Minutes of the State Appeals Board
Appeal #16-01
Monday, October 24, 2016
Hearing 8:45 a.m.

Preliminaries:

- **Appeals Board Members:**
  - ➢ Scott McKown, Chair – State Appeals Board, Assistant Director – Construction Codes & Licensing Division (CCLD) – DLI
  - ➢ Michael Godfrey, Manager of Education, Rules and Code Development, CCLD
  - ➢ Chris Meier, Regional Construction Code Representative, CCLD
  - ➢ Rich Lockrem, Construction Code Representative, CCLD
  - ➢ Ryan Rehn, Construction Code Representative, CCLD
- **Other Appearances:**
  - ➢ Jeff Lebowski, Attorney, State Appeals Board, DLI
  - ➢ Jonathan Moler, Assistant Attorney General representing the Board – Office of the Attorney General
  - ➢ Dean Wick, Outsource Architecture LLC, Applicant
  - ➢ David Barsody, Building Official, Benton County
  - ➢ Lyndy Lutz, Administrative support, CCLD – DLI

- Scott McKown welcomed everyone and introduced himself as the Chair of the State Appeals Board, introduced board members and Jonathan Moler. The State Appeals Board convened to hear an appeal from Dean Wick and the determination made by the Building Official, David Barsody.

- Chair McKown stated that the appeal is based on:
  - ➢ Dean Wick contends that Mighty Max Hops should be classified as an "F-2" low-hazard factory industrial use instead of an "F-1" Moderate-hazard factory industrial use as determined by the building official.

- Chair McKown noted that the meeting would be recorded in order to produce minutes of the hearing and he asked that speakers clearly state their name and who they are representing. He then asked Mr. Moler to address the Board.

- Mr. Jonathan Moler introduced himself as an Assistant Attorney General with the State representing the Board. According to Minnesota Rule 1300.0230, the Board of Appeals has the authority to reverse a decision if it determines the state building codes were incorrectly interpreted, if the provisions of the code don't apply, or if a better form of construction is proposed. The Board has no authority to waive any part of the code. The Board's decision must be made exclusively on the evidence in the record and Board members can utilize their experience, technical competence, and specialized knowledge to evaluate evidence in the record.

Call to order/ 8:45 am

- Chair McKown called the hearing to order and reviewed procedures:
    - The applicant and building official will each have an opportunity to address the board. He asked that both limit their comments to 30 minutes. The issue before the Board is an interpretation of the building code. The applicant, Mr. Wick, will begin testimony with Mr. Barsody, Building Official, next, followed by Board members asking questions for clarification.

- Dean Wick - Outsource Architecture LLC. He has been in the architectural field for 30 years and registered since 2006. Prior to this he was a full time building official. He is representing Mighty Axe Hops, a new company in state of Minnesota that currently owns a 2 acre parcel where they grow hops in Ham Lake. They are moving to the Benton County area and have purchased approximately 180 acres where they are putting a facility on to dehydrate and dry hops. After they are grown they go through a process with a pellet coming out at the end. Through the process of designing this over the last 8 or 9 months he has learned a lot about the hop process. Most of the equipment comes from Germany. This is the third facility located in the United States of this type of process. There are some larger facilities in Yakima, Washington and he believes David (Barsody) spoke with someone at one of the facilities regarding their process. He referred to **Attachment A** and said the hops grow vertically on a string and then they are brought into the building and harvested. The hop harvester is similar to a combine without wheels and separates the hop flour. The hop is the flour of the hop plant and it is separated from the string and the stem then those are re-composted and put back in the field for the next year. After the hop flour is separated it goes into a hopper then the dehydrating facility. Cooler air, somewhere between 90 and 110 degrees, is pushed up through the bottom of the layer of hops. They come out of the kiln at approximately 6%. They are then brought over to a rehydrating box where air conditioning flows through them until they are at a moisture level of approximately 10%. Next they are conveyed to a baler and then a freezer. Once harvesting is done, approximately 4 to 6 weeks every year, the frozen bales are brought out and put through a de-baler and a pelletizer. He referred to pictures in Attachment A and noted the following:
    - Photo1 – Harvester
    - Photo 2 – Hop or silo – stored until the conveyer belt can be run
    - Photo 3 – Top of the kiln
    - Photo 4 – Storage box
    - Photo 5 – Baler

- Wick noted the pelletizer, shown on Attachment A, is about the size of a 5 gallon bucket. When Mighty Axe started the process, they were under the impression that the whole facility was going to be an Ag, which would be a U facility. Much like some of the facilities that are going in now over closer to the Wisconsin border, they are post frame buildings, total wood construction with a harvester and possibly a pelletizer. Winkleman Building Corporation, a construction management firm in St. Cloud, and a bale and building distributor, designed a rigid frame, pre-engineered steel building to handle Mighty Axe's equipment, harvester and kiln. Preliminary drawings were done by Wolf Manufacturing from Germany, the supplier of all the equipment. Wick began reviewing Wolf's rough design, then learned the process and construction techniques in order to classify the building as a U occupancy under the state building code. Wick said that David (Barsody) said the building doesn't fit under the Ag situation because of the pelletizer. This is the same determination made by Benton County with the farm. Mighty Axe went through a conditional use permit because of the pelletizer and 1 acre of land and the building was assessed as industrial as taxes as such. Wick and Mighty Axe still believe it should be classified as an Ag building much like a barn where all this farm work is being done and brought into the facility. During the CUP testimony, Benton County said Mighty Axe needed a building permit due to the pelletizer. During the permitting process, David (Barsody) and Tom Bruce, Winkelman, discussed about whether Mighty Axe is an F-1 or F-2. The F-2 classification in the building code talks about significant fire hazard. It all comes down to whether the dehydrating or drying hops are flammable. Wick referred to **Attachment B**, Appendix – Ignitability and Explosibility Data for Dusts from Laboratory Tests, page 689, Hops, malted, and said he discussed the flammability designations with the St. Cloud Fire Marshal and the Building Official and Fire Marshal from Wade Park. Malted hops don't have a classification for flammability as shown on the table which is described on page 685, Class 1. No self-sustained combustion and Class 6. Explosive combustion and he noted that malted hops would be classified as a zero. Wick is confident that flammability is non-existent and not a hazard. Wick was only able to find a Safety Data Sheet from Europe for raw hops and they were not classified as a dangerous product according to the European Union. Wick wasn't able to find a U.S. Safety Data Sheet.

- David Barsody, Benton County Building Official. Barsody explained that Mighty Axe first came in as a U occupancy and after discussion with the state it was determined it didn't fit the U occupancy classification. Next he looked into manufacturing and backed into F-1 because it didn't fit an F-2. Looking at the product itself as being a dehydrated or dried product but the packaging, bales, palletizing, and storage of the products in the building make them combustible products. Barsody discussed possible combustibility issues with local building officials and after explaining the entire process, overwhelmingly everyone agreed it should be an F-1. Barsody spoke with the facility in Yakima, Washington, and the drying process was fully explained and he was told that during the drying process there is a possibility of fire. However, the only information on fires he found after researching the Internet was regarding self-combusting or storing too wet. No information was found on dryer fires. Barsody educated himself and arrived at the F-1 occupancy classification due to the size of facility – it exceeds the 12,000 square foot rule; therefore, it would need to have a sprinkler system per the drawing. He was unable to find a similar facility in Minnesota.

- McKown asked Wick if he had anything to add.

- Wick – The facility is approximately 13,111 square feet; therefore, during the permitting process a 3-hour fire wall was put in to separate the freezer from the rest of the building. The cost of the firewall is pushing the owners to see if they can get rid of it. If the facility were 12,000 sq. ft. or less we probably wouldn't be here right now; however, the next facility could be larger. As a new industry coming in, as David mentioned, it is best for the state to determine. Wick said they tried to make the facility up to code or better than what a typical barn is. He believes they have done this.

- McKown closed testimony proceedings and Board members were directed to ask questions of Wick and Barsody for clarification.

Board discussion:

- Mike Godfrey referred to Attachment A, page 3 of Wick's letter, F-2 description – "Factory industrial uses that involve the fabrication or manufacturing of noncombustible materials which during finishing, packing, or processing <u>do not involve a significant fire hazard</u> shall be classified as F-2 occupancies and shall include, <u>but not be limited to</u>, the following:…" Godfrey said the problem he sees is you have to start with a non-combustible material in the beginning to be classified as an F-2. To drop from an F-1 to and F-2 you need to start with a non-combustible material, such as steel. If you are bringing in a non-combustible material but during the finishing, packaging, or processing stage you create a significant fire hazard then that bumps you back to an F-1. The problem is the product. It cannot be classified as non-combustible. It may not be a significant fire hazard. F-2 is a very limited category.

- Chris Meier asked Wick – Is there information on what type of cooler it is? Wick said no, only designed on how much the system needs to cool down and how fast. Wick said he thinks the cooler is less than 1,000 sq. ft. but said yes, it is over 500 sq. ft. Meier said the reason for the question was regarding Chapter 26 for coolers and the only allowance for non-sprinkled buildings is under 400 sq. ft. in relation to a cooler with foam plastics. If the building were classified as an F-2, the cooler could represent a situation where it would need to sprinklered because it is within the building.

- Godfrey – asked if Fire Door G at the cooler is a roll-up or rolling fire door? Wick responded yes, it is a roll-up fire door.

- Godfrey – Is the building classed as a Type II-B building? Wick said no, this was changed in the code review. Godfrey said Sheet S2.1 shows a lot of wood floor framing and the walkway platforms are all wood. This wouldn't be permitted in a Type B construction; therefore, the construction type for the building would be V-B.

- Richard Lockrem – referred to Section 302.1 General Provisions – and said that it wasn't even close to an F-2. The raw products are a living plant that more resembles an F-1 occupancy.

- Wick said they started with the U occupancy for agricultural buildings and made it fit the building code. Then it changed to an F-1 during the permitting process. The Owner doesn't understand why the U classification is in the building code if it can't be used for an agricultural building which is what this is.

- Meier told Wick it would be hard to say it is a volatile product in respect to combustibility although it doesn't say it isn't and this is the issue at hand. Meier said that in western states they are approving a similar product for ground cover around the perimeter of homes in dry, inclement climates with high fire hazards. A "less fire resistant" classification was given for conifers, grasses, shrubs, decorous trees, perennials, annuals, and vines such as their product, and all were classified as the most fire resistive products to be used on the exterior of homes in western states. Meier noted that a 1,000°C flammability test was used on the above products. He also said it isn't noted how much is going to be processed – this information isn't indicated.

- Wick said that Mighty Axe has determined how many bales they needed to process their acreage. Meier said that it was mentioned that Mighty Axe may entertain others product and Wick said Barsody mentioned this but he isn't aware if this is true. Wick said he doesn't know if they owners know how much can be processed due to the freezer capacity because the hops have to maintain a lower temperature, staying green through the entire process, or they lose their value. If they burn or get charred or below 6% humidity, they are of no use. They have to stay between 6 and 10% humidity – they are at 10% when frozen. If they get higher than 10% they will have to be used for compost. This is why the dehydrator works at approximately 19° C (90 to 110°). They are moved into the boxes in order to humidify them with cooler air going in. Wick said he would be more worried about a corn dryer.

- Meier asked why Wick would be more concerned with a corn dryer and Wick responded due to dust, noting he has seen elevators blow up. This doesn't happen in (hops) facilities as far as he knows. Wick said the product is organic, but non-combustible with very low flammability.

