Combustible Dust Test Report

Didion Milling Dusts

8480 PR Bran C170651M, 4300 Flour C17159K, Torit Sample #1, D4 Flex Kleen Filter EFI 9067, Coarse Grinder B EFI 466

Final Report to:
Mr. William Hougland
Mechanical Engineer/Investigator
U.S. Chemical Safety and Hazard Investigation Board
1750 Pennsylvania Ave NW
Suite 910
Washington DC 20006

Report No.: ioK18065-2
Date: August 10, 2018

AT-1922

Table of Contents

Appendices

List of Tables

List of Figures

Executive Summary

This report presents the results of dust explosibility measurements performed on five dust samples received from the U.S. Chemical Safety and Hazard Board. The dust samples were taken from various locations of the Didion Milling site in Cambria, Wisconsin. The samples were labeled as follows:

1. 8480 PR Bran C170651M
2. 4300 Flour C17159K
3. Torit Sample #1
4. D4 Flex Kleen Filter EFI 9067
5. Coarse Grinder B EFI 466

The materials were all determined to be explosible with an explosibility classification of St-1. These tests are accredited under laboratories ISO 17025 by ANAB.

Table of Test Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
Max Explosion P (bar)	8.2	8.1	8.1	8.8	8.3
Max Rate of P Rise (bar/s)	506	546	583	587	453
K_{St} Value (m·bar/s)	137	148	158	159	123
C_W (g/m³)	1000	750	500	1000	750
MEC (g/m³)	60 < MEC < 75	70 < MEC < 80	70 < MEC < 80	70 < MEC < 80	70 < MEC < 80
MIE (mJ)	30 < MIE < 100	30 < MIE < 100	10 < MIE < 30	10 < MIE < 30	10 < MIE < 30
MAIT (°C)	350 < MAIT < 360	370 < MAIT < 380	360< MAIT < 370	350 < MAIT < 360	360 < MAIT < 370
HSIT (°C)	250 < HSIT < 260	270 < HSIT < 280	*	270 < HSIT < 280	260 < HSIT < 270
Moisture Content (wt%), as received	7	11	12.3	>15	>15
Moisture Content (wt%), as tested	3.08 – 4.02	3.55 – 4.72	3.77 – 4.51	4.00 - 4.59	3.97 – 4.65
Particle size distribution, percentage less than 75 µm, as received	52.9%	48.2%	71%	85.9%	N/A**
Particle size distribution, percentage less than 75 µm, as tested	95.7%	98.8%	96.6%	98.1%	95.3%
Bulk density (g/cm3)	0.341	0.422	0.407	0.494	0.489

*Not enough sample to complete HSIT

**Sample particles were too big for laser particle size analysis

1 Test Results

As requested by the U.S. Chemical Safety and Hazard Board, dust characterization tests were completed on five dust samples to determine the extent of potential dust explosion hazards. The samples were labeled:

1. 8480 PR Bran C170651M (Bran)
2. 4300 Flour C17159K (Flour)
3. Torit Sample #1 (Torit)
4. D4 Flex Kleen Filter EFI 9067 (Flex Kleen Filter)
5. Coarse Grinder B EFI 466 (Coarse Grinder)

The tests conducted were as follows:

- Moisture Content Analysis
- Particle Size Analysis
- Explosion Severity, K_{St}, P_{max} and dP/dt_{max}, of a Dust Cloud
- Minimum Explosible Concentration (MEC) of a Dust Cloud
- Minimum Ignition Energy (MIE) of a Dust Cloud
- Minimum Auto Ignition Temperature (MAIT) of a Dust Cloud
- Hot Surface Ignition Temperature (HSIT) of a Dust Layer

These tests are accredited under laboratories ISO 17025 by ANAB. Refer to certificate Number AT-1922 found on ANAB's and ioKinetic's websites.

The results are presented below. Complete data sets are included in Appendix B. Test descriptions are included in Appendix C. The values obtained are specific to the samples tested, the method applied, and the test equipment used. The values are not to be considered intrinsic material properties. Any change in particle size, shape, volatility, or moisture will impact the results.

1.1 Particle Size, Moisture Content, and Bulk Density

ASTM recommends that dust testing be performed on samples with a moisture content less than 5% and a particle size of 95% less than 75 µm. The CSB requested that samples be prepared to the ASTM recommendations.

For moisture content, analysis of the as-received samples indicated that each sample exceeded 5% moisture content. To reduce the moisture content, the dusts were dried at 60°C under vacuum. The as received and as tested moisture content of each sample are presented in Table 1.

For particle size, analysis of the as-received samples indicated a particle size distribution larger than the recommended 95% less than 75 µm. Both sieving and grinding were employed to reduce the particle size distribution. The Bran, Flour, Torit, and Coarse Grinder samples were ground and sieved to reduce the particle size distribution. The Flex Kleen Filter sample was sieved to reduce the particle size distribution. The as received and as tested particle sizes are presented in Table 1.

To measure the bulk density, the dust was 'fluffed' in a bag by stirring it a few times. The scale was tared with a copper cylinder and a weighing pan. The cylinder has a radius of 2.1 cm and height of 3.1 cm for a volume of 42.95 cm^3. The copper cylinder was placed on a tray and the dust was poured into it. A spatula was used to level the dust taking care to not press the dust into the cylinder to maintain 'bulk' characteristics. The filled cylinder was inverted onto the weighing pan. The dust was weighed in the cylinder on the weighing pan. The bulk density was found by dividing the mass by the volume of the cylinder. The densities applied in the MAIT tests on Bran, Flour, Torit, and Flex Kleen Filter were measured using a simpler approach to find an approximate density. In that measurement, the dust was poured into a graduated cylinder up to the 5 mL line. The cylinder was tapped on the side to level the dust layer. The density was calculated by dividing the weight of the dust by the 5 mL volume.

Table 1: Moisture Content, Particle Size, and Bulk Density Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
Moisture Content (wt%), as received	7	11	12.3	>15	>15
Moisture Content (wt%), as tested	3.08 – 4.02	3.55 – 4.72	3.77 – 4.51	4.00 - 4.59	3.97 – 4.65
Particle size distribution, percentage less than 75 µm, as received	52.9%	48.2%	71%	85.9%	N/A*
Particle size distribution, percentage less than 75 µm, as tested	95.7%	98.8%	96.6%	98.1%	95.3%
Bulk density (g/cm^3)	0.341	0.422	0.407	0.494	0.489

*Sample particles were too big for laser particle size analysis

1.2 Explosion Severity

Explosion severity testing is conducted to determine the magnitude of a possible explosion, defined as pressure generation and pressure generation rate. In this study, each sample was measured to be explosible with an explosibility classification of St-1. The measured K_{St}, P_{max}, dP/dt_{max}, and C_W values are presented in Table 2.

Table 2: Explosion Severity Test Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
Max Explosion P (bar)	8.2	8.1	8.1	8.8	8.3
Max Rate of P Rise (bar/s)	506	546	583	587	453
K_{St} Value (m·bar/s)	137	148	158	159	123
C_W (g/m^3)	1000	750	500	1000	750

Any non-zero value for K_{St} indicates a sample is explosible.

The values measured can be used to design deflagration vents in accordance with NFPA 68.

1.3 Minimum Explosible Concentration (MEC)

The minimum explosible concentration (MEC) test provides an estimate of the minimum concentration of a combustible dust suspended in air that will support a deflagration. The measured MEC values are presented in Table 3.

The ranges listed represent the lowest concentration where ignition was observed and the highest concentration where ignition was not observed. Testing was conducted throughout a range of concentrations until a concentration was found where ignition does not occur. Two repeat series are conducted to confirm the MEC range.

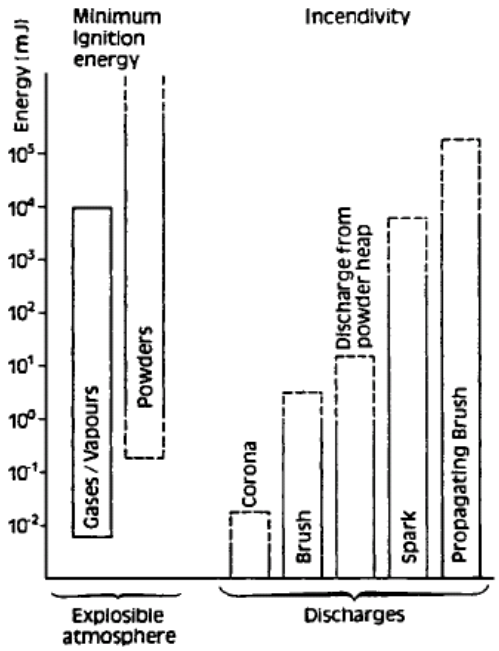
Table 3: Minimum Explosible Concentration Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
MEC (g/m^3)	60<MEC<75	70<MEC<80	70<MEC<80	70<MEC<80	70<MEC<80

1.4 Minimum Ignition Energy (MIE)

The minimum ignition energy (MIE) test determines the amount of energy required to ignite a dust cloud in air. Two of the dusts where found to have ignition energies between 30 and 100 mJ while the other three were found to be between 10 and 30 mJ. Ignition energies in these ranges indicate the dusts pose an electrostatic ignition hazard (refer to Figure 1 and Table 4). The results of MIE testing are presented in Table 5.

Figure 1: MIE Verses Type of Discharges



Source: Eckhoff, "Dust Explosions in the Process Industries"

Table 4: Ignition Probability Based on MIE

Flammable Hybrid Mixture or Dust with:	Ignition Sources	Ignition Probability
MIE < 4 mJ	Almost all ignition sources, including brush discharges	Imminent
4 < MIE < 10 mJ	Most ignition sources, probably not brush discharges	Very probable
10 < MIE < 100 mJ	Some electrostatic discharges	Less probable
100 < MIE < 1,000 mJ	Only very intensive electrostatic discharges	Not probable
MIE > 1,000 mJ	Only extremely intensive electrostatic discharges (lighting)	Not probable

Table 5: Minimum Ignition Energy Test Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
MIE (mJ)	30<MIE<100	30<MIE<100	10<MIE<30	10<MIE<30	10<MIE<30

1.5 Minimum Auto-Ignition Temperature (MAIT)

The minimum auto-ignition temperature (MAIT) test determines the lowest temperature at which a dust cloud will auto ignite when exposed to air heated in a furnace at local atmospheric pressure. The results of MAIT testing are presented in Table 6.

The test data developed can be used to help define a limit temperature for dust cloud exposure. The data is most applicable to processes where dust clouds are present for a short time.

Table 6: Minimum Auto-Ignition Temperature Test Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
MAIT Cloud (ºC)	350 < MAIT < 360	370 < MAIT < 380	360< MAIT < 370	350 < MAIT < 360	360 < MAIT < 370

1.6 Hot Surface Ignition Temperature (HSIT)

The hot surface ignition temperature (HSIT) test determines the minimum temperature that a dust layer will ignite and burn when exposed to air. The results of HSIT testing are presented in Table 7.

Note that there was not enough sample supplied of Torit to complete this test.

The HSIT data can be used to define limits for dust layer exposure to high temperature surfaces. The data is most applicable to hot surfaces where dust accumulates into a layer.

Table 7: Hot Surface Ignition Temperature Test Results

Parameter	8480 PR Bran C170651M	4300 Flour C17159K	Torit Sample #1*	D4 Flex Kleen Filter EFI 9067	Coarse Grinder B EFI 466
HSIT Layer (ºC)	250 < HSIT < 260	270 < HSIT < 280	-	270 < HSIT < 280	260 < HSIT < 270

*Not enough sample to complete HSIT

2 Conclusions

The measured K_{St} value for each sample categorizes them as explosible dusts with explosibility classification of St-1, comparable to dusts which are considered to be energetic. St-1 corresponds to K_{max} values between 0 and 200 m*bar/s. The sample with the highest measured K_{St} was Flex Kleen Filter with a value of 159 m*bar/s. This sample also gave the highest value for P_{Max} of 8.8 bar. The lowest measured value for K_{St} was 123 m*bar/s for the Coarse Grinder. The materials present explosion and deflagration hazard risks when dispersed and ignited in air. Once an initial explosion occurs, there is a risk of secondary explosions with the presence of a combustible dust or powder in the area.

The measured MIE value was between 30 and 100 mJ for the Bran and Flour samples and between 10 and 30 mJ for the Torit, Flex Kleen Filter, and Coarse Grinder samples. Each dust poses a hazard where sources of electrostatic sparks are present. Appendix D provides some general guidance on protections for unit operations as a function of measured MIE values of a material.

The measured MEC value was found to be between 60 and 75 g/m^3 for the Bran and between 70 and 80 g/m^3 for the other four samples. This again demonstrates that the dusts had similar behavior during testing. Dust clouds of concentrations above 60 g/m^3 for the Bran and 70 g/m^3 for the other four samples pose a risk of explosion where ignition sources are present.

The measured MAIT range was found to be 350°C to 360°C for the Bran and Flex Kleen Filter samples, 360°C to 370°C for the Torit and Coarse Grinder samples, and 370°C to 380°C for the Flour sample. Precautions should be taken in areas where equipment surfaces may reach this temperature.

The measured HSIT ranges varied slightly between samples. For the Bran, the HSIT was found to be between 250°C and 260°C. The Coarse Grinder gave a range of 260°C to 270°C. For the Flour and Flex Kleen Filter samples, the range was 270°C to 280°C. The Torit sample HSIT was not determined due to a limited amount of sample. Dust should not be allowed to accumulate on any surfaces that may reach these temperatures.

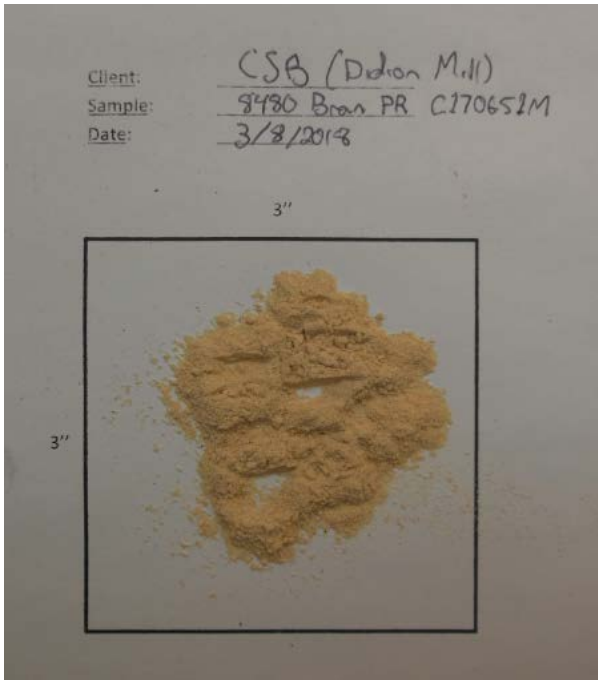
With combustible dusts, initial dust explosion prevention steps include full containment of the dusts to areas that are properly designed and located, preventing ignition sources and ensuring any equipment handling a combustible dust is designed in accordance to recognized and generally accepted good engineering practices (RAGAGEPs).

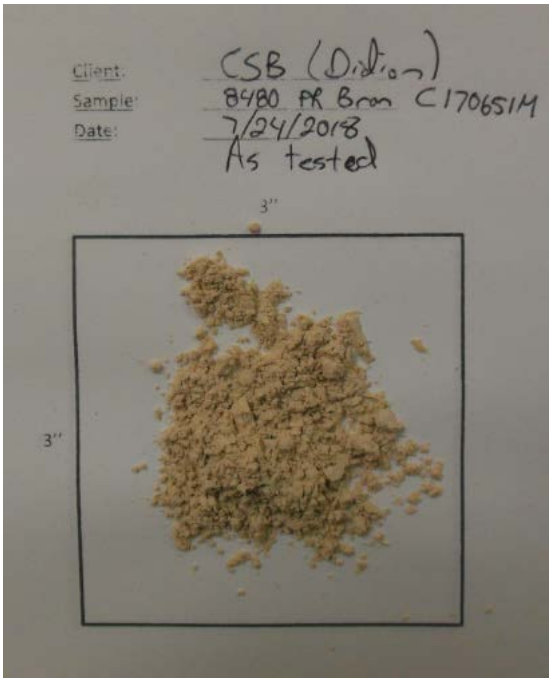
NFPA 652, 61, 68, 69, and 77 should be consulted for ignition prevention and explosion mitigation strategies for agricultural materials. These strategies can include completion of dust hazards

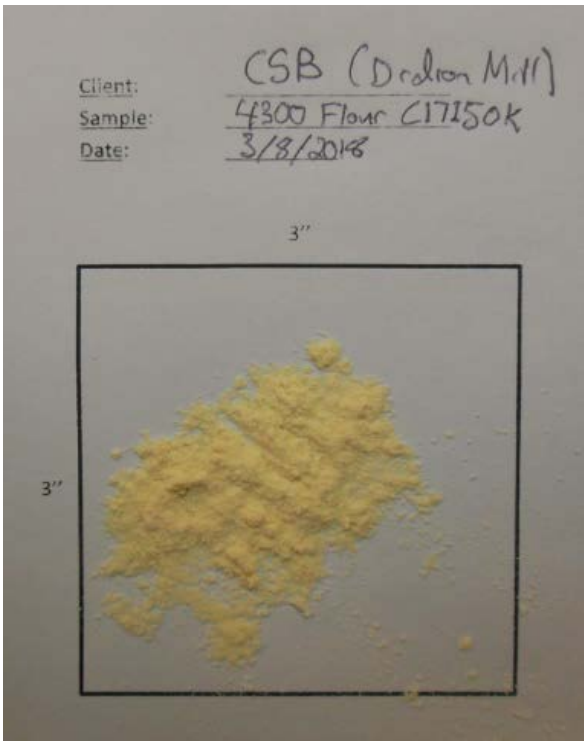
analyses, development of management of change procedures as well as implementation of specific prescriptive requirements or performance-based requirements.

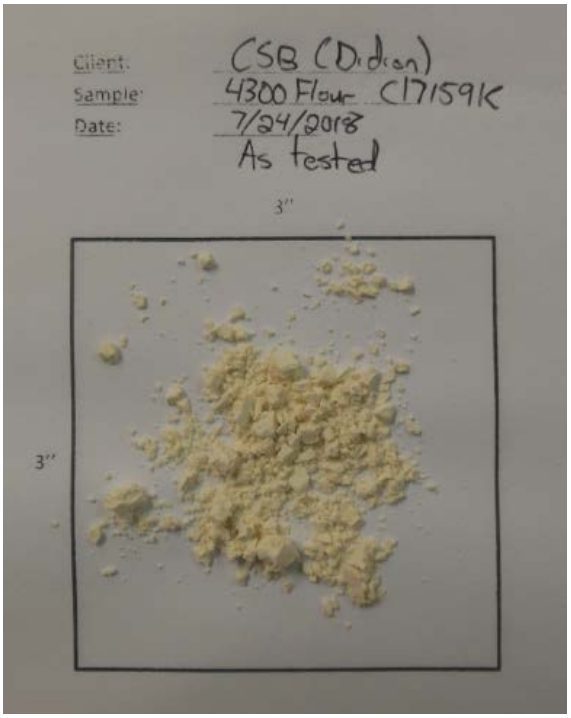
Note: If a process is changed in such a way that either the composition of the sample or the statistical distribution of the particles sizes is altered, the new material should be tested as the explosibility of the material may have changed.

