of concentrations".

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[a] While NFPA 650 was withdrawn in 2000 and relevant content was transferred into NFPA 654, similar guidance still exists in NFPA 654 (2017 and 2020 editions) section A.3.3.6, p. 30 and section A.3.3.7, respectively.

[b] By simply inserting 100% into Didion's calculation, in place of the 5.2% of the total solids actually counted in the Didion calculation submitted to OSHA. See **Figure C-1**.

[c] Although the calculations would still have been incorrect for all the other reasons mentioned here, this would at least have led Didion to conclude that the hazard existed.

Didion did not properly assess the potential hazard of combustible particles larger than 425 microns that could contribute to a fire or deflagration within the dust collection systems or processing equipment. The failure to consider these particles as contributory to deflagration resulted in an inadequate dust concentration calculation and a false sense of security with the existing system.

Influence of Process Changes or Upsets

Didion's dust collector calculations included one concentration calculation for each dust collector and compared that concentration to MEC. Each dust collector's concentration was calculated at only one set of conditions that represented normal operation at steady state. Thus, if any process upset, change in characteristic particle size due to process changes or equipment changes upstream of the dust collector occurred, that concentration was no longer representative of dust collector feed conditions. After the 2013 calculations were presented to OSHA, there is no evidence that Didion ever revisited those calculations or airflow measurements to verify that the 2013 calculations were still valid, and that dust collector performance or process conditions had not changed.

In its dust collector calculations, Didion only considered normal, steady-state operating conditions, and never considered upset conditions or any process changes that could have changed dust concentration or particle size. Instead, Didion could have analyzed the dust collectors' calculations each time a change was made upstream of the dust collectors, and periodically monitored dust collector performance to verify that their calculations had used valid input.

Accumulation in Dust Collectors

Since Didion's dust collector calculations were solely based on the combustible dust concentration in the supply ductwork at normal steady-state conditions, any accumulation that occurred in the system could not have been accounted for. After the 2013 calculations were presented to OSHA, there is no evidence that Didion ever tested this assumption of zero dust accumulation in the dust collector systems by examining the interior of the ductwork or the dust collectors. As discussed in **Section 4.1.6**, Didion provided no evidence of periodic testing, inspection, or cleaning for any of its dust collectors or associated ductwork to ensure no material buildup occurred in the dust collectors or supplying ductwork.

For ductwork requirements in exhaust systems such as in Didion's dust collection systems, NFPA 61 *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities* (2017 Edition) referenced NFPA 91 *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids* (2015 Edition). NFPA 91 contains requirements for dust collection systems, such as:

> Exhaust systems shall be tested, inspected, and maintained to ensure safe operating conditions. […] When installation of a new system is complete, the system shall be tested to demonstrate performance before acceptance by the user. Modified systems shall be retested. […] Existing systems shall be tested annually by the user to demonstrate continued performance. Where the manufacturer's requirements are more stringent or where conditions of service and documented past test results dictate, testing

> frequencies shall be permitted to be adjusted accordingly, but not to exceed every 2 years. […] All system components shall be inspected monthly. When the manufacturer's requirements are more stringent or where conditions of service and documented past inspection results dictate, inspection frequencies shall be permitted to be adjusted accordingly, but not to exceed quarterly. […] Accumulations of conveyed materials and residues shall be removed from hoods and enclosures, ducts and fittings, and air-moving devices. Ductwork shall be examined periodically to determine adequacy of cleaning frequency [49, p.14].

These requirements first appeared in the 2013 edition of NFPA 61, by referencing the 2010 edition of NFPA 91, and were identical to the requirements above.

In its dust collector calculations, Didion only considered normal, steady-state operating conditions, and did not inspect for dust accumulations inside the dust collectors or ductwork, or any changes that could have caused combustible dust accumulation. Instead, Didion could have analyzed the dust collector calculations each time a change was made to dust collection systems, and periodically monitored dust collector performance to verify that their calculations had used valid input by inspecting ductwork for dust accumulations, measuring airflows in the system, and sampling materials inside the dust collectors to verify particle size distribution.