- Lockrem said it is confusing how hops are less combustible than the other products with the same moisture content that are being used as a bio fuel. How is there a difference? Wick said he doesn't know what the process is for bio fuels. In the process for brewing beer it is the aroma and the flavor from the hops. The hops stay green through the entire process. The hops need to maintain a lower temperature.

- Lockrem – any living thing can be made into a bio fuel. How is there a difference?

- Wick doesn't know the process for bio fuels.

- Barsody – during the CUP process Benton County asked the owners if they would be entertaining the processing of other farmer's hops. This would determine if it was industrial and not agricultural. The minutes show the owner saying it would be dumb not to take others hops in if someone asked because this is what their facility is for.

- Godfrey said he did some basic floor calculations of the floor area of the building and with the cooler being sprinklered it appears it wouldn't matter if it were F-1 or F-2 – it is close. The biggest problem is the cooler room isn't sprinklered.

- Wick said there is a provision in the fire code that allows for larger, high pile storage than 500 (sq. ft.) without a sprinkler system. Godfrey said it is just the cooler room he was concerned with.

- McKown said the bottom line is the 3 hour wall. Wick said the 3 hour wall was put in to allow the building to get permitted for an F-1 facility. If it gets changed by the Board to an F-2 facility then the 3 hour wall fire wall could be removed.

- Chair McKown closed the presentation portion of fact finding and advised a member of the Board to make a motion. The motion should be specific to the classification by Mr. Barsody on whether the facility should be an F-1 or an F-2 classification. McKown asked Mr. Moler if it would be acceptable for the board members to have a discussion amongst themselves with Moler responding yes, as long as it is on the open record. McKown said he would ask Mr. Moler to help the board propose a motion.

- Meier stated he would need more clarification to drop to an F-2 classification.

- Godfrey said he found a material safety data sheet from Germany. They use the European and ISO Standard and under regulatory information it states not applicable for hazard identification. Normally a U.S. report would be relied upon but nonetheless the Germany report is a valid piece of information. He is not uncomfortable with an F-2 classification and noted he watched the video Wick provided and the amount of dust was very negligible.

- Ryan Rehn –If you explore an F-1 as a separated use then you can get into an area where you wouldn't require a sprinkler system for the F-1 but if you kick it into an F-2 category as a separated use then you are going to get into a 2 hour separation between all other occupancies. Whether it is combustible or not, the building could still fit as an F-1 or combustibility, and may not require a sprinkler system if the building area doesn't exceed the ratio of one. The cooler would still be required to be sprinklered based on IBC Section 2603.4.1.3.

- Meier agreed with Rehn if breaking up the B from the S with a two hour wall then the other would need to be broken up.

- Rehn said if an F-1 then there is no separation required. Rehn and Meier said a 5B might need to be re-evaluated.

- McKown said that this is fabricating a product, one that is relatively new to the state of Minnesota. The question is it an F-1 or an F-2 based on the information at hand.

A motion was made by Meier but was rescinded.

A motion was made by Meier, seconded by Godfrey, based on the information in the record, the board moves to classify the processing portion of the facility as an F-2. The majority vote ruled in favor; the motion carried.

A motion was made by Meier, seconded by Godfrey, to move that Chair McKown and Attorney Jonathan Moler prepare the Findings of Fact and Order. The vote was unanimous; the motion carried.

A motion was made by Chair McKown to adjourn the meeting at 9:47 a.m. The vote was unanimous to adjourn the meeting.

OUTSOURCE
ARCHITECTURE
P.O. Box 7274; St. Cloud, MN 56302
Office: (320) 267-3206

October 13, 2016

Project Title: Mighty Axe Hops
8505 95th St. NE
Foley, MN 56329

Doug Nord
MN Department of Labor & Industry
443 Lafayette Road N.
St. Paul, Minnesota 55155

Dear Mr. Nord;

We are respectfully appealing the interpretation of the Benton County Building Official, David Barsody of Inspection Services of Central Minnesota, Inc. concerning the above referenced project. We understand the complexity of the project and the new industry to Minnesota. The Owner, the Contractor and I, the Architect, make ourselves available for any additional questions or clarifications required through-out this process. We have a summary of the project and the resulting facts below:

We initially decided that the building was an agricultural building covered under the State Building Code as a U-Occupancy. The building was designed as such. During the code review process Mr. Barsody wanted to classify the building as an F-1 Occupancy as he had conversations with Building Officials in the Yakima Valley in Washington State. I explained that these western producers handle the hops in a different manner than what is planned at Mighty Axe Hops. These discussions were not fully understood by Mr. Barsody. I will further explain the hop harvesting process, the humidification process and the pelleting process. As my research will show, there is not a "significant fire hazard" posed by pelletizing hops.

Mr. Barsody classified the building as an F-1 because "The definition of hops is that it is of the hemp family and hemp is found under F1 classification."(see paragraph 3 of his letter dated 9-21-2016). While it is true that a hop plant (*Humulus lupulus*) is a member of the Cannabaceae family same as hemp or hackberry trees, a hop plant is classified as a separate genera. The Cannabaceae family includes about 170 species grouped in about 11 genera, including *Cannabis* (hemp, marijuana), *Humulus* (hops) and *Celtis* (hackberries). To say that a hop flower is hemp would be much like saying corn is bamboo or the grass in your lawn. Those are all in the Poaceae family but very different in structure and use.

The easiest way to explain why a hop flower product is different from hemp stem product is that the hop stem is not processed. The hop plant produces a flower or a seed cone that is typically called a hop. The hop harvester separates the seed cone (the hop) from the stem prior to drying and baling of the seed cone. The green hops when freshly picked have a moisture content of close to 80%; this is reduced to 6% by the use of a flow of heated air (70-110 degrees) in a "kiln", rather than a firing process in a dryer bin. The hops are then humidified (think air conditioning) in storage boxes. Once to the proper moisture content (about 10%) the hops are baled for storage. This process does not change the form of the hop.

The term "hemp" is used to name the durable soft fiber from the Cannabis plant stem (stalk). However, hemp can refer to any industrial or foodstuff product that is not intended for use as a drug. Cannabis for industrial uses is valuable in tens of thousands of commercial products, especially as fiber ranging from paper, cordage, construction material and textiles and clothing. It also is a useful source of foodstuffs (hemp milk, hemp seed, hemp oil) and biofuels. Other products made from hemp fiber include: insulation, particleboard, fiberboard, rope, twine, yarn, newsprint, cardboard, paper, horse stable bedding, and compost.

In hemp production the stem is harvested and manipulated for its fiber. The stem is chemically treated to breakdown the fibrous material and then it is dried (above 210 degrees) until it resembles cotton candy or batt insulation.

In Mr. Barsody's letter dated September 21, 2016, paragraph 4 states that he had conversations with a building official in Yakima, Washington concerning hop production facilities in his jurisdiction. These facilities should not be compared at all to the business model for Mighty Axe Hops. The Mighty Axe Hops facility is only the third of its kind in the nation. The first USA facility with the same equipment was built in Michigan. I have personally toured this facility. In my opinion, Mighty Axe Hops' building is far superior to it in code protection. The second facility is being constructed in Nebraska. I have included pictures of what Mighty Axe Hops is proposing for equipment and pictures of facilities in Yakima, Washington, for comparison.

Benton County classified the 80 acre hop farm, harvesting, drying of the hop, baling and storage of the hop as agricultural. At the point the hop bale is pelletized, the County determined that a Conditional Use Permit would be required. The Owner went through the process to secure the CUP. During the public hearing, it was stated by the County that if the pelletizer wasn't a part of this project, the Owner would not be going through the CUP process and would have been able to obtain a building permit at the counter without much documentation, similar to a "barn". While it is true that the pelletizing of the hops does change the form of the hop it does not pose a "significant fire hazard". The hop flower and associated dust is not flammable (see attached documentation). Pictures of the hop pelletizer can be found in this package. The manufacturer of the pelletizer has commented on the local requirement for a sprinkler system in this facility. These comments are also attached to this appeal. The Mighty Axe Hops' pelletizer is the size of a 5-gallon bucket; compare this to the Yakima Washington pelletizers which are the size of a small house.

We are not asking for any agricultural exemption with this appeal. We have designed this facility with the MN State Building Code in mind. The building is a pre-engineered steel building with a concrete block kiln area. We are asking that this facility be classified as an F-2 instead of the F-1 classification the local building inspector has placed on the building because of a misunderstanding of what the facility does and how it differs from a hemp processing facility. Section 306.3 Low-hazard factory industrial, Group F-2 is defined as: "Factory industrial uses that involve the fabrication or manufacturing of noncombustible materials which during finishing, packing or processing <u>do not involve a significant fire hazard</u> shall be classified as F-2 occupancies and shall include, <u>but not be limited to</u>, the following:..." A hop harvesting facility does not involve a "significant fire hazard" as shown by the attached documents. An F-2 classification is not and should not be limited to the short list provided within Section 306.3.

The MN State Building Code Section 306.2 classifies those "Factory industrial uses which are not classified as Factory Industrial F-2 Low Hazard shall be classified as F-1 Moderate Hazard..." It seems that the building code attempts to first classify a structure as F-2 before dumping it into the layer category of F-1. We are able to explain why this structure should be an F-2 Occupancy therefore it doesn't belong to the F-1 Occupancy.

Please review the letter and attached documentation at your earliest convenience. We feel very confident that an F-2 classification is the appropriate occupancy with regards to the concept of equivalent risk.

If additional information should be required please contact my office. Thank you for your consideration of this request.

Respectfully submitted,

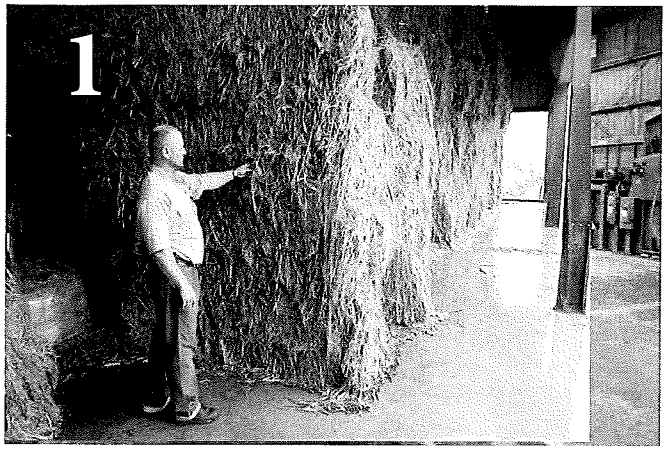
Dean A. Wick

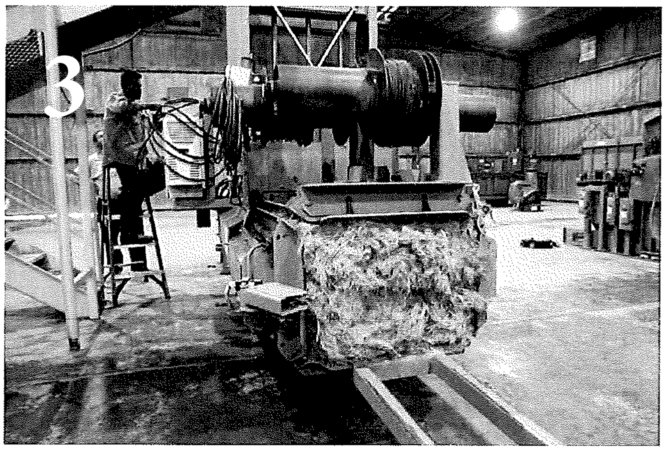
Dean A. Wick, Architect
MN Registration #44794

Enclosures

Cc: Benton County
Mighty Axe Hops
Winkelman Building Corp.