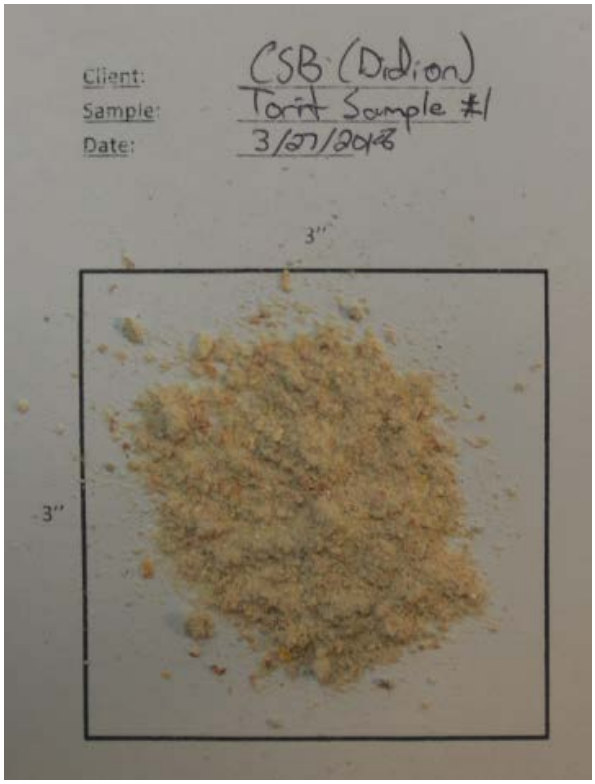
Appendix A: Sample Photos

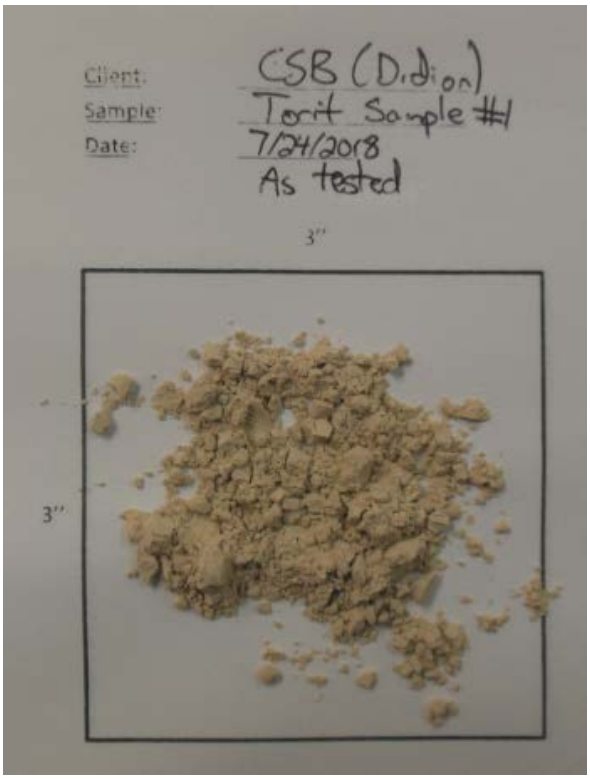


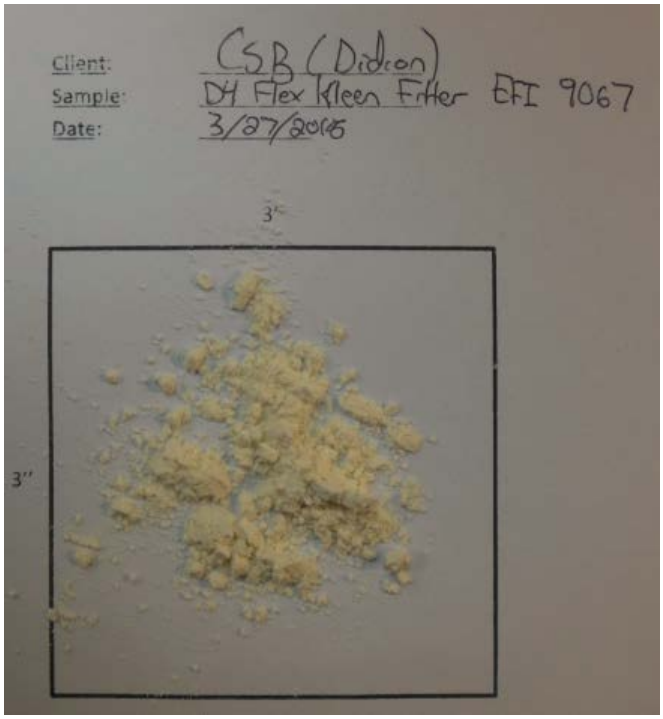


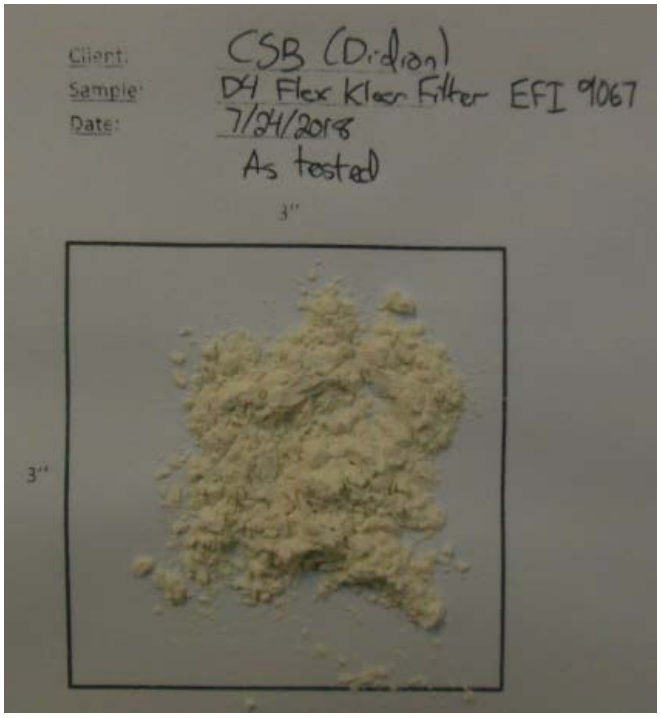


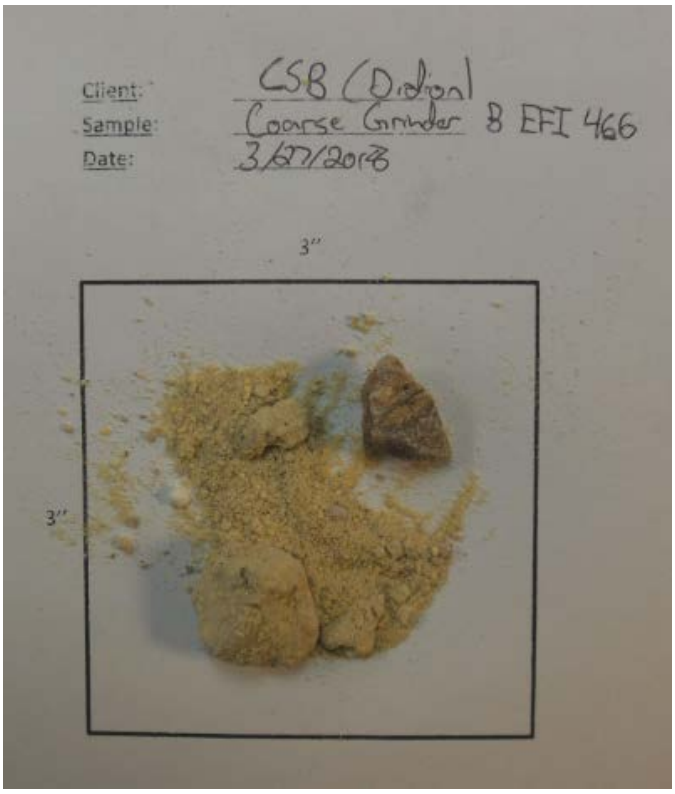


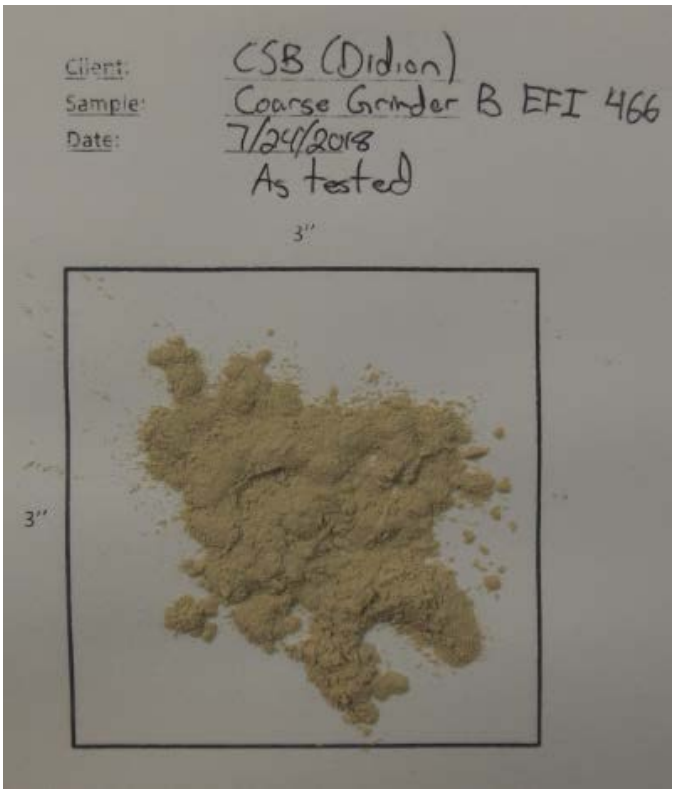












Appendix B: Test Data Reports

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

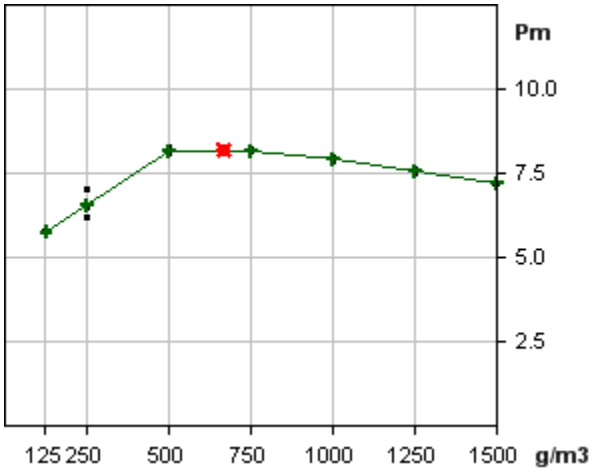
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

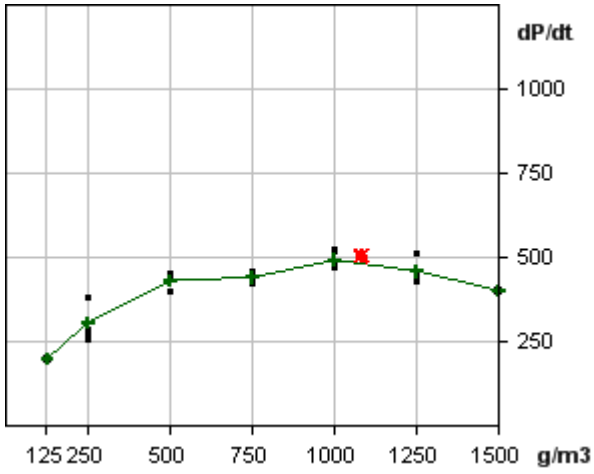
ioKinetic - Salem, NH

Sample:	**Bran 8480 PR C170651M**
Customer:	CSB
Reason:	KSt Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.71% < 75 micron, Mean Diameter: 32.48 micron

Explosion Characteristics

Max. explosion pressure:	Pmax	=	**8.2**	bar	± 10%
Max. rate of pressure rise:	(dP/dt)max	=	**506**	bar / s	± 12%
Product specific constant:	Kmax	=	**137**	m·bar / s	± 12%





Room Temperature: 21.2 C
Relative Humidity: 27.3 %
Barometric Pressure: 1006 mbar
Moisture Content: 3.08 %
Technician: CBarrett
Date: 04/30/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: Pmax, Kmax **Bran 8480 PR C170651M**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
2	1	250	6.2	258	60
3	1	500	**8.3**	454	60
4	1	750	8.2	421	60
5	1	1000	7.9	**488**	60
6	1	1250	7.6	443	60
7	1	1500	7.2	402	60
8	1	125	5.8	199	60
9	2	250	6.5	283	60
10	2	500	8.1	400	60
11	2	750	**8.1**	444	60
12	2	1000	7.9	**520**	60
13	2	1250	7.5	428	60
14	3	250	7.0	381	60
15	3	500	8.1	441	60
16	3	750	**8.2**	458	60
17	3	1000	8.0	469	60
18	3	1250	7.6	**510**	60

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

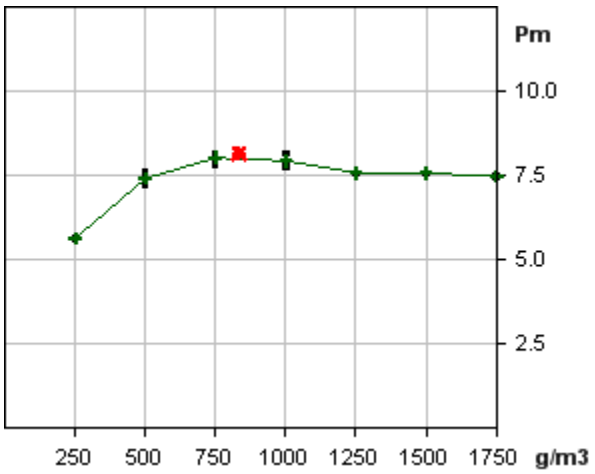
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

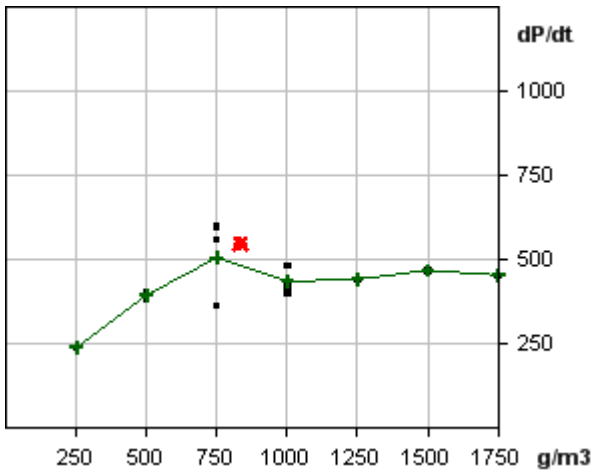
ioKinetic - Salem, NH

Sample:	**4300 Flour C17150K**
Customer:	CSB
Reason:	KSt Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.80% < 75 micron, Mean Diameter: 22.74 micron

Explosion Characteristics

Max. explosion pressure:	Pmax	=	**8.1**	bar	± 10%
Max. rate of pressure rise:	(dP/dt)max	=	**546**	bar / s	± 12%
Product specific constant:	Kmax	=	**148**	m·bar / s	± 12%





Room Temperature: 23.1 C, 22.7 C
Relative Humidity: 64.9 %, 31.1 %
Barometric Pressure: 1002 mbar, 1011 mbar
Moisture Content: 4.38 %, 4.65 %
Technician: CBarrett
Date: 06/02/2018, 06/03/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: Pmax, Kmax 4300 Flour C17150K

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
3	1	250	5.6	239	60
4	1	500	7.6	396	60
6	1	750	**8.1**	**558**	60
7	1	1000	7.8	424	60
8	1	1250	7.6	441	60
9	1	1500	7.6	468	60
10	1	1750	7.5	454	60
11	2	500	7.4	382	60
12	2	750	7.8	362	60
14	2	1000	**8.2**	**481**	60
15	3	500	7.2	406	60
16	3	750	**8.1**	**598**	60
17	3	1000	7.9	401	60

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

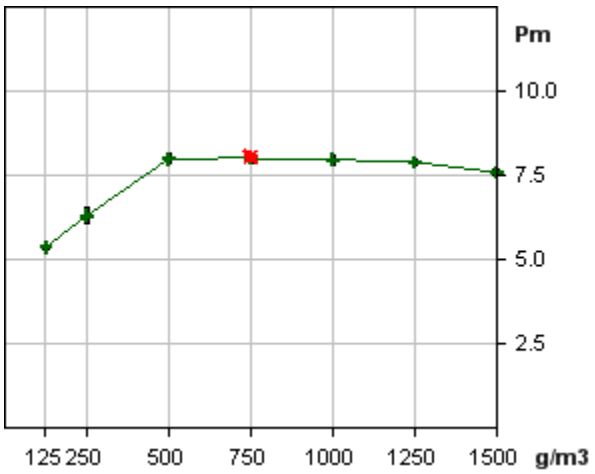
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

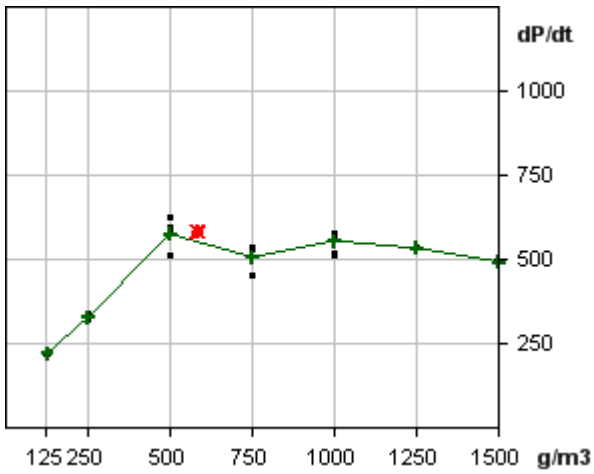
ioKinetic - Salem, NH

Sample:	**Torit Sample #1**
Customer:	CSB
Reason:	KSt Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 96.56% < 75 micron, Mean Diameter: 26.05 micron

Explosion Characteristics

Max. explosion pressure:	Pmax	=	**8.1**	bar	± 10%
Max. rate of pressure rise:	(dP/dt)max	=	**583**	bar / s	± 12%
Product specific constant:	Kmax	=	**158**	m·bar / s	± 12%





Room Temperature: 20.6 C, 22.9 C
Relative Humidity: 52.4 %, 54.2%
Barometric Pressure: 1003 mbar, 1003 mbar
Moisture Content: 4.24 %, 4.24 %
Technician: CBarrett
Date: 06/20/2018, 06/21/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: Pmax, Kmax **Torit Sample #1**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
2	1	250	6.1	320	60
3	1	500	**8.1**	**626**	60
4	1	750	**8.1**	536	60
5	1	1000	8.0	575	60
6	1	1250	7.9	534	60
7	1	125	5.4	222	60
8	1	1500	7.6	494	60
16	4	250	6.3	328	60
17	4	500	8.0	510	60
18	4	750	**8.1**	**531**	60
19	4	1000	7.9	515	60
20	5	250	6.5	339	60
21	5	500	7.9	**593**	60
22	5	750	7.9	454	60
24	5	1000	**8.0**	577	60