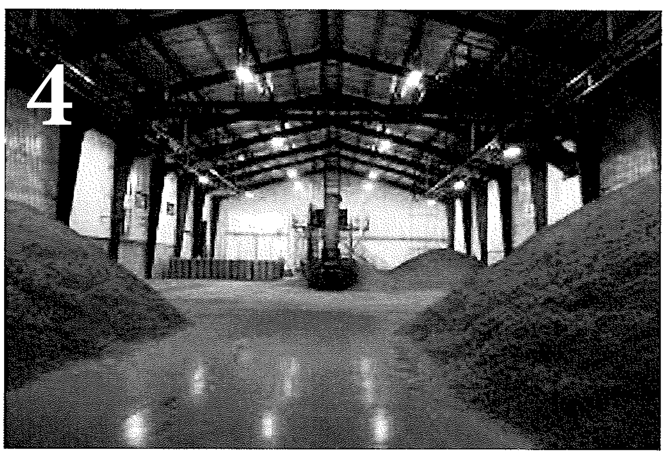
Attachment A

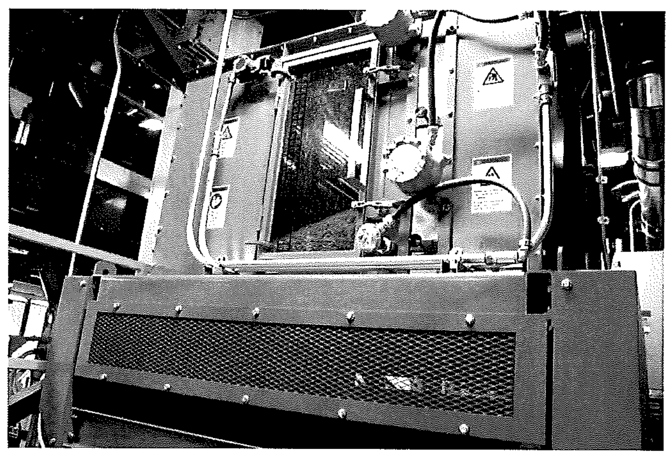


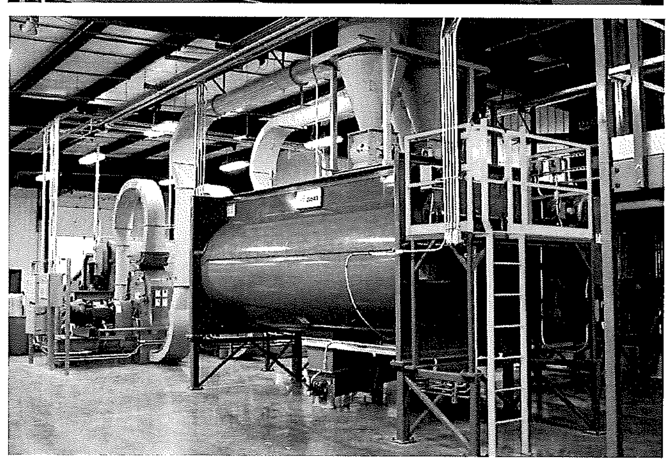


Hemp processing facility

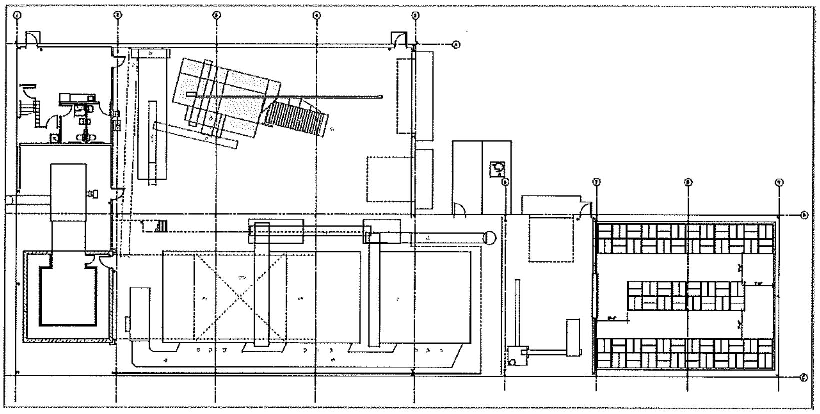
Yakima Washington Hop
Storage & Pelletizing Machines

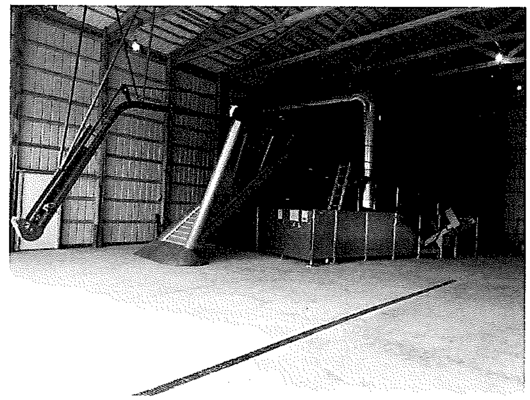




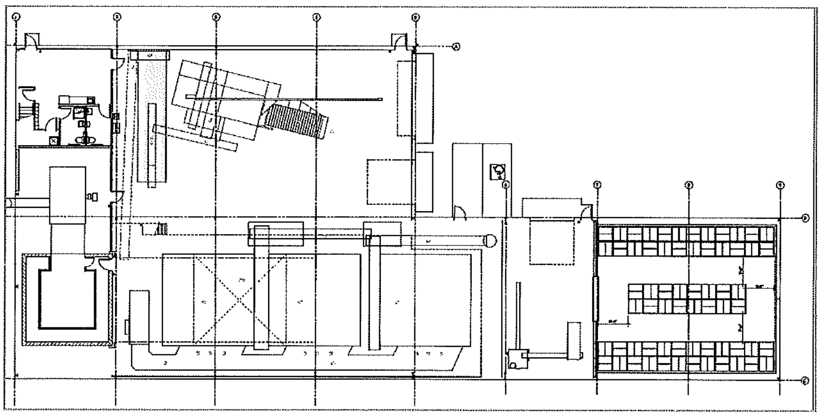


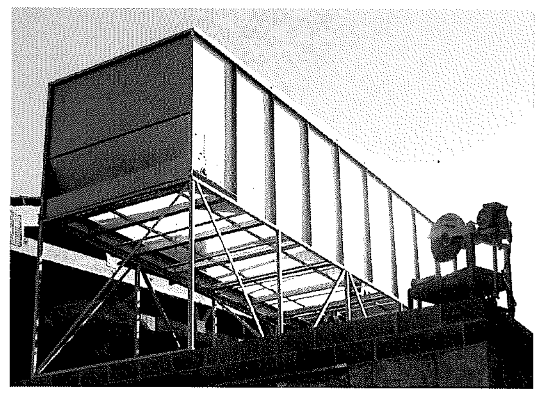
Mighty Axe Hops



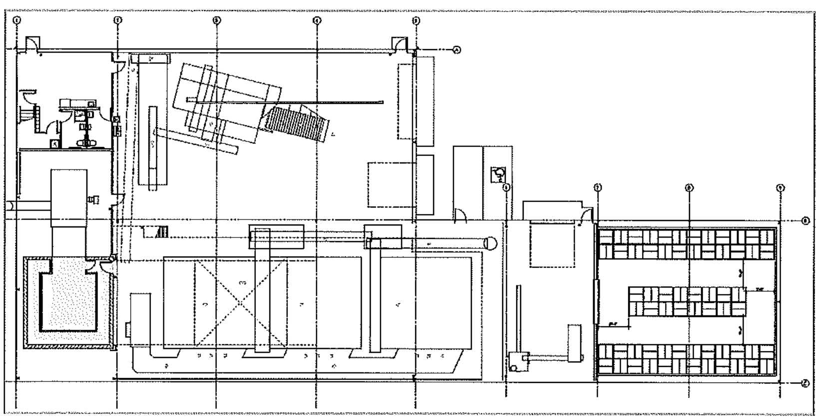


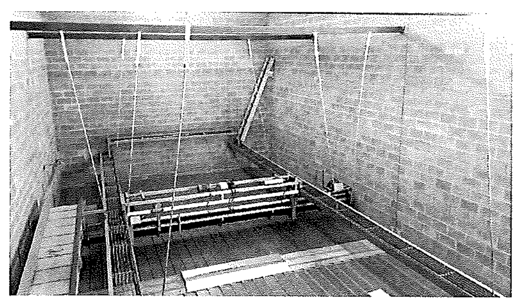
Harvester



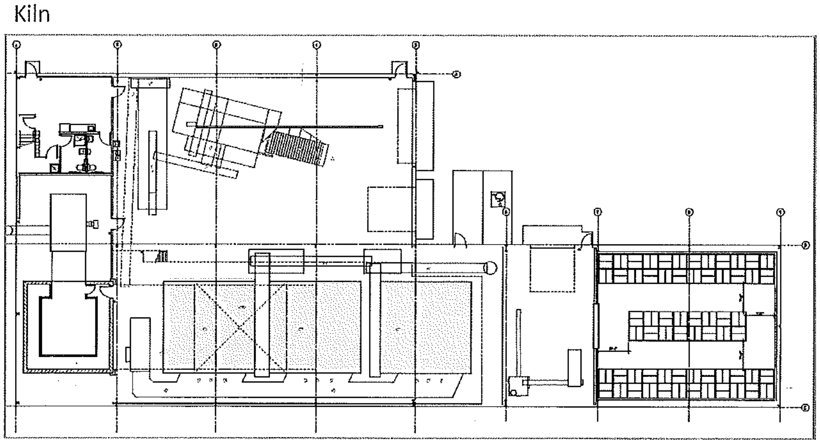


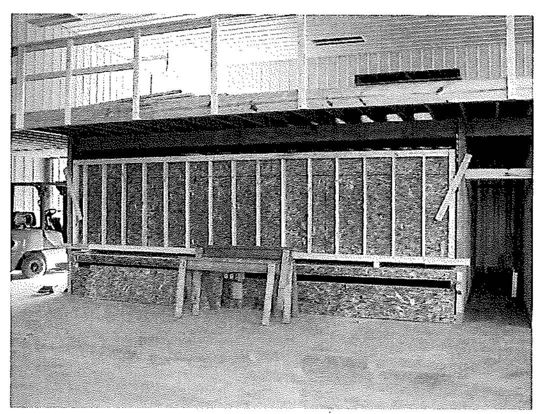
Silo





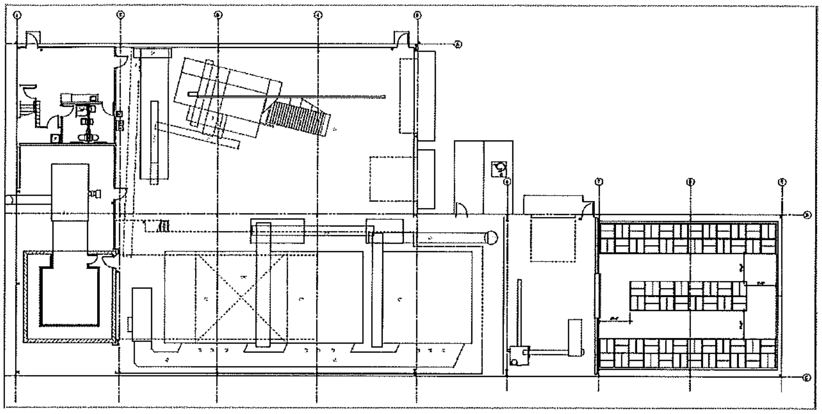
Kiln

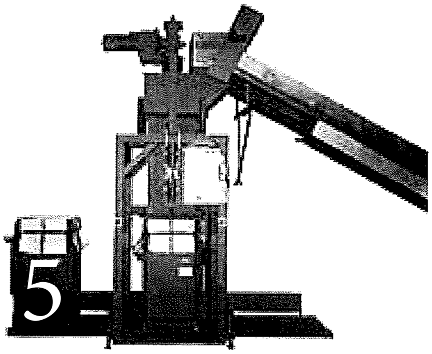




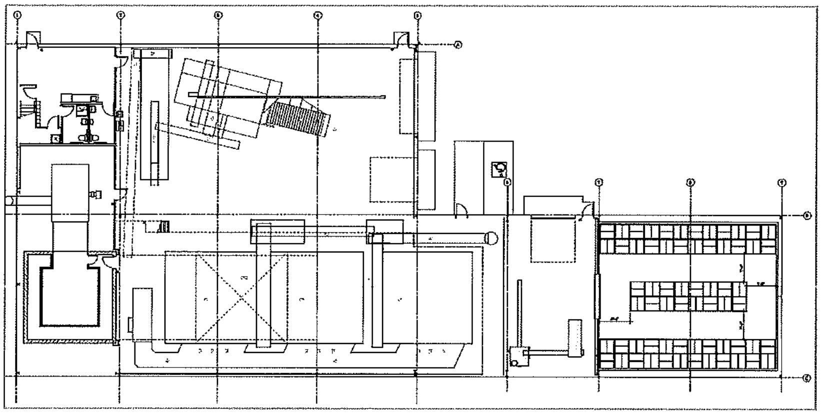
Boxes

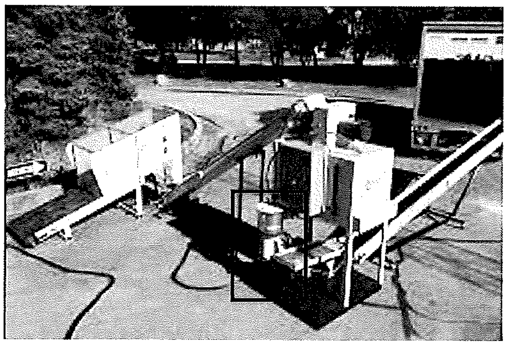
Attachment A





Baler





Pelletizer

Pelletizer Mill

Attachment A

Gmail

Dean Wick <wick.outsource@gmail.com>

Fwd: PM1220

Eric Sannerud <eric@mightyaxehops.com>
To: Dean Wick <wick.outsource@gmail.com>
Cc: ben@mightyaxehops.com

Thu, Sep 8, 2016 at 5:41 PM

Hi Dean - here are the photos!

Eric

Eric R. Sannerud
952.201.4227

CEO
Mighty Axe Hops

MSPBJ 40 Under 40

---------- Forwarded message ----------
From: "Ty Stoppenhagen" <ty@buskirkeng.com>
Date: Sep 8, 2016 17:04
Subject: PM1220
To: "Eric Sannerud" <eric@mightyaxehops.com>
Cc:

Eric.

Get these pictures to Dean. We had a conversation this afternoon that was quite funny. The building inspector is comparing this equipment to the equipment out in Yakima, after he made a call out there. I think that's why he feels you guys need fire protection.

Also... note that this a conveyer fed system meaning that there is no air involved in handling of the hops, deeming it less likely for combustion to occur.

Let me know what else you need.

Ty Stoppenhagen

Sales Manager

Buskirk Engineering

260.622.5550 Ext 1

ty@buskirkeng.com

www.buskirkeng.com

Attachment A

BUSKIRK ENGINEERING

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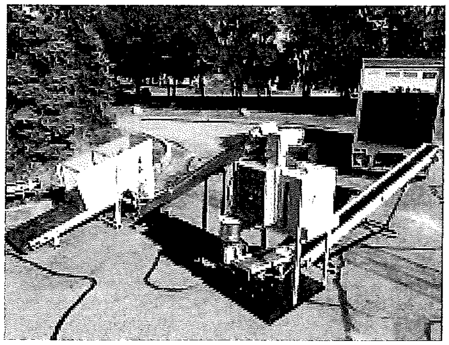
2 attachments



Single PM1220 Hops System.JPG
3279K

1220 SINGLE HOPS SYSTEM.pdf
205K

Eric Sannerud

Sep 9

to me

FYI!

---------- Forwarded message ----------
From: **Ty Stoppenhagen** <ty@buskirkeng.com>
Date: Thu, Sep 8, 2016 at 5:23 PM
Subject: Re: Single PM1220 System
To: Eric Sannerud <eric@mightyaxehops.com>
Cc: "ben@mightyaxehops.com" <ben@mightyaxehops.com>

They're not flammable would be my answer. If the mill was running at like 220 then we may have an issue. I have never come across this topic for hops.

Ty Stoppenhagen
Sales Manager
Buskirk Engineering
260.622.5550 Ext 1
ty@buskirkeng.com
www.buskirkeng.com

On Sep 8, 2016, at 5:09 PM, Eric Sannerud <eric@mightyaxehops.com> wrote:

Here is his one question! How flammable are the hops as they pellet?

Eric R. Sannerud
952.201.4227

CEO
Mighty Axe Hops

MSPBJ 40 Under 40

---------- Forwarded message ----------
From: "Dean Wick" <wick.outsource@gmail.com>
Date: Sep 8, 2016 16:05
Subject: Re: Single PM1220 System

Attachment A

Eric Sannerud

Sep 9

to me

More fire risk information.

Eric R. Sannerud
952.201.4227

CEO
Mighty Axe Hops

MSPBJ 40 Under 40

---------- Forwarded message ----------
From: "Ty Stoppenhagen" <ty@buskirkeng.com>
Date: Sep 9, 2016 08:56
Subject: RE: Single PM1220 System
To: "Eric Sannerud" <eric@mightyaxehops.com>
Cc: "ben@mightyaxehops.com" <ben@mightyaxehops.com>

Yep on the quote.

Talked to a couple of bigger growers. Zero chance of hops catching fire during the pelletizing process. They said if anything, you would be more likely to have combustion while packing the hops into bale form, although they've never heard of a bale blowing up.

FYI. I tried to start a really dry hop bale on fire here in the shop. No luck.

Appendix

Ignitability and Explosibility Data for Dusts from Laboratory Tests

A.1
TABLES A.1, A.2, AND A.3 AND COMMENTS FROM THE BIA (1987)

A.1.1
LIMITATIONS TO THE APPLICABILITY OF THE DATA

A.1.1.1
Particle Size and Moisture Content

The applicability of the data in Tables A.1, A.2, and A.3 to other dusts of apparently identical materials is limited. In practice, dusts of a given overall chemistry may differ widely in particle size, particle shape, and sometimes also in particle surface reactivity. Furthermore, most ignitability and explosibility parameters are influenced by inherent features of the test method. Therefore, as a general rule, the tabulated data should be used only as indications and not as the ultimate basis for design of actual safety measures in industry. On the other hand, data obtained using the same test method allows relative comparison of ignitability and explosibility of various dusts. It is always necessary, however, to account for any significant differences between the particle size distributions and particle shape of the actual dust of interest and those in Tables A.1, A.2, and A.3.

For a given dust material, the maximum explosion pressure (P_{max}) and the maximum rate of pressure rise (K_{St}) increase systematically with decreasing particle size and moisture content. The minimum ignition energy (MIE) generally decreases with decreasing particle size and moisture content. Decreasing the moisture content and particle size can also cause a decrease in both the minimum explosible dust concentration (C_{min}) and the minimum ignition temperature of a dust cloud (T_{min}). The dusts were tested "as received," and general lack of information on the moisture content presents a further uncertainty concerning the specific applicability of the data. This applies, in particular, to the data for wood and cellulose and food and feedstuffs. Such dusts often contain considerable fractions of moisture in the "as received" state.

It is generally advisable to have the actual dust of interest tested in a professional laboratory.

A.1.1.2
Initial State and Composition of the Gas in Which the Dust Is Dispersed or Deposited

The data in Table A.1 apply to

- Atmospheric pressure (from −0.2 to +0.2 bar(g)).
- Oxygen content of air (from 18 to 22 vol% O_2).
- Normal ambient temperature (from 0 to 40°C).

In general, P_{max}, and under certain conditions also $(dP/dt)_{max}$ or K_{St}, increase proportionally with the absolute initial pressure. Increased oxygen fraction in the atmosphere increases both the ignitability and the explosibility, whereas a lower oxygen content than in air reduces the hazard correspondingly. Increased initial temperature increases the ignition sensitivity (reduces MIE). Normally, data for conditions that deviate significantly from the standard test conditions have to be determined specifically in each case.

If the gas phase contains some combustible gas or vapor, even in concentrations considerably below the lower explosibility limit for the gas or vapor, hybrid effects can give rise to considerable increase of both ignition sensitivity and explosibility. In such cases, specific tests definitely have to be conducted.

A.1.2
COMMENTS ON THE VARIOUS ITEMS IN TABLE A.1

A.1.2.1
Selection and Identification of Dusts

The original table, published in German by the BIA (1987), contains nearly 1900 dusts. Therefore, the selection of about 375 dusts in Table A.1 constitutes about 20% of those in the original tables. When making the selection, the samples of a given dust material that gave the most severe test data were normally preferred. In addition, sequences for some given dust materials showing systematic effects of, for example. moisture content or particle size were included. Examples of this are data for peat and aluminum.

In the original German table, the dusts are identified by a code number, which has been omitted here. However, the sequence of the dusts in the condensed table is identical to that in the original table. If required, the dusts in the condensed table can be easily identified in the original German table by means of the particle size data and the ignitability and explosibility data.

A.1.2.2
Particle Size Distribution

Most of the dusts were tested as received. However, in some cases, fractions passing a 63 μm sieve were tested.

A.1.2.3
Minimum Explosible Dust Concentration (C_{min})

Most of the tabulated data were determined in the standard closed 1 m^3 ISO (1985) vessel or in the closed 20 liter Siwek sphere. Experience has shown that the latter apparatus tends to give lower values than the 1 m^3 vessel, often by a factor of 2. (Note: Another standard small-scale method, approved by Nordtest, 1989, seems to give data in somewhat closer agreement with those from the 1 m^3 ISO vessel.) The C_{min} values in brackets were determined in the modified 1.2 liter Hartmann apparatus in terms of the smallest dispersed dust quantity that propagated flame, divided by the vessel volume. These values are sometimes higher than the true C_{min} because of the comparatively weak ignition source used.

A.1.2.4
Maximum Explosion Pressure (P_{max})

The maximum explosion pressures were obtained either in the standard 1 m^3 ISO vessel or in the 20 liter Siwek sphere. The data in brackets were obtained in the 20 liter sphere using a simplified test procedure due to limited amounts of dust for testing. The standard procedure requires at least three replicated tests at each dust concentration over a range of different concentrations.