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

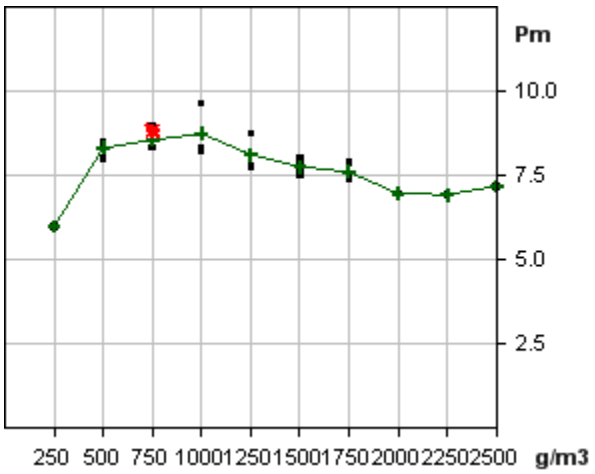
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

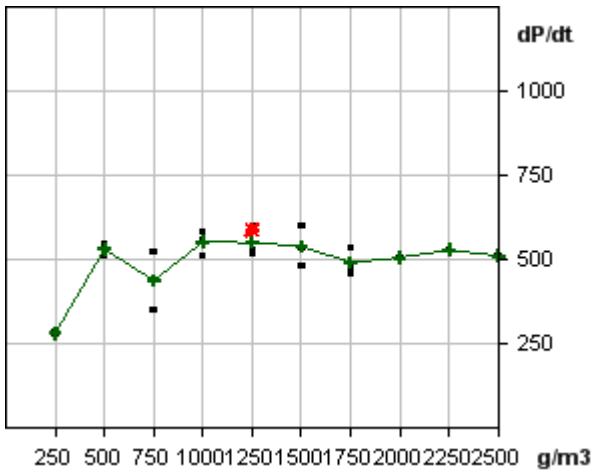
ioKinetic - Salem, NH

Sample:	**D4 Flex Kleen Filter EFI 9067**
Customer:	CSB
Reason:	KSt Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.07% < 75 micron, Mean Diameter: 24.24 micron

Explosion Characteristics

Max. explosion pressure:	Pmax	=	**8.8**	bar	± 10%
Max. rate of pressure rise:	(dP/dt)max	=	**587**	bar / s	± 12%
Product specific constant:	Kmax	=	**159**	m·bar / s	± 12%





Room Temperature: 21.1 C, 20.1 C, 23.4 C
Relative Humidity: 54.4 %, 73.3 %, 59.1 %
Barometric Pressure: 1010 mbar, 1003 mbar, 1009 mbar
Moisture Content: 4.36 %, 4.05 %, 4.00 %
Technician: CBarrett
Date: 06/27/2018, 06/28/2018, 07/01/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2

Tested by: CBarrett

Approved by: MRMurphy

Project Number: 18065

Dust: Pmax, Kmax **D4 Flex Kleen Filter EFI 9067**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
1	1	250	6.0	282	60
2	1	500	8.0	532	60
4	1	750	**8.3**	522	60
5	1	1000	8.2	512	60
6	1	1250	7.8	531	60
7	1	1500	7.8	**602**	60
8	1	1750	7.4	476	59
9	1	2000	7.0	506	60
10	1	2250	6.9	528	60
12	1	2500	7.2	512	60
13	2	500	8.4	515	60
14	2	750	9.0	350	60
16	2	1000	**9.6**	584	60
19	2	1250	8.8	**601**	60
20	2	1500	8.0	481	60
21	2	1750	7.9	462	60
23	3	500	**8.5**	547	60
24	3	750	8.3	441	60
25	3	1000	8.3	**559**	60
26	3	1250	7.8	520	60
27	3	1500	7.5	535	60
28	3	1750	7.6	536	60

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

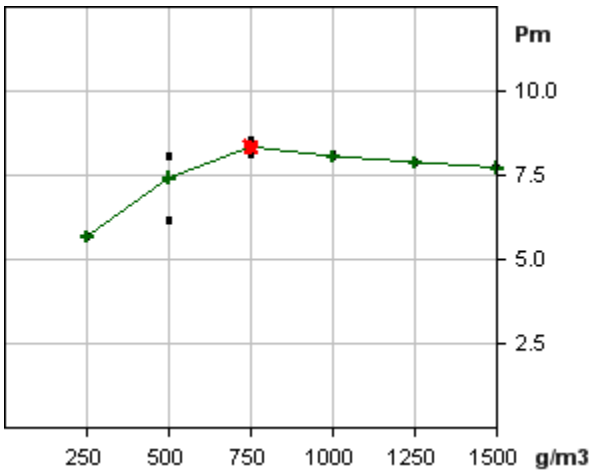
Report No.: ioK18065-2
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

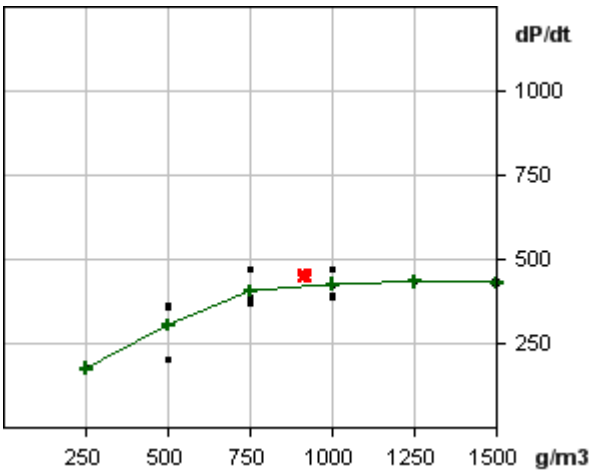
ioKinetic - Salem, NH

Sample:	**Coarse Grinder B EFI 466**
Customer:	CSB
Reason:	KSt Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.25% < 75 micron, Mean: 30.96 micron

Explosion Characteristics

Max. explosion pressure:	Pmax	=	**8.3**	bar	± 10%
Max. rate of pressure rise:	(dP/dt)max	=	**453**	bar / s	± 12%
Product specific constant:	Kmax	=	**123**	m·bar / s	± 12%





Room Temperature: 19.8 C, 20.4 C
Relative Humidity: 68.4 %, 50.7 %
Barometric Pressure: 1004 mbar, 1005 mbar
Moisture Content: 4.36 %, 4.52 %
Technician: CBarrett
Date: 07/17/2018, 07/18/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: Pmax, Kmax **Coarse Grinder B EFI 466**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
3	1	250	5.7	178	60
4	1	500	6.2	201	60
5	1	750	**8.5**	**469**	60
6	1	1000	8.0	389	60
7	1	1250	7.9	435	60
8	1	1500	7.7	432	60
9	2	500	8.1	357	60
10	2	750	**8.1**	383	60
11	2	1000	8.0	**470**	60
16	4	500	8.0	360	60
17	4	750	**8.4**	370	60
18	4	1000	8.1	**421**	60

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2

Tested by: CBarrett

Approved by: MRMurphy

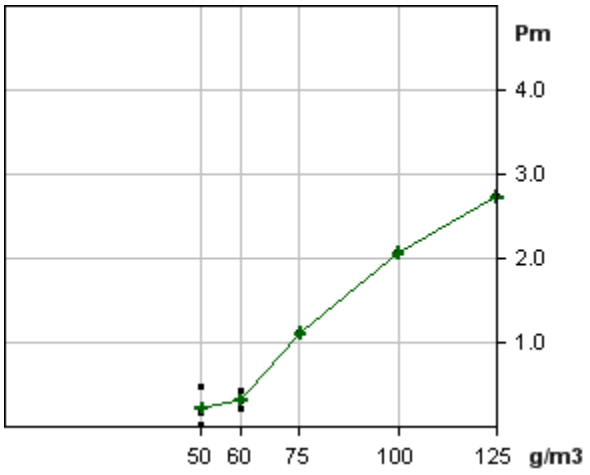
Project Number: 18065

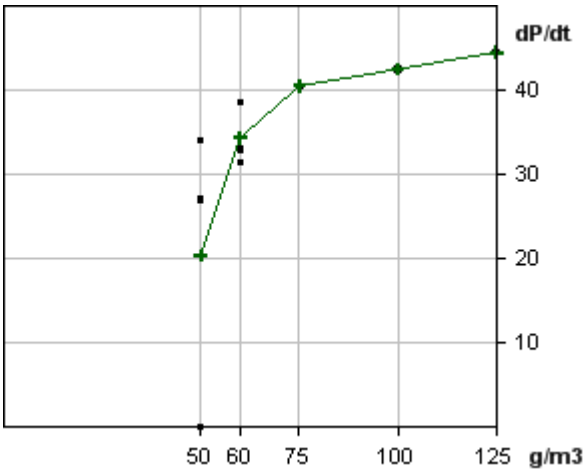
ioKinetic - Salem, NH

Sample:	**Bran 8480 PR C170651M**
Customer:	CSB
Reason:	MEC Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved Below 75 micron
Median value:	Particle Size: 95.71% < 75 micron, Mean Diameter: 32.48 micron

Explosion Characteristics

Minimum explosible concentration: **60 g/m3 < MEC < 75 g/m3** ± 10%





Room Temperature: 23.7 C
Relative Humidity: 28.9 %
Barometric Pressure: 1009 mbar
Moisture Content: 3.89 %
Technician: CBarrett
Date: 05/01/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: MEC **Bran 8480 PR C170651M**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
3	1	60	.3	33	60
4	1	125	**2.7**	**45**	60
5	1	100	2.1	43	60
6	1	75	1.1	41	60
7	1	50	.5	34	60
8	2	60	**.2**	**32**	60
9	2	50	.0	0	60
10	3	60	**.4**	**39**	60
11	3	50	.2	27	60

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

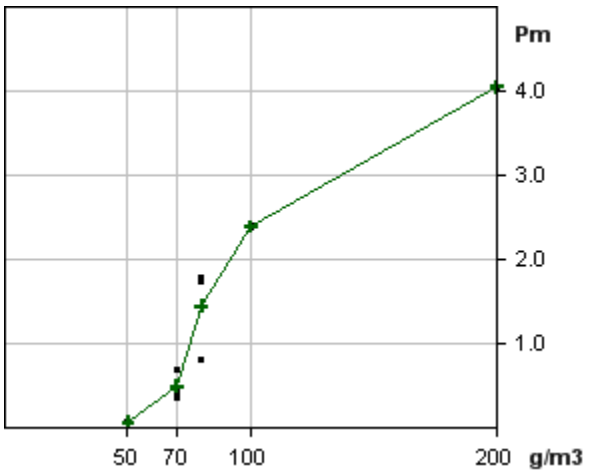
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

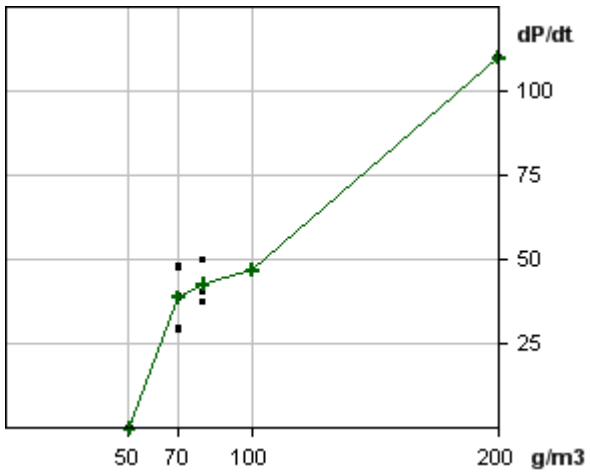
ioKinetic - Salem, NH

Sample:	**4300 Flour C17150K**
Customer:	CSB
Reason:	MEC Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.80% < 75 micron, Mean Diameter: 22.74 micron

Explosion Characteristics

Minimum explosible concentration: **70 g/m3 < MEC < 80 g/m3** ± 10%





Room Temperature: 23.8 C
Relative Humidity: 60.5 %
Barometric Pressure: 1001 mbar
Moisture Content: 3.55 %
Technician: CBarrett
Date: 06/02/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: MEC **4300 Flour C17150K**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
3	1	200	**4.0**	**110**	60
4	1	100	2.4	47	60
5	1	80	1.7	38	60
6	1	70	.4	48	60
7	1	50	.1	0	60
8	2	80	**.8**	**41**	60
9	2	70	.4	39	60
10	3	80	**1.8**	**50**	60
11	3	70	.7	30	60

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

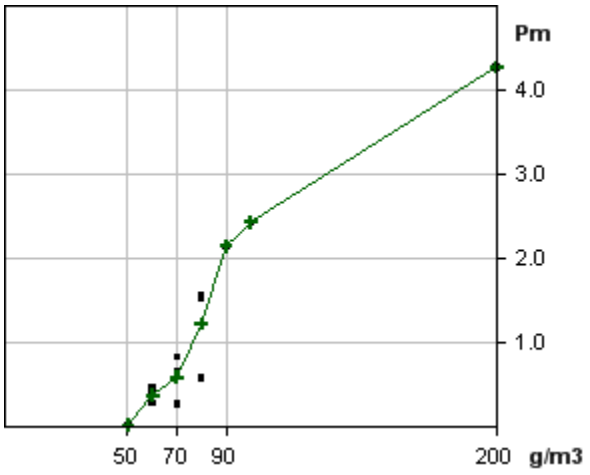
Report No.: ioK18065-2
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

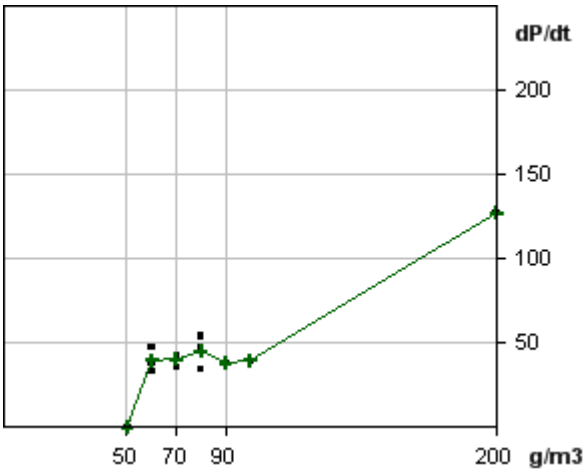
ioKinetic - Salem, NH

Sample:	**Torit Sample #1**
Customer:	CSB
Reason:	MEC Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 96.56% < 75 micron, Mean Diameter: 26.05 micron

Explosion Characteristics

Minimum explosible concentration: **70 g/m3 < MEC < 80 g/m3** ± 10%





Room Temperature: 23.4 C
Relative Humidity: 45.7 %
Barometric Pressure: 1006 mbar
Moisture Content: 3.77 %
Technician: CBarrett
Date: 06/20/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2

Tested by: CBarrett

Approved by: MRMurphy

Project Number: 18065

Dust: MEC **Torit Sample #1**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
5	1	200	**4.3**	**127**	60
6	1	100	2.4	40	60
7	1	80	.6	35	60
8	1	70	.7	42	60
9	1	50	.0	0	60
10	1	90	2.1	38	60
11	2	80	**1.6**	47	60
12	2	70	.8	43	60
13	2	60	.5	**48**	60
14	1	60	.4	33	60
15	3	80	**1.5**	**54**	60
16	3	70	.3	36	60
17	3	60	.3	39	60

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

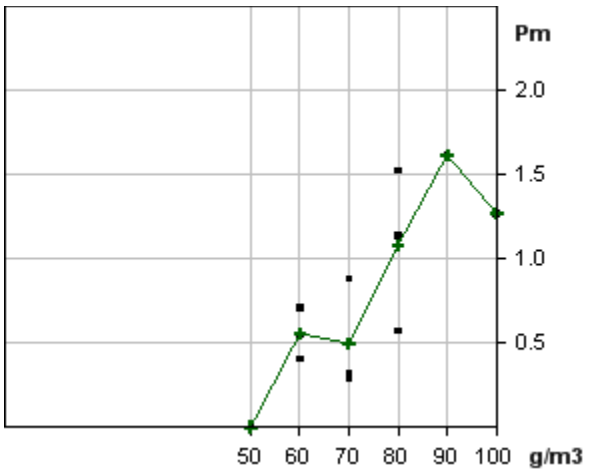
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

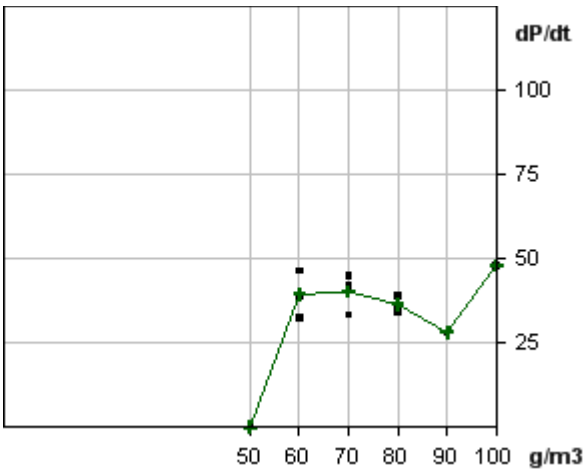
ioKinetic - Salem, NH

Sample:	**D4 Flex Kleen Filter EFI 9067**
Customer:	CSB
Reason:	MEC Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.07% < 75 micron, Mean: 24.24 micron

Explosion Characteristics

Minimum explosible concentration: **70 g/m3 < MEC < 80 g/m3** ± 10%





Room Temperature: 20.2 C
Relative Humidity: 58.4 %
Barometric Pressure: 1012 mbar
Moisture Content: 4.36 %
Technician: CBarrett
Date: 06/27/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: MEC **D4 Flex Kleen Filter EFI 9067**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
3	1	100	1.3	**48**	60
4	1	90	**1.6**	28	60
5	1	80	1.5	34	60
6	1	70	.9	45	60
7	1	60	.4	39	60
8	1	50	.0	0	60
9	2	80	**1.1**	**36**	60
10	2	70	.3	34	60
11	2	60	.6	33	60
12	3	80	.6	39	60
13	3	70	.3	42	60
14	3	60	**.7**	**47**	60

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

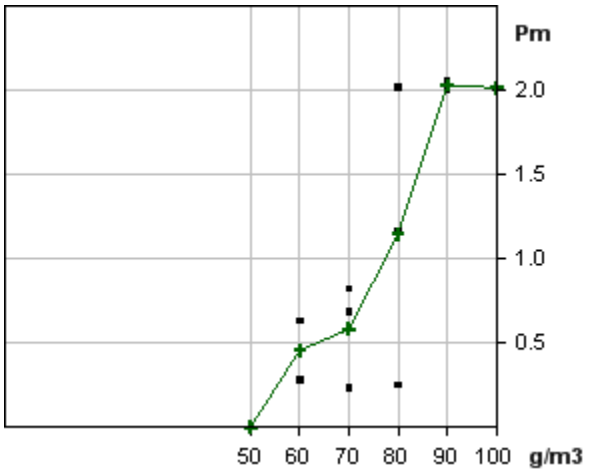
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