A.1.2.5
Explosion Violence (K_{St}, St class)

K_{St} is defined as the maximum rate of pressure rise during a dust explosion in an equidimensional vessel, times the cube root of the vessel volume. K_{St} (bar m/s) is numerically equal to the maximum rate of pressure rise (bar/s) in the 1 m^3 standard ISO (1985) test. The K_{St} data in the table were obtained either in the standard ISO test or in the 20 liter Siwek sphere, adopted by ASTM (1988), which has been calibrated to yield comparable K_{St} values.

The St class was determined using the modified Hartmann tube with a hinged lid at the top. Brackets indicate that this test method is not considered adequate in the Federal Republic of Germany for conclusive classification of St2 and St3 dusts (St2 means that 200 bar m/s $\leq K_{St} <$ 300 bar m/s, and St3 that $K_{St} \geq$ 300 bar m/s).

A.1.2.6
Minimum Ignition Temperature of Dust Clouds

These data were acquired using either the Godbert-Greenwald furnace or the BAM furnace. The data in brackets were obtained using a modified, elongated version of the Godbert-Greenwald furnace, yielding somewhat lower values than the version proposed as an IEC (International Electrotechnical Commission) standard.

A.1.2.7
Minimum Ignition Energy (MIE)

In the original BIA (1987) publication, the MIE values appear in a separate table. However, because the dusts could be identified by their reference numbers, it was possible to incorporate the MIE values in Table A.1. These values are determined using soft sparks (long discharge times) in agreement with the VDI method described by Berthold (1987). Down to net spark energies of about 1 mJ, this method is in complete accordance with the CMI method described by Eckhoff (1975). The VDI and the CMI methods are the basis of the method for measuring MIE that is being evaluated by the IEC. The VDI and CMI methods differ from the earlier U.S. Bureau of Mines (USBM) method, in which an appreciable fraction of the $^1/_2CV^2$ quoted as MIE was lost in a transformer and never got to the spark. Therefore, the USBM MIE values are generally higher than those determined by the new method. A tentative correlation for transforming USBM data to equivalent VDI/CMI data is given in Figure A.1 (see also Section A.2.4).

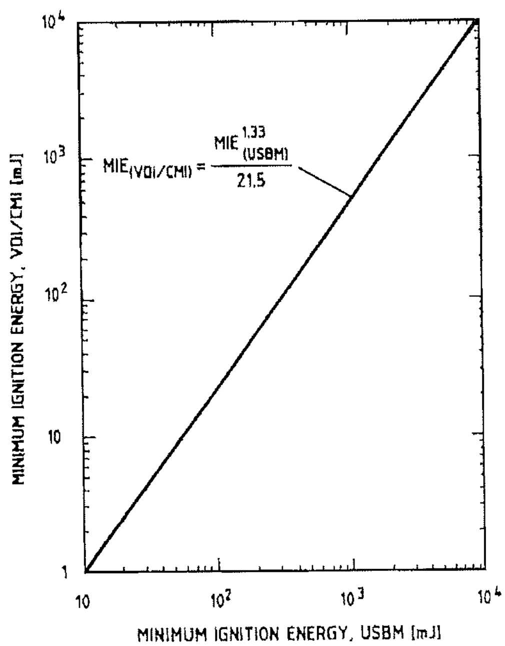


Figure A.1 *Approximate empirical correlation between the minimum ignition energies measured by the earlier USBM method described by Dorsett et al. (1960), and values generated by the more recent methods described by Eckhoff (1975) and Berthold (1987), and the method being evaluated by the IEC (see Chapter 7). Note: The correlation must be used as an indication only and must not be extrapolated*

A.1.2.8
Glow Temperature

These data were obtained with a 5 mm thick layer of dust resting on a hot plate of known, controllable temperature (equivalent to proposed standard IEC method for determining the minimum ignition temperature of a dust layer on a hot surface).

A.1.2.9
Flammability

The dusts are classified according to their ability to propagate a combustion wave when deposited in a layer. Ignition is accomplished using either a gas flame or a glowing platinum wire at 1000°C. The test sample is a 2 cm wide and 4 cm long dust ridge resting on a ceramic plate. Ignition is performed at one end. The classifications are

- Class 1. No self-sustained combustion.
- Class 2. Local combustion of short duration.
- Class 3. Local sustained combustion but no propagation.
- Class 4. Propagating smoldering combustion.
- Class 5. Propagating an open flame.
- Class 6. Explosive combustion.

The numbers in brackets refer to a modified test procedure according to which 20 weight% diatomaceous earth is mixed with the powder or dust to be tested. By this means, some materials that otherwise would not propagate a flame because they melt may show sustained flame propagation.

A.2
APPLICABILITY OF EARLIER USBM TEST DATA

A.2.1
BACKGROUND

The U.S. Bureau of Mines in Pittsburgh, PA, developed a comprehensive set of laboratory test methods for characterizing ignitability and explosibility of dusts, and published a large number of test data, which have been widely used throughout the world. The test apparatuses and procedures were described by Dorsett et al. (1960). Test data for 220 agricultural dusts were reported by Jacobson et al. (1961); for 314 dusts in the plastics industry, by Jacobson, Nagy, and Cooper (1962); for 314 metal powders, by Jacobson, Cooper, and Nagy (1964); for 241 carbonaceous dusts, by Nagy, Dorsett, and Cooper (1965); for 175 chemicals, drugs, dyes, and pesticides, by Dorsett and Nagy (1968); and for 181 miscellaneous dusts, by Nagy, Cooper, and Dorsett (1968); that is, for 1445 dusts altogether.

In more recent years, alternative test methods have been developed, and there is a need to indicate the extent to which the substantial amount of the earlier USBM data are compatible with more recent data, as for example those in Tables A.1, A.2, and A.3.

A.2.2
MINIMUM IGNITION TEMPERATURE OF THE DUST CLOUD

The apparatus used was the original Godbert-Greenwald furnace, which is essentially the same apparatus as the Godbert-Greenwald furnace used for determining the data in Table A.1. The earlier USBM data should therefore be compatible with those in Table A.1.

Table A.1 Ignitability and explosibility of dusts

Dust type	Particle size distribution: Weight % <Size (µm)								Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel			Mod. H.			Dust layers: VDI	DIN	
	500	250	125	71	63	32	20	Median (µm)	C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Explos. <63 µm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	MIE (mJ)	Glow temp. (°C)	Flam. <250 µm (Class)
Cotton, wood, peat																	
Cotton			98	72		38	25	44	(100)	7.2	24	St. 1	560			350	3
Cellulose			92	71		20	3	51	60	9.3	66		500		250	380	5
Wood dust				90		47	7	33					500		100	320	
Wood dust	58		57	55		43	39	80					480		7	310	
Wood dust (chipboard)				70		30		43	60	9.2	102	St. 2	490			320	3
Wood, cardboard, jute									30	5.8	26		610		245	360	5
Wood, cardboard, jute, resin									30	8.4	67		520		3	350	5
Lignin dust			96	85		66	57	18	15	8.7	208		470			>450	5
Paper dust				91		83	73	<10		5.7	18		580			360	
Paper tissue dust			75	58				54	30	8.6	52	(St. 2)	540			300	4
Paper (phenolresin treated)				100		90	25	23	30	9.8	190		490			310	
Peat (15% moisture)			84	58		26	3	58	60	10.9	157	St. 1	480			320	4
Peat (22% moisture)			82	65		40	15	46	125	8.4	69	St. 1	470			320	4
Peat (31% moisture)			87	76		43	20	38	125	8.1	64		500			320	
Peat (41% moisture)			88	76		40	18	39	No ignition				500			315	
Peat (from bottom of sieve)			78	48		22		74	125	8.3	51	St. 1	490			310	4
Peat (dust deposit)				66		33	11	49	60	9.5	144		(360)			295	
Paper pulp				93		76		29		9.8	168						
Food, feedstuffs																	
Gravy powder (21% starch)					100					5.1	12			500	>1000		
Citrus pellets					100				60	7.7	39			460	250		
Dextrose, ground			100		94	71		22				St. 2					2
Dextrose				38		5	4	80	60	4.3	18	St. 1	500			570	3
Fat/whey mixture	76		11	3				330		7.0	23		450		180	410	5
Fat powder (48% fat)		100	75		24	7		92	30	6.4	20	St. 2					2
Dough					100									430	>100		

Fishmeal	68		23		12			320	125	7.0	35		530				
Fructose (from filter)	99		39	17				150	60	9.0	102		430		<1	Melts	
Fructose	92		15					200	60	7.0	28		440		180	440q	
Fructose	81							400	125	6.4	27		530		>4000	Melts	
Barley grain dust	79	51	25		8	3		240							100		4
Dough					100				125	7.7	83			400			
Oats grain dust	64		24		8			295	750	6.0	14	St. 1				350	3
Wheat grain dust				48		30		80	60	9.3	112	St. 1				290	3
Wheat grain dust	100	81	50		32	25		125				St. 2					3
Coffee (from filter)				100		99	89	<10	60	9.0	90		470			>450	
Coffee (refined)					100					6.8	11			460	>500		4
Cocoa bean shell dust					100				125	8.1	68				>250		4
Cocoa/sugar mixture	53		20					500	125	7.4	43	St. 1	580			460	2
Potato granulate					100					6.4	21			440	>250		3
Potato flour			86	53		26	17	65	125	9.1	69		480			>450	
Lactose (from filter)				83		60	47	22	125	6.9	29		450		80	>450	
Lactose (from cyclone)				97		70	41	23	60	7.7	81	St. 2	520			>450	3
Maize seed waste (9% moisture)	98	67	40		23	16		165	30	8.7	117			440	>10		
Milk powder			34	18				165	60	8.1	90		460		75	330	
Milk powder	98		15	8				235	60	8.2	75		450		80	320	
Milk powder (low fat, spray dried)	100	100	99		60	17		46	30	7.5	109				>100		
Milk powder (full fat, spray dried)				30				88	60	8.6	83	St. 1	520			330	2
Whey fat emulgator	62		7	2				400		7.2	38		450		90	420	5
Olive pellets					100				125	10.4	74			470	>1000		
Rice flour					100				60	7.4	57			360	>100		
Rye flour			94	76		58	15	29		8.9	79		490			>450	
Soy bean flour				85		63	50	20	(200)	9.2	110	St. 1	620			280	2
Potato starch					100				30	7.8	43			420	>1000		
Potato starch				100		50	17	32		(9.4)	(89)		520		>3200	>450	2
Maize starch				99		98	94	<10		10.2	128		520		300	>450	2
Maize starch				94		81	60	16	60	9.7	158	St. 1	520			440	2