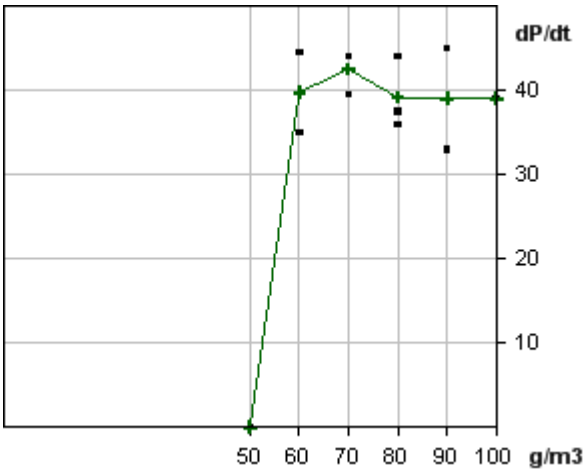
ioKinetic - Salem, NH

Sample:	**Coarse Grinder B EFI 466**
Customer:	CSB
Reason:	MEC Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.25% < 75 micron, Mean: 30.96 micron

Explosion Characteristics

Minimum explosible concentration: **70 g/m3 < MEC < 80 g/m3** ± 10%





Room Temperature: 23.5 C
Relative Humidity: 64.2 %
Barometric Pressure: 1008 mbar
Moisture Content: 3.97 %
Technician: CBarrett
Date: 07/16/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Dust: MEC **Coarse Grinder B EFI 466**

Test	Series	Conc. [g/m3]	Pm [bar]	dP/dt [bar/s]	tv eff [ms]
2	1	100	**2.0**	39	60
3	1	90	2.0	**45**	60
4	1	80	.3	44	60
5	1	70	.7	44	60
6	1	50	.0	0	60
7	2	90	**2.1**	33	60
8	2	80	1.2	36	60
9	2	70	.8	40	60
10	2	60	.3	**45**	60
11	3	80	**2.0**	38	60
12	3	70	.2	**44**	60
13	3	60	.6	35	60

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

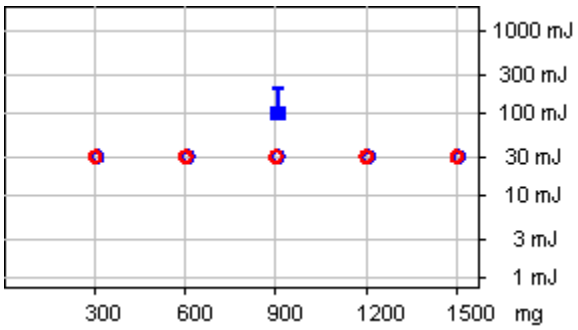
ioKinetic - Salem, NH

Sample:	**Bran 8480 PR C170651M**
Customer:	CSB
Reason:	MIE Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.71% < 75 micron, Mean Diameter: 32.48 micron

Minimum Ignition Energy

Result with inductance L = 1 mH

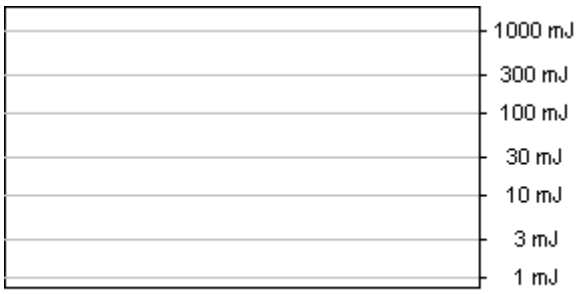
30 mJ < MIE < 100 mJ / Es = 55 mJ



E2 [mJ]:	100
Es [mJ]:	55
E1 [mJ]:	30
tv [ms]:	90 120

Result without inductance L = 0 mH

- / -



E2 [mJ]:	-
Es [mJ]:	-
E1 [mJ]:	-
tv [ms]:	-

Room Temperature: 21.5 C
Room Humidity: 56.4%
Barometric Pressure: 1002 mbar
Moisture Content: 3.96%
Technician: CBarrett
Date: 05/04/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Tests

Bran 8480 PR C170651M

series	conc. [mg]	IE [mJ]	tv set [ms]	tv eff [ms]	ind. [mH]	ign.at (NI)
1	900	100	120	124	1	7
2	900	30	120	126	1	(10)
3	600	30	120	124	1	(10)
4	300	30	120	125	1	(10)
5	1200	30	120	125	1	(10)
6	1500	30	120	126	1	(10)
7	300	30	90	96	1	(10)
8	600	30	90	94	1	(10)
9	900	30	90	94	1	(10)
10	1200	30	90	94	1	(10)
11	1500	30	90	95	1	(10)

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

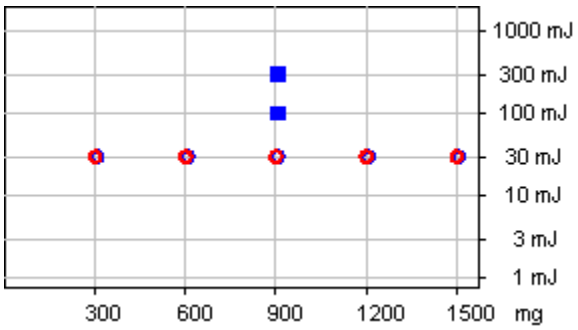
ioKinetic - Salem, NH

Sample:	**4300 Flour C17150K**
Customer:	CSB
Reason:	MIE Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.80% < 75 micron, Mean Diameter: 22.74 micron

Minimum Ignition Energy

Result with inductance L = 1 mH

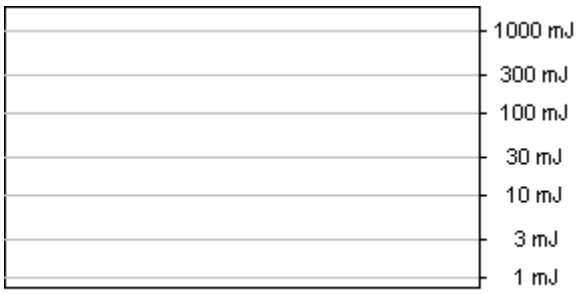
30 mJ < MIE < 100 mJ / Es = 55 mJ



E2 [mJ]:	100
Es [mJ]:	55
E1 [mJ]:	30
tv [ms]:	90 120

Result without inductance L = 0 mH

- / -



E2 [mJ]:	-
Es [mJ]:	-
E1 [mJ]:	-
tv [ms]:	-

Room Temperature: 23.1 C
Room Humidity: 29.1 %
Barometric Pressure: 1011 mbar
Moisture Content: 4.65 %
Technician: CBarrett
Date: 06/03/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Tests

4300 Flour C17150K

series	conc. [mg]	IE [mJ]	tv set [ms]	tv eff [ms]	ind. [mH]	ign.at (NI)
1	900	300	120	121	1	1
2	900	100	120	128	1	1
3	900	30	120	124	1	(10)
4	300	30	120	126	1	(10)
5	600	30	120	124	1	(10)
6	1200	30	120	126	1	(10)
7	1500	30	120	124	1	(10)
8	1500	30	90	97	1	(10)
9	1200	30	90	96	1	(10)
10	900	30	90	95	1	(10)
11	600	30	90	94	1	(10)
12	300	30	90	95	1	(10)

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

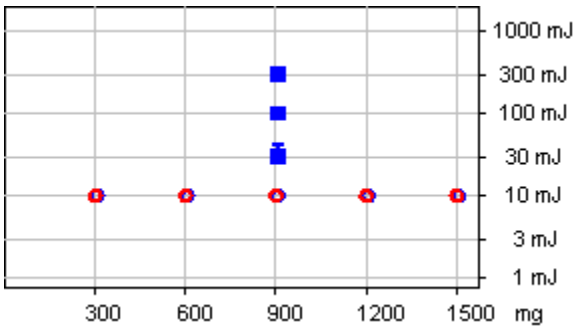
ioKinetic - Salem, NH

Sample:	**Torit Sample #1**
Customer:	CSB
Reason:	MIE Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 96.56% < 75 micron, Mean Diameter: 26.05 micron

Minimum Ignition Energy

Result with inductance L = 1 mH

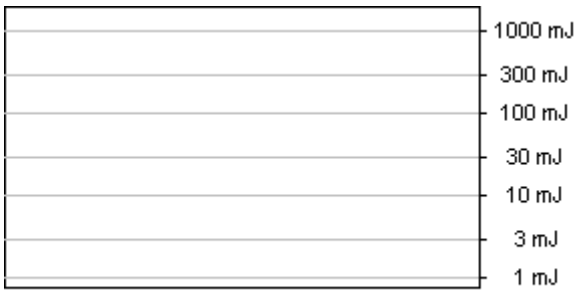
10 mJ < MIE < 30 mJ / Es = 17 mJ



E2 [mJ]:	30
Es [mJ]:	17
E1 [mJ]:	10
tv [ms]:	90 120

Result without inductance L = 0 mH

- / -



E2 [mJ]:	-
Es [mJ]:	-
E1 [mJ]:	-
tv [ms]:	-

Room Temperature: 24.6C
Room Humidity: 43.9 %
Barometric Pressure: 1003 mbar
Moisture Content: 4.56 %
Technician: CBarrett
Date: 06/21/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Tests **Torit Sample #1**

series	conc. [mg]	IE [mJ]	tv set [ms]	tv eff [ms]	ind. [mH]	ign.at (NI)
1	900	300	120	121	1	1
2	900	100	120	124	1	1
3	900	30	120	124	1	2
4	900	10	120	123	1	(10)
5	600	10	120	124	1	(10)
6	300	10	120	126	1	(10)
7	1200	10	120	123	1	(10)
8	1500	10	120	125	1	(10)
9	300	10	90	97	1	(10)
10	600	10	90	96	1	(10)
11	900	10	90	96	1	(10)
12	1200	10	90	97	1	(10)
13	1500	10	90	96	1	(10)

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

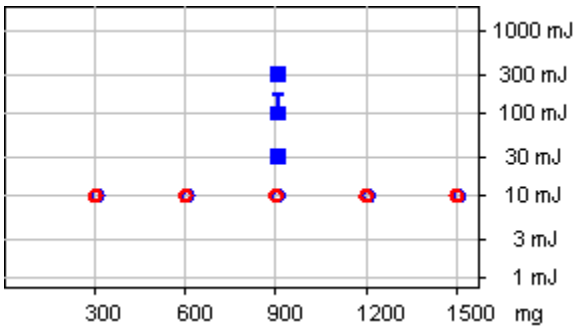
ioKinetic - Salem, NH

Sample:	**D4 Flex Kleen Filter EFI 9067**
Customer:	CSB
Reason:	MIE Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Sieved below 75 micron
Median value:	Particle Size: 98.07% < 75 micron, Mean Diameter: 24.24 micron

Minimum Ignition Energy

Result with inductance L = 1 mH

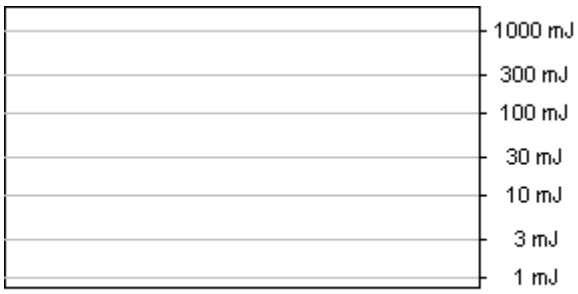
10 mJ < MIE < 30 mJ / Es = 17 mJ



E2 [mJ]:	30
Es [mJ]:	17
E1 [mJ]:	10
tv [ms]:	90 120

Result without inductance L = 0 mH

- / -



E2 [mJ]:	-
Es [mJ]:	-
E1 [mJ]:	-
tv [ms]:	-

Room Temperature: 24.3 C
Room Humidity: 60.9%
Barometric Pressure: 1009 mbar
Moisture Content: 4.00%
Technician: CBarrett
Date: 07/01/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Tests

D4 Flex Kleen Filter EFI 9067

series	conc. [mg]	IE [mJ]	tv set [ms]	tv eff [ms]	ind. [mH]	ign.at (NI)
1	900	300	120	122	1	1
2	900	100	120	126	1	5
3	900	30	120	126	1	1
4	900	10	120	123	1	(10)
5	300	10	120	126	1	(10)
6	600	10	120	124	1	(10)
7	1200	10	120	124	1	(10)
8	1500	10	120	123	1	(10)
9	300	10	90	96	1	(10)
10	600	10	90	95	1	(10)
11	900	10	90	94	1	(10)
12	1200	10	90	95	1	(10)
13	1500	10	90	93	1	(10)

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

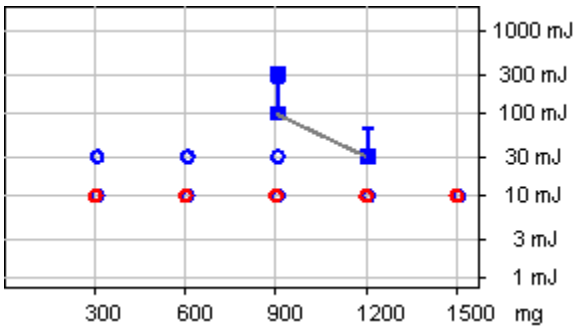
ioKinetic - Salem, NH

Sample:	**Coarse Grinder B EFI 466**
Customer:	CSB
Reason:	MIE Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Sieved below 75 micron
Median value:	Particle Size: 95.25% < 75 micron, Mean Diameter: 30.96 micron

Minimum Ignition Energy

Result with inductance L = 1 mH

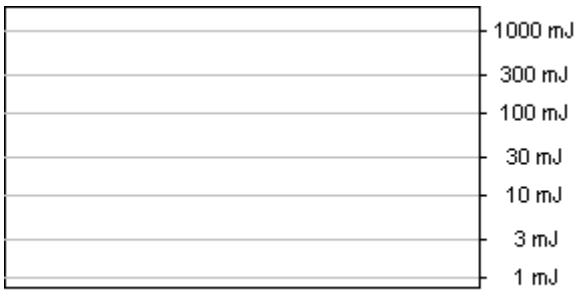
10 mJ < MIE < 30 mJ / Es = 24 mJ



E2 [mJ]:	30
Es [mJ]:	24
E1 [mJ]:	10
tv [ms]:	90 120

Result without inductance L = 0 mH

- / -



E2 [mJ]:	-
Es [mJ]:	-
E1 [mJ]:	-
tv [ms]:	-

Room Temperature: 19.9 C
Room Humidity: 49.6%
Barometric Pressure: 1014 mbar
Moisture Content: 4.65%
Technician: CBarrett
Date: 07/19/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

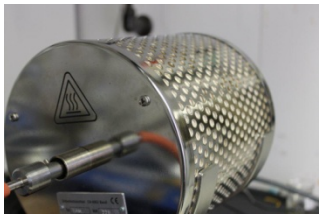
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

Tests **Coarse Grinder B EFI 466**

series	conc. [mg]	IE [mJ]	tv set [ms]	tv eff [ms]	ind. [mH]	ign.at (NI)
1	900	300	120	120	1	1
2	900	100	120	126	1	9
3	900	30	120	124	1	(10)
4	300	30	120	125	1	(10)
5	600	30	120	125	1	(10)
6	1200	30	120	124	1	8
7	1500	10	120	124	1	(10)
8	1200	10	120	126	1	(10)
9	900	10	120	125	1	(10)
10	600	10	120	124	1	(10)
11	300	10	120	126	1	(10)
12	300	10	90	95	1	(10)
13	600	10	90	95	1	(10)
14	900	10	90	93	1	(10)
15	1200	10	90	96	1	(10)
16	1500	10	90	94	1	(10)

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065



ioKinetic, LLC - Salem, NH

Sample:	**Bran 8480 PR C170651M**
Customer:	CSB
Reason:	MAIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved Below 75 micron
Median value:	Particle Size: 95.71% < 75 micron, Mean Diameter: 32.48

Explosion Characteristics

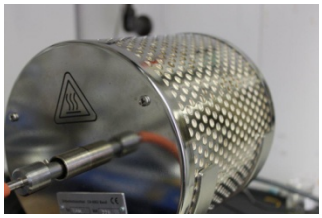
Minimum Auto-Ignition Temperature : 350ºC < MAIT < 360ºC

Temperature (ºC)	Quantity (mL)	Mass (g)	Go/No Go
450	1	0.371	Go
400	1	0.371	Go
356	1	0.371	No Go
360	1	0.371	Go
350	1	0.371	No Go
340	1	0.371	No Go
340	2	0.742	No Go
343	0.5	0.185	No Go
353	1	0.371	No Go
354	0.5	0.185	No Go
355	2	0.742	No Go
360	1	0.371	Go

Room Temperature: 23.2 C, 23.1 C
Relative Humidity: 34.6 %, 38 %
Barometric Pressure: 1012 mbar, 1019 mbar
Moisture Content: 3.89 %, 3.84 %
Technician: CBarrett
Date: 5/7/2018, 5/8/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065



ioKinetic, LLC - Salem, NH

Sample:	**4300 Flour C17150K**
Customer:	CSB
Reason:	MAIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.80% < 75 micron, Mean Diameter: 22.74 micron

Explosion Characteristics

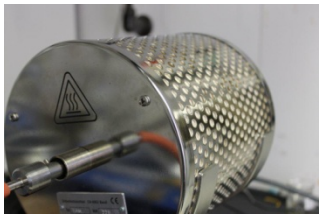
Minimum Auto-Ignition Temperature : 370ºC < MAIT < 380ºC

Temperature (ºC)	Quantity (mL)	Mass (g)	Go/No Go
450	1	0.410	Go
402	1	0.410	Go
376	1	0.410	Go
360	1	0.410	No Go
352	1	0.410	No Go
362	1	0.410	No Go
370	1	0.410	No Go
380	1	0.410	Go
370	2	0.820	No Go
370	2	0.820	No Go
370	0.5	0.205	No Go
380	1	0.410	Go

Room Temperature: 23.8 C, 23.9 C, 23.7 C
Relative Humidity: 60.5 %, 47.6 %, 60.9 %
Barometric Pressure: 1001 mbar, 1013 mbar, 1012 mbar
Moisture Content: 3.55%, 3.79 %, 4.45 %
Technician: CBarrett
Date: 6/2/2018. 6/7/2018. 6/8/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065



ioKinetic, LLC - Salem, NH

Sample:	**Torit Sample #1**
Customer:	CSB
Reason:	MAIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 96.56% < 75 micron, Mean Diameter: 26.05 micron

Explosion Characteristics

Minimum Auto-Ignition Temperature : 360ºC < MAIT < 370ºC

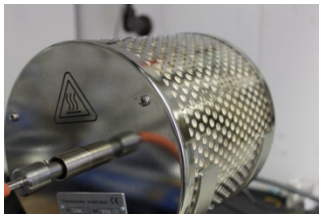
Temperature (ºC)	Quantity (mL)	Mass (g)	Go/No Go
400	1	0.472	Go
340	1	0.472	No Go
350	1	0.472	No Go
360	1	0.472	No Go
370	1	0.472	Go
362	1	0.472	No Go
350	1	0.472	No Go
354	2	0.944	No Go
352	0.5	0.236	No Go
360	1	0.472	No Go
360	0.5	0.236	No Go
360	2	0.944	No Go
360	1	0.472	No Go
370	1	0.472	No Go