Table A.1 continued

Dust type	Particle size distribution: Weight % <Size (μm) 500	250	125	71	63	32	20	Median (μm)	Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Mod. H. Explos. <63 μm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	Dust layers: VDI MIE (mJ)	DIN Glow temp. (°C)	Flam. <250 μm (Class)
Rice starch (hydrolyzed)				29		15		120	60	9.3	190	(St. 2)	480			555	5
Rice starch				99		74	54	18					470		90	390	3
Rice starch				86		62	52	18		10.0	190	(St. 2)	530			420	3
Wheat starch						84	50	20	60	9.8	132	(St. 2)	500			535	3
Tobacco			81	64		29		49		4.8	12		470			280	
Tapioca pellets				61		42		44	125	9.0	53	St. 1	(450)			290	4
Tea (6% moisture)					100				30	8.1	68			510			≥3
Tea (black, from dust collector)			64	48		26	16	76	125	8.2	59	St. 1	510			300	4
Meat flour			69	52		31	21	62	60	8.5	106	St. 1	540			>450	2
Wheat flour								50					500		540	>450	
Wheat flour			97	60		32	25	57	60	8.3	87		430			>450	
Dough					100									400	>100		
Wheat flour 550				60		34	25	56	60	7.4	42		470		400	>450	
Milk sugar				99		92	77	10	60	8.3	75		440		14	Melts	5
Milk sugar				98		64	32	27	60	8.3	82	St. 1	490			460	2
Sugar (icing)				88		70	52	19					470			>450	
Coal, coal products																	
Activated carbon				99		80	55	18	60	8.8	44		790			>450	
Activated carbon				88		64		22			No ignition			670		335	
Activated carbon (16% moisture)			84	65		38		46	125	8.4	67		(630)				
Brown coal			83	69		40	20	41		9.1	123		420		160	230	4
Brown coal (from electrostatic filter)			75	60		27		55	60	9.0	143	St. 1	450			240	4
Brown coal (dust from grinding)			71	56		38	30	60		8.9	107		420		230	230	3
Brown coal/anthracite (80:20)				66		43	24	40	60	8.6	108		440		>4000	230	
Brown coal/anthracite (20:80)				91		85	80	<10		0.4	1		590			280	
Brown coal coke	93		18	13				290	250	8.4	115	St. 1	560			>450	3

Brown coal (graphitized)				82		55	35	28	No ignition					>850		>450	
Char coal				99		88	67	14	60	9.0	10	St. 1	520			320	4
Char coal				95		85	58	19	60	8.5	117		540			270	
Char coal	36							>500	No ignition					>850		>450	
Asphalt				83		54	32	29	15	8.4	117		550			Melts	
Bituminous coal				97		93	85	<10		9.0	55		590			270	
Bituminous coal (Petchora)			76	65		46	37	38	125	8.6	86		610			360	
Anthracite (dust from filter)				99		97	85	<10	No ignition				>850			360	
Bituminous coal (high volat.)							99	4	60	9.1	59		510			260	
Other natural organic products																	
Cotton seed expellers	66		24	10			245	125	7.7	35	St. 1	(480)				350	3
Dextrin				57		26	55		8.8	109	St. 1	490				>450	2
Wheat gluten (after mill)			78		28	13	48	30	8.7	105		540				Melts	
Blood flour			93	61		27	5	57	60	9.4	85		610			>450	1
Hops, malted	52		14	9				490		8.2	90		420			270	
Leather dust (from collector)									(100)			(St. 2)					5
Linen (containing oil)	63		21					300		6.0	17		(440)			230	
Lycopodium					100	91								410		280	
Oil shale dust				99		79	50	20	125	5.2	35		520			290	2
Oil shale dust				71		50	39	32	No ignition				610			>450	
Grass dust	96		26					200	125	8.0	47		470			310	
Walnut shell powder									(100)			St.1					4
Plastics, resin, rubber																	
Acrylnitrile-Butadiene-Styrene-Co-polym.	79	37	24					200	60	9.2	147	(St. 2)	480			>450	5
Epoxy resin (for powder coating)		100	82		58	28		55	(100)			(St. 2)					2
Cellulose-2, 5-acetate				100		89	53	19	30	9.8	180		520			>450	
Polyester resin with glass	92	91	89		80	72		14	(100)			(St. 2)					5
Rubber				93		45		34	(100)	7.4	106	(St. 2)					5
Rubber (dust from grinding)			78	43		12		80	30	8.5	138		500		13	230	5
Resin (from filter)				97		44		40	30	8.7	108		460			Melts	
Epoxy resin (60% resin + 36% TiO_2)				99		67	43	23		7.8	155						

Table A.1 continued

Dust type	Particle size distribution, Weight % <Size (μm)								Ignitability and explosibility of dust clouds						Dust layers		
									1 m³ or 20 L vessel			Mod. H.			VDI	DIN	
	500	250	125	71	63	32	20	Median (μm)	C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Explos. <63 μm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	MIE (mJ)	Glow temp. (°C)	Flam. <250 μm (Class)
Epoxy resin				95		60	36	26	30	7.9	129	St.1	510			Melts	2
Epoxy resin with Al				90		46		34		8.9	208		570			Melts	
Melamin resin				99		84	55	18	125	10.2	110	St. 1	840			>450	2
Melamin resin				66		24	13	57	60	10.5	172	St. 1	470			>450	2
Phenol resin				100		99	94	<10	15	9.3	129	(St. 2)	610			>450	2
Phenol formaldehyde resin	100	98	81		50	30		60	(100)			St.1				4	4
Polyamid resin				95		84		64	15	3.0	8.9	105		450		Melts	
Polymethacrylate	56				100	33			15	8.0	199					(2)	
Silicon resin	91		59	39		20	13	100	60	7.2	80		480			Melts	
Caoutchouc			58	40		20		95	30	9.5	192		450			230	
Synthetical caoutchouc			66	46		18	9	80	15	8.6	145	(St.2)	450			240	5
Methylmethacrylate-Butadiene-Styrene			45	18				135	30	8.6	120		470		11	Melts	5
Methylmethacrylate-Butadiene-Styrene			34	11				150	30	8.4	114		480		30	Melts	5
Polyacrylamide (from filter)				100		95	81	10	250	5.9	12	St. 1	780			410	2
Polyacrylate (from filter)			100	63		11	1	62	125	6.9	38		460		>1800	420	5
Polyacrylnitrile (32% H_2O)			95	47		16		63	60	7.4	41						
Polyamide flock (3.3 dtex 0.5 mm)				100		25	3	37	30	9.8	93	St. 1	520			Melts	2(3)
Polyester								<10		10.1	194		570			Melts	
Polyethylene			91	51		10		72		7.5	67		440			Melts	
Polyethylene	82			8	2				280		6.2	20		470		Melts	
Polyethylene (high pressure)			98	93		65	10	26		8.7	104		490			>450	
Polyethylene (low pressure)						95	86	<10	(30)	8.0	156	(St. 2)	420			Melts	2(5)
Polyethylene (low pressure)			36	10				150	125	7.4	54	St. 1	480			Melts	3(5)
Polyethylene (low pressure)	90		20	9				245	125	7.5	46	St. 1	460			Melts	3(5)
Polymethacrylate (from filter)				90		70	48	21	30	9.4	269	(St. 2)	550			Melts	5
Polymethacrylimide			45	15				105	30	9.6	125	(St. 2)	530			Melts	5

Polypropylene				92		61	40	25	(30)	8.4	101	(St. 2)	410			Melts	3(5)
Polypropylene	100		12					162	(200)	7.7	38	St. 1	440			Melts	2(5)
Polystyrene (copolymer)			32	11				155	30	8.4	110		450			Melts	
Polystyrene (hard foam)	30		10	5				760		8.4	23						
Polyurethane					100	90		3	<30	(7.8)	(156)						5
Polyvinylacetate (copolymer)						83	50	20	60	8.7	86	St. 1	660			Melts	2
Polyvinylalcohol				74		55	44	26	60	8.9	128	(St. 2)	460			Melts	5
Polyvinylalcohol				57		29	9	56	60	8.3	83	St. 1	460			Melts	5
Polyvinylchloride						100		<10	30	8.4	168						
Polyvinylchloride			46	15				125	30	7.7	68		530			340	
Polyvinylchloride (em., 97.5% PVC)				97		73	26	25	125	8.2	42		750		>2000	>450	
Polyvinylchloride (em., 97% PVC)				60		31	14	51	125	8.5	63		790		>2000	350	
Polyvinylchloride (susp.)			66	23				105	125	7.7	45	St. 1	510			>450	2
Polyvinylchloride (susp.)			30					137	No ignition				>800			>450	
Urea-formaldehyde (molded form)				99		91	75	13	60	10.2	136	St. 1	700			390	2
Melamine-formaldehyde (molded form)				93		86	70	14	60	10.2	189	St. 1	800			>440	2
El.stat. coating powder (epoxy)				100		70		29	30	8.9	100	(St. 2)	540			Melts	2(3)
El.stat. coating powder (polyurethane)				100		66	22	29	30	7.8	89	St. 1	490			Melts	2(2)
Shellac					100	33			15	7.6	144	(St. 2)					
Wax (NN ethylene distearamide)					100	95		10	15	8.7	269	(St. 2)					2(2)
Pharmaceuticals, cosmetics, pesticides																	
Acetyl salicylic acid					100				15	7.9	217	(St. 2)		550			2(5)
Amino phenazone						100	98	<10		10.3	238		330			>450	
Ascorbic acid, L(+)-				93		75	61	14	60	6.6	48	(St. 2)	490			Melts	2(2)
Ascorbic acid				92		38	15	39	60	9.0	111	(St. 2)	460			Melts	2(2)
Caffeine					100				30	8.2	165	(St. 2)		>550		Melts	2(5)
Cysteine hydrate				100		98	94	<10	125	7.4	40		420		>2000	Melts	
L-Cystin				100		95	69	15	60	8.5	142		400		40	Melts	

Table A.1 continued

Dust type	Particle size distribution: Weight % <Size (μm) 500	250	125	71	63	32	20	Median (μm)	Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Mod. H. Explos. <63 μm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	Dust layers: VDI MIE (mJ)	DIN Glow temp. (°C)	Flam. <250 μm (Class)
Digitalis leaves				59		42		46	250	8.5	73						
Dimethylaminophenazone						100		<10		10.0	337						
2-Ethoxybenzamide					100				15	8.6	214	(St. 2)		490		Melts	2(5)
Fungicide (Captan)			100		99	93		5	(500)			St. 1					5
Fungicide (org. zinc comp.)						99	96	<10	60	9.0	154		480			300	
Fungicide (Maneb)				98		97	93	<10					380		>2500	200	
Methionine				100		99	95	<10	30	9.4	143		390		9	Melts	5
Methionine				100		98	87	<10	30	8.7	128		390		100	Melts	5
Sodium - L (+) ascorbate				97		67	45	23	60	8.4	119	St. 1	380			380	2
Paracetamole					100				15	7.9	156	(St. 2)		>550		Melts	2(5)
Pesticide				99		98	95	<10	60	8.6	151		410			320	
Intermediate products, auxiliary materials																	
Adipinic acid				98		92	86	<10	60	8.0	97	(St. 2)	580			Melts	2(5)
Aging protective					100	67		<32	15	8.2	256	(St. 2)					2(3)
Anthracene	89		20	7				235	15	8.7	231		600			>450	
Anthrachinone						100		<10		10.6	364						
Anthrachinone				100		90	75	12	30	9.1	91						
Azodicarbonamide						100		<10		12.3	176						
Benzoic acid									(30)			(St. 2)					2(5)
Betaine hydrochloride				93		85	78	<10	60	9.8	114	(St. 2)	400			>450	3
Betaine monohydrate	34		4					710	60	8.2	63	St. 1	510			>450	5
Diphenol ketylene				98		80	60	15		9.0	270						
Calcium acetate			74	41		25	17	92	500	5.2	9	St. 1	730			>460	2
Casein				99		65	40	24	30	8.5	115		560			>450	
Sodium caseinate (from filter)				100		99	77	17	60	8.8	117		560		740	>450	
Carboxy methyl cellulose				97		89		<15		9.2	184						
Carboxy methyl cellulose				50		20	12	71	125	8.9	127	St. 1	390			320	3

Methyl cellulose				96		87	30	22		10.0	157		400		12	380	
Methyl cellulose				100		69	10	29	60	10.0	152		400		105	>450	5
Methyl cellulose				93		37	12	37	30	10.1	209		410		29	450	5
Ethyl cellulose				66		40		40		8.1	162		(330)			275	
Chloroacetamide	98	79	33		13	3		170	(200)			St. 1					2(2)
Cyanoacrylicacid methylester	69		20					260	30	10.1	269	(St. 2)	500			>450	5
Dicyandiamide				99		98	97	<10		3.7	9		> 850			>450	
1.3-Diethyldiphenyl urea				98		93	83	<10	15	8.8	163	(St. 2)	530			Melts	2(5)
1.3-Diethyldiphenyl urea	8							1300	30	8.7	116	(St. 2)	600			Melts	2(5)
Dimethyl terephtalate						60		27	30	9.7	247		460		2	> 450	
Diphenyl urethane	93		49	27				128	30	8.9	218	(St. 2)	660			Melts	2
Diphenyl urethane	31							1100	30	7.6	51	(St. 2)	660			Melts	2
Emulgator (50% CH, 30% fat)			89	50		11		71	30	9.6	167		430		17	390	
Ferrocene			71	33				95	15	8.3	267		500		5	>450	5
Fumaric acid	100	75	24		15	11		215	(100)			(St. 2)					5
Epoxy resin hardener				97		85	60	17	60	10.0	64		>850			Melts	2
Urea	4	2	<1					2900				St. 1					1(2)
Hexamethylene tetramine				100		69	42	27	30	10.5	286						
Hexamethylene tetramine	100		30	9				155		10.0	224		530			Melts	
Cellulose ion exchange resin								<10	60	10.0	91	(St. 2)	410			>450	5
Cellulose ion exchange resin				27		9		112	30	9.4	112		(350)			>465	
Condensation product (phenol)				92		74	50	20	15	8.2	171	(St. 2)	560			Melts	2(5)
D(-)-Mannite				61		24	13	67	60	7.6	54	St. 1	460			Melts	2
Melamine				98		95	88	<10	1000	0.5	1	St. 1	>850			>450	2
Melamine peroxide				61		56	46	24	250	12.2	73	St. 1	>850			380	2
Melamine phosphate					100	79		22				St. 1					2
Melamine phtalate				99		89	65	16	125	8.1	52	St. 1	910			Melts	2
Metal soap (Ba/Pb-stearate)					100	48			15	8.1	180	(St. 2)					2(2)
Metal *soap (Zn-behenate)*					100	80			15	8.1	119	(St. 2)					2(3)
Methacrylamide	42						580		8,5	113			530		180	>450	
Naphtalene	89		66		35	12		95	15	8.5	178		660		<1	>450	(5)
Naphtalic acid anhydride					97	69	16	60	9.0	90			690		3	Melts	
2-Naphtol				100		96	94	<10		8.4	137		430		5	>450	

Table A.1 continued

Dust type	Particle size distribution: Weight % <Size (µm) 500	250	125	71	63	32	20	Median (µm)	Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Mod. H. Explos. <63 µm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	Dust layers: VDI MIE (mJ)	DIN Glow temp. (°C)	Flam. <250 µm (Class)
Sodium amide									(200)			(St. 2)					2
Sodium cyclamate	97	52	13		5	2		260				St. 1					5
Sodium hydrogen cyanamide			95	90		28	8	40	125	7.0	47		460			Melts	
Sodium ligno sulphonate			100		63	20		58	(200)			St. 1					2
Oil absorber (hydrophobic cellulose)			65	51		31	21	65	60	7.2	42		540			>450	
Paraformaldehyde				89		65	41	23	60	9.9	178	(St. 2)	460			>480	5
Paraformaldehyde				86		58	37	27	60	10.7	222		460			>450	
Pectin			86	61		21		59	60	9.5	162		460			300	
Pectinase				91		47	20	34	60	10.6	177		510		180	>450	3
Pentaerythrite				100		98	86	<10	30	9.6	120		470		<1	Melts	2(5)
Pentaerythrite (from filter)		90	33		6	3	85	30	9.1	188			490		6	Melts	5
Pentaerythrite	86		47	36		20	12	135	30	9.0	158				27	Melts	5
Phtalic acid anhydride									(100)			(St. 2)					5
Polyethylene oxide	99	83	53		29	14		115	(30)			(St. 2)					3(5)
Polysaccharide					100	78		23	(500)			St. 1					4
Propyleneglycol alginate			57	24				115	125	8.8	82		440			450	
Salicylic acid									(30)			(St. 2)					2(5)
Saponin				93		77	65	13		9.4	150	St. 1	440			>450	3
Lead stearate			99	96		90	80	<10					480		<1	Melts	
Lead stearate							90	12	30	9.2	152	(St. 2)	630			Melts	5
Calcium stearate				99		92	84	<10					520		9	Melts	
Calcium stearate						92	80	<10	30	9.2	99		580		16	>450	
Calcium stearate	100		43	25				145	30	9.2	155		550		12	>450	
Magnesium stearate									(100)			(St. 2)					2(2)
Sodium stearate				92		67	45	22	30	8.8	123	St. 1	670			Melts	2
Zinc stearate									(100)			(St. 2)					2(5)
Zinc stearate				95		86	72	13					520		5	Melts	
Stearin/lead				99		95	75	15	60	9.1	111		600		3	>450	

Stearin/calcium				100		89	64	16	30	9.3	133		620		25	>450	
Stearic acid	12							1300	8	7.2	34	(St. 2)	500			Melts	1(1)
Terephthalic acid dinitrile					100	78			<30	8.8	260	(St. 2)					5
2.2-Thiodiacetic acid				48		27	18	75	30	6.5	72	St. 1	350			410	2
Thio urea	56		1					460	250	3.5	8	St. 1	440			Melts	2(2)
Trimellitic anhydride	4							1250	30	6.8	33		740		>2500	Melts	2(5)
Trisodium citrate	36	2	1					800				St. 1					2
Tyrosine (final product)	100		99			48		10				(St. 2)					5
Tyrosine (raw product)	99		96		91	74		15				(St. 2)					5
Viscose flock					100	94		13	(100)			St. 1					4
Tartaric acid	100	5	1					480				St. 1					2
Zinc cyanamide				99		96	94	<10	No ignition				>850			>450	3
Zinc cyanamide	47	34			27	14		600		(4.8)	(53)	No ignition					2
Zinc pyridine thione						100			(500)			St. 1					2(5)
Other technical and chemical products																	
Organic dyestuff (blue)				99		98	95	<10		9.0	73		710			360	
Organic dyestuff (khaki)				86		29	11	44					690			450	
Organic dyestuff (red)								<10	50	11.2	249		520			Melts	
Organic dyestuff (red)				65		33	23	52	60	9.8	237	(St.2)	470			>450	5
Organic dyestuff (Azo, yellow)				100		98	95	<10	60	11.0	288	(St.2)	480			Melts	2(5)
Organic dyestuff (disp., brilliant pink)			91	73		25		46					610		>4000	450	
Organic dyestuff (brown)									(200)			St. 1					4
Organic dyestuff (Phthalocyanine)				96		86		<10	(200)	8.8	73	St. 1	770			355	4
Fuchsin base				74		45	26	36		8.4	115		640			Melts	
Bituminous hydrocarbon			23	11			260	30	7.6	63			500			Melts	2
Light protection agent				97		92	83	<10		8.9	214		530			>450	
Light protection agent				100		93		<15		10.0	310						
Soap								65	30	9.1	111		580			Melts	
Surfacer (epoxy based)					100	77		24	(200)			St. 1					2
Surfacer (polyester based)					100	85		19	(500)			St. 1					2
Washing agent (Na-sulphate)	88			14				275	30	9.0	287	(St. 2)	330			Melts	5

Table A.1 continued

Dust type	Particle size distribution: Weight % <Size (μm) 500	250	125	71	63	32	20	Median (μm)	Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar · m/s)	Mod. H. Explos. <63 μm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	Dust layers: VDI MIE (mJ)	DIN Glow temp. (°C)	Flam. <250 μm (Class)
Wax raw material (Alkylaryl sulphonate)												St. 1					5
Wax raw material (olefin sulphonate)			60	28			105	30	8.6	115			390			>590	
Metal alloys																	
Aluminum powder				94		88	79	<10	60	11.2	515		560			430	
Aluminum powder				98		70	45	22		12.5	400		650			270	
Aluminum powder				99		64	47	22	30	11.5	1100		500			>450	
Aluminum powder				94		60	17	29	30	12.4	415	(St.3)	710			>450	
Aluminum grit				100		96		23	30	11.0	320		850			>450	
Aluminum grit				99		16	2	41	60	10.2	100		>850			>450	
Aluminum grit	92		26	6				170	No ignition				>850			>450	1
Aluminum shavings	80		35	20				190					620		>1800	>450	
Aluminum shavings	79		29	17				240	No ignition				>850			>450	
Aluminum/iron (50:50)				93		68	48	21	250	9.4	230		760			>450	
Aluminum/magnesium			47					130		10.4	52	St.1	>850			>450	
Aluminum/nickel				95		86		<10		11.4	300						
Aluminum/nickel (50:50)				37		18		90	No ignition				>850			>450	
Bronze powder						97	60	18	750	4.1	31	St.1	390			260	4
Calcium/aluminum (30:70)						68	46	22		11.2	420		600			>450	6
Calcium/silicon (from cyclone)				94		75	48	21	60	9.8	200	(St.2)	770			>440	1
Calcium/silicon				87		55		28					770		145	>450	
Iron (from dry filter)				98		82	67	12	500	5.2	50		580			>450	
Iron carbonyl							96	<10	125	6.1	111	(St.2)	310			300	3
Ferrochromium				96		82	73	<10	500	6.4	86		>850			>450	
Ferromanganese				99		97	90	<10		6.8	84		730			>450	
FeSiMg (22:45:26)				99		77	57	17		9.4	169		670		210	>450	
Ferrosilicon (22:78)				97		70	47	21	125	9.2	87		>850			>450	

Hard metal (TiC, TiN, WC, VC, Mo)		100	95		68	40		43	(200)			St.1					4
Co-Al-Ti (62:18:20)				92		61	41	25	500	7.4	134		730			>450	
Magnesium				100		70		28	30	17.5	508						
Magnesium	99		1					240	500	7.0	12	(St. 2)	760			>450	5
FeSiMg(24:47:17)				99		70	47	21		9.9	267		560		35	>450	
Manganese (electrolyt.)				82		70	57	16		6.3	157		(330)			285	
Manganese (electrolyt.)				70		41		33		6.6	69						
Molybdenum				100		96	92	<10		No ignition			>850			390	
Niobium (6% Al)	87	44	24		9	3		250	(200)			St.1					2
Silicon				99		98	97	<10	125	10.2	126		>850		54	>450	3
Silicon (from filter)					100	99	<10	60	9.5	116			>850		250	>450	1
Silicon (from dust extr.)				90		70	57	16	60	9.4	100		800			>450	
Steel (100 Cr6) dust					100	74	(30)	(4.0)	(82)			(St. 2)					2
Titanium				98		55	24	30					450			>450	
Titanium (preoxidized)				77		46	26	35					380			400	
Ti/TiO_2 (dust deposit)	61	40	28		12	6		310	(100)			(St.3)					5
Zinc (from zinc coating)				91		72	53	19		6.0	85	St.1	800			>450	2
Zinc (from zinc coating)				93		70		21	250	6.8	93		790			>450	
Zinc (dust from collector)							99	<10	250	6.7	125	(St.2)	570			440	3
Zinc (dust from collector)				97		91	72	10	125	7.3	176	St.1					2
Other inorganic products																	
NH_4NO_3/Dicyanamide (66:34)				60		42	35	50	250	7.0	21		390			>450	
Graphite (99.5% C)					100	97		7	<30	5.9	71			>600		680	1
Carbon fibers (99% C)									(100)			St. 1					2
Molybdenum disulphide				92		75	53	19	250	5.6	37	St. 1	520			320	4
Petroleum coke				93		75	59	15	125	7.6	47	St. 1	690			280	4
Petroleum coke			83	51		22	14	71	125	3.8	3		750			>450	3
Petroleum coke (calcinated)			94	86		64	47	22	250	6.8	14		>850			>450	3
Phosphorus (red)				100		92	59	18		7.9	526		400			340	5
Soot							99	5	60	9.2	85		760			590	
Soot (from filter)								<10	30	8.8	88		840			570	
Sulfur				97		85	71	12					240		<1	250	
Sulfur				96		70	51	20	30	6.8	151	(St. 2)	280				5