Room Temperature: 23.4 C, 23.2 C, 21.1 C, 22.4 C
Relative Humidity: 51.3 %, 53.6 %, 55.2 %, 64.9 %
Barometric Pressure: 1003 mbar, 1009 mbar, 1003 mbar, 1014 mbar
Moisture Content: 4.24 %, 4.51 %, 4.37 %, 4.30 %
Technician: CBarrett
Date: 6/21/2018, 6/25/2018, 6/28/2018, 7/2/2018

Report No.: ioK18065-2

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065



ioKinetic, LLC - Salem, NH

Sample:	**D4 Flex Kleen Filter EFI 9067**
Customer:	CSB
Reason:	MAIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.07% < 75 micron, Mean: 24.24 micron

Explosion Characteristics

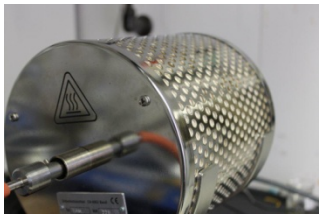
Minimum Auto-Ignition Temperature : 350ºC < MAIT < 360ºC

Temperature (ºC)	Quantity (mL)	Mass (g)	Go/No Go
390	1	0.459	Go
380	1	0.459	Go
362	1	0.459	No Go
370	1	0.459	Go
360	1	0.459	Go
350	1	0.459	No Go
350	0.5	0.229	No Go
350	2	0.918	No Go

Room Temperature: 17.4 C
Relative Humidity: 56.6 %
Barometric Pressure: 1005 mbar
Moisture Content: 4.56 %
Technician: CBarrett
Date: 7/26/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065



ioKinetic, LLC - Salem, NH

Sample:	**Coarse Grinder B EFI 466**
Customer:	CSB
Reason:	MAIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.25% < 75 micron, Mean: 30.96 micron

Explosion Characteristics

Minimum Auto-Ignition Temperature : 360ºC < MAIT < 370ºC

Temperature (ºC)	Quantity (mL)	Mass (g)	Go/No Go
450	1	0.489	Go
400	1	0.489	Go
390	1	0.489	Go
360	1	0.489	No Go
380	1	0.489	Go
370	1	0.489	Go
360	1	0.489	No Go
360	0.5	0.245	No Go
361	2	0.978	No Go

Room Temperature: 19.4 C
Relative Humidity: 53.0 %
Barometric Pressure: 1005 mbar
Moisture Content: 4.20 %
Technician: CBarrett
Date: 7/26/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

ioKinetic, LLC - Salem, NH

Sample:	**Bran 8480 PR C170651M**
Customer:	CSB
Reason:	HSIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved Below 75 micron
Median value:	Particle Size: 95.71% < 75 micron, Mean Diameter: 32.48

Explosion Characteristics

Hot-Surface Ignition Temperature : 250ºC < HSIT < 260ºC

Hot Surface Temperature (ºC)	Layer Thickness (in)	Max Temperature (ºC)	Time to Max T (min)	Result of Test
400	0.5	450+	10:10	Ignition
300	0.5	350+	12:40	Ignition
260	0.5	310+	43:20	Ignition
240	0.5	162.4	50:30	No Ignition
250	0.5	154.2	30:15	No Ignition
260	0.5	310+	40:15	Ignition
250	0.5	168.9	33:30	No Ignition

Room Temperature: 23.7 C, 24.3 C, 24 C
Relative Humidity: 39.9 %, 48.7 %, 66.2 %
Barometric Pressure: 1017 mbar, 1019 mbar, 1011 mbar
Moisture Content: 4.02 %, 3.82 %, 3.96 %
Technician: CBarrett
Date: 7/12/2018, 7/13/2018, 7/16/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2

Tested by: CBarrett

Approved by: MRMurphy

Project Number: 18065

ioKinetic, LLC - Salem, NH

Sample:	**4300 Flour C17150K**
Customer:	CSB
Reason:	HSIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.80% < 75 micron, Mean Diameter: 22.74 micron

Explosion Characteristics

Hot-Surface Ignition Temperature : 270ºC < HSIT < 280ºC

Hot Surface Temperature (ºC)	Layer Thickness (in)	Max Temperature (ºC)	Time to Max T (min)	Result of Test
300	0.5	316	55	No Ignition
300	0.5	350+	54:15	Ignition
270	0.5	224.4	37:10	No Ignition
280	0.5	291	82	No Ignition
290	0.5	310	56	No Ignition
290	0.5	423	69:15	Ignition
280	0.5	502	79	Ignition
270	0.5	244.8	37:20	No Ignition
270	0.5	233.8	40	No Ignition
280	0.5	461	96:50	Ignition

Room Temperature: 24.7 C, 20.2 C, 21.2 C, 23.7 C
Relative Humidity: 65.4 %, 61.6 %, 47.3 %, 40.4 %
Barometric Pressure: 1008 mbar, 1004 mbar, 1005 mbar, 1013 mbar
Moisture Content: 4.67 %, 4.60 %, 4.72 %, 4.72 %
Technician: CBarrett
Date: 7/16/2018, 7/17/2018, 7/18/2018, 7/19/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2

Tested by: CBarrett

Approved by: MRMurphy

Project Number: 18065

ioKinetic, LLC - Salem, NH

Sample:	**D4 Flex Kleen Filter EFI 9067**
Customer:	CSB
Reason:	HSIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 98.07% < 75 micron, Mean: 24.24 micron

Explosion Characteristics

Hot-Surface Ignition Temperature : 270ºC < HSIT < 280ºC

Hot Surface Temperature (ºC)	Layer Thickness (in)	Max Temperature (ºC)	Time to Max T (min)	Result of Test
300	0.5	490.1	91:20	Ignition
290	0.5	280.8	12:40	No Ignition
290	0.5	378.7	128:20	Ignition
280	0.5	345.8	66:10	Ignition
270	0.5	229.9	32:27	No Ignition
270	0.5	208.6	38:20	No Ignition
280	0.5	576.6	87:10	Ignition

Room Temperature: 21.8 C, 20.8 C, 19.8 C
Relative Humidity: 60.0 %, 49.9 %, 71.4 %
Barometric Pressure: 1015 mbar, 1009 mbar, 1017 mbar
Moisture Content: 4.59 %, 4.33 %, 4.53 %
Technician: CBarrett
Date: 7/20/2018, 7/21/2018, 7/23/2018

95 Stiles Road
Salem, NH 03079
P: 603.893.7009

Report No.: ioK18065-2
Tested by: CBarrett
Approved by: MRMurphy
Project Number: 18065

ioKinetic, LLC - Salem, NH

Sample:	**Coarse Grinder B EFI 466**
Customer:	CSB
Reason:	HSIT Testing
Data to sample origin:	Didion Mill
Preparation of sample:	Ground and sieved below 75 micron
Median value:	Particle Size: 95.25% < 75 micron, Mean: 30.96 micron

Explosion Characteristics

Hot-Surface Ignition Temperature : 260ºC < HSIT < 270ºC

Hot Surface Temperature (ºC)	Layer Thickness (in)	Max Temperature (ºC)	Time to Max T (min)	Result of Test
300	0.5	436.7	56:20	Ignition
280	0.5	507.4	67:10	Ignition
270	0.5	495.1	84:40	Ignition
260	0.5	140.8	48	No Ignition
260	0.5	174.0	52:30	No Ignition
270*	0.5	208.3	54:40	No Ignition
270*	0.5	191.0	49:20	No Ignition

*Only one test at 270ºC ignited but this was taken as the conservative upper bound for the HSIT

Room Temperature: 20.6 C, 19.9 C, 21.6 C
Relative Humidity: 67.1 %, 75.4 %, 65.2 %
Barometric Pressure: 1016 mbar, 1019 mbar, 1012 mbar
Moisture Content: 4.11 %, 4.21 %, 4.47 %
Technician: CBarrett
Date: 7/23/2018, 7/24/2018, 7/28/2018

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 8480 PR Bran C170651M
Approved by	: MMurphy
Comments	: As Received

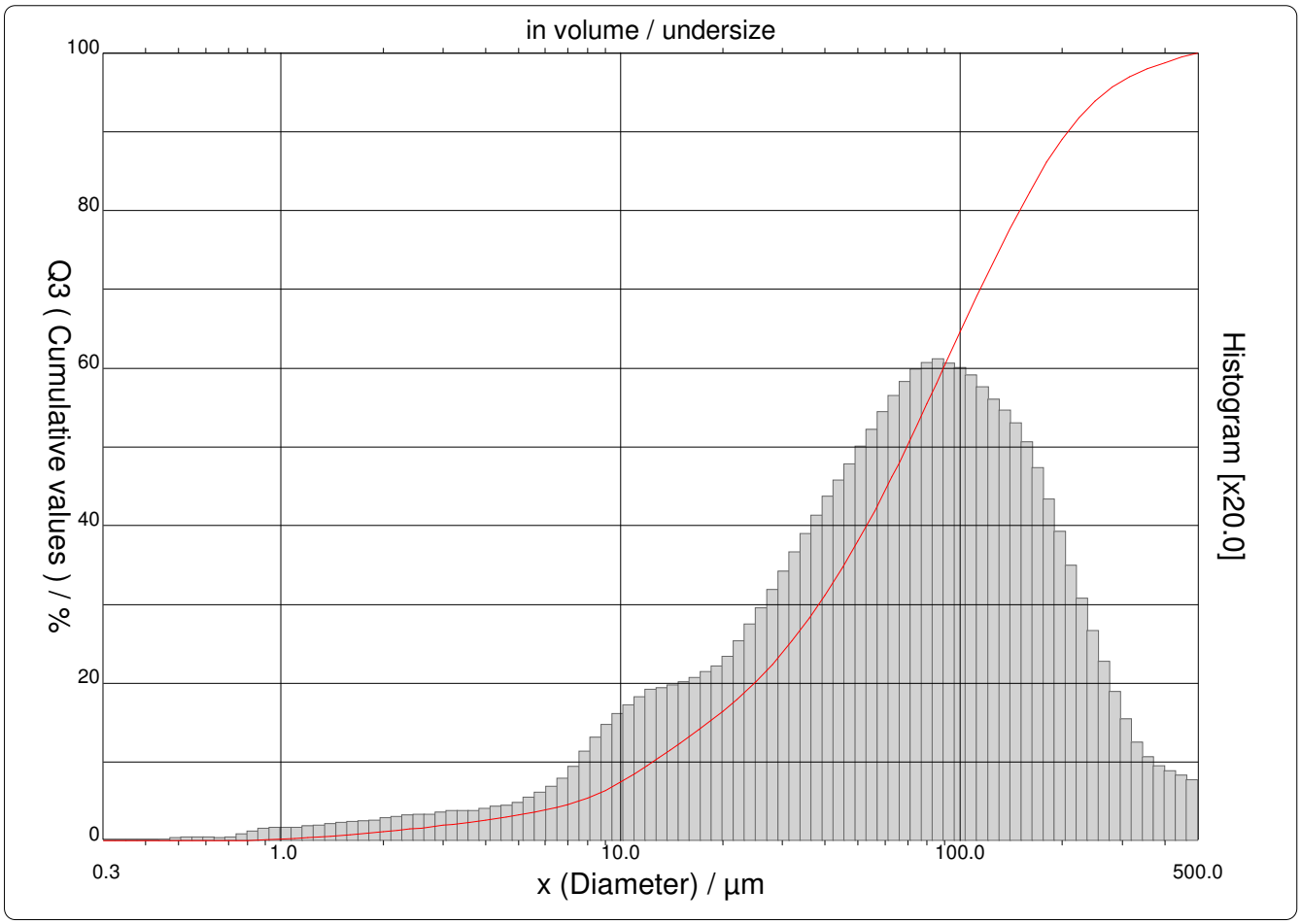
Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/09/2018	Time : 02:57:07PM
Index meas.	: 1657
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 7 %	
Diameter at 10%	: 12.42	µm
Diameter at 50%	: 69.66	µm
Diameter at 90%	: 208.08	µm
Mean diameter	: 93.95	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes — in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	52.93	80.41	94.01	99.14	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1657*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 8480 PR Bran C170651M
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/09/2018	Time : 02:57:07PM
Index meas.	: 1657
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 7 %	
Diameter at 10%	: 12.42	µm
Diameter at 50%	: 69.66	µm
Diameter at 90%	: 208.08	µm
Mean diameter	: 93.95	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.03	0.06	0.09	0.16	0.26	0.36
q3	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.06	0.10	0.11
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.45	0.54	0.63	0.81	0.99	1.16	1.33	1.50	1.67	1.98
q3	0.11	0.12	0.12	0.14	0.16	0.17	0.18	0.20	0.22	0.22
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	2.13	2.42	2.68	2.87	3.06	3.30	3.67	3.93	4.27	4.63
q3	0.24	0.25	0.25	0.27	0.29	0.30	0.34	0.39	0.44	0.50
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	5.45	6.42	7.46	8.52	9.56	10.58	11.54	12.45	14.14	16.47
q3	0.63	0.85	1.02	1.14	1.23	1.31	1.33	1.36	1.39	1.47
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	17.94	20.16	22.39	25.36	28.30	31.18	34.68	38.03	41.88	46.15
q3	1.59	1.79	2.02	2.29	2.57	2.81	3.06	3.27	3.49	3.73
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	47.91	50.74	52.93	55.54	58.02	60.37	64.66	69.20	77.65	82.36
q3	3.89	3.99	4.11	4.16	4.21	4.23	4.19	4.12	3.89	3.63
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	86.12	89.06	91.75	93.89	95.64	97.00	97.99	98.77	99.45	100.00
q3	3.28	2.87	2.44	2.00	1.59	1.19	0.85	0.67	0.59	0.54

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 8480 PR Bran C170651M
Approved by	: MMurphy
Comments	: Sieved 63um, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 04/30/2018	Time : 04:59:52PM
Index meas.	: 1729
Database name	: CilasDB1

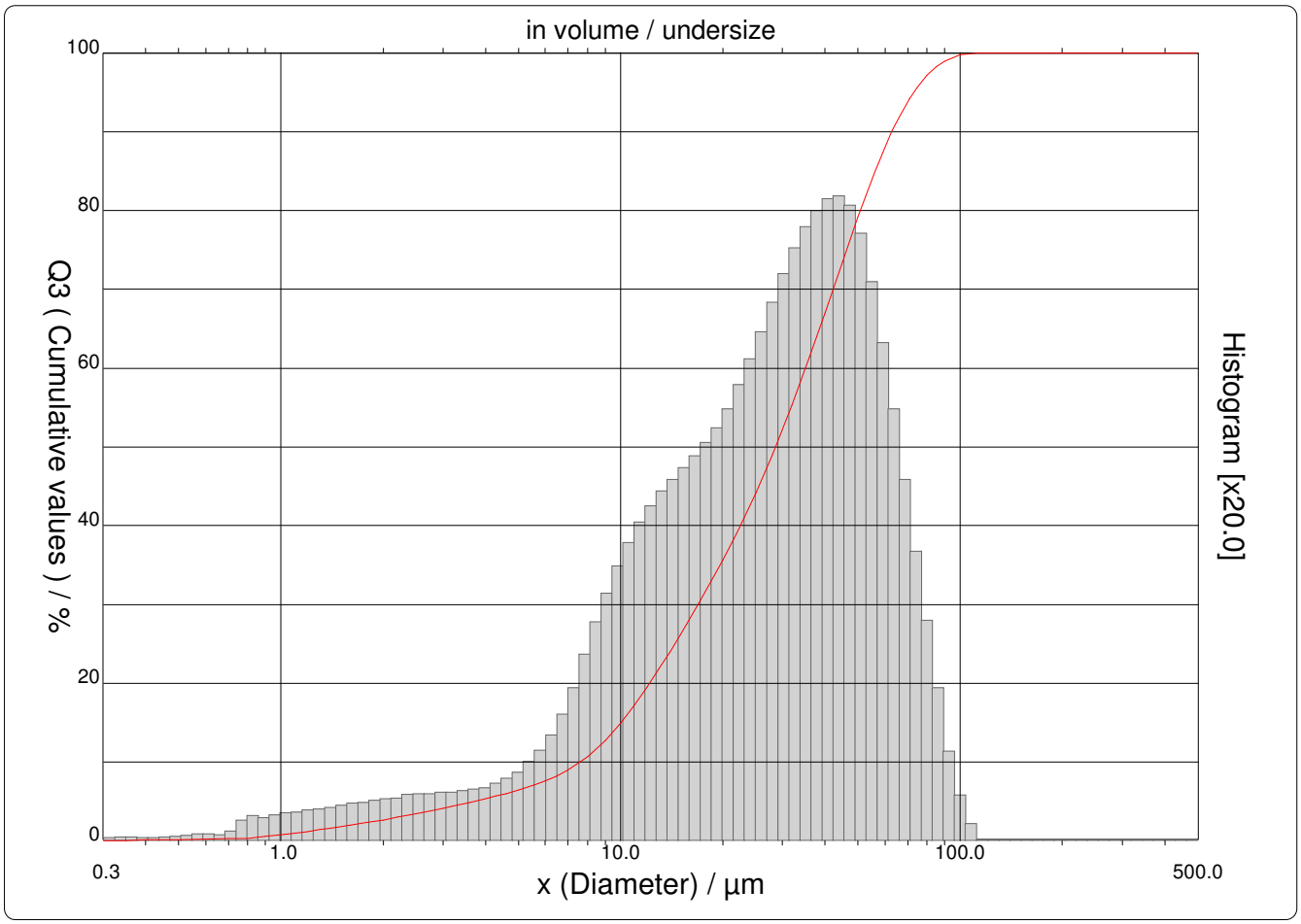
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 7 %	
Diameter at 10%	: 7.59	µm
Diameter at 50%	: 28.58	µm
Diameter at 90%	: 62.87	µm
Mean diameter	: 32.48	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	95.71	100.00	100.00	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1729*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 8480 PR Bran C170651M
Approved by	: MMurphy
Comments	: Sieved 63um, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 04/30/2018	Time : 04:59:52PM
Index meas.	: 1729
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 7 %	
Diameter at 10%	: 7.59	µm
Diameter at 50%	: 28.58	µm
Diameter at 90%	: 62.87	µm
Mean diameter	: 32.48	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.06	0.08	0.11	0.15	0.21	0.28	0.37	0.60	0.80	1.01
q3	0.00	0.01	0.02	0.02	0.03	0.05	0.07	0.20	0.19	0.22
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	1.21	1.41	1.60	1.97	2.33	2.67	3.00	3.31	3.62	4.18
q3	0.23	0.25	0.26	0.28	0.31	0.33	0.35	0.36	0.39	0.40
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	4.44	4.92	5.37	5.69	6.01	6.44	7.11	7.60	8.25	8.97
q3	0.41	0.41	0.43	0.45	0.48	0.52	0.60	0.72	0.82	0.98
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	10.66	12.71	14.94	17.25	19.56	21.82	24.01	26.12	30.11	35.63
q3	1.28	1.76	2.14	2.45	2.69	2.86	2.99	3.10	3.23	3.44
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	39.10	44.14	49.03	55.34	61.35	66.98	73.44	79.18	84.95	90.09
q3	3.69	3.99	4.37	4.78	5.17	5.41	5.55	5.52	5.16	4.42
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	91.83	94.22	95.71	97.17	98.23	98.97	99.73	100.00	100.00	100.00
q3	3.79	3.31	2.75	2.29	1.77	1.31	0.73	0.24	0.00	0.00
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 4300 Flour C17150K
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/09/2018	Time : 03:14:58PM
Index meas.	: 1662
Database name	: CilasDB1

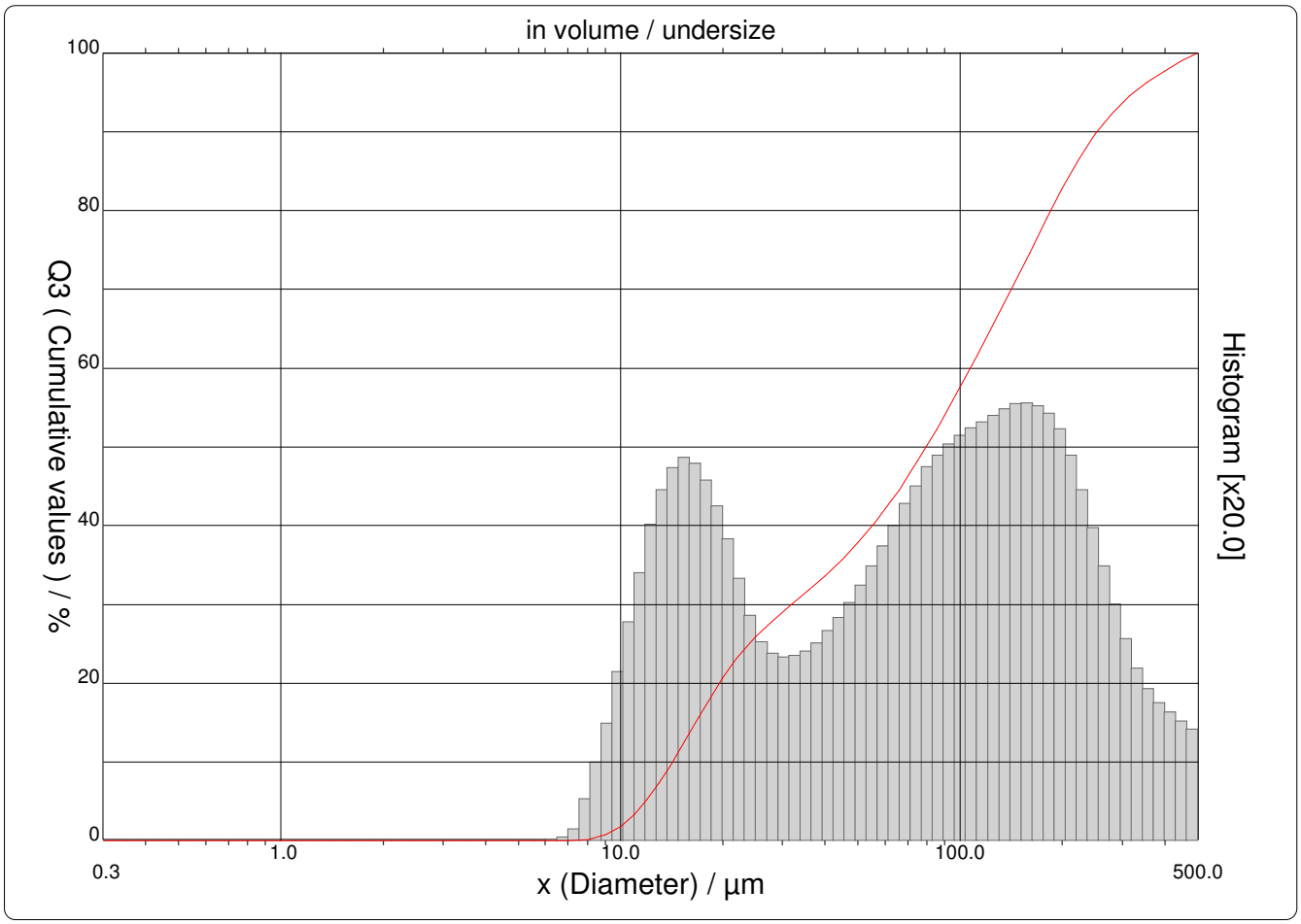
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 7 %	
Diameter at 10%	: 14.23	µm
Diameter at 50%	: 79.46	µm
Diameter at 90%	: 253.51	µm
Mean diameter	: 109.11	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	48.22	72.57	89.89	98.44	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1662*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: 4300 Flour C17150K
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/09/2018	Time : 03:14:58PM
Index meas.	: 1662
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]
Obscuration	: 7 %
Diameter at 10%	: 14.23 µm
Diameter at 50%	: 79.46 µm
Diameter at 90%	: 253.51 µm
Mean diameter	: 109.11 µm
Fraunhofer	
Density/Factor	----------
Specific surface	----------
Meas./Rinse No.	: 30s/30s/0
SOP name	: ioK 03/26/2015

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	0.13	0.75	1.83	3.37	5.22	7.31	9.49	11.66	15.74	20.71
q3	0.09	0.55	1.08	1.70	2.24	2.75	3.10	3.31	3.44	3.22
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	23.23	25.98	27.93	30.03	31.89	33.64	35.78	37.88	40.39	43.30
q3	2.79	2.27	1.81	1.66	1.66	1.75	1.91	2.10	2.33	2.60
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	44.54	46.60	48.22	50.21	52.16	54.04	57.61	61.57	69.64	74.62
q3	2.81	2.97	3.11	3.25	3.39	3.47	3.57	3.68	3.81	3.93
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	78.99	82.78	86.53	89.67	92.35	94.55	96.29	97.73	98.99	100.00
q3	3.91	3.79	3.49	3.01	2.49	1.97	1.53	1.27	1.13	1.01

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average P315
Sample Name	: 4300 Flour
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/02/2018	Time : 12:08:41AM
Index meas.	: 1771
Database name	: CilasDB1

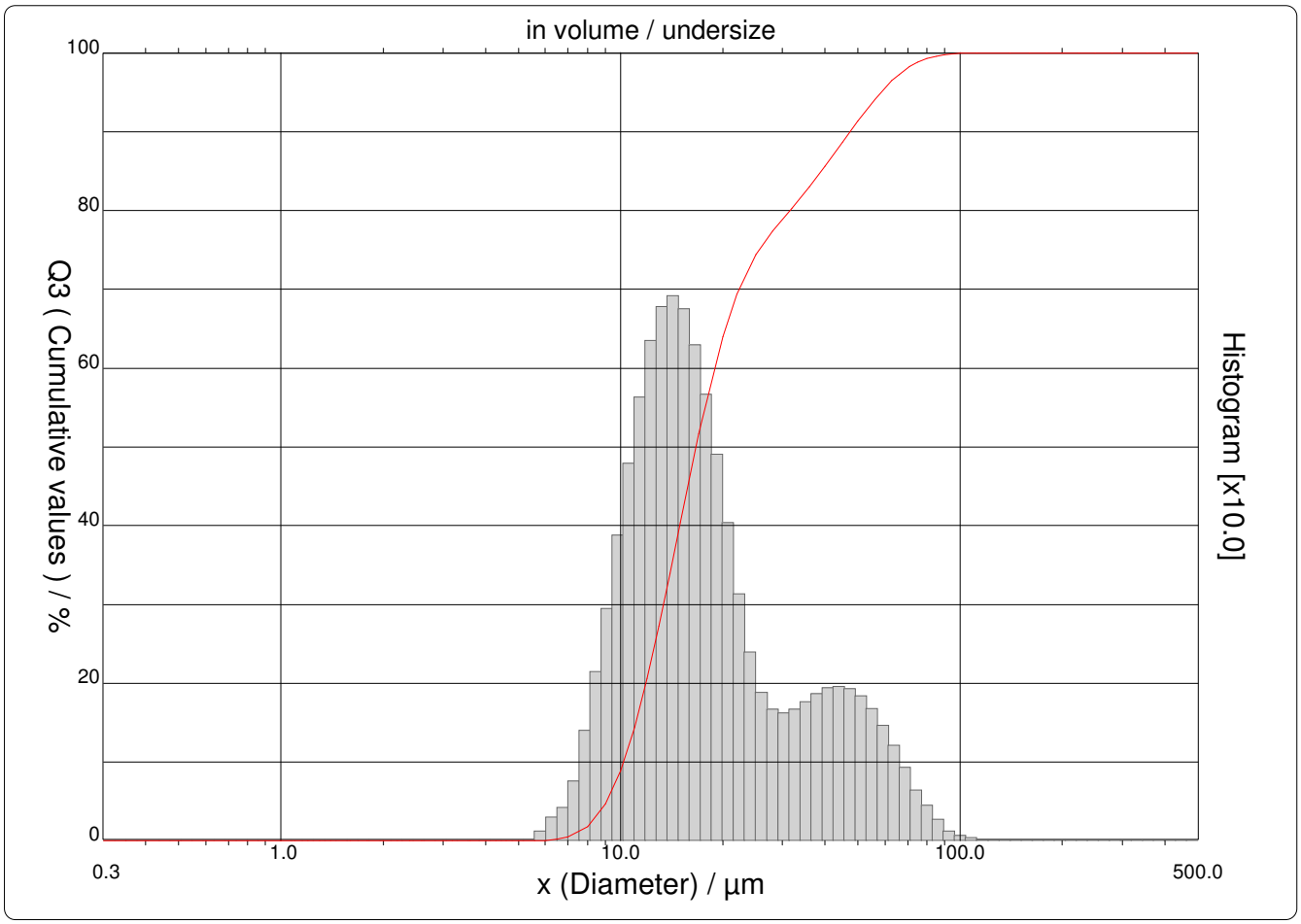
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 11 %	
Diameter at 10%	: 10.19	µm
Diameter at 50%	: 16.69	µm
Diameter at 90%	: 47.43	µm
Mean diameter	: 22.74	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	98.80	100.00	100.00	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1771*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average P315
Sample Name	: 4300 Flour
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/02/2018	Time : 12:08:41AM
Index meas.	: 1771
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 11 %	
Diameter at 10%	: 10.19	µm
Diameter at 50%	: 16.69	µm
Diameter at 90%	: 47.43	µm
Mean diameter	: 22.74	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.55
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.44
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	1.82	4.68	8.92	14.38	20.61	27.29	33.98	40.39	51.66	63.97
q3	0.96	2.46	4.07	5.79	7.24	8.44	9.13	9.40	9.11	7.66
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	69.42	74.46	77.41	80.33	82.99	85.58	88.64	91.37	94.10	96.48
q3	5.78	3.99	2.63	2.21	2.28	2.49	2.63	2.62	2.44	2.04
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	97.25	98.25	98.80	99.28	99.60	99.80	99.95	100.00	100.00	100.00
q3	1.67	1.38	1.01	0.75	0.53	0.35	0.14	0.04	0.00	0.00
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Torit Sample #1
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/27/2018	Time : 05:29:55PM
Index meas.	: 1674
Database name	: CilasDB1

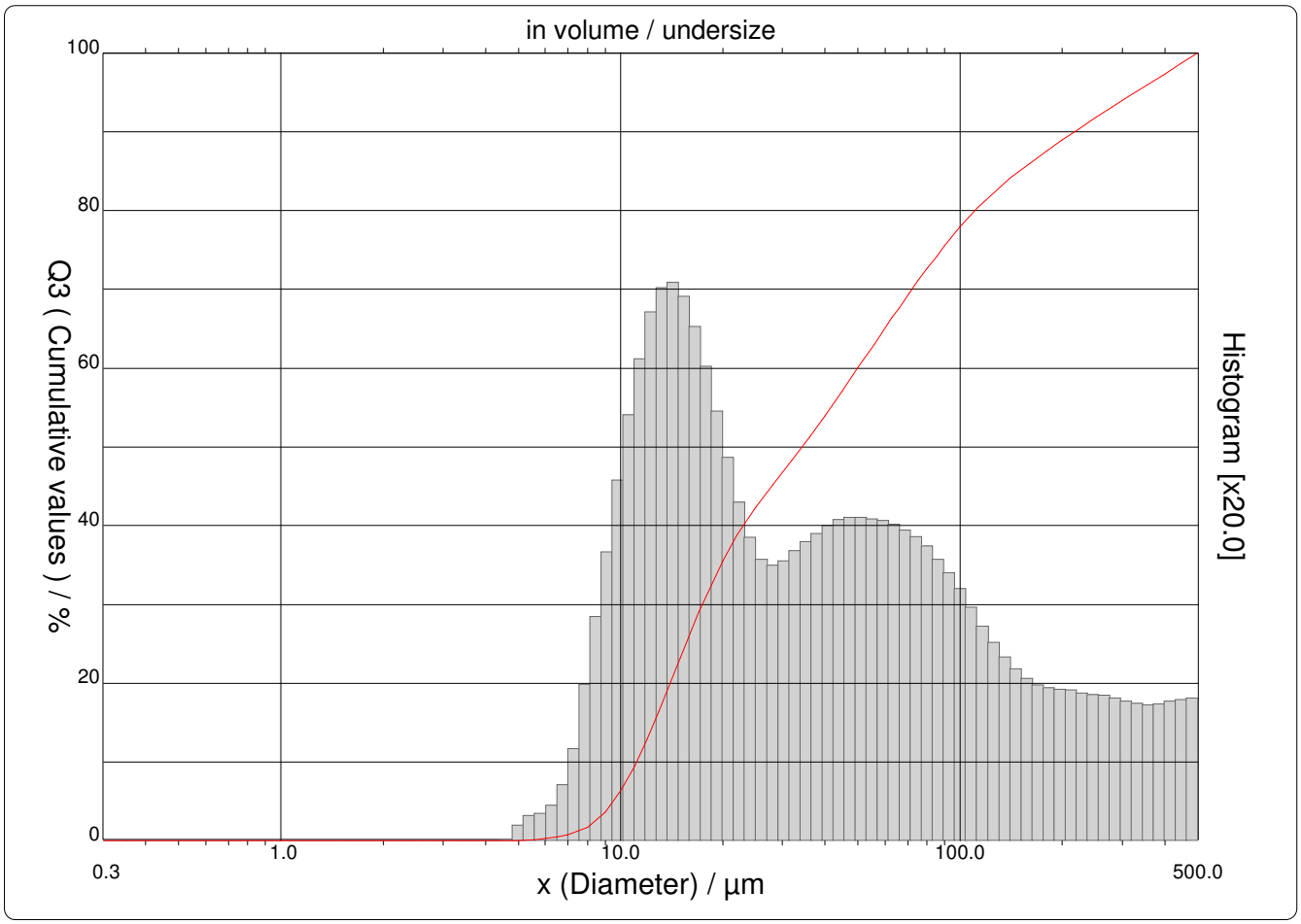
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 5 %	
Diameter at 10%	: 11.14	µm
Diameter at 50%	: 34.28	µm
Diameter at 90%	: 217.44	µm
Mean diameter	: 83.75	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	71.02	82.94	90.32	97.69	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1674*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Torit Sample #1
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/27/2018	Time : 05:29:55PM
Index meas.	: 1674
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]
Obscuration	: 5 %
Diameter at 10%	: 11.14 µm
Diameter at 50%	: 34.28 µm
Diameter at 90%	: 217.44 µm
Mean diameter	: 83.75 µm
Fraunhofer	
Density/Factor	----------
Specific surface	----------
Meas./Rinse No.	: 30s/30s/0
SOP name	: ioK 03/26/2015

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.50	0.77
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.22	0.24	0.37
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	1.76	3.71	6.34	9.50	12.93	16.48	19.96	23.25	29.03	35.59
q3	0.76	1.69	2.55	3.39	4.03	4.53	4.80	4.87	4.72	4.13
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	38.80	42.39	45.13	48.29	51.22	53.96	57.14	60.04	63.16	66.38
q3	3.44	2.87	2.47	2.42	2.54	2.66	2.76	2.81	2.81	2.79
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	67.64	69.58	71.02	72.67	74.18	75.55	77.94	80.27	84.09	86.01
q3	2.77	2.71	2.69	2.61	2.55	2.45	2.32	2.10	1.75	1.47
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	87.57	88.93	90.38	91.75	93.15	94.56	95.95	97.33	98.73	100.00
q3	1.35	1.32	1.31	1.27	1.26	1.22	1.19	1.18	1.21	1.23

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Torit Sample #1
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/20/2018	Time : 10:22:28AM
Index meas.	: 1788
Database name	: CilasDB1

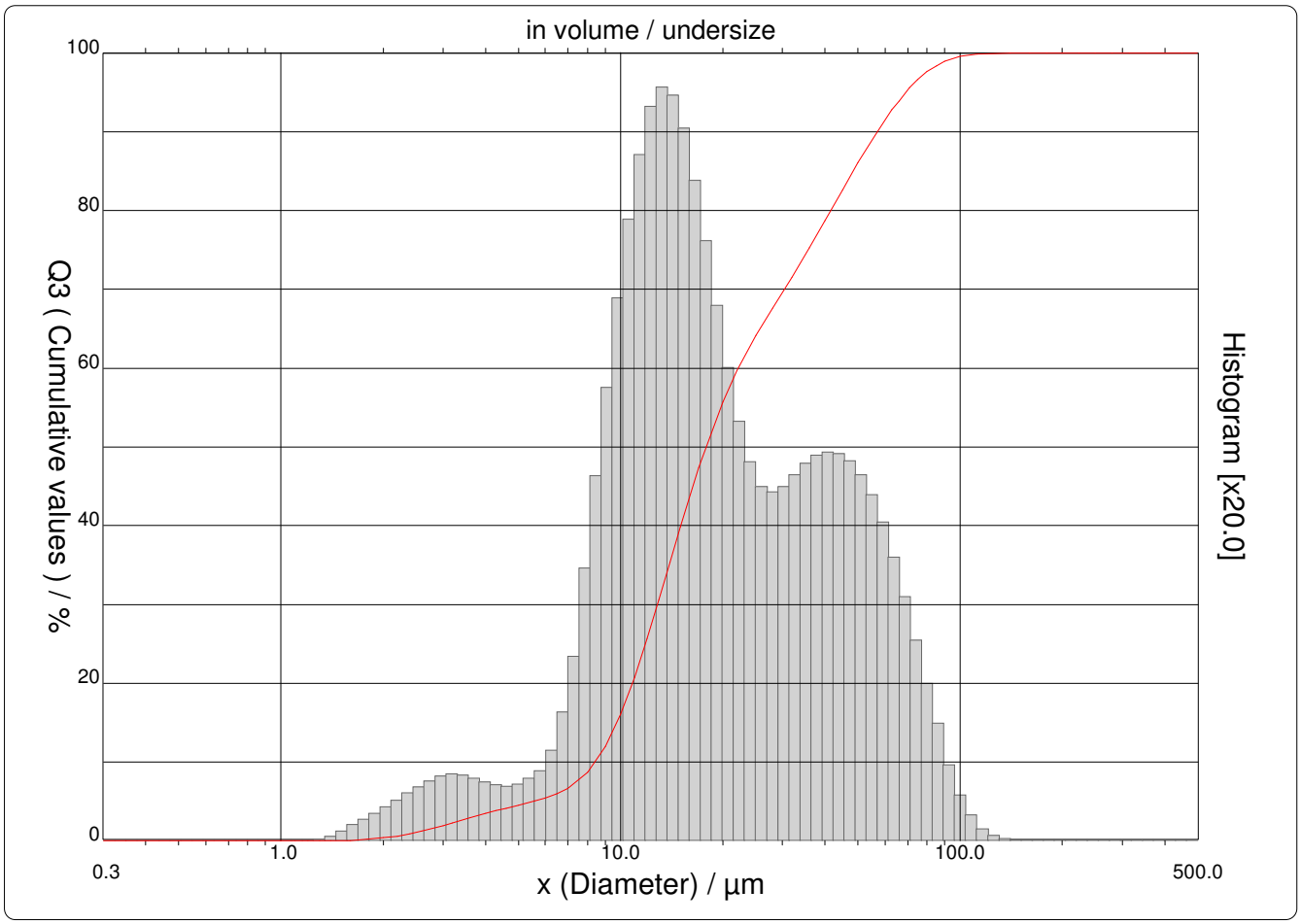
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 10 %	
Diameter at 10%	: 8.39	µm
Diameter at 50%	: 17.89	µm
Diameter at 90%	: 56.94	µm
Mean diameter	: 26.05	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	96.56	100.00	100.00	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1788*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Torit Sample #1
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/20/2018	Time : 10:22:28AM
Index meas.	: 1788
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 10 %	
Diameter at 10%	: 8.39	µm
Diameter at 50%	: 17.89	µm
Diameter at 90%	: 56.94	µm
Mean diameter	: 26.05	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.05	0.19	0.39	0.64	0.93	1.25	1.93
q3	0.00	0.00	0.00	0.04	0.12	0.19	0.26	0.33	0.40	0.47
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	2.28	2.94	3.50	3.86	4.18	4.56	5.11	5.49	6.00	6.67
q3	0.54	0.56	0.53	0.50	0.47	0.45	0.48	0.55	0.64	0.90
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	8.69	11.95	16.07	20.76	25.69	30.65	35.41	39.83	47.39	55.69
q3	1.51	2.76	3.90	4.91	5.65	6.18	6.41	6.39	6.03	5.10
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	59.66	64.12	67.57	71.57	75.27	78.72	82.62	86.05	89.54	92.80
q3	4.16	3.48	3.04	2.99	3.13	3.27	3.30	3.25	3.07	2.76
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	93.94	95.54	96.56	97.58	98.34	98.91	99.56	99.88	100.00	100.00
q3	2.45	2.19	1.86	1.58	1.25	1.00	0.62	0.28	0.05	0.00
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: D4 Flex KleenFilterEFI9067
Approved by	: MMurphy
Comments	: As Received