Table A.1 continued

Dust type	Particle size distribution Weight % <Size (μm) 500	250	125	71	63	32	20	Median (μm)	Ignitability and explosibility of dust clouds: 1 m³ or 20 L vessel C_{min} (g/m³)	P_{max} (bar(g))	K_{St} (bar·m/s)	Mod. H. Explos. <63 μm (Class)	T_{min} (°C) G.G.	T_{min} (°C) BAM	Dust layers: VDI MIE (mJ)	DIN Glow temp. (°C)	Flam. <250 μm (Class)
Sulfur				86		23		40					330		3	270	
Sulfur			53			7		120					370		5	270	
Titanium carbide									(100)			(St. 2)					4
Titanium hydride									(200)			St. 1					2
Titanium monoxide									(200)			(St. 2)					4
Other materials																	
Fly ash (from electrofilter)			100		99	92		6	125	1.9	35	No ignition					1
Ash concentrate				87		61	48	21	60	8.6	91		580			260	
Bentonite/asphalt/coal/org. (15:45:35:5)		90			55			54	(100)			St. 1					2
Bentonite/coal (50:50)		98	86		69	41		42	(100)			St. 1					2
Bentonite der. + org. comp.				89		45	23	35	60	7.4	123		430			>450	3
Pb and Ca stearate mixture		98			70			35	(100)			(St. 2)					2(2)
Break liner (grinding dust)				98		95	89	<10	250	6.9	71		530			310	
Brush dust (Al brushes)				99		74	30	25	30	11.4	360		590		<1	450	
CaC/diamide lime/Mg (72:18:10)		99		93		87	80	8	125	5.8	30						4
Mud from setting chamber			99	91		62	45	23	60	7.7	96		430			260	5
Dust from polishing (Al)			44	26				150		5.0	18		440			320	5
Dust from polishing (Zn)		60	35		15	2		190	(200)			St. 1		400		350	2
Dust from polishing (brass)									(100)			St. 1					4
Dust from grinding (Al)					100	85			(30)	(5.7)	(214)	(St. 2)					4
Dust from grinding (Zn)					100	67			(500)	(2.3)	(24)	St. 1		480			1
Dust from grinding (cardboard)	70	64	44		25	10		160	(100)			St. 1					5
Dust from grinding (polyester)				98		95	93	<10	30	9.5	153		500			>450	5
Dust from grinding (polyester)			97	84		60	41	25		9.4	237		550			>450	5
Dust from grinding (Ti)	89	64	37		18	4		170	(100)			(St. 2)					2
Dust from grinding + polish. (polyester)				99		96	91	<10					530		<1	>450	

Blasting dust (light metals)					100	82			15	7.6	242	(St. 2)		370		280	4
Immersion polishing agent	46							600	(30)	6.2	11	St. 1	580			340	2
Textile fibers (nat. + synth.)									(30)			St. 1					5
Toner							100	<10	60	8.9	196			520	4	Melts	
Toner							100	<10	30	8.7	137			530	<1	Melts	5
Toner				100		96	48	21	60	8.8	134			530	<1	Melts	(3)
Toner				100		95	30	23	60	8.8	145			530	8	Melts	(3)
Toner/iron powder				58		37		60	60	8.2	169			570		>450	
Toner resin				98		78	55	18						580	<1	>450	(5)
Zinc stearate/Bentonite (90:10)									(100)			(St. 2)					3
Zinc stearate/Bentonite (20:80)												(St. 1)					2

Source: BIA (1987).

Table A.2 Maximum permissible O_2 concentration for inerting dust clouds in atmospheres of $O_2 + N_2$

Dust type	Median particle diameter by mass (μm)	Maximum O_2 concentration for inerting by N_2 (vol%)
Cellulosic materials		
Cellulose	22	9
Cellulose	51	11
Waste from wood cutting	130	14
Wood	27	10
Food and feedstuffs		
Pea flour	25	15
Maize starch	17	9
Waste from malted barley	25	11
Rye flour 1150	29	13
Starch derivative	24	14
Wheat flour 550	60	11
Coals		
Brown coal	42	12
Brown coal	63	12
Brown coal	66	12
Brown coal briquette dust	51	15
Bituminous coal	17	14
Other materials		
Ground hops	500	17
Hops draff	490	18
Plastics, resins, rubber		
Resin	<63	10
Rubber powder	95	11
Polyacrylnitril	26	11
Polyacrylnitril	26	10
Polyethylene, h.p.	26	10
Pharmaceuticals, pesticides, etc.		
Aminopheenazone	<10	9
Herbizide	10	12
Methionine	<10	12
Intermediate products, additives		
Barium stearate	<63	13
Benzoyl peroxide	59	10
Bisphenol A	34	9
Cadmium laurate	<63	14
Cadmium stearate	<63	12
Calcium stearate	<63	12
Methyl cellulose	29	15
Methyl cellulose	49	14
Methyl cellulose	70	10
Dimethyl terephtalate	27	9
Ferrocene	95	7
Bistrimethylcilyl-urea	65	9
Naphthalic acid anhydride	16	12
2-Naphthol	<10	9

Table A.2 continued

Dust type	Median particle diameter by mass (μm)	Maximum O_2 concentration for inerting by N_2 (vol%)
2-Naphthol	<30	9
Sodium methallyl sulphonate	280	15
Paraformaldehyde	23	6
Paraformaldehyde	27	7
Pentaerythrite	<10	11
Pentaerythrite	<10	11
Other technical and chemical products		
Blue dye	<10	13
Organic pigment	<10	12
Metals, alloys		
Aluminum	22	5
Aluminum	22	6
Calcium/aluminum alloy	22	6
Ferrosilicon	17	7
Ferrosilicon	21	12
Magnesium alloy	21	3
Other inorganic products		
Soot	<10	12
Soot	<10	12
Soot	13	12
Soot	16	12
Soot desorbed from acetylene	86	16
Soot desorbed from acetylene	120	16
Others		
Bentonite derivative	43	12

Source: BIA (1987).

Table A.3 Inerting of dust clouds by mixing the combustible dust with inert dust (1 m^3 standard ISO (1985) vessel, 10 kJ chemical ignitor)

Combustible dust		Inert dust		
Type of dust	Median particle size by mass (μm)	Type of dust	Median particle size by mass (μm)	Minimum mass% inert of total mass required for inerting
Methyl cellulose	70	$CaSO_4$	<15	70
Organic pigment	<10	$NH_4H_2PO_4$	29	65
Bituminous coal	20	$CaCO_3$	14	65
Bituminous coal	20	$NaHCO_3$	35	65
Sugar	30	$NaHCO_3$	35	50

Source: BIA (1987).

A.2.3
MINIMUM IGNITION TEMPERATURE OF THE DUST LAYER

The earlier USBM method differs significantly from the hot-plate method used to produce the data in Table A.1. The latter is illustrated in Figure 7.17 in Chapter 7. In the USBM method, 6 cm^3 of the dust was placed in a small stainless steel mesh basket kept suspended at the center of the Godbert-Greenwald furnace (see Figure 7.24 in Chapter 7), while a controlled, small flow of air was passed through the furnace. The temperature of the furnace was controlled and maintained at a predetermined value, and the temperature inside the dust sample was monitored by a thermocouple. Ignition was defined as a distinct increase in the dust temperature beyond that of the furnace within 5 minutes. The minimum ignition temperature was defined as the lowest furnace temperature at which ignition occurred.

As would be expected, the USBM layer ignition temperatures are generally significantly lower, by 100° or more, than the "glow temperatures" of Table A.1 for similar dusts.

A.2.4
MINIMUM IGNITION ENERGY OF THE DUST CLOUD (MIE)

Due to the design of the electric spark generator used earlier by the USBM, part of the stored capacitor energy $\frac{1}{2}CV^2$ was lost in a high-voltage transformer, and therefore the net spark energy was smaller than the nominal $\frac{1}{2}CV^2$ quoted as the spark energy. However, when comparing MIE data for similar dusts, determined by the earlier USBM method and the more recent methods described by Eckhoff (1975) and Berthold (1987), an approximate empirical correlation is indicated, as shown in Figure A.1 in Section A.1.2.7. Note that the correlation should not be extrapolated beyond the range of Figure A.1.

A.2.5
MINIMUM EXPLOSIBLE DUST CONCENTRATION

The earlier USBM method was based on the 1.2 liter open Hartmann tube, with its top opening covered by a paper diaphragm. A comparatively weak continuous induction spark source was used for ignition. The dust concentration was defined as the quantity of dust dispersed, divided by the 1.2 liter volume of the tube. In spite of several probable sources of error, this method often yielded reasonable values as compared with more recent methods such as Nordtest (1989). This is probably because the effect of some of the sources of error partly cancel each other. However, data from the early USBM method must be regarded as indicative only.

A.2.6
MAXIMUM EXPLOSION PRESSURE

The early USBM data were determined in the original version of the closed 1.2 liter Hartmann bomb. Due to incomplete combustion and cooling by the walls, the maximum explosion overpressures in the Hartmann bomb are generally considerably lower, by up to 50%, typically 25–30%, than those generated by the same dusts in larger vessels, such as the 1 m^3 standard ISO (1985) vessel and the 20 liter Siwek sphere. It does not seem advisable to indicate any general relationship between P_{max} from the early USBM tests and more recent data from larger vessels.

A.2.7 MAXIMUM RATE OF PRESSURE RISE

These data were determined in the same Hartmann bomb experiment as the maximum explosion pressures. However, there seems to be some justification for indicating the following tentative correlation between $(dP/dt)_{max}$ in the closed Hartmann bomb and the K_{St} from the 1 m^3 standard ISO (1985) method (see Table A.4).

Table A.4 Examples of correlation of rates of pressure rise

$(dP/dt)_{max,Hartm.}$ (bar/s)	K_{St} (bar·m/s)
100	35
200	70
400	140
800	280
1600	560
3200	1120

Note: For quite coarse powders (nonhomogeneous dust concentration distribution in Hartmann bomb) and for very fine, cohesive powders (poor dust dispersion in Hartmann bomb), this correlation can be substantially in error.

A.2.8 MAXIMUM PERMISSIBLE O_2 CONCENTRATION FOR INERTING

USBM used two methods, an open glass tube with electric spark ignition and the Godbert-Greenwald furnace at 850°C. As would be expected, the latter method gave considerably lower limiting O_2 concentrations for inerting than the former.

Generally, the values of Table A.2 fall somewhere between the two USBM values for similar dusts. The arithmetic mean of the two USBM values then might be compatible with the data in Table A.2.

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