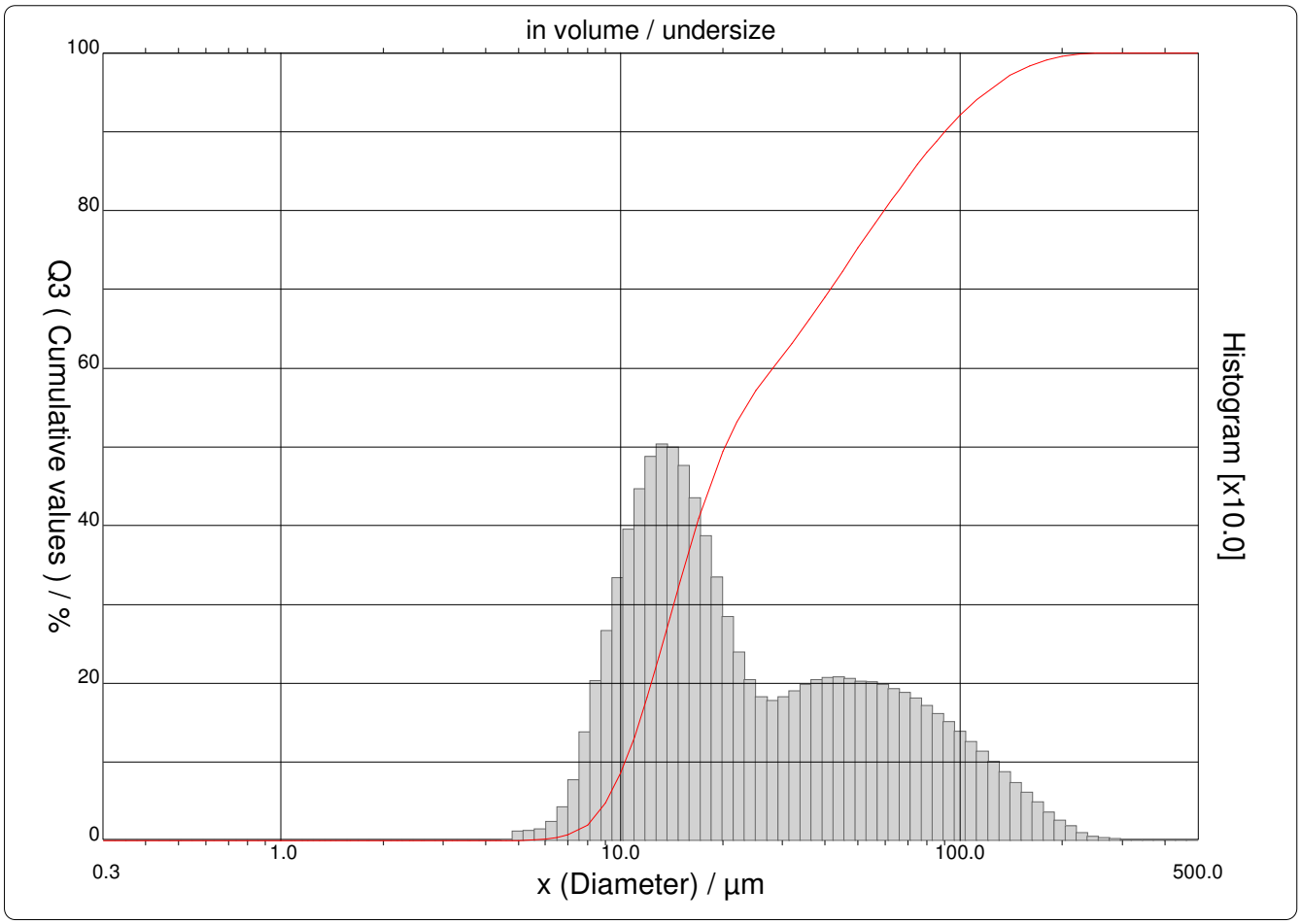
Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/27/2018	Time : 04:58:29PM
Index meas.	: 1670
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 10 %	
Diameter at 10%	: 10.29	µm
Diameter at 50%	: 20.30	µm
Diameter at 90%	: 90.09	µm
Mean diameter	: 39.47	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes — in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	85.85	96.98	99.84	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1670*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: D4 Flex KleenFilterEFI9067
Approved by	: MMurphy
Comments	: As Received

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 03/27/2018	Time : 04:58:29PM
Index meas.	: 1670
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 10 %	
Diameter at 10%	: 10.29	µm
Diameter at 50%	: 20.30	µm
Diameter at 90%	: 90.09	µm
Mean diameter	: 39.47	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.27	0.45	0.75
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.23	0.41
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	2.04	4.79	8.61	13.22	18.23	23.39	28.39	33.05	40.99	49.40
q3	0.97	2.34	3.63	4.84	5.76	6.45	6.75	6.76	6.35	5.18
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	53.19	57.13	59.94	63.16	66.19	69.05	72.32	75.23	78.30	81.44
q3	3.98	3.08	2.48	2.41	2.57	2.72	2.78	2.76	2.71	2.67
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	82.64	84.50	85.85	87.38	88.75	89.98	92.09	94.08	97.13	98.38
q3	2.58	2.55	2.46	2.37	2.26	2.15	2.00	1.76	1.37	0.94
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	99.16	99.58	99.85	99.95	99.99	100.00	100.00	100.00	100.00	100.00
q3	0.66	0.40	0.24	0.09	0.04	0.01	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: D4 Flex Kleen
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/27/2018	Time : 11:59:44AM
Index meas.	: 1792
Database name	: CilasDB1

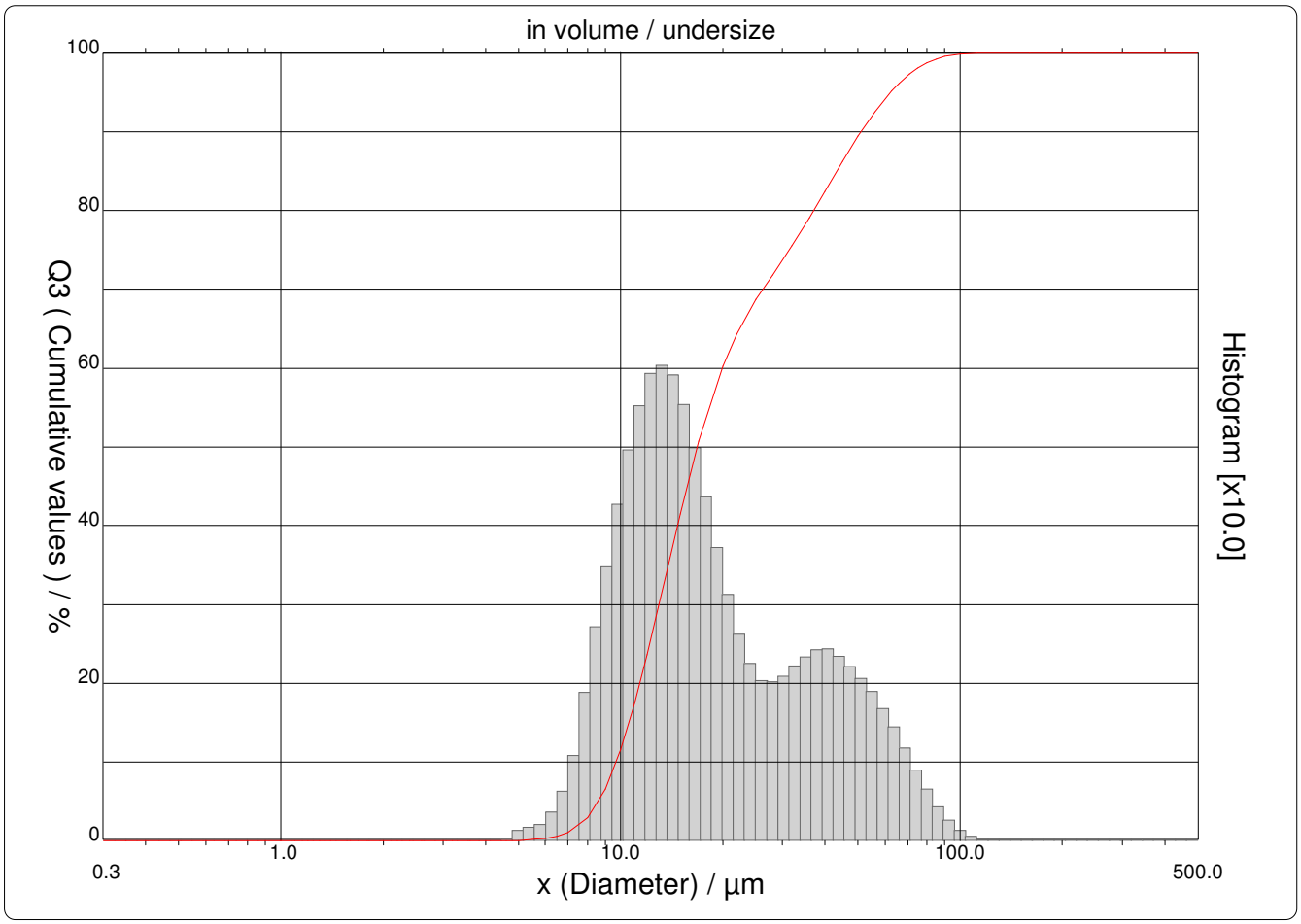
Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 11 %	
Diameter at 10%	: 9.67	µm
Diameter at 50%	: 16.83	µm
Diameter at 90%	: 51.10	µm
Mean diameter	: 24.24	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	98.07	100.00	100.00	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1792*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: D4 Flex Kleen
Approved by	: MMurphy
Comments	: Sieved < 63 micron, FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 06/27/2018	Time : 11:59:44AM
Index meas.	: 1792
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 11 %	
Diameter at 10%	: 9.67	µm
Diameter at 50%	: 16.83	µm
Diameter at 90%	: 51.10	µm
Mean diameter	: 24.24	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.34	0.60	1.06
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.22	0.33	0.62
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	2.89	6.60	11.58	17.43	23.66	29.96	35.97	41.50	50.73	60.22
q3	1.38	3.16	4.74	6.16	7.19	7.90	8.14	8.05	7.40	5.86
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	64.39	68.71	71.84	75.51	79.05	82.44	86.25	89.41	92.48	95.20
q3	4.39	3.39	2.77	2.76	3.02	3.23	3.25	3.01	2.72	2.32
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	96.11	97.34	98.07	98.76	99.24	99.56	99.89	100.00	100.00	100.00
q3	1.96	1.69	1.34	1.07	0.79	0.56	0.31	0.10	0.00	0.00
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Coarse Grinder
Approved by	: MMurph
Comments	: Ground and Sieved FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 07/25/2018	Time : 02:19:50PM
Index meas.	: 1801
Database name	: CilasDB1

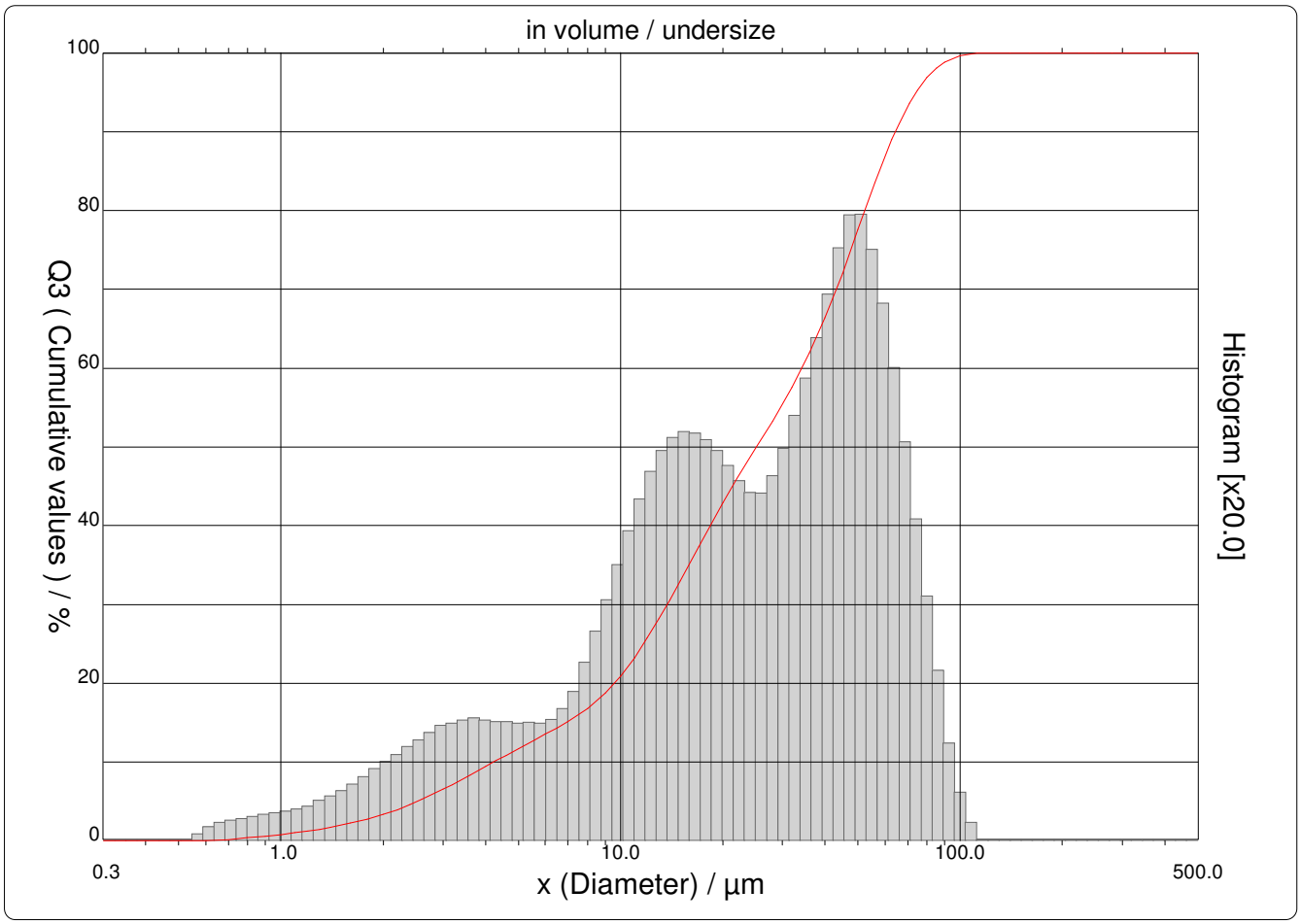
Pressure/Distributor	: 1000 mb / [51][51]			
Obscuration	: 8 %			
Diameter at 10%	: 4.23	µm		
Diameter at 50%	: 25.09	µm		
Diameter at 90%	: 64.47	µm		
Mean diameter	: 30.96	µm		
Fraunhofer				
Density/Factor	----------			
Specific surface	----------			
Meas./Rinse No.	: 30s/30s/0			
SOP name	: ioK 03/26/2015			

Customer defined classes

in volume / undersize

x	75.00	150.0	250.0	425.0	500.0
Q3	95.25	100.00	100.00	100.00	100.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution



Serial No. : 3109 | Ref : 2.r243.m0.88A1818/7.00/1801*/m112.6.0.0.1Eh.10.0.0.Dh/Q-.0.0.0.0//600.0.15.g10.0.9.10.1.10.P4500.1.10.N.0/V 9.28/635

PARTICLE SIZE DISTRIBUTION

CILAS 990 Dry

Range : 0.30 µm - 500.00 µm / 70 Classes

Report No.: ioK18065-2

Sample ref.	: Average
Sample Name	: Coarse Grinder
Approved by	: MMurphy
Comments	: Ground and Sieved FINAL

Operator	: CBarrett
Company	: ioKinetic
Location	: Salem, NH
Date : 07/25/2018	Time : 02:19:50PM
Index meas.	: 1801
Database name	: CilasDB1

Pressure/Distributor	: 1000 mb / [51][51]	
Obscuration	: 8 %	
Diameter at 10%	: 4.23	µm
Diameter at 50%	: 25.09	µm
Diameter at 90%	: 64.47	µm
Mean diameter	: 30.96	µm
Fraunhofer		
Density/Factor	----------	
Specific surface	----------	
Meas./Rinse No.	: 30s/30s/0	
SOP name	: ioK 03/26/2015	

Standard classes in volume / undersize

x	0.30	0.35	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10
Q3	0.00	0.00	0.00	0.00	0.00	0.16	0.38	0.60	0.83	1.05
q3	0.00	0.00	0.00	0.00	0.00	0.10	0.16	0.18	0.22	0.23
x	1.20	1.30	1.40	1.60	1.80	2.00	2.20	2.40	2.60	3.00
Q3	1.27	1.49	1.73	2.24	2.79	3.38	4.00	4.63	5.27	6.54
q3	0.25	0.27	0.32	0.38	0.46	0.55	0.64	0.71	0.79	0.88
x	3.20	3.60	4.00	4.30	4.60	5.00	5.60	6.00	6.50	7.00
Q3	7.17	8.35	9.44	10.18	10.86	11.70	12.83	13.52	14.32	15.11
q3	0.96	0.99	1.02	1.01	0.99	0.99	0.98	0.99	0.99	1.05
x	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	17.00	20.00
Q3	16.78	18.74	20.92	23.28	25.73	28.21	30.65	33.01	37.37	42.92
q3	1.23	1.64	2.04	2.44	2.78	3.06	3.25	3.37	3.43	3.37
x	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
Q3	46.00	49.89	53.25	57.57	61.93	66.36	71.97	77.54	83.53	89.05
q3	3.19	3.00	2.92	3.19	3.65	4.15	4.70	5.21	5.21	4.62
x	66.00	71.00	75.00	80.00	85.00	90.00	100.0	112.0	140.0	160.0
Q3	90.96	93.59	95.25	96.87	98.05	98.88	99.71	100.00	100.00	100.00
q3	4.05	3.55	2.99	2.48	1.92	1.43	0.78	0.25	0.00	0.00
x	180.0	200.0	224.0	250.0	280.0	315.0	355.0	400.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : Diameter / µm Q3 : Cumulative Value / % q3 : density distribution

Appendix C: Test Procedures

Dust Deflagration Index, K_{St}

Scope

This test method is used to determine if a dust cloud is explosible and to measure the severity of the potential explosion hazard. The test method is in accordance with ASTM E1226. The maximum pressure (P_{max}) and the maximum rate of pressure rise (dP/dt_{max}) are measured in the test and an explosibility index (K_{St}) is calculated. Data obtained from this test can be utilized in the design of explosion protections such as deflagration vents.

Terminology

P_{max} – maximum pressure (above pressure in the vessel at the time of ignition) reached during a test

$(dP/dt)_{max}$ – maximum rate of pressure increase reached during the course of a deflagration for the optimum concentration of dust tested

K_{St} – deflagration index, is the maximum dP/dt normalized to a 1.0-m^3 volume. It is calculated using the maximum rate of pressure rise in the following equation:

$$K_{St} = \left(\frac{dP}{dt}\right)_{\max} \times \sqrt[3]{V}$$

where:
- P = pressure, bar
- t = time, sec,
- V = test chamber volume, m^3,
- K_{St} = deflagration index, bar·m/sec
- C_W = worst-case dust concentration (as defined by NFPA 654, 6.1.5.1)

Test Setup

The test is conducted in a 20-liter vessel, depicted in the figure below. The apparatus consists of a dust chamber connected to a high-pressure air source used for dispersion. Two electrodes on the top of the vessel are used for connecting two chemical igniters (2 × 5 kJ = 10 kJ of ignition energy) to a voltage source. The vessel is equipped with two piezoelectric pressure transducers to measure the pressure data of the explosion. The test is automated and pressure-time data is collected by a high-speed data acquisition system. A more detailed description of the apparatus is available from the manufacturer.

Figure: Explosion Severity Test Setup

Sample Preparation

ASTM recommends the moisture content of the test sample not exceed 5% “in order to avoid test results of a given dust being noticeably influenced.” Samples which exceed the 5% moisture requirement are typically dried using a suitable method for the specific sample.

Similarly, ASTM recommends 95% of the particles in the sample be smaller than 75µm. For samples with larger particle size distributions, grinding and sieving may be conducted.

NFPA allows testing on ‘as received’ samples. ASTM notes that when “as-received” testing is conducted, “…the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal…may increase the explosion severity.”

Procedure

Once the vessel is determined to be ready for testing, the sample is weighed and placed in the dust chamber, starting with a dust concentration of 250 g/m^3. Dust particles that are too large to properly feed through the dispersion nozzle are instead placed on top of the dispersion nozzle. High pressure air is used to disperse the dust particles throughout the vessel.

The ignition source is connected to the electrode assembly and sealed inside of the vessel. The vessel is sealed and partially evacuated to 0.4 bara. The dust chamber is pressurized to 21 bara. When this dispersion air is added with the dust to the main vessel, the resulting pressure is 1 bara.

After a specified time delay, the chemical igniters are initiated. Two piezoelectric pressure transducers record the resulting deflagration. The instrument software automatically corrects for the pressure generated by the igniters. Testing is conducted at increasing dust concentrations until maximum values of dP/dt_{max} and P_{max} are found. If it is indicated that the optimum concentration for dP/dt_{max} or P_{max} is less than the initial amount tested, the tested concentration is lowered until the maximum is determined. At least two (2) additional test series are run that include the concentrations where the maximums are found and at the concentrations on each side of the maximums.

Minimum Ignition Energy (MIE) of a Dust Cloud in Air

Scope

This test method covers the determination of the minimum ignition energy of a dust cloud in air by a high voltage spark. Data obtained from this test method provide a relative measure of ignition sensitivity of a dust cloud. The test is performed per ASTM E2019, "Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air" using a Mike 3 MIE test apparatus manufactured by Kühner A.G. of Basel Switzerland.

Terminology

MIE – minimum energy required to ignite the material when dispersed in a cloud at a given concentration

Test Setup

The Mike 3 apparatus, as depicted in the figure below, is equipped with a dust dispersion cup, a dispersion nozzle (mounted at the center of the dispersion cup), a compressed air source (7 bar), and a pair of electrodes mounted on the clear glass cylinder wall (one a fixed high voltage electrode, the other a moving ground electrode). The discharge circuit consists of a high voltage supply (15kV or 11kV), interchangeable capacitors, and inductance source. A more detailed description of the apparatus is available from the manufacturer.

Figure: MIKE 3 Minimum Ignition Energy (MIE) Test Setup

Sample Preparation

ASTM recommends the moisture content of the test sample not exceed 5% “in order to avoid test results of a given dust being noticeably influenced.” Samples which exceed the 5% moisture requirement are typically dried using a suitable method for the specific sample.

Similarly, ASTM recommends 95% of the particles in the sample be smaller than 75µm. For samples with larger particle size distributions, grinding and sieving may be conducted.

NFPA allows testing on ‘as received’ samples. ASTM notes that when “as-received” testing is conducted, “…the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal…may increase the explosion severity.”

Procedure

For each test, a desired amount of dust material is placed in the cup around the dispersion nozzle. The electrode gap is set at 6 mm. using the computer control/data acquisition software, the desired energy level is selected, and the program is initiated. Using high pressure air, the dust is then dispersed as a dust cloud inside the chamber. After a set delay time the computer-controlled spark discharges and observations are made of flame ignition/propagation.

The difference between an ignition (Go), and a non-ignition (No Go) is evidenced by the appearance of a fireball in the chamber. Various dust concentrations are tested.

The MIE is then reported as being greater than the highest energy that was not able to ignite the dust cloud and lower than the lowest energy that was able to ignite the dust cloud (Energy for Non-ignition < MIE < Energy for Ignition). In the situation where the dust is ignited at the lowest instrument energy (1 mJ), the MIE is reported as being < 1 mJ.

Minimum Explosible Concentration (MEC)

Scope

This test method is used to find the lowest concentration of dust that will be explosible when dispersed in a uniform cloud. This concentration, the minimum explosible concentration (MEC), can provide a relative measure of the concentration necessary for an explosion. The test method is in accordance with ASTM E1515-14.

Terminology

MEC – minimum concentration of a combustible dust that is capable of propagating a deflagration through a uniform mixture of the dust in air, under the specified conditions of the test

Test Setup

The test is conducted in a 20-liter vessel, depicted in the figure below. The apparatus consists of a dust chamber connected to a high-pressure air source used for dispersion. Two electrodes on the top of the vessel are used for connecting a chemical igniter (5 kJ of ignition energy) to a voltage source. The vessel is equipped with two piezoelectric pressure transducers to measure the pressure data of the explosion. The test is automated and pressure-time data is collected by a high-speed data acquisition system. A more detailed description of the apparatus is available from the manufacturer.

Figure: MEC Test Setup

Sample Preparation

ASTM recommends the moisture content of the test sample not exceed 5% “in order to avoid test results of a given dust being noticeably influenced.” Samples which exceed the 5% moisture requirement are typically dried using a suitable method for the specific sample.

Similarly, ASTM recommends 95% of the particles in the sample be smaller than 75µm. For samples with larger particle size distributions, grinding and sieving may be conducted.

NFPA allows testing on ‘as received’ samples. ASTM notes that when “as-received” testing is conducted, “…the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal…may increase the explosion severity.”

Procedure

Once the vessel is determined to be ready for testing, the sample is weighed and placed in the dust chamber. Dust particles that are too large to properly feed through the dispersion nozzle are instead placed on top of the dispersion nozzle. High pressure air is used to disperse the dust particles throughout the vessel.

The ignition source is connected to the electrode assembly and sealed inside of the vessel. The vessel is sealed and partially evacuated to 0.4 bara. The dust chamber is pressurized to 21 bara. When this dispersion air is added with the dust to the main vessel, the resulting pressure is 1 bara.

After a specified time delay, the chemical igniter is initiated. Two piezoelectric pressure transducers record the resulting deflagration. The instrument software automatically corrects for the pressure generated by the igniter. To determine the minimum explosible concentration, successive tests are run at decreasing dust concentrations. An explosion is differentiated from a No Go by evaluating the increase in pressure (due to air-dust mixture deflagration) above that of the igniter. If peak pressure is 1 (one) bar more than the igniter pressure, the test is considered a Go. An initial concentration of 100 g/m3 is typically tested. The dust concentration is then incrementally decreased until a No Go is observed. The dust concentration is systematically adjusted by 5 g/m^3 to 10 g/m^3 until the MEC of the sample is determined. If a deflagration is not recorded at the initial concentration, the concentration is increased until a deflagration is observed.

Minimum Autoignition Temperature (MAIT) of Dust Cloud

Scope

The test method covers the determination of the minimum temperature at which a given dust cloud will auto ignite when exposed to air heated in a furnace at local atmospheric pressure. The data obtained from this test method will provide a relative measure of dust-cloud autoignition temperature.

The test is conducted per ASTM E 1491, "*Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*". The apparatus used is the BAM Oven manufactured by Kühner A.G. of Basel Switzerland.

Terminology

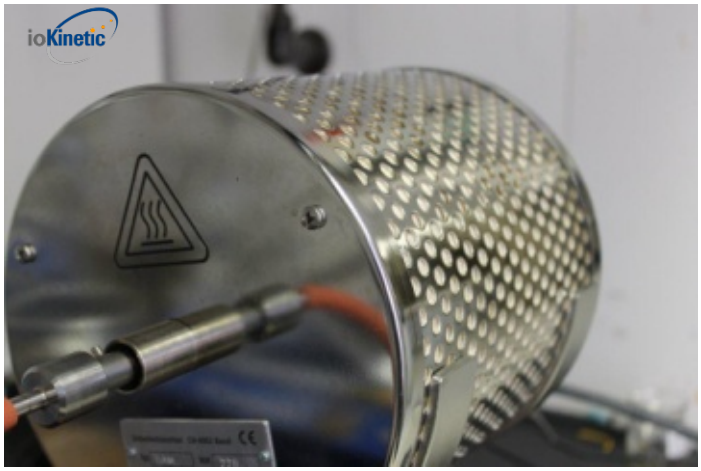
MAIT – minimum temperature at which a dust cloud will self-ignite under the specified conditions of the test

Test Setup

The test is conducted in BAM Oven, depicted in the figure below. The apparatus consists furnace connected to a control system to measure and control the temperature. A squeeze bulb is used for dispersion. A more detailed description of the apparatus is available from the manufacturer.

A more detailed description of the apparatus is available from the manufacturer.

Figure: MAIT Test Setup



Sample Preparation

ASTM recommends the moisture content of the test sample not exceed 5% “in order to avoid test results of a given dust being noticeably influenced.” Samples which exceed the 5% moisture requirement are typically dried using a suitable method for the specific sample.

Similarly, ASTM recommends 95% of the particles in the sample be smaller than 75µm. For samples with larger particle size distributions, grinding and sieving may be conducted.

NFPA allows testing on ‘as received’ samples. ASTM notes that when “as-received” testing is conducted, “…the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal…may increase the explosion severity.”

Procedure

Once the instrument is determined to be ready for testing, the sample is weighed and placed in the dispersion bulb. An initial estimate of the MAIT is made by heating the oven to 600°C and allowing the temperature to fall. At intervals of 50°C, as the temperature decreases, premeasured dust (1 ml) is dispersed into the furnace with a blast of air. Observations for the presence or absence of flame exiting the rear of the oven are made. After obtaining an estimate of the MAIT, a more precise value is determined by a series of tests at temperatures near the initial estimate.

The test report lists the MAIT as a range between the lowest temperature at which no positive result (flame) is observed and the highest temperature at which a positive result is observed.

Hot-Surface Ignition Temperature (HSIT) of Dust Layer

Scope

This test method is used to determine the minimum temperature at which a layer of dust will ignite. The parameter measured is the minimum hot surface ignition temperature in ºC.

The test is conducted per ASTM E2021, " *Standard Test Method for Hot Surface Ignition Temperature of Dust Layers"*. The apparatus used is shown in the figure below.

Terminology

HSIT – lowest set pressure of the hot plat that causes ignition of the dust layer

Ignition of a dust layer – initiation of self-heating or combustion in the material being tested

Test Setup

The test set up consists of a 200 mm diameter 20 mm thick aluminum plate placed on top of a hotplate with a maximum temperature setting of 450 ºC. See figure below. A thin aluminum pan sits above of the aluminum plate. A stainless-steel ring with diameter 100 mm and 12.7 mm depth is put inside the aluminum plate and the sample to be tested is poured in a layer inside of the ring. Thermocouples are positioned just below the upper surface of the aluminum plate, and in the center of the layer of sample.

Figure: HSIT Test Setup

Sample Preparation

ASTM recommends the moisture content of the test sample not exceed 5% “in order to avoid test results of a given dust being noticeably influenced.” Samples which exceed the 5% moisture requirement are typically dried using a suitable method for the specific sample.

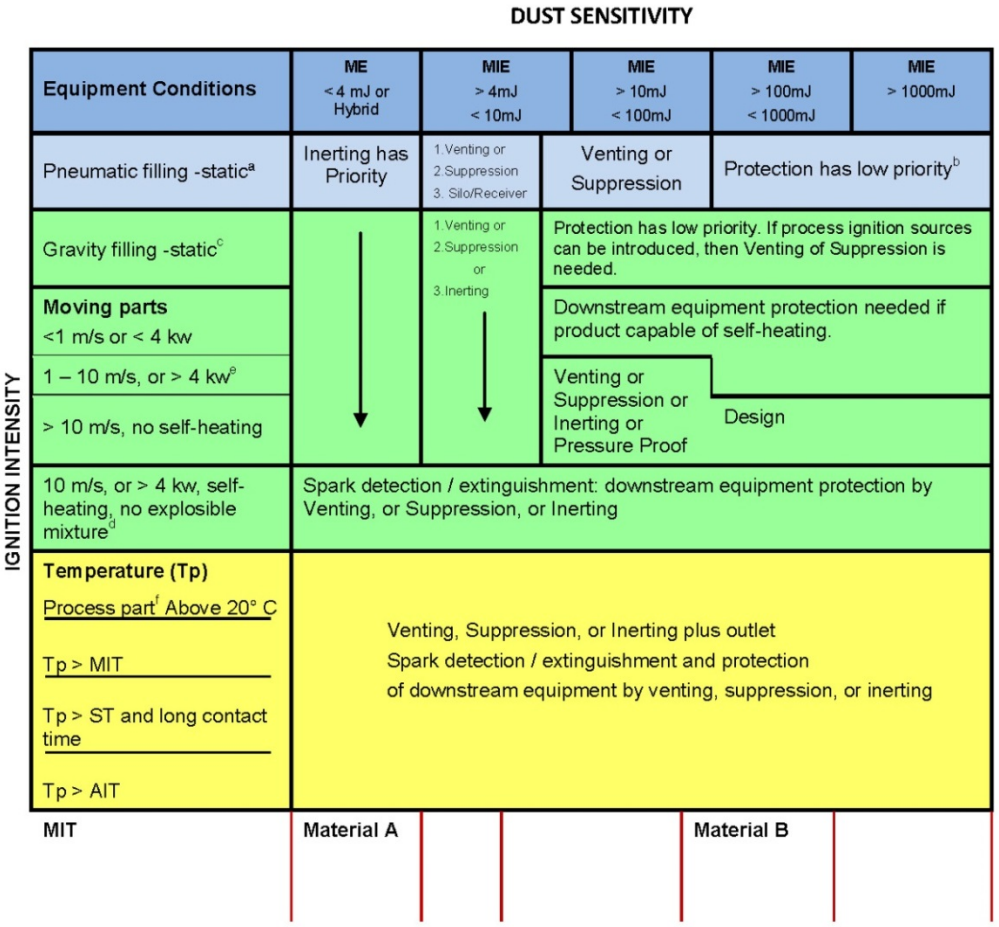
Similarly, ASTM recommends 95% of the particles in the sample be smaller than 75µm. For samples with larger particle size distributions, grinding and sieving may be conducted.

NFPA allows testing on ‘as received’ samples. ASTM notes that when “as-received” testing is conducted, “…the test results may not represent the most severe dust deflagration possible. Any process change resulting in a higher fraction of fines than normal…may increase the explosion severity.”

Procedure

The testing apparatus is set up. The hotplate is turned on and adjusted to the desired temperature. Once the temperature has stabilized the sample to be tested is placed inside of the stainless-steel ring in a layer. The temperature of both the sample as well as the aluminum plate is recorded with respect to time on a data sheet. The test is run for a maximum of 120 minutes, or until the sample layer melts, ignites, or reaches a maximum temperature without ignition and begins to cool down. Visual observations of the sample layer are also made during the test. The test is terminated if no evidence of self-heating exists after 120 minutes. Ignition is considered to have taken place if there is visible evidence of combustion such as a red glow or flame, or if the temperature of the dust layer raises at least 50ºC above the temperature of the aluminum plate. The test is repeated at different set temperatures until the minimum temperature at which self-heating occurs is found. The test series is terminated if ignition of the dust layer does not occur at 450ºC, the maximum temperature of the testing apparatus. If during the test series, melting occurs, the test series is terminated, and the melting temperature of the material is reported.

Appendix D: Guidance for Management of Potential Dust Hazards



a) Assumes all process components (silos, filters, cyclones, blenders, etc.) are made of metal and grounded and bonded. Flexible joints and filter bags are made of antistatic or conductive materials.

b) The choice will depend on the explosion effects. If the effect is unacceptable, then the component should be protected.

c) Filling the vessel from a rotary valve, fall pipe, transport conveyor, container, bag or large bag. All components except bags, are made of metal or antistatic or conductive materials and are adequately grounded and bonded.

d) In some equipment (e.g., redlers and blenders with slowly moving parts) hardly any dust/air mixtures are produced. In other cases, explosive dust air mixtures should be expected unless proven otherwise.

e) Only friction between CS and SS components considered. In case other materials are involved, the hazard should be evaluated further. Particular attention should be given to combinations of light metals with corroded steel, since the frictional sparks produced are intense ignition sources.

f) The process could be a vessel wall, hot gases, hot product material (exothermic reactions) and hot probes, such as an oxygen analyzer. Direct fired product driers are not addressed here.